ACCIDENT

Aircraft Type and Registration:	EMB-145EP, G-CKAG	
No & Type of Engines:	2 Rolls-Royce AE3007A1 turbofan engines	
Year of Manufacture:	1998 (Serial no: 145118)	
Date & Time (UTC):	22 December 2017 at 1137 hrs	
Location:	Runway 27 at Bristol Airport	
Type of Flight:	Commercial Air Transport (Passenger)	
Persons on Board:	Crew - 3	Passengers - 22
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Left main landing gear fairing strut broken; wheel rims and tyres damaged	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	50 years	
Commander's Flying Experience:	8,600 hours (of which 5,100 were on type) Last 90 days - 97 hours Last 28 days - 51 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The flight crew were conducting an ILS Category II[1] approach and landing on Runway 27 at Bristol Airport. On touchdown they noticed that the aircraft de-rotated sharply. The pilot flying (PF) was unable to maintain directional control during the landing roll and the aircraft ran off the left side of the runway onto the grass. At some point during the landing the throttles were moved forward, reducing the rate of deceleration. As the aircraft left the paved surface the crew realised that the landing had been carried out with the Emergency/Parking brake set. The aircraft may have remained on the runway surface but for the addition of forward thrust during the landing roll.

Following the accident, the operator introduced a revision to the Landing Checklist to require the handling pilot to confirm the parking brake is OFF.

History of the flight

The flight crew reported for duty at Bristol Airport at 0540 hrs for a flight from Bristol Airport to Frankfurt and back; the accident occurred on the return sector. Occupying the left seat was a captain-under-training, new to both the operator and the aircraft type. Occupying the right seat was a company training captain, who was the commander of the flight.

Footnote

[1] Decision height lower than 200 ft but not lower than 100 ft and RVR of not less than 350 m.

The outbound sector to Frankfurt was uneventful with the captain-under-training designated as PF; a Category II approach and landing was carried out. The return sector was also flown by the captain-under-training and a Category II approach and landing was planned for Runway 27 at Bristol due to the meteorological forecast for fog.

The approach briefing was started by the captain-under-training during the descent at 1113 hrs but, just as he began, the aircraft came within range of the ATIS broadcast. The briefing was deferred while the crew noted the 1050 hrs Bristol ATIS: Runway 27, surface damp, low visibility procedures in force, surface wind variable 3 kt, visibility 150 m, Runway Visual Range (RVR) Runway 27 400 m, fog, sky obscured, temperature 10°C, dewpoint 10°C and pressure 1035 hPa. The briefing resumed but was then delayed further by a series of interruptions for gathering additional weather information, ATC instructions and cabin crew communications.

At 1120 hrs, London ATC instructed the aircraft to descend to FL160 and reduce speed to 250 kt, and the crew were advised to expect holding for arrivals at Bristol. At 1125 hrs, the aircraft was transferred to Bristol ATC and, after confirming that an approach in the prevailing weather conditions was acceptable, the crew were advised they were number one for the approach. The aircraft was descending through FL 140 and Bristol ATC asked if 30 track miles was sufficient distance. The crew discussed the distance and accepted the routeing.

The PF decided to deploy the speed brake to lose the excess height and announced: "SPEED BRAKE COMING ON". However, the speed brake parameter recorded on the FDR did not indicate that the speed brake had deployed. The approach briefing was completed at 1127 hrs.

At 1129 hrs, each pilot carried out a radio altimeter test generating a sequence of aural alerts, which interrupted crew communications over the next two minutes. During this time the commander commented that engaging speed mode and deploying speed brake was the quickest way to lose height. The PF acknowledged and responded that it was already open, but his reply came just as the commander responded to an ATC call and went unnoticed.

At 1130 hrs, the commander suggested directly that the speed brake should be used and the PF responded: "IT IS, OH NO ITS NOT, WHO CLOSED THAT?". He deployed the speed brake, which now indicated on the FDR data, and asked the commander to request another five track-miles from ATC.

The aircraft was routed by ATC through the extended runway centreline to provide the requested additional distance before being turned to intercept the ILS localiser from the south. The descent checklist was completed and the approach checklist was started. At the second item, '*Seatbelt Sign ….ON',* the commander instead read out "PARK BRAKE" and the PF responded "ON" (Figure 1). This was immediately followed by an instruction from ATC to descend to 2,500 ft and turn right heading 360°. The crew followed the ATC instructions and then, because of the interruption, the commander restarted the approach checklist from the beginning, this time completing it as published.

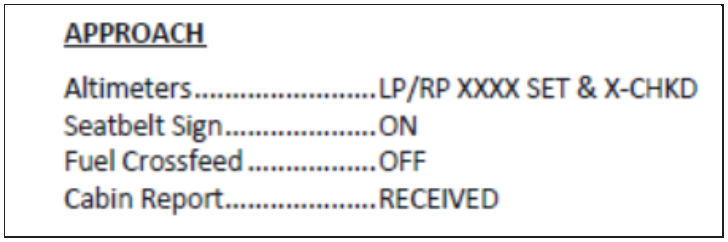

Figure 1

Approach checklist

The approach continued, the required visual references for landing were achieved and, at 80 ft agl, the PF disconnected the autopilot in accordance with procedures for a manual landing.

On touchdown, the PF noticed an unusually rapid de-rotation and then found he had difficulty in maintaining directional control despite using corrective rudder. The commander thought that the PF might be "riding the brakes", a common error during training, and advised him to take his feet off the brakes. The PF, still unable to control the aircraft, attempted to use the steering tiller but when the commander noticed this he called out "NO NO DON'T USE THE NOSEWHEEL STEERING". The PF recalled afterwards that he had considered using asymmetric thrust but did not think he had moved the thrust levers. The aircraft ran off to the left side of the runway, at which point the commander realised the parking brake was ON, and onto the grass, continuing for 120 m before coming to a halt. In the confusion on the runway after touchdown, the thrust levers had been advanced and as the aircraft stopped the PF, realising they were forward, closed them.

The crew reviewed the situation, using their company failure management process, to stop, think and consider the options. They assessed that the aircraft was in a safe condition and decided not to initiate an evacuation. The commander contacted ATC, the initial post-accident communications are shown at Table 1.

Time	Station	Transmission
1137:52	Aircraft (commander)	"ER [CALLSIGN] ONE EIGHT TWO TWO WE'RE OFF THE RUNWAY"
1137:59	ATC	"[CALLSIGN] ONE EIGHT TWO TWO COPIED [UNINTELLIGIBLE] GOLF X-RAY"
1138:03	Aircraft (commander)	"NEGATIVE WE'RE OFF THE RUNWAY"
1138:07	ATC	"ROGER"
1138:16	ATC	"[CALLSIGN] ONE EIGHT TWO TWO YOUR APPROXIMATE POSITION"
1138:20	Aircraft (commander)	"ER JUST OPPOSITE FOXTROT"
1138:21	ATC	"ROGER EQUIPMENT ON THE WAY"

Table 1

Post-accident communications

While the commander was communicating with ATC, the captain-under-training made an announcement to the cabin to advise the passengers to remain seated. The crew then carried out their normal shutdown procedures and started the Auxiliary Power Unit (APU).

Once ATC realised that the aircraft had left the paved surface, the controller activated the crash alarm and alerted the Rescue and Fire Fighting Services (RFFS). ATC asked the commander whether they were evacuating the aircraft. He responded that they were not and advised that the engines were shut down with the APU running. The RFFS vehicles arrived at the aircraft within three minutes of the accident and two-way communications were established on the dedicated frequency 121.6 MHz.

The captain-under-training had a good recollection of events during the flight and soon after the aircraft had come to rest identified that he must have set the parking brake instead of deploying the speed brake. He could not recall having increased the thrust during the landing roll.

Meteorology

A ridge of high pressure extended across the UK and a slow moving, weak occlusion affected the southern part. The slack pressure gradient gave rise to a light and variable surface flow around Bristol Airport.

The terminal area forecast for Bristol Airport, issued at 0505 hrs on 22 December 2017 was: surface wind from 240° at 5 kt, visibility 300 m, fog, overcast cloud on the surface, with temporary changes in conditions.

The meteorological report from Bristol Airport issued at 1120 hrs was: surface wind variable at 2 kt, visibility 300 m, Runway 27 visibility 500 m, fog, sky obscured, temperature 10 °C, dewpoint 10 °C and pressure 1035 hPa.

Airfield information

Bristol Airport is the ninth largest UK airport in terms of number of movements of Commercial Air Transport aircraft and in terms of passenger numbers per annum.

The frequency of the implementation of Low Visibility Procedures at Bristol Airport is not recorded. Surface Movement Radar is not installed at the airport and in foggy conditions ATC personnel in the visual control room may not be able to see a landing aircraft. The airport Manual of Air Traffic Services (MATS) Part II includes a Fog Search Plan which is activated when: '*there is a suspicion of an Aircraft Accident/Ground Incident or in the event of a sudden and sustained loss of communication between ATC and an aircraft'*. Once activated no further aircraft movements are authorised on the manoeuvring area and a search can begin. The aerodrome is divided into discrete search zones with the primary one being the runway strip. ATC provides all available information to the RFFS to assist them in the decision as to which locations to search.

Personnel information

The captain-under-training had recently joined the operator having previously been qualified on the SAAB 2000 with another operator. He had completed 17 hours of flight time on the Embraer 145; this was his eighth sector, his fourth Category II approach and his second in actual low visibility conditions. His training had progressed well up to the time of the accident.

Recorded information

More than two hours of audio and 50 hours of data were recovered from the aircraft CVR and FDR respectively. Other sources of recorded data supporting the investigation were the airfield recordings of radio transmissions and airfield primary radar, airfield CCTV cameras, and NATS Clee Hill secondary radar. Some of the content of the recordings are reflected in other parts of the report.

Figure 2 shows pertinent extracts from the CVR and FDR overlaid on the radar track of the aircraft. There was significantly more RT than shown due to the weather, and ATC vectoring and management of another aircraft with marginal capability given the runway visibility. There were also significantly more crew communications than shown relating to checklists, minima, alternate airports and other operational issues.

There was no recorded parameter for the parking brake. At the point of ATC handover to Bristol, the PF expressed the intent to set the speed brake but the recorded parameter for the speed brake did not change from closed.

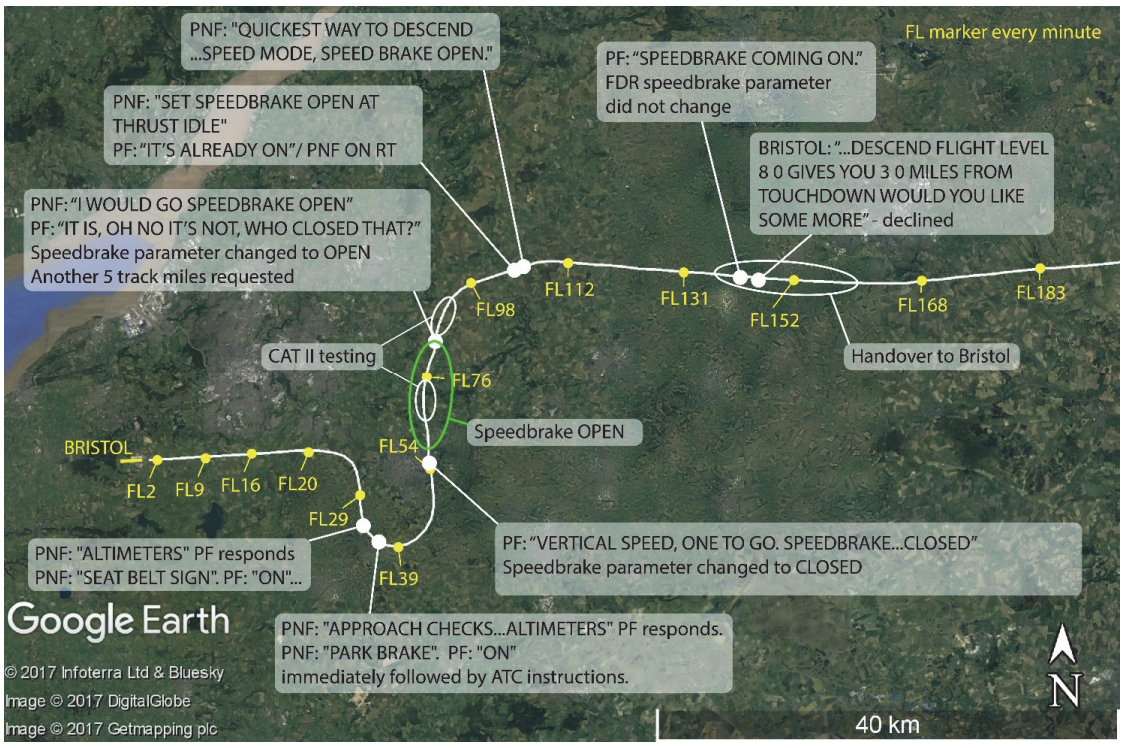

Figure 2

Pertinent extracts from the CVR and FDR overlaid on the aircraft radar track

Figure 3, shows pertinent extracts from the CVR and FDR during the landing. The autopilot was disengaged at about 80 ft aal and the aircraft touched down on the centreline. The aircraft started tracking right of the runway centreline and opposite rudder was used. The aircraft heading swung to the left of the centreline, skidding approximately along the centreline as indicated by the localizer (the antenna is in the tail). Right rudder was applied but the yawing to the left continued. With a heading of between 15 and 30° to the left of the runway heading the thrust levers were advanced, slightly more left thrust than right. The aircraft carried on yawing to the left and the previous longitudinal deceleration was eroded. The divergence from the runway heading peaked at approximately 50° before starting to reduce, but with thrust applied the aircraft tracked to the left and went off the side of the runway with a groundspeed of approximately 45 kt. The aircraft was decelerating and as the groundspeed reduced to approximately 20 kt the thrust levers were brought back to IDLE. The aircraft came to a stop about three seconds later. The crew identified that the parking brake was applied as the aircraft left the runway.

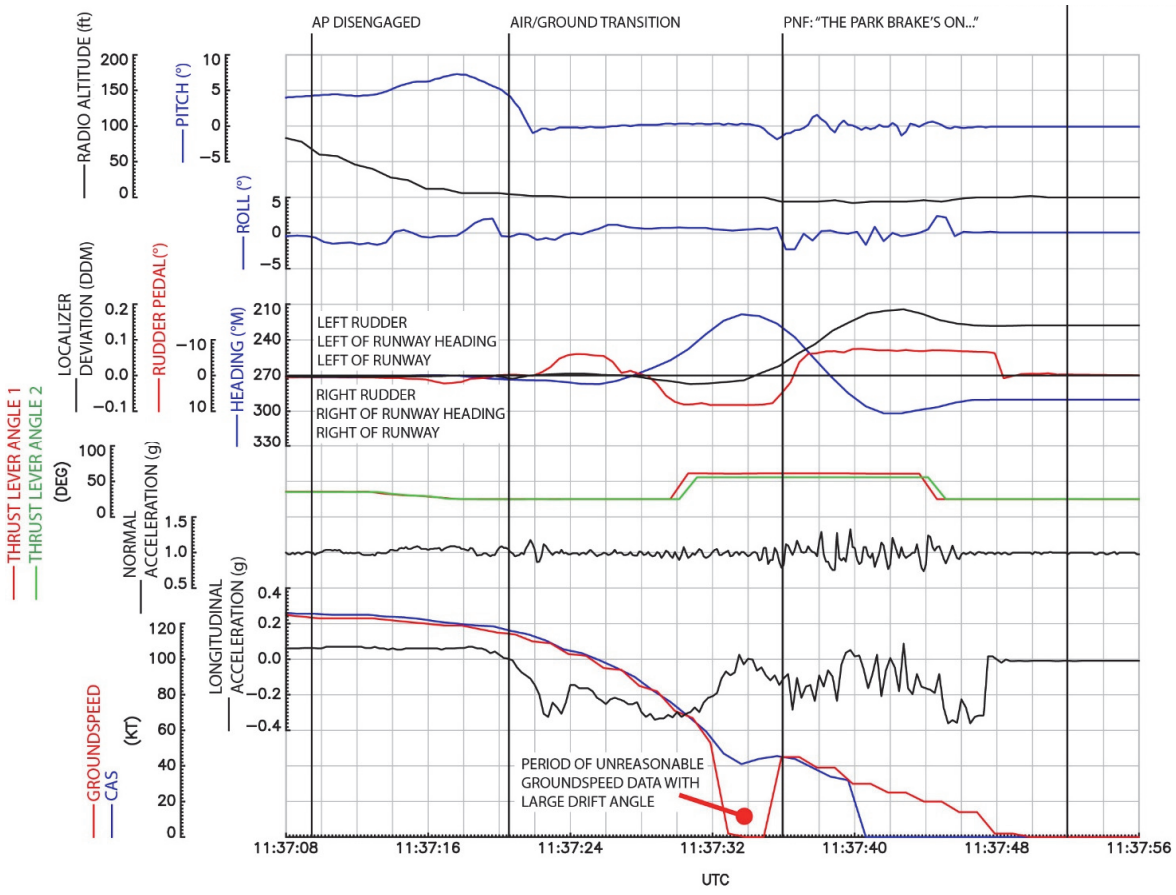

Figure 3

Pertinent extracts from the CVR and FDR during the landing

CCTV

There were various CCTV cameras around the airfield covering the path taken by the aircraft during the landing roll but, despite being in the camera field of view, the aircraft was not always visible in the recordings because of the poor visibility.

Accident site and aircraft damage

Figure 4 shows the aircraft where it had come to rest and the poor visibility shortly after the time of the accident. Marks and rubber fragments on the runway defined the touchdown point, approximately 468 m from the threshold, and showed the aircraft initially tracking on the runway centreline before drifting first slightly to the right of the centreline and then veering left over 280 m. Overheated fragments of vulcanised rubber were found at various points along the runway, with a cluster of larger fragments approximately 400 m from the touchdown point over an area of approximately 40 m by 3 m. After this point there were faint but reasonably clear lines left on the runway surface made by the wheel rims up to the point where the aircraft left the runway and continued onto the grass.

Figure 4
G-CKAG off the runway

Once on the grass the aircraft left deep furrows in the top soil up to where it traversed a disused taxiway with further deep furrows beyond leading to its final position. The distance from where the aircraft left the main runway until coming to stop was approximately 120 m. Marks showed that it had 'fishtailed' from right to left whilst on the grass. The path of the aircraft from the runway is shown in Figure 5.

The aircraft stopped on a heading of 296º(M) and all four main wheels were buried up to their axles. The components attached to the front of the left and right main landing gear were clogged with soil and turf. Apart from the detached and loose lower fairing mounting strut on the left landing gear, there appeared to be no other damage. The nose landing gear, fuselage, wings and engines were undamaged although the left wing leading edge had soil residue along its length. Figure 6 shows the extent that aircraft main wheels and landing gear had dug in.

The aircraft was lifted using a combination of hydraulic jacks and air-bags with excavation beneath the main wheels.

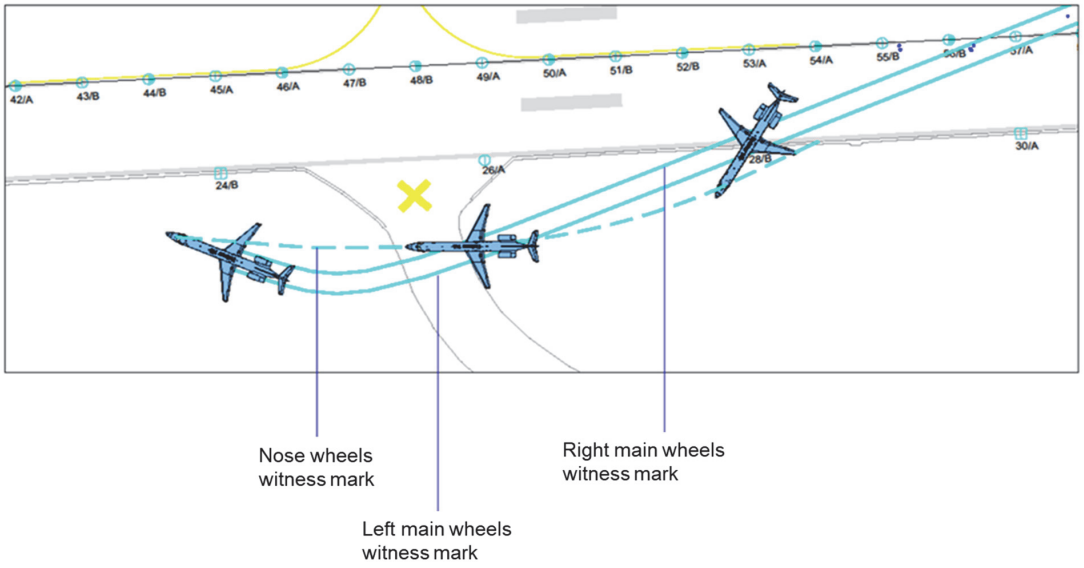

Figure 5

The aircraft's path leaving the runway

Figure 6

The extent of the entrapment of the main wheels and landing gear (left side shown, the right side was similar)

Wheels and tyres

The wheels were removed and examined on site. The damage to all the main wheel tyres was similar and they were all deflated.

The wear pattern on the tyres showed the tread surface abraded through leaving ragged edges and missing material. Abrasion then carried on symmetrically though the sidewalls over an approximately 140º arc down to the wheel rims. There was also abrasion of some of the wheel rims where they had contacted the runway surface. None of the tyre beads de-seated and the fusible plugs and valves were not affected. Figure 7 shows the damage to one of the main wheel and tyre assemblies. The other main wheels and tyres exhibited the same extent of damage.

Figure 7
Main wheel and tyre damage

The brake packs were examined and found to be within wear limits and undamaged. The brake hydraulic pipes were undamaged and free from leakage and the anti-skid system wiring and associated components were intact.

Cockpit controls

The aircraft had been shut down and made safe by the crew with the parking brake left in the OFF position. During examination of the aircraft, the parking brake was operated and, with aircraft electrical power on, the parking brake indicator on the centre panel illuminated. However, the nomenclature on the light did not appear to be as well defined as would be expected, consistent with one of its filaments having failed. Figure 8 shows the parking brake indicator.

Figure 8

Parking brake indicator

Aircraft information

The Embraer 145 is a twin-engine, pressurised fixed-wing aeroplane designed for short haul passenger operations. Thrust reversers are optional equipment and were fitted to G-CKAG.

Spoiler system

The aircraft is fitted with a system of four spoilers designed to slow the aircraft in flight and reduce lift on the ground to increase braking effectiveness.

The hydraulically actuated spoilers are installed on the upper wing surface in front of the outboard and inboard flaps. The outboard spoilers provide both speed brake and ground spoiler functions whilst the inboard only provide a ground spoiler function.

The speed brake function is electrically controlled by a small lever next to the power levers on the left side of the centre console (Figure 9). A green 'OPN' caption is displayed on the lower right area of the central Engine Indication and Crew Alerting System[2] (EICAS) screen when any of the surfaces are open.

Landing gear

The aircraft is fitted with retractable tricycle landing gear with a steerable nose wheel. The main landing gear is fitted with double wheel and tyre assemblies. The main wheels are mounted on a fixed axle and their bearing design allows them to rotate independently of

Footnote

[2] EICAS provides flight crew with a three-level alerting and message indication system: warning, caution and advisory.

each other. Shock absorption is carried out by a conventional air-oil strut on the nose landing gear and cantilever air-oil strut with trailing link assemblies on the main landing gear. The main wheels were fitted with cross-ply tubeless tyres with a speed rating of 210 mph (182 kt).

Braking system

The aircraft is fitted with multiple disc brake packs on all four main wheels with brake actuation pressure supplied from hydraulic Systems One and Two. The outer main wheel brakes are powered by System One and the inner main wheel brakes by System Two. All are controlled by an electronic brake control unit which takes its inputs from the toe brake levers fitted on the rudder pedals. The system includes an electronic anti-lock system. Friction pad wear indicator pins are fitted to all four brake pack assemblies.

The aircraft is fitted with a combined parking and emergency braking system. This consists of an accumulator which is charged and kept at working pressure by System Two. Pressure from the accumulator is supplied to all four main wheel brakes. The emergency and parking brake system is controlled and operated by a handle, painted with yellow and black stripes, on the left side of the centre console just behind the speed brake lever (Figure 9). When emergency braking is required the handle is pulled upwards and can be modulated to apply varying pressure to the main wheel brakes as required. This action opens and closes a variable port valve which allows pressure from the parking brake accumulator into the system. When parking brake is required, the handle is pulled fully up and twisted anti-clockwise to lock it in position. This opens the valve fully and traps pressurised hydraulic fluid in the system which holds the brakes on. This system bypasses the brake control unit and the anti-skid system is not available during parking or emergency brake use. The accumulator is designed to allow six complete actuations of the emergency brake system and can hold the parking brake on for up to 24 hours. The parking brake emergency function requires the system to be a simple design without the inhibition of interlocks linked to other landing gear and braking systems within the aircraft. This ensures the emergency brake is always available and cannot be affected by malfunctions of associated systems, and hence the parking brake can be applied with the landing gear retracted.

Apart from the extended position of the parking brake handle when the parking brake is applied, the only other brake condition indication is on a small illuminated indicator on the instrument panel marked BRAKE ON. Figure 9 shows the location of the controls on the centre console and Figure 10 shows the parking brake in the ON condition.

Figure 10 shows the left seat in its rearwards position. When the seat is towards its fully forward position the parking brake handle is out of the seat occupant's direct line of sight and is likely to be operated by 'feel'. When the aircraft is on the ground with the parking brake set to ON there is a warning feature built into the system which displays an EICAS caution NO TAKEOFF CONFIG if the power levers are advanced to 60%. This system does not apply when the aircraft is airborne.

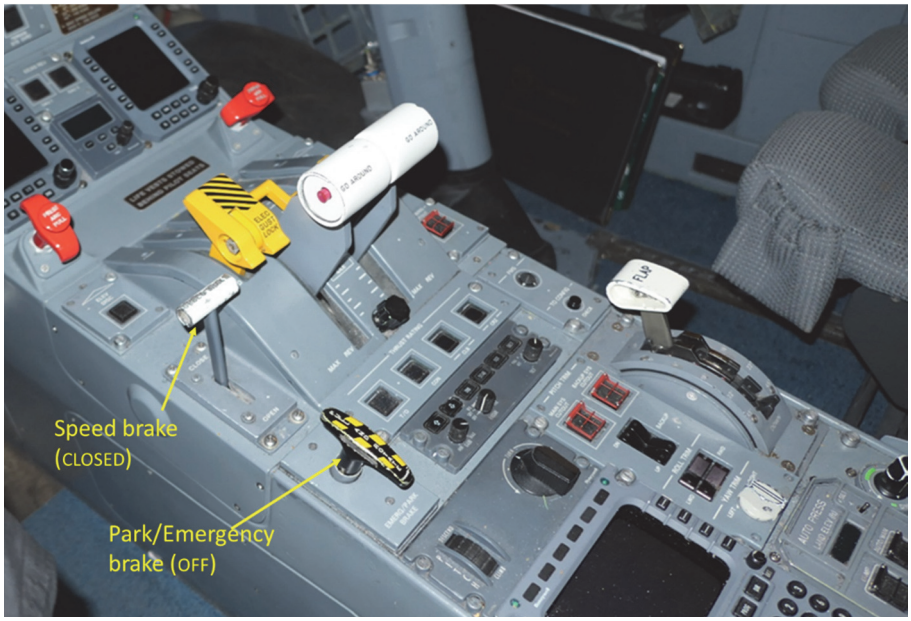

Figure 9

Location of the controls on the centre console (viewed from the left)

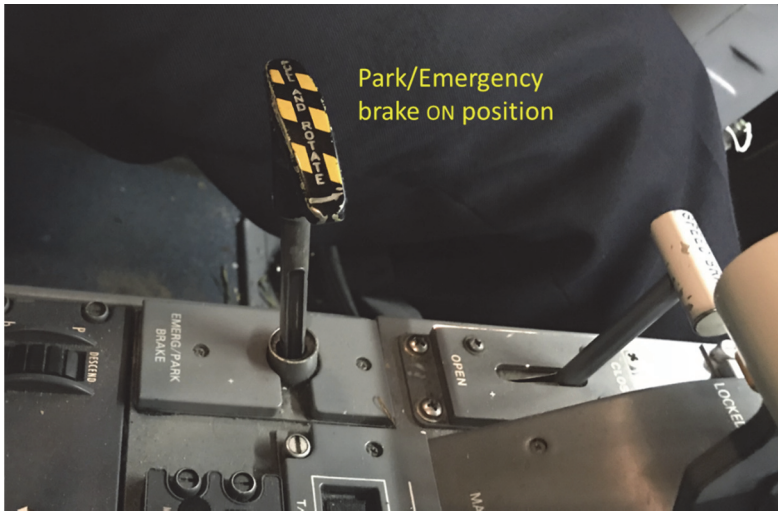

Figure 10

Parking/Emergency brake ON (viewed from the right, seat in most rearwards position)

The manufacturer's aircraft systems safety case classified the severity of landing with the parking brake on as major but the likelihood that it would happen due to a system fault was determined as 1 in 10^{-9} flight hours (extremely improbable) and therefore the risk was considered acceptable. The inadvertent selection of the parking brake while airborne was not considered as part of the safety case and the manufacturer advised the AAIB that '*it does not have a plan to conduct a system review related to the parking brake status.*'

Dependent on the aircraft build standard there are two different locations, both on the centre panel, for the parking brake ON indication. The first, as fitted to G-CKAG, is on the lower right

section of the centre panel and the alternative, to accommodate the introduction of a dual FMS configuration for the newer aircraft, is higher up on the centre panel adjacent to the landing gear selector lever.

Certification standard

The EMB-145 received its original Type Certificate from Centro Tecnico Aeroespacial (CTA), Brazil National Aviation Authority, in November 1996. The Federal Aviation Administration's (FAA) official type certification was in December 1996 and European type certification was in May 1997.

Federal Aviation Administration (FAA) Advisory Circular (AC) AC No: 25 .1309-1A describes various acceptable means for showing compliance with the requirements for FAA certification. This includes the FAA Fail-Safe Design concept which uses a set of design principles to ensure a safe design and is reflected in European Aviation Safety Agency Certification Specifications for Large Aeroplanes, CS-25. One of these principles is: '*Error-Tolerance that considers adverse effects of foreseeable errors during the airplane's design, test, manufacture, operation, and maintenance.*'

Weight and balance

The aircraft had a calculated takeoff weight of 17,865 kg. Its maximum landing weight was 18,700 kg and at the time of the accident the aircraft weight was approximately 16,150 kg. The CG was within limits and the aircraft landed with approximately 1,700 kg of fuel. The aircraft essential documents were all in date and the technical log showed nothing of any relevance to the accident.

Human factors

Civil Aviation Authority publication '*CAP 737 Flight-crew human factors handbook'* identifies 'slips' and 'lapses' as unintended actions or omissions and 'mistakes' as intended, but mistaken, actions.

Cognitive intrusion speech errors

According to Harley (2014)[3] there are many different types of speech error. Cognitive intrusion errors occur when material unrelated to the speech being produced intrudes into it. The names of objects or words noticed in the outside environment can intrude into speech. Internal thoughts not related to the intended speech can also intrude. People monitor their speech but not perfectly accurately. In many cases, when finishing speaking, a person may not be aware that they have made an error.

Pincott (2012)[4] stated that speech errors are very common. For every 1,000 words spoken, an individual may make one or two errors. Every day, most people make between 7 and 22 verbal slips. Stressors, such as distraction or time pressure, make verbal slips more likely.

Footnote

[3] Harley, T.A. (2014) The psychology of language: From data to theory 4th edition. Routledge: Abingdon.
[4] Pincott, J.E. (2012). Slips of the Tongue. Psychology Today. March 2012.

Organisational information

The training captain advised the AAIB that it was common practice, but not a Standard Operating Procedure (SOP), for the pilot flying to announce use of the speed brake, to keep the pilot monitoring informed.

Several of the operator's aircraft are fitted with thrust reversers, including G-CKAG, but because the greater number of aircraft in the fleet do not have them, their use is prohibited.

Since the accident, the operator has introduced a revision to the Landing Checklist in their Operations Manual which requires the handling pilot to confirm the parking brake is OFF.

Previous similar events

Landing with parking brake set

The aircraft manufacturer advised that within the ERJ family (E135/140/145) there had been two previous instances in which a landing occurred with the Emergency/Parking Brake set[5]. Neither of these incidents was investigated because neither resulted in a runway excursion. One of the incident aircraft was equipped with the original panel layout (the same as G-CKAG), and the other was equipped with the newer panel layout, with the parking brake light located higher on the centre panel and adjacent to the landing gear selector.

The AAIB investigated an incident to Airbus A319-131, registration G-DBCI, which occurred on 24 January 2007 (AAIB Bulletin 12/2008), where the parking brake was inadvertently selected to ON when the intention was to select landing flap. All four mainwheel tyres deflated on landing, but the aircraft remained on the runway surface. The Flight Warning Computer (FWC), as fitted to G-DBCI at the time, did not provide a master caution light or activate an audible 'attention getter' tone for Park Brake set in flight. For aircraft fitted with a later standard of FWC, and for all subsequent FWC standards, a master caution light and audio alert are generated if the Park Brake is set in flight.

Selection of wrong control

On 31 March 1986 and 30 June 1987, there were two similar incidents of double engine flameouts on Boeing 767 aircraft during the initial climb phase after takeoff. Both incidents were attributed to the pilot's selection of the two engine fuel control switches to OFF instead of the intended selection of the engine electronic control (EEC) switches. The switches were dissimilar in shape and action but located close to each other, on the console aft of the thrust levers. The engines were subsequently restarted in flight.

The AAIB investigated two events in February 2016 in which flap was retracted shortly after takeoff instead of the landing gear being selected UP. The location, shape and feel of the respective controls are different, but the mis-selections still occurred.

Footnote

[5] MSN 145-0025 / August 24, 2000 / Newark, NJ, USA and MSN 145-0521 / August 08, 2008 / Nashville, TN, USA.

Analysis

Conduct of the flight

The crew anticipated that a Category II approach would be required and planned accordingly. However, on arrival in the Bristol area the expected holding was cancelled and the approach timeframe thereby shortened. Also, the approach briefing was delayed until after the ATIS was available and was then interrupted several times. Thus, although not unduly rushed, the crew requested additional track mileage and the approach briefing was conducted with numerous interruptions. Despite this the pre-landing checks were completed, the approach was stable, the required visual references for landing were acquired and a normal touchdown was achieved.

Effect on the wheels and tyres

The material evidence supported the conclusion that the aircraft landed with all the main wheel brakes locked on which did not allow any rotation of the main wheels.

The crew noted a more rapid than normal de-rotation on touchdown consistent with the effect of higher drag loads imparted by the tyres as they contacted the runway surface. The small overheated tyre material 'rubbings' suggested the tyres did not immediately burst or deflate on touchdown. However, the cluster of larger fragments and ply material approximately 400 m from touchdown suggested that all the tyres burst either simultaneously or in very quick succession at that point. This left the sidewalls to take the weight and abrade uniformly down to the wheel rims, evidenced by the marks left on the runway, until the aircraft traversed on to the grass.

Effect of increased thrust

During the skid the aircraft was directionally unstable as shown by it drifting to the right and then to the left of the runway centreline. The action of increasing the thrust on the runway exacerbated the loss of directional control and probably led to the runway excursion because, when thrust was applied, the nose of the aircraft was pointing to the left of the runway centreline. It might have been intended as an attempt to maintain directional control by using asymmetric thrust but the captain-under-training did not recall having moved the thrust levers. It could also have occurred inadvertently through a biomechanical reaction as the aircraft decelerated. The increased thrust reduced the deceleration and, with the nose pointing to the left, applied a thrust vector which took the aircraft further from the runway centreline. The interaction between the thrust, damaged wheels and the soft ground exacerbated the tendency of the aircraft to 'fishtail' before it eventually came to a stop.

Inadvertent parking brake application

Inadvertent application of the parking brake in flight is possible using the normal action of the handle, and there are no mechanical interlocks to prevent the wheel brakes locking the mainwheels. The Emergency/Parking Brake handle has its own unique action and has a different appearance, feel and action to the nearby speed brake lever, and these characteristics should reduce the likelihood of inadvertent parking brake application in flight.

Once the parking brake has been inadvertently set, the extended position of the handle and the BRAKE ON indication light may alert crews to the condition. In this event, however, neither the extended handle nor the partially lit BRAKE ON light were noticed.

On G-CKAG, the BRAKE ON light is situated out of the normal field of view of a pilot in the right seat. For some other variants of the type it is situated higher on the centre panel, next to the landing gear selector lever and closer to the normal field of view, thereby providing an additional opportunity to notice that the light is on when lowering the landing gear. Although this is likely to be a more effective position, the aircraft in one of the two previous events recorded had this configuration. Thus, there was insufficient evidence to draw conclusions about the effectiveness of the different panel layouts in preventing this type of accident.

It is not anticipated that a parking brake will be selected in flight and yet it has happened on three recorded occasions, each resulting in a landing with the parking brake applied. This suggests that the design of the Emergency/Parking brake handle and BRAKE ON light do not function as effective risk controls on all occasions. The aircraft systems safety case conducted by the manufacturer classified the severity of landing with the parking brake on due to a system fault as 'major' but with a likelihood classified as extremely improbable; the overall risk was classified as 'acceptable'. There was no consideration given to the possibility that the parking brake would be applied before landing because of an operational error.

The design requirement for FAA and EASA type certification is to consider possible system failure modes including the adverse effects of foreseeable errors during operation. This report has shown that inadvertent application of the parking brake does occur during operation, but there was not enough evidence to quantify the likelihood and, therefore, the risk associated with this type of operational error. Further, it was probably the application of power while the aircraft was on the runway which caused the aircraft to leave the paved surface, not the act of landing with the parking brake applied; in previous similar incidents, the aircraft have remained on the runway. The manufacturer stated that, in the circumstances, it did not intend to conduct a system review relating to the parking brake status.

Opportunities to detect that the parking brake was applied

The selection of the parking brake instead of the speed brake is an example of a slip, an appropriate action which is carried out incorrectly. There was a moment when the captain-under-training might have resolved the situation, when he remarked on the speed brake having been 'closed', (comment, "WHO CLOSED THAT") but he did not explore the inconsistency further, perhaps because there were multiple interruptions on the flight deck and he was focussed on other tasks.

During the approach checklist the commander read out "PARK BRAKE" instead of the second checklist item '*seatbelt sign'*. This is an example of a cognitive intrusion error and might indicate that on some level the commander had the parking brake in mind. The commander might have seen the illuminated parking brake indicator without consciously processing it and this unconsciously intruded into his speech. The speech error had the potential to trigger one or both crew members to check the status of the parking brake if

they had noticed it. However, the checklist was interrupted immediately after this by an ATC instruction and this reduced the crew's opportunity to notice the speech error. It was then not repeated the second time the checklist was carried out.

Conclusion

The accident arose as a result of the inadvertent selection of the Emergency/Parking brake instead of the speed brake. The levers are of similar shape and sited close to each other but with a different appearance and mode of action. There is also a BRAKE ON indicator light. These risk controls proved ineffective in preventing the inadvertent selection of the Emergency/parking brake both on this occasion and on at least two previous occasions. Once the parking brake had been set there were opportunities to detect and correct the error, but a busy flight deck environment together with a high workload contributed to it going unnoticed.

After touchdown, the aircraft may have remained on the runway surface but for the addition of forward thrust during the landing roll.

The manufacturer stated that it did not intend to conduct a system review relating to the parking brake status.

Safety action

Following this accident, safety action was taken as follows:

> The operator introduced a revision to the Landing Checklist in the Operations Manual which requires the handling pilot to confirm the parking brake is OFF.