ACCIDENT

Aircraft Type and Registration:	Slingsby T67M-MkII Firefly, G-BUUD
No & Type of Engines:	1 Lycoming AEIO-320-D1B piston engine
Year of Manufacture:	1993
Date & Time (UTC):	16 July 2006 at 1356 hrs
Location:	Hoxne, Suffolk (close to the Norfolk border)
Type of Flight:	Private
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:	40 years
Commander's Flying Experience:	83 hours (of which 18 were on type) Last 90 days - 8 hours Last 28 days - 2 hours
Information Source:	AAIB Field Investigation

Synopsis

The pilot was performing a solo aerobatics sequence, in good weather. The aircraft appeared to depart from controlled flight at a height of around 4,500 ft agl during a looping manoeuvre and settled into an erect spin to the left. After the aircraft had descended about 2,500 ft, the pilot transmitted a 'MAYDAY' call in which he said that he was in a spiral dive and could not recover. The aircraft continued to spin and descend vertically until it struck the ground. The pilot was fatally injured in the impact.

No signs of a pre-impact anomaly with the aircraft were found, but the amount of evidence available from the wreckage was limited by severe ground fire damage and the possibility that a pre-impact deficiency had contributed to the accident could not be eliminated.

Two recommendations have been made, regarding the wearing of parachutes and the performing of solo aerobatics while undergoing a course of instruction.

History of the flight

Before the flight, the pilot had told a few close relatives that he was planning to perform an aerobatic sequence for a neighbour's retirement party, which was being held in the garden of a house in the village of Hoxne, Suffolk. He took off from Old Buckenham Airfield in G-BUUD at 1335 hrs with an estimated 60 to 70 litres of fuel on board, having made no mention of his intentions to those present during his preparations for the flight. The weather was good. At 1347 hrs the pilot contacted Norwich ATC to advise them that he was climbing to

5,000 ft amsl to carry out aerobatics in the area to the east of Diss. ATC acknowledged this radio call and gave the pilot a transponder code to 'squawk' so that he could be identified by secondary surveillance radar. The pilot selected this code, which the aircraft continued to transmit for the remainder of the flight.

Shortly after 1350 hrs those attending the party, and other witnesses in the vicinity, saw G-BUUD carry out some aerobatic manoeuvres just to the east of their position. A number of them described seeing the aircraft perform a rolling manoeuvre in a westerly direction, before turning onto a southerly course and enter a loop. At some stage after reaching the top of the loop G-BUUD was seen to enter a spiral descent.

One witness recalled seeing the aircraft perform the loop, then turn, following which the engine stopped. The aircraft then pitched nose down, possibly turning inverted, before appearing to tumble as it descended. Another witness, a current Private Pilot's Licence (PPL) holder, who was positioned 2 nm to the north of Hoxne, was alerted to the sound of an aircraft performing aerobatics. When he looked up he saw a yellow, low wing aeroplane at an estimated height of about 3,500 ft, in a spin. The aeroplane was descending vertically; it was pitched approximately 30º nose down and continued to spin without appearing to change its attitude. When the aircraft was at an estimated height of 1,500 ft, this witness perceived the engine noise to increase momentarily before becoming silent. He saw the aircraft complete 12 to 15 spin rotations, after which it disappeared below the tree line. Shortly afterwards he saw black smoke rising from the same direction. He thought he recognised the aircraft as being the Slingsby T67, which he had seen on a number of occasions at Old Buckenham Airfield.

Another witness, a PPL holder with experience of aerobatics, observed G-BUUD from a property 1.5 nm to the east of Hoxne. He described seeing the aircraft perform a rolling manoeuvre on a westerly heading whilst climbing slightly. During the course of this manoeuvre the aircraft's track altered 10º to 15º to the right. He considered that the rate of roll sped up during the last 180º of the manoeuvre. Following this, the aircraft entered a loop in the last quarter of which it appeared to perform a vigorous rotation, possibly to the right. After two full rotations, the aircraft settled into a flatter attitude and began to spin in a "stable upright fashion". This witness recalled being concerned because he considered that the entry into the spin was unintentional and he believed that the engine noise reduced after four or five rotations. The aircraft continued to spin in a stable manner with no discernible change in pitch attitude, which he assessed as being 20º nose down, at a constant speed of rotation and with a high rate of descent. Following the reduction in engine noise he saw the aircraft complete another three full turns before it disappeared from his view.

Other witnesses also recalled hearing the engine noise cease. Two people who were at the garden party stated that this happened after the aircraft had completed about three turns, following the commencement of spinning.

At 1355:44 hrs, as the aircraft was descending, the pilot transmitted a 'MAYDAY' call saying, initially, that he was "IN A SPIRAL SPIN" and then amplified this by adding that he was "OVERHEAD HOXNE IN A SPIRAL DIVE CANNOT RECOVER".

The aircraft continued to spin, probably to the left, until it struck the ground in a field about 10 m away from the back gardens of two semi-detached cottages. Immediately after it had struck the ground and stopped, two witnesses, one in each garden, saw the pilot slumped forward and motionless inside the aircraft. They both observed that a fire had developed on the right side of the fuselage, in front of the right wing. One of these witnesses ran to collect two fire extinguishers from his cottage, which was 30 m away but, by the time he had returned to the end of his garden, the fire had developed and was so intense that he was unable to approach it. In addition, he was concerned that there was a danger of explosion. Another witness in one of the two cottages called the emergency services immediately after the crash and they arrived ten minutes later.

A number of other witnesses rushed to the scene as well but they were also unable to approach the aircraft. About three minutes after it had struck the ground, there were two loud explosions from the aircraft.

The aircraft's manoeuvres were recorded on still photographs taken bytwo witnesses on the ground. One set of photographs, taken sequentially, appear to show the aircraft inverted, initially, and then in descending turns to the left in an erect attitude. Another camera captured the aircraft as it disappeared from view behind a hedge shortly before it struck the ground. At this point G-BUUD appears to be pitched nose down about 35º.

A post-mortem examination indicated that the pilot had died almost instantaneously as a result of the injuries he had sustained during the crash, and before the subsequent fire. There was no evidence of any medical factor that had contributed to the accident, which was considered non-survivable.

Recorded information

Recorded radar data for G-BUUD was provided by the National Air Traffic Service. The aircraft was fitted with a Mode C transponder and therefore, in addition to positional information, altitude data (to the nearest 100 ft) was available; these data were recorded every 5 seconds.

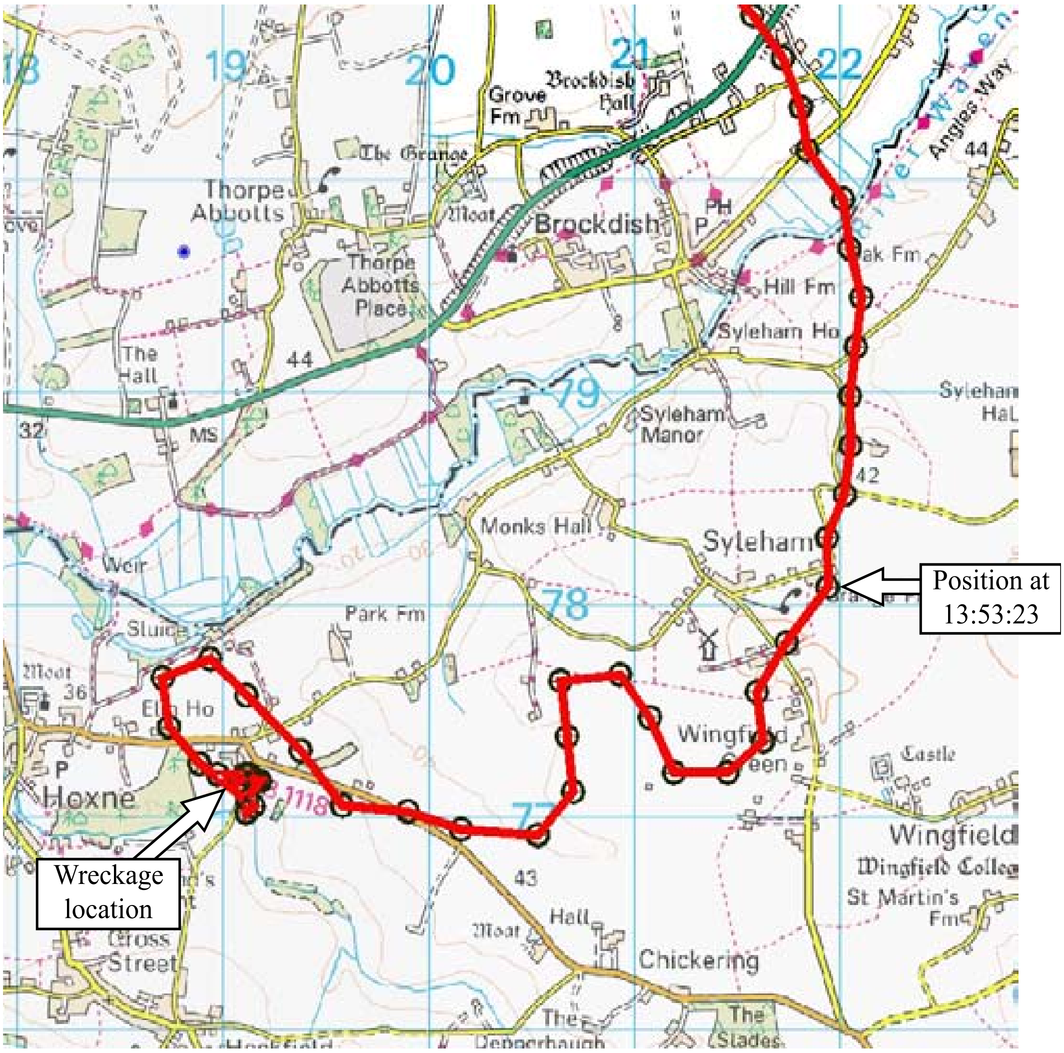

Figure 1

Plan view of G-BUUD recorded radar

The radar returns commenced around 2 nm north-east of Old Buckenham Airfield and the track shows the aircraft flying in a southerly direction towards Syleham. The first radar return was recorded at 13:43:57 hrs; around 5 minutes later the first Mode C altitude was recorded as 4,800 ft.

At 13:53:23, at a recorded altitude of 5,000 ft, G-BUUD began a turn to the right towards Hoxne (Figure 1). Correcting this altitude for a QNH of 1027 hPa, and the elevation of the local terrain, gives a height of 5,238 ft agl.

The data shows the aircraft continuing in the general direction of Hoxne (Figure 2), making several turns on the way whilst maintaining an altitude of about 5,000 ft. The final concentration of 10 radar returns occupy a small area, which contained G-BUUD's ground impact position, with the final radar return recording an altitude of 1,100 ft.

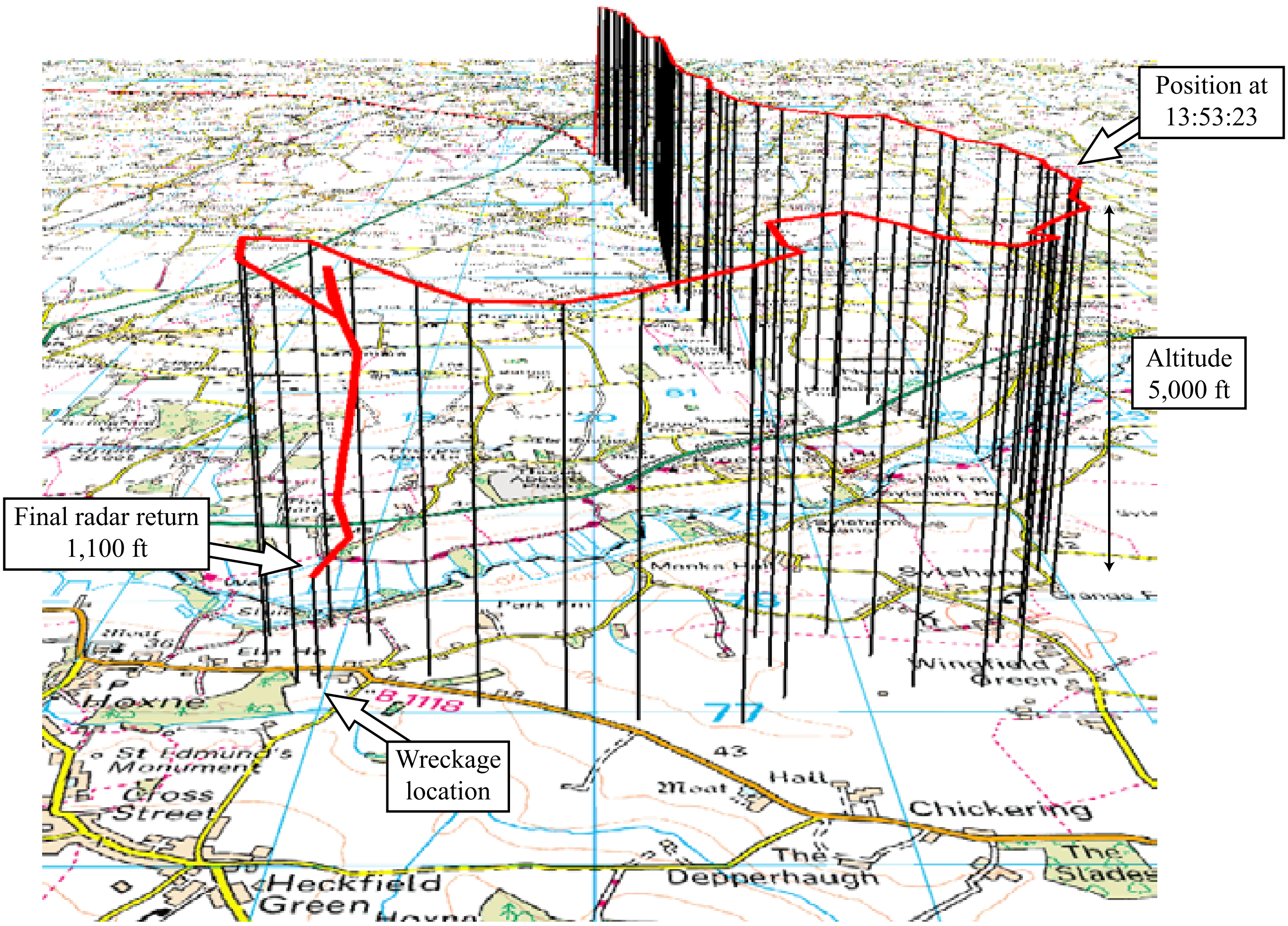

Figure 2

Isometric view of G-BUUD recorded radar

Aircraft description

Aircraft details

The Slingsby T67M-MkII Firefly is a single-engined low-winged monoplane with a low-mounted tailplane and fixed tricycle landing gear (Figure 3), designed to be fully aerobatic. Two side-by-side seats are provided. The aircraft is constructed principally of glass reinforced plastic; carbon fibre reinforced plastic and timber are also used in some areas. It is powered by a 160 shp, fuel-injected, petrol, reciprocating engine driving a constant-speed, two-bladed propeller. The aircraft's wingspan is 34.8 ft, the length 23.9 ft and the maximum takeoff weight 2,150 lb.

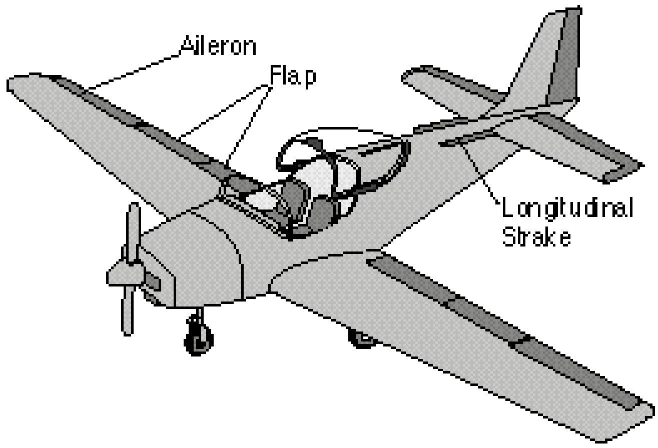

Figure 3

Fuel is carried in a tank in each wing. Cockpit transparencies consist of a fixed windscreen and a canopy that swings upwards and rearwards to open.

Flight controls are conventional, with dual cockpit controls. Each control stick operates the ailerons and elevators via a cockpit mechanism that drives rod and bellcrank linkages connected to the control surfaces. Pitch trim is provided by a trim wheel on the cockpit centre console driving a trim tab on the left elevator via a push-pull cable. Wing flaps are manually operated, via a lever and a rod and bellcrank system.

Rudder pedal assemblies operate a dual cross-shaft mechanism in the cockpit that is connected by a cable and fairlead system to the rudder. Deflection of the mechanism by the pedals also steers the nose wheel, via a control rod. Each pedal can be pivoted by pushing a bar at its top which applies the brake on its respective main wheel. The pedals are numbered from 1-4 across the aircraft from left to right. A slider mounting mechanism allows each pedal pad to be individually adjusted fore and aft to accommodate variations in leg length. This machanism can then be locked by a pin that locates in one of four holes in the slider.

Most components of the control system mechanisms within the cockpit are of steel but some, including the rudder pedal pads, are of aluminium. Outside the cockpit, the rudder and pitch trim cables are of steel but the rods, bellcranks and fairleads in the systems are of aluminium.

The aircraft manufacturer reported that, prior to initial type certification, there had been some difficulty in achieving recovery from a spin within a maximum allowable time when an incorrect recovery action was applied and the specified recovery actions were reversed (ie control stick moved forwards before anti-spin rudder applied). In order to resolve this problem a longitudinal strake had been fitted to each side of the fuselage immediately forward of the horizontal stabiliser. Additionally, the rudder rigging requirements had been altered, to change the maximum rudder angle from 30±2° to 30±1°. These measures had been incorporated on all production T67 aircraft at manufacture.

Background of the Slingsby T67 Firefly

The Firefly was first certificated in 1984, as the T67B, by the UK Civil Aviation Authority (CAA). A number of other versions were subsequently developed, including the 160 shp T67M-MkII, the 200 shp T67M200 and the 260 shp T67M260. In total 280 aircraft have been built. The different models were generally similar to each other but the T67M260 was provided with a larger rudder than the other versions to counteract the effects of the heavier powerplant. The United States Air Force (USAF) had acquired 113 T67M260 aircraft, designated as the T-3A, starting in 1993. The USAF aircraft were grounded in 1997 and were subsequently scrapped. At the time of G-BUUD's accident around 130 T67 aircraft remained in service, including around 15 T67M-MkII aircraft.

History of G-BUUD

Aircraft records indicated that G-BUUD (Serial Number 2114) had been maintained in accordance with the appropriate Maintenance Schedule; CAA/LAMS/A/1999/Iss 2. The last scheduled maintenance of the aircraft, including its engine and propeller, had been on 9 March 2006, at a 6 Monthly/ 50 Hour Inspection conducted 37 operating hours before the accident. At the time of the accident the Certificates of Airworthiness, Registration and Scheduled Maintenance Statement Release to Service were valid. The records indicated that the level of deficiencies experienced in the months prior to the accident had been low and that no major rectification work had been necessary. The only reported known defect at the time of the aircraft's departure on the accident flight was an inoperative landing light. G-BUUD had accumulated a total of 2,991 operating hours since new at the time of the accident.

Aircraft examination

Photographic evidence

A study of the photographs taken by witnesses of G-BUUD during its descent did not indicate any anomaly with the aircraft. Efforts were made to computer-enhance the images but, because of the appreciable distance from which the photographs were taken, their intrinsic resolution proved insufficient to enable the deflections of the aircraft control surfaces to be reliably determined.

Accident site

The aircraft crashed in gently rolling countryside 0.5 nm east of the village of Hoxne, at an elevation of 118 ft amsl. Ground impact was onto a field of sugar beet, on a level area with dry sandy soil of moderate density. The impact was close to two houses located outside the village and the aircraft came to rest 7 m from a fence separating the rear gardens of the houses from the field.

Witness evidence suggested that a ground fire had started in the region of the engine compartment immediately after ground impact. The fire had grown to engulf and destroy much of the aircraft, until extinguished by the fire service.

Examination of the accident site showed that the aircraft had remained substantially intact on impact. The windscreen frame and parts of the canopy were found on the ground around 12 m from the cockpit, consistent with these parts having fractured and been forcibly ejected from the aircraft when it struck the ground. In addition, small fragments of the transparencies, glass reinforced plastic material and other small aircraft parts had been distributed on the ground in the immediate vicinity of the aircraft. The engine remained generally in place, but came to rest rotated about 25º right of the fuselage heading. The pilot was located in the left seat.

Ground markings and wreckage distribution, together with the available evidence from aircraft damage characteristics, indicated that G-BUUD had initially struck the ground while upright and with a pronounced nose-down and left wing down attitude. Because of the extensive ground fire damage the impact attitude could not be quantified. The lack of extensive break-up indicated a moderate descent rate at impact. At initial ground contact the aircraft's heading had been approximately 302ºM. During the ground impact sequence it had yawed 25-30º to the left (anti-clockwise rotation, viewed from on top) before coming to rest. The evidence showed that there had been virtually no horizontal translational movement of the main wreckage after the initial ground contact.

Detailed wreckage examination

Much of the aircraft had been severely damaged by the ground fire, including almost the whole of the fuselage and the powerplant and most of the right wing and the empennage. In the affected areas the structure had largely been reduced to glass or carbon fibre cloth or rovings with the resin burnt away. Steel components remained intact, albeit severely corroded, consistent with the effects of fire exposure, but many aluminium components in the fire-damaged areas had melted and most of the combustible materials, such as furnishings, seat belts and papers, had burnt away.

Examination indicated that the aircraft had been complete at ground impact, including all primary and secondary flight control surfaces. No signs suggestive of pre-impact structural failure were found.

Reliable evidence on the settings of the primary control surfaces at impact was not available. Most pivots for the primary control surfaces and their operating linkages were located. Ground fire damage had destroyed appreciable portions of aluminium control rods and/or bellcranks of the aileron, flap and, particularly, the elevator systems. Most parts of the rudder control system were identified, including the steel cockpit mechanism. However, the aluminium pedal pads had been destroyed and extensive fire damage to the pedal adjustment mechanism prevented the pedal fore and aft adjustment position from being positively established. Examination of the available components revealed no signs of pre-impact disconnection of the flight control linkages. A detailed inspection was made for any evidence of a pre-impact restriction or jam of the controls and for the presence of foreign objects but, given the level of destruction, the results were not conclusive and it was not possible to determine whether a restriction or jam might have occurred.

Evidence suggested that the flaps had been in the retracted position at impact. The pitch trim system components, mostly of steel, largely survived the ground fire and the evidence indicated that the trim had been set close to neutral.

Both propeller blades had been severely fire-damaged but the fibre cloth laminates forming their main structural elements remained intact without any signs of impact damage. It was concluded that the propeller had not been rotating when the aircraft struck the ground. No signs of anomaly with the powerplant were apparent, although fire damage prevented meaningful assessment of many of the accessories; it was judged, given the circumstances of the accident, that engine strip examination was not relevant.

Meteorology

During the investigation, a meteorological aftercast was obtained. The weather at the time of the accident was fine and dry. An area of high pressure was covering the British Isles, feeding a light easterly flow over the county of Suffolk. In general, the winds in the area were calculated to be from 120º at 8 kt on the surface, and from 130º at 15 kt at 5,000 ft.

The surface visibility was between 20 and 40 km but the air to ground visibility was not determined. There were, perhaps, some very isolated patches of shallow cumulus cloud at 3,800 ft and thin layers of cirrus cloud at 24,000 ft. However, photographs taken of the aircraft during and after the aerobatics sequence showed only scattered high level cloud.

The actual weather, recorded at 1350 hrs, at Norwich Airport, 20 nm to the north of the accident, gave a: surface wind of 070º/12 kt, visibility in excess of 10 km, no cloud below 5,000 ft, a surface temperature of 26ºC and a dew point of 11ºC. At the same time, at Wattisham Airfield, 16 nm to the south west, the conditions were very similar; except the surface wind was from 120º at 8 kt and the surface temperature was 27ºC.

The mean sea level pressure was 1027 hPa.

Pilot information

The pilot had received a trial flying lesson in 1999 and commenced training for a Private Pilot's Licence (Aeroplanes) (PPL(A)) in August 2004. All except one hour of his flying training was conducted in a Cessna 150. In November 2005, after a total of 57 hours of flying instruction, he was issued with his PPL(A).

In January 2006 the pilot commenced the Aircraft Owners and Pilots Association (AOPA) Aerobatics Course in the Firefly T67M-MkII. His initial training included instruction on flying the type and revision on stalling and steep turns.

The pilot had completed 18 flights in the T67, all in G-BUUD, of which nine had included aerobatic manoeuvres. He was trained by two instructors, both of whom taught him aerobatics. He flew three solo flights, for a total of 2 hours and 20 minutes; he had not been briefed to carry out any aerobatic manoeuvres on these flights and did not record doing so. His last flight before the accident was with an instructor on 29 June. Apart from two flights in January, on a PA-28 and Cessna 150 respectively, and another flight in February in the same Cessna 150, the pilot flew only in G-BUUD, carrying out his flying on a total of 10 days, over a period of six months.

In March, the pilot had received instruction in stalling in the turn and spinning in both directions, recovering successfully from two spins himself. In April, during another dual training flight his instructor demonstrated a further spin to point out the rate of descent and the importance of the turn needle.

Recorded comments on the pilot's progress sheet indicate that his proficiency at general handling and aerobatics was inconsistent. It was noted that he had a tendency to roll the aircraft to the right or to the left in looping manoeuvres, rather than following a vertical flight path, and one of his instructors commented that the pilot did not always maintain a smooth rate of pitch during the manoeuvre, sometimes pulling back on the control column unevenly, giving the loop a 'square' shape. There was also evidence that his level of alertness varied and that during some flights he was unable to process information at the necessary rate. It was assessed that, on the basis of his progress, the pilot was between 33% and 50% of the way through the AOPA Aerobatics syllabus.

The pilot was in the habit of wearing light clothing during his training flights and the importance of having a clean cockpit and empty pockets for aerobatic manoeuvres was particularly impressed upon him. Other than a map, it was considered that he would not have had anything else with him on the accident flight.

In March 2006 the pilot had bought a half share in G-BUUD, thereby becoming a co-owner with one of his instructors.

Two parachutes, each weighing 9 kg, were available to the pilot as part of the aircraft's equipment. However, he had not worn one during his previous flights and did not do so on this occasion either, although it would not have adversely affected the weight or balance of the aircraft if he had done so.

Aerobatic training

The Rules of the Air Regulations state that:

> *'an aircraft shall not carry out any aerobatic manoeuvre… over the congested area of any city, town or settlement.'*

No other rules apply specifically to flights outside controlled airspace during which a pilot carries out aerobatic manoeuvres, and a pilot is not required to have any qualification or rating to perform solo aerobatics beyond possession of a PPL(A). The CAA considers that completion of an AOPA Aerobatics Course is a practical alternative to a compulsory rating for any pilot who wishes to perform solo aerobatics.

The AOPA course comprises eight hours of ground instruction plus a minimum of eight hours dual flying with an approved instructor who is qualified to give aerobatic instruction, covering the basic aerobatic manoeuvres. Spin training is included in the course, covering both incipient spinning, in which recovery is commenced at the first stage of the spin, and fully developed spinning. Pilots are also taught recoveries from markedly unusual attitudes, including those near the vertical and when semi-inverted.

The AOPA Guide and Syllabus of Instruction for the Aerobatics Certificate Course emphasises that the aerobatic manoeuvres covered in the syllabus must only be undertaken if the Owner's/Flight Manual/ Pilot's Operating handbook specifically states that these manoeuvres are permitted on the aeroplane type, as is the case with all variants of the T67.

During the course of the investigation a visit was made to a UK military flying training establishment where ab-initio pilots are instructed on the T67M-260. It was noted that these student pilots are not authorised to practise solo aerobatics until they have completed a 'spinning and aerobatics' check flight with an instructor. It is also standard practice for the instructors and students to wear parachutes on all flights.

Spinning and aerobatics

General

The CAA General Aviation Handling Sense 3 leaflet, entitled *Safety in Spin Training*, explains that:

> *'the spin is a stalled condition of flight with the aeroplane rolling, pitching and yawing all at the same time. There are aerodynamic forces and gyroscopic forces (caused by the rotating mass of the aeroplane) which may be pro-spin or anti-spin. In a stable spin the aerodynamic and gyroscopic forces balance out leaving the aeroplane rolling, pitching and yawing at a constant rate.'*

The CAA General Aviation Safety Sense Leaflet 19a, entitled *Aerobatics,* advises pilots who are learning to fly aerobatics to:

> *'become familiar with the entry to and recovery from a fully developed spin since a poorly executed aerobatic manoeuvre can result in an*

> *unintentional spin. Training in recovery from incorrectly executed manoeuvres and unusual attitudes is essential.'*

Following a spinning accident to G-BLTV on 3 November 2002, the AAIB made the following Safety Recommendation:

> *'The Civil Aviation Authority should conduct a review of the present advice regarding the use of parachutes in GA type aircraft, particularly those used for spinning training, with the aim of providing more comprehensive and rigorous advice to pilots.'*

This was accepted by the CAA and an updated Safety Sense Leaflet 19a *Aerobatics* was published containing the following information on parachutes:

> *'While there are no requirements to wear or use specific garments or equipment, the following options are strongly recommended:*
>
> *.....Parachutes are useful emergency equipment and in the event of failure to recover from a manoeuvre may be the only alternative to a fatal accident. However, for physical or weight and balance reasons their carriage may not be possible or practicable, the effort required and height lost while exiting the aircraft (and while the canopy opens) must be considered. If worn, the parachute should be comfortable and well fitting with surplus webbing tucked away before flight. It should be maintained in accordance with manufacturer's recommendations. Know, and regularly rehearse, how to use it, and remember the height required to abandon your aircraft when deciding the minimum recovery height for your manoeuvres.'*

T67 information

During the investigation G-BUUD's weight and CG position were calculated and found to be within the prescribed limits. The Take Off Weight was 852 kg (the maximum for aerobatics is 975 kg), and the aircraft CG was at 24.7% mean aerodynamic chord, which represents a mid CG position. As such, the aircraft was approved for aerobatics. The manufacturer's Pilot's Notes advise the following precaution:

> *'Ensure that aerobatics are carried out at sufficient altitude to recover to normal flight and to switch fuel tanks if the engine should cut.'*

The advised entry speeds for the slow roll and the loop are given as 110 kt IAS and 115 kt IAS, respectively.

The Pilot's Notes also give guidance on the height loss to expect during a spin. They state:

> *'The height loss is about 250 ft per turn and recovery takes about 500 ft. These height losses may vary, dependant on how many turns of the spin are done and how prompt and correct the recovery action is. They may be used as a basis for planning recovery which should be complete by 1500 ft above ground level. It is recommended that inexperienced pilots allow a further 1000 ft to the entry height. Thus the entry height for a 4 turn spin for an inexperienced pilot should be…… 4000 ft above ground level.'*

The technique for intentional spin entry is:

> *'At stall warning apply full rudder in the intended direction of spin and at the same time bring control column fully back. Hold these control positions. If the correct control movements are not applied a spiral dive may develop as shown by an airspeed increasing above 80 kts.'*

The Pilot's Notes also include the following information about *Erect Spin Recovery*.

The *Standard Recovery Technique'* is:

> *'a) Close the throttle.*
> *b) Raise the flaps.*
> *c) Check direction of spin on the turn co-ordinator.*
> *d) Apply full rudder to oppose the indicated direction of turn.*
> *e) Hold ailerons firmly neutral.*
> *f) Move control column progressively forward until spin stops.*
> *g) Centralise rudder.*
> *h) Level the wings with aileron.*
> *i) Recover from the dive.*
>
> *WARNING: WITH C OF G AT REARWARD LIMIT THE PILOT MUST BE PREPARED TO MOVE CONTROL COLUMN FULLY FORWARD TO RECOVER FROM SPIN'*

The guidance for use in the event of an *Incorrect Recovery* is as follows:

> *'A high rotation rate spin may occur if the correct recovery procedure is not followed, particularly if the control column is moved forward, partially or fully, BEFORE the application of full anti-spin rudder. Such out-of-sequence control actions will delay recovery and increase the height loss. If the aircraft has not recovered within 2 complete rotations after application of full anti-spin rudder and fully forward control column, the following procedure may be used to expedite recovery.*
>
> *a) Check that FULL anti-spin rudder is applied.*
> *b) Move the control column FULLY AFT then SLOWLY FORWARD until the spin stops.*
> *c) Centralise the controls and recover to level flight (observing the 'g' limitations).'*

Later in the same publication information is given about the aircraft's characteristics during erect spinning. After initiation:

> *'the spin progressively stabilizes over about three turns, ending up with about 50º of bank and the nose about 40º below the horizon. The rate of rotation is about 2 seconds per turn [and] the IAS stabilizes at about 75 kts to the right and 80 kts to the left. If full pro-spin control is not maintained throughout the spin, the aircraft may enter a spiral dive or a high rotational spin. A spiral dive is recognised by a rapid increase in airspeed with the rate of rotation probably slowing down as the spin changes to a spiral dive. The wings can be levelled by using aileron with rudders central and the dive then recovered using elevator. A high rotational spin is recognizable by a steeper nose down attitude and a higher rate of rotation than in a normal spin; airspeed will be higher than a normal spin but will not increase rapidly; recovery is as given [for] Incorrect Recovery.'*

This guidance indicates that the rate of descent during a stable spin is about 6,000 fpm.

As part of the investigation a flight was conducted in a T67M-MkII, during which aerobatic and spinning manoeuvres were carried out. In the course of performing a loop, it was noted that the vertical distance between the top and the bottom of the manoeuvre was 600 ft. An aileron roll was also completed, as well as exercises in stalling and intentional spinning. The height loss during a four-turn spin to the left, plus standard recovery, was 1,500 ft, as advised in the Pilot's Notes. A further two loops were carried out, during which the controls were mishandled after the aircraft had reached the top of the manoeuvre, in an attempt to induce a spin. On each occasion the aircraft departed from controlled flight. The controls were immediately centralised, the normal procedure for recovery from an incipient spin, and the aircraft responded within one turn. This flight also demonstrated the potentially disorientating effects of spinning.

These results reflected the comments by the manufacturer, T67 instructors at two UK military flying training establishments and an experienced international aerobatics competitor, that the aircraft is predictable and responds as described in the manufacturer's Pilot's Notes. Their comments also complemented the results of tests on other models of the T67, all of which have been designed with the stability characteristics required for an aerobatic aircraft.

As a military training aircraft, the T67M-MkII has been spun many hundreds of times. Instructors involved in this training have observed students using the correct and incorrect techniques to recover from spins. In all cases, the aircraft recovered when the correct technique was employed.

The pilot owned a copy of the AOPA publication, *Basic Aerobatics* (by R D Campbell and B Tempest). The book includes a section on *The Spiral Dive*. It describes the condition as one in which the nose of the aircraft is allowed to drop too low during the entry into, or while in a steeply banked turn. It states that:

> *'once the aircraft has adopted this attitude the airspeed will increase rapidly…. The correct recovery action is to close the throttle completely and positively roll the wings level, following this the aircraft can be eased out of the dive.'*

Amongst the pilot's possessions was a copy of an Essential Knowledge Quiz which had been compiled by his instructors and which students were encouraged to complete before commencing flying on the aerobatics course. The quiz had been completed and included answers to questions which asked for the symptoms of a spiral dive and a spin, respectively. The two answers given indicated the differences between the two conditions.

T67 studies

Certification testing

A T67M-MkII aircraft was submitted for flight trials prior to type certification. It was established that the aircraft spin recovery characteristics fully complied with the appropriate British Civil Airworthiness Requirements (BCARs) and Federal Aviation Regulations (FARs). Also, the specific requirements of the CAA in relation to an incorrect recovery action, in which forward movement of the control column precedes application of full anti-spin rudder, were met. In that case the aircraft was required to recover within four turns. These trials were conducted over a range of aircraft weights and CG positions.

Aerobatics trials were also conducted and the aircraft type was again shown to comply with the relevant BCARs and FARs.

Tests by United States Air Force

Tests carried out by the USAF in 1998 on the T-3A (the 260 hp version of the T67) included approximately

1,000 spins. It was established that spins were predictable and easily recognisable and that the Flight Manual spin recovery technique was always effective.

Tests by a CAA test pilot

Another variant of the T67, the T67C, was flown twice by a CAA Test Pilot following an accident in 2005 involving G-FORS (see AAIB Bulletin 3/2006). This assessment confirmed that the aircraft characteristics in a spin, and during the recovery, were in accordance with the Pilot's Notes. On the second flight the Test Pilot deliberately released the back pressure on the control column during three of the spins. As a result, the turn rate increased and the recovery from the consequent high rotational spins took between two and three turns.

Previous relevant events

T67 spinning

The Incorrect Recovery procedure was issued by the manufacturer following two events involving Slingsby T67M-MkIIs in 1993 and 1995. The incident in 1993 involved a delayed recovery from a spin following initial incorrect recovery action. In July 1995 an instructor and his student pilot abandoned G-BUUH (see AAIB Bulletin 10/95) during an instructional flight when they were unable to recover from an intentional spin. In this instance, the student had put the aircraft into a spin to the left at Flight Level (FL) 70 and was ordered to recover from the manoeuvre as the aircraft passed FL57, having completed four turns, as planned. The student applied partial opposite rudder and simultaneously moved the control column about half way from the back stop to the neutral position. Then, or shortly afterwards, the nose of the aircraft suddenly pitched down and the rate of rotation increased. The instructor took control and, checking that the throttle was closed and the flaps were retracted, applied full anti-spin rudder and moved the control column progressively to the fully forward position. He later stated that these actions had no noticeable effect on the apparent stability of the spin. He made another check of the configuration and confirmed that the attitude and rotation still showed no indication of recovery. Consequently the crew commenced abandonment of the aircraft as it descended through FL43 and parachuted to safety.

Spinning accidents with other aircraft types

This investigation prompted a review of light aircraft accidents in the UK since 1976 in which spinning has been a factor. The list includes aerobatic and training aircraft but also features a wide variety of other aircraft types. There were peaks in 1976, 1988 and 1996, when the accident numbers reached double figures, and from January 2001 to December 2006 there have been an average of four such accidents per year.

T67 flight control incidents

No evidence was found to indicate that control deficiencies had been a factor in previous T67 accidents. The aircraft manufacturer reported receiving no reports of cases of disconnection of any T67 flight control system linkages, or of restriction or jamming of the aileron or elevator controls. A number of instances of restriction in T67 rudder pedal movement had been experienced. These restrictions were all considered to have been caused by interference between moving parts of the cockpit rudder mechanism (generally a pedal pad or brake bar or a pilot's boot) and either other parts of the rudder, wheelbrake and steering mechanisms or adjacent static parts of the aircraft.

In one incident, to a T67M260 aircraft (G-EFSM) in November 2006, an instructor attempting to recover from an intentional left spin initiated by his pupil found himself initially unable to move the pedals from their full left position. After pushing very hard on his right pedal the mechanism released with a loud noise and a recovery was made from the spin. Inspection indicated that the jam had probably been due to interference between part of the No 3 pedal and an engine control cable support bracket. The bracket, associated with quadrant-type engine controls used on the T67M260 and the T67M200 aircraft, is not fitted to the T67M-Mkll. However, clearances for the rudder pedal mechanism are relatively small in a number of areas.

Procedures aimed at ensuring adequate rudder mechanism clearance were not provided in the Aircraft Maintenance Manual but at the time of G-BUUD's accident they were contained in a number of Service Bulletins (SBs) issued by the aircraft manufacturer over the service life of the T67. Following the incident to G-EFSM the manufacturer issued two additional SBs (Slingsby No 187, for the T67M260 and two T67M200 aircraft; and No 188, for the T67B, T67C, T67M-Mkll and the other T67M200 aircraft). These latter Bulletins aimed to bring together the various check and adjustment procedures for rudder mechanism clearance provided in the previously published SBs. The intention was:

'to reinforce the importance of ensuring correct clearances and maintenance of the rudder operating mechanism, mountings and stops to ensure the required clearance for safe operation.'

The European Aviation Safety Agency issued Airworthiness Directive (AD) No 2007-0132 on 11 May 2007, which mandated incorporation of the Slingsby SBs 187 & 188.

Specified minimum rudder mechanism clearances were generally in the range 10-20 mm (0.39-0.79 inch) but were considerably less in two areas, including that between the No 2 Pedal and the steering arm bolt, specified as 1 mm (0.04 inch). SBs 187 and 188 noted that 'during the clearance checks the pedals do not necessarily have a direct fore and aft load applied, there will be side loads on the pedal pads deflecting the pedal pad laterally or pivoting it about its slider'. The magnitude of the lateral load to be applied during the checks was not specified but was intended to take up any play in the mechanism.

The manufacturer considered that cockpit rudder mechanism clearances, while small in some areas, were adequate, provided the SB measures had been incorporated and the system was correctly adjusted and maintained. The AAIB concluded from the investigation of G-EFSM's incident that, in view of the small clearances, modification was required in order to reduce the risk of rudder restriction. The proposed measures were for improvements to the lateral stiffness and strength of the rudder bar support brackets and to the bracket attachments, and for changes to the engine control cable bracket, where fitted.

Discussion

The pilot commenced the aerobatic manoeuvres at around 5,000 ft agl in good weather. The aircraft departed from controlled flight during the second half of a loop and entered a spin, probably at a height of at least 4,500 ft agl. It is unclear in which direction the aircraft first entered the spin but photographic and radar evidence and the recollections of witnesses support the conclusion that the aircraft settled into a spin to the left, which it sustained until striking the ground. The indications from the crash site and the aircraft wreckage of moderate vertical speed, very low horizontal speed and yaw rotation of the aircraft to the left at impact also showed that G-BUUD had impacted the ground whilst in a left spin. Any other manoeuvre, such as a spiral dive, would inevitably have resulted in a much higher descent rate and more severe aircraft break-up.

The complete absence of impact damage to the propeller blades indicated that the engine had stopped rotating before ground impact. While no definitive reason for this was apparent, the gyroscopic effects of spinning could cause the engine idle speed to reduce and it was possible that centrifugal effects experienced during prolonged spinning could affect the fuel supply to the engine. Stoppage of the engine would not hinder spin recovery but could be distracting.

The evidence indicated that the aircraft had not suffered structural failure in flight and that no parts had detached before ground impact. The possibility of a disconnection in the flight control system could not be positively eliminated as some components of the flight control linkages had been destroyed in the post-crash fire. However, there was no aircraft type history of failure of any of the missing rods and bellcranks and it was possible to examine most of the linkage pivots, the most likely area for a disconnection. Thus it was judged that pre-impact disconnection of the flight controls was unlikely.

The possibility of a control system restriction or jam was considered. Any interference that occurred could leave witness markings on the components, but it was unlikely that this evidence would have been available during the wreckage examination, given the severe and extensive fire damage. A number of in-service instances of rudder restriction had been experienced with the aircraft type, although this had been a rare occurrence and the manufacturer considered that all the known problem areas in this regard had been addressed. Moreover, if the pilot had encountered a control restriction or jam it is probable that he would have made some mention of this in his radio transmission. It was therefore judged unlikely that a control system restriction or jam had occurred on G-BUUD and that this had hindered the recovery from the spin. However, the possibility could not be eliminated.

There was sufficient height for the pilot to carry out a standard recovery from the spin. The pilot had conducted intentional spinning, under instruction, some three months earlier. When entering these intended spins, full rudder in the direction of the spin together with full aft stick would have been applied and maintained. In this instance, having entered an unintentional spin from an aerobatic manoeuvre, the flight controls would most probably have been in different positions, and this may have confused the pilot.

The timing of his 'MAYDAY' radio transmission was estimated to have been made after the aircraft had descended about 2,500 ft from the point of entering the spin, during which time it could have completed up to 10 turns. This number of turns was potentially very disorientating, but the pilot had sufficient awareness to transmit the radio call. From the information he gave, albeit in extremely stressful circumstances, it is not clear whether he had accurately determined the aircraft's flight profile.

In his brief radio transmissions the pilot referred to both "A SPIRAL SPIN" and "A SPIRAL DIVE..". Although he had covered the differences between the two conditions during his training, it is not possible to know what flying control inputs he made, or techniques he employed, in an attempt to recover from the situation. The first action in the recovery from both a spiral dive and a spin is to close the throttle. Allowing for any delay between the engine being throttled back and witnesses on the ground perceiving a reduction in the engine noise, it seems that this action was taken as, or shortly after, the aircraft departed from controlled flight. If the pilot then took the recovery actions for a spiral dive, the aircraft would never have recovered from the spin.

If the pilot had correctly diagnosed that the aircraft was spinning, and applied the standard spin recovery, all the evidence indicates that the aircraft would have recovered. Even if the pilot had moved the control stick forward before applying anti-spin rudder, and maintained these control positions, the aircraft would still have recovered, although this incorrect recovery technique would have delayed the recovery and increased the height loss. If the pilot attempted to recover from the spin using an incorrect technique then a high rotation rate spin might have occurred, although the witness accounts did not reflect the high rate of rotation and steep nose-down attitude associated with such a spin.

For an inexperienced pilot used to the aircraft recovering within one turn after application of the correct recovery procedure, who was probably becoming increasingly disorientated and progressively more concerned, it would have taken a high degree of discipline to recall the guidance given in his training, maintain the flying controls in the full recovery position and wait for the aircraft to stop spinning.

The increase in engine noise during the descent, reported by one witness, cannot be explained other than that the pilot may have been trying further control inputs to recover from the spin.

The CAA do not require a pilot with a PPL(A) to have a compulsory rating in order to perform solo aerobatics, considering the AOPA Aerobatics Course to be a practical alternative. In addition, CAA General Aviation Safety Sense leaflets give advice on aerobatics and spin training. The accident pilot had elected to undertake the AOPA Aerobatics Course, during which he had received training in both basic aerobatics and spin recoveries. He was considered to be part of the way through the course but was making inconsistent progress. The accident occurred on what seems to have been his first attempt to fly aerobatics on a solo flight, although this had not been authorised by his instructor.

Therefore, the following Safety Recommendation was made:

Safety Recommendation 2007-081

It is recommended that the Aircraft Owners and Pilots Association advise those pilots undertaking their Aerobatics Course not to fly solo aerobatics until they have been trained and proved competent in spin recognition and recovery, and their instructor has advised them that they are competent to practise specific aerobatic manoeuvres solo.

A parachute was available to the pilot but, as was his custom, he flew the aircraft without one; he therefore had no opportunity of abandoning the aircraft. The wearing of parachutes may not always be possible or practical; nevertheless, the following Safety Recommendation was made:

Safety Recommendation 2007-082

It is recommended that the Aircraft Owners and Pilots Association provide comprehensive and robust advice on the use of parachutes for flights where spinning and aerobatics are planned, reflecting the guidance given in the Civil Aviation Authority's Safety Sense Leaflets.

Conclusion

Failure to recover from a spin continues to be a cause of accidents to light aircraft types. Considerable flight test and operational experience indicates that recovery from a spin reliably occurs if the appropriate actions, as published in the Pilot's Notes, are taken. However, a successful recovery relies on correct identification of the spin and the maintenance of anti-spin flight control inputs until the spinning ceases.