Lockheed L1011-385-1-14, G-BBAF

AAIB Bulletin No: 1/99 Ref: EW/A98/7/1 Category: 1.1

Aircraft Type and Registration:	Lockheed L1011-385-1-14, G-BBAF
No & Type of Engines:	3 Rolls Royce RB211-22B turbofan engines
Year of Manufacture:	1974
Date & Time (UTC):	19 July 1998 at 0200 hrs
Location:	Kos Airport, Greece
Type of Flight:	Public Transport
Persons on Board:	Crew - 13 - Passengers - 357
Injuries:	Crew - None - Passengers - None
Nature of Damage:	Extensive structural damage to lower fuselage in the area of the rear pressure bulkhead
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	16,000 hours (of which 5,900 were on type)
	Last 90 days - 77 hours
	Last 28 days - 42 hours
First Officer's Flying Experience:	1,367 hours (of which 410 were on type)
	Last 90 days - 57 hours
	Last 28 days - 9 hours
Flight Engineer's Experience:	158 hours (all on type)
	Last 90 days - 97 hours
	Last 28 days - 25 hours
Information Source:	AAIB Field Investigation

Synopsis

This accident occurred on landing. Shortly before landing the aircraft experienced a high sink rate and, in an attempt to arrest this, the pitch attitude was increased to such an angle that the aft fuselage contacted the runway. The aircraft sustained damage but there were no injuries. The passengers and crew remained unaware of the accident until a heavy landing inspection was carried out after the aircraft was parked.

Under the provisions of ICAO Annex 13, Chapter 5.1.1, the Greek authorities delegated responsibility for the accident investigation to the United Kingdom Air Accidents Investigation Branch.

History of flight

The aircraft and crew were operating a charter service from London Gatwick Airport to Kos Airport, Greece. The flight deck crew were not originally rostered to operate this flight; all three were called out from standby duty which had commenced at 1400 hrs and was scheduled to finish at 2000 hrs.

At the time of departure the aircraft had one significant technical defect. On some previous sectors the stall warning system stick shaker had been activating at speeds well above the stall during the late stages of the approach. The crew were asked by the ground maintenance engineers to perform some troubleshooting observations on the return sector. The crew were not advised, and were not aware, that there would be any change to the handling characteristics of the aircraft should this defect occur during the flight.

The flight was originally scheduled to depart at 2120 hrs but was delayed due to the late arrival of the aircraft from a previous flight, and then by some passengers who had checked in but were late arriving at the aircraft. The flight departed at 2230 hrs with 357 passengers and 13 crew members on board.

The flight proceeded without incident and 10 minutes before the top of descent the commander gave an approach briefing for Kos. The ATIS report from Kos, recorded at 0100 hrs, gave a surface wind 010°/16 kt, CAVOK, temperature 25°C and pressure 1007 mb. It was still dark on the ground,

the local time of sunrise being 0315 hrs. The wind conditions required a landing on Runway 33 and so the brief was for a VOR/DME 33 approach. The company Standard Operating Procedures (SOP) were briefed except that the commander asked the flight engineer to give two extra radio altimeter callouts, at 20 feet and 10 feet, because of the existence of a ravine just before the touchdown end of the runway.

The aircraft arrived overhead KOS VOR at 0155 hrs and was cleared by ATC for the approach procedure. The outbound leg was flown at flap 10. On the base leg flap 22 was selected and speed was reduced accordingly. At this point the ALPHA flag (indicating a mode change in the autothrottle system) came into view in the IAS display window and as a result the commander disconnected the autothrottle and then reconnected it. This action had no effect upon the alpha flag.

When established on final approach at 6 miles the crew had visual contact with the runway. The commander disconnected the autopilot and then land flap 33° was selected. The aircraft experienced a considerable amount of turbulence on the approach but the commander had not considered it to be unmanageable at any stage. Landing checks were completed by 1500 feet amsl, and landing clearance was received with a reported surface wind of 010°/16 kt. The landing checks included a cross check by all three crew members that the Direct Lift Control (DLC) system was in operation.

At several stages during the approach cross checks on DME range and altitude were given by the first officer showing the aircraft to be slightly high. The VASIs were several times reported to be showing "two whites". At an altitude below 900 feet the crew noticed the stick shake on four occasions, each time briefly. The first officer checked the speed and gave a callout of "speed" because the aircraft was flying at more than 20 kt above the Vref speed of 142 kt. None of the crew observed any stick shake immediately before touchdown.

On the final stages of the approach the flight engineer saw the radio altimeter move rapidly from 700 feet, down to 300 feet, and up again. He was distracted by these movements; his concern was that he should be able to give accurate callouts as requested by the commander.

For the last 400 feet of the approach the aircraft went a little below the target 3° glidepath angle. All three crew members felt the aircraft lose altitude rapidly in the final few seconds. The commander responded by increasing the pitch attitude of the aircraft and then the aircraft touched down hard. Reverse thrust of 85% was applied; and a normal rollout and taxi to stand was completed.

The flight crew all reported that they thought the aircraft had touched down in the normal position on the runway, at least 1,000 feet from the beginning. The measured position of the first contact with the runway was 310 feet from the start of the paved surface.

Flight crew information

The flight deck crew was called out from standby duty which had commenced at 1400 hrs and was scheduled to finish at 2000 hrs. The commander and the first officer enquired if there were any other crew available to operate the flight. The report time was beyond their standby period and they were concerned about carrying out a long night flight with little opportunity for pre-flight rest. They were informed that no other crew members were available. The commander, who had been called at 1500 hrs to advise him of the flight, had attempted to sleep in the afternoon. He was not able to do so because of noise from a local pub. He decided to arrive at the airport early and slept in his car for 40 minutes prior to reporting for duty. Other than this both he and the first officer had been awake in excess of 20 hours at the time of the accident.

The commander had operated into Kos on one previous occasion but it was the first visit for both the first officer and the flight engineer.

Airfield information

Kos airport is located towards the western end of the island and lies approximately half way between the north and south coasts. The airfield elevation is 409 feet. The first part of the final approach course to Runway 33 lies over the water, the coast is crossed at 3 miles before touchdown. The terrain in this area is very rugged and there is a rocky ravine running from northwest to southeast before the threshold of the runway. There are no approach lights for the runway and there is no lighting from habitation on the final approach.

Runway 33 is 2,400 metres (7,874 feet) long and 45 metres (148 feet) wide. For this flight the landing distance required was 6,000 feet. The runway has white edge lights and red runway end identifier lights. The runway slopes upward from the touchdown end with an average slope of 0.51%. The airfield charts available to the crew showed the average slope for Runway 33 as 0.51% down. The VOR/DME 33 approach chart gave DME range against altitude for an advisory 3° angle of descent, terminating at 3 miles and 1,240 feet. The chart included a caution to the crew about a ravine 500 metres short of the threshold which may cause updrafts in northwesterly wind conditions. The ramp area was at the north eastern side of the runway and was illuminated.

The airfield was equipped with 2 bar VASIs located on each side of the runway and set at an angle of 2.75°. The operator's approved flight manual states:

"Two bar (shortbody) VASIs must not be used"

The operator defined Kos Airport as " Category B" and there was a published special brief issue dated 11 August 1997. All the flight deck crew had read the operator's special brief on Kos Airport before departure from Gatwick.

Aircraft information

The L1011 aircraft has a Direct Lift Control (DLC) system the purpose of which is to enable improved vertical control on the final approach. The system is operative when the flaps are in the land position. It operates by moving some of the spoilers from a null position in response to control wheel commands. The crew confirm DLC operation by reference to the spoiler position indicator and the speedbrake lever. The DLC is automatically deactivated by a stall warning.

The flight manual states that the Autothrottle System (ATS) can normally be left engaged until just before the flare manoeuvre. On the accident aircraft this resulted in a speed of up to 20 kt above the target speed during the approach The flight manual also cautions that:

> "When autothrottle is engaged during an approach without visual glideslope information, the altimeter and VSI must be closely monitored. In this control mode high rates of descent can build up rapidly....."

The Minimum Equipment List (MEL) for the stall warning system is reproduced as follows:

> 'NBR NBR
>
> INSTD RQD Notes and Qualifications
>
> 2 2 Two must be operative'

Flight recorders

General

The CVR contained the period of the incident flight from just prior to the selection of first stage of flap (during the approach) to the time when the aircraft was shut down. When the FDR and Quick Access Recorder (QAR) recordings of the event were replayed, it was apparent that all the data originating from a synchro type transducer on the aircraft had been incorrectly encoded before recording. This was subsequently traced to a fault in the Flight Data Acquisition Unit. The synchro data from the FDR was recalibrated to take account of the error and it is from this source, together with the unaffected parameters from the QAR, that the following information was derived.

Other anomalies were also observed within the recorded data; the system 1 stick shaker discrete parameter showed very frequent activity during the entire flight although there was no corresponding noise of the control column being shaken on the CVR. The auto-throttle system, although engaged, maintained airspeed at between 15 kt to 20 kt higher than that expected for most of the approach. The commander also commented on a spurious ALPHA flag which appeared in the airspeed selection display window when only 10 degrees of flap had been selected stating "it comes in early".

Apart from a single activation of the control column stick shaker identified by the first officer and later proved to be spurious, the initial approach was uneventful. All three crew confirmed the various SOP calls made.

Final approach

With the auto-throttle engaged, the auto-pilot out and the airspeed between 150 kt and 160 kt, flap 33 was selected. At this stage, the aircraft was about 5 nm from touchdown and slightly high on the prescribed 3° angle of descent. Both the first officer and flight engineer confirmed that the leading edge slats were deployed, DLC was operative and the ALPHA flag was present in the airspeed selection display window. Although there was evidence of some spoiler movement at the time of this confirmation, there was very little for the remainder of the flight, with the spoiler surfaces remaining, for the most part, retracted. It was also observed that the pitch and roll of the aircraft were moderately unstable with recorded nose-up attitudes ranging from 3.7° to 8.3° and roll angles of ±6.5°.

With 2 nm to go before touchdown, the aircraft flew below the 3° angle of descent and maintained airspeed between 150 kt and 160 kt. As the aircraft crossed the coast and the radio altimeter readings began to show more activity, the pitch attitude, still destabilised, began to increase along with angle of attack. At 1.4 nm to touchdown, just prior to the first significant terrain peak, it was

observed that airspeed increased to 165 kt and, with auto-throttle still engaged, engine power then reduced from 1.1 EPR to 1.02 EPR.

The radio altitude alert, which is active between 350 feet agl and 300 feet agl, was audible on the CVR as the aircraft flew over the first peak. Moments later, whilst the angle of attack was greater than 12.5°, the sound of the stick shaker was also audible for a period of 3 seconds and DLC operation was disengaged. Over the period between the 2 terrain peaks, airspeed reduced from 165 kt to 147 kt whilst recorded ground speed showed a similar reduction of 151 kt to 132 kt.

Ten seconds before touchdown, with the aircraft now below the 3° angle of descent and passing over a second terrain peak, the radio altitude alert was again audible for 2 seconds and there was a momentary increase in engine power which temporarily arrested the reduction in airspeed at 146 kt. The radio altitude alert stopped when the aircraft descended through 300 feet agl but, as angle of attack increased through 12.5°, was immediately followed by the continuous reactivation of the control column stick shaker.

During the remaining eight seconds of flight, as the aircraft passed over the rapidly rising ground up to the threshold of the runway, the radio altitude reduced rapidly from 298 feet agl, airspeed reduced by 15 kt and pitch attitude increased to 13.7°. During this period, four seconds from touchdown, the auto-throttle was disconnected and engine power reduced to 1.06 EPR; also, the flight engineer made rapid radio altitude announcements of "100", "50", "30", "20" and "10". The aircraft landed, wings level, at an airspeed of 130 kt between the "30" and "20" calls and a normal acceleration of 2.05g was recorded. A plot of the time history of relevant parameters recorded during the final approach is shown in Figure 1.

Ground spoilers and thrust reverse was used to slow down after the landing followed by an uneventful taxi and shutdown.

Wind Effects

From an analysis of the behaviour of ground speed, airspeed, barometric rate of descent, pitch and angle of attack, it is evident that there was some variation in the wind speed and direction encountered during the final approach. As the aircraft crossed the coast there was an increase in the headwind component in the order of 14 kt, together with a smaller increase (about 3 kt) in updraft. During the period between the second terrain peak and the threshold, the analysis shows a further momentary increase to a total of 20 kt in headwind component. This was immediately followed by a reduction in both headwind and updraft to 8 kt and -2 kt respectively. This change occurred just prior to the disconnection of the auto-throttle system and the ensuing reduction in engine power.

Engineering investigation

Examination of the aircraft by the flight engineer after the landing at Kos revealed substantial skin damage in the area of the rear pressure bulkhead and abrasion of the retractable tail skid. When maintenance engineers made a more detailed examination, they found that there was also extensive damage to aft fuselage frames, as well as a 12 inch crack in the rear pressure bulkhead (RPB): most of the skin and frame damage was between the RPB and the APU compartment, also affecting the integrity of the flight controls. The damage resulted in temporary structural repairs at Kos before the aircraft could be safely ferried, unpressurised, to a maintenance facility for repair.

The runway surface showed clear witness marks of the aircraft's arrival as the marks started 95 metres from the arrival threshold and were thus well short of the majority of the touchdown tyre marks on Runway 33. The distinctive marks showed that the main landing gear, tail skid and aft fuselage had contacted the runway in quick succession and the pitch attitude at that point was between 13° and 15°.

The aircraft's Technical Log showed that on two very recent sectors the flight crew had reported apparent false activation of the 'stick shaker' stall warning. The first 'Action Taken' entry in the Technical Log showed that the maintenance engineers had changed the right hand angle-of-attack (AOA) sensor whereas on the second occasion the maintenance engineers entered a request that the flight crew monitor the performance of one of the AOA sensors.

The stall warning function in the L1011 is commanded by the Flight Control Electronic System (FCES): the FCES also provides other functions including flight controls monitoring and DLC. For the stall warning function the main inputs are signals to the FCES computer for landing gear position, wing flap and slat positions and the angle of attack sensors: the computer then provides stall warning to the crew based on the relationship between the slat/flap configuration and sensed angle of attack signal. From analysis of the FDR in this accident, it appears likely that premature activation of the stall warning was consistent with the FCES computer sensing a 'no slat' configuration, whereas the FDR clearly shows the slats deployed for the landing. During the repair of the aircraft it was found that there had indeed been a fault with the 'slat switch' input to the FCES computer, confirming that the premature stall warning was a product of the FCES computer sensing incorrect aircraft configuration.

Discussion

Crew duty period

The commander and the first officer had expressed their reservations about carrying out a flight at a late report time with no opportunity for adequate rest. At the time of report it would have been difficult for the crew to estimate how their performance would be affected later in the night.

Time since sleep is a recognised factor contributing to fatigue in air crew. Both the commander and the first officer had awakened early on the morning of the 18 July. The time of circadian trough falls between 0300 and 0500 hrs local time, 0200 to 0400 UTC for this crew. Most human functioning is affected by circadian rhythms, including heart rate, brain activity, vigilance and performance. The crew must therefore have been experiencing a reduced level of alertness at the time of the accident.

Airworthiness aspects

The commander accepted a technical defect without having been aware that it might affect the handling characteristics of the aircraft. The MEL did not clearly state if false stall warnings rendered the system unserviceable, or if there were any other implications of such warnings. The stick shake activated at a critical phase of flight and the resulting loss of the DLC may have contributed to the approach becoming destabilised. The fact that the crew had recognised and discounted the stick shake earlier on the approach may have led their not recognising it later.

Aircraft handling aspects

The runway, seen from the flight deck, would have appeared as a strip of lights surrounded by darkness. Depth and distance perception would have been difficult because there was no surrounding cultural (man-made terrestrial features) lighting. There were several methods available to the crew to help them judge the correct approach path. One way was to cross check the KOS DME range against altitudes from the chart. The last published check was 3 miles at 1,240 feet and this altitude was confirmed by the crew.

Another method was to estimate the angle of approach visually by the appearance of the runway lights. In this case the upward slope of the runway would have given the crew the illusion of being too high on the approach. The runway chart available to the crew depicted the runway slope incorrectly. They therefore would not have been expecting this illusion, and a failure to allow for it would have caused the aircraft to land short of the touchdown zone. An indication of the difficulty experienced by the crew is that, after the event, none of them had the correct impression of where, along the runway, the aircraft had touched down.

The VASIs installed at the airfield are for short bodied aircraft and are not recommended for use by the L1011. If they were used for guidance on the approach the expected wheel height at the threshold for this aircraft would be between 10 and 15 feet.

The loss of the updraft, at a time when the aircraft was marginally low and slow, led to the aircraft sinking suddenly below the original approach path. As a result the aircraft landed short and hard on the runway. The commander's input of elevator in an attempt to arrest the descent caused the aft fuselage to strike first.

A combination of factors resulted in a high workload for the crew at a time of day when they were likely to be experiencing a reduced level of alertness arising from their scheduling and work cycle.

Follow-up action

The Kos Airfield chart has since been amended by the supplier to show the correct angle of slope for Runway 33.

The operator has taken action to remind crew members of the change to handling characteristics of the aircraft resulting from a false stall warning.