



Australian Government

Australian Transport Safety Bureau



ATSB TRANSPORT SAFETY REPORT
Occurrence Investigation Report AO-2007-070
Final

Leading edge device failure
Norfolk Island
29 December 2007
VH-OBN, Boeing 737-229



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Abstract

On 29 December 2007, a Boeing Company 737-229 aircraft, registered VH-OBN, was being operated on a scheduled passenger service from Brisbane, Qld to Norfolk Island. At 0352 Coordinated Universal Time, the flight crew conducted a missed approach at Norfolk Island due to poor weather.

During the flap retraction, the flight crew felt a high frequency vibration through the airframe, while observing control yoke deflection to the left. Due to the vibration, the aircraft's autopilot system could not be engaged and controlled flight was manually maintained with difficulty. The flight crew elected to continue to the designated alternate airport at Nouméa, New Caledonia. During that diversion flight, the cabin crew prepared the passengers for a possible ditching.

An engineering inspection determined that the number-4 leading edge slat, inboard main track had failed. An examination of the failed track identified fatigue cracking that originated at the intersection of diverging machining marks at the fracture site. Further inspection of the number-4 slat found corrosion damage on the outboard auxiliary track, with the inboard auxiliary track adjacent to the failed main track having failed in overload at the slat attachment.

The investigation also identified a number of cabin safety issues during the diversion flight, and poor passenger handling after the subsequent landing at Nouméa.

As a result of this investigation, the aircraft operator advised the Australian Transport Safety Bureau of the implementation of a number of safety actions, including:

- the revision of flight crew flight planning - alternate fuel load provisions
- the revision of cabin crew equipment and procedures
- a review of company emergency response procedures.

At the time of finalising this report, the original operator's air operator's certificate had been taken over by a different organisation. The new organisation does not use the aircraft type involved in this occurrence. It has, however, reviewed its operations to ensure that hazards identified in this investigation are mitigated appropriately.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The Bureau is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

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.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not a function of the ATSB to apportion blame or determine liability. However, an investigation report must include factual material of sufficient weight to support the analysis and findings. 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.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

When safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation, the person, organisation or agency must provide a written response within 90 days. That response must indicate whether the person, organisation or agency accepts the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

TERMINOLOGY USED IN THIS REPORT

Occurrence: accident or incident.

Safety factor: an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include the occurrence events (e.g. engine failure, signal passed at danger, grounding), individual actions (e.g. errors and violations), local conditions, risk controls and organisational influences.

Contributing safety factor: a safety factor that, if it had not occurred or existed at the relevant time, then either: (a) the occurrence would probably not have occurred; or (b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or (c) another contributing safety factor would probably not have occurred or existed.

Other safety factor: a safety factor identified during an occurrence investigation which did not meet the definition of contributing safety factor but was still considered to be important to communicate in an investigation report.

Other key finding: any finding, other than that associated with safety factors, considered important to include in an investigation report. Such findings may resolve ambiguity or controversy, describe possible scenarios or safety factors when firm safety factor findings were not able to be made, or note events or conditions which ‘saved the day’ or played an important role in reducing the risk associated with an occurrence.

Safety issue: a safety factor that (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a specific point in time.

Safety issues can broadly be classified in terms of their level of risk as follows:

Critical safety issue: associated with an intolerable level of risk.

Significant safety issue: associated with a risk level regarded as acceptable only if it is kept as low as reasonably practicable.

Minor safety issue: associated with a broadly acceptable level of risk.

FACTUAL INFORMATION

History of the flight

On 29 December 2007, a Boeing Company 737-229 aircraft, registered VH-OBN, was being operated on a scheduled passenger service from Brisbane, Qld to Norfolk Island. At 0352 Coordinated Universal Time¹, the flight crew briefed the cabin crew that they may not be able to land at Norfolk Island due to poor weather.

The flight crew later reported that the Norfolk Island aerodrome became visual at 2 NM (4 km), with virtually the full length of the runway visible: however, excessive manoeuvring would have been required in order to land from the straight-in approach. Consequently, a visual circling manoeuvre over the ocean was made. As the aircraft was turned through the base leg and onto final approach, the visibility deteriorated and a missed approach procedure was conducted.

The flight crew reported that, following the missed approach, and while retracting the flaps, they felt a high frequency vibration through the airframe, and observed a control yoke deflection to the left. That deflection increased to about 40°, when a constant buffeting and uncommanded roll and yaw occurred. Controlled flight was maintained manually by the crew with difficulty, and the aircraft's autopilot system could not be engaged due to the vibration. There were no other cockpit indications to assist the crew to identify the problem. The cabin crew reported that they also noticed that the aircraft was shaking and vibrating, similar to the effect of flying through cloud and turbulence.

With no flight deck cues to explain the control difficulty, the pilot in command (PIC) requested the cabin manager (CM) to visually check through the cabin windows for any anomalies. At that time, a passenger reported a protruding slat to the CM. The CM visually inspected the right wing with the passenger and reported to the PIC that the leading edge slat on the right wing (later identified as the number-4 slat) was at an unusual angle to the airflow. The CM also took a photograph of the protruding leading edge slat with a mobile phone and showed it to the flight crew.

The flight crew reported that, after levelling the aircraft at flight level (FL)² 237, they considered the possible effect of the additional drag from the number-4 slat on the aircraft's fuel usage, and of the potential controllability problems. It was concluded that relying on the fixed fuel reserve of 1,300 kg to take account of any additional drag entailed the risk of there being insufficient fuel to reach the designated alternate airport at Nouméa, New Caledonia. In response, the captain directed the copilot to broadcast a PAN³ call.

1 The 24-hour clock is used in this report to describe the time of day, Coordinated Universal Time (UTC), as particular events occurred.

2 Cruising level above 10,000 ft using a pressure reference datum of 1013.2 hPa, expressed in hundreds of feet.

3 Radio code indicating uncertainty or alert, general broadcast to widest area but not yet at the level of a MAYDAY.

In the absence of a non-normal checklist for this situation, and considering the possible adverse effect on aircraft controllability, the crew decided to cycle the flaps from zero to flap (unit)⁴ 1, then to flap 5⁵ and back to flap 1. That action reduced the vibration slightly. When flap zero was selected, the number-4 slat retracted marginally, improving the aircraft's controllability and climb performance. The autopilot was engaged and the aircraft was climbed to FL240.

Due to the controllability problems, the PIC advised the cabin crew to prepare the cabin for a possible ditching.

Preparation of the cabin for ditching

The available cabin staff consisted of three operating cabin crew members, with two additional positioning cabin crew also onboard who were in transit to Norfolk Island. During the preparation of the cabin for a possible ditching, the CM's duties were taken over by one of the positioning cabin crew members, who was a more experienced cabin manager and held senior cabin crew training roles with the operator. The remaining positioning cabin crew member provided additional assistance and was placed at an over-wing exit as an 'able bodied passenger' (ABP).⁶

The replacement CM informed the flight crew of the change and was advised there was no time for a NITS⁷ emergency briefing from the flight crew. That briefing normally entailed the CM proceeding to the flight deck to be briefed by the PIC on the nature of the emergency and on the PIC's intentions. The cabin crew retrieved their emergency procedure cards (EPC)⁸ and lifejackets. They also disarmed and cross-checked the forward and rear exits,⁹ and secured the toilets and galleys as instructed by the CM.

The CM gathered the cabin crew in the forward galley for a short briefing about preparing the passengers and cabin for a ditching. The passenger who initially identified the protruding slat entered the galley, identified herself as a trained cabin crew member for another operator, and asked to be involved in the crew briefing. The CM designated that passenger as an ABP and placed her at an over-wing exit.

When the cabin crew attempted to review the EPC booklets, two of the four booklets fell apart, with the pages scattering on the floor. All of the cabin crew

4 Boeing aircraft flap position reference points were expressed in flap units.

5 The leading edge devices in the 737-239 operated between the flap 1 and 5 unit selection range.

6 The operator's procedures called for ABPs to be identified to perform cabin crew duties in the event of cabin crew incapacitation during an emergency. Criteria to be used when selecting ABPs included being; English speaking, willing to assist, positioning airline crew or staff, military personnel, ship's crew, oil rig crew or similar, persons travelling alone, physically able, and calm nature.

7 NITS – Acronym encompassing the nature of the emergency, the intentions of the flight crew, the time available before landing, and the need for a special instructions brief.

8 Emergency procedures card. A 26-page emergency procedures quick reference booklet.

9 When an aircraft ditches, the exits need to be opened without the evacuation slides inflating as passengers step directly into life-rafts from the cabin floor. 'Disarming' the exits disables the inflation of the evacuation slides.

reported difficulty finding the relevant pages in the booklets, before abandoning them and relying on their memory of the emergency procedures.

The cabin crew then conducted an emergency ditching briefing of the passengers. Passengers were instructed to remove loose items of clothing, high-heeled shoes and jewellery, and to fit their lifejackets. Passengers were then asked to ensure their seat belts were fastened before the brace position was explained and practiced.

Following the ditching briefing, all cabin crew moved through the cabin assisting passengers with their lifejackets, securing loose items, and identifying infants that needed to be fitted with infant lifejackets.¹⁰ The CM also identified the passengers in row one as ABPs and briefed them on their role in opening the emergency exits in the case of ditching, should the crew in the forward crew seats be incapacitated. Passengers designated as ABPs at the aircraft's other exit rows were not briefed at that time.

The CM was advised by the flight crew that it would be an hour before reaching Nouméa, and that the passengers should be kept in their lifejackets. A short time later, the PIC made an announcement, informing passengers that he had 'now regained control of the aircraft' and would be diverting to Nouméa.

The CM directed the other cabin crew to re-arm the doors and to brief the ABPs on the operation of the aircraft's exits and slides.

Before the descent into Nouméa, the flight crew briefed the CM that the landing may be harder and faster than normal, and that lifejackets should be kept on and the doors armed. The flight crew carried out a controllability check at about 7,000 ft above mean sea level (AMSL) on descent and, during the approach, the flaps were selected in stages to flap 15 as per the operator's LEADING EDGE FLAPS TRANSIT non-normal checklist. A speed margin of 10 kts was added to the published flap 15 landing speed by the flight crew in case the disrupted airflow over the right wing increased the aircraft's stall speed above the published figure. Although considered, the option of a flapless landing with a minimum landing speed of 176 kts (or 40 kts in excess of a flaps 15 landing) was judged by the flight crew to hold more risk and was discounted. No control difficulties were experienced during the approach and the landing was uneventful.

Flight planning

Prior to departure from Brisbane, the flight crew accessed the National Aeronautical Information Processing System (NAIPS) at 2339 UTC for the latest weather forecasts and reports. The flight crew reported that they used the Aerodrome Forecast (TAF) for Norfolk Island for their decision making. The TAF showed good visibility and scattered cloud¹¹ at 800 ft, but with TEMPO (temporary)¹² reductions in visibility to 3,000 m in rain and broken cloud at 800 ft.

10 The operator's operations manual stated that infant life jackets were to be fitted to '...all persons under 16 kg [that were] aged up to approximately three years'.

11 Cloud amounts are reported in oktas. An okta is a unit of sky area equal to one-eighth of total sky visible to the celestial horizon. Few = 1 to 2 oktas, scattered = 3 to 4 oktas, broken = 5 to 7 oktas and overcast = 8 oktas.

The operational effect of the TEMPO reduction in visibility was to require the carriage of 60 minutes of holding fuel or, alternately, the nomination of an alternate airport¹³. The flight crew's fuel planning included sufficient to take account of the TEMPO reduction in visibility, meaning that the nomination of an alternate airport was not required. In any case, the flight was commenced with an excess of 2,362 kg of fuel on board.

Injuries to persons

Although no physical injuries were reported by any of the passengers or crew as a direct result of the accident¹⁴, a number of passengers reported psychological issues and resultant physical problems following the flight. That included one passenger who suffered two seizures after disembarkation at Nouméa (Appendix A: Summary of passenger survey).

Damage to aircraft

Leading edge flap/slat system

The leading edge flap/slat system formed part of the aircraft's high-lift devices, which changed the camber of the wing to increase lift during low-speed flight. Three leading-edge slats were installed on each wing outboard of the respective engine, with two leading edge flaps installed inboard of the engine on each wing. The slats were numbered 1 through 6 from left to right. The number-4 slat was directly outboard of the right engine (Figure 1). Each slat was attached to the wing by two main tracks and two auxiliary tracks (Figure 2).

-
- 12 TEMPO. Used to indicate a temporary change in the previously-given mean prevailing conditions that was expected to last for a period of between 30 and 60 minutes in each instance. *Aeronautical Information Publication (AIP) Australia, GEN3 Aviation Forecasts*.
- 13 In the case of forecast TEMPO deteriorations, the provision of an alternate was not required if sufficient additional fuel was carried to allow the aircraft to hold for 60 minutes. *AIP ENR 73, Alternate Aerodromes*.
- 14 An accident, as defined under the *Transport Safety Investigation Act 2003*, includes where a transport vehicle is seriously damaged. Serious damage is defined in the *Transport Safety Investigation Regulations 2003* includes damage that significantly affects the structural integrity, performance or operational characteristics of the transport vehicle.

Figure 1: Leading edge flap/slat system

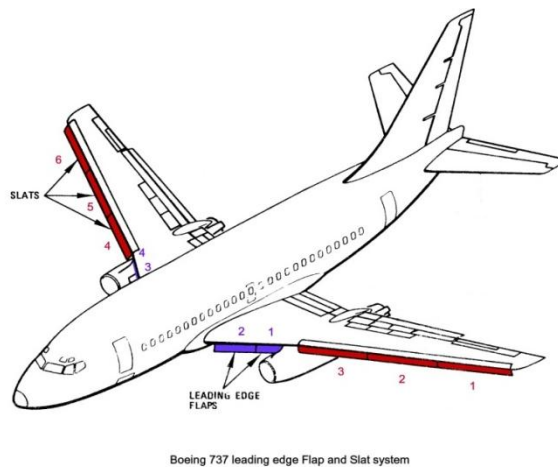
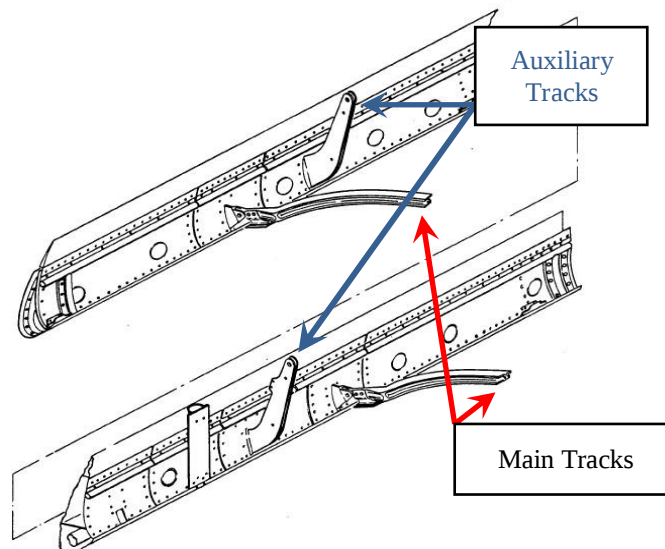


Figure 2: Leading edge slat construction



Source: Boeing overhaul manual 57-56-21.

Number-4 slat examination

Main tracks

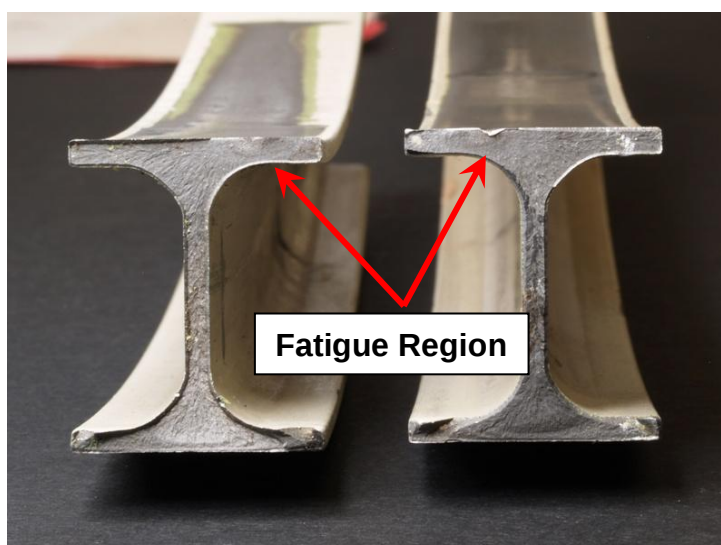
An examination of the number-4 leading edge slat determined that the inboard main track had failed. The slat and fractured track were removed from the aircraft and sent to the Australian Transport Safety Bureau (ATSB) for examination (Appendix B).

The inboard main track assembly had fractured close to the mid-span position. Areas of heavy wear on the rolling surfaces consistent with the location of the main track rollers were observed. The most significant wear was associated with the upper track rollers when the slat was in the fully-retracted position. The outboard main track showed similar wear patterns, but was otherwise undamaged.

A visual examination of the fracture surfaces showed evidence of a fatigue crack that extended across a substantial portion of the lower flange¹⁵ (Figure 3). A series of machining marks were also observed on the upper and lower track surface. Those marks were considered to be associated with the manufacture of the track. Optical and scanning electron microscopy revealed that the fatigue crack origin was adjacent to the area where two of these machining marks intersected.

Hardness testing was also conducted, which revealed that the hardness of the main track was at the upper end or possibly marginally higher than the allowable range. The hardness of the outboard main track was found to be similar to that of the inboard track.

Figure 3: Inverted mating halves of the Slat Track fracture



The inboard and outboard main tracks were examined for additional cracks using magnetic particle inspection; however, no indication of cracking was observed. The aircraft manufacturer reported that this was the only known failure of a slat track in this manner for this aircraft model.

Auxiliary tracks

The auxiliary tracks were designed to be securely fixed at two points within the slat, but were found to have considerable vertical movement, indicative of failure at the attachment closest to the upper surface of the slat.

The inboard auxiliary track was found to have failed in ductile overload through one of its bolt holes. That bolt hole had also elongated in the direction of the liberated section. The material around the bolt hole was scored, consistent with the movement of the track in the support (Figure 4).

¹⁵ The horizontal portion or portions of steel shapes, such as the top and bottom flange of an I-shaped-beam.

Figure 4: Inboard auxiliary track showing failed bolt hole (highlighted)



One of the support ribs on the outboard auxiliary track had failed as a result of extensive exfoliation corrosion¹⁶. The corrosion was centred adjacent to the cadmium-plated steel bolt that attached the track to the slat ribs. The remaining rib failed through the bolt hole, which had fractured up to the rib flange. The flanges on both ribs had buckled outwards and were fractured along their length (Figure 5).

Figure 5: Outboard auxiliary track attachment corrosion



Personnel information

Flight crew

Pilot in command

The PIC had been employed by the operator for 12 months at the time of the accident. The PIC's command qualifications and experience are at Table 1.

¹⁶ Exfoliation corrosion is typically associated with high strength aluminium alloys with a markedly directional grain structure. Corrosion product builds up along grain boundaries and layers of uncorroded metal are split apart, resulting in a layered or leafed effect.

Table 1: Pilot in command qualifications and experience

Type of licence	Air Transport Pilot (Aeroplane) Licence
Medical Certificate	Class 1
Flying experience (total hours)	18,000
Hours on type	700
Most recent simulator training	Command Instrument Rating (CIR) renewal on 28 Jan 2007, valid to 31 Jan 2008

Copilot

The copilot had been employed by the operator for 14 months prior to the accident. The copilot's qualifications and experience are at Table 2.

Table 2: Copilot qualifications and experience

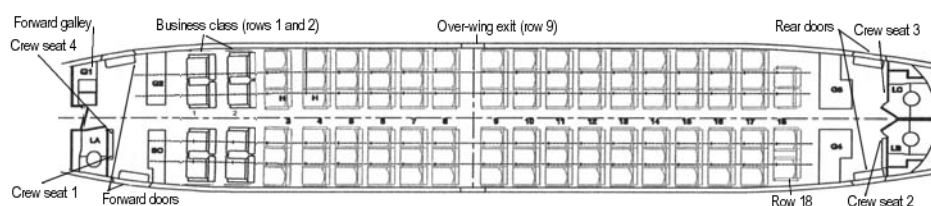
Type of licence	Air Transport Pilot (Aeroplane) Licence
Medical Certificate	Class 1
Flying experience (total hours)	10,500
Hours on type	700
Most recent simulator training	CIR renewal on 10 Dec 2007, valid to 31 Dec 2008

Both pilots were appropriately trained and licensed and reported that they had no issues with their workload, health or fatigue.

Cabin crew

Although two of the five cabin crew members were rostered to travel as positioning crew in passenger seats, all five cabin crew were wearing their uniform and all participated as operating crew following the missed approach at Norfolk Island and during the diversion to Nouméa.

The original CM and the replacement CM were positioned in the forward crew seats. Of the remaining cabin crew, two were positioned in the rear crew seats and one sat in an over-wing passenger seat (Figure 6).

Figure 6: Cabin configuration of VH-OBN

The original CM had been employed as cabin crew with the operator for 16 months, and was promoted to the CM position 2 weeks before the accident. The replacement CM had been employed by the operator for about a year at the time of the accident, held a senior position, and was an emergency procedures instructor. She had over 14 years experience as cabin crew and had previously held similar positions with other operators and at a cabin crew training institution.

Aircraft information

The aircraft, a Boeing Company 737-229, serial number 21137, was manufactured in the US in 1975. It was registered in Australia on 16 February 2006 and commenced operations with the operator on 27 April 2006.

The aircraft was maintained in accordance with Civil Aviation Safety Authority (CASA) requirements. At the time of the accident, the aircraft had accumulated 64,748 hrs total time in service (TTIS) and 43,467 landings. The number-4 leading edge slat was fitted to the aircraft on 19 May 1981, at 13,032 hrs TTIS.

On 18 September 2007, at 64,253 hours TTIS, or 495 hours prior to the accident, a major inspection that included a detailed visual examination of the leading edge slats was completed by the operator. There were no reports of any damage or defects to the leading edge slats being identified during that inspection. The slat had 51,716 hrs TTIS at the time of failure.

Meteorological information

The ATSB obtained copies of meteorological data from the Australian Bureau of Meteorology. A review of that data indicated that, at the time of the accident, the forecast weather at Norfolk Island included strong and gusty winds, moderate low-level turbulence, low cloud, reduced visibility and rain.

The original forecast was amended several times throughout the flight from Brisbane to Norfolk Island, indicating progressively worsening weather conditions in terms of; increased wind strength, lowering and increasing cloud cover, and reduced visibility. The low-level turbulence was also expected to increase in intensity to severe, and an Aerodrome Warning was current for Norfolk Island, forecasting strong and gusty winds up to 41 kts.

The flight crew were advised by air traffic control of the deteriorating weather when en route; however, the PIC advised that he was not advised of, and therefore unaware of the Aerodrome Warning affecting his arrival.

The actual weather conditions during the aircraft's approach included gusty winds of between 20 and 35 kts, visibility reducing to 3,000 m in rain and low cloud at 500 ft.

Communications

The flight crew reported that they used very high frequency (VHF) radio communications after departing Brisbane, and they changed to using high frequency (HF)¹⁷ radio communication while en route. At about 163° east longitude, the air traffic control responsibility changed from Brisbane Centre to Auckland Centre, with communications remaining on HF radio.

¹⁷ HF was the principal means of beyond-line-of-sight communication. HF by its nature tends to suffer from poor signal quality due to environmental and seasonal changes.

Approaching Norfolk Island, the flight crew communicated with the Norfolk Island Unicom¹⁸ operator (Norfolk Unicom) on VHF frequency 118.1 MHz¹⁹.

During the missed approach and subsequent diversion to Nouméa, communications were described by the flight crew as difficult, noting the signal strength as 1 on a scale of 1 to 5. In addition, they reported that, due to the limitations of HF communications, they had difficulty contacting Brisbane Centre, Auckland Centre, or Nadi in Fiji. The PAN call that was broadcast due to the controllability issue and the uncertainty regarding the fuel status was relayed to air traffic services (ATS) through the Norfolk Unicom operator.

Aerodrome information

Norfolk Island aerodrome was a certified aerodrome that consisted of a 1,950 m long bitumen main runway that was oriented east-south-east/west-north-west (runway 11/29), and a shorter runway that was oriented north-east/south-west (runway 04/22), which was only available for aircraft of less than 5,700 kg. The aerodrome elevation was 371 ft. There was high terrain to the immediate north of the aerodrome (1,067 ft) and the 25 NM (46 km) minimum sector altitude (MSA)²⁰ was 2,200 ft.

Runway 11/29 was suitable for the operation of the Boeing 737-200 and, due to the strong easterly wind, the pilots chose to make a non-precision VOR²¹ approach to runway 11.

Recorded information

The aircraft was fitted with a tape-based Sundstrand digital flight data recorder (DFDR) part number 981-6009-011, and a tape-based Fairchild A100 cockpit voice recorder (CVR) part number 93-A100-30. The DFDR contained the last 25 hours of flight data, and the CVR contained the last 30 minutes of cockpit audio. The DFDR and CVR were downloaded by the ATSB. Examination of the DFDR data quantified the flight crew reports (Appendixes C and D).

Departure from Brisbane

During the takeoff from Brisbane, the trailing edge flaps and leading edge slats were extended to flap 5 and mid-extension respectively. Passing 3,600ft in the climb, the slats and flaps were retracted. No abnormal indications or behaviour were evident in the slat parameters at that time.

18 'Unicom' was a local non-Air Traffic Services communications service that provided additional information to pilots at a non-towered aerodrome.

19 Also used as the Common Traffic Advisory Frequency (CTAF).

20 Minimum Sector Altitude – the lowest altitude that provided a minimum clearance of 1,000 ft above all objects located within 25 NM or 10 NM (19 km) radius of a radio aid or, if an airfield does not have a radio aid, from the Aerodrome Reference Point.

21 VOR refers to VHF omni-directional radio range. A suitably-equipped aircraft's bearing from a VOR could be interpreted by a pilot on that aircraft's panel instrumentation.

Approach to Norfolk Island

During the approach to Norfolk Island, the leading edge slats were extended with the aircraft maintaining about 3,000 ft. The extension commenced at an airspeed of 201 kts, 4 seconds after the trailing edge flap deployment commenced. Full slats extension was recorded 233 seconds (or 3 minutes 53 seconds) later at 169 kts, prior to the aircraft commencing the final approach. The DFDR data indicated that all leading edge slats extended normally through mid-extension to being fully-extended. The trailing edge flaps were extended to the flap 30 setting.

Missed approach

The missed approach was commenced with a flap 30 setting from about 550 ft and an airspeed of 146 kts. Ten seconds later, with the aircraft climbing through 631 ft at 143 kts, the retraction of the trailing edge flaps was commenced. Seventy seconds later, while climbing through 2,940 ft at 154 kts, the slats began transition from the fully-extended position to the mid-extension position. The DFDR data indicated that all of the slats, except the number-4 leading edge slat, retracted normally. The number-4 leading edge slat remained 'in transit' for 63 seconds, while the other slats were at the mid-extended position.

At an altitude of 4,505 ft and airspeed of 187 kts, the numbers 1, 2, 3, 5 and 6 leading edge slats commenced transition to the fully-retracted position. The indication of the number-4 leading edge slat 'in transit' ceased. The DFDR data confirmed that during the subsequent climb, left control yoke application increased steadily to about 40° and was erratic, with aircraft roll recorded at $\pm 15^\circ$.

The trailing edge flaps were activated twice (initially to the flap 5 and then to the flap 1 setting) during the climb between about 21,000 ft and 23,000 ft. Subsequent leading edge slat movement to the mid-extension position was normal, except for the number-4 leading edge slat, which remained in the 'in transit' position. Control yoke deflection then reduced to a normal level. All of the flaps and slats were then fully retracted and the aircraft was levelled at 24,000 ft. Once the aircraft was established in the cruise, the left control yoke application became less erratic, reducing to 20° deflection with the aircraft's roll stabilising. The autopilot was then engaged.

The flaps were later deployed at about 7,300 ft during the descent into Nouméa. That resulted in an 'in transit' number-4 leading edge slat indication. The control yoke deflection remained stable during the descent.

Animation of the missed approach

An animation of the missed approach and subsequent leading edge and flap extension and retraction during the climb was prepared using the DFDR data. The animation is available on the ATSB website at www.atsb.gov.au

Cockpit voice recorder

The available CVR recording was of on-ground maintenance communications that took place more than 30 minutes after the event. That information was not relevant to the investigation.

Survival aspects

Cabin crew procedures

The cabin crew's procedures were outlined in the operator's Operations Manual Part A – Cabin Safety.²²

Section 4.3.1 (Authority) of the manual, detailed the procedure for flight crew to alert cabin crew in the case of an emergency, and how they should be briefed. That brief included the PIC making a public address (PA) announcement to the cabin crew, requiring the cabin manager (CM) to proceed to the flight deck and the remaining cabin crew to discreetly proceed to their designated alert stations for briefing. On arrival at the flight deck, the CM was to be given a NITS briefing by the PIC.

The PIC advised that during this occurrence, there was insufficient time for the PIC to provide the CM with the NITS emergency briefing; however, the PIC confirmed that the cabin should be prepared for a ditching.

A copy of the aircraft-specific emergency procedures card (EPC) booklet²³ was available at each of the four cabin crew positions, and replicated the 'Emergency Evacuation Drill and Cabin Preparation - Life-rafts when carried' procedures from the operations manual. There were specific procedures for the distribution of infant lifejackets, and for the fitment of adult lifejackets to older children.

The cabin crew pre-flight check for the EPC documented in Section 3.17 of the operations manual was to 'check cards are under your seat' and 'not damaged'. The cabin crew reported that the pre-flight checks did not entail the removal of the booklet from its stowage. The cabin crew stated that they experienced difficulty locating the relevant EPC pages as they prepared for the ditching. That difficulty was felt by the cabin crew to have resulted from the need to search the 26-page booklet, and from two of the booklets falling apart onto the cabin floor when accessed.²⁴ In response, the cabin crew reverted to completing the relevant emergency preparations by memory.

Section 4.22.5 of the operations manual contained the announcement to be read out during the passenger briefing for an expected ditching. The CM reported making this announcement word-for-word from the EPC booklet. An examination of the responses to the passenger survey confirmed that all relevant topics were covered in this case (Appendix A).

Before landing in Nouméa, the replacement and original CMs completed the cabin secure check; a procedure that was normally designated to the other cabin crew. As a result, the other cabin crew were unaware that the check had been completed.

²² Issue 2, released 1 February 2007.

²³ Issue 1, Revision 2, dated 1 January 2007.

²⁴ It was reported that an EPC booklet on another aircraft had fallen apart, as had the EPC booklet that was used in emergency procedures training.

Able bodied passengers

Section 4.9 of the operations manual detailed the requirements, locations and procedures that were able to be delegated to ABPs during an emergency. That included the identification and briefing of ABPs in the over-wing exit row seats prior to take-off. Additional ABPs were to be identified in the case of an emergency.

The rear exits were designated as not to be used in a ditching, and the operator's procedures required that the ABPs in the rear cabin were to be briefed to assist with removing and carrying the life-rafts to the over-wing exits.

The replacement CM reported identifying and briefing the ABPs in row one on the operation of the forward door soon after the passenger ditching announcement was completed. However, the other cabin crew reported that, as the aircraft vibration had stopped by the time the passenger ditching briefing had finished, they were told by the original CM not to identify or brief ABPs at that time. As a result, only the ABPs in row one were briefed at this time.

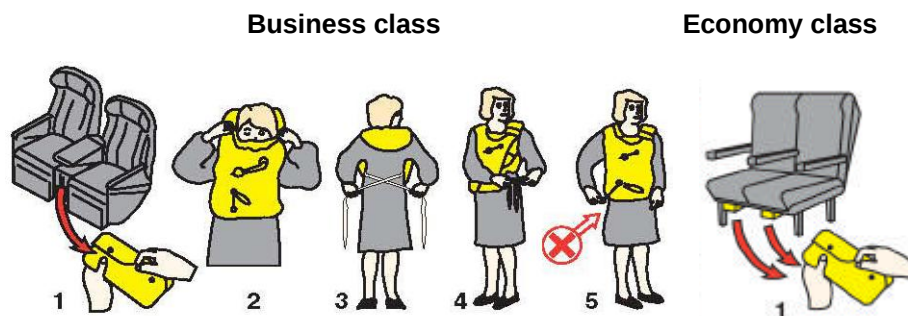
At the top of the descent into Nouméa, the ABPs were briefed on their responsibilities in the case of cabin crew incapacitation should an emergency occur during the landing at Nouméa. The replacement CM re-briefed the ABPs in row one, while the original CM and one of the cabin crew briefed the passengers in the rear cabin. Another cabin crew member briefed the three passengers in the right over-wing exit row. The fifth cabin crew member, who was sitting at the left over-wing exit, briefed the two other passengers in that row. As the instruction to re-arm doors was given during the ABP briefings, the re-arming and cross-checking of the rear doors was conducted by non-assigned cabin crew members, which led to some confusion as to whether these tasks had been carried out.

The ABP passenger who had initially identified the protruding slat, and was seated in the right over-wing exit row (row nine), described a different emergency exit opening technique to the adjacent passengers after their briefing by the cabin crew. That led to confusion among those passengers and required a re-brief of the exit opening instructions by the cabin crew.

Lifejackets

The cabin crew reported that a number of passengers found it difficult to locate their lifejackets under their seat or armrest, and that some passengers in business class (rows one and two) needed assistance locating them. It was noted that in business class, the lifejackets were at floor level under the armrest, which may have contributed to them being difficult to find (Figure 7).

Figure 7: Lifejacket instructions from the business class passenger safety card (left) and step 1 from the economy class safety card (right)



It was also reported that some passengers were surprised that the lifejackets were wrapped in a container when they found them, and that may have also contributed to some passengers finding it difficult to locate them.

There were a number of passengers that put on their lifejackets incorrectly, but that were subsequently corrected by the cabin crew. The most common problems were putting them on backwards, or tying the cord over the top of the jackets instead of under them (see Figure 7, business class diagram number 4). Tying the cord over the top of a jacket would restrict or modify its inflation.

Chapter 3 of the operations manual, 'Safety Equipment – General' stated that an infant lifejacket was required for 'all persons under 16 kg, aged up to approximately 3 years'. All children and persons over 16 kg were required to wear an adult lifejacket. The cabin crew reported that infant lifejackets were distributed to children who met these criteria.

Although a passenger reported that she had to ask a cabin crew member for an infant lifejacket, cabin crew reported that the request occurred as the crew were moving through the cabin assessing which passengers required an infant lifejacket.

Public address system

It was reported by the cabin crew and some passengers, that the public address (PA) announcement by the PIC about the diversion to Nouméa could not be heard in the rear and over-wing sections of the aircraft.

The operator's normal procedures required the PA system to be tested before the first flight of the day. It was reported that the cabin crew did not usually comment on the audibility of these test announcements, just that they were heard. However, cabin crew reported difficulty hearing PAs in the rear section of the aircraft on a number of previous flights, and on several of the operator's other aircraft.

A subsequent review of the aircraft's maintenance records revealed that the PA system was checked on 17 December 2007 in accordance with the manufacturer's maintenance manual requirements and was found to be serviceable.

During the event, the cabin crew and passengers reported a very loud 'siren-like' sound within the cabin. The PIC advised that the sound was the result of the displaced position of the number-4 slat in the air flow.

Tests and research

The ATSB conducted a survey of passengers about their experiences on the flight. Seventy five surveys were sent to the passengers, covering all of the adult passengers. Of those, 59 responses were received. A summary of the survey is attached at Appendix A. The main findings from the survey included:

- Sixty one per cent of respondents indicated that they were confident they would know what to do if the aircraft was ditched following the briefing from the crew.
- Most respondents indicated that they knew they could use the over-wing exits (83%), with about half of the respondents also indicating they could use the front doors (56%). Most respondents indicated that they could not use the rear doors (83%).
- The majority of respondents did not know which direction they should have alighted from the wing (68%). Only 8% indicated they should exit in the forward direction as indicated on the passenger safety information cards in the case of a ditching.
- Ten respondents indicated that they were sitting in exit rows and all reported that they received a briefing from a cabin crew member about the operation of an exit door. Nine of those respondents indicated that they felt confident to conduct their assigned actions, while the tenth reported swapping seats with another passenger to not have exit row responsibilities.
- Just over half of the respondents (54%) indicated that they easily located their lifejacket, while the remainder indicated they needed some searching.
- Most respondents (79%) indicated that they fitted their jacket correctly without assistance, but 10% indicated their jacket needed to be adjusted by a cabin crew member.
- The majority of respondents (63%) thought that they were adequately informed about the diversion to Nouméa by the cabin manager.
- One third of the respondents who were seated in the rear of the aircraft (rows 13 to 18) and near the wing (rows 7 to 12) indicated the PAs were not loud enough to hear, while all of the respondents who were sitting in the front rows (rows 1 to 6) indicated that the PAs were loud enough to hear (Figure 6).
- Five respondents to the survey indicated that they sustained an injury or other adverse effect during the flight, and another 25 indicated that they had suffered adverse effects after the flight. The majority of the reported adverse effects involved psychological reactions during and, in particular, after the flight.

Organisational and management information

Aircraft operator

The aircraft operator held a valid air operator's certificate (AOC) for regular passenger transport (RPT) operations within Australia and internationally, and for

conducting charter and aerial work operations, utilising its fleet of Boeing 737-229 aircraft. The operator also had an aircraft charter agreement with the Administration of Norfolk Island to operate RPT services between mainland Australia and Norfolk Island.

Post-incident response by the operator

When the flight and cabin crew disembarked the aircraft, four (two flight crew and two cabin crew) were immediately flown back to Australia so that they could operate on a flight the following morning. The four remaining cabin crew were initially told by the operator's crew scheduling personnel, to sign on for duty at 0400 local time the following morning, to operate as crew on the aircraft that was sent to retrieve the passengers from Nouméa. After further consultation with the CM, that decision was revoked and the crew were stood down to recover.

Due to operational requirements, the crew did not debrief together until 6 days after the accident. All of the cabin crew attended the debriefing; however, only one of the two flight crew was in attendance as the other was required to operate an aircraft.

It was reported that the operator did not have a corporate emergency response plan in place. There were no documented procedures to follow to coordinate activities involving the operator's responses to the crew, or passengers following an incident such as this occurrence. The CM informed management that counselling should be offered to all crew, including herself. As a result, all crew were contacted during the week after the incident and offered counselling.

When the cabin crew initially disembarked the aircraft and went through customs, they discovered that all the passengers were still waiting for information about what was going to happen, and that they needed water to drink. The crew had expected these activities to be looked after by another operator's local ground agent. In the apparent absence of the local agent, the CM arranged for the passengers to be taken to their hotels.

ANALYSIS

Introduction

During a scheduled flight from Brisbane, Qld to Norfolk Island, the flight crew initiated a missed approach procedure as they were not able to gain the required visual reference for landing. Following the go-around and during the retraction of the slats and flaps, the number-4 leading edge slat failed, resulting in a high frequency vibration through the airframe, and a left control yoke deflection.

As a result, the flight crew declared a PAN and diverted to Nouméa. Due to the increased aerodynamic drag, the flight crew were unsure if sufficient fuel was available to reach their destination, so the cabin crew were directed to prepare the cabin for a possible ditching.

The analysis of the circumstances of the leading edge device failure and subsequent diversion to Nouméa will focus on the failure mode of the number-4 leading edge slat and the flight and cabin crew actions to recover from the emergency.

Approach to Nouméa

The flight crew opted to use the LEADING EDGE FLAPS TRANSIT non-normal checklist. That procedure recommended a flaps 15 landing. Crew interviews and recorded data confirmed that the crew carried out a controllability check at about 7,000 ft on descent to Nouméa. The flight crew added a speed margin for the flap 15 approach and landing in case the disrupted airflow over the right wing increased the aircraft's stall speed above the published figure. A flapless landing option was considered, but rejected as it had its own risks, with a minimum landing speed of 176 kts or 40 kts in excess of a flaps 15 landing. Given the circumstances, these actions were considered to be appropriate to maximise the chance of a safe landing.

Weather

The flight departed Brisbane with fuel in excess of the minimum required by the forecast weather conditions for their arrival at Norfolk Island. However, updated weather reports while en route indicated deteriorating weather at Norfolk Island, and the likelihood of a diversion to Noumea. The excess fuel carried, plus the required 60 minutes of holding fuel due to the deteriorating weather, was more than enough for the diversion in normal circumstances. However, the fuel available for a diversion was eroded by the aerodynamic drag from the protruding slat, leading to the possibility of having to ditch the aircraft. Those circumstances could not have been predicted by the crew.

Ultimately, the troubleshooting by the crew resulted in the failed slat retracting further, improving aircraft controllability and performance. That resulted in the aircraft being able to land in Noumea with its fixed fuel reserve of 1,300 kg intact.

Crew actions

Flight crew appraisal of the event

In circumstances such as experienced in this occurrence, a flight crew can, as a result of their relative remoteness from the source of an event, have difficulty understanding the nature of an emergency. Reliance is placed on the available in-cockpit warning and caution indications, and on sound communication between the flight and cabin crews.

The recorded data showed that during the missed approach, the number-4 leading edge slat remained in the 'in transit' position, while the remaining slats were at their mid-range position. However, when the remaining slats reached full retraction, the number-4 slat 'in transit' indication extinguished. As a result, the flight crew would not have had any in-cockpit indication that the number-4 slat had not retracted fully.

The pilot in command (PIC) advised that, in this case, the photograph of the right wing leading edge that was taken by the cabin manager (CM) on a mobile phone was invaluable, and enhanced his understanding the event and assessment of the appropriate response.

Non-normal checklist selection

Non-normal checklists cannot cover every possible problem that might arise in flight. In this occurrence, the only checklist procedure of potential relevance to the problem experienced was the LEADING EDGE FLAPS TRANSIT procedure. Although the LEADING EDGE FLAPS TRANSIT light was not illuminated in the cockpit, visual observation confirmed that there was an asymmetric condition with the right wing leading edge slats.

Flap selection

Following the missed approach and after the aircraft was levelled at 23,700 ft above mean sea level, the flight crew cycled the flaps from zero to flap 1, then to flap 5 and back to flap 1. That action resulted in a slight reduction in the vibration through the airframe. The selection of flap zero soon after appeared to result in the number-4 slat retracting slightly, with an associated improvement in the aircraft's controllability and climb performance, and allowing the autopilot to be engaged.

The flight crew reported that, as there was no specific checklist or emergency procedure for the anomaly, the decision to cycle the flaps was based on their estimation that fuel consumption was becoming critical. Despite the knowledge that cycling the flaps may exacerbate the situation, the decision to reduce the drag on the aircraft by reducing flap reduced the risk of a ditching.

Leading edge slat failure

Number-4 leading edge slat main track

The inboard main slat track failed as a result of a fatigue crack that initiated and propagated on the lower rolling surface. Measurements taken of the track indicated that the failure occurred about 15 mm forward of the leading upper track roller,

with the slat in the fully-extended position. The failure occurred at a location considered to be the maximum load point when fully extended due to the generation of lift and upward forces acting on the slat in that position.

The orientation of the associated fatigue region along the machining marks indicated that the marks probably acted as a local stress concentrator. The fatigue initiation point was potentially also influenced by the pitting of the rolling surface. The machining marks were a normal product of the manufacturing process, and were also evident on the aircraft's other slat tracks that did not fail.

The investigation could not determine if the crack had originated prior to the last maintenance inspection. In any case, had the crack existed at that time, its detection would have been difficult, given the visual nature of the inspection. The aircraft manufacturer reported that, at the time of this occurrence, this was the only known failure of a slat track in this manner and advised that, given the age of the aircraft, there appeared to be no system-wide issue in relation to the maintenance of the slats.

The hardness of the steel in the main tracks was found to be at the upper end, or possibly marginally higher, than the allowable range. While the influence of the higher hardness on the initiation of the fatigue could not be determined; as a general rule, an increase in material hardness results in a decrease in toughness, which reduces the ability of a material to resist fracture.

Number-4 leading edge slat auxiliary tracks

The location of the exfoliation corrosion around the outboard auxiliary track bolt hole, indicated that the corrosion protection in and around that hole had broken down, leaving the region susceptible to corrosion damage. The corrosion in the auxiliary track rib had been present for a considerable period of time, but had not been identified in the previous detailed slat inspection, 495 hours prior to the incident. The investigation could not determine if the corrosion originated prior to the last maintenance inspection; however, its detection during that inspection was unlikely, as it was hidden behind a riveted panel.

The appearance of the fracture surface through the bolt hole in the support rib was consistent with a rapid, rather than a progressive overload fracture. There was no direct evidence to suggest that the outboard auxiliary track was not being fully supported by its rib at the time the inboard main track failed.

Similarly, the appearance of the inboard auxiliary track failure was consistent with a rapid overload fracture.

Therefore, the auxiliary track fractures probably occurred immediately after the failure of the main track, which would have resulted in a sudden and significant increase in loading on the auxiliary tracks. On that basis, the contribution of the corrosion to the rapid failure of the main track was discounted.

Survival factors

The cabin and passengers were prepared for an emergency ditching in a timely fashion by the crew. However, a number of safety issues were identified during the investigation as discussed in the following sections.

Briefing of passengers

Soon after the passenger ditching briefing, the row one passengers were briefed as able bodied passengers (ABPs) in support of the possible ditching. However, the remaining ABPs were not identified or briefed until the top of descent into Nouméa, and were only briefed for an emergency landing situation. While the failure to brief all of the ABPs on their ditching responsibilities early in the diversion ultimately did not result in a reduction in passenger safety, it would have provided less time to fully prepare the aircraft for ditching had that become necessary.

One ABP was assigned to the right over-wing exit early in the diversion after identifying herself as cabin crew from another operator. The briefing by that ABP to the other row nine ABPs of an inappropriate over-wing exit opening technique for this aircraft model meant that the row nine ABPs were unaware of the correct over-wing exit opening procedure until the aircraft was at the top of descent for Nouméa. That would have been problematic had the aircraft been ditched before that time.

Passengers in the rear of the cabin were required to assist cabin crew to carry the life-raft to the over-wing exit in the case of a ditching. However, no passengers were briefed for that task, meaning that the liferafts would have likely been unavailable after a ditching.

Cabin crew role confusion

Given that the replacement CM had many more years experience than the original CM, and several years of involvement in cabin crew emergency procedures and emergency training, the transfer of the CM role to the replacement CM was understandable. However, this resulted in some instances of cabin crew role confusion, which was exacerbated by the involvement of the positioning cabin crew.

The replacement CM understood that all of the ABPs were briefed at the time she briefed the row one passengers. However, a number of the other cabin crew reported that the original CM told them it was not necessary at that stage, so some ABPs were not identified or briefed until later.

The cabin crew in the forward cabin also conducted some of the rear-position crew duties; actions that were designed to maximise efficiency (such as utilising the original CM to co-brief ABPs). However, doing so led to further confusion amongst the cabin crew, especially during the re-arming of the rear door and during the cabin secure check before landing.

Public address system

The maintenance records showed that the aircraft's public address (PA) system had been recently checked and found serviceable. However, the results of the passenger survey and crew interviews suggested that the initial PA announcement by the PIC following the diversion was not heard by many of the passengers and crew in the over-wing and rear sections of the cabin.

Any reduction in the audibility of the PA system had the potential to increase risk in the case of an emergency. However, the cabin crew member who carried out the PA system pre-flight test did not identify any deficiencies in its operation. The

inaudibility of the PA in the over-wing and rear sections of the aircraft may have been the result of the loud ‘siren-like’ noise from the protruding number-4 slat in combination with the normal aircraft operating noises in older aircraft.

Post-occurrence operator actions

The operator’s crew scheduling personnel were unaware of any processes for dealing with crew following an accident or incident. This led to a number of flight and cabin crew initially being assigned to fly the next day, without any assurance that those crew were in a fit state to operate an aircraft safely. Management did follow up on the wellbeing of the crew in the days following the accident but this, and the debriefing that was provided 6 days later, appear to have only occurred as a result of advice from the crew themselves.

FINDINGS

From the evidence available, the following findings are made with respect to the leading edge device failure involving VH-OBN, Boeing 737-229 at Norfolk Island, on 29 Dec 2007 and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- The number-4 leading edge slat inboard main track failed due to a fatigue crack that initiated in the lower flange. The location of the crack was consistent with it originating during periods when the slat was fully extended, and therefore under maximum loading.
- The presence of machining marks and surface pitting on the rolling surface of the main track probably had some influence on the origin of the fatigue crack.

Other safety factors

- Exfoliation corrosion was present in one of the ribs supporting the outboard auxiliary track, resulting in failure of the support around the attaching bolt hole.
- Inadequate early identification of able bodied passengers (ABPs) in the over-wing and rear exits resulted in ABPs in those areas not being briefed about their operation of the emergency exits, or about the need for them to assist with the liferafts when the cabin was being prepared for ditching.
- The extent of the emergency procedures cards (EPC), and failure of two of the EPC cards' bindings rendered them difficult to use, and resulted in the affected cabin crew carrying out the emergency procedures by memory. *[Minor safety issue]*
- Cabin crew did not restrict their activities during the diversion to Nouméa to the procedures that were assigned to their operating positions. That led to confusion on whether tasks had been completed.
- The operator did not have a process in place to ensure that crew members were in a fit state to resume operations after such an event, or to assist the crew to recover from their experiences during an occurrence. *[Significant safety issue]*

Other key findings

- The aircraft manufacturer reported that, at the time of the occurrence, this was the only known failure of a slat track in this manner and that, given the age of the aircraft, there appeared to be no system-wide issue in relation to the maintenance of the slats.
- The investigation could not determine if the crack in the main inboard slat track originated prior to the last maintenance inspection; however, had the crack existed at that time, its detection would have been difficult as a result of the visual nature of the inspection.

- The investigation could not determine if the corrosion in the auxiliary slat track rib originated prior to the last maintenance inspection; however, its detection during that inspection was unlikely, as it was hidden behind a riveted panel.
- The provision to the flight crew of a mobile phone photograph of the protruding number-4 leading edge slat enhanced their understanding of the event and assessment of the appropriate response.

SAFETY ACTIONS

The safety issues identified during the investigation are listed in the Findings and Safety Actions sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

All of the responsible organisations for the safety issues identified during this investigation were given a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

Aircraft operator

Difficulty using the emergency procedures cards

Safety issue

The extent of the emergency procedures cards (EPC), and failure of two of the EPC's bindings rendered them difficult to use, and resulted in the affected cabin crew carrying out the emergency procedures by memory.

Action taken by the operator

The operator advised the ATSB that it had reviewed the construction of the EPC booklets, and that they have been replaced.

ATSB assessment of action

The ATSB is satisfied that the action taken by the aircraft operator adequately addresses the safety issue.

Crew resumption of operations

Safety issue

The operator did not have a process in place to ensure that crew members were in a fit state to resume operations after such an event, or to assist crew to recover from their experiences during an occurrence.

Action taken by the operator

The operator advised the ATSB that it intends to:

- review company procedures to ensure crew are handled appropriately after a serious incident; an Employee Assistance Program has been implemented as a result
- review the company emergency response procedures, which was ongoing at the time of writing this report
- ensure that the Operations Manual Part A – General 9.2.2 debriefing requirements are followed after an incident and/or unusual event.

ATSB assessment of action

The ATSB is satisfied that the action taken by the aircraft operator adequately addresses the safety issue.

Other safety action

In addition to the safety action by the aircraft operator in response to the identified safety issues, the aircraft operator has advised that, as a result of this occurrence, the following proactive safety actions have also been undertaken:

Review flight planning system to ensure divert to alternate fuel load will account for depressurised flight. Implemented

Review alternate methods for communications between aircraft and company. Satellite telephone is currently being trialled in one aircraft

Review CRM [crew resource management] training material to include the following topics:

Flight deck door procedures for improved communications in an emergency situation as per Operations Manual Part A – General

Remind cabin crew of their responsibilities in the nominated crew positions
– Include role play scenarios

At the time of finalising this report, the original operator's certificate had been taken over by a different organisation. The new organisation does not use the aircraft type involved in this occurrence. It has, however, reviewed its operations to ensure that hazards identified in this investigation are mitigated appropriately.

NOTE FOR WEBSITE REGARDING ANIMATIONS

Graphical and animated representation of flight data

Various representations of key parameters were prepared from the aircraft's downloaded flight data to assist in the analysis of the event.

Graphical representation of relevant recorded data

Selected recorded parameters over a 125-minute period containing the missed approach to Norfolk Island, subsequent control difficulties, and the approach and landing at Nouméa are represented graphically at Appendix D).

Animated representation of relevant recorded data

An animation of relevant portions of the flight was prepared using Insight Animation™ software and is part of this report. Files containing the animation in Insight View™ format (.isv) are available for download from the Australian Transport Safety Bureau (ATSB) website www.atsb.gov.au. This requires the installation of an Insight Viewer that can be downloaded from www.flightscape.com/products/view.php at no charge.

Animation download

The following files are available for download from the ATSB website:

- the takeoff at Brisbane [aairAO-2007-070_001.isv]
- the missed approach and climb from Norfolk Island [aairAO-2007-070_002.isv].

Instructions for the replay of those files are included in the discussion above.

APPENDIX A: SUMMARY OF PASSENGER SURVEY

This survey was completed by passengers about 2 months after the incident.

Of the 97 passengers, 16 were children. The children were not sent individual surveys; however, the survey contained a section for parents to complete in respect of their children's experiences. The ATSB could not obtain any contact details for a further six passengers, resulting in 75 surveys being distributed to adult passengers. Of those, 59 individual surveys were returned (a response rate of 79%). A number of the non-responding passengers had other family members who were also passengers, and so did respond to the survey.

Respondents' perception of the problem

Most respondents reported that they could feel severe vibrations and/or shuddering of the aircraft; with some initially thinking that the vibration was a result of severe turbulence. Some also reported that the aircraft felt unstable or was swinging from side to side. The vibrations were generally reported as commencing when the aircraft was climbing following the missed approach at Norfolk Island, after the engine power was increased. Many passengers on the right of the aircraft from the wing rearwards also reported hearing a 'siren-like' sound.

Passengers that were seated near the right wing reported that they could see the leading edge slat protruding into the airflow and 'flapping around'. Most passengers reported understanding that there was an aircraft malfunction, but some did not know there was an issue with the wing when they were preparing for the ditching. These passengers became aware of the problem with the wing when the pilot in command (PIC) made an announcement during the diversion.

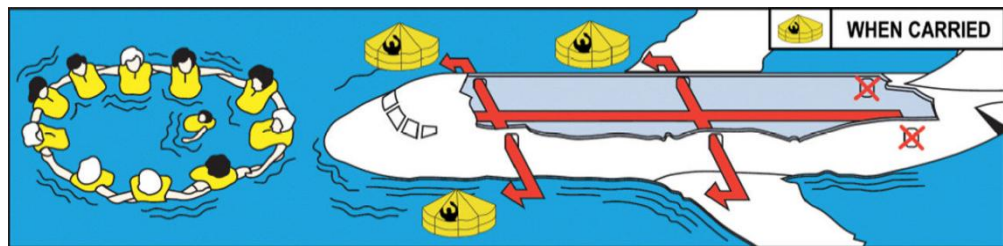
Preparation for the possible ditching

Sixty one per cent of the respondents to the survey indicated that they were confident that they would know what to do if the aircraft was ditched in the ocean following the briefing they were given. Of the others, 31% were not confident, and 8% were not sure.

Most respondents (81%) thought that the safety cards were of assistance for knowing what to do.

The passenger safety card indicated that, once the aircraft landed on the water, only the forward and over-wing exits were to be used, and that passengers should leave the aircraft in the forward direction from the wings (Figure A1).

Figure A1: Excerpt from the passenger safety card directing passengers not to use the rear exits and to alight the wing in the forward direction.



Most respondents indicated that they knew they could use the over-wing exits (83%), with about half indicating that they could use the front doors (56%). Most respondents also indicated that they could not use the rear doors (83%).

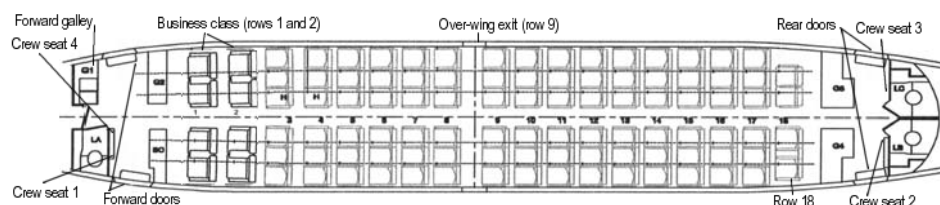
The majority of respondents did not know which direction they should have exited the wing (68%). Only 8% indicated they should exit in the forward direction. One respondent indicated that, although they were advised which exits to use, they were not told which direction to alight from the wing. Of the three passengers sitting in the over-wing exit row who responded, two indicated they did not know which direction to move off the wing, while the third indicated they should exit rearwards.

Several respondents commented that the cabin crew were calm, professional and appeared capable, while successfully conveying the seriousness of the situation. However, seeing the crew in the galley and aisle with their lifejackets before receiving any information about the event did lead several passengers to panic or worry. A number of respondents also commented that they could see that the ocean was very rough and that if the aircraft did have to ditch, that would have affected the survivability of the ditching and the subsequent evacuation into the liferafts.

Passenger seating & exit row briefings

Three respondents indicated that they moved seats before the descent into Nouméa. A male passenger replaced a female passenger in the over-wing exit row (row 9), and a woman who was travelling with her daughter moved out of row 18 so that another passenger, who did not have to look after a child, could occupy the rear exit row seats (Figure A2).

Figure A2: Cabin configuration



Ten respondents indicated that they were sitting in exit rows and all reported that they received a briefing from a cabin crew member about the operation of an exit door. Nine of those respondents indicated that they felt confident to conduct the actions about which they were briefed, while the tenth passenger

reported that she later swapped seats with a male passenger so that she had no exit row responsibilities. Respondents reported they were briefed on; how to operate the doors, how to remove cabin crew from the crew seats if they were incapacitated, and how to operate the evacuation slides.

Lifejackets

Just over half of the respondents (54%) indicated that they easily located their lifejacket, while 46% indicated they needed some searching. Of the six passengers from the business class rows who responded to the survey, three indicated that they could locate their jacket easily and three required some searching.

Most respondents (78%) indicated they fitted their jacket easily, although 22% indicated they fitted their jacket with some difficulty. Most (79%) also indicated that they fitted their jacket correctly, but 10% indicated that their jacket needed to be adjusted by a cabin crew.

Of the respondents who reported some difficulty with their lifejackets, 15 commented that the lifejackets were difficult to remove from under the seats, and seven commented that they were very difficult to remove from their container. The press-studs were difficult to open, and some respondents had to pull the jackets out of the corner of the container and/or needed others to help to remove the jacket. That made it difficult for a number to keep up with the passenger ditching briefing.

Passenger announcements

The majority of respondents (63%) thought that they were kept adequately informed about the diversion to Nouméa by the cabin manager (CM). However, only 43% indicated they were adequately informed about the diversion by the announcements (PA) from the PIC. In contrast, most respondents indicated that they were not adequately informed about the state of the aircraft by either the CM (86%) or PIC (89%).

Although a number of passengers thought that they could have been informed more quickly and with more information, many also indicated that they understood that the flight and cabin crews were both very busy following the missed approach from Norfolk Island.

The CM reported that she needed to repeat a PA from the PIC as the passengers in the rear of the aircraft could not hear it. One third of the respondents who were seated in the rear of the aircraft (rows 13 to 18) and near the wing (rows 7 to 12) indicated that they could not hear all of the PAs, while all respondents who were seated in the front rows (row 1 to 6) indicated that they could hear all of the PAs. Respondents who commented on the audibility of the PAs referred to the PIC's announcement as being difficult to hear.

Children

Eight respondents reported they were travelling with children. Five of these indicated that their children's needs were not adequately catered for. That was consistently reported as being a result of cabin crew needing to move on to

attend to other passengers with more pressing needs. One respondent reported that her 5 year old child was not offered an infant lifejacket. However, that may have been due to the size requirements for infant lifejackets.²⁵

Passenger needs

Most respondents (78%) indicated that their needs were looked after by the cabin crew *during* the diversion. The remaining 22% of respondents did not comment about what aspects they thought were not adequately looked after.

After the flight, nearly all respondents (92%) indicated that their needs were not looked after. Comments generally reflected the immediate post-flight situation. Once passengers passed through customs at Nouméa, the respondents reported that they waited outside in a shelter, standing for about 1.5 hours in the summer heat, without water, and without any communication from the ground staff of another Australian airline (who they were told would look after them) or the crew (who were still on the aircraft). As New Caladenia is French speaking, there was a considerable language barrier with the available airport personnel. Many of the respondents were still suffering from stress at that time, as many had expected the flight would end in fatal consequences for themselves. One passenger collapsed and was assisted by other passengers who also organised for an ambulance to take him to hospital.

After some of the cabin crew arrived, the passengers boarded a number of waiting buses to transport them to two hotels. The respondents who stayed at one of the two hotels indicated they did not receive any information from the operator, and only found out through other passengers that there would be a replacement flight for them the next morning. As a result, one of the two buses arrived at the airport 2 hours after the first bus. Passengers were not initially told they were travelling directly to Brisbane and not to Norfolk Island as expected.

Some of the respondents reported that, after arriving in Brisbane, they were upset at the operator's attitude towards them over the event (indicating that it was a simple diversion due to weather), and that the operator had given no support to passengers for the stress and emotional issues they were experiencing. They were given a telephone number to ring, but there was no answer when called. Other respondents indicated that counselling was offered by the operator, but only after 10 days.

Passenger injuries

Five people indicated that they sustained an injury or adverse effect during the flight, and another 25 indicated that they had suffered similarly after the flight. The majority of adverse effects reported involved psychological reactions during and especially after the flight.

²⁵ The operator's operations manual stated that infant lifejackets were to be fitted to '...all persons under 16 kg aged up to approximately three years'.

One respondent reported having a panic attack during the diversion for 20 to 35 minutes, resulting in her becoming very cold and shivering. She reported that she was assisted by the (original) CM and a number of the other passengers. The other four respondents who indicated that they experienced adverse effects during the flight all reported panic attacks or anxiety/stress.

The most common adverse effects reported to have occurred following the flight were anxiety (10 respondents), stress or trauma (14), insomnia (7), and depression (3). Other reported conditions included: one passenger who had a seizure while waiting outside the terminal in Nouméa following the flight, and again at the hotel later that night, both involving hospitalisation; one passenger who sustained tinnitus (strong ringing in the ears), and required medical attention; and one passenger who required hospital care for a kidney stone problem in the days after the flight.

APPENDIX B: TECHNICAL ANALYSIS REPORT

ATSB TECHNICAL ANALYSIS
AO-2007-070

Examination of number-4 slat track
Norfolk Island - 29 December 2007
VH-OBN
Boeing 737-229

Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

FACTUAL INFORMATION

Introduction

On 29 December 2007, during a missed approach at Norfolk Island, a Boeing 737-229 registered VH-OBN, experienced increasing airframe vibrations and control difficulties. The aircraft was diverted to Nouméa where a safe landing was completed. The number-4, inboard main slat track and both auxiliary tracks were found to have failed. The slat was forwarded to the ATSB for technical analysis.

Scope

Failure analysis was conducted on the fractured main track and associated slat.

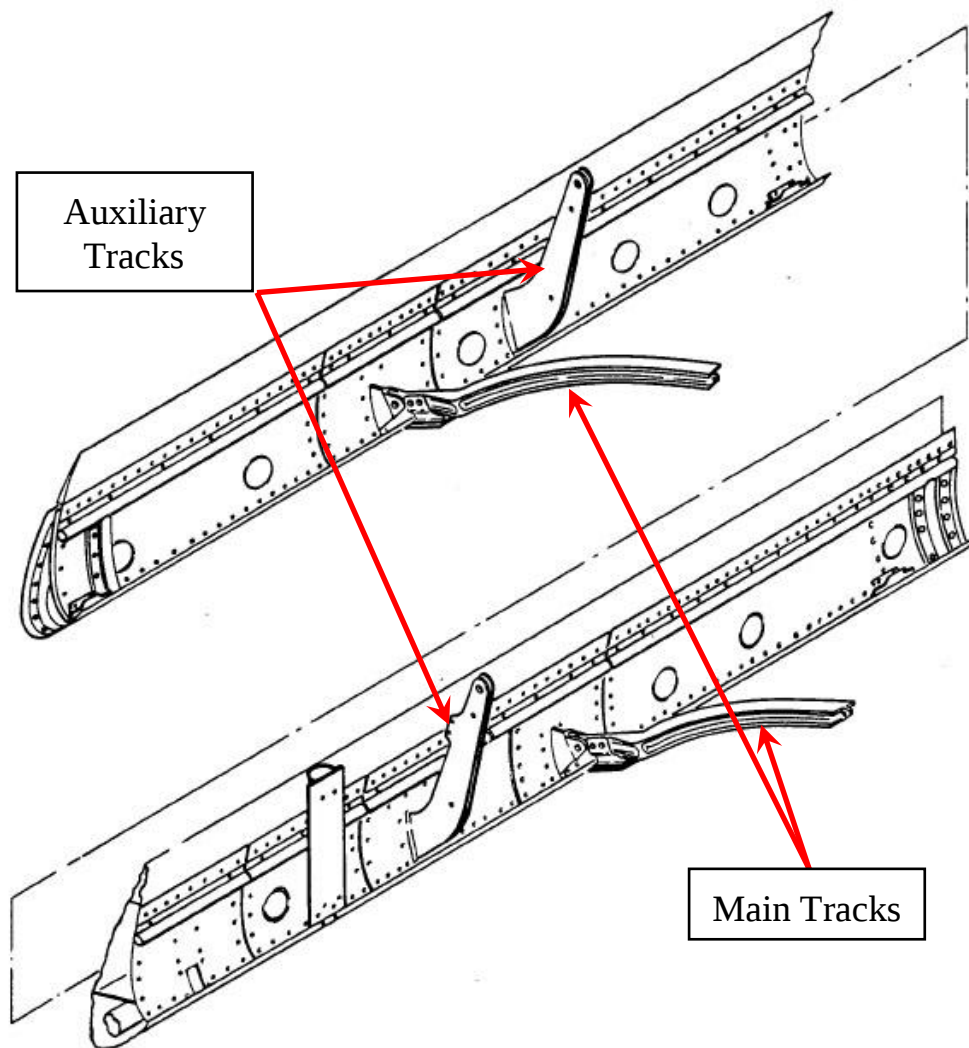
Leading-edge slat overview

Slats form part of the high-lift, leading-edge devices which change the camber of the wing to increase lift. Three leading-edge slats were installed on each wing outboard of the engine. The slats were numbered 1 through 3 on the left wing and 4 through 6 on the right. The number-4 slat was the inboard slat on the right wing.

The Boeing 737 maintenance manual 27-81-0 described the slats (Figure 1) as follows:

The slats consist of ribs attached to a beam, inner and outer clad aluminium skins and a honeycomb trailing edge. A void between the inner and outer skins provides a path for thermal anti-icing. Anti-icing ducts installed in the slat leading edge connects with hot air supply lines through a telescoping tube. A three position hydraulic actuator is attached to the centre of all leading edge slats (1 thru 6). Each slat has two main tracks and two auxiliary tracks which ride on rollers in the wing leading edge. A third auxiliary track is installed at the outboard end of slats No. 1 and 6. Structural stops are provided in both the extended and retracted slat positions. The downstops are attached to the slat tracks and contact with track guides in the extended position. The upstops consist of three adjustable plates which contact with the slat beam when the slats are retracted. All slats (1 thru 6) are stabilised at the intermediate position by a torsion rod and support arm assembly attached to the front spar between the auxiliary slat tracks.

Figure 1. Leading edge slat*



* Taken from Boeing overhaul manual 57-56-21.

Main track examination

The inboard main track assembly (part number: 65-49448-9) fractured slightly aft of mid-span (Figure 2). Examination of Boeing maintenance manual 27-81-21 determined that areas of heavy wear on the rolling surfaces were associated with the location of the main track rollers. The most significant wear was associated with the upper track rollers with the slat in the fully retracted position (Figure 3). The outboard main track showed similar wear patterns, but was otherwise undamaged.

Measurements taken of the track concluded that the failure occurred approximately 15mm forward of the leading upper track roller with the slat in the fully extended position (Figure 4).

Visual examination of the fracture surfaces showed evidence of a fatigue crack that extended across a substantial portion of the lower flange (Figure 5). Figure 6 shows the fatigue region and associated beach marks²⁶ in greater detail.

A series of machining marks was observed on the upper and lower track surface (Figure 7). The marks were predominantly visible at the edges of the track, indicating that they had probably been worn away in the centre by the track rollers. The marks were also visible under the paint which indicated that they were probably associated with the manufacture of the track.

Figure 2. Failed inboard main slat track.



²⁶ Beach marks are the most characteristic feature associated with fatigue-fracture surfaces and classically present as a series of concentric rings radiating outward from a common point, corresponding to the fatigue crack origin.

Figure 3. Main upper track roller wear marks

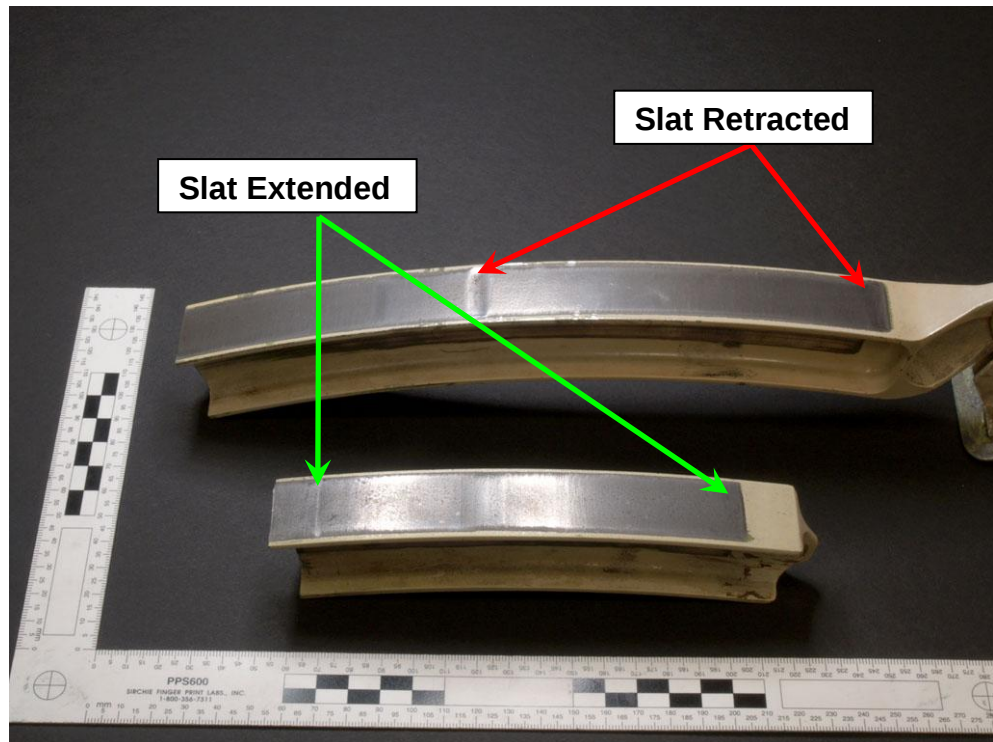
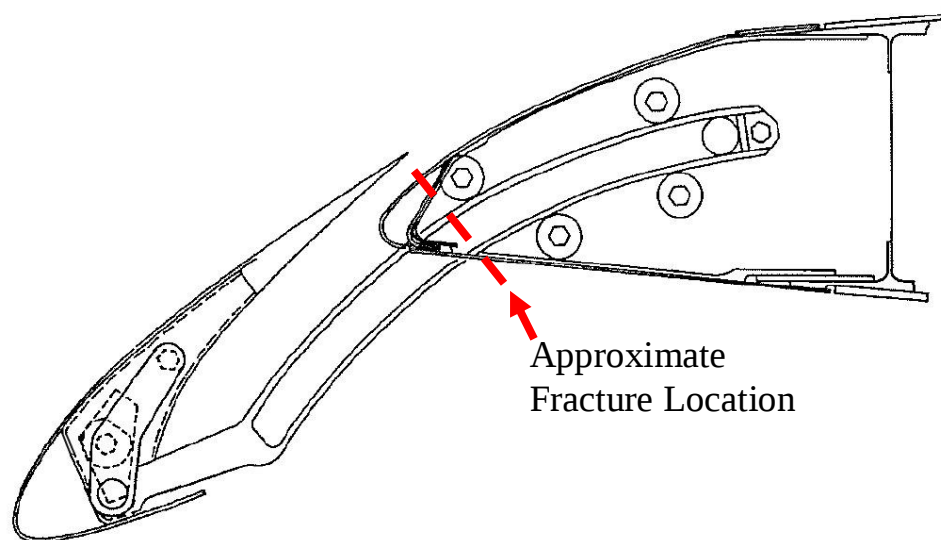


Figure 4. Fully extended slat indicating fracture location*



* Taken from Boeing maintenance manual 27-81-21.

Figure 5. Mating halves of Slat Track fracture

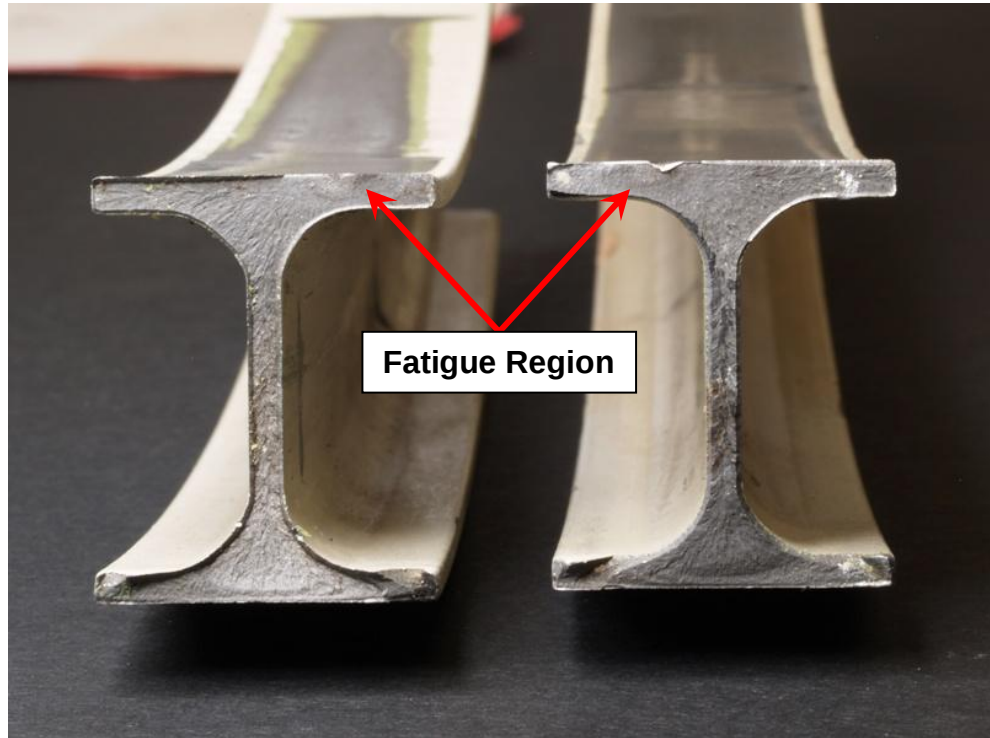
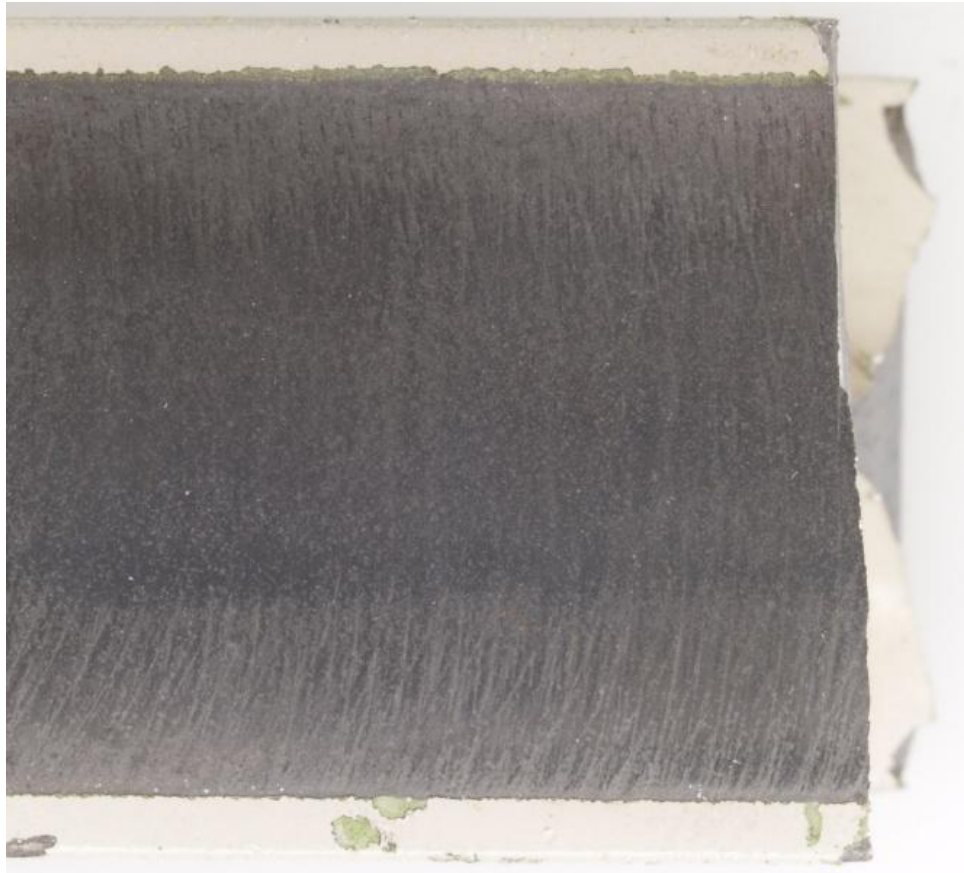


Figure 6. Fatigue region on lower flange exhibiting beach marks



Figure 7. Machining marks on track rolling surface



Microscopy

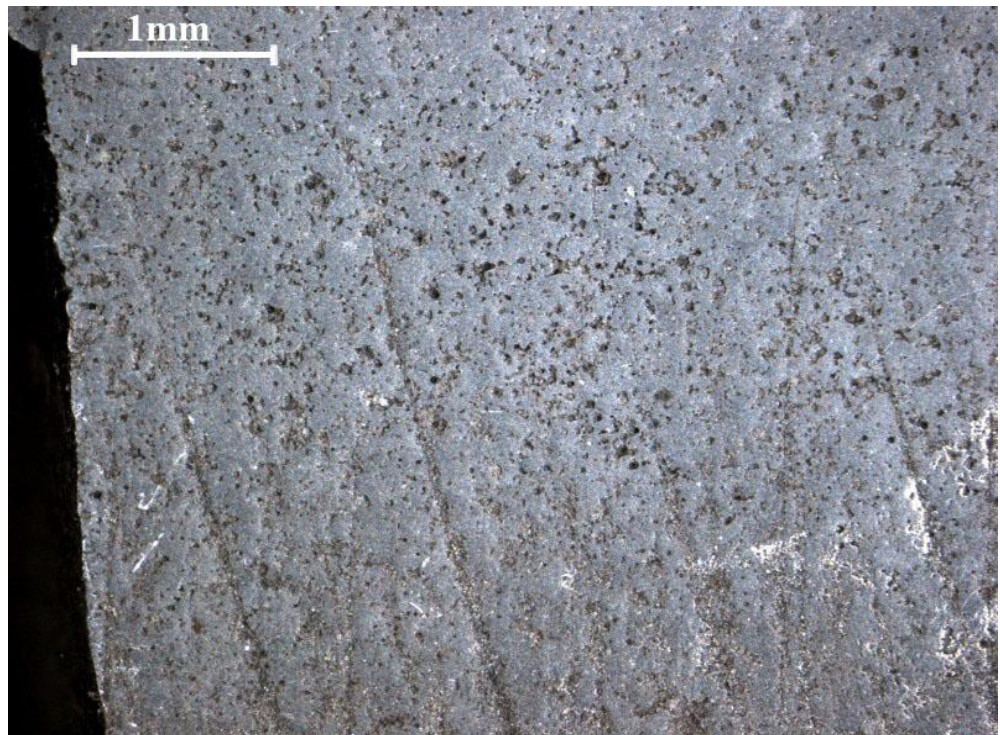
The fracture surface of the main track was examined using optical and scanning electron microscopy. There were no indications of material defects or anomalies observed at the fatigue origin.

Examination of the rolling surfaces revealed surface pitting. Figure 8 shows the extent of the pitting adjacent to the fracture surface on the lower flange, however the most extensive pitting was observed on the upper flange of the failed track. The deepest pits observed measured approximately 50µm in depth. A cross section of the pits is shown in Figure 9.

The most prominent machining marks were found to occur at regular intervals. The location and curvature of the fracture surface surrounding the fatigue origin was consistent with one of the regular machining marks. The fatigue origin was found to be adjacent to the area where two of these marks intersected (Figure 10).

The microstructure of a section of metal adjacent to the fatigue origin was examined. The martensitic²⁷ microstructure observed was consistent with heat-treated 4340M that was specified on the drawing. No microstructural anomalies were observed.

Figure 8. Pitting on the lower flange adjacent to the fracture surface



²⁷ Martensite refers to a needle-like, microstructural constituent of steel that is typically hard and highly strained.

Figure 9. Cross section showing pitting of rolling surface

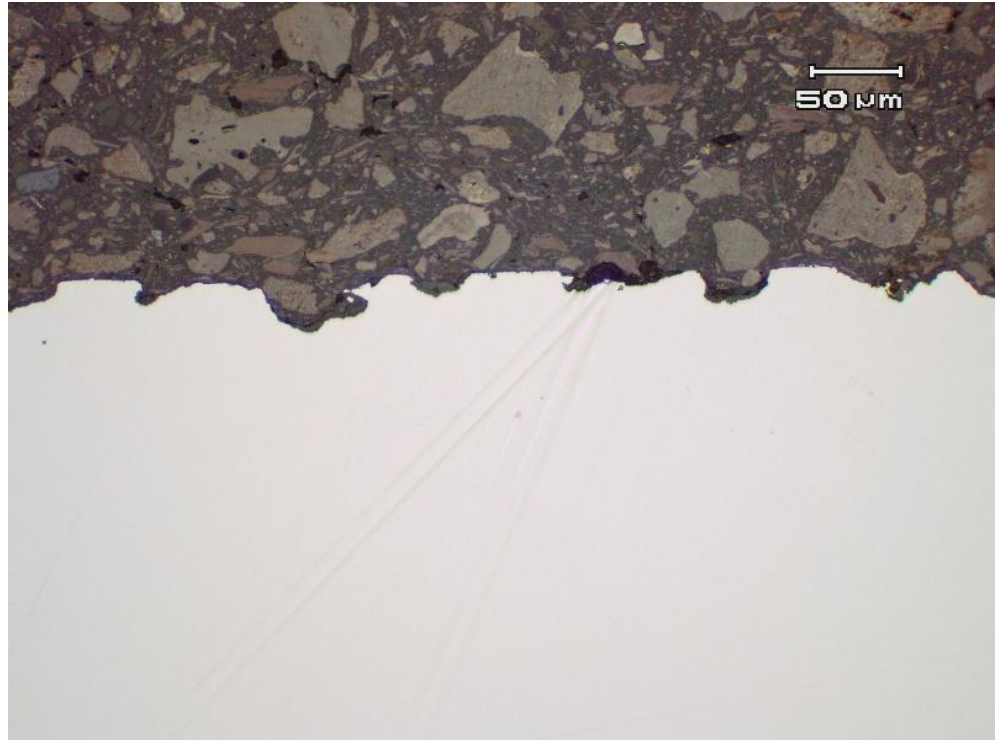
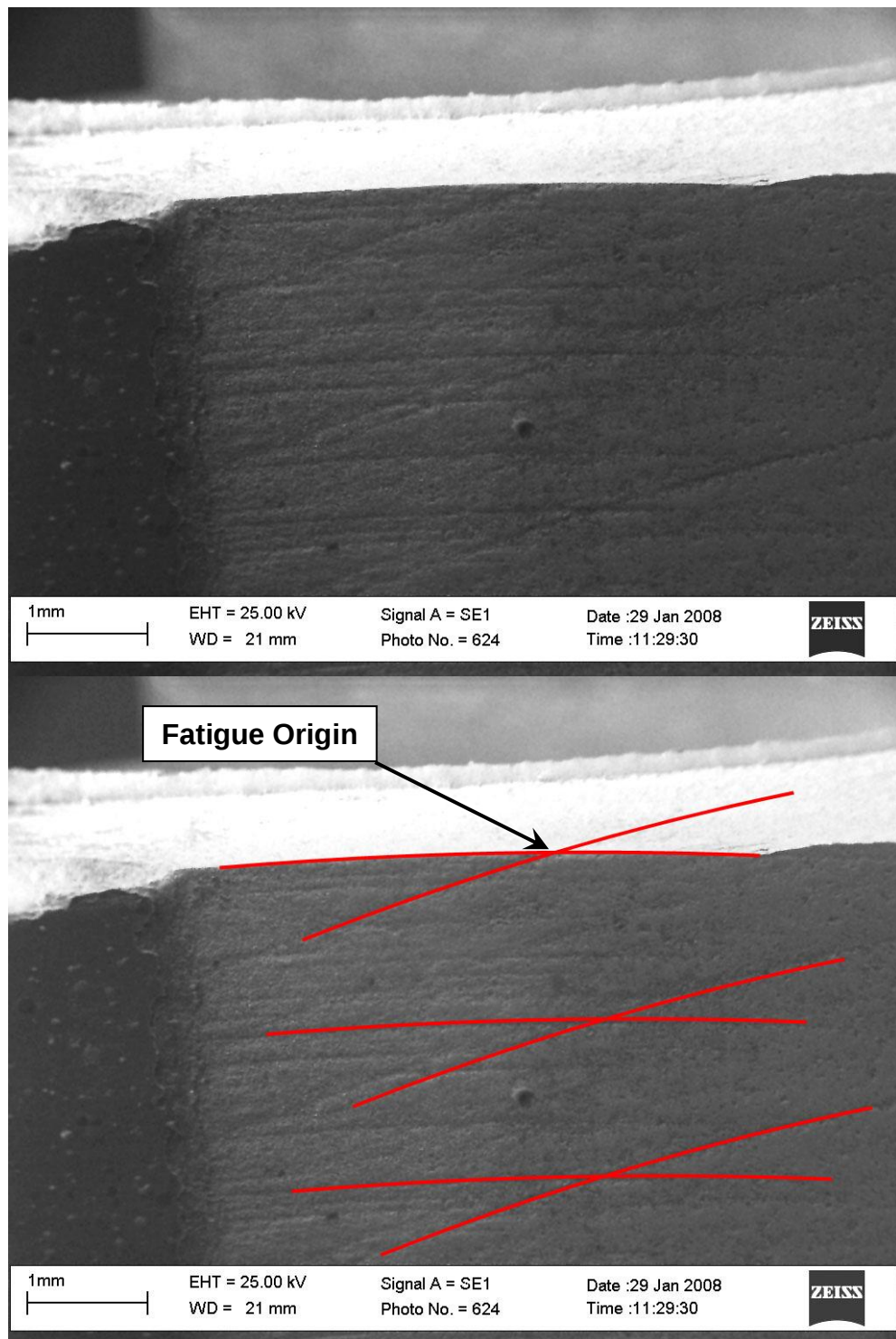


Figure 10. SEM image of machining marks adjacent to fatigue origin.



Hardness testing

Drawing specifications indicated that the main track material should have been 4340M, heat treated to 270 – 300 ksi. The Boeing heat-treatment specification (BAC5617) has a hardness requirement of 51 – 56 HRC (Rockwell C scale) for an equivalent 270 – 300 ksi strength range.

A section of the inboard main track was Vickers hardness tested using a 50 kg mass. The average hardness measured was 635 HV, which was approximately equal to 57 HRC per the hardness conversion table in BAC5617. Allowing for the fact that the conversions are approximate, the hardness of the main track was at the upper end or possibly marginally higher than the allowable range.

The hardness of the outboard main track was also tested and was found to be equal to that of the inboard track.

Dimensional inspection

The Boeing overhaul manual, 57-56-21, page 401, dated Dec 1/97, indicated that for track assembly 65-49448-1, -3, -9, worn areas of the flange should be blended out to an acceptable upper and lower flange thickness of 0.10-0.12 inch for 65-49448-9 track assembly.

A micrometer was used to take measurements at various intervals along the inboard track. There was only one measurement taken that was outside the thickness limits. A point close to the aft end of the track and distant from the failure region had a thickness measuring 0.09 inches. The remaining upper flange and all lower flange measurements were within the prescribed limits.

Magnetic particle inspection

The inboard and outboard main tracks were examined for additional cracks using magnetic particle inspection. No indication of cracking was observed.

Auxiliary tracks

The auxiliary tracks should have been fixed at two joints in the slat but were found to have considerable vertical movement, indicative of failure of the joint closest to the upper surface of the slat (Figure 11).

The inboard auxiliary track failed through the bolt hole as pictured in Figure 12. Examination of the fracture surfaces indicated that the failure occurred by ductile overload. The bolt hole in the track was also found to be elongated in the direction of the liberated section. The material around the bolt hole was scored, consistent with movement of the track in the support.

One of the aluminium support ribs for attachment of the outboard auxiliary track had failed as a result of extensive exfoliation corrosion (Figure 13). The corrosion was centred around the cadmium-plated steel bolt attaching the track to the ribs. The remaining rib failed through the bolt hole, which had fractured up to the rib flange. The flanges on both ribs had buckled outwards and were fractured along their length.

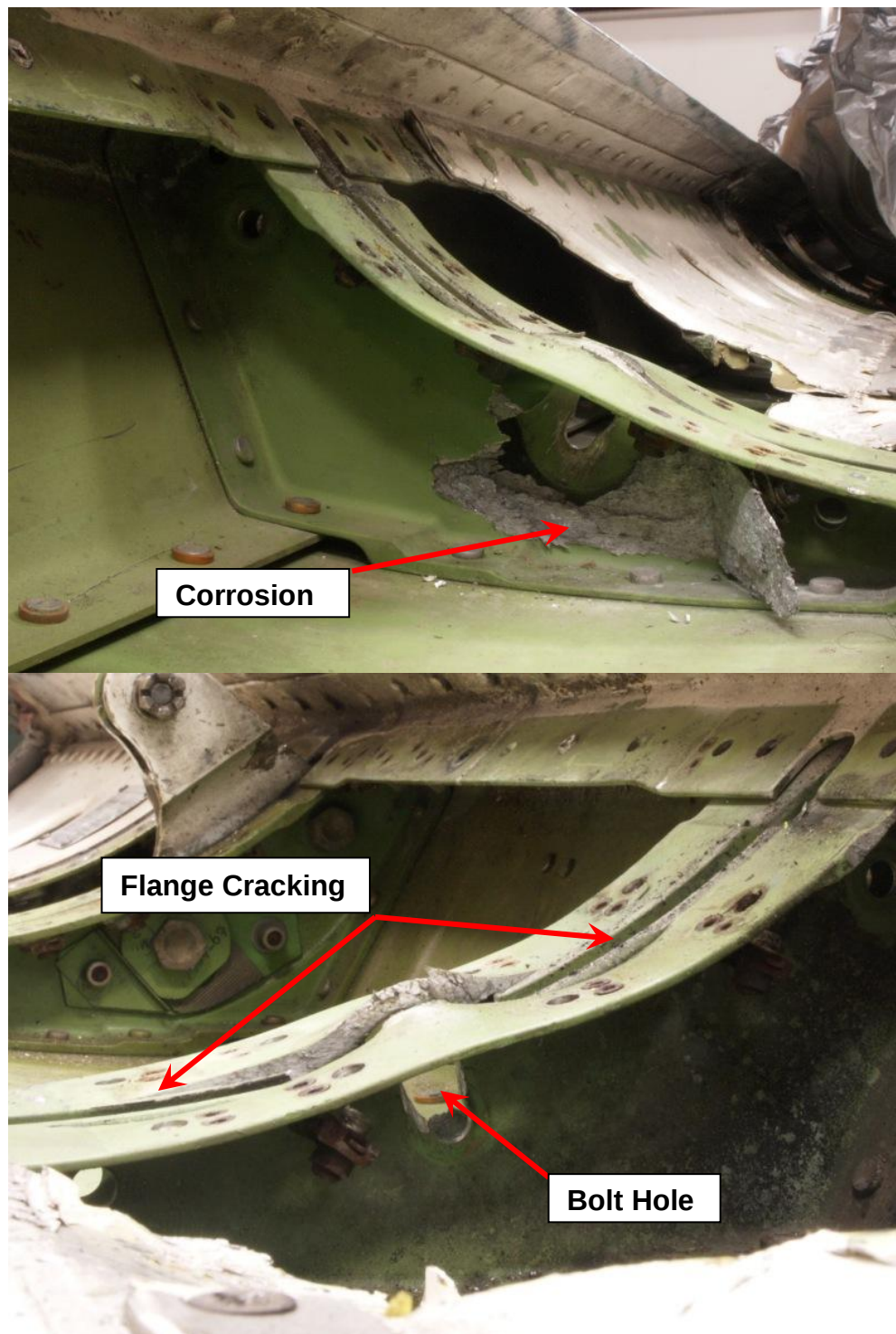
Figure 11. Inboard auxiliary track in situ



Figure 12. Inboard auxiliary track failure



Figure 13. Outboard auxiliary track support ribs



ANALYSIS

Main Track

The inboard main slat track failed as a result of a fatigue crack which initiated and propagated on the lower rolling surface.

The forces acting on the slat track would have been in an upward direction as a consequence of generating lift, and been at a maximum when the slat was fully extended. The large bending moment acting around the track roller would have placed the lower flange of the main track under a high tensile load at the point of failure. Therefore, in the circumstances, the fracture location in this occurrence was as expected.

The orientation of the fatigue region of the main track failure along the machining marks indicated that the marks probably acted as a local stress concentrator. The fatigue initiation point was potentially also influenced by pitting of the rolling surface, which would also have acted as stress concentrators.

The hardness of the steel in the main tracks was found to be at the upper end or possibly marginally higher than the allowable range specified on the drawing. While the extent of any influence the higher hardness had on the fatigue initiation could not be determined, as a general rule, an increase in material hardness results in a decrease in toughness, which reduces the ability of a material to resist fracture.

Auxiliary Tracks

The location of the corrosion around the outboard auxiliary track bolt hole indicated that the corrosion protection in and around the bolt hole had broken down, leaving the region susceptible to corrosion damage. The corrosion in the auxiliary track rib had been present for a considerable period of time.

The appearance of the fracture surface through the bolt hole in the support rib was consistent with a fast overload fracture rather than a progressive one. There was no direct evidence to suggest that the outboard auxiliary track was not being fully supported by the rib at the time the inboard main track failed.

Likewise, the appearance of the inboard auxiliary track failure was consistent with a rapid, overload fracture.

Therefore, the fractures associated with the auxiliary tracks probably occurred immediately after main track failure, which would have resulted in a sudden and significant increase in loading on the auxiliary tracks. In this case, the corrosion would have had no influence on the main track failure.

FINDINGS

The following statements are a summary of the substantiated findings made during the progress of the main and auxiliary track examination.

- The number-4 slat inboard main track failed due to a fatigue crack initiated in the lower flange. The location of the crack was consistent with it being originated during periods when the slat was fully extended and therefore under maximum loading.
- The presence of machining marks and surface pitting on the rolling surface probably had some influence on the origin of the fatigue crack.
- The hardness of the main slat tracks was found to be at the upper end or possibly marginally higher than the range specified in the Boeing heat treatment specification for a 4340M steel with a strength requirement of 270 to 300 ksi. A high hardness may have reduced the resistance to fatigue cracking.
- Exfoliation corrosion was present in one of the ribs supporting the outboard auxiliary track, causing failure of the support around the bolt hole.

APPENDIX C: SEQUENCE OF EVENTS FROM THE DFDR DATA

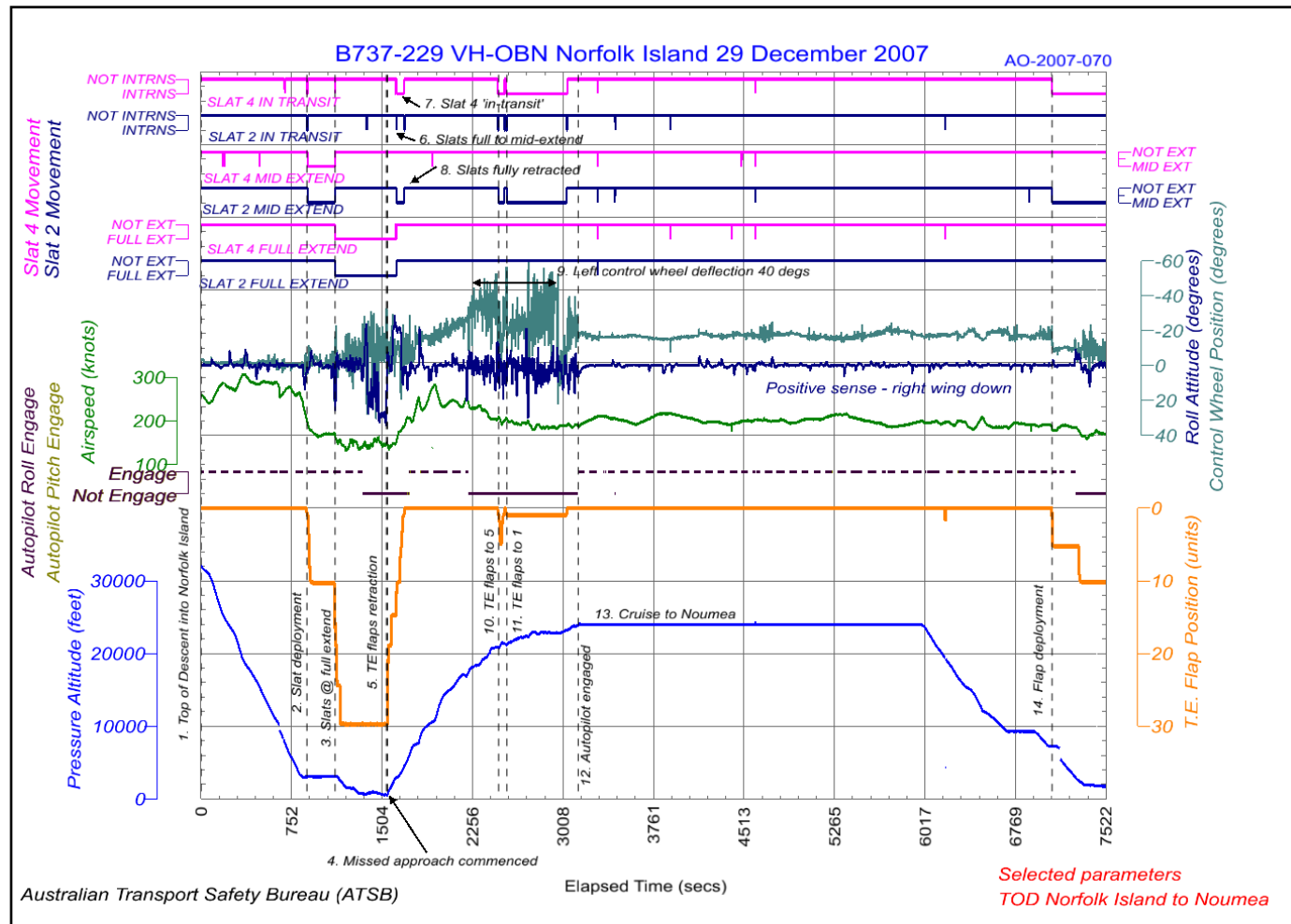
Approx Elapsed Time (secs) ²⁸	Event number ²⁹	Event	Pressure Altitude (ft)	Airspeed (kts)	Trailing edge flap position (Units)	Slats position
0	1	Top of descent	31,973	258	0	Retracted
881	2	Leading edge slat deployment on approach to Norfolk Island	3,033	201	0 - 1	Slats indicate 'in-transit'
1,115	3	Slats recorded at full extension position	3,066	169	15 – 18	All leading edge slats extended normally with transition through the mid-extend and full-extend positions
1,541	4	Missed approach commenced. Aircraft pitch increases and climb commenced	550	146	30	All slats at full extend
1,551	5	Trailing edge flap retraction commenced following missed approach	631	147	30 - 28	All slats at full extend
1,625	6	Slats transitioned from full to mid-extend	2,943	154	12 - 11	Slats indicate 'in-transit'
1,626 – 1,689	7	All slats except number-4 slat transition to mid-extend position	2,950 - 4,468	155 - 188	10 - 1	Number-4 slat remains 'in transit'

²⁸ Approximate elapsed time only, due to tape download discontinuities.

²⁹ Refer to graphical representation at Appendix D.

Approx Elapsed Time (secs)²⁸	Event number²⁹	Event	Pressure Altitude (ft)	Airspeed (kts)	Trailing edge flap position (Units)	Slats position
1,690	8	Slats transition to the fully-retracted position	4,505	187	0.5	Number-4 slat 'in transit' indication ceases as other slats transit from mid-extend position to fully retracted
2,254 – 2,464	9	Left control yoke deflection oscillates around 40°. Roll attitude $\pm 15^\circ$ range during the period	18,098 - 20,888	230 - 204	0	
2,474	10	Flaps extended through flap 1 to the flap 5 setting	20,810	209	1	Number-4 slat remains 'in transit' while other slats move to the mid-extend position
2,543	11	Flaps extended to flap 1 setting	21,233	203	1	Number-4 slat remains 'in transit' while the other slats move to the mid-extend position
3,136	12	Autopilot pitch and roll modes engaged	23,940	189	0	
3,162	13	Cruise to Nouméa commenced	24,010	192	0	Control yoke deflection reduces
7,073 – 7,076	14	Flap deployment on descent	7,237 - 7,292	178 – 187	0 - 5	Number-4 slat remains 'in transit' while the other slats move to the mid-extend position

APPENDIX D: GRAPHICAL REPRESENTATION OF DFDR DATA



APPENDIX E: SOURCES AND SUBMISSIONS

Sources of information

The sources of information during the investigation included the:

- flight and cabin crew of VH-OBN
- aircraft operator
- aircraft manufacturer
- Bureau of Meteorology
- aircraft's Digital Flight Data Recorder.

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the Transport Safety Investigation Act 2003, the Executive Director may provide a draft report, on a confidential basis, to any person whom the Executive Director considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the Executive Director about the draft report.

A draft of this report was provided to the aircraft operator, aircraft manufacturer, Civil Aviation Safety Authority (CASA), flight crew, cabin crew, and the US National Transportation Safety Board.

Submissions were received from the pilot in command and CASA. The submissions were reviewed and, where considered appropriate, the text of the report was amended accordingly.

Leading edge device failure, Norfolk Island, 29 December 2007,
VH-OBV, Boeing 737-229