

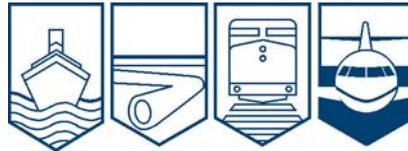
Transportation Safety Board
of Canada



Bureau de la sécurité des transports
du Canada

AVIATION INVESTIGATION REPORT

A05W0059



COMPONENT FAILURE

WING-TO-FUSELAGE ATTACH ANGLE

BRADLEY AIR SERVICES LTD. (FIRST AIR)

LOCKHEED L382G HERCULES C-GHPW

VICINITY OF HIGH LAKE, NUNAVUT

12 APRIL 2005

Canada

The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

Aviation Investigation Report

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Bradley Air Services Ltd. (First Air)
Lockheed L382G Hercules C-GHPW
Vicinity of High Lake, Nunavut
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Report Number A05W0059

Summary

On 12 April 2005, a Lockheed L382G Hercules (registration C-GHPW, serial number 4799) owned and operated by Bradley Air Services Ltd. (First Air) and designated as flight FAB702, departed High Lake, Nunavut, for Yellowknife, Northwest Territories, with four crew members on board. At 1139 mountain daylight time (MDT), approximately 10 minutes after departure, as the aircraft was climbing through 18 000 feet, the crew heard a bang from the cargo area. When they examined the cargo compartment, they heard the sound of air escaping from the left side of the compartment and discovered a crack estimated to be 24 inches long and approximately one-half inch wide in the left wing-to-fuselage attach angle (drag angle).

When the flight crew learned there was a major structural failure, the aircraft was levelled off at flight level (FL) 230 and depressurized. Speed was reduced to 180 KIAS (knots indicated airspeed), an emergency was declared, and all crew members went on oxygen. The aircraft was level for about five minutes then descended to FL 220 for the direction of flight, and remained level for about 35 minutes. The flight crew later descended to 10 000 feet to ensure they were well supplied with oxygen. By this time the crack was no longer visible. On nearing Yellowknife, the aircraft was slowed to 140 KIAS (rather than 170 KIAS) when the landing gear was lowered. The aircraft landed safely at 1312 MDT with the flap retracted. Aircraft rescue and firefighting crews and equipment were standing by. There were no injuries.

Ce rapport est également disponible en français.

Other Factual Information

The crew was certified and qualified for the flight in accordance with existing regulations and very experienced in Lockheed L382G Hercules operations. After the crack was discovered, the crew had several options, including returning to High Lake, Nunavut, or diverting to an alternate airport. The runway at High Lake was a 5150-foot-long ice strip that was unsuitable for a precautionary zero-flap landing, and all the other available alternates were gravel airstrips where aircraft rescue and firefighting (ARFF) services were unavailable. The decision to continue to Yellowknife, Northwest Territories, was predicated on the availability of ARFF and a 7500-foot-long runway.

Visual meteorological conditions, with generally clear skies and light winds, prevailed for the entire flight. Weather was not considered a factor in the occurrence.

After the aircraft landed, at 1312,¹ the crack was inspected; it had closed up and was not visible. The aircraft was subsequently flown unpressurized to a repair facility in Edmonton, Alberta. It was determined that the crack had propagated to 33 inches in length in the radius of the left attach angle, PN 390624-7, near fuselage station (FS) 577, butt line (BL) 61. Records indicate the attach angle had accumulated 35 789 hours time in service and had undergone 31 205 pressure cycles. The one-piece left and right wing-to-fuselage attach angles² secure the fuselage sidewall to the lower skin of the centre wing box beam in the aircraft. The attach angles are installed on the upper corners of the cabin, from forward of the centre wing at FS 477 to aft of the centre wing at FS 617 (see Figure 1). They provide a pressurization seal at the centre wing-to-fuselage juncture and support the fuselage sidewall against pressurization blow out (see Photo 1). Primary wing-to-fuselage

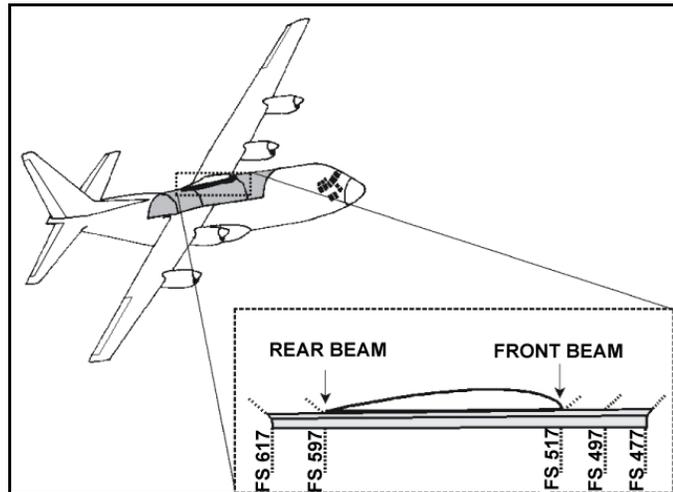


Figure 1. Attach angle location



Photo 1. Dashed lines indicate wing attach angle.

¹ All times are mountain daylight time (Coordinated Universal Time minus six hours).

² Attach angles may also be referred to as drag angles.

structural loads are carried by vertical beams extending down the side of the fuselage, below the centre wing. To date, attach angle cracking has never contributed to the loss of an aircraft due to catastrophic structural failure.

The attach angles installed on L382/C-130 aircraft manufactured prior to serial number 5306 are machined from a 7075-T6 aluminum extrusion. To increase the bending strength of the attach angles in aircraft serial numbers 4383 to 5305, strap doublers are installed on the vertical and horizontal legs of the attach angles from FS 477 through FS 617. Many Lockheed Hercules aircraft, including the L382G stretched versions, have additional thick step doublers installed aft of FS 588, below the rear spar. The occurrence aircraft had both strap doublers and step doublers.

As of serial number 5306, aircraft are fitted with improved attach angles manufactured from 7050 aluminum. These attach angles are thicker and do not require reinforcing straps to be fitted to the legs. However, they are not dimensionally compatible with earlier aircraft due to the location of the fastener holes in the lower wing skin.

The manufacturer's original recommendations for inspecting and servicing cracks in the wing-to-fuselage attach angles allowed stop drilling and repair of cracks. Lockheed Service Bulletin (SB) 382-53-61/82-752 Basic and Revision 1 specified the overriding requirements for inspection of wing-to-fuselage attach angles in commercial and military L382/C-130 aircraft and included an X-ray inspection from FS 517 to FS 617. However, due to the difficulty in placing the x-ray film behind the attach angle, many operators were not able to perform this inspection with confident results. Visual inspection was also ineffective due to the position and thickness of the reinforcing strap and step doublers and to the application of sealant in aircraft serial numbers 4383 to 5305. Numerous other inspection methods were tried. However, a suitable method short of extensive disassembly of the subject area could not be found. A review of the in-service cracking data by the manufacturer indicated that the areas adjacent to FS 497 and FS 577 were both common origins for cracks. Reportedly, all attach angles that had cracking at FS 577 also had cracking at FS 497. Relatively small cracks at FS 497 could be detected by existing x-ray inspection, but the area near FS 577 could not be easily examined by any usual inspection method. Cracking at FS 497 will not result in pressure loss until the crack becomes large enough to extend aft of FS 517.

SB 382-53-61/82-752, Revision 2, dated 28 February 2003, specified the manufacturer's current requirements for inspection of the wing-to-fuselage attach angles in commercial and military L382/C-130 aircraft. The requirement to inspect the areas between FS 517 and 617 was removed. Instead, Revision 2 recommended replacing the attach angle once cracks are detected at FS 497 by x-ray examination. The left attach angle on the occurrence aircraft had already been repaired at FS 497 on 08 September 1987 in accordance with Lockheed Aircraft Corporation drawing SK382-57-093 at 14 498 hours and 13 282 cycles. Revision 2 did not address replacing previously repaired attach angles.

The left wing-to-fuselage attach angle of the occurrence aircraft was removed during repair and shipped to the TSB Engineering Branch to determine the mode of failure. Examination of the crack at the forward end of the attach angle, near FS 497, determined that the crack had resulted from the overload extension of some 10 or 11 small fatigue-generated pre-cracks. The forward crack had been stop drilled and re-enforced during the repair that had been accomplished in 1987, and no further growth of the crack had occurred in the 18 years since that repair. The crack

in the radius at the aft end of the attach angle, near FS 577, resulted from the initiation of three regions of fatigue cracking that had extended as a result of an overstress to form a single crack measuring 33 inches in length (see Photo 2). Measurements of crack growth rates suggested that the crack was growing slightly every time the fuselage was pressurized and had been active over a number of years. No indication of stress corrosion was found in the crack. In communications with Lockheed representatives during this investigation, they stated that stress corrosion cracking had been the mechanism of crack initiation in all previous attach angle failures. The number of failures was not made known to TSB investigators.

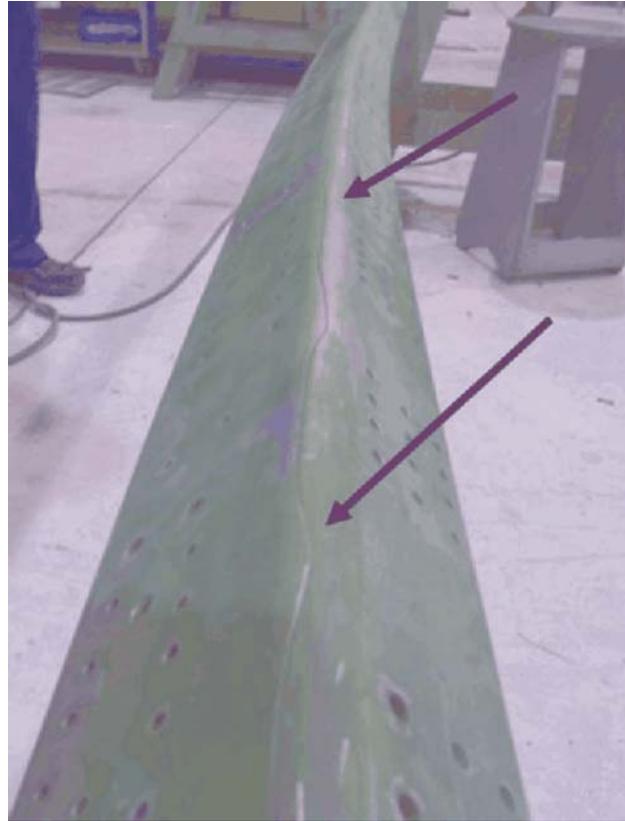


Photo 2. Arrows indicate crack in attach angle.

The occurrence aircraft had undergone a C check at Aero Aviation in Calgary, Alberta, during January to March 2005, at 35 708:31 hours and 31 147 cycles. First Air was authorized to perform line maintenance, and A and B checks on the L-382G. Transport Canada issued a one-time authorization to First Air to allow the company to perform the final maintenance release following the C check. Certification of the inspection and the associated repairs was completed by a First Air representative, and the aircraft was returned to service on 27 March 2005.

No cracking was identified during the examination of the forward repaired section of the left attach angle during the C check. Cracking was discovered in the right attach angle at FS 497, and the right attach angle was repaired in accordance with Aerotech Structures Inc. Drawing #R05-002-01, Rev. 1R. This was an FAA (United States Federal Aviation Administration) Designated Engineer Representative (DER) FAA 8110-3 approval. Although Lockheed Service Bulletin 382-53-61/82-752, Revision 2 recommends replacing an attach angle whenever cracking is detected, a DER approval can override an SB. The repair at FS 497 restored the right attach angle to original strength at that location. However, the repair approval did not include a continuing maintenance program covering inspection for cracks at FS 577.

Weight and balance was not a factor in this occurrence. However, the investigation identified a concern relating to the use of a specific electronic, low-profile, platform scale system for weighing aircraft. Ramp or platform type scale systems are commonly used to weigh large aircraft, one advantage being that an aircraft can be weighed without using jacks. Although the system recently used to weigh the occurrence aircraft had been marketed as an aircraft scale system, it had not been specifically designed for that purpose. Electronic scale systems can be assembled from a variety of digital indicator and electronic platform combinations.

Aero Aviation had purchased the portable electronic scale system in March 2005. The system, supplied by A & A Scales LLC, consisted of six 40 000-pound capacity Massload Technologies Ultra Slim Weigh Pad electronic, low-profile, platform scales and two Tara Systems Model TR-1-NK digital weight indicators. The weigh pads were lightweight and portable and were designed primarily for weighing transport trucks. They have been used only sporadically in the aviation industry. The weigh pads measured 28.5 inches by 16.5 inches by 0.7 inches thick and contained no moving parts. Twenty transducers were embedded into the bottom of each light-weight aluminum platform. The weigh pads had to be level and well supported by the underlying floor structure when in use. The two digital weight indicators provided for single-point calibration. Scale accuracy is known to increase when the systems use digital indicators that provide multiple point calibration over numerous load points and that are calibrated to each size of tire footprint.

The system was first used to weigh the occurrence aircraft on 22 March 2005. One digital indicator was connected to platforms placed under the nose wheels and the other digital indicator was connected to platforms placed under the main wheels. The aircraft was weighed twice using the new scale system, with consistent results, and the new basic empty weight was recorded as 71 039 pounds. This corresponded to a reduction of 3943 pounds compared to the aircraft basic empty weight of 74 982 pounds from the previous weight and balance report, which had been prepared in October of 2003. An estimated 222 pounds of equipment had been added to the aircraft since October 2003; however, review of the October 2003 weight and balance report indicated a large, unexplained increase in the aircraft empty weight over the previous weight and balance report. Based on the unexplained weight increase in the October 2003 weight and balance report, and on the fact that the aircraft had been weighed twice with consistent results, the aircraft was returned to service with the basic empty weight recorded as 71 039 pounds.

The discrepancy was re-examined approximately 75 hours after the aircraft was returned to service, and the October 2003 weight and balance report was temporarily reinstated. As a precaution, an overweight landing inspection of the aircraft was performed on 11 April 2005. The aircraft was re-weighed on 13 September 2005, and the basic empty weight was determined to be 75 477 pounds, which was 4438 pounds heavier than the weight recorded on 22 March 2005.

The electronic scale system had been calibrated on 11 March 2005 before it was delivered to Aero Aviation. The calibration plate used was only slightly smaller than the platform surface. After the aircraft had been weighed, First Air requested that the system be re-calibrated. The system was re-calibrated on 05 April 2005 using a smaller calibration plate. The revised calibration data identified that the indicators were displaying weights between 240 and 360 pounds lower than actual, per pad, with an applied load of 5000 pounds, and between 760 and 1260 pounds lower than actual, per pad, with an applied load of 20 000 pounds. Aero Aviation returned the scale system to the vendor for refund following re-calibration, and the vendor no longer markets scale systems for weighing aircraft. Aero Aviation replaced the system with single-point, jack load cell type equipment.

Analysis

A crack in the wing-to-fuselage attach angle of a Lockheed L382/C-130 aircraft could lead to failure of the attach angle, pressurization blow out, and subsequent loss of cabin pressure. This analysis reviews the adequacy of current procedures for inspection, repair, and replacement of this component. In addition, the use of electronic, low-profile, platform scale systems for weighing aircraft is analysed.

Prior to the availability of SB 382-53-61/82-752, the manufacturer allowed stop drilling and repair of cracks in the wing-to-fuselage attach angles. SB 382-53-61/82-752, including the Basic release, Revision 1 and Revision 2, specified the continuing maintenance methods to be used to detect subsequent cracking. Although inspection methods to detect cracks in the vicinity of FS 497 were effective, aircraft structure prevented these same methods from being effective in the area of FS 577. Lockheed in-service cracking data showed that when cracks were detected at FS 497 this was an indicator that there were also cracks at FS 577. By issuing the SB, the manufacturer relied on replacement of any attach angles found cracked at FS 497 to prevent failure of the attach angle at FS 577.

SB 382-53-61/82-752 up to and including Revision 2 did not address replacement of previously repaired attach angles. No cracking was identified during the NDT³ examination of the occurrence aircraft's repaired left attach angle during the recent C check. At that time, there was no requirement within the Lockheed or First Air L382 maintenance programs to replace previously repaired attach angles. The component failed due to fatigue shortly after the C check. Examination of the crack revealed that it had been present and actively propagating over a number of years. A manufacturer's requirement to establish a maximum cycle life on previously repaired attach angles to reduce the risk of attach angle fatigue cracking and failure might have accomplished the same failure prevention goal as the recommendation in SB 382-53-61/82-752 Revision 2 to replace attach angles if new cracks are detected at FS 497. As there is no specific requirement to replace attach angles that have been previously repaired, all L-382 or C-130 aircraft serial numbers 4383 to 5305 that are operating with attach angles that have been repaired at FS 497 are at an increased risk of in-flight failure of the attach angles at FS 577.

Revision 2 of the SB was in effect at the time of the recent C check of the occurrence aircraft. However, the DER repair approval overrode the SB recommendation to replace attach angles found cracked. Overriding the SB recommendation increased the risk for undetected cracking at FS 577 as there was no suitable continuing maintenance program to cover crack detection at FS 577.

While not a factor in the occurrence, the electronic, low-profile, platform scale system that was used to weigh the aircraft used digital indicators that provided single-point calibration only, which limited overall precision. As well, the low-profile Massload Technologies Ultra Slim Weigh Pads were sensitive to differences in tire footprint size. The system was originally calibrated using a calibration plate that covered almost all of the platform surface; follow-up

³ NDT refers to non-destructive testing, that is, methods of testing structures for integrity, especially absence of manufacturing flaws or cracks, that do not impair serviceability or future life.

testing using a smaller calibration plate showed the indicated weights to be significantly lower than the actual weights at all data points. The system, as configured and calibrated, was unsuitable for weighing an aircraft that had the weight, and nose tire and main tire footprint sizes of a Lockheed L382. This contributed to the aircraft flying approximately 75 hours with a large error in the recorded basic empty weight on the weight and balance report. The continued use of this type of electronic, low-profile, platform scale system for weighing aircraft, without awareness of the potential and inherent shortcomings of the system, may increase the risk of recording erroneous aircraft basic empty weights.

The following TSB Engineering Laboratory reports were completed:

LP 037/2005 - FDR Analysis, L-382G, C-GHPW LP
LP 049/2005 - Examination of Wing-to-fuselage Attach Angle

These reports are available from the Transportation Safety Board of Canada upon request.

Finding as to Causes and Contributing Factors

1. Fatigue crack initiation and propagation occurred in the bend radius of the left attach angle at FS 577, which resulted in failure of the component. The left wing-to-fuselage attach angle repair that was accomplished at FS 497 in 1987 extended the component installation time in service, with no suitable method to cover crack detection at FS 577.

Findings as to Risk

1. SB 382-53-61/82-752, including the Basic release and Revisions 1 and 2, did not address replacement of previously repaired attach angles, increasing the risk that L-382 or C-130 aircraft (serial numbers 4383 to 5305) that were operating with repaired attach angles might have experienced an in-flight failure of the attach angles at FS 577.
2. The DER approved repair at FS 497 restored the right attach angle to original strength; however, the repair approval did not include a continuing maintenance program to cover crack detection at FS 577, increasing the risk of attach angle cracks occurring at FS 577 due to extended time in service.

Other Finding

1. The electronic, low-profile, platform scale system that was used to weigh the aircraft was unsuitable, as configured and calibrated, for weighing a Lockheed L382.

Safety Action Taken

On 09 May 2005, the Transportation Safety Board sent an Aviation Advisory (A050011-1) to Transport Canada suggesting that Transport Canada advise other commercial and military L382/C-130 operators of the circumstances of this incident. The advisory also suggested that regulators and the manufacturer consider a requirement for operators to replace repaired attach angles and establish a service or cycle life for attach angles on L382/C-130 aircraft manufactured prior to serial number 5306.

On 29 September 2005, Transport Canada responded to the Safety Advisory. The letter stated that the aircraft involved in the occurrence is the only civilian version registered and operating in Canada, and that the operator has complied with the recommended replacements of the attach angles. The letter also stated that the information the TSB provided has been forwarded to the responsible design authority, the United States Federal Aviation Administration, and the Canadian Department of National Defence, which operates military versions of this aircraft.

Following the occurrence, First Air replaced the left and right attach angles on aircraft C-GHPW.

As a result of this occurrence, Lockheed Martin issued Revision 3 of Service Bulletin 382-53-61/82-752, dated 04 August 2005. Revision 3 of the SB specifically identified the need for a visual inspection of the wing-to-fuselage attach angles on applicable aircraft, to be accomplished within 30 days after receipt of the Service Bulletin to determine if repairs have been installed, and further recommended replacement of any previously-repaired attach angle within 365 days.

The FAA Atlanta Aircraft Certification Office is evaluating this Service Bulletin and the history of this problem to determine if further regulatory requirements should be issued.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 07 February 2006.

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