Department of Transport and Regional Development

Bureau of Air Safety Investigation

INVESTIGATION REPORT

9601590

De Havilland Canada Dash 8 VH-JSI Broome, Western Australia 17 May 1996

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Bureau of Air Safety Investigation

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CONTENTS

1. FACTUAL INFORMATION

History of the flight

The de Havilland Dash 8 with a crew of three and 14 passengers was passing 4,800 ft on descent to Broome at 243 kts indicated air speed when it struck a wedge-tailed eagle. The bird impacted the leading edge at the root of the left wing. The wing-to-fuselage fairing was punctured and the forward wing spar and the electrical components attached to the spar were damaged.

The left engine instrumentation failed and the master caution panel indicated multiple systems failures. The crew shut down the left engine 2 minutes and 9 seconds after the bird strike when the aircraft was passing through 1,860 ft at a speed of 220 kts.

The left main landing gear unsafe warning light illuminated when the landing gear was extended. The crew discontinued the landing approach and elected to hold between 5 NM and 10 NM north-west of the aerodrome while they checked the aircraft systems.

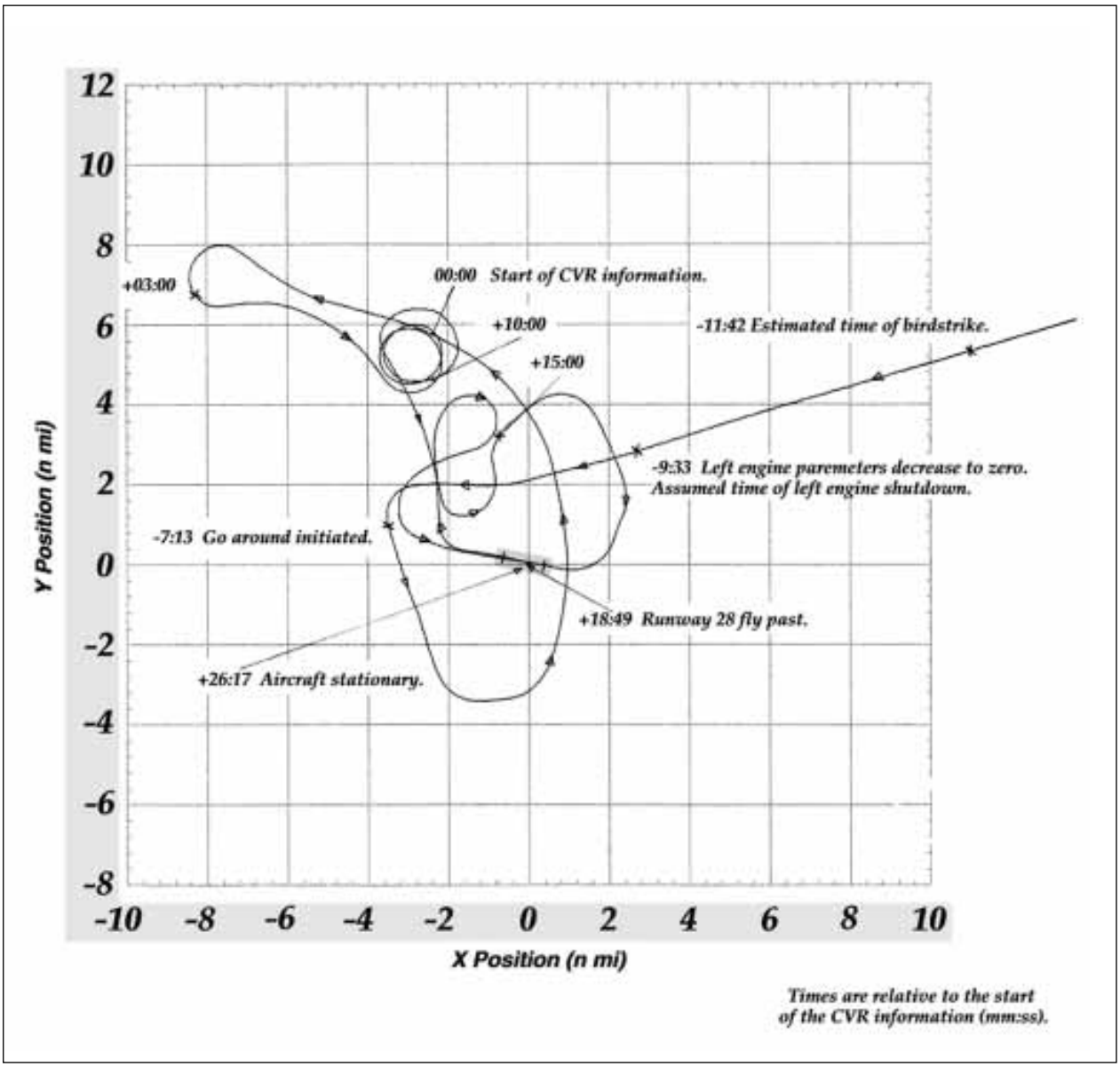

Figure 1. Derived ground track of VH-JSI

Thirty-seven minutes after the bird strike, the aircraft was landed on runway 10. During the latter part of the landing roll, the pilot in command was unable to maintain directional control through the nosewheel steering. He attempted to slow the aircraft using reverse thrust on the right engine and the normal brakes, but the brakes failed. The aircraft veered off the sealed runway to the right before the pilot stopped it, using the emergency brake system.

Damage to the aircraft

The Bureau's investigation team was unable to inspect the aircraft in the as-damaged condition. The manufacturer's personnel supervising the repair of another Dash 8 aircraft, together with the operator's engineers, had commenced disassembly of the aircraft before the investigator arrived at Broome. This action precluded a methodical recording of damage and assessment of the effects of the bird strike on the aircraft by the investigation team.

The wiring looms routed along the leading edge of the wing between the left engine nacelle were significantly damaged. At least 30 of the single or twisted pair wires from this area, as well as one of the two main electrical power cables, had been severed during the impact. Maintenance engineers reported that all the wires in the looms routed along the wing inboard leading edge had been severed or stretched. Wires had also pulled from their respective multi-pin connectors, and whole connectors had been ripped from their airframe mounted counterpart.

The wiring for the attitude and heading reference system and the weight-on-wheels was routed on the forward face of the wing spar. Damage to the attitude and heading reference system wiring rendered the flux valve ineffective and caused the attitude and heading reference system to revert to directional gyro mode.

The wing front spar assembly and the wing lift tie strap sustained structural damage. The wing spar web was permanently bowed aft approximately 3 mm, and the lower spar cap forward flange was cracked. The wing lift tie was also deformed, with several solid rivets sheared. The composite wing-to-fuselage fairing and its supporting rib assembly were destroyed by impact forces.

Figure 2. Damage at wing-fairing to fuselage.

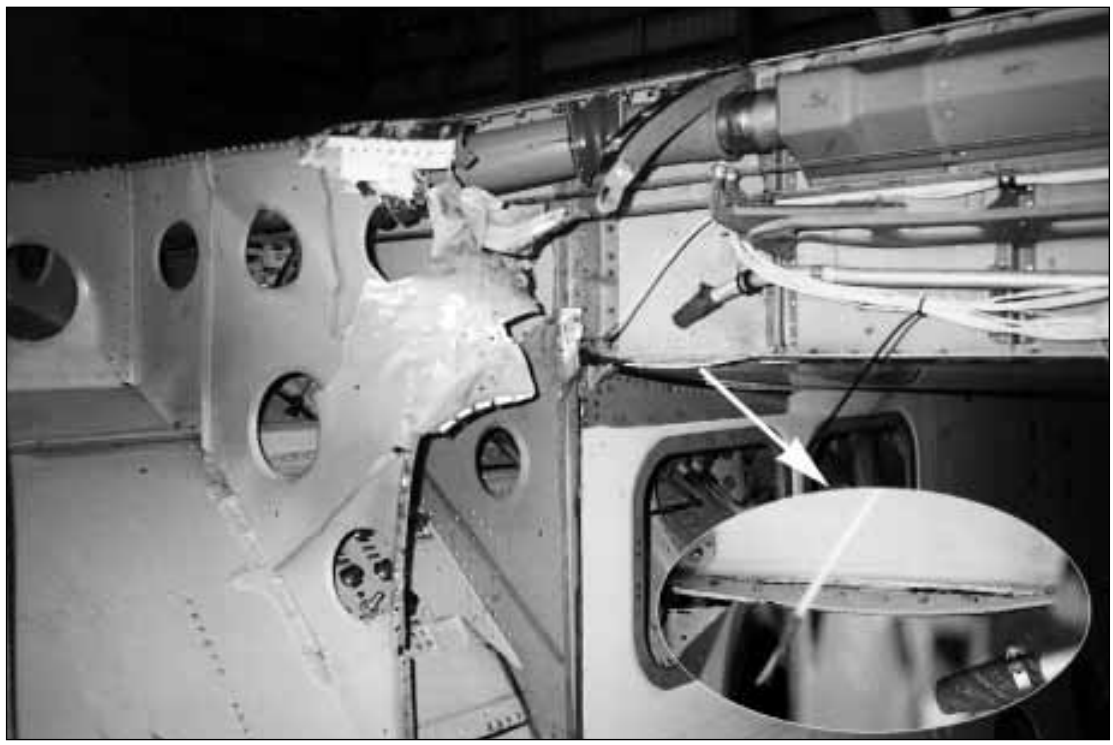

Figure 3. Damage to main spar and associated components.

Personnel information

Both pilots were appropriately licensed and qualified to undertake their respective duties as pilot in command and co-pilot on this flight. They held valid class 1 medical certificates. The pilot in command's medical certificate was endorsed with a condition that vision correction be used. He complied with the requirement. The flight attendant was also qualified to perform her assigned duties. All crew members had received adequate rest periods prior to commencing duties on the occurrence flight.

Meteorological information

The weather information supplied by the Bureau of Meteorology indicated that at the time of the approach and landing, visibility was unrestricted with no significant weather. The wind was 170 degrees at 6 kts and the temperature was 27 degrees Celsius.

Crew actions

The crew reported conducting a power check on the left engine following the loss of engine instrument indications. However, the flight data recorder did not show evidence of a power check before the crew shut down the left engine. The fuel shut-off check was not completed during the engine shut-down drills but was completed 18 minutes and 34 seconds after the engine had been shut down.

The pilot in command elected to carry out a go-around from the base leg of the circuit because of a gear-unsafe indication on the left main landing gear system.

Following the go-around the crew spent the next 31 minutes holding between the airfield and a position 10 NM north-west while they attempted to ascertain the status of the landing gear.

During this time the company engineers on the ground asked the crew to check the landing gear alternate system indication. The crew noted that three green lights illuminated.

Nine of the turns during the holding, including four orbits, were to the left into the failed engine and three turns were to the right. Three of the orbits during the holding were conducted at bank angles which produced a rate of turn greater than rate one.

The crew expressed concern about holding so far from the airstrip with one engine shut down and getting in the way of other aircraft. They repeatedly gave way to other aircraft instead of requesting the other aircraft to make way for them. During a subsequent radio contact with an inbound aircraft conducting a practice instrument approach, the Dash 8 crew informed them that they had shut down one engine. The other crew immediately discontinued the instrument approach in order to clear the airspace for the disabled Dash 8.

The crew informed the Perth Flight Service officer that they were having trouble with the landing gear. However, they did not declare an emergency or inform the flight service officer that they had shut down the left engine as required in section 6 of the company operations manual.

Twenty-three minutes after the left engine had been shut down, the manufacturer's representative in Perth asked the crew, via the company engineer in Broome, to shut down the left engine prior to the landing. The crew informed the engineer that they had already shut down the left engine.

Although the landing gear standby system indicated that the gear was down, with three green lights illuminated, the crew decided to follow the company engineer's suggestion that they carry out a low single-engine fly-past in an attempt to have ground staff confirm the landing gear position.

Prior to conducting the fly-past, the pilot in command took over pilot flying duties. The co-pilot informed the pilot in command that it had been difficult to maintain height in the turns with less than maximum continuous power of 97.5% engine RPM on the right engine. The fly-past was conducted along the runway at 96 ft pressure altitude with the indicated air speed reducing to a minimum of 114 kts at a power setting of 94.7% engine RPM and 61.8% torque. The landing gear was extended and the flaps were extended to 15 degrees.

During the subsequent climbout, the maximum torque and engine RPM values recorded were 107.5% and 101.2% respectively. The minimum airspeed recorded during the climbout was 103 kts.

On completion of the fly-past, the manufacturer's representative confirmed that if the alternate gear system showed an indication of three greens, the crew could consider it safe to land the aircraft.

The crew then completed a normal one-engine inoperative circuit for a landing on runway 10. During the landing roll, the pilot in command applied reverse thrust of 96.8% engine RPM and 62.4% torque to the right engine. The pilot in command subsequently used emergency brakes to stop the aircraft.

System description

Engine instruments

Each engine instrument has a dedicated signal path from its source. The signal path is routed via the same electrical loom carrying the weight-on-wheels wiring on the forward face of the wing spar. The indicator generates both the digital and analogue displays as well as the 0-5 volt DC output to the digital flight data recorder.

The left engine RPM and torque instruments and the propeller RPM instrument were inspected and bench tested. The instruments were found to be capable of operating within specified tolerances and they complied with airworthiness directive AD/INST/9 AMDT 5. The

signal path from each instrument to the flight data recorder was serviceable and test signals corresponded to the instrument indications throughout each instrument's range.

No reason could be found for the loss of engine instrument indications without a loss of digital flight data recorder data. The manufacturer of the aircraft and the engine instrument supplier are continuing to research this aspect.

Landing gear brakes and nose-wheel steering

The aircraft is fitted with a proximity switch electronic unit which utilises inputs from proximity sensors and micro switches to operate indicators in the landing gear extension and retraction system to verify uplock and downlock conditions.

The landing gear has a warning horn which is activated by the proximity switch electronic unit at a steady 2,000-Hz tone whenever the following conditions exist:

1. landing gear not down and locked, flaps selected to 15 degrees or greater, auto-feather system deactivated, and power levers below take-off setting; and
2. landing gear not down and locked, one or both power levers at or near flight idle, and indicated airspeed below 130 kts.

The proximity switch electronic unit also provides weight-on-wheels and gear position information to systems such as spoilers, auto-feather, auto-flight control and stall warning, and operates a warning horn and provides warning information if certain doors are not properly closed. The wires to these systems are contained within co-located wiring looms which were severed or disconnected during the impact.

For nosewheel steering to operate, a valid weight-on-wheels signal must be received by the proximity switch electronic unit.

To work normally the brake system also requires valid weight-on-wheels and wheel transducer signals.

Weight-on-wheels information is supplied to the proximity switch electronic unit by dual proximity sensors incorporated on each landing gear. These sensors and redundant circuits ensure the proximity switch electronic unit has continued valid weight-on-wheels information in the event of failure of one sensor or circuit. Warning of such a failure is indicated by illumination of the weight-on-wheels caution light. Signals from these weight-on-wheels sensors are transmitted through wiring routed through two co-located looms and connectors.

In this occurrence the severing and disconnection of wires in the looms and the connectors at the fuselage resulted in a failure of both left weight-on wheels signals to reach the proximity switch electronic unit.

As a result the nosewheel steering, anti-skid braking, and ground spoiler deployment systems were rendered inoperative. The loss of the anti-skid system also rendered the normal brakes inoperative.

Systems knowledge

At the commencement of the fly-past, the aircraft was configured with flaps extended to 15 degrees, landing gear extended and power levers below the take-off setting. The indicated air speed was 140 kts. The landing gear standby system was indicating that the gear was down and locked. However, the landing gear warning horn was sounding and the indicator on the landing gear selector panel showed that the left main landing gear was not locked down.

Because they considered that the aircraft was configured outside the horn activation parameters, the crew could not understand why it had activated. However, in the

configuration as sensed by the proximity switch electronic unit, (i.e. landing gear not down and locked, 15 degrees of flap extended, auto-feather system deactivated and power levers below the take-off setting), the system would have activated the landing gear warning horn regardless of airspeed.

Quick reference handbook

The manufacturer's quick reference handbook checklist used by the operator details crew awareness items in the event of a weight-on-wheels caution light illuminating. It states that crew should be aware that landing gear may not retract and illumination of the caution light at any time in flight requires rectification before the next flight even though the caution light may go out on touchdown.

This was predicated on system redundancy having worked. Redundancy was based on having a single failure in the weight-on-wheels signal. The weight-on-wheels system has one caution light. There is therefore no difference in the caution information presented to the crew in the event of failure of both weight-on-wheels systems.

The checklist also does not have information to alert the crew that the illumination of the weight-on-wheels caution light may also be warning of a failure or loss of systems such as nosewheel steering, anti-skid braking, normal brakes and ground spoilers.

Sections 04 to 14 of the operator's quick reference handbook set out checks and procedures to be adopted during non-normal operations.

Section 08 sets out checks and procedures to be adopted during emergency and forced landings and an emergency evacuation.

The procedures for an emergency landing with both engines operating and the gear either extended or retracted require that the crew:

- Ensure that no passengers are seated in the vicinity of the propeller arcs.
- Review proposed landing and evacuation procedures with the co-pilot.
- Warn crew and passengers to brace before touchdown.

Section 05.13 of the operator's quick reference handbook sets out checks and procedures to be adopted during non-normal operations such as a one-engine inoperative landing. The non-normal checklists do not refer to procedures or checks to be adopted with one engine inoperative and when there is uncertainty about the status of the landing gear.

The crew reported that following the bird strike they used the non-normal checklist to resolve system faults indicated on the master caution panel. However, at that time the crew had not attempted to extend the landing gear. During the last 30 minutes of the flight the crew did not refer to the non-normal checklist but acted from memory to resolve non-normal situations and indications. Even though the crew had expressed concern about the status of the landing gear, they did not follow the emergency checklist procedures to ensure that the passengers were prepared for a possible non-normal touchdown, nor did they conduct a pre-landing review of evacuation procedures. Recorded information from the cockpit voice recorder revealed that the crew made four announcements to the passengers to keep them informed of the status of the situation (three before and one after the landing).

The pilots stated that following the bird strike they prepared for a landing, and as part of the checklist, chimed the flight attendant to indicate that she should secure the cabin and take her seat for the landing. When completing the subsequent pre-landing checklist after 31 minutes of holding, the crew decided that the pre-landing chime to the flight attendant was not necessary. They expected that she would have remained seated since the chime prior to the go-around.

Dash 8 type training

The company had recognised the advantages of simulator-based training and had acquired a part share in a Dash 8 simulator. However, because the simulator had not been available until just prior to this occurrence, endorsement training and pilot proficiency checks had been conducted in the aircraft. The aircraft is being used by the company in a Civil Aviation Safety Authority approved training and proficiency check program which includes crew resource management line-oriented flight training (LOFT) for pilots.

Crew resource management

Research conducted by the US National Aeronautics and Space Administration's Ames research centre has indicated that improvements in crew teamwork and coordination can be achieved through training which focuses on non-technical skills such as delegation of tasks, communication, priority management and leadership.

Both pilots had completed a crew resource management training course which involved pilots and flight attendants in September 1995. However, the flight attendant involved in this occurrence was unable to attend the course due to her flying roster and had not participated in a crew resource management course since.

The company's training policy did not require flight attendants to complete crew resource management training. During her initial flight attendant training the flight attendant had viewed the video Dryden: The Accident. The video was produced by Australian Airlines specifically for cabin crew training to highlight the importance of good communication between cabin and flight crews in maintaining operational safety.

The flight attendant remained seated throughout the incident and the holding period. Immediately prior to a general announcement from the pilot in command about the nature of the occurrence, the flight attendant reassured the passengers that the aircraft could be safely operated on one engine. She was assured by the pilot in command that her assistance was not needed. By not instructing the flight attendant to ensure that procedures for non-normal landing preparation were implemented, the pilot in command did not adequately use the resources of the flight attendant.

The flight crew involved the engineers in problem solving when they sought engineering advice from company engineers at Broome and Perth. The manufacturer's representative in Perth also relayed information to the crew through the company's radio at Broome.

At the time of the occurrence the Civil Aviation Safety Authority had no legislated or regulated crew resource management training requirements.

Flight recorders

Digital flight data recorder

The aircraft was equipped with a Loral Data Systems model F800 digital flight data recorder that recorded 31 parameters. The recorder was required to be operating during taxiing and flight. After the occurrence, the flight data recorder was removed from the aircraft and the data successfully recovered.

The flight data recorder received engine data directly from the engine instruments in the cockpit. It continued to record left-engine parameters until the crew shut down the left engine even though the engine instrument indications failed at the time of the bird strike.

Cockpit voice recorder

The aircraft was fitted with a Loral Data Systems model A100 cockpit voice recorder which was required to be operating prior to engine start and to remain operating until after engine shutdown. It had a recording duration of approximately 30 minutes which allowed recorded information to be continuously overwritten so that the last 30 minutes of information was always available.

After the occurrence, the cockpit voice recorder was removed from the aircraft and the recorded information was successfully recovered.

During this occurrence the cockpit voice recorder continued to operate until the crew switched off the aircraft's electrical power. As a result, cockpit voice recorded information commenced 11 minutes and 42 seconds after the bird strike and information from the earlier part of the flight was unavailable because it had been overwritten.

Bird information

Examination of the remains of the wedge-tailed eagle by an amateur ornithologist placed its weight at approximately 10 kg (22 lb). The bird had the undigested carcass of a rabbit-sized animal in its gut.

Bird-strike design requirements

The aircraft was manufactured to comply with US Federal Aviation Regulation 25 design criteria covering transport category aircraft. A search of the regulation failed to highlight any section dealing exclusively with bird-strike design criteria for wing components. However, Amendment 25-23 to Federal Aviation Regulation 25 states:

> One of the comments recommended that both the windshield and the wing should be included in the bird strike criteria of Section 25.631. Moreover, it was suggested that the use of an eight-pound bird in this requirement may not be realistic and that a larger sized bird should be considered. Other comments suggested that only smaller sized birds be considered. The Federal Aviation Administration does not agree that the wing and windshield should be included in this proposal. Service experience has not shown that the current windshield strength requirements for bird strikes in Section 25.775 are inadequate or that a special investigation of wing structures for resistance to bird strikes is necessary. Moreover, the bird strike records indicate that encounters with birds weighing more than eight pounds are a rarity and that on the basis of probability, eight pounds is a reasonable value.

This amendment explains that, based on service experience, the US Federal Aviation Administration was not prepared to amend their current design criteria for windshields and wings to include birds weighing more than 8 lb. Consequently, the wing-to-fuselage fairing was not designed, nor was it required to be designed, to enable the structure beneath it to withstand a bird weighing 22 lb.

Structural damage to the aircraft was significant. However, within the framework of Federal Aviation Regulation 25, impact with such a massive bird at high speed was not contemplated.

2. ANALYSIS

The investigation determined that the damage to the wiring looms attached to the forward face of the left wing forward spar caused a failure of at least the left engine instrument systems, the left landing gear weight-on-wheels system to the proximity switch electronic unit, and the left attitude and heading reference system.

Decision making

The low one-engine-inoperative fly-past at the request of engineers was unnecessary given that the crew had already ascertained the status of the landing gear through the alternate gear system. However, at no time did the crew appear to completely accept the safe status of the landing gear as indicated by the standby system.

A number of operational decision making problems which impacted on the safe operation of the aircraft were highlighted in this occurrence. The crew did not follow company procedures when they acted from memory to resolve non-normal situations and indications and when they did not refer to pre-landing checks and briefings for a non-normal landing.

The combined effect of no nosewheel steering, reverse thrust on the right engine and weather cocking from the crosswind caused the aircraft to turn right through approximately 44 degrees.

Training

The operator had commenced pilot training and proficiency checks in a recently acquired Dash 8 simulator. The crew involved in this occurrence subsequently completed this Civil Aviation Safety Authority approved training and proficiency check program.

Crew resource management

Since the introduction of the Dash 8 simulator the company's policy on resource management training has reflected a bias towards cockpit rather than crew resource management training.

Checklists

The operator used the manufacturer's checklist for Dash 8 operations. The checklist was found to be inadequate in that it did not alert crew to the systems that would be affected by a dual weight-on-wheels system malfunction. The one-engine-inoperative checklist in Section 05.13 also does not cover procedures to be adopted and briefings to be given when one engine is not operating and there is uncertainty about the status of the landing gear. It would seem more appropriate to detail such non-normal situations in Section 08 of the quick reference handbook.

The crew believed that with the left engine shut down they had lost hydraulics resulting in a failure of the normal brakes and nosewheel steering. The fact that a dual weight-on-wheels system failure will result in the loss of brakes and nosewheel steering is not covered in the checklists. Given the status of the aircraft and a lack of adequate documentation to cover such an occurrence, the crew's incomplete understanding of the problem with which they were faced may be partly explained. It is possible that many Dash 8 pilots may also be unaware of this anomaly in the description of the weight-on-wheels system.

3. CONCLUSIONS

Findings

1. System redundancy was compromised when the wiring was damaged, resulting in the failure of the left weight-on-wheels signal to the proximity switch electronic unit.
2. The nosewheel steering, anti-skid and normal braking, and ground spoiler deployment systems were rendered inoperative.
3. The aircraft was manufactured to comply with US Federal Aviation Regulation 25 design criteria covering transport category aircraft. Consequently, the wing-to-fuselage fairing was not designed, nor was it required to be designed, to protect the structure beneath it from impact with a bird weighing 10 kg.
4. The manufacturer's quick reference handbook checklist does not contain information to alert the crew that the illumination of the weight-on-wheels caution light may be warning of a failure or loss of systems such as nosewheel steering, anti-skid braking, normal brakes and ground spoilers.
5. The one-engine-inoperative checklist also does not cover procedures to be adopted and briefings to be given when one engine is not operating and there is uncertainty about the status of the landing gear.
6. The crew did not declare an emergency or inform the flight service officer that they had shut down the left engine.
7. Although the landing gear standby system indicated that the gear was down with three green lights illuminated, the crew carried out a low single-engine fly-past in an attempt to have ground staff confirm the landing gear position.
8. Both pilots were appropriately licensed and qualified to undertake their respective duties as pilot in command and co-pilot on this flight.
9. The flight attendant was qualified to perform her assigned duties on the flight.
10. Both pilots had completed a crew resource management training course which involved pilots and flight attendants.
11. The flight attendant had not completed a crew resource management training course and was not required by company policy to complete such training.
12. The company's policy on resource management training reflected a bias towards cockpit rather than crew resource management.
13. The crew did not follow company procedures when they acted from memory to resolve non-normal situations and indications.

Significant factors

1. The aircraft struck a 10 kg wedge-tailed eagle.
2. The left engine instrumentation failed and the master caution panel indicated multiple system failures.
3. System redundancy was compromised when the wiring was damaged, resulting in the failure of the left weight-on-wheels signal to the proximity switch electronic unit.
4. The nosewheel steering, anti-skid and normal braking, and ground spoiler deployment systems were rendered inoperative.
5. The crew did not follow company procedures by not using checklists to resolve non-normal situations.

4. SAFETY ACTION

The Bureau of Air Safety Investigation issued interim recommendation IR960057 to the Civil Aviation Safety Authority:

The Bureau of Air Safety Investigation recommends that the Civil Aviation Safety Authority alert all Australian operators of DHC-8 aircraft that if the weight-on-wheels caution light is illuminated, systems other than the landing gear could be affected.

The Bureau of Air Safety Investigation also recommends that the Civil Aviation Safety Authority alert Transport Canada about a suggested revision to the manufacturer's quick reference handbook for the DHC-8 aircraft. The revision should include a note to aircrew that if a weight-on-wheels caution light is illuminated, systems other than the landing gear may not be operating normally. In particular, reference to the nosewheel steering and normal braking systems should be made as a crew awareness item under the weight-on-wheels caution light illuminated checklist.

The Bureau of Air Safety Investigation also recommends that the Civil Aviation Safety Authority ask Transport Canada to consider moving the one-engine-inoperative landing checklist to the emergency landing section of the manufacturer's quick reference handbook.

Should a revision to the checklist be made, the Bureau of Air Safety Investigation recommends that the Civil Aviation Safety Authority alert all Australian operators of DHC-8 aircraft to revise their checklists where these are at variance with the manufacturer's checklist.