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Aircraft Accident Investigation Bureau AAIB

Final Report No. 1973 by the Aircraft Accident Investigation Bureau

concerning the serious incident

to the Embraer 145LR aircraft, HB-JAD

operated by Crossair under flight number LX 500

on 24 December 2001

at Basle Airport

Bundeshaus Nord, CH-3003 Berne

Ursachen

Der schwere Vorfall ist darauf zurückzuführen, dass nach dem Start die Stabilizertrimmung blockierte, weil die fliegerischen Grenzwerte überschritten wurden und die Besatzung in der Folge nicht zweckmässig vorging.

Das Überschreiten der fliegerischen Grenzwerte wurde begünstigt durch:

- Die langsame Rotation des Flugzeuges beim Start
- Die tiefe Startmasse des Flugzeuges

General information on this report

This report contains the AAIB's conclusions on the circumstances and causes of the serious incident which is the subject of the investigation.

In accordance with Annex 13 of the Convention on International Civil Aviation of 7 December 1944 and article 24 of the Federal Air Navigation Law, the sole purpose of the investigation of an aircraft accident or serious incident is to prevent future accidents or serious incidents. The legal assessment of accident/incident causes and circumstances is expressly no concern of the accident investigation. It is therefore not the purpose of this investigation to determine blame or clarify questions of liability.

If this report is used for purposes other than accident prevention, due consideration shall be given to this circumstance.

The definitive version of this report is the original in the German language.

All times mentioned in this report, unless otherwise indicated, follow the coordinated universal time (UTC) format. At the time of the serious incident, Central European Time (CET) applied as local time (LT) in Switzerland. The relation between LT, CET and UTC is:
LT = CET = UTC + 1 h.

For reasons of protection of privacy, the masculine form is used in this report for all natural persons, regardless of their gender.

Contents

Final Report

Owner	State Street Bank and Trust Company of Connecticut, 8027 Zurich, Switzerland
Operator	Crossair Ltd., 4002 Basle, Switzerland
Aircraft type	Embraer EMB-145LR
Country of registration	Switzerland
Registration	HB-JAD
Location	Shortly after take-off from Basle Airport
Date and time	24 December 2001 at 06:27 UTC

General

Synopsis

On 24 December 2001, aircraft EMB-145, registration HB-JAD, took off from Basle (LFSB) on a scheduled flight, flight number LX500, to Hamburg (EDDH). Shortly after take-off, the "PIT TRIM 1 INOP" warning appeared on the EICAS (Engine Indicating and Crew Alerting System). The main trim system was jammed and inoperative. The aircraft was difficult to control when climbing.

An emergency was declared and a return to Basle airport was requested. The emergency checklist for PITCH TRIM INOPERATIVE was performed. With the aid of the back-up trim system the approach could be carried out normally and the landing took place at 06:46 UTC. Neither crew nor passengers were injured.

Investigation

The Aircraft Accident Investigation Bureau (AAIB) was informed about the serious incident on 24 December 2001 and opened an investigation on the same day, in agreement with the French Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA).

The digital flight data recorder (DFDR) and the cockpit voice recorder (CVR) were removed from the aircraft and analysed.

The serious incident is attributable to the fact that after take-off the stabiliser trim became jammed because the flying limits were exceeded and the crew did not subsequently proceed appropriately.

The exceeding of the flying limits was favoured by:

- the slow rotation of the aircraft on take-off
- the aircraft's low take-off mass

1 Factual Information

1.1 Pre-flight history and history of the flight

1.1.1 General

The flight recorder recordings, radio communication recordings and radar data recordings, as well as the reports of the operator and the crew members, were used for the following description of the pre-flight history and history of the flight. Throughout the entire flight the copilot was pilot flying (PF) and the commander was pilot not flying (PNF).

The flight took place under instrument flight rules.

1.1.2 Pre-flight history

In a Flight Crew Information Bulletin dated 8 May 2001, crews were provided with introductory information by the Technical Pilot of the EMB-145 as follows:

As you know, some EMB-135/145 aircraft have been involved in temporary loss of pitch trim situations after take off. I hereby would like to take the opportunity to give you more information about these instances and to forward the latest news and outcome regarding Embraer investigation on this subject.

Up to the time of the serious incident, there had been three incidents of similar problems with the operator: an initial incident on 18 November 2000 with aircraft HB-JAA, a second one on 30 December with the same aircraft and a third on 1 December 2001 with aircraft HB-JAR.

1.1.3 History of the flight

On 21 December 2001, the Embraer EMB-145 aircraft, registration HB-JAD, took off at 06:27 UTC from Basle (LFSB) on a scheduled flight, flight number LX 500, to Hamburg (EDDH).

Corresponding to an aircraft mass of 17 500 kg, the speeds were set as follows: V_1 = 128 (TO-1); V_R = 128; V_2 = 131, V_{FO} = 146 (V_2 + 15). The stabilizer was set to 8 degrees ANU (Aircraft Nose Up).

According to the DFDR recordings, rotation[1] took place at a speed of 132 KIAS and the lift-off speed was 149 KIAS. Rotation time to an ANU value of 18° was 17 seconds. The maximum speed of 160 KIAS for initial trim application had already been reached at 10° ANU. The aircraft continued to accelerate and its speed was 173 KIAS at 18° ANU. This speed was actually 27 KIAS above the rated value of 146 KIAS.

Immediately after lift-off, at 06:27:28 UTC, at a height of 620 ft AGL (Above Ground Level) the "PIT TRIM 1 INOP" master warning appeared on the EICAS. The initial climb speed was 171 KIAS, according to the DFDR. At 06:27:44 UTC, 16 seconds later, the autopilot was engaged. The DFDR subsequently indicated that the trim did not change and at 06:28:27 UTC the master caution "AUTO TRIM FAIL" appeared. At this time the aircraft was 14° ANU, at a speed of 176

[1] In the following, the aviation expression “rotation” is used to describe the process of rotation about the lateral axis of the aircraft during the transition from the take-off roll to the initial climb.

KIAS and at an altitude of 4596 ft AMSL. The autopilot disengaged automatically 11 seconds later and could be reengaged after five seconds. The flaps were then retracted at a speed of 180 KIAS. At 06:30:54 UTC, the autopilot was disengaged again and according to the copilot's (PF) statement the aircraft was then difficult to control in climb. The trim was not reacting, according to the DFDR recordings. The correct attitude could only be maintained with a relatively high AND (Aircraft Nose Down) control force. During this phase, the aircraft accelerated up to a speed of 241 KIAS.

In order to re-establish better controllability of the aircraft, the copilot ordered the commander (PNF) to extend the landing gear; the gear was extended at 06:31:41 UTC, at an altitude of 10 635 AMSL and at a speed of 216 KIAS. At 06:32:21 UTC, 40 seconds later, or 04:53 min. after the warning was triggered, he used the back-up trim, which was functioning.

At no time did the commander take over control of the aircraft. According to his statement during the crew debriefings by the operator's Flight Safety Officer, he said that he was not acquainted with the pitch control problems of the EMB-145, that he was new to this aircraft type and that the copilot had much more experience of this aircraft type.

At 06:32:42 UTC, the crew of LX 500 reported to the air traffic controller (ATCO) on the Zurich ACC North-West Sector frequency: "*Zurich Control, CRX500, mayday, mayday, mayday*". At 06:32:48 UTC, the crew responded to the ATCO's enquiry: "*We have a pitch trim problem, aircraft is hardly controllable, we want to come back to Zurich, to Basle*". At 06:32:55 UTC, the ATCO answered as follows: "*Roger, you are cleared back to Basle, descend to flight level 70*". This was read back by the crew.

At 06:33:15 UTC, the crew of LX 500 requested radar vectors to Basle: "*CRX 500, give us please vectors for to come back to Basle, and inform Basle, please*". The ATCO then instructed the crew to contact Basle on the 118.57 MHz frequency.

The Basle Approach ATCO then instructed the crew of LX 500 to turn right onto a course corresponding to the downwind heading. The crew then executed the items in the "PITCH TRIM INOPERATIVE" emergency checklist. It was then possible to control the aircraft without any restrictions using the back-up trim. The commander informed the passengers in English that they would be returning to Basle for technical reasons. The flight attendant then translated this information into German, as all four passengers were of German mother tongue.

The crew of LX 500 received radar vectors to make an approach on runway 16. The landing which was uneventful took place at 06:46 UTC and once the engines had been shut down at 06:55 UTC on the stand, the passengers were able to disembark the aircraft normally.

1.2 Injuries to persons

The three crew members and the four passengers were not injured.

1.3 Damage to aircraft

There was no damage to the aircraft.

1.4 Other damage

There was no damage to third parties.

1.5 Personnel information

1.5.1 Commander

Person	French citizen, born 1966
Licence	Air transport pilot licence aeroplane (ATPL(A)) according to JAR (Joint Aviation Requirements), first issued by the FOCA on 28.06.2000
Ratings	RTI (VFR/IFR), NIT (A), IFR (A)
Instrument flying rating	Instrument flight aircraft IR(A) Category II-III instrument approaches, valid till 11.04.2002
Last proficiency check	Conclusion of conversion to aircraft type EMB-145 (type rating) on 11.10.2001
Medical fitness certificate	Class 1, without restrictions valid until 11.11.2002
Last medical examination	27.09.2001
Commencement of commercial pilot training	1994

1.5.1.1 Flying experience

Total	2655:00 hours
On the type involved in the incident	75:18 hours
During the last 90 days	75:18 hours
Of which on the type involved in the incident	75:18 hours
As commander	75:18 hours

1.5.1.2 Crew times

Start of duty	on 23.12.2001, 08:00 UTC
End of duty	on 23.12.2001, 10:00 UTC
Flight duty time on 23.12.2001	02:00 hours
Rest time	20:10 hours

1.5.2 Copilot

Person	French citizen, born 1972
Licence	Commercial pilot licence aeroplane (CPL-(A)), according to JAR, first issued by the FOCA on 09.05.2000
Ratings	Type rating Embraer EMB-145 as copilot, valid till 09.05.2002
Instrument flying rating	Instrument flight aircraft IR(A)

Last proficiency check	Line check / LPC on 23.05.2001 Simulator check / OPC on 08.09.2001
Medical fitness certificate	Class 1, without restrictions, valid until 06.08.2002
Last medical examination	22.06.2001
Commencement of pilot training	1991 in the USA

1.5.2.1 Flying experience

Total	1677:00 hours
On the type involved in the incident	995:00 hours
During the last 90 days	137:00 hours
Of which on the type involved in the incident	137:00 hours

1.5.2.2 Crew times

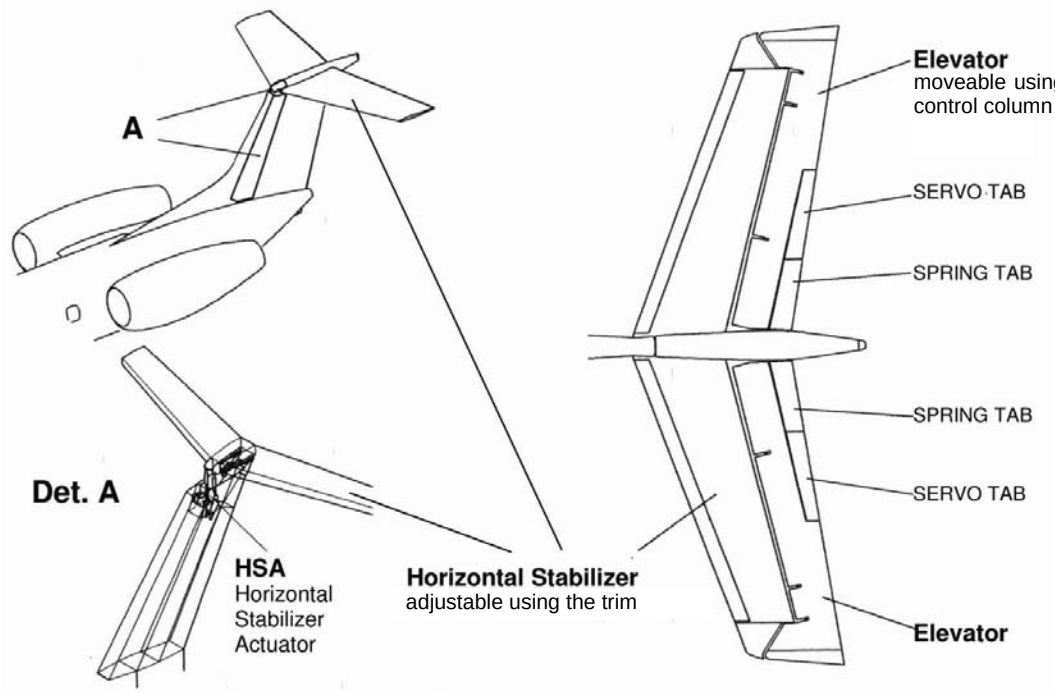
The copilot was not on duty from 20.12.2001 to 23.12.2001.

1.6 Aircraft information

1.6.1 General

Aircraft type	Embraer EMB-145LR
Characteristics	Twin-jet commercial aircraft
Manufacturer	Embraer – Empresa Brasileira de Aeronautica S.A. São José dos Campos – SP – Brazil
Year of construction	2000
Serial number	145269
Owner	State Street Bank and Trust Company of Connecticut, 8027 Zurich, Switzerland
Operator	Crossair Ltd., 4002 Basle, Switzerland
Engine	2 Rolls-Royce AE 3007 A1 jet engines
Max. permitted take-off mass	21 990 kg
Mass and centre of gravity	The mass of the aircraft on take-off was 17 051 kg. The mass and centre of gravity were within the permitted limits.
Fuel grade	JET A1 kerosene
Registration certificate	Issued by the FOCA on 31.05.2000, valid till removal from the aircraft register

1.6.2 Horizontal stabilizer



Movement of the horizontal stabilizer is performed by means of the Horizontal Stabilizer Actuator – HSA. This in turn is controlled by the Horizontal Stabilizer Control Unit – HSCU. The HSCU has two channels, in order to ensure the primary and backup operating modes (see Annex 1).

In primary operating mode, the HSCU controls HSA motor M1 and in back-up operating mode it controls HSA motor M2. Both are identical electric motors.

During trimming, the stabilizer is adjusted on the one hand automatically by the autopilot or by actuation of the speed brakes and on the other hand by the manual trim using trim switches on both pilots' control column or by means of the back-up trim switch on the centre console (see Annex 2).

The trim system has the following system safeguards:

- 3-second timer. This timer prevents constant trim activation in all operating modes, except when trim is performed by the autopilot.
- 7-second timer. Both halves of the trim switch on the control column must be operated simultaneously for the stabilizer movement to take place. If only one of the two halves of the trim switch is actuated continuously for more than seven seconds, the HSCU rejects any control signal from this switch until the system is reset.
- The trim switch on the left control column has priority over the trim switch on the right control column.
- There is no priority between the trim switches on the control column and the back-up trim switch in the centre console. The one which is activated first controls stabilizer movement.
- In addition to the trim switches, each control column has a spring-loaded button to interrupt trimming. As long as this button is kept pressed the trim commands remain interrupted.

- The main and back-up cut-off buttons in the centre console can be used to definitively switch off the control channels.
- If the stick shaker is activated, pitch up signals cannot be given.

1.6.3 Jamming of the stabilizer

The Horizontal Stabilizer Actuator (HAS) may jam for two different reasons:

- the HSA motor's 33 amp load limit is exceeded
- the HSA clutch slips due to excessive torque

The 33 amp load limit is exceeded when an HSA load of approximately 1500 kg occurs. If the aircraft is not trimmed after take-off, this limit is reached at approximately 200 to 220 KIAS. A force equivalent to 30 kg on the control column results in an HSA load of approximately 1700 kg.

If the trim switches are periodically activated four times for three seconds (or several times over a total of 12 seconds) while the HSA is blocked, the control unit interprets this as a jammed actuator and the control unit switches off the systems concerned (main or back-up). In this case, the "PIT TRIM 1 INOP" or "PIT TRIM 2 INOP" warning appears on the EICAS.

1.6.4 Findings after the serious incident

The fault recording in aircraft HB-JAD showed the following message at the time of the serious incident: "HOR STAB CTL UNIT FAILURE". The Horizontal Stabilizer Control unit (HSCU), part number P/N 362100-1007 and serial number S/N 4001, was then sent to the manufacturer for detailed examination.

An inspection and test on the HSCU were carried out under work order number #83967679. No faults could be found and the HSCU was cleared for operation under JAA Acceptance Certificate Number JAA.4732.

On 20 December 2001, Service Bulletin SB 145-27-A089 was issued by the aircraft manufacturer. This SB requires the removal of all Series 4000 HSCUs with less than 100 cumulative flying hours. Among other things, the reason for this SB was listed as follows:

Two instances of inverted pitch trim "nose up" command shortly after liftoff have occurred at Embraer during production flights. The crew used the backup trim switch to retrim the airplane and subsequently made an uneventful landing.

Further analysis has shown that a premature failed component in HSCUs with S/N greater than 4000 was causing the inverted command....

The HSCU fitted to aircraft HB-JAD, S/N 4001 already had more than 185 cumulative flying hours and was therefore not affected by this SB.

1.7 Meteorological information

1.7.1 General

The information in sections 1.7.2 and 1.7.3 was provided by MeteoSwiss.

1.7.2 General weather situation

A high-pressure area extending from the Atlantic over France and as far as Hungary is affecting the weather in Switzerland.

1.7.3 Weather at the time and location of the accident

Weather/cloud	No cloud
Visibility	7 km
Wind	150 degrees, 3 knots
Temperature/dewpoint	-14 °C / -16 °C
Atmospheric pressure	QNH 1020 hPa
Hazards	-
Position of the sun	Azimuth: 116°
Elevation	-8°
Runway report	Runway 08: compressed snow on 26-50% of the surface of the runway, thickness of no operational significance, braking coefficient 0.68.
Comments	A (not very pronounced) ground inversion prevailed over Basle airport. The temperature increased from the elevation of the airport (270 m AMSL) up to approximately 740 m AMSL from -14 °C to -10 °C. Theoretically, the temperature from the elevation of the airport to an altitude of approximately 700 m AMSL could still drop by 2-3 °C to -16 °C to -17 °C and then rise to -10 °C up to 740 m AMSL, which would correspond to an altitude inversion of 6-7 °C. No pronounced wind shear should have been present.

1.8 Aids to navigation

DVOR/DME BLM and ILS DME 16 were used as navigation aids. The ILS DME 16 system is CAT III capable.

DVOR BLM is an omni directional radio range which functions on the Doppler principle. It is equipped with distance measuring equipment (DME).

1.9 Communications

Radio communication between the crew and the air traffic controllers involved took place without any particular occurrences.

1.10 Aerodrome information

1.10.1 General

EuroAirport Basle Mulhouse Freiburg international airport lies 6 km north-west of Basle (CH) and 30 km south-east of Mulhouse (F) in the area of the French town of Saint-Louis. Uniquely in the world, the airport is operated jointly by two states, namely France and Switzerland. The EuroAirport is Switzerland's third largest airport.

The dimensions of Basle airport's runways are as follows:

Runway	Dimensions	Elevation of runway thresholds
16/34	3900 x 60 m	864/882 ft AMSL
08/26	1820 x 60 m	881/884 ft AMSL

The reference elevation of the airport is 885 ft AMSL and the reference temperature is specified as 27.0 °C.

1.10.2 Runway equipment

Basle airport has two runways. The two runways (16 and 08) cross at the airport reference point. Runway 16 is equipped with a CAT III instrument landing system (ILS) and is therefore suitable for precision approaches. It is used for the majority of landings (about 90%).

At the time of the serious incident, runway 34 did not have an instrument landing system. The use of runway 08/26 depends on the type and performance of aircraft. It is mainly used for take-offs by smaller and medium-sized aircraft to the west.

1.11 Flight recorders

1.11.1 Flight data recorder

Type	Digital Flight Data Recorder - DFDR
Manufacturer	Allied Signal
Part Number P/N	980-4700-019

The data were recorded in their entirety and could be read satisfactorily for the analysis.

1.11.2 Cockpit voice recorder

Type	Solid State Cockpit Voice Recorder - SSCVR
Manufacturer	Honeywell
Part Number P/N	980-6022-001
Serial Number S/N	1298

The installed CVR has a two-hour recording time. Analysis showed that the CVR recordings had been erased on the aircraft. According to the commander's statement, neither he nor the copilot had erased the recordings.

Since the CVR manufacturer is able in some circumstances to retrieve data which have been erased, the CVR was handed over to the manufacturer for further examination (see section 1.18).

1.12 Wreckage and impact information

Not applicable.

1.13 Medical and pathological information

There are no indications that the crew were in any way impaired at the time of the serious incident.

1.14 Fire

Not applicable.

1.15 Survival aspects

Not applicable.

1.16 Tests and research

Not applicable.

1.17 Organisational and management information

1.17.1 The operator Crossair

1.17.1.1 General

The Crossair airline was founded in 1975 and in the first few years handled mainly charter traffic using twin-engined business aircraft. In 1979, the company purchased the SA 227 TC Metroliner II aircraft and began regular scheduled flights. Over the following two decades, the company became a large regional airline, which at the time of the serious incident had some 3500 employees and operated over 80 aircraft of the following types: SAAB 2000, Embraer 145, Avro 146 RJ 85/100 and Boeing MD 83.

1.17.1.2 Take-off procedures

In the Operations Manual A (OM A) it was stated in chapter 5.2.3.2 that the copilot may carry out take-off under certain conditions. These conditions include, among other things, a corresponding published procedure in the OM B.

This procedure was set down in the OM B, Chapter 3.8 TAKEOFF. Among other things, it stated:

"When cleared for takeoff, the left pilot switches on the LDG 1, NOSE and LDG 2 lights and switches off the taxi light.

If the takeoff is to be carried out by the right pilot, a handover of the controls is now performed. The left pilot will call "YOUR CONTROLS", the right pilot will respond "MY CONTROLS". The left pilot will retain control of the thrust levers, setting take off thrust. The right pilot will take control of the steering via the rudder pedals, and hold the control column."

In particular, the following was stated under “Right Pilot Takeoff”:

"The autopilot shall be coupled to the right Flight Director, during the TAXI checklist.

...

The handover should commence after completion of the LINE UP checklist.

In both cases, the left pilot maintains control of the thrust levers. When ready for take off, the right pilot calls out "SET THRUST". The right pilot maintains directional control through the rudder pedal steering. Follow the information on the paragraph (Takeoff Procedure) below for the work distribution."

The following was stated in this above-mentioned paragraph:

LEFT PILOT	*RIGHT PILOT*
When passing 80 KIAS call out: "Eighty knots"	
	Check the speed on his / her Speed Tape and call out: "Checked"
When passing V_1 call out: "V-one"	
When passing V_R call out: "Rotate"	
	Monitor airspeed noting V_1 and rotate smoothly at V_R
When passing V_2 call out: "V-two"	
	Check when a positive RoC is indicated and call out: "Gear up"
Verify positive RoC, select the Landing Gear Lever up and call out: "Gear in transit" When all gears are retracted, call out: "Gear is up, V-Flaps zero ___"	
Check flight instruments indications	

The rotation technique during take-off was described in the "Pilot Information Handbook EMB-145" (PIH) dated 8 May 2001 (see Annex 3).

1.17.1.3 Procedures relating to faulty trim behaviour

Reference was made in the operator's PIH to the aircraft manufacturer's Operational Bulletin OB 145-012/00 and the following point was mentioned:

"20 production flights show consistently first trim command shortly after airborne. In this condition, the HSA loads are well below the stabilizer stall threshold."

Reference was then made later in the PIH to Revision 54 dated 19 April 2001 in the Airplane Flight Manual (AFM), which includes the following new limitation:

PITCH TRIM

Maximum Airspeed after Takeoff/During Climb
Without Retrimming ..... 160 KIAS

The PIH also refers to an Alert Service Bulletin which recommends affixing the following label in the cockpit:

AIRSPEED AFTER TAKEOFF/
DURING CLIMB WITHOUT
RETRIMMING MAX 160 KIAS

In addition, a new procedure relating to PITCH TRIM INOPERATIVE was published in the PIH (see Annex 4). This procedure is based on Revision 51 published by the aircraft manufacturer and dated 30 January 2001 (see Annex 6).

1.17.2 The aircraft manufacturer

1.17.2.1 General

Embraer, based in São José dos Campos, Brazil, was founded in 1969 as a state-owned company and privatised on 7 December 1994.

Embraer is one of the largest aircraft manufacturers and has focused on special market segments with high growth in commercial, military and business aviation.

Embraer was Brazil's largest exporter during the years 1999 to 2001.

1.17.2.2 Information concerning trimming on take-off

On 1 December 2000, Embraer published Operational Bulletin OB 145-012/00 for all operators of EMB-145 and EMB-135 aircraft. This OB is entitled: PITCH TRIM INOPERATIVE DURING TAKEOFF and the manufacturer mentions as the reason for publication: *To provide information about temporary loss of pitch trim command during takeoff*.

The manufacturer refers to six incidents during which pitch trim did not function temporarily during take-off. In all the incidents, the aircraft was in the acceleration phase and was flying at a speed of more than 200 KIAS. In five cases pitch trimming was able to be re-activated when the speed was reduced to below 200 KIAS. Nothing is known about the sixth case in this context.

The manufacturer describes that during take-off, if initiation of the pitch trim signals is delayed, the necessary control forces on the stabilizer also increase. These greater forces do not cause a structural problem, but may cause the Horizontal Stabilizer Actuator (HAS) to jam, leading to a temporary loss of pitch trim.

Among other things, the manufacturer published the following in the above-mentioned OB:

NOTE: *If pitch trim adjustments are delayed after takeoff, high pilot force on the control column may induce loads on the HSA close or above its maximum operating load*

Therefore, in case of loss of pitch trim command associated with high pitch control forces during takeoff, proceed as follows:

Airspeed ..... REDUCE

Among other things, the manufacturer's Airplane Flight Manual dated 12 May 1997, revised on 30 January 2001, mentions the following regarding trim in the BEFORE START checklist:

Set the pitch trim to the units required for takeoff. Set the roll and yaw trims to zero.

PITCH TRIM UNITS	*8*	*7*	*6*	*5*	*4*
CG POSITION (%)	*LESS THAN 25*	*30*	*35*	*40*	*43*

For the take-off of flight LX 500, aircraft HB-JAD had set the stabilizer to 8° ANU and the CG for the effective take-off weight was 20.6.

1.17.3 Emergency/abnormal checklist for PITCH TRIM INOPERATIVE

The procedure for PITCH TRIM INOPERATIVE is described in the Emergency/Abnormal Checklist in the manufacturer's Quick Reference Handbook (QRH) dated 1 May 2000 (see Annex 5). This procedure is considerably expanded in the QRH by the revision dated 27 November 2001, in order to take account of the known problems with trim after take-off (see Annex 6).

1.18 Additional information

Since the CVR recordings had been erased on the aircraft, the CVR was sent for further investigation to the manufacturer.

When the ERASE button on the CVR is pressed, the recordings are not actually erased; only the "pointer" is set back by a specific amount, so that the recorded data can no longer be played back. The manufacturer has access to this pointer and can reset it so that the data can be read again. This procedure is called data recovery.

Despite technically satisfactory data recovery, no recordings of flight LX 500 on 24 December 2001 were present. The recordings that were present were those of a full test, as normally carried out only by the manufacturer. Since the operating hours were also recorded in memory, it was able to be established that the CVR still indicated the same number of hours as at the time of its last repair by the manufacturer on 17 May 2001.

From these facts it must be concluded that the CVR was never in operation since its last repair on 17 May 2001. It must remain an open question whether the CVR S/N 1298 had been installed in aircraft HB-JAD and was not functioning or whether the investigating authority was given an incorrect CVR for analysis by mistake.

1.19 Useful or effective investigation techniques

Not applicable.

2 Analysis

2.1 Technical aspects

There are no indications of any pre-existing technical defects which may have caused the serious incident. However, the various incidents with partially ineffective trim after take-off indicate that the designed performance of the horizontal stabilizer trim system is rather weak and was above all very limiting for the initial climb in the take-off phase. Thus functional shortcomings occurred several times even in the case of slightly excessive speeds and the corresponding increasing aerodynamic forces.

The problem occurred above all after rotation in the take-off phase on transition to a stabilized climb. The trim jammed because the aerodynamic forces on the stabilizer, reinforced by the use of the elevators, became so large at overspeeds that they could no longer be handled by the Horizontal Stabilizer Actuator (HSA).

In all known occurrences, pitch trim was able to be re-activated once the speed had been reduced to below 200 KIAS.

On the basis of these findings, the aircraft manufacturer on the one hand amended the procedures for inoperative trim (see chapter 1.17.3) and on the other hand introduced a limit of 160 KIAS for trim on take-off.

2.2 Human and operational aspects

2.2.1 Flight crew

Since no cockpit voice recorder (CVR) recordings were available, essential information on assessing the implementation of the procedures laid down by the operator, such as briefings, crew coordination and performance of the corresponding checklists was missing. The DFDR recordings as well as the crew statements and the operator's flight safety officer's statement were available.

Generally, rotation on the EMB-145 is effected at a rate of 3-4 degrees per second. The DFDR data indicate that the copilot required a period of 17 seconds to reach a value of 18° ANU. This period is extremely long and, as the present serious incident shows, leads to an excessive initial climbing speed. In the serious incident, the target speed of 146 KIAS was exceeded by 27 KIAS.

The limit of 160 KIAS after take-off demands a highly disciplined rotation, particularly on a light, nose-heavy aircraft as was the case with flight LX 500. It demands corresponding mental preparation from the crew and should be part of a take-off briefing. The recorded data allow the conclusion to be drawn that the crew were surprised by the rapid take-off sequence and were not adequately prepared to comply with the target values for ANU (pitch) and speed within the necessary tolerance range. In addition, the low external temperature of -14 °C and the atmospheric pressure of 1020 QNH favoured the rapid acceleration of the aircraft on take-off.

Publication of target values concerning rotation per unit of time and on an initial pitch value in the operator's procedures could have helped to prepare the crew better for take-off.

The recordings also show that the copilot activated the trim for the first time at 173 KIAS. This means that the speed was already above the maximum value of

160 KIAS required by the manufacturer. This is very probably the reason why the Horizontal Stabilizer Actuator (HSA) was overloaded, jammed and triggered the PITCH TRIM 1 INOP warning.

It must be assumed that the copilot was aware of the excessively high speed, as he subsequently increased the pitch attitude to the maximum value of 20° ANU to bring the speed back from 173 KIAS to 160 KIAS.

At a speed of 159 KIAS the trim could be operated and the warning disappeared. The autopilot was subsequently engaged and the flaps were retracted in a continuous climb.

As the speed continued to increase to the 250 KIAS preselected by the crew, the recordings show that the autopilot was not able to trim to a lower pitch value. The crew therefore disengaged the autopilot and according to the copilot's statement the aircraft was difficult to control in its untrimmed state. He needed to apply a high AND (aircraft nose down) control force. He then instructed the commander to lower the landing gear and after 40 seconds he used the back-up trim, which was functioning.

According to the copilot's statement, the emergency checklist for PITCH TRIM INOPERATIVE was performed and the aircraft's controllability was again ensured. Whether the use of the back-up trim took place as a result of the emergency checklist or whether it was activated beforehand as a "by heart item" cannot be ascertained because of the missing CVR data.

The recordings and the crew statements permit the conclusion that the back-up trim was used for the first time 40 seconds after the gear was lowered, or 04:53 min. after the warning appeared. The PITCH TRIM 1 INOP warning indirectly implies that the system 2 (back-up) is available. The question of whether inadequate crew knowledge of the system or other circumstances meant that the back-up trim system was not applied much earlier cannot be answered.

2.2.2 The operator

All known occurrences on the EMB-145 aircraft concerning inoperative trim after take-off were examined and analysed by the operator. As a result, a detailed information bulletin was issued. In this "Flight Crew Information Bulletin" dated 8 May 2001, entitled: "Stabilizer Trim Operation EMB-145", the trim system was briefly described, the rotation technique was explained and the new procedure for inoperative trim was published. Crews were also informed of the relevant actions which had been taken and which were planned for the future. In addition, reference was made to all the relevant documents published by the aircraft manufacturer.

This bulletin was comprehensive, appropriate and included all the information which was important for pilots. The commander's statement to the operator's Flight Safety Officer to the effect that he was not acquainted with the pitch control problems on the EMB-145 leaves open the question of the extent to which this information had been dealt with in training and generally with regard to crews.

The assigned tasks on take-off for the two pilots, as published by the operator in tabulated form, does not mention anything about the technique to be applied on take-off regarding how rotation should take place, within what timeframe, and to what aircraft nose up (ANU) attitude. Such information would give the pilots valuable information for continuous rotation on take-off and would establish a better initial situation for a smooth transition to a stabilized climb.

3 Conclusions

3.1 Findings

3.1.1 Crew

- The pilots were in possession of the necessary licences for the flight.
- The commander concluded conversion to the EMB-145 aircraft on 11 October 2001 with the type rating. At the time of the serious incident, he had 75:18 hours experience on this aircraft type.
- The copilot had two years flying experience with 995 hours on the EMB-145 aircraft.
- There are no indications of any health problems of the pilots.
- The scheduled rest times before the LX 500 flight duty were 20:10 hours for the commander; the copilot had four days off duty.
- Throughout the entire flight the copilot was pilot flying (PF) and the commander was pilot not flying (PNF).

3.1.2 Technical aspects

- The investigation produced no indications of any pre-existing technical defects which might have caused the serious incident.
- The mass and centre of gravity of the aircraft were within the permitted limits.
- The occurrences concerning partially inoperative trim after take-off on the EMB-145 aircraft were known and had been published several times.
- The investigation of the Horizontal Stabilizer Control Unit (HSCU) showed no indications of any malfunction.
- No recordings were present on the CVR handed over to the investigating authority.

3.1.3 History

- The stabilizer was set to 8° ANU for take-off.
- Rotation on take-off was slow and lasted for 17 seconds.
- The initial climbing speed of 146 KIAS after rotation was exceeded by 27 KIAS.
- After the first activation of the trim at a speed of 173 KIAS, the PITCH TRIM 1 INOP warning was displayed.
- The maximum published limit of 160 KIAS for the initial trim activation after take-off was therefore exceeded by 13 KIAS.
- As the climb continued, the autopilot could be used and the flaps were retracted.
- During the acceleration above flight level 100, the autopilot was unable to trim and was disengaged.

- The aircraft was then in an untrimmed state and was difficult to control manually.
- The landing gear was lowered to reduce speed.
- The crew declared an emergency, performed the corresponding emergency checklist and requested a return to the departure airport.
- 04:53 min. after the appearance of the PITCH TRIM 1 INOP warning, the back-up trim, which was working, was activated.
- The aircraft was normally controllable again and the landing was uneventful.

3.1.4 General conditions

- Low take-off mass of the aircraft with only 4 passengers and 47 kg of baggage.
- Rapid acceleration on take-off because of the atmospheric conditions

3.2 Causes

The serious incident is attributable to the fact that after take-off the stabilizer trim became jammed because the flying limits were exceeded and the crew did not subsequently proceed appropriately.

The exceeding of the flying limits was favoured by:

- the slow rotation of the aircraft on take-off
- the aircraft's low take-off mass

4 Safety recommendations and measures taken since the serious incident

4.1 Safety recommendations

None.

4.2 Measures taken since the serious incident

4.2.1 By the operator

The operator's Flight Safety Office investigated and analysed the serious incident in detail, raised some highly self-critical issues in a confidential report and drew the conclusions.

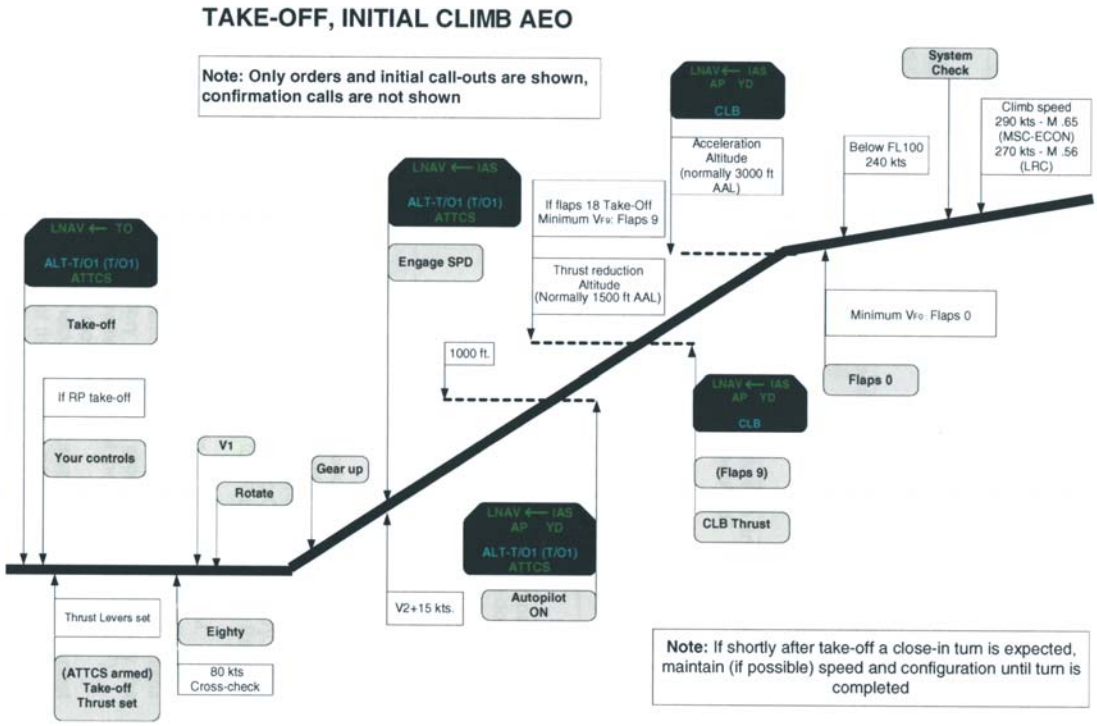
About three months after the serious incident, a new operator named "Swiss International Air Lines" was founded, combining Swissair, which had gone into liquidation, and the Crossair operator. This new airline operated a fleet of more than 80 aircraft of the following types: SAAB 2000, Embraer 145, Avro 146 RJ 85/100, Airbus A319/20/21, Airbus A330 and MD11.

Within this new airline, an attempt was made in the training, among other things, to standardise take-off procedures by specifying target values such as rotation rate and initial pitch attitude. This also concerned the EMB-145 aircraft.

In the Operational Manual (OM) B, in chapter 1.02.10, among other things, the take-off roll and initial climb were adjusted as follows:

– *...*
– *At 80 kts **PNF** calls out **"Eighty"** and **PF** checks speed annunciator on his side and confirms **"Checked"***   ***NOTE:** If the 80 kts call out is missed, the actual speed shall be called out to avoid any confusion (e.g. **"100"**)*
– ***PNF** calls out **"V_1", "Rotate"** at the appropriate speeds.*
– *At V_1 **LP** takes his right hand away from the thrust levers.*
– *At V_R, **PF** starts smooth rotation with about 3-4 deg/sec to 14 deg. After lift off follow FD pitch bar. If FD not usable, climb with V_{2+15} (initially 14° ANU, maximum 20° ANU)*
– ***PF** orders **"Gear up"** when clear of ground and positive rate of climb is established.*   – ***PNF** checks positive rate, selects the gear up and monitors proper gear retraction.*
– *When reaching V_{2+15} kts **PF** orders **"Engage speed"***   – ***PNF** engages speed mode and adjusts speed bug to V_{2+15} kts (=V_{F0} for Flap 9 T/O; = V_{F9} for Flap 18 T/O)*
– *Above 1000 ft RA:*   – *AP may be engaged. At discretion, **PF** orders **"Autopilot ON"***
– *...*

In addition, in the OM B, chapter 1.02.10 (Normal Procedures, Standard Operating Procedures), the following take-off/climb profile was published:



4.2.2 By the aircraft manufacturer

The aircraft manufacturer Embraer reacted to the known incidents of a partially inoperative trim system after take-off with the publication of Operational Bulletin OB 145-012/00 and a limit on initial climb speed of 160 KIAS before the first trim activation.

In a further phase, the aircraft manufacturer made various improvements to the trim system to increase its reliability. In particular, these concerned the Horizontal Stabilizer Actuator (HSA), the Horizontal Stabilizer Control Unit (HSCU) and the corresponding warning annunciations.

The most important improvements are briefly summarised below:

- The power of the trim motor was increased by increasing the feed voltage from 19 V A/C to 20-25 V A/C and the fuse was increased from 33 A to 45 A.
- The HSA coupling was configured for a higher power transmission.
- The reliability of the HSCU was improved to make it less susceptible to malfunctions.
- The reliability, or rather the functional efficiency, of the two trim switch halves on the control column was increased by means of improved electrical contacts.
- An aural warning call out: “trim” was incorporated. It is activated if only one of the two trim switch halves is activated for more than 3 seconds.

In the EICAS, the information for crews was improved. Existing annunciations are now selectively shown more clearly and additional warning messages are displayed.

The two warning messages concerning PITCH TRIM were changed as follows:

- PITCH TRIM 1 INOP became PTRIM MAIN INOP.
- PITCH TRIM 2 INOP became PTRIM BACKUP INOP.

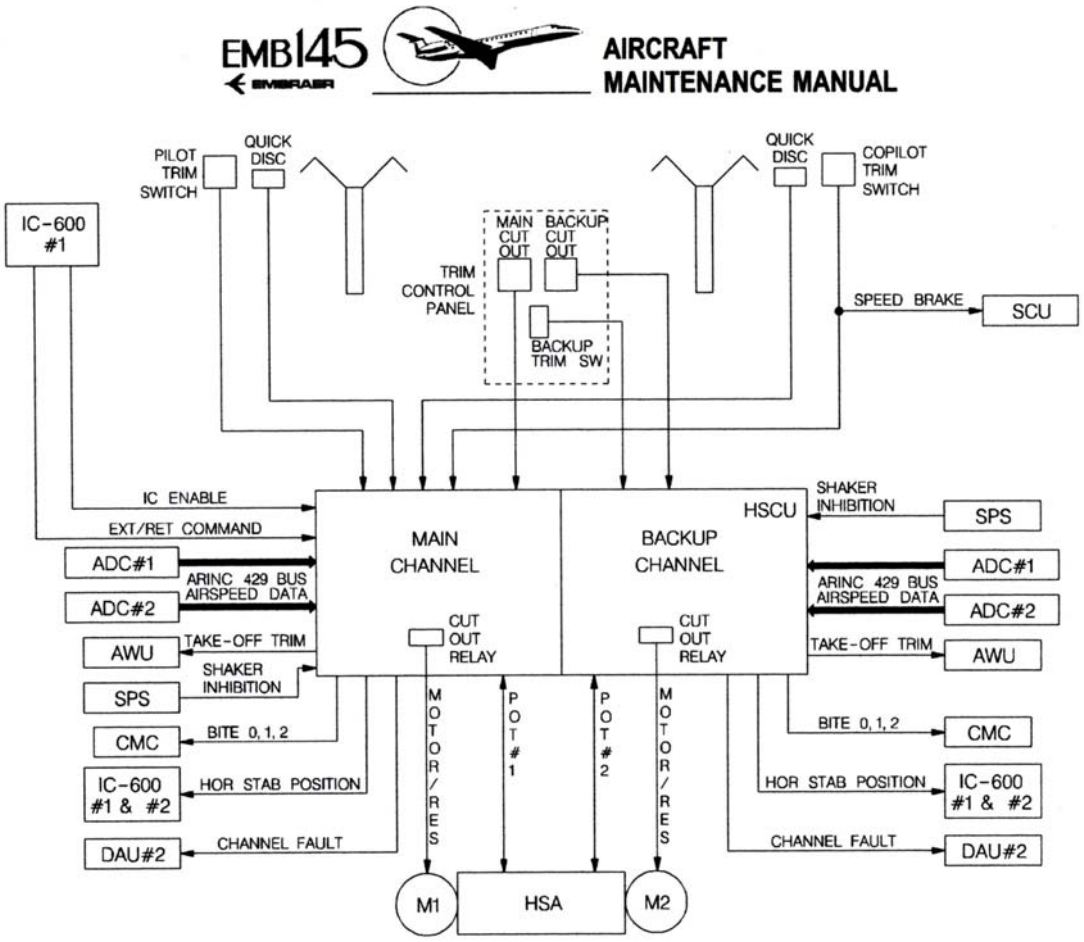
In the event of pitch trim switch failures, the following new messages appear:

- PTRIM CPT SW FAIL – CAUTION
- PTRIM F/O SW FAIL – CAUTION
- PTRIM BKP SW FAIL – CAUTION

Berne, 16 January 2008 Aircraft Accident Investigation Bureau

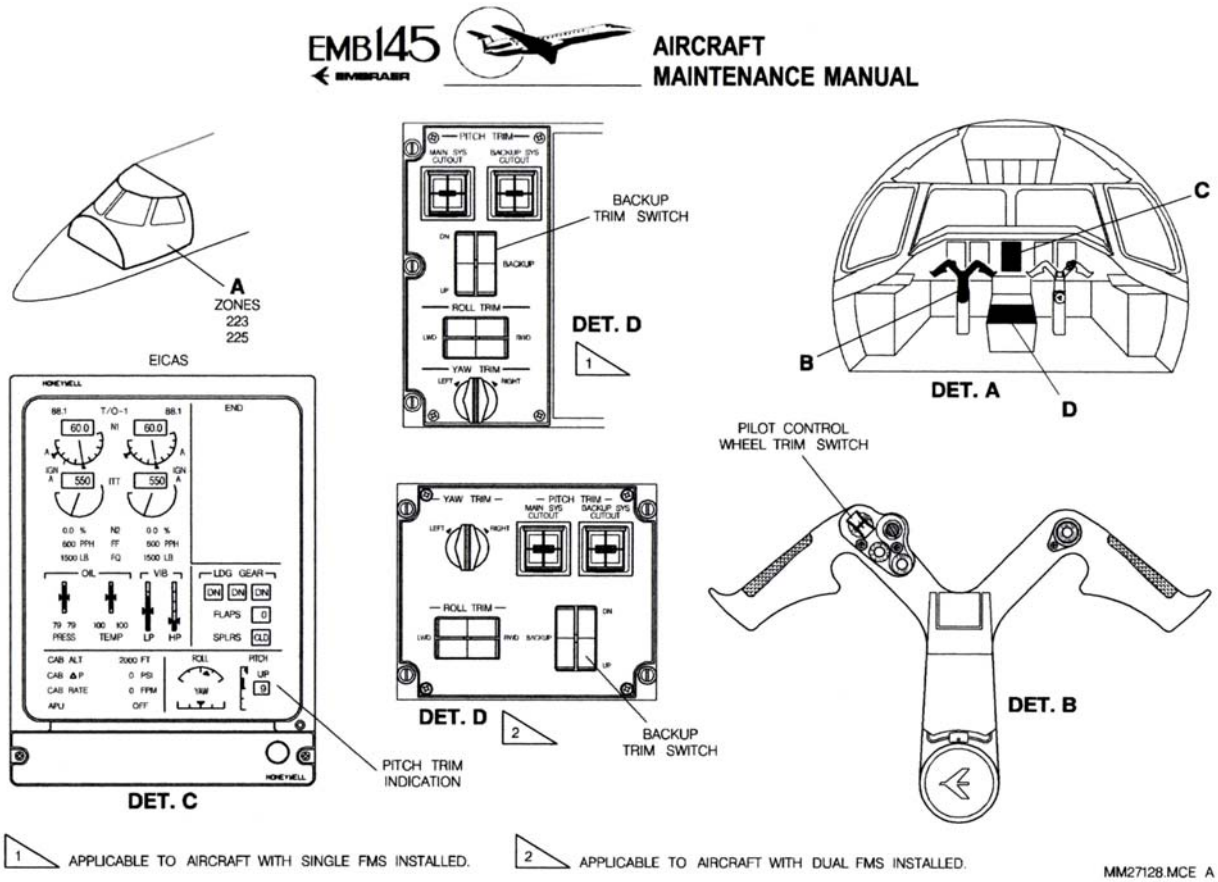
Annexes

Annex 1: Horizontal Stabilizer Control System Schematic



HORIZONTAL STABILIZER CONTROL SYSTEM SCHEMATIC

Annex 2: Pitch Trim Control and Indication



PITCH TRIM CONTROL AND INDICATION

Annex 3: Rotation technique during take-off

Rotation Technique

During rotation on ground the airplane rotates around the main wheel, which is located aft of the CG position.

Once airbone the airplane rotates around the CG, which requires less elevator down force, as the CG is located in a much more forward position than the main wheel.

1) pull the yoke to rotate

2) push the yoke forward ...and <u>start trimming nose down</u> to alleviate yoke force !!

Annex 4: Procedures for handling inoperative pitch trimming applicable at the time of the serious incident

EMERGENCY / ABNORMAL PROCEDURES

PITCH TRIM INOPERATIVE

EICAS Message: PIT TRIM INOP warning message. AUTO TRIM FAIL caution message may be presented.

LIGHT: Master Warning light illuminates if PIT TRIM INOP message is presented. Master Caution light illuminates if AUTO TRIM FAIL caution message is presented.

Remaining Pitch Trim System.....AS REQUIRED
If both Pitch Trim Systems are inoperative:
Altitude.....BELOW 20000 ft
DOWN TO MEA
Airspeed.....REDUCE
Below 250 KIAS:
Flaps.....9°
Below 200 KIAS:
Flaps.....22°
Stabilize the airplane around 190 KIAS. Consider landing at the nearest suitable airport.

Approach and landing configuration:
Landing Gear.....DOWN
NOTE: Gear extension should be delayed as long as possible.
Flaps.....22°
Airspeed.....V_{REF45} + 20 KIAS
CAUTION: TO DETERMINE THE MINIMUM SUITABLE LANDING DISTANCE, MULTIPLY THE UNFACTORED LANDING DISTANCE FOR FLAPS 45° BY 1.41.

ORH-145/1169 - JAA

MAY 01, 2000 EAP-61

Annex 5: New procedure concerning handling of inoperative pitch trimming

PITCH TRIM INOPERATIVE

EICAS Message: PIT TRIM 1 (2) INOP warning message (may be presented). AUTO TRIM FAIL caution message (may be presented).

If at least one message is presented:
Affected Pitch Trim System ..... OFF
Continue the flight with the remaining Pitch Trim System.

If both Pitch Trim Systems are inoperative:
Pitch Trim Main System ..... OFF
Pitch Trim Back Up System ..... OFF
Consider landing at the nearest suitable airport.

If no message is presented:
Pitch Trim Command — CHECK ALL SWITCHES

If any Pitch Trim Command is reestablished:
Continue the flight with the remaining Pitch Trim System.

NOTE: When Main Pitch Trim System is INOP, Autopilot is not available.

WARNING: **IF PITCH TRIM COMMAND IS NOT REESTABLISHED, DO NOT OPEN SPEEDBRAKE.**

If Pitch Trim Command is not reestablished and the airplane presents a NOSE UP tendency:
Airspeed ..... REDUCE
Airspeed reduction alleviates control column forces and may permit Pitch Trim Command to be recovered.

NOTE: Turning the airplane and extending the landing gear helps to maintain safe minimum airspeed in the presence of an unwanted pitch up tendency.

If it is necessary to reduce airspeed below 180 KIAS (or 200 KIAS in icing conditions), extend flaps to 9° (at 20000 ft maximum).

If it is necessary to reduce airspeed below 160 KIAS, extend flaps to 22°.

Pitch Trim Command — CHECK ALL SWITCHES

If Pitch Trim is recovered, retrim the airplane and proceed with flight normally.

If Pitch Trim is not recovered:
Consider landing at the nearest suitable airport.
Approach and landing configuration:
Landing Gear ..... DOWN
Flaps ..... 22°
Airspeed — $V_{REF\ 45}$ + 10 KIAS

CAUTION: TO DETERMINE THE MINIMUM SUITABLE LANDING DISTANCE, MULTIPLY THE UNFACTORED LANDING DISTANCE FOR FLAPS 45° BY 1.27.

If Pitch Trim Command is not reestablished and the airplane presents a NOSE DOWN tendency:
Airspeed — REDUCE AS REQUIRED

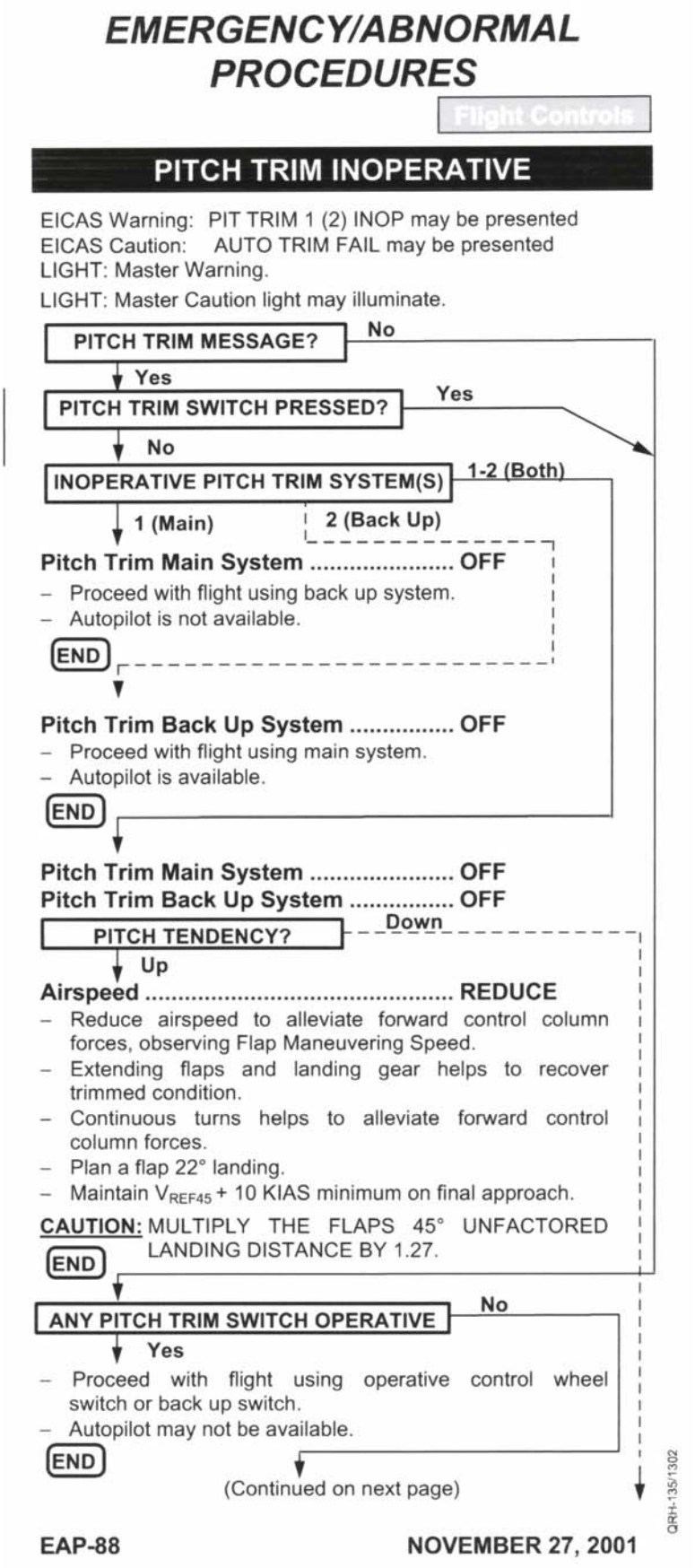
Below 250 KIAS:
Flaps (at 20000 ft maximum) ..... 9°
Below 200 KIAS:
Flaps ..... 22°
Approach and landing configuration:
Landing Gear ..... DOWN

NOTE: Gear extension should be delayed as long as possible.

Flaps ..... 22°
Airspeed — $V_{REF\ 45}$ + 25 KIAS

TO determine the minimum suitable landing distance, multiply the unfactored landing distance for flaps 45° by 1.44.

Annex 6: Aircraft manufacturer's EMERGENCY / ABNORMAL PROCEDURES



EMERGENCY/ABNORMAL PROCEDURES

Flight Controls

PITCH TRIM INOPERATIVE

EICAS Warning: PIT TRIM 1 (2) INOP may be presented
EICAS Caution: AUTO TRIM FAIL may be presented
LIGHT: Master Warning.
LIGHT: Master Caution light may illuminate.

PITCH TRIM MESSAGE? — No

Yes

PITCH TRIM SWITCH PRESSED? — Yes

No

INOPERATIVE PITCH TRIM SYSTEM(S) — 1-2 (Both)

1 (Main) — 2 (Back Up)

Pitch Trim Main System ..... OFF
- Proceed with flight using back up system.
- Autopilot is not available.

END

Pitch Trim Back Up System ..... OFF
- Proceed with flight using main system.
- Autopilot is available.

END

Pitch Trim Main System ..... OFF
Pitch Trim Back Up System ..... OFF

PITCH TENDENCY? — Down

Up

Airspeed ..... REDUCE
- Reduce airspeed to alleviate forward control column forces, observing Flap Maneuvering Speed.
- Extending flaps and landing gear helps to recover trimmed condition.
- Continuous turns helps to alleviate forward control column forces.
- Plan a flap 22° landing.
- Maintain V_{REF45} + 10 KIAS minimum on final approach.

CAUTION: MULTIPLY THE FLAPS 45° UNFACTORED LANDING DISTANCE BY 1.27.

END

ANY PITCH TRIM SWITCH OPERATIVE — No

Yes
- Proceed with flight using operative control wheel switch or back up switch.
- Autopilot may not be available.

END

(Continued on next page)

QRH-135/1302

EAP-88 NOVEMBER 27, 2001

EMERGENCY/ABNORMAL PROCEDURES

Flight Controls

(Continued from previous page)

PITCH TENDENCY — Down

Up

WARNING: **DO NOT OPEN SPEED BRAKE.**

Airspeed..... REDUCE

- Reduce airspeed to alleviate forward control column forces, observing Flap Maneuvering Speed.
- Extending flaps and landing gear helps to recover trimmed condition.
- Continuous turns helps to alleviate forward control column forces.

When control column force is alleviated:

Pitch Trim Switches..... CHECK

PITCH TRIM CONTROL — Not Recovered

Recovered

- Proceed with flight normally.

END

- Plan a flaps 22° landing.
- Maintain V_{REF45} + 10 KIAS minimum on final approach.

CAUTION: MULTIPLY THE FLAPS 45° UNFACTORED LANDING DISTANCE BY 1.27.

END

WARNING: **DO NOT OPEN SPEED BRAKE.**

When necessary to reduce airspeed:

Airspeed..... 250 KIAS MAX
Flaps (20000 ft maximum)..... 9°
Airspeed..... 200 KIAS MAX
Flaps..... 22°

- Plan a flaps 22° landing.
- Maintain V_{REF45} + 10 KIAS minimum and V_{REF45} + 25 KIAS maximum on final approach.
- Delay gear extension as long as possible.

CAUTION: MULTIPLY THE FLAPS 45° UNFACTORED LANDING DISTANCE BY 1.44.

END

QRH-135/1302

MAY 21, 2001 **EAP-89**