ACCIDENT

Aircraft Type and Registration:	Beech B200 Super King Air, OO-LET
No & Type of Engines:	2 Pratt & Whitney Canada PT6A-42 turboprop engines
Year of Manufacture:	1994 (Serial no: BB-1473)
Date & Time (UTC):	28 July 2012 at 1540 hrs
Location:	Cambridge Airport
Type of Flight:	Aerial Work
Persons on Board:	Crew - 4 Passengers - None
Injuries:	Crew - None Passengers - None
Nature of Damage:	Extensive to propellers, engines, undercarriage doors and luggage pod
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	68 years
Commander's Flying Experience:	13,180 hours (of which 3,111 were on type) Last 90 days - 187 hours Last 28 days - 74 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was returning to Cambridge Airport after completing an airborne communications relay task for the 2012 Olympic Games when it suffered a complete electrical failure. This necessitated the use of the manual landing gear extension procedure to lower the landing gear. The gear collapsed during the landing and the aircraft came to a halt on the runway.

The investigation was unable to determine the cause of the electrical failure and no fault was found with the landing gear system. It is possible that the crew did not operate the alternate extension system sufficiently to extend the landing gear fully prior to landing.

History of the flight

The aircraft was engaged in communications relay duties over London in support of the 2012 Olympic Games and was operating in the London TMA at FL240 in VMC conditions. It was crewed by two pilots, with two technicians in the cabin to operate the relay equipment. This was the second flight of the day for both the aircraft and crew.

After completing the task, the pilots prepared to return to Cambridge Airport. ATC cleared the aircraft to descend to FL180 and route to the BKY VOR. The co-pilot, who was PF and operating from the left seat, selected the engine anti-ice system on in the

understanding that this would provide additional drag[1] for the descent and the pilots then commenced the 'Descent' checklist. Due to the workload in the cockpit, neither pilot recalled seeing the anti-ice annunciations or the inertial vane bypass doors extend on the underside of the engine nacelles. When the PF checked the aircraft fuel gauges as part of this checklist, he noticed that they were indicating zero. Almost immediately, ATC informed the pilots that the Mode C transponder readout was no longer being received. The commander transmitted that they may have an electrical problem; this transmission was received by ATC but there was no further radio communication with the aircraft. The last Mode C readout detected by ATC was at FL183.

Over the next two to three minutes, the pilots experienced a progressive failure of all of the electrical equipment, with the exception of the left instrument panel Electronic Flight Information System display[2]. This remained powered by a backup power supply. However, as the display was giving erroneous information, the pilots decided to turn it off. The abnormal checklist did not contain a procedure for a total electrical failure, so the PF turned off both generators and the battery switch before selecting them on again in an attempt to restore the electrical supply. He also selected the alternate inverter and the PNF recycled the cabin power supply switches. The PF stated that he did not attempt to select the generators to RESET. The left instrument panel had functioning ASI and vertical speed indicator (VSI) instruments; the right panel had a working attitude indicator (which was vacuum-driven), ASI and altimeter indications. The engine rpm gauges and standby compass remained operational. Both pilots reported that they saw no warning lights on the annunciator panel at any stage and that they were not wearing sunglasses, which might otherwise have affected their ability to see any warnings. The technicians in the cabin reported that they could see the alternating current frequency gauge, located in the roof panel, and that, at one point, this could be seen oscillating over full-scale deflection. The PF turned off the engine anti-ice system, but he could not recall when he did this.

Mindful of avoiding a security alert during the Olympic Games, the crew carried out the pre-briefed communications failure procedure and turned the aircraft onto a northerly heading to clear the London TMA, before proceeding towards a designated holding area.

As the aircraft approached the Wisbech area, the commander recognised some land features. The aircraft descended to 5,000 ft from where the crew were able to identify additional landmarks and navigate visually towards Cambridge Airport. By this time the aircraft had been flying for some time without electrical power and therefore without operating fuel gauges, and the crew were concerned about the aircraft's remaining endurance. When they arrived near the airport, they circled it to alert ATC to their presence and then carried out the Landing Gear Manual Extension procedure. When carrying out the procedure the pilots operated the landing gear control handle, but omitted to pull the landing gear relay circuit breaker. The PF operated the alternate extension handle to extend the landing gear. Initially, the handle was easy to operate and the pilots could see the main landing gear as it started to extend. The PF stated that he stopped operating the handle when heavy resistance was felt, in order not to damage the system. The PF also stated that the PNF had mentioned to him not to force the handle. The PF asked the PNF to check the resistance of

Footnote

[1] Operation of the engine anti-icing system causes inertial vane bypass doors to extend on the underside of the each engine cowling causing a small increase in airframe drag.

[2] The electrical symptoms experienced by the crew were similar to those reported by the pilot in a previous incident investigated by the AAIB (see AAIB Bulletin 6/2007 on the incident to Beech B200, G-PCOP, on 28 March 2006).

the handle, which he did. The PF continued to operate the handle whilst they positioned the aircraft downwind and onto base leg, but stopped pumping each time he felt heavy resistance.

The PF carried out a flapless approach and the aircraft touched down gently at approximately 100 kt. Almost immediately after touchdown, the landing gear started to collapse. The PNF immediately operated the fuel condition levers which shut down the engines and feathered the propellers. The aircraft settled onto the centreline luggage pod and the main undercarriage doors. It came to rest after a total ground run of approximately 400 m, during which it yawed slightly to the right. The PF was able to counteract the yaw with rudder sufficiently to prevent the aircraft from leaving the paved surface. After it had come to a halt, the commander ordered the technicians to evacuate. The pilots then completed the shutdown checklist before also vacating the aircraft. The flight time from the electrical failure until the landing was approximately 37 minutes.

Electrical system description

This aircraft type is equipped with a 28 V DC electrical system, supplied by a 24 V battery and two 30 V, 250 ampere starter-generators. Either one of two inverters can supply the AC requirements of the engine instruments and avionics. Each component is capable of supplying power to all systems necessary for normal operation of the aircraft, although the battery, in the absence of both generators, has a limited endurance.

The start cycle for each engine is controlled by a three-position switch on the pilot's left sub-panel. The central position is OFF and the switch toggle must be pulled over a gate to place it in the up, or ON position, which engages the starter. The switch remains in this position until it is returned to the OFF position. Holding the switch to the down, or STARTER ONLY position, causes the associated engine to motor, but without ignition. Releasing the switch causes it to spring back to the OFF position which is the normal in-flight position. After the engine has started, the starter current reduces until, at around 35-49% N_1, the engine drives the starter. The generator can be turned on at approximately 70% N_1. The Ignition and Engine Start switches are on the same panel as, and close to, the Engine Anti-ice switches.

Immediately above the start switches are the GEN 1, GEN 2 and Battery switches, located under a gang bar. The generators are turned on by holding the switch in the GEN RESET position for a minimum of one second before releasing it, when it returns under spring pressure to the ON position. If a generator trips off for any reason, (for example, moving the associated start switch to the ON position), it can only be reset by moving the control switch momentarily to the GEN RESET position.

Landing gear operating system

The landing gear system comprises an electrically-powered hydraulic power pack that operates three hydraulic actuators, one each for the main and nose landing gears. In the event of an electrical power loss or hydraulic power pack malfunction, a hydraulic hand pump is provided as a means of alternate gear extension. The manufacturer stated that the hand pump system has a relief valve that will port fluid when a pre-determined pressure is exceeded. Earlier models of the aircraft are fitted with an electrically operated system in which a 28 V DC motor is connected to a chain drive and torque tubes that transmit power to mechanical actuators at each landing gear. In the event of a motor failure, an alternate extension handle is provided, located in a similar position to that on aircraft with hydraulically operated systems. When pumped, the handle engages the operating mechanism via an emergency drive system.

Aircraft examination

After the accident the aircraft was lifted onto a trailer and taken to a hangar for further examination. On lifting the aircraft, the landing gears had partially extended and they were lashed in this position to prevent additional damage. This allowed a visual inspection of the gear and wheel wells, which revealed that the hydraulic lines had remained intact and that no landing gear component had broken.

At the time of the AAIB examination of the aircraft, it was still on the trailer and was being worked on in preparation to being flown, landing gear locked down, to a maintenance facility in Denmark for a full repair. This immediate rectification work included replacing the engines and propeller assemblies.

The aircraft was fitted with a luggage pod attached to the underside; this accommodated some of the equipment associated with the video relay operation, and served to protect other parts of the airframe such as the flaps.

After removing the engine cowls, it was evident that significant movement of the engines had occurred as a result of the propellers striking the ground. This had taken the form of a 'nodding' action and had caused both starter/generators, which are mounted at the top of the accessory gearbox at the rear of each engine, to contact the underside of their respective upper nacelle panels. This had resulted in some damage to the terminal block dust covers. However, the starter/generators themselves were otherwise intact and there was no evidence of burning or heat damage.

Using a crane and a sling, the aircraft was lifted off the trailer with a technician in the cockpit. He operated the alternate extension handle and all three landing gears were observed to extend to their locked down positions. After a visual inspection to verify that the gears were safe, the aircraft was lowered to the ground and towed to a hangar where the subsequent engine removal and replacement was conducted.

The aircraft battery, which had been disconnected immediately after the accident, was reconnected and the Battery Master switch turned on. Some captions glowed dimly and the battery voltmeter indicated 10 V, so it was apparent that the battery was fully discharged.

The starter/generators were tested before being overhauled, with no fault being found. They were re-installed on the aircraft prior to the ferry flight to Denmark, during which the electrical system functioned normally. Additional investigation of the landing gear during the repair did not reveal any fault with the system.

B200 landing gear system variants

There are two different types of landing gear system commonly fitted to B200 aircraft. The system fitted to OO-LET is usually referred to as a hydraulic system. The other B200 that the crew frequently flew (OO-ASL) was fitted with an electrically-powered mechanical system, usually referred to as a mechanical system. The Pilot's Operating Handbook (POH) describes the landing gear systems and the appropriate abnormal checklists describe the procedures relating to the alternate extension procedures for the system relevant to that aircraft.

OO-LET landing gear system

The manufacturer stated that the alternate extension system for the hydraulic system fitted to this aircraft contains a relief valve that will port fluid if excessive pressure is generated and that there are no adverse system consequences to continued operation of the handle when the landing gear is locked down. This information is

not contained in the POH or the abnormal procedures and the manufacturer stated that this information is not required to operate the landing gear system properly.

The abnormal checklist for alternate landing gear extension states:

> *'Alternate Extension Handle - PUMP UP AND DOWN UNTIL THE THREE GREEN GEAR-DOWN ANNUNCIATORS ARE ILLUMINATED. WHILE PUMPING, DO NOT LOWER HANDLE TO THE LEVEL OF THE SECURING CLIP DURING THE DOWN STROKE AS THIS WILL RESULT IN LOSS OF PRESSURE.'*

The abnormal checklist goes on to state:

> *'If one or more green gear-down annunciators do not illuminate for any reason and a decision is made to land in this condition:*
>
> *Alternate Extension Handle – CONTINUE PUMPING UNTIL MAXIMUM RESISTANCE IS FELT.'*

OO-ASL landing gear system

Under the description of the Manual Landing Gear Extension (Mechanical System) that relates to this aircraft, it states:

> *'Stop pumping when all three green gear-down annunciators are illuminated. Further movement of the handle could damage the drive mechanism and prevent subsequent electrical gear retraction.'*

The abnormal checklist for alternate landing gear extension states:

> *'Alternate Extension Handle - PUMP UP AND DOWN UNTIL THE THREE GREEN GEAR-DOWN ANNUNCIATORS ARE ILLUMINATED. ADDITIONAL PUMPING WHEN ALL THREE ANNUNCIATORS ARE ILLUMINATED COULD DAMAGE THE DRIVE MECHANISM AND PREVENT SUBSEQUENT ELECTRICAL GEAR RETRACTION.'*

The abnormal checklist goes on to state:

> *'Alternate Extension Handle – CONTINUE PUMPING UNTIL MAXIMUM RESISTANCE IS FELT, EVEN THOUGH THIS MAY DAMAGE THE DRIVE MECHANISM'*

Analysis

It was not possible to determine the cause of the electrical failure experienced by the crew. Although, due to their proximity, it is possible that the Ignition and Engine Start switches could have been operated by mistake instead of the anti-ice switches, this action would have caused the generators to go off-line and for associated captions to illuminate on the annunciator panel. Both pilots were confident that they would have noticed these annunciators had they illuminated and that they were confident that no annunciator warning lights illuminated at any time. Subsequent ground tests did not reveal any fault with the electrical system. If the generators had gone off-line for some reason, resetting them might have restored electrical power. However, as the crew did not select the generator switches to RESET, no conclusions can be drawn regarding the state of the generators during the electrical failure.

Although the crew omitted to pull the Landing Gear Relay circuit breaker when carrying out the landing gear manual extension procedure, it is unlikely that this would have adversely affected the operation of the manual extension system, as electrical power had already been lost by this stage.

The two B200 aircraft that the pilots regularly flew had different landing gear operating systems. One aircraft, OO-ASL, had a mechanical system, the drive mechanism of which could be damaged by continued operation of the alternate extension handle after the landing gear was locked down. The POH and the Abnormal Procedure checklist contained specific statements alerting the crew to the possibility of such damage.

In contrast, the hydraulic landing gear system fitted to OO-LET could not be damaged by excessive operation of alternate extension handle. The alternate extension system has a relief valve that will port fluid if excessive pressure is generated, but no information was given in either the POH or the abnormal procedures checklist about this, or the consequences of continuing to operate the handle when the landing gear is locked down.

Without electrical power on the aircraft, the crew were unable to determine landing gear position. The PF operated the alternate extension handle until he felt maximum resistance and he did this on more than one occasion before the aircraft turned onto final approach. However, he stopped pumping when he felt maximum resistance to avoid damaging the system and his perception that the system could be damaged by excessive operation of the handle was reinforced by advice from the PNF. As a result, it is most likely that the landing gear was in the unlocked position for the landing, causing it to collapse after touchdown. The lack of contrasting advice relating to the consequences of continued pumping of the hydraulic system compared with the advice for the mechanical system probably contributed to the crew's confusion between the two systems.

Conclusions

No cause for the electrical failure could be determined and no fault was found with the landing gear system. It is possible that the gear collapsed on landing because the crew ceased operating the alternate extension handle before the landing gear was fully extended. The electrical failure meant that the crew had no indication of the landing gear position and therefore could not confirm that the gear was down and locked prior to landing.