S2/2000 - Boeing 747-2B5F, HL-7451

AAIB Special Bulletin No: S2/2000

Aircraft Type and Registration:	Boeing 747-2B5F, HL-7451
No & Type of Engines:	4 Pratt and Whitney JT9D-7Q turbofan engines
Year of Manufacture:	1980
Date & Time (UTC):	22 December 1999 at 1838 hrs
Location:	Hatfield Forest (N 51· 51.385' E 000· 12.988'); 1.9 nm on a bearing of 204· (M) from the centre point of Runway 23/05 at Stansted Airport
Type of Flight:	Public Transport (Cargo)
Persons on Board:	Crew - 4 - Passengers - None
Injuries:	Crew - 4 Fatal - Passengers - N/A
	(1 crew member was operator's ground engineer)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Airline Transport Pilot's Licence (Republic of Korea)
Commander's Age:	57 years
Commander's Flying Experience:	13,490 hours (approximately 8,495 hours were on type)
	Last 90 days - 208 hours
	Last 28 days - 56 hours
Information Source:	AAIB Inspector's Investigation

History of flight

The aircraft arrived at Stansted Airport at 1505 hrs on 22 December 1999, after a flight from Tashkent, Uzbekistan. Prior to leaving the aircraft, the flight engineer made an entry in the Technical Log to the effect that the commander's Attitude Director Indicator (ADI) was 'unreliable in roll'; he also verbally passed the details to the operator's ground engineer who met the aircraft on arrival. The inbound flight crew then left the aircraft without meeting the outbound crew who were due to operate HL-7451 to Milan (Malpensa) Airport later that day.

During the turnround, some cargo was offloaded and other cargo, which had been transported by road from London, was loaded. The total cargo on board for the sector to Milan was 140,452 lb. The loading was

almost complete when the outbound crew arrived; this crew comprised the commander who was to be the handling pilot, the first officer and flight engineer. The dispatcher went to the cockpit to meet the outbound crew and gave them the navigation logs and weather information for their flight. Prior to engine start, the commander accompanied the load controller through the aircraft to check the security of the cargo, and then checked the loadsheet before signing it and leaving a copy with the load controller. The load sheet copy indicated that the aircraft weight for take-off was 548,352 lb; this included 68,300 lb of fuel. The ground engineer who had met the aircraft on arrival at Stansted boarded the aircraft for the flight to Milan.

At 1727 hrs, the crew called 'Stansted Delivery' on frequency 125.55 MHz for their flight clearance; however, this frequency is only manned when a high number of airport movements are planned. After two unsuccessful attempts to contact ATC on the 'Delivery' frequency, the crew contacted 'Stansted Ground' at 1729 hrs on frequency 121.72 MHz to request start and push back clearance from their position at Stand Alpha 6. They were informed by ATC that they had no details for their flight and were requested to standby. Then, at 1733 hrs the crew were informed that no flight plan had been received and that they should contact their handling agents. The agents submitted the flight plan and the crew of HL-7451, callsign KAL 8509, were advised at 1742 hrs that their clearance was to Malpensa with a Dover 6R departure and a transponder setting of 2230; the crew read back their clearance correctly.

There was then some delay providing a tug for the aircraft and the crew requested push back clearance at 1813 hrs. However, during the push back the tug experienced problems and was unable to complete the manoeuvre; the result was that HL-7451 was left in a position from which it required marshalling onto the taxyway centre-line. The marshalling vehicle was in position by 1823 hrs and KAL 8509 was cleared to taxy at 1825 hrs to 'Hotel November' (holding point for Runway 23) via 'Hotel Lima'. Shortly after, the 'Ground' controller transferred KAL 8509 to 'Tower' on frequency 123.8 MHz.

The crew contacted the 'Tower' at 1835 hrs and were instructed: "After the next landing aircraft on final line up and wait Runway Two Three". Subsequently, at 1836 hrs KAL 8509 was cleared to take-off with a reported surface wind of 190·/18 kt. The Tower controller considered that the take-off was normal and, as the aircraft indicated altitude passed 1,400 feet at 1838 hrs, transferred KAL 8509 to 'London Control' on frequency 118.82 MHz. The air assistant, alongside the controller, also watched the take-off and described it as normal; he also watched the aircraft climbing into cloud. No radio calls were heard from the aircraft subsequent to the frequency transfer instruction from 'Stansted Tower'. The ATC personnel in the Tower then saw an explosion to the south of the airport and realised that KAL 8509 had crashed; they immediately implemented their emergency actions. The Aerodrome Fire Service recorded receipt of the alerting action from ATC at 1840 hrs and dispatched all available vehicles and crews to the reported accident position.

Other witnesses heard and saw the aircraft impact the ground. Some reported feeling the shock waves and others reported seeing the aircraft flying much lower than normal. One eyewitness, close to the impact location, reported two fireballs either just before or just after the aircraft crashed. The second fireball was intense and reported as 'Mushroom' shaped. Essex police recorded the first emergency call at 1843 hrs and initiated their emergency response.

Weather

Subsequent to the accident, the Meteorological Office at Bracknell provided an aftercast of the weather situation at 1830 hrs on 22 December 1999. The synoptic situation showed a strong, mild and very moist southwesterly airstream over the area. A Warm Front was lying just to the west of Stansted Airport, moving quickly eastwards. A strong wind warning was in force at the time of the accident. The METARs (Meteorological Actual Reports) for Stansted were as follows:

1820 hrs: Surface wind of 190·/16 kt; visibility of 3,100 metres in mist; cloud few at 400 feet agl and scattered at 500 feet agl; temperature 10·C/ dew point 9· C; QNH 1008 hpa.

1850 hrs: Surface wind of 190·/17 kt; visibility of 4,200 metres in mist; cloud scattered 500 feet agl, scattered at 600 feet agl and broken at 900 feet agl; temperature 10· C/ dew point 9· C; QNH 1008 hpa.

On the initial call to ATC, the crew of KAL 8509 reported that they had received ATIS information 'Mike' (timed at 1650 hrs). The reported surface wind was 180·/17 kt; visibility 5,000 metres; cloud scattered at 500 feet agl and broken at 700 feet agl; temperature 9·C/ dew point 8·C; QNH 1008 hpa.

Other flight crews, who were in the area close to the time of the accident, were contacted to confirm the weather conditions. All stated that the weather was as reported, but some pilots in medium sized aircraft experienced turbulence.

Wreckage investigation

Shortly after the crash, reports were received that debris had been found on the airfield in the vicinity of the runway. An initial search of the runway that evening, and a more comprehensive search of the surrounding areas at first light, revealed many pieces of lightweight material. Examination of the crash site revealed that the impact had resulted in a large fireball capable of carrying many items aloft; when airborne, these items would have been carried back to the north and onto the airfield by the strong Southerly wind.

The Cockpit Voice Recorder (CVR) was found on the evening of the accident just beyond the impact crater.

Examination of the initial impact area and wreckage trail indicated that the aircraft had crashed on a track of approximately 105· M, close to but fortunately clear of some local houses. On impact, the aircraft was assessed to be pitched approximately 40· nose down and banked close to 90· to the left; the speed was high in the region of 250 to 300 kt. Indications are that the aircraft was structurally complete at impact. The impact crater was 43 metres long and 13 metres wide with a maximum depth of 3.5 metres. The wreckage trail extended, in a fan shape towards the east of the impact crater to a distance of approximately 450 metres.

Further examination of the wreckage indicated that all four engines had been developing high power when the aircraft hit the ground and it was possible to confirm that the landing gear was retracted. Examination of the trailing edge flap actuators indicated that the flaps were in the take-off position of 10·; the condition of the limited wreckage recovered from the leading edge flaps was consistent with them having been extended.

The wreckage investigation and recovery is ongoing and has now resulted in the recovery of the Flight Data Recorder (FDR) and some primary flight instruments, including an ADI.

Radar recording

A radar recording was available from the Stansted Watchman radar. Based on the transponder setting of 2230 with mode C selected, the first return was just past the centre-point of the runway indicating an altitude of 660 feet amsl; airport elevation is 348 feet amsl. At the end of the runway, the aircraft was at approximately 1,200 feet amsl. It maintained a track close to the extended runway centre-line before turning to the left. The radar returns cover a period from 1837.46 hrs to 1838.36 hrs; the last return indicated an altitude of 1,060 feet amsl. The maximum altitude achieved was recorded as 2,460 feet amsl and the rate of descent, from the highest point to the last return, exceeded 5,000 feet per minute. Additionally, the ground speed increased after the highest point achieved, with the maximum speed calculated to be 228 kt over the last two radar returns. The southerly wind and the aircraft change in heading from Southwest, through South to East, would have affected the ground speed.

Flight Data Recording

The FDR, a Sundstrand Universal Flight Data Recorder (UFDR) was successfully replayed. It had a recording duration of 25 hours using magnetic tape and amongst the parameters recorded was altitude, heading, pitch attitude, engine power, control wheel position and roll attitude. The roll attitude data was obtained from the No 1 Inertial Navigation Unit (INU). The data covered the period of the accident flight and two other flights; the roll attitude data for the accident flight and the previous flight showed a constant roll attitude of around wings level.

The data showed the aircraft take-off and climb, initially on runway heading. It reached an altitude of 2,150 feet amsl, 37 seconds after take-off, when it commenced a left turn. The pitch attitude then started to decrease and continued to decrease in a continuous turn to the left until the end of the data. The maximum

altitude reached was 2,532 feet amsl, 11 seconds before the end of the data. The data ended 55 seconds after take-off. The final recorded data indicated an altitude of 967 feet amsl, with a pitch attitude of 38· nose down on a heading of 126·M. Throughout the short flight all four engines were developing power at, or close to, the take-off setting of 1.4 EPR.

The CVR, a Sundstrand AV557C was replayed and contained a 30 minute recording of R/T transmissions and sound from an area microphone which included crew conversation. The recording commenced at the time 'Stansted Tower' instructed KAL 8509 to standby for push back clearance and continued to the time of the crash. The speech was a mixture of Korean and English. The investigation benefited from the assistance of a member of the Republic of Korean Civil Aviation Bureau, appointed, by the Korean Accredited Representative to the AAIB investigation, to assist in translating the text and interpreting the nuances of the crew speech.

There was no recording of any departure brief, however, company procedures required this to have been completed prior to pushback. All 4 engine starts were normal and the after start and pre take-off checks were completed without any stated problems. During the taxy, the commander commented on the fact that his DME was displaying 399 nm and the first officer confirmed that he had a similar indication. The commander then asked how they would identify the 1.5 nm DME distance (for the departure SID) and the flight engineer replied that, "now it was working correctly".

Following take-off clearance, the commander called "Rolling" and the flight engineer gave a time check of "37". Standard calls were made during the take-off run. Then, following a call of "positive climb", the landing gear was selected up and the first officer set the IAS as requested by the commander. After the first officer called the altitude as 900 feet, the ADI 'Comparator' buzzer sounded three times. Shortly afterwards, the warning sounded a further two times, coincident with the commander expressing concerns over his DME indication. There was then an input from the first officer about the heading of 158· (SID track to Detling VOR). At the same time, ATC instructed the crew to contact 'London Control' and the 'Comparator' warning sounded again some 9 times. This occurred about 21 seconds before the end of the recording. During this final period, the flight engineer made two calls of "Bank", and the first officer made a radio transmission acknowledging the frequency change.

Previous flight

The three-man crew that had taken over the aircraft at Tashkent, had met the off-going crew and confirmed that the aircraft was serviceable on the previous sector from Seoul. The commander was the handling pilot and he used full power for the take-off from Runway 08 Left at Tashkent, where the departure required a right turn at 1,000 feet amsl onto a heading of 257· M. Take-off was at 0729 hrs UTC (1229 hrs local); the weather was good with no cloud, but visibility limited to 3,600 metres in smoke.

As the commander made the right turn after takeoff the ADI 'Comparator' warning triggered; his recollection was that the buzzer sounded, the 'ATT' flag appeared on his ADI, the Instrument 'Warn' flashing red and 'ATT' steady amber lights illuminated. When the warning activated, the commander looked at both the standby horizon and the first officer's ADI and realised that his own ADI indication was in error. He instructed the first officer to take control. Once he had done so, the commander selected his ATTITUDE/COMP STAB switch to ALT. After approximately 5 seconds, his ADI indicated correctly and the warnings disappeared.

This instrument configuration was retained until the aircraft was level and steady in the cruise at an altitude of 9,600 metres. The commander then reselected NORM on the ATTITUDE/COMP STAB switch. In that configuration, the captain's ADI appeared to indicate correctly with wings level but, for turns in either direction the instrument continued to indicate wings level. From take-off and throughout the flight with NORM or ALT selected, the pitch indication appeared to be reliable. The commander returned the ATTITUDE/COMP STAB switch to ALT and left it there for the rest of the flight. There were no other problems with the aircraft.

On arrival on 'Stand Alpha 6' at Stansted, the crew made an entry into the Technical Log including the phrase: 'Captain's ADI unreliable in roll'; the flight engineer had used the 'Fault Reporting Manual' and 'Fault

Codes' for the correct terminology. The commander returned his ATTITUDE/COMP STAB switch to the NORM position before leaving the aircraft. An operator's ground engineer met the aircraft and the flight engineer explained to him the effect of selecting ALT on the captain's ATTITUDE/COMP STAB switch. The inbound flight crew did not meet with any of the outbound crew.

Inertial Navigation System and Attitude Director Indicators

The aircraft was equipped with three independent Inertial Navigation Systems (INS). Each INS computed navigation data and sensed the aircraft displacement in pitch, roll and azimuth from local horizontal and vertical references. Output signals from the INS were used for a variety of navigation functions and to provide input to the captain's and first officer's ADIs. Each INS had an Inertial Navigation Unit (INU) located in the main equipment centre, a Control Display Unit (CDU) on the centre console and a Mode Selector Unit on the Overhead Panel.

A set of Navigation Transfer Switches was located at the bottom of each of the captain's and first officer's Instrument panels, both included a two position ATTITUDE/COMP STAB switch. With both switches selected to the guarded NORM position, the captain's ADI received its attitude information from INU No 1 and the first officer's ADI received its attitude information from INU No 2. Either pilot can switch his ADI data source to INU No 3 by selecting from NORM to ALT on the ATTITUDE/COMP STAB switch.

A comparator module monitored the pitch and roll indications on the two ADIs; a warning would be triggered if a difference of 4 degrees was detected in either axis for more than one second. The warning consisted of flashing red instrument 'warn' lights and amber 'ATT' lights on the instrument panels in front of each pilot**.** The subject aircraft was additionally equipped with a warning buzzer, incorporated in production. If the 'Warn' light was to be pushed, the 'Buzzer' would cancel, the 'Warn' light extinguish and the 'ATT' light dims. The 'ATT' lights would remain until the bank and/or pitch difference returned to less than 4·.

In the event of an ADI disagree, the pilots could refer to a standby attitude indicator, which was an independently powered, self-contained gyro instrument, located on the left side of the Centre Instrument Panel.

Pre-flight maintenance

The aircraft had arrived on Stand at 1505 hrs. During the subsequent turnround, the operator's ground engineer was involved in rectification of the reported instrument fault. However, he was fatally injured on the accident flight; additionally, no copy of the Technical Log for the flight from Tashkent to Stansted was left at Stansted. The result was that there was no record of what the ground engineer entered in the Technical Log to clear the fault and no way of knowing if he briefed the on-coming commander about the fault.

A maintenance company at Stansted had a contract with the operator to provide engineering support for turnround and rectification of their aircraft. When HL-7451 arrived on Stand, a licensed engineer was tasked with attending the aircraft. After checking the oil levels, which were satisfactory, he completed a 'Walk around' before going up to the flight deck where he met an operator's engineer, whom he had previously noticed also doing a 'Walk around'. The two engineers confirmed the oil checks and then left the flight deck to complete the operator's Boeing 747 transit checklist; each item on the checklist was designated T1, T2 or T3 and required a signature. The local engineer stated that the operator's engineer asked him to cover the T2 and T3 checks and that he, the operator's engineer would complete the two T1 checks. The T1 checks were to: 'Accomplish final walk around inspection' and 'check the maintenance and flight log and rectify all flight squawk items'.

Then, as the local engineer was about to leave to complete his checks, the operator's engineer took him back to the flight deck because the incoming crew had reported an aircraft defect. The operator's engineer gestured towards an entry in the Technical Log and then towards the Captain's ADI and reportedly said that he wanted the appropriate tools to remove the ADI and cleaning fluid to clean the connectors. The local engineer looked at the entry and saw that it related to a defect with the captain's ADI but could not recall the precise wording. He did recollect the words 'unreliable indication', 'normal' and 'alternate' but was unsure if these were written in the Technical log or mentioned in conversation. However, as avionics was not his

discipline he was not able to judge the nature of the fault. Nevertheless, as the task of removing the ADI was straight forward, he went to his van for tools before returning and removing the ADI. During the latter part of this task, the operator's engineer sat in the first officer's seat and watched the procedure. Then, with the ADI removed the operator's engineer noticed that Socket No 2 on the smaller plug had been pushed back and he seemed to indicate that he felt this was significant. At that point, the local engineer stated that he would contact an avionics engineer with the necessary tools and expertise to reseat the socket. He contacted a colleague who could attend in about half an hour.

On his arrival, the avionics engineer went to the flight deck and met the operator's engineer. His recollection was that the operator's engineer pointed to the hole in the instrument panel where the captain's ADI should be and said that: 'there is a push back pin and can you reset it?' The avionics engineer was confident that he fully understood the request. He examined the connectors and identified a pushed back socket, 'Socket No 2 of the Small Connector'. After going to his vehicle for a special tool, he returned and heard the distinctive 'click' as the socket was relocated in position. He confirmed the remedial action by connecting the ADI and then disconnecting it and checking both of the plugs and sockets; he then reconnected the ADI and located it in the instrument panel. Prior to testing the instrument, he turned on all three INS. About this time, another operator's employee wearing flight crew uniform came to the flight deck and sat in the first officer's seat. There was some problem with inserting the 'present position' into the INS and this individual successfully carried out that action. Thereafter, the avionics engineer was aware of the 'ATT' flag on each ADI retracting from view but not simultaneously and therefore causing the 'Comparator' warning to activate; he heard an audio warning and saw a visual warning. He then pressed the 'Test' button on the captain's ADI and saw the correct instrument response, which also activated the 'Comparator' warning. The test was repeated with the same results with the ATTITUDE/COMP STAB switch in ALT. He then secured the ADI to the instrument panel before successfully testing it a further time in NORM. Following a check that the captain's instrument lights were serviceable, the avionics engineer asked the operator's engineer, who had been watching throughout the procedure, if he could be of any further assistance. He replied that he did not require any further help. At an early stage in the rectification, the avionics engineer had asked what the problem was and was shown the Technical Log entry; he recalled the entry as: 'The captain's ADI unreliable in roll'. He also stated that the operator's engineer said that he would complete the Technical Log.

Future activity

The Chief Inspector of Air Accidents has ordered an Inspector's Investigation into the circumstances of the accident under provision of the Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996.

Work at the accident site continues to recover and identify, flight instruments, avionics boxes and other electrical equipment. Work has already begun, in co-operation with all relevant organisations, to reinstate the landscape to its original condition.

Further areas of focus for the ongoing investigation will include efforts to refine the CVR and FDR data; more detailed consideration of the INS and ADI systems failure modes and warnings; detailed review of the maintenance activity at Stansted; review of the operator's engineering and flight crew training practices and standard operating procedures.