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King Air C90 Pilot Continues Takeoff After Engine Fails at Minimum-control Speed

The landing gear were not retracted, and the propeller on the failed engine was not feathered. A control loss occurred, and the aircraft struck terrain. Before the accident, engine-condition trend-monitoring data indicated that a potentially significant problem was developing in the engine.

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FSF Editorial Staff

About 0836 local time on Nov. 27, 2001, the left engine on a Beech Aircraft Corp. (now Raytheon Aircraft Co.) King Air C90 failed on takeoff from the Toowoomba (Queensland, Australia) airport. The aircraft rolled left and struck power lines and the ground. The pilot and three passengers were killed.

The Australian Transport Safety Bureau (ATSB) said, in its final report, that the following were significant factors in the accident:

- "The left engine failed during a critical phase of the takeoff. The failure was probably the result of a developing problem in the cold [compressor] section of the engine, which was not detected or corrected due to several compounding deficiencies in the operator's maintenance system;

- "The aircraft manufacturer's specified procedures for responding to an engine failure in LQH [the accident aircraft's registration number was VH-LQH] stated that the takeoff should be rejected below the 'takeoff speed,' specified as 100 knots. The short flight continued at a speed close to V_{MCA} [air minimum control speed with the critical engine inoperative[1]] (90 knots), and the aircraft was not configured to minimize drag; [and,]

- "Control of the aircraft was lost in circumstances where recovery was not possible, and the subsequent ground impact and fire [were] not considered survivable."

The aircraft had been chartered for a flight from Toowoomba to Goondiwindi, Queensland. The operator, Eastland Air, operated three King Air C90s, a Super King Air B200 and two de Havilland Canada Twin Otters; all the aircraft had Pratt & Whitney Canada PT6A series turboprop engines.

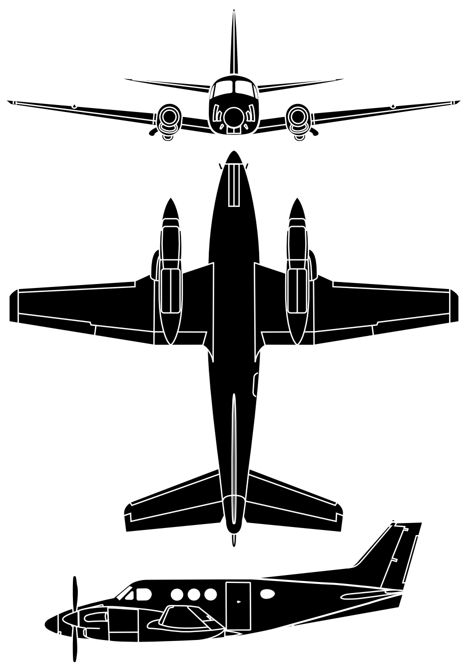
The accident aircraft was manufactured in 1975 and imported into Australia from the United States in 1998. At the time of the accident, the aircraft had accumulated 6,969 hours in service.

The pilot, 28, held an air transport pilot license and had 3,840 flight hours, including 480 flight hours in type. He was employed by Eastland Air in August 2000 and completed King Air C90 endorsement training in September 2000. He failed a base check in October 2000 because of inadequate knowledge of civil aviation regulations and the operator's policies and procedures; he passed the re-test in November 2000. He passed an instrument proficiency check, a base check and a route check in February 2001.

The pilot initially flew from Eastland Air's base in Roma, Queensland, but had been flying from the company's main base at Toowoomba for almost five months before the accident occurred. He had conducted 52 takeoffs from the Toowoomba airport.

"The pilot was reported to have been well-rested and in good health prior to the flight," the report said. "A review of his flight history showed that he had worked a total of 9.3 hours on the day prior to the accident. This included 7.8 hours flight time and involved seven takeoffs and landings. He had the previous three days free of duty. Witnesses reported that on the day of the accident, the pilot's preflight activities appeared normal and unhurried."

The aircraft's takeoff weight was calculated as 4,170 kilograms (9,193 pounds) — 207 kilograms (456) pounds less than the maximum takeoff weight (MTOW). The passengers' seating positions were not determined, but the report said that even with the least-favorable seating arrangement, the aircraft would have been within weight-and-balance limits.



Raytheon Beech King Air C90

Beech Aircraft Corp. (now Raytheon Aircraft Co.) introduced the King Air C90 in 1970. The airplane has accommodations for a pilot and up to nine passengers, and is powered by two Pratt & Whitney Canada PT6A-20 turboprop engines, each rated at 550 equivalent horsepower (410 kilowatts) and driving a three-blade Hartzell propeller. Bleed air from both engines provides cabin pressurization; the cabins of previous 90-series King Airs were pressurized by a single hydraulically driven supercharger.

Maximum takeoff weight is 4,377 kilograms (9,650 pounds). Maximum landing weight is 4,159 kilograms (9,169 pounds).

At sea level and at maximum takeoff weight, maximum rate of climb is 2,000 feet per minute; maximum single-engine rate of climb is 555 feet per minute. Maximum cruising speed at 16,000 feet is 220 knots. Power-off stall speeds are 80 knots in clean configuration and 72 knots in landing configuration.♦

Source: *Jane's All the World's Aircraft*

Weather conditions included surface winds from 249 degrees at five knots, a temperature of 20 degrees Celsius (68 degrees Fahrenheit), broken clouds at 1,500 feet and visibility greater than 10 kilometers (six statute miles). Airport elevation was 2,086 feet.

The pilot began the takeoff on Runway 29, which was 1,121 meters (3,678 feet) long and 30 meters (98 feet) wide. The report said that the end of the runway cannot be seen from the runway threshold because the first 800 meters (2,625 feet) of the runway slope upward and the last 321 meters (1,053 feet) of the runway slope downward.

"To assist in overcoming the visual limitation associated with the runway gradient, the aerodrome operator had installed distance-to-go markers at positions 600 meters, 400 meters and 200 meters (1,969 feet, 1,312 feet and 656 feet) from the respective ends of Runway 11-29," the report said.

A 60-meter (197-foot) clear area began at the end of Runway 29. The report said that this clear area met Australian Civil Aviation Safety Authority (CASA) standards for a runway strip and for a runway end safety area (RESA), both of which are designed to reduce damage to an aircraft that overruns the runway or touches down before the runway threshold.[2] The clear area beyond the end of Runway 29 did not meet International Civil Aviation Organization (ICAO) standards, which required a 60-meter runway strip beyond the end of the runway and a 90-meter (295-foot) RESA beginning at the end of the runway strip.

"For Toowoomba aerodrome to have complied with ICAO standards, Runway 29 needed a minimum of 150 meters [492 feet] of clear area beyond the end of the runway," the report said. "At the time of the accident, there was about 100 meters [328 feet] of clear area." The last 40 meters (131 feet) of the clear area, however, sloped downward at a gradient of about 9 percent, which was too steep to meet CASA or ICAO requirements for a RESA.

Runway 29 did not meet the accident aircraft's accelerate-stop distance requirements. Beech Aircraft Corp. defined accelerate-stop distance as the "distance required to accelerate an aircraft to a specified speed [100 knots for the King Air C90] and, assuming failure of an engine at the instant that speed is attained, to bring the airplane to a stop."

"The aircraft manufacturer advised that, under the circumstances prevailing at the time of the accident, the accelerate-stop distance was about 1,300 meters [4,265 feet]," the report said. "Therefore, the accelerate-stop distance … extended beyond the end of Runway 29 at Toowoomba."

A takeoff-distance chart in Eastland Air's operations manual included rotation speeds between 92 and 97 knots, based on takeoff weight; at the accident aircraft's takeoff weight, the rotation speed was 96 knots. Nevertheless, another section of the operations manual specified a rotation speed of 90 knots. Several company pilots told investigators that they rotated the C90s at about 85 knots to 90 knots.

"Personnel responsible for the compilation of the manual reported that the 90 knots rotation speed was based on operator experience," the report said. "The operator considered that 'to hold the aircraft on the ground would be pointless and that by rotating the aircraft at 90 knots, the aircraft was able to accelerate in the air to achieve 100 knots by 50 feet above the runway."

The aircraft flight manual recommended that a takeoff be rejected if an engine failure occurs below 100 knots. The report said that the accident aircraft's airspeed likely never was "significantly above" V_{MCA} (90 knots) during the 20-second flight.

"The aircraft's speed when it became airborne was probably close to V_{MCA} and not sufficient to allow the aircraft to accelerate to the best one-engine inoperative rate of climb speed (V_{YSE}) of 107 knots with an engine failure," the report said. "With an engine failure or malfunction near V_{MCA}, the safest course of action would be to reject the takeoff due to the likelihood of the aircraft not being able to accelerate to V_{YSE}. Although in some cases this will mean that the aircraft will overrun the runway and perhaps sustain substantial damage, the consequences associated with such an accident will generally be less serious than a loss of control after becoming airborne."

Two witnesses said that the aircraft lifted off about 700 meters (2,297 feet) from the approach threshold of the runway. One witness said that he heard three noises that sounded like "whomp" before the airplane lifted off; the other witness said that he heard a "banging" noise as the aircraft lifted off.

Workers in an industrial shed near the extended centerline of Runway 29 said that they heard noises that sounded like gravel being thrown on the roof of the shed; two small pieces of metal later found on the roof likely came from the aircraft's left engine.

The report said that when the left engine failed, all thrust from the engine likely was lost immediately. The investigation determined that the right engine was developing "significant power" on impact.

"The *Approved Flight Manual* indicated that at a V_{YSE} of 107 knots, LQH should have been capable of climbing at a rate of about 430 feet per minute with the flaps up, the landing gear retracted, the inoperative engine's propeller feathered and maximum continuous power on the operative engine," the report said.

The propeller on the left engine was not feathered automatically by the auto-feather system or manually by the pilot. The investigation did not determine why the auto-feather system did not feather the propeller.

"To activate the system, the auto-feather arm switch must be placed in the 'ARM' position prior to takeoff," the report said. "The operator's normal procedure was for the auto-feather system to be armed for takeoff."

The investigation did not determine whether the auto-feather system was armed for takeoff. Records indicated that maintenance had been performed on the auto-feather system for the right engine in July 2001.

"A micro-switch was found to be out of adjustment," the report said. "Corrections were made according to the manufacturer's procedures, and there were no reported recurrences of any problems. There was no evidence of any recent propeller-feathering-system defects associated with the left engine."

"As the aircraft was rolling through about 90 degrees left bank, it struck power lines …"

The aircraft initially drifted left in a left-wing-low attitude. A control loss then occurred, and the aircraft rapidly rolled left and pitched nose-down.

"As the aircraft was rolling through about 90 degrees left bank, it struck power lines about 10 meters [33 feet] above ground level and about 560 meters [1,837 feet] beyond the end of the runway," the report said. "It then continued to roll left and impacted the ground inverted in a steep nose-low attitude. An intense fuel-fed fire erupted upon initial impact with the ground."

Examination of the left engine indicated that the engine failure was caused by the fracture and separation of one or more compressor-turbine blades.

"The manufacturer reported that the separation of the compressor-turbine blades and their subsequent impact with adjacent blades would create a gross disruption of gas flow and compressor efficiency, resulting in a severe power loss," the report said.

Examination of the left engine by the Transportation Safety Board of Canada (TSB) indicated that the engine failed "as the result of the conditions under which it was operated rather than as the result of any manufacturing defect," the report said. "The TSB found that the compressor-turbine blades had been exposed to higher-than-normal operating temperatures."

The left engine had accumulated 6,831 hours of operation. The engine was operated for 3,275 hours before it was overhauled in January 1999; the engine was operated for 3,556 hours after the overhaul. Pratt & Whitney Canada recommended a time between overhaul (TBO) of 3,600 hours for the PT6A-20A engine.

"However, the aircraft's engines were [being operated] on a life extension to 5,000 hours TBO in accordance with the provisions of [CASA] Airworthiness Directive AD/ENG/5 Amendment 7," the report said.

The AD, *Turbine Engine Continuing Airworthiness Requirements*, specified intervals for the inspection and overhaul of PT6A engines. Among the AD's requirements for the 5,000-hour TBO extension was the use of Pratt & Whitney Canada's engine-condition trend-monitoring (ECTM) program.

The ECTM program involved the recording — by the pilot or by installed equipment — of engine data (e.g., compressor speed, inter-turbine temperature [ITT], fuel flow and torque), propeller speed and other data (e.g., outside air temperature, pressure altitude and indicated airspeed). A computer program provided by Pratt & Whitney Canada compared the recorded data against predicted normal engine-operating parameters and displayed trends of deviations from the predictions.

The ECTM manual generally required data to be recorded each day the aircraft was flown and to be processed the next day. Eastland Air's operations manual required pilots to record data once each day while flying the aircraft between Flight Level (FL) 110 (approximately 11,000 feet) and FL 190. The manual said, "If operational requirements preclude flight at the above levels, then the occasional missed recording is acceptable."

Flight logs indicated that data were recorded on 87 percent of the days the company's C90 aircraft were flown from January through July, 2001, and that data were recorded on 61 percent of the days the aircraft were flown from August to the day of the accident.

"There were occasional flights when it was not possible to record trend data due to the nature of the flight, such as its limited duration at cruise or that it was flown at an altitude outside of the range specified in the operator's manual," the report said. "However, the flight logs revealed that there were many opportunities for the data to be recorded on days when it was not recorded."

Although ECTM data were not recorded as frequently as required, sufficient data were recorded to detect trends. Data recorded for the accident aircraft's left engine between May 21 and Nov. 21 showed a gradual increase in compressor speed and ITT above the predicted parameters.

"The pattern of ECTM data from the left engine indicated that a potentially safety-critical problem existed in [the cold section of] that engine for several weeks prior to the accident," the report said. "For a variety of reasons, that evidence was not detected and analyzed, nor was appropriate remedial action initiated. … The ECTM data for the right engine suggested that a potential problem had also been developing in the cold section of that engine."

Maintenance of Eastland Air's aircraft was performed by another company until March 2001, when Eastland Air established its own maintenance organization. A review of documents from April 1998 to February 2001 indicated that maintenance of the accident aircraft had been conducted "in accordance with applicable schedules and requirements," the report said.

In August 2001, the company's maintenance controller resigned, and the company's chief engineer (chief maintenance technician) assumed the additional responsibilities of maintenance control. The responsibilities of a maintenance controller were to "develop, control, organize and supervise all maintenance activities carried out on the aircraft as specified in the *Maintenance Control Manual*," the report said.

"His workload increased significantly when he took on these additional responsibilities," the report said. "The chief engineer had minimal preparation for his role as maintenance controller."

Because the chief engineer/maintenance controller had not completed ECTM training, Eastland Air sent ECTM data to the engine manufacturer's field representative for analysis.

"However, the ECTM data were not being recorded or submitted for analysis as frequently as required by the engine manufacturer's requirements or [by] AD/ENG/5," the report said. "CASA surveillance had not detected any problems with the operator's ECTM program prior to the accident."

AD/ENG/5 required a compressor-performance-recovery wash (compressor wash) to be performed when indicated by ECTM data or at maximum intervals of three months or 220 hours, whichever occurred first.

"A [compressor] wash involves the injection of a chemical solution into the compressor internal section of the engine to clean possible contaminants, such as dust and salt deposits, for the purpose of performance recovery," the report said.

Maintenance records indicated that the last compressor wash was performed on the left engine more than five months before the accident occurred.

"Had the [compressor] wash been conducted on the left engine at the appropriate time, it may have been effective in removing the source of deterioration in cold-section efficiency," the report said.

CASA in June 2003 revised AD/ENG/5 to require that ECTM data collection, data analysis and follow-up actions comply with the Pratt & Whitney Canada *ECTM Users Guide and Reference Manual*, and that ECTM programs include requirements for qualification and training of personnel conducting the programs. The AD revision also required operators to review and to revise if necessary their ECTM programs at least every two years and to report to CASA "all major defects and defects that affect engine durability."

CASA in April 2004 told ATSB that its ECTM-compliance program had been strengthened by:

- "The participation of several CASA compliance staff in ECTM training conducted by [Pratt & Whitney Canada];
- "A program to develop guidance material for ECTM-compliance assessment;
- "A program to improve the awareness of CASA staff and industry on the critical nature of ECTM; and,
- "[Publication of an article, 'A Stitch in Time'] in the CASA magazine [*Flight Safety Australia*, January–February 2004] on ECTM."

Eastland Air ceased operations after the accident occurred. During the accident investigation, CASA reviewed the ECTM programs used by other aircraft operators in southeastern Queensland.

"However, at the date of this investigation report [June 25, 2004], CASA had not conducted a national audit to determine the level of compliance with the requirements of AD/ENG/5," the report said.

Based on these findings, ATSB made the following recommendations:

- "That CASA conduct a national review of the level of operator compliance with the requirements of mandatory turbine-engine condition-monitoring programs, particularly for passenger-carrying operations;
- "That CASA review its surveillance processes to ensure that during future surveillance activities, priority is given to confirming operator compliance with the requirements of mandatory turbine-engine condition-monitoring programs, particularly for passenger-carrying operations;
- "That CASA review its airworthiness surveillance processes and certificate of approval assessment processes to ensure that it provides adequate guidelines to assist CASA inspectors to identify priority areas for consideration during surveillance and approval activities, such as programs for compliance with the requirements of airworthiness directives;
- "That CASA review its airworthiness surveillance processes and certificate of approval assessment processes to ensure that it provides specific guidelines to assist CASA inspectors to assess whether a maintenance organization has adequate personnel resources to conduct its required activities;
- "That CASA consider providing formal advisory material for operators and pilots, based on relevant research and publications, about managing engine failures and other emergencies during takeoff in multi-engine aircraft below 5,700 kilograms[/12,500 pounds] MTOW. This material should include the factors to be considered by operators when developing procedures for responding to such emergencies;
- "That CASA consider and evaluate options to improve the suitability of industry practices for training pilots to make appropriate decisions when responding to engine failures and other emergencies during critical phases of flight in multi-engine aircraft below 5,700 kilograms MTOW. This review should include an assessment of the suitability of utilizing synthetic training devices for the purpose of training pilots to make decisions regarding emergencies; [and,]
- "That the Toowoomba City Council liaise with CASA to evaluate an engineering solution to enhance aircraft deceleration in the [RESA] of Runway 11-29 at Toowoomba aerodrome."♦

[FSF editorial note: This article, except where specifically noted, is based on Australian Transport Safety Bureau Aviation Safety Investigation report no. 200105618, *Beech Aircraft Corporation C90, VH-LQH, Toowoomba, Qld, 27 November 2001*. The 123-page report contains illustrations and appendixes.]

Notes

1. The accident report said that *air minimum control speed* (V_{MCA}) was defined by Beech Aircraft Corp. as "the minimum flight speed at which the airplane is directionally controllable. … The airplane certification conditions include one engine becoming inoperative and windmilling, a five-degree bank toward the operative engine, takeoff power on the operative engine, landing gear up, flaps in the takeoff position, and the most rearward CG [center of gravity]."
2. International Civil Aviation Organization Annex 14, *Aerodromes*, defines *runway strip* as "a defined area … intended to reduce the risk of damage to aircraft running off a runway and to protect aircraft flying over it during takeoff or landing operations." Annex 14 defines *runway end safety area* as "an area symmetrical about the extended runway [centerline] and adjacent to the end of the strip primarily intended to reduce the risk of damage to an aeroplane undershooting or overrunning the runway."

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