ACCIDENT

Aircraft Type and Registration:	Yak-52, G-YAKR	
No & Type of Engines:	1 Ivchenko Vedeneyev M-14P piston engine	
Year of Manufacture:	1989 (Serial no: 899803)	
Date & Time (UTC):	29 March 2014 at 1453 hrs	
Location:	Near Highwood, Chelmsford, Essex	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - 1 (Fatal)	Passengers - 1 (Fatal)
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	50	
Commander's Flying Experience:	in excess of 15,000 hours[1] (of which approximately 40 hours[2] were on type) Last 90 days - 1 hour Last 28 days - 1 hour	
Information Source:	AAIB Field Investigation	

Synopsis

The aircraft was carrying out a local flight when, five minutes into the flight, it was observed flying at low level. Having carried out a level turn, the aircraft climbed sharply and entered a stall or spin, from which it did not recover before striking the ground. Both occupants received fatal injuries and there was a fire. The reason the aircraft was flying at low level and the cause of the final manoeuvre could not be determined.

History of the flight

The pilot, who was one of three co-owners of the aircraft, arrived at North Weald mid-morning and prepared for a short local flight. He had not made an arrangement to take anyone with him, until he met someone at the airfield and offered him the opportunity to fly as a passenger.

Following pre-flight preparations, some of which were witnessed by onlookers at the flying club, the aircraft's engine was started and at 1439 hrs the pilot booked out by radio for a "TWENTY MINUTE LOCAL FLIGHT". The aircraft taxied for departure from Runway 02 and took off

Footnote

[1] No up-to-date log books were available; the total hours stated is taken from the pilot's medical declaration in October 2013.

[2] Flight records for G-YAKR were audited but did not match records kept of movements at North Weald; time on type is derived from information on an insurance application in March 2013 adjusted to reflect some recent flying.

at 1447 hrs. Following an apparently normal takeoff run, the aircraft lifted off and climbed before turning on course towards the east. The AFISO last saw the aircraft climbing away from the airfield, above 1,000 ft aal. In the pilot's final communication to the AFISO, at 1448 hrs, he reported that he was "VACATING TO THE EAST". No further transmissions from the pilot were heard.

Primary radar returns show that the aircraft then flew a predominantly easterly track. Although the aircraft was fitted with a transponder which, according to the other co-owners, was serviceable, no secondary radar responses from the aircraft were recorded. Therefore, there was no height information. The aircraft's track included a left and then right turn, which were co-incident with the position of a small airfield. However, aside from the radar recordings, no other information was found concerning the course of the flight until over twenty eye-witnesses observed the aircraft flying near Highwood, Essex.

Although some of their accounts differed in detail, there was general consensus about the aircraft's flight profile. The aircraft was first seen flying slowly, or at a "normal speed", more-or-less straight and level, in a south-easterly direction, and at low height; estimated to be between 100 and 200 ft agl. The aircraft then executed a level turn. Some witnesses recalled that this was through only a few tens of degrees, while others perceived it to be more significant and a small number believed the aircraft had turned onto an approximately westerly track.

The aircraft then climbed relatively abruptly to approximately twice its earlier height, to 200 to 400 ft agl. Some witnesses then described it entering an incipient spin, before descending into the ground. A few others stated that the aircraft pitched dramatically nose-down, descended and struck the ground. Witness accounts of the sound made by the aircraft varied. Some said the aircraft made no unusual sounds, while others mentioned "sputtering" sounds from the engine.

Although a number of people reached the crash site very soon after impact, they were unable to approach the aircraft because of the severe post-crash fire that developed.

Both occupants were fatally injured in the impact.

The pilot

The pilot was employed by a commercial airline as a co-pilot flying wide-body aircraft, although in recent months he had been engaged in office duties, rather than flying. Prior to his civil flying career, he had been commissioned in the Royal Air Force, mostly as a pilot flying transport aircraft; he had also instructed navigation in single-engined piston aircraft.

The pilot's light aircraft flying involved tutoring civilian pilots in formation flying, and flying G-YAKR, usually carrying out aerobatics. The pilot held a Class One medical certificate, which equated to a Class Two medical certificate for private flying. He was diabetic and managed his condition by a regime of testing and injections of insulin, in accordance with the CAA's protocols.

The pilot had passed a Single Pilot Aircraft skills test, in G-YAKR, on 1 December 2013. This flight included incipient spin recoveries and aerobatic manoeuvres, which the examiner reported were "carried out with a high degree of competence".

Meteorology

The Met Office provided an aftercast of conditions affecting the area around the accident site. Their report stated:

> *'…the accident occurred in a fairly stable environment with a moderate southeasterly airflow. METARs and observations in the area show that there was a fair amount of haze around with most places reporting visibilities between 6 KM and 10 KM. The further inland the visibilities improved up to 19 KM in places. There was no significant cloud reported during this period. Looking again at the METARs and observations in the area we can see a moderate east to southeasterly airflow at the surface between 10 and 15 Knots, with a few isolated gusts in the area between 25 and 30 Knots, these mainly to the south and west of the incident area.'*

Around the time of the accident, meteorological observations at Stansted, approximately 11 nm north-north-west of the accident site, were:

291450Z 12015KT CAVOK 17/03 Q1014
291520Z 10011KT CAVOK 17/04 Q1014

Those at Southend-on-Sea, approximately 15 nm south-east of the accident site, were:

291450Z 09014KT 8000 NSC 14/07 Q1014
291520Z 10014KT 9000 NSC 14/08 Q1014

Recorded information

Radar data for the accident flight was available from the Debden and Stansted radar heads, 16 nm and 10 nm north of the track respectively (Figure 1).

The radar returns were primary only, so no altitude information was available. However, both recorded radar tracks were intermittent, suggesting that the aircraft was flying at an altitude on or near the lower line-of-sight height limit of both radar heads. The lower limit for both radar heads, in the region of the aircraft's track, was about 200 ft agl, and in places it was down to ground level. The average groundspeed for the accident flight was 86 kt.

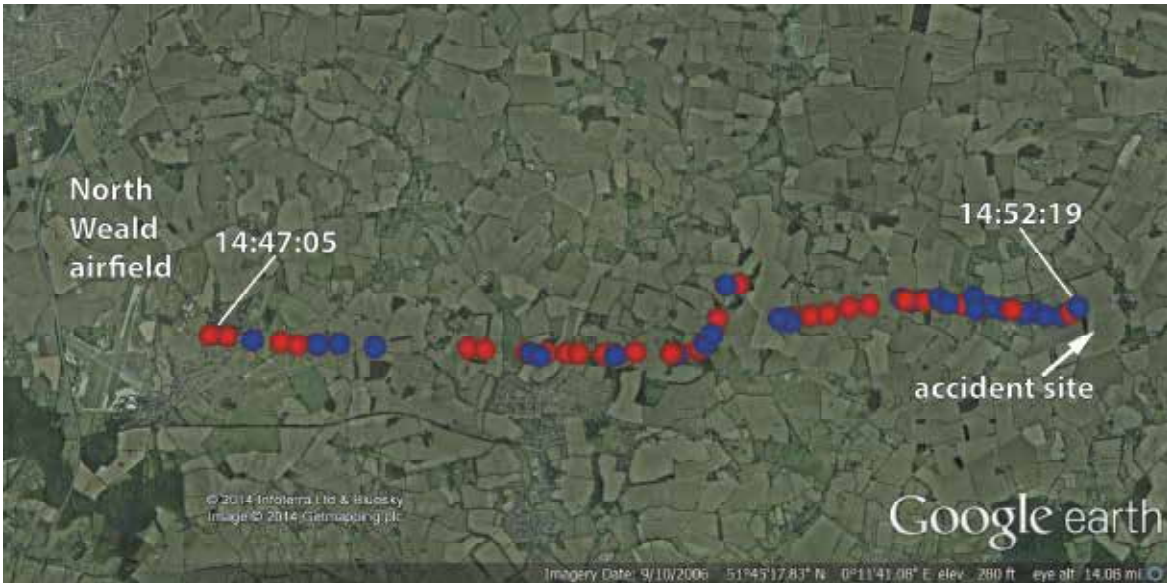

Figure 1

Debden (red) and Stansted (blue) radar ground tracks for the accident flight

Pathology

A specialist aviation pathologist carried out post-mortem examinations of the pilot and passenger. He noted that both *'died of multiple injuries which were sustained in the non-survivable crash of their aircraft'*. Toxicological investigation revealed nothing that could have contributed to the accident.

Toxicological evidence indicated that the pilot was not hypoglycaemic at the time of the accident and there was nothing to suggest that his diabetes had played any role in the accident.

Yak-52 description

The aircraft is an all metal two-seat, tandem, single-engine low-wing monoplane, originally designed and manufactured as a military basic training aircraft in the Eastern bloc. Yak-52 aircraft are now relatively commonplace in the UK and are often used for aerobatic flying and training.

The never-exceed speed (V_{NE}) of the Yak-52 is 420 kph (227 kt) and its design manoeuvring speed (V_A) is 360 kph (194 kt). Its published stalling speed, with power off in 1g normal flight, is 105 kph (57 kt). The aircraft is cleared to operate to load factors of +7g and -5g.

The aircraft is powered by a nine-cylinder, single-row, air-cooled radial engine driving a two-bladed, variable pitch propeller via an epicyclic reduction gear. Mounted on the rear of the engine are a carburettor and an accessory gearbox. The latter drives a single stage supercharger together with a compressor, magnetos and generator.

The electrical system is 28 volt DC, supplied by two batteries and a 3KW engine-driven

generator. This is chiefly used to power the aircraft instruments, the radio and intercom. The large capacity generator was originally required to power a rack of avionic equipment located behind the aft cockpit; this is largely redundant when operating the aircraft in the UK. The flaps, landing gear and engine starting are powered by a pneumatic system fed by two pressure vessels which, in turn, are supplied by the engine-driven compressor.

Accident site details

The aircraft had crashed into an oilseed rape crop, on a track of approximately 265°M, approximately 300 m north of the A414 road that runs in an east-west direction between Chelmsford and Stansted. There was no ground slide and it was apparent that the impact had been steeply nose-down. The pitot probe, attached to the left wing leading edge, was found buried in the ground to a depth of around 0.5 m, inclined at an angle of 80° to the horizontal, and was considered to be indicative of the flight path angle. Immediately after the impact the aircraft had fallen back on the ground, such that it had come to rest in an upright, level attitude. There had been extensive disruption to the nose and forward fuselage and an intense fire had destroyed the cockpit area. Despite the steep impact angle, the aircraft structure aft of the wing spar had remained substantially intact, suggesting a low impact speed.

The leading edge of the right wing had made an impression in the ground and the wing had come to rest immediately above it. A similar impression had been made by the left wing, although it was clear that the aircraft and wing had subsequently rotated some 15º anti-clockwise before coming to rest. This suggested that the aircraft was rotating at the time of impact which, together with the steep, low speed impact and witness evidence, was indicative of the aircraft striking the ground following a stall-spin manoeuvre. Additional evidence of rotation in an anti-clockwise direction was provided in the form of some cockpit debris and canopy fragments which had been thrown on the ground to the right-hand side of the aircraft.

It was established that the aircraft was structurally complete at impact, the flaps and landing gear were retracted and the cockpit canopy was closed.

No fuel was found in the aircraft or in the immediate surroundings. There were two fuel tanks in each wing; inboard and outboard. The 80 litre outer tanks were intact but empty, with no fuel odour, and had clearly not held fuel for some time. (Note: aerobatics in this aircraft are prohibited with fuel in the outer tanks and, in the case of G-YAKR, they were seldom used.) The 60 litre inboard tanks had been damaged in the impact, thus releasing their contents into the area of the forward fuselage. The subsequent fire had damaged the inboard end of the left tank; the right tank, together with the forward wing structure in which it was located, had been completely destroyed.

The engine had become buried in the ground at an attitude that reflected the impact angle of the aircraft, and its rear face, including the accessory gearbox, had been severely damaged in the post-impact fire. Excavating the engine revealed the two wooden propeller blades which had failed primarily in bending as the pressure of the earth had folded them in an aft direction. There was otherwise very little chord-wise scuffing or leading edge damage,

which suggested the engine had been developing little power at impact and had been at a low rpm. It was additionally observed that the propeller counterweights were in their forward, ie fine pitch positions, despite the fact that contact with the ground would have tended to push them rearwards, in a coarsening direction.

Following an on-site examination the wreckage was recovered to the AAIB's facility at Farnborough for a detailed analysis.

Detailed examination of the wreckage

Airframe

The forward fuselage, including both cockpits, had been severely damaged by the fire, which had been sufficiently intense to partially melt the wing spar and destroy most of the instruments. The primary flying control system was simple and conventional, consisting of cables, rods and bellcranks. Some of the aluminium components had melted and were thus unavailable for inspection, although the cables had remained connected to the control surfaces. The elevator trim tab was found in the approximately neutral position.

The remains of the throttle lever were identified in the forward cockpit and appeared to be towards the rear of its range of travel, which agreed with the low power indication on the propeller blades. However, the linkage would have been stretched when the aircraft fell back onto the ground after impact, leaving the engine in its crater so little confidence can be placed in the as-found position.

One of the few cockpit items to survive was the warning and caution panel from the rear cockpit. This incorporates a number of amber and red caption segments that light up in the event of a detected failure or hazardous condition. Red segments include warning captions for a generator fault, stall warning, low fuel state and maximum 'g' exceedence. Amber segments include caution captions for compass failure and an engine metallic chip detector, whilst green segments illuminate when the battery, stall warning heater or pitot heater are switched ON. The filaments of all the bulbs in the segments were examined under a microscope for evidence that indicated whether they may have been illuminated at impact.[3] There were two bulbs in each segment and it was found that only those in the green BATTERY ON segment featured distended filaments. This caption would normally have been illuminated in flight.

Footnote

[3] When bulbs are illuminated, the heated filaments become extremely ductile and an impact can result in extensive filament stretching within the glass envelope. This feature can thus provide evidence that the bulb was lit at impact.

Engine

The engine was taken to an overhaul organisation with experience on this engine type and subjected to a strip examination under AAIB supervision.

Firstly, the propeller hub was removed and was found to be full of oil and in good condition internally. Similarly, the reduction gearbox components, together with the propeller constant speed unit (CSU) drive components, were also found to be in good condition. The magnetic chip detector and scavenge filter were clear of debris.

The engine had achieved only 55 hours or so since overhaul and this was reflected in the general condition of the internal components, such as the pistons, cam profiles and cam followers.

The rear of the engine, as noted earlier, had been severely affected by the fire. In particular, the magnesium alloy carburettor had been completely destroyed and part of the accessory gearbox casing was missing. On disassembling the gearbox, two features were noted. These were: an apparently seized bearing in a supercharger spur gear and the fracture of the splined gearbox drive shaft, where it emerged from the rear of the engine. It initially appeared that these findings may have been connected, in that the bearing was in the high speed, low torque part of the drivetrain whereas the shaft operated at a lower speed but higher torque. These components were then subjected to a detailed metallurgical examination.

It was found, on sectioning the bearing, that there had been no metal pick-up or extensive rotational scoring and that the apparent seizure was simply the result of heat distortion and post-fire corrosion.

The shaft failure was found to be the result of torsional overload. It was noted that the fracture surfaces were heavily 'blued', as a result of heat generated in the relative rotation between the fracture faces that occurred immediately following the failure. Most important, however, was the *direction* of the torque that precipitated the failure. It was concluded that this was consistent with the engine end of the shaft suddenly stopping, and the rotational momentum of the gearbox drivetrain components and that of the accessories, particularly the considerable flywheel effect from the generator, creating the overload torque.

The propeller CSU was the only engine accessory capable of being tested, the magnetos having been severely fire-damaged. There was no documentation accompanying the CSU, although it was established, as far as possible, that it was a newly overhauled component supplied with the engine.

The CSU was placed on a test rig and tested in accordance with the manufacturer's test schedule. This demonstrated that the functionality was satisfactory in all respects apart from the delivery flow rate, which was around half the specified value. It was not clear what effect this would have on propeller operation. The CSU was subsequently disassembled, when it was found that all the internal components were in good condition. There was thus no explanation as to the cause of the low flow rates.

Aircraft history

G-YAKR was constructed in 1989 and imported into the United Kingdom in 2002. In the absence of a Type Certificate for the Yak-52, the aircraft was assessed against an Airworthiness Approval Note, following which the Civil Aviation Authority (CAA) issued a Permit to Fly. This was renewed on an annual basis, subject to appropriate maintenance inspections; the last Permit Renewal coincided with an Annual Inspection on 19 July 2013 and was valid for one year. An overhauled propeller was also fitted to the aircraft at this time. The engine was overhauled in 2009 and fitted to the aircraft in May 2011.

The airframe, engine and propeller log book contained no flight entries after 13 April 2013. Some daily flight sheets, from which the log books would have been subsequently made up, were recovered during the investigation, but these finished at approximately the same time. However, movement logs obtained from North Weald Airfield indicated that G-YAKR had conducted a total of 32 flights, totalling approximately 16 hours, between 5 March 2013 and 29 March 2014.

At the time of the accident, the available records indicated that the aircraft had achieved a total of around 1,117 flight hours, with the engine and propeller having achieved approximately 55 and 15 hours, respectively, since overhaul.

Analysis

Operations

The pilot was a professional aviator, who was suitably qualified and acquainted with the area and the aircraft. Also, the weather conditions were benign. He was diabetic and managed his condition in accordance with the CAA's protocols. He held a Class One medical certificate and the post-mortem examination revealed nothing that could have contributed to the accident. Toxicological evidence indicated that the pilot was not hypoglycaemic at the time of the accident and there is nothing to suggest that his diabetes had played any role in the accident.

There was no evidence to explain why the aircraft was flying at a low height when first noticed by eyewitnesses. It is possible that a problem, which had developed after takeoff, led to the pilot descending to that height or that the aircraft was not capable of flight at a higher altitude. However, there was no evidence of a radio transmission by the pilot to provide an explanation, if that was the case.

Witness accounts, and the engineering investigation, indicated that the aircraft's final manoeuvre involved a stall or spin, which occurred at a low height. If, as some witnesses recalled, the final direction of flight was westerly, the last turn would have been on to a downwind heading. This might have been associated with a reduction in airspeed. Why the aircraft then pitched up, climbed and entered a stall or spin could not be determined. Having done so, there was little height in which to recover the aircraft to controlled flight before it struck the ground.

Engineering

The engineering investigation was hampered by the fact that some components were damaged or destroyed in the post-crash fire. Despite this, no defects were found in those parts of the flying controls that remained.

The investigation did not discount the possibility of a significant loss of engine power. As the carburettor had been destroyed and the magnetos severely damaged a failure or malfunction in these components may have prevented the engine from developing full power. However, it was confirmed that the engine was at least rotating, albeit at low power, at the time of impact. Evidence of this was provided by the accessory gearbox shaft overload failure, from which it was concluded that the engine was stopped by the steep impact with the ground.

Analysis of bulb filaments in the rear cockpit warning and caution panel indicated that the green BATTERY ON caption had been illuminated at impact. This would be a normal indication in flight and at least validated the analysis method. There was thus reasonable confidence in the conclusion that no other captions had been illuminated. It also reinforced the finding that the engine was rotating, as the generator caption would normally light up if the engine had stopped in flight, or if the rpm had reduced significantly below idle.

The propeller CSU test showed that it did not meet the test schedule requirements in that the delivery flow rates were low. Although the effect on the propeller is not known, it was considered that it may have resulted in sluggish operation such that the rpm varied more than usual in response to power changes. The good condition of the internal components suggested that nothing had changed during the accident flight, in comparison to previous flights. It was therefore concluded that it was unlikely that the CSU's non-conformity with the test schedule had contributed to the accident.

The intensity and extent of the fire indicated the presence of a significant amount of fuel on board the aircraft. Following the impact damage to the fuel tanks, it is likely that the fuel was released onto the rear of the engine, where it was ignited after coming into contact with the hot engine exhaust manifold. This could be taken as another indication that the engine was operating at impact, as an earlier in-flight failure would have allowed a degree of cooling to occur. It is possible that there was an electrical ignition source, although this is considered less likely due to the absence of any high current cables in the area.

Conclusions

The pilot was an experienced aviator and suitably qualified. He was diabetic and managed his condition in accordance with the CAA's protocols. He held a Class One medical certificate and the post-mortem examination revealed nothing that could have contributed to the accident.

The low height at which the aircraft was flying when first noticed by eyewitnesses may indicate that the flight was not proceeding normally. It is possible that a problem led to the pilot choosing to descend to low height. There was evidence that the engine was running

at the moment the aircraft struck the ground but the possibility of a significant loss of engine power could not be discounted.

No defects were found in those parts of the flying controls that remained but the engineering investigation was hampered by the fact that some components were damaged or destroyed in the post-crash fire.

The aircraft's final manoeuvre could not be explained but, having entered a stall or spin, there was little height in which the pilot could regain control before it struck the ground.