Australian Government
Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Aviation Occurrence Report – 200504340

Final

Flight control system event

Bankstown, NSW

1 September 2005

VH-OZF

Embraer-Empresa Brasileira de Aeronautica

EMB 110-P2

Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Aviation Occurrence Report
200504340

Final

Flight control system event
Bankstown, NSW
1 September 2005
VH-OZF
Embraer-Empresa Brasileira de Aeronautica
EMB-110P2

Published by: Australian Transport Safety Bureau
Postal address: PO Box 967, Civic Square ACT 2608
Office location: 15 Mort Street, Canberra City, Australian Capital Territory
Telephone: 1800 621 372; from overseas + 61 2 6274 6590
Accident and serious incident notification: 1800 011 034 (24 hours)
Facsimile: 02 6274 6474; from overseas + 61 2 6274 6474
E-mail: atsbinfo@atsb.gov.au
Internet: www.atsb.gov.au

ISBN and formal report title: see 'Document retrieval information' on page iii.

DOCUMENT RETRIEVAL INFORMATION

Report No.	Publication date	No. of pages	ISBN
200504340	October 2006	13	1 921164 09 3

Publication title

Flight Control System Event - Bankstown NSW, 1 September 2005, VH-OZF, Embraer–Empresa Brasileira de Aeronautica EMB-110P2.

Prepared by

Australian Transport Safety Bureau
PO Box 967, Civic Square ACT 2608 Australia
www.atsb.gov.au

Abstract

On 1 September 2005, the crew of an Embraer EMB110-P2 (Bandeirante) aircraft, registered VH-OZF, was conducting a private flight under the visual flight rules from Bankstown Airport to Camden, NSW. At 1343 Eastern Standard Time, on the initial climb from runway 11 Left (11L), the pilot in command (PIC) experienced excessive nose down pitch control forces.

The PIC attempted to correct the pitch force with the manual elevator trim wheel and electric trim, but the trim did not move. The copilot assisted by applying back pressure to his control column and observed that the elevator trim wheel was in the full nose down position. The pilots were unable to maintain altitude and the aircraft descended from approximately 470 to 150 ft.

The PIC reduced engine power and the airspeed reduced. The copilot applied significant force to the elevator trim wheel and the wheel released from the full nose down position. The pilots regained control and landed.

The investigation found that the left yoke-mounted trim switch did not to return to the neutral position, when operated and released, due to a sticky substance binding the levers. It also found that the elevator electric trim servo mechanical clutch did not release at the specified setting due to a lack of maintenance.

The circumstances of this event were consistent with an electric trim runaway occurring during or shortly after take-off. The investigation established that the trim runaway was probably due to the non return of the switch from the nose down position or an unidentified electrical fault.

The pilots reported that they were unable to pull the electric trim circuit breaker, in accordance with the manufacturer's procedure, because they were unable to release the control column.

As a result of the investigation the operator and manufacturer initiated a number of safety actions.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Transport and Regional Services. ATSB investigations are independent of regulatory, operator or other external bodies.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations. Accordingly, the ATSB also conducts investigations and studies of the transport system to identify underlying factors and trends that have the potential to adversely affect safety.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and, where applicable, relevant international agreements. The object of a safety investigation is to determine the circumstances in order to prevent other similar events. The results of these determinations form the basis for safety action, including recommendations where necessary. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations.

It is not the object of an investigation to determine blame or liability. However, it should be recognised that an investigation report must include factual material of sufficient weight to support the analysis and findings. That material will at times contain information reflecting on the performance of individuals and organisations, and how their actions may have contributed to the outcomes of the matter under investigation. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. While the Bureau issues recommendations to regulatory authorities, industry, or other agencies in order to address safety issues, its preference is for organisations to make safety enhancements during the course of an investigation. The Bureau prefers to report positive safety action in its final reports rather than making formal recommendations. Recommendations may be issued in conjunction with ATSB reports or independently. A safety issue may lead to a number of similar recommendations, each issued to a different agency.

The ATSB does not have the resources to carry out a full cost-benefit analysis of each safety recommendation. The cost of a recommendation must be balanced against its benefits to safety, and transport safety involves the whole community. Such analysis is a matter for the body to which the recommendation is addressed (for example, the relevant regulatory authority in aviation, marine or rail in consultation with the industry).

FACTUAL INFORMATION

Introduction

On 1 September 2005, the crew of an Embraer[1] EMB110-P2 (Bandeirante) aircraft, registered VH-OZF, was conducting a private flight under the visual flight rules from Bankstown Airport to Camden, NSW. At 1343 Eastern Standard Time[2], on the initial climb from runway 11 Left (11L), the pilot in command (PIC) experienced flight control difficulties. The crew recovered control and landed.

Sequence of events

The PIC was the chief pilot of a charter operator. The flight was to re-establish recency in the operation of the aircraft and to practice the operator's recently developed two-crew procedures for that aircraft type.

The PIC was the pilot flying in the left control seat. Another of the operator's pilots performed the role of copilot/supervisory pilot, in the right control seat. A third pilot was to observe from a forward passenger seat in preparation for aircraft endorsement training.

At about 1230, the PIC and copilot reviewed the planned flight and then conducted a pre-flight inspection. During the inspection, they noted that the elevator trim tab was in a fully nose-down position.[3] Neither pilot had moved the trim tab to that position and they assumed that the tab had been moved to facilitate parking in the hangar.

In the cockpit, the PIC performed the before start checklist, including manual and electric operation of the elevator trim in both directions.

Shortly after, the crew exited the aircraft because the Automatic Terminal Information Service[4] advised that the aerodrome was closed due to an aircraft emergency. Outside the aircraft, the PIC noticed that the elevator trim tab was not deflected up as previously observed and appeared to be in the 'normal position'.

About 20 minutes later, the PIC and copilot conducted an aircraft walk-around before they and the observer pilot boarded the aircraft. The PIC recalled confirming the neutral elevator trim position before starting the engines and proceeding to the holding point for runway 11L. The PIC and copilot conducted the lineup checks that included a functional check of the primary flight controls.

---

1 Empresa Brasileira de Aeronautica.

2 The 24-hour clock is used in this report to describe the local time of day, Eastern Standard Time (EST), as particular events occurred. Eastern Standard Time was Coordinated Universal Time (UTC) + 10 hours.

3 A trim tab is deflected up when in the nose-down position.

4 A continuous broadcast of recorded non-control information.

The PIC recalled that the aircraft rotated normally, but the flight controls were 'heavier than he had remembered'. As the landing gear retracted and the airspeed increased, the nose down pitch force increased. The PIC reported that he manually and electrically applied nose up elevator trim, but there was no indication of movement or any reduction of the nose-down pitch forces. The PIC indicated to the copilot that he was having control difficulties. The copilot assisted the PIC by applying backpressure on the right control column. The copilot reported that he saw that the elevator trim indicator was in the full nose down position and that he attempted to manually apply nose up elevator trim, without success.

The PIC reported that he reduced engine power, and as the airspeed reduced to about 90 kts, the control force lessened, but still required control inputs from both pilots. The pilots reported that the aircraft descended to about 150 ft above ground level during the incident. The copilot transmitted a PAN[5] broadcast, alerting the aerodrome controller (ADC) to the control problem and advising of their intention to return to runway 11L for a landing.

The copilot reported that as the aircraft became more manageable, and in desperation, he released the right control column and applied backpressure to the elevator trim wheel with both hands. The copilot reported that after using 'excessive force', the trim wheel released from the nose down position and was moved towards the neutral position. The pilots regained control of the aircraft and landed shortly after.

Recorded radar data indicated that the Bandeirante reached an altitude of about 470 ft Above Mean Sea Level with an airspeed of about 150 kts before the control forces exceeded the capability of both pilots to maintain a climb.

The ADC reported that, when the aircraft was on crosswind, it disappeared behind a hill to the north-east of the aerodrome and was not seen again until it was mid-downwind, where it appeared for a few seconds before descending out of sight. The ADC then saw the aircraft on late downwind, apparently under control, and issued a landing clearance to the crew.

Personnel information

The PIC held an air transport pilot (aeroplanes) licence and had flown a total of about 7,000 hours including 150 hours on the Bandeirante aircraft type. He had last flown a Bandeirante 7 years prior to the incident flight.

The copilot held an air transport pilot (aeroplanes) licence and had flown a total of about 15,000 hours, including 2,000 hours on the Bandeirante aircraft type. He had flown VH-OZF a total of 5.5 hours, all as pilot in command. That flight time included a 3-hour ferry flight to Bankstown approximately 1 month before the incident flight. The copilot reported that when he had flown the aircraft he did not operate the electric trim system.

5 Urgency call by pilot to alert all listening parties of a special handling condition which will receive Air Traffic Control priority for issuance of a clearance or assistance.

Aircraft information

The aircraft was manufactured in 1979 and was certified for single pilot operation. At the time of the incident, the aircraft had 21,619 hours total time in service (TTIS). The incident flight was the first flight since the aircraft's arrival at Bankstown. There was no evidence of any maintenance having been performed since the aircraft's arrival.

The aircraft's Maintenance Release was issued on 1 June 2005 at 21,613.9 hours TTIS and was due to expire at 21,713 hours TTIS, or 1 June 2006. There were no defects recorded prior to the flight.

The aircraft logbooks showed that the autopilot servos and cockpit controller were removed in 2001 at 20,391 hours TTIS. An Engineering Order dated 23 May 2005 authorised the removal of individual autopilot components for maintenance. After the incident, the ATSB examination found that the autopilot elevator servo and controller were not fitted.

The PIC calculated the weight and balance prior to the flight, which showed that the aircraft was within allowable centre of gravity limits.

Elevator trim system

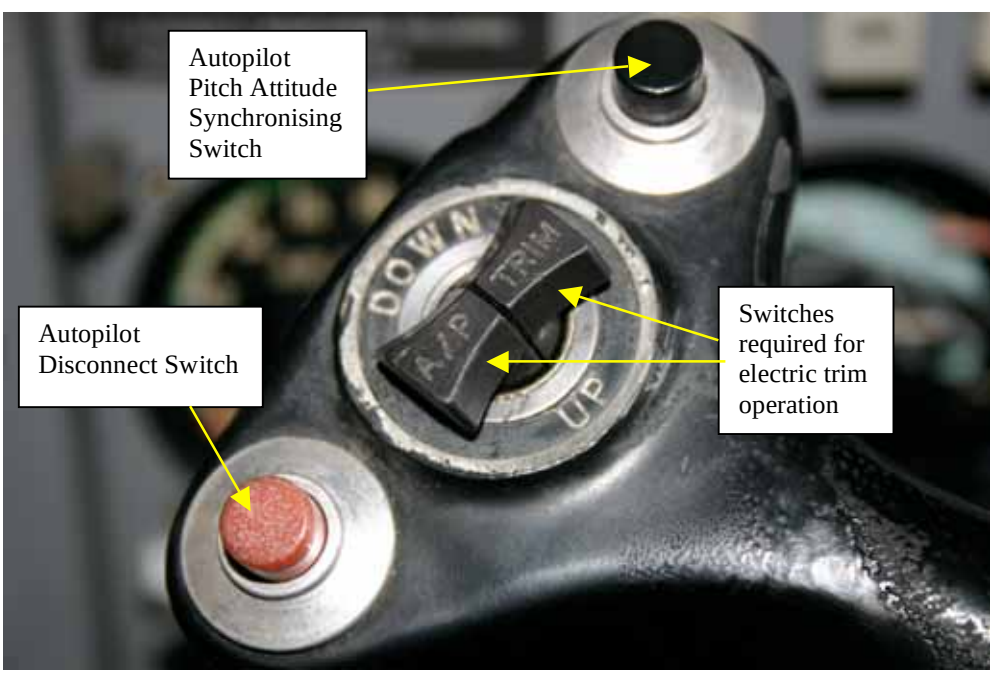
The elevator trim tab could be manually adjusted by rotation of a control wheel on the centre pedestal (Figure 1). The control wheel moved a Teleflex cable, which operated the trim tab. A position indicator adjacent to the control wheel showed the position of the trim tab.

Figure 1: Cockpit Layout

The trim tab position could also be controlled electrically through simultaneous selection of two yoke[6]-mounted switches, A/P and TRIM (Figure 2). A set of switches were located on the left side of the left yoke and on the right side of the right yoke. Those switches were spring-loaded to the neutral position and had a forward DOWN position and a rear UP position. Selection of both switches provided electrical power via an adaptor box to an elevator trim servo assembly located in the rear fuselage that drove a transmission box, the Teleflex cable, an actuator and the manual trim control wheel in the desired direction. There were no visual or aural warnings to alert a pilot if the switches did not return to the neutral position. The PIC reported that he could not recall activating the electric trim switch immediately prior to the control difficulty.

The red switch to the left of the trim switch was for autopilot disconnect, and the black switch to the right of the trim switches was for autopilot pitch attitude synchronising.

Figure 2: Left yoke switch layout



The elevator trim servo assembly consisted of an electric motor, electric engagement clutch and mechanical slip clutch. The mechanical clutch was designed to slip when resistance to movement of the Teleflex cable exceeded 55 inch pounds (6.2 Nm) of force. The aircraft manufacturer advised that 55 inch pounds of force corresponded to 13 pounds[7] of force at the trim control wheel.

The elevator trim circuit breaker was located on the left circuit breaker panel adjacent to the left control seat. The PIC reported that the elevator trim circuit breaker did not activate during the incident.

---

6 The control wheel of an aircraft, akin to an automobile steering wheel.

7 Force input by the pilot.

Examination of elevator trim system

The copilot reported that, after the flight, he attempted to operate electric trim from the left yoke-mounted trim switch. On the sixth attempt, the trim moved in the forward direction, but when the switch was released, the trim continued to operate. When the copilot manipulated the switch, the trim stopped operating.

The Australian Transport Safety Bureau (ATSB) examined the aircraft the following day. The elevator trim was manually operated through the full travel range several times with no difficulties. The left yoke A/P and TRIM switches were activated to the DOWN and UP positions and released. The switches did not return to the neutral (centre) position. With electrical power on, selection of UP or DOWN produced a noise consistent with operation of the trim servo motor, but did not result in movement of the trim tab. That was consistent with an inadequate electrical supply being available to the elevator trim servo. The quality of the internal and external battery supply used during the operational checks was not established.

The left control yoke A/P and TRIM switch was removed and examined. Debris was found inside the switch and a sticky substance was evident between the auto-pilot switch lever and the elevator trim switch lever. Corrosion was also evident on the pivot bearing of both switch levers and ball roller surfaces. The internal electrical contacts were tested and found to be operational. There was no evidence of electrical arcing in the switch.

The electric trim switches mounted on the right yoke returned to the neutral position when selected to the UP or DOWN position and released.

A functional check of the elevator trim drive components between the servo and Teleflex cable was performed. There was no evidence of drive discontinuity.

The elevator trim servo was examined by an approved maintenance and repair organisation. When tested, the mechanical clutch slipped initially at 80 inch pounds and subsequently at 50 inch pounds. An inspection of the rotor and stator plates of the clutch revealed uneven surfaces, the presence of moisture and inadequate lubrication. Wear marks on the clutch plates were indicative of limited slippage. There was no evidence of sustained slippage. There was also no evidence of any defects in the electric clutch or motor. The elevator trim servo functioned in accordance with approved test parameters, with the exception of the clutch breakout force.

At the time of the incident, the manufacturer specified mechanical clutch maintenance at 800-hour intervals. That requirement was included in the autopilot section of the technical publication. There were no logbook entries found that indicated that this maintenance had been performed within the specified period.

The trim adaptor box was examined by an approved maintenance and repair organisation. There was no evidence of any defects that could have affected the operation of the pitch trim servo.

The operator reported that after the ATSB examination, a detailed system inspection was performed by a Licensed Aircraft Maintenance Engineer (LAME) that did not reveal any additional damage or discrepancies to the system.

Operating procedures

The emergency procedures in the operator's *Operations Manual* and *Quick Reference Checklist* in the aircraft did not provide any information to assist a pilot with an electric trim or autopilot emergency situation. The *Pilot's Operating Handbook and CTA[8] Approved Airplane Flight Manual* (Flight Manual) carried in the aircraft did not contain any electric trim or autopilot items in the main emergency procedures, but did specify emergency actions in the autopilot and electric trim supplements.

Supplements number 5 and 10 of the aircraft's Flight Manual included emergency procedures applicable to the electric trim system. Both supplements stated that:

> If an undesired pitch trim command occurs (which can be detected by means of progressive increase of the control stick force to maintain the same flight path and simultaneous manual trim wheel rotation) proceed as follows:
>
> a. If the manual trim wheel is still rotating, stop it and hold it (or overpower it if required).
>
> b. Pull the elevator trim circuit breaker.
>
> c. Use manual trim wheel as required.

During the investigation, the aircraft manufacturer confirmed that in relation to an undesired pitch trim situation without apparent trim wheel movement:

> If an undesired pitch trim command occurs, regardless of trim wheel rotation, [the pilot should] pull the elevator trim circuit breaker and use manual trim wheel as required

The PIC reported that he was aware of the action to take if an undesired elevator trim occurred, but due to the high control force he was unable to release the control column to carry out the procedure. The copilot reported that when he reduced back pressure on the control column the aircraft descended. It was in desperation to rectify the situation that he eventually released the control column to apply maximum possible force to the trim wheel.

8 Centro Technico Aeroespacial (CTA) is the Brazilian airworthiness authority.

ANALYSIS

The full nose-down elevator trim position observed after takeoff was consistent with a runaway[9] elevator electric trim condition. Given that the control difficulty was noticed soon after takeoff, the trim runaway probably occurred during or shortly after take-off.

A runaway elevator electric trim can only occur as a result of either an autopilot or electric trim system malfunction. With the autopilot controller and servos previously removed from the aircraft, the investigation focused on the electric trim system.

The onsite inspection of the left and right yoke AP/TRIM switches confirmed that the right switches returned to the neutral position when operated and released. However, the left switches did not return to the neutral position when operated and released. Accordingly, it is possible that during the high workload phase of takeoff and initial climb, the left trim switches were moved to the nose down position, and being defective, the switch did not return to the neutral position.

The PIC stated that he did not activate the switch prior to the control difficulty. He also stated that he moved the switch to the nose up direction during the control difficulty. This did not change the elevator trim position. Based on that evidence, the investigation considered that an unidentified defect in the airframe electric trim wiring system was also a possible factor in this incident.

The electric trim circuit breaker did not trip at the time of the incident and therefore it was unlikely that the electric trim system had sustained an over current supply. Although there was no supporting evidence, the investigation could not dismiss the possibility of the signal (switch logic) wiring electrically contacting in such a way that it bypassed the switch and operated the servo in a nose down direction.

Given the sustained resistance to trim wheel movement from the full nose-down position, it is likely that the electric trim continued to operate in the nose-down direction while the pilots were experiencing control difficulties. Although the mechanical clutch was designed to slip once it reached a travel limit, the evidence of limited slippage indicated that the mechanical clutch breakout value was equal to, or higher than, the torque of the electric trim motor. If that was the case, the pilots were effectively trying to overcome trim servo motor torque.

Manual operation of the elevator trim was regained as the copilot was applying significant force to the trim wheel. As there was limited slippage evident in the mechanical clutch, it is likely that the recovery was coincident with the cessation of electric trim drive. With a switch-related trim runaway, cessation of the trim drive would result from the switch returning to neutral by the internal spring tension. In the case of a wiring related trim runaway, cessation of the electric trim drive would have been a result of wiring disengaging.

The pilots initially thought that the problem was elevator control related rather than elevator trim related. That was probably a result of the gradual nature of trim application, lack of aural cues, and the trim wheel movement being out of the pilots' normal field of view.

---

9 Undesired operation of a device when not commanded.

Given that the electric trim was probably driving when the crew were having control difficulties, pulling the electric trim servo circuit breaker would have deactivated the electric trim servo motor and should have allowed the pilots to regain manual trim control. However, the PIC did not pull the circuit breaker as specified in the manufacturer's procedures.

The pilots explained, that in this case, the electric trim circuit breaker could not be pulled as they were unable to release either yoke while maintaining control at minimum altitude. Individual circuit breakers were difficult to identify and this aircraft did not have a yoke-mounted disconnect switch. A yoke-mounted switch would have allowed the trim to be disconnected without releasing the controls.

The apparent failure of the mechanical clutch to slip while the elevator trim was at the full nose-down position was probably due to inadequate clutch lubrication. The investigation did not find any record of clutch lubrication that was required in accordance with the manufacturer's maintenance schedule.

In this incident, an uncommanded full nose-down elevator trim produced control forces that required the actions of two pilots to prevent an accident. The action of the PIC to reduce the aircraft's airspeed decreased the control force and enabled the pilots to arrest the descent. Given that this aircraft was certified for single pilot operation, it is probable that a single pilot in a similar situation would not have recovered control of the aircraft.

Although the PIC recalled the trim runaway procedure, this incident highlighted the importance of all pilots being able to recall and perform time-critical emergency procedures. Making those procedures memory items, placing them in the main emergency checklists and including them in pilot training would increase the likelihood of a pilot responding effectively in an emergency situation.

SAFETY ACTIONS

Aircraft manufacturer

As a result of this incident the manufacturer made the following changes to its aircraft technical publications:

- Revised the EMB110P2/145 Maintenance Planning Guide to add an additional requirement of a calendar time to the existing flying hours requirement of inspection/servicing of the elevator electric trim servo and clutch maintenance.
- Revised the EMB110P2/145 Maintenance Planning Guide to add an additional requirement of a calendar time for an operational check of the elevator trim tab control operation and a detailed inspection of the Yoke Pitch Trim switch.
- Revised the Aircraft Maintenance Manual to move the maintenance requirements of the Elevator Pitch Trim electric system from the auto-pilot section to the flight control section.

Aircraft operator

As a result of this incident the operator advised that it proposed to implement the following changes:

- All electric trim systems in company EMB110 aircraft will be removed / deactivated.
- An engineering inspection of the elevator flight control system has been made to ensure no damage to the system has occurred as a result of this incident[10].
- A single crew member (the pilot in command) will be responsible for the conduct of the Daily Inspection and the initial internal flight deck scans and interchanging of these roles is not permitted.
- Checklist Procedures have been changed to reflect an additional check of the elevator trim prior to take-off but after engine start.
- Both crew members will respond to safety of flight issues after the item is read as a challenge when conducting checklists.
- Induction training for company pilots will now include guidance material for actions of flight crew in the event of primary flight control jams and abnormal flight control issues that are not dealt with by manufacturer's checklists.

10 The inspection has been certified by a Licensed Aircraft Maintenance Engineer and details entered into the aircraft log book.