Limited review by Lt-Col (ret'd) Harry Horlings/ AvioConsult, graduate FTE of the USAF Test Pilot School (class 1985A) and former chief Flight Test of the Royal Netherlands Air Force.

The sole objective of this review is the improvement of investigations of engine failure related accidents to prevent future accidents. It is not the purpose of this activity to apportion blame or liability.

Australian Government
Australian Transport Safety Bureau

A written analysis of the control and performance of this accident is included in the paper ***Airplane Control and Analysis of Accidents after Engine Failure*** that is available from the Downloads Page of website www.avioconsult.com (#3). This page also offers papers with background theory, URLs to formal references and a URL to the YouTube Channel of AvioConsult for a lecture on airplane control after engine failure, in which this accident is discussed.

Please check the Accidents Page of the website for the most recent version of this review. Date this version: 2016-05-14.

Loss of control — Embraer S.A. EMB-120ER Brasilia, VH-ANB

Darwin Airport, Northern Territory | 22 March 2010

Investigation

ATSB Transport Safety Report
Aviation Occurrence Investigation
AO-2010-019
Final

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Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT

Aviation Occurrence Investigation

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Final

Loss of control
Darwin Airport, Northern Territory
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In the added text boxes, reference could not be made to paragraph numbers because these are not used in this report (as Annex 13 requires).

CONTENTS

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Figure 1: Google Earth
Figure 3: Courtesy of Martin Eadie.
Figures 6, 8 and 9: Flight Safety International Inc.
Figure 16: Embraer-Empresa Brasileira de Aeronautica S.A.

Abstract

On 22 March 2010, an AirNorth Embraer S.A. EMB-120ER Brasilia aircraft (EMB-120), registration VH-ANB, crashed moments after takeoff from runway 29 at Darwin Airport, Northern Territory, fatally injuring both pilots. The flight was for the purpose of revalidating the command instrument rating of the pilot under check and was under the command of a training and checking captain, who occupied the copilot’s seat. The takeoff included a simulated engine failure.

Data from the aircraft’s flight recorders was used to establish the circumstances leading to the accident and showed that the pilot in command (PIC) retarded the left power lever to flight idle to simulate an engine failure. That introduced a simulated failure of the left engine and propeller autofeathering system.

The increased drag from the ‘windmilling’ propeller increased the control forces required to maintain the aircraft’s flightpath. The pilot under check allowed the speed to decrease and the aircraft to bank toward the inoperative engine. Additionally, he increased power on the right engine, and engaged the yaw damper in an attempt to stabilise the aircraft’s flight. Those actions increased his workload and made control of the aircraft more difficult. The PIC did not restore power to the left engine to discontinue the manoeuvre. The few seconds available before the aircraft became uncontrollable were insufficient to allow ‘trouble shooting’ and deliberation before resolving the situation.

Shortly after the accident, an EMB-120 simulator and its staff were approved to undertake the operator’s training requirements. In response, the operator transitioned the majority of its EMB-120 proficiency checking, including asymmetric flight sequences, to ground-based training at that facility.

No organisational or systemic issues that might adversely affect the future safety of aviation operations were identified. However, the occurrence provides a timely reminder of the risks associated with in-flight asymmetric training and the importance of the work being carried out by the Civil Aviation Safety Authority to mandate the use of simulators for non-normal flying training and proficiency checks in larger aircraft. In addition, the importance of appropriate operator procedures, and pilot awareness of the potential hazards were reinforced as risk mitigators where the only option was in-flight asymmetric training and checking.

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 identify and reduce safety-related risk. ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated. The terms the ATSB uses to refer to key safety and risk concepts are set out in the next section: Terminology Used in this Report.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, 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 initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred 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 to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept 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.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

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, current risk controls and organisational influences.

Contributing safety factor: a safety factor that, had it not occurred or existed at the time of an occurrence, 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 in the interests of improved transport safety.

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.

Risk level: The ATSB's assessment of the risk level associated with a safety issue is noted in the Findings section of the investigation report. It reflects the risk level as it existed at the time of the occurrence. That risk level may subsequently have been reduced as a result of safety actions taken by individuals or organisations during the course of an investigation.

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

- **Critical** safety issue: associated with an intolerable level of risk and generally leading to the immediate issue of a safety recommendation unless corrective safety action has already been taken.
- **Significant** safety issue: associated with a risk level regarded as acceptable only if it is kept as low as reasonably practicable. The ATSB may issue a safety recommendation or a safety advisory notice if it assesses that further safety action may be practicable.
- **Minor** safety issue: associated with a broadly acceptable level of risk, although the ATSB may sometimes issue a safety advisory notice.

Safety action: the steps taken or proposed to be taken by a person, organisation or agency in response to a safety issue.

FACTUAL INFORMATION

History of the flight

At about 0900 Central Standard Time[1] on 22 March 2010, two AirNorth pilots commenced duty for a rostered training flight from Darwin Airport, Northern Territory in one of the airline's Embraer S.A. EMB-120ER[2] (EMB-120) aircraft, registered VH-ANB. The training flight was to revalidate the command instrument rating of the pilot under check, an experienced EMB-120 captain. The flight was under the command of a training and checking captain, also an experienced EMB-120 captain and the nominated pilot in command (PIC). The pilots were reported to have planned and briefed in preparation for the check flight.

The operator's flight training manual required 45 minutes for briefings prior to training flights. Briefings were to include the manoeuvres that were to be flown, the method intended for the simulation of engine failure on takeoff, and the expected responses and responsibilities in the event of an actual engine failure. A company pilot later described seeing three columns of briefing information on the whiteboard used by the PIC, but he had not examined it closely. The board was cleaned after the briefing and no record of the briefing was retained.

The flight was planned as an instrument flight rules (IFR) airwork category flight that followed a typical sequence for an instrument rating renewal. That included a departure to the north-east for some training manoeuvres between 5,000 and 10,000 ft above mean sea level (AMSL) before returning to practice non-directional beacon (NDB) and very high frequency (VHF) omnidirectional radio range (VOR) instrument approaches, and a circling approach. The two pilots prepared the aircraft for the flight and arranged for additional fuel before they boarded the aircraft.

At 1005:15, the pilots taxied for takeoff from the intersection of taxiway E2 with runway 29. The PIC, who occupied the copilot's (right) seat, advised the aerodrome controller (ADC) that the departure would incorporate asymmetric flight (a simulated engine failure on takeoff) and was approved by the ADC to perform that manoeuvre.

The takeoff was commenced at 1009:14. Witnesses reported that the takeoff appeared 'normal' until a few moments after the aircraft become airborne, when it was seen to roll and diverge left from its take-off path. They watched as the aircraft continued rolling left into a steep nose-down attitude. The witnesses lost sight of the aircraft behind trees to the south of the upwind end of the runway, from where a column of black smoke was seen shortly afterwards. The aerodrome rescue and fire fighting services were in attendance very shortly thereafter and extinguished the fire. Both pilots were fatally injured and the aircraft was destroyed due to impact forces and an intense post-impact fire. The aircraft's track is depicted at Figure 1.

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1 Central Standard Time was Coordinated Universal Time (UTC) + 9.5 hours.

2 The aircraft type is commonly referred to as a *Brasilia*. The letters ER denote an 'Extended Range' version of the EMB-120 aircraft.

Figure 1: Aircraft's flightpath as reconstructed from the recorded data

Flight sequence

Data from the cockpit voice recorder (CVR) and the flight data recorder (FDR) were used to establish a sequence of events (Table: 1). A graphical representation of the FDR data is at Figure 2.

Table 1: Sequence of events

Time to end of recording (seconds)	Airspeed (indicated) Heading (°Mag.) Bank Angle (°)	Event / *Comments*
-51	286 M	Power levers advanced for takeoff.
-44	286 M	Airspeed began to increase during the takeoff roll. *In response to the pilot under check's command to 'set power', the engine power is adjusted to 94% torque for each engine.*
-33	80 kts	*'80 kts' Airspeed check in accordance with SOP.*
-25.5	113 kts	Aircraft becomes airborne at V_2.[3] *Initially 7° nose-up attitude but that increased as the climb was established.*
-24.5	114 kts 287 M 0 (wings level)	Left engine torque reduced from 93% power. *PIC advised 'Simulated Only' to indicate that the loss of power was simulated, and not an actual engine failure.*
-23	117 kts 289 M 1 left	Nose attitude stabilised at 9° nose-up and remains between 8.5° to 9.5° nose-up for the next 12.5 seconds. *The published procedure required an initial pitch attitude of 7° nose-up.* (Page 35).

V_{MCA} = 97 kt.
FAR 25.107(b): V_{2min} is the highest of $1.1 \cdot V_{MCA}$ and $1{,}13 \cdot V_{SR}$. For this flight: $V_{2min} = 1.1 \cdot 97 = 110$ kt.
V_{MCA} with the wings kept level is not published, but must have been approx. 110 kt.
V_{2min}, like V_{MCA}, is only providing the 10% safety margin above V_{MCA} during straight flight while maintaining a small bank angle away from the inoperative engine (at low all up weight).

V_2 (FAR 25.107(c)) requires a minimum climb gradient and may not be less than:
- V_{2min},
- V_R + the speed increment reached before 35 ft, and
- the speed providing maneuver capability (FAR 25.143(h) - bank 30°, ROC pos. when gear down, 2.4% when gear up)

A V_2 of 113 kt is way too low, as will be shown on page 48.

climb performance and control,

and

[3] V_2 is the minimum speed at which a transport category aircraft complies with those handling criteria associated with climb, following an engine failure. It is the take-off safety speed and is normally obtained by factoring the stalling speed or the minimum control (airborne) speed, whichever is the greater, to provide a safe margin.

Time to end of recording (seconds)	Airspeed (indicated) Heading (°Mag.) Bank Angle (°)	**Event / *Comments***
-22	116 kts 286 M 3 left	Gear selected UP. Right aileron control shows approximately half right deflection and over half right rudder application. *PIC advised 'Positive rate' and, in response to the pilot's command, retracted the landing gear.*
-20.7	113 kts	Airspeed decreased to V_2. *The flight manual procedure required that airspeed be maintained at V_2 (PIC's notes – V_2 +10).*
-18.7	113 kts 285 M 1 left	The first of five significant variations to aileron input occurred as the control yoke was moved left from over half right deflection to almost neutral for 1.5 seconds. Left engine torque decreased to 0% and remains there.
-17	111 kts 284 M 3.5 left	Right aileron input increasingly reapplied.
-16	111 kts 283 M 8 left	Power on right engine increased. *Pilot under check advises 'Engine failure, No 1 confirmed'.*
-15.5	111 kts 282 M 8 left	Second significant left aileron movement as control yoke moved from more than a third right deflection to almost neutral again for about 1 second. Right rudder deflection started to steadily decrease.
-14	112 kts 281 M 7 left	Right engine torque increased to 120%, right rudder deflection less than a half for over 1 second. *The operator's procedures allowed for up to 110% torque on the operating engine, if required. Aircrew reported that it was the pilot flying's role to adjust the operating engine's torque with the power lever, hence no instruction recorded on the CVR from the pilot under check to the pilot not flying (PIC) to make that adjustment.*

showed

rudder showed

V_2 here must be V_{2min}, or is already a margin added and is +10 an additional (company) margin? Refer to page 21.

Because the wings returned to level. No attempt was made to increase bank angle to +5 degrees for V_{MCA} to be valid. Unknown to pilots?

Because the bank angle increased to the left again, under influence of propulsive lift right wing. The right aileron input was however not large enough to maintain wings level. Now the sideslip and hence drag increased, airspeed decreased as well. Rudder increased to max., preventin heading change for the next few seconds.

This initiated yawing and rolling continuously during the remainder of the flight, because they were not appropriately countered by rudder (decreased to ½) and ailerons (less than max.). Loss of Control was imminent.

This increased actual V_{MCA}: yaw to left increased (heading decreased) into the dead engine. Bank angle decreased a few degrees as response to aileron input.

FDR data on page 7 shows no attempt to maintain heading by adequate rudder, and maintaining a safe small bank angle away from the inop engine to keep actual V_{MCA} low and minimize sideslip, hence drag.

In TCDS: "acceptable for take-off"

Time to end of recording (seconds)	Airspeed (indicated) Heading (°Mag.) Bank Angle (°)	**Event / *Comments***
-13.7	112 kts	Airspeed started to decrease.
-13	111 kts 277 M 8 left	Landing gear confirmed UP. Right rudder deflection reapplied. *PIC advises 'Gear is up'*
-12.5	110 kts	Third significant left aileron movement recorded as the control yoke was moved from nearly half right deflection to less than a third right deflection for about 1 second.
-12	109 kts 274 M 11 left	Right engine power momentarily peaks at 124% before being steadily reduced.
-10.5	108 kts	Fourth significant left aileron movement recorded as the control yoke was deflected from more than half right to less than a third right deflection for just over1 second.
-10	107 kts 271 M 13 left	Nose attitude reduced to 7.5° nose-up.
-9	105 kts 267 M 15 left	Right engine torque stabilised at 110%. Right aileron reapplied to about half right deflection. *PIC commands 'Heading mate disengage ...'. Aircraft heading nearly at the maximum tolerance for the manoeuvre (20° left of runway heading) and increasing.*
-8	104 kts 260 M 21 left	No changes to recorded engine parameters. Fifth and final significant aileron movement recorded as the control yoke was moved left to less than a third right deflection for about half a second. *Pilot under check responds 'yeah disengaging'.*

After which the yaw rate reduced for two seconds, but yaw continued to increase. Directional control was lost, 2 seconds later.

At this point, lateral control was also lost because roll to the left kept increasing. The airspeed had obviously decreased below the actual static V_{MCA}. Re-application of rudder to max. had only little effect on the yaw rate. Directional control was already lost.

Loss of lateral control might happen before loss of directional control because of large propellers that produce large propulsive lift which the ailerons cannot counteract. This leaves the concern whether the AFM published V_{MCA} applied to this EMB-120 version and its engines/ propellers.

"Disengage" would mean that procedures were not followed, because the yaw damper may only be engaged after takeoff, at airspeeds above 120 kt when OEI (page 20).

20° is the tolerance for determining dynamic V_{MCA}, the V_{MCA} after a sudden engine failure during flight-testing (FAR 25.149(d)). FAR 25 is for design and certification, not for use (unchanged) by pilots and investigators.

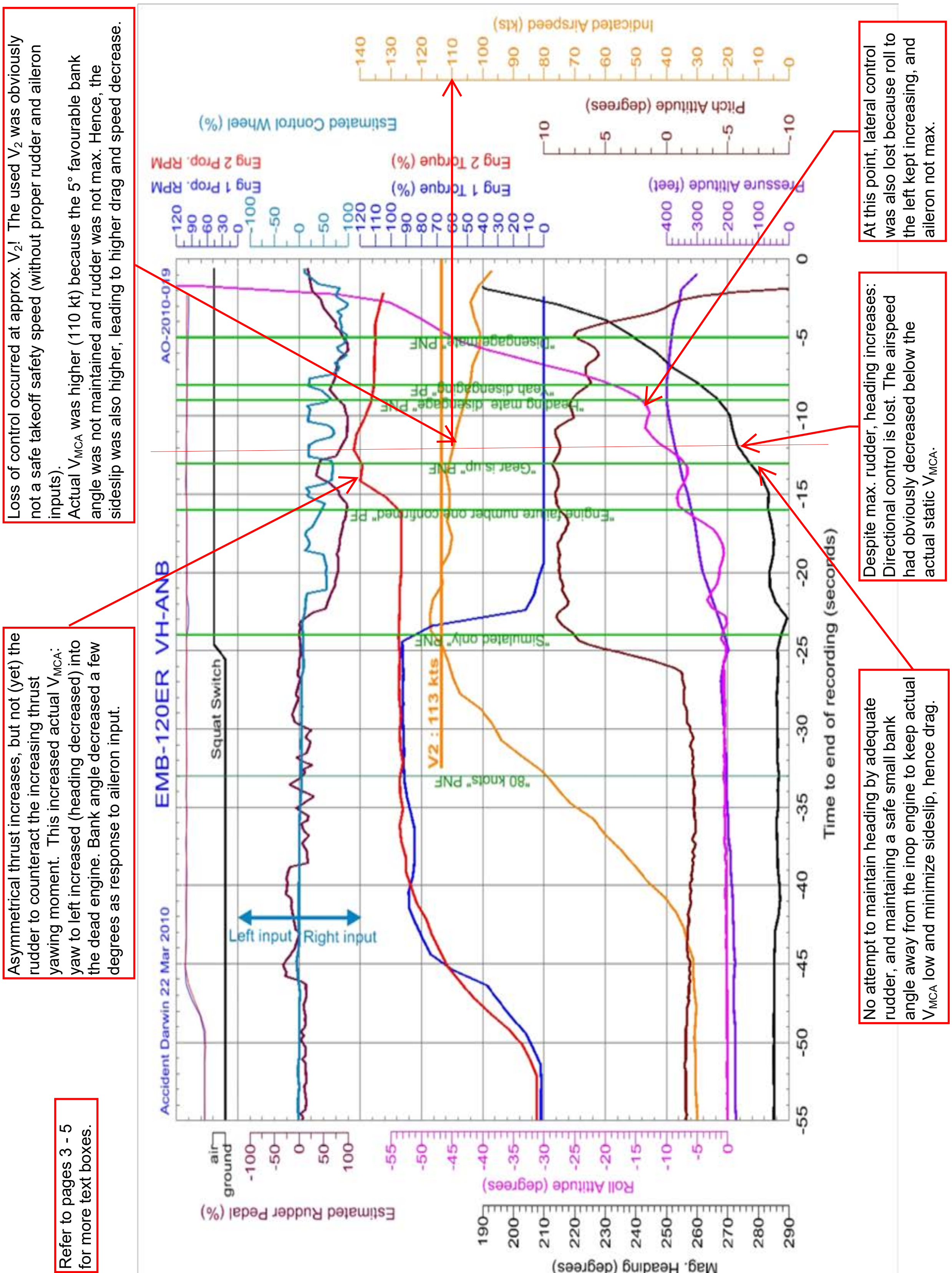
Published V_{MCA} = 97 kt. The additional drag from the unfeathered left propeller increased the yawing moment to the left which was not counteracted by (max.) rudder.
The actual V_{MCA} was 110 kt (yawing continued), and hence higher than 97 kt. Loss of control occurred at approx. the used V_2! This proves that the V_2 as applied by the operator is not a safe takeoff safety speed without maintaining a small bank angle away from the inop engine.

Time to end of recording (seconds)	Airspeed (indicated) Heading (°Mag.) Bank Angle (°)	Event / *Comments*
-7	103 kts 252 M 30 left	Stall[4] warning sounds. Nearly full right aileron application. *(No comment on CVR from either pilot about the stall warning).*
-6	102 kts 247 M 39 left	Nose attitude decreased to 6° nose-up.
-5	101 kts 239 M 46 left	Full right aileron deflection and right rudder control input started to decrease. *PIC repeats command 'Disengage mate'.* *(No comment on CVR from either pilot about engine or control problems).*
-4	103 kts 230 M 50 left	Abrupt nose-up elevator application. Nose attitude increased momentarily to 8° nose-up.
-3	104 kts 215 M 55 left	Nose attitude - level.
-2	101 kts 191 M 85° left	Nose-down attitude of -7.5°.
-1	97 kts 180 M 168° left	Last recorded FDR data (immediately prior to impact).

4 The term describing the aerodynamic characteristic of an aerofoil at a critical angle of attack (usually about 15°) where, due to separation of the airflow over the upper surface, a significant decrease in lift results.

Does the stall warning system include the bank angle data? Believe not. So 103 kt is not the stall speed Vs of the aircraft. Vs must be below 100 kt (page 3: V_2/1.13 = 113/1.13), most probably below V_{MCA} (97 kt). Review stall warning system for sideslip influences.

Figure 2: Flight data parameters and relevant extracts from cockpit voice recorder (superimposed in light green)



Simulated engine failure on takeoff

In order to better understand the information relating to this occurrence, it is first necessary to explain aspects of simulated engine failures and associated training procedures.

It is a requirement during training for aircraft endorsements and in subsequent proficiency checking that the pilot of a transport category aircraft demonstrates competency to fly the aircraft following failure of the critical engine just after obtaining V_1[5] on take-off. The simulation of an engine failure at that point during takeoff is known as the 'V_1-cut' manoeuvre.

"critical engine" is out of FAR 25.149 which is for design and certification of airplanes, not for ops use. The critical engine is off for sizing the vertical tail and during flight tests to determine the worst case, the highest V_{MCA}. For pilots, only one V_{MCA} applies after failure of any engine, critical or non. V_{MCA} after failure of the non-critical engine is just a few knots lower, but still a factor to consider (not maintaining the proper 5° bank angle has a much greater effect).

The V_1-cut is an exacting manoeuvre because accurate control of the aircraft is required to accelerate to a safe flying speed, become airborne and obtain a predicted climb performance with the critical engine powered back to simulate an inoperative engine with its propeller feathered.[6] A simulated left engine failure was normally chosen for a check flight because it was the 'critical' engine in an EMB-120 (an explanation appears in a later section of this report titled *Characteristics of asymmetric flight*), requiring the pilot under check to demonstrate competency in the most demanding circumstances. The sequence requires an aircraft to be flown at low airspeed and with reduced performance, while controlling asymmetric thrust, at low altitude. The low speed and altitude at which the manoeuvre is undertaken reduces the margin for error.

During training, failure of both engines should be simulated alternatively, to prevent pilots from always applying right rudder after engine failure.

A V_1-cut in a real aircraft is dangerous when pilots are not very well prepared, and not know all about V_{MCA}.

Experienced training and checking pilots reported that the EMB-120 required careful attention to maintain the correct attitude and considerable aileron and rudder force to maintain lateral and directional control in asymmetric flight following a simulated failure of the left engine after V_1. They reported that three to four units (out of 10) of right rudder trim were required to offset the rudder force in the case of that 'failure'. One of those pilots reported a candidate selecting the aircraft's yaw damper to compensate for 'overcontrolling'[7] of the aileron and rudder controls following a simulated engine failure (see the later section of this report titled *Rudder control system*).

Only of the left engine?

It should not be "while controlling", but "while maintaining straight flight with" because V_{MCA} and V_2 only apply during straight flight while maintaining a small bank angle away from the inop engine. In addition, only then the clmb performance is maximal.

Prior to the development of ground-based synthetic training devices (simulators) that were capable of simulating realistic flight characteristics, all training and checking was conducted in an aircraft. Engine failures, including V_1-cuts, were regularly practised during endorsement training and proficiency checking. A training or check pilot simulated a failure by manipulating the power controls so that, should it be needed, power could be quickly restored and continued safe operation of the aircraft be assured. A simulated V_1-cut in an aircraft did not permit a training or check pilot any time to analyse a candidate's actions, or allow a few extra moments in anticipation of a candidate's corrective actions. Diagnosis of any faults and errors took place later, either in-flight at a safe height and speed, or during a post-flight debriefing.

Restoring power during engine failure training is very dangerous. The airplane might enter a spin because of the (trimmed) off-centre controls and the actual roll and yaw angles! Test pilots always reduce thrust on the operating engine first, then recover and continue.

No, these are two different speeds: Vef and V_1 (refer to FAR 25.107(a)).
Not critical. On the runway during the takeoff run, the P-vector of all propellers is in the centre (of the spinners), except on some airplanes where the propellers are pointing down a bit. Then ground and flight criticality changes.

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[5] V_1 is the ~~critical~~ engine failure speed or decision speed. Engine failure below this speed shall result in a rejected takeoff; above this speed the take-off run should be continued.

[6] The term used to describe rotating the propeller blades to an angle edge on to the air flow that minimises aircraft drag following an engine failure or shutdown in flight.

[7] The term used to describe the application by the pilot of more control inputs than necessary, commonly resulting in a succession of deviations from normal flight.

In turboprop aircraft like the EMB-120, the failure of an engine was detected by torque sensors that activated a propeller feathering or 'auto-coarsening' system, streamlining the propeller blades and reducing the drag from the 'windmilling[8]' propeller. During a simulated engine failure, a training or check pilot retarded the power lever of the 'failed' engine to a thrust setting that corresponded to the equivalent drag of a feathered propeller. Retarding the power lever beyond that setting to the flight idle position resulted in significantly increased drag from the windmilling propeller and effectively simulated a failure of both the engine and the automatic propeller feathering or auto-coarsening system.

Associated risks

Any flying involving simulated engine-out operations increases the level of risk. Only those flight instructors and training and check pilots with experience on type and demonstrated proficiency are selected to conduct the training and checking of that simulated failure. Having demonstrated an ability to perform the training sequences safely, including V_1 cuts, candidates are approved by the Civil Aviation Safety Authority (CASA) to carry out those manoeuvres in accordance with an operator's approved training and checking syllabus.

Simulated engine failures were not conducted on revenue flights where passengers, other than nominated flight crew members, were carried. Normally, that limited the crew compliment to two pilots, although on occasions another check pilot or a safety pilot was carried.

Terminology used in training and checking

The operator's documentation did not contain any specific terminology for discontinuing a manoeuvre, but did provide clear instruction as to how control of an aircraft was to be changed between crew members.

To take over control from the pilot flying, or for the pilot flying to relinquish control to the other pilot in a multi-crew aircraft, very specific terminology was used. To avoid any confusion as to which pilot was manipulating the controls, the operator's General Policy and Procedures Manual, section 4.7.2.2 *Crew Communication - Handing Over and Taking Over* stated:

> The process of handing over control of the aircraft shall always be conducted in a positive manner. To minimise confusion or operational risk, the following terminology shall be used.
>
> To assume control, the pilot monitoring shall call "taking over". To relinquish control, the pilot flying shall call "handing over".
>
> Control of the aircraft cannot be handed over until the pilot monitoring has called "taking over"...

The term 'disengage' that was used by the PIC during this simulated engine failure was not standard phraseology. Other EMB-120 pilots reported that they had never heard the term 'disengage' used for any action other than deselecting the autopilot/yaw damper and had never heard it used to discontinue a manoeuvre.

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[8] Term used to describe a rotating propeller being driven by the airflow rather than by engine power, and results in increased drag at normal propeller blade angles.

They also reported that if a training or check pilot decided to discontinue a simulated engine failure procedure, they would expect that check pilot to restore power to the 'failed' engine. Alternately, if the training or check pilot wanted to assume control of the aircraft, they would expect to hear the term 'taking over'.

Dangerous practice. Refer to text box on page 8.

Check pilot's role and responsibility

As a training and checking pilot, the PIC's function was to assess a candidate's flying competency in normal and emergency flight procedures. That required him to initiate simulated emergencies as well as to perform the duties of the pilot not flying in a multi-crew environment while monitoring and assessing the performance of the candidate. The different roles required check pilots to be well rehearsed in performing simulated emergencies. Attempting to replicate an engine failure as realistically as possible in an aircraft, in order to test a candidate's ability to handle the situation, had to be moderated in the interest of safety.

Section 5.4 of the operator's Flight Operations Training and Checking Policy Manual stated:

> During a check flight, when a Check Pilot occupies a control seat, the Check Pilot shall be the Pilot in Command (PIC).

Section 2.8.3 of that manual was titled *Responsibility during flight – Pilot* and stated that:

> On all local proficiency and endorsement flights the Check Pilot is responsible for the safety of the aircraft and he must take adequate steps to ensure that no undue risks are taken. ...

It was the PIC's responsibility to ensure the safety of the flight at all times and especially during simulated emergencies. Directions to training and checking pilots conducting simulated engine failures were unambiguous. The operator's Flight Operations Training and Checking Policy Manual Section 5.26 – *Simulation of Engine failure*, stated:

> Check Pilots must continuously monitor the reaction of the trainee to the loss of power, by keeping one hand guarding the control column, feet resting on the rudder pedals and thrust levers guarded throughout the exercise, and must be ready to oppose incorrect control inputs or to **discontinue the exercise by restoring power.**

Repeated from page 8: Restoring power during engine failure training is very dangerous. The airplane might enter a spin because of the (trimmed) off-centre controls and the actual roll and yaw angles! Test pilots always reduce thrust on the operating engine first, then recover and continue.

Experienced EMB-120 training and checking pilots reported that when performing simulated engine failures after takeoff, they would not allow an aircraft to exceed the maximum flight tolerances for a satisfactory demonstration of asymmetric handling before discontinuing the exercise.

What are these? +_20°? (Page 38)

Pilot information

Pilot in command (non-handling training and checking captain)

The PIC held an Air Transport Pilot (Aeroplane) Licence (ATPL(A)) and a Class I Medical Certificate that was valid until 13 October 2010 and had a restriction that required distance vision correction to be worn at all times. He held a command and copilot endorsement for the EMB-120 ER aircraft and had a current Command

(Multi-Engine Aeroplane) Instrument Rating. He had a total flying time of 5,664 hours, of which 3,085 hours were on EMB-120 ER aircraft.

The PIC had accumulated considerable flying experience as a flight instructor since qualifying as a Grade 3 flight instructor in November 2002. In August 2003, the pilot was issued a Grade 2 flight instructor rating and Multi-Engine (aeroplane) training approval and was issued a Grade I flight instructor rating in July 2004. He commenced employment with the operator as a line pilot in January 2006 and obtained a copilot endorsement for the EMB-120 ER and subsequently a command endorsement in that aircraft. In May 2008, the company appointed him as a supervisory pilot.

In June 2009, the PIC was appointed as a Check Pilot[9] after additional training and CASA approval. Following that approval, the PIC logged nine instrument rating renewals and proficiency check flights in EMB-120 aircraft. Pilots that were checked by him reported that he gave thorough pre-flight briefings before each check flight and that those included the engine failure procedures that were to be expected during the subsequent check flight, including a simulated engine failure on takeoff.

The PIC was selected as a simulator instructor as part of the operator's transition to simulator training for its EMB-120 crews. During simulator training in February 2010 for the renewal of his command instrument rating, the PIC demonstrated proficiency in handling engine failures on takeoff.

The PIC was off duty for the 2 days prior to the accident and was reported to have spent that time participating in his normal outdoor recreational activity and with family. He was reported to be well rested before commencing duty that morning. The people who saw the PIC that morning reported that he appeared to be in good health and a good frame of mind.

Pilot under check (pilot flying)

The pilot under check held an ATPL(A) and a valid Class 1 Medical Certificate. He held a command and copilot endorsement for the EMB-120 ER aircraft and a Command (Multi-Engine Aeroplane) Instrument Rating. He had a total flying time of 8,217 hours, of which 3,749 hours were on EMB-120 ER aircraft.

The pilot under check had previously held a Grade I Instructor Rating with Multi-Engine (Aeroplane) training approval and had 1,217 hours of flight instructor experience. In June 2004, CASA appointed him as an Approved Test Officer for the renewal of command instrument ratings.

The pilot under check commenced employment with the operator as a line pilot in 2006 and obtained a copilot endorsement for the EMB-120 ER and, in March 2007,

9 A Check Pilot was authorised to: conduct and certify command instrument rating renewals, conduct and certify initial and the renewal of copilot instrument ratings; and carry out aircraft conversion training, flight proficiency checks, base checks, annual emergency procedures training, route qualifications, and line training for the operator's pilots.

a command endorsement. In November 2008, the company appointed him as a supervisory pilot.[10]

The pilot under check satisfactorily completed an EMB-120 flight proficiency check in August 2009 in accordance with the recent experience requirements for a check on the aircraft type within the preceding 15 months. [11] That check was the first time that the pilot under check was checked by the PIC in his role of training and checking captain, and the PIC recorded that the pilot under check demonstrated satisfactory handling of a simulated engine failure on takeoff. The accident flight was the pilot under check's second proficiency check flight with the PIC and his second experience of a simulated engine failure on takeoff with the PIC.

The pilot under check was off duty for the 2 days prior to the accident. He was reported to have made an all-day fishing trip on the first rostered day off and spent the following day at home with his family and studying for the next day's flight test. He was reported to have been well rested before commencing duty that morning and appeared to be in good health and a good frame of mind.

Aircraft information

The EMB-120ER was a twin-turboprop aircraft that was manufactured in Brazil and had a maximum weight of 11,900 kg. It was powered by two Pratt and Whitney Canada model PW118A gas turbine engines. Each was rated at 1,800 shaft horsepower and drove through a reduction gearbox to a four-bladed Hamilton Standard constant speed, full-feathering, reversing propeller of composite construction (Figure 3).

Rotating direction?

[10] A supervisory pilot was authorised to conduct line training for the operator's pilots in normal operations, and the consideration of en route emergency and abnormal operations, including during training for route qualification.

[11] Civil Aviation Order Part 40.1.5 Conditions on Air Transport Pilot (Aeroplane) Licences. subsection 11 – *Recent Experience Requirements*.

Figure 3: VH-ANB

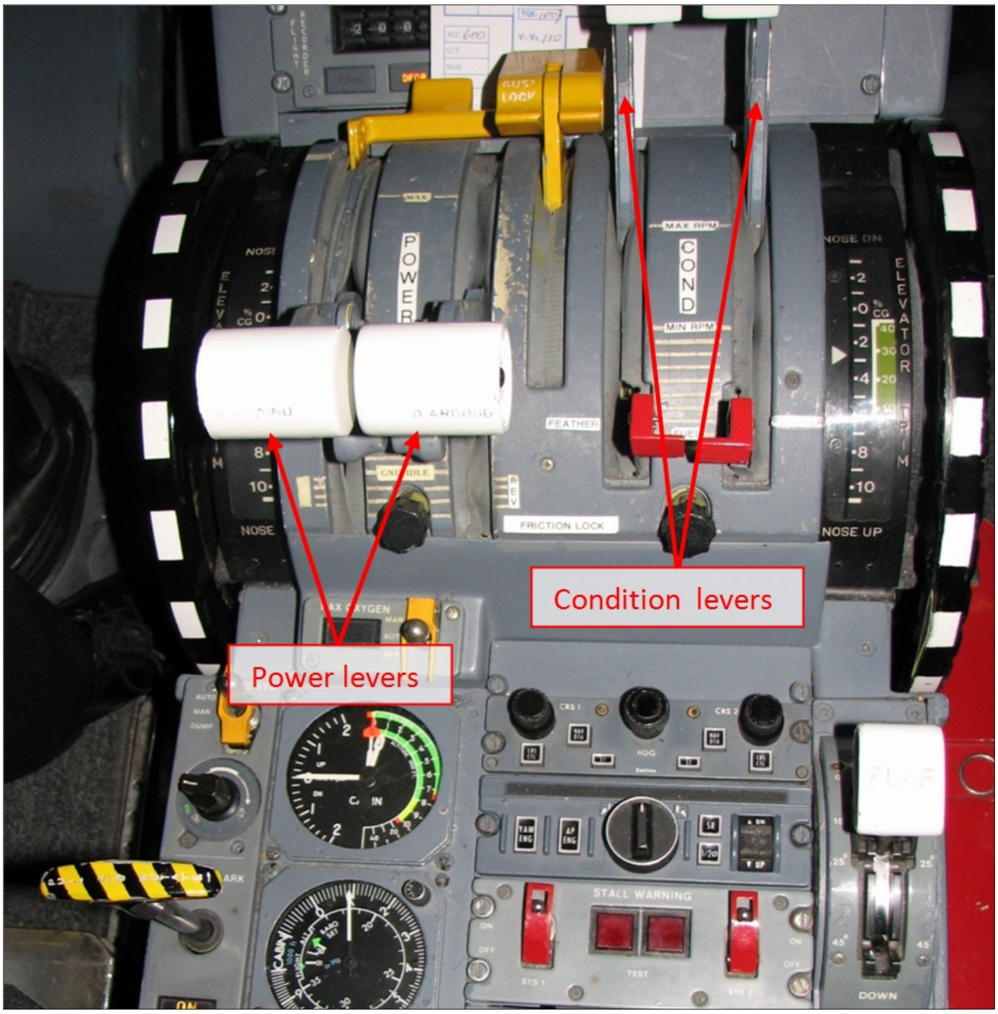
The aircraft was certified in the transport category for the carriage of passengers and freight. In the passenger role, it had a maximum passenger seating capacity of 30. There were 21 of these aircraft on the Australian register at the time of the accident, most of which were operated by regional airlines on scheduled flights.

The aircraft, serial number 120116, was manufactured in 1989 and was first registered in Australia on 2 August 1993. It had accumulated 32,799.4 hours total time in service and completed 33,700 cycles at the time of the accident.

Engine and propeller controls

The engine and propeller controls in the EMB-120 were mounted on a central pedestal between the left (PIC) and right (copilot) seats (Figure 4).

Figure 4: Power quadrant with the power levers (left) at flight idle and the condition levers (right) at maximum RPM



Power levers

Two power levers, one for each engine, were located on the left of the quadrant and controlled the fuel fed to the engines through a hydromechanical unit (HMU) in conjunction with each engine's electronic engine control (EEC). A warning lamp on the centrally-mounted multiple alarm panel (MAP) illuminated when a failure was detected in the respective EEC. Both EEC warning lamps were recovered from the wreckage and their globes examined. The condition of the filaments was consistent with the warning lamps not being illuminated at impact.

The position of the power levers was dependent on the torque required and ranged from flight idle (FLT IDLE) at the most rearward lever travel to maximum power (MAX PWR) toward the forward limit of travel. Maximum power was partly determined by environmental conditions and the power levers were advanced until the required torque value or temperature limit was achieved on the engine gauges. The PW118A engine permitted the use of 110% torque for up to 5 minutes during takeoff if required, and a maximum transient torque of 120% for 20 seconds. Torques in excess of those values were possible, although engine damage would probably result.

Were the engine and propeller types and max. thrust in accordance with the type certificate (data sheet)?
Were the manuals properly amended for these engines?

For aircraft that are equipped with PW118A engines, the max. continuous power setting is still 120% torque. Are you saying that the AFM derates a 118A engine on paper, rather than in the engine control unit? This paragraph is difficult to understand because of the use of the past tense.

Derated or reduced? 'Derating' is done by engineers on the ground in the engine control unit after ftting a more powerful engine than the flight controls etc. can handle, by arcraft design. Pilots use 'reduced' power: less than max. throttle or by using an assumed temperature. Controllability does not represent that of max. TO Weight; the thrust yawing moment is less. "Reduced" is also called "flexible ".

For the ambient conditions at takeoff on the training flight, the take-off and maximum continuous power setting for a PW118A engine in typical configuration[12] was 100% torque. Aircraft that were equipped with PW118A engines could use ~~derated~~ power[13] in order to increase engine life or, in training, to represent the performance of an aircraft at maximum take-off weight. Supplement 13 of the EMB-120 AFM described the derated operation. According to the AFM, the take-off and maximum continuous power setting for a PW118A that was derated to a PW118 was 97% torque. When the ~~derated~~ procedure was used, a caution in the AFM stated:

Is this caution because the listed V_{MCA} and calculated V_1 and V_2 are only valid for a lower torque setting (97%) than max. with this engine? Or are the AFM published V_{MCA} and V_2 data still for a less powerful engine of an earlier EMB-120 version, and for 120% torque?
I.e. were V_{MCA} and V_1, V_2 data not adjusted for a PW118A engine?

V_{MCA} is always determined at the highest power level that the pilot can set from the cockpit, in this case 120% torque.

So what's going on here? See also text boxes on page 38.

> IN THE EVENT OF ENGINE FAILURE ABOVE V1, THE TAKEOFF POWER SETTING ON THE OPERATING ENGINE MUST NOT BE CHANGED.

When a power lever was retarded in flight to the flight idle position, low pitch stops prevented the affected propeller blade angle from decreasing below 17.6°. That prevented uncommanded low or reverse pitch (negative blade angles) in flight that would cause the propeller to overspeed, creating excessive drag from the windmilling propeller and making control of the aircraft impossible. Power lever movement below flight idle in flight was prevented by solenoid locks that engaged when a ‘weight-off-wheels’ condition was detected by a microswitch on the aircraft’s main landing gear.

The power levers also controlled the propellers in ground or beta[14] range for ground operations. The beta mechanism controlled the propeller in an under speed condition, when the propeller governor was deactivated due to low propeller speed and the propeller blade angle was controlled directly by power lever movement. The blade pitch angle range in the beta schedule was from -11° (full reverse) through to +25°.

The propeller beta mode parameters were recorded on the FDR. The data showed that, as the power was increased for takeoff, both beta parameters changed from ground to flight mode and remained there throughout the remainder of the flight. Those parameters corresponded to the cockpit beta lights, which illuminated whenever the propeller blade angle was less than 12.6° (or 5° below flight idle fine pitch), being extinguished.

Condition levers

Two condition levers on the right of the quadrant were mechanically connected to the propeller control unit (PCU) and controlled propeller pitch (blade angle) for constant speed operation and feathering. The levers could be set at any position between the most forward limit (maximum RPM (MAX RPM)) and the most rearward limit (minimum RPM (MIN RPM)). Lifting the condition levers up and rearwards from the minimum RPM stop engaged the mechanical feathering operation. For takeoff, the condition levers were set to MAX RPM and a propeller speed governor increased or decreased propeller pitch to maintain the selected propeller speed or RPM while airspeed increased.

could be set? Prior to the accident?

---

12 Bleed air valves open and pack (air conditioner) and bleed switches in "low".

13 Where the maximum power of an engine is governed or set to a lower value than normally used.

14 Control mode in normally automatic propellers, in which a pilot exercises direct (or manual) command of the propeller pitch (blade angle) for braking and ground manoeuvring.

Engine and propeller gauges

Gauges for engine torque in percent (% TORQUE), propeller speed in percent RPM (N_p) and inter-turbine temperatures (T_6) for each engine were located in the central panel, adjacent to the captain's flight instruments (Figure 5). Those gauges provided analogue and digital representations of the respective parameters.

Figure 5: Engine Inter-turbine Temperature (T_6) (top row) and Torque (centre row) gauges and Propeller RPM (N_P) gauges (bottom row)

Automatic feathering system

An automatic feathering system was installed to automatically feather the affected propeller following an engine failure. Microswitches on the power lever quadrant and torque signal conditioning units on the engines provided information to the autofeather system. The requirements for arming the system were:

- Autofeather control switch - ON
- Power lever angle – both greater than 62°
- Torque – both engines above 62±1.4%.

When armed, the autofeather system actuated the electrical feathering system when the torque on either engine dropped below 23.6±2.5%.

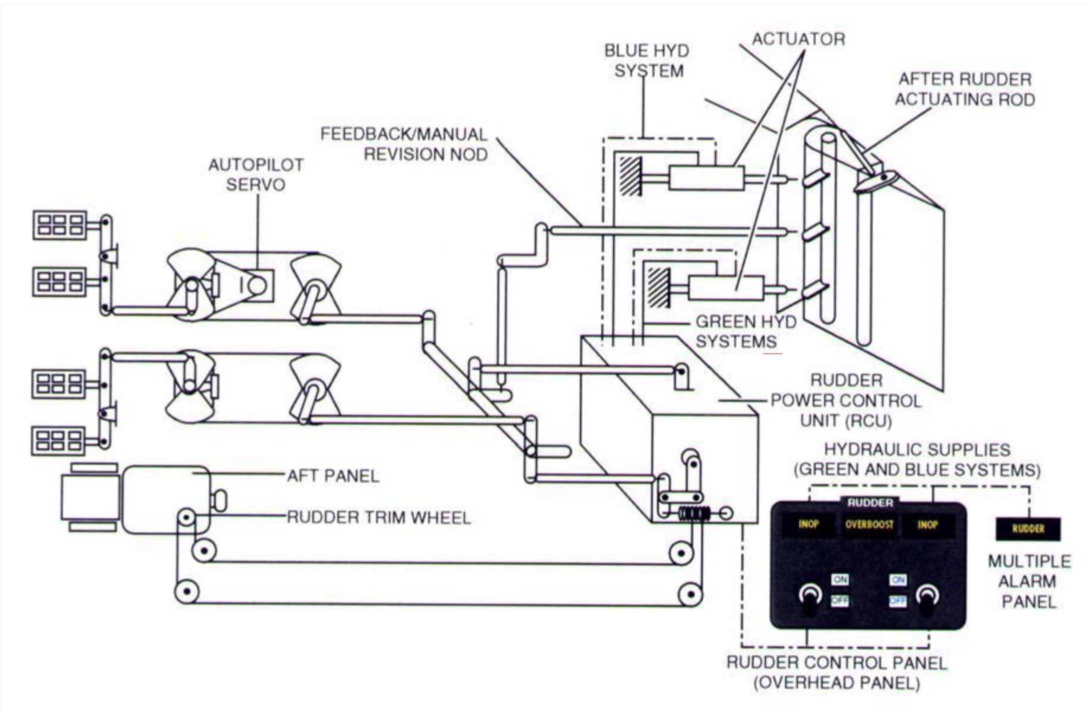
When the autofeather system was unintentionally not armed for takeoff, a three-chime aural alert sounded and a voice message warning ‘Takeoff autofeather’ activated 8 seconds after the power levers were advanced.

Rudder control system

The rudder consisted of split control surfaces; the main rudder or forward section and the after rudder or rear section. Each was attached to the rear of the vertical fin. The after rudder was mechanically linked to the main rudder and operated in the same direction, but with 75% increased travel. Greater rudder deflection to the right was provided to counteract the increased asymmetric forces resulting from failure of the left, or critical, engine at slow speed and at maximum power.

The rudder control system consisted of two sets (pilot and copilot) of rudder pedals that were mechanically connected to the hydraulic rudder power control unit (RPCU) and to the lower rudder control surface by a series of mechanical linkages (Figure 6).

Figure 6: Rudder control system



One on each engine?

The RPCU was operated by two independent hydraulic systems that provided segregation and redundancy. Each system incorporated its own rudder actuator that deflected the main rudder in the commanded direction. At speeds below 120 kts, both hydraulic systems operated to maintain adequate rudder authority when, at such slower airspeeds, greater rudder deflections were required. In the event of a total hydraulic failure, the rudder system was mechanically actuated by the rudder pedals without hydraulic assistance. The control force required to move the rudder was considerably greater without hydraulic assistance.

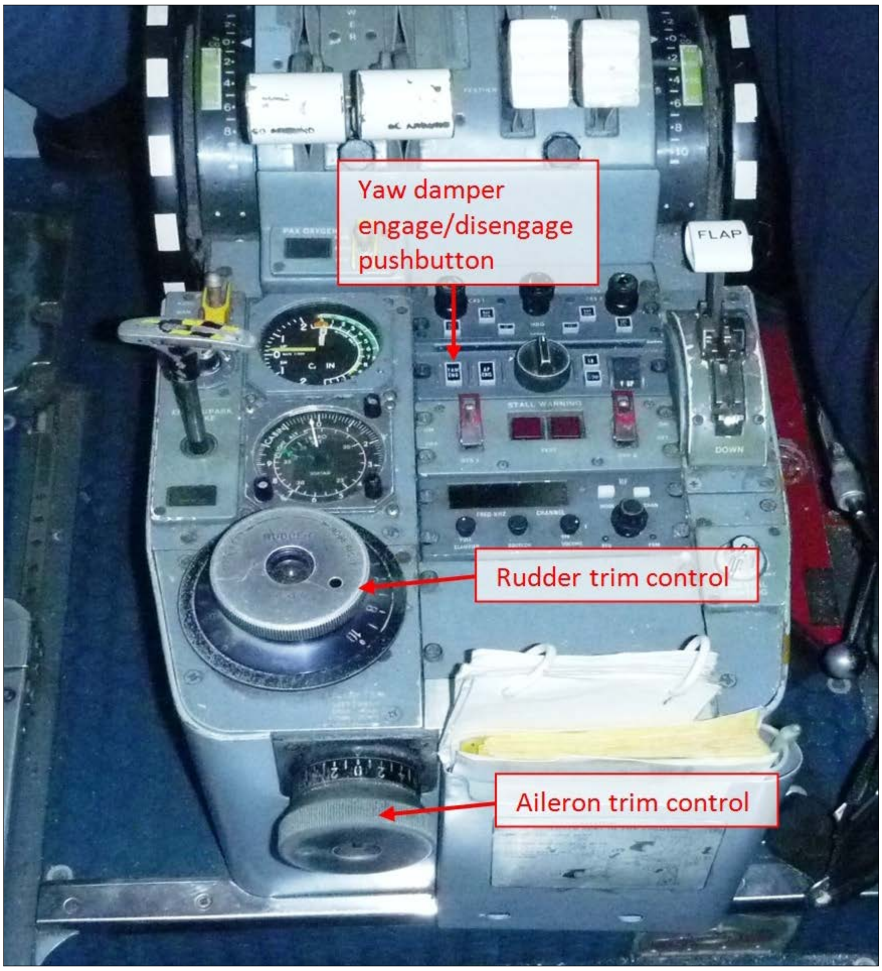
And what happens when the simulated failed engine is left running? And in the event one engine fails?

Rudder and aileron trims

The rudder and aileron trim systems allowed the flight crew to minimise the rudder and aileron control forces required to maintain a desired rudder and aileron deflection, as required during asymmetric flight.

Rudder trim was adjusted by rotating a trim wheel on the control pedestal in the direction of the applied rudder force (Figure 7). A scale from 0 to 10 either side of neutral provided a relative indication of rudder trim. Pilots reported that between three and four turns of the wrist were required to obtain maximum rudder trim.

Figure 7: Centre pedestal with the manual rudder and aileron trim wheels shown



The rudder trim included a 'load feel' mechanism that provided a progressive increase in artificial feel to the rudder pedals as they were deflected. There was no trim tab on the rudder control surface to provide aerodynamic trimming. Instead, the rudder itself was deflected by adjusting the hydraulic centre of the RPCU. This also caused the rudder pedal neutral position to adjust so that any rudder pedal displacement would appear normal for the rudder force being applied. Rudder trim was dependent on the RPCU, and rudder trim capability was lost in the event of a total hydraulic failure.

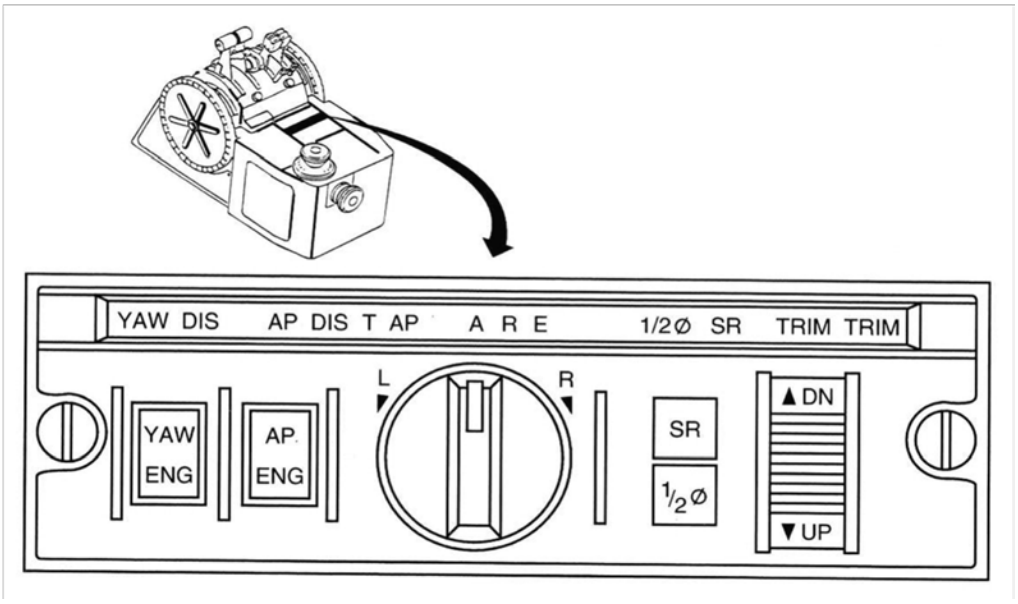
The aileron trim was adjusted by rotating the wheel on the rear of the control pedestal left or right as required to minimise aileron control forces (Figure 7). A scale from 0 to 10 either side of neutral provided a relative indication of aileron trim. The trim wheel was mechanically connected to the right aileron's trim tab surface by cables, chains and rods.

Aileron trim was normally only used during extended periods of simulated one-engine inoperative flight to relieve the pilot flying of sustained aileron control loads.

Yaw damper

A yaw damper was installed as a subsystem of the automatic flight system that sensed the onset of yaw[15] and immediately applied corrective rudder to eliminate it. Its function was to enhance the aircraft's lateral and directional stability by dampening any 'Dutch roll'[16] tendencies and to correct for excessive yawing due to turbulence. It was actuated by a YAW ENG button on the autopilot control, which was mounted on the pedestal between the pilots (Figures7 and 8). Operation of the yaw damper was achieved by momentarily pushing the ON/OFF push-button. When pushed, it engaged the yaw channel of the autopilot and the rudder servo. A second push disengaged the rudder servo only; thus, disengaging the yaw damper.

Figure 8: Autopilot control panel



Additionally, disconnect buttons, which disengaged the autopilot and yaw damper, were located on the left horn of the captain's control column (Figure 9), and on the right horn of the copilot's control column. The button was mounted so that a pilot holding the control column normally (as one grips a motorcycle handlebar) could use the extended thumb of the relevant hand to push the disconnect button. That allowed a pilot to disconnect the yaw damper and autopilot without having to direct attention away from controlling the aircraft's flightpath, either by external or instrument reference, and without looking for the ENGAGE/DISENGAGE button on the pedestal-mounted autopilot control panel.

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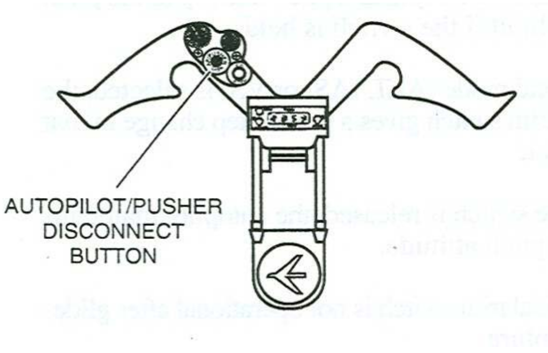
15 Term used to describe the motion of an aircraft about its vertical or normal axis.

16 Lateral oscillation of an aircraft's motion, with both rolling and yawing components.

Figure 9: Left control column showing the autopilot/yaw damper disconnect button



The operator's flight operations manual for the EMB-120 stated that the yaw damper was not to be used for takeoff or landing, and that the minimum speed for its use during one engine inoperative (OEI) flight was 120 kts indicated airspeed (KIAS).

Does this also apply when an engine is kept idling, i.e. still providing hydraulic power?

Aileron and elevator disconnect

The aircraft had an aileron disconnect system to disconnect the left aileron control from the right aileron control if either system became jammed. The Quick Reference Handbook included the following procedure:

JAMMED AILERONS

1. Yoke……………………….……………HOLD
2. Autopilot…………..……………………DISENGAGE
3. Aileron Disconnect………………..…...SQUEEZE AND PULL

An aileron disconnect handle on the right or copilot's side of the central control pedestal disconnected the aileron control subsystems when pulled. When actuated, a single chime audio warning sounded, the master caution light flashed and an amber caution light labelled CONTR DISENG (control disengaged) illuminated on the multiple MAP.

A similar disconnect was provided for the elevator control system with a disconnect handle located on the left or captain's side of the central control pedestal. A CONTR DISENG lamp on the MAP was recovered from the wreckage and examined. The condition of its filament was consistent with the lamp not being illuminated at impact.

Aircraft maintenance

The aircraft was maintained as a Class A, regular public transport aircraft that was operated under the instrument flight rules. It was maintained under a phased inspection system of maintenance in accordance with the operator's approved Maintenance Control Manual, which accorded with the aircraft manufacturer's requirements. The maintenance schedule was based on an average flying rate of 500 flight hours per year and included phased maintenance consisting of a 'phase A' inspection at 500-hour intervals and a 'phase C' inspection at 4,000-hour intervals.

A review of the aircraft maintenance documentation did not reveal any abnormalities. The flight deck log was not identified in the wreckage and it was not possible to determine what, if any, defects had been recorded.

Fuel

Fuel records for that day showed that 1,240 L of fuel was added to the aircraft at Darwin. Due to the post-impact fire, no fuel was able to be recovered from the wreckage for analysis. As no other aircraft using AVTUR[17] from the same source as used for the training flight reported any fuel-related problems that day, it was unlikely that fuel quality was a factor.

Weight and balance

The aircraft load and trim sheet that was prepared by the captain showed a brakes-release weight of 9,633 kg, which was 80 % of the aircraft's maximum take-off weight of 11,990 kg. The load included 1,633 kg (2,041 L) of fuel and 80 kg of ballast (filled plastic water containers) in the rearmost baggage section.

Although close to the maximum allowable forward limit, the aircraft was loaded within its centre of gravity (c.g) limits. However, with a c.g at its forward limit the longitudinal static margin is at a maximum and the aircraft will therefore be very stable and more difficult to manoeuvre with associated heavier pitch control loads.

Take-off performance and Control

On Page 35: V_1 and V_R are not the same speed.

V_2 doesn't guarantee a margin of 10% if a small bank angle is not maintained. Refer to text box on page 3. There is a difference between V_{2min} and V_2.
V_{2min} is highest of10% above V_{MCA} or 13% above Vs.
V_2 should be higher than V_{2min}.
This 10% margin above V_{MCA} is only guaranteed when a small bank angle is being maintained, depending on the airspeed; 5° at V_{MCA}, 2 - 3° when V_2, and in addition, both during straight flight only; see top of next page.
The AFM and Ops manuals are needed to further analyse takeoff speeds.

Charts in the EMB-120 aircraft flight manual (AFM) enabled the determination of V_1/V_R[18] (decision speed) and V_2 (take-off safety speed) for different aircraft weights, configurations, environmental and runway conditions. Flying at a speed of V_2 guaranteed a margin of 10% above V_{MCA}[19] and ~~20%~~ above V_S, whichever was greater. Adjustable airspeed reference markers or speed bugs on the bezel of the airspeed indicator dial were set to display the reference speeds for takeoff. A pitch attitude of 7° nose-up was used as the initial target attitude to establish V_2 during climb, and subsequently adjusted to achieve V_2 speed tolerances following an engine failure on takeoff. The decision and take-off safety speeds for the training flight at a brakes-release weight of 9,633 kg, using derated take-off power and for the ambient temperature on the day of 30 °C, were determined to be 100 and 113 KIAS respectively.

This definition is definitely not correct. Not "controllable", but "can maintain straight flight" (FAR 25.149). Not with a maximum 5° bank, but "while banking 5°". The "max. 5°" is for tail design engineers for sizing the vert. tail. Once the tail is sized, pilots must use the exact bank angle that was used by the design engineer, usually exact 5°. Not 'critical engine'. V_{MCA} applies after failure of any one engine, critical or non. Published V_{MCA} is the worst case V_{MCA}, the highest a pilot will experience in-flight, provided the pilot uses rudder up to max. to maintain heading. V_{MCA} not only applies during takeoff, but also during the remainder of the flight and during approach.

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17 Aviation turbine engine fuel.

18 Rotation speed V_R is the speed at which rotation (aircraft nose raised) is initiated during the takeoff to attain V_2 speed at or before a height of 35 ft above the runway surface.

19 The airborne minimum control speed, V_{MCA} was defined in the EMB-120 Flight Operations Manual as

> ...the minimum flight speed at which the aircraft ~~is controllable~~ with ~~a maximum~~ 5° bank [toward the operative engine] when one engine ~~[critical engine] suddenly~~ becomes inoperative with the remaining engine operating at ~~takeoff~~ power. The value presented represents the most critical combination of power, weight, and centre of gravity. ~~In aircraft with auto-feathering, V_{MCA} is calculated with a feathered propeller.~~

max

or is

Do not all EMB-120's have auto-feathering?
Delete, or replace this line with: If not feathered, V_{MCA} is (xx kt) higher than the published value.

OK, you know! Great, but why not used in the analysis?
Not mentioned under Performance is that when the small bank angle is not being maintained, sideslip increases, hence the drag, decreasing performance.

V_{MCA} was determined to be 97 KIAS with 15° take-off flap selected. The increasing angle of bank toward the left (inoperative) engine that was evident in the aircraft's roll angle plot (Appendix A, Analysis section, Figure A-2) ~~would have resulted~~ did result in an increasing V_{MCA}, well above the 97 KIAS extracted from the chart in the EMB-120 Flight Operations Manual (An explanation is provided in a later section of this report titled *Characteristics of Asymmetric Flight).*

Meteorological information

The automatic terminal information service (ATIS) provided pilots with current aerodrome information incorporating meteorological conditions. The Darwin ATIS current at the time of the accident reported a wind of 320° (M) at 5 kts, visibility greater than 10 NM (19 km) with few[20] clouds at 2,000 ft above ground level (AGL) and a temperature of 30 °C. Witness descriptions of the weather at the time were consistent with the recorded data.

Communications

Communications between the crew and the air traffic controllers (ATC) at Darwin tower were normal. The ATC recordings of those radio communications were consistent with the transmissions recorded on the aircraft's CVR.

All radio communication from the aircraft was made by the PIC, as a function of his pilot not flying duties.

Aerodrome information

Darwin Airport was a joint civil/military user aerodrome. Air traffic control was administered and staffed by personnel from the Australian Defence Force. The category 8 aviation rescue and fire fighting (ARFF) service was provided by Airservices Australia.[21]

The airport elevation was 103 ft and there were two 60 m wide sealed runways and their associated taxiways and aprons. Taxiway E2 linked the civilian apron to runway 29/11. Although the distance available from the intersection of taxiway E2 and runway 29, where ANB commenced its takeoff, was adequate for the aircraft at its brakes release weight of 9,633 kg, the distance required using derated takeoff power of 94% torque was not determined. ???

reduced

[20] Cloud cover is normally reported using expressions that denote the extent of the cover. The expression Few indicates that up to a quarter of the sky was covered,

[21] The level of ARFF service provided ranges from Category 6 to Category 10 as determined by CASA and international protocol. Those categories of service are determined based on the size of the aircraft serving an airport, the required foam and water requirements and discharge rates, and the stipulated ARFF response times.

Flight recorders

The aircraft was equipped with a flight data recorder (FDR) and cockpit voice recorder (CVR), as required by the regulations.[22] Both recorders were removed from the wreckage and transported to the Australian Transport Safety Bureau's (ATSB) facilities in Canberra for examination and data download. Examination reports for the FDR and CVR appear in Appendixes A and B.

A computer graphics animation of the FDR data was produced to assist in the analysis of the accident. The animation covered a 2-minute period commencing with the aircraft taxiing onto the runway and continuing until the end of recording.

The animation consisted of two windows and a panel of instruments (Figure 10). A plan view was located in the upper right corner while an elevation view was located in the main window. A control wheel and a rudder index were incorporated into the main display to provide a representation of the flight control inputs.

The instrument panel was a general representation of key flight and engine instruments and was not intended to be an exact representation of the actual aircraft instrument panel. The animation can be viewed at http://www.atsb.gov.au/publications/investigation_reports/2010/aair/ao-2010-019.aspx and a sequence of frames from the animation is at Appendix C.

Figure 10: Animation display

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[22] Civil Aviation Order (CAO) 20.18 paragraph 6. The equipment standards regarding the flight recorders are specified in CAO 103.19 (FDR) and 103.20 (CVR) respectively.

Flight data recorder

The aircraft's Loral Data Systems F800 digital FDR recorded 40 parameters, including 11 aircraft flight parameters, five aircraft control or control surface parameters, 20 engine parameters and four documentary parameters. The FDR successfully recorded all of those parameters for the flight but, due to a fault,[23] retained the most recent 16.7 hours of data, rather than the most recent 25 hours as required. The FDR data was used to develop a sequence of events (Table 1) and to aid in the interpretation of those events.

An attempt was made to source FDR recordings of previous proficiency check flights that had been carried out in EMB-120 aircraft for comparison with this flight. However, none was available because the recordings of those flights had been overwritten.[24]

Cockpit voice recorder

The aircraft's CVR was an L-3 Communications Aviation Recorders (formerly Fairchild Aviation Recorders) model A100S solid state recorder. The CVR recording contained 30 minutes 11 seconds of audio information from the flight.

The recorded communication showed normal interaction between the crew as they prepared the aircraft for departure and completed the supporting checklist actions. There was no comment about any aircraft defects or abnormal circumstances. The relevant crew communications were extracted from the CVR and graphically integrated with the FDR data (Figure 2).

Wreckage and impact information

The wreckage was situated about 500 m south of runway 11/29, adjacent to the threshold of runway 11. It was in partially-wooded bushland on level ground within the airport boundary, on a part of the military air base not far from occupied buildings. The aircraft had descended through the surrounding trees and impacted terrain in a steep 65° nose-down, partly inverted, right wing-low, attitude (Figure 11).

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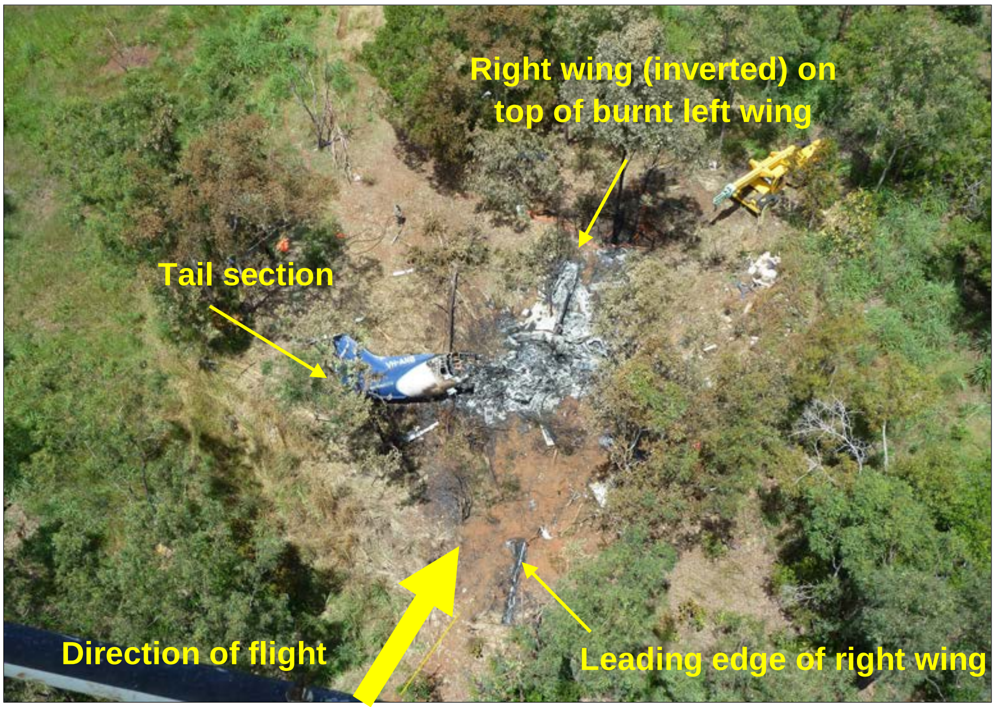
23 The FDR tape contained six tracks and examination of the data showed that tracks one and six (located on the edges of the tape) were being bypassed, and that the recording was repeatedly progressing from track five to track two.

24 FDRs and CVRs record using an 'endless loop' principle, where the oldest data is continuously overwritten by the newest data. As a result, only the most recent data is retained. The required recording durations were 25 hours for the FDR and 30 minutes for the CVR.

Figure 11: Aerial view of the accident site



The fuselage forward of the cargo door, the inboard sections of the right wing, and most of the left wing including the engines and propellers were destroyed by impact forces and a post–impact, fuel-fed fire (Figure 12).

Figure 12: Aircraft wreckage, showing the extensive fire damage

The damaged right wing was separated from the main aircraft wreckage and was located on top of the left wing. The leading edge of the right wing had been liberated from the structure following ground impact and was extensively fire damaged. The right aileron and aileron trim tab were fire damaged and the trim position was unable to be determined.

The rear fuselage and tail section were damaged from contact with the trees but remained relatively intact. The vertical fin displayed minor compression wrinkling from impact forces.

The propeller blades exhibited significant damage and some were shattered. Three of the four blades from each of the left and right propellers had detached from their hubs and were found at distances up to 15m from the wreckage. The reduction gearboxes had separated from each engine due to impact forces.

The landing gear was retracted and the flaps were extended to 15º, the normal take-off setting. All flight control surfaces were accounted for at the accident site.

The aircraft was equipped with a 406 MHz emergency locator transmitter in the rear fuselage that activated as intended when the aircraft collided with the ground.

The aircraft's engines and propeller hubs and a number of other components were recovered from the accident site for further examination.

Aircraft component examination and testing

Examination of the engines and propellers

Both engines were examined by the engine manufacturer's technical personnel under ATSB supervision. Those examinations revealed impact damage to both engines but no indications of pre-impact unserviceability of either engine's internal components.

The left engine was transported to the manufacturer's facilities in Canada for disassembly and further examination under the supervision of the Transport Safety Board of Canada. That examination indicated normal in-service wear of the engine and its associated components. No anomalies or pre-existing conditions were identified that would have affected the normal operation of the engine.

Both of the propellers were examined by the propeller manufacturer's technical personnel under ATSB supervision. Measurements were made of the pitchlock screws and ballscrews[25] in order to determine the angles of the propeller blades at impact. The results were forwarded to the propeller manufacturer for assessment of the relative blade positions.

The propeller manufacturer reported that, on the basis of the measurements provided, the right propeller blades were at a pitch angle of 37.9°, which was above the flight idle position and that the propeller blades were under power at that time.

The left propeller blades were at a pitch angle of 22.2°, which was in the beta range. Although that blade angle was within the beta range, the beta parameter on the FDR showed that the propeller was operating in flight mode.

---

25 Internal components of a constant speed propeller mechanism. The pitchlock functions whenever there is a loss of oil pressure to the propeller, locking the affected blade's pitch at a slightly lower pitch angle than when the pitch was under the control of the governor. This feature prevents the blade pitch from decreasing while still allowing the blades to increase pitch to the feather position if so commanded.

Examination of the elevator trim

The elevator trim actuator was measured and photographed to determine the elevator trim setting at impact. The photographs and measurements were sent to the manufacturer in the United States (US) for comment on the trim setting. The manufacturer noted that the as-photographed measurement of 12 mm indicated a moderate nose-up trim setting at the time of impact, about halfway between neutral and full nose-up.

Testing of the rudder PCU and actuators

The aircraft's rudder power control unit (PCU) and rudder hydraulic actuators were removed for testing and examination by the component manufacturer in the US under the supervision of the US National Transportation Safety Board (NTSB). The internal leakage test performed by the component manufacturer found both rudder actuators exhibited excessive leakage in the extended position. However, the component manufacturer advised that, although the components were outside specified tolerances, an in-the-field differential pressure check would not necessarily have shown the actuators to have been unserviceable.

The component manufacturer also measured the rudder trim drum on the PCU to ascertain the rudder trim setting. That examination determined that the rudder trim was set to full right (aircraft nose right) at ground impact.

The components were returned to Australia where differential pressure testing was carried out in accordance with the aircraft manufacturer's maintenance manual under ATSB supervision. In order for that testing to occur, the actuators were installed in an EMB-120 aircraft. Both actuators passed the defined test criteria for serviceable operation. In addition, the application of full right rudder trim was tested using the components from ANB. In that test, the application full right rudder trim resulted in about mid-right rudder pedal travel.

Following this testing, the rudder actuators were taken to an overhaul facility for disassembly and examination under ATSB supervision. That examination revealed normal in-service wear associated with serviceable components.

Examination and analysis of the recovered instruments

Due to impact and fire damage, only two of the aircraft's flight instruments were identifiable and relatively intact; the standby attitude indicator and an airspeed indicator. It could not be determined whether the airspeed indicator was from either the captain's or copilot's panel.

The standby attitude indicator display was captured at impact and showed a left bank in excess of 150° and that the aircraft was almost inverted with a steep nose-down attitude at that time. That was consistent with the aircraft's attitude at impact as recorded by the flight data recorder and from witness accounts.

The airspeed indicator did not display any witness marks that might have indicated the speed of the aircraft at impact. However, the instrument's two 'speed bugs' were set to 100 KIAS and 113 KIAS, consistent with the aircraft's calculated V_1/V_R and V_2 for the take-off weight of 9,633 kg.

On Page 35, Fig 13 out of the AFM: V_1 and V_R are not the same speed.

Medical and pathological information

The post-mortem reports for both crew members described injuries that were consistent with the accident and that neither pilot exhibited any physiological condition that would have affected the performance of their duties.

Toxicological testing confirmed that neither pilot was affected by drugs or alcohol.

Fire

There was no evidence of any in-flight fire. An intense post-impact, fuel-fed fire resulted in significant fire damage to the wreckage before being extinguished.

Survival aspects

The accident was not considered survivable.

Tests and research

Simulator flight testing

ATSB commissioned simulator trials

In an attempt to understand the flight characteristics and handling of the EMB-120 as configured during the flight, a series of tests was undertaken on a Flight Safety EMB-120 simulator at a Melbourne-based training facility. The simulator represented an EMB-120 model with PW 118 engines, not the -118A as fitted to the aircraft. The effect of this difference was that the engine power programmed in the simulator could not simulate torques greater than 118%.

The testing was performed by pilots with considerable experience on the EMB-120, including one instructor with training and checking experience in both the actual aircraft and the simulator. The simulator's full motion function was disabled during the testing to enable video recording of the test sequences.

The simulator testing attempted to duplicate the sequence of events during the accident flight, using the same aircraft configuration, weight and balance, and atmospheric conditions that existed for the flight. Difficulties were experienced with emulating exactly the crew's actions because the precise timing and application of some of the ancillary controls was not recorded by the FDR and could only be trialled during repeated rehearsal by the simulator crew.

Normally in a simulator, engine failures are initiated by a simulator instructor from a control panel remote from the simulator's cockpit. The pilots in the left and right seats of the simulator performed the normal pilot and copilot duties associated with the simulated emergency. For testing purposes, the simulated engine failure was initiated in exactly the same way as it would have been in the actual aircraft. That was, by manipulating the left power lever to 'simulate' the left engine failure.

The simulator testing revealed that, with flight idle selected on the left engine just after becoming airborne, control of the simulator could be maintained, although it

Did the simulator not comply with roll control forces required in FAR 25.143? Two hands 50 lb, one hand 25 lb. Long term 5 lb.

was physically difficult for the pilot flying because of the magnitude of the control inputs required. The pilot flying, who was seated on the left, demonstrated that the only way to maintain sufficient aileron control was to place his left hand under the end of the left control yoke 'rams horn' to provide the additional leverage necessary for lateral (aileron) control. A rate of climb was maintained even with the wings held level,[26] but with significantly diminished performance. Variation in attitude and heading was noted while the pilot flying attempted to establish a power setting of 110% for the right engine and to introduce right rudder trim as required.

Sure? The left engine would then still provide hydraulic power, or not? Page 20.
A yaw damper doesn't normally use rudder pedal input, but input from yaw/directional gyro.

It was also possible to control the simulator with the left propeller windmilling and with the yaw damper engaged, but the pilot flying reported that it required significantly greater right rudder force.

During takeoff and below 120 kt while OEI, the yaw damper should not be engaged (page 20 above). So was it?
Reaching for the button on the pedestal would mean engaging the yaw damper, not disengaging. Would be a pilot error.
Was the checklist correct?

The pilot flying found that holding the controls in the unorthodox manner described above meant that he could not operate the yaw damper disengage button on the yoke with his left thumb. Instead, he had to take his right hand off the right horn of the control yoke and disengage the yaw damper by depressing the yaw disengage button on the autopilot panel that was located on the pedestal between the two pilots. The need to look down at the autopilot panel meant diverting his attention from maintaining attitude and heading.

Although the pilot flying was able to maintain control of the simulator, some variation in attitude and heading occurred while he attempted to disengage the yaw damper. When the right aileron control force was relaxed, the control yoke moved momentarily to the left, consistent with the control wheel movement that was recorded on the flight data record for the accident flight. In consequence, the simulator began rolling left. Despite the reapplication of full opposite (right) aileron and rudder, the simulator continued to roll rapidly and uncontrollably left. It was reasoned that, when the aircraft was allowed to roll toward the inoperative engine in that configuration and at that speed, a roll inertia would have developed that was greater than the forces available from the flight controls to correct it.

The use of the yaw damper during asymmetric flight was introduced to the simulator testing following consideration of the cockpit voice recording references to the PIC's command 'disengage' and the pilot under check's response, 'yeah, disengaging'. It was assumed that the reference was to the yaw damper and not the autopilot because the chime that sounds when the autopilot was disengaged was not heard on the CVR recording. Additionally, the simulator instructor reported having previously observed pilots engage the yaw damper during simulated engine failures in the EMB-120 in response to pilots 'overcontrolling' rudder and aileron following a simulated engine failure.

The sequence was repeated with the pilot not flying (right seat) restoring power on the left engine just after the simulator commenced the uncontrollable left roll. The reintroduction of power at that point demonstrated that recovery to normal flight was possible in the simulator.

Aircraft manufacturer simulator trials

In June 2011, at the request of the ATSB, the aircraft manufacturer conducted a series of tests in a full flight simulator to better understand the aircraft's control and

What meant by optimum? 5° is only for V_{MCA}. At the speed for max. ROC, which is higher than V_{MCA}, the bank angle for which the sideslip is minimal should be 2 - 3°.

---

26 The optimum single-engine climb performance is established with the aircraft banked up to 5° toward the operating engine.

flight behaviour in the same configuration and aircraft operation as seen in the recorded data for the accident flight. The testing was carried out at the Escola Paranaense de Aviação (EPA) facility in Curitiba, Paraná, Brazil.

Was this a graduate Experimental Test Pilot of a Test Pilot School, knowledgeable and licensed to conduct these kind of trials?

The manufacturer reported that, in a re-enactment of the flight in the simulator, it was possible to avoid loss of control of the aircraft after the power to the No 1 (left) engine was reduced to 0% torque, without propeller feathering, and with the No 2 (right) engine set to approximately 124% torque. In conditions very similar to the accident[27], controllability depended upon effective flight control responses, while maintaining airspeed greater than 105 kts.

Weight? cg?

What do you mean? Airplane design (i.a.w. FAR 25.149) doesn't guarantee controllability at V_{MCA}, only straight flight.

The unrecoverable control situation that developed with ANB was observed when the test pilot did not apply full right aileron control, which permitted a momentary roll to the left with increasing pitch, resulting in the airspeed decreasing to below 105 kts.

At less than max. aileron, the (lateral) V_{MCA} is higher. This is why the roll increased, but also the drag (thrust was asymmetrical!), decreasing the airspeed.

What is meant by controlled? V_{MCA} is for straight flight only. V_{MCA} was 97 kt, with wings level may be 105 kt. What about the other variables that influence V_{MCA}? This conclusion may not be drawn from simulating.

According to the manufacturer's flight simulations, the minimum control speed for situations where the aircraft could still be controlled when the power to the No 1 engine was reduced to 0% torque without propeller feathering, and the opposite engine torque was increased to 124%, was 105 kts.

During the flight simulator session conducted by the manufacturer, when the V_2 established by the AFM was maintained, even with the No 1 engine at 0% torque and its propeller not feathered, and with the No 2 engine at 110% torque, aircraft control could be maintained.

Were the other conditions the same as well? W, cg, etc. How good was the simulator model for engine-out flight at airspeeds as low as V_{MCA}?

Organisational and management information

Introduction - zero thrust versus zero torque

Most engine inoperative training on large aircraft is conducted in flight simulators. When simulators are not available, the training is conducted in-flight, where reducing power on one of an aircraft's engines simulates an engine failure. The appropriate technique for a turboprop engine is to retard the appropriate power lever to a power setting that equates to the 'zero thrust' condition of a feathered propeller. The power lever should be retarded at a rate that is commensurate with the engine's normal deceleration behaviour.

Simulating an engine failure by retarding the power lever to zero torque or flight idle simulates a failure of both the engine and the autofeathering system. This produces much more drag from the 'windmilling' propeller than had the propeller automatically feathered. The increased drag results in difficulty maintaining directional control that requires a high degree of pilot skill to manage as well as a reduction of performance that may not provide required obstacle clearance.

In addition and more important, a windmilling propeller increases the actual V_{MCA} of the airplane to a much higher value than the published V_{MCA}, which was determined with a feathered propeller if feathering is automatic (FAR 25.149(c)(7)(iii). The increased asymmetrical drag requires a larger counteracting yawing moment from the rudder. If the rudder is max., only a higher speed can provide the larger yawing moment, hence the actual V_{MCA} is higher. The drag is only minimal if the aircraft is banked a few degrees away from the inoperative engine. V_{MCA} is also measured at this bank angle hence, is only valid if the aircraft is banked. Dr. Jan Roskam (University of Kansas) in his Airplane Design Series of Books: "V_{MC} and performance are tied together by bank angle".

27 The technical accuracy of the re-enactment flight in the simulator relied on extrapolation of a mathematical model to conditions well beyond the normal operational envelope and foreseeable abnormal situations considered during the aircraft's development.

Managing and training for an engine failure after takeoff

Civil Aviation Safety Authority advice

The Flight Crew Licensing Procedures Manual (Version 6.1: December 2006) provided guidance on the conduct of flight testing. Section 16.2.1 of the manual offered the following guidance:

> *Multiple Failures*
>
> Only one emergency should be simulated at a time. Double failures are beyond the requirements of the flight test, **are unrealistic and are likely to overload the applicant and increase the likelihood of errors**.
>
> *Engine Failure Simulation in Turbo-Propeller Aircraft*
>
> Some recent incidents have also highlighted the dangers associated with engine failure simulation in multi-engine turbo-propeller aeroplanes. Approved Test Officers conducting flight tests in turbo-propeller aeroplanes should ensure that they are completely familiar with the procedures specified in the aircraft flight manual for engine failure simulation, **as mishandling of engine controls has the potential to place the aircraft in an extremely high drag configuration which may not be recoverable**.
>
> As a general rule, engine failure in turbo-propeller aeroplanes should only be **simulated by moving the power lever to a zero thrust setting rather than flight idle**. The power lever should never be moved beyond the flight idle stop and into the Beta/reverse range for any reason in flight, as high drag configuration and resulting loss of control is highly probable.

Civil Aviation Advisory Publications (CAAP) are issued by CASA to provide guidance and information on designated subject areas, or to explain options for compliance with a related Civil Aviation Regulation. The CAAPs are not binding, but provide guidance on the preferred method of compliance.

Refer to comments on this publication on the downloads page of website www.avioconsult.com, download #9.

In September 1996, CASA issued CAAP 5.23-1 (0) to provide advice on the syllabus of training for the initial issue of a multi-engine aircraft type endorsement (rating) and subsequent multi-engine type endorsements. In July 2007, a revised CAAP 5.23-1(1) titled *Multi-engine Aeroplane Operations and Training* was published that provided additional and comprehensive information, including the risks involved with multi-engine training and the mitigation of those risks. The CAAP reinforced the ATSB statistic that 16% of multi-engine aircraft accidents occur during training or assessment.

The CAAP also noted that pilots were required to be competent in dealing with an engine failure during or just after takeoff. Guidance to those giving instruction or assessing multi-engine aircraft training included:

> One of the hallmarks of a good pilot or instructor is their ability to maintain situational awareness. This is particularly important during multi-engine asymmetric training at low altitude. Instructors must be able to think ahead and anticipate. **At critical stages of flight such as engine failures after take-off, the instructor must constantly monitor the trainee’s performance and be ready to take over and rectify any dangerous event**.

The CAAP advised that although risks associated with asymmetric operations were obvious, these risks could be mitigated by the use of robust procedures such as adherence to standard operating procedures, compliance with flight manual instructions and warnings, and comprehensive and on-going training. The CAAP also encouraged the incorporation of Threat and Error Management (TEM) into the conduct of training flights, describing the difference between risk management and TEM as follows:

> ... Generally, risk management is the process of deciding whether or not operations can be can be conducted to an acceptable 'level' of risk (go or no-go) safely, whereas TEM is the concept applied to managing and maintaining the safety of a particular flight.

Threats were defined as hazards outside the control of the pilot(s) and which threaten the safety of a flight. Errors, however, were an inevitable part of human activity:

> ... The TEM model accepts that it is unavoidable that pilots, as human beings, will make errors. Errors may be intended or unintended actions or inactions on the part of a pilot(s) and can be classified as handling errors, procedural errors or communication errors.

The CAAP contained advice for simulating engine failures in turboprop aircraft. It emphasised that 'zero thrust' power was to be set because these aircraft have autofeathering systems. The CAAP indicated that the power lever should be smoothly retarded to the 'zero thrust' setting and that check pilots should know how to set zero thrust on that particular aircraft. Operator's operations manuals or checking and training manuals should state:

- the procedure for setting zero thrust
- the power setting that represents zero thrust
- that engine failures should be simulated by setting zero thrust on aircraft fitted with a negative torque sensing (NTS) or autofeather capability.

The CAAP noted that:

> ...reports from Australia and overseas have repeatedly shown that **fatal accidents have occurred following practice engine failures because instructors have failed to set zero thrust on a windmilling engine to simulate a feathered propeller**.

To assess performance, high weight is required (if the AFM still predicts some climb performance at that weight).
V_{MCA} should be demonstrated/ assessed at lowest possible weight, because V_{MCA} is determined at low weight. At low weight V_{MCA} is higher than at high weight when a small bank angle is being maintained to reduce the drag to a minimum.
Refer to Flight Test Guides (ref. list on Downloads page of www.avioconsult.com)

In addition, the CAAP recommended that, for training purposes and to provide candidates with a realistic assessment of an aircraft's one engine inoperative performance, an aircraft should be loaded to about 90% of its maximum all-up weight (MAUW). If loading to that weight was not practicable, then:

> ... use of a properly developed Training Power setting that approximates the performance of the aircraft at MAUW may be utilised.

Using a power setting greater than the training power may engender unrealistic expectations of engine-out performance. However, using a lower power setting to represent the performance of a heavier aircraft would effectively lower V_{MCA}. If, after simulating an engine failure, power of the 'live' engine was increased to the manufacturer's maximum permitted power of 110% torque, the published V_{MCA} was valid.

Which V_{MCA}? High weight? Wings level? cg? The max. power was 120% (page 14).

On 18 July 2008, CASA issued CASA Communication (CASAComm) 05/08/0 titled *Simulation of Engine Failure in Aircraft.* That document provided guidance to operators within the oversight of CASA's Air Transport Operations Group on the techniques to be used for the in-flight simulation of engine failures. The document accepted that, although the majority of engine-out training on large aircraft was carried out in flight simulators, there was a need for in-flight training because simulators were either not available or not suitably approved for some aircraft types.

In that document, under the section *Guidance for training Captains,* the following recommendation was made:

> When power failure is simulated during take-off, the speed should always be at or above V_1 or Take-off Safety Speed (TOSS) (V_2) and **the training captain should assume control if there is any indication that action by the trainee is leading to a reduction below these speeds**.

In addition, in the section titled *Recommended techniques for simulation of engine failure on takeoff - Turbo-prop Engines,* the document recommended that:

> a) The simulation of engine failure by throttling back can introduce particular handling and performance problems. The primary problem arises from the fact that **a turbo-prop engine that has been throttled back to flight idle will produce much more drag than an engine which has failed and auto-feathered**. A further problem is that any automatic feathering or drag limiting devices fitted are usually made inoperative when the throttle is closed. Consequently, if an engine that has been throttled back to simulate failure suffers a real failure, it may go to a very high drag 'wind-milling' condition, remaining un-feathered unless correct feathering action is taken by the crew. Furthermore, because the engine is in a low power condition, failure may not be noticed until after severe handling difficulties have arisen.

an increase in drag and

> b) There will also be a reduction in performance which may well lead to decay in airspeed and an inability to maintain adequate clearance over obstacles. **Any such loss in airspeed can of course contribute to the loss of directional control.**

Actual V_{MCA} is already higher than the published V_{MCA} when the popeller is not feathered and the wings are kept level. Any manoeuvring away from the small bank angle into the good engine during straight flight will contribute to the loss of directional control, because actual V_{MCA} can easily increase above IAS during takeoff (and during the final turn for landing when the thrust has to be increased for maintaining the glidepath).

> c) These potential problems can best be avoided by appropriate methods of simulating engine failure. Advice from engine or aircraft manufacturers specific to type should always be sought and followed. Where this is lacking, the following general advice is likely to be appropriate: **The throttle should be retarded smoothly towards a predetermined torque setting approximating to zero thrust.** This torque setting should be maintained during the remainder of the take-off and initial climb; if it falls due to a suspected malfunction the throttle should be realigned with that of the operative engine.

Dangerous, see text box on page 8.

CASA also published an article in the March-April 2002 edition of its *Flight Safety Australia* magazine that addressed the simulation of engine failures in turboprop aircraft. The article, titled drew on the findings of the former Bureau of Air Safety Investigation (BASI)[28] aviation safety report BO/200000492 (Beech 1900) and ATSB report 9503057 (Metro III) and emphasised the used of zero thrust for simulating engine failure.

[28] On 1 July 1999, BASI was amalgamated with the then Marine Incident Investigation Unit and an, embryonic rail unit to form the ATSB.

Other regulators advice

In 1999, the United Kingdom (UK) Civil Aviation Authority Advisory Information Circular 52/1999 provided guidance to UK operators for simulating engine failure in multi-engine aircraft. The section on in-flight asymmetric training stated that:

> Simulated failures on the runway after V_1 are potentially very hazardous. Consequently, many organizations and individuals consider it an area best avoided.

Engine failure training close to the ground is simulated by a power reduction. The UK requirements recognise that the best method of simulation of engine failure through power reduction will vary from one class of aircraft to another. The requirements stipulate that the rate of power lever retardation should simulate normal engine deceleration, and that all drills close to the ground should be touch drills only.

The UK circular noted that, where specific information was not available from engine or airframe manufacturers in respect of the simulation of one-engine inoperative conditions, the following general advice was likely to be appropriate:

> **The throttle should be retarded smoothly towards a pre-determined torque setting appropriate to zero thrust.** This torque setting should be maintained during the remainder of the takeoff and initial climb.
>
> **Trainers should be aware that simulating engine failure by throttling back to idle to train for manual feather produces a much higher drag condition than certification requirements may have considered. Certification usually assumes that autofeather, NTS, or other drag-limiting devices are operative. This potentially hazardous situation can rapidly lead to control difficulties in some airplanes. Therefore, simulation of an engine failure by setting zero thrust at the outset is the recommended option. The training captain must know the torque value (zero thrust) for the equivalent drag of a fully-feathered propeller.** Trainers should also be aware that autofeather or other low-drag safety devices are inhibited with one engine throttled back. In the event of a real failure of the 'failed' engine, a high-drag situation will result unless the retarded engine control is immediately advanced to match the other, or a manual feather is carried out.

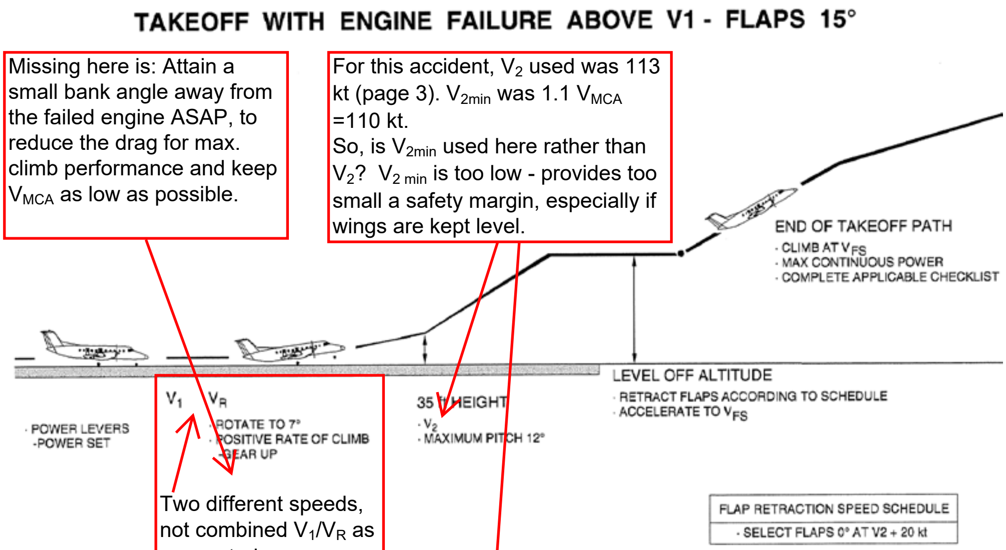
European Joint Aviation Authorities (JAA) policy allows simulated engine failures as soon as safety considerations permit after passing V_2. Any additional restrictions addressing minimum speeds and heights for engine failure drills should be observed.

Manufacturer's advice

The aircraft manufacturer did not provide any specific instructions for the demonstration or simulation of in-flight engine failure. However, Section 3-18 of the AFM gave the procedure to be followed after an engine failure above V_1 (Figure 13).

The procedure was designed for a level-off height between a minimum of 400 ft AGL and 1,500 ft AGL maximum. At that altitude, the aircraft was to be levelled, accelerated to V_2 + 20 KIAS, have the flaps retracted, and then be accelerated to V_{FS} (final segment speed).[29]

Figure 13: EMB-120 Flight Manual procedure



Missing here is: Attain a small bank angle away from the failed engine ASAP, to reduce the drag for max. climb performance and keep V_{MCA} as low as possible.

For this accident, V_2 used was 113 kt (page 3). V_{2min} was 1.1 V_{MCA} =110 kt.
So, is V_{2min} used here rather than V_2? $V_{2\ min}$ is too low - provides too small a safety margin, especially if wings are kept level.

Two different speeds, not combined V_1/V_R as suggested on pages 21 and 27.

At V_R rotate to the takeoff attitude (7deg)

At 35 ft height and positive rate of climb:

Landing Gear..........UP

Airspeed.................V_2

The EMB-120 AFM needs a critical review on the subject of engine failures, including V_{MCA}, V_{2min}, V_2 and procedures. This manual was not available for review.

Retract flaps at V_2 + 20 KIAS at the level off height and accelerate to final segment speed or, if a close-in turn is performed, maintain the takeoff flaps and the airspeed at V_2 with a maximum bank of 15 deg.

Not V_2 + 20 here? V_{2min} = 110 kt at low weight, not much higher , if any, than the V_{MCA} for wings level. This V_2 is not safe to turn with 15° bank either side! Control problems might not occur, (pages 3, 21).
This cannot be right.

Complete PRECAUTIONARY ENGINE SHUTDOWN or ENGINE FIRE procedure, as applicable.

The manufacturer forgot, or the writer didn't know that the most important and life-saving action is to bank 5° away from the inop engine ASAP to both maintain control margin above V_{MCA} and reduce sideslip/ drag.

The manufacturer reported that the only cockpit action required by the crew from rotation (takeoff) to the level-off height was to retract the landing gear, an action normally performed on all takeoffs. The manufacturer's intent was that, when the aircraft was accelerated at the level-off height, take-off power could be readjusted if necessary.

The aircraft manufacturer advised that the procedure conformed to US Federal Aviation Regulation Part 25 section 25.111(c)(4), which stated:

> The airplane configuration may not be changed, except for gear retraction and automatic propeller feathering, and no change in power or thrust that requires action by the pilot may be made until the airplane is 400 feet above the takeoff surface.

FAR 25 is for the certification of an airplane. This § is to make sure that the FAR 25.111 takeoff path requirements below 400 ft are met during certification. It does not apply to airline operations. If an airline pilot knows the effects of thrust changes, especially a thrust increase if the takeoff was on reduced thrust, he or she may do so. It may save lives.
Remember though to bank 5° into the good engine first and maintain straight flight until reaching a safe altitude.

---

29 Final segment speed, to which an aircraft is accelerated during the level segment following an engine failure on takeoff. Flaps are retracted and any power adjustments made during that segment.

In respect of aircraft configuration changes during the simulation of one engine inoperative flight, section 25.111(c)(4) of US Federal Aviation Administration Advisory Circular AC 25-7A titled *Flight Test Guide for Certification of Transport Category Airplanes* explained that:

Meant here are flight test crew during certification to ensure that the requirements in FAR 25.111 are met. AC 25 is not for use by airline pilots (only for review to learn from).

Experience resulted in this requirement for flight-testing and certification, to ensure adequate climb performance. It does not say that an airline pilot may not increase thrust.
See text box previous page. A pilot better increases thrust if the reduced thrust is not adequate to continue flying, but should first attain the favourable bank angle and maintain straight flight.

> (i) The intent of this requirement is to permit only those crew actions that are conducted routinely to be used in establishing the one-engine-inoperative takeoff path. The power levers may only be adjusted early during the takeoff roll, as discussed in paragraph 12b(2), and then left fixed until at least 400 ft above the takeoff surface.
>
> (ii) Simulation studies and accident investigations have shown that when heavy workload occurs in the cockpit, as with an engine failure during takeoff, the crew might not advance the operative engines to avoid the ground, even if they know the operative engines have been set at reduced power. This same finding applies to manually feathering a propeller. The landing gear may be retracted, however, as this is accomplished routinely once a positive rate of climb is observed. This also establishes the delay time to be used for data expansion purposes.

The power level may not be that low that the requirements of FAR 25.111 are not met anymore. Was this included in the 97% torque advice (page 15)?

On 4 September 2009, the manufacturer issued a letter to all Australian EMB-120 operators advising them of the manufacturer's recommended engine torque and propeller speed configuration to simulate zero thrust for single-engine training manoeuvres. It stated:

> According to Australian EMB-120 operators' reports, traditionally, since the EMB-120 first came to Australia back to 1990s [sic], 13% engine torque has been used to simulate "zero" thrust for single engine go-around training maneuver [sic].
>
> Also operators report that this 13% engine torque is recorded nowhere in their flight operations or training publications available.
>
> Following discussions among experienced EMB-120 instructor pilots, flight test pilots and flight operations engineering, the common understanding was that 13% engine torque was too low and that 20% engine torque instead should be used to simulate "zero" thrust for single engine training maneuvers.
>
> The purpose of this letter is to inform EMB-120 operators about the recommended engine torque and propeller speed configuration to simulate "zero" thrust for single engine training maneuvers, according to Embraer's understanding:
>
> Should single engine training maneuvers are to be performed[sic]:
>
> Engine torque (affected side) 20%
>
> N_P (affected side) ....MAX RPM
>
> **Nevertheless, Embraer strongly recommends that all EMB-120 training be performed in an EMB-120 simulator.**

The manufacturer should have issued an AFM amendment, not write a letter (that will not be an effective page in AFM's).

Why not recommend to add a radial line at the torque for zero thrust on the torque indicators?

The operator's procedures

Procedures in the operator's Training and Checking Policy Manual for simulating engine failures during takeoff in EMB-120 aircraft complied with the guidelines set down in CAAP 5.23-1(1) and were approved by CASA. The technique that was taught to the PIC followed those procedures and used a zero thrust power setting for simulation of an engine failure with propeller autofeathering. The operator's

Training and Checking Policy Manual gave direction to training and checking pilots for when and how the simulation of an engine failure was to be conducted. At the time of the accident Section 5.26 of that manual, titled *Simulation of engine failures*, stated:

> The following are basic Company requirements for simulation of engine failure. Refer to the Manufacturer's Operations Manual or the Company Training Manual for the aircraft type for more detailed instructions.
>
> Turbo-prop engine failure shall be simulated **by smoothly and slowly setting zero thrust.**

Better: "torque for zero thrust (20%)".

??

> After 60 knots during takeoff an engine failure may not be simulated until achieving the lesser of V_1 + 5kts or V_R + 5kts. If the latter speed, power/thrust should not be reduced until rotation has been completed.
>
> The need to set maximum thrust on the "good" engine following simulated engine failure shall be at the Check Pilot's discretion, unless otherwise restricted on the aircraft type. The decision will often need to be a compromise between the need for the PF to experience the associated yaw at maximum thrust and the need to provide a more accurate representation of OEI (one engine inoperative) performance at high TOW (takeoff weights) by maintaining thrust at a lower setting (for example: maximum continuous thrust or climb thrust).

The operator's Flight Operations Manual Volume 2 - *Training and Checking* included a number of directions about simulating engine failures in the operator's turbine-powered aircraft. Section 2.8.7 – Simulating engine failures of that manual stated:

> Simulated engine failures in turbine powered aircraft will be carried out by retarding the power lever to the appropriate torque setting, which simulates zero thrust. ...
>
> All check pilots must, when simulating engine failures, exercise caution and monitor the pilot/crew under check to ensure that the correct operating technique is being performed, that the applicable checks are being carried out, and that the aircraft is maintaining a safe flight profile.

Good, only 6 days after the Embraer letter.

On 15 September 2009, following the letter from the aircraft manufacturer, the operator issued Temporary Amendment (TA) 2.1-001 to the training and checking manual directing that for EMB-120 training operations, a torque setting of 20% was to be used for simulating zero thrust. The operator's training and checking pilots reported that following that amendment, a zero thrust setting of 20% torque was used in all subsequent EMB-120 asymmetric training.

How to read this line? Autofeathering is not a failure. You mean throttling back to idle which looks like a simultaneous failure.

In respect of simultaneous failures, such as the simultaneous loss of power and of propeller autofeathering on one engine, the operator's Training and Checking Policy Manual stated:

> Multiple or compound failures during proficiency training should be either the logical result of an initial failure, or the failure of the crew to apply correct and appropriate procedures.

The use of flight idle (0% torque) to simulate loss of engine power represented a simultaneous failure of both the engine and the propeller autofeathering system as the latter was not a consequence of the loss of engine power, but an additional failure.

It was not an additional failure, but normal operation. A propeller does not feather when the thrust is idled. The drag was higher, that's right, but was the drag as high as when the autofeather system would fail, i.e. when the propeller was windmilling?

"Derated" is not the correct term, reduced is. Derating is done by technicians on the engines to permanently reduce the engine thrust which is required when new/more powerful engines are installed on airplanes of which the vertical tail was designed and built for less powerful engines. Derated thrust is the maximum thrust that is available to the pilots after setting max. thrust with the throttles. Reduced thrust is less than derated thrust.

Big difference was that the actual V_{MCA} was lower than the published V_{MCA}.

The operator's pilots reported that, like other Australian operators of the EMB-120, they had adopted the use of ~~derated (~~reduced~~)~~ take-off power for training flights. That reduced training power setting meant that the aircraft's performance more closely approximated that of an aircraft at maximum take-off weight. In the operator's case, a training take-off power of 94% torque and V-speeds applicable to the aircraft's actual weight were used for training flights.

used initially

reduced

The use of 110% torque on the operating engine during asymmetric training flights, when derated engine power was used to approximate the performance of a heavier aircraft was unrealistic as it resulted in a single-engine climb performance that was better than would normally be expected in an aircraft at a greater take-off weight. A takeoff using derated power of 94% torque would generally require a corresponding torque value of 103.4% on the operating engine to approximate the climb performance of a heavier aircraft with its operating engine at 110% torque.

This § is difficult to understand, as written.

No. The pilot could obviously set >120% torque from the cockpit, so this torque was used to determine the (standardized) V_{MCA}. The actual V_{MCA}, the value that the pilot experiences in-flight, is always lower. The actual V_{MCA} increases with the torque, but never higher than the AFM listed V_{MCA}, unless the pilot does not apply full rudder and does not bank the favourable 5° bank angle away from the inoperative engine.

In addition, the use of asymmetric thrust greater than the 110% torque used to establish V_{MCA} for certification, increased the V_{MCA} , affecting controllability.

The operator's training and checking manual specified the tolerances for heading and airspeed in asymmetric flight were the same as those prescribed for an instrument rating flight test, being: [30]

Heading (from datum heading)	**+/- 20° initially**, then +/- 5°
Indicated airspeed	initial climb nominated one engine inoperative climb speed +**5, -0 knots**. Subsequent operations +/- 10 knots of nominated speed, not below minimum approach speed for the configuration.

FAR 25.149 allows 20° after sudden engine failure for sizing the vertical tail and rudder. Is 25.149 the source of this operator limit? Experimental test pilots use this number during conducting dynamic V_{MCA} testing.
If the pilot returns to the original heading, rather than maintaining the heading after recovery (straight flight), controllability is at stake (page 52).

The manual did not state that asymmetric flight be discontinued if those limits were exceeded during training or checking flights where engine failure after take-off was simulated.

Other Australian EMB-120 operators' procedures

Some EMB-120 pilots reported that other operators had introduced 'Phase One', or memorised checklist items, into their engine failure on take-off procedures. Those pilots reported that by introducing the 'Phase One' checks, a failure of the autofeather system would be identified and manual feathering of the propeller would be completed much earlier than from the manufacturer's procedure.

One of those operator's 'Phase One' checks stated:

Is immediate 5° bank into the good engine also included?

Engine failure after take-off

1. Power Lever…………………………….FLT IDLE
2. Condition Lever………………………….FEATHER, THEN CHECK

In case no feathering is observed:
3. ELEC FEATHER Switch ....ON, THEN CHECK PROPELLER FEATHERING

[30] See CAO 40.2.1, Appendix 1.

The pilots advised that in the event of an engine failure, the pilot not flying would confirm the failure and, on the pilot flying's command, manually feather the propeller using the condition lever. Confirmation that the propeller had feathered was made by checking that the relevant propeller RPM (N_P) was less than 20%. If the propeller had not feathered, then the pilot not flying would select the electrical feathering switch on the overhead panel.

When simulating an engine failure, a check pilot would select flight idle. The pilot under check would continue to fly the aircraft and identify the 'failed' engine before the check pilot, performing the role of pilot not flying, identified the appropriate condition lever by touch. After the pilot flying had confirmed the identification of the correct condition lever and commanded feathering, the check pilot would select zero thrust.

During a simulated engine failure, the autofeather was disarmed because two of the parameters that were used to arm the autofeather system were not met: the affected power lever angle was less than 62° and the corresponding engine torque was less than 62%. That meant that, should an actual engine failure occur while simulating an engine failure, the propeller of the failed engine would not autofeather. Returning the power lever to maximum would not re-arm the system if the torque had reduced to less than 62%, necessitating manual feathering.

Certainly preferable. But it is not only required to get rid of (asymmetrical) drag ASAP, but also to attain a 5° bank angle away from the failing engine immediately, to reduce the actual V_{MCA} and maximize climb performance.

Incorporating the Phase One checks into the engine failure on take-off procedures meant that manual feathering, if required, was performed immediately and drag from a 'windmilling' propeller eliminated. That was seen as preferable to the manufacturer's procedure that required the aircraft be first climbed to the acceleration altitude, where the precautionary engine shutdown procedure, including manual feathering if required, was performed from the checklist in the Quick Reference Handbook (QRH).

This is not right; then the airplane might already be crashed.

Is a lot safer, but then the student pilot will never get to experience and recognise V_{MCA}. Why not simulate an engine failure during a 'go-around' from V_1 at a higher safe altitude using applicable take-off speeds for that altitude at that moment?

The EMB-120 training and checking pilots that were contacted during the investigation reported that, when flight training, they initiated ~~a~~ simulated engine failures at speeds well above V_1 to provide a greater margin of safety. Some operators used the V-speeds applicable to an aircraft at maximum take-off weight (MTOW), even though training flights were typically conducted at much lighter weights and where the applicable V-speeds were much lower

PIC's procedure

The PIC's actual procedure for simulating engine failures could not be verified. His training for a check pilot approval was conducted in accordance with the syllabus in the operator's CASA-approved training and checking manual. The PIC had been assessed by company check pilots and been required to brief and demonstrate V_1 cut manoeuvres in the EMB-120. During that training, a check pilot noted in the PIC's training record in March 2009 'Particular attention was taken [in that flight] with simulating engine failures and how to set 13% torque or zero thrust.' The PIC was assessed as satisfactory by a CASA inspector for his check pilot approval during an EMB-120 proficiency check. That check included his simulation of a V_1 cut procedure.

The operator's check pilots reported that the torque used to represent zero thrust (then 13%) was set by a check pilot in the right seat, using their left hand to move the power lever to the desired position. The check pilots reported that it was relatively easy to set zero thrust accurately. When commanded by the pilot flying to raise the landing gear, a check pilot would then keep their left hand on or near the power lever, and operate the landing gear switch, which was immediately to the right of the power quadrant, by using their right hand.

Pilots who had previously completed proficiency check flights with the PIC in the EMB-120 described the procedure that was employed by the PIC for simulating an engine failure on takeoff. Two pilots, who were both check pilots, reported that the PIC used zero thrust to simulate the engine failure on takeoff, another pilot was unable to recall the exact power setting used by the PIC to simulate a failed engine, and another two pilots reported that the PIC would initially select flight idle for the simulated engine failure.

The latter two pilots described the technique used by the PIC to simulate an engine failure as selecting flight idle with the appropriate power lever after first advising ‘simulated only’. After the pilot flying acknowledged ‘power loss, check feather’, the PIC acting as the pilot not flying, would identify the affected engine and check the N_P gauge to confirm that propeller autofeathering was taking place. However, during simulation the propeller would not actually autofeather and the PIC would set zero thrust to represent the feathered propeller.

One of those pilots provided an unidentified document that the PIC had produced as a training aid and that formed the basis of his briefing for training flights that incorporated the practice of engine failures on take-off. A copy of the page relating to the practice V_1 cut was found in the pilot under check’s flight bag.

The relevant section of those notes stated:

V1 Cut takeoff technique and departure

- Hold a/c with brakes. Whilst on the brakes, with hands at base of power levers, bring forward to approx 75% Tq, call “set power”.
- Slowly release brakes sliding feet to floor and release pressure.
- Apply enough right rudder to keep the aircraft straight.
- The PNF will call “power set, 80kts”. You respond with “checked”.
- The PNF will call “V_1 Rotate”. Positive control – rotate and fly the aircraft into the V-bars at 2°/sec to attain V_2+10.
- When VSI shows climb, the captain will call “simulated only”
- Initially, simultaneously keep the wings level and keep straight – use rudder to control the yaw.
- The PNF will call “Positive Rate”, Call “Gear Up”.
- The PNF will select the gear up and call “Selected, Six Reds”. When the six red lights are out, PNF calls “Gear is Up”.

OK, its here, but too late. Should be ASAP because V_R is very close to wings level V_{MCA}.

- Apply 3 - 5° bank towards the live engine – ball ~~in centre~~. Fly the aircraft into the 7° nose up command bars and climb at V_2.
- Call “power loss, check feather”. PNF will identify the failed engine and confirm the prop has feathered by reference to N_P < 20%. The PF will increase power on the live engine (can be 110% Tq for up to 5mins if necessary).

half ball width towards live engine (doesn't show sideslip when power is asymmetric).

Although the document described the pilot flying's actions and responses, it did not specify the actions and power selections to be used by the training and checking pilot to simulate the engine failure.

Pilot workload following engine failure on takeoff

Workload has been defined as 'reflecting the interaction between a specific individual and the demands imposed by a particular task. Workload represents the cost incurred by the human operator in achieving a particular level of performance[31].' In order to understand workload, understanding an individual's strategies for managing tasks is necessary. An individual has a finite set of mental resources they can bring to bear on a set of tasks (for example, handling an emergency). The resources available to an individual can change given the experience and training they have had or the level of stress and fatigue they are experiencing.

An individual can shed tasks in an efficient manner by eliminating performance on low priority tasks or they can shed tasks in a non-efficient fashion by abandoning tasks that should be performed.[32] Tasks make demands on an individual's resources through the mental and physical requirements of the task, temporal demands and the wish to achieve performance goals.[33]

The operator's pilots and the simulator instructors demonstrated the expected pilot response following a V_1 cut using zero thrust to simulate propeller autofeather. After recognising the engine failure, a pilot had to maintain airspeed at V_2 while maintaining runway heading. That required a firm application of the appropriate rudder pedal in order to keep straight and a firm two-handed grasp of the control yoke with positive application of elevator control to maintain a 7° nose-up attitude and aileron control to maintain up to 5° bank toward the operating engine. The pilot not flying raised the landing gear as would occur during a normal takeoff.

Again, it's here, but the mishap pilots didn't use it. Was most probably not understood.

maintain airspeed?

Any actions that required a pilot flying to divert his or her attention from maintaining aircraft attitude and direction or to take his or her hands off the controls, increased pilot workload at a critical part of the flight. Raising flaps at V_2+20 kts and selecting the autopilot were normally actioned during level flight after the aircraft had attained 400 ft AGL and was accelerating to V_{FS}. The aircraft manufacturer's procedures for manually feathering the propeller, when autofeather had not occurred, increasing power on the operating engine when required and retrimming the aircraft, were to be made during this segment to avoid increasing pilot workload.

... airspeed,

The crashed airplane never reached this segment.
Something is wrong here with manufacturers procedures.
Is the workload really high for two pilots?

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31 Orlady, H.W., & Orlady, L.M. (1999). *Human factors in multi-crew flight operations.* Ashgate: Aldershot, UK p.203.

32 Wickens, C.D. & Hollands, J.G. (2000). *Engineering psychology and human performance, 3rd Edition.* Prentice Hall: New Jersey.

33 Lee, Y-H., & Liu, B-S. (2003). Inflight workload assessment: Comparison of subjective and physiological measurements. *Aviation, Space and Environmental Medicine, 74,* pp. 1078-1084. Hart, S.G. & Staveland, L.E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In P.A. Hancock and N. Meshkati (Eds.) *Human Mental Workload.* Amsterdam: North Holland Press.

Simulator training

Synthetic training devices, such as simulators, provide the obvious safety benefit of enabling emergencies and non-normal procedures, such as engine failure and asymmetric training, to be conducted without risk. However, there was no regulatory requirement at the time of the occurrence for simulators to be used in pilot training and checking. In practice, the larger regular public transport operators used approved simulators for type conversion and the recurrent training of crews. The smaller regional operators, who did not have ready access to simulators, conducted asymmetric training in the actual aircraft.

EMB-120 simulator approval

Part 60 – Synthetic training devices of the Civil Aviation Safety Regulations (CASR) 1998 described those devices that could be used to train pilots in aircraft manoeuvres and procedures without the need for flight experience in an aircraft. The applicable synthetic training device approved for full type conversions and recurrent training was a flight simulator.

The fidelity of a flight simulator, as classified by the Manual of Standards, Part 60 - Synthetic Training Devices (June 2008), determined whether full type conversions and recurrent training were authorised. Approvals were issued after a simulator was demonstrated to have met the specific requirements. Generally, those requirements included that: it simulated the aircraft in ground and flight operations and comprised of a full size replica of the flight deck that replicated the aircraft instrumentation and equipment and the way that the equipment influenced the aircraft's behaviour; a visual system, to provide an 'out-of-the-flight deck' view; and a force-cueing motion system to provide some sensation of appropriate aircraft movement.

On 30 March 2010, an EMB-120 (Brasilia) simulator at a Melbourne training facility was approved by CASA as having satisfied Level B requirements. That permitted simulator training for endorsements and proficiency checks that included the conduct of emergency procedures such as V_1 cuts. A limitation to the crew's visual display in that simulator, and its lack of 'daylight' visual representation, meant that it could not be used for the demonstration of circling approaches. That necessitated a circling approach to be flown in an actual aircraft for type proficiency checks. The circling approach was not required to be flown with one engine inoperative.

The operator's simulator training

Following the introduction of an approved EMB-120 simulator into Australia in May 2009, the operator commenced negations with the Melbourne-based training facility for the provision of simulator training for its EMB-120 flight crews. Although accredited by the CASA at that time for initial training, the facility did not have any approved simulator instructors to undertake the operator's recurrent training. That required the operator's EMB-120 crews to complete instrument rating renewals and proficiency checks, both of which required simulated engine failure on take-off, in the aircraft.

In July 2009, following an audit of the operator's training and checking system, a CASA flying operations inspector made the following observations:

> The current practice of conducting conversion training, proficiency checks etc in the aircraft alone, in the case of turboprops, will prohibit the complete training of pilots due to the fact that many aspects of training simply cannot be accomplished physically or within adequate safety margins.

The argument for simulator training was further explained in the CASA audit report that followed that inspection. The CASA report outlined the following disadvantages of in-flight training:

> This limitation has the following issues that should now be seriously considered given the availability of these simulators in Australia.
>
> - The scope of training is reduced as conversion training in aircraft is limited to a much smaller time frame (due to cost and availability) where the student is typically provided with a quarter of the time that would otherwise be given in a simulator.
> - The use of competency based training syllabi is limited as the applicant cannot be trained in all aspects due to aircraft limitations and or safety concerns.
> - Training can only be conducted with a check captain in a control seat and the opportunity to train in a normal two crew environment is reduced.
> - Pilots undergoing proficiency tests can only be viewed singularly rather than as a member of a normal operating crew. This makes the assessment of pilots while in the supporting roll [sic] very limited as pilots are never assessed in abnormal operations while operating in the crew environment.
> - The opportunity for scenario based training such as LOFT or LOE[34] is practically unavailable. Such training is now considered as one of the most important by operators worldwide as it provides considerable value to a pilot's professional development and management skills. Without this style of training the core elements and objectives of non-technical skills specified in CAAP SMS-3(0) will be difficult to achieve.

In September 2009, CASA issued the simulator training facility's instructor his EMB-120 simulator instructor approval. That approval allowed the training facility to deliver initial EMB 120 endorsements. However, to carry out an operators' recurrent training, a simulator instructor had to be familiar with the airline's operating procedures and approved under their training and checking procedures.

The operator finalised a contractual agreement with the training facility for its EMB-120 training in December 2009 and sent four pilots to start their simulator check and training approval process. The PIC was one of those pilots.

In February 2010, three of the operator's pilots (including the PIC) completed their simulator training and checking as part of the requirements for their CASA approval to conduct EMB-120 simulator training. The CASA delegate expected it would take a further 6 weeks to finalise and issue the pilots' approvals. Later that month, two of the operator's pilots commenced ground school and simulator endorsement training for the EMB-120.

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34 Line oriented flying training and line oriented evaluation. Non-jeopardy training and assessment of aircrew performance from observations that were made on the flight deck during normal line flying.

The training facility's simulator instructor's approval to conduct the operator's recurrent training was issued on 3 March 2010. However, that instructor had not completed the requisite operator induction course and line flying at that time.

At the time of the accident, the operator was about to transition all of its EMB-120 asymmetric training and checking to the simulator. The accident flight was to have been one of the last training and checking flights to have involved asymmetric flight in the actual aircraft.

Shortly after the accident, the simulator training facility's instructor completed the required operator induction training, which allowed the operator to transition the majority of its EMB-120 proficiency checking, including asymmetric flight sequences, to ground-based simulator training.

Additional information

Characteristics of asymmetric flight

The following material has been drawn from information contained in ATSB aviation safety report BO/200000492 of December 2001 following the investigation of a serious incident involving a loss of control during engine-out training in a Beech 1900 Airliner at Williamtown, New South Wales in February 2000. The information has been amended to more adequately explain the issues in the context of this occurrence. It is provided here to give readers unfamiliar with the concepts of asymmetric flight a better understanding of the difficulties associated with engine-out training in multi-engine, aircraft, especially as they pertain to turbine-engined aircraft.

Should be P-vector: Propulsion - has a magnitide and a direction. P-vector is a factor though.

Asymmetric propeller loading ('P' factor) and the 'Critical Engine'

Asymmetric propeller loading or 'P' factor is the result of dissimilar thrust from rotating propeller blades during certain flight conditions. Downward moving propeller blades have a greater angle of attack than upward moving blades when the relative airflow striking the blades is not aligned with the thrust line. The effects of asymmetric propeller loading are most pronounced when engines are operating at a high power setting and the aircraft is flown at a high angle of attack.

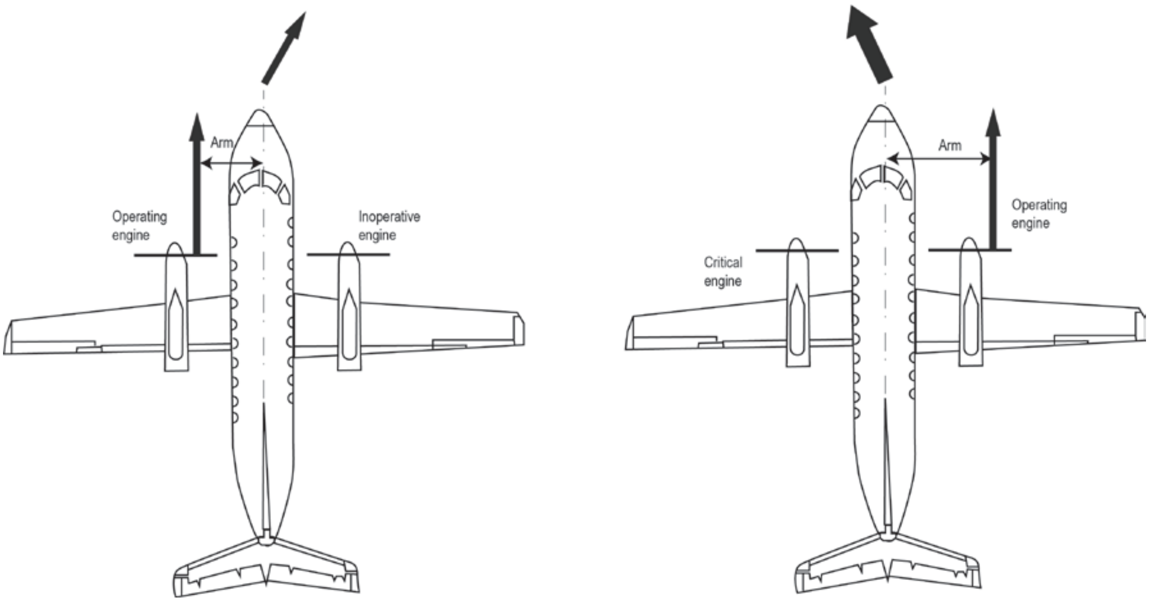
at low speeds, i.e. at

The propellers of most multi-engine aircraft, which use US-designed engines, rotate clockwise when viewed from the rear. At low airspeed and high engine power, the downward-moving propeller blades of each engine develop more thrust than the upward-moving blades. That asymmetric propeller thrust, or 'P' factor results in the centre of thrust shifting to the right of the propeller's centreline. As a result, the ~~turning (or~~ yawing) force of the right engine is greater than the left engine, because the centre of thrust is farther from the fuselage centreline, and therefore has a longer leverage arm than the centre of thrust for the left engine (Figure 14).

the airplane doesn't turn under influence of asymmetrical thrust, but yaws (body axes).

P-vector

Figure 14: Asymmetric propeller loading ('P' factor)



When the right engine is operative and the left inoperative, the ~~turning (or~~ yawing) force is greater than when the left engine is operative and the right engine inoperative. In other words, directional control ~~is more difficult~~ when the left ~~or 'critical' engine is suddenly~~ inoperative.

moment

Not more difficult, requires a larger counteracting yawing moment from the rudder, i.e. a larger rudder deflection or if already max., a higher airspeed.

An aircraft with large diameter propeller discs has its engines mounted further outboard, increasing the length of the moment arm from the centre of thrust to the aircraft's centre of gravity (c.g). Consequently, any asymmetric thrust ~~turning~~ yawing moment is greater, requiring greater rudder force to counter the resulting ~~turning~~ moment. In addition, large propellers increase the (propulsive) rolling moments. Lateral V_{MCA} might be close to or larger than directional V_{MCA} (if aileron not max.).

Torque effect

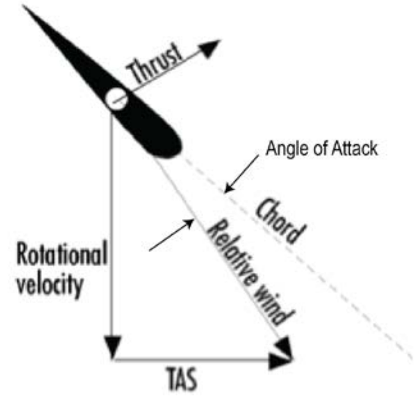
This effect acts on the engine mounts, i.e. on the wings in case of a multi-engine aircraft, and might cause a small rolling moment. The effect is negible for a multi-engine airplane and included in (dynamic) V_{MCA}; is not separately tested. The rolling moment due to propulsive lift (energized airstream behind the operative propeller) is much larger. The torque effect is more pronounced on single engine aircraft.

Torque effect is the reaction that rolls the aircraft in the opposite direction to the propeller rotation. In aircraft, where propeller rotation is clockwise (when viewed from behind), the torque reaction will try to roll the aircraft left. Torque effect with a left engine failure exacerbates the yawing moment while a right engine failure opposes it, again making the left engine the more 'critical' in an engine failure. The effect is more pronounced on aircraft with more powerful engines.

Drag from a windmilling propeller

The thrust used to propel an aircraft forward is produced when the propeller blades are driven (rotated) by an engine and the blades are at an angle and speed that produces a positive angle of attack to the relative airflow. Lift is created, the forward component of which is termed 'positive thrust' (Figure 15).

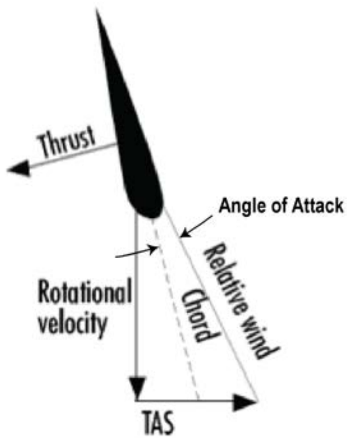
Figure 15: Angle of attack of a propeller in normal flight



A propeller will normally continue rotating following an in-flight engine failure, a condition known as 'windmilling'. When drive from the engine ceases, the propeller stops producing thrust and drag causes its rotation to decrease. A 'constant speed' propeller system incorporates a control unit known as a 'governor' that detects changes in rotational speed (propeller RPM) as set by the pilot, and automatically adjusts the propeller blade angle to maintain that RPM. As the propeller RPM decreases the governor signals the blade angle to decrease toward a low blade angle, or fine pitch setting, in an attempt to maintain the speed set by the pilot. As the blade angle decreases to the low pitch stop there may not be sufficient energy in the airflow to maintain the selected propeller speed and RPM will decay.

As the propeller RPM decreases, the angle of attack of the blades eventually becomes negative, and blade thrust commences to act in a rearward direction, causing further drag. The energy to maintain propeller rotation comes from the relative airflow over the propeller. Therefore, instead of producing positive thrust, a 'windmilling' propeller increases the amount of drag being experienced by an aircraft. That drag comprises drag from the action of the relative airflow against the propeller blades, and frictional drag within the engine itself (Figure 16).

Figure 16: Angle of attack of a windmilling propeller



Most multi-engine aircraft 'constant speed' propellers are also capable of being feathered to reduce the drag from the blades and engine. Feathering is the action of moving the propeller blades to an angle that presents the lowest propeller cross-section to the airflow. That is, the propeller is aligned to the direction of flight.

The text on V_{MCA} in this paragraph is nearly good, why was this not used during the analysis of this accident?
V_{MCA} might not be understood.

Air minimum control speed (V_{MCA})

A multi-engine aircraft equipped with wing-mounted engines will experience asymmetric thrust if one engine sustains a total or partial loss of power. Consequently, the aircraft will yaw towards the failed engine, and the pilot must counteract that asymmetric thrust moment by applying rudder towards the operative engine. The rudder's effectiveness will depend on the velocity of airflow across its surface. If the aircraft decelerates, the airspeed will eventually reach a speed below which the effect of the rudder (the rudder moment) can no longer balance the asymmetric thrust moment. Directional control will then be lost.

Critical engine is not for pilots to 'analyse' after engine failure, it is for determining the highest, worst case V_{MCA} by experimental test pilots.
For pilots: "with one of the engines"
refer to text boxes on pages 8 and 21.

The minimum speed at which it is possible to maintain ~~directional aircraft control~~ with ~~the critical engine~~ inoperative is termed V_{MCA}. When flown at V_{MCA}, and with a bank angle of about 5º towards the operating engine, the pilot should be able to maintain ~~directional control~~ of an aircraft. Aircraft certification processes for turbine-propeller aircraft included the demonstration of flight at V_{MCA} under specified conditions with a requirement that controllability be maintained when one engine became inoperative with autofeather armed, and the aircraft flown with:

V_{MCA} aplies after failure of any engine. After failure of the non-critical engine, V_{MCA} is a little lower - safer.
Effects of the criticality of an engine are included in the published V_{MCA}.
Pilots do not have to know about the critical engine.

straight flight (FAR 25.149).The vertical tail is sized for straight flight only on asymmetrical thrust, while banking 5° into the good engine.

- 5º of bank towards the operative engine
- ~~take-off~~ max power on the operative engine
- landing gear up
- wing flaps at the take-off setting
- the aircraft at ~~MTOW~~ and loaded with the c.g at its most rearward position.

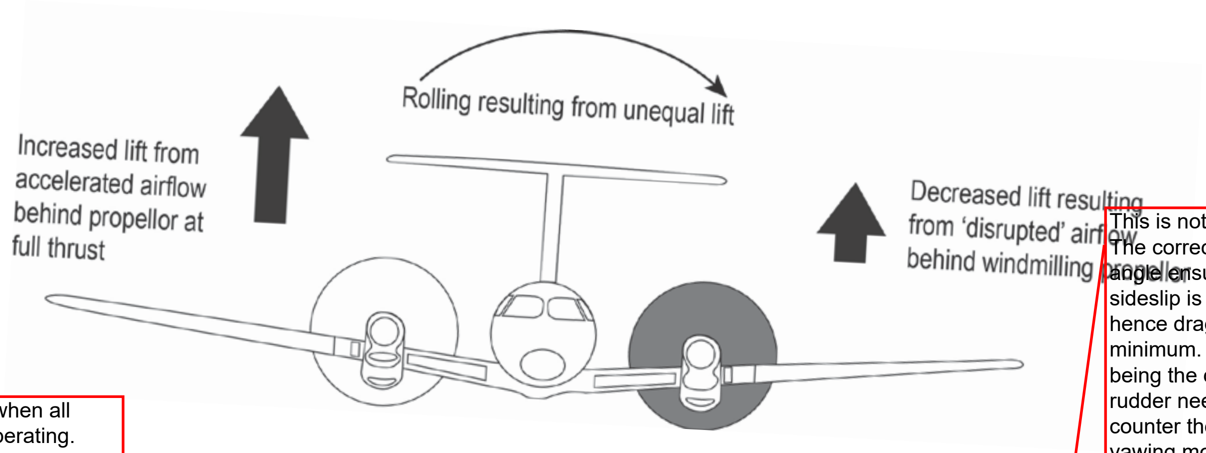
Minimum weight, because V_{MCA} at low weight is higher than at high weight (effect of 5° bank angle). Low weight is worst case for V_{MCA} and is therefore used. Refer to Figure 4 on page 52.

... that the pilot can set from the cockpit.
Max. power, because "takeoff power" might be reduced power.

Asymmetric lift resulting from a windmilling propeller

Aircraft with a relatively large propeller diameter (3.2 m on the EMB-120) have about one third of their wing surface area 'swept' by the thrust from the propellers. At high thrust values, the accelerated airflow behind the propeller disc produces greater lift. When a propeller is feathered, or an engine's power is reduced to zero thrust, a reduction of lift occurs. However, at flight idle a windmilling propeller disrupts the airflow over the affected section of the wing, further reducing lift. With one propeller producing maximum thrust and the other windmilling, the resulting lift imbalance on the wings produces a roll around the aircraft's longitudinal axis and increases the rolling moment (Figure17). In that instance, significant opposing aileron input is required to maintain lateral control.

Figure 17: Unequal lift during asymmetric flight



This is not correct. The correct bank angle ensures that sideslip is zero, hence drag is minimum. That being the case, the rudder needs only counter the thrust yawing moment, not the moment due to sideslip anymore. Please refer to the downloads page of www.avioconsult.com and download paper #2 (free), or refer to the Airplane Design Series of books by Dr. Jan Roskam, KU.

Yes, but only when all engines are operating. When one engine is inoperative, forces and moments are different, also because a rudder deflection is required to counteract the thrust yawing moment. This causes a sideslip to the dead engine when the wings are kept level. A small bank angle can reduce the sideslip to zero by sideforce W.sin phi (bank angle) which acts in the cg. V_{MCA} is determined at this same bank angle for zero sideslip.

neutralizing

inoperative

weight (body axes). Sideforce is W.sin phi.

Relationship between bank angle and V_{MCA}

By banking the aircraft towards the operative engine, the ~~wings~~ develop a lateral force that results in the aircraft sideslipping towards the ~~operative~~ engine. ~~The sideslip creates a positive angle of attack of the airflow over the rudder. The resulting moment around the aircraft's c.g counters the moment produced by operating with one engine inoperative, and the other engine producing thrust.~~

The US Federal Aviation Administration (FAA) publication FAA-H-8083-3 titled *Airplane Flying Handbook* included an examination of multi-engine handling techniques. That publication stated that banking towards the operative engine would reduce V_{MCA} by about 3 KIAS per degree of bank. Banking away from the operative engine would increase V_{MCA} by a similar amount. An increase in V_{MCA} of 24 kts has been shown in a test aircraft during asymmetric flight when the wings were held level.

And decreases drag and hence, increases climb performance.

The published V_{MCA} was determined while banking 5° towards the operative engine. Wings level V_{MCA} is 8 - 30 kt higher, depending on airplane type. This V_{MCA} is not reduced by banking, but only the actual V_{MCA}, the V_{MCA} that the pilot would experience in-flight. This line is confusing and should be deleted from manuals for pilots.

Please refer to page 52 for figures and explanation.

3 for a small twin. For a 707 type: 6

Why not used in the analysis of this accident?

Relationship between thrust and V_{MCA}

yawing

In asymmetric flight, the ~~turning~~ moment produced by the thrust of the operating engine, and the drag of the windmilling propeller has to be countered by the moment produced by the rudder force, and is proportional to that thrust (and drag) and its distance from the aircraft's c.g. It follows that on any particular aircraft, if the thrust is changed, V_{MCA} changes correspondingly. Generally, available engine power decreases with increasing altitude and so thrust is reduced and V_{MCA} decreases. On aircraft with engines that are capable of developing power above their normal maximum rated power, by exceeding torque or temperature limits, the thrust will be greater and the V_{MCA} will be increased above the aircraft's published limit.

If the thrust is reduced, actual V_{MCA} decreases. Published V_{MCA} is determined while the thrust is maximum (SL) - is the worst case, the highest V_{MCA} that the pilot will experience in-flight.

The highest thrust the pilot can set from the cockpit is used during flight-testing V_{MCA}. The published V_{MCA} is the worst case V_{MCA}. Exceeding torque limits will result in loss of control right away if the airspeed is published V_{MCA}.

Relationship between weight and V_{MCA} is illustrated in Figure 4 on page 52.

Relationship between c.g and V_{MCA}

FAA-H-8083-3 *Airplane Flying Handbook* also contained advice that V_{MCA} would be less when an aircraft's c.g was at the foremost allowable position. Although the thrust moment remains unaffected, a forward c.g lengthens the arm to the centre of

This handbook regrettable doesn't conform to the FAA Flight Test Guides and Airplane Design books used at Aeronautical Universities. Comments are on the Downloads Page of www.avioconsult.com.

No, not for the lateral cg changes (fuel asymmetry on longer flights with an inop engine).

A cg max. aft and max. lateral into the dead engine is the worst case cg, and results in highest V_{MCA} and is therefore considered during tail design and used during flight-testing to determine V_{MCA}.

the rudder's horizontal lift. That requires less force (airspeed) to counter the yaw resulting from an inoperative engine. The c.g location toward an aircraft's foremost allowable position ~~at the brakes release weight~~ would result in a lower actual V_{MCA} but would be insignificant ?? is not tested

If this is insignificant, why is P-vector not insignificant either? (page 44)

Other related occurrences

First recorded turboprop asymmetric training accident in Australia

The first recorded asymmetric training accident in a turboprop aircraft in Australia occurred on 31 October 1954, when a Vickers 720 Viscount, registered VH-TVA, on an asymmetric training flight crashed soon after lifting off the runway at Mangalore, Victoria with the loss of three of its crew.[35] The investigation report into that accident stated that the aircraft became airborne at a speed below V_{MCA}, following loss of directional control during the ground run. The training flight was associated with the introduction of the aircraft type into service.

More recent asymmetric training occurrence in Australia[36]

In more recent times, there have been numerous occurrences involving asymmetric training in turbine-powered aircraft in Australia and overseas. The ATSB and its predecessor BASI have published several reports on accidents and serious incidents that occurred during asymmetric flight training.

EMB-120 loss of aircraft control in the US in 1991

In 1992 the NTSB published an investigation report into the loss of an EMB-120 that resulted from a mechanical failure of the left propeller systems and subsequent loss of aircraft control. The NTSB testing of aircraft control with a windmilling propeller provided useful information about the aircraft's handling.

EMB-120 loss of aircraft control in Australia in 2007

On 26 June 2007, the crew of an EMB-120ER Brasilia, registered VH-XUE, experienced a loss of aircraft control on a scheduled flight to Jundee Airstrip, Western Australia. ATSB transport safety report AO-2007-017[37] found that the aircraft drifted left on final approach to the airstrip and, when the crew commenced a go-around, the aircraft aggressively rolled and yawed left, causing the crew control difficulties. The aircraft's left engine had lost power when the left fuel tank was exhausted, and the flight crew did not identify the power loss.

A number of safety issues were identified as a result of the investigation, in particular that there was no regulatory requirement for simulator training in Australia. Two associated safety issues were also identified:

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35 Air Crash Volume 2 Aerospace Publications Pty Ltd, Canberra. Macarthur Job. Pp 144-151.

36 A more detailed description of these occurrences and the resulting safety actions is in Appendix D.

37 Available for download at http://www.atsb.gov.au/publications/investigation_reports/2007/aair/ao-2007-017.aspx

- The absence of simulator training meant that, in the case of the Jundee event, the flight crew's endorsement and other training did not adequately prepare them for the event.
- Where simulator training was not involved, the minimum endorsement training requirements did not ensure that pilots were aware of the indicators and/or aircraft behaviour during critical emergency situations.

Initial safety action by CASA was successful in increasing the use of simulators for endorsement and other training in Australia. However, the ATSB issued safety recommendation AO-2007-017-SR-084[35] that recommended CASA address the lack of a regulatory requirement for simulator training in Australia.

In December 2009, CASA published Discussion Paper (DP) 0911OS on the issue of mandatory flight simulator training. After consultation with the aviation industry, in October 2010, CASA issued Notice of Proposed Rule Making (NPRM) 1007OS -*Mandatory Flight Simulator Training*. The purpose of the NPRM was to facilitate consultation on a graduated proposal to mandate the use of flight simulators and flight training devices (FTDs) for non-normal aircraft exercises.

It was proposed that if an appropriately qualified flight simulator or FTD was not available for prescribed aircraft in Australia or overseas, then any non-normal exercise might only be performed in the aircraft with CASA approval. CASA would require the submission of a safety risk management plan in considering the approval.

Industry responses to the NPRM were required by 21 January 2011

On 8 July 2011, CASA advised that:

> The Notice of Proposed Rule Making (NPRM) published in October 2010 proposed that pilots must be trained in certain abnormal aircraft manoeuvres in simulators, if available, rather than in aircraft. In general terms, for aircraft certificated for 20 or more passengers, or weighing more than 8618 kg, the NPRM proposed that pilot training be provided in simulators, if available in Australia or in a recognised country overseas. For multi-engine aircraft certificated for between 10 and 19 passenger seats, the training would have to be conducted in a simulator, if available in Australia. If a simulator was not available in Australia but was available overseas, the operator's check pilots would have to travel overseas for the training.
>
> CASA has assessed the comments received to NPRM 10070S and has developed a revised proposal taking into account some of the identified issues. A cost and impact assessment of this proposal is currently being undertaken. It is anticipated that the revised proposal, with a cost assessment, will be provided to the joint CASA/industry Standards Consultative Committee for further consultation.

The progress made by CASA and the aviation industry toward the mandatory use of simulators for non-normal flying training and proficiency checks in larger aircraft is commendable. The introduction of regulations that mandate the use of simulator training has the potential to eliminate asymmetric training accidents in these types of aircraft.

Notwithstanding, the need remains for in-flight asymmetric training in those aircraft types where there is no suitable simulator-based alternative. In those circumstances, provided appropriate operator procedures are in place and followed, and pilots are alert to the potential hazards, simulated engine failures and asymmetric flight should not present unacceptable risks.

Figures to support the relationship between bank angle, weight and V_{MCA} (page 48).

Forces and moments in the figures below are in and around the body axes of the airplane, i.e. X-axis through nose and tail, Y-axis from left to right wingtip, and Z-axis up and down, all three perpendicular to each other and through the cg. Only the most relevant forces and moments are shown that act on the airplane while the thrust is asymmetrical.
The figures are copied from the 71-page paper (#3): *Airplane Control and Accident Investigation after Engine Failure* that is available from the Downloads Page of www.avioconsult.com.
This accident is also discussed in that paper, and in a YouTube video: http://youtu.be/Wbu6X0hSnBY.
.

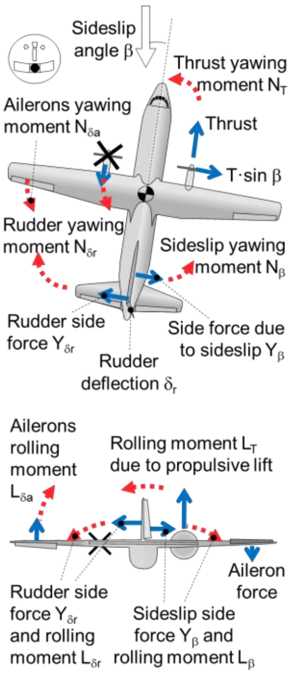

Figure 1. Forces and moments when wings are kept level.

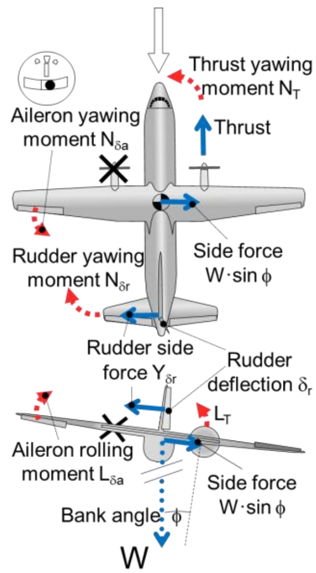

Figure 2. Forces and moments when maintaining a small 5° bank angle away from the inoperative engine.

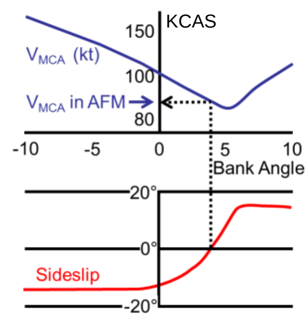

Figure 3. The relationship between bank angle and V_{MCA} after failure of engine #1, sample airplane.

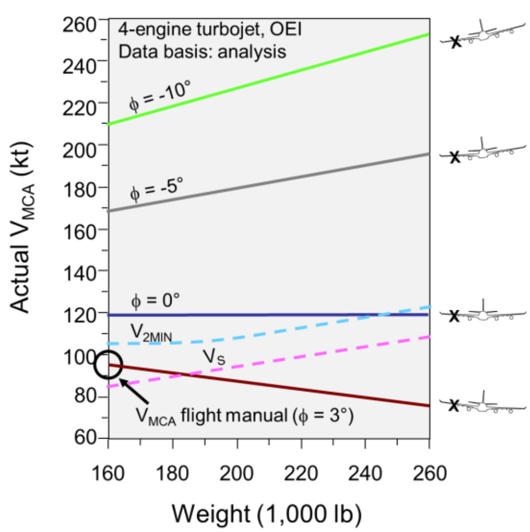

Figure 4. Effect of weight and bank angle on VMCA.

Figure 1 shows that balance of side forces can only exist with a sideslip. The rudder deflection required to balance the asymmetrical thrust moment causes the airplane to accelerate to the left increasing the sideslip. The side force due to sideslip increases until the side forces are in balance. This equilibrium results in additional drag and a flight path to the left (of the extended takeoff runway centerline).

Figure 2 shows that the side force due to sideslip can be replaced by the side force due to the small bank angle (W·sin ϕ). The rudder now only has to counteract the thrust yawing moment, and not the sideslip yawing moment anymore. Airspeed can be decreased until the rudder is again fully deflected: V_{MCA} is lower than for wings level.

Figure 3 shows the relationship between V_{MCA} and sideslip of a sample airplane. The V_{MCA} is determined at the bank angle for zero sideslip (for maximum remaining climb performance). As shown, (actual) V_{MCA} varies with bank angle. When the wings are level, (actual) V_{MCA} in this case is 15 kt higher than the AFM published V_{MCA}. At bank angles greater than +6°, the airspeed needs to be higher to avoid the vertical fin to stall.

Figure 4 shows the effect of weight and bank angle on V_{MCA}. V2min for this sample airplane is also presented.
Notice that when the wings are kept leven, V2min is lower than V_{MCA}.
Lockheed Hercules and Electra pilots will recognize this figure, because it is similar to a figure in their Performance Manual SMP777.

ANALYSIS

A written analysis of the control and performance of this accident is included in the paper Airplane Control and Analysis of Accidents after Engine Failure that is available from the Downloads Page of website www.avioconsult.com (#3).

Introduction

This accident occurred during a training flight that included a simulated engine failure after takeoff. The authority to initiate and discontinue a simulated engine failure rested solely with the training and checking captain as pilot in command (PIC).

Simulated engine failures on takeoff have been routinely performed during training and checking flights on aircraft such as the Embraer S.A. EMB-120ER (EMB-120) aircraft. While an element of risk has always been present with manoeuvres involving asymmetric thrust at low altitude and slow speed, the advent of high-quality simulators has allowed most training and checking on air transport aircraft to be transferred to the safety of ground-based facilities. At the time of the training flight, the operator was nearing approval for its EMB-120 training and checking to be undertaken in such a simulator.

The investigation found no evidence of mechanical failure, nor had local conditions contributed to the development of the accident. Analysis of the flight data and cockpit voice recordings found that a flight condition was allowed to develop that rapidly became uncontrollable. Although many of the facts of the short flight are known from information on those recorders and from the wreckage examination, the circumstances leading to the loss of control were not immediately apparent and a series of simulator tests were performed to establish what crew actions could have led to the loss of control.

The aircraft motions after engine failure were typical for the loss of control, that occurred because the bank angle was allowed to increase to the dead engine side which increased actual V_{MCA} to a value higher than the IAS.

This analysis attempts to explain why two experienced pilots in a serviceable aircraft, performing a training manoeuvre that had been performed safely by both pilots many times before, allowed a flight condition to develop and go uncorrected before control was lost and the aircraft impacted the ground. Significantly, there was only a very short period of time – possibly between 4 and 5 seconds – from when the (PIC) first recognized that the manoeuvre was not being flown within prescribed tolerances to when the loss of control occurred. This was such a brief period of time that it did not allow the PIC to analyse and 'troubleshoot' the problem. The only course of action that would have avoided a loss of control would have been to immediately restore power to the left engine and to stop the exercise.

Restoring power when control inputs of rudder and aileron after engine failure are large is not without danger! Sideslip can be high during asymmetrical flight, if wings are level or banked into the dead engine and the airspeed is low; adding thrust initially increases the sideslip unless the rudder deflection is decreased simultaneous with the thrust increase, which results in the decrease of the yawing moment. Test Pilots will never do this, but reduce thrust on the other engine (temporarily)

Selection of flight idle instead of zero thrust

The operator's procedures complied with the guidelines in Civil Aviation Advisory Publication (CAAP) 5.23-1(1) *Multi-engine Aeroplane Operations and Training* and had been approved by the Civil Aviation Safety Authority (CASA). That included the stipulation of the use of zero thrust when simulating engine failures in turbine aircraft. The PIC had correctly demonstrated the simulation of engine failures during his training for check pilot approval; however, on the accident flight he selected flight idle. This meant that, instead of a simulated engine failure, the PIC had in fact simulated the failure of both the left engine and its propeller autofeather system.

Zero thrust sounds like zero torque. Why not use zero drag, or torque for zero thrust.

Not "in fact" a failure. Fact is that the system is designed and certified to not feather when power is reduced to idle. The difference is the propeller rpm. The drag was higher, that's right, but was the drag as high as when the autofeather system would fail, i.e. when the propeller was windmilling (at lower rpm)?
The error was not selecting thrust for zero drag.

Rather dangerous technique, especially if the PIC does not have his hands and feet on the controls and delays taking control.

It was not possible to determine if selection of flight idle was deliberate or inadvertent. Two of the pilots who were recently assessed by the PIC reported that he selected flight idle (zero torque) to simulate an engine failure after takeoff in their check flights. It was possible that the PIC had decided to deviate from the operator's approved procedure in order to test the recognition by the candidate of the additional failure of the autofeather, before setting zero thrust. A technique that was reported to have been used by other training and checking pilots in the industry.

The simultaneous failure of an engine and its propeller autofeather system has much greater consequences for aircraft handling than the failure of the engine alone. Although it should have been possible to control the aircraft with the left propeller windmilling and at the speed initially flown, any degradation of the aircraft's performance so close to its take-off safety speed (V_2) meant that there was little margin for any mishandling. By not resetting ~~zero~~ thrust, the PIC increased the risk of experiencing control difficulty.

or because the airspeed was too low, or the pilot did not maintain the heading by adequate rudder input and the bank angle by applying ailerons to maintain the favourable bank angle of 5° away from the inoperative engine.

that resulted in an uncontrollable airplane.

??? How do you know? V_{MCA} data for this case?

This margin was even smaller because the pilots did not maintain a small bank angle away from the inoperative engine.

Aircraft handling

The pilot under check flew the aircraft in a manner that ultimately led to a combination of speed and attitude ~~that was uncontrollable~~. This may have been because of the unexpectedly heavier control forces resulting from the selection by the PIC of flight idle instead of zero thrust.

The airspeed also decayed due to the increased sideslip into the dead engine' side, because the pilot didn't maintain the bank angle for zero sideslip, minimum drag. Refer to Figure 3 on page 52.

The situation developed progressively and occurred because the pilot under check adopted a higher nose attitude than that required in response to an engine failure and allowed the aircraft's speed to decay. Compounding the problem, the simultaneous roll left towards the simulated 'failed' engine, increased the V_{MCA}.[38] At no time was the aircraft banked toward the right (operating) engine as required for the procedure.

Good! But why did the pilots not know this? Why is there no recommendation to review training and engine-out procedures?

The left roll developed incrementally over the course of five cycles of aileron input. The amplitude of the left bank increased with each cycle until roll inertia was too great to be counteracted by aileron control and, despite full right aileron input, the aircraft continued rolling left and became inverted.

Initially, bank could be controlled. Then aileron to near centre (-18); bank increased. After increasing thrust to 120, bank increased further because aileron not adequate to counter roll: lateral control was lost.

No, not inertia. The control power of the (limited deflected) ailerons was not adequate anymore to counteract the thrust rolling and other moments. Lateral V_{MCA} increased above the IAS.

Recognition of the ~~imminent~~ loss of control

The sudden loss of control took the flight crew by surprise. The PIC apparently did not recognise the seriousness of the situation or the imminent loss of aircraft control. His repeated command to 'disengage', even after the stall warning sounded, suggested a preoccupation with looking for an explanation of the control difficulties experienced by the pilot under check and his actions, and that the PIC did not associate those difficulties with his selection of flight idle (0% thrust).

Was not sudden, bank angle and yawing had already increased for 15 seconds! Control was already lost at -15 sec. When IAS = actual V_{MCA}, the heading starts changing slowly.

Refer to explaining text box on page 21, footnote 19.

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[38] V_{MCA} was defined in the EMB-120 Flight Operations Manual as

> ...the minimum flight speed at which ~~the aircraft is controllable with a maximum 5° bank [toward the operative engine]~~ when one engine ~~[critical engine] suddenly~~ becomes inoperative with the remaining engine operating at ~~takeoff~~ power. The value presented represents the most critical combination of power, weight, and centre of gravity. ~~In aircraft with auto-feathering, V_{MCA} is calculated with a feathered propeller.~~

straight flight can be maintained while banking 5°

maximum

or is

And with the inappropriate response with the controls to maintain heading and bank angle of 5° away from the inoperative engine. The PIC was not familiar with the real value of V_{MCA}.

This definition is definitely inappropriate, is copied out of FAR 25.149 which is for design and certification, not for operational use. Refer to the paper for investigators on the downloads page of www.AvioConsult.com.

Do not all EMB-120's have auto-feathering? Replace this line with: If propeller not feathered, V_{MCA} is higher than the published value.

The term 'disengage' was typically used in the context of disengaging the autopilot or the yaw damper. Neither was normally used that early in the climb out and, although the yaw damper was not to be used during one engine inoperative flight, its use had been observed on at least one previous occasion in similar circumstances.

Was or (still) is?

It was unlikely that the use of the term 'disengage' referred to the aileron or elevator disconnect systems, as the phraseology was not used in connection with that action. Nor was there an associated audio alarm recorded that would have activated if one of the disconnect handles had been pulled. Similarly, there was no evidence of the illumination of the associated warning lamp on the master alarm panel, which would have indicated a disconnection of either system. The repeated command to 'disengage' suggested that the PIC was referring to a system under the control of the pilot under check, most likely the yaw damper.

What are the consequences of disengaging the yaw damper on this airplane? Was rudder deflection available in FDR data?

Continuing the exercise

The PIC, regardless of either inadvertently or deliberately selecting flight idle, did not abandon the exercise and restore power on the left engine as soon as the heading and speed tolerances for the exercise were exceeded. Those limits represented the maximum tolerances for a satisfactory demonstration of asymmetric handling proficiency, and they also represented the limits for the safe operation of an aircraft during a simulated engine failure on takeoff exercise.

See text box on the top of page 53.

..., bank angle and ... Were tolerances defined for normal (airline) operations? These are for flight-testing the airplane to determine V_{MCA} and the dynamic response following a sudden failure, page 38.

As demonstrated in simulator testing, restoring power to the left engine after flight tolerances were exceeded could have restored the aircraft to a normal flight condition and should have been an immediate and intuitive response by a training or checking pilot to such a situation. Likewise, a prompt remark from the pilot under check that he was unable to control the aircraft might have triggered such a response from the PIC.

This should never be done! Not safe. See text box on page 53. Reducing the asymmetrical thrust a bit, temporarily, will reduce the adverse moments and restore control. After 5° of bank is attained, increase asymmetrical thrust again and maintain straight flight.

The hesitation by both pilots to say or do something about the developing situation might be explained by the perceived negative consequences for the pilot under check of failing to meet an important flight standard during a check flight, the PIC waiting to see the pilot's response to the simulation, or a combination of both.

Almost certainly, neither pilot realised the brief time available in which to affect recovery and avoid a loss of control.

Simulation of the engine failure at low speed

The difficulty controlling the aircraft was increased, and the margin for handling error decreased, by the simulation of the engine failure by the PIC just after the aircraft became airborne at a speed 2 to 3 kts above V_2. Although greater than the minimum speed specified in the operator's training manual for initiating a simulated engine failure, the operator-specified minimum speed related to the use of zero thrust. As such, the use in this case of flight idle, with the associated increased propeller drag, would have eroded the intended safety margin. The higher speeds used by some other operators allowed greater margins for unforseen eventualities or mishandling, and provided better aircraft control.

No, initially the airplane remained controllable, even with the high propeller drag. At -16 (page 7), the asymmetrical thrust was increased and the rudder released, rather than increased. The safety margin started to erode. Control was lost while neither rudder nor aileron were maximum.

above V_{2min}, which was almost equal to V_{MCA} for wings level!

Was elevated by not maintaining the controls from the instant the engine 'failed' as required for flight while an engine is inoperative, because the pilots were not aware of the limitations that apply for V_{MCA} (and V_2) to be valid, hence for maintaining control.

????
The severity of the situation was increased because of inappropriate training, and inappropriate manuals and procedures. The PIC did not recognize the loss of control and took no action; was not adequately familiar with V_{MCA} and its limitations.

Increased pilot workload

The pilot under check's workload was elevated by the many task demands immediately following the V_1 cut, especially the physical demands of handling the aircraft after the selection of flight idle on the left engine. The workload was at that time increased by the diverging flightpath and the need to diagnose the reason for that divergence. The situation was exacerbated by the application of increased power on the right engine, the selection of the yaw damper and the application of full right rudder trim, all of which would have required the pilot under check to take one hand off the flight controls at a time when both hands were needed to fly the aircraft. It was likely that the pilot under check became overloaded, which severely limited his ability to keep the aircraft under control.

As a flight check manoeuvre, the PIC would avoid assisting the pilot under check except in those tasks he was required to perform as co-pilot. Given the PIC's preoccupation with observing the pilot under check's responses to the simulated engine failure, it is likely that he shed his monitoring task and the task of discontinuing the simulated engine failure.

Conclusion

No organisational or systemic issues that might adversely affect the future safety of aviation operations were identified as a result of this investigation. However, the occurrence does provide a timely reminder of the risks associated with in-flight asymmetric training and the importance of the work being carried out by CASA to mandate the use of simulators for non-normal flying training and proficiency checks in larger aircraft. In addition, the risk reduction possible as a result of the application of appropriate operator procedures and pilot awareness of the potential hazards was reinforced where the only option was in-flight asymmetric training and checking.

The probable **cause** of the accident was the inappropriate crew response to the simulated engine failure and inappropriate V_{MCA} definition and V_2 data in the AFM.
The engine failure procedures issued by the manufacturer, and/ or operator were inappropriate, as was the pilot training for airplane control after engine failure. Procedures and training are the responsibility of the manufacturer, the operator and the airworthiness authorities.

Contributing factors were:
- the inappropriate use of V_{MCA} and V_2 in the EMB-120 manuals, and most probably also in pilot training manuals;
- V_{MCA} and V_2 data in the AFM might have been applicable to a less powerful engine;
- the setting of zero torque, rather than the torque for zero drag (or zero thrust) on the simulated failed engine;
- the crew obviously not being aware of the real value of the minimum control speed V_{MCA} and take-off safety speed V_2, and of the conditions that are required for these speeds to be valid.

As for most accidents after a propulsion system malfunction, the pilots are not to be blamed.

FINDINGS

From the evidence available, the following findings are made with respect to the loss of control that occurred at Darwin Airport, Northern Territory on 22 March 2010 and involved Embraer S.A. EMB-120ER Brasilia aircraft (EMB-120), registered VH-ANB. They should not be read as apportioning blame or liability to any particular organisation or individual.

Speed was V_{2min}. This speed provides a small, though adequate safety margin, provided the pilots maintain straight flight while banking a few degrees away from the inoperative engine.

Contributing safety factors

V_{MCA} correctly explained on page 48, but obviously not understood, because here it is not mentioned that bank angle was not maintained and rudder not adequate for maintaining heading.

Page 22: "bank to left would have resulted in increasing V_{MCA}, well above the 97 KIAS published in the AFM".

- The pilot in command initiated a simulated left engine failure just after becoming airborne and at a speed that did not allow adequate margin for error.
- The pilot in command simulated a failure of the left engine by selecting flight idle instead of zero thrust, thereby simulating a simultaneous failure of the left engine and its propeller autofeather system, instead of a failure of the engine alone.

?? See remarks above.

- The pilot under check operated the aircraft at a speed and attitude (bank angle) that when uncorrected, resulted in a loss of control.

because

- The pilot under check increased his workload by increasing torque on the right engine and selecting the yaw damper.
- The pilot in command probably became preoccupied and did not abandon the simulated engine failure after the heading and speed tolerance for the manoeuvre were exceeded and before control of the aircraft was lost.

workload? He was loosing airspeed while maintaining 9° pitch. He did not attain and maintain a small favourable bank angle, as a consequence of which the actual V_{MCA} increased.
He was obviously not properly trained.
His manuals were not perfect either.

See contributing factors in text box on previous page.

Other key findings

- Shortly after the accident, when an Australian aviation training facility operating an EMB-120 simulator and its staff were approved to undertake the operator's training requirements, the operator transitioned the majority of its EMB-120 proficiency checking, including asymmetric flight sequences, to ground-based training at that facility.

Recommendations

It is strongly recommended to:

1. Review the EMB-120 Flight and Ops manuals and improve the definitions of V-speeds. Increase the V-speeds to more safe values and make sure these speeds comply with the airplane design and flight-test methods and procedures. Add the bank angle criteria to V_{MCA} and $V_{2(min)}$ for these speeds to be valid and for which these provide minimum drag/ maximum climb performance.

2. Review engine-out training and procedures for compliance with airplane design and flight test methods on the subject of engine failure and engine-out flight.

3. Review and improve other (training) publications used by multi-engine rated pilots that do not present the correct theory on engine-out flight. In addition, accept textbooks and manuals only if they are written or reviewed by adequate qualified personnel holding an aeronautical science degree, such as graduates of one of the formal Test Pilot Schools.

Hippocrates said long time ago:
There are in fact two things, science and opinion.
The former begets knowledge, the latter ignorance.

It is recommended that pilots and investigators read the papers available on the Downloads page of www.AvioConsult.com to beget the knowledge for analysing accidents after engine failure.

On the next page Additional Findings.

Additional Findings of the accident and the report

1. According to the AFM, "the take-off and maximum continuous power setting for a PW118A that was derated to a PW118 was 97% torque" (pages 15 and 38). This could mean that the rudder and ailerons were not (re-)sized for the PW118A engine, and that V_{MCA} and V_2 data in the AFM were not adjusted for the PW118A engine either and hence, not certified appropriately. The use of derating thrust in pilot manuals is incorrect. A pilot can only reduce the thrust for take-off. Derating is done by engineers after fitting more powerful engines or propellers to an airplane that was designed for less powerful engines. The pilots could still set 120% from the cockpit as FDR data shows, which results in a catastrophe if an engine fails or is inoperative. If the AFM indeed presents a caution as presented on page 15, then airworthiness regulations are violated.

2. The definition of V_{MCA} as published in the EMB-120 Flight Operations Manual (page 21) is not in accordance with the methods of designing the vertical tail with rudder of multi-engine aircraft and not with the flight test techniques to determine V_{MCA} either. The definition is copied out of FAR 25.149 or equivalent, which is for the design and certification of airplanes, not for their operational use. Most manual writers make this catastrophic mistake. V_{MCA} is the minimum speed to recover from a sudden failure and thereafter maintain straight flight only, while maintaining a fixed small bank angle that is to be determined by the manufacturer, and usually is 5° away from the inoperative engine. Refer to the text boxes on page 21 for comments.
The published, standardized V_{MCA} was 97 kt (page 22), V_2 was 113 kt. The actual V_{MCA} was 110 kt because at that speed the yawing started slowly. The report writes about the change of V_{MCA} with bank angle (pages 22 and 48), but doesn't use this in the analysis. V_2 was dangerously close to the actual V_{MCA}. During the remainder of the flight, the airspeed decreased further and the bank angle was allowed to increase into the dead engine' side, because the aileron and rudder control inputs were not maximum opposite, resulting in an increase of the sideslip and drag, and an increase of the actual V_{MCA} far above the IAS, which led to the loss of both directional and lateral control.

3. Take-off speeds V_1 and V_R are used as a single combined speed in the report (pages 21, 27, 35), but in the AFM procedure as two different speeds (page 35). The V_1-cut take-off technique calls for "V_1 rotate" and attain "V_2+10" (page 40). On page 37, the operator procedures allow a speed of "the lesser of V_1+5 or V_R+5 kt". Pilot notes (page 4) showed V_2+10. V_{2min} might have been used as V_2, hence without an increment to adequately increase the safety margin as required by FAR 25.107. The (calculated) V_2 used by the operator was definitely too low; control was lost while the indicated airspeed was very close to this V_2, rather than a safety margin above it.

4. Several paragraphs of this report seem to be copied out of FAR 25 or equivalent. This Regulation however, is for design and certification of aircraft, and does definitely not fully apply to operational use. Copied paragraphs include, but are not limited to:
- The definition of V_{MCA} in the AFM was copied from FAR 25.149 but is definitely incorrect for pilots. The bank angle for which the published V_{MCA} is valid was, although not required, not presented with V_{MCA} data to inform pilots of this important condition. Refer to page 21.
- Changing the power setting and feathering (if not automatic) should not be performed below 400 ft. But delaying these actions might lead to accidents (page 36).
- The use of derated rather than reduced (page 15).
- The use of "critical engine" is for design engineers and test pilots, not for operational pilots. The published V_{MCA} applies after failure of either engine. When the non-critical engine fails, the actual V_{MCA} is a few knots lower - safer. Bank angle has a much greater effect on V_{MCA} and is not appropriately included in the definition (pages 8 and 21).

5. The pilots are not to be blamed; the few inappropriate procedural steps presented in this report are an indication of misunderstanding of V_{MCA}, V_2 and their true value with the writers of those manuals. It is strongly recommended to improve pilot manuals and training on the subject of engine failures and flight with an inoperative engine.
Manufacturer should consider adding a radial line to the Torque indicators showing the torque for zero thrust. Torque for zero thrust should be included in the AFM as well.

6. Restoring thrust during engine-out training when control seems lost or the exercise is abandoned is a very dangerous recommendation. Adding thrust while rudder and aileron control inputs are high might result in a spin (page 53). Experimental Test Pilots do never restore thrust, but reduce thrust on the live engine a bit, then recover to straight flight and increase both throttles, as required (pages 8, 10, 53, 55).

7. Although this Safety Report presents (not 'presented'...) the correct conditions for which V_{MCA} is valid (page 47) and the factors that influence this important speed limit (page 48), these are not used to draw conclusions on the airplane handling by the pilots. The relation between V_{MCA} and performance, and the possible increase of V_{MCA} above the published value were obviously not understood. The analysis of this accident was not complete and adequate, so that recommendations that would prevent future engine failure accidents from happening were not presented. Additional training for investigating engine failure related accidents is recommended.

8. The unconditional and report-wide use of the past tense is incorrect and annoying. It makes the report difficult to read and understand. The report has a date of issue too.
Why is the ICAO (Annex 13) recommended paragraph numbering not used?

Conclusion and cause are on page 56.

APPENDIX A: TECHNICAL ANALYSIS REPORT

Flight Data Recorder examination
EMB-120ER VH-ANB
Darwin, NT
22 March 2010

TECHNICAL ANALYSIS REPORT

Neil A. H. Campbell
Senior Transport Safety Investigator – Engineering

FACTUAL INFORMATION

Introduction

The EMB-120ER Brasilia aircraft was fitted with flight data recording and cockpit voice recording equipment. This report details the results of the recovery and analysis of information from the FDR unit, as part of the Australian Transport Safety Bureau's investigation of the 22 March 2010 accident event.

Flight data recorder fitment

EMB-120ER Brasilia aircraft, such as VH-ANB, are required by legislation to be fitted with a flight data recorder (FDR) and a cockpit voice recorder (CVR). The equipment standards regarding the flight recorders are specified in Civil Aviation Order (CAO) 103.19 and 103.20 respectively.

FDR system

The FDR system on VH-ANB was installed during aircraft manufacture and comprised:

- the digital FDR (DFDR) unit
- a Teledyne flight data acquisition unit (FDAU)
- aircraft sensors
- a flight data entry panel (FDEP).

The programming of the FDAU determined which parameters were recorded and VH-ANB was equipped with a 17 channel unit (P/N 2229951-1-A).

The FDEP enabled the crew to enter documentary data such as the flight number, which was then recorded by the FDR. The FDEP also contained fault lights for the FDAU and DFDR.

FDR details

The aircraft was equipped with a Loral Data Systems tape-based FDR. Details of the FDR were:

Table A-1: FDR details

Manufacturer	Loral Data Systems
Model	F800
Part number	17M800-261
Serial number	4049
Hardware mod status	1, 2, 5-8, 10, 12, 16, 19 & 22
Program revision	R4
Date code	04/90

Parameters

The FDAU was programmed to acquire and transmit the following aircraft parameters to the FDR for recording:

Table A-2: List of parameters recorded by the FDR

Parameter name	Sampling rate (times per second)
Flight parameters	
Pressure altitude	1
Indicated airspeed	1
Magnetic heading	1
Pitch attitude	4
Roll attitude	2
Air/ground (squat) switch	1
VHF keying (press-to-talk)	1
Static air temperature	1
Vertical acceleration	8
Lateral acceleration	4
Longitudinal acceleration	2
Control surface parameters	
Flap angle	4
Pitch trim	2
Elevator (control column) position	4
Aileron (control wheel) position	4
Rudder pedal position	4
Engine parameters	
Left engine torque	1
Right engine torque	1
Left propeller RPM (N_P)	1
Right propeller RPM (N_P)	1
Left engine speed - high pressure spool (N_H)	1
Right engine speed - high pressure spool (N_H)	1
Left engine speed - low pressure spool (N_L)	1
Right engine speed - low pressure spool (N_L)	1
Left inter-turbine temperature (T_6)	1
Right inter-turbine temperature (T_6)	1

These data did not appear in FDR graph on page 7, estimated data instead.

Left engine fuel flow	1
Right engine fuel flow	1
Left engine condition lever position[39]	1
Right engine condition lever position	1
Left engine beta mode[40]	1
Right engine beta mode	1
Left engine bleed condition	1
Right engine bleed condition	1
Left engine propeller imbalance	1
Right engine propeller imbalance	1
Documentary data parameters	
UTC (hours, minutes and seconds)	0.25
Date (day and month)	0.25
Flight number	0.25
Frame counter	25
FDAU parameters	
Frame counter	0.25
Software version	0.25

[39] The condition lever position indicated either 'shut-off', i.e. less than 9° propeller control unit (PCU) lever angle or 'power', i.e. greater than 9° PCU lever angle. 'Shut-off' corresponded to the MIN STOP position and 'power' included the feather, MIN RPM and MAX RPM positions.

[40] The beta range of operation is intended for ground use only. It is the range of propeller blade angles between flight idle and full reverse. In this range, the propeller blade angle is controlled directly by power lever movement, and the propeller governor has no effect on blade angle.

Engine torque parameters

Engine torque parameters were sourced from the signal conditioning units (SCUs) attached to each engine. The SCU torque signals were also used by the cockpit torque indicators. The SCU signals were high-level DC voltages and a full-scale range of 0 to 7.708 V DC corresponded to a recorded torque range of 0% to 150%. Negative torque values would be clamped at 0% and torque values greater than 150% would be clamped at 150%. A torque value in excess of 110% corresponded to a torque exceedance.

Control surface position parameters

Control position, rather than surface positions - any boosting?

Control ~~surface~~ positions were sensed by potentiometers connected to the flight controls and located under the floor in the cockpit. The potentiometers, P/N D12901/45/1V (pitch trim) or P/N D12901/75/1V (control wheel, control column and rudder pedals), were manufactured by Penny & Giles. Potentiometers rely on mechanical contact between a wiper and a resistive element to generate a signal. As a result, they are subject to wear and the signal can become increasingly 'noisy' with use.

FDR data recovery

ATSB investigators recovered the FDR from the accident site on 22 March 2010. It was transported to the ATSB's technical facilities in Canberra and was received on 23 March 2010 in a lightly sooted, but undamaged condition.

Figure A-1: The FDR as received in Canberra

The FDR was disassembled to expose the magnetic tape (the recording medium) and carefully inspected.

A data recovery was performed using specialised digitizing hardware and the *CAE Flightscape* Recovery, Analysis and Presentation System (RAPS) software.

Results

Data from the accident flight was successfully recovered and, with the exceptions described below, all the parameters were correctly recorded. In addition to the accident flight, 16 previous flights were recorded. Data listings, plots and an animation of the data were produced.

Torque data

Maintenance manual procedures required that recorded torque data be within 2% of the values shown on the torque indicators.

Crews were required to manually record, once per flight, engine trend data during stable cruise. These manually recorded torque values were consistent with the values observed from the FDR.

Torque values from earlier flights were examined, particularly during takeoff and initial climb. This examination did not show any evidence that the accuracy of recorded torque values was outside normal tolerances.

Anomalies observed in the recorded FDR data

Control input parameters

It was observed that the recorded data for the control wheel (aileron), control column (elevator), rudder pedal and pitch trim parameters showed rapid changes (noise) and were also offset from their expected datum (neutral) positions.

These problems only affected the recorded data. They would not have been apparent to the flight crew and would not have affected the control of the aircraft in any way.

Other cases of control input parameter problems

As a result of seven investigations involving EMB-120s, in which potentiometer malfunctions prevented accurate control input data from being recorded, in 1996, the US National Transportation Safety Board (NTSB) issued two recommendations[41]:

[41] http://www.ntsb.gov/recs/letters/1996/A96_33_34.pdf

> Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:
>
> Conduct a design review of the Embraer EMB-120 flight data recorder system, with emphasis on potentiometer failures, and mandate design, installation, and/or maintenance changes, as necessary, to ensure that reliable flight control data are available for accident/incident investigation. (Class II, Priority Action) (A-96-33)
>
> Require Embraer EMB-120 operators to perform a flight data recorder (FDR) readout or a potentiometer calibration test per section 31-31-00 of the EMB-120 Maintenance Manual every 6 months until FDR sensor design, installation, and/or maintenance improvements are incorporated. (Class II, Priority Action) (A-96-34)

In September 1997, the FAA issued a *Flight Standards Handbook Bulletin for Airworthiness 97-14B*, 'Embraer EMB-120 Flight Data Recorder Test', which directed operators to conduct FDR potentiometer calibration testing every 6 months. As a result, in May 1998, the NTSB classified Safety Recommendation A-96-34 'Closed—Acceptable Action'.

In December 2002, the FAA issued a Supplemental Type Certificate (STC) that authorised the replacement of the potentiometer sensors for the EMB-120 FDR system with more reliable sensors. As a result, in October 2004, the NTSB classified Safety Recommendation A-96-33 'Closed—Acceptable Action'.

Examination of the FDR data from an EMB-120, during a previous ATSB investigation (AO-2007-017), also revealed that the control surface position potentiometers were noisy.

Control input parameter datums

The nominal datum for each of the control surface positions was 0 degrees (neutral). To determine any offsets from the nominal datums, data recorded during the 'full and free' control check that crews performed before takeoff was examined. Twelve control checks, including the check before the accident flight, were examined.

Table A-3: Control input parameters

Control input	Nominal datum	Observed datum (approx.)	Nominal range of movement	Observed range of movement
Control wheel (aileron)	0°	-25°	±45°	±45°
Control column (elevator)	0°	-7°	-7.1° to +9.4°	-12° to +10°
Rudder pedal	0°	-4°	±19°	-14.5° to +12.5°

Control input parameter interpretation

Control wheel (aileron position) and rudder pedal parameters were of particular relevance to the investigation. Due to the noisy data, no confidence could be placed in any particular individual value of these two parameters. In spite of this, qualitative trend information could still be obtained from these parameters by comparing a series of recorded values. As spikes were more likely to be of shorter rather than longer duration, a spike that consisted of a single sample[42] was ignored. By correlating control wheel position with roll attitude and rudder pedal position with magnetic heading, further confidence could be placed in qualitative trend information for these parameters.

In the graphs of the estimated control inputs, the first roll input occurred 3.5 sec. after initiation of torque reduction.

For the control wheel, the data showed that the first significant right roll input occurred at the same time that the left engine torque was reduced. From that time, a series of right roll inputs and then movements to the neutral position were observed. Refer to Figure A-2.

Not either, it is both. The force on the pedals decreases while trimming.

Rudder pedal movement can be due to either pilot input or to rudder trim activation. For the rudder pedal parameter, the data showed that the first significant right rudder pedal movement occurred at the same time that the left engine torque was reduced. From that time, right rudder was consistently applied with one reduction in position evident about ~~13~~ to ~~14~~ seconds before the end of recording. The reduction reduced the magnitude of the right rudder pedal position, but an input to the right was still maintained. Refer to Figure A-3.

but increased V_{MCA}.

No, 1.5 sec. later.

No, two: from 16 to 11.5 and from 10 to 6 seconds before the end of the recording.

[42] The control wheel parameter was sampled four times per second.

Figure A-2: Estimated control wheel (aileron) input

legend?

Are you sure this is noise?
Why not this first peak in the estimation?

How was estimating done?

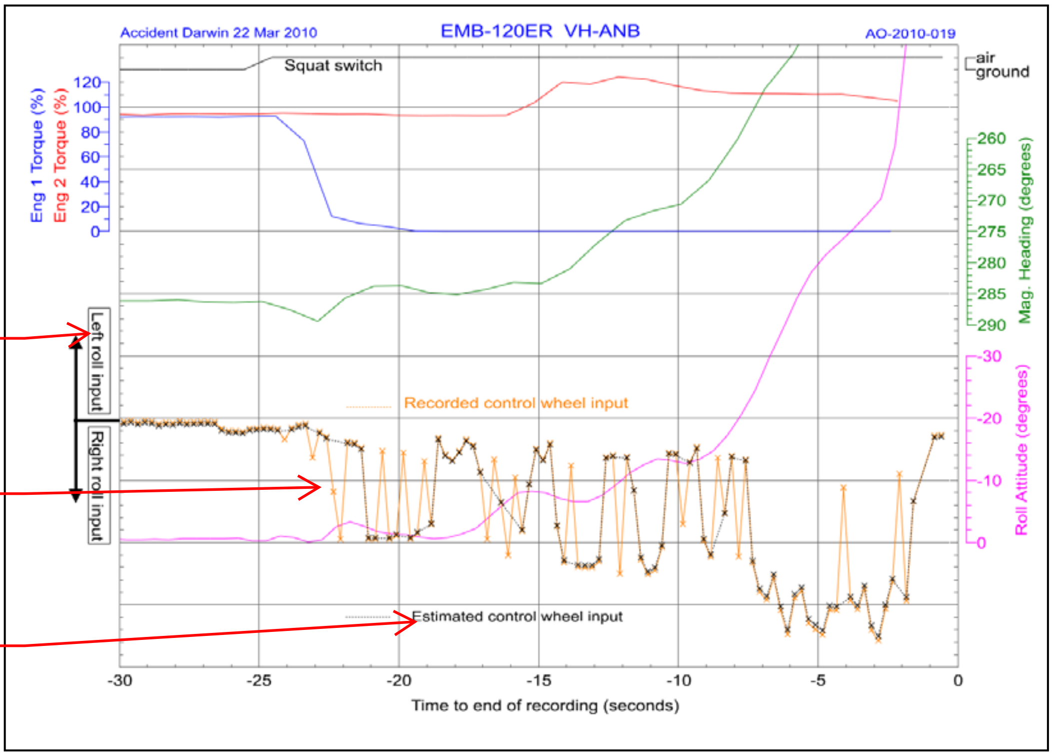
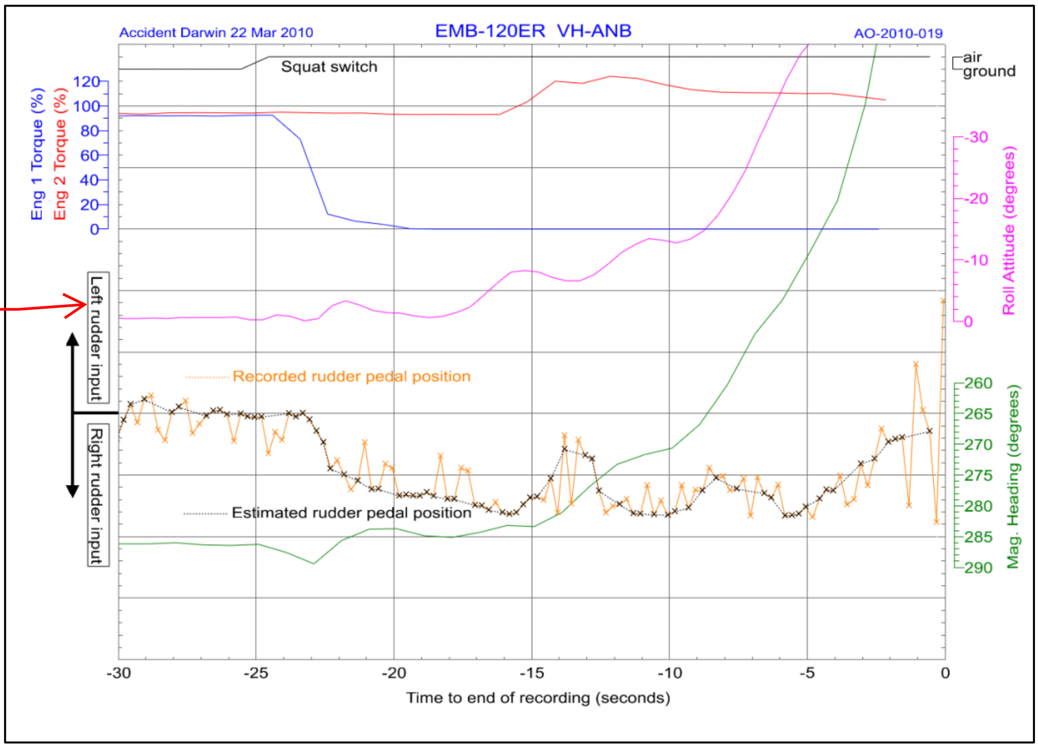


Figure A-3: Estimated rudder pedal input

legend?



APPENDIX B: TECHNICAL ANALYSIS REPORT

Cockpit Voice Recorder examination
EMB-120ER VH-ANB
Darwin, NT
22 March 2010

TECHNICAL ANALYSIS REPORT

Kenneth Kell
Senior Transport Safety Investigator – Technical Analysis

Released in accordance with section 26 of the *Transport Safety Investigation Act 2003*

FACTUAL INFORMATION

Introduction

The EMB-120ER Brasilia aircraft was fitted with flight data recording and cockpit voice recording equipment. This report details the results of the recovery and analysis of information from the CVR unit, as part of the Australian Transport Safety Bureau’s investigation of the 22 March 2010 accident event.

Cockpit Voice Recorder fitment

EMB-120ER Brasilia aircraft, such as VH-ANB, are required by legislation to be fitted with a flight data recorder (FDR) and a cockpit voice recorder (CVR). The equipment standards regarding the flight recorders are specified in Civil Aviation Order (CAO) 103.19 and 103.20 respectively.

In June 1990, in accordance with CAO 103.20, the CVR system fitted to Embraer EMB-120RT (construction number 120181, registered VH-XFW) was considered to be the Australian first-of-type aircraft / cockpit voice recorder combination. The copy of the first-of-type recording submitted to the Bureau was utilised as a reference tape for this investigation.

The CVR unit fitted to VH-XFW was a *Fairchild* model A100A, which utilises magnetic tape as the recording medium. This recorder was manufactured to Federal Aviation Administration (FAA) Technical Standard Order (TSO) C-84. The recording unit crashworthiness specified under TSO-C84 was reviewed in the 1980’s and resulted in the TSO being cancelled in 1986.

The CVR unit installed in VH-ANB was a *Fairchild* model A100S. This recorder is manufactured to FAA TSO C-123. This modern standard is more reliable, has increased crashworthiness and also incorporates digital signal processing technology, including the use of solid state memory devices to store the audio information.

CVR system

The CVR system was installed during aircraft manufacture and comprised:

- CVR Unit - is the unit which records and stores the audio signals in four individual tracks or files.
- CVR control unit - provides remote control of the CVR unit through TEST and ERASE switches. A meter and headset jack allows cockpit indication of CVR unit monitor signals for checking the correct function of the CVR. The unit also houses a preamplifier for the area microphone.
- Area Microphone - a remotely-mounted microphone that captures the audio environment of the flight deck.
- Interwiring to connect the CVR components, aircraft radio equipment, aural alerting systems and the flight crew microphones to make the overall CVR system.

The CVR system fitted to aircraft operated as a two-crew configuration has a separate channel dedicated to each flight crew position and signals detected by the area microphone. The fourth channel can be utilised for signals from the public address system.

CVR details

The CVR was an *L-3 Communications Aviation Recorders* (formerly Fairchild Aviation recorders) model A100S solid-state cockpit voice recorder. 'Solid-state' refers to the recording medium comprising of electronic integrated-circuit memory devices. The model A100S CVR unit contained enough memory to store a minimum of 30 minutes of recording.

Table B-2: CVR details

Manufacturer	Fairchild Aviation Recorders
Model	A100S
Part number	S100-0080-00-261
Serial number	00785 U
Hardware mod status	1, 2, 4, 5, 6, 7
Program revision	R2
Date code	03/95

CVR download and data recovery

ATSB investigators recovered the CVR from the accident site on 22 March 2010. The CVR was transported to the ATSB's technical facilities in Canberra and was received on 23 March 2010, in a lightly sooted, but undamaged condition.

Figure B-1: Cockpit Voice Recorder as received in Canberra

The CVR dust cover was removed to allow access to the download connector and an inspection of the internal circuits and modules did not reveal any damage.

The CVR was downloaded using the ATSB's specialist audio interface equipment and a copy was made of the four recorded channels of information.

Results

Audio relating to the accident

The recording contained about 30 minutes and 11 seconds of audio information. The context of recorded conversations confirmed that the recovered audio was related to the accident flight.

A summary of the CVR content, in the form of a *record of communication*, was prepared to provide a sequence of events from the recorded information.

A *record of communication* regarding checklist conversation was also requested to address issues arising during the investigation of the rudder system. The *After Engine Start* checklist conversation and the *Before Take-Off* checklist conversation indicated that the appropriate checklist items were being actioned by the flight crew.

The CVR timebase was correlated with the FDR data using the very high frequency (VHF) radio keying recorded parameter. Conversation with Air Traffic Control (ATC) recorded on the CVR was also examined and correlated with ATC logging recorder audio files. The correlation of the separate recordings produced a common timebase for use in the sequence of events.

Recorder System Checks

The model A100S CVR conducts internal tests to confirm correct operation. Unlike the digital flight data recorder (DFDR), there is no continuous monitoring indication to the crew that the CVR unit or the CVR system is operating correctly or otherwise. A failure of the CVR unit may be detected by invoking and monitoring a test cycle using a cockpit mounted facility. During the CVR TEST sequence, a 640 Hz tone is generated to test the throughput circuitry of the audio channels. The 640 Hz tone is monitored to provide a meter indication and an audio signal may be heard via a headset plugged into the jack located on the CVR control unit. The 640 Hz test tone audio is also recorded by the CVR unit.

The internal CVR unit tests are not comprehensive enough to detect all scenarios that may result in a corrupted recording. Therefore, to assure continued correct operation, the CVR manufacturer details test procedures, to be performed at regular intervals. The CVR manufacturer also recommends specific pre-flight CVR unit test procedures, and these were incorporated into the aircraft manufacturer's standard operating procedures (SOPs).

The pre-flight check of the CVR system was included in the operator's *Before Start* checklist and was to be performed during preparation for the first flight of the day. The expanded procedure for the voice recorder system check was published in the operator's *Operations Manual*, reference Volume 3, Issue 3 revision 0 Mar 2004 page 325.

> RHS *Voice Recorder CHECKED
>
> Press the test button for approximately 5 seconds.
>
> Note that the meter needle stabilises in the green. If any of the 4 channels is inoperative, the needle will take a pronounced dip into the red during the test.
>
> A headset may also be plugged into the panel during the test. Each time a channel is tested, a 600 Hz tone will be heard through the headset. Speech directed into the Area Microphone should be audible with a slight delay.

The accident flight recording from VH-ANB (which was the first flight of the day) did not include a 640 Hz test tone at the time the flight crews' conversation indicated the CVR check was performed. Assuming the serviceability of the system, a possible explanation for the absence of the tone may be that the CVR TEST button was pressed, but not fully held for 5 seconds.

The operator's *Before Start* checklist also included a flight data recorder check. The accident flight CVR recording included the challenge and response conversation regarding this checklist item. The data recorded by the FDR indicated that the FDR checklist item had been actioned correctly.

Aural alerts

From the recorded audio, a large number of aural alarms and tones sounded during the engine start process. This was considered normal, as there was considerable electrical switching and engaging of aircraft systems during the start cycle. The flight crew conversation did not indicate or suggest any abnormal operation during their activity.

Following takeoff, a 'triple chime' sounded with a *Landing Gear* voice message; this was noted by the flight crew as an appropriate warning that corresponded with the landing gear being retracted.

About 7 seconds prior to the end of recording, the stall warning 'clacker' sounded for about 2 seconds, and then, after a 0.4 second break, sounded again. The flight crew did not comment on the activation of the stall warning.

Propeller Speed (RPM) derivation

The conduct of an asymmetric departure for training purposes requires the manipulation of engine controls to simulate an engine failure. The CVR can record information related to the operation of the propellers, which can be directly related to the operation of the aircraft engines.

Sounds relating to propeller operation were observed on the area microphone recording (Figure B-2). The frequency of the tones detected was measured and used to calculate the propeller speed, in revolutions per minute (RPM).

The results showed a close correlation with the propeller rotational speed recorded by the FDR. A split in the frequency of the recorded sounds confirmed the reduction in RPM of one propeller (Figure B-3).

Figure B-2: Spectrograph of cockpit area microphone channel recording of take off showing frequency variation following lift off

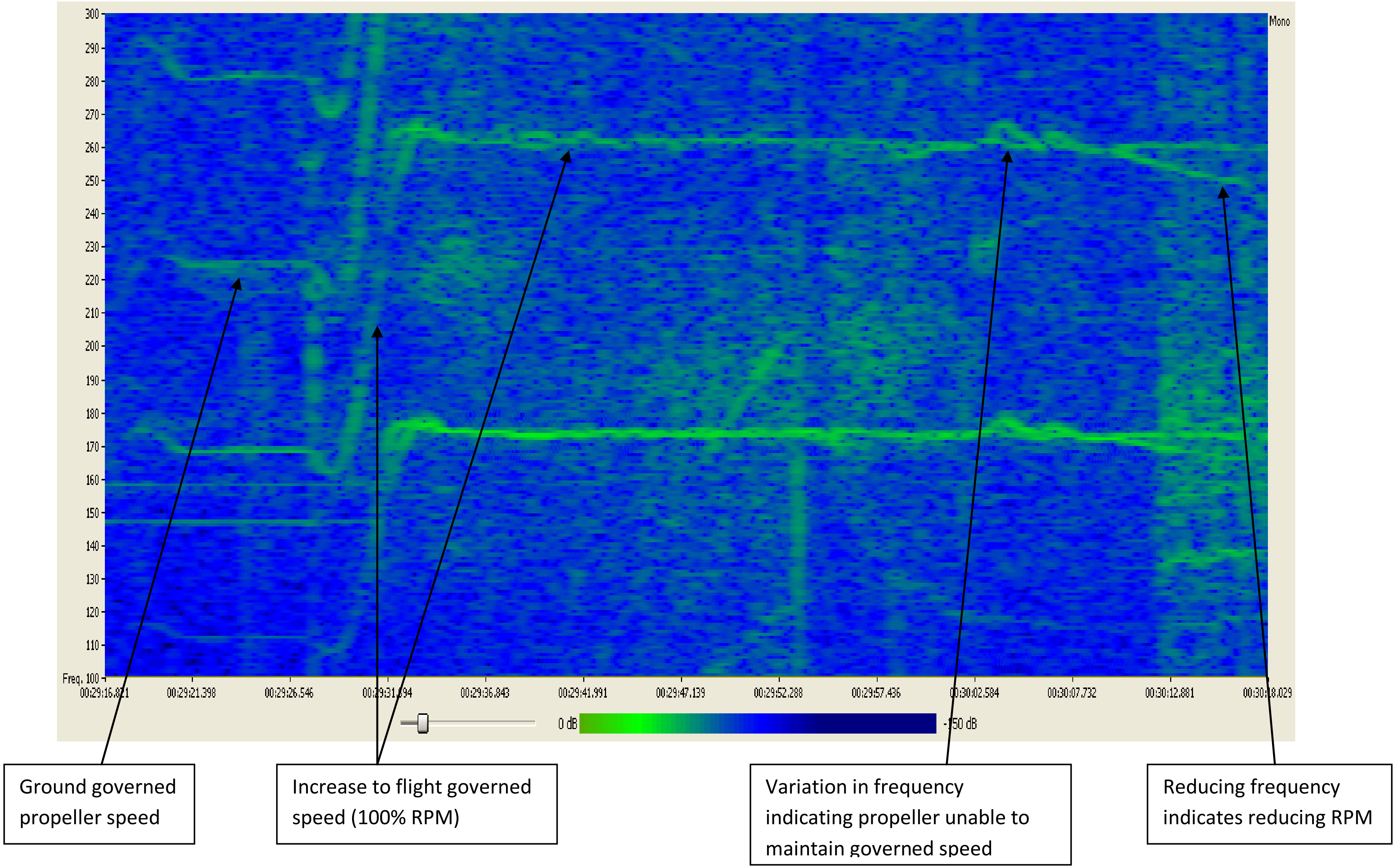
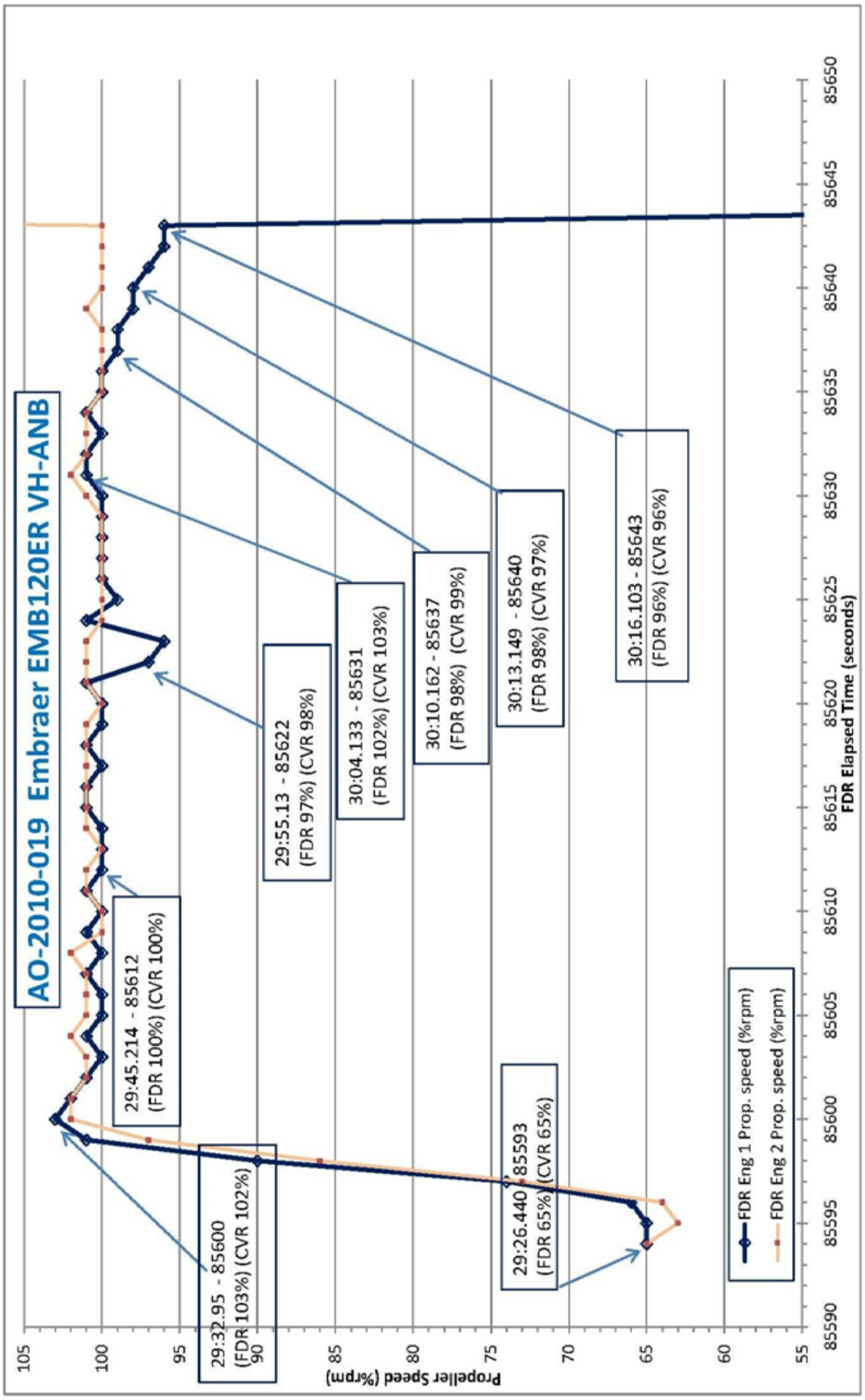


Figure B-3: Plot of propeller speed recorded by the FDR, CVR derived rpm comparison included in text boxes



APPENDIX C: ANIMATION

The following representative frames were taken from the animation of the flight to provide a ‘snapshot’ of the sequence of events. A full animation is available at http://www.atsb.gov.au/publications/investigation_reports/2010/aair/ao-2010-019.aspx

Refer to the YouTube channel of AvioConsult for a lecture on V_{MCA} in which this accident is used. The URL is: http://youtu.be/Wbu6X0hSnBY

Figure C-1: Start of take-off roll

Figure C-2: At rotation (V_1/V_R) and 25 seconds to end of recording

Figure C-3: Left engine torque decreases to 0% V and 19 seconds to end of recording

Throttle #1 closed at V_2, 111 kt. Yawing starts, no attempt to bank into good engine, while rudder is right..

Figure C-4: Heading 20° left of runway, banking left and 8 seconds to the end of recording

Airspeed decreasing, power increased, bank to dead engine increases, increasing actual V_{MCA}.

Figure C-5: Bank angle 50° left and 4 seconds to the end of recording

Figure C-6: End of recorded data

APPENDIX D: RELATED OCCURRENCES

Turbine asymmetric training occurrences

The following significant occurrences were associated with asymmetric flight training in Australian-registered turbine aircraft over a period spanning the last 15 years.

Bureau of Air Safety Investigation report 9503057

On 16 September 1995, a Fairchild SA227-AC Metro III, registered VH-NEJ, was destroyed when it crashed shortly after takeoff at night from Tamworth, New South Wales. The flight was under the command of a check-and-training pilot, who was conducting type-conversion training for the copilot. Four seconds after the aircraft became airborne the check-and-training pilot retarded the left engine power lever to flight idle. The landing gear was selected up and shortly thereafter the aircraft struck a tree and collided with the ground, about 350 m beyond the end of the runway and 250 m left of the extended centreline. It caught fire and was destroyed. The copilot and another trainee on board were killed while the check-and-training pilot received serious injuries.

As part of the investigation into that occurrence, the then Bureau of Air Safety Investigation (BASI) sought assistance from a qualified test pilot to examine the effects of simulating an engine failure by retarding the power lever to 'FLIGHT IDLE'. The main focus of the BASI investigation was the climb performance of the aircraft following a simulated engine failure on takeoff where zero torque was used to simulate one engine inoperative (OEI) flight, instead of zero thrust. Flight tests were conducted using zero torque to simulate a failed engine and feathering mechanism and the test pilot found that climb performance deteriorated to almost zero and that control of the aircraft could be maintained by using three-quarters rudder and aileron deflection.

The test pilot subsequently reported that:

> Overall, it seems there is little if any difference in the drag produced when a propeller is windmilling in the NTS (negative torque sensing) mode and when it is feathered. Furthermore, it is clear that in all published data dealing with OEI (one-engine inoperative) performance, no allowance or consideration has been made for the engine operating at flight idle.
>
> **Simulating engine failure by retarding a power lever to flight idle is therefore unrepresentative of any practical emergency. Moreover, the consequences in terms of further degraded performance and the potential for larger control displacement to counter the greater asymmetry, are serious. The practice is unwarranted and should be discouraged.**

BASI issued recommendations as a result of its investigation, including IR960035 that recommended the Civil Aviation Safety Authority (CASA) review the endorsement training requirements in aircraft above 5,700 kg maximum take-off weight where a flight simulator was not available. CASA responded that it had no power to mandate the use of flight simulators, but that it encouraged the use of an approved type simulator for the conduct of endorsement training.

A further BASI recommendation, IR960098, was issued in respect of the use of 'FLIGHT IDLE' to simulate engine failure in practice situations on Garrett-powered aircraft. The Metro was powered by two Garrett turboprop engines. CASA agreed with the recommendation and advised that all District Offices had been asked to bring the recommendation to the attention of Chief Pilots responsible for the operation of Garrett-powered aircraft.

This report is available for download at http://www.atsb.gov.au/publications/investigation_reports/1995/aair/aair199503057.aspx

Australian Transport Safety Bureau report BO/200000492

On 13 February 2000, a Beech 1900D aircraft, registered VH-NTL, was on a local training flight at Williamtown, New south Wales. The check pilot simulated an engine failure shortly after takeoff by reducing power on the left (critical) engine by retarding the power lever to the 'Flight Idle' position. The pilot flying, despite applying full right rudder and aileron, was unable to control the resulting left yaw, until power was restored to the left engine.

No evidence of any defect or aircraft system malfunction was found that had contributed to the difficulties experienced with control the aircraft during asymmetric flight. However, the investigation found that it had been the practice of the operator's check pilots to simulate engine failure by retarding the power lever to 'Flight Idle', contrary to the aircraft manufacturer's prescribed procedures in the aircraft flight manual.

The report noted that the use of 'Flight Idle' simulated a simultaneous failure of an engine and the propeller autofeather system, which was contrary to the provision of the CASA guidance and the operator's training and checking manual.

As a result of the investigation, Australian Transport Safety Bureau (ATSB) safety recommendation R20010072 recommended that CASA publish information for the guidance of operators and pilots regarding the correct procedures for simulating engine failures in turboprop aircraft. The CASA response to that recommendation was:

- That an amendment to Civil Aviation Advisory Publication (CAAP) 5.23-1(0) be made to highlight the appropriate engine-out training procedures.
- That CASA's aviation safety compliance division, as part of the scheduled surveillance, would ensure that operator's manuals contained the appropriate procedures for the conduct of multi-engine training, and that targeted surveillance was performed on operators of turbo-propeller aircraft conducting multi-engine training.

The subsequent amendment to CAAP 5.23-1(1) that was issued in July 2007 addressed the safety concerns of that recommendation.

This report is available for download at http://www.atsb.gov.au/publications/investigation_reports/2000/aair/aair200000492.aspx

ATSB report 200404589

On 21 November 2004, the crew of a Fairchild Industries SA227-AC Metro III aircraft, registered VH-TAG, was conducting an endorsement training flight near Lake George, 33 km north-east of Canberra Airport. The flight included a planned in-flight engine shutdown and restart, conducted at a safe altitude. During the engine restart preparation, the instructor departed from the published procedure by moving the power lever for the left engine into the beta range and directed the pilot to select the unfeather test switch. These actions were appropriate to starting an engine on the ground, but not during an airstart.

As a result, the crew lost control of the aircraft and it descended to about 450 ft above ground level (AGL), before they regained control. The crew could not diagnose the source of the loss of control and proceeded to re-start the left engine while the propeller was incorrectly configured and lost control of the aircraft for a second time before they regained control about 300 ft AGL.

The SA226/SA227 aircraft contain no lockout system to prevent pilots from intentionally moving the power lever into the beta range during flight. It was the first time the instructor had given a Metro endorsement and he was subject to time pressure to complete the endorsement. The instructor had a limited understanding of the aircraft's engine and propeller systems, and had not practiced an airstart in 8 years because the CASA check and training approval did not include an assessment of all flight critical exercises.

This investigation report is available at http://www.atsb.gov.au/publications/investigation_reports/2004/aair/aair200404589.aspx

EMB-120 asymmetric occurrences

The following occurrences were not associated with asymmetric flight training and are included because they involved asymmetric events involving EMB-120 aircraft.

The second occurrence, although resulting from a mechanical failure, included asymmetric flight testing of the EMB-120 by the United States National Transportation Safety Board (US NTSB) as part of that investigation. The report contained a description of the EMB-120's asymmetric flight behaviour.

ATSB report AO-2007-017

On 26 June 2007, the crew of an Embraer EMB-120 ER, registered VH-XUE, was on approach to Jundee Airstrip, Western Australia when it sustained a loss of power from the left engine. The crew detected the engine failure after initiating a go-around and almost lost control of the aircraft during that single-engine go-around.

The investigation found that the loss of engine power resulted from fuel starvation. In addition to the methods of recording and measuring fuel quantities, the investigation found that the crew's recognition of engine failure, and their handling of the asymmetric flight, may have benefited from the training available to pilots in simulators.

The report identified, as a safety issue, the lack of any mandatory requirement for simulator training in Australia. Although acknowledging that the activities already undertaken by CASA appeared to have facilitated an increased use of simulators for endorsement and other training, the ATSB issued safety recommendation AO-2007-017-SR-084 that CASA address the lack of mandatory simulator training.

This report is available for download at http://www.atsb.gov.au/publications/investigation_reports/2007/aair/ao-2007-017.aspx

US NTSB report PB92-910403 (NTSB/AAR-92/03)

On 5 April 1991, Atlantic Southeast Airlines Inc. flight 2311, an EMB-120 aircraft, registered N270AS, crashed during a landing approach to runway 07 at the Glynco Jetport, Brunswick, Georgia, USA. The investigation determined that the 'probable cause' of the accident was a loss of control in flight as a result of the malfunction of the left engine propeller control unit, which allowed the propeller blade angles to go below the flight idle position.

As part of the investigation, a number of flight tests were carried out with a specially modified left propeller system to establish the flight characteristics and controllability of the EMB-120 with the propeller at low (fine pitch) blade angles, including below flight idle.

The NTSB report advised that:

> The flight test pilots stated that they did not perceive any problem with the airplane (sic.) until the propeller blade angle was between 24 and 26 degrees. They stated that **the airplane became very difficult to control after the propeller reached the 22-degree [fine pitch] stop**. ...

Since many of the possible conditions that could lead to the accident were potentially too hazardous to duplicate in flight, the NTSB requested that the aircraft manufacturer make its engineering flight simulator available for a series of tests. Some of the simulator tests studied EMB-120 controllability with abnormally low propeller blade angles on the left engine. The flight simulator-derived report stated that:

> Aerodynamic principles dictate that as propeller thrust increases, there is a corresponding rise in the dynamic pressure of the airflow behind the propeller disk. Similarly, as propeller thrust decreases, there is a corresponding reduction in the dynamic pressure of the airflow behind the propeller disk. These changes in pressure occur over a substantial portion of the EMB-120 wing because of the relatively large diameter of the propeller. ...
>
> The high dynamic pressure of the airflow behind a normally operating engine/propeller produces a sizable lift "gain" on the affected wing. When the propeller is generating reverse thrust, there is a reduction in airflow behind the propeller disk that produces a sizable lift "loss" on the affected wing. These changes in lift contribute to the total rolling moment that must be offset by the flight controls to maintain wings-level flight.

> ... The most critical situation occurs while one propeller is producing forward thrust and the other is producing **substantially less** or reverse thrust. The lift "loss" and lift "gain" on each wing unite to roll the airplane toward the reversing propeller. The simulation model showed that roll control became increasingly difficult as thrust and blade angle decreased on the left propeller. The left rolling moment was most pronounced at high power levels on both engines and was the most significant factor affecting airplane controllability during the simulations. The yawing moment produced by the asymmetrical thrust was a less critical factor.

The NTSB testing was primarily concerned with the effects of in-flight reverse thrust. However, the testing also indicated that while not as extreme as the reverse thrust case, the aerodynamic forces affecting an EMB-120 with its left engine at flight idle and the propeller windmilling would still be significant.

This report is available for download at
http://www.ntsb.gov/investigations/reports.html

APPENDIX E: SOURCES AND SUBMISSIONS

Sources of information

Sources of information during the investigation included the:

- aircraft operator
- operator of the flight simulator training facility
- Bureau of Meteorology (BoM)
- Civil Aviation Safety Authority (CASA)
- aircraft manufacturer
- propeller manufacturer
- manufacturers of a number of aircraft components
- Northern Territory Police Service
- Office of the Coroner (Northern Territory)
- engine manufacturer
- Royal Australian Air Force.

References

US Department of Transportation (USA) Federal Aviation Administration (FAA) H-8083-3A - *Airplane Flying Handbook*

Submissions

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

A draft of this report was provided to the aircraft, the engine, the propeller and the rudder actuator and power control unit manufacturers, the aircraft operator, the operator of the flight simulator training facility and CASA.

Submissions were received from the aircraft manufacturer, the aircraft operator and the operator of the flight simulator training facility. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.