Supplementary Analysis
of the

Catastrophic Accident involving Beech Aircraft Corp C90, VH-LQH Toowoomba, QLD Australia, 27 Nov. 2001

Harry Horlings
Avio*Consult*, an independent aircraft expert and consultant
The Netherlands
www.avioconsult.com

References:

1) ATSB report 200105618:
http://www.atsb.gov.au/publications/investigation_reports/2001/AAIR/aair200105618.aspx
2) ATSB report 200707077:
http://www.atsb.gov.au/publications/investigation_reports/2001/AAIR/aair200507077.aspx
3) Airplane Control after Engine Failure, abbreviated version
http://www.avioconsult.com/downloads/Airplane Control after Engine Failure - Abbreviated.pdf

Author biography

Harry Horlings is a retired pilot and graduate Flight Test Engineer of the USAF Test Pilot School, Edwards Air Force Base, CA, December 1985. Following his Air Force career, which he concluded as Chief Experimental Flight Test, he founded Avio*Consult* and dedicated himself to improve aviation safety using his knowledge of experimental flight-testing. He researched many catastrophic accidents with multi-engine airplanes that occurred after engine failure or while an engine was inoperative. He published several papers and reports on the prevention of this kind of accidents and presented these to the European Aviation Safety Seminar of the Flight Safety Foundation, to the Dutch TSB, the Engine and propeller Directorate of the FAA and to a number of Airlines, Air Force and Navy organizations. He also wrote supplementary analyses of individual catastrophic accidents, of training and airplane flight manuals and of deficiencies in Aviation Regulations FAR, CS 23 and 25 and equivalent, all of which can be downloaded (for free) from the products page of www.avioconsult.com.

1. Introduction

1.1. After reviewing many accident investigation reports, it was noticed that there are huge differences in the interpretation and the use of the air minimum control speed V_{MCA} (and of takeoff safety speed V_2) of a multi-engine airplane between airplane manufacturers and experimental test pilots on one side and airline pilots as well as accident investigators on the other side. These differences in interpretation have lead to catastrophic accidents caused by the loss of control and/ or performance after engine failure and to incorrect conclusions in the accident investigation reports.

1.2. To improve the knowledge of airplane control while an engine is inoperative and to improve accident investigations, the report 'Airplane Control after Engine Failure' was written, using the theory and flight test techniques as taught at the USAF Test Pilot School, as well as using the criteria used for designing the vertical tail of an airplane as taught at the aviation faculties of universities around the globe.

1.3. Accident investigation is always performed to learn from the accidents and to recommend improvements in order to prevent similar accidents from happening again. From the reviewed investigation reports, it became clear that many, if not most accident investigation reports do not analyze the controllability of a multi-engine airplane after engine failure in the same way that was used to design the vertical tail and to flight-test the airplanes to determine V_{MCA}. Therefore, a supplementary analysis to the investigation report of a number of engine failure related accidents was written, including the subject accident. To understand the analysis presented below, it is recommended to read the above mentioned report, that can be downloaded from the products page of website: www.avioconsult.com. An abbreviated version can be downloaded with the link in ref. 3).

2. The accident

Just prior to, or at about the time the aircraft became airborne, the left engine failed. After liftoff, the aircraft remained airborne for about 20 seconds. The aircraft was rolling through about 90 degrees left bank, it struck power lines about 10 m above ground level and about 560 m beyond the end of the runway. It then continued to roll left and impacted the ground inverted in a steep nose-low attitude.

3. Supplemental Analysis

A limited number of quotes in *italic* print from the report (ref. 1), followed by comments:

3.1. *The abrupt left roll just before ground impact, and the steep nose-low attitude at impact, indicated a loss of control of the aircraft when the airspeed fell below the minimum control speed (V_{MCA}, or 90 kt).*
Comment: It seems very clear that the airplane was out of control, but loss of control does not happen only because the airspeed falls below published V_{MCA} (90 kt). V_{MCA} is determined by the manufacturer using a 5-degree bank angle towards the operating engine, according to the report (page 47). Once the pilot allows, or cannot prevent the airplane to bank away from this 5 degree bank angle, the actual V_{MCA} increases and might increase above the indicated airspeed (see explanation in ref. 3). The listed V_{MCA} no longer applies, because the bank angle is no longer the same as used to determine V_{MCA} and to design the vertical tail of the airplane.
Depending on the value of the other factors that have influence on the actual V_{MCA} (like power setting, prop feathering, cg, weight, etc.), the actual V_{MCA} might have increased to over 100 kt while the wings were level (at liftoff), or even higher as a consequence of banking into the dead engine. This might have led to an uncontrollable airplane already from the moment of liftoff, even if the airspeed was equal to the published V_{MCA} (90 kt). A catastrophe was unavoidable because the airspeed at liftoff was too low as the engine failed and the pilot did not apply controls to maintain the bank angle that was used to design the vertical tail and to determine V_{MCA} as required to be able to maintain straight flight while an engine is inoperative.

3.2. *Although there was no means of accurately establishing the speed profile during the flight, the aircraft attitude in the initial segment of the flight (left yaw, left-wing low, drifting left) also suggested that it was probable that the speed during that phase was never significantly above Vmca.*
Comment: Using the first comment above, the speed might have been above the listed V_{MCA}, but was most probably never above *actual* V_{MCA}. If the wings are kept level after engine failure as opposed to 5 degrees into the operating engine, the actual V_{MCA} will be 8 - 10 kt higher than the listed V_{MCA}. Although the Beech 90 flight manual presents a V_{MCA} (90 kt) that is determined using a 5 degree bank angle towards the operating engine, it does (in the emergency procedure, report page 103) not recommend or require the pilot to bank 5 degrees into the dead engine immediately after engine failure and maintain that attitude until reaching a safe altitude and airspeed. This is a very serious deficiency in the manual. The manual writers do obviously not know either that the vertical tail of the airplane is only designed to maintain straight flight after engine failure while banking 5 degrees away from the inoperative engine.

3.3. *The aircraft never attained the most appropriate attitude for achieving the best one engine inoperative climb performance; that is, banked towards the operative engine.*
Comment: The very first worry of a pilot after engine failure should be to restore and maintain control; then to achieve the best one engine inoperative climb performance. The aircraft never attained the most appropriate attitude for maintaining control because the airspeed was most probably below the actual V_{MCA} from the instant of liftoff. The required attitude for both control and best performance after engine failure is 5 degrees of bank into the operating engine which, as a consequence, means maintaining straight flight only. If this attitude cannot be achieved using the controls, the indicated airspeed is at or below the actual V_{MCA}, which can be much higher than the listed V_{MCA}. In order to regain control, this actual V_{MCA}

needs to be lowered to below the indicated airspeed, which - at low altitude - can only be achieved by temporarily reducing the thrust of the operating engine just a little, until the airplane responds again to the roll and yaw control inputs. Once control is regained and a 5 degree bank angle towards the operating engine is achieved, then thrust can be restored to max. allowable. The only alternative is closing the throttles and land (controlled, in the dirt). If the engine failure occurs at higher altitude, the (indicated) airspeed can be increased by pitching down and exchange altitude for airspeed, instead of reducing the thrust for lowering actual V_{MCA}. These are often the only ways to survive an engine failure.

3.4. *For most multi-engine aircraft below 5,700 kg, such as the C90, the aircraft cannot climb with one-engine inoperative until the aircraft is correctly configured and the specified speed is achieved.*
Comment: The most important factor is missing here: a 5 degree bank angle towards the operating engine. The sideslip due to the asymmetrical thrust and the rudder deflection are minimum only if a bank angle of 5 degrees into the operating engine is attained. Without the bank angle, the resulting sideslip increases the drag and hence deteriorates the remaining performance even more; it also causes a drift to the dead engine side after which the weathercock stability turns the nose of the airplane, also into the dead engine side.
For maximum performance, it is of utmost importance that drag is kept to a minimum by cleaning up the airplane (gear (and flaps)), by feathering the propeller of the inoperative engine, **and** by maintaining the small 5 degree bank angle away from the failed engine. Then the slip ball is a half ball-width into the good engine.

3.5. *The left propeller of the airplane was found to be unfeathered.*
Comment: V_{MCA} was determined by the manufacturer using a wind milling propeller, according to the report (page 47). Hence, the manufacturer provided a worst case V_{MCA} for propeller positions, which is good for control after engine failure. Feathering the propeller would have decreased the *actual* V_{MCA} to below 90 kt, which would have increased the control margin, but if the bank angle of 5 degree was not maintained, this advantage would have been lost.
The fact that the pilot could not maintain straight flight after liftoff proves that the *actual* V_{MCA} must have been higher than liftoff speed.
An unfeathered propeller is of course bad for performance too, but if the lack of performance would have been the problem, the flight path would not have deviated to the left.
The definition of V_{MCA}, as used during designing the vertical tail and during flight-testing, is that at that speed, straight flight can just be maintained, provided a bank angle of 5 degrees is maintained away from the inoperative engine. V_{MCA} is definitely not a minimum maneuvering speed.
The small bank angle also reduces the drag and hence increases performance.

3.6. *The use of a rotation speed of 90 kt, which was the same as V_{MCA}, had the effect of compromising the one-engine inoperative performance capability of the aircraft following an engine failure at liftoff.*
Comment: Again, only performance is discussed and not controllability. A rotation speed equal to V_{MCA} is not only compromising the performance capability, but also the controllability, instantaneously. The V_{MCA} of the C90 was determined while using a bank angle of 5 degrees into the operative engine (see the report page 47). Keeping wings level, as will be the case during rotation, will lead to an *actual* V_{MCA} that can be up to 10 knots higher than the V_{MCA} that is listed in the flight manual. If the airplane is lifted off the ground at the listed V_{MCA} and the other factors that influence V_{MCA} happen to be at their worst case value too, then the airplane will definitely not be controllable anymore. The airplane rolls and yaws in the direction of the failed engine, while the natural reaction of the pilots of course is to use aileron and rudder to get the airplane to yaw and roll back to the original attitude and heading. But the airplane won't listen - it is already out of control, a catastrophe cannot be avoided unless the power on the operating engine is reduced temporarily just a bit, until control is recovered. This decreases *actual* V_{MCA} just enough to recover control.

3.7. *There is currently no formal advisory material issued by CASA to Australian operators and pilots regarding the most appropriate ways to consider the management of engine failures during takeoff in these aircraft.*
Comment: CASA, ATSB and operators are recommended to read the Paper and the Report that Avi-o*Consult* presents on the products page of its website www.avioconsult.com. It includes advisory material for improving manuals, training programs, etc.

3.8. *The aircraft manufacturer defined air minimum control speed (Vmca) as:*
…the minimum flight speed at which the airplane is directionally controllable… The airplane certification conditions include one engine becoming inoperative and windmilling, a 5-degree bank towards the operative engine, take-off power on operative engine, landing gear up, flaps in the take-off position, and most rearward C.G. [centre of gravity]
Comment: This is a near perfect definition of V_{MCA}. The only comment on the definition is that V_{MCA} is not the minimum speed at which the airplane is directional controllable, but the minimum speed at which only straight flight is possible. That is how V_{MCA} is to be determined in accordance with Part 23.149. The presented configuration and conditions lead to the highest V_{MCA}, which is the worst case V_{MCA} and hence the safest V_{MCA} to be published in flight manuals.

3.9. *Engine failure during takeoff procedure in Flight Manual.*
Comment: The real deficiency is that neither the manufacturer, nor the operator use the V_{MCA} definition to provide a perfect engine failure emergency procedure. In the C90 AFM (page 103 of the investigation report) the pilots are not required to attain and maintain the 5 degree bank angle that was used to determine V_{MCA}. The listed V_{MCA} is not valid without applying this bank angle. Using the engine failure procedure as listed on page 103 will - after engine failure - lead to an instantaneous increase of the *actual* V_{MCA} of approximately 10 kt and to an uncontrollable airplane at once if the other factors that have influence on V_{MCA} are at their worst case values too. This obviously was the case during this accident.

4. Cause of the accident

As might be clear by now after reading the above, the accident was caused by an incomplete and deficient engine emergency procedure. In addition, the real value and meaning of V_{MCA} was neither clear to the pilot, nor to the accident investigators.

It is the objective of the Report '*Airplane Control after Engine Failure*' that Avio*Consult* presents on the products page of its website to improve this, and to improve procedures, engine-out training, aviation regulations, etc. Many recommendations are presented. ■