Aircraft Type and Registration:	Piper PA-23-250 Aztec, G-BFBB	
No & Type of Engines:	2 Lycoming IO-540-C4B5 piston engines	
Year of Manufacture:	1973	
Date & Time (UTC):	29 November 1995 at 1332 hrs	
Location:	Luton Airport	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Both engines shock loaded, damage to both propellers, lower fuselage and nacelles	
Commander's Licence:	Private Pilot's Licence with IMC and Night Ratings	
Commander's Age:	55 years	
Commander's Flying Experience:	1,395 hours (of which 46 were on type) Last 90 days - 42 hours Last 28 days - 12 hours	
Information Source:	AAIB Field Investigation	

The pilot of the aircraft was preparing to depart from Luton on a return trip to Wycombe Air Park. During the taxi out for a Runway 08 departure, having been cleared to hold Bravo 1, he was asked by the ground movements controller if he intended to carry out power checks. Upon replying in the affirmative, he was instructed to turn right on reaching the hold and complete the checks in the compass swing area. This he did and later reported that all was normal. After changing to the tower frequency and calling "ready for departure", he was asked to "hold position". About this time he became aware that a large aircraft, later determined to be a Boeing 737, had just touched down just beyond the point where taxiway Bravo joined the runway, this landing being timed by the controller at 1329 hrs. G-BFBB was then cleared to enter Runway 08 and backtrack as far as required. After reading back this clearance, and whilst backtracking, the pilot expressed concern to the controller about the possibility of the wake vortices from the landing 737 not having dissipated by the time he might be taking off, and asked if he could hold on the runway for a while. This was agreed, following which the tower asked him to standby for departure clearance. As the aircraft turned to line up approximately 100 metres from the 08 threshold, the pilot noticed the 737 clearing the runway, having itself backtracked. At this time, the controller passed departure instructions to G-BFBB, which were read back correctly and, after a short pause, clearance to take off was given at 1332 hrs. In accordance with his normal technique (when flying from Wycombe) the pilot held the aircraft with the brakes until 20 ins of manifold pressure was achieved after which the take-off run, conducted without the use of flaps, was commenced. This was reported as normal, with full power available on both engines. The pilot later reported that he rotated the aircraft at 90 mph and retracted the landing gear as soon as a positive rate of climb was indicated (again, as was normal when he operated from Wycombe). Almost immediately, the right wing dropped, the aircraft began to sink and the pilot felt the controls become less responsive than usual. As there was sufficient runway distance remaining the pilot, who in retrospect believed he had regained control, elected to land the aircraft back on the runway. As he closed the throttles, however, the gear warning horn operated and before any further action could be taken the propellers struck the runway and the aircraft landed with its gear retracted.

Examination of the runway marks revealed that the aircraft's propellers had struck the surface some 1,120 metres from the 08 threshold, significantly to the left of the centreline; the aircraft came to rest some 1,500 metres along the 2,160 metre runway. Analysis of these marks suggested that the aircraft had been travelling with a ground speed of around 80 kt to 90 kt, with low power on both engines, when it first made contact with the runway, and that the gear was retracted at the time. Data contained in the Information Manual for this model of aircraft indicates that the gear and flaps up stalling speed, for standard conditions and at maximum weight, is 74 mph (64 kt) and the minimum controllable single engine speed is 80 mph (70 kt). During the ground slide, the aircraft deviated to the left, demolishing three runway edge lights, before slewing to the right and coming to rest on the left side of the runway centreline. At no time did it depart the paved surface. The pilot, who was uninjured, turned off the fuel cocks and the master switch and vacated the aircraft unaided. The airport rescue services were quickly on the scene and attended to a small fuel spillage which had occurred. There was no fire. After the aircraft had been raised, the landing gear was lowered and the aircraft towed to a maintenance facility on the airfield, the airfield having been closed to traffic for some two hours. A later examination failed to reveal any pre-impact defects associated with the aircraft's flying controls.

In a frank and detailed report, the pilot stated that he considered the vortex* from landing of the 737 may have contributed to the control difficulties that he experienced just after lift off. He also felt that he could have landed the aircraft without any problems had he not retracted the gear so soon after lift off, or not forgotten that the gear had been selected up in his haste to regain the runway. Two characteristics of wake vortices are of interest in relation to this accident. Firstly, the wake vortex from a landing aircraft continues to be generated until the nosewheel touches down. Secondly, vortices generally persist for up to 80 seconds, but in conducive conditions they can last as long as two and a half minutes and tend not to decay gradually, but come to a sudden end. They also tend to move apart at *about* 5 kt in still air, and at a height approximately equal to half the aircraft's wingspan, so a crosswind component *around* 5 kt can keep the upwind vortex stationary on or near the runway. The downwind vortex will move away at *about* 10 kt.

This accident occurred at 1332 hrs, some $2^1/_2$ to 3 minutes after the landing 737. The wind passed to G-BFBB just prior to takeoff was 130°/11 kt with the weather observations at 1320 hrs and 1350 hrs reporting the wind at 140°/10 kt and 130°/11 kt respectively, all values being derived from an anemometer sited atop the Runway 08 glideslope aerial. Thus, over the time period in question there was a steady crosswind component of some 8 kt from the right, which could have resulted in the upwind vortex drifting to the left at *around* 3 kt. During the time between the landing of the 737 and the takeoff of G-BFBB, it might therefore be expected that the upwind vortex would have drifted some 230 metres to 275 metres to the left. In addition, the headwind component, at 7 kt, would have drifted the vortex some 540 metres to 650 metres towards the Runway 08 threshold. A reduction of the average wind speed over this period to 6 or 7 kt would be required for the upwind vortex to remain on or close to the runway, if the 5 kt value is considered accurate. It was not possible to positively establish if any such reduction had occurred as the wind speed on the airfield is not recorded and the observed winds are averaged over a ten minute period. However, such a reduction was unlikely to have occurred as it is a requirement that the wind passed to an aircraft landing or taking off is a two minute averaged wind (although at the discretion of the controller, usually in turbulent or gusty conditions, the instantaneous wind may be passed). Therefore, for a vortex from the landing 737 to have remained over the runway until G-BFBB took off, the outward motion of the vortex from the 737's track would have had to exceed the published figure of 5 kt.

Figure 1 illustrates the estimated points of landing and takeoff of the two aircraft, and it may be seen that G-BFBB probably became airborne at approximately the same point along the runway as its pilot remembered seeing the 737 touch down, although the take-off distance to a height of 50 feet, derived from the PA-23-250 manual, indicates that a shorter ground run was possible. Thus the initial flight path of G-BFBB after lift off overlapped the initial section of the 737 rollout, where its wing would have been generating vortices before the nose gear made contact with the runway. By this time, however, any residual vortices over the runway would have drifted towards the threshold, to a position around the estimated point that G-BFBB lifted from the runway.

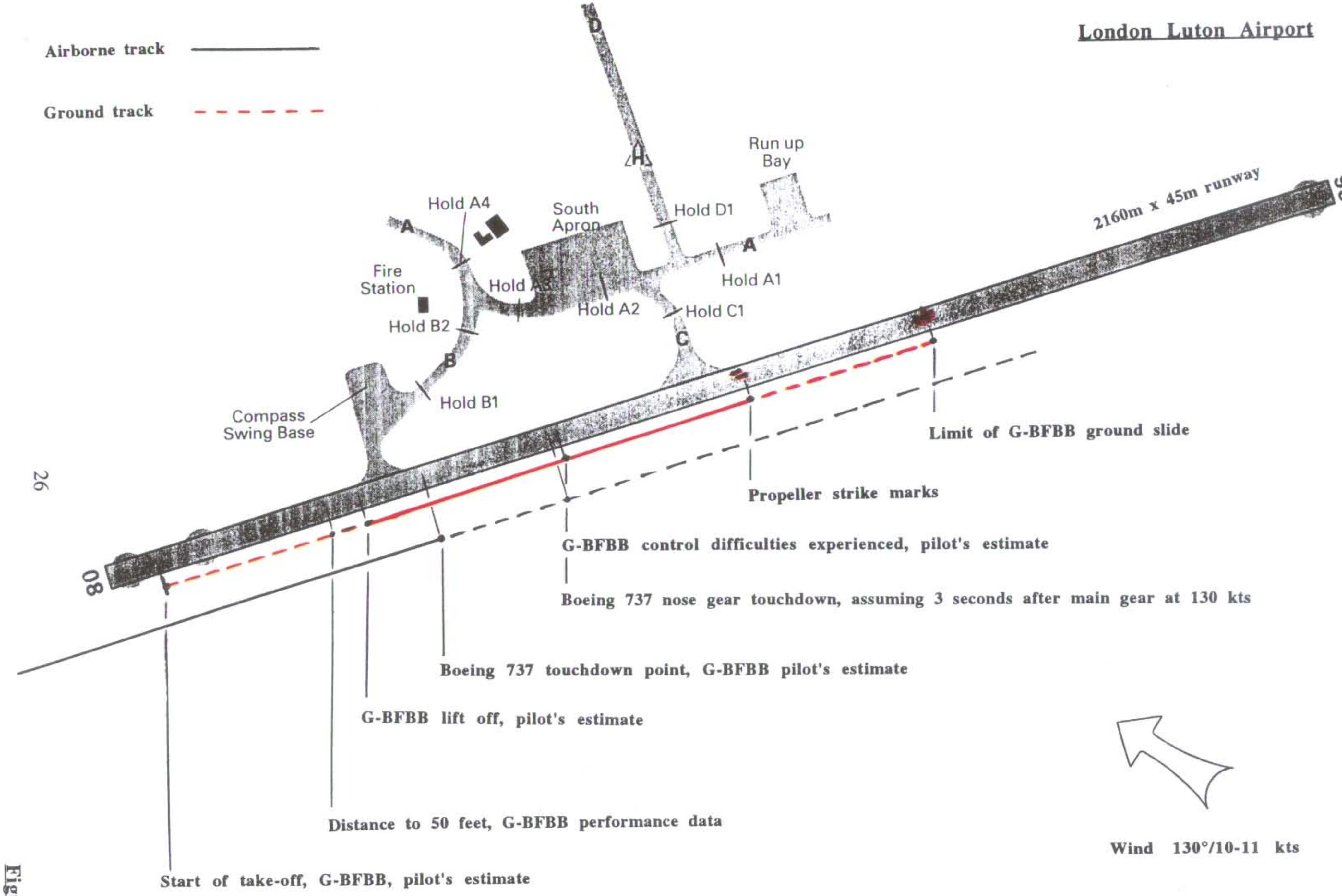
On 16 December 1993 the CAA issued a UK Aeronautical Information Circular, AIC 178/1993 (pink 95), detailing the dangers associated with turbulence caused by aircraft wake vortices. This circular gives a general warning on wake vortex characteristics and illustrates a number of suggested wake vortex avoidance techniques. Aircraft are categorised as Light, Small, Medium, or Heavy, with minimum separation times and distances quoted for most aircraft/runway combinations during takeoff, landing and aircraft tracks which cross. The nearest condition covered in this document (and the Manual of Air Traffic Services, Part 1) to that described above is where a Light aircraft is departing behind an arriving Medium aircraft, albeit on a runway with a displaced threshold, where the projected flight paths are expected to cross. In this circumstance it is stated that "a separation of 2 minutes shall be provided". It is emphasised in this document, however, that "the separation minima stated cannot entirely remove the possibility of a wake turbulence encounter. The objectives of the minima are to reduce the possibility of a vortex wake encounter to an acceptably low level, and to minimise the magnitude of the upset when an encounter does occur. Care should be taken when following any substantially heavier aircraft, especially in conditions of light winds. The majority of serious incidents, close to the ground, occur when winds are light".

In 1992, the CAA also issued General Aviation Safety Leaflet No 15 entitled 'Wake Turbulence', selected passages from which are reproduced below:

"A light aircraft penetrating a vortex from a larger aircraft on the same trajectory and axis can be rolled severely. For most types it may be beyond the power of the ailerons to counteract fully the roll."

"Although a vortex encounter at altitude is uncomfortable and alarming, it is recoverable; closer to the ground there may not be room to recover. A significant proportion of the incidents reported in the UK occur below 200 feet ie mainly just before landing, but some were shortly after take-off (including some years ago a fatal accident). This is when the affected aircraft is most likely to be directly behind a larger aircraft." (A report on such an accident is included in AAIB Bulletin 10/94, ref EW/G94/05/23).

* A vortex is a mass of rotating air and consists of a core and a flow field about the core. Lift is created by a pressure differential between the upper and lower surface of the wing and this pressure differential results in a rollup of the airflow behind the wing towards the tip, thus creating a vortex. The tangential velocities of the core are proportional to the distance from the centre of the core whereas the tangential velocities in the flow field are generally inversely proportional to the square of the distance from the core. The vortex core tends to be small (typically 3 inches for a B757), but is not considered the primary factor in the risk associated with a vortex encounter. Vortex Circulation is a measure of the angular momentum of the air in the flow field and defines the strength of a vortex. The size and strength of the flow field determine the risk of upset posed to a following aircraft and it is generally recommended that pilots should not come within 100 feet of a vortex core. The strength of the vortex is governed by the weight, speed and shape of the wing of the generating aircraft. The vortex characteristics of any given aircraft can also be changed by extension of flaps, or other wing configuring devices, as well as by speed. However, as the basic factor is weight, vortex strength increases proportionally. Peak vortex tangential speeds exceeding 300 feet per second have been recorded. The greatest strength occurs when the generating aircraft is HEAVY, CLEAN and SLOW.



London Luton Airport
Airborne track
Ground track
Run up Bay
Hold A4
South Apron
Hold D1
2160m x 45m runway
26
Fire Station
Hold A1
Hold A2
Hold C1
Hold B2
Hold B1
Compass Swing Base
08
Limit of G-BFBB ground slide
Propeller strike marks
G-BFBB control difficulties experienced, pilot's estimate
Boeing 737 nose gear touchdown, assuming 3 seconds after main gear at 130 kts
Boeing 737 touchdown point, G-BFBB pilot's estimate
G-BFBB lift off, pilot's estimate
Distance to 50 feet, G-BFBB performance data
Start of take-off, G-BFBB, pilot's estimate
Wind 130°/10-11 kts

Figure 1