ACCIDENT

Aircraft Type and Registration:	Airbus A320-232, G-EUUF
No & Type of Engines:	2 International Aero Engine V2527-A5 turbofan engines
Year of Manufacture:	2002
Date & Time (UTC):	26 June 2006 at 1645 hrs
Location:	Taxiway Kilo, London Heathrow Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 7 Passengers - 83
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to right engine and to tractor
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	51 years
Commander's Flying Experience:	16,022 hours (of which 4,122 were on type) Last 90 days - 186 hours Last 28 days - 37 hours
Information Source:	AAIB Field Investigation

Synopsis

After an uneventful pushback from Stand 139 at London Heathrow Airport the tractor was disconnected from the aircraft. After receiving taxi clearance from Air Traffic Control G-EUUF started moving under its own power. Shortly afterwards it collided with the tractor that had just performed the pushback, damaging the right engine and the tractor. The headset operator had given the 'all clear' signal to the flight crew before the tractor had been repositioned to a safe distance from the aircraft. The co-pilot did not see the tractor and a defect prevented the tractor from being driven away before the aircraft began to taxi.

History of flight

The aircraft was prepared for a routine departure from London Heathrow Airport to Munich, Germany. There was no significant weather and good visibility. Due to ATC delays the pushback was delayed for ten minutes. Once ATC clearance was received the aircraft was pushed back from Stand 139 onto Taxiway Kilo. ATC requested a long pushback to allow another aircraft onto Stand 139. This meant that the aircraft would need to be pushed back into the narrower part of Taxiway Kilo, abeam Stand 118 and adjacent to a blast wall on the right side (Figure 1 - Airport diagram).

The pushback, during which both engines were started, proceeded without incident until the headset

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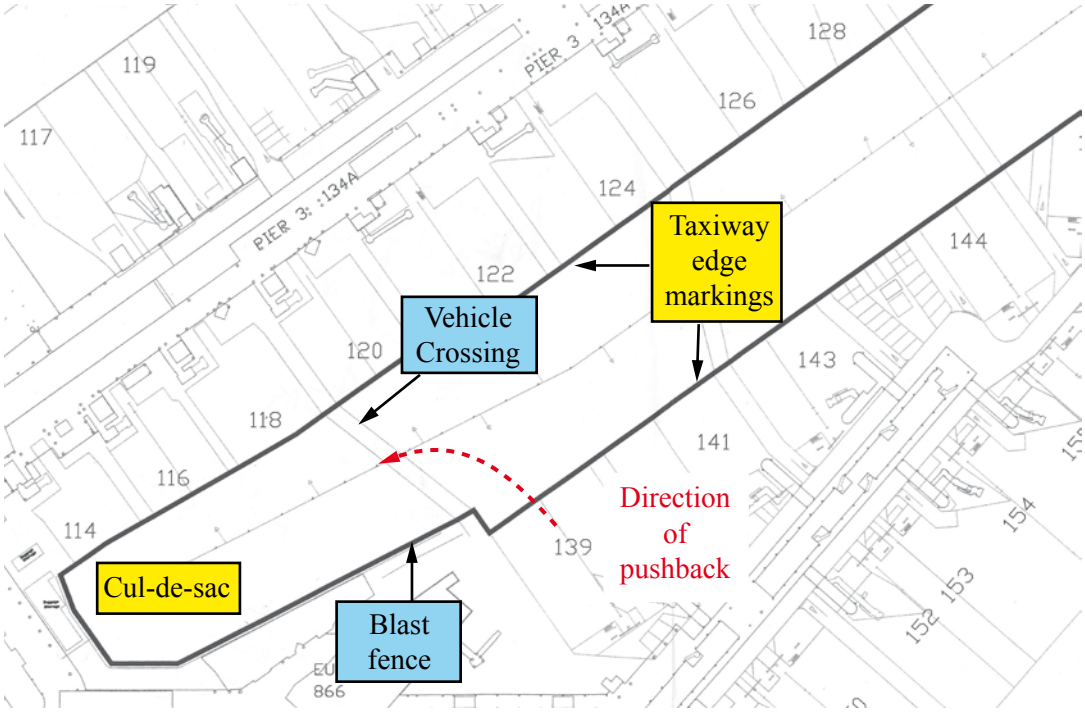

Figure 1

Plan of cul-de-sac, showing pushback details

operator (HO) requested that the commander apply the parking brake. On receiving acknowledgment from the commander that the parking brake was set the ground crew disconnected the 'towbarless' (TBL) tractor from the aircraft and the tractor driver moved it to the right side of the aircraft's nose. Having disconnected his headset, the HO removed and showed the steering lockout pin to the flight deck, received the correct acknowledgement from the co-pilot and got into the tractor.

As the HO entered the cabin of the tractor, the driver informed him that the 'cradle up' indicator light was not illuminated and that it was not possible to move the tractor. At this point the HO and the driver heard the aircraft's engines start to increase power and saw the aircraft start to move. They both got out of the tractor in an attempt to indicate, with hand signals, that they wanted the aircraft to stop as the tractor was not clear of the aircraft manoeuvring area. It became apparent that the flight crew were not looking in their direction and thus could not see their signal. They both returned to the tractor to make another attempt to move it and also for their own protection. The aircraft continued to move forward and the underside of the right engine struck the rear of the tractor, pushing it into the middle of the vehicle crossing point between Stands 139 and 118/120. The aircraft continued to taxi along Taxiway Kilo.

The ground crew believed the operating crew were unaware of the impact so the tractor driver contacted ATC and asked them to stop the aircraft. ATC then informed the operating crew of G-EUUF of the accident and instructed them to stop in their present position. The commander stopped the aircraft and applied the parking brake. The Aerodrome Fire & Rescue Service (AFRS) attended and the right engine was shut down and the APU started. After clearance from the AFRS

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was received the aircraft taxied to Stand 158 where the remaining engine was shut down and the right engine fire handle operated, to isolate the engine as a precaution after smoke was reported from the engine jetpipe.

Operating crew's comments

Commander's comments

The commander stated that, prior to the pushback, the boarding and dispatch of the aircraft proceeded without haste and uneventfully. When ATC instructed the crew to carry out a long pushback the commander asked why and was told: it was to allow an Airbus A320 onto Stand 139.

Both engines were started during the pushback. The commander later recalled that, after the pushback was complete, the headset operator asked for the parking brake to be applied. Upon informing the HO that the brake was applied, the commander was advised by the HO that the visual clearance would be given on the right of the aircraft. At this point the commander asked the co-pilot for the 'After Start' checklist. This was completed up to 'GROUND CREW CLEARANCE……RECEIVED.' At this point the co-pilot waited for, and shortly received, the visual clearance from the ground crew. As the commander could not see the tractor or HO from his seat he was reliant on the co-pilot in this situation. The 'After Start' checklist was then completed and taxi clearance was requested and received from ATC.

After the operating crew visually cleared the left and right sides of the aircraft the commander released the parking brake and applied a small amount of power to start the aircraft moving; he then checked the operation of the foot brakes. At that instant he heard a "graunching" sound, but was not sure where it had come from. He asked the co-pilot "What was that?", thinking they had taxied over an object on the taxiway. All engine parameters were checked, found to be normal and the tyre pressures were indicating correctly. No abnormal indications were noted, nor did the aircraft slow down or yaw with the impact. The taxi continued and a discussion took place between the two pilots regarding the event. They decided that, prior to taxiing from the cul-de-sac, an inspection by engineering would be required. Just as the commander was about to transmit a request for ATC to dispatch a vehicle to inspect the aircraft, he heard a transmission advising ATC to stop an aircraft as it had hit a tractor. Realising they were the aircraft involved, the crew stopped the aircraft and applied the park brake. At the same time ATC advised them to stop the aircraft in its present position, abeam Stand 144, and that the emergency services were on their way.

After stopping, the crew again noted that all engine indications were normal. When the AFRS arrived the commander established communications with them on radio frequency 121.6 MHz. The AFRS asked for the right engine to be shut down to aid their inspection. Upon inspection of the engine the AFRS reported significant damage but no fuel leaks. Having secured the engine and discussed with the AFRS that the engine appeared safe, it was agreed that the aircraft could be moved. The aircraft was then configured for a normal single-engine taxi to Stand 158.

On arrival on stand the left engine was shut down and the right engine fire handle operated after smoke was reported from the engine jetpipe. When the aircraft was on stand, with the jetty attached and passenger door open, the Police entered the flight deck and breathalysed both operating flight crew. The result of the breathalyser proved negative for both pilots.

Co-pilot's comments

The co-pilot stated that when he looked to his right to "Clear starboard" he did not see the tractor in his

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field of view. He predominately looked from his "three o'clock" rearwards to clear the aircraft's wing tip as he was aware of the proximity of a blast screen to the right of the aircraft.

Ground crew's comments

Headset operator (HO)

The HO stated that he had been working in this role for the past 4½ years and was fully conversant with the airline's procedures for pushback, contained in the Aircraft Towing and Pushback Manual (ATPM).

On the day of the accident he started work at 0515 hrs and was scheduled to do an eight hour shift plus overtime, to finish at 2045 hrs. He added that he had been working with the tractor driver involved in this accident throughout the afternoon and all other pushbacks had proceeded uneventfully.

He reported that a normal pushback from Stand 139 involves the aircraft being pulled forward to abeam the stand after the initial push, prior to disconnecting the tractor and signalling it to withdraw from the manoeuvring area. If a long pushback is required the tractor stops very close to an uncontrolled vehicle crossing point. In this situation, traffic should stop at the edge of the taxiway and wait for the aircraft and ground manoeuvring equipment to clear the crossing point before proceeding to cross.

Normally, a third member of the pushback team would be used to stop the traffic. However, the HO commented that, if a third man were not available, then some vehicles would stop while others would continue across the crossing. This might even involve vehicles overtaking waiting traffic and swerving off the marked crossing in order to get around the aircraft and tractor that might be parked across the crossing. The reason he did not signal the tractor to withdraw to the edge of the manoeuvring area was so he could be offered some protection by the tractor from crossing traffic. He added that he had performed long pushbacks from Stand 139, as he did in this accident, "lots of times."

Tractor driver

The tractor driver reported that he was not aware of any previously reported faults when he picked up the tractor at the beginning of his shift.

Weather information

The Met Office provided an aftercast for the time of the accident. The METAR published 30 minutes before the accident stated that the weather was light rain with visibility in excess of 10 km. The METAR issued five minutes after the accident stated that there was no significant weather and the visibility was in excess of 10 km.

Aircraft and tractor damage

The aircraft and tractor were examined at Stand 158, where they had been positioned following the accident.

The underside of the engine inlet cowl, fan cowl and thrust reverser 'C'-duct of the aircraft's No 2 (right) engine were badly damaged (Figure 2) from contact with the rear of the tractor. Scoring on the lower right side of the engine cowls correlated with blue paint transfer and score marks on the tractor legs. From these marks, it was deduced that the tractor had been positioned on the right side of the aircraft, with its longitudinal axis oriented between 70 and 80 degrees to the right of the direction of travel of the aircraft, with the rear of the tractor in line with the No 2 engine.

The engine had initially grazed the right leg of the tractor (aft, looking forward), scoring the lower right side of the

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Figure 2

Damage to No 2 engine caused on impact with tractor

cowls, before riding over the top of the left leg, which caused more extensive damage to the underside of the engine. A piece of the thrust reverser 'C'-duct aluminium structure was found embedded in the reinforcing rib on the top of the left leg of the tractor.

The damage to the tractor was largely confined to its left leg. The force of the No 2 engine bearing down on the leg had deformed the wheel spat which is manufactured from 10 mm steel plate, reinforced by a stiffening rib. Two of the mounting bolts attaching the wheel spat to the chassis leg had also sheared.

Flight Recorders

The aircraft was fitted with a solid-state 25-hour Flight Data Recorder (FDR) recording a range of flight parameters from the time of engine start. The aircraft was also fitted with a solid-state two-hour Cockpit Voice Recorder (CVR) which recorded crew speech and area microphone inputs when electrical power was applied to the aircraft. Both recorders were downloaded at the AAIB and data and audio recordings were recovered for the accident.

A 'time history' plot of the relevant parameters is given at Figure 3. The data presented at Figure 3 starts after pushback, with the park brake set and starting checks complete, just over 10 seconds before G-EUUF started moving forward under its own power.

G-EUUF was cleared to turn right at 'Bravo' and hold at 'Bravo-One'. The crew then stated that the view from their respective sides of the cockpit were clear of obstacles, after which the park brake was released. Five seconds later the thrust levers[1] were advanced for six seconds, resulting in a peak EPR of just less than 1.02, just as the thrust levers were brought back to idle. As G-EUUF started to move forward and gradually accelerate, it also started a gentle turn to the right from its initial heading of 064ºM. Eight seconds later the aircraft had accelerated to about four knots, after which the foot brakes were applied

Footnote

[1] For clarity, only the thrust lever position (angle) for the right-hand engine is shown but this is also representative of the left-hand engine. Similarly, only the EPR for the left-hand engine is shown.

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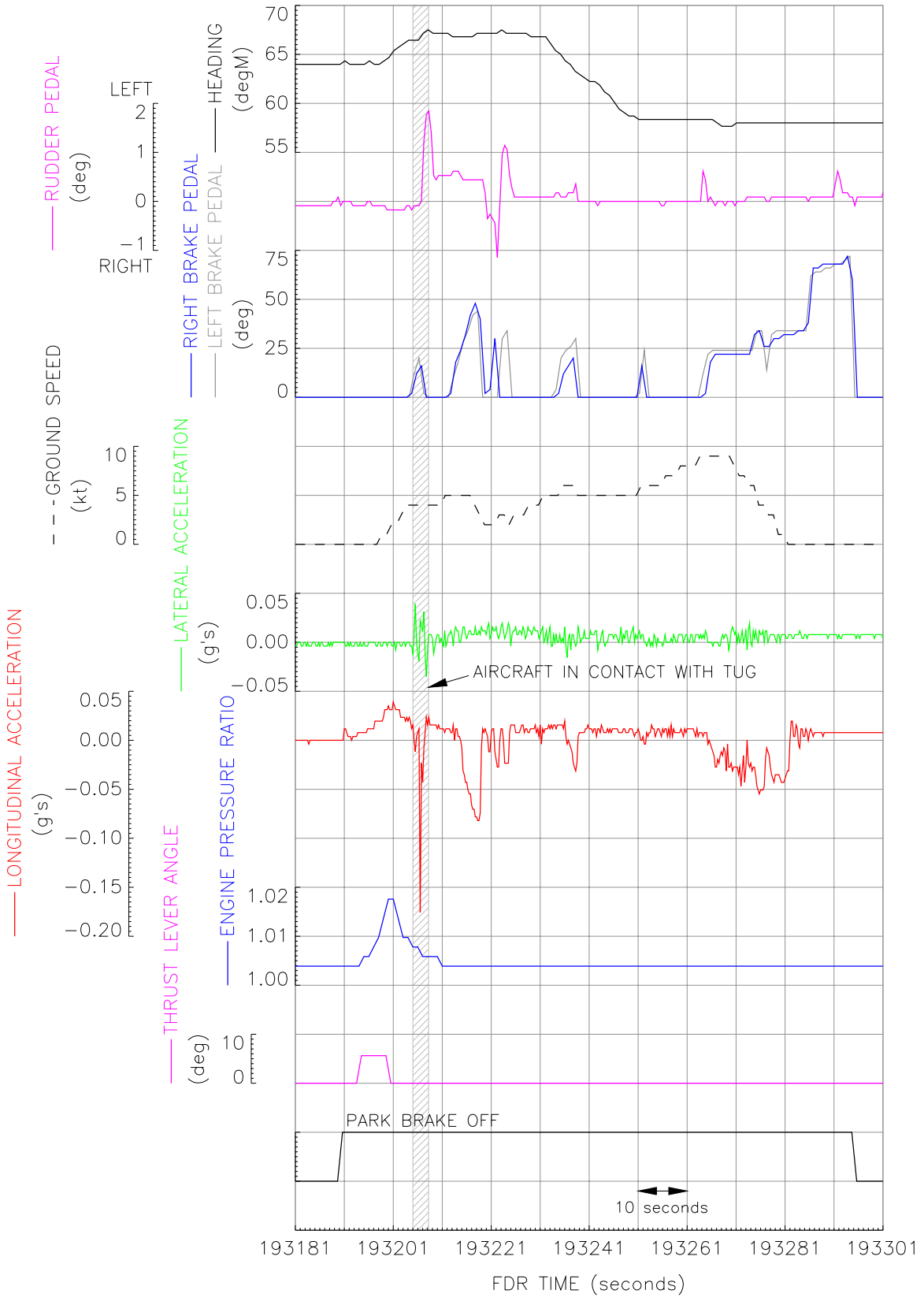

Figure 3

Salient FDR Parameters

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momentarily as the commander performed a brake check. During this check G-EUUF struck the tug - indicated by spikes in both lateral and longitudinal acceleration over a three second period (highlighted). This jolt was also noted by the crew. A small amount of left pedal was applied immediately after the collision, lining the aircraft up on a heading of 067ºM, followed by braking which decelerated the aircraft to about two knots. The distance travelled before the collision was calculated to be 13 m.

G-EUUF then accelerated forward before starting a turn to the left onto a heading of 058ºM, following the bend in the taxiway. It continued to accelerate to nine knots whilst the crew discussed the possible reasons for the jolt, before being informed by ATC that they had collided with the tug. The brakes were then applied bringing the aircraft to a stop, after which the park brake was applied. The total distance covered by the aircraft was calculated to be approximately 150 m over a period of 105 seconds.

Published pushback procedures

The airline's procedures for pushback are contained in the Aircraft Towing and Pushback Manual (ATPM).

The ATPM procedure once the aircraft has been released by the tractor after pushback and the aircraft parking brake has been applied, is as follows:

'36) Headset operator signals tug driver to pull away a minimal distance[2] from the aircraft (to position in full view of the flight deck - this may require the tug to be at an angle to the A/C).

37) Position a chock in front of the nose wheel.

Note:

Tug position and chocking.

These actions are to prevent the A/C moving away until all ground crew and equipment are clear. The tow crew will also provide fire cover while the engines are started on completion of push out.'

38) On completion of the movement, the cradle must be closed and raised, and the driving position rotated to face the direction of travel.

39) Torque links, re-connected by Engineering as appropriate.

40) Remove steering lockout pin and or set Nose Gear Steering mechanisms for taxi as required by specific A/C type.

41) When clearance from flight deck is given, disconnect headset lead from A/C and close panel.

42) Remove the nose landing gear wheel chock and place on tug.

43) When all crew clear of the nose leg, headset operator signals tug driver to move off manoeuvring area (two arm forward sweep).

44) Ground crew walks to edge of taxiway, in line with nose of A/C.

45) Headset operator displays steering isolation pin and flag to the flight deck crew (as appropriate to A/C type), gives visual sign (thumbs up) that all towing crew and equipment are clear of the A/C and that it may taxi away when given clearance by ATC.'

Footnote

[2] The tractor is deliberately placed so as to block the path of the aircraft, to protect the headset operator if the aircraft should begin to taxi prior to receiving clearance.

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Aircraft tractor information

The tractor, chassis number N4345 and fleet number AT0858, was a Douglas-Kalmar Tugmaster Type TBL280 Mark 2 'towbarless' tractor (Figure 4). This type of tractor clamps onto the nosewheel of the aircraft, eliminating the need for a tow bar.

Figure 4

Post-accident photograph of Tractor AT0858
(Stand 139 in background)

The front of the vehicle contains the cab, with the engine and gearbox being mounted in the mid-section. The driver's seat can be positioned to face forwards for towing and rearwards for pushback operations. A hydraulically-operated docking cradle is located at the rear of the vehicle, mounted between the chassis legs. A gate, which is hinged at one side, opens to allow the tractor to engage with the aircraft's nosewheels and is then closed, securely clamping them in the cradle. The entire cradle is then raised, lifting the aircraft nose gear off the ground by several inches, in preparation for towing or pushback. The sequence is reversed to release the nose gear from the cradle. The cradle is operated by a joystick located in the cab. Sensors detect when the cradle is in the raised or lowered position, causing the corresponding 'cradle up' or 'cradle down' indicator light in the cab to illuminate.

The tractor may be driven with the cradle either in the raised position, with the gate closed, or in the down position and the gate open. Drive to the wheels is electronically inhibited with the cradle or gate in any other position. A 'drive inhibit' override button located under the steering wheel allows the inhibit feature to be bypassed, so that the tractor can still be driven if there is a cradle malfunction.

The 'cradle raised' and 'cradle lowered' sensors are of the proximity switch type. An 'L'-shaped bellcrank (called the 'boomerang') is mounted in front of the sensors, one arm of which forms the target for the sensors (Figure 5). The other arm is connected to an adjustable operating rod, which converts the vertical movement of the cradle into rotation of the boomerang. The proximity sensors are mounted in locations that correspond to the positions of the target arm of the boomerang when the cradle is in the raised and lowered positions. The position of each sensor is adjustable.

The operation of raising the cradle is relatively slow and it is reported that tractor drivers often 'rev' the engine when raising the cradle, as this speeds up the movement of the cradle through the increased hydraulic flow to the actuators.

The tractor is predominantly blue and white in colour, but a significant area of its upper surface is covered with a dark grey anti-slip material. There is also a flashing orange beacon mounted on the top of the cab.

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Tractor examination

The tractor was required to be moved from the accident location, as it was blocking both the taxiway and the vehicle crossing. The recovery crew who attended the tractor observed that the cradle was in the up position, but the 'cradle down' indicator light was lit. The drive was inhibited and the tractor could only be driven using the 'drive inhibit' override button. It was recovered to Stand 158, where it was first examined by the AAIB.

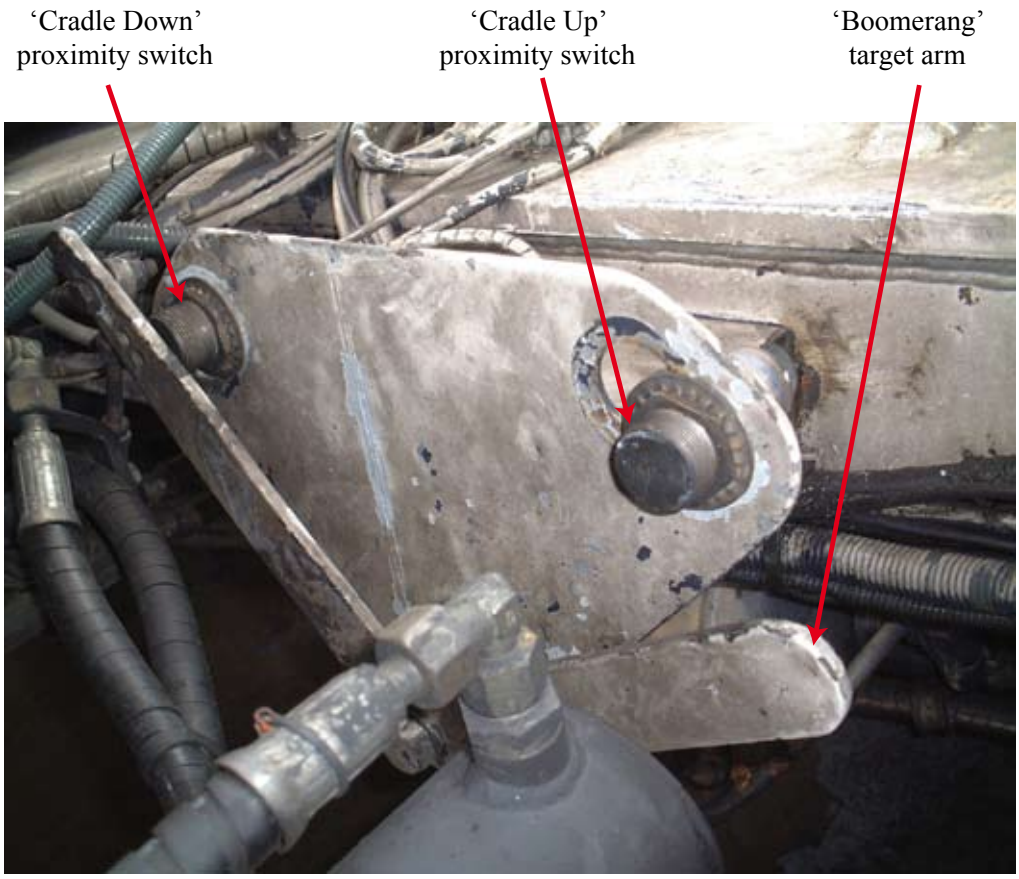

Figure 5

Cradle position sensor location showing 'boomerang' overtravel

On closer inspection, the target arm of the boomerang was found to have travelled past the 'cradle up' proximity sensor, to the extent that the boomerang operating arm was triggering the 'cradle down' sensor (Figure 5). During testing, it was found that the cradle overtravel could be reproduced occasionally if the tractor engine was 'revved' whilst raising the cradle. The defect was cured by adjusting the 'cradle up' and 'cradle down' proximity switch air gaps to the manufacturer's specified gap of 4 mm and reducing the hydraulic fluid flow rate to the cradle rams to slow the cradle raise speed. Following these adjustments, it was no longer possible to reproduce the fault.

The 'cradle raised' indicator light was also found to be missing its lens and the light was intermittent in operation. This was repaired by installing a new lamp holder.

The 'drive inhibit' override function was tested and found to operate satisfactorily.

Tractor maintenance history

A review of the maintenance history did not identify any previous recorded occurrences of the cradle overtravel problem.

The tractor was required to undergo a comprehensive inspection every six weeks. The most recent inspection prior to the accident took place on 19 May 2006. During this inspection, the 'cradle raised' height was found to be too low. One of the boomerang mounting bracket bolts was found sheared, requiring replacement. This

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was actioned and subsequent cradle checks proved satisfactory.

Tractor maintenance and defect reporting

The allocation of tractors to the crews and the logging of tractor defects is the responsibility of the 'duty allocators', based in the airline's Aircraft Movements department. The tractor drivers and headset operators working in this area of the airport are also based there. The duty allocators have face-to-face contact with the tractor crews and are also able to communicate with them via radio.

Although the tractors are owned and operated by the airline, their repair and maintenance is subcontracted to a separate organisation. This organisation has a number of mobile mechanics who are responsible for repairing the more urgent defects. A tractor with a drive failure which is blocking an aircraft or a taxiway, is an example of a situation that would warrant an immediate response. If the defect cannot be repaired *in situ*, the tractor is recovered to the maintenance organisation's workshop, which is remote from the ramp area.

When a tractor defect is reported, the duty allocators are required to log the defect on an electronic database, which is also accessible by the subcontract maintenance organisation. The defects are allocated a priority to assist the subcontract organisation in planning its work.

There was anecdotal evidence of another crew having experienced cradle problems with tractor AT0858 on the morning of the day of the accident. They had experienced an intermittent problem of difficulty in raising the cradle and on one occasion it was necessary to use the 'drive inhibit' override button to move the tractor. Although the problem was allegedly reported to the duty allocator, the AAIB could find no record of it in the defect tracking database.

Pushback/towing crew training

The training of the airline's tractor drivers and headset operators is currently performed by the airline's Airport Operations Training department.

The department is responsible for the initial training of tractor drivers and headset operators and also for conducting the three-yearly revalidation of headset operators. The revalidation requires the headset operator to be checked by a Line Trainer, who will monitor the headset operator on two aircraft pushback operations.

Tractor drivers are not required to undergo revalidation.

Monitoring of pushback and towing standards

The monitoring of the standards for towing and pushback was previously the responsibility of the former Ramp Standards and Training Department. However, some time ago this function was devolved to the Aircraft Movements department, which is currently responsible for aircraft pushback and towing operations, in addition to toilet servicing and aircraft external cleaning.

Annual audits of the ground operations activities, including pushbacks, are performed by the Heathrow Customer Service (HCS) department of the airline. There is currently no established requirement to monitor the day-to-day standards and compliance with procedures. The most recent HCS audit, conducted in late 2005, concluded that the management of health and safety standards within the Aircraft Movements department did not meet the corporate standard. This was deemed to be largely due to the lack of supervisory staff in the ramp area, which had allowed staff to lose sight of the importance of health and safety procedures. This was a general conclusion with respect to all of the Aircraft Movements department's activities and some shortfalls were found in the pushback and towing activities.

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Accident reconstruction

The accident was reconstructed with the cooperation of the airport and the airline. Due to congestion it could only be carried out during the hours of darkness.

The purpose of the exercise was primarily to establish, as accurately as possible, with the help of eyewitnesses, the position of the aircraft and the tractor before the aircraft started taxiing. Once placed in their respective positions, the visibility of the tractor from the co-pilot's seat was assessed.

The exercise showed that if the co-pilot had been sitting upright in his seat, most of the tractor would have been visible to him through his side window. However, if he had been leaning forward in his seat, the tractor would have been largely obscured by the pillar between the co-pilot's windscreen and his side window.

Analysis

When the co-pilot saw the HO show him the nosewheel lockout pin, the HO was just visible in the left hand edge of the right hand window. However, having completed the 'After Start' checks, which included changing the view on the lower ECAM screen, the co-pilot's body position would most likely have been more leaning forward. As a result, the tractor could have been concealed behind the window frame upright. Given that the colouring on the tractor's upper surface was similar to that of the taxiway, there may have been some camouflaging effect, making it less visible to the co-pilot. There had been some rain in the previous 30 minutes and this may also have affected the likelihood of the co-pilot spotting the tractor through his side window.

Additionally the co-pilot's 'clear starboard' lookout scan would have been predominately to look for wing tip clearance. The co-pilot reported that he was concerned by the proximity of the adjacent blast screen and, as a result, he would have been leaning forward, to rotate his upper torso to see as far rearwards as possible, probably starting his scan no further forward than his three o'clock position.

While the HO's reason for not completing the pushback in accordance with the ATPM may have been due to traffic failing to stop at the taxiway crossing point, had he used the published procedure the problem with the tractor would have been highlighted earlier. He thus might have still had his headset connected to the aircraft and could have then informed the operating crew of the problem, avoiding this accident.

The accident might also have been avoided had the tractor not experienced a defect with the cradle, which caused the drive to be inhibited. It is believed that another tractor crew had reported intermittent problems with the cradle operation earlier that day, but the defect was not entered on the defects database and thus no rectification action was taken. This may have been an isolated lapse but it is also possible that the defect recording procedures were not being strictly followed.

It is also noted that, even with the cradle defect, the tractor could still have been moved out of the path of the aircraft had the tractor driver immediately used the 'cradle override' button. His decision to leave the cab robbed him of valuable time so that, by the time he returned to the cab, the collision had become unavoidable. In hindsight a better option would have been to have immediately used the override button in order to position the tractor clear of the aircraft as quickly as possible.

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Conclusions

The primary causal factor of the accident was the headset operator giving the 'all clear' signal to the flight crew before the tractor had been repositioned to a safe distance from the aircraft. Contributory factors were the co-pilot failing to see the tractor and a defect which prevented the tractor from being driven away once the aircraft had begun to taxi.

Safety Actions applied by the airline

Following the incident, the airline's Corporate Safety Department conducted its own investigation into the accident. The investigation made several recommendations for changes to procedures to prevent similar accidents in the future. Key recommendations included:

- that Aircraft Movements should ensure that the headset operator, prior to giving the 'thumbs up' clearance, must positively confirm that the aircraft is clear of all ground equipment and is clear to taxi.

- that the airline should have a stronger and more visible supervisory presence on the ramp to improve the safety and security of both aircraft and staff by controlling and enforcing adherence to procedures.

- that Flight Operations should circulate the event through the flight crew community highlighting the requirement to ensure that all ground equipment is clear prior to taxi.

In light of these safety actions by the airline, it is not deemed necessary for the AAIB to make further safety recommendations.

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