

**Report 06-003 Boeing 737-319, ZK-NGJ, electrical malfunction and 12 September 2006  
subsequent ground evacuation, Auckland  
International Airport**

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**Report 06-003**

**Boeing 737-319**

**ZK-NGJ**

**electrical malfunction and subsequent ground evacuation**

**Auckland International Airport**

**12 September 2006**

### **Abstract**

On Tuesday 12 September 2006 at 0727, flight NZ503, a Boeing 737-319 registered ZK-NGJ started its take-off at Auckland International Airport on a scheduled flight to Christchurch. On board were 2 pilots, 3 cabin crew and 96 passengers.

Partway through the take-off roll an electrical relay failed, causing a loss of battery bus power. The pilots identified an escalating number of electrical malfunctions after take-off and elected to return to Auckland. After landing, the aircraft started to slowly fill with smoke, so the captain ordered a ground evacuation of the aircraft. All passengers and crew exited the aircraft without injury.

The evidence available pointed to the failure of the relay being due to faulty manufacture, which led to the contacts within the relay deteriorating over its 7-year life to the stage they were unable to remain closed because of the vibration encountered during the take-off.

The operator had initiated actions to monitor the performance of the relay and establish more robust procedures for crews to identify and handle a loss of battery bus power.

The ground evacuation provided valuable guidance on the effectiveness of the operator's crew resource management and emergency procedures training. Safety recommendations were made to the regulator to improve the effectiveness of ground evacuation procedures and to disseminate the lessons learnt from the event.



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## Abbreviations

AAIB	Air Accidents Investigation Branch (United Kingdom)
AC	alternating current
ACM	air cycle machine
APU	auxiliary power unit
ATC	air traffic control
Boeing	Boeing Commercial Aeroplanes
CCTV	closed-circuit television
CRM	crew resource management
CVR	cockpit voice recorder
DC	direct current
DFDR	digital flight data recorder
EADI	electronic attitude direction indicator
EFIS	electronic flight information system
FA	flight attendant
FAA	United States Federal Aviation Administration
ft	feet
IRS	inertial reference system
km	kilometre(s)
kt	knot(s)
°M	degrees magnetic
mm	millimetre(s)
PA	passenger address
QRH	quick reference handbook
TRU	transformer rectifier unit
UTC	Co-ordinated Universal Time

## Glossary

$V_1$	take-off decision speed. The speed during take-off whereby it is possible to continue the take-off safely if an engine failure occurs, or abandon the take-off and stop the aircraft safely on the runway length remaining
$N_1$	a measurement of engine compressor speed as a percentage

## Data Summary

<b>Aircraft registration:</b>	ZK-NGJ
<b>Type and serial number:</b>	Boeing 737-319
<b>Number and type of engines:</b>	2 General Electric CFM56-3C1
<b>Year of manufacture:</b>	1999
<b>Operator:</b>	Air New Zealand Limited
<b>Date and time:</b>	12 September 2006, 0728 <sup>1</sup>
<b>Location:</b>	Auckland International Airport latitude: 37° 00' south longitude: 174° 47' east
<b>Type of flight:</b>	scheduled air transport
<b>Persons on board:</b>	crew: 5 passengers: 96
<b>Injuries:</b>	crew: nil passengers: nil
<b>Nature of damage:</b>	nil
<b>Pilot in command's licence:</b>	Airline Transport Pilot Licence (Aeroplane)
<b>Pilot in command's age:</b>	45
<b>Pilot in command's total flying experience:</b>	11 135 hours (about 5000 on type)
<b>Investigator-in-charge:</b>	I R M <sup>c</sup> Clelland

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<sup>1</sup> Times in this report are New Zealand Standard Time (UTC + 12 hours) and are expressed in the 24-hour mode.



## Factual Information

### 1.1 History of the flight

- 1.1.1 On Tuesday 12 September 2006, NZ503 was a scheduled flight from Auckland to Christchurch operated by Air New Zealand Limited (the operator). The aircraft allocated for the flight was ZK-NGJ, a Boeing 737-319<sup>2</sup>. The flight was planned to depart Auckland at 0710, crewed by 2 pilots and 3 cabin crew.
- 1.1.2 The pilots reported for duty at about 0630 and the operator provided them with briefing information for the flight. At this time the pilots met with another flight crew who had flown ZK-NGJ the previous day. The other flight crew advised the pilots of NZ503 that the aircraft auxiliary power unit (APU)<sup>3</sup> was inoperative and a ground air supply would be required to start the engines. They commented that there was a loud “clunk” when the ground power supply was disconnected and an associated delay before the aircraft instrument readings “came back up”.
- 1.1.3 The pilots completed their pre-flight checks and at about 0700 the 96 passengers, comprising 87 adults, 7 children and 2 infants, were boarded. At 0712 the pilots started the first engine in accordance with supplementary procedures for an unserviceable APU, as contained in the aircraft operations manual. The pilots reported that, after the electrical generator for the first engine came on line, they heard a slightly louder than normal clunk as the ground power supply was disconnected and the electrical relays reset. The aircraft instruments also went blank for longer than usual before returning to their normal indications. The aircraft was pushed back clear of the air-bridge and the pilots started the second engine. The cabin crew completed the passenger safety briefing during this time. The first officer was the nominated “pilot flying” for the leg to Christchurch, with the captain undertaking the “pilot monitoring” duties.
- 1.1.4 The pilots taxied the aircraft and at 0727 the captain applied power and commenced the take-off roll on runway 23 left, then passed control of the aircraft to the first officer. The captain called at 80 knots (kt) for the airspeed cross-check, then started an instrument scan before reaching  $V_1$ , the take-off decision speed, calculated to be 127 kt. The captain recalled that as he scanned the instruments he observed the gyro flag showing on the standby horizon indicator.<sup>4</sup> Because this was a non-critical instrument he noted the fault and continued his scan, which was otherwise normal, before looking to the electronic attitude direction indicator (EADI) to check the airspeed and call  $V_1$  and rotation. The captain reported seeing the speed markers on the EADI suddenly disappear, so he looked at the first officer’s EADI and noticed a similar indication. He then moved his view to the mach/airspeed indicator and called for rotation.
- 1.1.5 At about 138 kt the first officer rotated the aircraft and it lifted off at about 148 kt. After establishing a positive rate of climb, the first officer called for the retraction of the landing gear. The captain reported that when he attempted to raise the gear lever he was unable to get it past the Off position.<sup>5</sup> The captain advised air traffic control (ATC) that they had a technical problem and requested clearance to maintain runway heading. ATC cleared NZ503 to continue heading towards Westpoint beacon. The pilots observed that both main landing gear indicators were not illuminated and the nose gear indicator was showing red. After a brief discussion the captain returned the gear lever to the Down position, where all 3 gear position indicators remained blank or not illuminated.
- 1.1.6 At about 0730, the captain advised ATC that they wanted to stop the climb to remain in visual meteorological conditions, and head in a safe direction to investigate the problem further. The aircraft was eventually levelled at 4000 feet (ft) on a heading of 180° magnetic (M). This kept the aircraft below the cloud base at about 5000 ft. The aircraft flaps were kept in the “Flaps 1”

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<sup>2</sup> A division of The Boeing Company.

<sup>3</sup> A self-contained gas turbine engine located in the tail of the aircraft that supplied bleed air for engine starting or air conditioning. An alternating current (AC) electrical generator on the APU provided auxiliary AC power.

<sup>4</sup> The gyro flag indicated that the attitude was unreliable.

<sup>5</sup> The gear lever selector had 3 positions: Down, Off and Up.

position to assist in the manoeuvring of the aircraft. The captain suggested that the aircraft had remained in the ground mode, similar to a previous occurrence that he had experienced.

- 1.1.7 The captain, aware that the cabin crew and some of the passengers would be concerned that the aircraft had reduced power and stopped climbing, attempted to call the purser using the attendant call button. The purser was positioned in the forward part of the cabin. However, the attendant call button didn't function, so the captain tried to use the passenger address (PA) system, again unsuccessfully. After engaging the autopilot, the first officer also attempted to call the purser with similar results. The captain then reached back and unlocked the flight deck door, which swung back, attracting the purser's attention.
- 1.1.8 The captain briefed the purser on the landing gear problem and advised that they intended to return to Auckland and might conduct a flypast of the control tower to confirm the position of the landing gear. Further, the captain advised they had about 10 minutes until landing and the aircraft should be prepared for a precautionary landing.<sup>6</sup> With the PA not working, the cabin crew needed to brief the passengers personally.
- 1.1.9 The purser returned to the forward galley area and briefed the 2 flight attendants (FA2 and FA3),<sup>7</sup> who had moved forward to the front of the cabin after they were unable to contact the purser by intercom. The purser and FAs reviewed the precautionary landing procedures before dividing the cabin into 3 sections and briefing the passengers for the return to Auckland. The purser relocated 2 positioning company pilots to seats adjacent to the over-wing exit windows on each side of the aircraft and briefed them on the situation. The aircraft was equipped with 2 megaphones, but the FAs decided that the use of the megaphones was not necessary and it was more effective to talk personally to the passengers. Further, the megaphones may have caused unnecessary confusion and anxiety.
- 1.1.10 Meanwhile, at about 0735 the first officer had turned the aircraft onto an easterly heading and the captain informed ATC of their intention to return to Auckland. After reviewing the situation the pilots carried out a master lights test to check the landing gear lights. No lights illuminated, including the master caution light. The pilots then observed several fail lights illuminated on the overhead panel, in particular the speed trim, mach trim and auto slat fail lights. Shortly afterwards the pilots noticed the background colour disappear from the first officer's electronic flight information system (EFIS).<sup>8</sup> About one minute later the captain's EFIS also went to the monochromatic mode. The captain called ATC and gave an update on their situation and started coordinating a flyover of the control tower to get a visual check on the position of the landing gear before returning to land.
- 1.1.11 The captain and first officer discussed the apparently escalating electrical malfunctions and agreed that they should land as soon as possible rather than spend time trying to identify quick reference handbook (QRH)<sup>9</sup> checklists that might address the situation. The captain called ATC and requested that rescue services be placed on "local standby". Meanwhile the first officer talked to the operator's engineering organisation on the second radio to see if they could suggest a cause of the faults. According to the pilots, the engineers suggested the problem might be related to the aircraft's inertial reference system (IRS) and to check also the circuit breaker panels to see if any breakers had popped, thereby possibly indicating the source of the failures. The pilots discarded the IRS as a likely cause because of the range of electrical failures. However, the circuit panels were checked and no anomalies were found.
- 1.1.12 In preparation for landing, the captain elected to vacate his seat and complete a visual inspection of the landing gear using the viewing panels located about the aircraft. After checking the nose wheel and main gear indicators, the captain was satisfied that the landing gear was down and

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<sup>6</sup> A landing expected to be normal, but the crew are at a heightened level of alertness.

<sup>7</sup> FA2 was responsible for the left rear emergency exit (3L) and FA3 for the right rear emergency exit (3R).

<sup>8</sup> The EFIS consisted of the EADI and electronic horizontal situation indicator located below.

<sup>9</sup> The QRH included non-normal checklists that provided steps to correct a situation or condition and were designed for convenient flight crew use.

locked, so returned to his seat. He considered that a flypast of the control tower was unnecessary and informed the tower accordingly. About this time, the first officer noticed that there were no engine N<sub>1</sub><sup>10</sup> and fuel flow gauge indications. The pilots again reviewed the situation, with the captain observing that the clock on the instrument panel had also stopped.

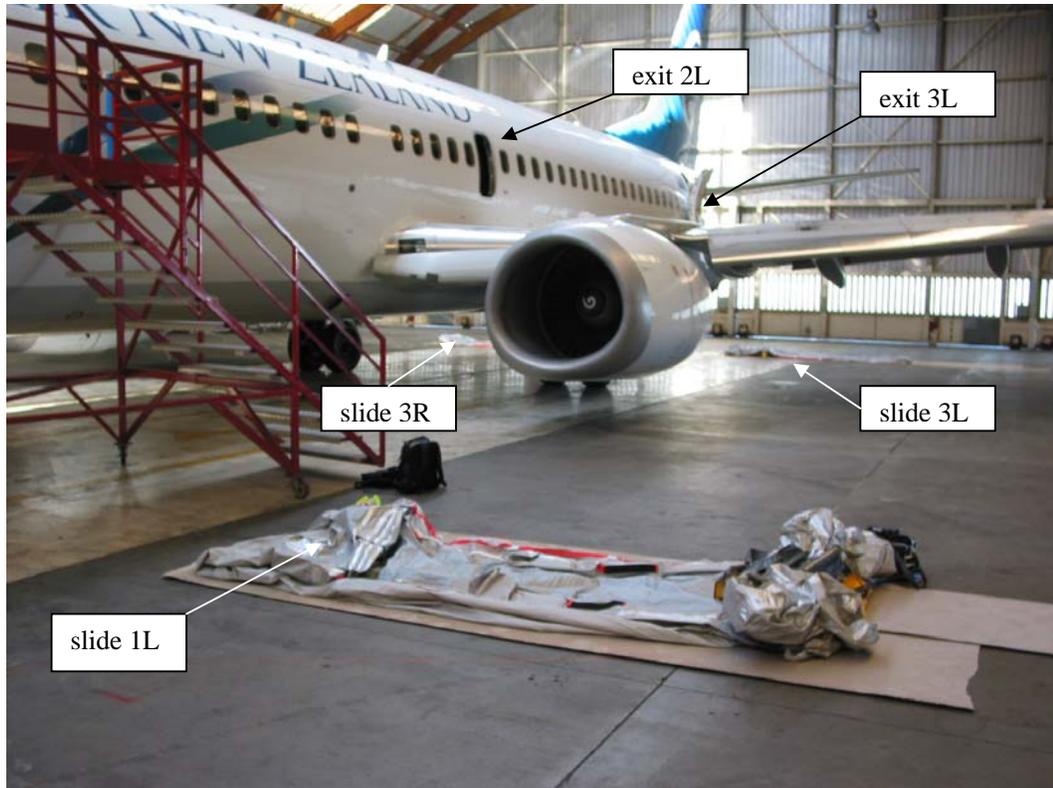
- 1.1.13 At about 0742, the purser returned to the flight deck and advised that the cabin was ready for landing. The captain briefed the purser that after landing they would taxi clear of the runway and come to a stop. The purser would then return to the flight deck and, providing everything was satisfactory, they would conclude the precautionary landing checklist before taxiing to the terminal.
- 1.1.14 At 0745, the captain requested ATC priority for the return and the first officer briefed for the visual approach, noting that the auto brakes would not arm. As a backup the first officer also loaded an instrument approach for runway 23 left into the aircraft Flight Management Computer. ATC gave radar vectors to runway 23 left. The pilots disconnected the autopilot and lowered flaps.
- 1.1.15 At 0752, the first officer made a normal manual landing, however he was unable to select reverse thrust so he slowed the aircraft using manual braking. At about 60 kt, the captain took control of the steering and manoeuvred the aircraft clear of the runway at high-speed taxiway A8, about halfway down the runway.
- 1.1.16 After the aircraft was brought to a halt, the purser returned to the flight deck. The pilots and purser agreed that all appeared well and they would conclude the precautionary landing drills and continue to the terminal. The purser returned to the cabin to brief the 2 FAs while the captain prepared to taxi the aircraft back towards the terminal. As the purser met with the FAs, comment was made about a burning smell in the cabin. On seeing a “whitish grey smoke” starting to fill the cabin, the purser returned to the flight deck and reported the smell and observation of smoke to the pilots. The purser and pilots also observed a light smoke haze in the flight deck. The captain advised ATC and the attending Response Unit<sup>11</sup> crew chief that they were taxiing for the terminal as they were starting to get a smell in the cockpit. The pilots later reported that they were still able to breathe easily and the environment was acceptable, but they decided to open their side windows to help disperse the smoke on the flight deck. The captain also commented that they weren’t overly concerned as they had just turned downwind and unusual smells occasionally entered the aircraft from outside through the air conditioning system.
- 1.1.17 ZK-NGJ was taxied along the main taxiway about 800 m when the purser, followed by the FAs, returned to the flight deck and advised the pilots that the smoke was getting thicker in the cabin. After a short discussion, the captain told the crew to prepare for evacuation. The purser instructed the FAs to return to the rear of the aircraft and to await her signal to commence the evacuation. The captain brought the aircraft to a halt as he turned off the main taxiway onto stub taxiway B5, while the first officer started to lower flaps and advise ATC. On shutting down the engines, the captain called for the evacuation to commence. The purser gave a “thumbs up” to the FAs and then opened the forward left door, identified as 1L. The evacuation slide deployed automatically.
- 1.1.18 The 2 FAs said they were initially a little hesitant to open their doors, but on hearing the forward slide deploy they opened doors 3L and 3R at the rear of the aircraft. All slides deployed successfully. The passengers were then instructed to move towards the exits and vacate the aircraft. At the same time, the 2 pilots located at the over-wing exits, 2L and 2R, observed that flaps had not fully deployed so directed passengers to move forward or aft towards the door slides. The pilot at 2L also removed the emergency window exit to help clear the smoke in the cabin. As the evacuation commenced, the purser at 1L noted that the smoke was dissipating (see Figure 1).

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<sup>10</sup> Speed of the low pressure engine compressor (fan) stage.

<sup>11</sup> The Response Unit included the functions of the airport rescue fire service.

- 1.1.19 The evacuation was reported by crew and passengers to be orderly and unrushed. All cabin crew reported that some of the passengers took their carry-on bags with them as they moved to the exits. Rather than have the passengers leave their bags at the emergency exits, and thereby possibly block access to the exits and slow the evacuation, the cabin crew allowed passengers to take their bags with them down the slides.
- 1.1.20 Noting the clearing air and the situation with carry-on bags, the purser elected to remain at 1L to manage the passengers, rather than move across and open 1R, which would have left 1L unattended. By the time the pilots exited the flight deck into the cabin, there were about 8 passengers remaining to exit through 1L and possibly fewer through the rear 2 exits. After the last passenger had exited through 1L, the first officer and purser walked the length of the aircraft to ensure there were no remaining persons on board. The crew then exited the aircraft.



**Figure 1**  
**Boeing 737-319 ZK-NGJ**

- 1.1.21 After exiting the aircraft the passengers were directed by Response Unit personnel to an assembly area in front of the aircraft. Passengers were then taken by bus to the terminal.
- 1.1.22 The attending Response Unit personnel inspected the aircraft, and using heat-sensing equipment attempted to detect the origin of the smoke. No source was identified, so the aircraft was removed from the taxiway to a secure facility for further investigation.

## **1.2 Injuries to persons**

- 1.2.1 There were no injuries during the electrical malfunction or ground evacuation.
- 1.2.2 The operator's medical staff confirmed that passengers and crew suffered no significant smoke inhalation. Medical staff cleared the crew members to return to normal duties at their discretion.

### **1.3 Damage to aircraft**

1.3.1 There was no damage to the aircraft.

### **1.4 Other damage**

1.4.1 There was no other damage.

### **1.5 Personnel information**

1.5.1 The captain held an Airline Transport Pilot Licence (Aeroplane) and Class 1 Medical Certificate valid until 29 November 2006. He had joined the operator in 1994 and, after flying as a first officer on Boeing 737 and Airbus A320 aircraft, qualified as a captain on the Boeing 737 in April 2005.

1.5.2 The captain had flown some 11 135 hours, including about 5000 hours on the Boeing 737. His last instrument and simulator check ride had been on 22 April 2006 and last line check on 14 July 2006. He had flown 146 hours in the previous 90 days and had been off duty for 56 hours before the incident flight.

1.5.3 The first officer held an Airline Transport Pilot Licence (Aeroplane) and Class 1 Medical Certificate valid until 7 August 2007. He had joined the operator on 25 October 2004 and was rated on the aircraft type. He had flown some 6030 hours, including 1116 hours on the Boeing 737.

1.5.4 The first officer had been off duty for 48 hours before commencing duty on 12 September 2006. He had flown 126 hours in the previous 90 days. His last simulator check had been on 11 May 2006 and last line check on 18 August 2006.

1.5.5 The purser had joined the operator in April 1993 and qualified as a purser on 29 November 1999. She had last completed emergency procedures refresher training on 30 March 2006.

1.5.6 FA2 had joined the operator on 24 January 2005 and completed her emergency procedures refresher training on 19 January 2006.

1.5.7 FA3 had joined the operator in 1984 and had qualified in the purser and FA roles. She had last completed emergency procedures refresher training on 3 August 2006.

### **1.6 Aircraft information**

1.6.1 ZK-NGJ was a Boeing Commercial Aeroplanes (Boeing) 737-319, serial number 25609, line number 3130, constructed in the United States in December 1999 and delivered new to the operator on 9 January 2000. The aircraft was fitted with 2 General Electric CFM56-3C1 turbofan engines. The aircraft had been issued with a non-terminating Certificate of Airworthiness in the standard category.

1.6.2 According to the operator's records, at the time of the incident ZK-NGJ had accrued 16 703 flying hours and 18 758 cycles.<sup>12</sup> The records showed the aircraft had been maintained in accordance with its Certificate of Airworthiness and manufacturer's maintenance schedule.

1.6.3 ZK-NGJ's last scheduled major inspection had been a "C, 2C, 4C" check completed on 25 September 2005. The next check was planned for March 2007. The aircraft was also subject to daily inspections.

1.6.4 The APU was a self-contained gas turbine engine that supplied bleed air under pressure for starting the engines or air conditioning. An electrical generator on the APU provided auxiliary AC power. An unserviceable APU meant that a ground air supply needed to be connected to

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<sup>12</sup> A take-off and landing.

the aircraft to start the first engine. This could then be disconnected and thereafter the aircraft was self-sufficient in bleed air supply and electrical power generation.

- 1.6.5 During normal operation the Number 3 transformer rectifier unit (TRU) supplied 28-volt direct current (DC) power to the battery bus through the R1 relay. In the event of a main AC or TRU 3 failure the battery bus was able to be powered by the 28-volt hot battery bus. There was no warning system to alert pilots of a loss of battery bus power. To confirm a fault, the pilots could rotate the voltmeter selector on the overhead panel to battery bus and check the voltage reading (see Figure 2 for a diagram of the aircraft's basic electrical system).
- 1.6.6 The battery bus supplied 28-volt DC power to 56 systems, some of which were PA amplifier, standby horizon, clock display, master warning and control, anti-skid control and equipment cooling normal fan control.
- 1.6.7 A non-powered battery bus would also cause the landing gear air/ground sense relay to drop out, thus preventing the pneumatically driven aircraft air conditioning pack cooling turbfans from operating. When on the ground, this would cause a lack of cooling airflow through the air cycle machine (ACM) heat exchangers. The ACMs would overheat, causing any residual oil and other material in the ACMs and adjacent ducts to produce smoke and fumes, which could spread to the cabin and flight deck.

**QRH checklists**

- 1.6.8 The operator's QRH contained checklists for normal and non-normal actions, and guidance material on how the checklists should be used. The checklists were grouped in logical sections which matched the system description (for example air systems, communications, electrical, engines and fire). The checklists were also arranged in alphabetical order within each section.
- 1.6.9 The QRH was designed to be used when time permitted, possibly following a critical emergency where pilots had completed initial recall or memory actions. The checklists began with actions to correct a situation or condition, followed by information for planning the remainder of the flight. The QRH noted that it was "not possible to develop checklists for all conceivable situations, especially those involving multiple failures." In these situations "the flight crew may have to combine elements of more than one checklist and/or exercise judgement to determine the safest course of action. However, unless the safety of the aircraft is in doubt, do not attempt additional actions beyond that contained in the checklist".
- 1.6.10 Most of the checklists required a specific warning light or condition to then direct pilots to the appropriate checklist in the QRH. For example, illumination of the DUCT OVERHEAT light or the BLEED TRIP OFF light would direct pilots to the QRH checklist for that condition. Similarly, a concentration of air conditioning smoke or fumes would direct pilots to the smoke or fumes checklists.
- 1.6.11 The operator's checklist for ground evacuation contained within the first QRH section was as follows:

*PASSENGER EVACUATION*

*Condition: Evacuation of passengers and crew is required.*

*On the Captain's command, simultaneously accomplish individual checklist items.*

**CAPTAIN**

*PARKING BRAKE.....SET*

*SPEED BRAKE LEVER.....DOWN DETENT*

*[Prevents possible interference or injury to*

**FIRST OFFICER**

*FLAP LEVER 40*

*[Aids in evacuating passengers over the wing.]*

*STANDBY POWER SWITCHBAT*

*passengers evacuating through the overwing escape hatches.]*

*PRESSURIZATION MODE  
SELECTORMAN*

*ENGINE START LEVERS (both).... CUTOFF  
If time permits, verify flaps are full down before placing the engine start levers to CUTOFF.*

*OUTFLOW VALVE SWITCH OPEN  
[Ensures the airplane is depressurized for opening exits.]*

*[Shuts down the engines to reduce the possibility of slide damage or injury.]*

*TOWER NOTIFY*

*EVACUATION.....INITIATE  
Notify the cabin crew.*

*ENGINE AND APU FIRE WARNING  
SWITCHES...OVERRIDE PULL & ROTATE*

*Rotate engine fire switches in opposite directions.*

*Rotate all switches to the stop and hold for one second.*

*[Reduces the risk of fire and injury.]*

1.6.12 The QRH electrical section included the indications and action for a battery bus failure. The text was as follows:

*BATTERY BUS FAILURE*

*Any of the following symptoms could indicate that the battery bus has failed.*

- *NI zero*
- *FF zero*
- *Stby ADI failure*

*Note: The standby power Off light will only illuminate for loss of the AC standby bus. There is no light or message to indicate a battery bus failure.*

*If battery bus failure is suspected, select BAT BUS on the overhead DC meters and check reading.*

*If battery bus failure is confirmed:*

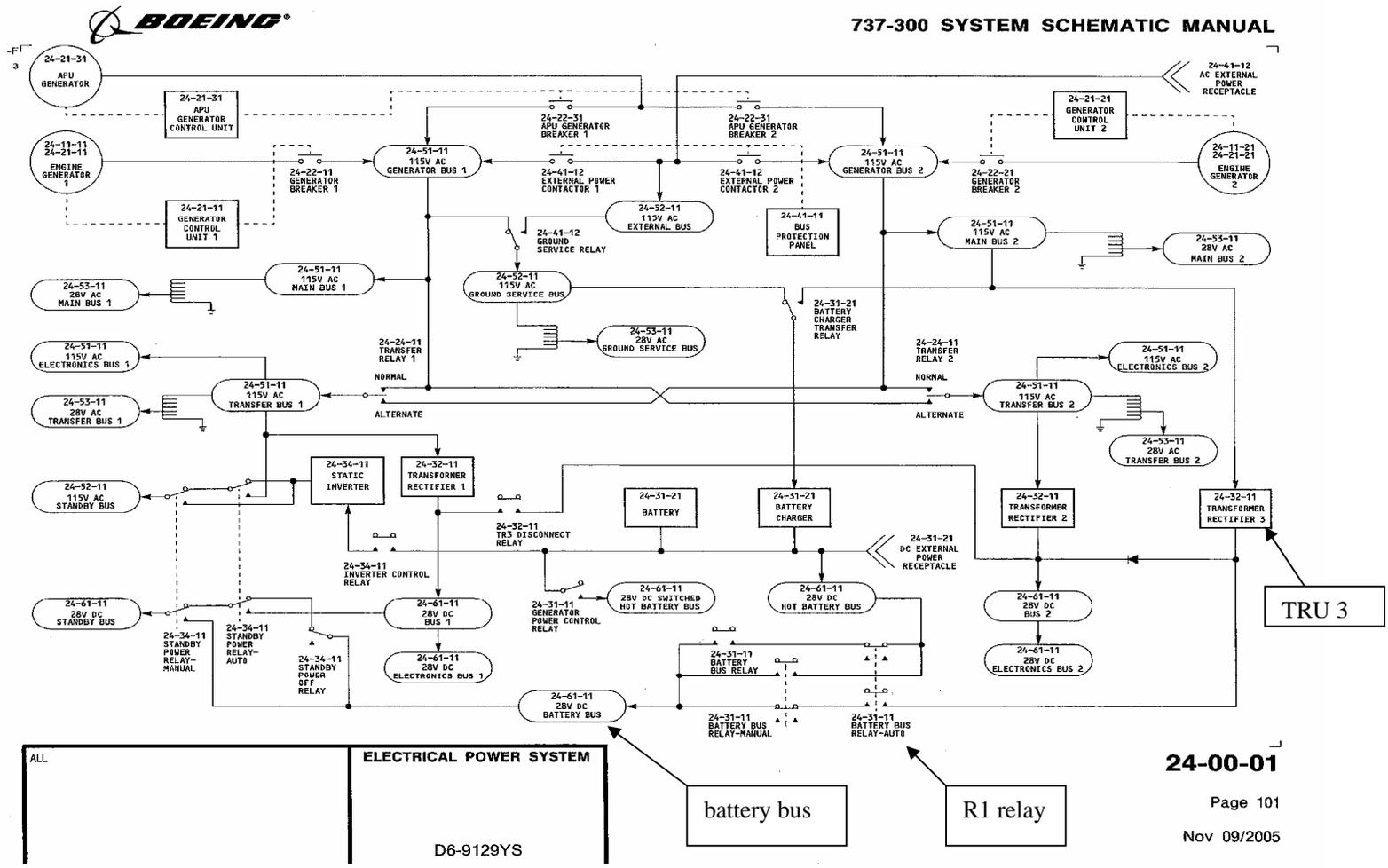
*STANDBY POWER SWITCH.....BAT*

*Restores battery bus.*

- *With one or both generator busses powered and the standby power switch selected to battery, the battery charger will supply power to the battery indefinitely.*

*Note: If battery bus not restored, landing gear green lights will also be inoperative.<sup>13</sup>*

<sup>13</sup> Air New Zealand 737 Operations Manual, Non-Normal Checklists, Electrical, page NNC.6.3, effective 2 May 2002.



**Figure 2**  
**Boeing 737-300 electrical diagram**  
 (Courtesy of Boeing Commercial Aeroplanes)

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- 1.6.13 The QRH landing gear section contained a checklist covering the landing gear lever not moving. The checklist was as follows:

*GEAR LEVER WILL NOT MOVE UP  
AFTER TAKEOFF*

*Condition: The landing gear lever cannot be placed to the UP position in the normal manner due to one or more of the following:*

- failure of the landing gear lever latch solenoid*
- failure of the air/ground system*
- failure of the ground spoiler bypass valve to close*

*Note: Do not use FMC fuel predictions.*

*LANDING GEAR LEVER .....DOWN*

*If the takeoff configuration warning remains silent after the flaps are fully retracted and the thrust levers are beyond the vertical position:*

*Note: This condition indicates a failure of the landing gear latch solenoid.*

*LANDING GEAR OVERRIDE TRIGGER.....PULL*

*LANDING GEAR LEVER .....UP & OFF*

*Continue normal flight after landing gear retraction.*

*If the takeoff configuration warning sounds when flaps are fully retracted:*

*Note: This condition indicates a failure of the air/ground system.*

*LANDING GEAR AIR/GND RELAY  
AND LIGHTS C/B (P6).....PULL*

*Note: Identification of the Landing Gear Lights C/B is aided by a blue collar.*

*Plan to land at the nearest suitable airport.*

*CAUTION: Do not operate the speed brakes in flight.*

*(Note: The checklist continued with deferred items in preparation for landing.)*

- 1.6.14 As part of the Boeing 737's certification requirements, the manufacturer was required to demonstrate a full ground evacuation of the aircraft within 90 seconds using half the emergency exits that were fitted to the aircraft. For the Boeing 737 this was 3 doors only, including the normal passenger entry and exit door at 1L.

## **1.7 Meteorological information**

- 1.7.1 The weather conditions at Auckland International Airport were reported as a surface wind of 150°M at 5 kt. Visibility was in excess of 40 km and the cloud base was 5000 ft.

## **1.8 Aids to navigation**

- 1.8.1 All navigation aids were recorded as serviceable. Although the crew tuned and identified an instrument landing system approach for runway 23, the instrument approach was not flown.

## **1.9 Communication**

- 1.9.1 All radio-telephone and ATC communications were normal. The Commission obtained an audio tape of ATC communications recorded during the incident.

## **1.10 Flight recorders**

- 1.10.1 ZK-NGJ was fitted with a digital flight data recorder (DFDR) capable of recording 40 parameters, and a solid-state cockpit voice recorder (CVR) capable of recording the last 30 minutes of communications.
- 1.10.2 The CVR was secured until the completion of the interviews with the 5 crew members and the return to service of the aircraft following the identification of the cause of the electrical malfunction. The CVR was returned to the operator without the recording being downloaded.
- 1.10.3 The DFDR information was downloaded for analysis by the Commission. No unusual parameters were noted until the aircraft reached 115 kt during the take-off roll. At this time the gear position for the nose and left and right landing gear changed from Down to Up. The next sample, one second later at 0728:07, recorded the air/ground relay indication for the left and right main landing gear changing from Ground to Air. The nose gear remained on Ground. These indications remained constant for the duration of the flight. Also at this time, the clock stopped. About 4 seconds later the engine temperature, fuel flow and N<sub>1</sub> and N<sub>2</sub> engine readings became erratic and unreliable.

## **1.11 Fire**

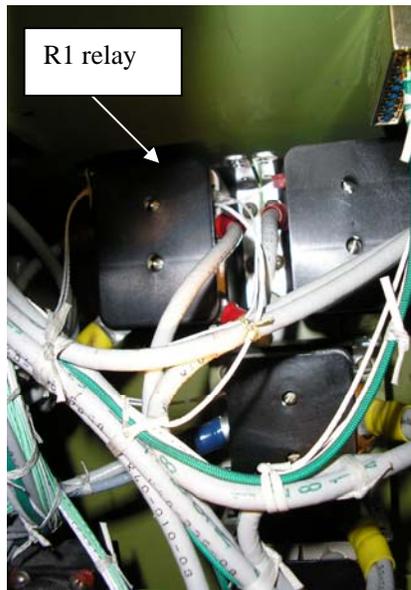
- 1.11.1 There was no fire. The haze observed in the cabin and flight deck was identified as originating from the aircraft's air conditioning system, probably from residual dust and oil that became heated to the point of giving off fumes.

## **1.12 Survival aspects**

- 1.12.1 Auckland International Airport Limited's closed-circuit television (CCTV) coverage of the evacuation was limited to the right side of ZK-NGJ. This, combined with the presence of 7 children and 2 infants among the passengers, meant that an exact count of evacuees through each door was not possible. However, an examination of the recordings indicated about 57 evacuees exited through door 1L, 17 through 3L and 27 through 3R.
- 1.12.2 ZK-NGJ was recorded being brought to a halt at about 0756 on the CCTV. The first slide, 1L, was deployed 20 seconds later, followed by the deployments of slides 3L and 3R after another 9 and 10 seconds respectively. From the deployment of the slides, about 8 to 10 seconds elapsed before passengers were observed vacating the aircraft. The last passenger vacated the aircraft 2 minutes and 9 seconds after the deployment of the first slide, and the last crew member 25 seconds later.
- 1.12.3 The recording showed Response Unit vehicles following ZK-NGJ as it came to a halt in preparation for the evacuation. The majority of the vehicles were then positioned at the front of the aircraft where an assembly area was established. Initially one then a second vehicle were positioned behind the aircraft, with 2 Response Unit personnel moving forward to assist at slides 3R and 3L.

## 1.13 Tests and research

- 1.13.1 Under the supervision of the Commission, ZK-NGJ was inspected and, after no fault was found, aircraft battery power, followed by ground power, were connected to the aircraft. Again no fault was identified, so a low-power engine ground run was conducted with the aircraft-engine-driven electrical generators providing all the electrical power. During the ground run a smell was noted to start and found to originate from the aircraft air conditioning vents. An examination of the aircraft electrical buses at this time identified that the battery bus was not powered and the fault was eventually traced to the R1 electrical relay (see Figure 3). The relay was replaced and after a second ground run the aircraft was test flown and returned to service.



**Figure 3**  
**Installation of R1 relay on Boeing 737-300 aircraft**

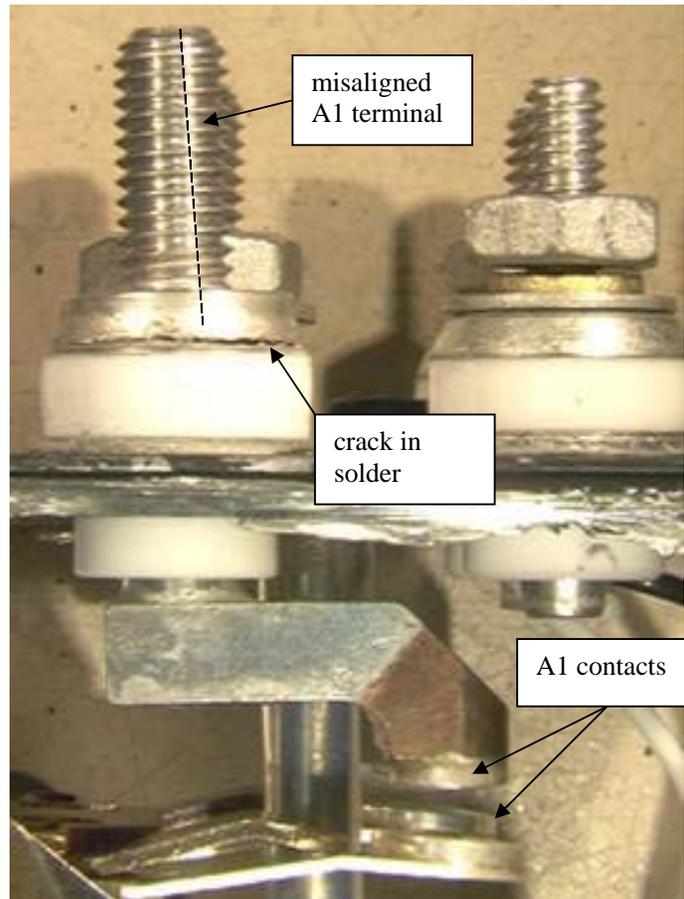
- 1.13.2 The R1 relay was examined to determine the mode of failure. The relay was identified as a Leach International H-X9A-101 relay, serial number 03320, manufactured in 1998 and fitted to ZK-NGJ at production. Visual, microscopic and X-ray examinations identified no defects other than that one of the terminal posts was misaligned and there was a partial circumferential fracture or crack in the solder junction at the base of the terminal where the post entered the relay case (see Figure 4).
- 1.13.3 The relay was subjected to electrical testing at near-rated loads for 4 hours, followed by the contacts being cycled 25 times. To further simulate flight conditions, the relay received random vibrations and shocks during the testing. The relay performed as designed.
- 1.13.4 The relay cover was removed and further load testing undertaken, resulting in arcing being observed on the A1 contact pair at both make and break.<sup>14</sup> Further examination identified a larger gap at open for the A1 contact pair than the A2 contact pair, at 0.072 inches and 0.042 inches (1.82 mm and 1.06 mm) respectively. Evidence of arcing and material transfer was also noted on the A1 contact pair. The B contacts were considered normal.
- 1.13.5 During further testing the force required to open the electrically closed contacts was measured. The A1 contact set required a 50-gram force to open, reducing to 25 grams after 20 minutes. The A2 contact set recorded 376.5 grams, reducing to 375 grams after 20 minutes. The

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<sup>14</sup> Contacts closed and open.

B contact sets were all about 375 grams. The manufacturer's specifications for normal opening were 400 to 450 grams.

- 1.13.6 Boeing advised the Commission that "cracking of the solder junction in earlier manufactured relays has previously been documented". Boeing noted that voids in the solder reduced the ability of the junction to withstand torque being applied during repeated removal or installation of the wire lugs attached to the terminal. Further, the stress condition could be exacerbated by the attached wiring bending or vibrating.



**Figure 4**  
**Side view of A1 terminal and contact assembly**  
(Courtesy of Boeing)

Boeing believed that the failure in ZK-NGJ was unique in that the contact gap at A1 was so large in comparison with A2. Boeing reported that there was "no data or experience to suggest this discrepancy is the result of a batch or widespread problem". Boeing also noted that "this condition has not previously been witnessed during any previous analysis at Boeing". The relay manufacturer has been notified of these findings and the apparent manufacturing discrepancy.

- 1.13.7 The R1 type relay was used on 5 locations on the Boeing 737-300 and later models of 737 aircraft, and 3 locations on earlier models. The relay was an "on condition" item, serialised but not tracked. This meant that the relay would normally only be removed from an aircraft in the event of a failure or perhaps if required as a replacement for another relay. The manufacturing origin of a relay could therefore be identified but not necessarily the in-service history.

- 1.13.8 Boeing reported that in response to early operator reports of the deteriorating performance of the original Antex model of relay, the Hartman DH-7JA relay was approved as a replacement part from about March 1992. This relay was installed on production aircraft from this time. In June 1994, the Hartman relay was replaced by the Leach International H-X9A-101 relay, which had an “improved inrush current handling capability”. Boeing advised this was the preferred relay type to replace the Antex and Hartman relays. The type of relay fitted to ZK-NGJ was the later Leach International H-X9A-101.
- 1.13.9 The operator reported 5 previous occurrences of relay failure of the same type as the R1 relay over the entire fleet of Boeing 737 aircraft. Of these, one was an R1 relay failure that occurred on 17 June 2006. The failure occurred after landing and as the aircraft was taxiing to a gate. The mode of failure of the relay was not determined as the relay was replaced and disposed of without further testing. The remaining 4 failures were in the R355 relay position, also known as the battery bus relay located between the hot battery bus and the battery bus. Again, the relays were replaced without testing.
- 1.13.10 Boeing advised that failure of the relays was considered most likely to occur when the relay changed position, normally associated with start-up and shutdown that is, before and after flight. Typically, following the identification of a fault, the relay would be replaced and there would be no further investigation.
- 1.13.11 During the investigation, the Commission was made aware of 2 in-flight failures of R1 relays on Boeing 737 aircraft, concerning Hartman or Leach types of relay. The first involved a Boeing 737-300 and occurred as the aircraft was on approach to land at Copenhagen Airport, Denmark on 20 July 1997.<sup>15</sup> After landing, smoke was observed in the cockpit and cabin and a successful ground evacuation was completed using the aircraft’s 4 slides. The relay was identified as a Hartman DH-7JA model of relay. In its report, the investigating authority recommended that the national aviation regulator evaluate the performance of the R1 relay. In response, the report recorded that Boeing issued a Service Letter informing operators of the preferred relay, the Leach International H-X9A-101, for use in 737 aircraft.
- 1.13.12 The second event concerned a Boeing 737-33V on 22 March 2005. The aircraft was flying from Nice, France to Luton, Great Britain when the crew experienced “progressive abnormal annunciator indications”.<sup>16</sup> The aircraft was diverted to Lyons, France. “After an uneventful landing, the commander made a reassuring PA to passengers ... and the aircraft was taxied to a stand and shut down without further incident.” According to available information, the relay was a Leach model relay. The investigating authority, the British Air Accidents Investigation Branch (AAIB), subsequently recommended that a procedure be developed to deal with a loss of power from the battery bus.
- 1.13.13 In an incident in August 2006 that was investigated by the AAIB, a Boeing 737-36Q had 2 intermittent in-flight battery bus failures before a third failure during taxi confirmed a fault with the R1 relay.<sup>17</sup> The AAIB report restated the recommendation for a procedure for loss of battery bus power. The report also noted that a generic procedure was impracticable due to the “high number of different electrical system configurations on affected aircraft”. Further, Boeing had issued an Alert Service Bulletin on the subject (refer paragraph 1.15.2).
- 1.13.14 In each of the above cases, the mode of failure was different: a bent B1 contact blade or a broken post, possibly due to fatigue. In the first 2 incidents the pilots did not have checklists to cover battery bus failure. Safety recommendations were made by the relevant investigating authorities to address that issue.

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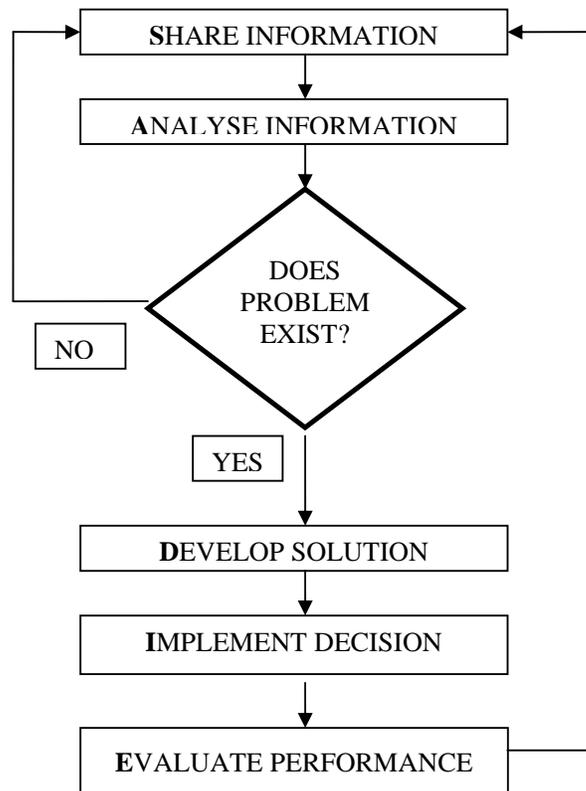
<sup>15</sup> Danish Air Accident Investigation Board Report HCL 34/97, EI-CDT, 20 July 1997.

<sup>16</sup> AAIB Bulletin 4/2006, G-EZYN, 22 March 2005.

<sup>17</sup> AAIB Bulletin 1/2007, G-THOJ, 13 August 2006

## 1.14 Organisational and management information

- 1.14.1 On initial induction to the operator, pilots and cabin crew were given information on CRM and its objectives within the company. Within 12 months of joining, crews were put through specific CRM training provided by the operator. Pilots undertook a 3-day course, with cabin crew normally joining them for the first day. Additional and refresher CRM training was given during later upgrade courses.
- 1.14.2 Subjects covered during the 3-day course included teamwork, decision-making, communications, information processing, leadership, performance indicators and situational awareness. These subjects were supported by case studies and practical exercises.
- 1.14.3 According to the operator, central to having an effective CRM process was the use of a decision-making tool called SADIE, an acronym for **S**haring and **A**nalysing information, **D**eveloping solutions, **I**mplementing decisions and **E**valuating performance. The SADIE diagram was as follows:



- 1.14.4 The operator informed the Commission that, during emergency training, cabin crew were instructed in the use of multiple exits for evacuations. This enabled flexibility, with one crew member being able to operate and manage 2 doors and evacuation slides should a second crew member not be available. Passengers seated in the exit rows adjacent to the over-wing exits were provided with an additional briefing card describing the use of the exits, and asked if they were willing and able to assist in any evacuation.
- 1.14.5 The operator's safety and emergency procedures directed that cabin crew were to "use all usable exits". To complement this, the briefing cards and cabin crew training emphasised that, while the Boeing 737 was equipped with 6 emergency exits, they might not all be available for an evacuation. For example, an engine fire or a very strong wind on one side of the aircraft could

restrict evacuation to the opposite side only. Cabin crew and passengers were therefore to exercise their discretion on which exits were used.

- 1.14.6 The operator's Boeing 737 passenger evacuation checklist was described in the operations manual and was to be initiated by the captain. The checklist required simultaneous actions by the flight crew, with the first officer to lower flaps followed by the captain shutting down the engines and then notifying the cabin crew to initiate evacuation.<sup>18</sup>

## **1.15 Additional information**

- 1.15.1 On 4 August 1998, Boeing issued Flight Operations Technical Bulletin 737-300/400/500 98-1, describing the possible indications of a loss of battery bus due to electrical system relay failures. This was updated on 19 May 2005 with Bulletin 737-98 R1. Boeing advised operators that it would not issue a generic checklist for battery bus failure due to the "many different electrical configurations throughout the 737 fleet". Boeing considered the loss of battery bus power not to be hazardous, as "normal AC power would provide sufficient instrument indications to the flight crew for continued safe flight and landing". However, Boeing had no objections to operators incorporating procedures for a loss of battery bus power specific to their models of 737 into their manuals.
- 1.15.2 On 20 June 2006, Boeing issued Alert Service Bulletin 737-21A1156, advising operators of 737-300/400/500 airplanes that there was no warning in the event of a battery bus failure. Should such a failure occur, the standby horizon, the equipment cooling normal supply fan for the EFIS and the cooling low-air-flow sensor would not function. The loss of the equipment cooling fan would cause the EFIS to get hot. Once too hot the EFIS would "automatically stop operation by first going to monochromatic and then, after 60 minutes or more, it will power-down". The pilots would then be left without any attitude indication.
- 1.15.3 The Alert Service Bulletin gave instructions to separate the normal supply fan control power wiring for the EFIS equipment cooling system from the equipment low-air-flow sensor power. Illumination of the equipment cooling supply off light would alert the pilots to a loss of EFIS cooling, requiring the selection of the alternative power supply. It would also give an indication of a possible loss of battery bus power.
- 1.15.4 The operator advised the Commission that it had reviewed the Alert Service Bulletin and asked Boeing to provide further information before proceeding with fleet-wide implementation of the Bulletin.
- 1.15.5 On 26 September 2006, the United States Federal Aviation Administration (FAA) advised the Commission that work was under way to issue an airworthiness directive to make the actions of the above Alert Service Bulletin compulsory for operators to implement.

## **2 Analysis**

- 2.1 Flight NZ503 was a scheduled flight from Auckland to Christchurch by a qualified crew. The aircraft was recorded as serviceable for the flight, with a faulty APU annotated as an acceptable deferred item. The flight proceeded normally until part-way through the take-off roll when the captain observed the gyro flag showing on the standby horizon indicator instrument.

### **Electrical malfunction**

- 2.2 The electrical failure indications that the flight crew reported were all consistent with a loss of power to the battery bus. Subsequent ground testing identified the R1 relay as the cause for the loss of power supply. Further specialist testing and examination of the relay showed a larger-

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<sup>18</sup> 737 Operations Manual, pages NNC.0.11 and 12, Passenger Evacuation, dated 20 July 2006.

than-normal gap between the A1 contact pair, probably resulting from the terminal post being misaligned during manufacture. Over time, the contacts overheated, causing arcing and fatigue. A fracture at the base of terminal stud A1 was initiated and propagated around the solder junction, increasing the gap, causing material transfer and further reducing the contact forces. Eventually there was sufficient vibration during the take-off roll to cause the contacts to release and stop current flow to the battery bus.

- 2.3 The report by the previous flight crew, and the observation by the pilots of NZ503, of a loud “clunk” during the start and when ground power was disconnected, may have been related to the deteriorating condition of the R1 relay. However, this was not proved and while perhaps not normal was nevertheless not unusual or severe enough to cause further investigation.
- 2.4 The failure of an R1 relay, while serious, should not be critical to the safe conduct of a flight. If the failure occurred during the cruise phase of a flight, pilots would have time to diagnose the fault and select the alternative power supply to the battery bus. The normal flow of cooler air should ensure that flight-critical instruments, such as the EFIS, would remain fully functional for longer periods. Even after overheating and changing to the monochromatic mode, the EFIS would still provide useful information for at least a further 60 minutes.
- 2.5 For the approach and landing phase, pilots would still have been able to fly an instrument or visual approach and have full flap available for the landing. The landing gear would be able to be lowered normally, followed by a visual check to confirm that the gear was down and locked.
- 2.6 The most significant aspect of a loss of battery bus power has occurred after landing and during the taxi. The loss of the aircraft air conditioning pack cooling turbofans and the associated lack of cooling airflow through the ACM heat exchangers resulted in the ACMs overheating, causing fumes from residue oil and other material to enter the cabin. This has necessitated passenger evacuations on at least 2 other occasions.
- 2.7 Failures of the R1 relay on Boeing 737 aircraft were not common, especially in-flight failures. However, it was not possible to obtain an accurate figure of R1 failures as most failures were likely to have occurred on the ground during start or shutdown and the faulty part replaced with little or no technical investigation, and no statistical data retained or centrally collated.
- 2.8 Of the in-flight failures of the R1 relay that were investigated, all had different modes of failure. While the newer models of relay may offer improvements over previous types, until statistical data on the mean failure rate and types of failure is gathered, operators and pilots need to be alert to the possibility of a failure occurring and the appropriate actions to be taken.
- 2.9 The operator’s inclusion of a battery bus failure checklist partly addressed the need for pilots to have a set of actions to remedy a fault. However, pilots also needed to be directed to look at the overhead DC meters and check the voltage to confirm a bus failure.
- 2.10 The implementation of Boeing Alert Service Bulletin 737-21A1156, concerning warning and alternative power supply for EFIS cooling, should provide greater instrument reliability. It could also give pilots an added direct indication of a loss of battery bus power. Once a Service Bulletin was issued as an airworthiness directive, operators were required to implement it as instructed.

### **Crew actions**

- 2.11 The crew of NZ503 accomplished their primary tasks of getting the aircraft back onto the ground and then evacuating the passengers without injury. This section of the report focuses on the crew’s actions, both during the flight and after landing, and identifies the lessons that can be learnt.
- 2.12 Flight and cabin crews were trained to be able to handle a wide range of normal and abnormal situations. While much of the training was conducted separately due to the specialist nature of

the crew positions, regular joint training was also performed to ensure all crew members were able to operate as a cohesive unit. Central to any training was the use of standardised checklists and procedures to ensure the rapid and effective handling of a situation.

- 2.13 Emergency procedures in particular enabled a crew to perform in a coordinated manner under the most demanding conditions, and should be adhered to whenever possible. Notwithstanding the above comments, crew members were often in the best position to assess a situation and were therefore directed to use sound judgement to determine the safest course of action.
- 2.14 The loss of power to the battery bus occurred at about 115 kt during the take-off roll – a time of high workload for the pilots. The captain’s decision in not calling for the first officer to stop the take-off for the failure of a standby horizon indicator was in this case correct because this was not a critical instrument for this stage of the flight. It was also not apparent at that time that this was part of a greater system failure. To have stopped the take-off may have exposed the aircraft to greater risk.
- 2.15 The first failure the pilots observed once airborne was their inability to raise the landing gear lever. This was associated with a loss of gear position indicator lights. The pilots’ decisions to stop the climb, remain in visual meteorological conditions, address the problem or problems and return to Auckland were reasonable in this case. Had the pilots needed to raise the landing gear in the event of another emergency or to divert to another more suitable aerodrome, the override trigger could have been pulled and the gear retracted.
- 2.16 The lack of intercom and PA meant that the purser needed to have ready access to the flight deck, so the decision to leave the door unlocked, although not standard practice, was reasonable. The flow of information and instructions between flight and cabin crew and between individuals was timely and effective. This highlighted the benefits of having good CRM and emergency procedures training, including the use of tools like the SADIE model.
- 2.17 The actions of the cabin crew in dividing the cabin into sections and individually briefing the passengers for the return were efficient and effective. This was not an emergency return requiring a fully prepared cabin. Rather it was expected to be a normal landing and the crew was being vigilant.
- 2.18 The pilots, having stopped the departure and positioned the aircraft on a safe heading and altitude, were then faced with an increasing number of electrical faults. The priority now was not in raising the landing gear but in maintaining the safety of the aircraft. Knowing that they were returning to land as soon as possible, it was advantageous to leave the gear down and not try to analyse this fault further. The priority and focus became how to manage the various electrical and instrument failures.
- 2.19 Given the timing of the failure and the lack of a single flight deck warning indication of a battery bus failure, the pilots observed what appeared to them to be an “escalating” number of electrical malfunctions as the flight continued. Some failures were seemingly unrelated; others, like the landing gear lever and position lights, were potentially connected.
- 2.20 Unrelated multiple malfunctions, while possible, were rare. It would be easy to say that the pilots should have associated a large number of electrical failures with a common source for example, a generator, bus or relay and therefore focused attention on the electrical panel to identify a potential cause. The 3 symptoms identified in the battery bus relay failure QRH checklist (N<sub>1</sub> zero, FF zero and Standby ADI failure) were all showing and had been noticed by the pilots. However, the pilots were not able to decipher these 3 failures among the array of other failures. Also, there were no caution panel alerts as would often be the case to direct the crew to a particular checklist.
- 2.21 As described in the SADIE model, the pilots conducted several “evaluations” of the situation to identify what had failed, and what other actions were required before landing. However, they did not do any extended fault analysis to determine how the landing might be affected and therefore did not identify that reverse thrust would not be available for landing. From the pilots’

perspective, their priority was landing the aircraft as soon as possible, they had full control of the aircraft and sufficient operating systems to make a safe landing, and they believed they did not have the time to do anything other than the essential actions required to land the aircraft. With more than ample runway length available, the loss of auto-braking was not crucial. Neither was the unavailability of reverse thrust, but it would have been preferable to have known that rather than find out at a crucial time of flight, on landing.

- 2.22 The captain had overall responsibility for the safe management of the flight. He also had discretion of when and how checklists, including the QRH, were to be run. As discussed above, there were no caution panel alerts to indicate which checklist to use. Indeed, there were no checklists for the loss of an engine indication and pilots were instructed to continue normally unless a limit was exceeded. The captain, having determined the aircraft was safe to fly, prioritised his actions in returning to land as soon as possible, and not in trying to identify the cause or causes of the multiple failures displayed around the flight deck. Consequently the aircraft was landed within about 20 minutes of the crew recognising they had a major problem.
- 2.23 There would have been some degree of relief amongst the flight and cabin crew after ZK-NGJ was landed. With the “precautionary landing” satisfactorily completed, the objective now was to return to a gate to disembark the passengers. The first report of a smell and smoke in the cabin, followed by the observation of a “light smoke haze” on the flight deck focused the pilots on this new event. They assessed the situation and, while obviously concerned, determined that the level of smoke would not prohibit them from safely reaching the gate and shutting down the aircraft.
- 2.24 Smells entering the aircraft, especially when following another aircraft or turning downwind during taxi, did occasionally occur and usually only required close monitoring. However, the report and observation of smoke should have raised concerns about a possible escalation of the in-flight emergency for which a cause had not been identified at that stage.
- 2.25 There was ample overseas evidence of fire spreading quickly through aircraft on the ground causing numerous injuries and fatalities. For ZK-NGJ the level of smoke eventually reached the point that the crew knew an evacuation was necessary. While there was no sign of fire, meaning no flame or heat, it would have been prudent for the captain to call for an immediate evacuation on the first report of smoke. In cases of fire, to delay an evacuation call or permit a slower evacuation to occur increases the potential for significant serious harm.
- 2.26 The evacuation of the aircraft was successful, in that all passengers and crew escaped without injury. From the deployment of the first slide, passenger evacuation took 129 seconds. The total evacuation time, including the crew, took 151 seconds. This was against the certification requirement of 90 seconds for a full evacuation with only half the number of exits available. With ZK-NGJ, because the crew did not think they were escaping a life-threatening scenario, their priority was on vacating the aircraft in an orderly manner and preventing injuries, and so the extra time taken was understandable.
- 2.27 The evacuation highlighted the interaction between the passengers and crew during an emergency situation. Shortly after the cabin exits were opened and evacuation was commenced, passengers realised that there was no obvious danger and so started to take their carry-on bags with them. This action was reinforced when the cabin crew did not immediately counter the practice. The cabin crew then identified the greatest danger as a blocked exit, so allowed the bags to be carried with the passengers down the slides.
- 2.28 Immediately and more forcibly directing passengers to vacate and leave their bags behind at their seats or in the overhead lockers, possibly by using aircraft megaphones if necessary, should assist in a speedier evacuation the conundrum being that injuries were more likely to occur the more rapid the evacuation. However, at that time the cause of the smoke had still not been identified and notwithstanding the smoke having started to dissipate, the situation could have been more serious than it actually was. Fires can be unpredictable and smoke and fumes can be highly toxic. The risk of minor or moderate injury to passengers is more acceptable than loss of life.

- 2.29 There was about a 10-second delay between the opening of the forward exit, 1L, and the 2 rear exits. This was due in part to FA2 and FA3 wanting to have confirmation of the “thumbs up” instruction by the purser. Any hesitation was soon dispelled once they heard the forward slide deploying.
- 2.30 The “thumbs up” was a standardised signal taught under alternative cabin clearance procedures. Again, because there was no fire, crew members had more time to assess the threats and act accordingly. However, the “thumbs up” signal can also have other meanings, so either training should be enhanced to clarify the use of the signal, or another form of the signal should be developed to remove the possibility of any confusion or hesitation in the future.
- 2.31 The distribution of passengers through the 3 emergency exits, with over half vacating through the forward 1L exit, was as expected. Passengers will tend to use the exit they are facing or the door through which they entered the aircraft, which was 1L in both cases. The cabin safety briefing given by the operator before each flight correctly emphasised the location and use of the nearest exit. However, crews should be aware that door 1L will continue to be the preferred exit door in most cases.
- 2.32 The decision by the purser to stay at door 1L and not move across and open 1R was reasonable in this situation. Despite the direction given in the manuals, leaving a door unattended especially with infants, children and elderly among the passengers could have resulted in unnecessary injuries. However, any decision to open one or both forward doors needs to be made quickly by the attending crew member. Further, the positioning or repositioning of crew members about the aircraft for prepared emergency landings should also be considered.
- 2.33 The 2 transiting company pilots repositioned to the centre exits row were vigilant in recognising that the flaps had not fully deployed and in directing passengers to the forward or rear exits. The flaps did not fully deploy, despite being selected, because the crew were eager to shut down the engines and gave insufficient time for the flaps to run fully down before operating hydraulic pressure was lost. Had passengers been required to evacuate via the over-wing exits, injury may have resulted from their needing to jump the nearly 2 m to the ground. Where time permits, flight crews need to positively check that the flaps have been fully lowered before shutting down the engines, thereby ensuring that the maximum number of exits is available for use. Alternately, the crew knowingly shutting down the engines immediately and accepting that flaps may not have extended.
- 2.34 A safety recommendation was made to the Director of Civil Aviation for operators of Boeing 737 aircraft to review emergency training procedures and to take into consideration the positioning of cabin crew for abnormal landings, the use of hand signals, the running of evacuation checklists and crew management of passengers during evacuations.
- 2.35 The purser’s use of the 2 additional crew members was a good use of resources. However, it should be standard practice to have transiting flight or cabin crew seated adjacent to the emergency exits before the commencement of a flight where practicable. This would avoid the additional workload of relocating passengers and aircrew before landing, especially when there is little or no warning of an emergency landing or evacuation.
- 2.36 The reactions by ATC and the aerodrome Response Unit to the initial electrical malfunction and the need to land immediately, and the evacuation, were in accordance with emergency response procedures. The proximity of the Response Unit vehicles when the evacuation commenced meant that rescue personnel were able to provide assistance as required and direct passengers to the assembly area forward of the aircraft. They were also correctly positioned should a fire have erupted.

### 3 Findings

Findings are listed in order of development and not in order of priority.

- 3.1 The aircraft was serviceable and correctly crewed for the flight.
- 3.2 The flight and cabin crews were appropriately qualified, fit and rested for the flight.
- 3.3 An R1 electrical relay failure caused the loss of power to the battery bus, which in turn caused a loss of power to numerous items of equipment and indications.
- 3.4 The failure of the electrical relay occurred during the take-off when the flight crew did not have time to identify the fault immediately.
- 3.5 The timing of the escalating failures at a critical phase of flight, during take-off and while under radar control, created a high workload for the pilots which made troubleshooting the failures more difficult.
- 3.6 The pilots' actions in abandoning the flight and returning to land as soon as possible were appropriate.
- 3.7 The indications noticed by the pilots following departure were indicative of an electrical failure of some sort. A better first-hand knowledge of the contents of the QRH should have directed the pilots to the battery bus failure checklist, which would have resolved the emergency at an early stage of the flight.
- 3.8 The aircraft was capable of safe flight even with the loss of battery bus power.
- 3.9 The evidence suggested that the failure of the electrical relay was caused by its contacts releasing through a combination of vibration and low holding force.
- 3.10 The evidence available pointed to the relay failure having its origins at manufacture, which led to its condition progressively deteriorating over time.
- 3.11 The relay manufacturing fault appeared to be isolated.
- 3.12 Given the number of known and unknown causes of R1 relay failures, confidence in the performance of the relay needs to be supported by statistical data.
- 3.13 The fumes that entered the aircraft were from residue oil and other material that overheated in the air conditioning system, which reduced as soon as the aircraft engines were shut down.
- 3.14 Although in hindsight the use of only 3 slides was adequate for this evacuation, without the knowledge of what was causing the smoke, the crew should have followed standard operating procedures and used all available or suitable exits.
- 3.15 The evacuation time could have been reduced by:
  - the reallocation of resources, including the repositioning of cabin crew;
  - the use of all the exits; and
  - a more urgent initial approach to the evacuation.
- 3.16 Unable to identify the cause of the in-flight emergency and then confronted with smoke appearing in the aircraft after landing, the crew would have been wise to initiate an immediate and rapid evacuation.

## 4 Safety Actions

- 4.1 On Friday 15 September, 3 days after the incident, the operator's Boeing 737 Fleet Manager issued a memo to all Boeing 737 flight and cabin crew advising them of the incident, the likely cause and the actions in the event of an R1 relay failure and subsequent loss of battery bus power. On 21 September the Fleet Manager issued a follow-up memo to all Boeing 737 pilots providing greater technical detail of the R1 relay failure, the indications of a loss of battery bus electrical power and required actions.
- 4.2 On 14 February 2007 the FAA determined that "an Airworthiness Directive will be issued by way of NPRM [Notice of Proposed Rule Making] which will mandate the affected operators to incorporate the corrective actions proposed by the Boeing Service Bulletin 737-21A1156". At the time of writing this report, the operator confirmed that it intended to action the Boeing Alert Service Bulletin 737-21A1156. A QRH procedure was also to be added to address EFIS display degradation. This would provide an added defence against pilots not recognising a loss of battery bus power and would ensure they had adequate attitude reference information to land aircraft safely.
- 4.3 On 16 November 2007, Boeing issued Service Bulletin 737-21A1156, Revision 1. The FAA subsequently reviewed the bulletin and was proceeding with the NPRM. FAA anticipated the NPRM will be issued for public comment "around June 2008 or sooner".
- 4.4 The operator had amended maintenance procedures to allow the tracking of Leach International H-X9A-101 relays installed on the fleet of Boeing 737 aircraft. This would assist in establishing an accurate indication of the performance of the relay.
- 4.5 The operator advised that pilot simulator training would include elements of a loss of battery bus power in its range of aircraft emergencies given to pilots. Pilot and cabin crew CRM training would also use the lessons learnt from the loss of electrical power, in particular the lack of the communications, and the evacuation.
- 4.6 The operator advised that check-in staff would be reminded that, where possible and practicable, transiting flight crew should be allocated seats adjacent to aircraft over-wing exits.

## 5 Safety Recommendations

5.1 On 5 June 2007 the Commission recommended to the Director of Civil Aviation that he:

- 5.1.1 ensure that the Chief Executive of Air New Zealand and other New Zealand operators of Boeing 737 aircraft review and enhance emergency training procedures. The review should include the positioning of all crew members on board for abnormal landings and possible evacuations, and the associated use of all appropriate emergency exits, the use of hand signals in emergencies and the management of the ground evacuation checklist to ensure that flap has been fully deployed if time permits. (007/07)
- 5.1.2 promote the lessons learnt from this incident, in particular the value of good CRM training and the use of resources. (008/07)

5.2 On 14 June 2007, the Director of Civil Aviation replied:

- 5.2.1 I will accept this recommendation and this will be carried out as part of our regular meetings with operators and will be completed within six months of the final report date. (007/07)
- 5.2.2 I will accept this recommendation and will write to all operators of aircraft with more than 19 passenger seats, drawing attention to the report posted on the TAIC website within three months of the report being promulgated. This will promote the lessons learnt from this incident, in particular the value of good CRM training and use of resources. (008/07)

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