AIRCRAFT ACCIDENT REPORT 5/2009

Air Accidents Investigation Branch

Department for Transport

Report on the serious incident to BAe 146-200, registration EI-CZO at London City Airport on 20 February 2007

This investigation was carried out in accordance with
The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996

The sole objective of the investigation of an accident or incident under these Regulations shall be the prevention of accidents and incidents. It shall not be the purpose of such an investigation to apportion blame or liablility.

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This report contains facts which have been determined up to the time of publication. This information is published to inform the aviation industry and the public of the general circumstances of accidents and serious incidents.

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Air Accidents Investigation Branch
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August 2009

The Right Honourable Lord Adonis
Secretary of State for Transport

Dear Secretary of State

I have the honour to submit the report by Mr P Claiden, an Inspector of Air Accidents, on the circumstances of the serious incident to BAe 146-200, registration EI-CZO at London City Airport on 20 February 2007.

Yours sincerely

David King
Chief Inspector of Air Accidents

Contents

GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

AAIB	Air Accidents Investigation Branch
aal	above airfield level
AC	alternating current
AFM	Aircraft Flight Manual
AFRS	Aerodrome Fire & Rescue Service
agl	above ground level
AIP	Aeronautical Information Publication
AMM	Aircraft Maintenance Manual
arte	above runway threshold level
ATC	Air Traffic Control
°C,M,T	Celsius, magnetic, true
CDG	Paris Charles De Gaulle Airport
CVR	Cockpit Voice Recorder
DAAV	Dual Adaptive Anti-skid Valves
DC	direct current
EDP	Engine Driven Pump
FDR	Flight Data Recorder
ft	feet
ft/min	feet per minute
g	normal acceleration
GNS	Global Navigation System
GPWS	Ground Proximity Warning System
HP	Handling pilot
hrs	hours (clock time as in 12:00 hrs)
IAA	Irish Aviation Authority
ICAO	International Civil Aviation Organization
ILS	Instrument landing system
kg	kilogram(s)
km	kilometre(s)
kt	knot(s)
LAA	Light Aircraft Association (formerly PFA)
lb	pound(s)
lbf	pounds force
LCY	London City Airport
LDA	landing distance available
m	metres
mb	millibar(s)
mm	millimetre(s)
MP	Monitoring pilot
N_1	engine fan or LP compressor speed
N_2	gas generator shaft speed
PAPI	Precision Approach Path Indicator
PF	Pilot flying
PTU	Power Transfer Unit
QNH	pressure setting to indicate elevation above mean sea level
RESA	Runway End Safety Area
RIBS	rigid inflatable boats
SAMOS	Semi-Automatic Meteorological Observation System
SOP	Standard Operating Procedure
TDZ	Touchdown Zone
TORA	Takeoff Run Available
V_{APP}	Approach speed
V_{REF}	Reference airspeed (approach)
VHF	very high frequency
ZFW	Zero Fuel Weight

Stopped position of EI-CZO

Air Accidents Investigation Branch

Aircraft Accident Report No: 5/2009 (EW/C2007/02/06)

Registered Owner and Operator	CityJet
Aircraft Type	BAe 146-200
Serial No	E2024
Nationality	Irish
Registration	EI-CZO
Place of Accident	London City Airport
Date and Time	20 February 2007 at 0833 hrs All times in this report are UTC (equivalent to local time)

Synopsis

On 20 February 2007 London City Airport notified the Air Accidents Investigation Branch (AAIB) of a serious incident involving EI-CZO in which the aircraft burst all four main landing gear tyres during the landing. Enquiries by AAIB revealed that the aircraft had overrun the landing distance available (LDA), but remained on the paved surface, and that the flight crew had reported a total failure of the aircraft's brakes. In light of previous overrun events involving the BAe 146 and Avro RJ series of aircraft the Chief Inspector of Air Accidents ordered an Inspectors Investigation to be carried out into this incident.

The Inspectors involved in the investigation were:

Mr PT Claiden	Investigator-in-Charge
Mr T Atkinson	Operations
Mr P A Sleight	Engineering
Mr A Burrows	Flight Data Recorders

Three Safety Recommendations are made.

The following causal factors were identified:

1. The incorrect determination of the approach reference speed (V_{REF}) as 119 kt, resulted in the aircraft landing faster than was necessary.

2. The data suggested that the control columns may have been positioned forward of their customary position after touchdown, which could have contributed to a reduction of the aircraft's weight applied to the main wheels during the first part of the landing roll.

3. Despite the commander's recollection that he moved the airbrake/lift spoiler lever to the 'lift spoiler' position, the lift spoilers did not deploy, although the system was determined to have been serviceable.

4. The non-deployment of the lift spoiler surfaces after touchdown did not enable the timely transfer of the aircraft's weight from the wing to the main wheels, and hence the effectiveness of the wheel brakes during the early part of the landing roll was not maximised.

5. The commander's perception of brake system failure led him to select the emergency braking system which removed the anti-skid protection.

6. The lack of any positive force required to hold the lift spoiler lever at the lift spoiler activation position probably resulted in the lever moving away from the point of activation before the conditions required to satisfy the lift spoiler deployment logic could be met.

1 Factual Information

1.1 History of the flight

The crew reported for duty at Paris Charles De Gaulle Airport (CDG) to operate return flights to London City (LCY) and then to Dublin. Their pre-flight preparations were delayed by security procedures which initially prevented the crew from accessing their crew room and briefing facilities. The procedures required that all crew members must meet before proceeding through the security cordon to their crew room. Apart from this delay, the pre-flight preparations were routine.

The aircraft operator had stipulated that landings at LCY were only to be carried out by aircraft captains, so the commander was to be pilot flying (PF) for the first sector.

The flight plan provided to the crew showed that a minimum of 3,934 kg fuel was required for the flight but, in light of commercial considerations, the commander elected to load a total of 5,000 kg of fuel. He was presented with a loadsheet which showed that the aircraft's takeoff weight was 34,168 kg (34.2 tonnes) and the predicted landing weight 31,968 kg (32 tonnes).

The departure from CDG, climb, and cruise, were all normal. In preparation for their arrival at LCY, the co-pilot obtained the 0750 hrs ATIS information, which indicated the following:

> A wind of 170°/5 kt, varying in direction between 140° and 220°, visibility of 10 km or more, one or two octas of cloud at 600 ft aal and five to seven octas at 1,300 ft aal, a temperature of 10° C and dewpoint 8°C, and a QNH of 1,006 mb. The runway surface was described as 'wet' throughout its full length.

The co-pilot then calculated the landing weight, using information from the aircraft's GNS (Global Navigation System). This showed a zero fuel weight of 29.4 tonnes and a landing fuel weight of 3.7 tonnes, making the landing weight 33.1 tonnes. He consulted a flip-card which gave takeoff and landing speeds to be flown at various aircraft weights, and he completed the landing data 'bug card'.

It was customary to use speeds for the aircraft weight rounded up to the nearest whole tonne, and so the flip-card for 34 tonnes was consulted. The Flap 33 V_{REF} for this landing weight was 114 kt, but the co-pilot actually wrote down 119 kt on the landing data card.

The flight crew prepared for an ILS approach followed by a manual landing. The appropriate checklists were carried out, and the Green hydraulic system was selected for the wheel brakes and tested satisfactorily during the approach[1].

The aircraft was vectored by ATC onto an ILS approach for Runway 10. The aerodrome controller stated that the wind was "FROM THE SOUTH AT FIVE KNOTS" and that "TAILWIND HAS BEEN REPORTED ON SHORT FINAL PLUS UP TO FIFTEEN KNOTS". The flight crew of an aircraft which had landed then confirmed by radio that "WE DID HAVE A TAILWIND ON FINAL ON THIS APPROACH". The controller then cleared EI-CZO to land, and transmitted that the wind was from 170° at 6 kt. By this time, the runway surface was damp rather than wet throughout its length.

The commander and co-pilot both recalled that the approach followed the ILS localiser and glidepath accurately, and that they gained visual contact with the runway well before their decision altitude, at just below 1,000 ft aal. They recalled seeing two white and two red indications on the PAPIs continuously during the visual phase. By 500 ft aal, the aircraft was fully configured for landing with the landing gear DOWN, Flap 33 set, airbrake fully out, and with the landing checklist complete.

At about 200 ft aal, the commander briefly increased the thrust on all four engines to approximately 60% N_1, before retarding the thrust levers to 'flight idle' immediately before touchdown. Shortly before touching down, the co-pilot observed the windsock adjacent to the runway threshold and saw that it indicated approximately two or three knots of wind from the south.

The aircraft touched down at the far end of the touchdown zone, at 119 kt, and in an approximately level pitch attitude. The commander later recalled that he selected the thrust levers to ground idle power and the airbrake/lift spoiler lever to 'lift spoilers', before depressing his brake pedals. The co-pilot confirmed to the commander that ground idle had been selected, and was about to check for indications that the lift spoilers had deployed and that the wheel brake pressure was normal. However, before he could complete these checks, the commander perceived that the brakes were not having any effect, and called "NO BRAKES, BRAKES, BRAKES". He recalled pressing the brake pedals to their full travel but, sensed that there was 'not a hint of deceleration'. In the belief that the Green brake system had failed, he selected the Yellow system and continued to apply pressure to the pedals. However, he did not notice any change in the deceleration but later described that he felt 'the aircraft was only coasting down the runway'. The commander released and then re-applied the brakes, but this seemed to make

1 The BAe146 aircraft has three brake systems, Green, Yellow, and Yellow emergency, ref. Para 1.6.3.

no difference. The commander called "BRAKES, BRAKES" again and glanced at the overhead panel to see whether there were any abnormal indications; there were not. By this time, both pilots were concerned that the aircraft was not decelerating adequately, given the length of runway remaining. The commander selected the emergency Yellow brake system, and the aircraft then seemed to decelerate slowly. The co-pilot also applied pressure on the brake pedals during the landing roll.

As the aircraft neared the end of its landing roll, the aerodrome controller noticed smoke coming from the landing gear, and alerted the Aerodrome Fire and Rescue Service (AFRS), informing them that an Aircraft Ground Incident was taking place.

The aircraft came to rest on the paved surface but with its nose some 50 m beyond the end of the LDA, and approximately 160 m from the dock edge. It had turned through approximately 30° over the last part of the ground roll, onto a heading of 130°. During the final part of the roll, all four main landing gear wheels locked and the tyres were worn down by friction with the surface until they burst. The flight crew were not aware of the tyre failures.

The commander instructed the cabin crew by the public address system, to take their stations in case an evacuation proved necessary. Within 30 to 40 seconds of the aircraft coming to rest, the AFRS vehicles arrived, and the flight crew communicated with the AFRS commander by radio. Fire fighters inspected the landing gear using thermal imaging equipment, which showed that the maximum temperature in the brakes was 63°C. The AFRS commander informed the flight crew that the main landing gear tyres had blown and that there was no fire or smoke. The aircraft commander informed the cabin crew, and then the passengers, that the aircraft could not be moved. Mobile steps were brought to the aircraft, and the passengers were disembarked without incident.

When shutting the aircraft down, the commander distinctly remembered that, after touchdown, he had moved the lift spoiler lever from its maximum airbrake detent to the lift-spoiler position and that, during the landing roll, he had not looked at the brake pressure gauges.

Just after touchdown, the co-pilot recalled seeing the commander's right arm moving in his peripheral vision, but was not certain that this movement was a selection of lift spoilers. He also recalled that he saw pressure indicated on both brake systems at times during the landing roll.

Neither pilot recalled seeing any warning indications during the landing roll.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	0	0	0
Serious	0	0	0
Minor/none	5	55	0

1.3 Damage to aircraft

The four main wheel tyres had been worn through by surface friction until they deflated. The main wheel hubs were also damaged.

1.4 Other damage

None.

1.5 Personnel information

1.51 Commander

Male:	Aged 32 years	
Licence:	Airline Transport Pilot's Licence	
Aircraft Ratings:	BAe 146, ATR 42/72	
Last Licence Proficiency Check:	27/03/2006	
Last Line Check:	25/05/2006	
Last Medical:	27/11/2006	
Flying experience:	Total all types:	4,749 hrs
	On type:	469 hrs
	Last 90 days:	95 hrs
	Last 28 days:	32 hrs
	Last 24 hours:	3 hrs
Previous rest period:	20 hours	

1.5.2 First Officer

Male:	Aged 39 years	
Licence:	Airline Transport Pilot's Licence	
Aircraft Ratings:	BAe146	
Last Licence proficiency Check:	08/09/2006	
Last Line Check:	N/K	
Last Medical:	N/K	
Flying experience:	Total all types:	2,861 hrs
	On type:	213 hrs

	Last 90 days:	61 hrs
	Last 28 days:	31 hrs
	Last 24 hours:	3 hrs
Previous rest period:	20 hrs	

1.6 Aircraft information

1.6.1 General information

Manufacturer:	British Aerospace
Type:	BAe 146-200
Aircraft serial number:	E2024
Year of manufacture:	1984
Number and type of engines:	4 Lycoming ALF502R-5 turbofan engines
Total airframe hours:	37,515 hours and 34,774 cycles
Certificate of registration:	Issued by IAA[2] on 5 March 2003
Certificate of airworthiness:	Issued by IAA Category - Transport of Passengers Date of expiry 4 March 2007

No outstanding defects relevant to this event were recorded in the aircraft's technical log.

The aircraft is a short-haul airliner, designed specifically to provide good short field performance. To achieve this, it has a single piece, large span, wide chord, trailing edge flap on each wing. No leading edge devices are fitted. This configuration means that the aircraft exhibits a nose-low pitch attitude on approach, and typically touches down close to a level attitude. The four engines are not fitted with thrust reversers. The aircraft therefore uses a combination of lift spoilers (which ensure that the aircraft's weight is firmly borne by the wheels very shortly after touchdown), hydraulic wheel brakes and airbrakes to achieve stopping performance commensurate with its short field task.

In still air[3], the the BAe 146 approach should be flown at V_{REF} plus 5 kt and the threshold crossed at V_{REF}; touchdown typically occurs around 7 kt below this speed.

2 The Irish Aviation Authority.
3 There are additional factors for strong or gusty winds.

1.6.2 Hydraulic System

The BAe 146-200 has two hydraulic systems, designated Yellow and Green. The Yellow system is pressurised from an engine-driven pump (EDP) fitted to the No 2 engine. In addition, a small DC electric pump may be used to pressurise the wheel braking system.

The Green system is pressurised by an EDP attached to engine No 3, and can be pressurised by the Yellow system, via a power transfer unit (PTU), in the event of a failure of the EDP.

1.6.3 Wheel braking system

A three-position handle on the centre pedestal, Figure 1, selects the hydraulic system source for the wheel brake system on the aircraft. In normal operation, hydraulic pressure is supplied to brake shuttle valves, via brake control valves connected to both pilots' pedals, and anti-skid control valves, Figure 2.

Wheel brake system selector handle

Figure 1

The brake control valves modulate the available brake pressure in proportion to the force/deflection applied to the pedals. The antiskid control valves use speed signals from the wheels, processed by the antiskid control unit, to further modulate the available brake pressure to prevent the wheels from locking.

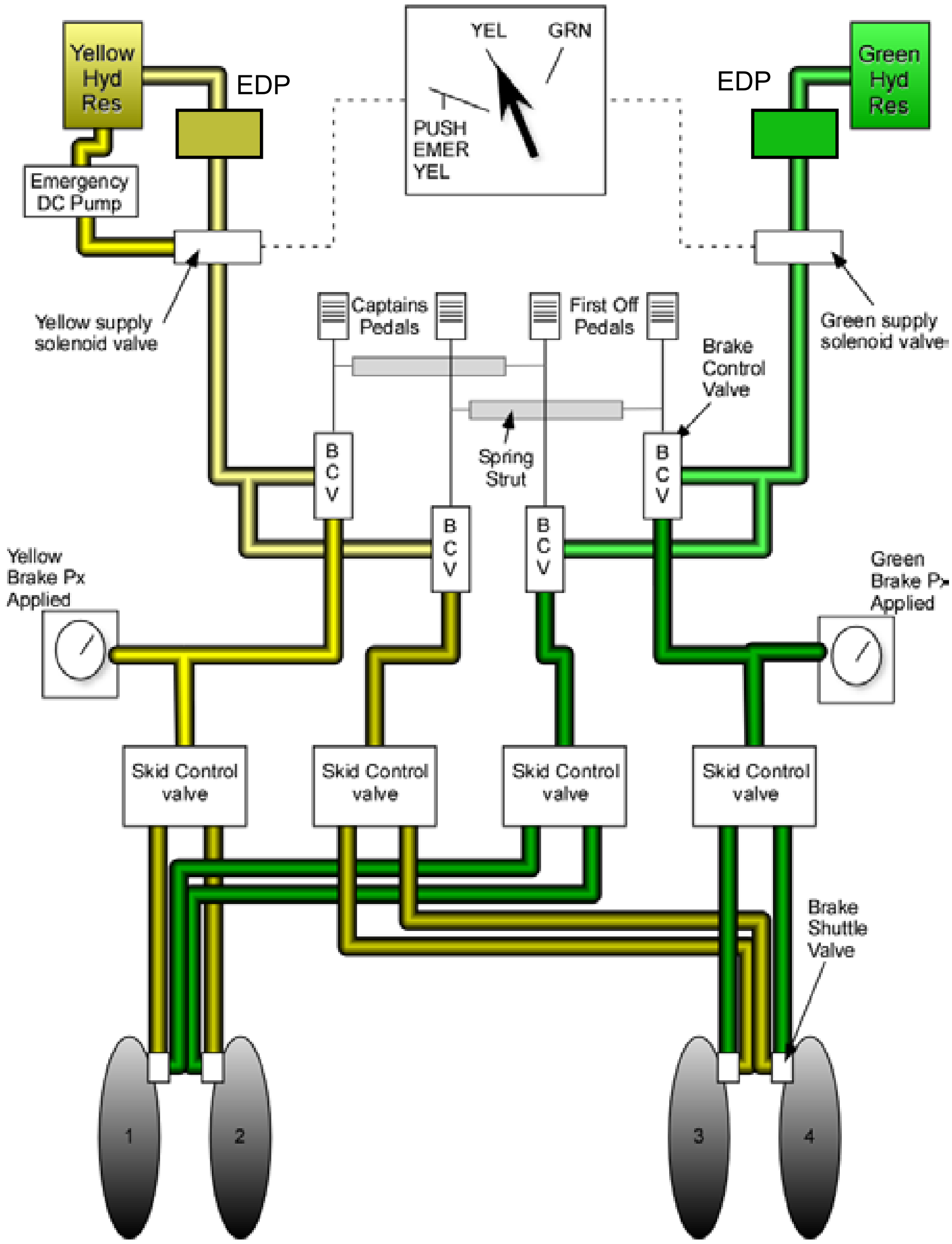

Figure 2

Schematic diagram of the hydraulic braking system

With the brake selector set at GRN, the system is pressurised from the Green hydraulic system. Selecting YEL on the brake selector changes the hydraulic supply to the Yellow system. Selection of EMER YEL, which requires the brake selector to be pushed down and twisted, selects the hydraulic source to the emergency Yellow system. This uses the small DC hydraulic pump to pressurise the system. In EMER YEL, the force applied to the brake pedals is directly proportional to that applied to the brakes, but no skid protection is provided. There is no requirement to release the applied brake pedal force during selection of alternative hydraulic pressure sources.

Dual pressure gauges, located on the lower part of the instrument panel, indicate the brake pressure being applied downstream of the brake control valves. One gauge indicates Yellow system pressure, the other Green system.

1.6.4 Anti-skid system

Each wheel is fitted with a speed transducer and its output signal is used by the anti-skid system to determine if a wheel is skidding or not. When anti-skid is operational, each of the anti-skid control valves modulates the brake pressure in proportion to the brake pedal force application. If there is insufficient brake pedal force to cause skidding, then no anti-skid modulation takes place. When the onset of skidding is sensed, the associated anti-skid control valve is commanded to release its brake pressure, by opening the pressure line to the hydraulic reservoir return line, which allows the wheel to rotate freely. The anti-skid control valve then allows the brake pressure to build up again, at a controlled rate, until the wheel momentarily skids again. The valve, again, starts to reduce the brake pressure, but to a lesser degree than previously, until the wheel no longer skids. Again, the anti-skid control valve increases brake pressure until a skid occurs.

This iterative process takes a short, but finite, amount of time, during which the braking action is less than optimum. This process also assumes that the friction between the tyres and the runway surface is constant and that full brake pressure is available via the brake control valves.

Any change in runway friction, or the brake pressure available, will cause the system to adapt to these changes and begin the iterative process again. Therefore, if the brake pedal force applied is reduced and then re-applied the anti-skid system has to begin the iterative process again, to regain the best braking performance. Each iterative process causes a reduction in optimum performance and hence increases the braking distance.

A similar effect occurs with varying friction levels. If the friction suddenly increases or reduces the system has to reschedule the anti-skid control valves to the new friction level by either increasing, or reducing the brake pressure, after which the iterative process begins again.

1.6.5 Lift spoiler and air brake system, Figures 3, 4 and 5

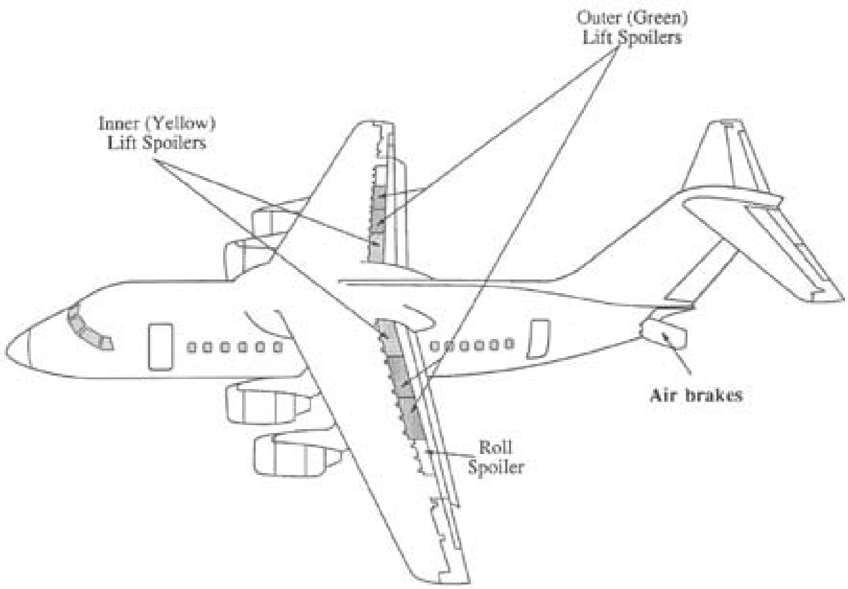

Figure 3

Lift spoiler and airbrake surface locations

The tail-mounted clamshell-type airbrake and the lift spoilers are controlled by a lever located at the left side of the control pedestal. With the airbrake stowed, the lever sits 27° forward of the vertical and moves rearwards through an arc of 38° to deploy the airbrake surfaces fully. These move in proportion to the lever movement. At this position, the lever comes up against a detent. To pass through this detent when selecting lift spoilers after touchdown, a force of between 13 lbf and 19 lbf is required. The lever then moves through a further 13° of travel in order to operate a microswitch which signals the lift spoilers deployment. This switch is only operated with the lever positioned at the extreme of its travel. With the lever in the 'lift spoilers' position, the airbrakes remain deployed.

Close to zero force is required to move the lever from 'LIFT SPOILER' back to 'AIRBRAKE'.[4]

4 These figures are only applicable to the Mod. state of EI-CZO at the time of the incident at LCY. (See para 1.18.6 - Manufacturer's Service Bulletins, page 32.

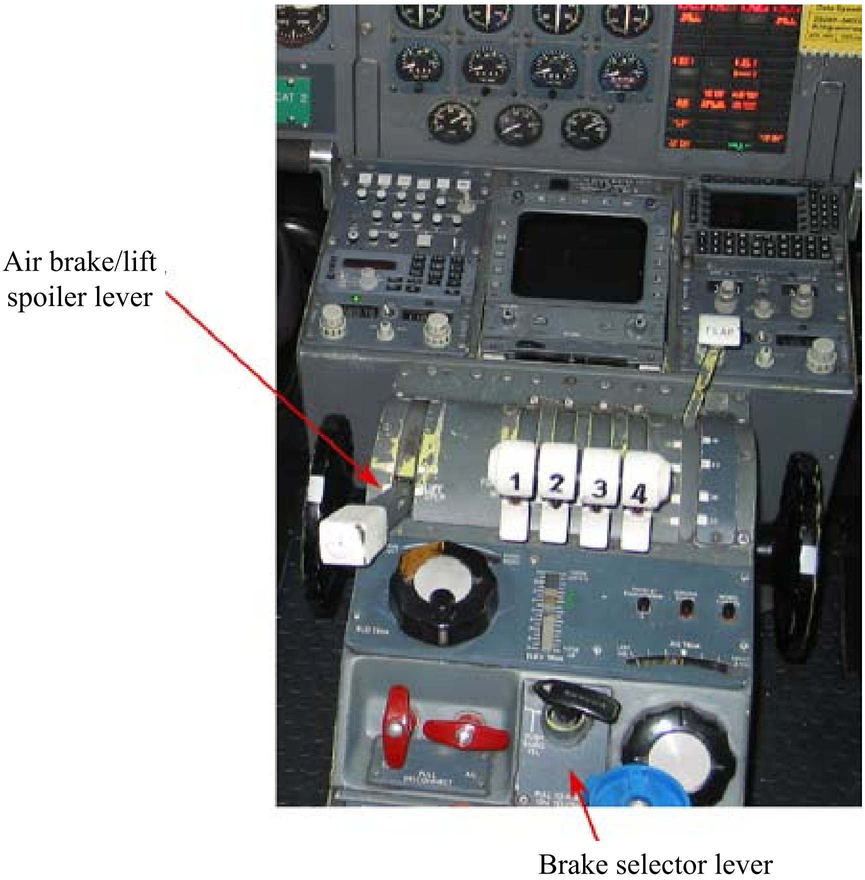

Figure 4

Airbrake/lift spoiler lever location

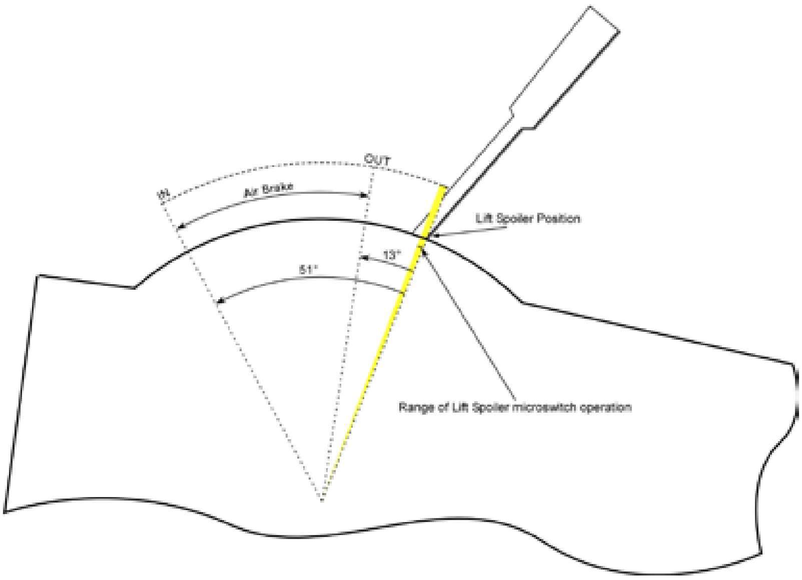

Figure 5

Airbrake/lift spoiler lever location and range of movement

The BAe 146 is equipped with six spoiler panels, three on each wing. The two inboard panels on each wing are powered by the Yellow hydraulic system and deploy when the following conditions are met:

- Airbrake/lift spoiler lever set to 'LIFT SPOILER'
- Yellow system lift spoiler switch on the overhead panel is ON
- Three out of the four thrust lever microswitches indicating that the levers are below the flight idle setting
- Either both left and right main landing gears are compressed, as indicated by weight-on-wheel switches, or
- Left or right main landing gears are compressed and the nose leg is compressed, or
- Either the left or right main landing gear is compressed and then extended, with the nose leg compressed within 10 seconds of the main landing gear being compressed.

The outboard surfaces on each wing are powered by the Green hydraulic system and are deployed 1.5 seconds after the following conditions are met:

- Airbrake/lift spoiler lever set to 'LIFT SPOILER'
- Green system lift spoiler switch on the overhead panel is ON
- Three out of the four thrust lever microswitches indicating that the levers are below the flight idle setting
- Both left and right main landing gears are compressed, as indicated by weight-on-wheel switches

1.6.6 Flight-idle baulk

For the thrust lever microswitches to indicate a power demand below flight idle, the flight idle baulk on the throttle quadrant has to be removed. The baulk restricts the levers to a position equivalent to a minimum engine speed of 60% N_2. When both left and right main landing gears are compressed, the baulk is removed and ground idle power may be selected. The weight-on-wheel switch signals, which indicate compressed main landing gear, are used by both the flight idle baulk system and the lift spoiler system.

1.6.7 Lift spoiler deployment indication system, Figure 6

Indication of deployed spoiler panels is by the illumination of SPLR Y and SPLR G lights on both sides of the instrument panel. Switches operate when they sense hydraulic pressure in the inner and outer panel 'extend' lines and provide the signal to illuminate the lights.

In the event of a failure to deploy, the SPLR Y and SPLR G lights remain extinguished. However, amber LIFT SPLR warning lights, mounted on the glareshield in front of each pilot, illuminate if either of the following conditions are met:

> Left or right main landing gear compressed, and the lift spoilers not deployed within six seconds. (The light remains illuminated for 14 seconds before extinguishing)
>
> The airbrake/lift spoiler lever is in 'lift spoiler', but the panels do not deploy within three seconds. (In this case, the light remains illuminated until the lift spoilers deploy or the lift spoilers are deselected.)

1.7 Meteorological information

Records were obtained from the Semi-Automatic Meteorological Observation System (SAMOS) in use at London City Airport. These showed that at 0820 hrs, 13 minutes before the incident, the surface wind was 160°/05 kt, visibility was 10 km or more, there was no significant weather, the cloud was FEW at 800 ft and BKN at 1,000 ft, the temperature was 10°C and the dewpoint 8°C, and the QNH was 1,006 mb. At 0840 hrs, 7 minutes after the incident, the report was identical, except that the wind was recorded as 170°/06 kt.

1.8 Aids to navigation

The flight crew executed an approach using the ILS system installed at the airport. The system functioned correctly and was not a factor in the incident.

The ILS approaches to each runway are 'steep glidepath angle approaches' and have a glidepath set to 5.5°. The document ICAO PANS Ops Doc 8168 states the following:

Figure 6

Lift spoiler warning lights and wheel brake pressure gauges

> *'Glide path angles above 3.5° should be used in approach procedure design only for obstacle purposes and must not be used as a means to introduce noise abatement procedures. Such procedures are non-standard and require special approval.*
>
> *A special note shall be included on the instrument approach chart stating that appropriate aircraft and crew qualifications are required to use such a procedure.'*

1.9 Communications

The flight crew communicated with ATC and the AFRS using VHF radio on published aeronautical frequencies. These communications were without difficulty.

1.10 Aerodrome information

London City Airport is situated in the Docklands area to the east of the financial centre of the City of London. The airport was built on land between the Royal Albert Dock, to the north, and the King George V dock, to the south. It has one runway, orientated 10/28, with a grooved concrete surface measuring 1,508 m by 30 m. The Takeoff Run Available (TORA) in each direction is 1,199 m, the Takeoff Distance Available on Runway 10 is 1,319 m and that on Runway 28, 1,385 m. The Landing Distance Available (LDA) is 1,319 m in both directions.

The runway lighting is non-standard, and includes two pairs of white inset high-intensity lights on the runway, 336 m beyond the thresholds, which mark the ends of the Touchdown Zones (TDZs). The AIP entry for the airport states:

> *'The end of the 336 m TDZ is marked with two pairs of white inset high intensity lights. This visual reference may be lost prior to landing depending on point of touchdown and attitude of the aircraft. If during final approach it is anticipated that the touchdown point will be outside this area, a missed approach procedure should be initiated.'*

1.11 Flight Recorders

The aircraft was fitted with a 25-hour Flight Data Recorder (FDR) and a 30-minute Cockpit Voice Recorder (CVR). Both recorders were downloaded at the AAIB and data from the FDR was recovered for the incident landing. However, the CVR audio recordings for the approach and landing were overwritten with later recordings while the aircraft was on the ground with electrical power still applied.

A time history of the relevant parameters during the incident is shown at Figure 7. The data presented begins with the aircraft at 620 ft agl, with the autopilot engaged, on the ILS approach to Runway 10. At this point, the aircraft's descent rate was approximately 1,250 ft/min, the airspeed was reducing through 136 kt, the pitch attitude was 8° nose-down, the flaps were set at 33°, the landing gear was down and the airbrakes were fully extended (60°). The thrust from each engine throughout the descent from 1,600 ft agl remained constant at just under 35% N_1 (flight idle), until 900 ft agl, where it increased slightly before reducing back to flight idle by 480 ft agl.

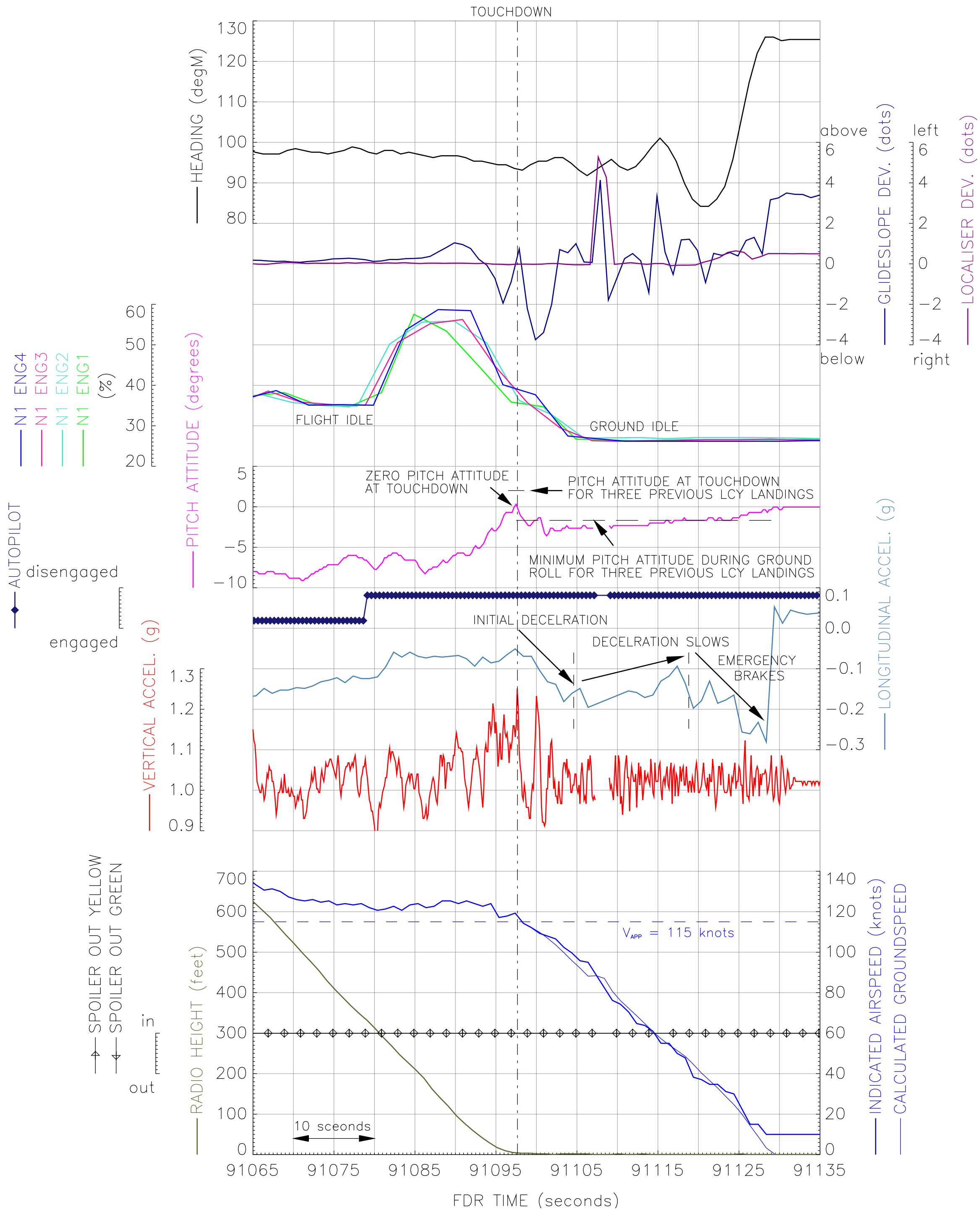

Figure 7

Salient FDR Parameters

At 380 ft agl, with the airspeed at 124 kt (ie, V_{APP} +9), the autopilot disengaged while the engine thrust increased. The thrust reached between 55% and 59% N_1 eight seconds later, as EI-CZO passed through 200 ft agl, before reducing back to about flight idle just before touchdown[5]. As the thrust decreased, the pitch attitude increased (at a rate of no more than 1º/second) until touchdown.

The aircraft touched down at 0º pitch attitude[6] with an indicated airspeed of 119 kt (V_{APP} +4) and vertical load factor of 1.25g. The aircraft then bounced, pitching down to -2.3º before pitching up to about -1.5º for the second and final touchdown, again with a vertical load factor of 1.25g, 2.5 seconds later. The aircraft then pitched down again.

There were no indications of Yellow or Green lift spoiler deployment during the landing rollout.

From initial touchdown, the aircraft slowed to a halt over a period of 31 seconds during which it veered to the left and right with increasing amplitude, until finally veering off to the right on a heading of 126ºM. Three distinct phases of deceleration were noted:

> The first phase started immediately after touchdown as the thrust reduced to about 26% N_1 (ie, ground idle) over a period of seven seconds, during which time EI-CZO slowed to about 96 kt groundspeed.
>
> In the second phase, lasting 14 seconds, the aircraft's deceleration gradually reduced[7].
>
> The final stage, lasting 10 seconds and corresponding to the known application of the emergency brakes, the aircraft slowed from about 43 kt to a stop.

The specific use of brakes cannot be determined as braking parameters were not recorded as part of the FDR installation.

5 No weight-on-wheels parameters were recorded as part of the FDR installation. However, the touchdown position was determined by examination and comparison of such parameters as radio height, pitch attitude and normal acceleration (vertical load factor), and the timing of the engine thrusts reducing to ground idle.

6 Note that for each of the three previous and uneventful landings of EI-CZO at London City Airport, the recorded pitch attitude at touchdown peaked at about 2º nose up.

7 Comparing with the three previous London City landings, the initial rate and peak level of deceleration recorded for the incident landing were half of that recorded for these previous landings, during which EI-CZO was slowed to a halt over a period of approximately 20 seconds.

Elevator deflection data during the landing roll was analysed, and comparison made with the three previous landings at LCY, with a view to the determination of control column position. It was not possible to determine its position with any accuracy as, although the peak deflections were the same on at least two of the previous landings, they were not sustained for as long a period as on the subject landing. The aircraft manufacturer was also asked to examine the FDR evidence of elevator/control column position. Unfortunately, because of uncertainties over the relationship between the various factors at play, this was not possible.

However, it was apparent that during the first two deceleration phases, the aircraft's pitch attitude was less than the minimum value of -1.7º (ie nose-down) measured on the previous three landings at LCY during the ground rolls. This started at -3º just after touchdown, and gradually increased to -1.7º over the next 21 seconds.

1.12 Aircraft and site examination

1.12.1 Ground marks, Figures 8 and 9

The aircraft came to rest in the undershoot area of Runway 28, 161 m short of the dock edge. Based on witness evidence, it touched down at the end of Runway 10 touchdown zone and, on this basis, the aircraft travelled 554 m prior to the start of the skid marks. These were evident for each of the four main wheel tyres over a distance of 473 m. Toward the end of the skid, the aircraft tracked to the left of the runway centreline, but with the aircraft heading to the right, before coming to a halt on a heading of 130°. During the skid, the four main wheel tyres had been worn through, causing all to deflate, and all the tyre carcasses to start to roll over the rims of their wheel hubs.

1.12.2 Aircraft examination

The operator replaced the aircraft wheels, tyres and brakes to allow the aircraft to be towed from the runway to a safe area for further investigation. Full functional and visual checks of the hydraulic, flap, normal brake, emergency brake and anti-skid systems, were satisfactory. Later, a high-speed taxi test to assess braking action was carried out, with satisfactory results. Calibration of the aircraft's airspeed indicators showed both to be within the limits given in the maintenance manual.

A detailed examination of the lift spoiler system was also carried out, including checks of each of the weight-on-wheels switches, the thrust lever

Figure 8

Damage to left Main Landing Gear tyres; right similar

microswitches and the lift spoiler/airbrake lever microswitches. Despite extensive checks in many configurations, no faults could be found with the system. The lift spoilers responded as expected and the flight deck warnings displayed correctly. A test of the loads required to operate the airbrake/lift spoiler lever revealed that operation from ‘airbrake’ to ‘lift spoiler’ required a force of 14 lb, whereas the force to move the lever from ‘lift spoiler’ back to ‘air brake’ was very close to zero. Both these forces were within the limits specified in the aircraft’s maintenance manual.

A test of the compression required of each landing gear unit, in order to operate the weight-on-wheel switches, was carried out. The left main landing gear switch operated at 0.75” of compression and the right main landing gear switch at 0.5” of compression. The two nose landing gear switches, designated as GM2 and GM5, operated at 0.125” and 0.9675” of compression respectively. All the measurements were within the limits of the Aircraft Maintenance Manual (AMM), with the exception of switch GM5 on the nose landing gear.

The AMM defines two limits for GM5: the compression at which the switch operates (before 1.8” of compression) and a second limit based on the point at which the switch deactivates during extension. The switch must be de-activated at a point greater than 0.75” of compression. GM5 de-activated

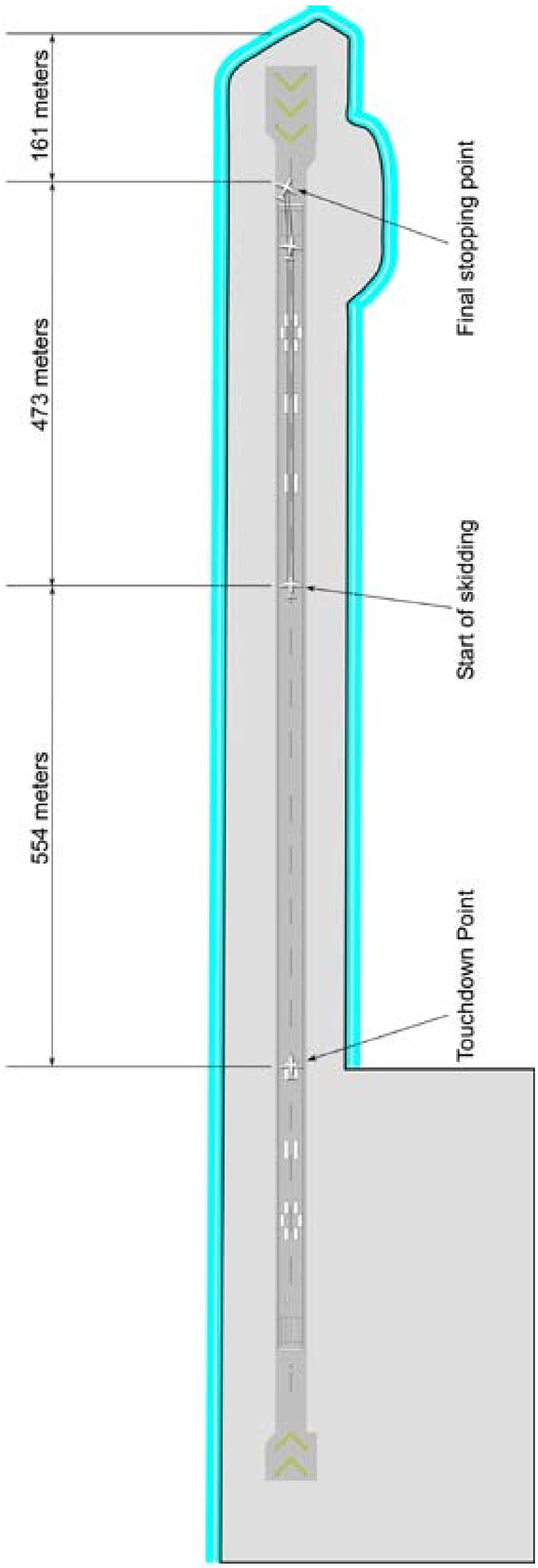

Figure 9

Landing/stopping distances for EI-CZO

at 0.0625” of compression, and therefore fell outside the manual limits. This meant that switch GM5 would have activated and provided a ground signal at a low degree of compression and remained in this state longer than necessary as the weight was removed from the nose gear.

1.13 Medical and pathological information

Both pilots held valid medical certificates. A short time after the incident, police officers breathalysed both pilots, with negative results.

1.14 Fire

None.

1.15 Survival aspects

There were no immediate survival issues in this incident. The aircraft stopped on the paved surface, there was no fire and all the occupants were uninjured and deplaned via steps.

The overrun area for Runway 10 at LCY is 192 m, and the Runway End Safety Area (RESA) is 132 m. The RESA therefore forms the majority of the overrun area and exceeds the ICAO recommended length of 120 m for a code two instrument runway. Runway 10 overrun area does not include an arrestor bed; although, the paved surface is grooved. Beyond this area is a small water channel linking the two main water-filled areas of the old dock, located either side of the runway, Figure 10. Overshooting the paved surface or departing the runway to the side would, therefore, carry a significant risk of an aircraft entering the water, possibly in a damaged condition.

The water surface is approximately 1 metres below the level of the runway, and is maintained around this level by lock gates between the docks and the River Thames, which is tidal at this point. When the docks were originally constructed, the water depth was approximately 20 metres, but they have silted up since their commercial use ended. In places, the water depth is only around 1 to 2 metres.

The London City Airport Fire and Rescue Service (AFRS) operates three rapid intervention rigid inflatable boats (RIBS), Figure 11, two of which are on standby at any one time, and which are capable of deploying buoyancy aids. Two towable slide rafts can be used in conjunction with the RIBS, which are capable of seating up to 60 persons. Both RIBS are positioned on the south side of the runway at a location which ensures the minimum of delay in their deployment by the AFRS.

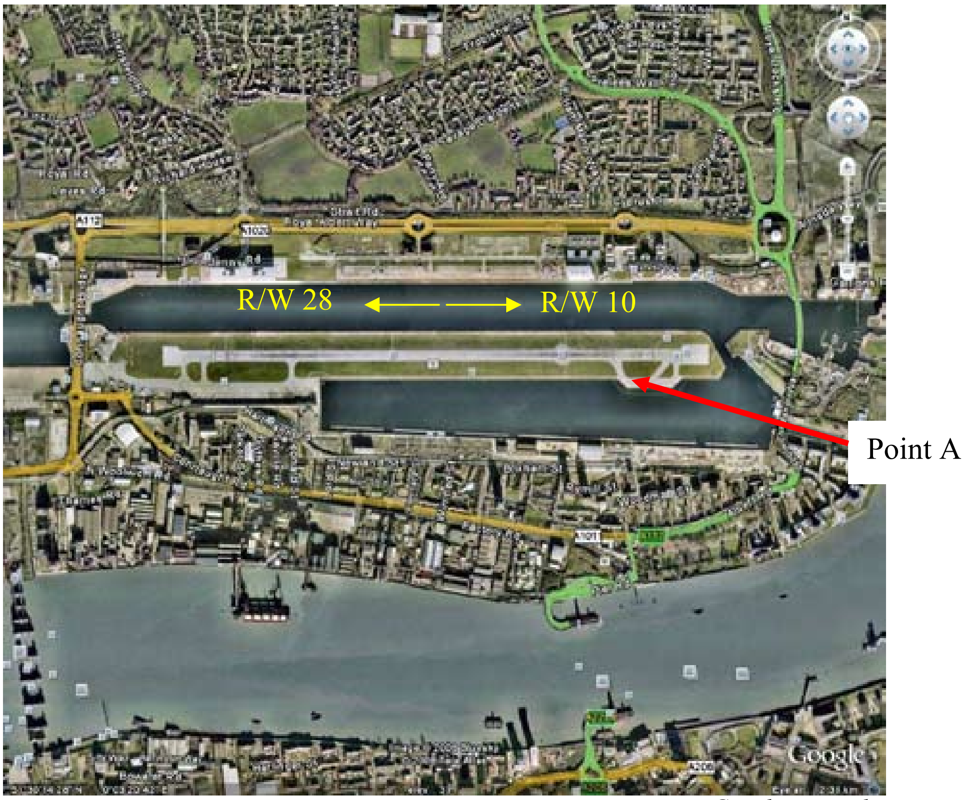

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Figure 10

Photograph illustrating the nature of the undershoot and overrun areas, and the proximity of the water-filled docks to Runway 10/28

Figure 11

Photograph taken from point A in Figure 10, looking west, showing one of the rapid intervention boats, and illustrating the proximity of the southern 'old' dock to the taxiway and runway

1.16 Tests and research

1.16.1 Braking performance

The aircraft manufacturer calculated the stopping distances for the BAe 146-200 based on parameters taken from the incident to EI-CZO but with a landing weight of 33.0[8] tonnes. The calculated distances for a dry[9] runway surface under the various conditions, are shown in Figure 12, (1)-(5). They also assume that the correct braking technique is employed in all cases.

These calculations showed that, with fully operational spoilers, anti-skid operation, no wind and the aircraft's speed at the V_{REF} of 112 kt at the threshold[10], the distance from the threshold to touchdown is 170 m and from touchdown to a full stop is a further 402 m (1). With the spoilers inoperative, the distance from touchdown to full stop increases to 604 m (2).

When EI-CZO's recorded speed over the threshold of 124 kt is used, and with the lift spoiler and anti-skid systems operational, the threshold to touchdown distance extends to 198 m, and the touchdown to full stop distance increases to 479 m (3). Under the same conditions, but with the spoilers inoperative, the distance from touchdown to full stop increases to 842 m (4).

The last calculation, (5), uses EI-CZO's actual threshold speed, the distance from the threshold to its touchdown of 336 m, and assumes that the lift spoilers are inoperative. Assuming the anti-skid system is fully operational and the correct braking technique is applied, the touchdown to full stop distance is 842 metres. These distances are within the LDA for Runway 10 at LCY.

In summary, if all other parameters are correct (ie, V_{APP} and V_{REF}), non-deployment of the spoilers should be absorbed within the 1.67 safety margin contained in the AFM landing distance figures, provided that maximum braking is applied and maintained throughout the landing roll to taxi speed.

8 The aircraft's landing weight was 32 tonnes, hence these calculations represent a slightly worse case.
9 The Clculations for a dry runway are deemed to be applicable to a 'damp' runway.

10 The aircraft's V_{REF} for a landing weight of 33 tonnes.

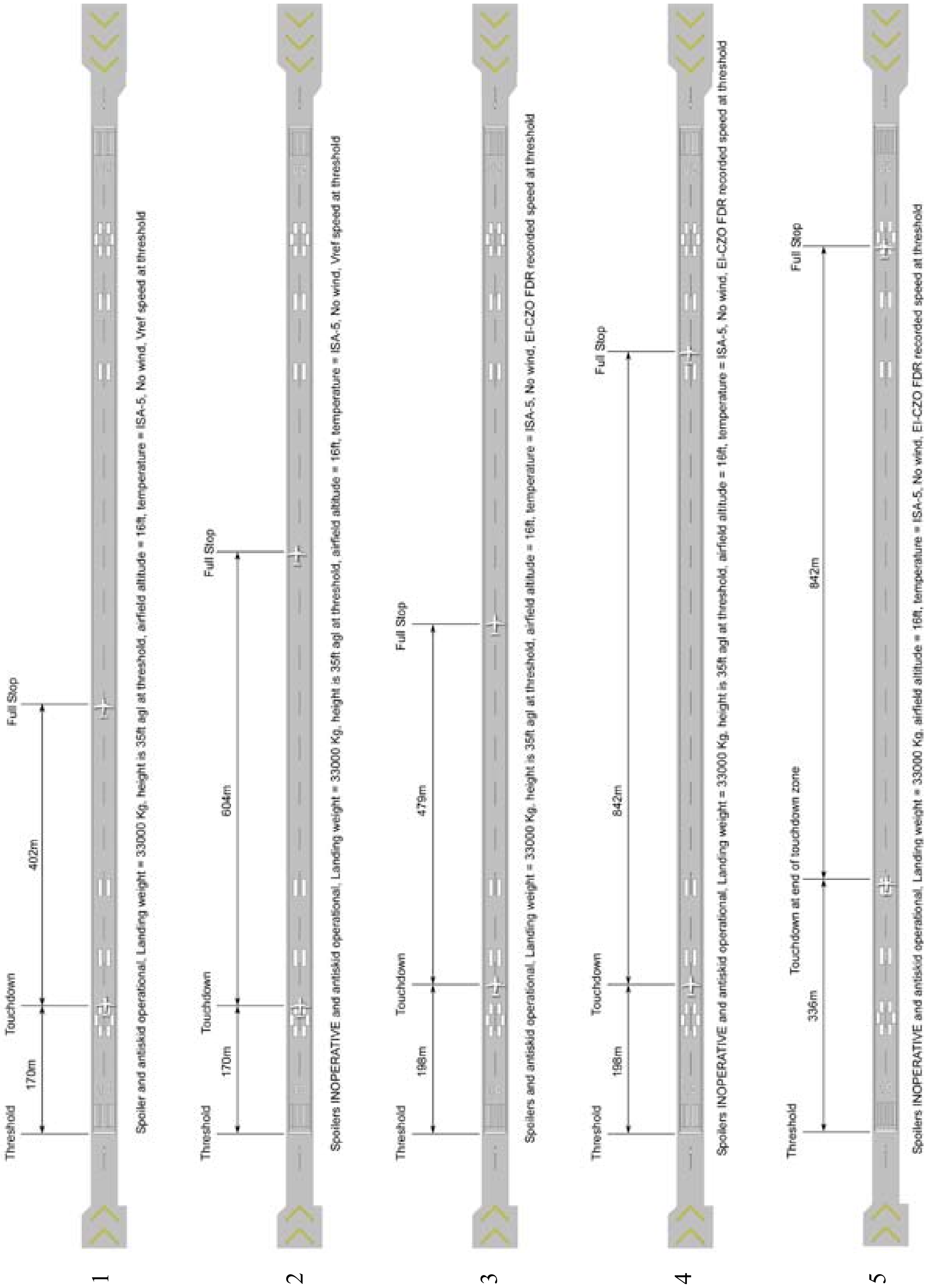

Figure 12

BAe 146-200 landing/stopping distances calculated by the manufacturer

1.17 Organisational and management information

1.17.1 Operator

The Operator holds an Air Operators Certificate issued by the Irish Aviation Authority, and conducts commercial air transport operations throughout Europe with a fleet of 22 BAe 146 and RJ 85 aircraft.

1.18 Additional information

1.18.1 Landing weight and approach speed

The aircraft's Zero Fuel Weight (ZFW) on the flight was 29.4 tonnes. The loadsheet prepared at Paris Orly prior to departure, recorded a takeoff fuel figure of 4.8 tonnes and a trip fuel of 2.2 tonnes. Therefore, the fuel remaining on landing was predicted to be 2.6 tonnes and the landing weight, 32.0 tonnes.

However, when the co-pilot calculated the landing weight during flight, he used a landing fuel figure from the aircraft's Global Navigation System of 3.7 tonnes, and therefore determined a landing weight of 33.1 tonnes. The operating company provided a book of laminated cards giving appropriate speeds for operations at various weights, and it was customary to use the speeds relevant to the next highest tonne value above actual landing weight. Therefore, the co-pilot consulted the card for a landing weight of 34 tonnes and determined the approach reference speed (V_{REF}) to be 114 kt. However, he wrote down a V_{REF} of 119 kt on the landing data card, which was in fact the appropriate V_{REF} value for 37.6 tonnes, 5.6 tonnes heavier than the actual landing weight.

The V_{REF} appropriate to a landing weight of 32.0 tonnes (the actual landing weight) is 110 kt, and for 33.1 tonnes (the erroneously calculated landing weight), 112 kt; the rounding up process to 34 tonnes gave a V_{REF} 4 kt higher than was appropriate for the aircraft's actual weight. However, the V_{REF} written on the landing data card was actually 9 kt higher than was appropriate.

The operator's Operations Manual part B stated:

> *'Speed at threshold must not exceed VREF +14. If higher, the aircraft may land nose wheel first. Minimum threshold speed is VREF –5. When the speed at threshold is greater than VREF +7, the landing distance required must be increased by 2% per knot above VREF +7. Please refer to NTA OP 45 in the NTA section of this manual for guidance on approach and landing speeds.'*

1.18.2 The operator's stabilised approach requirements

The operator's Operations Manual, part B, contained the following statements with regard to stabilised approaches:

> *'Approach and Landing Accident Reduction – the Stabilised Approach*
>
> *A large proportion of transport aircraft accidents occur in the approach and landing phases of flight.*
>
> *We require all precision approaches (prior to any "Contact" call) to be stabilised by 1,000ft arte[11], non-precision approaches to be stabilised by 1,000ft above MDA and all visual approaches to be stabilised by 500ft arte. Pilots should establish a firm habit of flying the approach accordingly. They must not allow themselves or each other to adopt casual habits in the later stages of the approach and landing. Good disciplines, firmly established at an early stage of each pilot's experience on type, will lay good foundations for safe operations subsequently.*
>
> *'The panel below gives guidelines for determining whether an approach is stabilised. An approach is stabilised when all the conditions listed are met and maintained:*
>
> ***Stabilised Approach Conditions***
>
> *The aircraft is on the correct flight path*
>
> *The aircraft is in the correct landing configuration.*
>
> *Only small changes in heading, pitch and speed are required to maintain the correct flight path.*
>
> *The vertical speed (also called rate of descent or sink rate) is no greater than 1,000 fpm*
>
> *The thrust setting is appropriate for the aircraft configuration.*
>
> *All briefings and checklists have been completed (subject to SOPs)*

11 arte - above runway threshold elevation.

Additional Approach Criteria:

A Cat 1 ILS approach must be flown within one dot of the glideslope and localizer

A Cat 2 ILS approach must be flown within half a dot of the glideslope and localizer.

A non-precision approach must be flown within ± 5° of the inbound course.

On a circling approach, the aircraft must be wings-level on final by 300ft arte.'

As the aircraft passed through 700 ft aal, its speed was approximately 138 kt; the approach speed was only stabilised at about 124 kt when the aircraft was approximately 400 ft aal.

The manufacturer of the BAe146 had produced flight crew training documents until some years prior to this event; no such documentation was currently available and no written instructions on landing technique appeared in the operations manuals.

1.18.3 Published instructions to flight crew

Landing procedure

The procedure to be followed after landing was laid down in the Operations Manual part B[12], Figure 13.

The Note clarifies that when the right seat pilot (usually, the co-pilot), is pilot flying, they move the thrust levers to GROUND IDLE after landing, while the left seat pilot selects the lift spoilers to OUT; if the left seat pilot is the pilot flying, they move the thrust levers to ground idle and then select the lift spoilers.

Thus, depending upon whether he is the pilot flying or not, the left seat pilot makes either one or two selections with his right hand during the early part of the landing roll. Both selections are on controls which are critical for the safe execution of the landing and move in the fore/aft sense, and both are

12 The operations manual referred to Handling Pilot (HP) and Monitoring Pilot (MP) in place of pilot flying and pilot monitoring.

HP	MP
Select Ground Idle Fly wings level Lower nose wheel gently onto runway.	
	Confirm: **"Ground Idle"**
Select lift spoilers OUT Maintain wings level.	
	Confirm lift spoilers out **"Spoilers, Yellow/Green"**
Apply brakes as required.	
	Monitor brake pressure **"Positive brake pressure"**
"Your stick" Transfer left hand to nose wheel steering before rudder effectiveness lost (around 60kts)	
	Take stick and maintain wings level. **"My stick"**

Note: If the RP is the HP he shall call for the lift spoilers as only the Commander may make the selection.

(RP - right seat pilot)

Figure 13

Operations Manual - Post-touchdown procedure

relatively small movements on controls which have a much greater range of movement.

On 1 December 2006, the operator published a Flight Crew Instruction, entitled *'Prevention of landing overruns'*, which stated:

> *'Following a recent landing accident to a 146 series aircraft, it is considered important to remind all pilots of the necessity to positively select the Lift Spoilers and monitor the associated annunciations, select and check that ground idle has been selected, and check the effectiveness of the applied brake pressure after touchdown.'*

The operator's operations manual included a BAe 146 manufacturer's Notice to Aircrew on the topic of *'Approach and landing speeds'*. The notice stated, *inter alia*:

> *'Background*
>
> *Throughout the aviation industry, approach and landing accidents cause the highest number of airframe losses and the second highest number of fatalities. A worldwide safety analysis has identified the fact that the absence of a stable approach path was a significant in approach and landing overrun accidents. An essential element of achieving stability is the selection and flying of the correct airspeed during approach and landing.'*

It included advice on landing speeds as follows:

> *'Landing*
>
> *A touchdown with excessive speed may result in a nosewheel first landing and subsequent delay in spoiler deployment. In addition, the aircraft energy that has to be dissipated during landing increases in proportion to the square of the touchdown speed. If the speed at the threshold is greater than V_{ref} 14 kt, a go-around must be carried out because of the risk of landing nosewheel first. Beware of tailwind landings: high groundspeeds quickly use up the available landing distance. During the landing flare, retard the thrust levers to idle, so that no excess thrust is present at touchdown. Pilot may begin to retard the thrust levers earlier if the threshold speed was higher than intended.*
>
> *The threshold speed provides for safe flight during the approach and landing. There is some margin in the aircraft landing performance for small errors in speed, touchdown position or aircraft handling, but the scheduled performance does not account for combined or large errors. If there is any doubt as to the accuracy of the landing, especially considering the threshold crossing height, the threshold crossing speed and the expected touchdown point, then a go-around should be flown.*
>
> *The optimum touchdown speed will be 7 kt below the threshold speed. Do not extend the flare to achieve a smooth touchdown. Commence wheel braking immediately all three gear units are on the ground and confirm positively that the lift spoilers have deployed, following up immediately with a manual selection for aircraft fitted with autospoiler.*

When landing on a short runway or when at or near maximum landing weight for the available length, use maximum wheel braking. When operating on wet or contaminated runways safety margins may be reduced and the effect of an error in speed or touchdown position will be greater - always use maximum braking in these conditions. Below 80 kt with the lift spoilers deployed, move the control column aft to increase the weight on the main wheels and improve braking effectiveness.'

The operator set out procedures for steep approaches in its operations manual. The section concerning 'Short field landing/braking techniques' included advice on landing and braking technique, including:

'For short field landings, commence maximum braking to ensure that the brakes are operating normally and as soon as the aircraft has decelerated significantly, reduce to light braking. The natural tendency for pilots is to brake lightly at first and increase the pressure progressively. This technique does not allow for malfunctions within the brake system.'

It also included the statement:

'IF BRAKING PERFORMANCE IS LESS THAN EXPECTED, CHANGE TO THE ALTERNATE SYSTEM.'

1.18.4 Simulator evaluation

A series of landings were flown in a BAe146 simulator configured to represent the incident aircraft, at a landing weight of 32.0 tonnes, but with speeds appropriate to 33.1 tonnes. Landings were carried out with and without simulated failures of the flight spoilers and wheel brake systems to assess aircraft handling. V_{REF} was calculated to be 114 kt, and approaches were also flown at 119 kt and 129 kt.

During a simulated landing from an approach speed of 129 kt, it was noted that the aircraft touched down on its nose landing gear, and could not easily be controlled in pitch to compress the main landing gear. It was not possible to select ground idle and nor did the spoilers travel to the 'lift spoiler' position until the conditions detailed in section 1.6.3 were met. This occurred some time after the initial touchdown. During this period, a sensation of loss of deceleration was felt, and it was difficult to maintain directional control of the aircraft.

The manufacturer was asked whether it would be realistic to instruct flight crew to execute a baulked or rejected landing, in cases where the flight spoilers did not deploy or deceleration seemed inadequate. The manufacturer's advice that this was not appropriate was borne out by evaluation during the simulator exercise, which showed that such a manoeuvre was uncertain and potentially hazardous.

1.18.5 Previous Events

The aircraft manufacturer identified 25 landing overrun incidents and accidents involving BAe146 and RJ aircraft. In some cases, it proved impossible to obtain verifiable information about the event as, either no investigation had been carried out or, no copy of the report could be obtained. Appendix A contains brief summaries of these previous events for which information was available.

The manufacturer also conducted an analysis of other factors which could have contributed to 17 of these previous overrun incidents and accidents, Appendix B. Factors assessed were whether the aircraft landed long, whether it was fast, the condition of the runway, its length and slope, the weather, braking technique, the type of approach, whether a technical problem was present, and whether the spoilers deployed late or not at all.

They concluded that the dominant three factors in these events were that the aircraft landed long (360 m or more beyond the runway threshold for the 146-200 version), the condition of the runway (wet or contaminated), and the presence of a tailwind. These three factors appeared in 59% of the cases studied. Non-deployment, or late deployment of the spoilers, was identified as having been one of the factors in 35% of the overruns, but only two of these events occurred together with the dominant three factors. In only one case was there a report of a technical problem with the aircraft.

1.18.6 Manufacturer service bulletins

Since the BAe 146 type has entered service there have been several modifications to the spoiler system.

In 1983, BAe issued an Alert Service Bulletin (SB 27-A-24), which was made mandatory by the CAA. This required operators to inspect the combined airbrake/lift spoiler selector lever to establish whether the point at which the spoiler arming microswitches were actuated was at least 2" of lever movement forward of the aft limit of its travel. This was later reinforced by two modifications, 27-24-00321A and D (recommended) and 27-30-00321E (optional, if A and D were insufficient) directed towards ensuring that there would be a minimum overtravel of the selector lever beyond the point at which the arming microswitches operated. The rationale behind this was that inadequate overtravel of the selector would expose the spoilers to easy de-selection with only a small inadvertent forward movement of the lever.

At about the same time, service experience had revealed a need to modify the logic associated with the landing gear squat switches and this was introduced by SB 27-29-00485A and B. In addition to the selection of the lever and throttle conditions, there is a requirement to sense correct landing gear condition, in order to enable spoiler deployment. The original logic required that both main gear oleos should be compressed for at least one second, and that the nose gear oleo was also compressed. It had been found that this requirement could significantly delay the deployment of the spoilers during difficult landings in crosswind conditions and in 'wheelbarrowing' situations. Therefore trials were conducted to determine whether it was possible to dispense with the nose gear compression requirement.

In 1988 BAe issued a change to the spoiler indication system logic, under modification SB 27-70-00913 (modification HCM00913A, B and C). The reason for the modification was to reduce the possibility of the flight crew failing to deploy the lift spoilers on landing. The modification introduced the LIFT SPLR warning lights on the glareshield and the associated logic circuitry required to illuminate these lights. A later modification (HCM 00913D) introduced a dim and test facility for the LIFT SPLR warning light.

It was also considered that correct operating lever overtravel, to ensure that the spoilers would remain selected, could be compromised by the loss of lever friction. To combat this, SB 27-31-00402A was introduced to prevent any reduction of friction. However, as a result of this latter modification, SB 27-39-00402B had to be introduced to eliminate the effects of a possible tolerance build-up on the earlier 402A service bulletin. SB 27-69-00905A introduced a positive detent force for the selection of the lever from 'full airbrake' to 'lift spoiler'.

In March 1988 the aircraft manufacturer issued service bulletin 27-73-00889 to amend further the force characteristics of the lift spoiler selector lever. Prior to the modification, the force required to move the airbrake/lift spoiler lever from 'airbrake' to 'lift spoiler' was between 13 and 14 lb, with no force required to move the lever from 'lift spoiler' to 'airbrake'. This was the configuration on

EI-CZO, as the SB had not been incorporated. Following modification, the force characteristics are changed so that a force of 12 lbs is required to move the lever from 'lift spoiler' to 'airbrake'. The service bulletin was not mandatory. The SB was initially applicable to 114 aircraft, 105 of which remain in service.

1.18.7 BAe 146 Auto Spoiler system

The later version of the BAe 146 aircraft, the RJ series, have automatic lift spoilers as a standard fit from manufacture. The auto-spoiler is armed by a switch and the system then uses wheel spin up signals for deployment of the lift spoilers. It operates in parallel to the original manual spoiler system. Although the system removes the need to select the airbrake/lift spoiler lever to 'lift spoiler', it does not absolve the crew's responsibility to monitor the spoiler system on landing. Also, in certain contaminated runway conditions the wheel spin-up may be delayed, hence delaying the deployment of the spoilers.

The system may be fitted to BAe 146-100, -200 and -300 series aircraft under modifications HCM 00970B and HCM 00970C, approved by the CAA under Airworthiness Approval Notice (AAN) 20814. This was an optional modification and has only reportedly been embodied on four aircraft.

1.18.9 Thrust lever microswitches

For the lift spoilers to operate during the ground roll, one of the conditions is that three out of the four thrust lever microswitches operate to indicate that the thrust levers are below the flight idle setting. The design philosophy for this is to prevent spoiler operation if more than one thrust lever is above flight idle. The Yellow and Green lift spoiler hydraulic systems are signalled by the same switch on each lever.

With the levers below the flight idle setting, the microswitches are closed. Therefore, a microswitch which fails open-circuit would always indicate to the system that the thrust demand was above flight idle. However, due to the logic of 'three out of four', failure of the spoilers to deploy due to a failure of thrust lever switches would require two switches to fail open-circuit co-incidentally. With the failure of only one throttle microswitch, the system would operate normally and not be detected by the operating crew. This could lead to a faulty microswitch remaining undetected, until a functional test is carried out or a failure of a second throttle microswitch during normal operation. The latter case would lead to a failure of the lift spoilers to deploy and would only be evident when the lift spoilers are selected on landing. The current maintenance inspection that would detect a failure of a throttle microswitch is detailed in the AMM. The frequency of the inspection, however, is dependant on the modification standard of the aircraft. The modification (MOD01195A/B) introduced an improvement to the throttle microswitch operating arms to reduce the possibility of the arms bending. On pre-modification aircraft the system is tested once every 625 flights. Post-modification, this is carried out once every 2,500 flights

The four thrust lever microswitches on EI-CZO were found to be fully serviceable.

1.18.10 Probability of failure

Between 1986 and the end of 2006, there have been 24 overrun events involving the BAe 146 or Avro RJ aircraft. Of these 24 overruns, five have resulted in aircraft hull losses, giving a rate of 0.53×10^{-6}. The aircraft manufacturer carried out a comparison with other aircraft types over the period 1959-2005, Table 1. From this, it was concluded that the BAe 146/RJ was no more prone to overrun the runway on landing than most other types of aircraft.

Aircraft Type	Overrun Rate	Fatalities
BAe 146/Avro RJ	0.9×10^{-6}	24
Airbus A300	1.2×10^{-6}	None
Airbus A310	1.3×10^{-6}	126
Airbus A340	1.8×10^{-6}	None
Airbus A320	0.7×10^{-6}	2
DC-10	2.2×10^{-6}	18
DC-9	0.4×10^{-6}	None
MD-11	2.8×10^{-6}	None
MD-80	0.4×10^{-6}	38
Boeing 727	0.3×10^{-6}	169
Boeing 737	0.7×10^{-6}	31
Boeing 747	1.3×10^{-6}	None
Boeing 767	0.5×10^{-6}	None
Fokker 100	0.2×10^{-6}	None
Fokker F28	3.8×10^{-6}	None
L1011	0.4×10^{-6}	None

Table 1

2 Analysis

2.1 General

Examination of the aircraft after this incident found no faults in the flying controls or wheel braking systems. The aerodrome and its associated radio aids were functioning normally, and the flight crew were appropriately rested and qualified for their duty. Also, the meteorological conditions were benign. Hence the investigation concentrated upon the operation of the aircraft.

The BAe 146 exhibits certain features which are relevant to its landing performance and require particular piloting techniques. It has a high wing with high lift single section flaps fitted on the trailing edge; there are no wing leading edge devices. This causes the aircraft to approach in a nose-low attitude and contributes to the possibility that it may wheelbarrow after landing, if not handled correctly.

The engines are not equipped with thrust reversers and, aside from aerodynamic drag, the aircraft relies entirely upon the wheel brakes to slow down. The effective operation of the wheel brakes early in the landing roll is, in turn, dependent upon deployment of the lift spoilers soon after touchdown.

2.2 Engineering analysis

The aircraft examination revealed no defects that could explain the reason for the lift spoilers not deploying on landing. However, tests on the airbrake/lift spoiler lever did show that it was very easy to move the lever forward from ‘lift-spoiler’ to the full ‘airbrake’ position, due to the lack of friction in the mechanism. Indeed, during the aircraft tests it was noted that just nudging the lever whilst in the lift spoiler detent, caused the deployed lift spoilers to retract. With this lack of resistive force, it is possible that a lever that has already been placed in the lift-spoiler position by the pilot in the left seat, could be nudged or vibrated out of the selection, thereby stowing the deployed spoilers.

The aircraft manufacturer had already dealt with this issue by issuing a Service Bulletin which modified the lever mechanism by introducing a resistive force of 12 lb to move the lever forward from the ‘lift-spoiler’ position. However, this SB was not mandatory, so operators were not obliged to incorporate the modification. Some have done so, but the operator of EI-CZO had not.

Therefore, the following Safety Recommendation is made:

It is recommended that the European Aviation Safety Agency should mandate BAe Systems Service Bulletin 27-73-00889 for the BAe 146 series of aircraft, which increases the operating force in the forward direction from zero to 12 lb, of the lift spoiler/airbrake selector lever, to prevent the lever moving forward under the influence of vibration or being inadvertently nudged forward during the landing roll. (**Safety Recommendation 2008-062)**

2.3 Operational analysis

2.3.1 Approach speed

The speed flown by the aircraft for the approach and landing was higher than was appropriate for the aircraft's actual landing weight of 32 tonnes. This resulted from a combination of several errors.

The co-pilot calculated the landing weight to be 33.1 tonnes, apparently because the GNS provided an inappropriately high landing fuel figure. Then, in accordance with company practice, this weight was rounded up to the next complete tonne, in this case 34 tonnes. Having consulted the flip-cards, the V_{REF} for an approach made at a weight of 34 tonnes was identified as 114 kt, and it was this figure that should have been written on the landing data card.

However, a figure 5 kt higher, of 119 kt, was written instead and this figure would have been the correct value for V_{APP}, given a V_{REF} of 114 kt and the conditions at the time. It is therefore possible that the co-pilot made a straightforward 'slip' in writing down the V_{APP} speed instead of the V_{REF} speed he had derived.

Once 119 kt had been written on the landing data card, the flight crew consulted the card as the speed was reduced for the final approach and, in accordance with their normal procedures, thus selected and flew a speed 5 kt above this figure, of 124 kt, during the final approach. Although there were reports of tailwind during the approach, including one by an aircraft which landed just before EI-CZO, evidence from the airport's SAMOS records, and the flight crew recollection, show that the wind on the surface was benign, and amounted to a very slight crosswind.

The high approach speed had two principal consequences: the landing distance required was greater than that following an approach at the correct speed, and the propensity for the aircraft to touch down in a flat attitude and then to 'wheelbarrow' was increased.

2.3.2 Stabilised approach criteria

The operator's Operations manual Part B contained the following statements with regard to stabilised approaches:

> *'We require all precision approaches (prior to any 'Contact' call) to be stabilised by 1,000 ft arte,…………………….and all visual approaches to be stabilised by 500 ft arte.*
>
> *Only small changes in heading, pitch and speed are required to maintain the correct flight path'*

The Manual did not quantify what amounted to a '*small change*'.

The *'Additional Approach Criteria'* section stated that:

'A Cat 1 ILS approach must be flown within one dot of the glideslope and localizer' and made a similar provision for a Cat 2 ILS approach. However, the ILS at London City is defined as a 'steep glidepath angle approach' (it is not unique in this respect) and thus the operations manual did not stipulate deviation criteria for the approach. Therefore, the following Safety Recommendation is made:

> It is recommended that Cityjet should incorporate in their Operations Manual allowable heading, pitch attitude and speed deviation criteria with respect to steep glidepath angle ILS approaches. (**Safety Recommendation 2008-063)**

2.3.3 Flight crew actions during the landing roll

Very soon after touchdown, the co-pilot was interrupted in his checks by the commander's urgent call indicating that he believed that the wheel brakes had failed. The commander's action interrupted the co-pilot's check of lift spoiler deployment and brake pressure, but the commander's priority lay in informing his co-pilot, as he perceived it, that the aircraft was in difficulties. The flight crew's actions were then concentrated on dealing with their perceived braking problem; they did not recognise that the brakes were, in fact, operating normally, but the spoilers had not deployed.

Had the co-pilot resumed his after-landing scan of spoiler and brake indications, he might have been able to inform the commander of the true condition of the aircraft's systems. However, previous events (not only involving the BAe 146) show that pilots may mis-diagnose failure of the lift-spoilers to deploy as brake failure. Having diagnosed brake failure, a pilot's focus on using whatever braking effect is at his disposal may be difficult to interrupt.

The commander selected the Yellow brake system, and perceived no increase in the aircraft's retardation. This might have served as an indication that the problem did not lie with the brakes but, in the event, he took what seemed to him to be a logical step, ie, he selected the Yellow emergency brakes. Once he had done so, with the application of maximum brake pedal and the absence of anti-skid protection to the wheels, it was inevitable that the wheels would lock and the tyres burst.

Although there was a great deal of documentation relating to landing performance and technique available to flight crews, no clear guidance was given about the action to be taken in the event of a landing not proceeding as intended.

The aircraft performance is such that, provided pilots apply maximum braking effort upon landing, the aircraft will stop within the landing distance available, even if the spoilers do not deploy. However, achievement of scheduled landing distances requires effective braking and this, in turn, requires prompt deployment of the spoilers. To achieve the scheduled landing distance, it is paramount that the aircraft touches down in the correct attitude

The history of the aircraft type illustrates that technical failure of the lift spoiler and wheel braking systems is very uncommon, compared with non-deployment of the lift-spoilers.

The installation of additional systems, or modification of existing ones, in many cases can provide a purely technical solution to a particular problem. However, in this instance, it is difficult to perceive a technical solution to the apparent problem of misdiagnosis of failed lift-spoiler deployment after touchdown, even with the implementation of the auto-spoiler modification. The likelihood of both the Green and Yellow lift spoiler systems failing is very low, with an incorrect or late selection of the spoilers being a more significant risk to the aircraft. If all other parameters are correct (ie, V_{APP}, V_{REF}), the effect on the landing distance of non-deployment of the lift spoilers should be absorbed within the 1.67 safety margin contained in the AFM landing distance figures, provided that maximum braking is applied and maintained throughout the landing roll to taxi speed.

On landing, the flight crews' priority should be to confirm that the spoilers have deployed, and that hydraulic pressure is being applied to the brake units. Any sense that the aircraft's retardation is less than expected should, initially, cause the flight crew to establish whether the lift-spoilers are actually deployed, before making any assumptions about the wheel brake system performance. Although standard procedures exist which require crews to perform the above actions when the spoilers do not deploy as expected, the consequent lack of initial deceleration is sometimes determined by the crew as failure of both the primary and, after manual selection, the secondary brake systems. In these cases, selection of the emergency system results in locked wheels and consequent tyre failures.

In order to minimise such events, the manufacturer issued Notice to Aircrew NO.OP 56 (Issue No 1) on 3 December 2007, applicable to all BAe 146 series aircraft, in which they re-emphasise the need for crews to ensure that the lift spoilers have been selected out before selecting an alternative braking system. In addition, flight crews are reminded that if the emergency brake system is selected, the anti-skid system will be turned off and, consequently, the braking distance required will be increased. The operator issued this notice to their pilots, who were (electronically) required to confirm that they had read the document.

2.3.4 Elevator position during the landing roll

It was not possible to determine the control column position by analysis of the aircraft's recorded pitch attitude. However, as the aircraft's attitude after touchdown peaked at -3°, 1.3° lower than that recorded on the three previous landings at LCY, and was sustained below this value for some 21 seconds, it is possible that a forward position of the control column could have been a contributing factor to this. The manufacturer has advised that any excessive forward movement of the control column during the landing roll will contribute to a reduction of the aircraft's weight applied to its main landing gear wheels, and hence delay the full effectiveness of the wheel brakes.

The operator had already issued instructions to its flight crew on this topic.

2.3.5 Human factors and flight deck design

It is noticeable that in most previous events, landing incidents occurred when the commander (the pilot in the left seat) was the pilot flying. Many operators stipulate that, at challenging airports, commanders must land the aircraft. This means that co-pilots tend not to land routinely in challenging circumstances and so may account for the disparity.

However, the sequence of actions carried out after landing may also be a factor: When the pilot in the right seat lands the aircraft, the pilot in the left seat must select the lift spoilers after touchdown, with one rearward movement of their right hand. When the pilot in the left seat lands the aircraft, they make two such movements; firstly the thrust levers are selected to ground idle and then the lift spoiler lever is moved fully aft. It is possible that some pilots have unknowingly omitted the second action, on account of the similarity of the two actions and the fact that the second action is only necessary some of the time, ie, when the co-pilot lands the aircraft.

2.3.6 Notification and retention of recorded data

The original notification of this incident to the AAIB, that the aircraft had '*burst all main gear tyres on landing*', was accurate, but not complete. It was not until further enquiries were made that the seriousness of the event became clear and consequently the initiation of a Field investigation was delayed. Although data was successfully recovered from the aircraft's flight data recorder (FDR), the information on the 30-minute duration Cockpit Voice Recorder was overwritten as the recorder continued to run post-event, depriving the investigation of potentially useful information. In the immediacy of the events and the pressure to clear the aircraft from the runway, electrical power to the recorders was not isolated.

Therefore, the following Safety Recommendation is made:

> It is recommended that Cityjet should remind their flight crews of the necessity to preserve recorded data on Flight Data Recorders and Cockpit Voice Recorders following an incident or accident, by isolating the electrical power to the recorders as soon as practical after any such event. (**Safety Recommendation 2008-064)**

2.4 Safety actions

Following this incident, the operator has taken the following safety actions:

- December 2006: A Flight Crew Instruction on Prevention of landing Overruns was issued

- March 2007: A simulator training programme was begun which highlighted this incident and which included training on the prevention of landing overruns

- September 2007: A simulator training programme was initiated reviewing stabilised approach criteria with a briefing and simulation of failures after touchdown on a short runway

- October 2007: There was a further Flight Crew Instruction regarding landing SOPs

- November 2007: A training programme was initiated covering bounce recovery, rejected landings, and tailstrike risk

The operator has advised that the current guidance given to pilots on Stabilised Approach Conditions for steep and normal approaches is modelled on the manufacturer's data and which specifies the following:

1	*Speed*	*Between V_{ref} and V_{ref} +20 kt*
2	*RoD*	*No greater than 1,500 ft/min on a steep approach*
3	*Thrust*	*Engine power not below 40% - 45% N1 for an extended period*

Additionally, all Precision Approaches are to be flown within one dot of the Glideslope and Localiser. Also, London City Airport operations now receive more attention in pilot's simulator conversion and refresher training, with failure of the lift-spoilers to deploy being specifically emphasised.

3 Conclusions

The combination of touching down at a speed higher than was appropriate for the aircraft's weight at the end of the touchdown zone, the failure of the lift-spoilers to deploy at any time during the landing roll, the commander's mistaken belief that the aircraft's wheel braking systems had failed, and an incorrect braking technique, combined to cause the aircraft to overrun the specified landing distance available. Use of the emergency brake system, which is not fitted with anti-skid protection, caused all four main landing gear tyres to burst.

(a) Findings

1. The flight crew was properly licensed, adequately rested and medically fit to conduct the flight.

2. The flight crew operated the aircraft within the limits laid down by the operator's Flight Time Limitations scheme.

3. The aircraft's documentation was in order and there were no relevant outstanding defects recorded in the technical log.

4. The operator required that landings at London City Airport were only to be carried out by aircraft captains, so the commander was the Pilot Flying for the sector.

5. The approach reference speed (V_{REF}) was incorrectly determined for the aircraft's actual landing weight as 114 kt, instead of 110 kt, but 119 kt was entered on the landing data card.

6. The commander flew an ILS approach to Runway 10 and gained visual contact at around 1,000 ft aal.

7. The flight crew reported seeing two white and two red PAPI lights during the visual phase of the approach.

8. By 500 ft aal, the aircraft was fully configured for landing with the checklist completed.

9. The reported wind at the time the aircraft was cleared to land was 170°/6 kt.

10. The later stage of the approach was flown at 124 kt, ie, the incorrectly written down V_{REF} of 119 kt + 5 kt (referenced to a 34 tonne landing weight).

11. The aircraft was seen to touch down at the far end of the touchdown zone.

12. The aircraft touched down in a zero degree pitch attitude and with an indicated airspeed of 119 kt.

13. The correct touchdown speed for the aircraft's actual weight was 103 kt.

14. After touching down, the commander selected the thrust levers to ground idle, the airbrake/lift spoiler lever to 'lift spoilers' and applied pressure to the rudder pedals to operate the wheel brakes.

15. As the co-pilot was about to check for indications that the lift spoilers had deployed and that the wheel brake hydraulic pressure was normal, the commander called "NO BRAKES…." as the aircraft was not decelerating normally.

16. The commander selected the wheel brake hydraulic system from Green to Yellow and because the aircraft was still not decelerating normally, then selected the emergency braking system.

17. Skid marks on the runway surface indicated that all four main wheels had locked up over the last 473 m of the ground roll.

18. The locked main wheels caused all four tyres to be worn through by friction with the surface and to deflate.

19. The aircraft came to a halt on the paved surface beyond the end of the declared landing distance available (LDA), approximately 160 m from the edge of the dock, after a total ground roll of 1,027 m.

20. The flight crew was not aware of the tyre failures.

21. The lift spoiler surfaces did not deploy at any time during the ground roll.

22. Subsequent examination of the aircraft failed to find any defects within the lift spoiler or wheel braking systems.

23. It was established that the force required to move the lift spoiler lever from full airbrake to lift spoiler was 14 lb, and from lift spoiler to airbrake, close to zero. Both values were within the limits specified in the aircraft's Maintenance Manual.

24. A non-mandatory modification, issued in March 1988, to change the operating force characteristics of the lift spoiler lever when moving from 'lift spoiler' to airbrake, from close to zero to 12 lb, had not been embodied on EI-CZO.

25. A manufacturer's analysis of 17 BAe 146/Avro RJ series overrun accidents indicated that non-deployment of the lift spoilers on landing was a factor in only 35% of these events, but three predominant factors were identified; landing long, the condition of the runway (wet or contaminated) and landing with a tailwind component.

26. An analysis made by the manufacturer indicates that the BAe 146/RJ aircraft is no more prone to overrun the runway on landing than other aircraft types with which it was compared.

(b) Causal factors

The following causal factors were identified:

1. The incorrect determination of the approach reference speed (V_{REF}) as 119 kt, resulted in the aircraft landing faster than was necessary.

2. The data suggested that the control columns may have been positioned forward of their customary position after touchdown, which could have contributed to a reduction of the aircraft's weight applied to the main wheels during the first part of the landing roll.

3. Despite the commander's recollection that he moved the airbrake/lift spoiler lever to the 'lift spoiler' position, the lift spoilers did not deploy, although the system was determined to have been serviceable.

4. The non-deployment of the lift spoiler surfaces after touchdown did not enable the timely transfer of the aircraft's weight from the wing to the main wheels, and hence the effectiveness of the wheel brakes during the early part of the landing roll was not maximised.

5. The commander's perception of brake system failure led him to select the emergency braking system which removed the anti-skid protection.

6. The lack of any positive force required to hold the lift spoiler lever at the lift spoiler activation position probably resulted in the lever moving away from the point of activation before the conditions required to satisfy the lift spoiler deployment logic could be met.

4 Safety Recommendations

4.1 **Safety Recommendation 2008-062:** It is recommended that the European Aviation Safety Agency should mandate BAe Systems Service Bulletin 27-73-00889 for the BAe 146 series of aircraft, which increases the operating force in the forward direction from zero to 12 lb, of the lift spoiler/airbrake selector lever, to prevent the lever moving forward under the influence of vibration or being inadvertently nudged forward during the landing roll.

4.2 **Safety Recommendation 2008-063:** It is recommended that Cityjet should incorporate in their Operations Manual allowable heading, pitch attitude and speed deviation criteria with respect to steep path angle ILS approaches.

4.3 **Safety Recommendation 2008-064:** It is recommended that Cityjet should remind their flight crews of the necessity to preserve recorded data on Flight Data Recorders and Cockpit Voice Recorders following an incident or accident, by isolating the electrical power to the recorders as soon as practical after any such event.

Peter Claiden
Inspector of Air Accidents
Air Accidents Investigation Branch
Department for Transport
August 2009

Appendix A

N146QT on 9 December 1986 at Vagar, Faroe Islands – Danish Havarikommissionen Accident Investigation Board report HCL 71/86

The down-sloping Runway 13 at Vagar was wet, but described by the pilot as having good braking action. The aircraft touched down 100 m beyond the desired touchdown position, but still within the allowable zone. After touchdown, the pilot flying applied normal wheel braking and, although the antiskid system was operational, the crew did not perceive any braking action. The commander steered the aircraft off the runway and applied the Yellow emergency brake system. The aircraft came to rest some 70 m from the runway. There were no injuries and the aircraft was later removed from the area under its own power.

The manufacturer's investigation determined that the spoilers had not deployed at all during the landing. The weight-on-wheels switches were found to be out of adjustment, meaning that sensing of weight on wheels was delayed after landing; this delayed the selection of ground idle thrust. The investigation also determined that the force required to move the airbrake/lift spoiler lever to EXTEND was high and may have resulted in the lever not being moved to its full extent to engage the lift spoiler microswitches.

OY-CRG on 02 August 1989 at Vagar, Faroe Islands – Danish Havarikommissionen Accident Investigation Board report HCL 43/89

The flight crew made an approach to Runway 31, in visibility of 2,500 m with the cloud base of 300 ft in rain. The runway condition was described as wet with 25% standing water. The approach was not stable, so the commander carried out a go-around and repositioned for a landing on the down-sloping Runway 13.

Visual contact with Runway 13 was established at 1.2 nm and a stable approach was flown at 119 kt with visual reference to the PAPIs. The touchdown was within the touchdown zone, the braking action appeared normal and the lift spoilers deployed. After travelling about ⅔ of the runway length, the aircraft did not decelerate, despite maximum braking being applied. The aircraft overran the runway and came to rest in soft ground. The passengers and crew evacuated the aircraft and there were no injuries.

Appendix A

G-OSKI on 19 April 1990 at Belfast, Northern Ireland – CAA MOR 90/01606H

The aircraft was on a visual approach to Runway 22. At the same time another aircraft was departing from Runway 22. G-OSKI was given landing permission with a wind of 15 kt from 330°, giving a tailwind component of 3 kt. The runway was described as wet.

The aircraft crossed the threshold at a speed of V_{REF} +10 kt. On landing, the spoilers deployed and the brakes were applied normally. However, the aircraft failed to stop and ran off the end of the runway by 100 m into grass. The aircraft later taxied off the grass under its own power. There were no injuries. No technical cause for the overrun was found, and the aircraft returned to service without further incident.

ZK-NZB on 28 April 1990 at Queenstown Aerodrome, New Zealand – New Zealand Office of Air Accident Investigation Aircraft Incident Summary 90-0-445.

A landing was carried out on the Runway 05 (1,342 m LDA). The wind was reported as from 320° at 10-14 kt; the runway was wet, but with no standing water. The commander, in the left seat, was the pilot flying. The approach was initially high, but was corrected by 500 ft agl, with some sink on short final. The landing was normal but 530 m beyond the threshold. Recorded flight data showed that the air brake lever was selected to only 50% before touchdown; normally, it would be selected to 100%. Then, just after touchdown, the lever was moved to the full airbrake position, rather than the lift spoiler position.

Braking was applied, and a pressure of 2,000 psi observed on the gauge, but there did not appear to be adequate deceleration. The commander realised that the aircraft would overrun the runway, and steered it off the surface to avoid obstacles beyond the runway end. Just before the aircraft left the paved surface, the lift spoilers were deployed. The aircraft travelled over grass and passed through the boundary fence before coming to rest in soft ground. Analysis of recorded wind information suggested that there may have been a tailwind of up to 9 kt at touchdown. The investigation identified that a number of factors conspired to cause the accident, including an unstable approach and late touchdown.

Appendix A

CC-CET on 29 February 1991 at Puerto Williams, Chile

The aircraft failed to stop on landing on the wet Runway 08 at Puerto Williams, Chile, resulting in 20 fatalities. The FDR indicated at touchdown speed of 112 kt; V_{REF} was 110 kt with a target touchdown speed of 103 kt. The aircraft landed with a 5 kt tailwind component and the touchdown was 427 m from the runway threshold (LDA 1,440 m).

Unknown 1992 at Florence, Italy

The landing was carried out on Runway 05, which had a 0.2 % downslope gradient. The runway was wet and the landing was described as being long and fast, with a tail wind component (the strength of which was not known). The runway friction was low and the flight crew did not apply the correct technique of applying and maintaining pressure to the brake pedals, but instead 'pumped' the brakes.

G-UKHP on 31 March 1992 at Aberdeen Airport, Scotland – AAIB Aircraft Accident Report 4/93

The incident occurred when the aircraft, which was on a scheduled passenger flight from Edinburgh to Aberdeen, overran Runway 34 after landing in heavy rain and strong crosswind conditions. The lift spoilers did not deploy and the brakes produced insufficient retardation to stop the aircraft on the wet runway surface. The aircraft suffered mud contamination of its wheels, brakes and engines; there were no injuries.

The investigation identified the following causal factors:

i) The commander omitted to select lift spoilers as a result of his pre-occupation in controlling the aircraft's attitude following the initial touchdown in strong crosswind conditions

ii) The consequences of lift spoiler non-deployment after touchdown were that the aerodynamic drag was not increased, and wing lift was not shed to transfer the aircraft's weight to the main wheels, resulting in markedly reduced braking effectiveness on the wet runway

(iii) The oversight was not identified by the first officer, who was required to make a spoiler deployed confirmation call, but who instead warned the commander of the need to keep the right wing from rising in the gusting crosswind conditions

(iv) The failure of the spoiler not deployed warning lights to illuminate resulted in the crew not being alerted to their error

(v) Although difficulties encountered during the landing in strong crosswind conditions delayed the commander's application of wheel brakes on the wet runway until the aircraft had travelled some 550 m beyond the normal touchdown point, this delay only became a factor in the incident when compounded by the related events

(vi) When it became apparent to the commander that normal deceleration was not being achieved, he still did not associate this with lack of lift spoiler deployment but instead assumed that a braking system malfunction had occurred

(vii) On changing over to the alternate braking system the commander momentarily released brake pedal pressure, which further reduced the aircraft's deceleration

(viii) During the latter stages of the overrun the aircraft's deceleration reduced, probably as a result of the wet conditions on the heavy rubber deposits within the touchdown zone of the reciprocal runway

Six Safety Recommendations were made.

C-FBAB on 21 January 1994 at Terrace, Canada – Transportation Safety Board of Canada report number A94P0016

The landing was on the down-sloping Runway 15, the wind was 350° at 5 kt and visibility was 2.5 miles in freezing drizzle and snow. The aircraft touched down at 108 kt and 1,650 ft from the threshold and overran the runway by 315 ft. The investigation determined that the approach was unstable. This, compounded by a tailwind component, resulted in the deep touchdown. The lift spoilers deployed correctly after touchdown.

Appendix A

N606AW on 4 February 1994 at Garfield County, USA – FAA accident and incident report brief 19940204006869C

The aircraft overran the end of the runway after landing on the down-sloping Runway 26. Thirty minutes prior to the landing, another landing aircraft described the braking action of the runway as poor. However this information was not passed to the flight crew of N606AW. The weather was described as a visibility of 4 miles, cloud base of 2,500 ft and calm wind. Light snow had accumulated during the day to a depth of ¼ inch.

ZE700 on 29 June 1994 at Islay airfield, Scotland – MOD military aircraft accident summary

The landing was on Runway 13, which had an LDA of 1,245 m. The wind was 250° at 20 kt, giving a tailwind component of 12 kt. The approach was unstable, being above the normal approach path and too fast. The aircraft's speed across the threshold was V_{REF} +32 kt and it landed long, with only 784 m of the runway remaining. The aircraft touched down on its nose landing gear, and 'wheelbarrowed', delaying the activation of the weight-on-wheels switches and hence the deployment of the lift spoilers and the selection of ground idle power. The weight-on-wheels switches activated with 509 m of the runway remaining. The aircraft ran off the end of the runway and was damaged.

N832BE on 20 February 1996 at Rifle, Colorado, USA – NTSB event 20001208X05242

The co-pilot flew a VOR/DME approach to Runway 26, with a V_{REF} of 110 kt. The aircraft landed 4,600 ft beyond the threshold at an indicated airspeed of 119 kt and a groundspeed of 138 kt. The runway had a 1.2% downhill gradient. The touchdown was flat, possibly nosewheel first. After touchdown, the flight crew felt that deceleration did not appear normal and the aircraft was not slowing. Indication showed that both wheel brake systems were providing normal pressure. The NTSB determined the probable causes to be:

> *'The co-pilot's failure to compensate for wind conditions, resulting in excessive airspeed, and his failure to attain the proper runway touchdown point. Factors [included] a tail wind, a wet downhill runway, hydroplaning conditions, and the captain's failure to adequately supervise the co-pilot.'*

Appendix A

G-ZAPK on 18 November 1996 at London City Airport, UK – AAIB report EW/C96/11/7 Bulletin No 8/97

The landing was on Runway 28, the runway surface was dry and the wind was 325° at 10 kt. The commander, in the left seat, was pilot flying.

During the approach the first officer noted that the airspeed was high at V_{REF} +15kt, he later noted that the speed at the threshold was V_{REF} +12 kt.

On landing, the thrust levers were moved to GROUND IDLE and the lift spoiler lever was moved to LIFT SPOILER and braking was applied. However, there was little retardation. The commander called "no brakes", but the first officer replied "no spoilers" as there were no spoiler deployed lights illuminated. On recycling the airbrake/lift spoiler lever, the spoilers deployed and the aircraft decelerated.

The aerodrome controller witnessed the landing and assessed that the touchdown had been about ⅓ to ½ of the way down the runway, and nose wheel first. It was concluded that the aircraft bounced, momentarily engaging the weight on wheels switches and allowing the flight idle baulk to retract as the throttles were retarded. However, the aircraft then floated with the weight-on-wheels switches remaining 'in air' as lift spoilers were selected, thus preventing the deployment of the lift spoilers until the aircraft's speed had decayed enough to allow the weight-on-wheels switches to indicate 'on ground'.

The AAIB made one Safety Recommendation in its report. Recommendation 97-27 stated: *'It is recommended that the CAA, in conjunction with the manufacturer, airport authority and operators, carry out a project to determine the scatter of significant landing parameters for the BAe146 aircraft operating into London (City) Airport.'*

The CAA accepted this Recommendation, and undertook a research project, which '*…concluded that there were no unexpected patterns, trends or operating techniques associated with the steep approaches being conducted at London City Airport. Of particular interest was evidence that the glidepath was being followed sufficiently accurately during the final stage of the approach such that the screen height was being crossed at close to nominal values. This finding is particularly significant for those steep approach operations (such as those carried out by the BAe 146) which also need to take credit for a reduced landing distance based on a reduced screen height, (i.e. 35ft as opposed to 50ft) in order to be able to operate viably to shorter runways.*

Appendix A

It was considered that the project confirmed that there was no evidence to indicate the existence of a fundamental safety risk associated with BAe 146 operations at London City Airport, or with the landing distance in general. Therefore, no further action as a result of this work was considered necessary.'

EI-CMY on 25 June 1997 at London City Airport, UK – AAIB report EW/C97/6/3 Bulletin 4/98

The approach was made to Runway 28, with a wind from 160° at 08 kt, giving a tail wind of 4 kt. The commander, in the left seat, was pilot flying, and the runway surface was damp. The touchdown was within the touchdown zone and the spoilers deployed. When braking was commenced the commander considered that the brakes were 'snatching' and that the retardation was inadequate. On approaching the end of the runway the brakes were switched to the Yellow systemwhich improved the retardation. The aircraft then came to a halt beyond the end of the declared landing distance available but on the concrete surface.

Although a definitive technical reason for the Green braking system degradation was not found, investigation and analysis concluded that there had been a fault within the anti-skid system.

EI-CNJ on 7 January 1998 at London City Airport, UK – AAIB report EW/C98/1/2 Bulletin 7/98

The landing was on Runway 28, which was dry; the commander. The left seat, was pilot flying. The wind was reported as 240°/18-28 kt with reports of windshear on short finals. During the approach, the aircraft deviated below the glideslope causing a GPWS warning, after which the glideslope was re-attained. The touchdown, at 121 kt (V_{REF} + 13 kt), was nosewheel first and 336 m beyond the threshold (ie, just beyond the touchdown zone). The control column was held fully forward after touchdown, contrary to advice in the aircraft manual. The main landing gear remained clear of the ground until a point ⅔ down the runway and 560 m from touchdown, at which point the lift spoilers deployed automatically[1]. The aircraft then overran the end of the landing distance available, but remained on the concrete surface.

1 On the RJ series of aircraft, the spoilers are armed in flight to deploy automatically once the air/ground logic senses the aircraft is on the ground.

Appendix A

N607AW on 11 March 1998 at Aspen, USA – FAA accident and incident report brief 19980311007009C

Just prior to landing on Runway 33, the Green hydraulic system warning illuminated on the overhead panel. The Green system showed low pressure and quantity so the crew selected the alternate Yellow hydraulic system. On landing the crew perceived that braking was inefficient and elected to use the emergency Yellow system. The main wheels then immediately locked and the left main gear tyres deflated, followed shortly by the right main gear tyres. The aircraft veered to the left and then slid into snow approximately 3 ft deep at the end of the runway. Subsequent investigation revealed a failure of a Green system hydraulic hose in the nose landing gear bay. With a failure of the Green system involving a loss of fluid, only the inboard flight spoilers on each wing will deploy when selected; the middle and outer spoilers remain stowed.

G-JEAW on 22 July 1998 at Belfast City, Northern Ireland – AAIB report EW/C98/7/3 Bulletin 1/99

The landing was on Runway 22, with runway reported as 'wet with water patches' with a visibility of 5 km in rain. The wind was reported as 070° at 12 kt, giving a tailwind of 10 kt. At 500 ft agl on approach, the airspeed was 11 kt to 14 kt above the required 122 kt, but this was corrected by 300 ft agl. At 10 ft agl the aircraft was over the touchdown zone markings. However, the aircraft floated, requiring the control column to be nudged forward to ensure ground contact. Touchdown was at 111 kt, 1 kt higher than the target of 110 kt, and with 968 m of runway remaining.

Following touchdown, the lift spoilers deployed and maximum braking was applied. The aircraft overran the end of the runway and came to rest in mud, some 7 m beyond the end of the runway.

G-FLTA on 22 February 2002 at Arvidsjaur, Sweden – Statens Haverikommisssion report RL 2003:08e

The landing was on Runway 30, the wind was from 190° at 11 kt, gusting 21 kt, with a visibility of 10 km in light snow. The runway had been sanded and had patches of ice. Shortly after landing, the aircraft's speed did not reduce as expected and it departed the runway, coming to rest 80 m beyond its end.

Appendix A

The investigation determined that the incident was probably caused by the following contributory factors:

‘– *The landing prerequisites were marginal*

– *The touchdown speed was somewhat too high*

– *The touchdown took place far down the runway*

– *The initial wheel braking was applied moderately*

– *The reduction of engine thrust after touchdown was delayed*

– *The aircraft may have been affected after touchdown by strong wind gusts that temporarily increased the tailwind component*

– *The actual braking action was probably worse than that which had been reported’*

EI-PAT on 18 April 2002 at London City

This event was investigated by the operator. The aircraft made an ILS approach to Runway 28. The commander, in the left seat, was pilot flying, and the surface wind was 210° at 11 kt. After touchdown, the commander perceived that braking was ‘not normal’. He called for the co-pilot to take over braking, which disrupted the co-pilot’s scan of the thrust setting and spoiler operation. The aircraft did, however, stop before the end of the concrete surface.

Examination of the aircraft immediately after shutdown showed that the brakes seemed cooler than normal. An anti-skid system test was carried out, which indicated faults in brake system B and all four Dual Adaptive Anti-skid Valves (DAAVs). The test was repeated later with no fault apparent. The FDR was downloaded and analysed by the manufacturer, who found that the aircraft was 40ft above profile passing the runway threshold, the control column was held fully forward after touchdown, and the lift spoilers did not deploy. The operator’s report noted that *‘there is no guidance provided for degradation in braking performance’*.

Appendix A

OY-CRG on 10 October 2006 at Stord, Norway

At the time of writing, the Accident Investigation Board Norway had published a preliminary report on this accident, summarised below:

The crew made a visual approach to Runway 33 and had visual contact with the airport at an early stage. The ungrooved runway was classified as DAMP, and the crew were passed a surface wind of 120° at 6 kt. After landing, they realised from cockpit indications that the lift spoilers had not deployed. Maximum wheel braking was applied but this did not result in the expected retardation. The alternate braking system was then selected and finally the emergency system, without making any difference. There was evidence that one or more of the main wheels had locked during the ground roll. The aircraft failed to stop before the end of the runway, and continued down a steep slope, sustaining significant damage as it collided with lighting poles, trees and large rocks. A fire broke out which eventually consumed much of the aircraft. Four people on board received fatal injuries.

The investigation continues but, so far, an explanation as to why the lift spoilers did not deploy has yet to be determined.

Appendix B

Event No	Hull loss	Landed long	Runway condition	Wind	Runway 1.500 m or less	Weather	Landed fast	Incorrect braking technique	Spoilers	Runway slope	Approach	Technical problem	No of contributing factors
1		■	■		■				■	■			5
2		■	■		■		■			■			5
3		■	■	■			■						4
4		■	■	■				■	■				5
5	■	■	■	■	■		■						5
6		■	■	■	■	■	■	■					7
7		■	■	■		■			■	■			6
8		■	■	■		■		■		■			6
9		■	■					■		■			4
10		■		■	■		■		■		■		6
11		■	■	■			■			■			5
12		■			■		■		■		■		5
13				■	■	■		■				■	5
14		■			■				■		■		4
15		■	■	■		■		■			■		6
16	■	■	■	■		■		■					5
17		■	■	■		■	■	■			■		7

■ = Factor identified

Contributing Factors to BAe146/Avro RJ Landing Overruns - Manufacturer's analysis

Landed long: highlighted if the aircraft landed long (touched down 450 m or more beyond the threshold for 146-300 and all series Avro RJ, and 360 m for 146-100 and -200)

Runway condition: highlighted if the runway was wet or contaminated

Wind: highlighted if there was a tailwind

Landed fast: highlighted if the aircraft touched down with a speed equal to or greater than V_{REF}

Runway length: highlighted if the runway length was less 1,500 m or less

Highlighted if there was any precipitation, cloudbase was 1,000 ft or lower or visibility was less than 3 nm

Spoilers: highlighted if the spoilers were not deployed or were deployed late

Runway slope: highlighted if there was a downhill slope

Appendlx B

Braking technique: highlighted if the braking technique was specified as incorrect or that maximum braking was not initially applied

Approach: highlighted if the approach was not stabilised by 500 ft above runway threshold elevation (arte)

Technical problem: highlighted if there was a reported technical problem with the aircraft

RECENT FORMAL AIRCRAFT ACCIDENT AND INCIDENT REPORTS ISSUED BY THE AIR ACCIDENTS INVESTIGATION BRANCH

THE FOLLOWING REPORTS ARE AVAILABLE ON THE INTERNET AT http://www.aaib.gov.uk

3/2008	British Aerospace Jetstream 3202, G-BUVC at Wick Aerodrome, Caithness, Scotland on 3 October 2006.	February 2008
4/2008	Airbus A320-214, G-BXKD at Runway 09, Bristol Airport on 15 November 2006.	February 2008
5/2008	Boeing 737-300, OO-TND at Nottingham East Midlands Airport on 15 June 2006.	April 2008
6/2008	Hawker Siddeley HS 748 Series 2A, G-BVOV at Guernsey Airport, Channel Islands on 8 March 2006.	August 2008
7/2008	Aerospatiale SA365N, G-BLUN near the North Morecambe gas platform, Morecambe Bay on 27 December 2006.	October 2008
1/2009	Boeing 737-81Q, G-XLAC Avions de Transport Regional ATR-72-202, G-BWDA, and Embraer EMB-145EU, G-EMBO at Runway 27, Bristol International Airport on 29 December 2006 and 3 January 2007.	January 2009
2/2009	Boeing 777-222, N786UA at London Heathrow Airport on 26 February 2007.	April 2009
3/2009	Boeing 737-3Q8, G-THOF on approach to Runway 26, Bournemouth Airport, Hampshire on 23 September 2007.	May 2009
4/2009	Airbus A319-111, G-EZAC near Nantes, France on 15 September 2006.	August 2009