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AAIB
Air Accidents Investigation Branch

AAIB Bulletin S4/2015 *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	

Introduction

The aircraft was taking part in an air 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.

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 is published 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' announced on 9 September 2015. A final report will be published in due course.

Seven Safety Recommendations are made.

Safety of first responders

Some ex-military jet aircraft are fitted with aircrew escape systems, including ejection seats and canopy jettison systems that contain pyrotechnic cartridges.

Following the accident to G-BXFI, and a separate accident to a Folland Gnat[1] during an air display at Oulton Park on 1 August 2015, the ejection seats fitted to both aircraft were found in a damaged condition. Some of the pyrotechnic cartridges were still live but had been subject to impact forces and post-crash fire. This posed a significant hazard to the first responders and to other personnel on the accident site. Accident response and investigation work in the vicinity of the seats was delayed until competent persons were brought to the site by the AAIB to make the seats safe. In both cases, the respective air display organisers did not have access to relevant aircraft hazard information or emergency contact details for organisations which could render the seats safe. Ex-military aircraft may be equipped with other devices, such as miniature detonation cords (MDC) or other pyrotechnic charges, which can also represent a hazard to first responders and accident site personnel. The following Safety Recommendation is therefore made:

Safety Recommendation 2015-041

It is recommended that the Civil Aviation Authority require operators of ex-military aircraft fitted with ejection seats or other pyrotechnic devices operating in the United Kingdom, to ensure that hazard information is readily available which includes contact details of a competent organisation or person able to make the devices safe following an accident.

Maintenance of ejection seats

The ejection seats and the canopy jettison system in the Hawker Hunter T Mk 7 rely on a number of pyrotechnic cartridges to provide the propellant for the ejection sequence. The ejection seat manufacturer recommends that the installed life of the cartridges does not exceed 2 years and that the total life does not exceed 6 years from the date of cartridge manufacture.

Footnote:

[1] The accident involving Folland Gnat G-TIMM is the subject of a separate AAIB investigation.

Ex-military aircraft on the UK civil register must operate in accordance with Civil Aviation Publication (CAP) 632 '*Operation of Permit-to-Fly ex-military aircraft on the UK register.*' This document requires that all swept-wing ex-military aircraft equipped with ejection seats are operated with 'live' ejection seats. Paragraphs 5.8 and 5.9 state:

> *'5.8 Where ejection seats are an integral part of the aircrew escape system, as specified in the relevant Pilots Notes, Flight or Aircrew Manuals, it is recommended that they be fully serviceable for all flights. Approval should be sought from the CAA (Application and Approvals) at the earliest opportunity if it is intended to operate with inert ejection seats (or other escape systems). It is unlikely that the CAA will allow swept-wing aircraft fitted with ejection seats to be flown unless the equipment is fully operational.*
>
> *5.9 Ejection seat cartridge lives are typically 2 years installed, within a 6 year shelf life. To be fully serviceable the cartridges installed must be within their appropriate lives.'*

In addition, each aircraft in this category is issued with a unique Airworthiness Approval Note (AAN) by the CAA, which forms the basis of its airworthiness approval. AAN No 26172 was issued by the CAA in 1998 for G-BXFI, when it was accepted onto the civil aircraft register, and states:

> *'Cartridges for the Aircrew Assisted Escape System have a 6 (six) year overall/ shelf life and 2 (two) year installed life…..'*

The CAA commented that an AAN is a 'snapshot' of the aircraft status at the time it was placed on the civil register and that any change to a specified component life would need to be approved by the CAA. Any proposed extension would require technical justification.

Chapter 5 of CAP 733 - '*Permit to Fly Aircraft*' describes maintenance of ex-military aircraft. Paragraph 5.4 of that chapter states:

> *'5.4 Ex-military aircraft may have specific life limits for the aircraft structure or critical components defined by the manufacturer, these limits must not be exceeded. Where the manufacturer permits further operation for a period dependent upon the embodiment of additional modifications by more comprehensive and in-depth maintenance checks, these must be carried out before an extension to the operating life will be agreed. There will be no extension of aircraft life limits beyond those that are defined and supported by the manufacturer.'*

The foregoing indicates that the cartridge life specified in ANN No 26172 was a requirement, not guidance or a recommendation.

The ejection seat and canopy jettison cartridges fitted to G-BXFI were manufactured in June and July 2008, and were installed in November 2012, shortly after the maintenance

organisation assumed responsibility for the aircraft. The technical records were updated to correctly indicate the cartridge expiry dates as June and July 2014.

In January 2014, the maintenance organisation placed an order for new ejection seat cartridges and was advised by the supplier that they would be delivered in approximately 52 weeks. During the aircraft's annual maintenance inspection in February 2014 the maintenance organisation decided to leave the cartridges installed until the next scheduled annual inspection and updated the technical records to indicate that the cartridge installation had been extended until February 2015.

During the next annual inspection in February 2015, the maintenance organisation again decided to leave the cartridges installed, as the new cartridges had not yet been delivered. The technical records were updated indicating that cartridge replacement was due in February 2016. The new cartridges were delivered in June 2015, but were not fitted to the aircraft.

The maintenance organisation stated to the AAIB that it operates a 'six-year installed life' policy for ejection seat cartridges. This is not consistent with the manufacturer's recommendations, the guidance in CAP 632, or the requirements of AAN No 26172. The technical records indicate that the maintenance organisation was aware of the cartridge expiry dates at the time they were first installed and stated to the AAIB that the extension of the cartridge lives had been discussed with the CAA, but it did not seek formal approval for this. The maintenance organisation's Maintenance Exposition document stated:

> *'The Chief Engineer will approve the variation if he is satisfied that airworthiness will not be affected. If it is outside his power to approve the variation then he will refer the matter, in writing to the local CAA supervising Surveyor for consideration. Any variation agreed will be entered in the serialised variation file held in Technical Records, and in the aircraft's log books.*
>
> *Variations to scheduled maintenance check periods and component lives may be granted within the limits laid down by the schedule, subject to mandatory requirements or ultimate lives not being exceeded in the extension period.'*

The maintenance organisation informed the AAIB that it considered the decision to extend the cartridge lives was taken within the privileges of its maintenance approvals and therefore it did not consider it necessary to seek formal approval from the CAA to extend the cartridge lives. The CAA stated that any extension of ejection seat cartridge lives would require written approval, and would be based on a technical justification and proof that new cartridges had been ordered.

Neither the maintenence organisation nor the CAA have provided evidence of a written approval or technical justification. Therefore, the ejection seats installed in G-BXFI did not meet the definition of '*fully serviceable*' in CAP 632 paragraph 5.9, nor the requirements of ANN No 26172, and had not done so since June 2014, because they were fitted with time-expired cartridges.

The AAIB understands that other civil-operated ex-military aircraft have been operated with time-expired ejection seat cartridges installed.

The ejection seat manufacturer advised the AAIB that using time-expired cartridges could increase the risk of an un-commanded ejection; or, when ejection is commanded, could result in increased discharge time of cartridges affecting the ejection sequence, or uncontrolled explosion of the cartridges.

In February 2015 the ejection seat manufacturer ceased to provide technical support or replacement parts for ejection seats fitted to aircraft which no longer operate in their original military role. Ejection seats installed in civil-operated ex-military aircraft fall into this category and replacement cartridges manufactured by the original manufacturer are no longer available. As a result, the ejection seat manufacturer considers that such ejection seats should be deactivated to prevent the risk of inadvertent operation. This is contrary to the current CAP 632 requirement for ejection seats in swept-wing aircraft to be operated in a fully operational and armed condition.

The service and maintenance of ejection seats is a specialist task. Civilian organisations which operate or maintain ex-military jet aircraft in the UK often rely on individuals or organisations with specialist skills and prior military experience in ejection seat maintenance to accomplish these tasks. The CAA does not currently issue specific Maintenance Approvals for specialised tasks such as ejection seat maintenance, and these tasks are instead performed under the Maintenance Approval of the designated maintenance organisation.

Ex-military aircraft are accepted onto the UK civil register on the basis of a satisfactory military safety record. Where the presence of aircrew escape systems, such as ejection seats, contributed to that safety record, the CAA expects that the aircraft will continue to operate with these systems in a serviceable condition. The CAA has approved the disarming of ejection seats in some straight-wing ex-military aircraft, where it considers the aircraft has a landing speed low enough to allow a pilot to make a forced landing. However, based on the higher operating speeds of swept-wing ex-military jet aircraft, the CAA requires these aircraft to operate with serviceable ejection seats to provide a means of aircrew escape. Charged systems such as ejection seats carry an inherent safety risk to operational and maintenance personnel and to first responders in the event of an accident. It is acknowledged that, in requiring civilian-operated ex-military aircraft to be equipped with live ejection seats, the CAA must consider the benefits of having a means of aircrew escape against the inherent risks presented by such systems.

The following Safety Recommendation is made:

Safety Recommendation 2015-042

It is recommended that the Civil Aviation Authority review the guidance in CAP 632 with respect to ejection seats and the means by which operators of ex-military aircraft equipped with them comply with this guidance. This review should include:

- The benefits and hazards of aircrew escape systems in civilian operated aircraft
- The use of time-expired components
- The availability of approved spares
- The seat manufacturer's guidance on deactivating its historic products
- Adoption of a dedicated Maintenance Approval for persons or organisations competent to perform ejection seat maintenance

Aircraft maintenance

Training

Aircraft like the Hawker Hunter were built for military service and it was intended that they would be maintained by organisations with comprehensive facilities and personnel who had undergone extensive training. The aircraft's operation, in military service, was also supported by the Original Equipment Manufacturer (OEM) who provided type-specific training, maintenance planning documentation, aircraft and component manuals, a publication amendment service and specialist technical support.

The OEM was also able to share the experience of the worldwide fleet among operators and other relevant organisations. When the aircraft type was retired from military service the support provided by the OEM ceased, limiting the ability of individual civilian organisations operating the type to benefit from worldwide experience.

The technical publications for these ex-military jet aircraft were written in the 1950s and 1960s and assumed a certain level of training and skill. For example, they did not always include comprehensive instructions for component removal and installation. The investigation has found that civil organisations maintaining ex-military aircraft may rely on a core of personnel with prior military aircraft maintenance experience, and who may be familiar with the aircraft type and its manuals.

The lack of OEM support, and the limited number of aircraft of these types on the civil register, means that there are no training courses available for civilian maintenance personnel to maintain ex-military jet aircraft. Informal type-specific training may be undertaken in-house, using ex-military personnel to pass on their knowledge and experience of the aircraft, but this process relies on individual experience and recollection and may therefore vary from organisation to organisation.

Given the limited scope for the dissemination of relevant information from global fleet experience to individual maintenance organisations, and the variability in maintenance training, the following Safety Recommendation is made:

Safety Recommendation 2015-043

It is recommended that the Civil Aviation Authority promote a process for the effective dissemination of ex-military jet aircraft experience and type-specific knowledge between individual maintenance organisations.

Publications

For an ex-military aircraft to be accepted onto the civil register it must comply with the requirements of CAP 733 *'Permit to Fly Aircraft'* Section 5. The CAA issues an Airworthiness Approval Note (AAN) for the aircraft which, among other items, details the documents required to operate and maintain it. These documents are no longer subject to routine amendment and the AAN does not usually specify the required document amendment standard. One manual supplied by the Royal Air Force, to assist the AAIB, was found to contain 20 amendments which were not included in the equivalent manual for G-BXFI. The maintenance organisation confirmed that, in order to try to determine if a more recent revision of the manual was available, it had contacted other maintenance organisations and museums. The AAIB has not established the effect of the variations in manual amendment standard but the lack of a defined minimum amendment standard for technical publications may lead to variations in the maintenance of aircraft of the same type. Therefore the following Safety Recommendation is made:

Safety Recommendation 2015-044

It is recommended that the Civil Aviation Authority establish a minimum amendment standard for the technical publications for each ex-military jet aircraft operated on the United Kingdom civil register.

Maintenance programmes

Discussion with the CAA and maintenance organisations revealed that the maintenance programme for a specific aircraft, whilst based on the OEM's planned maintenance schedule, is developed by the respective maintenance organisation and approved by the CAA. When responsibility for the aircraft's maintenance is transferred to another organisation, the maintenance programme remains the property of the originating organisation and therefore might not be given to the new organisation. The new maintenance organisation must then develop its own maintenance programme, possibly with a limited understanding of the previous maintenance regime, and submit it to the CAA for approval. Therefore the following Safety Recommendation is made:

Safety Recommendation 2015-045

It is recommended that the Civil Aviation Authority require that the maintenance programme relating to an ex-military jet aircraft is transferred with the aircraft when it moves to another maintenance organisation to ensure continuity of the aircraft's maintenance.

Permit to Fly

Ex-military aircraft do not qualify for a Certificate of Airworthiness and are operated under a National Permit to Fly[2] issued under the provisions of Article 21 of the UK Air Navigation Order (ANO). The aircraft is also issued with a Certificate of Validity (C of V) on an annual basis which confirms that the aircraft continues to meet the requirements of its Permit to Fly[3]. Article 22 of the ANO states that a Permit to Fly ceases to be in force if the CAA has issued a directive that requires an inspection, until that inspection has been satisfactorily completed.

Maintenance approval

An approved maintenance organisation that holds the privilege to recommend the issue of a C of V, but does not hold the privilege to issue a C of V, will make a recommendation to the CAA for the revalidation of the aircraft's Permit to Fly. This includes a statement that the aircraft complies with the relevant requirements for British Civil Airworthiness Requirements (BCAR) Section A, which includes the applicable Mandatory Permit Directives (MPD) and life-limited components. On receipt of the recommendation the CAA checks the information submitted with the statement before issuing a new C of V.

The CAA may grant an approved maintenance organisation the privilege to issue its own C of V in respect of a particular category of aircraft. In these circumstances, there is no requirement for the CAA to verify the validity of the statements made as part of the C of V renewal process or to inspect the aircraft or its records. The organisation responsible for the maintenance of G-BXFI had been granted this privilege.

Mandatory Permit Directive (MPD) 2001-001

The aircraft was fitted with a Rolls-Royce Avon 122 engine. The CAA issued MPD 2001-001, applicable to the Rolls-Royce Avon 1, 100 and 200 series engines in response to AAIB Safety Recommendation 99-27, made after a fatal accident to a Hawker Hunter in 1998. This introduced a maximum engine calendar life of 15 years between overhauls, however, recognising that the condition of the engine could be monitored by routine inspection and tests, the CAA allowed operators, and maintenance organisations, to propose an Alternative Means of Compliance (AMOC) for the MPD. If approved, the operator could, through the application of the AMOC, continue to operate the engine beyond the 15-year life stated in the MPD. AMOCs vary from aircraft to aircraft due to a number of factors including aircraft utilisation. The CAA has confirmed that a number of AMOCs to MPD 2001-001 have been in place for several years. However, since their approval, techniques for inspection and monitoring have improved and new methods may be available.

As a result of the accident to G-BXFI, the CAA published Safety Directive SD-2015/003 on 25 August 2015 which required all operators of Hawker Hunter aircraft on the UK civil register to cease all flying operations. At the date of publication of this Special Bulletin CAA Safety Directive SD-2015/003 remains in effect.

Footnote:

[2] Granted under BCAR A3-7.
[3] CAP 733 Section 1.

The CAA has stated that, prior to any return-to-service of Hawker Hunter aircraft, it will require a comprehensive airworthiness review which will include the effectiveness of relevant MPDs.

In order to ensure that all of the currently approved AMOCs for MPD 2001-001 continue to provide adequate monitoring of engine condition and take account of developments in inspection and monitoring methods, the following Safety Recommendation is made:

Safety Recommendation 2015-046

It is recommended that the Civil Aviation Authority review the effectiveness of all approved Alternative Means of Compliance to Mandatory Permit Directive 2001 001.

A review of the records for G-BXFI confirmed that when the maintenance of the aircraft transferred to the current maintenance organisation in August 2012, the previous maintenance organisation had an approved AMOC in place for MPD 2001-001 which consisted of a series of inspections carried out every two years. As part of the maintenance performed after the aircraft's transfer, the CAA permitted the use of the existing AMOC to verify the engine's serviceability until December 2014, to allow the current maintenance organisation time to submit its own AMOC for approval. At the end of this maintenance input the CAA issued a new C of V, valid from 5 December 2012 to 4 December 2013.

The maintenance organisation subsequently issued a new C of V at the end of November 2013 covering the period from 28 November 2013 to 4 December 2014. It then completed an online form which included a compliance statement to confirm the aircraft's airworthiness status.

In mid-January 2014 the maintenance organisation contacted the CAA with its proposal for an AMOC to MPD 2001-001. Email correspondence, provided to the investigation by the CAA, confirmed that the CAA responded at the end of January 2014. This response identified a list of additional information which should be included in any formal submission for an AMOC. The maintenance organisation had no recollection or record of the CAA response and no formal proposal for an AMOC to MPD 2001-001 was made to the CAA.

During annual maintenance between January and March 2014 the maintenance organisation removed the engine from the aircraft and completed the tasks outlined in its proposed AMOC to MPD 2001-001. The aircraft records were annotated stating compliance with MPD 2001-001. In April 2014, the maintenance organisation contacted the CAA for an update on the progress of its AMOC proposal for MPD 2001-001. The investigation has not been able to identify any response from the CAA to this enquiry.

Between December 2014 and March 2015 the aircraft underwent another period of scheduled maintenance where no significant tasks relating to MPD 2001-001 were carried out. In March 2015 the maintenance organisation issued a new C of V covering the period from 11 March 2015 to 10 March 2016.

The work completed by the current maintenance organisation in 2012, using the previous maintenance organisation's approved AMOC, allowed the aircraft's engine to remain in operation until December 2014.

The maintenance organisation was required, under its CAA maintenance approvals, to ensure that systems and procedures were in place to ensure any aircraft under its care met the UK airworthiness requirements. The maintenance organisation believed that the package of work it carried out in March 2014 met the requirements of an AMOC for MPD 2001-001.

In a formal representation to the AAIB, in relation to this Special Bulletin, the CAA reported that it was unclear whether a legally valid AMOC to MPD 2001-001 was in place for G-BXFI at the time of the accident. On this basis it could not determine if the aircraft met the requirements of its Permit to Fly from December 2014 onwards. The CAA indicated that it was trying to clarify the postion. In order to provide certainty of the airworthiness status of ex-military jet aircraft in future, the following Safety Recommendation is made:

Safety Recommendation 2015-047

It is recommended that the Civil Aviation Authority review its procedures to ensure that a *'Permit to Fly-Certificate of Validity'* is valid when it is issued.

Further investigation

The AAIB continues to examine the aircraft and its maintenance records to determine its condition before the accident. It will also explore the operation of the aircraft, the organisation of the event with regard to public safety, and associated regulatory issues.

The AAIB will report any significant developments as the investigation progresses.

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