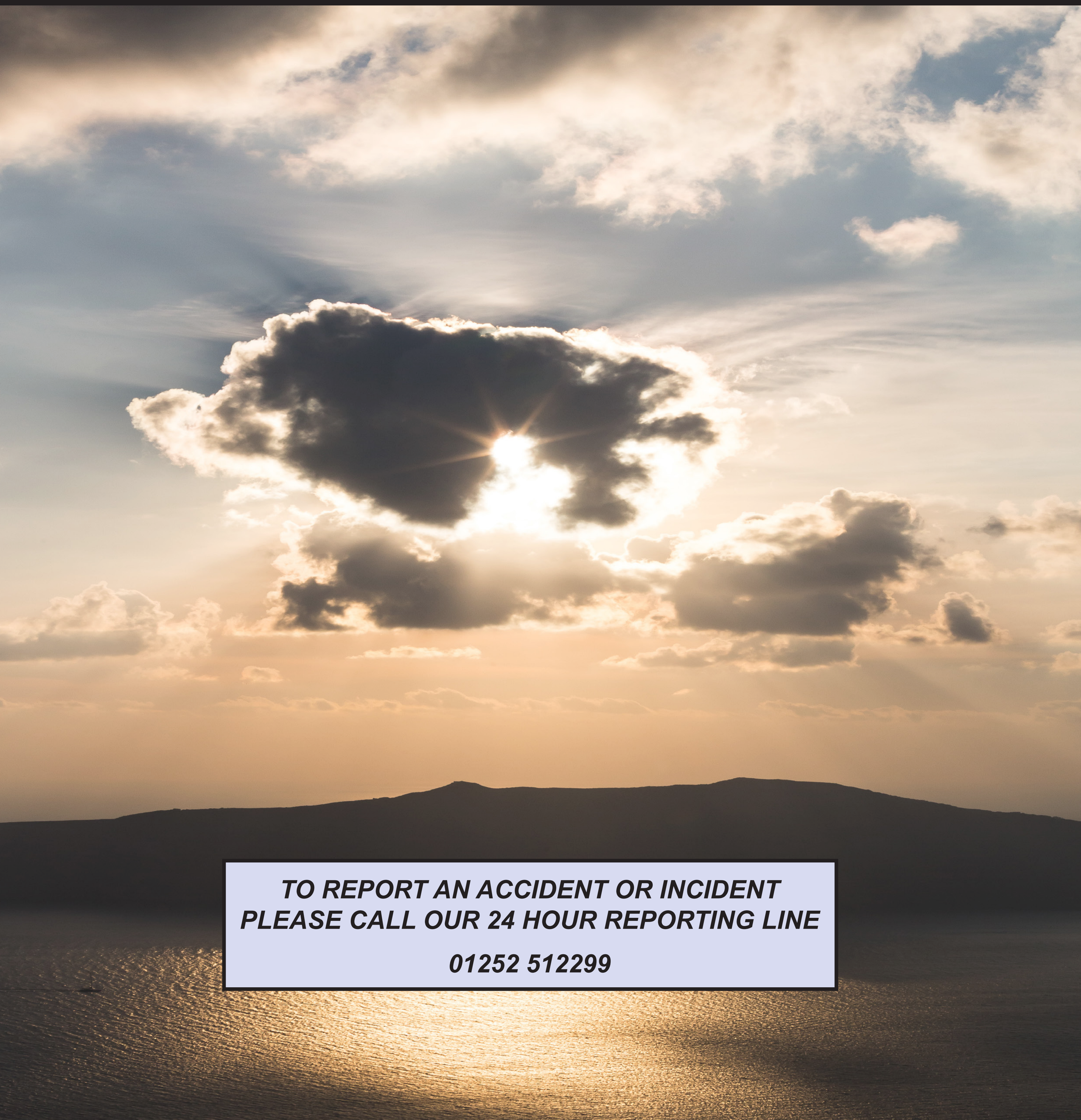
AAIB
Air Accidents Investigation Branch

AAIB Bulletin 5/2016



TO REPORT AN ACCIDENT OR INCIDENT PLEASE CALL OUR 24 HOUR REPORTING LINE

01252 512299

Air Accidents Investigation Branch
Farnborough House
Berkshire Copse Road
Aldershot
Hants GU11 2HH

Tel: 01252 510300
Fax: 01252 376999
Press enquiries: 0207 944 3118/4292
http://www.aaib.gov.uk

AAIB investigations are conducted in accordance with Annex 13 to the ICAO Convention on International Civil Aviation, EU Regulation No 996/2010 and 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 is the prevention of future accidents and incidents. It is not the purpose of such an investigation to apportion blame or liability.

Accordingly, it is inappropriate that AAIB reports should be used to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

AAIB Bulletins and Reports are available on the Internet
http://www.aaib.gov.uk

This bulletin contains facts which have been determined up to the time of compilation.

Published 12 May 2016

Cover picture courtesy of Stephen R Lynn
(www.srlynnphotography.co.uk)

ISSN 0309-4278

Published by the Air Accidents Investigation Branch, Department for Transport
Printed in the UK on paper containing at least 75% recycled fibre

CONTENTS

SPECIAL BULLETINS / INTERIM REPORTS

SUMMARIES OF AIRCRAFT ACCIDENT ('FORMAL') REPORTS

None

AAIB FIELD INVESTIGATIONS

COMMERCIAL AIR TRANSPORT

FIXED WING

ROTORCRAFT

None

GENERAL AVIATION

FIXED WING

None

ROTORCRAFT

None

SPORT AVIATION / BALLOONS

AAIB CORRESPONDENCE INVESTIGATIONS

COMMERCIAL AIR TRANSPORT

GENERAL AVIATION

CONTENTS Cont

AAIB CORRESPONDENCE INVESTIGATIONS Cont

SPORT AVIATION / BALLOONS

MISCELLANEOUS

ADDENDA and CORRECTIONS

(ALL TIMES IN THIS BULLETIN ARE UTC)

AAIB Special Bulletins / Interim Reports

AAIB Special Bulletins and Interim Reports

This section contains Special Bulletins and Interim Reports that have been published since the last AAIB monthly bulletin.

Farnborough House
Berkshire Copse Road
Aldershot, Hants GU11 2HH

Tel: 01252 510300
Fax: 01252 376999
www.aaib.gov.uk

AAIB
Air Accidents Investigation Branch

AAIB Bulletin S1/2016
SPECIAL

ACCIDENT

Aircraft Type and Registration:	Hawker Hunter T7, G-BXFI
No & Type of Engines:	1 Rolls-Royce Avon Mk 122 turbojet engine
Year of Manufacture:	1959 (Serial no 41H-670815)
Location:	Near Shoreham Airport, West Sussex
Date & Time (UTC):	22 August 2015 at 1222 hrs
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Serious) Passengers - N/A Others - 11 (Fatal)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	51 years
Commander's Flying Experience:	14,249 hours (of which 40 were on type) Last 90 days - 115 hours Last 28 days - 53 hours
Information Source:	AAIB Field Investigation

1 Introduction

The aircraft was taking part in a flying display at Shoreham Airport during which it conducted a manoeuvre with both a vertical and rolling component, at the apex of which it was inverted. Following the subsequent descent, the aircraft did not achieve level flight before it struck the westbound carriageway of the A27. Eleven people on the ground were fatally injured.

Special Bulletin S3/2015 was published on 4 September 2015 to provide preliminary information about the accident gathered from ground inspection, radar data, recorded images and other sources.

This Special Bulletin contains facts which have been determined up to the time of issue. It is published to inform the aviation industry and the public of the general circumstances of accidents and serious incidents and should be regarded as tentative and subject to alteration or correction if additional evidence becomes available.

A further Special Bulletin, S4/2015, was published on 21 December 2015 to highlight findings of the AAIB investigation regarding ejection seat safety and the maintenance of ex-military jet aircraft, and to assist the Civil Aviation Authority in its '*Review of UK Civil Air Displays*' (the CAA Review) announced on 9 September 2015.

On 28 October 2015 the Civil Aviation Authority (CAA) published Civil Aviation Publication (CAP) 1351 - *'CAA Review of Civil Air Displays: progress report',* setting out the progress it had made in its review to date, and explaining the next steps it would be taking.

On 26 January 2016 the CAA published CAP 1371 - *'UK Civil Air Display Review: Actions that impact on UK civil air displays in 2016'*.

The AAIB investigation of the accident to G-BXFI is an independent process but it has and will continue to inform the CAA Review.

The AAIB recognises that as well as being enjoyed by large numbers of spectators and participants, flying displays are also considered to provide important economic and educational benefits[1]. The sole purpose of an AAIB investigation is to improve aviation safety by determining the causes of accidents and serious incidents to make Safety Recommendations intended to prevent recurrence. It does not therefore consider the balance between those benefits and improvements.

This Special Bulletin considers public protection and safety management at flying displays. A final report will be published in due course.

Fourteen Safety Recommendations are made.

2 Risk management of flying displays

The 2015 annual report of the CAA General Aviation Unit referred to its:

> *'…statutory duties to ensure the safety of those who are affected by GA, not least, third parties on the ground and passengers.'*

Article 162 of the Air Navigation Order (ANO) 2009 states:

> *'…no person may act as the organiser of a flying display (in this article referred to as 'the flying display director') without first obtaining the permission[2] of the CAA for that flying display.'*

Relevant guidance to Flying Display Directors (FDD) and others involved in the organisation of flying displays is provided by the CAA in CAP 403 - '*Flying displays and special events: A guide to safety and administrative arrangements*'. The 13th edition, current at the time of

Footnote

1 Response of the Royal Aeronautical Society to the CAA air display charges consultation, 29 February 2016.
2 Referred to as 'an Article 162 permission' in this Special Bulletin.

the accident to G-BXFI, was published in February 2015 and refers to itself as *'a complete rewrite of CAP 403'.* Its introduction stated:

> *'Participating in or organising flying displays and special events carries a heavy responsibility. Safety is paramount; not only that of the participants, but arguably even more important, that of the spectators, whether paying or not.'*

And:

> *'Displays must be carefully planned both on the ground and in the air and nothing should be considered without careful thought to ensure that it is safe.'*

Air displays may be large events, or part of large events, and involve the hazards associated with any mass participation event. CAP 403 highlights that, in addition to aviation specific safety management, normal event safety management processes should be followed. CAP 403 states:

> *'The information contained in the Health and Safety Executive (HSE) Event Safety Guide – known as the Purple Guide[3] – applies to flying displays.'*

Following an application to hold a flying display the CAA may authorise an individual to be the Flying Display Director (FDD) if it is satisfied that the person is suitable. CAP 403 states that the FDD is '*the person responsible to the CAA for the safe conduct of a flying display*' and:

> *'Before a Permission can be issued, the CAA must be satisfied that: A person is fit and competent as an FDD, having regard in particular to his previous conduct and experience, his organisation, staffing and other arrangements, to safely organise the proposed flying display.'*

When applying to the CAA for a display permission the FDD completes an application form and certifies that the display will be organised in accordance with CAP 403. The application includes a map showing where the FDD intends the 'display line' to be positioned. The display line is a line defining the closest a display aircraft should approach the crowd. Where the display line is not clearly delineated by a paved runway or other obvious line feature it should be marked. When the CAA issues an Article 162 permission it specifies where the display line should be located in relation to spectators at the event but not to others who may be at risk.

In its regulation of general aviation, the CAA uses the hierarchy of protection described in the European Aviation Safety Agency (EASA) GA Safety Strategy. This outlines six stakeholder categories in descending order of priority for protection:

Footnote

3 The Purple Guide is now published by the Event Industry Forum.

> ‘ 1. *Uninvolved third parties*
> 2. *Fare-paying passengers in CAT*[4]
> 3. *Involved third parties (e.g. air show spectators, airport ground workers)*
> 4. *Aerial work participants / air crew involved in aviation as workers*
> 5. *Passengers (“participants”) on non-commercial flights*
> 6. *Private pilots on non-commercial flights’*

In relation to flying displays, this hierarchy accords a higher priority to the uninvolved general public than to air show spectators, who in turn have a higher priority than performers, such as display pilots, who are either Aerial Work participants or private pilots on non-commercial flights.

2.1 Management of the 2015 Shoreham Airshow

The 2015 Shoreham Airshow was organised by a company formed for that purpose. This company leased the aerodrome from the operator of Brighton City Airport (Shoreham) for the period surrounding the displays. The organiser contracted a safety consultancy to produce an Event Plan, an Emergency Response Plan, risk assessments for the ground operations and to liaise with the emergency services. An Emergency Services Group (ESG), comprising members of the local emergency services, the local authority and others, provided comment on the Event Plan and Emergency Response Plan. Elements of the event, other than the flying display, required a licence from the local authority.

The FDD booked the display items, arranged ‘the Article 162 permission’ from the CAA, was responsible for the flying activity, attended the ESG meetings and a ‘table-top’ simulated emergency response exercise, and conducted a risk assessment for the flying display.

2.2 Risk assessments

The Health and Safety Executive (HSE) states that risk assessments should be conducted by a competent person and defines such a person as:

> *‘…someone who has sufficient training and experience or knowledge and other qualities that allow them to assist you properly. The level of competence required will depend on the complexity of the situation.’*

CAP 403 states:

> *‘Displays must be carefully planned both on the ground and in the air and nothing should be considered without careful thought to ensure that it is safe. A risk assessment procedure is included to help in this process.’*

This process was included in Appendix A to CAP 403, which among other things provided tables for deciding levels of severity and likelihood of an occurrence.

Footnote

4 Commercial Air Transport.

The Purple Guide, referred to above, states that organisers should:

> *'Carry out a systematic assessment of the risks to employees, volunteers and the public.'*

Both CAP 403 and the Purple Guide have similar five-step processes which the CAA stated it intended should be conducted by the event organiser.

CAP 403 states:

> ' *1. Identify the hazards associated with activities contributing to the event, where the activities are carried out and how they will be undertaken*
> *2. Identify those at risk and how they may be harmed*
> *3. Identify existing precautions*
> *4. Evaluate the risks*
> *5. Decide what further actions may be required, i.e. mitigation'*

Where identified risks require mitigation the HSE and other safety organisations use a hierarchy of control, as follows:

> ' *1. Elimination (e.g. Remove the hazardous element entirely)*
> *2. Substitution (e.g. Replace the material or process with a less hazardous one)*
> *3. Engineering Controls (e.g. Separate the hazard from others by enclosing or guarding)*
> *4. Administrative Controls (e.g. Use warning signs, briefings and procedures)*
> *5. Personal protective clothes and equipment (Not relevant for this accident)'*

2.3 Risk assessment of the Shoreham flying display

The risk assessment for the flying display element of the 2015 Shoreham Airshow stated, in part:

> *'For the effective safety management of Flying Display Operations at Shoreham RAFA Air Display 2015 it is essential that all Airshow-specific aircraft operation, both on the ground and in the air are assessed and the risk quantified.'*

The risk assessment document listed 10 hazards that had been identified and subject to risk assessment:

> ' ● Airside unauthorised access
> ● Mid-air collision – Display and non-display aircraft
> ● Mid-air collision display formation
> ● Ejector seat impacts crowd
> ● Loss of control due to pilot disorientation
> ● Location road and local built up areas
> ● Public assembly on the A27 and local roads
> ● Aircraft crash outside the airfield boundary
> ● Fast jet collision into crowd area
> ● Fatigue amongst key staff'

Each hazard was considered based on a probability of occurrence and the severity of the consequence. A risk tolerability matrix was then applied which defined the risk associated with each hazard as either:

> ‘
> - *acceptable (may be continued without further reference)*
> - *unacceptable (positive actions must be taken to reduce the risk to an acceptable level before the activity is undertaken)*
> - *review (review must be undertaken at the earliest opportunity in an effort to reduce the risk to an acceptable level)’*

The risk assessment for the 2015 Shoreham Airshow did not show the range of hazards presented by different display aircraft that formed the display and did not consider specifically where the hazards would occur or who would be exposed to them. There was no evidence of an attempt to consider either a hierarchy of protection or control.

CAP 403 stated:

> *‘The simple procedure detailed at Appendix A [to CAP 403] should suit most flying display and Special Events needs.’*

It did not provide detailed guidance on the conduct of risk assessments in relation to flying displays.

Therefore the following Safety Recommendation is made:

> **Safety Recommendation 2016-031**
>
> It is recommended that the Civil Aviation Authority review and publish guidance that is suitable and sufficient to enable the organisers of flying displays to manage the associated risks, including the conduct of risk assessments.

The CAA stated to the AAIB that it is in the process of improving its guidance.

The FDD for the Shoreham display had been responsible for previous flying displays, is a display pilot and Display Authorisation Evaluator (DAE), and was formerly Head of the CAA General Aviation Department. He stated to the AAIB that he believed the risk assessment for the 2015 Shoreham Airshow was compliant with CAP 403, and the CAA had granted an Article 162 permission for the event.

The AAIB commissioned a review, by the Health and Safety Laboratory, of the risk assessment for the 2015 Shoreham Airshow. The review also considered the equivalent risk assessments for the 2013 and 2014 Shoreham Airshows but did not compare these with risk assessments for other flying displays. Its report stated:

> *‘It was found that the Shoreham Airshow Air Display Risk Assessment contained a number of deficiencies compared to what would have been expected for a risk assessment to control risks to the public.’*

And:

> *'It is not clear that those who assessed the risks and recorded the assessment had a full understanding of the purpose of the risk assessment.'*

There is no requirement in CAP 403 for a risk assessment to be submitted to the CAA when applying for approval to hold a display. The CAA informed the AAIB that when considering applications for air displays, and when attending air displays to conduct audits, it did not inspect or request copies of hazard logs or risk assessments.

The FDD of the Shoreham flying display was the FDD at two flying displays after 22 August 2015, for which he applied to the CAA for Article 162 permissions. The risk assessments he presented in support of these applications were not materially different from that for Shoreham. Nevertheless, Article 162 permissions were issued in both cases and the FDD stated that he interpreted this as confirmation these risk assessments were considered fit for purpose.

The CAA is responsible for ensuring that an FDD has the required competencies to manage the safety of the display, amongst other tasks. The CAA stated that:

> *'Currently a FDD is assessed on the basis of the personal knowledge of the CAA's Flight Display Inspector about the individual, his competence and capabilities and any other specific intelligence from prior activities. Also taken into account are the arrangements being made for the flying display…There is currently no written policy document that describes selection criteria for a person in relation to acceptance as a FDD'*

Therefore the following Safety Recommendation is made:

> **Safety Recommendation 2016-032**
>
> It is recommended that the Civil Aviation Authority specify the safety management and other competencies that the organiser of a flying display must demonstrate before obtaining a Permission under Article 162 of the Air Navigation Order.

The CAA stated that it held a workshop as an element of a pre-season symposium in February 2016 as part of its strategy to improve the selection criteria for FDDs.

2.4 CAA enhanced risk assessment

The CAA stated that prior to the accident to G-BXFI it did not require to see risk assessments completed by FDDs.

On 24 August 2015, following the accident to G-BXFI, the CAA instigated an enhanced risk assessment process, to be carried out by CAA assessors. This process was applied to all displays conducted in 2015 after that date and the CAA has stated that it will continue to be applied during the 2016 display season. On 21 January 2016 it provided a copy of this process to the AAIB, with a list of the display sites where additional risks and mitigating actions had been identified since its implementation.

The enhanced risk assessment process required the CAA assessor to focus on the proximity of infrastructure and transport links, such as major roads, to the display line. The CAA stated that this activity relied on information provided by FDDs, including features shown on maps.

There were no site visits and the process did not benefit from local knowledge of the display sites and their surroundings. The enhanced process did not require the assessor to allocate probability or consequence to the identified hazards, as would be expected in a risk assessment, made no reference to a hierarchy of protection or control, and did not consider which groups of people would be exposed to the identified hazards.

Where the CAA's enhanced risk assessment identified a hazard to major roads in close proximity to a site, the stated risk mitigation for those sites was that traffic must be *'actively managed'* to avoid congestion. At the 2015 Shoreham Airshow, traffic management was in place and traffic at the accident site had been flowing. This indicated that traffic management was not an effective risk mitigation.

In some cases the CAA, in issuing an Article 162 permission, changed the position or orientation of a display line. There was no evidence, in these cases, that the CAA or the FDDs for those events, had assessed how this might change the risks involved or who was ultimately responsible for the safety of the chosen line, thereby introducing the potential to confuse the ownership of risk and to diffuse responsibility[5].

Therefore, the following Safety Recommendation is made:

Safety Recommendation 2016-033

It is recommended that the Civil Aviation Authority introduces a process to ensure that the organisers of flying displays have conducted suitable and sufficient risk assessments before a Permission to hold such a display is granted under Article 162 of the Air Navigation Order.

2.5 Identifying where the activity will take place

CAP 403 states that risk assessments should:

> *'Identify the Hazards associated with activities contributing to the event, where the activities are carried out and how they will be undertaken'.*

Footnote

[5] Diffusion of responsibility occurs when responsibility for an action is divided between several individuals or organisations with the result that each assumes another is taking necessary action.

The Shoreham FDD was an experienced display pilot but was not provided with, or was not aware of, the sequence of display manoeuvres that the pilot of G-BXFI intended to perform. Without prior knowledge of G-BXFI's display routine or the ground area over which the pilot intended to perform it, it was not possible for the FDD to identify the specific associated hazards, where the various aerobatic manoeuvres would be conducted, and therefore to determine which groups of people would be exposed to those hazards and to what extent.

The AAIB has explored regulation of flying displays in other countries where there is some regulation of flying display activity. The circumstances in these countries may be different to those in the UK, but they nevertheless provide examples of alternative frameworks. Transport Canada (the aviation regulator in Canada)[6], requires organisers of flying displays to provide the following information at least 10 days before the intended flying display:

> *'sequential listing of all manoeuvres to be flown by the performer, including:*
>
> *(i) the distance of each manoeuvre from spectator areas, including, where applicable, the point of entry into and recovery from each manoeuvre,*
> *(ii) the point of entry to, and departure from, the flying display area, where applicable,*
> *(iii) the directions of flight relative to the spectator areas,*
> *(iv) the location of water drops, pyrotechnics, helicopter rappelling and similar operations relative to the spectator areas,*
> *(v) the maximum and minimum speeds for the entire performance, and*
> *(vi) the minimum altitudes for each manoeuvre to be performed'*

2.6 Accident to Hawker Hurricane G-HURR

Following the accident to Hawker Hurricane, G-HURR, at Shoreham on 15 September 2007, the AAIB issued the following Safety Recommendation[7]:

> **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.

The CAA accepted this recommendation and in its formal response to the AAIB stated that it would amend CAP 403 at Edition 11 as follows:

> *'a) the Flying Display Director during the planning phase of the event will be required to consider and manage pilot display programmes.*

Footnote

[6] Canadian Aviation Regulations (CARs) 2015-1 Standard 623 – Special Flight Operations, Division I Special Aviation Events Chapter One Air Shows.
[7] AAIB Aircraft Accident Report 6/2009.

> *d) the Flying Display Director is charged with circulating, prior to the event a written brief to all participants which will include details of manoeuvres to be flown at the event that are known and have been practised…'*

When published, Edition 11 of CAP 403 did not include that sentence, but stated:

> *'The event organiser and the Flying Display Director will, in particular need to consider and make arrangements for…m) pilot display programmes'*

In Edition 11 and subsequent editions of CAP 403 the phrase '*pilot display programmes*' had replaced the words '*details of manoeuvres*'. The term '*pilot display programmes*' is not defined in CAP 403.

When interviewed during the course of the G-BXFI investigation, the CAA and the 2015 Shoreham FDD interpreted this phrase in different ways. The definitions they provided did not refer to a sequence of manoeuvres.

2.7 Reactive control of flying displays

CAP 403 states:

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

Paragraph 2.10 of CAP 403 states:

> *'It is very strongly recommended that a Flying Control Committee (FCC) is utilised at display of 7 or more items[8]. The roles of the FCC are:*
>
> *a) to assist the FDD in monitoring display standards;*
> *b) to provide specialist knowledge for specific display items; and*
> *c) to offer in-depth opinion in the case of infringement of the regulations.'*

Paragraph 2.14 of CAP 403 states:

> *'The FCC should have the clear authority of the Event Organiser to curtail or stop, on the grounds of safety, any display item or, in extreme cases, the whole flying display.'*

The Article 162 permissions for the 2014 and 2015 Shoreham flying displays included the condition that:

> *'no aircraft shall take part in a Flying Display pursuant to this Permission over any building or vessel which the commander has reason to believe is occupied by persons'*

Footnote

8 An item is a display act which may consist of one or more aircraft flying together.

Furthermore, G-BXFI's Permit to Fly, issued by the CAA included the condition:

> *'The aircraft shall not be flown over any assembly of persons, or any congested area of a city town or settlement…'*

Also, the ANO states:

> *'Congested area' in relation to a city, town or settlement, means any area which is substantially used for residential, industrial, commercial or recreational purposes.'*

Video footage of a previous display of G-BXFI at the 2014 Shoreham Airshow indicated that the majority of the aerobatic manoeuvres (including steeply banked turns) were conducted away from the airfield, over areas accessible to the public and outside the control of the display organisers. Footage and tracks determined from radar data showed that the aircraft overflew residential areas along the A259 south of Shoreham Airport several times and in one manoeuvre overflew the central area of the town of Lancing at an angle of bank in excess of 90°. (Figure 1). The pilot was not instructed to stop this display. Either these regulatory infringements were not detected by the display organisers or were not understood.

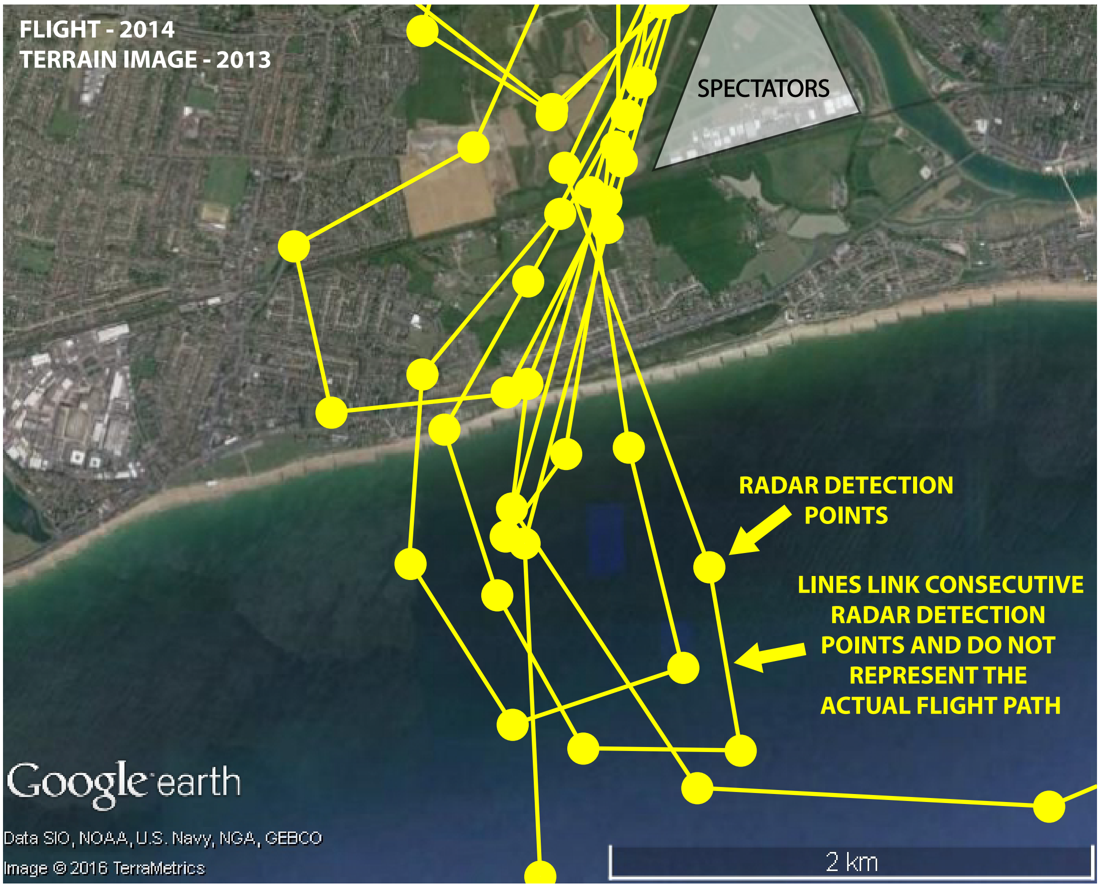


Figure 1

Overflights of congested area by G-BXFI during 2014 Shoreham flying display

2.8 Provision of information to the organisers of flying displays

It is not possible to conduct a comprehensive risk assessment without knowing the intended sequence of manoeuvres and the ground area over which the pilot intends to perform them, and the specific hazards created by each displaying aircraft. Evidence from the 2014 Shoreham display indicated that it was not possible for G-BXFI to complete the intended sequence of manoeuvres while complying with the condition of its Permit to Fly; not to overfly congested areas. Knowledge of its intended routine would have enabled the FDD to determine if its attendance at the flying display was appropriate.

Therefore the following Safety Recommendation is made:

Safety Recommendation 2016-034

It is recommended that the Civil Aviation Authority specify the information that the commander of an aircraft intending to participate in a flying display must provide the organiser, including the sequence of manoeuvres and the ground area over which the pilot intends to perform them, and require that this be done in sufficient time to enable the organiser to conduct and document an effective risk assessment.

The Article 162 permission issued by the CAA allows for a deviation from certain aspects of the Rules of the Air only on the display line and then only as allowed by the individual pilot's Display Authorisation (DA). It does not allow for deviation from the Permit to Fly of the display aircraft either in terms of overflight of normally prohibited areas or of operation outside the aircraft's flight manual.

A sample of flights by other aircraft at the 2015 Shoreham display and elsewhere showed that infringements of this nature were not confined to one aircraft, pilot or venue. A similar issue was previously identified by the Ministry of Defence Service Inquiry into the loss of Hawk XX179 near Bournemouth on 20 August 2011[9]. It found that, during the flying display prior to the accident, at least one aircraft of the Royal Air Force Aerobatic Team had been '*in contravention of extant Regulations governing flight over Congested Areas'*. This was not considered to be a deliberate breach of regulation but due to the pilot believing they were cleared to do so by their display permission. However, they were not and the Service Inquiry commented that '*the societal risks associated with such manoeuvring had not been fully considered*.'

Therefore the following Safety Recommendation is made:

Safety Recommendation 2016-035

It is recommended that the Civil Aviation Authority require operators of Permit to Fly aircraft participating in a flying display to confirm to the organiser of that flying display that the intended sequence of manoeuvres complies with the conditions placed on their aircraft's Permit to Fly.

Footnote

[9] Service Inquiry: accident involving Red Arrows Hawk T Mk1 XX179 near Bournemouth on 20 August 2011 published 18 December 2012.

3 Minimum heights

A pilot's DA states the minimum height at which the holder may fly during a display. The CAA commented that this is intended to be an absolute minimum, not a target. The CAA informed the AAIB that the pilot must comply with the Rules of the Air when not on the display line[10]. Consequently, depending on the aircraft type and length of the display line, the minimum height listed on the pilot's DA might not be achievable over the entire length of the display line, if at all.

In its enhanced risk assessment of flying display sites conducted after the accident to G-BXFI, the CAA referred to *'normal rules of the air'* applying away from the display line as a mitigation related to aircraft overflying roads. The risk assessment for the 2015 Shoreham Airshow identified '*compliance with the Rules of the Air'* as a mitigation for the hazard of an '*Aircraft Crash Outside the Airfield Boundary*'. This information suggests that both the CAA and the Shoreham FDD, separately, assumed that pilots would only descend to their approved minimum height over the display line. The risk assessment appears to have relied upon this protection to manage the risk associated with flight at low heights during the flying display.

European Union Regulation 923/2012 issued on 26 September 2012 sets out the Standardised European Rules of the Air (SERA). Section 3, paragraph 3105 '*Minimum heights*' states:

> *'Except when necessary for take-off or landing, or except by permission from the competent authority, aircraft shall not be flown over the congested areas of cities, towns or settlements or over an open-air assembly of persons, unless at such a height as will permit, in the event of an emergency arising, a landing to be made without undue hazard to persons or property on the surface. The minimum heights for VFR flights shall be those specified in SERA.5005(f)…'*

Section 5 paragraph 5005(f), requires aircraft under Visual Flight Rules (VFR) to be at minimum heights of either 500 ft or 1,000 ft depending on other conditions[11].

The European Aviation Safety Agency '*Acceptable Means of Compliance (AMC) and Guidance Material to the Rules of the Air*' published in July 2013 states:

> *'The permission from the competent authority to fly at lower levels than those stipulated in SERA.5005(f) and SERA.5015(b) may be granted either as a general exemption for unlimited number of cases or for a specific flight upon specific request. The competent authority is responsible for ensuring that the level of safety resulting from such permissions is acceptable.'*

Footnote

[10] Aircraft must *always* comply with the Rules of the Air except in an emergency, and the exemptions available to aircraft participating in flying displays are part of those Rules of the Air. The CAA statement in this context is taken to mean the Rules of the Air that apply other than at flying displays.

[11] 5005(f) states: Except when necessary for take-off or landing, or except by permission from the competent authority, a VFR flight shall not be flown: (1) over the congested areas of cities, towns or settlements or over an open-air assembly of persons at a height less than 300 m (1 000 ft) above the highest obstacle within a radius of 600 m from the aircraft; (2) elsewhere than as specified in (1), at a height less than 150 m (500 ft) above the ground or water, or 150 m (500 ft) above the highest obstacle within a radius of 150 m (500 ft) from the aircraft.

On 13 August 2015[12] the CAA, as the competent authority in the UK, issued '*Official Record Series 4-1124'* (ORS4-1124) relating to SERA. It stated in paragraph 4:

> *'Flying Displays, Air Races and Contests*
>
> *The Civil Aviation Authority permits, under SERA.3105 and SERA.5005(f), an aircraft taking part in a flying display, air race or contest to fly below 150 metres (500 feet) above the ground or water or closer than 150 metres (500 feet) to any person, vessel, vehicle or structure if it is within a horizontal distance of 1,000 metres of the gathering of persons assembled to witness the event.'*

The effect of this exemption to the low flying rules for aircraft taking part in displays is to remove the minimum height and separation requirements within 1,000 metres (1 km) of the event.

The EASA AMC requires the competent authority to ensure that the resulting level of safety is acceptable. The CAA has not provided any risk assessments or other relevant documentation to support its decision to issue the exemption, but stated:

> *'Rule 5 and Rule 6 of the Rules of the Air Regulation 2007 were the relevant rules in place in the UK prior to the publication and implementation of the SERA rules. These rules had been in place since at least 1996 and there was no evidence to suggest that these rules were inherently unsafe.'*

In August 2005 a glider (BGA 4665), involved in an air race in Leicestershire, struck and fatally injured a person standing outside the boundary of the aerodrome at which it was operating. The AAIB report[13] stated:

> *'the root cause was the practice of flying too low outside the confines of the airfield and resorting to pop-up manoeuvres to clear obstacles.'*

Five Safety Recommendations were made, including the following:

> **Safety Recommendation 2006-120**
>
> The Civil Aviation Authority should clarify and publicise whether permission from the Authority is required before exemption from the 500 feet low-flying rule in accordance with Rule 5 (3)(f) is applicable.

In an interim response, in April 2007, the CAA indicated that it accepted this Safety Recommendation stating:

> *'the CAA intends to change Rule 5 (3)(f) as it is unsatisfactory in its present form.'*

Footnote

[12] Although the ORS exemption was issued in August 2015 this continued a previous UK derogation from the EU standards.
[13] Glider BGA 4665, published in AAIB Bulletin 2/2007.

However, Rule 5(3)(f) was not changed until superseded by the SERA, and the permission in ORS4-1124 has the same effect as Rule 5(3)(f). Consequently the regulations currently in force do not reflect the view that aircraft must comply with the *'normal rules of the air'* when not on the display line. Therefore the following Safety Recommendation is made:

Safety Recommendation 2016-036

It is recommended that the Civil Aviation Authority remove the general exemptions to flight at minimum heights issued for Flying Displays, Air Races and Contests outlined in Official Record Series 4-1124 and specify the boundaries of a flying display within which any Permission applies.

4 Regulatory oversight

4.1 Accident rates at flying displays

The CAA does not define a target acceptable level of safety[14] for UK air displays. Although it records and monitors all accidents it does not monitor the accident rate for display flying, the number of display items or the number of hours flown by civil display aircraft in any year. It estimated that the overall UK general aviation fatal accident rate between 2005 and 2014, including display flying, was approximately 1.5 fatal accidents per 100,000 flying hours.

CAA records show that in 2015 there were 254 'Article 162 permissions' granted. These included approximately 1,480 individual civil display items[15].

There were two fatal accidents at organised displays in 2015, however, considering a longer period and assuming the planned 2015 activity was typical[16] there has been 1 fatal accident per 2,960 display items in the period 2008 to 2015.

The International Council of Air Shows (ICAS), the flying display industry body in the United States of America (USA) and Canada, estimated that in the USA the civil air display accident rate is 1 fatal accident per 5,600 display items[17].

The AAIB has estimated the fatal accident rate in the UK, expressed in hours, by assuming that a display item has an average duration of 8 minutes.

Over the ten years to the end of 2015 there were nine display accidents in which the aircraft was destroyed and either a fatal or serious injury resulted. This equates to one such accident per 219 display hours or 456 such accidents per 100,000 flying hours of which historically 55% have involved fatalities.

Footnote

[14] Acceptable level of safety is a safety management concept which '*provides the minimum safety objective acceptable to the oversight authority to be achieved by operators.*'
[15] This included 1,730 items approved at civil displays minus approximately 250 UK military items at civil air displays. It was not possible to correct for foreign military or items approved but which did not perform due to weather, technical failure or other reasons.
[16] The average number of Article 162 displays for each of the previous 6 years was 235.
[17] ICAS estimate for the period 2008-2015, excluding parachutists, wing walkers, military and air races.

65% of UK display accidents involved the aircraft crashing outside the area controlled by the organisers of the display. This equates, at 2015 levels of activity, to one display aircraft crash in an area accessible to the public every 1.7 years.

4.2 Accident rates for GA activities other than flying displays

The CAA publishes a General Aviation policy framework which includes the following statement:

> *'A series of questions have been developed to ensure that we minimise the risks to those we are required to protect; that our regulation is consistent; and that we do not gold-plating European regulations. We are focused primarily on protecting third parties from risks associated with GA activities, whilst enabling GA participants to manage their own risks[18].'*

The policy framework is designed for considering changes to existing legislation and includes at Annex B a risk matrix to assist in decision-making. This states that an event that is likely to happen more often than once per 100,000 operational hours is '*probable'* and an event that involves '*multiple deaths, usually with the loss of the aircraft*' is considered '*catastrophic'*. Risks of this nature are considered to be '*high / unacceptable*' and the policy framework states *'if such a risk is at a high level using the criteria in Annex B, STOP*'.

5 Air display separation distances

5.1 UK air display separation distances

CAP 403 states the minimum separation distances required between the crowd line and relevant display line based on the speed of the displaying aircraft (see Table 1). These separation distances have been unchanged for several years.

AIRCRAFT SPEED	CAA	FAA
Less than 100 kt	100 m	152 m
100 - 200 kt	150 m	152 m till 156 kt then 304 m
200 - 300 kt	200 m	304 m to 245 kt then 457 m
Above 300 kt	230 m	457 m

Table 1

UK and US separation distances.

The CAA commissioned a study in 1993 to assist it in determining if the distances in CAP 403 were appropriate (referred to here as the 1993 Study[19]).

The 1993 Study considered a structural failure, during a display flight, of two different aircraft types: a fast jet travelling at 350 kt and a single piston-engined aircraft travelling at 100 kt. Computer modelling predicted the distance that debris would travel until the debris reached

Footnote

[18] http://www.caa.co.uk/General-aviation/Safety-information/General-Aviation-Policy-Framework/ Accessed Jan 2016.

[19] Airshow Separation Distances, Cranfield Aviation Safety Centre, July 1993.

a height of 5 feet above the surface. No allowance was made for the aircraft being in anything other than level flight[20]. The modelling assumed each aircraft was making a level, 4G turn onto its respective display line, separated from the crowd by the relevant distance shown in CAP 403. Table 1 shows these distances.

The Study concluded that:

> *'The current issue of CAP 403[21], 'Flying Displays: A Guide to Safety and Administrative Arrangements', reference 2, includes regulations concerning minimum crowd line to display axis distances that are well judged and for the majority of conditions appear to offer a sensible compromise between airshow attractiveness and safety'*

The study did not determine the likely number or severity of casualties. It showed that in the circumstances considered, and in the case of both types of aircraft, substantial pieces of wreckage such as engines would cross the crowd line. In the case of the fast jet aircraft it was predicted that the engine(s) would enter the crowd area by at least 130 m. (Figure 2).

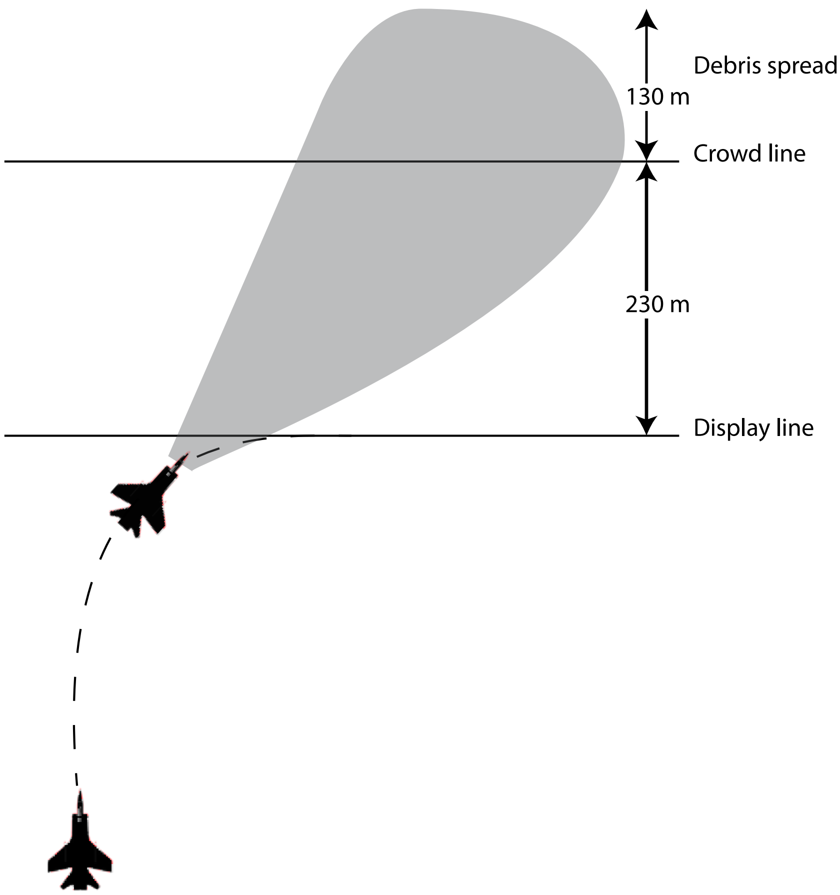


Figure 2

Debris modelling based on the 1993 Study

Footnote

[20] As an aircraft flightpath increases towards 45° above the horizon any debris or accidentally released component, such as a drop-tank, will travel further.

[21] Current at that time.

A CAA Air Display Review, conducted in 1996, considered the 1993 Study to be '*generally supportive*' of the existing crowd separation distances and no changes were made.

5.2 Alternative modelling

The FAA requires different separation distances based on a wreckage scatter pattern model. This results in minimum crowd separation distances, for aerobatics in fast jet aircraft, which are approximately double the current UK standards (see Table 1). UK distances are based on the aircraft's speed at that moment, which varies during the display, whereas FAA distances are based on a set speed category, simplifying the monitoring of compliance.

Alternative, more sophisticated, wreckage scatter pattern models have been developed by special event organisers. Those for military range safety and civil spaceflight purposes involve injury prediction.

5.3 On-crowd energy

The UK Military Aviation Authority (MAA) requires a minimum separation distance of 450 m for military fast jet aircraft participating in air displays with a flightpath toward the crowd[22]. NATO, Transport Canada and Australia's Civil Aviation Safety Authority use similar minimums (see Figure 3). The FAA does not permit fast jet displays by civil operators to have on-crowd energy vectors for aerobatic flight.

In 2015, before the accident to G-BXFI, the MAA commissioned an external consultancy to review its flying display separation distances and develop models and tools relevant to its current aircraft. This review has not yet reported.

In 2012 the AAIB investigated the accident to North American Rockwell OV-10B Bronco, G-BZGK, which occurred during a display practice. Control of the aircraft was lost during a rolling manoeuvre that started parallel to the planned crowd line and resulted in a flightpath towards the crowd area before the aircraft struck the ground. Although the aircraft crashed outside the crowd area large parts of it, including the fuselage and engines, crossed the crowd line. In otherwise identical circumstances they would not have crossed a crowd line determined to US separation distances.

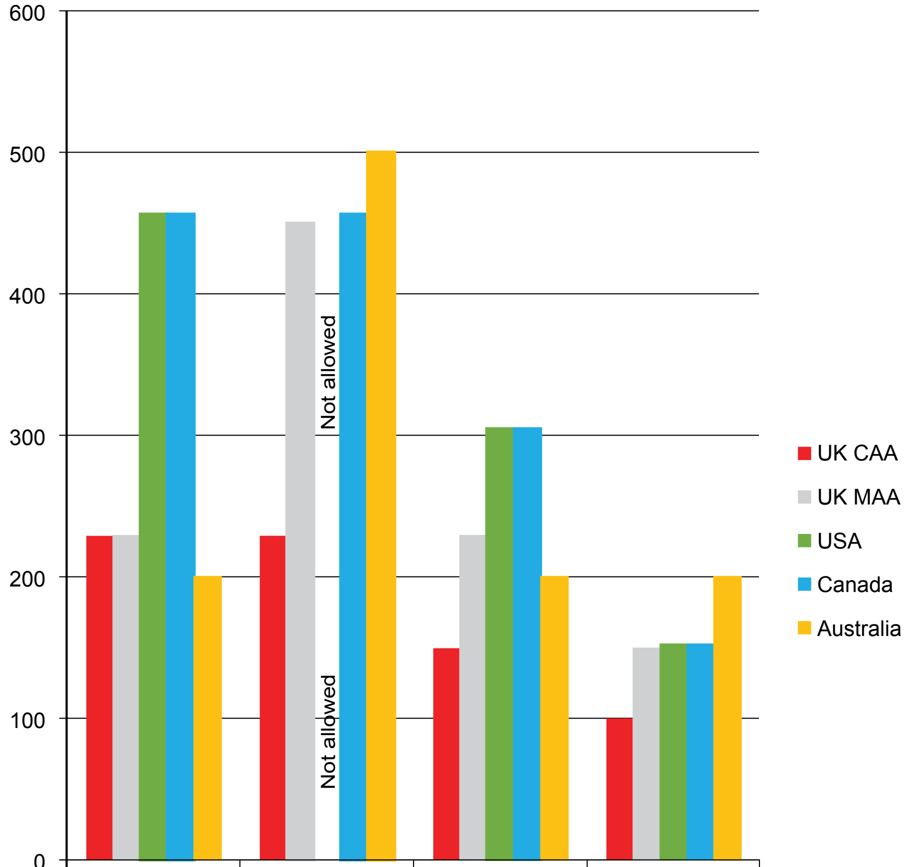
The CAA-commissioned 1993 Study, the FAA model and aircraft accident experience all show that the current UK civil separation distances will not always protect the crowd. Therefore, the following Safety Recommendation is made:

Safety Recommendation 2016-037

It is recommended that the Civil Aviation Authority require that displaying aircraft are separated from the public by a sufficient distance to minimise the risk of injury to the public in the event of an accident to the displaying aircraft.

Footnote

22 Sometimes referred to as on-crowd energy or an on-crowd energy vector.



	Fast Parallel	Fast on-crowd	Medium	Slow
UK CAA	230	230	150	100
UK MAA	230	450	230	150
USA	457	Not allowed	304	152
Canada	457	457	304	152
Australia	200	500	200	200

Figure 3

Comparative air display separation distances in metres

5.4 Non-participant third-parties and secondary crowds

Fatalities occurred when G-BXFI impacted the ground in an area which was open to the public, involving those who had stopped at the junction of the A27 and Old Shoreham Road to view the flying display and those who were passing by on the A27. CAP 403 requires display organisers to consider:

> *'The proximity of congested areas, particularly if they include schools or hospitals.'*

It also states:

> *'At many events… the congregation of spectators, outside the airfield boundary, on the live-side may give organisers cause for concern…it is recommended that the event organiser anticipates this during the planning process and takes necessary steps to reduce it by, where possible blocking the view from obvious vantage points.'*

CAP 403 makes no explicit safety provision for the public who choose to view a flying display from an area that is not part of the official crowd area, other than to advise they be discouraged as stated above. Conversely, the FAA requires that organisers separate the display and secondary spectator areas. These are defined in the FAA FSIMS 8900 Section 33 as follows:

> *'Secondary Spectator Areas: Any area, not designated as a primary spectator area, where people have a natural tendency to gather to observe the event. This includes, but is not limited to, private property or property not under the control of the event organizer, public roads and private access roads.'*[23]

The 2015 Shoreham Airshow organisers knew that the junction of the A27 was a popular location from which to view the display. The AAIB was informed that in previous years several hundred people had been observed at this road junction and in the grounds of a nearby, now closed, public house. The display organisers and the local emergency services had been concerned about the road traffic risk to these crowds and the display organisers had taken steps to minimise the number of people in this area.

The same arrangements had been in place for several years and had restricted the view of the airfield, placed various signs in the area[24] (Figure 4) and used stewards to ask people to move on. However, neither the organisers nor the police had requested or been granted the legal power to prevent people from being in this area and their efforts did not prevent a gathering at the A27 junction.

Figure 4

Sign at A27 / Old Shoreham Road junction

Footnote

23 Unlike the primary crowd area permission may be given for display aircraft to overfly the secondary crowd area if at height of more than 500 ft with wings-level and climbing.

24 It is believed that the sign wording had been agreed with the West Sussex Police Emergency Planning Officer at least five years previously.

Discouraging spectators from congregating in certain areas outside the airfield has been unsuccessful and therefore cannot be relied upon as an effective risk mitigation measure. The enhanced risk assessment process introduced by the CAA, following the accident to G-BXFI, acknowledges the problem of secondary crowds however, the efficacy of this approach is doubtful as the Shoreham display organisers were already taking action in relation to an area that was well known to involve crowds. Had FAA style protection of a secondary crowd area been imposed then G-BXFI would not have been permitted to display in this area. Therefore the following Safety Recommendation is made:

Safety Recommendation 2016-038

It is recommended that the Civil Aviation Authority specify the minimum separation distances between secondary crowd areas and displaying aircraft before issuing a Permission under Article 162 of the Air Navigation Order.

5.5 Non-participant third parties

The CAA's risk hierarchy designates uninvolved third parties as being the most protected group. However, at many locations display-line to crowd-line separation distances result in the aircraft, and thus the associated risk, being moved away from spectators and towards non-participant public. This appears at odds with the CAA risk hierarchy by transferring risk towards the non-participant. Without the provision of additional protections, any increase in the current CAP 403 distances might further reduce safety for non-participants. Therefore it is necessary for the display aircraft to remain safely clear of these non-participant public locations and above a height at which they will not present a hazard to those on the ground.

Both the FAA and Transport Canada require that flying display-related aerobatic flight, below normal heights[25], must be conducted within a designated volume of airspace known in Canada as a '*flying display area'* or in the USA as an '*aerobatic box'*. The UK does not require a specific minimum height for aerobatics, whether display related or not. The Canadian requirements are set out in CAR 20151 Standard 623 as:

'(a) *the certificate holder has control of the property that underlies the airspace of the flying display area;*
(b) *the property underlying the flying display area is kept clear of all persons other than essential personnel;*
(c) *buildings inside a flying display area that are normally occupied by nonessential personnel are kept vacant during the execution of a flight program; and*
(d) *access roads that lead to property underlying the flying display area are blocked by crowd control personnel'*

In this way the Transport Canada and FAA systems seek to protect the area below displaying aircraft.

Footnote

25 The FAA prohibits aerobatic flight below 1,500 ft agl, Transport Canada prohibits aerobatic flight below 2,000 ft agl.

If an aerobatic flying display area had been defined at Shoreham the looping and rolling manoeuvre conducted by G-BXFI could have been required to remain within it. Alternatively if, during the planning stage, it was identified that the aerobatic elements of the proposed display by G-BXFI could not be completed within that box there would have been an opportunity to refuse or modify its display.

Therefore the following Safety Recommendation is made:

Safety Recommendation 2016-039

It is recommended that the Civil Aviation Authority require the organisers of flying displays to designate a volume of airspace for aerobatics and ensure that there are no non-essential personnel, or occupied structures, vehicles or vessels beneath it.

6 Pilot standards

Flying displays may place aircraft in proximity with crowds and congested areas. Although display separation distances can offer some protection from aircraft that break-up in flight they offer reduced protection against loss of control. Therefore, it is important that pilots achieve and maintain the appropriate competence.

6.1 Conflicts of interest

In 2014 the pilot of G-BXFI was evaluated in relation to his Display Authorisation (DA) by a member of the same display team. This was also the case for the pilot involved in the 2015 fatal accident to Folland Gnat T.Mk1 G-TIMM[26] at a flying display at Oulton Park, Cheshire.

EASA regulation and CAA policy for examiners in areas other than display flying requires the examiner to avoid any potential conflict of interest in their role.

For example, CAA Standards Doc 24(A) Version 2 '*Policy and Guidance for Examiners*' states, at section 5.1:

> *'Examiners shall not conduct skill tests or assessments of competence of applicants for the issue of a licence, rating or certificate to whom they have provided flight instruction for the licence, rating or certificate for which the skill test or assessment of competence is being taken or when they have been responsible for the recommendation for the skill test, in accordance with FCL.030(b). Examiners shall not conduct skill test, proficiency checks or assessments of competence whenever they feel that their objectivity may be affected". Examples of situation [sic] where the examiner should consider if his objectivity is affected are when the applicant is a relative or a friend of the examiner, or when they are linked by economical interests / political affiliations etc…'*

Footnote

[26] The fatal accident to G-TIMM is being investigated separately, a report of which will be published in due course.

Also, CAP 804 - *'Flight Crew Licensing'* Part 1, Part F - '*Skill Tests*' states:

> *'1 Where applicants for a Part-FCL or UK National Licence or a rating to be included in a licence are required to pass a Skill Test, this shall be with an appropriately qualified Flight Examiner. With the exception of skill test for Microlight privileges and other NPPL privileges, examiners shall not test applicants to whom they have given more than 25% of the flight instruction for the qualification applied for.'*

In the USA and Canada the Aerobatic Competence Examiner (ACE) system is administered by industry body ICAS rather than by the regulators. The ICAS ACE manual Version 8 (dated April 1 2015), requires examiners to:

> *'Confirm that the applicant is not a family member, team member, employee, aerobatic student, or an individual being mentored by, and/or who may have a financial involvement with, the ACE who has been asked to conduct the evaluation. Although ACEs are authorized to make these determinations themselves, ICAS urges evaluators to err on the side of not conducting the evaluation if there may be even an appearance of a conflict of interest. If an ACE believes that he/she requires some independent assessment on this issue, he/she is urged to contact ICAS headquarters. The headquarters staff will be directed to also err on the side of avoiding even the perception of a possible conflict of interest when making these determinations.'*

The CAA stated:

> *'The flying display community in the UK is a small group of individuals who are often well known to each other and the potential for conflicts of interests will always exist to some degree.'*

Therefore the following Safety Recommendation is made:

> **Safety Recommendation 2016-040**
>
> It is recommended that the Civil Aviation Authority require Display Authorisation Evaluators to have no conflicts of interest in relation to the candidates they evaluate.

6.2 Maintaining pilot competence

Many display pilots either fly, or have flown, multiple types or classes of aircraft. Renewal of a DA on one type or class of aircraft renews the DA on all the types that the pilot's DA has listed. Therefore a display pilot may be assessed to renew their DA on singleengined piston aeroplanes and this would also renew their DA for a fast jet that they had not flown for several years. There can be significant differences in flying techniques and in particular energy management, between different types or classes of aircraft. This policy is different from common CAA aviation practice where a proficiency check for one type or class is only valid for that type or class and pilots must therefore be assessed separately for aircraft requiring different flying techniques. The pilot of G-BXFI had last renewed his DA in a different aircraft type. Therefore the following Safety Recommendation is made:

Safety Recommendation 2016-041

It is recommended that the Civil Aviation Authority require a Display Authorisation to be renewed for each class or type of aircraft the holder intends to operate during the validity of that renewal.

CAP 403 states:

> *'The FCC should have the clear authority of the Event Organiser to curtail or stop, on the grounds of safety, any display item or, in extreme cases, the whole flying display.'*

The CAA does not require that these occurrences should be reported or investigated, and where it is made aware of them it does not record them formally or report on them. It stated that:

> *'Matters of concern for FDDs and display pilots are often discussed informally with the CAA. Furthermore, FDDs and display pilots have the opportunity to discuss specific or general concerns at the post-season display symposium.'*

The purpose of occurrence reporting is to improve aviation safety by ensuring that relevant safety information relating to civil aviation is reported, collected, stored, protected, exchanged, disseminated and analysed. At the time of the accident this function was performed in the UK by the Mandatory Occurrence Reporting Scheme. Since November 2015 occurrence reporting in the UK and the rest of Europe has been governed by Regulation (EU) No 376/2014. It defines an occurrence as:

> *'Any safety-related event which endangers or which, if not corrected or addressed, could endanger an aircraft, its occupants or any other person and includes in particular any accident or serious incident;'*

Commission Implementing Regulation (EU) 2015/1018 lists reportable occurrences, but does not specify those relating to flying displays. Therefore the following Safety Recommendation is made:

Safety Recommendation 2016-042

It is recommended that the Civil Aviation Authority publish a list of occurrences at flying displays, such as 'stop calls', that should be reported to it, and seek to have this list included in documentation relevant to Regulation (EU) No 376/2014.

The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996 specify the duty to report certain occurrences, including serious incidents, to the AAIB. The Annex to Regulation (EU) No 996/2010 – *'on the investigation and prevention of accidents and incidents in civil aviation',* lists examples of serious incidents, including:

> *'a near collision requiring an avoidance manoeuvre to avoid a collision or an unsafe situation or when an avoidance action would have been appropriate.'*

In 2014 a display by the pilot of G-BXFI, in another aircraft type and at a different venue, was stopped by the FDD of that display following concerns about the execution of a manoeuvre. A CAA Flight Standards Officer (FSO) was present but did not witness the occurrence.

Following an informal discussion with the pilot later that day the CAA took no further action and did not formally record the occurrence. The occurrence was not otherwise investigated and was not reported to the AAIB. It may not have been apparent to those involved that the duty to report could apply to such occurrences at flying displays or they may have concluded that this occurrence was not reportable. Nevertheless, the occurrence could have provided an opportunity to explore the pilot's continued competence.

The FAA publishes a relevant policy:

> *'When an airshow performer is involved in an accident or incident that occurs during any portion of an airshow routine at a public aviation event,… the performer's competency to hold a Statement of Acrobatic Competency is in doubt.*
>
> *Rescission of FAA Form 8710-7. If the incident that gave reason to doubt the airman's competency is of a serious nature, it may be necessary to immediately rescind the performer's FAA Form 8710-7 pending reevaluation.*
>
> 1) *Any incident that occurs during any portion of an airshow routine that directly threatens the safety and well-being of spectators, regardless of damage or injury, shall be grounds to rescind a performer's FAA Form 8710-7.*
>
> 2) *Any incident that occurs during any portion of an airshow routine that arises from flagrant and willful disregard for FAA safety rules and policy and/or when a performer exhibits an attitude of recidivism concerning FAA safety rules and policy shall also be grounds to rescind a performer's FAA Form 8710-7.*
>
> 3) *Concerning accidents or incidents at air shows, the FSDO that issued the FAA Form 7711-1 for the event shall immediately rescind the performer's FAA Form 8710-7. It is important that this be completed before the next opportunity for the performer to perform at a public event.'*

If a pilot's approval is revoked, the industry body ICAS requires that the examiner committee will appoint the examiner and that:

> *'In all cases, the ACE Committee will ensure that the designated ACE is not the ACE who had previously evaluated the applicant.'*

The CAA has no equivalent written policy or formal process. Therefore the following Safety Recommendation is made.

> **Safety Recommendation 2016-043**
>
> It is recommended that the Civil Aviation Authority introduce a process to immediately suspend the Display Authorisation of a pilot whose competence is in doubt, pending investigation of *the occurrence and if appropriate r*eevaluation by a Display Authorisation Evaluator who was not involved in its issue or renewal.

6.3 Monitoring of safety standards

CAP 403 states:

> *'The CAA GA Unit is required to inspect and monitor safety standards at a number of events annually.'*

On 28 October 2015 the CAA published CAP1351 - 'CAA Review of *Civil Air Displays: progress report', which stated that:*

> *'CAA experts visit a significant number of air displays each year to:*
>
> - *monitor safety standards*
> - *confirm the rules are being complied with*
> - *identify measures that might further enhance safety standards'*

The CAA informed the AAIB that in 2014 it gave permission for 281 displays and attended 4 of them (1.4%)[27]. In 2015 the CAA attended 18 of the 254 displays (7.1%).

By comparison, regulatory staff of the US Federal Aviation Administration (FAA) attend every authorised display[28]. The FAA states that:

> *'The inspector's responsibility is to provide adequate safety oversight of the aviation event and to ensure compliance with the provisions of the waiver or authorization* [sic].*'*

Footnote

[27] The CAA provided evidence of having attended a fifth event, which was a model flying display.

[28] The FAA occasionally waives this requirement, in specific circumstances, generally for fewer than 10 events each year.

Determining the appropriate level of regulatory oversight of an activity requires an understanding of the level of risk it presents. Therefore the following Safety Recommendation is made:

Safety Recommendation 2016-044

It is recommended that the Civil Aviation Authority establish and publish target safety indicators for United Kingdom civil display flying.

7 Further investigation

The AAIB continues to investigate the accident to G-BXFI and will report any significant developments as this progresses.

Published 10 March 2016

AAIB Field Investigation Reports

A Field Investigation is an independent investigation in which AAIB investigators collect, record and analyse evidence.

The process may include, attending the scene of the accident or serious incident; interviewing witnesses; reviewing documents, procedures and practices; examining aircraft wreckage or components; and analysing recorded data.

The investigation, which can take a number of months to complete, will conclude with a published report.

SERIOUS INCIDENT

Aircraft Type and Registration:	Airbus A319-111, G-EZAA
No & Type of Engines:	2 CFM56-5B5/P turbofan engines
Year of Manufacture:	2006 (Serial no: 2677)
Date & Time (UTC):	25 June 2015 at 1812 hrs
Location:	Belfast Aldergrove Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 156
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	33 years
Commander's Flying Experience:	7,400 hours (of which 4,000 were on type) Last 90 days - 250 hours Last 28 days - 90 hours
Information Source:	AAIB Field Investigation

Synopsis

The flight crew planned to perform a takeoff from Runway 25 using Intersection Bravo at Belfast Aldergrove Airport. The initial performance figures, calculated using the Electronic Flight Bag (EFB), were computed for a wet runway; this produced a full power thrust setting. Just before pushback, as the runway was dry, the crew elected to change the runway state on the EFB from wet to dry to see if this would produce a reduced engine thrust setting, which it did.

During the takeoff roll, as the end of the runway became visible at about 115 kt, the commander felt that a rejected takeoff would not provide sufficient stopping distance and thus became 'Go' minded. The aircraft subsequently became airborne with about 200 m of runway remaining.

After departure, analysis by the crew revealed that an incorrect runway was used to calculate the dry runway performance figures, resulting in erroneous figures being generated. The reason for this could not be confirmed but subsequent investigations revealed that in one scenario, an involuntary runway change could occur on the EFB. This anomaly was not known by the operator or manufacturer at the time of the event and is likely to have been the reason for the incorrect runway selection. These figures were not identified as erroneous and were subsequently used for takeoff.

History of the flight

The flight crew were scheduled to fly from Belfast Aldergrove Airport to Luton Airport. The co-pilot was the Pilot Flying (PF) and the commander was the Pilot Monitoring (PM) for the sector.

In preparation for the sector the commander entered the available data into his EFB. This included the meteorological data recorded from the ATIS, the runway for departure (Runway 25 from Intersection Bravo) and the flap setting for takeoff (FLAP 1+F)[1]. At this point he selected a WET runway, from the drop-down menu as, despite the runway appearing to be dry, there were showers in the vicinity. He did this to account for a possible degradation in the weather conditions. The crew recorded ATIS Information Alpha, issued at 1720 hrs, which stated: wind was from 160° at 12 kt, the visibility was in excess of 10 km, the temperature was 17°C, the dew point 15°C and the QNH 1015 hPa.

Prior to pushback the crew reviewed the performance inputs made into the EFB in accordance with the operator's standard operating procedures (SOPs). So that the co-pilot could have a clearer view, the commander removed his EFB from its stowage, by his left window, and placed it on his table in front of him. At this point the co-pilot noticed that the computed engine thrust setting was TOGA[2]/full power. As the runway was dry, and was forecast to remain so, the crew agreed to see if selecting a DRY runway would give a FLEX[3]/reduced engine thrust takeoff. The commander changed the runway condition box from WET to DRY, using the drop-down menu, with the co-pilot monitoring his actions, and then pressed COMPUTE. The new performance figures produced a FLEX takeoff as expected. After mentally assessing the generated speeds to see if they appeared sensible, they were input into the Flight Management and Guidance Computer (FMGC). As a gross error check the crew crosschecked the 'Green Dot' speed[4] and the engine out acceleration altitude in the FMGC with the EFB, but they did not conduct an independent review of all the EFB performance figure entries. The aircraft was then pushed back, and taxied out to Intersection Bravo of Runway 25 (Runway 25B).

The end of the runway is not visible from the start of the takeoff roll, due to a hump. Consequently, the commander became visible with the end of the runway at about 115 kt. Although the aircraft's acceleration appeared normal after takeoff thrust was set, it became apparent to him that, should there be a requirement to discontinue the takeoff at the calculated V_1 speed of 130 kt, there would be insufficient stopping distance available. He therefore committed to continuing the takeoff. At this point he believed there was an error in the entry of V_1 into the FMGC. He continued to monitor the aircraft's performance and satisfied himself that there was sufficient runway remaining for the aircraft to accelerate, rotate and take off at the calculated speeds. He also planned that, had there been an engine problem during the takeoff roll, he would have selected TOGA and taken control, rotating within the paved surface. He decided to maintain the FLEX thrust to avoid distracting the co-pilot.

Footnote

1 1+F represents slat extension and one stage of flap.
2 TOGA stands for Take Off and Go Around thrust.
3 FLEX is a reduced thrust setting used for takeoff.
4 Minimum clean manoeuvring speed.

The commander estimated that he called to "rotate" approximately 600-700m before the end of the runway with the aircraft becoming airborne soon thereafter. The rest of the departure was uneventful with the crew briefly acknowledging that something was likely to have been incorrect with the performance figures.

Later in the flight the commander opened his EFB to try to determine what may have been incorrect. He was surprised to notice that Runway 07 was in the runway drop-down box.

The following morning the commander completed a company Air Safety Report (ASR) having telephoned his Flight Data Monitoring Manager (FDMM) to obtain the actual takeoff speeds input into the FMGC. The FDMM informed the commander that there would be a company investigation into the event. After a review of recent ASRs on 7 July 2015, by the operator's management board, the event was notified to the AAIB.

Operator's manuals

The operator's Operations Manual Part B (OMB) Section 4.3 *AUTOMATION AND AIRBUS FLYSMART* and OMB Section 2.3.7 *Before Pushback or Start* contain guidance to crews on the processes in relation to this phase of flight.

OMB in Section 2.3.7, *Before Pushback or Start* states:

'TAKE-OFF DATA............................PREPARE AND CHECK/REVISE

When the load form has been received the PM performs the Computation of the take-off data. The expected or most likely take-off position should be used but it is acceptable to prepare a contingency set of data for an alternative position, e.g. an intersection.…Config [configuration] 1 + F is preferred for normal operations…The PF crosschecks all data, and specifically the displayed RWY [runway] Length in the EFB against the Aerodrome airport chart, and reviews the results noting the limiting codes…The PF reads the speeds, Take-off Runway, Config, trim setting and flex temperature if applicable, followed by the ENG OUT ACC altitude.

The PM inserts and verifies the data in the FMGS amending the THR RED [thrust reduction] altitude if necessary so that it is not less than the ENG OUT ACC [engine out acceleration] altitude and then calls out the green dot speed. The PF crosschecks this against the EFB as a gross error check.'

Additionally:

4.3 AUTOMATION AND AIRBUS FLYSMART

…Compared with paper, the risk of calculation errors with Flysmart is generally greatly reduced.

The consistency of various input parameters is checked by the system, but it can not detect all errors. Guard against erroneous input errors, as these are unlikely to be detected by the software. Input errors will lead to output errors, *with their associated risk. A careful check of the consistency of the results by the Flight Crew is very important. With single point performance calculations there is no visibility of the performance trend, so anomalous results may not appear out of place.*

Consider using the input fields of the Flysmart as you would a checklist. If you have been distracted during the input sequence to a performance calculation consider starting from the beginning once again. Take particular care when specific input parameters have changed due to rapidly changing ambient conditions, or airport/ATC environment, e.g. late offer of intersection departure or different departure runway.

Take particular care when Modify RWY [runway]*…have been used to make modifications to the runway or aeroplane configuration, and that they are applied correctly or indeed removed if appropriate. This is particularly the case when the Inop* [Inoperative] *Item Selection has been sent directly from the MEL* [minimum equipment list]*.*

…

Recheck the outputs using logical checks, e.g. is this take-off weight sensible for this length of runway? Are these speeds consistent with my actual take-off weight?'

The operator introduced EFBs and their associated SOPs, to their specific operation requirements, in 2003 which was accepted by the CAA. The aircraft manufacturer's recommended SOPs, introduced subsequently, are that each flight crew perform an independent calculation of the takeoff performance data which is then cross-checked. These were reviewed by the operator but they considered that their own SOPs were more appropriate for their own operational requirements.

Airfield information

The following table shows the declared lengths of the Runway 07/25 at Belfast Aldergrove Airport. The AIP chart is shown in Figure 1.

Runway designator	Takeoff Run Available (TORA)	Takeoff Distance Available (TODA)	Accelerate-Stop Distance (ASDA)
07	2,780 m	3,073 m	2,780 m
25	2,780 m	3,179 m	2,780 m
25B	1,607 m	2,006 m	1,607 m

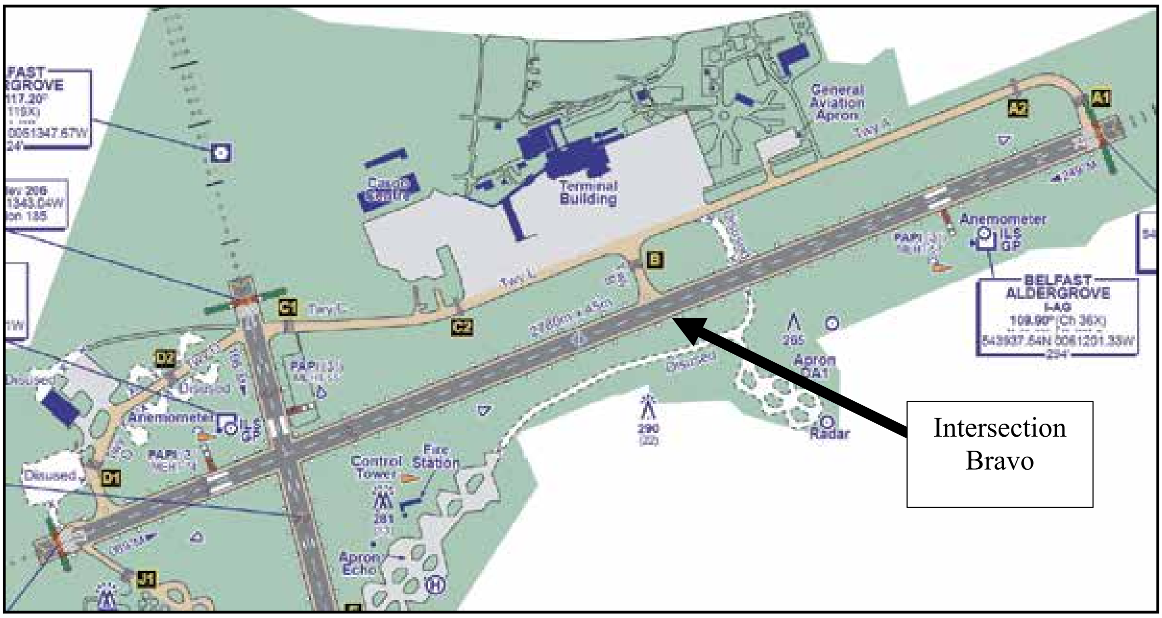


Figure 1

Extract from Belfast Aldergrove AIP Aerodrome Chart

Takeoff performance

Reduced thrust takeoff

On this aircraft type, the takeoff power can be adjusted by entering an artificial outside air temperature (OAT) into the FMGS. When the thrust levers are advanced to the FLX/MCT (FLEX / Maximum Continuous Thrust) position, the FADEC controls the thrust rating in accordance with the FLEX takeoff temperature that the crew has entered. The higher the FLEX temperature used, the lower the thrust generated.

Flight crew recollection

The aircraft takeoff mass used for the EFB calculations was 58.6 tonnes. From the flight crew recollection, the EFB takeoff performance figures calculated based on the recorded meteorological conditions were:

Runway	Runway condition	V_1 (kt)[1]	V_R (kt)[2]	V_2 (kt)[3]	Engine thrust setting
25B	Dry	130	135	139	FLEX 67°C

Table footnotes

[1] V_1 is the maximum speed at which a rejected takeoff can be performed.
[2] V_R is the rotation speed.
[3] V_2 is the takeoff safety speed, the speed at which the minimum climb gradient is achieved in the event of an engine failure.

Post-event calculations

After the incident, the following takeoff performance data was calculated by the aircraft manufacturer, using their engineering performance tool, for comparison:

Runway	Runway condition	V_1 (kt)	V_R (kt)	V_2 (kt)	Engine thrust setting
Rwy 07	Dry	135	135	139	FLEX 67°C
Rwy 25 Bravo	Dry	118	125	131	FLEX 49°C
Rwy 25 Bravo	Wet	112	124	131	TOGA

Electronic Flight Bag (EFB)

The EFB consisted of a 'ruggedised' touchscreen PC running Windows 7 with Airbus FlySmart software with data entry via a touchscreen interface. A stylus is provided with the EFB to achieve this, although the operator decided to remove them due to a potential FOD hazard caused by a loose/detached stylus with little or no benefit perceived by use of the stylus versus a finger. There were two EFBs present, one for the commander and one for the co-pilot. The operator used the EFBs for a number of functions including the calculation of takeoff and landing performance data.

At the time of the incident, the operator was running an EFB version internally designated as 1507 which is displayed on-screen to the flight crew (configured with FlySmart version L5.0.3). Having previously selected the takeoff airport, the user is presented with the screen in Figure 2. In simplistic terms, data is entered into the 'CONDITIONS' area and the runway number selected in the 'RWY' area after which the COMPUTE button is selected. This generates takeoff data and displays it in the 'RESULTS' section.

The FlySmart software is capable of recording data entered into the EFB and the performance computations produced for up to 90 days. This information can be transferred automatically or manually with user-configurable options.

FlySmart anomalies / limitations

The operator provided a 13-page list detailing nine known anomalies / limitations of the FlySmart software applicable to Version 1507. In addition to this, during the course of this investigation, another anomaly was highlighted which can allow an involuntary change of runway selection and airport in the takeoff and landing performance screens. This was also raised in a separate ASR by the operator after the event.

One method of modifying the runway selection is to use the touch-screen on the RWY drop-down menu. If this is performed, the selected runway will blank and the menu will open to display a list of the available runways which can then be selected. The on-screen keyboard will also display and a blue box will frame the first entry in the drop-down menu which will be the lowest numbered runway (see 'RWY' selection, Figure 2).

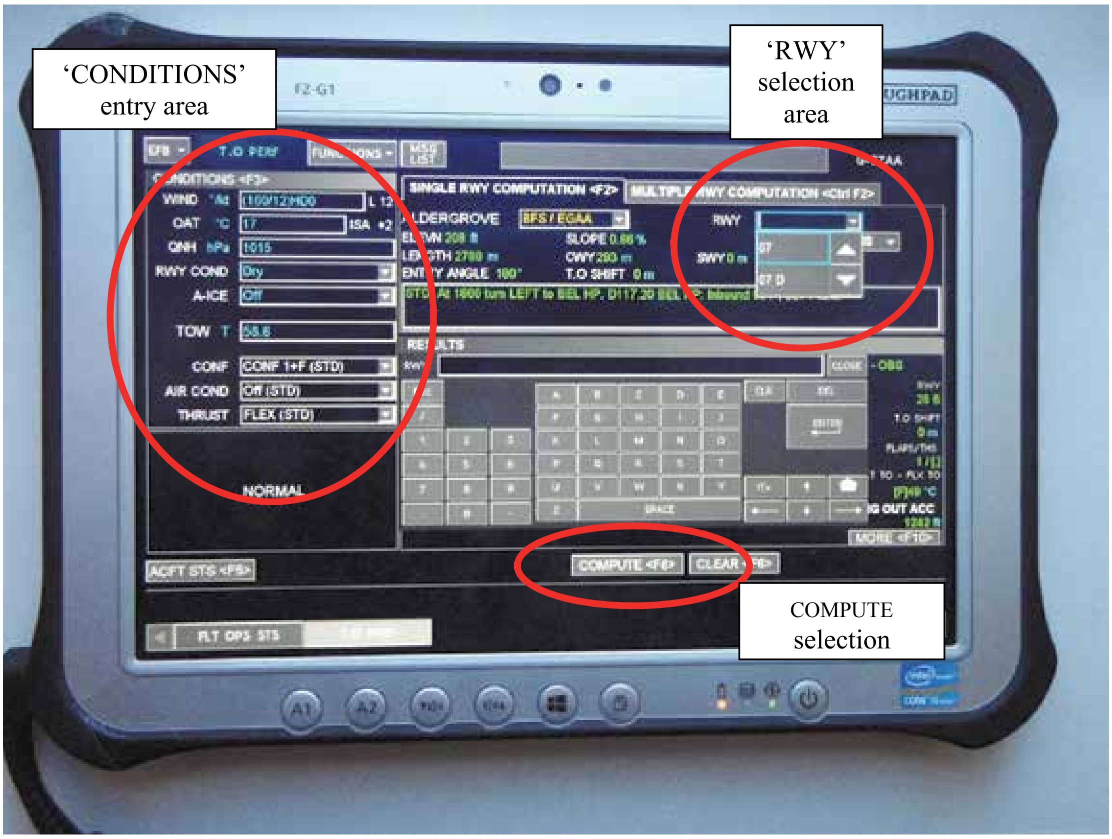


Figure 2

FlySmart takeoff performance screen

If the user then touches the screen anywhere other than the drop-down menu or keyboard, the runway selected in the RWY box will switch to the lowest number in the list of those at the airport selected, which will then be displayed. In the case of Belfast Aldergrove Airport, if Runway 25B was initially selected and the same process is applied, the drop-down menu would switch to Runway 07. This issue will be referred to the 'runway selection anomaly' in the rest of this report.

This behaviour applies for the RWY drop-down menus for both the takeoff and landing performance functions. It also applies to the airport selection drop-down menu but a change of airport triggers an on-screen warning. The software manufacturer confirmed that this anomaly was only present on the Windows versions of FlySmart on touchscreen portable devices for all software versions prior to L6.

EFB approval

In 2004, the JAA issued Temporary Guidance Leaflet (TGL) No 36 '*Approval of Electronic Flight Bags (EFBs)*' which provided guidelines to cover airworthiness and operational criteria for the approval of EFBs. The CAA granted the operator permission to use the EFB after an operational evaluation using the available guidance material.

EASA AMC 20-25

In 2014, the EASA published the most recent EU-specific provisions for EFBs which are contained in EASA AMC 20-25 '*Airworthiness and operational consideration for Electronic Flight Bags (EFBs)*'. The AMC was issued with a view to integrating TGL 36 into the structure of the Agency's rules and also enhance and update the content.

The first paragraph of AMC 20-25 states:

> *'This Acceptable Means of Compliance (AMC) is one, but not the only, means to obtain airworthiness approval and to satisfactorily assess the operational aspects for the use of Electronic Flight Bags (EFBs).'*

The operational approval section of AMC 20-25 provides guidance for operators on how to demonstrate to National Airworthiness Authorities (NAAs (in this case the UK CAA)) the suitability of the EFB system[5]. As AMC 20-25 is not linked to any Implementing Rule, its interpretation is open to each of the NAAs who have their own criteria to permit operation. The CAA have their own checklist they use to help operators evaluate an EFB.

The manufacturer of FlySmart confirmed that version L5.0.3 was successfully tested to the HMI requirements of AMC 20-25 in addition to their own. However, the runway selection anomaly was not discovered during this testing. They confirmed that this version of FlySmart was developed from a version developed for non-touchscreen PCs and that it was *'Not adapted to tablet use'* and '*not optimised for touchscreen*'.

AMC 20-25 does not require a specific EFB software test to identify unintended selections such as the runway selection anomaly identified during the course of this investigation. However, there is a section dealing with non-specific requirements of the Human-Machine Interface (HMI) which includes:

> *'The application should allow to clearly distinguish user entries from default values or entries'*

Also introduced in AMC 20-25 was a new Appendix entitled *'Flight Crew Training'.* Part of section F.1.3 Procedures states:

> *'(a) Crew procedures should ensure that calculations are conducted independently by each crew member before data outputs are accepted for use.'*

In addition:

> *'The performance and mass & balance applications should keep a trace of each computation performed (inputs and outputs) and the airline should have procedures in place to retain this information.'*

Footnote

[5] An EFB system refers to the complete EFB operation including risk assessments, human-machine interface, flight crew operating procedures and training, EFB administration and quality assurance.

The operator confirmed that as their EFB system approval pre-dated the issue of AMC 20-25, they were not required to take into account some of the new items introduced in AMC 20-25 including the need to retain performance information. They were aware of the capability of their EFB to record performance data but perceived no benefit in providing procedures to retain it.

FAA, Transport Canada and ICAO

The FAA and Transport Canada provide an Advisory Circular for EFBs[6] and both provide checklists for the operational approval of a new EFB. In addition to the Advisory Circular, the FAA provides the *Electronic Flight Bag Authorization for Use*[7] document which contains detailed criteria for assessing an operator's request to use an EFB.

In 2014, ICAO introduced new Standards and Recommended Practices (SARPs) for EFBs in Annex 6 Parts I, II and III[8]. EASA are currently studying these SARPS along with AMC 20-25 with a view to updating operational requirements as part of a Rulemaking Task[9]. This includes transposing the operational provisions contained in AMC 20-25 into new Air OPS EFB implementing rules.

Recorded information

Due to the delayed notification of this incident, the aircraft had completed 124 hours of operation since the event. As a consequence, the FDR and CVR data was overwritten. The operator provided data from their Quick Access Recorder (QAR), part of their Flight Data Monitoring (FDM) programme, which recorded a similar set of parameters to the FDR.

Prior to takeoff, the QAR recorded a FLEX temperature of 67°C, V_1 of 135 kt V_2 of 139 kt, a gross weight of 58,700 kg with the flaps extended to the 1+F position. At 1812:19 hrs, the thrust levers were advanced to the FLX/MCT position, and the autothrust engaged. Over the next 28 seconds, the average longitudinal acceleration was 0.22g as the aircraft accelerated along Runway 25. The first officer's sidestick was pulled back 27 seconds after the thrust levers were set, when the computed airspeed (CAS) was 139 kt. The aircraft rotated and climbed as the CAS stabilised at approximately 150 kt.

EFB download

The EFBs from G-EZAA were recovered to the AAIB as soon as possible after the notification and arrived on the 10 July 2015. Both EFBs were at Version 1507 but after investigation, the only recently recorded flights were those of the 7 July 2015 and the incident flight data was not available.

Footnote

6 FAA Advisory Circular No AC 120-76C, Transport Canada Advisory Circular AC 700-020.
7 FAA Flight Standards Information Management System (FSIMS) 8900.1 Volume 4, Chapter 15.
8 Operation of Aircraft - Part I International Commercial Air Transport – Aeroplanes, Part II International General Aviation – Aeroplanes, Part III International Operations – Helicopters.
9 EASA Rulemaking Task (RMT) .0601 and .0602.

A scheduled software update was performed on the EFBs on 7 July 2015 which involved a complete re-imaging of the hard disk and deletion of all previously recorded data. This software update process runs on a two-weekly cycle.

The EFB does not record the method by which the runway has been selected (on-screen keyboard, drop-down menu or involuntary default to the lowest number). As a result, even if the takeoff performance data had been recovered it would not be possible to determine whether an involuntary runway selection took place.

Other flights

The operator provided FDM data from other aircraft for a number of other representative takeoffs from Belfast Aldergrove Airport Runway 25B. This allowed a comparison of takeoff performance from the same aircraft types using similar takeoff parameters. Figure 3 shows G-EZAA QAR data in bold (black) with five other takeoffs from Runway 25B also plotted, in a lighter colour. The timelines have been aligned to the longitudinal acceleration peak at the start of the takeoff roll.

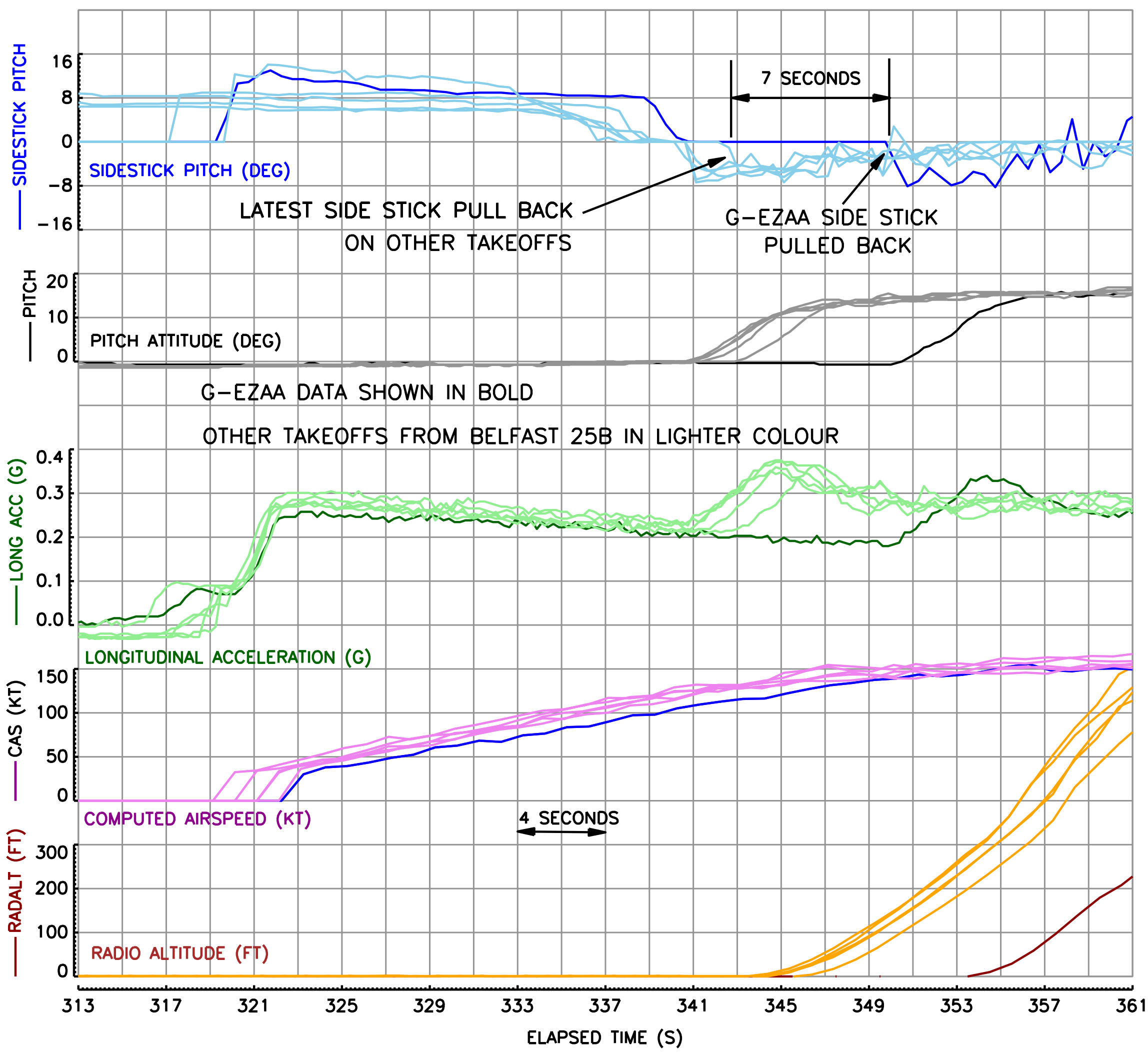


Figure 3

G-EZAA QAR data and other Runway 25B takeoffs

This data shows that the G-EZAA longitudinal acceleration was only marginally lower than other FLEX takeoffs. What is more notable is the time difference between when the G-EZAA sidestick is pulled back to initiate the aircraft rotation, and that from other takeoffs. This shows the effect of using a V_R which was 10 kt higher than it should have been and that the aircraft remained on the runway for longer. This also reduces the margins available in the event of a rejected takeoff (V_1 was also 17 kt too high).

Manufacturer's performance assessment

The aircraft manufacturer was provided with a copy of the FDM data and the reported airfield conditions. Using this data, they calculated that the approximate distance between the point the thrust was set and the point of rotation was 1,200 m and a total of 1,410 m to become airborne. With a Runway 25B takeoff, there would have been approximately 200 m of runway remaining.

Using a FLEX temperature of 67°C and V_1, V_R and V_2 speeds of 136 kt, 136 kt and 140 kt respectively[10], with both engines operating, they also calculated an approximate theoretical ground run to lift-off point of 1,350 m and an obstacle clearance of more than 35 ft. For One Engine Inoperative (OEI), the ground run would have been similar but obstacle clearance would have been '*around 30 ft*'[11]. In the event of a rejected takeoff at V_1 (136 kt) using maximum reverse and braking, the theoretical Accelerate-Stop Distance (ASD) was 1,770 m with an expected runway overrun at a groundspeed of 75 kt.

EFB testing

The sequence of input events reported by the flight crew was tested with the EFBs recovered from the incident aircraft. It was not possible to cause a change in the selected runway by altering the runway condition from WET to DRY. The test was repeated on an exemplar EFB of the same part number provided by the operator with the same results. However, all of the EFBs tested demonstrated the runway selection anomaly described previously.

FlySmart software upgrades

The manufacturer had a programme of updates in place for the FlySmart software prior to this incident. After this incident they stated, when referring to the runway selection anomaly, that:

> *'this behaviour is encountered when using a touchscreen which software is not optimized, i.e. pre-L6 software for windows touchscreens.'*

and:

> *'Relevant to the event units, L6.0.x version includes a new Human Machine Interface (HMI), optimized for touch screen devices. Accordingly, it becomes compatible with Windows 7 and 8'*

Footnote

[10] It was noted that the manufacturer used V speeds that are 1 kt higher than that calculated by their FlySmart software.

[11] Airworthiness requirements for this aircraft type state that obstacle clearance on takeoff is a minimum of 35 ft.

They also stated that the runway selection anomaly will be corrected by this new software version which was made available in summer 2015. This version also includes a number of other unrelated changes which, at the time of this report, was being evaluated by the operator.

Other occurrences

During the process of this investigation, the operator reported two additional events:

G- EZUH

On 16 July 2015 an Airbus A320, registration G-EZUH, took off from Intersection Bravo on Runway 08 at London Luton Airport with takeoff performance figures calculated using the full length of Runway 08. The report was published in the AAIB's January 2016 Bulletin.

G-EZIV

On 16 October 2015 an Airbus A319, registration G-EZIV, took off from Intersection U5 on Runway 21 at Lisbon Airport, Portugal with takeoff performance figures calculated using Runway 03. The report was published in the AAIB's May 2016 Bulletin.

The AAIB has investigated a number of takeoff performance-related events in recent years and made a number of Safety Recommendations. Other Safety Investigation Authorities (SIAs) have also performed investigations and a number of studies have been produced[12].

Other industry activity

There are a number of ongoing activities with EASA, CAA and the aircraft manufacturer suggesting that the industry continues to consider the risks posed by the various factors surrounding aircraft performance on takeoff. The approach is considering end-to-end options including EFB design requirements, flight crew crosschecking procedures, aircraft avionics gross error checks, development of real-time takeoff performance monitoring systems and research into using FDM data to identify events of degraded takeoff performance.

Recent work by EASA concluded that the *'risk level and its trend need to be monitored continuously'* and have a number of current measures in place. In February 2016, they published a Safety Information Bulletin (SIB) titled *'Use of Erroneous Parameters at Take-off'*[13]

Aircraft manufacturer

The aircraft manufacturer indicated that there are a number developments being studied as part of their 'Take Off Securing (TOS)' function. This include a number of error-checking measures when entering data into the FMS and also consideration of aircraft position at takeoff relative to the takeoff performance.

Footnote

12 ATSB Transport Safety Report. Aviation Research and Analysis report AR-2009-052
NASA (2012) *Performance Data Errors in Air Carrier Operations: Causes and Countermeasures.* NASA/TM-2012-216007
Laboratory of Applied Anthropology (2008). *Use of Erroneous Parameters at Takeoff,* DOC AA 556/2008
13 EASA SIB 2016-02 http://ad.easa.europa.eu/ad/2016-02

Analysis

Takeoff performance calculation

The crew appeared to have conducted the initial flight preparation, with the relevant crosschecking of the performance figures on the EFB, in accordance with the operator's SOPs. However, having only changed one variable, namely the runway state from WET to DRY, they did not cross-check the other entry fields on the EFB before computing the new figures.

The data input and output data to / from the EFB could not be recovered. The commander confirmed, when consulting the takeoff performance page of the EFB after takeoff, that Runway 07 was selected. When comparing FLEX temperature and V speeds recorded on the QAR with those calculated for a dry Runway 07 takeoff, it is highly likely that Runway 07 was that used to calculate the takeoff performance.

The reason for the selection of Runway 07 could not be confirmed but would have required some physical contact with the EFB's RWY drop-down menu. Given the flight crew recollection of initially confirming Runway 25B selection and then only changing the runway condition field, it is probable that the change to Runway 07 was involuntary and due to the runway selection anomaly highlighted during this investigation. The crew commented that they were unaware of this anomaly and thus felt there was not a requirement to crosscheck all the data entered in the EFB for a second time.

The aircraft manufacturer recommended that both flight crew perform individual computations and then crosscheck each other's. The operator elected not to adopt these procedures, stating that they preferred their SOPs which had been refined to their specific operational requirements over the 12 years of using EFBs and this approach had been accepted by the UK CAA.

EFB Involuntary runway selection change

The EFB did not record the method by which the runway has been selected (on-screen keyboard, drop-down menu or involuntary default to the lowest number). As a result, even if the takeoff performance data had been recovered, the reason for the Runway 07 selection would not have been known.

To reproduce this runway selection anomaly required physically touching the screen which could have been inadvertently achieved by the glance of a hand. The risk associated with using touchscreen input devices which are on all the time is that any inadvertent touch of the screen by a conductive source may change a field on the screen.

The EFB operational approval process did not test for this anomaly although AMC 20-25 does have generic HMI requirements. This highlights the need for detailed guidance to those performing an operational approval.

The manufacturer confirmed that the EFB version the operator was using was '*not optimised for touchscreen*' but was unaware of the anomaly before this event. They have confirmed that the next software version will correct it.

EASA AMC 20-25

As the operator's EFB approval predated AMC 20-25, they were not required to show compliance to it. The FlySmart software had been tested against AMC 20-25 so included a number of useful features that were introduced in AMC 20-25. As part of RMT .0601 and .0602, EASA will be considering transposing the operational provisions contained in AMC 20-25 into part of the new Air OPS EFB implementing rules.

Due to the bi-weekly update cycle, the operator's EFBs did not contain recorded information which would have been useful for this investigation. With their EFB approval predating AMC 20-25, they did not retain this recorded performance data but are now looking into a permanent solution. The CAA have also updated their criteria for EFB acceptance to include verifying that operators have this in place.

Safety action taken

The operator has undertaken a number of measures including:

- Establishing a 'Performance Working Group' to review all of the associated procedures that they use for performance calculation, data entry and crosschecking in the light of all these events and other available information
- Looking into the retention of recorded EFB information
- Recommending consideration for their FDM Manager to be authorised to report events to the AAIB of any serious incident
- Recommending consideration be given to review and influence future software versions for performance calculations on the EFB
- Evaluation of all changes in FlySmart version L6.0.x prior to its entry into service.

On 30 October 2015, the aircraft manufacturer sent a 'FlySmart Communication' to all operators of FlySmart on Windows[14]. The communication highlighted that, when referring to the FlySmart anomaly,

> *'A wrong runway or airport may be selected in Takeoff or Landing Performance applications of FlySmart L5 and previous versions, and used for computing the results.'*

Their proposed mitigation was,

> *'Erroneous performance results should be detected by an independent computation made by both pilots, and crosscheck of results.'*

The EFB software manufacturer has confirmed that the anomaly will be corrected in the L6.0.x version of FlySmart.

Footnote

[14] FlySmart Communication X46D15033792 v1.1.

Conclusion

The incident was caused by the use of incorrect takeoff performance data. The data was most likely calculated using Runway 07 instead of Runway 25B. The most likely reason for using Runway 07 was an involuntary runway selection by an anomaly within the EFB software which went undetected by the crew. They did not conduct an independent check of the selected runway when their recollection was of changing only the runway condition.

Operators have been informed of the anomaly and the EFB software will be corrected in future standards.

The commander recognised the limited stopping distance available just before V_1 but the potential seriousness of the event is highlighted by the theoretical result of a runway overrun at 75 kt if the takeoff had been rejected at that stage. A number of international, European and national initiatives are underway to consider and address the safety risks posed by using erroneous takeoff performance parameters.

INCIDENT

Aircraft Type and Registration:	British Aerospace 146-200, D-AMGL
No & Type of Engines:	4 Avco Lycoming ALF502R-5 turbofan engines
Year of Manufacture:	1986 (Serial no: 2055)
Date & Time (UTC):	16 August 2015 at 1736 hrs
Location:	London City Airport
Type of Flight:	Passenger Transport
Persons on Board:	Crew - 4 Passengers - 77
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to right main gear shock-absorber and hole in right main gear door
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	N/A
Commander's Flying Experience:	4,900 hours (of which 4,500 were on type)
Information Source:	AAIB Field Investigation

Synopsis

Fluid was seen on the ground around the right main gear after the aircraft parked. The head of a bolt on the shock-absorber on the right main gear leg was missing and there was a small puncture in the right main gear door. During the subsequent investigation it was concluded that the bolt had fractured due to fatigue, and the bolt had exceeded its 18,100 landing fatigue-life limit. The design of the shock-absorber is such that the small loss of oil does not cause a significant degradation in aircraft performance. At the time of the occurrence the operator was not monitoring the life of these bolts, but has since changed its procedures.

History of the flight

The aircraft was operating a scheduled service from Frankfurt to London City Airport (LCY). The approximate landing weight at LCY was 33,430 kg and the crew reported that the flight, including the steep approach to Runway 09 at LCY, was normal. The commander considered that the touchdown was "strongly positive with a slight bounce" before the aircraft settled onto the runway. The landing roll and taxi to the parking stand were both normal, and the crew later reported that there were no warnings or indications of any issue with the aircraft. However, after the aircraft was parked on the apron the ground crew informed the commander that there was fluid loss from the area of the right main landing gear. The crew then noticed that the aircraft was developing a slight tilt. The commander inspected the landing gear and withdrew the aircraft from service pending maintenance and investigation.

CCTV recordings from London City Airport showed the aircraft touching down in the appropriate place and that there was a 'bounce', as reported by the commander.

Inspection of the aircraft at London City Airport

The images in Figures 1 and 2 were taken by the commander shortly after the aircraft had taxied to the stand and the passengers had disembarked. An oil stain was readily visible on the ground around the right main gear leg and there was a piece of broken locking wire (Figure 1) attached to the top of the shock-absorber. Bubbles of oil were coming from a hole where a bolt head was missing and oil was seeping from the base of the bubbles. Over the next 24 hours the rate of bubbles originating from the hole slowed significantly. The shock-absorber was removed and taken to the manufacturer for examination.

Figure 1

Image taken just after landing - shock-absorber on the right main gear leg

Figure 2

Image taken just after landing - right main gear

The landing gear door had been punctured from the inside – see Figures 3 and 4. The location and the size of the hole was consistent with the missing bolt head being forced against the inside of the door without the bolt head passing through the door structure.

Figures 3 and 4

Images of the hole in the right main landing gear door.
Note: the coin and bolt head have approximately the same diameter

Recorded information

The aircraft was fitted with a Flight Data Recorder (FDR) and Cockpit Voice Recorder (CVR), both of which used magnetic tape. These were removed from the aircraft and successfully replayed.

The CVR did not contain any pertinent information related to this investigation and supported the account of the operating crew.

The FDR was used to plot the key parameters that were available for the landing and these are shown in Figure 5. However, it should be noted that around the point of touchdown the recording was corrupt for a number of parameters. Tape-based recorders are more sensitive to impact shock and such corruption does not affect solid-state devices.

It was not possible to make a precise assessment of the descent rate at touchdown; however, over the preceding few seconds of data, descent rates of around 10 ft/sec were recorded. The applicable Aircraft Maintenance Manual quotes, in the section related to '*Inspection after overweight, hard or high drag/side load landing*':

> *'The aircraft has been designed for a vertical descent velocity at touchdown of:-*
>
> - *6 ft/sec at Maximum take-off weight.*
> - *10 ft/sec at Maximum landing weight.*
>
> *In association with the recommended approach speeds.'*

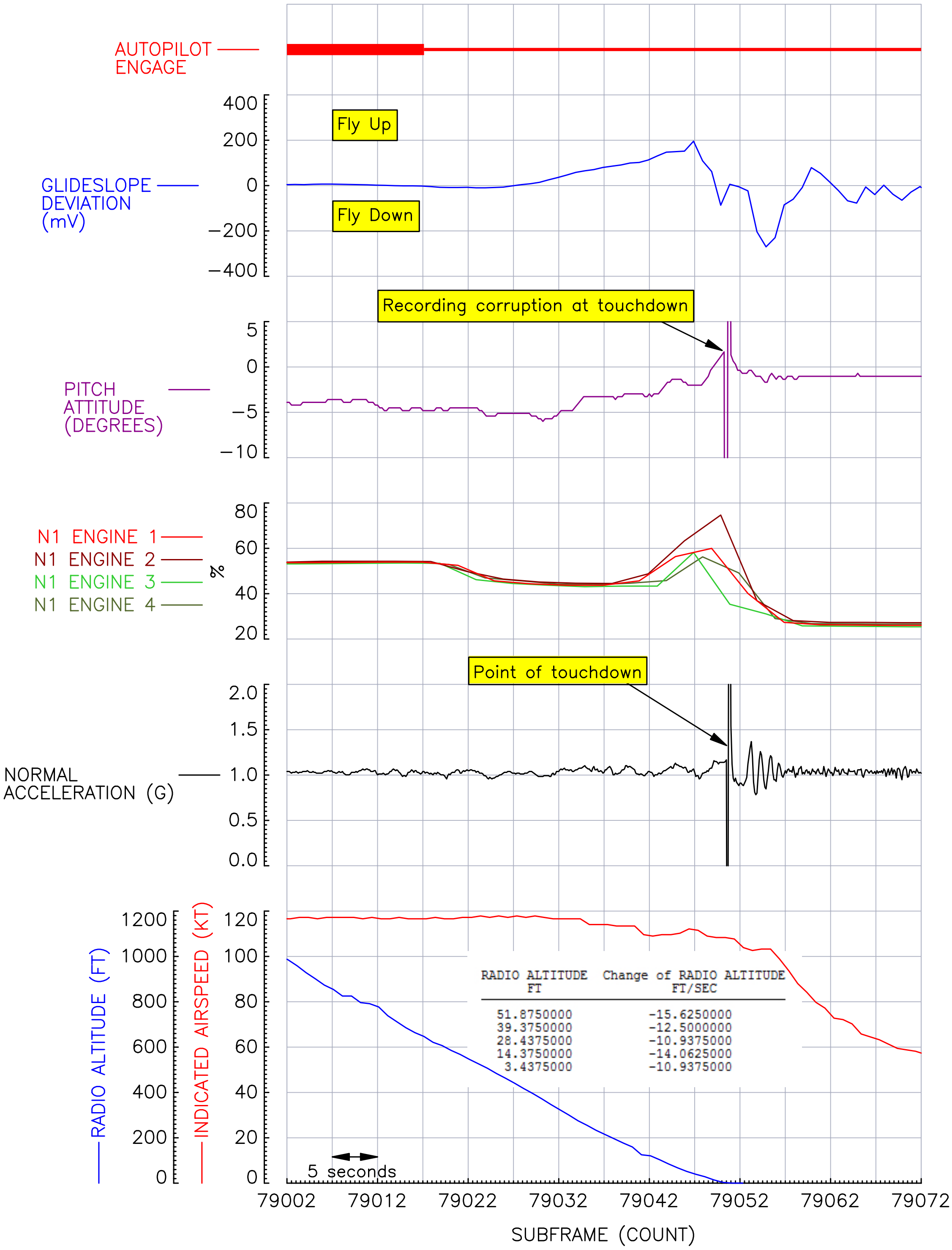


Figure 5

Flight Data Recorder parameters for the landing sequence including tabular information on the change of Radio Altitude over the last 5 seconds of flight

In addition to the FDR and CVR, the aircraft was also fitted with a Quick Access Recorder (QAR) which in this case was designed to record to a removable solid state CompactFlash (CF) card. The card was downloaded but found to be blank. On further investigation, the QAR was found to have damage to two pins that are part of the electrical interface from the unit to the CF card. Figure 6 shows the visible damage to one of these pins, highlighted in yellow.

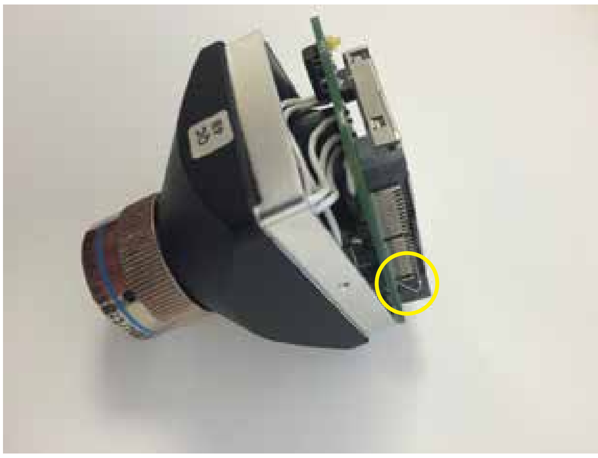


Figure 6

Damage to one of the pins forming the QAR unit's CF card electrical interface

The manufacturer of the QAR confirmed that the affected pins were the electrical ground signals for the CF card. The risk of potential damage to the QAR unit, by incorrect insertion of a CF card, had been highlighted by the manufacturer in a Service Information Letter, QAR001, dated 1 July 2005.

After the aircraft operator was informed of the damage to the QAR unit, a check of other units in their fleet highlighted two examples where damage had occurred. The operator subsequently published its own internal bulletin advising of the issue and has placed decals on the QAR units, showing the correct CF card orientation.

The QAR units were being used by the operator to provide data for their Flight Data Monitoring programme, with downloads planned for their fleet on a 28-day cycle. However, during the course of this investigation it was established that for the incident aircraft two download cycles had resulted in no data being recovered from the unit. Detection of this anomaly would have allowed the faulty QAR unit to be repaired or replaced at an earlier date.

On the QAR unit there is a FAULT light and a MEMORY FULL light on the front face of the unit. When the damaged QAR was tested with 115VAC power provided on the unit's main connector, as would be the case when the unit was installed on one of the operator's aircraft, the FAULT light did not immediately illuminate despite the presence of bent pins. However, the FAULT light did illuminate when the CF card was removed from the unit and the manufacturer has been asked to verify that the observed behaviour is as expected.

Aircraft information

The BAe 146 is a four-engined, high-wing passenger transport aircraft. The aircraft has two main landing gear legs mounted on the fuselage inside two fairings. Mounted on each main gear leg is a shock-absorber, which features a two-stage floating piston with four chambers. Nitrogen is contained in the lower outer and the upper inner chambers, and oil is contained in the upper outer and the lower inner chambers (Figure 7). The overhaul period for the shock-absorber is 15,000 landings (for European operations) or 12 years.

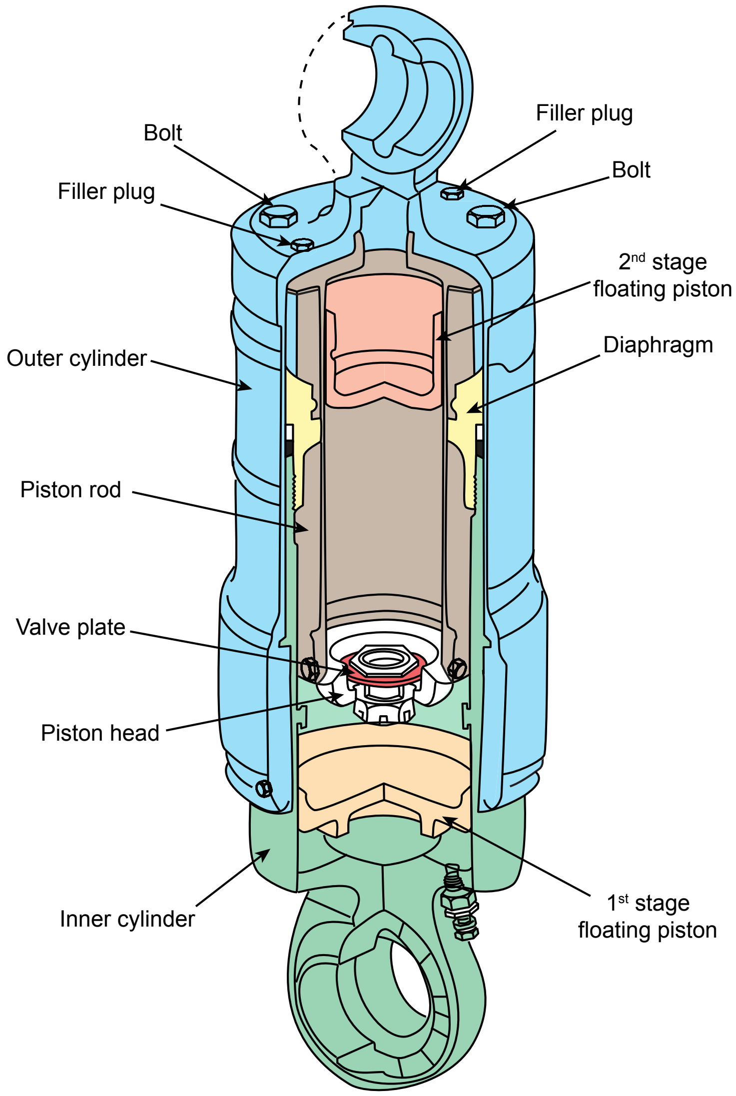


Figure 7

Cutaway drawing of the shock-absorber

At the top of the shock-absorber are six bolts. The two smaller bolts are oil filler plugs, the other four are bolts that attach the inner cylinder to the outer cylinder. These four bolts are lifed at 18,100 landings. Each bolt has a serial number written on its head. On assembly the bolts are lubricated, fitted with an ‘O’-ring, tightened to a torque of 66 lbft, wire-locked and then sealed with mastic.

Shock-absorber examination

The shock-absorber was removed and sent to the manufacturer for a teardown examination.

The torques on the three remaining attachment bolts were checked by carefully marking a line on both the bolt and the surrounding surface, the bolts were loosened, and then the torque required to re-tighten the bolt to the point where the two marks aligned was measured. This gave an estimate of the torque applied when the bolt was installed during assembly.

The 're-tightening' torque for the three bolts was measured at between 84 and 92 lbft. A further re-tightening of the bolts to the correct torque (66 lbft) resulted in the lines on the three bolts being within approximately 1° to 2° short of the line on the surrounding surface. It was concluded that the bolts might have been slightly over-torqued during reassembly at the previous maintenance, but it was not possible to be conclusive from the evidence available.

The half of the fractured attachment bolt that had remained in the shock-absorber was removed and subjected to a metallurgical examination (Figure 8a). Three crescent-shaped fatigue cracks were observed on the outer edge of the fracture surface (Figure 8b). The conclusion of the metallurgical examination was that the bolt had fractured due to the initiation of multiple fatigue cracks from a number of locations. These locations were where the bolt interfaced with the outer cylinder, and no defects were observed at these initiation sites. No evidence of cracking was found in the other three bolts.

Figure 8a

Image of fractured bolt compared with the three remaining complete bolts

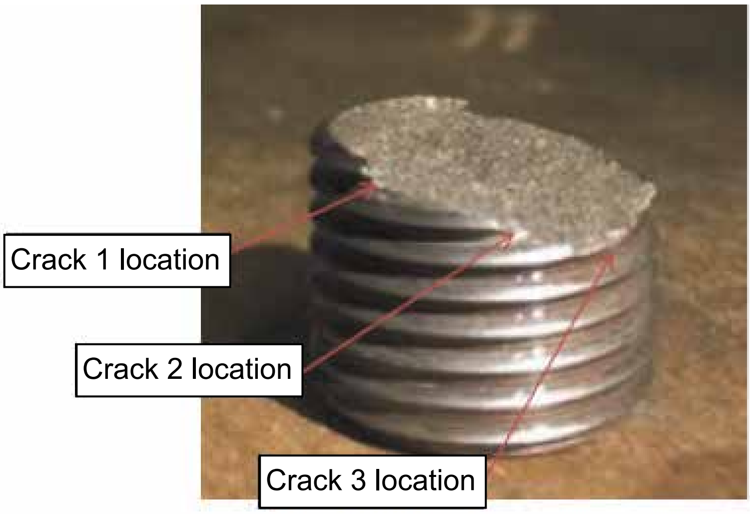


Figure 8b

Image of fractured bolt showing fatigue crack locations

The general condition of the shock-absorber was assessed as being good. A sample of oil was analysed and was found to be satisfactory. Prior to disassembly of the shock-absorber a test was carried out to measure the leakage rate in an un-pressurised condition. The leakage rate from the bolt hole with the bolt head missing was around 50 ml per hour.

Landing gear performance with a fractured shock-absorber bolt

With the two-stage floating piston design, the manufacturer calculated that the oil loss is only around 0.6 litres of the 12 litres capacity when the outer piston is on its stops. The pressure change due to this loss of oil is from around 86 psi to 74 psi. Thus the degradation in shock-absorber performance with a missing bolt was considered minimal in this condition.

Maintenance information

The shock-absorber was manufactured in 1985, and was overhauled by the manufacturer in 1998 when it had 2,013 landings. It was repaired by the manufacturer in 2002 at 4,327 landings; however there is no requirement to fit new bolts during a repair.

The serial number on the heads of the three remaining bolts confirmed that these three bolts were fitted during the overhaul in 1998. In April 2015 the shock-absorber had completed over 23,100 landings. Given that the bolts were replaced in 1998 after 2,013 landings, then at the time of the incident the bolts had completed at least 21,000 landings, which exceeds their 18,100 landing fatigue-life limit.

The operator did not record, and did not have a record for, the number of landings for these shock-absorber bolts. They noted that when the aircraft was bought from another operator they did not inherit any records for the bolts.

Safety action taken by the operator

> As a result of this occurrence the operator has put in place a system to record the landings for the bolts on the shock-absorbers.

Discussion

This investigation showed that, if a shock-absorber bolt fractures in this design, there is a significant 'tell-tale' warning in the form of an oil spill around the gear leg. This will be evident during a pre-flight walk-around and thus the bolt fracture does not represent a significant safety issue.

A subjective comparison of the rate of oil loss between that observed at London City Airport and that measured during the investigation of the shock-absorber suggested that the bolt became detached within a few hours of landing at London City. The location and dimensions of the hole in the landing gear door were consistent with the bolt becoming detached and then being pressed against the inside of the landing gear door on retraction. It is therefore probable that the bolt became detached either during, or shortly before, the takeoff from Frankfurt.

From the serial numbers on the three non-fractured bolts, together with the maintenance records, it was determined that these three bolts had exceeded their landing fatigue-life limit, and hence the bolt that fractured had also probably exceeded this limit. There was some evidence that the three remaining bolts were slightly over-torqued, which might have contributed to the bolt fracturing.

At the time of the incident the operator was unaware of the need to keep a record of the number of landing cycles that the bolts had experienced. However, since the incident the operator has changed its procedure to require monitoring of the usage of the bolts and hence there is no safety recommendation.

ACCIDENT

Aircraft Type and Registration:	Folland Gnat T Mk 1, G-TIMM
No & Type of Engines:	1 Rolls-Royce Orpheus 101 turbojet engine
Year of Manufacture:	1962 (Serial no: FL519)
Date & Time (UTC):	1 August 2015 at 1302 hrs
Location:	Approx 1 mile north of Oulton Park, Cheshire
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:	Private Pilot's Licence
Commander's Age:	39 years
Commander's Flying Experience:	706 hours (of which 218 hours were on type) Last 90 days - 6 hours Last 28 days - 2 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was carrying out an aileron roll at low level during a flying display when, at an angle of bank of 107° to the left, the nose attitude dropped relative to the horizon. The pilot reversed the direction of roll but also applied a large pitch input which increased the rate of descent, and caused the aircraft to depart controlled flight and impact with the terrain. The accident was not survivable.

It was concluded that the situation was recoverable until the application of the pitch input.

Three Safety Recommendations are made on: minimum aerobatic heights; managing the risk of loss of aircraft control; and medical examination requirements for pilots of high performance aircraft.

History of the flight

Preparation, departure and transit to the display site

On 1 August 2015, G-TIMM was one of two Folland Gnat T Mk 1 aircraft booked for a flying display at Oulton Park, Cheshire. The aircraft used Hawarden Aerodrome (EGNR), 13 nm to the west of Oulton Park, as a forward operating base. Prior to departure from Hawarden, the pilot of G-TIMM, who was the formation leader, contacted the Flying

Display Director (FDD)[1] for a final briefing and discussion which included reference to the display line[2] depicted in the Display Pilots' Notes[3] (Figure 1).

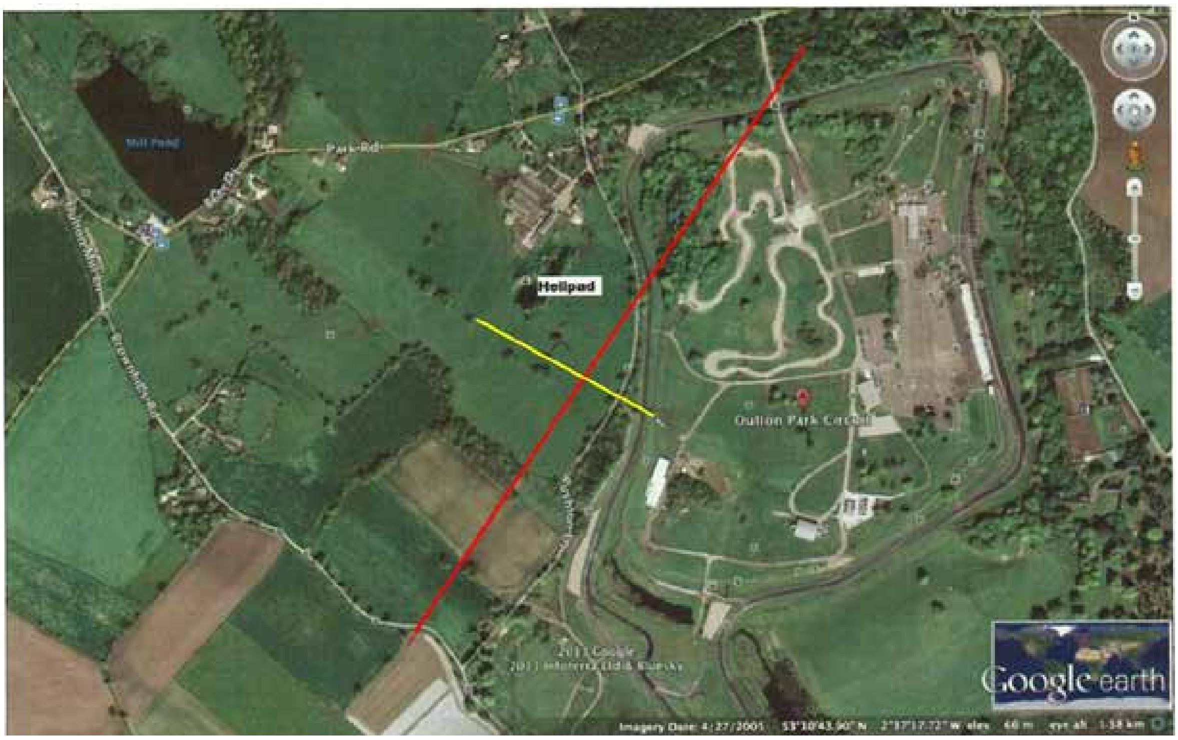


Figure 1

Display line depicted in the Display Pilots' Notes
(Display line in red and display datum line in yellow)

The pilot also contacted Liverpool ATC by telephone before departure because the formation would need clearance to enter controlled airspace during the display and he wished to explain his intentions in advance. Figure 2 depicts the local airspace around the display site.

The formation departed from Runway 22 at Hawarden at 1243 hrs. After departure, the formation contacted Liverpool Approach on 119.850 MHz and was immediately instructed to contact Liverpool Director on 118.45 MHz to obtain a Traffic Service[4]. After contacting Liverpool Director at 1247 hrs, the formation was instructed to remain clear of controlled airspace until the controller had coordinated entry clearance with Manchester ATC, so the aircraft remained in the vicinity of Beeston Castle Visual Reporting Point (VRP).

Footnote

1 See later sections: CAP 393 *Air Navigation: The Order and Regulations*, and CAP 403 *Flying displays and special events: A guide to safety and administrative arrangements.*

2 See later section: CAP 403 *Flying displays and special events: A guide to safety and administrative arrangements.*

3 See later section, Information from the Flying Display Director.

4 A Traffic Service is a radar-based air traffic service where a controller provides information to assist pilots in avoiding other traffic.

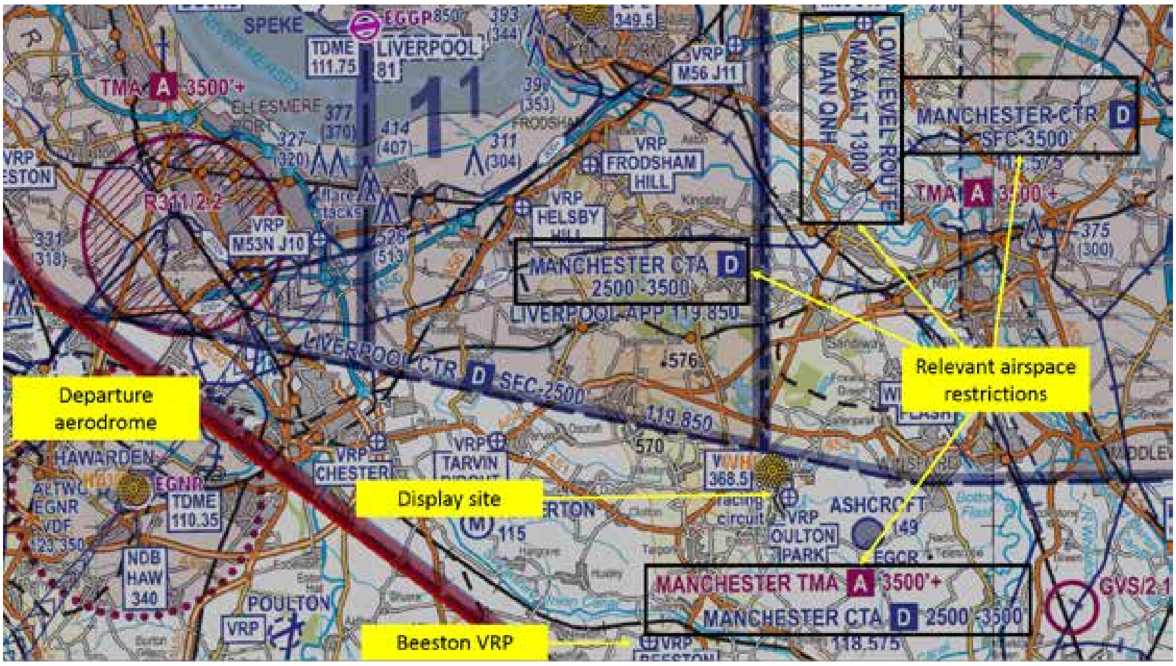


Figure 2

Airspace surrounding the accident site

At 1253 hrs, the Liverpool Director cleared the formation to enter controlled airspace, not above an altitude of 3,000 ft on the Liverpool QNH of 1013 hPa. The clearance was acknowledged by the pilot of G-TIMM who told the controller that he would switch to the display frequency (130.675 MHz) but would listen out on the Liverpool frequency at the same time.

The display

The METAR issued at 1250 hrs by Hawarden stated that the wind was from 240° at 17 kt, the visibility was more than 10 km, there was scattered cloud at 3,500 ft agl, a temperature of 19°C and a QNH of 1013 hPa. When cleared to commence their display by the FDD, the formation was told that the QFE at the site was 1005 hPa and the leader instructed the formation to use this pressure setting as the altimeter height reference.

The formation approached the display site from the south-west (from the left as seen by the crowd) and commenced the display which was planned to be a series of manoeuvres flown in close formation followed by a series of coordinated manoeuvres flown as individual aircraft. The first part of the display was uneventful and the formation split into two individual aircraft as planned. As part of his individual display, the pilot of G-TIMM positioned his aircraft so that he could fly along the display line from crowd left while rolling the aircraft about its longitudinal axis. The aircraft completed one 360° roll to the left, beginning and ending with the wings level, and, after a pause of less than a second, began to roll to the left again. As the aircraft reached 107° angle of bank, the nose of the aircraft dropped relative to the horizon, following which the pilot reversed the roll control input and the aircraft began to roll to the right. Approximately 0.2 seconds after the aircraft began rolling right, there was a marked pitch[5] input which lowered the nose attitude further relative to the horizon and increased the rate of descent. The aircraft struck the ground, approximately 4.3 seconds after commencing the second roll to the left[6].

Accident site

Examination of the accident site indicated that the aircraft initially struck trees of a height of approximately 80 feet whilst in a steeply descending flight path at a relatively low forward speed. The small size and cross section of the aircraft relative to the spacing of the tree trunks made it unclear as to the attitude of the aircraft at initial impact, but the overall site, bisected by a road, was compact.

With the exception of the rear fuselage, the tail surfaces, the majority of the wing structure, the three landing gear units and the combined engine and jet-pipe, the aircraft was grossly fragmented. This was probably because of the light construction of the forward and intermediate fuselage compared with that of the wing structure.

Owing to the age of the aircraft and because the aircraft manufacturer who designed and manufactured the ejection seat is no longer in existence, little knowledge of the ejection seat design was available to the investigators at the accident site during the 24 hours following the event. Lack of information detailing the general layout of the ejection seat, and the position of the various explosive cartridges[7], prevented early identification of the fragmented and burnt components of the seat. It was known however, that the aircraft normally flew with the front ejection seat armed and the unoccupied rear ejection seat unarmed but with live explosive cartridges in place. Live ejection seats present a hazard to those who work around them and, following the accident, this hazard presented a high risk of injury to the first responders and to accident investigators.

Eventually, the engineer who routinely serviced the seats in G-TIMM and other Gnats for the aircraft operator, travelled to the site and was able to examine the wreckage. He confirmed that both ejection seats had been installed at the time of the impact and that the head boxes of both had come to rest in an area of very severe disruption and fire. It was confirmed that main and drogue explosive cartridges from both seats had discharged as a result of heat from the ground fire. The remaining low-powered cartridges, associated with occupant separation, remained, undischarged, in an area clear of fire.

The engineer referred to above was thought to be the only person in the UK with the appropriate expertise to respond to an accident involving the type of ejection seat fitted to the Gnat.

Footnote

5 An aircraft pitches (rotates) about its lateral axis. Pitch control inputs are made by forward and aft movements of the control column which vary the position of the tailplane relative to the airflow.

6 See later section, Aircraft flightpath and control inputs, for an in-depth description of the flightpath.

7 A cartridge is a container of solid fuel or propellant, with self-ignition system, for propulsion by supplying pressure to a one-shot system.

Information from the Flight Display Director and flying display organiser

Approximately three months before the event, the organisers of the display provided the FDD with a document, *'Display Pilots Notes'*, which he was told by the display organiser contained information approved by the CAA for previous flying displays at the same site. This document, which included the display line shown in red in Figure 1 and an image of overall site activity shown in Figure 3, was sent to the operator.

An *Application for Flying Display Notification*, dated 4 July 2015, was sent to the CAA General Aviation (GA) Unit noting that the only change from previous applications was in respect of the FDD. On 27 July 15, the CAA issued a Permission under Article 162 of the Air Navigation Order (ANO) approving the FDD's appointment. One of the conditions of the Permission, however, was that the display line should be amended, in accordance with Schedule I to the Permission, as shown in Figure 4. The FDD saw the document for the first time during the evening before the event and realised that it required display pilots to avoid a farm (shown as an amber box in Figure 4). The following day, before the display began, the FDD contacted the occupants of the farm who confirmed that they would be attending the event at Oulton Park and that the buildings would not be occupied during the flying displays. The display organiser commented that this was the fourth annual show and an agreement was in place to ensure that the farm buildings were unoccupied between 1130 and 1300 hrs UTC. The north-west corner of the show site was also to be unused while display flying was taking place.

Figure 3

Overall site activity and enclosures

Figure 4

Amended display line from the CAA Permission

During their conversation before the formation left Hawarden, the FDD and pilot of G-TIMM discussed the fact that there was rising ground along the display line, from left to right as viewed from the crowd, and the FDD told the pilot where the display datum would be marked. He also instructed the pilot not to fly further east of a line, shown in yellow in Figure 5, which was parallel to the display line shown in the Display Pilots' Notes. Figure 5 also shows the display line in the CAA Permission, the location of the accident site, a camping site and a car park for day visitors to the show. The camping site and car park were expected to be inaccessible during the flying display, and the organiser stated that security staff had been briefed accordingly. He reported that he contacted Event Control on the radio just before the display to remind them of this requirement.

Information from the pilot of the second Gnat

The pilot of the second Gnat did not see the accident because it happened behind his aircraft but he stated that the pilot of G-TIMM gave no indication that anything was wrong at any stage of the flight.

Before the flight, the pilots realised that their display would take them outside the temporary restricted airspace (RA(T)) that had been created for the event[8], which had a radius of 1.5 nm and a vertical limit of 2,500 ft amsl. They decided that, because their display would take them into Class D airspace, the pilot of G-TIMM should discuss their requirements with Liverpool ATC before departure. They decided to use a display line, displaced north-west of the display line shown in Figure 1, passing through the farm buildings shown in Figure 6. The orientation of the buildings, ie parallel with the display

Footnote

[8] The airspace was restricted by The Air Navigation (Restriction of Flying) (Oulton Park) Regulations 2015 made on 4 June 2015 and in force on 31 July 2015.

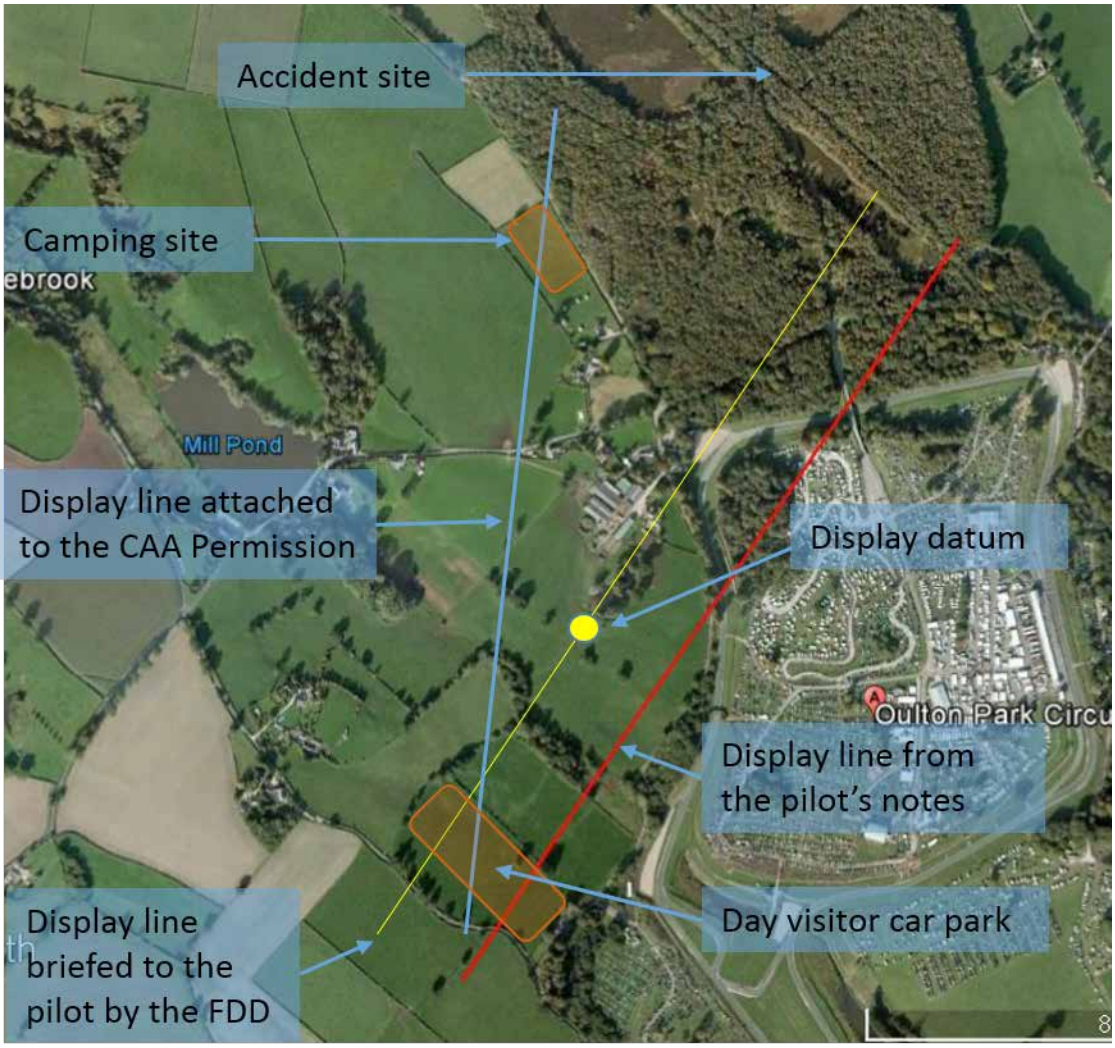


Figure 5

Display line briefed to the pilot of G-TIMM

line, made them a good feature to use from the air. Figure 6 also shows the location of a camera which recorded the accident and two witnesses who were standing in the car park referred to earlier. A tree, the relevance of which is discussed in the next section, is also highlighted in Figure 6.

The pilot of the second Gnat stated that, at the time of the accident, the pilot of G-TIMM would have been performing 'twinkle' rolls along the display line. He expected him to have flown a minimum of two rolls but a third would have been flown had it been necessary to position the aircraft correctly within the display. 'Twinkle' rolls would be flown at approximately 300 kt IAS and would begin with a nose attitude of approximately 3° above the horizon to allow for a drop in attitude of about 2° during the manoeuvre.

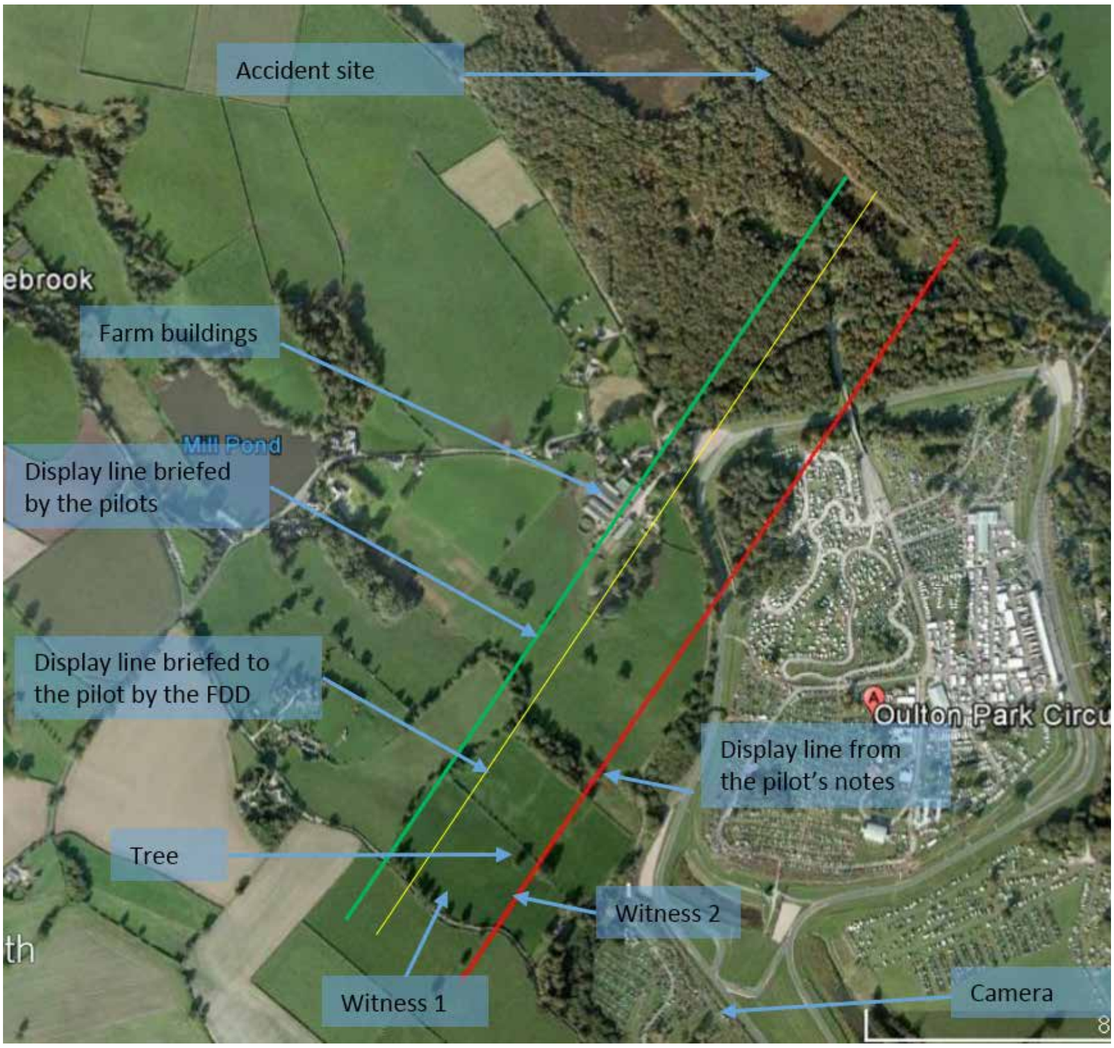


Figure 6
Display line briefed by the pilots

Information from witnesses

Witnesses 1 and 2 reported their location as shown in Figure 6. Witness 1 took the image shown in Figure 7 and stated that G-TIMM flew "directly overhead" as it began its final pass.

Figure 7 (right)
Image taken by Witness 1

Witness 2 took the image shown in Figure 8. He stated that "G-TIMM did not fly directly overhead … but further to the west of my position, and indeed, from the angle of the photos, some way to the west". The tree in the image is marked in Figure 6.

Figure 8 (right)
Image taken by Witness 2

Aircraft description

General

The Folland Gnat T Mk1 aircraft was formerly a military advanced trainer developed from an earlier Gnat light fighter design. The fighter was originally designed to be the smallest aircraft capable of fulfilling the single seat interceptor mission and, as developed into a two-seat trainer, was unusually small and light compared with other aircraft performing in that role. Consequently, the fuselage structure in particular employed lighter gauge panelling and needed to be less substantial than other, physically larger, aircraft designed and stressed to operate within a comparable flight envelope. The longitudinal strength and stiffness of the fuselage was partly dependent on the more substantial wing structure.

Controls

Flight control is normally by means of ailerons, rudder and an all-moving tailplane. Aileron movement is achieved by means of a cable and quadrant system within the forward and centre fuselage, and tubular push-pull rods situated in the wing leading edges, forward of the front spar. This system operates hydraulic servodynes, the bodies of which connect directly to the corresponding aileron drive rod. Tailplane movement is also achieved via cables and quadrants in the forward and centre fuselage, driving rods and levers in the rear fuselage connected to a two-way operating valve of an Integral-Beacham hydraulic motor. Hydraulic flow and pressure are supplied to the servodynes and the motor by a single engine-driven pump.

The tailplane hydraulic motor drives a gearbox situated within a special dedicated 'Hobson' unit. The latter incorporates two screw-jacks, both the outer elements of which are rotated by the gearbox system within the unit. Consequently, the inner threaded elements of each either extend or retract, depending on the direction in which the valve opens and the consequent direction of rotation of the motor. The aft end of the left inner screwjack drives a bellcrank on the left tailplane, whilst the right component provides a similar function to the right tailplane. The Hobson unit thus drives the tailplane halves and ensures they remain synchronised. Longitudinal trim is carried out via an electric motor driving an idler gear within the gearbox of the Hobson unit, whilst another idler gear drives a dedicated screwjack which in turn drives a rod, external to the gearbox, connected geometrically to the operating valve of the motor. Thus a feedback system is achieved whereby commanded selection of the valve on the motor to an open position causes the gears, screwjacks and tailplanes to move until consequent stroke of the rod shuts the valve and movement of the system and the tailplanes ceases.

Emergency provision

If main system pressure is lost, a hydraulic accumulator supplies short duration pressure via separate supply pipes to the aileron servodynes. A dedicated accumulator performs a similar function for the tailplane hydraulic motor, following hydraulic system failure. Such a hydraulic failure would be followed by a cockpit warning requiring the pilot to reduce speed, level the aircraft using the pressure and flow supplied from the accumulators and to use the normal pitch trim system. Thereafter it is necessary to operate a manual plunger on the upper left side of the instrument panel. This unlocks the pair of elevators, which in normal flight are locked to the tailplanes. These then operate without hydraulic assistance, responding to normal control column pitch inputs. Following loss of pressure, the tailplane is maintained at its final hydraulically driven position by the application of a brake within the Hobson unit which functions automatically once hydraulic pressure is lost. Following such loss of pressure, the ailerons operate manually with the control inputs acting on the bodies of the inactive servodynes. Manual control can only be fully effective at speeds below approximately 300 kt.

Escape system

The ejection seats of the Gnat were designed and produced by the aircraft manufacturer. The seats utilise only explosive cartridges, rather than a combination of cartridges and rockets that are used on most modern seats. The main and drogue cartridges are mounted in the head-box of each seat.

Normal operation is by handles on the head-box, which cause the canopy to release followed by ejection of the seat. A secondary method of ejection is by means of a seat pan handle which only operates the seat. The canopy must be manually released before the seat pan handle is operated although canopy breakers mounted above the head-boxes can destroy the transparency of the canopy as the seat exits the aircraft.

Power unit

The aircraft was powered by a single spool turbojet engine with an axial compressor.

Detailed examination

Airframe

Detailed examination of the wreckage at the AAIB indicated that all extremities of the aircraft, all flying control surfaces (including flaps) and the main landing gear doors (also acting as airbrakes) were present. Both underwing slipper tanks had clearly been correctly mounted at the time of impact. Sufficient fragments of the canopy structure and transparency were present to indicate that the latter remained secured to the aircraft at impact.

Flying controls

Since the flying controls were largely cable operated, passing through the destroyed cockpit and midships section of the fuselage, it was not possible to establish their integrity. The wing leading edge structure was destroyed during the impact and a significant proportion of the tubular aileron operating rod system housed within was fragmented and not identified. A number of other mechanical parts were also too fragmented to be identified. Examination of the mechanical section of the tailplane control in the remains of the rear fuselage revealed no evidence of any pre-impact failure. X-ray and strip examination of the hydraulic motor and the Hobson unit revealed that the brake assembly in the latter had correctly functioned following loss of pressure and there was no evidence of any form of failure in the internal parts of either component. The links from the screwjacks to the tailplane operating bellcranks were still connected and the latter correctly attached to their respective tailplane halves. The nature of the damage rendered it impossible to determine whether the elevators had been locked to their respective tailplane halves at impact.

Engine

Examination of the engine revealed no evidence of pre-impact failure. Although the compressor casing remained in a damaged but not totally destroyed state, with the exception of those on one stage, all compressor blades were absent, each having separated at the root. The remaining blades on the single stage were all severely distorted and damaged in a manner consistent with operation at high speed whilst in contact with the casing, or following blocking by debris whist rotating at high speed. The turbine casing was only lightly distorted but all turbine blades had been bent in a manner consistent with high rpm operation at the time the casing distortion occurred.

Impact and fire damage to the fuel control unit and other engine ancillaries precluded any useful further examination.

Ejection seats

The bulk of the remains of the ejection seats were identified in the wreckage although it was not possible to distinguish between the upper sections of the occupied front seat and those of the unoccupied rear seat. The seat remains were extensively damaged by impact and, in the separated upper parts of the seats, by fire. The condition of the seat structure within the mounting tubes and of the main and drogue cartridges (situated in the head boxes) was consistent with the consequences of the impact followed by the fire, ie all upper cartridges had completely discharged and the inner seat rails had remained fully engaged in the mounting tubes following the impact bending of both inner and outer tubes on both seats. Most of the canopy frame was recovered from the wreckage site as was a significant proportion of the transparency. Cartridges in the lower parts of the seats, associated with seat separation, had not fired. It was concluded that the canopy had not been released and neither seat had moved up its mounting tubes. These findings were consistent with the pilot having made no attempt to eject.

Pilot information

Licence

The pilot of G-TIMM held a Private Pilot's Licence (PPL) issued by the CAA under European licensing regulations. The licence was endorsed with a Single Engine Piston (SEP) (land) Class Rating valid until 31 January 2017. The pilot held an Exemption from the requirement to hold a Type Rating for the Folland Gnat T Mk 1[9] valid until 25 June 2016.

The pilot held a Display Authorisation (DA) issued by the CAA, valid until 26 May 2016, which permitted him to take part in flying displays in accordance with terms contained within the DA as follows[10]:

1. Type of aircraft: Single engine jet aircraft (Gnat; Jet Provost).
2. Minimum height for flypasts: 100 ft.
3. Aerobatic category: Standard
4. Minimum height for aerobatics: 300 ft.
5. Formation flying: Advanced formations with unlimited numbers of aircraft.
6. Tailchase flying: Advanced tailchases with up to four aircraft, flying as the leader or as a member of the formation.

General background and experience

The pilot began flying training with the RAF in December 1995 in the Bulldog T Mk 1, a single engine piston aircraft, and flew 110 hours in the period until August 1999. He then undertook training on the Tucano T Mk 1, a single engine turbo-prop aircraft, flying 148 hours between September 1999 and June 2000.

The pilot passed his PPL(A) SEP skills test in January 2003 and, in the same month, began training on the Jet Provost, a single engine turbine aircraft, flying 65 hours on that aircraft in the period up until December 2004. He first flew the Gnat in April 2005. A summary of the pilot's Gnat and Jet Provost flying since 2005, taken from his flying logbook, is shown in Table 1.

The pilot flew his last flight of the 2014 display season in a Gnat on 13 September 2014. His next flight, flown in a Cessna 152 to revalidate his PPL SEP (land) Class Rating, took place on 31 January 2015. On 25 April 2015, the pilot flew his annual currency flight in the Gnat, supervised by a DA Examiner (DAE) in the rear seat, during which he practised his solo display. Later that day, the pilot flew as number two in a three-aircraft formation display practice with a different DAE in the rear seat. On 26 April 2015, the pilot flew as number two in another three-aircraft formation display practice with one DAE leading the formation and another DAE in the third aircraft. The pilot's DA was renewed following the third flight, and he subsequently flew displays on 2 and 3 May, 28 June, and 23 and 30 July 2015.

Footnote

9 The Air Navigation Order (ANO) requires a pilot to have a valid Type or Class Rating to act as pilot of a particular Type or Class of aircraft. The Gnat is not classified as a particular Type or Class of aircraft and an Exemption to the requirements of the ANO is required before a pilot can fly the aircraft.

10 The framework within which display flying takes place is discussed later in this report.

Year	Number of flights	Hours flown		Displays or practices		Total Time
		Gnat	JP	Gnat	JP	All types
2005	37	24	4			441
2006	45	24	17	1	12	484
2007	55	33	17	6	14	549
2008	30	31		12		589
2009	46	32		31		627
2010	24	15	1	13	1	645
2011	11	6		5		652
2012	15	11		11		664
2013	18	13		13		677
2014	26	19		18		697
2015	9	10		7		707

Table 1

Flights, hours, displays and display practices flown by the pilot of G-TIMM

Prior to the accident, the pilot had flown:

a. A total of 707 hours (all types) of which 418 hours were in command.

b. An average of 23 hours per year on the Gnat and JP over the previous 10 years[11].

c. An average of 12 hours per year over the previous five years (flown in an average of 16 flights).

d. 2 hours 10 minutes in the previous 28 days (including 1 hour 15 minutes in the previous two days) and 6 hours in the previous 90 days.

e. One display in the previous eight days; two in the previous nine days.

Medical information

In July 2000, a routine electrocardiogram (ECG) conducted by the RAF indicated that the pilot of G-TIMM had a medical condition, Wolff-Parkinson-White syndrome, which required his Medical Employment Standard to be downgraded temporarily pending further tests. Although the RAF believed that medical intervention would probably allow him to return to flying, no such intervention took place and the pilot did not return to flying duties in the RAF.

On 11 January 2003, the pilot underwent his first medical examination for a Class 2 medical certificate issued on behalf of the CAA. His medical condition was not declared at this

Footnote

[11] The majority of the pilot's flying was undertaken between April and September each year.

examination and an ECG taken at the time showed no indications of its presence. The pilot's family were aware that he had been diagnosed with the condition but were not aware of any historic symptomatic episodes and stated that there had been none recently.

Typical symptoms of the pilot's medical condition include chest pain, rapid heartbeats (palpitations), dizziness, light-headedness, fainting, and shortness of breath. Some people do not experience any symptoms but, in others, episodes can last for seconds to hours and, in rare cases, days with the frequency varying from person to person. When the heart beats with an irregular or abnormal rhythm, there can be a drop in blood pressure which can compromise the supply of blood to the brain. The CAA stated that, if this is combined with circumstances where high acceleration (g) forces are experienced, such as in aircraft during high-performance manoeuvres, g-induced loss of consciousness (G-LOC) is more likely to occur. In addition, high-g manoeuvres can in themselves precipitate the arrhythmias which trigger the symptoms. The CAA also stated that the requirements for the issue of a Class 2 medical certificate, valid for use in display flying, do not include routine ECGs (before age 40) which might have highlighted this pilot's condition.

The pilot stated to the RAF in May 2001 that he had experienced some short episodes of palpitations in the past but had not suffered from blackouts, fainting or sudden incapacitation. His last ECG was the one taken on 11 January 2003 and the next one was due at age 40. At the time of the accident, he held a Class 2 Medical Certificate valid until 24 February 2017.

Recorded information

Three video cameras were recovered from the wreckage of G-TIMM along with two of their micro-SD cards. The micro-SD cards were damaged to an extent that no information could be recovered from them. Two GPS units were recovered from the wreckage but the non-volatile memory unit was missing from one and damaged in the other to an extent that no information could be recovered.

Data from ATC radar stations at St Anne's, near Blackpool, and Clee Hill, Shropshire, contained information relating to the accident aircraft up until it began its last pass. The final data showed the aircraft 0.5 nm from Oulton Park at an altitude of 600 ft based on 1013 hPa, equivalent to a height of 375 ft above the QFE datum which was near the display datum shown in Figure 5.

Aircraft flightpath and control inputs

Video footage of the accident, taken from the camera positioned at the point shown in Figure 6, is presented in a series of pairs of images (Figures 9 to 13) on which the time delay between images is shown in seconds. Because the aircraft was moving, the time delay means that each first image shows the aircraft from a slightly different perspective than does its pair. However, the time delays were short and the distances to the aircraft were estimated to be approximately 800 to 1,400 m[12]. In these circumstances, errors

Footnote

[12] The distance from the camera to the aircraft in each image was not determined. However, the distance from the camera to the farm buildings was approximately 800 m and, to the accident site, approximately 1,440 m.

introduced by the different perspectives were considered to be small enough to discount, especially since the analysis is qualitative rather than quantitative.

G-TIMM approached the display line from 'crowd left' and commenced a roll about its longitudinal axis, and the left image in Figure 9 shows the aircraft attitude at the end of that manoeuvre relative to the horizontal yellow line. The pilot then appeared to increase the attitude of the aircraft prior to commencing the second roll, as shown in the right image in the Figure, although the increase appeared slight on the video.

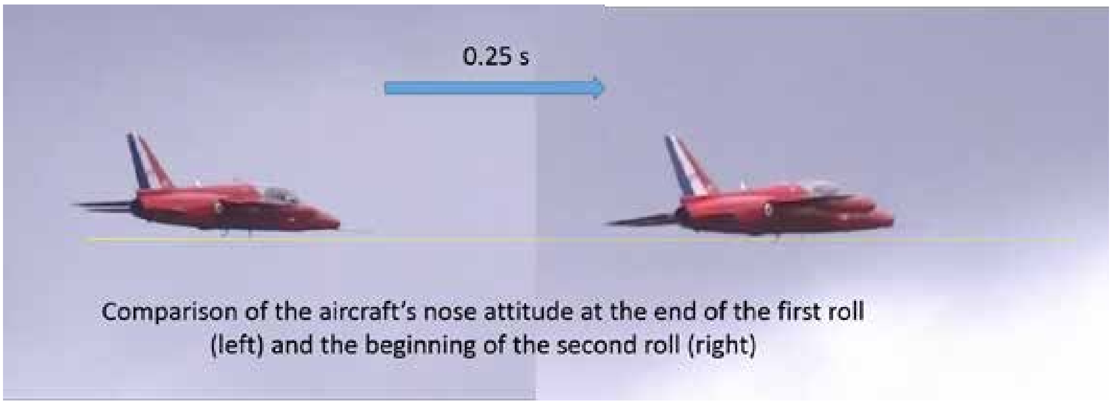


Figure 9

Aircraft attitude before the second rolling manoeuvre

When G-TIMM reached the attitude shown in the left image within Figure 10, the nose attitude dropped relative to the horizon, a drop which was marked on the video. The black lines on the Figure are drawn along a line from the nose of the aircraft through the centre of the jet pipe at its rear to illustrate the drop in nose attitude (shown by the fact that the lines are not parallel).

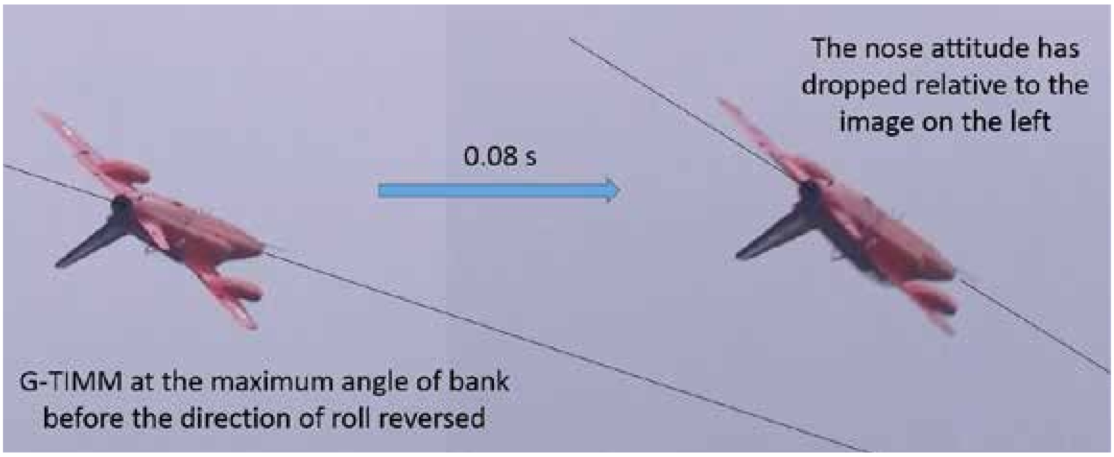


Figure 10

Comparison of the aircraft attitude during the rolling manoeuvre

Immediately after the nose dropped, the direction of roll reversed to the right. Control inputs consistent with this are shown in the left image of Figure 11 by the 'upward' deflection of the right aileron (upward relative to aircraft axes) and, in the right image, by the 'downward' deflection of the left aileron (downward relative to aircraft axes). Approximately 0.2 seconds after the direction of roll reversed, a control input was made to the tailplane whereby its trailing edge moved upwards considerably (upwards relative to aircraft axes). The white lines in Figure 11 are drawn through the leading and trailing edges of the tailplane to illustrate its movement (shown by the fact that the white line in the first image crosses the underside of the aircraft forward of the two aerials whereas, in the second, it passes aft of the two aerials).

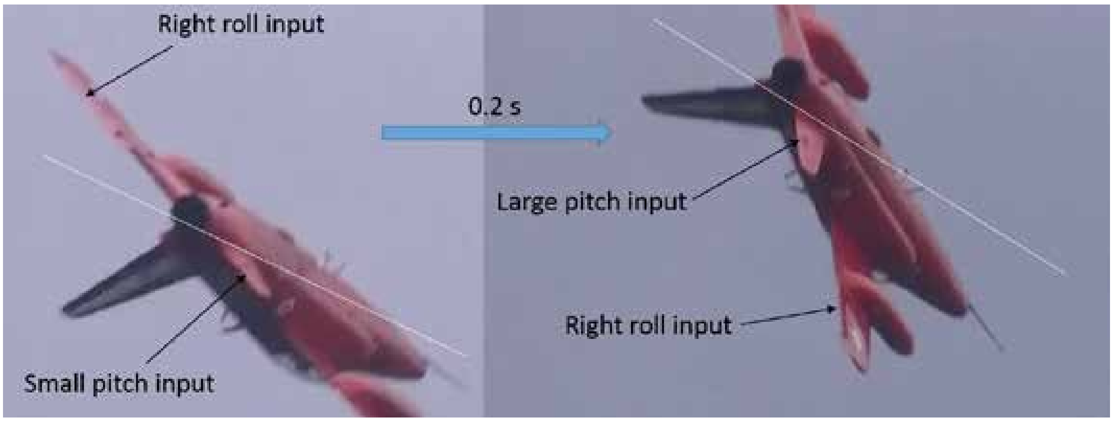


Figure 11

Reversal of roll direction and increase in pitch input

The movement of the tailplane caused the aircraft to pitch (rotate) markedly about its lateral axis. This is shown in Figure 12 by the fact that the first image shows the underside of the aircraft while the second shows its top surfaces. The black lines, once again drawn through the nose and jet pipe, also show the marked change in aircraft pitch attitude.

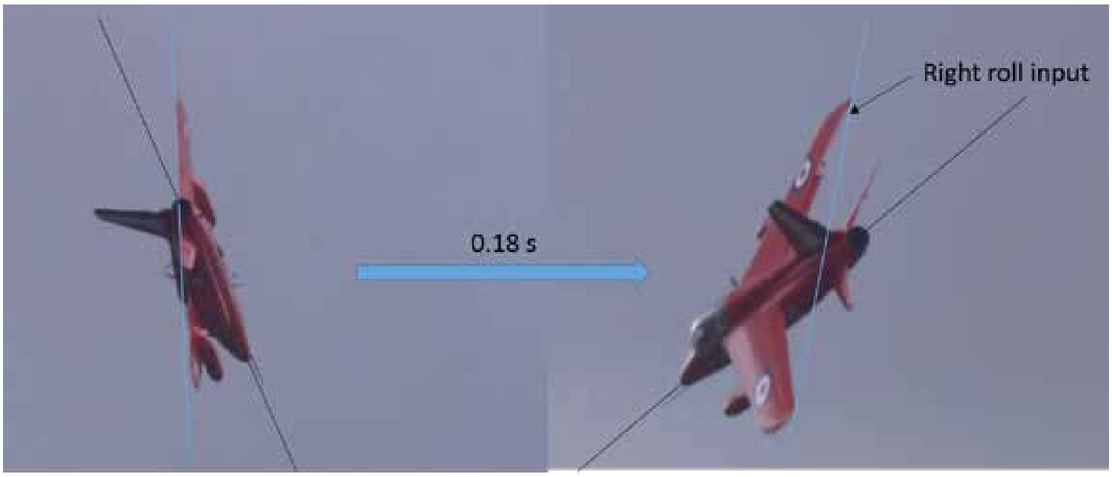


Figure 12

Increase in pitch attitude and reduction in bank angle

The right aileron in the second image is deflected upward indicating that there is a right roll control input. Reference to the blue lines, drawn through the trailing edges of each wingtip, shows that the angle of bank was reducing in response to this input ie the aircraft was rolling right towards a more upright attitude.

Following the marked change in pitch attitude shown in Figure 12, the nose attitude of the aircraft dropped further, illustrated by the fact that the black lines in Figure 13 are not parallel. The right aileron is still deflected upwards, indicating a control input for right roll. However, a comparison of the two blue lines shows that the aircraft was rolling left as it descended towards tree-top height.

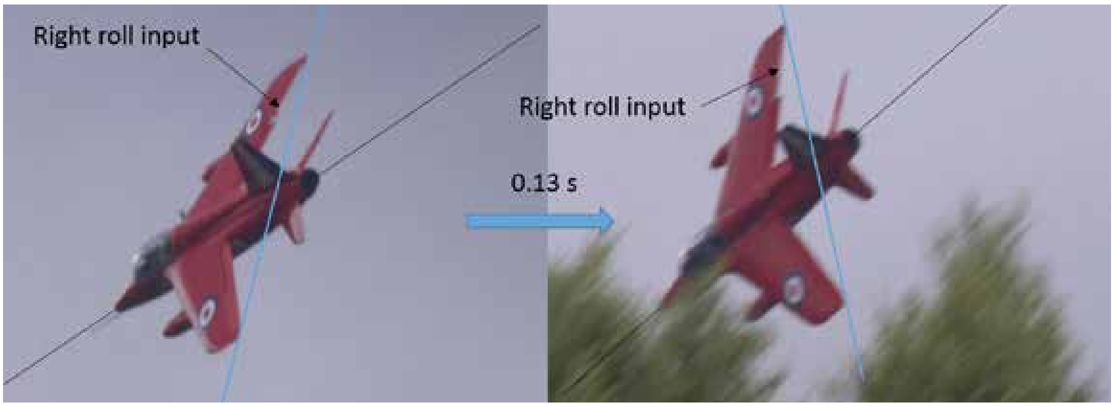


Figure 13
Left roll with right roll control input

Third party flightpath analysis

The video was submitted to the Ministry of Defence (MOD) for analysis. Measurements were made from individual frames with reference to known dimensions of the aircraft, and by matching a 3D computer aided design (CAD) model of the aircraft to sequential images captured from the video. It was not possible to determine the height and attitude of the aircraft relative to the ground from the video evidence but the remaining results, taken from the MOD's report, are presented in Figure 14 and Table 2.

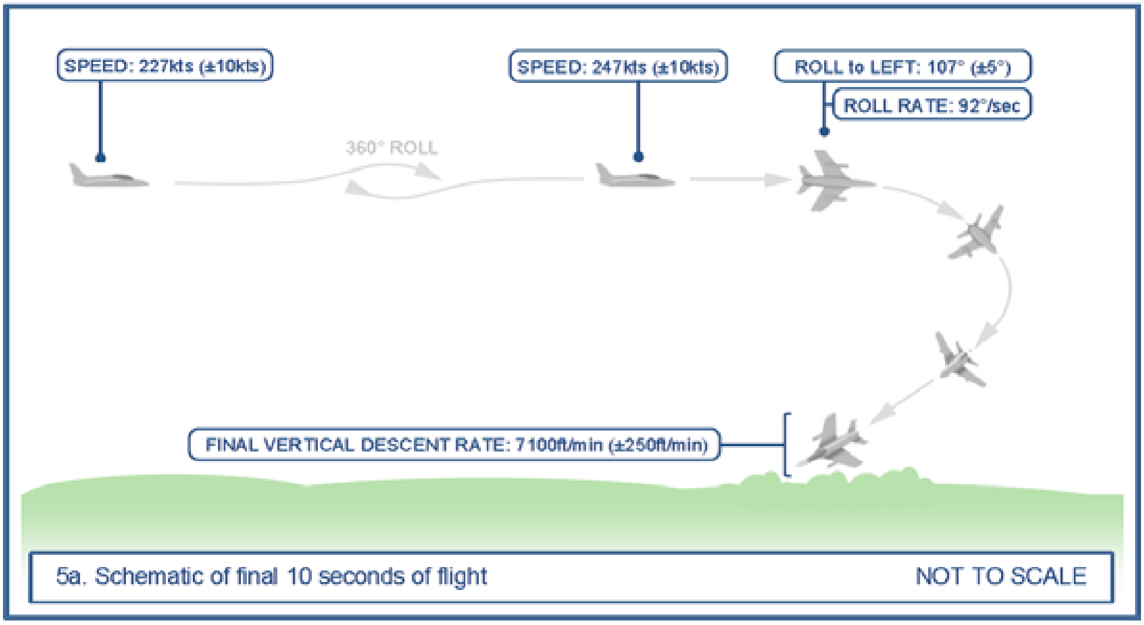


Figure 14

Schematic representation of the final 10 seconds of flight

Event	Measurement
Speed between 10.20 and 9.50 seconds from impact.	227 ± 10 kt
Speed between 5.64 and 5.00 seconds fro impact.	247 ± 10 kt
Roll to left between 4.32 and 3.16 seconds from impact.	107° ± 5°
Roll rate between 4.32 and 3.16 seconds from impact. NB. After 3.16 seconds before impact, the nose pitches down markedly.	92°/s
Vertical descent rate between 0.52 and 0.32 seconds from impact	7,100 ± 250 ft/min

Table 2

Table of measurements

The MOD analysed the still image in Figure 8 and determined that the aircraft was approximately 390 m ± 25 m from the camera used by Witness 2.

The path of the aircraft near the display line

The AAIB and the operator of the Gnat carried out independent analyses of an on-board video recording taken from the second Gnat to establish the aircraft's ground track during the time that G-TIMM was being positioned for its final pass in the area south-west of the display line (Figure 15). The position fixes were established by comparing features on the ground, seen from the on-board video recording, with the same features seen in an overhead view in Google Earth. The associated times were taken from the video and relate to the beginning of the recording. The red and yellow stars represent locations identified by the AAIB and operator respectively.

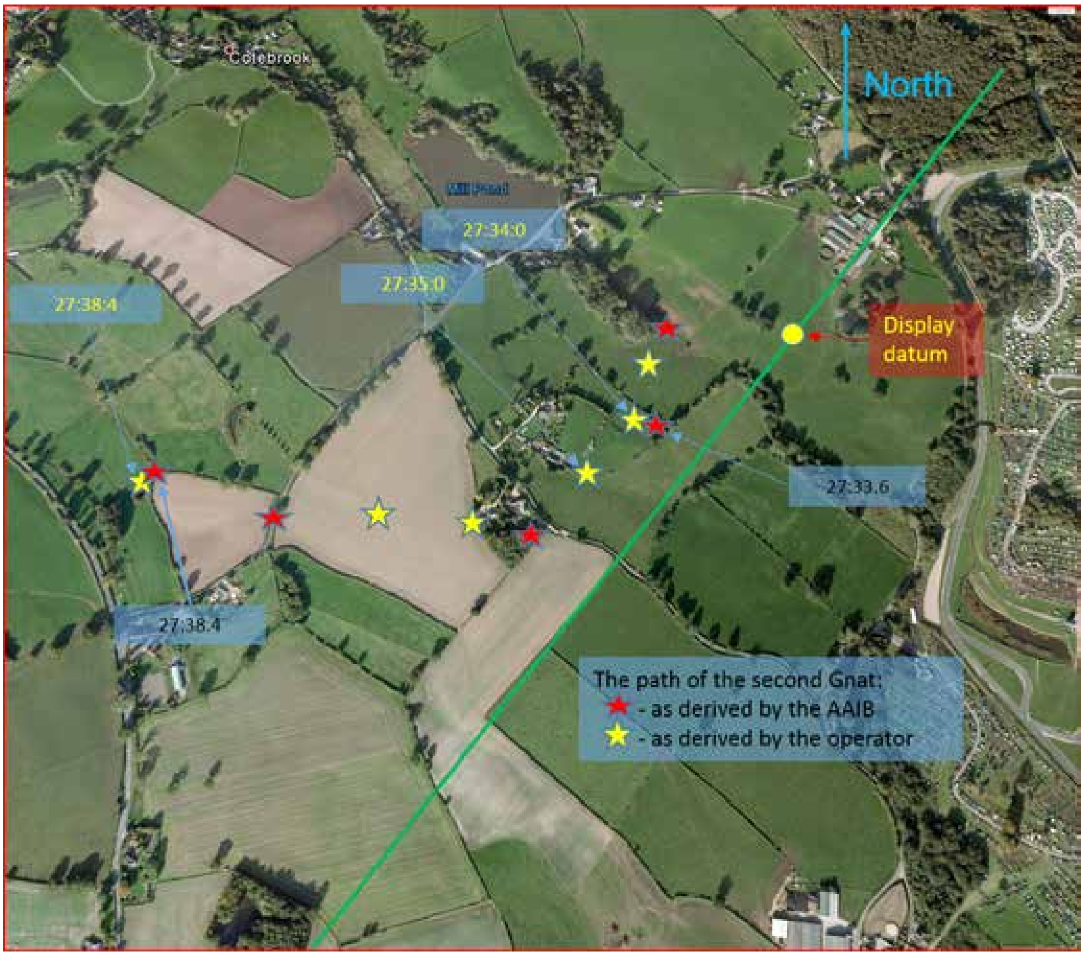


Figure 15

Ground track of the second Gnat

Figure 16 is an image, taken at 27:38.4, of G-TIMM and the second Gnat crossing the line of sight of a ground-based camera (the ground-based camera which provided the video discussed earlier) [13]. At 27:38.4, the operator and AAIB analyses of the second Gnat's

Footnote

[13] Timing between the on-board video and the video from the ground-based camera was synchronised against an aircraft manoeuvre recorded by both systems.

position agree to within approximately 50 m (Figure 17). A line of sight was drawn from the camera's location through the second Gnat's position at 27:38.4[14] and G-TIMM was on this line at this time, although its exact position along the line could not be determined.

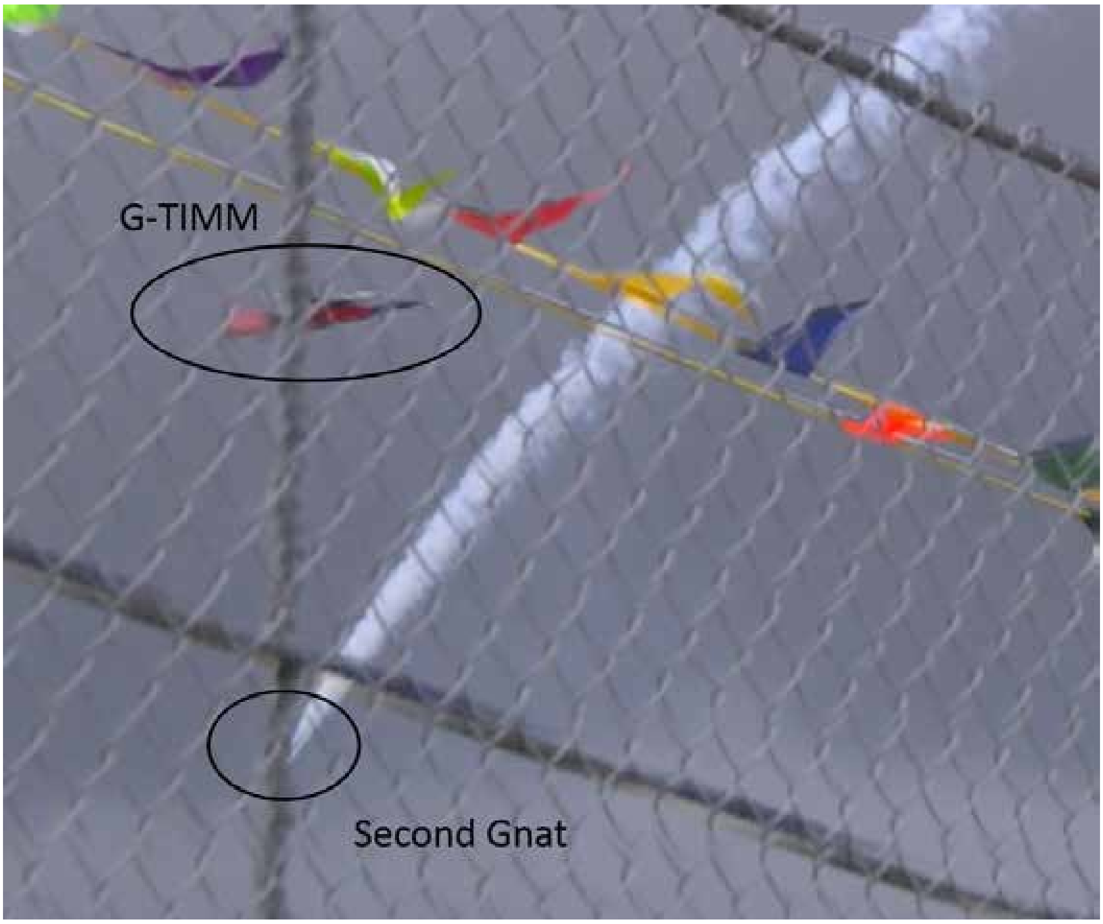


Figure 16

Image of both aircraft at 27:38.4 as G-TIMM commenced its final pass

Figure 17 shows a sight line from the camera of Witness 2 passing the tree shown in Figure 8 and the MOD measured the distance of G-TIMM along this line to be approximately 390 m. Using the last known height of G-TIMM (375 ft above the display datum), this is equivalent to a ground distance of approximately 370 m which suggested that G-TIMM was flying close to the display line (Figure 17). Evidence from Witness 1 suggested that the aircraft's location was bounded by a south-easterly limit shown by the yellow line 'A' in Figure 17.

No quantitative information was available about relative heights of the two aircraft. However, the on-board video in the second Gnat showed that the manoeuvre it flew (described by the points in Figure 15) was flown with vertical extent, and the operator stated that aircraft flying this manoeuvre would typically be between 1,500 and 2,000 ft agl at the apex.

Footnote

[14] The line was drawn through the mid-point between the AAIB- and operator-determined aircraft positions.

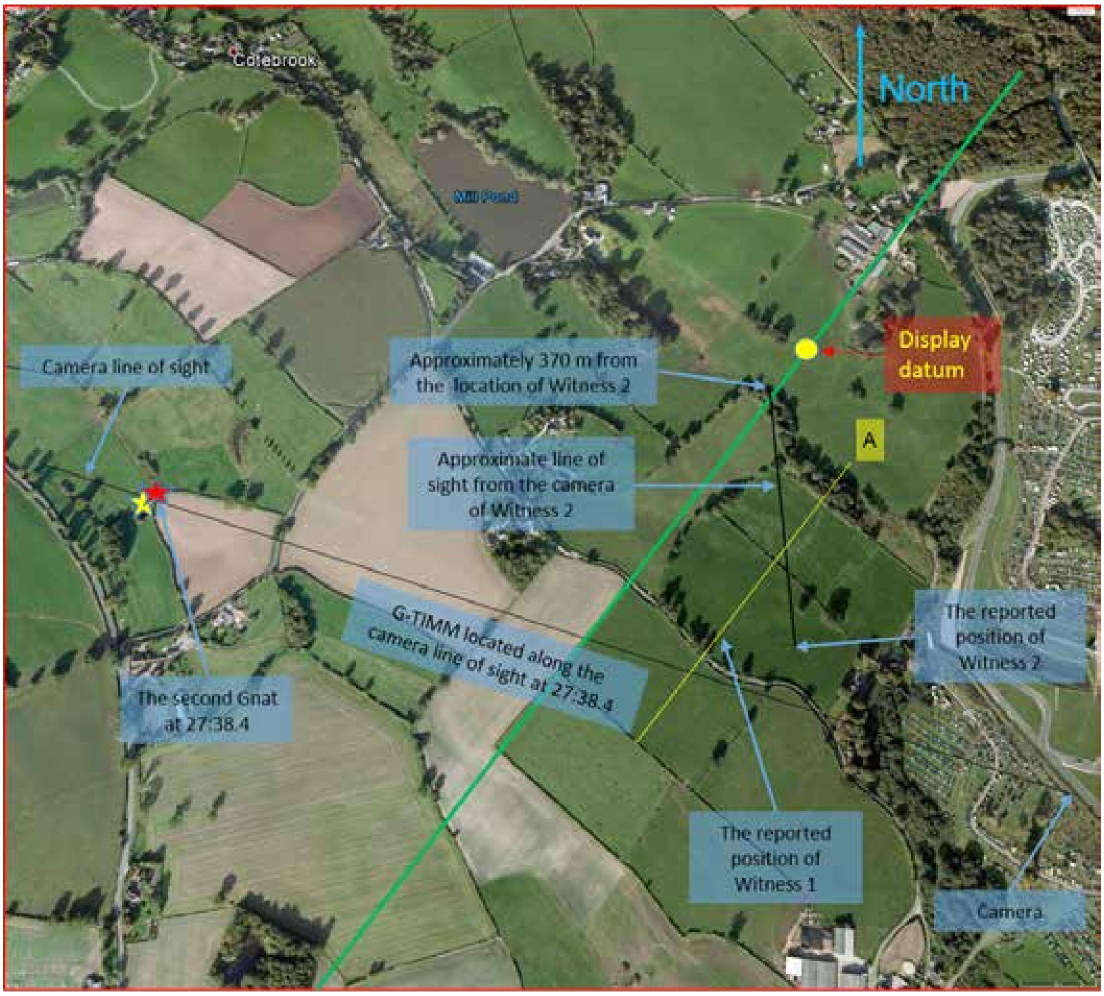


Figure 17
The camera line of sight at 27:38:4

CAP 393, *Air Navigation: The Order and Regulations*

The ANO empowers the CAA to regulate civil flying displays. Article 162 of the ANO states that a person wishing to organise a flying display must obtain permission from the CAA, and the CAA may grant permission subject to any conditions that it thinks fit. The ANO requires the CAA to grant a pilot a DA if it considers the pilot to be fit to hold the authorisation and to be:

> *'qualified by having the knowledge, experience, competence, skill, physical and mental fitness to fly in accordance with the authorisation.'*

CAP 403, *Flying Displays and Special Events: A Guide to Safety and Administrative Arrangements*

CAP 403 sets out the safety and administrative procedures to be followed by organisers and participants at civil flying displays. It sets out requirements for the appointment of a FDD, whom it defines as:

> *'the person responsible to the CAA for the safe conduct of a flying display.'*

The CAP states that car parks to which the public has access during a flying display must be considered the same as the spectator area.

The display line

The display line defines the closest a display aircraft may approach the crowd line. The crowd line is the forward edge of areas intended for spectators and any car park to which the public has access. The display line must be clearly identified but an obvious line feature can be used in the case of off-aerodrome sites.

Minimum distances from the display line to the crowd line are shown in paragraph 3.25 of CAP 403. Minimum distances from the crowd line relevant to this accident relate to aerobatic manoeuvres flown between 200 and 300 kt (requiring a minimum distance of 200 m) and for aircraft flying above 300 kt (requiring a minimum distance of 230 m).

Paragraph 3.28 of CAP 403 states that pilots should:

> *'always regain the display line without infringing the minimum lateral separation distance from the crowd line. Effects of any on-crowd velocity vectors … must be taken into account.'*

Minimum heights

A pilot's DA includes absolute minimum heights for respective manoeuvres but, at off-aerodrome sites, the CAA will normally impose a minimum height of 200 ft. The pilot of the second Gnat confirmed that the display team was using 300 ft agl as a minimum height for aerobatic manoeuvres and 200 ft agl for flypasts.

Liaison with the CAA

An FDD is required to obtain a Permission from the CAA in order to hold a flying display. The application form should reach the General Aviation (GA) Unit at the CAA at least 28 days before the display date, and it should include a 1:50,000 scale map showing the display line and the layout of the spectator enclosure.

Pilot display competency and recency

There are no specific minimum experience requirements within CAP 403 before a pilot can apply for a DA. However, paragraph 5.14 of the CAP gives DAEs guidance on the minimum sensible level of experience required before a DA application should be considered. For fixed-wing aeroplanes, the CAP suggests a total of 200 hours flying including at least 100 hours as pilot-in-command.

Paragraphs 5.33 to 5.36 of CAP 403 state that display pilots are required to have flown a minimum of three full display sequences or practices within the 90 days preceding a demonstration at a flying display. One of the sequences must have been flown in the specific aircraft to be displayed. The CAP emphasises that these are minimum requirements and encourages pilots to practise sufficiently to maintain a sufficiently high level of safety.

CAP 632, *Operation of 'Permit-to-fly' Ex-military Aircraft on the UK Register*

General and technical requirements

G-TIMM was an ex-military aircraft and one of the conditions of its Permit-to-Fly was a requirement for it to be operated in accordance with CAP 632. The CAP is divided into a number of parts covering, inter alia, pilot qualifications, operational requirements and audit procedures. Operators are required to comply with the CAP by compiling an Organisational Control Manual (OCM), agreed with the CAA, detailing how they propose to manage and operate their aircraft. The CAA normally audits operators annually.

CAP 632 encourages operators to develop a positive safety culture in order to achieve high safety standards and recommends that they adopt a Safety Management System (SMS).

Pilot qualification and currency

Pilots applying to fly high performance jet aircraft, such as G-TIMM, are required to have '*appropriate'* flying experience, and training requirements are assessed on an individual basis. Minimum experience levels and training requirements are required to be included in the OCM, as are currency requirements and levels of supervision. The operator is required to keep pilot flying and ground training records.

Guidance on experience requirements to fly jet aircraft

Appendix C to CAP 632 gives guidance on experience requirements for pilots to fly jet aeroplanes although it comments that each pilot must be judged individually. The CAP classifies pilots as:

a. Inexperienced when they have up to 50 hours pilot in command (PIC) post-licence issue.

b. Intermediate when they have between 50 and 450 hours PIC post-licence issue.

c. Experienced when they have over 450 hours PIC post licence issue.

The operator's OCM

Pilot experience and currency

The operator's OCM states that only Intermediate and Experienced pilots will be considered for training on the Gnat. In order to become self-authorising, pilots are required to gain a minimum of 15 hours on type and to have completed the operator's 'Folland Gnat Conversion Training Schedule' to the level of 'Self-authorising'. According to the schedule, this includes a minimum of 30 hours of airborne instruction including four check flights.

Self-authorising pilots remain current on the aircraft having flown a minimum of one flight in the previous 12 weeks. Pilots with more than 100 hours on type (defined as high performance, swept wing aircraft with hydraulically powered flying controls) require a minimum of one flight in the previous six months.

The pilot of G-TIMM was a self-authorising pilot with more than 100 hours on type. He was an Intermediate pilot based on the 418 hours he had logged as PIC[15].

Display criteria

The OCM states that pilots who display the Gnat will do so in accordance with the conditions set out in CAP 403 and within the operational parameters set out in the Gnat T1 Pilot's Notes.

Safety management

The operator of G-TIMM did not have an SMS as part of its OCM although it stated that it used a risk-based approach when formulating provisions within the OCM. The operator had not identified any elevated risk arising from the experience, training or currency of the pilot of G-TIMM.

CAA Audits

The CAA audited the operator of G-TIMM in October 2012 and January 2014 and, in each case, the only findings were Level Two findings[16] on the maintenance of training records.

Management of aircraft separation during a display

The operator stated that, although at the time of the accident there was no manual documenting in one place its formation display procedures, standard procedures were used to manage aircraft separation during displays and were well known by all its pilots. Prior to taking off, pilots discuss the likely effect of wind during the display and how to compensate for it. During the display, pilots use a 'contract' whereby responsibility for safe separation lies with the pilot positioning for his next pass, and a pilot clearing the display line must call "OUT" on the radio before the incoming pilot calls "VISUAL; RUNNING IN"

Footnote

[15] Some of the pilot's PIC hours were gained in the RAF before his PPL was issued. This did not affect his classification as an Intermediate pilot.

[16] Level Two findings are non-conformities considered to be in need of remedial action. Level One findings are serious non-conformities which require rectification before any further flying takes place.

and begins his pass. Should a pilot judge that he will arrive on the display line before the other aircraft has vacated it, he can delay his aircraft's arrival by reducing speed, or by flying S-turns or a 360° turn to create extra track distance. Should a pilot choose to slow his aircraft to generate separation, he should maintain sufficient speed to fly the following manoeuvre or, otherwise, not fly that manoeuvre. The Pilot's Notes recommends 280 kt as a minimum entry speed for an aileron roll '*until experience is gained',* although it does not record a minimum speed to be used once experience has been gained. The Flying Instructor's Handbook for the Gnat T1 states that slow rolls can be demonstrated at speeds between 250 and 300 kt.

The pilot of the second Gnat stated that, on clearing the display line, he transmitted "[*CALLSIGN*] TWO IS OUT" and recalls hearing the reply "[*CALLSIGN*] ONE IS VISUAL, RUNNING IN".

Safety Action

Following the accident, the operator produced a document, *Gnat Display Team 2-ship Formation Display Procedures/SOPs,* to document in one place the techniques and procedures to be used during flying displays.

The operator commented that it was possible that the pilot mis-read the airspeed indicator and that this led to him flying towards the display line at a speed lower than expected. They also considered the possibility that the pilot of G-TIMM was flying slower than expected because, while positioning for his next pass, he did not displace himself far enough away from the display line. In these circumstances, the pilot might slow down or extend his ground track as described earlier but should not fly below the minimum entry speed for the following manoeuvre.

Equivalent military regulations

The Royal Air Force (RAF) operated the Folland Gnat in the fast-jet training role currently undertaken by the BAe Hawk, and both aircraft are similar high performance jet aircraft. This section considers some of the regulations applicable to RAF display pilots flying the Hawk as a benchmark for further discussion.

Minimum experience

In order to undertake flying displays, an RAF Hawk pilot requires a 'Public Display Authority' (PDA) which is the equivalent to the CAA's DA. Hawk display pilots will be nominated by their Station Commander following a practical assessment of their flying ability, an interview to assess their suitability for display flying, and a review of their flying record. The nomination must be approved by a senior officer in the headquarters of RAF flying training. There are no specific requirements for the minimum number of hours a pilot should have flown. However, most Hawk pilots eligible to display the aircraft will have previously flown at least one front line fast jet tour and will therefore meet the CAA classification of Experienced.

Minimum heights

Hawk pilots develop their display sequence using a minimum height of 5,000 ft. They then fly a minimum of six practices to a minimum height of 1,500 ft before being cleared to use a minimum height of 1,000 ft. Following a minimum of six practices to a minimum height of 1,000 ft, the pilot may be cleared to display down to a minimum height of 500 ft (100 ft agl for flypasts as part of the display).

Display currency

In order to maintain PDA currency, an RAF Hawk pilot is required to have flown two displays or practice displays in the previous eight days using a minimum height of 500 ft.

AAIB Special Bulletins

The AAIB published Special Bulletin S4/2015[17] in relation to the accident to Hunter T7, G-BXFI, at Shoreham Airport on 22 August 2015. The Bulletin discussed the safety of first responders at accidents involving aircraft with ejection seats, the maintenance of ejection seats, and the maintenance of ex-military jet aircraft. AAIB Special Bulletin S1/2016[18], published in relation to the same accident, discussed, inter alia, risk management at flying displays, minimum display heights, and standards for display pilots. Both Bulletins made Safety Recommendations which are relevant in the context of the accident to G-TIMM.

Engineering analysis

The aircraft struck trees at a relatively low forward speed and with a steeply descending flight path; the final pitch and bank angles could not be determined. At the time of impact the aircraft was structurally complete, all control surfaces were present and the underwing tanks were attached. The landing gear appeared to have been retracted.

It was not possible to determine conclusively from wreckage examination whether the elevators were locked to the tailplanes or whether hydraulic power remained available to the tailplanes and ailerons. Figures 9 to 13, however, show synchronised inclination of the tailplanes with no separate deflection of the elevators, and a final tailplane angle considerably displaced in an aircraft pitch-up sense. To achieve this amount of tailplane deflection shortly after the aircraft had been in a flight condition with little tailplane deflection would have required hydraulic pressure to be available. Had it not been available, the hydraulic motor would have failed to respond significantly and the brake in the Hobson unit would have operated, preventing any significant tailplane movement.

The images show aileron deflection consistent with observed aircraft roll direction and expected pilot roll control input, ie towards a wings-level attitude. This indicated that aileron deflection was achieved in response to roll control input, regardless of whether manual or hydraulically assisted power was used. Since the tailplane behaviour was consistent with normal hydraulic operation up to the time the aircraft disappeared from the video, it was probable that hydraulic pressure remained available to the aileron control unit.

Footnote

[17] https://assets.digital.cabinet-office.gov.uk/media/5677d6bfed915d144f000000/S4-2015_G-BXFI.pdf
[18] https://assets.digital.cabinet-office.gov.uk/media/56e178f240f0b6037900001b/S1-2016_G-BXFI.pdf

The following conclusions were made about the aircraft before impact:

a. The hydraulic system was operating the tailplanes in normal mode with the elevators in the locked position.

b. Aileron deflection was consistent with expected pilot control demand.

c. No evidence was found of pre-impact failure in the flying control system.

d. The engine appeared to have been delivering significant thrust.

e. The canopy had not been released, and the ejection seats had not moved up their mounting tubes.

Analysis of the final manoeuvre

The drop in aircraft nose attitude during the roll

The images in Figures 9 to 14 and the information in Table 2 show that the accident sequence began when, with the aircraft at 107° angle of bank to the left, the nose attitude dropped relative to the horizon (Figure 10). The cause of this change in aircraft attitude was not determined.

Figure 14 shows that the first rolling manoeuvre was flown at 227 kt ± 10 kt, approximately 73 kt below the usual entry speed of 300 kt, and the second rolling manoeuvre at 247 kt ± 10 kt, approximately 53 kt slower than the usual entry speed. These speeds were below the recommended minimum speed of 280 kt (although the Pilot's Notes suggested that pilots with experience could fly aileron rolls at unspecified slower speeds). Aircraft rolling at lower speeds have an increased tendency for the nose attitude to drop during the manoeuvre and, if this is not anticipated, it can lead to a lower-than-normal nose attitude at the end of the roll. This can influence the following manoeuvre especially if, as video evidence suggested in this case, the nose attitude was raised only slightly ahead of the second roll. A lower-than-normal nose attitude at the beginning of the second roll, combined with a speed still below the recommended minimum, might account for the drop in nose attitude during the manoeuvre. However, other possibilities for the drop in nose attitude could not be discounted, such as disorientation, visual illusion or distraction.

Control inputs after the drop in nose attitude

After the nose attitude dropped, the aircraft could have been recovered to level flight by reversing the direction of roll, rolling back to a wings level attitude and, with the wings level, pitching the aircraft nose up to arrest the rate of descent and regain level or climbing flight. Figure 11 shows that a control input was made to reverse the direction of roll consistent with the pilot recognising the unusual change in attitude and beginning recovery action. Figures 11 to 13 show that the right roll input was present until immediately before impact, and Figures 11 and 12 show that the aircraft initially responded by rolling right.

Figure 11 shows a large pitch input at the tailplane, and Figure 12 shows that the aircraft responded with a large change of pitch attitude. A pitch input was consistent with the recovery action suggested above except that it occurred too soon, with the aircraft nose below the horizon and with an angle of bank greater than 90°. The pitch input rapidly increased the rate of descent and caused the aircraft to depart from controlled flight, shown by the fact that the aircraft began to roll left despite continued right roll control input. The high rate of descent and the departure from controlled flight were each sufficient to make the situation irrecoverable in the height available.

It took 1.16 seconds to roll to 107° of bank and it took a further 3.16 seconds before the aircraft struck the ground. Although the decrease in nose attitude would have caused the aircraft to descend, there was probably sufficient time to roll back to a wings level attitude and arrest the rate of descent before impact. This is because the short time to impact (3.16 seconds) resulted from a rapidly increasing rate of descent (7,100 ft/min immediately before impact) that would not have been present had the aircraft rolled to a wings level attitude. It was concluded, therefore, that the situation was recoverable after the nose attitude dropped during the roll to the left.

Reasons for the lower-than-normal entry speed

The pilot began his first roll approximately 73 kt below the normal entry speed of 300 kt and this was either deliberate or inadvertent. An inadvertent loss of 73 kt represented a large difference from the expected speed and was considered unlikely, although the operator considered that it might have been the result of mis-reading the airspeed indicator. Speed reduction was used by the display team as a method for delaying an aircraft's arrival on the display line (to allow the preceding aircraft to vacate it). Any decision by the pilot of G-TIMM to reduce speed would have been based upon his visual assessment of the progress along the display line of the second Gnat and would have to have been made early enough to have a meaningful effect. For example, an aircraft travelling at 227 kt, as opposed to 300 kt, would have to do so for 16 seconds to delay its arrival at a given point by five seconds[19].

Figure 18 shows the relative locations of G-TIMM and the second Gnat, had G-TIMM arrived on the camera sight line five seconds earlier than it actually did, travelling at 300 kt[20]. Although the Figure shows the outcome of a hypothetical set of circumstances, it suggests that, had G-TIMM not slowed down, the possibility existed that it would have reached the display line before the second Gnat had vacated it. This would have been contrary to the 'contract'[21] used by the operator to ensure safe separation on the display line and, if anticipated by the pilot of G-TIMM, provides a plausible reason for him to slow down. The second Gnat was flying a manoeuvre with vertical extent and it was unlikely that the pilot of G-TIMM perceived that there might be a risk of collision near the display line. Nevertheless, it was possible that G-TIMM was flown slower than usual, at least in part, to delay its arrival on the display line.

Footnote

[19] An aircraft at 300 kt would cover 2,464 m in 16 seconds. Flying at 227 kt, the same aircraft would cover 1,872 m in the same time and would require another five seconds to cover the extra 592 m.

[20] For clarity, the Figure only shows the positions of the second Gnat derived by the operator.

[21] See earlier section, Management of aircraft separation during a display

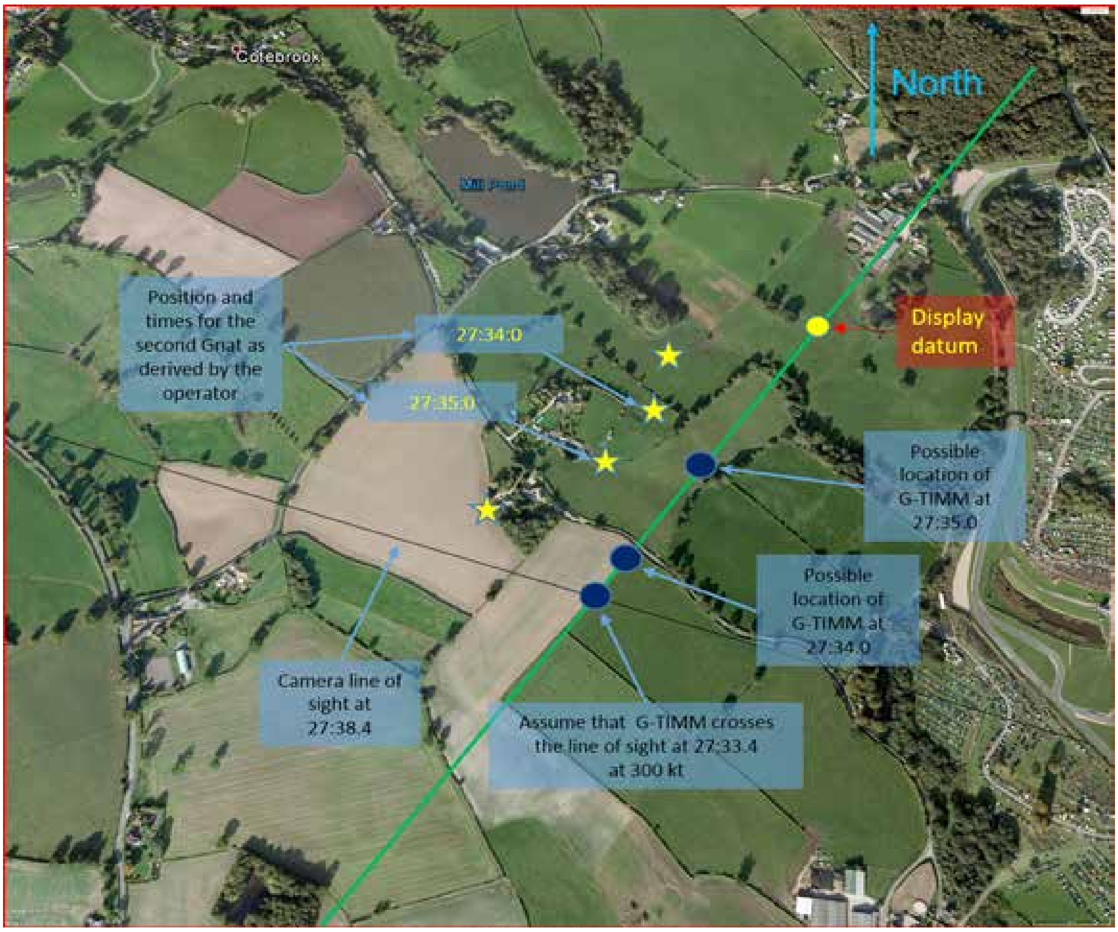


Figure 18

Hypothetical plan view of the aircraft had G-TIMM crossed the camera sight line at 27:33.4

Risk controls

The CAA recommends the use of risk assessment methodologies, such as 'Bowtie' assessments, for the analysis and control of risk within a Safety Management System (SMS)[22] and provides Bowtie templates for its 'Significant Seven' risks to Commercial Air Transport[23]. Bowtie analysis considers measures designed to prevent a 'loss of system control', measures designed to recover control should it be lost, and measures designed to minimise the consequences should control not be recovered.

The following discussion is adapted from two CAA templates: loss of aircraft control and human factors where an activity is not performed to a safe standard. The 'loss of system control' occurs when the aircraft deviates unintentionally from normal in-flight parameters (in this case, the unexpected drop in nose attitude), and the consequence is unrecovered

Footnote

[22] An introduction to Bowtie analysis is available here: https://www.caa.co.uk/Safety-Initiatives-and-Resources/Working-with-industry/Bowtie/

[23] The templates are available here: https://www.caa.co.uk/Safety-initiatives-and-resources/Working-with-industry/Bowtie/Bowtie-templates/Access-the-bowtie-templates/

loss of control and terrain impact. During the discussion, comparison is made with the way the Bae Hawk is operated by the RAF in the display environment as a means of comparing risk control measures.

Risk control measures intended to prevent an unintentional deviation from normal in-flight parameters

The drop in nose attitude while rolling was an unintentional deviation from normal in-flight parameters the risk of which should have been managed by prevention control measures discussed below.

P(a). *The use of suitably experienced pilots.*

The pilot of G-TIMM had not flown high performance, swept wing jet aircraft before converting onto the Gnat and, at the time of the accident, was of Intermediate experience according to CAP 632 criteria. He had flown the aircraft for 11 years, gaining approximately 218 hours on type. A notional RAF Hawk display pilot, having flown a front line fast-jet tour, would have experience of swept wing aircraft and would be classified as Experienced.

P(b). *Suitable currency requirements to maintain handling skills.*

The pilot of G-TIMM flew an average of 12 hours per year during the 5 years before the accident with the majority of the hours being flown on the Gnat. He had flown one display in the previous eight days (and two in the previous nine days, which was close to RAF currency requirements). He had flown four displays in the previous 90 days, which was close to, but in excess of, the CAA minimum of three. He had flown approximately 10 hours and seven displays or practices since 25 April 2015, when his 2015 Gnat flying began[24].

P(c). *A suitable choice of manoeuvres.*

The pilot had flown 'twinkle rolls' many times before and it should not have been a particularly demanding manoeuvre for him to fly. Displaying high performance jet aircraft in a pairs display requires a high degree of coordination but the pilots had displayed together over a number of years.

P(d). *A Safety Management System (SMS) and Quality Management System (QMS).*

SMS and QMS, rather than being barriers in their own right, help to manage the effectiveness of other barriers.

Footnote

[24] The pilot flew a Cessna 152 for 1 hour on 31 January 2015 to renew his SEP (land) rating.

The operator's OCM did not have an SMS. The operator did not identify any elevated risk associated with the accident pilot's competence to display the Gnat. Two CAA audits of the operator of the Gnat identified non-conformities with respect to training records but did not highlight any concerns with respect to experience levels, flying training (as opposed to training record-keeping) or recency.

Risk control measures intended to prevent a deviation from normal in-flight parameters from leading to unrecovered loss of control and terrain impact

In circumstances where an unintentional deviation from normal in-flight parameters is not prevented, recovery controls should reduce the risk that the deviation leads to a loss of control, impact with terrain, and casualties on the ground. These recovery control measures are discussed below.

R(a). *The pilot detects and recognises the mishandling.*

The reversal in roll direction suggests that the pilot of G-TIMM recognised the unintended change in nose attitude.

R(b). *The pilot attempts to recover the aircraft in the height available.*

After the nose dropped, the pilot applied an appropriate roll input followed by an inappropriately-timed pitch input, the magnitude of which made a recoverable situation irrecoverable in the height available. Increasing the minimum authorised height increases the margin for error and, with it, the likelihood that an aircraft will be recovered in the height available should control be lost. Increasing the minimum height therefore improves the effectiveness of this risk control measure.

The pilot of G-TIMM was operating to a minimum aerobatic height of 300 ft, although the actual height of the aircraft when the nose attitude dropped was not determined. The benchmark equivalent minimum height used by the RAF is 500 ft.

R(c). *The pilot fails to recover the aircraft and ejects.*

It was not determined whether there was any period after the initial nose attitude change during which the pilot might have ejected safely. The rapid increase in rate of descent, and the banked attitude of the aircraft, would each have reduced the likelihood of a safe ejection from low level. Figures 11 to 13 suggest that the pilot had at least one hand on the control column until very late in the accident sequence, and examination of the wreckage found that the canopy had not been released and the pilot's seat had not moved up its respective mounting tube. It was concluded that the pilot made no attempt to eject.

R(d). *The aircraft impacts terrain clear of the public.*

G-TIMM struck the ground in a wooded area and no other person was injured, although the wreckage straddled a minor public road with the obvious attendant risk of serious adverse consequences. Pilot control inputs observed on the video were highly unlikely to have been made in an attempt to avoid the public.

Figures 1 and 3 show that the display line contained within the display pilots' notes passed through an area marked 'event activity'. The CAA Permission changed the display line but the amended line was not the one used by the display pilots because they were unaware of the change. The day visitor car park and camping site were not included in the information provided to the CAA or display pilots because there was an expectation that they would not be accessible while flying was taking place. The images of G-TIMM provided by the witnesses who were standing in the car park suggests otherwise but it was not determined whether the campsite was also in use. Figure 5 shows that the display line in the CAA Permission passed over the car park and the camping site.

The performance of risk control measures

Prevention controls P(a). and P(b). above (experience and currency requirements) were weaker with respect to the pilot of G-TIMM than they would have been for a notional RAF pilot displaying a similar aircraft. The expense of operating high performance jet aircraft makes it unrealistic for civilian pilots to maintain currency at RAF levels but the pilot of G-TIMM – with an average of 12 flying hours per year over the previous five years – was also using a lower minimum height (300 ft) than the equivalent RAF minimum (500 ft). There is no obvious imperative to reduce the margin for error, or the height available to recover from a mishap, in circumstances where a pilot's experience and currency are relatively low. Therefore:

Safety Recommendation 2016-045

It is recommended that the Civil Aviation Authority amend its policy on minimum aerobatic heights for pilots of high performance jet aircraft such that authorised minima are appropriate to a pilot's experience and currency.

Regarding prevention control P(c). (suitable choice of manoeuvres), the rolling manoeuvres being flown immediately before the accident were relatively simple. However, they were flown at speeds lower than normal and this potentially introduced handling effects which, if not anticipated, might have set up conditions which contributed to the drop in nose attitude during the second roll.

Prevention control P(d). (SMS and QMS) aims to enhance the effectiveness of other controls. It is unlikely, therefore, that an SMS or QMS would identify directly an elevated risk of loss of aircraft control in the context of a pilot who meets all relevant requirements.

Recovery controls R(b). and R(c). above (attempting to recover control and ejecting if necessary) did not prevent impact with the ground and the pilot did not eject. It appeared that the pilot recognised that something was wrong but, faced with a startling, time-critical situation, the timing of his pitch input, and its magnitude, were inappropriate. In circumstances where the time available to act is very short, increased experience and currency are likely to reduce the risk of inappropriate action and improve the likelihood that an aircraft will be recovered safely. In this accident, it is likely that the cumulative effect of a lack of experience on high performance, swept wing jet aircraft prior to flying the Gnat, combined with a low average annual flying rate over the previous five years, contributed to the pilot's inability to recover to wings-level flight.

It is apparent that, in managing the risk of loss of control during display flying, pilot experience and currency are dominant factors influencing the effectiveness of prevention and recovery measures. In this event, these risk controls were not robust enough to prevent the accident and therefore:

Safety Recommendation 2016-046

It is recommended that the Civil Aviation Authority ensure that the experience and currency requirements contained within CAP 403, *Flying Displays and Special Events: A Guide to Safety and Administrative Arrangements,* and CAP 632, *Operation of 'Permit-to-fly' Ex-military Aircraft on the UK Register,* manage the risk of a loss of aircraft control to as low a level as reasonably practicable.

Although G-TIMM struck the ground clear of the crowd, recovery control R(d). (display lines) was weakened: the display line used was not the display line in the CAA Permission; and the display line in the Permission passed over at least one area open to the public. The FDD is responsible to the CAA for the safety of the display but, when the CAA stipulates where the display line should lie, it introduces uncertainty about who is responsible for regulatory compliance and who 'owns' the associated risks. AAIB Special Bulletin S1/2016 discussed the management of risk at flying displays and recommended that the CAA introduce a process whereby organisers of flying displays conduct appropriate risk assessments before a Permission is granted under Article 162 of the ANO.

Medical factors

The evidence available was that the pilot had not experienced any symptoms of his medical condition in the recent past and that, when he had experienced symptoms before 2001, they had been mild. Had the pilot experienced any appreciable symptoms immediately before the final manoeuvre, it is likely that he would have curtailed his display. The manoeuvre that the aircraft was flying was not a high-g manoeuvre, which the CAA stated can bring on symptoms, although the large pitch input would have led to a high-g situation. However, it was the pitch input which made the situation irrecoverable and any subsequent G-LOC would have been consequential rather than causal. The pitch input required the pilot to have made an aft input on the control column. The right-roll input was present until the aircraft was at tree-top height and the situation was beyond recovery.

Had the control column been released at any stage due to incapacitation, the ailerons and tailplane would have returned to their neutral positions and this was not observed. It was concluded that the pilot was consciously at the controls until immediately before impact and not incapacitated.

Notwithstanding this conclusion, according to the CAA the pilot's medical condition was unlikely to have been detected, given that it was not declared and the requirements of Class 2 medicals do not include routine ECGs before age 40. Routine ECGs, and/or more rigorous medical examinations might have identified this condition and might also help identify other medical conditions the symptoms of which could be detrimental to displaying high performance aircraft. Therefore:

Safety Recommendation 2016-047

It is recommended that the Civil Aviation Authority review the medical examination requirements for pilots displaying high performance aircraft to improve the likelihood that medical conditions are identified which are potentially detrimental to displaying such aircraft safely.

Conclusion

Examination of the aircraft revealed no evidence of a pre-existing problem that could have led to the accident. Examination of video evidence indicated that the flying controls were probably functioning normally. The aircraft was carrying out an aileron roll at low level when, at an angle of bank of 107° to the left, the nose attitude dropped relative to the horizon. The pilot applied an appropriate roll input, probably in an attempt to recover, but then applied an inappropriately-timed pitch input. The pitch input led to a high rate of descent, caused the aircraft to depart from controlled flight and made the situation irrecoverable in the height available. The pilot's experience and currency were considered to be contributory factors.

ACCIDENT

Aircraft Type and Registration:	Schempp-Hirth Duo Discus T, G-SAXT	
No & Type of Engines:	1 - Solo 2350D self-sustaining piston engine	
Year of Manufacture:	2007 (Serial no: 158)	
Date & Time (UTC):	6 September 2015 at 1437 hrs	
Location:	Droxford, Hampshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Damage to propeller and fuselage	
Commander's Licence:	BGA Gliding Certificate	
Commander's Age:	54 years	
Commander's Flying Experience:	2,500 hours (of which 300 were on type) Last 90 days - 58 hours Last 28 days - 30 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The pilot of the glider deployed the self-sustaining engine in preparation for crossing a stretch of water but, after about five minutes running, there was a bang followed by severe vibration as the propeller shed one of its five blades. He also sensed a restriction in aileron movement, so decided to force-land in a field, which he carried out successfully without further incident or damage.

It was found that two segments of the propeller hub had failed and caused release of the blade, which had embedded itself in the left wing root. Subsequent examination found that the failures were due to metal fatigue cracking, a known problem with this model of propeller.

History of the flight

It was intended to fly the aircraft from RAF Halton to Bembridge on the Isle of Wight and return. The engine was deployed and tested shortly after takeoff and the flight continued, unpowered, to the region of Lee-on-the-Solent without incident. Because the soaring conditions were poor, the engine was started at a height of 2,500 ft in preparation for crossing the Solent. However, after about 5 minutes and at a height of 3,000 ft, there was a loud 'bang' and substantial vibration was felt.

The ignition was turned off and, when the propeller had stopped, the pilot and passenger (also a pilot) could see that it was missing a blade. The handling pilot transferred control to the other pilot for a short period whilst he gathered up loose items, such as GPS navigation equipment, which had been thrown around the cockpit during the incident. When he returned his hands to the controls, he felt a restriction in aileron movement, so he looked straight ahead for a suitable field requiring minimal aileron input. He saw a suitable stubble field about 10-12 km away, which was also into-wind. He stowed the engine and landed in the field without further damage or incident.

Aircraft description

The Duo Discus is a two-seat glider; the 'T' denotes that it is fitted with a self-sustaining retractable engine which is intended to maintain, or slightly increase, altitude when required.

The engine fitted is a small, two-cylinder, two-stroke petrol engine driving a five-bladed folding propeller. When stowed, the engine and its mounting mast lie horizontally inside the fuselage in a hatch behind the cockpit, with the propeller blades folded forwards. When the pilot deploys the engine, the hatch doors open and the mast and engine are electrically extended – the propeller blades unfold on being exposed to the slipstream. The pilot must then decompress the engine, place the aircraft into a shallow dive and, when the windmilling propeller reaches a set rpm, the engine compression is restored and the engine should start. It will then run up to its rated power (the pilot cannot vary the power demand, he can only switch the engine off).

The propeller has five composite blades mounted on an aluminium alloy hub (Figure 1). The blades are of different lengths and the 'blocks' in which they are mounted on the hub are also different sizes.

Aircraft examination

Apart from the detached propeller blade, which had embedded itself in the left wing root causing damage to the aileron control circuit in that area, the adjacent blade had been badly damaged, apparently due to being struck by the departing blade. It was immediately apparent that the blade had detached due to failure of the metal hub blocks which locate it (Figures 1 and 2).

When examined by the AAIB, the detached blade had been removed from the fuselage/wing root, but there were also several small marks on the fuselage and wing where debris had impacted. There had also been damage caused by the engine moving on its flexible mounts under the severe out-of-balance forces which had been generated.

Figure 1

Photograph of propeller showing detached blade and damage to adjacent blade

The propeller was removed and sent to a materials laboratory for detailed examination. The metallurgical report states that the blade had detached due to pre-existing fatigue cracking of the metal hub blocks which retain it (Figure 2).

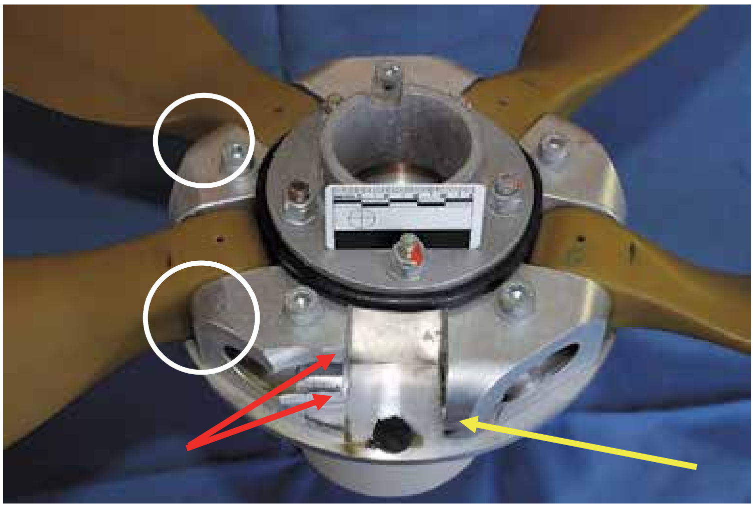


Figure 2

Photograph showing fractured hub blocks.
Yellow arrow points to the initial crack origin and double red arrows point to secondary cracking resulting from released section of right-hand block.
Additional cracks were found at the locations circled

Analysis of the fracture showed that the first crack to appear had originated on the outside of the block at the location arrowed in Figure 2. This then propagated inwards towards the blade trunnion bore. As this crack lengthened, the stresses created another crack at right angles propagating rearwards and eventually releasing a quarter-circular arc of the block. The out-of-plane loads this generated caused two more cracks to grow outwards from the bore of the other block until another, larger, section of metal broke off and the blade was released.

Cracks were also noted in the block retaining the trunnion for two other blades. Breaking these open confirmed that they were also fatigue cracks. The cracks were consistent with high frequency oscillations and did not appear to be associated with material defects.

Previous occurrences and safety actions

The subject propeller, with the part number FL5.110/83AV, was made by a German company called Technoflug. At the time of failure it had logged 36.8 flight hours.

The problem of hub cracking appears to have been recognised by the glider manufacturer at least as far back as 2006, when they issued a 'Technical Note' No. 890-8/868-11 in September of that year. The Technical Note required owners of aircraft up to Manufacturer's Serial Number 149 (later raised to MSN 174 in November 2012, when TN 890-13 was issued) to perform the following actions:

ACTION 1:	*Visual check of the propeller hub:*
	In the area of the five propeller blade roots the propeller hub has to be checked for cracks. If necessary the hub has to be cleaned before.
ACTION 2:	*Inspection and revision of the propeller hub:*
	For inspection and revision of the propeller hub the propeller has to be removed. Together with a declaration about the operating time it has to be sent to the manufacturer of the propeller: *Technoflug Leichtflugzeugbau GmbH* *Dr. Kurt Steim Straf3e 6* *D-78713 Schramberg*

ACTION 1 was to be performed on all propellers before further flight. ACTION 2 was to be done at the next annual inspection for propellers with fewer than 15 hours of operation; those with more than 15 operating hours were to perform the action before further flight.

Although the Technical Note requirements were not repetitive, in November 2011 the manufacturer's Flight Manual for the Duo Discus T was amended to include the following inspection as part of the Daily Inspection routine:

Check propeller hub and propeller blades for cracks or other damage, in particular also the area near the blade bearing marked in the following picture:

The BGA and the UK agent for Schempp-Hirth estimates that there are about 47 self-sustaining gliders in the UK which use the same type of propeller. Of these, cracks have been found in about six units. Owners of propellers found to have cracked hubs, and which have been returned to the manufacturer for repair, have found that they have been returned with a new design of hub (identifiable by the fact that all the hub blocks are of equal size). Informal inquiries by the AAIB suggest that no instance of cracking has been found with the later standard of hub, which has been available as a new or exchange item since the end of 2013.

AAIB Correspondence Reports

These are reports on accidents and incidents which were not subject to a Field Investigation.

They are wholly, or largely, based on information provided by the aircraft commander in an Aircraft Accident Report Form (AARF) and in some cases additional information from other sources.

The accuracy of the information provided cannot be assured.

SERIOUS INCIDENT

Aircraft Type and Registration:	Airbus A319-111, G-EZIV
No & Type of Engines:	2 CFM56-5B5/P turbofan engines
Year of Manufacture:	2005 (Serial no: 2565)
Date & Time (UTC):	16 October 2015 at 1539 hrs
Location:	Lisbon Airport, Portugal
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 147
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	32 years
Commander's Flying Experience:	5,260 hours (of which 3,500 were on type) Last 90 days - 201 hours Last 28 days - 43 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

During pre-flight preparation performance figures were calculated for a departure from Intersection November Two of Runway 03, at Lisbon Airport when Runway 21 from Intersection Uniform Five was used for takeoff. The error was not noticed during the crew's standard crosschecking procedures due to distraction in the cockpit and some complacency.

History of the flight

The aircraft was on a scheduled flight from Lisbon Airport, Portugal, to Basel Mulhouse Airport, Switzerland. The commander was to be the pilot flying and co-pilot the pilot monitoring.

During the crew's pre-flight preparation, prior to boarding the aircraft, it was noted that while Runway 21 was in use it was possible that Runway 03 could be in use as the wind was light and variable. On the aircraft, prior to pushback, the co-pilot entered the weather information and Runway 03 into the Electronic Flight Bag (EFB), despite Runway 21 being designated on the ATIS. The commander then calculated the takeoff performance for a departure from Runway 03 at Intersection November Two. Neither noticed that the runway in the EFB differed from the runway in use.

The takeoff data was then input into the Flight Management Guidance Computer (FMGC). During this time the commander's attention was distracted by people entering the cockpit.

This led to the Engine Out Standard Instrument Departure (EOSID) in the FMGC not being compared to the EFB's. The commander's brief of the EOSID was done from memory and the data entry error was not noticed.

The crew considered the takeoff normal until the aircraft approached V_1 when they noticed there was limited runway remaining, but the remainder of the flight was uneventful.

Upon checking the EFB en route they discovered that performance figures for takeoff from Runway 03 from Intersection November Two had been used for departure instead of figures for Runway 21 from Intersection Uniform Five.

Airport information

The following are the applicable distances of Runway 03/21 at Lisbon Airport:

Runway designator	TORA[1]	ASDA[2]
03 – Takeoff from Intersection November Two	3,530 m	3,530 m
21 - Takeoff from Intersection Uniform Five	2,410 m	2,410 m

Recorded information

The aircraft's Flight Data Monitoring system captured the incident, showing that the aircraft departed from Runway 21 at Intersection Uniform Five, at a takeoff weight of 62.8 tonnes with a takeoff distance available of 2,410 m. As the aircraft accelerated through a V_1 of 153 KIAS there was approximately 580 m of runway remaining. At the initiation of rotation approximately 297 m of runway remained; as the aircraft became airborne approximately 213 m of runway remained.

Commander's comments

The commander later commented that this occurrence was a result of multiple distractions during pre-flight preparation and some complacency as a result of operating from his home base. This had resulted in him and the co-pilot not concentrating fully when the performance figures were being calculated and crosschecked. The commander added that in future if he is interrupted during a brief or crosscheck of data he will start the process again to ensure it is completed fully.

Other recent events

G-EZUH

On 16 July 2015 an Airbus A320, registration G-EZUH, took off from Intersection Bravo on Runway 08 at London Luton Airport with takeoff performance calculated using the full length. This report was published in AAIB Bulletin 01/2016 on 14 January 2016.

Footnote

1 TORA – Take Off Run Available.
2 ASDA – Accelerate stop Distance Available.

G-EZAA

On 25 June 2015 an Airbus A319, registration, G-EZAA, took off from Intersection Bravo on Runway 25 at Belfast International Airport with takeoff performance calculated using the full length of Runway 07. This incident is the subject of an investigation by the AAIB.

SERIOUS INCIDENT

Aircraft Type and Registration:	1) DHC-8-402 Dash 8, G-FLBA 2) Cessna 210M, G-TOTN
No & Type of Engines:	1) 2 Pratt & Whitney Canada PW150A turboprop engines 2) 1 Continental IO-520-L piston engine
Year of Manufacture:	1) 2008 (Serial no: 4253) 2) 1977
Date & Time (UTC):	12 November 2015 at 0840 hrs
Location:	East Midlands Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	1) Crew - 2 Passengers - 6 2) Not known
Injuries:	1) Crew - 1 Passengers - Not known 2) Not known
Nature of Damage:	No damage
Commander's Licence:	1) Airline Transport Pilot's Licence 2) Not known
Commander's Age:	1) 37 years 2) Not known
Commander's Flying Experience:	1) 5,300 hours (of which 3,100 were on type) Last 90 days - 135 hours Last 28 days - 33 hours 2) Not known
Information Source:	Aircraft Accident Report Form submitted by the pilot; Flybe Investigation Report; East Midlands Airport Incident Report; CAA Air Traffic Services Investigations Report

Synopsis

G-TOTN was flying an approach under VFR to East Midlands Airport in deteriorating weather conditions. It turned onto the final approach without clearance and flew a go-around when it became apparent that the runway was occupied by G-FLBA.

History of the flight

G-TOTN, was flying an approach under VFR towards Runway 27 at East Midlands Airport and was cleared to position onto the left-base leg of the circuit. When asked if he could see the airport, the pilot reported that he could not because there was low level fog in his area. The METAR valid at the time was wind from 190° at 7 kt, visibility of more than 10 km, no cloud below 5,000 ft and a temperature of 9°C.

When G-TOTN was 5.5 nm south-southeast of the airport, G-FLBA was cleared to takeoff by the aerodrome controller. As G-FLBA entered the runway, the aerodrome controller asked the approach controller whether the pilot of G-TOTN could see the runway and, on being told that he could not, the aerodrome controller cancelled the takeoff clearance. The pilot of G-TOTN could still not see the runway when 1.5 nm southeast of the airport despite the runway lights having been turned on. He reported that he could see the runway when he was 0.25 nm to the east at which time the approach controller cleared him to continue the approach. Fifteen seconds later, the pilot of G-TOTN reported going around (the aircraft was indicating 700 ft amsl on the radar display and subsequently descended to a minimum of 500 ft (the airport elevation is 306 ft)). At the same time, the aerodrome controller instructed the approach controller to discontinue G-TOTN's approach.

The METAR issued seven minutes after the go-around reported greater than 10 km visibility with 1-2 oktas of cloud at 600 ft aal.

Information from the pilot of G-FLBA

As G-FLBA lined up on the runway, the crew saw on TCAS that the approach was clear although they could see an aircraft on the downwind leg indicating 1,300 ft above their aircraft. When their takeoff clearance was cancelled, the same traffic appeared to be on the centreline of the runway 800 ft above them. TCAS subsequently displayed a minimum vertical difference between aircraft of less than 100 ft before the aircraft was seen by the crew during its go-around.

When their takeoff clearance was cancelled, the crew of G-FLBA was told by the aerodrome controller that VFR traffic had become "situationally unaware". The crew did not hear any radio transmissions to or from G-TOTN because it was not on the tower frequency and, consequently, were not sure whether the aircraft on TCAS was the aircraft the aerodrome controller had referred to. The crew believed that, with more information, they might have decided not to line up on the runway.

CAA Air Traffic Services Investigations (ATSI) Report

The ATSI report commented that the deterioration in the weather, apparent to the aerodrome controller from the reports by the pilot of G-TOTN, was not communicated to the aerodrome controller at the first opportunity (the deterioration was not noticed within the tower because it was taking place behind the controller and assistant). Similarly, the approach controller was not made aware that the runway was occupied until G-TOTN was 0.25 nm from the airport at 1,000 ft amsl.

The ATSI report concluded that the pilot of G-TOTN turned on to final approach without a clearance to do so. There had been ineffective coordination between the aerodrome and approach controllers and the event had been influenced by changes to local weather conditions which were unnoticed and unreported.

The ATSI report recommended that the airport consider installing a surface movement radar display in the approach control room to give controllers a greater awareness of aerodrome activity.

Information from the operator of G-FLBA

The operator commented that poor communication had degraded the situational awareness of all concerned.

Note: the pilot of G-TOTN could not be contacted.

ACCIDENT

Aircraft Type and Registration:	Piper PA-E23-250 Aztec, G-LIZZ
No & Type of Engines:	2 Lycoming IO-540-C4B5 piston engines
Year of Manufacture:	1973 (Serial no: 27-7405268)
Date & Time (UTC):	20 August 2015 at 1631 hrs
Location:	St Mary's Airport, Isles of Scilly
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 2
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damaged beyond economic repair
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	4,300 hours (of which 2,000 were on type) Last 90 days - 110 hours Last 28 days - 57 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

The pilot was flying an NDB approach to Runway 32, with a 10 kt tailwind, in IMC. At MDA, having not acquired any visual references, the pilot commenced a go-around. Shortly thereafter the pilot saw the Precision Approach Path Indicators (PAPIs), discontinued the go-around and continued to land. The aircraft landed approximately 200 m from the threshold of the 603 m long runway. Believing the aircraft was too fast to stop before the end of the runway the pilot steered it to the right. The aircraft left the paved surface at the end of the runway onto grass at its edge. There were no injuries.

History of the flight

The aircraft was returning to St Mary's Airport from Essen Mulheim Airport, Germany. It had flown there the previous day to take a passenger, who occupied a seat in the cabin, for a meeting, leaving his wife and children behind on the Isles of Scilly. Occupying the co-pilot's seat was one of the pilot's Instrument Rating (IR) students.

En route the pilot received the latest weather for St Mary's. This indicated fog and low cloud, which could affect the ability of the aircraft to land there. The pilot descended to allow the passenger to try to find an alternative means of transport onto the island, using the internet on his mobile phone. This was unsuccessful.

As the aircraft approached St Mary's, ATC reported that the wind was from 190° at about

15 kt. Due to the wind the pilot requested an approach to Runway 14. This was not approved by ATC as there are no published approaches to Runway 14. The pilot decided to fly an NDB approach to Runway 32. Knowing that Runway 32 has a steep upslope, the pilot believed that this would counteract the 10 kt tailwind. He added that he based this on his previous experiences of landing on Runway 32 where he had to apply power after landing to taxi up the slope. However, he did not carry out a landing performance calculation to check if there was sufficient landing distance available on Runway 32 with the tailwind.

The pilot then commenced an approach to Runway 32 in IMC using the NDB. Based on the published MDA of 500 ft amsl he calculated a “derived decision altitude” of 530 ft (MDA + 30 ft). During the approach the student pilot advised the pilot of the distance to the runway using a GPS. At the MDA the aircraft was in IMC so the pilot commenced a go-around. However, very shortly thereafter, he saw the PAPIs, which indicated that the aircraft was on the ideal approach path angle, so discontinued the go-around and continued to land.

The aircraft landed approximately 200 m from the threshold, close to the top of the slope. As the aircraft reached the top, the pilot considered it was too fast to stop before the end of the runway. Aware of a precipice in the overshoot he steered the aircraft to the right. The aircraft departed the paved surface at the end of the runway and onto grass at its edge. As it did so, the nose and left main landing gear collapsed and the aircraft came to a halt. See Figure 1. The pilot secured the aircraft’s systems and the occupants vacated the aircraft uninjured. The RFFS were quickly in attendance.

Figure 1
G-LIZZ after the accident

Weather information

The forecast for St Mary's Airport, issued at 1107 hrs on 20 August 2015, stated that from 1200 hrs to 2100 hrs the wind would be from 200° at 15 kt, the visibility would be 300 m in fog and there would be OVERCAST cloud at 100 ft aal. There was a 40% probability that temporarily between 1200 hrs and 1800 hrs the visibility would be 2,000 m in moderate rain and drizzle with SCATTERED cloud at 100 ft aal and BROKEN cloud at 400 ft aal.

The following METARs were recorded at St Mary's:

METAR EGHE 201550Z 19015KT 5000 BR SCT001 BKN002 17/17 Q1017=
METAR EGHE 201620Z 19016KT 4500 BR SCT002 BKN003 17/17 Q1017=
SPECI EGHE 201631Z 19016KT 4500 BR SCT002 BKN003 17/17 Q1017=

The SPECI (special report) at 1631 hrs was recorded as a result of the accident.

Airport information

Runways 14/32 at St Mary's Airport have a LDA of 603 m. The first 300 m of Runway 32 rises at a 1:30 gradient (3.3%).

Pilot's comments

The pilot stated that he identified "about 10 opportunities" to discontinue with this flight and that continuing to land had been unwise. He added that as an IR instructor he knew that he should having completed the go-around having commenced it. However, he discontinued the go-around because he thought he might not see anything at the MDA on a subsequent approach.

After the accident the pilot highlighted the circumstances, and his learning points, at a Crew Resource Management seminar. He has also written an article to be published in a general aviation magazine.

ACCIDENT

Aircraft Type and Registration:	Cessna F172M Skyhawk, G-BEZR	
No & Type of Engines:	1 Lycoming O-320-E2D piston engine	
Year of Manufacture:	1976 (Serial no: 1395)	
Date & Time (UTC):	16 February 2016 at 1115 hrs	
Location:	Bembridge Airport, Isle of Wight	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 2
Injuries:	Crew - 1 (Minor)	Passengers - None
Nature of Damage:	Engine shock-loaded, propeller bent, wing struts bent, rear fuselage/fin disrupted, windscreen and one cabin window broken	
Commander's Licence:	Light Aircraft Pilot's Licence	
Commander's Age:	64 years	
Commander's Flying Experience:	303 hours (of which 123 were on type) Last 90 days - 3 hours Last 28 days - 1 hour	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Following a local flight, the pilot elected to land on Runway 30 at Bembridge due to its uphill gradient. He reported the wind conditions as 180°/5 kt and variable.

The landing and initial rollout were uneventful. However, just as the pilot started to apply the brakes as he passed abeam of the large hangar to the south, the left wing rose, the aircraft weather cocked to the left and then departed the left side of the runway. He regained control but, whilst manoeuvring back towards the runway, the nosewheel sank into soft ground and the aircraft turned over onto its back. He made the aircraft secure and ensured that he and his two passengers vacated the aircraft through the normal exit safely.

The pilot and one passenger had been wearing lap strap and diagonal harnesses and the other passenger a lap strap only; all escaped serious injury although the aircraft suffered extensive damage.

The pilot stated that whilst the "wind was not difficult", the brief, sharp movement of the aircraft during the rollout could have been due to a "sudden gust" or "windshear" and may have been associated with the wind direction and position of the hangar.

ACCIDENT

Aircraft Type and Registration:	Cessna 182H Skylane, G-PUGS
No & Type of Engines:	1 Continental Motors Corp O-470-R piston engine
Year of Manufacture:	1965 (Serial no: 182-56480)
Date & Time (UTC):	19 April 2015 at 1630 hrs
Location:	Stoke Golding Airfield, Leicestershire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Nosewheel, propeller and front lower cowling
Commander's Licence:	Private Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	79 hours (of which 12 were on type) Last 90 days - 9 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot reported that whilst landing on Runway 08 at Stoke Golding Airfield, the aircraft's nosewheel dug into wet ground causing the nose landing gear leg to fold under the fuselage. Both occupants were uninjured and exited the aircraft through their respective doors.

The pilot assessed that he had landed on an area of the runway that was too wet. He commented that he had used the opposite end of the runway, Runway 26, for departure and its condition was "fine".

ACCIDENT

Aircraft Type and Registration:	DA20-A1 Katana, G-BXPD
No & Type of Engines:	1 Rotax 912-F3 piston engine
Year of Manufacture:	1997 (Serial no: 10259)
Date & Time (UTC):	26 February 2016 at 1510 hrs
Location:	Redhill Aerodrome, Surrey
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - None
Nature of Damage:	Nose landing gear collapse and propeller ground impact
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	46 years
Commander's Flying Experience:	431 hours (of which 39 were on type) Last 90 days - 48 hours Last 28 days - 18 hours
Information Source:	Aircraft Accident Report Form submitted by the instructor and inquires made by the AAIB

The student pilot had landed the aircraft and was in the process of taking off for another circuit. The instructor stated, "Full power, right rudder, I'll do the flap". The student followed the instructions and the aircraft veered right, off the runway. The aircraft wheels instantly dug into the very soft muddy ground at the side of the runway, bringing the aircraft to a sudden stop. As a result the nose landing gear collapsed and the propeller struck the ground. The instructor concluded after the incident that the student had applied excessive rudder and held it. The aircraft had reacted too quickly for the instructor to intervene and correct the rudder pedal input before the aircraft left the narrow runway.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-161 Cherokee Warrior III, G-CEXO
No & Type of Engines:	1 Lycoming O-320-D3G piston engine
Year of Manufacture:	1998 (Serial no: 2842041)
Date & Time (UTC):	31 January 2016 at 1442 hrs
Location:	Durham Tees Valley Airport
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Minor paint damage under and aft of the engine cowling, ADF aerial scorched
Commander's Licence:	Private Pilot's Licence
Commander's Age:	24 years
Commander's Flying Experience:	142 hours (of which 139 were on type) Last 90 days - 68 hours Last 28 days - 39 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

After engine start, flames were seen by witnesses outside the aircraft around the lower cowling. They alerted the pilot, who shut down the engine and evacuated the aircraft along with his passenger. The fire was extinguished by a witness using a hand-held BCF extinguisher. The fire was caused by overpriming of the engine.

History of the flight

On the day of the accident, the pilot had flown the aircraft twice before. On the first flight, when the engine was cold, he used the electric primer pump for 50 seconds which he said was recommended by the engineer who maintained the aircraft following several previous pilot reports of starting difficulties.

The start was successful and, on the second flight, when the engine was warm, he used 25 seconds of prime and this, too was successful. However, during takeoff and climb at high power settings and low airspeeds, he noticed a faint smell of fuel. After landing he discussed this with two instructors who said that they had noticed the smell too and the aircraft had been inspected by the engineer who had found no leaks.

On the third engine start, when the engine was still warm, the pilot again primed for 25 seconds but this time it was reluctant to start, so he moved the mixture control to lean whilst continuing to crank the engine on the starter. It now sounded as though it was close to starting, so he advanced the mixture control to full rich whereupon the engine started and ran up to about 1,000 to 1,200 rpm. However, he now became aware of a person pointing at the aircraft and shouting - through the open cockpit window vent he heard the word "fire". He retarded the throttle and shut the engine down with the mixture control, telling his passenger to evacuate. Whilst this was in progress, he transmitted a MAYDAY before turning off the electrical master switch and exiting himself. As he did so, he noticed another pilot discharging a BCF fire extinguisher into the fuel water drain access hole, apparently succeeding in extinguishing the fire.

Discussion

The fire was most probably caused by overpriming the engine, leading to a fire in the airbox/carburettor as well as in the cowling. The 'standard' starting technique the club had been using involved priming only for some six seconds, but recent problems with starting had led to several pilots priming for up to 50 seconds. The pilot states that he had had reservations about using so much priming, but had been reassured that it was acceptable if "that was what was required to start the engine".

The Pilot's Operating Handbook (POH) gave no limits on duration of priming but states that initially no prime should be used but then 'prime as required' if the first attempt was unsuccessful.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-181 Cherokee Archer II, G-BRUD
No & Type of Engines:	1 Lycoming O-360-A4M piston engine
Year of Manufacture:	1983 (Serial no: 28-8390010)
Date & Time (UTC):	20 December 2015 at 1030 hrs
Location:	Blackpool Airport, Lancashire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Propeller damaged, engine shock-loaded
Commander's Licence:	Private Pilot's Licence
Commander's Age:	18 years
Commander's Flying Experience:	288 hours (of which 186 were on type) Last 90 days - 7 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot was taxiing to the refuelling pumps via Bravo taxiway at Blackpool Airport. As he approached the pumps to his right, he saw that a large fuel bowser was parked near them, marked by two traffic cones; this necessitated him steering the aircraft to the left in order to clear the obstruction. He turned the aircraft away from the yellow centreline markings at very slow speed but, before passing the bowser, he heard three loud bangs and the aircraft shuddered. It continued past the bowser and stopped near the pumps – it was evident that the propeller had struck the ground.

Examination of the taxiway surface showed that the nosewheel had entered a large pothole filled with water, coincident with three propeller slashes in the tarmac. The pilot says that no NOTAMS had been posted regarding the state of the taxiway and he had not been warned by Air Traffic Control about the presence of an obstruction near the pumps. He also took pictures to illustrate that the landing gear oleo extensions and tyre pressures appeared correct.

ACCIDENT

Aircraft Type and Registration:	Robin DR400/180 Regent, G-CGGO
No & Type of Engines:	1 Lycoming O-360-A3A piston engine
Year of Manufacture:	1987 (Serial no: 1756)
Date & Time (UTC):	13 December 2015 at 1445 hrs
Location:	Croft Marsh Airfield, Lincolnshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Left wing and propeller
Commander's Licence:	Private Pilot's Licence
Commander's Age:	69 years
Commander's Flying Experience:	648 hours (of which 130 were on type) Last 90 days - 2 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

The aircraft was heading approximately 050°M along the grass taxiway towards the runway, which was orientated 080°M. The pilot decided that, because the runway was only 500 m long and the surface was wet, he would move to the left of the taxiway to facilitate a "sweeping turn" onto the runway and a "rolling start". He applied full power while on the taxiway but the nose of the aircraft turned to the left, the left wingtip struck a tree and the propeller struck the ground, stopping the engine.

The pilot reported that he was flying the 180 HP variant of the Robin DR400 for the first time, having flown the 160 HP variant for the previous six years. He commented that he was surprised by the greater rate at which the larger engine caused the aircraft to turn left when power was applied.

ACCIDENT

Aircraft Type and Registration:	Robinson R22 Beta, G-EFON
No & Type of Engines:	1 Lycoming O-360-J2A piston engine
Year of Manufacture:	2005 (Serial no: 3833)
Date & Time (UTC):	25 February 2016 at 1533 hrs
Location:	Retford Gamston Airport, Nottinghamshire
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Tail rotor destroyed, damage to vertical fin and tail boom
Commander's Licence:	N/A (Student pilot)
Commander's Age:	27 years
Commander's Flying Experience:	57 hours (of which 57 were on type) Last 90 days - 11 hours Last 28 days - 8 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The student pilot was preparing to lift off for a solo flight. Having completed the magneto checks he increased the throttle but, as the governor engaged, the helicopter adopted a nose-high attitude and the tailskid and tail rotor struck the ground, crumpling the former and destroying both tail rotor blades. The helicopter rotated around the rear of the skids in a clockwise direction at least once before the pilot settled it back down onto its skids and shut down.

The pilot believes that he had inadvertently held aft cyclic stick and some raised collective input as the governor cut in and increased power, causing the helicopter to pitch up.

ACCIDENT

Aircraft Type and Registration:	Socata TB20 Trinidad GT, G-SCIP
No & Type of Engines:	1 Lycoming IO-540-C4D5D piston engine
Year of Manufacture:	2000 (Serial no: 2014)
Date & Time (UTC):	21 January 2016 at 1630 hrs
Location:	Sleap Airfield, Shropshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Propeller bent, engine cowling scraped and engine shock-loaded
Commander's Licence:	Private Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	2,602 hours (of which 1,621 were on type) Last 90 days - 25 hours Last 28 days - 6 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and additional enquiries by the AAIB

Synopsis

The pilot was unable to extend the nose landing gear fully during the approach to land. He diverted to another airfield where he performed a successful landing despite the nose gear collapsing shortly after touchdown. The maintenance company which maintained the aircraft believed there was some form of hydraulic lock in the retraction jack, but were unable to determine the cause.

History of the flight

The aircraft was returning to Welshpool from Elstree Aerodrome. On left base leg for Runway 22, the pilot selected landing gear and flaps down but saw only two green lights for the main gears, whilst the nose gear green remained unlit. He could also hear the electro-hydraulic pump running and saw the red gear-in-transit light illuminated.

The pilot recycled the gear several times without success as he continued the approach, so he asked the tower controller to look at the condition of the gear as he flew past. She reported that the nose gear appeared to be only about halfway down and that a medical helicopter pilot had confirmed this. The pilot aborted the landing and circled the airfield whilst he considered his options, eventually deciding to divert to Sleap Airfield because there would be more help available, a choice of two runways and the aircraft was also maintained there.

The light was fading but, after the ten-minute flight to Sleap, during which the pilot tried more reselections and emergency extensions whilst pulling ‘g’, he could sense that the pump motor was straining and decided to stop the attempts in case it overheated from repeated running. He also spoke to the owner of the maintenance company, who could only suggest what the pilot had already tried. Accordingly, the pilot agreed with the controller that Runway 23 would be used for an emergency landing and the runway lights were illuminated.

Following a request by the fire service to go around to allow more time for them to position, the pilot made his approach. As the aircraft crossed the start of the paved surface, he shut down the engine to try and avoid damage to the propeller. The aircraft sank rapidly and landed firmly on its mainwheels, followed by the nose gear which promptly collapsed. The aircraft then slid with its nose on the ground for some 100 metres, before coming to a halt. The pilot switched off fuel and electrics before rapidly evacuating the aircraft.

Investigation

The aircraft’s nose was lifted and supported on a trestle. A representative from the maintenance company then tried to extend the leg manually, but he was unable to move it until he undid a union on the retract line of the nose gear piston, after which he was able to pull the leg fully down and into lock. After the aircraft had been towed to the hangar and placed on jacks, no obvious mechanical anomalies were apparent, so the system was replenished and several retraction/extension cycles were performed. All were normal and the maintainer was at a loss to explain how what had appeared to be a hydraulic lock had occurred in the system. As a precaution, a number of components, including parts in the nose gear piston, were replaced.

ACCIDENT

Aircraft Type and Registration:	Quik GTR, G-GTRX
No & Type of Engines:	1 Rotax 912ULS piston engine
Year of Manufacture:	2013 (Serial no: 8646)
Date & Time (UTC):	22 November 2015 at 1530 hrs
Location:	Broadmeadow Farm Airfield, Herefordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Wing and trike damaged
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	107 hours (of which 71 were on type) Last 90 days - 29 hours Last 28 days - 6 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot reported that after a normal landing on the wet grass strip at Broadmeadow Farm Airfield the aircraft veered to the left and he was unable to prevent it from rolling onto its right side. The aircraft sustained substantial damage to its wing and trike. The pilot and his passenger, who were uninjured, made the aircraft safe and vacated it normally.

The pilot was unable to explain why the aircraft veered left, but thought either that the wind speed had increased suddenly, or the right brake may have locked on the wet grass.

Miscellaneous

This section contains Addenda, Corrections and a list of the ten most recent Aircraft Accident ('Formal') Reports published by the AAIB.

The complete reports can be downloaded from the AAIB website (www.aaib.gov.uk).

FORMAL REPORT CORRECTION

Aircraft Type and Registration:	Eurocopter (Deutschland) EC135 T2+, G-SPAO
Date & Time (UTC):	29 November 2013 at 2222 hrs
Location:	Glasgow City Centre, Scotland
Information Source:	Formal Investigation

AAIB Aircraft Accident Report 3/2015 refers

The report published on 23 October 2015 stated on page 28, second paragraph:

> In May 2014, GCH moved to a new location at Linthouse Road, Govan, about 1.5 nm east of Stobcross Quay. All distances in this report, based on GCH, are measured from its location at the time of the accident.

It should have stated:

> In May 2014, GCH moved to a new location at Linthouse Road, Govan, about 1.5 nm **west** of Stobcross Quay. All distances in this report, based on GCH, are measured from its location at the time of the accident.

On page 75, fourth paragraph, it stated:

> This is likely to be the point at which the systems supplied by the Avionic Shed Bus 1, including the radio altimeter and landing light, were lost.

It should have stated:

> This is likely to be the point at which the systems supplied by the Avionic Shed Bus 1, including the radio altimeter and **steerable** landing light, were lost.

On page 75, fifth paragraph, it stated:

> Without the RADALT, the pilot did not have accurate height information. Also, he did not have the benefit of a landing light to improve the visual cues.

It should have stated:

> Without the RADALT, the pilot did not have accurate height information. Also, he did not have the benefit of a **steerable** landing light to improve the visual cues.

On page 81, second paragraph, it stated:

> In this case, there was limited time for the pilot to take his hand off the collective, locate the correct guarded switch at the rear of the overhead panel and move it, to re-activate the RADALT and landing light.

It should have stated:

> In this case, there was limited time for the pilot to take his hand off the collective, locate the correct guarded switch at the rear of the overhead panel and move it, to re-activate the RADALT and **steerable** landing light.

On page 81, fourth paragraph, it stated:

> This would be difficult to judge at night without the aid of a RADALT and landing light, and could result in a flare recovery being initiated at a different height.

It should have stated:

> This would be difficult to judge at night without the aid of a RADALT and **steerable** landing light, and could result in a flare recovery being initiated at a different height.

On page 81, sixth paragraph, it stated:

> The RADALT and the landing light are optional equipment and are not standard on the EC135 helicopter. However, a RADALT is required for UK police night flying operations, in accordance with Civil Aviation Publication (CAP) 612, *Police Air Operations Manual*, Part 1. In the event of an autorotation at night, if the shed bus switch is not changed from NORM to EMERG, a pilot will not have accurate height information on which to judge the flare and landing. Also, he will not have the benefit of the landing light to enhance the visual cues.

It should have stated:

> The RADALT and the **steerable** landing light are optional equipment and are not standard on the EC135 helicopter. However, a RADALT is required for UK police night flying operations, in accordance with Civil Aviation Publication (CAP) 612, *Police Air Operations Manual*, Part 1. In the event of an autorotation at night, if the shed bus switch is not changed from NORM to EMERG, a pilot will not have accurate height information on which to judge the flare and landing. Also, he will not have the benefit of the **steerable** landing light to enhance the visual cues.

On page 94 it stated:

> 14. The radio altimeter and the landing light ceased to be powered following the second engine flameout.
>
> 15. The SHED BUS switch was not selected to EMERG, to repower the radio altimeter and landing light.

It should have stated:

14. The radio altimeter and the **steerable** landing light ceased to be powered following the second engine flameout.

15. The SHED BUS switch was not selected to EMERG, to repower the radio altimeter and **steerable** landing light.

BULLETIN CORRECTION

Aircraft Type and Registration:	Piper PA-38-112 Tomahawk, G-BWNU
Date & Time (UTC):	29 August 2015 at 1330 hrs
Location:	Cotswold Airport, Gloucestershire
Information Source:	Aircraft Accident Report Form submitted by the pilot

AAIB Bulletin No 2/2016, page 50 refers

The report published in AAIB Bulletin 2/2016 stated on lines 6 to 9:

> At the end of the downwind leg, at a height of about 1,000 ft, he closed the throttle, established the glide and selected the first stage of flap. The airspeed was reduced to 70 kt and the second stage of flap was selected while a continuous turn approach was flown. When the pilot was satisfied he would achieve his aiming point, he selected the third and final stage of flap.

That part of the report should have stated:

> At the end of the downwind leg, at a height of about 1,000 ft, he closed the throttle and established the glide. The airspeed was then reduced to 70 kt and a continuous turn approach was flown. The first stage of flap was selected on final approach and, once satisfied he would achieve his aiming point, the pilot selected the second and final stage of flap.

The online version of the report has been corrected accordingly.

TEN MOST RECENTLY PUBLISHED
FORMAL REPORTS
ISSUED BY THE AIR ACCIDENTS INVESTIGATION BRANCH

8/2010 Cessna 402C, G-EYES and Rand KR-2, G-BOLZ near Coventry Airport on 17 August 2008.
Published December 2010.

1/2011 Eurocopter EC225 LP Super Puma, G-REDU near the Eastern Trough Area Project Central Production Facility Platform in the North Sea on 18 February 2009.
Published September 2011.

2/2011 Aerospatiale (Eurocopter) AS332 L2 Super Puma, G-REDL 11 nm NE of Peterhead, Scotland on 1 April 2009.
Published November 2011.

1/2014 Airbus A330-343, G-VSXY at London Gatwick Airport on 16 April 2012.
Published February 2014.

2/2014 Eurocopter EC225 LP Super Puma G-REDW, 34 nm east of Aberdeen, Scotland on 10 May 2012 and G-CHCN, 32 nm south-west of Sumburgh, Shetland Islands on 22 October 2012.
Published June 2014.

3/2014 Agusta A109E, G-CRST Near Vauxhall Bridge, Central London on 16 January 2013.
Published September 2014.

1/2015 Airbus A319-131, G-EUOE London Heathrow Airport on 24 May 2013.
Published July 2015.

2/2015 Boeing B787-8, ET-AOP London Heathrow Airport on 12 July 2013.
Published August 2015.

3/2015 Eurocopter (Deutschland) EC135 T2+, G-SPAO Glasgow City Centre, Scotland on 29 November 2013.
Published October 2015.

1/2016 AS332 L2 Super Puma, G-WNSB on approach to Sumburgh Airport on 23 August 2013.
Published March 2016.

Unabridged versions of all AAIB Formal Reports, published back to and including 1971, are available in full on the AAIB Website

http://www.aaib.gov.uk

GLOSSARY OF ABBREVIATIONS

aal	above airfield level
ACAS	Airborne Collision Avoidance System
ACARS	Automatic Communications And Reporting System
ADF	Automatic Direction Finding equipment
AFIS(O)	Aerodrome Flight Information Service (Officer)
agl	above ground level
AIC	Aeronautical Information Circular
amsl	above mean sea level
AOM	Aerodrome Operating Minima
APU	Auxiliary Power Unit
ASI	airspeed indicator
ATC(C)(O)	Air Traffic Control (Centre)(Officer)
ATIS	Automatic Terminal Information System
ATPL	Airline Transport Pilot's Licence
BMAA	British Microlight Aircraft Association
BGA	British Gliding Association
BBAC	British Balloon and Airship Club
BHPA	British Hang Gliding & Paragliding Association
CAA	Civil Aviation Authority
CAVOK	Ceiling And Visibility OK (for VFR flight)
CAS	calibrated airspeed
cc	cubic centimetres
CG	Centre of Gravity
cm	centimetre(s)
CPL	Commercial Pilot's Licence
°C,F,M,T	Celsius, Fahrenheit, magnetic, true
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
DME	Distance Measuring Equipment
EAS	equivalent airspeed
EASA	European Aviation Safety Agency
ECAM	Electronic Centralised Aircraft Monitoring
EGPWS	Enhanced GPWS
EGT	Exhaust Gas Temperature
EICAS	Engine Indication and Crew Alerting System
EPR	Engine Pressure Ratio
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
FAA	Federal Aviation Administration (USA)
FIR	Flight Information Region
FL	Flight Level
ft	feet
ft/min	feet per minute
g	acceleration due to Earth's gravity
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
hrs	hours (clock time as in 1200 hrs)
HP	high pressure
hPa	hectopascal (equivalent unit to mb)
IAS	indicated airspeed
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IP	Intermediate Pressure
IR	Instrument Rating
ISA	International Standard Atmosphere
kg	kilogram(s)
KCAS	knots calibrated airspeed
KIAS	knots indicated airspeed
KTAS	knots true airspeed
km	kilometre(s)
kt	knot(s)

lb	pound(s)
LP	low pressure
LAA	Light Aircraft Association
LDA	Landing Distance Available
LPC	Licence Proficiency Check
m	metre(s)
mb	millibar(s)
MDA	Minimum Descent Altitude
METAR	a timed aerodrome meteorological report
min	minutes
mm	millimetre(s)
mph	miles per hour
MTWA	Maximum Total Weight Authorised
N	Newtons
N_R	Main rotor rotation speed (rotorcraft)
N_g	Gas generator rotation speed (rotorcraft)
N_1	engine fan or LP compressor speed
NDB	Non-Directional radio Beacon
nm	nautical mile(s)
NOTAM	Notice to Airmen
OAT	Outside Air Temperature
OPC	Operator Proficiency Check
PAPI	Precision Approach Path Indicator
PF	Pilot Flying
PIC	Pilot in Command
PNF	Pilot Not Flying
POH	Pilot's Operating Handbook
PPL	Private Pilot's Licence
psi	pounds per square inch
QFE	altimeter pressure setting to indicate height above aerodrome
QNH	altimeter pressure setting to indicate elevation amsl
RA	Resolution Advisory
RFFS	Rescue and Fire Fighting Service
rpm	revolutions per minute
RTF	radiotelephony
RVR	Runway Visual Range
SAR	Search and Rescue
SB	Service Bulletin
SSR	Secondary Surveillance Radar
TA	Traffic Advisory
TAF	Terminal Aerodrome Forecast
TAS	true airspeed
TAWS	Terrain Awareness and Warning System
TCAS	Traffic Collision Avoidance System
TGT	Turbine Gas Temperature
TODA	Takeoff Distance Available
UHF	Ultra High Frequency
USG	US gallons
UTC	Co-ordinated Universal Time (GMT)
V	Volt(s)
V_1	Takeoff decision speed
V_2	Takeoff safety speed
V_R	Rotation speed
V_{REF}	Reference airspeed (approach)
V_{NE}	Never Exceed airspeed
VASI	Visual Approach Slope Indicator
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VOR	VHF Omnidirectional radio Range

AAIB
Air Accidents Investigation Branch