ACCIDENT

Aircraft Type and Registration:	Lockheed T-33 Silver Star Mk 3, G-TBRD
No & Type of Engines:	1 Rolls Royce Nene 10 turbojet engine
Year of Manufacture:	1953
Date & Time (UTC):	6 September 2006 at 1320 hrs
Location:	Duxford Aerodrome, Cambridgeshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Minor) Passenger - 1 (Serious)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	59 years
Commander's Flying Experience:	22,000 hours (of which 14 were on type) Last 90 days - 158 hours Last 28 days - 78 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was the lead of a pair of ex-military jet aircraft which were carrying out a stream takeoff. After it rotated, G-TBRD adopted a steep nose-up attitude; it remained airborne for approximately 200 m before stalling and crashing.

The Aircraft Operating Instructions and Training Manual advocated a lower pitch attitude and warned that excessive pitch rotation is hazardous.

Following the accident, the operator decided to use only pilots with a military background to operate their remaining F86 Sabre, and an experienced Qualified Flying Instructor (QFI) in the Royal Air Force, who was current on jet aircraft, was appointed as the operator's QFI. The operator also instigated a stricter regime of supervision for pilots who had been engaged on other flying duties prior to operating the F86.

History of the flight

The aircraft was departing on a flight to Jersey in company with an F86 Sabre. The two aircraft were carrying out a stream take-off from Runway 24, with G-TBRD as the lead aircraft. G-TBRD had taxied onto the runway and stopped on the left of the centre line, 100 m upwind of the start of the runway, thereby allowing space for the Sabre to line up astern and to the right of the centre line.

The pilot had little recollection of taxiing G-TBRD and

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did not remember any of the ground roll other than that the windsock confirmed the surface wind of 270º/10 kt, as advised by the Flight Information Safety Officer (FISO) in the control tower. However, he subsequently recalled that at some point during the takeoff he saw 'treble figures' on the airspeed indicator, probably between 110 and 115 kt, and thought that the aircraft should be flying by now. He was also aware of the F86 aircraft behind him and that the end of the runway was approaching.

The passenger, in the rear seat, was an engineer from the company which maintained the aircraft. He stated that the engine start had been normal and that, after taxiing on to the runway, the aircraft's brakes were applied and engine power was increased to maximum rpm. He noted that the engine temperatures and pressures were normal and that there were no warnings, abnormal indications or noises. After the brakes were released, he could remember no unusual indications during the round roll – he had flown in G-TBRD about 10 times previously – and stated that the aircraft took off at about 110 kt.

Once airborne, the pilot remembered thinking that the aircraft was 'not going anywhere', and it occurred to him that full flap may have been selected instead of the normal takeoff setting of 32º of flap. He checked the gauge, which confirmed the 32º setting. He was also concerned that the airspeed was reducing and wondered if a thermal was involved. Having decided that the airspeed had indeed decayed, he moved the throttle lever fully forward, a movement of about one inch, to achieve maximum thrust. After that his attention was devoted to trying to stop the aircraft from sinking. He recalled some buffet and seeing a speed of 85 to 90 kt on the ASI, whereas he would normally have expected it to be more than 125 kt, and concluded that there was something clearly wrong with the aircraft. He therefore decided to carry out an emergency landing in the field beyond a line of trees 250 m from the end of the runway. However, it became apparent that the aircraft would not be able to climb over the trees and the pilot recalled that he may have attempted to turn left to fly through a gap in the trees. (Note: The aircraft's ejection seats were disarmed, so the procedure for an engine failure away from an airfield was to carry out a forced landing, with the landing gear retracted, after jettisoning the wing tip drop tanks.)

The engineer in the rear seat was recording the takeoff on a video camera. He recalled the aircraft rotating into a climb attitude at the end of the takeoff roll and then not accelerating, or only accelerating very slowly. The aircraft climbed to a height of a few feet, then descended and struck the runway whilst still in a nose-high attitude and he heard a 'heavy' metallic noise from beneath the fuselage. G-TBRD became airborne again and climbed, he thought, to a height of 50 to 80 ft agl. He stated that there were no other unusual noises or indications during this sequence of events. Then, from a climbing attitude, the aircraft pitched down and rolled left to an attitude of about 10º nose-down and 50º left wing low. As the aircraft was rolling left the engineer stopped the video recorder. He recalled the aircraft turning slightly to the left before the left wing tip struck the ground and the left wing separated from the airframe. The aircraft then cartwheeled through some trees; its nose struck the ground, followed by the right wing, and then there was an explosion. At the same time, witnesses on the airfield saw a fireball which rose about 300 ft into the air.

The engineer recalled one more cartwheel before coming to a stop. The cockpit filled with smoke and he sensed that there was a fire behind him. He could see that there was fire around the canopy but he was unable to see outside and could not be certain of the aircraft's

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orientation. Consequently, he elected to use the canopy knife to break through the canopy glazing, rather than activate the canopy jettison mechanism. Before doing so, the engineer removed his helmet because the visor had been damaged in the crash and was further impairing his vision. Having difficulty breathing, he initially wielded the knife with his left hand, which was nearest to the knife stowage, but shortly transferred it to his stronger right hand, taking some 20 blows to make a sufficiently large hole through which he could escape. Meanwhile the pilot, who had briefly lost consciousness, was also aware of a fire and recalled trying to turn off switches in the cockpit and unlatching the canopy lock. He considered jettisoning the canopy but did not do so because the engineer was in the process of breaking his way through it.

Once outside the cockpit, the engineer successfully activated the external canopy jettison mechanism. The canopy shot approximately 50 ft into the air before landing about 10 ft from the forward section of the fuselage. The engineer then climbed on to the side of the cockpit to help the pilot, who appeared to be motionless in the front seat, and released the pilot's harness. The pilot came to and was assisted out of the cockpit. They both retreated about 30 m away from the wreckage to await assistance.

The Airfield Fire and Rescue Service (AFFS) arrived at 1323 hrs and proceeded to extinguish the fires in various parts of the wreckage. They also established that the occupants of the aircraft were clear of the aircraft and started to render first aid until paramedics arrived. The pilot, who had received various minor injuries, was taken to hospital by ambulance and was retained overnight. The engineer, who was apparently uninjured apart from a small cut and some bruising, was eventually given a lift back to his crew room. He was subsequently diagnosed with a broken rib and suffered mild concussion. The pilot sustained a lower back injury and mild concussion, in addition to lacerations to his legs and multiple bruising.

The F86 pilot was already committed to the takeoff when he saw G-TBRD in difficulty. He continued his takeoff and avoided the plume of smoke over the accident site by turning right. He subsequently diverted to Cambridge Airport.

Aircraft description

The Lockheed T-33 or 'T-Bird' is the world's first purpose-built jet trainer and evolved from the Lockheed P-80 Shooting Star jet fighter. Canadair signed an agreement to build the T-33 Mark 3 for the Royal Canadian Air Force and a total of 656 aircraft, called the 'Silver Star', were built under this agreement and fitted with the Rolls Royce Nene 10 turbojet engine. Aircraft Serial No 21261 was constructed in 1953 and came to the UK in 1974. The aircraft was restored in 2000 and was re-registered G-TBRD. In January 2005 a replacement ex-RCAF Nene 10 engine was fitted. At the time of the accident the total airframe hours were 2,963:45 hours, and total engine hours since overhaul 569:50 hours. The last annual check was carried out in February 2006 at 2,950:15 airframe hours.

G-TBRD had conventional flying controls. The elevators were operated via a system of push-pull rods and bell-cranks, and each elevator was equipped with a spring-loaded servo tab and a trim tab. The trim tabs were controlled by an electrically-driven actuator. Lateral control was effected by ailerons connected via torque tubes and control cables augmented by a hydraulic booster. The rudder pedal movement was transmitted to the rudder through a cable system. The split-type flaps were operated by an electrically-driven linear actuator.

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Accident site and wreckage examination

The initial ground contact was from the tailpipe, at the rear of the aircraft, scraping on the runway surface, approximately 230 m from the end of the runway. Beyond the end of the paved surface there was a trail on the grass where it had been scorched by the jet blast. There were also marks from the left main landing gear running along the ground. The initial impact was from the left wing tip tank, which contacted the ground just in front of a high hedge, 250 m beyond the end of the paved surface. Photographic evidence showed the aircraft was in a left bank of over 45º at the time. Pieces from the left wing tip tank were found in the flattened hedge. The aircraft continued ahead for approximately 100 m before the nose impacted the ground. The aircraft then broke up into three main pieces; the front fuselage containing both occupants and the remaining section of the left wing, the rear fuselage including the engine and empennage, and the outer section of the right wing. Fuel, contained in tanks located in the fuselage, both wings and tip tanks, was released on impact, ignited and was consumed in a large fireball.

From examination of the wreckage it was found that the landing gear was down at impact and the position of the electrically driven linear actuator indicated that the flaps were at 32º which was the takeoff setting. This flap position was also confirmed, from the photographic evidence, as being set during the takeoff roll.

The fuselage structure had been disrupted in the impact, however continuity of the elevator, aileron and rudder control systems was confirmed and there was no evidence of any pre-impact failures. The elevator trim tab was in a neutral position.

A post-accident calibration was carried out on the front cockpit airspeed indicator; the maximum error was -7 kt at 250 kt. At airspeeds within the takeoff range, between 80 and 120 kt the error was between zero and -3 kt; this would result in the airspeed indicator under-reading.

Witness information

One witness, who was positioned to the north of the runway, recorded the takeoff on a series of photographs. He had set his camera to take a rapid sequence of still images, automatically, at a rate of 34 photographs every 15 seconds. The series of photographs started when G-TBRD was still in the early stages of its takeoff roll and provided good evidence of the subsequent chain of events and the pitch attitude that was achieved during the takeoff, which was approximately 15º nose-up (see Figure 1).

It was possible to estimate from this information the aircraft position at points during the takeoff run. At around 510 m before the end of the runway the nose of the aircraft began to lift off, and at around 440 m from the end of the runway the main wheels began to leave the runway. The aircraft became airborne briefly, but then descended and contacted the ground at around 230 m from the end of the runway; this was consistent with the scrape marks on the runway surface. When the aircraft crossed the end of the runway it was still in a nose-up attitude but was not climbing.

The photographs showed the aircraft maintaining the same level beyond the end of the runway as the ground dropped away, enabling it to become airborne for the second time, until the left wing dropped by about 50° and the aircraft disappeared from view. The photographs continued until after the aircraft had struck the ground.

The accident sequence and wreckage location is shown at Figure 2:

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Figure 1

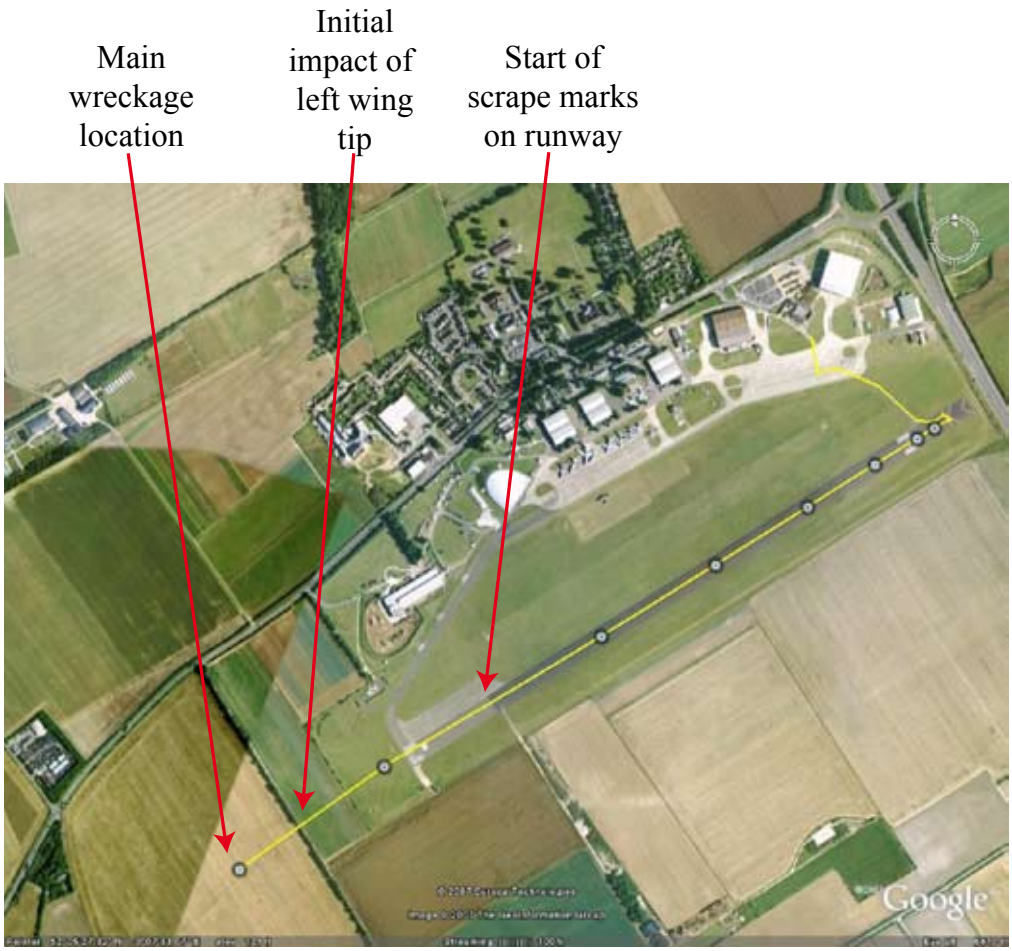

Figure 2

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Recorded Information

The aircraft was fitted with a portable GPS which recorded a track log of G-TBRD's position. The engineer in the rear seat also recorded a video of the taxi-out and takeoff. Both of these devices survived the impact and were successfully downloaded.

GPS

On the 6 September the GPS track log started at 14:12:36 with a taxi to Runway 24. At the end of the runway, G-TBRD waited for around one minute before starting the takeoff roll. From this point, GPS position is logged every six to ten seconds and there are a total of six points detailing the aircraft position on the runway.

Takeoff began at 14:18:35 with the final GPS point on the runway at 14:19:22. Two further positions are recorded beyond the runway paved surface showing the aircraft track over the fields at the end of the runway. As there are only eight recorded GPS positions from the takeoff point, accurate aircraft speed cannot be ascertained.

Video

Video downloaded from the engineer's video camera allowed analysis of both the aircraft position and engine noise. The engine manufacturer supplied data concerning the number of impeller blades and guide vanes, along with expected takeoff rpm, which was then used to analyse the engine speed. The expected engine takeoff rpm was 12,500 ±100 rpm.

Spectral analysis of the video revealed that when G-TBRD was positioned at the end of Runway 24, the engine speed was around 11,708 rpm. This speed increased throughout the takeoff and at the point where the aircraft left the paved surface, the engine speed was calculated to be 12,374 rpm. This was the peak speed calculated from the analysis and was maintained for a further 4.4 seconds. For the final 532 milliseconds of video, the analysis shows a decay in engine speed from 12,374 rpm to 10,686 rpm. This corresponds to a rate of decay of 3,173 rpm / second. The video recording ceased just prior to impact as the engineer switched it off.

Personnel information

The pilot had accrued a large amount of flying experience in commercial aviation and had also flown a wide variety of ex-military jet and propeller-driven aircraft, as well as various general aviation light aircraft.

He started flying the T-33 in June 2003 and displayed G-TBRD that season. That initial training included dual instruction with the operator's Chief Pilot. He did not fly the aircraft in 2004 but renewed his Exemption[1] in 2005, again flying a dual 'check'. He displayed the G-TBRD three times that summer and flew the aircraft for the last time in 2005 on 11 November. He next completed a solo refresher flight, under the Chief Pilot's supervision, on 8 April 2006. Not having flown the aircraft since then, the pilot elected to carry out a solo practice display on 6 September, before departing on the accident flight. Furthermore, at his request, he briefed the pilot of the F86 aircraft, who was himself an experienced T-33 pilot, on the complete practice display: the flight, which lasted 15 minutes, was completed successfully. Following the accident the pilot acknowledged that he had been busy that day but did not feel fatigued or unfit in any way.

The pilot's last flight with an occupant in the rear seat of G-TBRD, before the accident, was in April 2005. His regular commercial employment was as a captain on Boeing 747-400 aircraft. He was in current flying

Footnote

[1] The Civil Aviation Authority had issued an Exemption to the Air Navigation Order to allow the pilot to fly the T-33 aeroplane.

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practice on that type, as well as on various civilian and ex-military piston-engined aircraft.

Meteorology

The weather was good, with a surface wind from 250º at 10 kt, visibility in excess of 10 km and no cloud below 5,000 ft agl. There was no significant weather at or near the aerodrome, the temperature was 26ºC, the dew point was 15ºC and the QNH pressure setting was 1016 millibar.

Performance

The Maximum Total Weight Authorised for the aircraft is 16,800 lb. Its Take Off Weight (TOW) for the pilot's solo flight in the morning was 12,649 lb and the Take Off Distance Required (TODR), for the conditions at the time, was calculated to be 930 m. For the accident flight, when the weather was warmer and the TOW had increased to 14,161 lb, the TODR was calculated to be 1,326 m. At that weight, the stall speed, with takeoff flaps selected and the landing gear extended, was 101.5 kt.

The Take Off Distance Available (TODA) for Runway 24, as published in the Duxford Airfield Manual, is 1,603 m.

The aircraft's Centre of Gravity (CG) on the accident flight was calculated to be 236.3 inches aft of the datum, towards the aft end of the allowable range from 230.4 inches to 237.7 inches aft of the datum. The CG on the pilot's previous solo flight was further aft because of the lack of a rear seat passenger and the absence of baggage and equipment in the nose compartment.

Procedures

The operator used the Aircraft Operating Instructions for the Silver Star, as issued in 1996 by the Canadian Department of National Defence. Under *Take-Off Procedures* the instructions state:

> *'As elevator control becomes effective at about 70 KIAS, apply a gradual back pressure on the control column until, at about 80 to 90 KIAS, the nose-wheel is just off the ground. In this attitude the total drag is at a minimum and acceleration will be most rapid. Maintaining this attitude, the aircraft will become airborne at 105 to 115 KIAS, depending on fuel load and air temperature.'*

Advice is also given in the same authority's Manual of Flying Training for the Silver Star, issued in 1984. Under *Air Handling,* it states:

> *'Use the proper technique during the initial and final stages of the take-off. Typical errors, such as premature or excessive pitch rotation ... are incorrect and hazardous.'*

A further *Caution* in the Royal Canadian Air Force's Pilots Operating Instructions for the T-33 Mk 3, issued in 1957, states:

> *'...taking off at too slow an airspeed may cause the aircraft to settle back onto the ground.'*

Having lifted off the runway, a typical pitch attitude during the initial climb is 5-6º nose up.

The recommended pitch attitude to achieve during a takeoff in a Boeing 747-400, as detailed in the Boeing Flight Crew Training Manual for the type, is 15º nose up, using an average pitch rate of approximately 2.5º per second, initiated at V_R.

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Operational procedures

The aircraft was being operated under the auspices of Civil Aviation Publication (CAP) 632, entitled *Operation of 'Permit-to-fly' Ex-military Aircraft on the UK Register*. In accordance with this publication, the operator's operational procedures are contained in an Organisational Control Manual (OCM) which has been approved by the CAA. These procedures detailed the training required when one of the operator's pilots was new to type or had not flown on type for more than six months. This training included, amongst other comprehensive briefings, ground instruction and flying practice, a supervised solo flight, which could include a 'dual check' at the Chief Pilot's discretion.

Discussion

The technique used by the pilot during the takeoff produced an excessive nose-up pitch attitude of about 15º shortly after rotation. This differed from the advice given in the T-33 Operating Instructions and Training manuals held by the operator, in which the nosewheel should be lifted just off the ground during the latter stages of the takeoff roll, and that attitude maintained as the aircraft becomes airborne. Following lift off, a typical pitch attitude during the initial climb is 5-6º nose up.

As a result of the excessive rotation, the aircraft did not accelerate as normal and subsequently descended, sufficient for the tail pipe to make brief contact with the surface. As the ground beyond the runway dropped away, the aircraft maintained level flight before stalling and dropping its left wing, then striking the ground. During the ensuing impact the aircraft cartwheeled, broke into three main pieces and caught fire. The section containing the cockpit came to rest in an upright attitude and the rear seat occupant, an engineer, managed to exit through the fire damaged canopy using the canopy knife. Once outside the cockpit, he activated the canopy jettison mechanism using the external handle. The canopy landed clear of the aircraft and he then helped the pilot, who had lost consciousness for a period during the impact, to make an exit from the front seat.

The engineer showed remarkable presence of mind during the accident, and his subsequent recall of events was a significant help during the investigation.

From the wreckage analysis and the photographic and video evidence there appeared to be no technical fault with the aircraft. Spectrum analysis of the on-board video recording confirmed that the engine was developing takeoff power.

The pilot had extensive flying experience as a commercial pilot and a wealth of experience on a wide variety of ex-military jet aircraft and single and twin piston-engine aircraft. G-TBRD was the only ex-military jet aircraft that he was current on but with limited flying hours, particularly during the previous 10 months. The pitch attitude which was seen during the takeoff appears to have been more akin to that associated with the Boeing 747-400, which was the aircraft type he flew most frequently, and was not appropriate for the T-33. By all accounts, this was most uncharacteristic of this widely experienced display pilot who had completed a successful flight in G-TBRD, lasting 15 minutes, earlier that day.

The pilot was not aware of any fatigue but did acknowledge being busy before the accident. He was the leader for the formation flight to Jersey and, as the lead aircraft during the stream takeoff, he was aware that the F86 Sabre was taking off astern of him, and that was an added pressure. Whilst he would have

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encountered busy periods previously during his long flying career, this was the first time for 17 months that he had flown the aircraft with an occupant in the rear seat, his last training flight having been supervised from the ground five months earlier. The increased TOW and warmer temperature meant that the aircraft's performance during the takeoff on the accident flight was significantly different from that on his earlier solo flight that day, the TODR being increased by 43% in the latter case. Conversely, the CG was further forward on the accident flight, encouraging less of a pitch-up moment.

Action by the operator

Following the accident, the operator decided only to use pilots with a military background to operate their remaining F86 Sabre, and an experienced QFI in the Royal Air Force, current on jet aircraft, has been appointed as the operator's QFI. At the time of this report, all their pilots were experienced fast jet pilots with a display background. The operator also instigated a stricter regime of supervision for pilots who had been engaged on other flying duties prior to operating the F86.

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