FLIGHT SAFETY FOUNDATION
Accident Prevention
Vol. 59 No. 10 *For Everyone Concerned With the Safety of Flight* October 2002

Pilot Incapacitation by Hypoxia Cited In Fatal Five-hour Flight of Beech King Air

The report said that the pilot apparently was unable physically to respond to air traffic control radio transmissions after the aircraft ascended above the assigned altitude, 25,000 feet. The aircraft likely continued flying on autopilot, with no input from the pilot, for several hours before it struck terrain.

FSF Editorial Staff

On the evening of Sept. 4, 2000, a Beech Super King Air 200 struck the ground near Burketown, Queensland, Australia, about five hours after departing on a charter flight from Perth to Leonora, both in Western Australia (see Figure 1, page 2). The pilot and the seven passengers were killed. The aircraft was destroyed.

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

- "The aircraft was probably unpressurized for a significant part of its climb and cruise for undetermined reasons; [and,]
- "The pilot and passengers were incapacitated, probably due to hypobaric hypoxia, because of the high cabin altitude and their not receiving supplemental oxygen."

The report said, "Hypobaric hypoxia, also called hypoxic hypoxia or altitude hypoxia, is a result of a deficiency in alveolar oxygen exchange that may be due to a reduction in the oxygen partial pressure (tension) in inspired air or a reduction in the effective gas exchange area of the lungs. The result is an inadequate oxygen supply to the arterial blood, which in turn decreases the amount of oxygen available to the tissues. In aviation, breathing air at low barometric pressure frequently causes hypobaric hypoxia."

The report said, "Due to the limited evidence available, it was not possible to draw definitive conclusions as to the factors leading to the incapacitation of the pilot and occupants of VH-SKC [the registration number of the accident aircraft]."

The aircraft was manufactured in 1975 and had accumulated 18,771 service hours. Maintenance records indicated no recurring maintenance problems that might have been factors in the accident.

"All required maintenance and inspections of the pressure hull of the aircraft had been completed," the report said. "Maintenance records showed that the last inspection of the rear pressure bulkhead was conducted in March 2000 and no defects were recorded."

The report did not identify the aircraft operator.

"A pilot who flew the aircraft on the morning of the occurrence reported that the aircraft was fully serviceable," the report said. "In particular, the pressurization system operated normally during the flight at [Flight Level] FL 250 [approximately 25,000 feet], maintaining a pressure differential of 5.4 [pounds per square inch] and a cabin altitude of 7,500 feet."

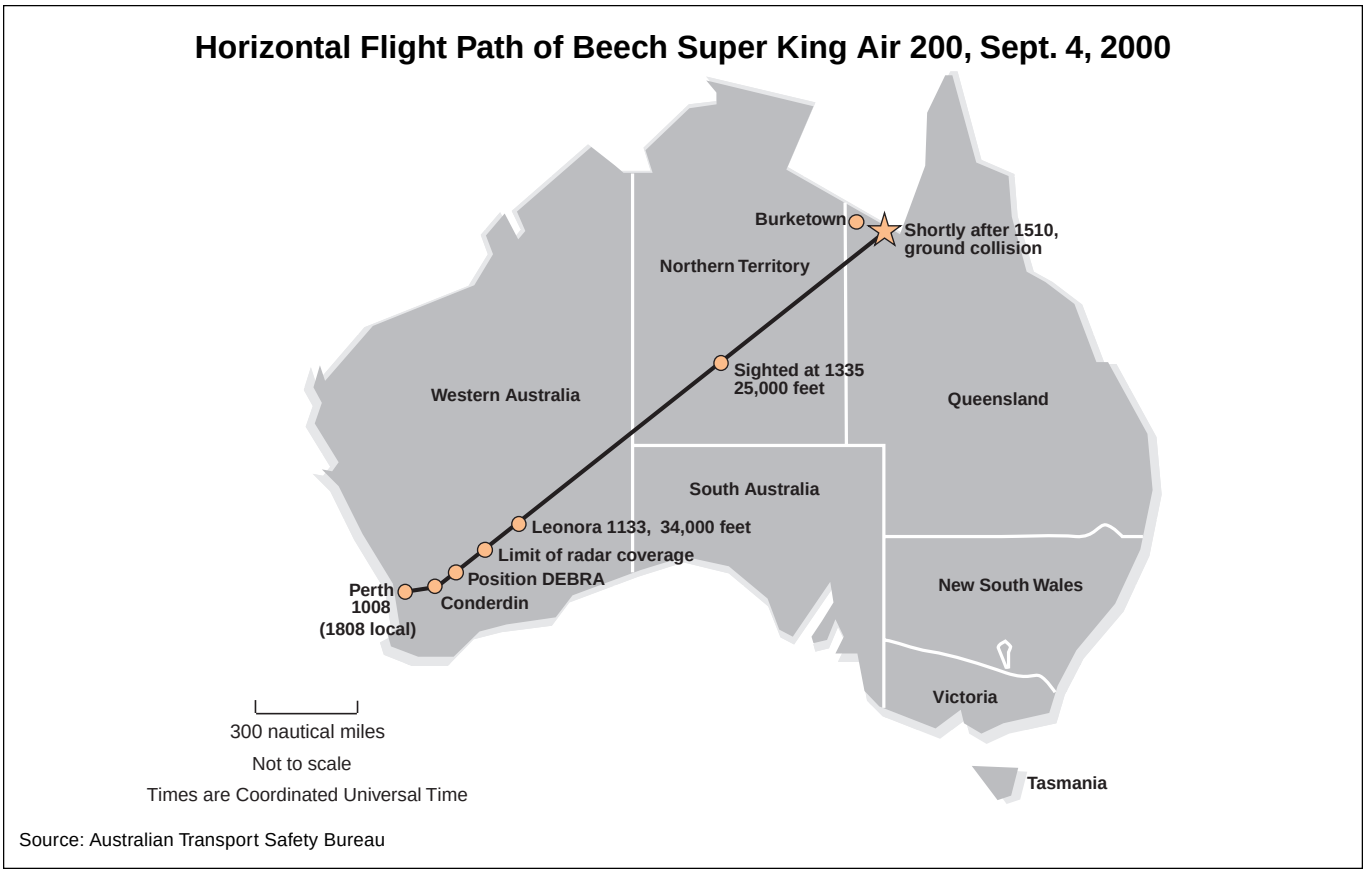


Figure 1

The accident pilot, 50, held an air transport pilot license and had 2,053 flight hours, including 138 flight hours in type. The pilot received an endorsement to operate a Super King Air 200 in January 2000; the endorsement training included a simulated loss of cabin pressure.

"It was reported that the pilot had a professional approach to flying and was methodical with his use of checklists," the report said. "Witnesses reported that the pilot appeared happy and physically well before the flight. There was no evidence to suggest that the pilot was other than medically fit. There was also no evidence that fatigue was a factor in the occurrence."

The passengers were employees of a mining company and were returning to work at a mine in Leonora.

The report said that the aircraft was within weight-and-balance limits and that there was no indication that any "dangerous goods" were aboard.

The aircraft departed from Perth at 1808 local time in visual meteorological conditions with patches of cloud between 3,000 feet and 4,000 feet. Clear weather conditions prevailed for the remainder of the flight.

At 1810, air traffic control (ATC) told the pilot to climb the aircraft to FL 130. About 1815, a Melbourne Center controller asked the pilot if he could climb the aircraft to FL 160 before flying a distance of 36 nautical miles (67 kilometers) from Perth.

"The pilot replied in the affirmative, and the controller cleared him to climb to FL 250, the planned cruising level, with the requirement to reach FL 160 by 36 [nautical miles] from Perth," the report said.

The aircraft was at about 15,600 feet at 1820 when the controller told the pilot to fly directly to DEBRA, an intersection on an airway that leads to Leonora.

The flight and the pilot's communication with ATC appeared normal until 1832, when the aircraft ascended above FL 250. The controller told the pilot to "verify altitude." The pilot told the controller to stand by.

"The pilot's speech became significantly impaired, and he appeared unable to respond to [ATC] instructions," the report said. "Open-microphone transmissions over the next eight minutes revealed the progressive deterioration of the pilot towards unconsciousness and the absence of any sounds of passenger activity in the aircraft."

The report said that the open-microphone transmissions from the accident aircraft contained the following information:

- "One unintelligible syllable;
- "Sounds of a person breathing;
- "Two chime-like tones, similar to those generated by electronic devices; and,
- "Background noise that was consistent with engine/propeller noise."

Investigators determined that the propeller setting remained at 1,900 revolutions per minute, which is a normal climb setting.

The pilot did not respond to instructions by the controller to select the "IDENT" mode on the aircraft's transponder and to change radio frequencies.

The controller told investigators that he initially believed that the pilot was preoccupied with an aircraft problem and that he later believed that the pilot had become incapacitated.

"[The controller] provided the pilot with a 'block altitude' clearance to permit the aircraft to fly at levels above FL 250 in anticipation of a request by the pilot to return to Perth," the report said. "When he heard the open-microphone transmissions, the controller thought that the pilot had a further problem involving the aircraft's radios. When the open-microphone transmissions ceased and the pilot did not respond to communication checks, the controller then suspected that the pilot might be incapacitated or hypoxic."

The report said that among the symptoms of hypobaric hypoxia is that "higher mental functions such as thinking and concentration can be impaired before any degradation of physical abilities becomes apparent. For example, a hypoxic pilot may be quite capable of pressing the [microphone] transmit button but may be unable to form the words to speak."

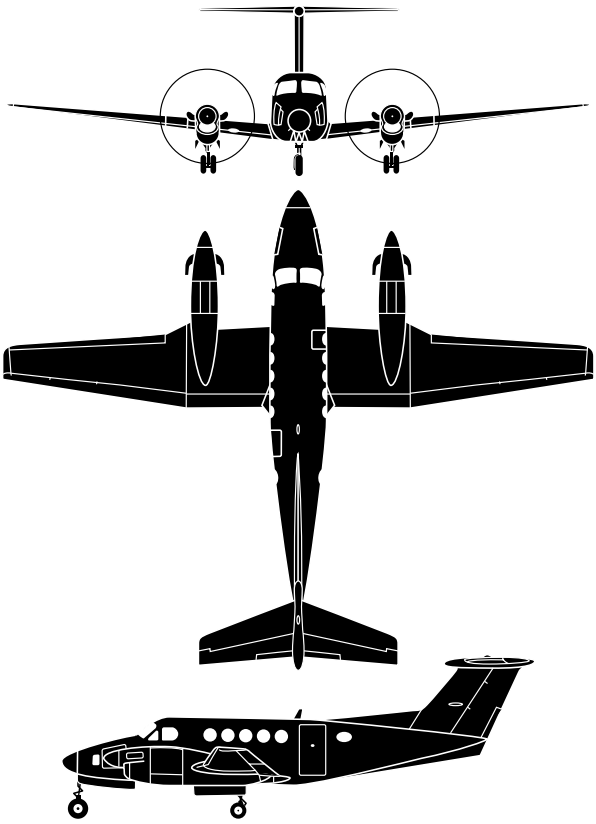
The controller told his supervisor about the problem, and they completed the "In-flight Emergency Response" (IFER) checklist.

"The IFER checklist at the time of the accident did not include procedures for [pilot] incapacitation/hypoxia," the report said. "Subsequent to the accident, Air Services Australia amended the [IFER checklist] to incorporate procedures to be followed by air traffic controllers when a controller suspects that a pilot has been affected by hypoxia."

The report said that the possibility was unlikely that the pilot, alone, was incapacitated by a medical condition such as a stroke or heart attack because no passenger activity or action was apparent from the aircraft's flight path or from sounds recorded during open-microphone transmissions from the aircraft.

Investigators determined that a rapid decompression or an explosive decompression of the cabin was unlikely.

"After the aircraft climbed above the assigned altitude of FL 250, the speech and breathing patterns of the pilot displayed changes that were consistent with hypoxia, but a rapid or



Beech Super King Air 200

Design of the Beech Super King Air 200 business and utility twin-turboprop aircraft began in 1970. The first prototype flew in 1972. The aircraft has the same basic fuselage as the King Air 100 and has increased wingspan, more powerful engines, increased fuel capacity, increased cabin pressurization and a higher gross weight.

The aircraft is certified for single-pilot flight under U.S. Federal Aviation Regulations Part 91. The cockpit has two seats, and the cabin has six seats. Maximum cabin pressure differential is 6.5 pounds per square inch (0.4 bar). The cabin door is in the aft, left side of the fuselage. The aft fuselage accommodates a lavatory and a baggage compartment of 410 pounds (186 kilograms) capacity.

Each of the two Pratt & Whitney PT6A-41 engines produces 850 shaft horsepower (634 kilowatts) and drives a Hartzell three-blade, metal propeller. Maximum fuel capacity is 3,645 pounds (1,653 kilograms).

Maximum takeoff and landing weight is 12,500 pounds (5,670 kilograms). Maximum cruise speed at 25,000 feet and average cruise weight is 289 knots. Maximum rate of climb at sea level is 2,450 feet per minute. Maximum single-engine rate of climb at sea level is 740 feet per minute. Stall speed with flaps up is 99 knots. Stall speed with flaps fully extended is 76 knots.♦

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

explosive aircraft cabin depressurization was unlikely to have occurred," the report said.

Recorded ATC radar data showed that the aircraft continued to climb to about 34,300 feet, which was approximately the aircraft's service ceiling (see Figure 2). The report said that the continued climb and the absence of a distress call indicated that the pilot was not aware that the aircraft was unpressurized or depressurizing and that he likely did not don his oxygen mask.

"The passengers may not have noticed a subtle and gradual depressurization of the aircraft or the aircraft climbing unpressurized," the report said. "Crew oxygen masks do not deploy and require crew action to don them. If the passengers were asleep, they may not have noticed deployment of the passenger oxygen masks or the illumination of a warning light. Had the passenger masks automatically deployed, it is questionable whether the pilot would have noticed the deployment."

The report said that the aircraft's vertical flight profile is consistent with operation of the autopilot in the heading-hold mode and in the pitch-hold mode with no input by the pilot. (The autopilot did not have an altitude-capture mode.)

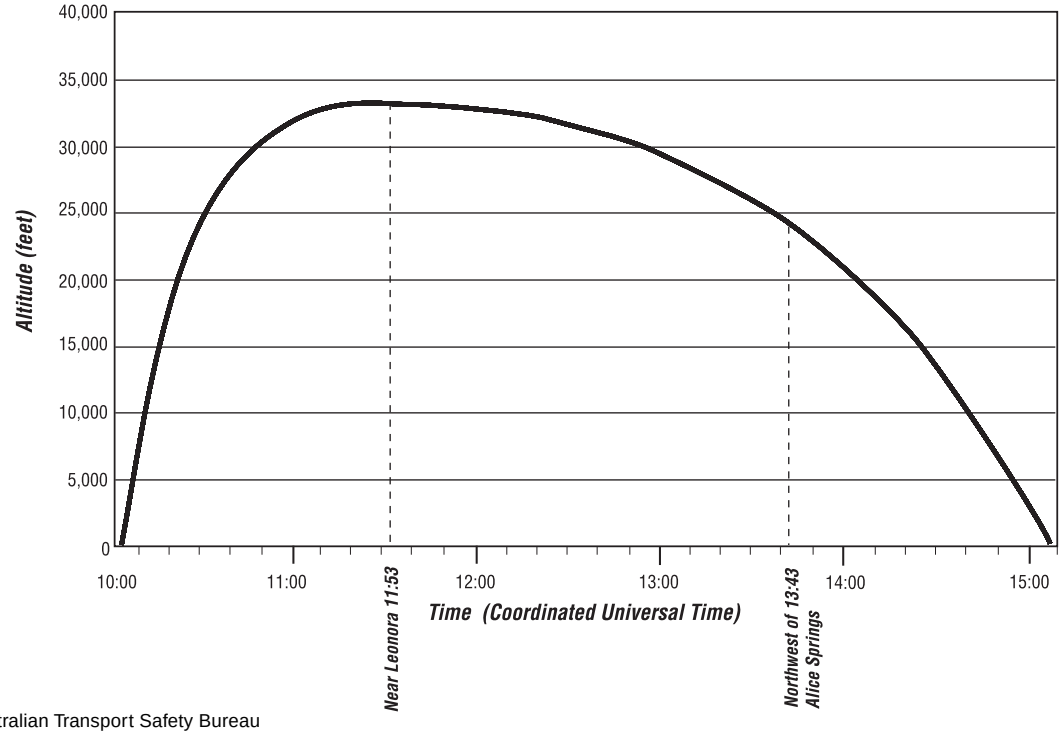
The aircraft flew out of ATC radar coverage at 1902. At the time, the aircraft was 218 nautical miles (404 kilometers) northeast of Perth and climbing through about 32,500 feet. Australian Search and Rescue asked the crew of a business jet, which was being flown near Leonora, to intercept the King Air. The crew intercepted the aircraft about 1933.

"The jet crew reported that the King Air was maintaining FL 343 on a steady heading of about 050 [degrees magnetic]," the report said. "Although the King Air's external navigation [lights] and strobe lights were on, the jet crew saw no lights or movements inside the aircraft. The jet crew reported that the brightness of the strobe lights in the night conditions made it difficult to see inside the King Air."

About this time, the King Air began to descend. The report said that because of autopilot "drift characteristics" during prolonged operation of the autopilot in the pitch-hold mode, the pitch attitude maintained by the autopilot would have changed significantly during the flight.

"The design of the aircraft systems were such that, with the autopilot engaged, the engines would continue to operate and the aircraft would continue to fly without human input until it was disrupted by other events, such as collision or fuel exhaustion," the report said.

The crews of two other aircraft intercepted the King Air at 2135. The accident aircraft was descending through FL 250 on a heading of 050 degrees.



Source: Australian Transport Safety Bureau

Figure 2

"The two chase aircraft remained with the King Air for the remainder of its flight," the report said. "The crews reported that as the rate of the descent of the King Air slowly increased, its airspeed increased to more than 200 knots. … The crews of the chase aircraft attempted to contact the pilot of the King Air by radio, but they did not receive a response.

"At [2310], the crew of one chase aircraft observed the King Air, at an altitude of less than 5,000 feet, turn left through 90 degrees."

The aircraft was in a shallow descent and in a left-wing-low attitude when it struck gently sloping terrain covered with dry, long grass and small trees about 35 nautical miles (65 kilometers) southeast of Burketown. Groundspeed at impact was about 239 knots. Witnesses observed a fireball when the aircraft struck the ground.

"The structure of the aircraft disintegrated during the collision sequence," the report said. "The cockpit, center fuselage, tail cone and fin were held together by various cables. The wings had broken into many pieces."

Postmortem medical examinations of the aircraft occupants were conducted three days after the accident.

"The high ambient temperatures at the accident site and the time between the accident and the postmortem examination resulted in some decomposition of the tissues before the examinations were conducted," the report said. "The postmortem examinations determined that all occupants of the aircraft had sustained multiple injuries during impact that would have proved fatal. The examination, however, could not determine the exact causes of death of the occupants."

Investigators found no indication of a pre-existing problem that would have affected the aircraft's pressurization system or oxygen system.

The report said that "hypobaric hypoxia rarely leaves any signs that would be detectable at a postmortem examination" of aircraft occupants.

Examinations were conducted to determine if the occupants froze during prolonged exposure to an unheated environment (the forecast temperature at FL 340 was approximately minus 42 degrees Celsius [minus 44 degrees Fahrenheit]). The examinations were inconclusive.

The examinations indicated that an in-flight fire likely did not occur.

"There were no indications that the occupants of the aircraft had inhaled products of combustion [e.g., carbon monoxide] or any other irritant material [e.g., hydrogen cyanide, which is toxic gas produced by the burning of materials commonly found in aircraft interiors]," the report said.

Rotational damage to the propellers and to the engine compressor sections and turbine sections indicated that both engines were operating and developing power when the impact occurred.

"There was evidence of a pre-existing leak of bleed air through the gaskets at the P3 customer air outlet on each engine," the report said. "The leaks were considered minor and were not factors in the occurrence."

Investigators did not determine why the aircraft cabin either did not become pressurized or became depressurized fully or partially during the flight, or why the pilot and passengers did not receive supplemental oxygen.

"Due to the extensive nature of the damage to the aircraft caused by the impact with the ground, and because no recording systems [e.g., cockpit voice recorder, flight data recorder] were installed in the aircraft (nor were they required to be), the investigation could not determine the reason for the aircraft being unpressurized or why the pilot and passengers did not receive supplemental oxygen," the report said.

Investigators found no indication of a pre-existing problem that would have affected the aircraft's pressurization system or oxygen system.

The cabin pressure controller, on the center pedestal of the accident aircraft, was found jammed at a position equivalent to 26,000 feet. Other pressurization-system controls and instruments were destroyed by a post-impact fire.

The cabin of a Super King Air 200 is pressurized by bleed air from both engine compressor sections. Cabin pressurization is controlled, in part, by two "BLEED AIR VALVE" switches on a subpanel located to the right of the center pedestal. Each of the switches — one for the left engine and one for the right engine — has three positions: "OPEN," "ENVIR OFF" and "INST&ENVIR OFF." Bleed air from either engine enters the cabin when the corresponding "BLEED AIR VALVE" switch is in the "OPEN" position; bleed air does not enter the cabin when the switch is in either the "ENVIR OFF" position or "INST&ENVIR OFF" position.

A cabin altimeter located on the bottom center of the instrument panel indicates cabin altitude and cabin pressure differential [the ratio of cabin pressure to ambient pressure].

A visual warning that cabin altitude is above 12,500 feet is provided by steady illumination of a red "ALT WARN" annunciator light and by pulsed illumination of the red "MASTER WARNING" annunciator lights. The "ALT WARN" light is one of 10 red annunciator lights and several yellow (caution) lights and green (advisory) lights in an annunciator panel in the bottom center of the instrument panel.

The "MASTER WARNING" lights are mounted on the glareshield in front of the pilot seats.

"The flashing 'MASTER WARNING' light can be extinguished by pressing the lens cover on either of the lights," the report said. "Extinguishing the 'MASTER WARNING' flasher does not extinguish the warning annunciator that triggered it. Removing the condition or defect [that] causes the annunciator to illuminate is required [to extinguish the 'MASTER WARNING' lights]."

The report said that the accident might have been prevented if the aircraft had been equipped with an aural warning — as well as a visual warning — of high cabin altitude, and if the aural warning and visual warning had occurred when cabin altitude exceeded 10,000 feet.

"The aircraft was fitted with three devices that produced aural warning tones," the report said. "They were:

- "An altitude alerting device that sounded a chime and illuminated a light when the aircraft was 1,000 feet [below or above] the selected altitude. Another chime was sounded and [a] light illuminated any time the aircraft deviated 200 feet or more from the selected altitude;
- "A buzzer that sounded continuously whenever the aircraft's angle-of-attack exceeded a preset value, indicating that an aerodynamic stall was imminent; and,
- "A horn that sounded intermittently whenever the landing gear was not locked down, in combination with various power lever and flap positions.

The report said that the accident might have been prevented if the aircraft had been equipped with an aural warning — as well as a visual warning — of high cabin altitude.

"The [accident] aircraft was not fitted with a high-cabin-altitude aural-warning device, nor was it required to be."

Aircraft records indicated that the oxygen system was replenished one month before the accident. Witnesses said that on the day of the accident, the oxygen system pressure gauge indicated 1,500 pounds per square inch, which was sufficient to provide oxygen for the pilot and passengers for 33 minutes.

Australian aviation regulations recommend but do not require an aural warning of high cabin altitude. Civil Aviation Order (CAO) 108.26 includes the following information:

> An oxygen system for an aircraft which is intended for operations at flight altitudes above 25,000 feet shall include a device to provide the flight crew with a warning whenever the cabin pressure altitude exceeds 10,000 feet.
>
> *Note:* The cabin pressure warning should not depend on the reading of the gauge. An aural warning is strongly recommended.

[Aircraft, such as the Super King Air 200, that are imported into Australia from countries whose certification standards are accepted by Australia do not have to comply with CAO 108.26.]

The report cited two incidents involving Super King Air 200s that indicated that the pilots "missed" visual warnings of high cabin altitude while occupied with other tasks.

[One incident occurred June 21, 1999, 39 nautical miles (72 kilometers) east of Edinburgh, South Australia. In its final report on the incident (occurrence no. 199902928), ATSB said that the aircraft was in cruise flight at FL 250 when a passenger observed that the pilot was attempting repeatedly to program the global positioning system (GPS) receiver and was not responding to ATC radio transmissions. The pilot then lost consciousness. The passenger, who was a Royal Australian Air Force (RAAF) pilot, took control of the aircraft and began an emergency descent. The other passenger, an RAAF navigator, unstowed the pilot's oxygen mask, took several breaths of oxygen from the mask and then placed the mask on the pilot.

"The pilot recovered consciousness during the descent, and once he had regained situational awareness, he noticed that the 'PASS OXYGEN ON' and both 'BLEED AIR OFF' green advisory annunciator lights were illuminated," the report said. "He also noticed that the engine bleed air switches were selected to the 'ENVIR OFF' position. The pilot reported that he did not see any low-cabin-pressure warning indications and that the passenger oxygen masks had not deployed. … None of the occupants recalled seeing or canceling the operation of the flashing master warning lights."

The pilot conducted an uneventful landing.

ATSB said that the following were significant factors in the incident:

- "Both bleed air switches were inadvertently selected to 'ENVIR OFF' at about 10,000 feet in the climb;
- "The cockpit warning system did not adequately alert the pilot to the cabin depressurization;
- "The oxygen mask deployment doors were incorrectly [installed], so that the masks would not automatically deploy when required; [and,]

- "Hypobaric ['altitude-chamber'] training did not provide an effective defense to ensure that the pilots or passengers would identify the onset of hypoxia."

The second incident occurred during an aeromedical flight Oct. 24, 2001, 12 nautical miles (22 kilometers) south-southeast of Timber Creek, Northern Territory. The aircraft was at FL 125 during climb when the flight nurse told the pilot that the passenger oxygen masks had deployed. The pilot then observed the master warning lights and the 'ALT WARN' annunciator and began an immediate descent to 10,000 feet.

"Once established at 10,000 feet, the pilot discovered that both the left and right bleed air 'OFF' green advisory annunciators were illuminated and that both bleed air switches were in the 'ENVIR OFF' position," the report said. "In that position, no bleed air was available for aircraft pressurization."

ATSB said that the following were significant factors in the incident:

- "The pilot did not complete the 'PRE TAKE OFF' and 'AFTER TAKE OFF' cabin pressurization checks;
- "The pilot became preoccupied with programming the GPS [receiver] after receiving a track change instruction [from ATC];
- "The aircraft was allowed to climb above 10,000 feet in an unpressurized state; [and,]
- "The effectiveness of the aircraft's cockpit warning system was reduced by the operator's practice of allowing postponement of the 'AFTER TAKE OFF' check."]

The accident report said that after the June 21, 1999, incident, ATSB recommended that the U.S. Federal Aviation Administration (FAA) consider requiring an audible cabin-altitude alert in aircraft with pressurized cabins. FAA aircraft-certification standards require pressurized aircraft to have either an aural signal or a visual signal to warn of cabin-pressure-altitude limits.

In response to the recommendation, FAA said, in part: "Although it is recognized that adding an aural warning is a desirable enhancement of the system, requiring such a warning for the existing fleet is not considered necessary to meet the minimum airworthiness standards."

ATSB also recommended that the Australian Civil Aviation Safety Authority (CASA) "mandate the fitment of aural warnings to operate in conjunction with the cabin-altitude-alert warning systems on all Beechcraft Super King Air [aircraft] and other applicable aircraft."

CASA in February 2001 accepted the ATSB recommendation and said that it would "move to prepare a regulatory amendment to make it mandatory for pressurized aircraft to have aural cabin altitude alert warning systems."

[CASA in April 2002 issued Notice of Proposed Rulemaking (NPRM) 0216CS, "Proposal for Aural Warning to Operate With Cabin Altitude Warning Systems." The closing date for public comment on the NPRM was June 30, 2002. As of Sept. 17, 2002, CASA had not issued a summary of responses to the NPRM.]♦

[FSF editorial note: This article, except where specifically noted, is based on Australian Transport Safety Bureau Aviation Safety Report BO/200003771, *Pilot and Passenger Incapacitation; Beech Super King Air 200, VH-SKC; Wernadinga Station, Qld; 4 September 2000*. The 54-page report contains illustrations and appendixes.]

Further Reading From FSF Publications

FSF Editorial Staff. "Flight Crew Incapacitation Follows Learjet 35 Cabin Depressurization." *Accident Prevention* Volume 58 (April 2001): 1–12.

FSF Editorial Staff. "Changes Recommended in Oxygen Bottle Regulator/Shutoff Valves." *Aviation Mechanic's Bulletin* Volume 49 (January–February 2001): 12–15.

Mohler, Stanley R. "Quick Response by Pilots Remains Key to Surviving Cabin Decompression." *Human Factors & Aviation Medicine* Volume 47 (January–February 2000): 1–8.

Sumwalt, Robert L. III. "Enhancing Flight-crew Monitoring Skills Can Increase Flight Safety." *Flight Safety Digest* Volume 18 (March 1999): 1–8.

Sumwalt, Robert L.; Watson, Alan W. "ASRS Incident Data Reveal Details of Flight-crew Performance During Aircraft Malfunctions." *Flight Safety Digest* Volume 14 (October 1995): 1–7.

Mohler, Stanley R. "A Sudden High-altitude Cabin Decompression Immediately Threatens Safety of Aircraft Crew and Passengers." *Human Factors & Aviation Medicine* Volume 41 (November–December 1994): 1–4.

FSF Editorial Staff. "U.S. Studies Say Altitude Chamber Training Offers Important Hypoxia Recognition Training at Low Cost." *Human Factors & Aviation Medicine* Volume 39 (November–December 1992): 1–7.

Dully, Frank E. Jr. "Altitude Chamber Training: Is It Worth the Risk?" *Human Factors & Aviation Medicine* Volume 39 (September–October 1992): 1–8.

Call for Nominations

Flight Safety Foundation–Airbus Human Factors in Aviation Safety Award

The Flight Safety Foundation–Airbus Human Factors in Aviation Safety Award was established in 1999 to recognize "outstanding achievement in human factors contributions to aviation safety." The award was instituted to encourage human factors research that would help reduce human error — one of the most common elements in aviation accidents.

The award — instituted by the Foundation and sponsored by Airbus — is presented to an individual, group or organization for a one-time contribution or sustained contributions in the field of human factors. The award includes an elegant engraved wooden plaque.

The nominating deadline is November 29, 2002. The award will be presented in Geneva, Switzerland, at the FSF European Aviation Safety Seminar, March 17–19, 2003.

Submit your nomination(s) via our Internet site.
Go to http://www.flightsafety.org/hf_award.html

For more information, contact Kim Granados, membership manager, by e-mail: granados@flightsafety.org or by telephone: +1 (703) 739-6700, ext. 126.

Want more information about Flight Safety Foundation?

Contact Ann Hill, director, membership and development, by e-mail: hill@flightsafety.org or by telephone: +1 (703) 739-6700, ext. 105.

Visit our Internet site at <www.flightsafety.org>.

What's Your Input?

In keeping with FSF's independent and nonpartisan mission to disseminate objective safety information, Foundation publications solicit credible contributions that foster thought-provoking discussion of aviation safety issues. If you have an article proposal, a completed manuscript or a technical paper that may be appropriate for *Accident Prevention*, please contact the director of publications. Reasonable care will be taken in handling a manuscript, but Flight Safety Foundation assumes no responsibility for material submitted. The publications staff reserves the right to edit all published submissions. The Foundation buys all rights to manuscripts and payment is made to authors upon publication. Contact the Publications Department for more information.

Accident Prevention

Staff: Roger Rozelle, director of publications; Mark Lacagnina, senior editor; Wayne Rosenkrans, senior editor; Linda Werfelman, senior editor; Karen K. Ehrlich, web and print production coordinator; Ann L. Mullikin, production designer; Susan D. Reed, production specialist; and Patricia Setze, librarian, Jerry Lederer Aviation Safety Library

Subscriptions: One year subscription for twelve issues includes postage and handling: US$240. Include old and new addresses when requesting address change. • Attention: Ahlam Wahdan, membership services coordinator, Flight Safety Foundation, Suite 300, 601 Madison Street, Alexandria, VA 22314 U.S. • Telephone: +1 (703) 739-6700 • Fax: +1 (703) 739-6708.