Aero Vodochody L-39C Albatros, G-BZVL

AAIB Bulletin No: 7/2003	**Ref: EW/C2002/06/02**	**Category: 1.3**
Aircraft Type and Registration:	Aero Vodochody L-39C Albatros, G-BZVL	
No & Type of Engines:	1 Ivchenko A1-25TL turbofan engine	
Year of Manufacture:	1977	
Date & Time (UTC):	2 June 2002 at 1248 hrs	
Location:	Duxford Airfield, Cambridgeshire	
Type of Flight:	Private	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - 1 (Fatal)	Passengers - N/A
		1 (Uninjured)
Nature of Damage:	Severe damage to both wings, landing gear and forward fuselage	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	39 years	
Commander's Flying Experience:	4,300 hours (of which 142 were on type)	
	Last 90 days - 148 hours	
	Last 28 days - 45 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The two-seat jet trainer landed at Duxford Aerodrome to refuel but during the landing roll, neither pilot was able to apply the wheelbrakes and the aircraft did not decelerate normally. Towards the end of the runway, as the aircraft was closing with the M11 motorway which adjoins the aerodrome's eastern boundary, the aircraft was deliberately steered to the right with rudder. It departed the runway and traversed open, level ground. As the aircraft penetrated the aerodrome boundary fence, the student pilot in the front seat ejected. He was killed upon impact with the ground on the far side of the motorway but the instructor, who remained in the aircraft, was unhurt. The aircraft came to rest on the M11 motorway but there were no subsequent collisions with motor vehicles. Two safety recommendations addressing issues of pilot training and over-run protection are included in this report.

Factual Information

Description and history of the aircraft

The Aero L-39 series of aircraft are two-seat tandem military jet trainers manufactured in the former Czechoslovakia. They were sold in large numbers, particularly to the former Soviet Air Force. With the break-up of the latter, a number of states have disposed of surplus examples to the civilian market. G-BZVL was operated by the Soviet Air Force from 1977 until 1995, when it was placed in storage. It was purchased by an Estonian company in 2000 and allocated an Estonian civil registration and a Certificate of Airworthiness in the 'Aerobatic' category. In April 2001 it was purchased by the current owner, who operated it for seven months on the Estonian register before transferring it to the UK register in April 2002.

The aircraft type has a maximum take-off weight of 4,700 kg and a maximum level speed of 750 km/hr (405 kt). This aircraft was equipped with two ejection seats, one for each pilot. When in horizontal motion at ground level, the minimum speed for successful ejection is 150 km/hr (81 kt) .

Duxford Aerodrome

Duxford is a licensed aerodrome near Cambridge. It has two landing surfaces: a single paved runway and a parallel grass strip between the apron and the runway. Construction of the M11 motorway beside the aerodrome in 1977 resulted in the runway being shortened and the motorway adjoins the eastern aerodrome boundary. The asphalt and concrete surfaced runway is now 1,503 metres long, 45 metres wide and orientated 06/24. Both Runway 06 and Runway 24 have published landing distances available of 1,353 metres. Runway 06 has a slight down slope and a Runway End Safety Area of 90 metres intended to minimise the risks to aircraft and their occupants when an aeroplane runs off the end of the runway. To arrest aircraft that fail to stop before they reach the aerodrome boundary, an earth bank was constructed between the landing surfaces and the motorway, essentially to protect the M11 motorway.

Duxford is the home of the Imperial War Museum's collection of 'warbird' aircraft. It is also the home of privately owned and airworthy 'historic' and high performance aircraft including some jet powered aircraft types. Several air shows featuring examples of high performance American and European fighting aircraft are held each year; the larger piston-engined aircraft and the jets invariably use the paved surfaces.

History of the flight

The planned flight was part of a conversion course onto the L-39 aircraft. The flight included navigation and general handling exercises and was to culminate in a landing at Duxford in order to refuel. The aircraft departed from its base at North Weald with the student occupying the front seat and the instructor in the rear seat. This is the conventional seating arrangement for an instructional flight in this tandem seat aircraft. The flight proceeded uneventfully and the aircraft joined the visual circuit at Duxford where Runway 06 was in use. The reported surface wind was 140°/10 kt, the visibility was greater than 10 km, there was no significant cloud or weather and the runway surface was dry.

When the aircraft arrived at Duxford the fuel quantity was 350 kg. The student pilot flew a slightly extended downwind leg, as requested by ATC, to allow time for a light aircraft to clear from the adjacent grass runway. The instructor considered that the subsequent approach profile was satisfactory although he noted that the airspeed during the final stages of the approach was reducing through 218 km/hr (118 kt) as opposed to the briefed speed of 200 km/hr (108 kt). During the landing flare the airspeed was 210 km/hr (113 kt) and still reducing. The instructor described the touchdown as "soft" (meaning a gentle touchdown) and noted that there was a slight drift to the left in the light crosswind. He estimated that the aircraft touched down about 150 to 200 metres along the runway and various eye-witnesses confirmed this estimate. This is the normal touchdown point for this type of aircraft. After landing the instructor was not aware of any retardation so he told the student pilot to "load the nose wheel and start braking". (Braking is inhibited until a micro switch on the nose wheel oleo operates). This instruction appeared to have been followed in that the control column moved further forward, but there was still no retardation. After further instructions to the student pilot to brake the instructor took control and applied the brake lever on his control column a number of times but to no avail.

When the aircraft was approaching the far end of the runway, with its attendant raised earth embankment, the instructor decided to steer the aircraft to the right towards open, level fields. However, he was able only to turn the aircraft through about 20° to 30° before the rudder became ineffective. ATC saw the aircraft deviate from the runway and asked the pilots if they had a problem; the student pilot replied "BRAKE FAILURE". The aircraft was, by then, running across a field of light crops towards the M11. The instructor asked the student in the front seat to operate the undercarriage retraction lever. He was unable to use the corresponding lever in the rear cockpit because the mechanism had been wire locked to prevent operation of the landing gear from that position. The instructor pilot did not use the emergency brake lever nor did he instruct the student pilot to do so. Moreover, the instructor did not shut down the engine nor did he instruct the student pilot to do so.

As the aircraft reached the airfield boundary, at a speed of about 20 kt, it passed to the south of the raised earth embankment and through the wooden boundary fence. It descended onto the motorway approximately 15 feet below, slid across the northbound carriageway, struck the central crash barrier and came to rest on the southbound carriageway. The instructor pilot, who had remained in his seat, was uninjured and the engine was still running.

At about the time that the aircraft went through the wooden fence and ran down the motorway embankment, the front ejection seat fired. The instructor had not ordered the student pilot to eject nor had he warned him not to do so (since by that time the aircraft's speed was well below the minimum for safe ejection on the ground). During the ejection sequence the student pilot separated from his seat but his parachute did not have sufficient time to deploy fully before he struck the ground.

The safety pins for the ejection seat and canopy jettison mechanisms were not carried on board the aircraft. Suitable safety pins were offered and fitted by a technician based at Duxford before the aircraft was removed from the motorway.

Pathology

There was no evidence of any medical factor having influenced this accident. The student pilot sustained fatal injuries upon impact with the ground. His injuries were consistent with other ejections at low speed when the parachute has had insufficient time to deploy fully.

Operation of the aircraft

The aircraft was operated on a Permit to Fly and in accordance with the requirements detailed in Civil Aviation Publication (CAP) 632. This document required the operator to produce an approved Organisation Control Manual (OCM) setting out the operational procedures for the aircraft.

The role of the Chief Pilot within such an organisation is pivotal in ensuring the safe operation of the aircraft. In particular, he is normally responsible for pilot training and for the selection and training of his staff pilots who will conduct such training. Guidance is provided in the CAP as to the training and supervision that might be applied. However, due to the variation in experience, skill, and ability of different pilots, there will be occasions when more or less training and supervision would be appropriate; in other words, each pilot is judged on his or her individual merits.

The OCM produced by the operator had been approved by the Civil Aviation Authority who had also audited the operator's Safety Management System and found this to be effective.

Pilot licensing, experience and training

Ex-military aircraft on the UK register with a Permit to Fly may be piloted by the holder of a current private or professional pilot's licence; for some piston-engined types the pilot may also be required to hold an aircraft class rating (ie Single or Multi-engine Piston) or a specific aircraft type rating. However, to fly an ex-military turbine-powered aeroplane, a pilot must have an Exemption from the need to hold a type rating. Such Exemptions are issued by the Civil Aviation Authority (CAA).

Conversion, refresher and technical training requirements are assessed on an individual basis and must be agreed by the CAA before training commences. Pilots wishing to be accepted for flying jet aircraft should have appropriate flying experience. After suitable training and testing, and on the recommendation of the Chief Pilot of the organisation, an Exemption against the requirement to hold a specific aircraft type rating is issued by the CAA.

The student pilot had a total of 195 hours of which 184 were on light, single, piston-engined aircraft. He had started his conversion to the L-39 aircraft in April 2002. Before occupying the front seat, he received two days of ground briefings using the approved Flight Manual as an instructional template. This included reference to the diagrammatical representations of ejection envelopes and the use of executive instructions by an instructor such as "Eject", "Evacuate" and "Brace". The student pilot was verbally tested on his knowledge of the aircraft and the operation of the escape systems by the operator's Chief Pilot on the day before the accident. The student's grasp of the systems and his understanding of the Flight Manual were assessed as very good. At the time of the accident, he had completed 18 flights and 11 hours on L-39 Albatros aircraft.

The instructor pilot had flown a total of 4,300 hours of which 1,300 hours were as an instructor on Hawk aircraft whilst serving in the Royal Air Force. Like the L-39, the Hawk is a tandem seat, training aircraft with the instructor normally occupying the rear seat. The instructor had converted to the L-39 aircraft in May 1998 and had recorded 142 hours on this type of aircraft. He was an approved 'Check Pilot' within the operator's OCM and he had undergone an airborne competency check with the operator's Chief Pilot during December 2001. He had been assessed by the Chief Pilot as 'extremely competent'.

Aircraft performance

The approach procedure detailed in the flight manual requires the pilot to achieve a minimum speed of 230 km/hr (124 kt) during the final approach. The airspeed is then gradually reduced to 200 km/hr (108 kt) as the aircraft passes over the runway threshold and to approximately 180 km/hr (97 kt) at touchdown. The calculated aircraft weight at the start of this approach was 3,938 kg. In the ambient conditions the calculated ground roll would have been 600 metres had the normal braking technique been used. From the estimated point at which the aircraft touched down there were approximately 1,200 metres of runway available. There should, therefore, have been ample runway available after touchdown.

If the pilot had believed that there was a need to achieve the minimum landing roll after touchdown then accurate speed control during the approach and landing would have been essential. In addition, the nose wheel should have been lowered immediately after touchdown, the flaps retracted and the control column held fully forward. Braking should then have been applied in a smooth and progressive manner. The instructor did not brief this procedure for the landing and he was content with the student's speed control. It is therefore apparent that he did not believe that the minimum landing roll technique was required for a landing on this runway.

Witness video

A witness video was obtained and analysed by a specialist photogrammetry organisation. The video clip lasted 12 seconds and commenced with the aircraft halfway along the runway, when all three wheels could be seen to be on the ground and the aircraft attitude was normal. The elevators could be seen deflected downwards and the application of rudder towards the end of the clip was clearly seen as the aircraft veered off the runway. At this point the witness stopped filming.

The analysis measured a ground speed of approximately 80 kt (148 km/hr) until the aircraft commenced the right turn. After that, the accuracy became less reliable as the aircraft had a velocity component away from the camera. However, it was noted that the speeds sampled at three different intervals whilst the aircraft was running straight along the runway showed no evidence of any retardation.

Flight Manuals

During the investigation two versions of the L-39 Flight Manual were acquired; one was an L-39ZA manual and the other an L-39C manual. The L-39ZA manual bore the aircraft manufacturer's logo whereas the L-39C manual did not.

The translation of the L-39ZA flight manual into English lacked clarity on the topic of emergency gear retraction. There was a reference to retracting the landing gear on the ground in the landing gear system description which, in respect of the control lever in the front cockpit stated: *'By means non-reversible two-positional electric switch provided with built-in third reversible position for emergency retraction of auxiliary resource'.* In this context, the auxiliary resource was the emergency electrical generator powered by a Ram Air Turbine (RAT) but this interpretation was not clear unless the reader studied the electrical system. Moreover, there was an adjacent diagram illustrating the retraction lever that had the words '*Emerg Retraction'* and '*Emerg Generator'* beside a horizontal detent in the lever's UP position. This annotation could be interpreted incorrectly as implying a gear retraction facility whereas it actually meant a RAT retraction facility. In the Emergency Procedures section of the manual there was another statement relating to gear retraction. In the context of main generator failure, the manual stated that one condition which would automatically retract the RAT was *'During landing gear emergency retraction'.* There was no statement qualifying whether this related to emergency gear retraction on the ground or in the air. There was an emergency procedure for gear extension but no mention of any procedure related to emergency gear retraction. However, within an earlier section of the manual concerned with systems descriptions was the statement that '*Emergency ground retraction of the landing gear is possible ONLY when the nose landing gear is off the ground.'*

The L-39C Flight Manual provided by the operator was written in much clearer language. The landing gear system was described in four paragraphs, all on the same page. One paragraph included a statement that *'The landing gear retraction on the ground is electrically blocked by means of WOW switch on the NLG'* (WOW meaning Weight on Wheel and NLG meaning Nose Landing Gear). There was also a note on the next page stating '*Retraction of the landing gear is possible only when the nose landing gear is off the ground*.' Significantly, there was no misleading text about 'Emergency Retraction' beside the illustration of the landing gear control.

The L-39C Flight Manual relates to the aircraft involved in this accident and is, therefore, the appropriate reference document.

Emergency braking procedure

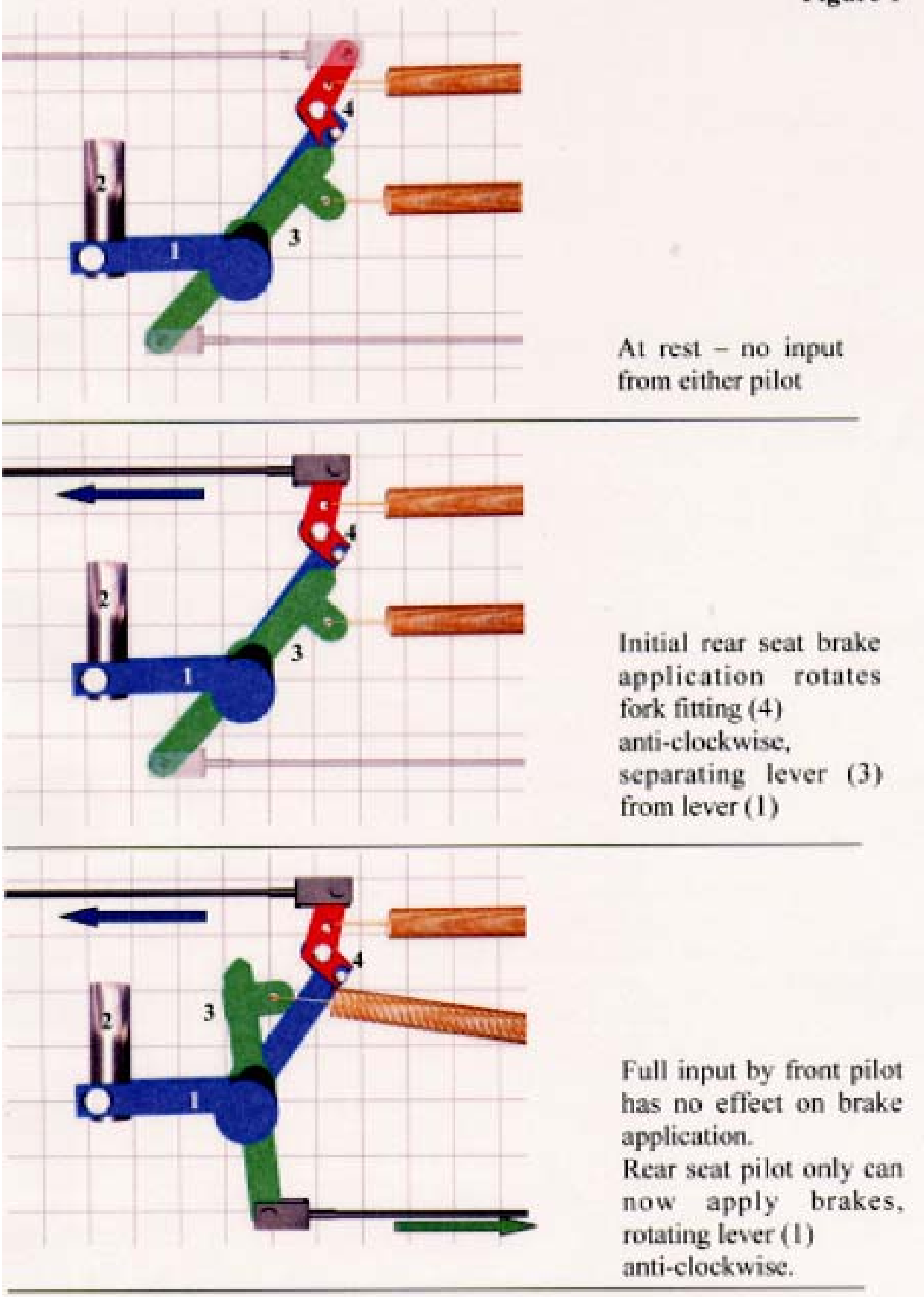
There is an emergency brake lever located on the left console in each cockpit. Both Flight Manuals contained essentially the same instructions for coping with a loss of normal braking capability. The instructions were that in the event of a loss of normal braking, the required action is for one of the pilots to pull one of the emergency brake levers in a gradual manner. Braking is then applied equally and simultaneously to both wheels, by-passing the anti-skid system.

Description of the hydraulic and braking systems

The Normal and Emergency hydraulic systems are pressurised to a nominal 15 MPa (MegaPascals) by a single Engine Driven Pump (EDP). Accumulators in both systems maintain pressure to allow some use of the services in case of EDP failure. It is also possible to transfer pressure from the Emergency system to the Normal system using a lever on the right side console in each cockpit. The Normal system, as its name implies, is the one that is used routinely in operation of the aircraft for flaps, landing gear, wheel brakes, speedbrake and Ram Air Turbine deployment.

The brakes use a conventional disc and friction lining arrangement at the wheels and are applied by a lever adjacent to the handgrip on the control column in each cockpit. These levers are connected to the Brake Control Valve (BCV), located behind the forward cockpit seat, by Bowden-type cables and, by design, the rear seat pilot has over-riding authority on brake application. Referring to Figure 1

Figure 1



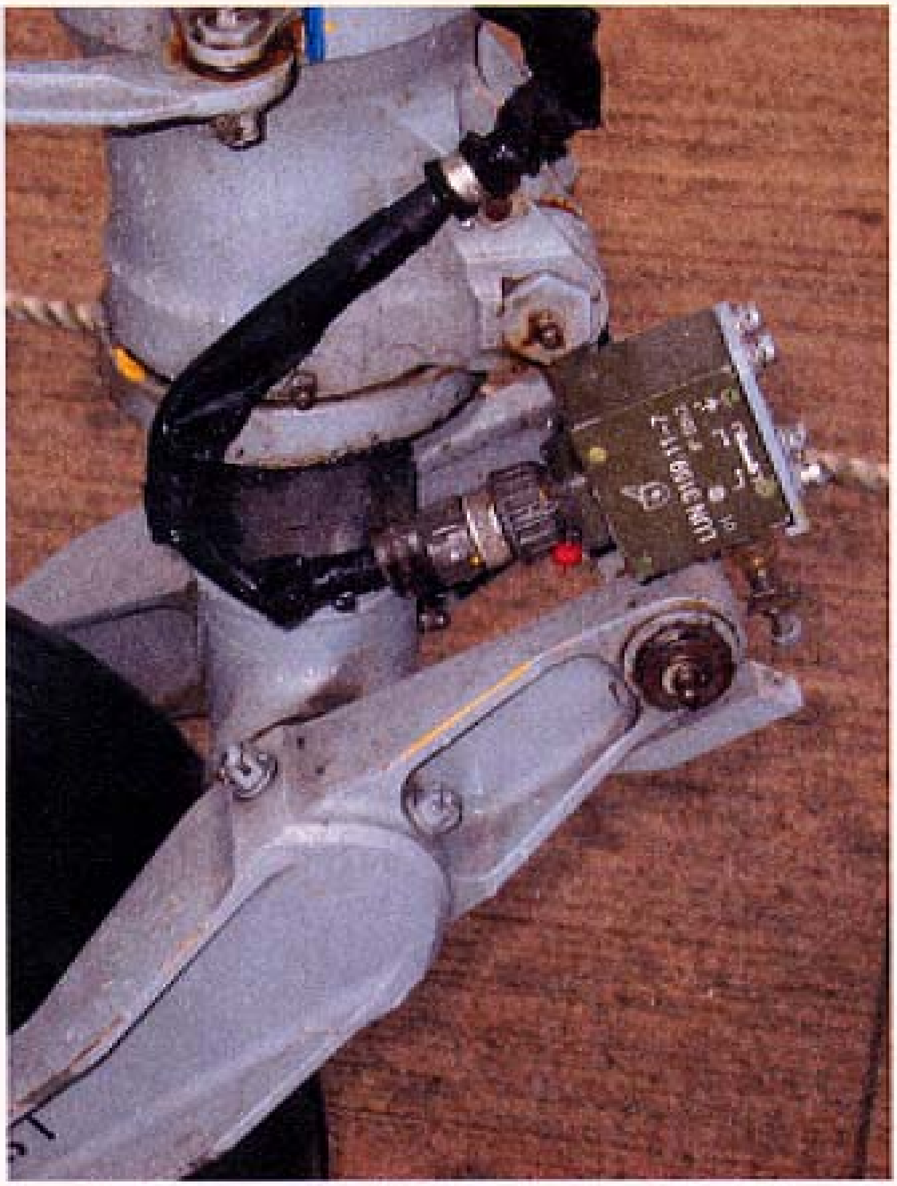
G-BZVL – schematic illustration of Aero L-39 rear-cockpit priority brake over-ride mechanism

shows how this is achieved: the rear seat lever cable is linked via fork fitting (4) to the arm (1) which is in turn directly connected to the spool valve (2) which ports fluid to the brakes. Thus movement of the rear seat lever will always apply the brakes in a normally-functioning system. The same is not true for the front seat lever because the arm (3) to which the front seat cable is connected can rotate freely about its common pivot point with arm (1). If there is no input from the rear seat, then the shaped tongue at the top of (3) abuts the fork fitting (4) and the two arms move together to apply the brakes. However, if there is any input from the rear seat, the fork fitting (4) first rotates anti-clockwise and releases arm (3) from arm (4); regardless of how much brake lever pressure the front-seat pilot applies, he no longer has any input to the BCV. The only way that brake control can be

Since the aircraft type has no nosewheel steering capability, differential braking of the left and right mainwheels is used to steer the aircraft whilst taxiing at low speeds and is accomplished by deflecting the rudder pedals, which are connected to the BCV, in the desired direction. This progressively reduces the brake pressure fed to the brake opposite to the direction of turn. At full pedal deflection, the associated brake is completely released whilst the other retains the pressure selected by the hand lever.

The Normal brake system is equipped with an electrical anti-skid system that releases the brakes when an impending wheel-lock condition is sensed by inertia switches in each wheel. The switch sends a signal to its associated electro-hydraulic valve which both blocks pressure to the brake and opens pressure already in the brake to return. As the wheel speeds-up again, the valve re-opens until a further locked-wheel condition is sensed. These same valves are also used by a circuit which prevents brake application whilst the nosewheel is off the ground. A microswitch on the Nose Landing Gear (NLG) detects a weight-on-wheel condition which de-energises a solenoid and opens the electro-hydraulic valves to allow braking (see Figure 2). Because the power-off condition of the valves and solenoids is with the valves in the 'open' position, the Normal brake system will operate in the complete absence of electrical power (albeit without anti-skid or nosewheel protection). It should also be noted that the NLG microswitch plunger is extended under spring pressure in the 'ground' condition and is pushed-in by movement of the torque links for the 'air' condition.

Figure 2



G-BZVL - photograph of L39 aircraft NLG microswitch which provides air/ground sense information to a number of systems, including the Normal wheel brakes

The Emergency brake system is a separate system, sharing only the brake pistons with the Normal system. Selection of Emergency brakes ports Emergency hydraulic system pressure directly to the brake pistons, a shuttle valve closing-off any open path to return through the electro-hydraulic valves. Thus selection of Emergency brakes will allow braking even with the nosewheel off the ground or in the presence of electro-hydraulic valve/anti-skid failures. Application of Emergency brakes is achieved by rearwards movement of a lever on the left side console in each cockpit. Although it is possible to modulate brake pressure using these levers, use of the system can result in burst tyres, due to the lack of anti-skid protection. In the front cockpit only, the Emergency brake lever can also be moved forwards, through a detent, to apply parking brakes. In both cockpits, rearwards movement of the levers breaks a 'telltale' copper wire showing that Emergency brakes have been selected.

Initial examination of the accident site

The aircraft and the accident site were examined about four hours after the accident. The aircraft had come to rest on the southbound carriageway of the M11, pointing approximately north. The front canopy and ejection seat were missing, with clear indications that an ejection had taken place. The rear canopy was closed with the seat in place and safety pins fitted. The emergency services advised that personnel from a maintenance company at Duxford who had witnessed the accident had provided and installed the pins as a safety precaution shortly after the accident.

The aircraft was substantially intact, with the fuselage almost undamaged apart from that caused to the nose when the nosewheel collapsed rearwards. The right main landing gear had also collapsed, dropping the aircraft onto its right wing but the left landing gear was still supporting the weight. All three tyres were still inflated.

The leading edges of both wings and both tip tanks were severely damaged by contact with the perimeter fence, the road and the central reservation barrier; the right wing was distorted upwards. There was, however, no sign of any fluid leakage from the fuel or hydraulic systems. The flaps were in the fully extended configuration and the speedbrake was closed.

The front canopy was found almost undamaged on the eastern embankment of the motorway and the front seat, parachute and pilot's helmet were found in close proximity some 45 metres into a field to the east of the aircraft. The pilot had been removed from the scene but the twin handles of the ejection seat were found in the area where he had lain. The main parachute had been pulled from its pack but had not inflated. It was lying streamed-out back towards the point where the aircraft ran down the embankment.

Examination of the aircraft's ground track showed no discernible marks until evidence of tyre rubber was found on the runway some 200 metres from the end of the paved surface. These occurred as the aircraft started to diverge from the centreline to the right (there were no marks visible whilst the aircraft was running straight nor could the touchdown location be determined). The marks were from the left and right mainwheels, heavy and continuous on the left but lighter and somewhat intermittent on the right. As the aircraft departed the paved surface onto the grass, imprints from the nosewheel as well as the mainwheels were visible all the way to the top of the western embankment above the motorway. Examination of the wheel tracks across the grass showed no evidence of brake applications. Because the angle subtended between the aircraft's track and the embankment was approximately 45°, the nosewheel and left mainwheel were the first to drop down the slope.

Despite the fact that the aircraft had crossed the northbound carriageway and come to rest on the southbound, no motor vehicles were involved in the accident. The aircraft was recovered onto the airfield the same evening.

Off-site examination.

The aircraft was intact as far as the major systems were concerned. Both the Normal and Emergency hydraulic systems still retained pressure but the battery had been removed for safety. It was noted that in both cockpits the telltale wires on the Emergency brake system were intact. In the front cockpit the landing gear was selected DOWN. In the rear cockpit the landing gear selector was wire locked in the central, inactive position.

Impacts on the nose landing gear had badly damaged the NLG weight-on-wheel switch, detaching it from its mounting and breaking off the striker plate. It was found, however, that the switch plunger, although bent, still functioned sufficiently for it to simulate the air/ground condition by depressing and releasing the plunger by hand. Some repairs to the wiring were required due to damage on both this and the anti-skid circuits before testing could commence. Repeated applications of the Normal brakes from both cockpits were then carried-out with no anomalies apparent. The operation of the 'priority' mechanism for the rear cockpit was also checked, with release of the front-seat input occurring at the expected times. After a further re-pressurisation of the accumulators, the Emergency system operation was also checked with no faults apparent. Operation of the nosewheel protection circuit was also verified, as was the differential braking using the rudder pedals.

Following recovery to the AAIB facility at Farnborough, two more series of tests were undertaken. The second series involved connecting the hydraulic systems to an external rig to allow more extended and repeated brake applications and to check the function of the anti-skid system. These latter tests were witnessed by a consultant with considerable experience of L-39 aircraft both in their former military role and subsequently in civilian applications. No anomalies were revealed at any time during this testing. During each series of tests, correct operation of the Emergency braking system was also verified.

The NLG microswitch was subjected to laboratory examination to check for any evidence that it may have been sticking or in any other way intermittent in operation. The switch assembly was found to be in good condition internally and the microswitch itself functioned normally. The fact that the plunger was bent and yet the assembly still operated was found to be due to distortion of the bronze bush in which it ran.

Ejection sequence

The purpose of the ejection system is to provide the crew with a fast, fully automatic, safe ejection capability throughout the flight envelope. Ejection is initiated when the pilot grasps the seat pan mounted ejection handles with both hands, squeezes the integral unlocking triggers and pulls the handles upwards.

The following actions occur on initial operation of the ejection seat handle:

a Canopy jettison is initiated.

b The pilots shoulder harness is tightened to position the pilot in the correct posture for ejection.

c The rocket motor is armed.

d The ejection gun is fired. As the seat starts to rise on the ejection rail various systems are disconnected, the pilot's legs are drawn towards the seat and further automatic elements of the ejection sequence are armed.

Once the seat is clear of the cockpit:

e The rocket motor is ignited.

f The stabilising parachute is deployed (its purpose is to stabilise the seat until pilot / seat separation occurs and to decelerate the seat to a speed suitable for deploying the main parachute).

c Pilot / seat separation occurs after a further 0·4 sec (when the speed is less than 450 km/hr).

d After a further 0·5 sec time delay the stabilising chute of the main parachute is deployed in order to ensure a correct attitude prior to deployment of the main parachute canopy. After a further 1·5 sec the main parachute is deployed if the pilot is below 13,000 feet.

When in horizontal motion at ground level there is a minimum speed for ejection of 150 km/hr (81 kt). Below this speed there is a possibility that the canopy will not clear the subsequent path of the ejection seat containing the pilot and there may also be insufficient energy to fully deploy the main parachute.

Hawk procedures

The instructor pilot had flown 1,300 hours as an instructor on Hawk aircraft whereas he had only flown 142 hours on the L-39 aircraft. It is therefore pertinent to review the corresponding emergency procedures for the Hawk aircraft. Firstly, there is no emergency brake system on the Hawk aircraft, which may explain why the instructor did not consider this option. Secondly, in the event of the

Hawk leaving the runway where a collision is likely or the terrain is hazardous, then the pilot should consider ejection or raising the landing gear.

L-39 wheelbrakes reliability

The instructor pilot stated that, in his experience of the L-39 Albatros, it was not unusual to make several brake applications from the rear seat position before the braking became operative.

During the investigation, two unrecorded (by either AAIB or CAA) incidents of L-39 Normal braking failure occurring in the UK in the late 1990's were described. It appeared that both aircraft were then on foreign registers (but operating in the UK) and neither pilot considered that it was appropriate to notify the authorities, despite the fact that one of the aircraft was damaged as a result. Following numerous inquiries, brief verbal accounts were obtained.

In one instance, the pilot encountered a lack of Normal system braking upon landing and applied Emergency system braking successfully but not before the aircraft had departed off the left side of the runway. It had drifted to the left due to crosswind and could not be steered with differential wheel brake because the emergency system has no differential braking capability. As the surface was grass, no damage to the aircraft occurred. Investigation showed that the NLG microswitch plunger was bent, possibly when the aircraft was towed from the hangar.

In the second instance, normal braking failed after the chocks were removed and the aircraft struck a hangar. It was reported that the NLG oleo had been over-inflated such that the microswitch was in the 'air' condition, even with the aircraft stationary on the ground. There had apparently been insufficient time to apply the Emergency brakes.

Residual engine thrust.

The L-39 Albatros's turbofan engine produces 135 KiloPascals (approximately 300 lbf) forward thrust at idle speed.

Safety pin stowage

The aircraft operator's Organisation Control Manual required that 'Prior to each flight, the pilot must activate the ejection seats as per the aircraft flight manual and must make the seats safe again at the end of each flight.' G-BZVL was not equipped with dedicated on board stowage for the ejection seat and canopy jettison safety pins and because space within the cockpit was limited, the commander decided not to carry the safety pins.

Analysis

The accident sequence started when the student pilot was unable to apply the normal wheel brakes. The instructor pilot took control but he too was unable to apply the wheel brakes, despite the design of the system giving him priority of control over the normal wheel brakes.

The correct procedure following the loss of normal braking is to use the emergency brakes and this emergency procedure is clearly stated in the Flight Manual. The instructor pilot did not use the emergency brake lever nor did he instruct the student pilot to do so. Instead he applied right rudder to deliberately steer the aircraft off the paved surface towards open ground. When the aircraft was running across the adjacent field, towards the M11, the instructor asked the student to raise the landing gear. In these actions it appears that the instructor may have reverted to the procedures required when flying the Hawk aircraft, which were more deeply ingrained in him than the L-39 procedures.

Landing gear retraction capability

Gear retraction on the ground is inhibited on this aircraft type when the nose landing gear microswitch is in the ground condition and thus the instruction to raise the landing gear was inappropriate. However, the instructor pilot believed gear retraction to be the correct action since, when converting to the aircraft type, he had been taught that the emergency retract position on the undercarriage lever was a means of retracting the landing gear on the ground in order to prevent a runway overrun.

Unfortunately there was an element of confusion amongst some UK based L-39 pilots regarding the ability to retract the landing gear on the ground that may have been partly due to the language and layout of the Flight Manuals. At least one Albatros Flight Manual (albeit for the ZA model but there is no difference in landing gear or braking systems between the ZA and the C models) was misleading on the possibility of gear retraction on the ground. Although the reference to emergency gear retraction in the ZA manual was not specifically in the context of retraction on the ground, gear retraction in the air is seldom an emergency unless the gear has failed to extend properly. There being no mention of an emergency gear retraction procedure in the list of emergency procedures, the assumption that it referred to emergency retraction on the ground was not wholly unreasonable. In fact, retracting the L-39's landing gear on the ground is possible provided that the nose landing gear is held off the runway. It is, however, difficult to conceive of a situation in which this capability is likely to be useful

The language and layout of some L-39 manuals may have been the source for a more general misconception amongst the UK's L39 pilots that gear retraction on the ground was appropriate after total failure of the wheel brakes. However, the L-39C Flight Manual used by the operator and appropriate to the accident aircraft had a different layout, different language and was much clearer regarding the mechanisation of the aircraft's systems than the ZA manual provided by a different operator. Nevertheless, the misconception that the gear could be retracted with the nosewheel on the ground still persisted within the instructor's understanding of the system. Moreover, most aircraft that the instructor had previously flown had the capability to raise the landing gear whilst the aircraft was on the ground and this would have reinforced the training that he received when converting to the L-39.

Although the instruction to raise the landing gear was inappropriate for this aircraft the landing gear selector (in the front cockpit) was found in the 'DOWN' position, suggesting that the student pilot did not select 'UP' as instructed. Had the failure of the normal wheel brakes been caused by a malfunctioning microswitch, selection of the landing gear to 'UP' may have caused the landing gear to retract, which would have stopped the aircraft.

Engine shut down

Although it was not a published emergency procedure, the engine could have been shut down by either pilot to eliminate the residual forward thrust at idle, thereby allowing the aircraft to decelerate as it crossed the field of light crops. Had he been instructed to do so the student pilot could have stopped the engine by retarding the throttle through the idle detent; alternatively the instructor could have shut the engine down himself using the electrical 'ENGINE STOP' switch on the left console in the rear cockpit.

Discussion of possible causes of failure of Normal braking system

Although during the course of the investigation the Normal braking system was operated and tested many times, a fault which could have lead to an inability to apply the wheel brakes was never reproduced. It should also be remembered that most single failures, such as an electro-hydraulic valve or anti-skid inertia switch will only affect one wheel: there is no doubt that this accident was characterised by an absence of braking from both wheels.

The need to make several brake applications from the rear seat position before the braking became operative had never been brought to the attention of the engineering organisation so opportunities to investigate this apparently recurrent deficiency were forfeited.

The instructor pilot stated that the airspeed just prior to landing was 210 km/hr and reducing. The hypothesis that the Normal brake system itself was functioning but the wheel brake friction linings suffered from fading due to usage above the maximum application speed of 190 km/hr was considered. Since this should have resulted, at least initially, in significant retardation, possibly decreasing as the brakes heated-up, this hypothesis appears unlikely and is contrary to the available evidence.

Another possibility revealed by close study and testing of the 'rear-seat priority' mechanism is that inability to apply brakes from the front seat would occur if the rear seat pilot exerted even the smallest pressure on his brake lever. As explained above and illustrated in Figure 1, minimal movement of the rear brake lever may not apply any brake pressure but it results in disconnection of the front seat arm. This would not preclude subsequent application of Normal braking by the rear-seat pilot at any stage. Moreover, it is unlikely that the rear seat pilot would have had his hand on the control column and around the brake lever when the front-seat pilot was initially attempting to apply the brakes.

The NLG microswitch

Since there appeared to be a complete absence of retardation when the brakes were applied from either cockpit, attention was focussed on the NLG microswitch as being the most likely reason for the failure. Anecdotal evidence was heard that other aircraft had experienced Normal braking system problems in service due to factors such as the student not applying sufficient forward pressure on the control column after landing or a misrigging of the microswitch and striker plate. It was even suggested that the difference in fuel weight before and after a long sortie could explain why the brakes might function during taxi for takeoff, but fail upon landing at a lighter weight. The attitude of the aircraft however, subjectively assessed from the eyewitness video, did not suggest other than that the nosewheel was firmly on the ground and the microswitch thus in the 'ground' condition.

Regarding the two earlier (unreported) cases of brake failure, in the first instance, when the pilot encountered a lack of Normal system braking upon landing and applied Emergency system braking successfully, the NLG microswitch plunger had been bent, possibly when the aircraft was towed from the hangar. Consideration of the system operation shows that, for normal braking action to take place during taxi and takeoff, the bend must have occurred with the plunger extended and that striker plate pressure to depress it after lift-off must have caused the deformed plunger to jam in its bush in the 'air' sense after landing. It is possible that G-BZVL suffered a similar microswitch jam after takeoff but there was no evidence to suggest that there was any pre-existing switch damage. The damage discovered after the accident did not jam the microswitch but it should be noted that the nose landing gear had probably undergone at least three impacts (perimeter fence, central reservation barrier and the road) during the accident. It is possible that pre-existing distortion of the plunger may have been overlaid by these impacts and gross damage to the bush freed a pre-existing jammed condition.

The second instance, when normal braking failed after the chocks were removed, occurred because the NLG oleo had been over-inflated. The NLG oleo on G-BZVL was correctly inflated so this too is an unlikely explanation.

It is quite remarkable that, given the extremely small operating experience in the UK, both known cases of Normal braking failure involved the NLG protection circuit. Anecdotal accounts revealed a number of other failure scenarios also related to this circuit to the extent that it was uppermost in the minds of many of those individuals with knowledge of the aircraft who assisted the AAIB investigation. There is no doubt that the location of the microswitch renders it vulnerable to damage. Consequently, it is necessary to query the precise reason for this feature on this aircraft, since most similar types, certainly those of western design, do not have any weight-on-nosewheel braking protection, even though they may be equipped with toe brakes which are arguably more prone to inadvertent application by an inexperienced student.

It would appear to be a simple wiring modification to remove the nosewheel braking protection (the microswitch itself must remain for other systems that it serves). Operators of L-39 aircraft might wish to consider the desirability of accomplishing such a modification which the CAA would consider permitting on the proviso that information was forthcoming from the manufacturer to the effect that there were no special reasons, peculiar to the L-39, why the braking protection was fitted. Unfortunately, it appears that Aero Vodochody do not supply any technical support to civilian operators of ex-military aircraft, so obtaining such information would be difficult. Nevertheless, it is understood that a small number of L-39 variants were produced with the WOW microswitch repositioned to one of the main landing gear legs.

Ejection seat performance

The aircraft passed through the wooden fence at the airfield boundary at about 20 kt; it was just after collision with this fence that the student pilot's ejection seat operated.

Although there is a minimum ground speed for safe ejection of 81 kt in a level attitude, it is not standard practice for a commander to issue an order not to eject below this speed because the word eject may be heard in isolation and the recipient may act upon it inappropriately.

There is, however, a minimum period of 2·4 seconds from the time that the ejection gun is fired to deployment of the main parachute. At the moment of ejection, the aircraft was running down the embankment towards the motorway and the aircraft had thus adopted a significant nose-down and left wing low attitude. Therefore, after ejection, the seat would have followed a low, forward, parabolic trajectory without attaining its normal height. This low trajectory was accurately described by a number of eye-witnesses who stated that the main parachute did not deploy. This was confirmed when the main parachute was examined on-site. It had been pulled from its pack, but had not inflated and was lying streamed-out and pointing back towards the point where the aircraft had crossed the embankment. There was, therefore, clearly insufficient time for the main parachute to deploy fully.

The student pilot had completed training in the use of the ejection seat and had demonstrated a good knowledge of the system. No command to eject was given yet he chose to initiate the ejection sequence below the minimum safe speed for ejection on the ground. It seems likely that the student pilot, faced with the risks of running on to the motorway versus those of ejecting, chose the latter.

Airfield safety

In this instance the aircraft landed on the runway, deviated from the paved surface and came to rest on the M 11 motorway, fortunately without additional injuries. It is therefore necessary to consider mechanisms that may have prevented this runway excursion onto the motorway.

There has only been one other recorded runway excursion at Duxford, involving the M11, since 1976. In October 1997 the pilot of an ME 109 aircraft attempted to carry out a forced landing on Runway 06 because of smoke and fumes in the cockpit. After touchdown it became apparent that there was insufficient runway remaining so the pilot lifted off, crossed the motorway and landed in a field just beyond.

The CAA audit local surveys for all licensed airfields within the UK on a regular basis. Duxford Airfield was last surveyed in August 2000 and the CAA inspection and audit was completed in December 2001. Existing aerodrome licensing requirements include minimum standards for runway end safety provision, designed to accommodate the statistical majority of overruns and to minimise their consequences. Runway End Safety Areas (RESAs) are, therefore, provided at each end of a runway strip and are intended to minimise the risks to aircraft and their occupants when an aeroplane overruns or undershoots a runway. The length of the RESA required for a specific runway depends upon a number of variables, such as the type and level of aircraft activity as well as local conditions. The RESA for Runway 06 at Duxford is 90 metres; this is the length required under guidance provided by the International Civil Aviation Organisation. Extending the RESA would not necessarily provide additional protection for an overrun onto the M11.

In an attempt to prevent aircraft from running onto the M11, an earth embankment was constructed at the far end of Runway 06 at Duxford. The embankment is 2 metres tall and extends 160 metres to the left of the centre line of Runway 06 and 100·5 metres to the right. The reason for this apparent asymmetry is that the area to the left provides additional protection against an overrun for aircraft landing on the grass Runway 06, which is to the left of the main Runway 06. In this instance the aircraft entered the M11 at a position 169 metres to the right of the runway centre line and thus avoided the embankment entirely. However, in the absence of any research, it is not clear what would have happened had the aircraft run into the embankment even at a moderate speed. In view of this uncertainty, together with evidence that the embankment can be avoided, it is recommended that:

The Civil Aviation Authority should review the current arrangements at Duxford Aerodrome for preventing aircraft over running onto the M11 motorway after a landing or rejected takeoff on Runway 06. (Safety Recommendation 2003-13).

Training syllabus

Although the aircraft was fitted with an emergency braking system, neither pilot used it when the normal wheel brakes failed to operate. If one of them had used it, the runway excursion might have been avoided or the aircraft could have been stopped before it penetrated the boundary fence.

When faced with a sudden and dire emergency, pilots have to react swiftly and rely on memorised procedures and the positions of vital controls. In circumstances such as an impending runway excursion, a pilot may have difficulty transferring his vision from compelling external visual cues to the layout of the internal controls in order to find a control or switch he has not used before. Had operation of the emergency brake been routinely practised or tested whilst taxiing, swift reversion from Normal to Emergency braking would have been more likely when the wheel brakes failed to operate. Also, the pilots would have known (perhaps intuitively and without looking) where to find the Emergency Braking lever. Therefore, it was recommended that:

The Civil Aviation Authority should encourage L-39 Albatros operators to include the use of the Emergency wheel brakes into the training syllabus and normal operation of the aircraft type. (Safety Recommendation 2003-14)

Safety pins

As the operator's OCM made clear, when a crew vacates the aircraft for any reason, the explosive elements of the aircrew escape systems should invariably be made safe by fitting safety pins. Had the aircraft diverted to another airfield along the route or landed successfully at Duxford and then become unserviceable, the crew would have had to make 'ad hoc' arrangements for the provision of safety pins before leaving the airfield. It was fortuitous that after this accident, a Duxford based engineer familiar with the L-39 was nearby. He was able to advise the rescue services and able to supply the required pins.

Although the operator's OCM implied the need to carry safety pins, it did not specify that they had to be carried in flight nor how or where they should be carried. They were not carried because it was inconvenient since, unlike most British military aircraft fitted with ejection seats, the L-39 was not fitted with a dedicated stowage for the pins within the cockpit(s).

It is appropriate that all aircraft fitted with live ejection seats and operated under the provisions of CAP 632 should invariably carry the safety pins required to make safe (for parking) the ejection seat and canopy jettison mechanisms. No such requirement is included within CAP 632. Consequently, it is recommended that the Civil Aviation Authority should require operators of civil registered aircraft fitted with live ejection seats to carry the aircraft's escape systems safety pins:

a. On all flights and high speed taxi tests.

b. In a position where they are likely to be found and identified without assistance from the aircraft's flight or ground crews.

Conclusions

The flight proceeded uneventfully until the student pilot landed the aircraft at Duxford. The landing, at the correct position, was about 20 km/hr (approximately 10 kt) faster than the recommended speed and was described by the instructor as "soft" (meaning a gentle touchdown). However, since the aircraft was designed as a trainer it should be tolerant of minor errors. Once on the ground, there was no retardation even after the student pilot apparently responded to the instructions to "load the nose wheel and brake". The instructor pilot also attempted to brake but without success. In response to the transmission from ATC the student pilot replied that they had a "brake failure". It has not been possible to replicate or explain this failure.

The correct procedure following the loss of normal braking is to use the emergency brakes. The instructor pilot did not use the emergency brake lever nor did he instruct the student pilot to do so. The instruction to raise the landing gear was inappropriate for this aircraft since gear retraction is inhibited whilst the aircraft is on the ground but if the landing gear selector had been moved to UP, the landing gear might have retracted. Nevertheless, when the gear did not retract, the engine could have been shut down to augment the aircraft's deceleration as it traversed the crop field.

The student pilot initiated his ejection but at the time he ejected, the seat was outside the parameters for safe operation. Ejection probably occurred whilst the aircraft was pitched down and to the left as it descended onto the motorway. The resultant low, forward, parabolic trajectory provided insufficient time for the main parachute to deploy fully and the student pilot received fatal injuries when he struck the ground.

Safety Recommendations

The following safety recommendations were made:

Recommendation 2003-13

The Civil Aviation Authority should review the current arrangements at Duxford Aerodrome for preventing aircraft over running onto the M11 motorway after a landing or rejected takeoff on Runway 06.

Recommendation 2003-14

The Civil Aviation Authority should encourage L-39 Albatros operators to include the use of the Emergency wheel brakes into the training syllabus and normal operation of the aircraft type.

Recommendation 2003-68

The Civil Aviation Authority should require operators of civil registered aircraft fitted with live ejection seats to carry the aircraft's escape systems safety pins:

a. On all flights and high speed taxi tests.

b. In a position where they are likely to be found and identified without assistance from the aircraft's flight or ground crews.