Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT

A99W0043

WING STRIKE ON LANDING

DELTA AIR LINES

BOEING 727-200 N8873Z

CALGARY INTERNATIONAL AIRPORT, ALBERTA

10 MARCH 1999

Canada

The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

Aviation Investigation Report

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Summary

The flight crew of the Boeing 727-200 were completing a regularly scheduled passenger flight into Calgary, Alberta. Because of poor weather in Calgary, the flight was delayed for one and a half hours in Salt Lake City, Utah, extending the crew's scheduled duty day. In Calgary, the crew conducted a flap-30, autopilot-coupled, instrument landing system approach in low visibility to runway 34. The autopilot was disconnected at about 130 feet above ground level. During the landing, the right wing struck the runway. There was damage to the wing tip, the leading edge flaps, the trailing edge flaps, the flap screw-jack, and track fairings of the right wing. The crew was not aware that the wing had struck the runway until the post-flight inspection was completed on the Calgary ramp. No one was injured in the accident.

Ce rapport est également disponible en français.

Other Factual Information

The flight crew's operating base was Atlanta, Georgia. The captain and the second officer lived outside of the Atlanta area and commuted by air to their base. On the day of the occurrence, the captain arrived at the Charleston, South Carolina, airport for his commute flight at about 0700 eastern standard time (EST).[1] After arriving in Atlanta, the captain spent his time in the company operations office until his crew check-in time of 1225. During that time, he reviewed flight information and his company mail. The second officer arrived at the Nashville, Tennessee, airport at about 0830 for his commute flight and also spent his time in the company operations office. The first officer arrived shortly before the crew check-in time, after a one-hour drive from his home in Macon, Georgia.

The crew were scheduled for an 11 hour 30 minute duty day, with the duty day ending in Calgary, Alberta. The crew operated the flight from Atlanta to Minneapolis, Minnesota, and then on to Salt Lake City, Utah. There was a 2 hour 30 minute scheduled wait in Salt Lake City before they were to operate the flight to Calgary.

The flight arrived at Salt Lake City close to the scheduled time, and the crew waited in the terminal building for their next flight. The captain and the first officer spent some of this ground time reviewing various company documents, including safety information that highlighted the problem of Boeing 727 wing strikes during landing.

After the passengers for the flight to Calgary had been boarded, the crew received information from their dispatch that the Calgary weather had gone below their landing limits. The decision was made to keep the passengers on board and then depart when the weather improved. After receiving a report of improved weather, the flight departed for Calgary about 1 hour 30 minutes late.

The actual duty day until the crew disembarked at Calgary was about 13 hours 15 minutes. The Delta pilots' association agreement with the company allows a maximum scheduled duty day of 13 hours. The company flight operations manual and the pilots' association agreement with the company permit flight crews to exceed the scheduled duty day by two hours for irregular operations such as weather problems.

The company indicated that a large percentage of its crews commute by air to their operating base. One estimate provided by the company indicated that 38 per cent of the Atlanta-based pilots commute by air; a large number of cabin crew members also commute by air. Crew members who commute by air typically do not take the last possible flight to their operating base because they require a back-up plan in case their commute flight is delayed or cancelled. The company expects that crews will leave themselves options so they arrive in time for their duty flight. There are no instructions to the company's crews regarding the requirement to pre-position themselves at their operating base the night before a scheduled duty day.

The occurrence crew were operating under the flight time limitations and rest requirements of the United States Federal Aviation Regulations (FARs). The FARs are silent on the subject of crews who commute by air to their operating bases. Canadian Aviation Regulations do not specifically address the subject of commuting by air either.

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[1] All times are EST (coordinated universal time [UTC] minus five hours).

Runway 34 at the Calgary airport is 12 675 feet long and 200 feet wide. The runway threshold elevation is 3 543 feet above sea level (asl). The decision height for the Category 1 instrument landing system (ILS) approach is 3 743 feet asl, which is 200 feet above ground level (agl). Runway 34 is equipped with medium-intensity runway-edge lighting and high-intensity approach lighting with runway alignment indicator lights. There is no centreline lighting on runway 34. The ILS has a three-degree glide slope and was serviceable at the time of the occurrence. As with most airports in Canada,[2] the runway is not equipped with a middle marker.

At the time of the occurrence flight's approach, the reported weather was as follows: obscured ceiling at 100 feet agl, visibility 0.5 statute mile in freezing fog, temperature minus four degrees Celsius, dewpoint minus five degrees Celsius, altimeter setting 30.00 inches of mercury, and wind 140 degrees true at four knots. The tower controller reported the runway visual range as 5 000 feet, with a runway light setting of five.

The crew of another aircraft, which landed about two minutes before the occurrence aircraft, indicated that there was a slight wind from the east but very little drift. They observed the runway environment at about 100 feet above the decision height. At first only the approach lights could be seen, then they could see the 1 000-foot lighting bar, followed by the end of the runway.

During the landing by the occurrence aircraft, the crew noted that the visibility was very limited until just before touchdown.

The aircraft weight at the time of the approach into Calgary was about 154 000 pounds, 500 pounds below the maximum landing weight. This is a heavier-than-normal landing weight because of the additional fuel carried on board in the event poor weather in Calgary forced the aircraft to return to Salt Lake City. The landing reference speed (V_{ref}) for a flap setting of 30 degrees at the occurrence weight is 134 knots indicated airspeed (KIAS); a flap 40-degree V_{ref} is a couple of knots lower. A straight-in autopilot-coupled approach was conducted to runway 34; the crew planned to use the autopilot to just above its minimum operating altitude of 50 feet agl.

The aircraft intercepted the ILS glide path at 6 000 feet asl and made a continuous descent on the glide path. Based on the flight data recorder and the radio transmissions, it was estimated that the aircraft descended through 1 500 feet radio-altimeter height at about 0121:12. The approach was flown at 142 KIAS, which yielded a true airspeed of 146 knots. The recorded radar data revealed that the average ground speed during the descent was 155 knots.

The aircraft was stabilized on the glide path until about 350 feet agl. At this point (about 84 seconds after descending though 1 500 feet agl), the aircraft pitched from 2 degrees nose-up to about 4 degrees nose-up. The aircraft then pitched down to 1 degree nose-up, then began pitching up again about 98 seconds after descending below 1 500 feet radio-altimeter height. A pitch angle of 5 degrees nose-up was reached just as the aircraft was descending through the decision height. The aircraft then pitched down again and reached a pitch angle of slightly less than 0 degrees. The captain disconnected the autopilot when the nose-down pitch was sensed during this pitch-down. The aircraft passed through 50 feet agl about 110 seconds after descending below 1 500 feet radio-altimeter height.

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[2] Canada has filed a difference with ICAO regarding the absence of ILS middle markers.

Just after the autopilot was disconnected, the aircraft started to drift left of the runway centreline. The captain attempted to correct back to the right by using right bank. The aircraft touched down during this banked turn. The bank angle during the initial touchdown was about 9 degrees, and the recorded vertical acceleration was 1.35 times the force of gravity (g). A second touchdown followed, with a recorded vertical acceleration of 1.54 g and an increased bank angle of about 12 degrees. The recorded time of the landing was 0123:07.

The *Boeing 727 Operations Manual*, Normal Procedures, states:

> The B727-200 aircraft have experienced numerous incidents involving tail-skid or wing-tip contact with the runway. . . . . As a result of pronounced sweep-back, a small increase in pitch dramatically increases the risk of wing-tip contact with the runway. It is possible to make contact with as little as 7° of roll where a firm landing is made with a corresponding degree of pitch-up.

The aircraft was equipped with a Sperry SP-150 autopilot. As with most autopilots, the autopilot sensitivity is designed to decrease as the aircraft gets closer to the ground during a coupled approach. The purpose of this sensitivity reduction is to eliminate overcontrolling by the autopilot. Small physical displacements from the glide path or localizer create large apparent angular displacements that the autopilot would otherwise attempt to correct too violently.

The Sperry SP-150 autopilot is designed to desensitize over a 150-second period after the radio altimeter senses a height of 1 500 feet agl. During the 150 seconds, the sensitivity (or gain) reduces to 22 per cent of the normal value. If a middle marker is sensed on the approach, before reaching the 150-second point, the gain would reduce to 22 per cent at twice the previous rate. The gain would then decrease to about 6 per cent of normal within another 30 seconds. During descent, this time-based design will properly schedule the desensitization only if the distance from the runway is consistent with a 3-degree glide slope and if the aircraft's actual ground speed is relatively close to the assumed ground speed designed into the autopilot. If the ground speed is higher than the design-assumed ground speed, the airplane will approach the runway before the desensitization period expires, and the sensitivity will be higher than that intended by the design.

One assumption in the designed ground speed was that approaches would be flown using a flap setting of 40 degrees; however, a 30-degree flap setting is now the standard practice. The lower flap setting results in a higher approach speed. Recognizing that the normal approach flap setting is now 30 degrees, Sperry issued a service bulletin (SB) for the SP-150 autopilot. By complying with SB 21-1132-122, the SP-150 autopilot time to desensitize was reduced to 105 seconds. Compliance with the SB is not mandatory, and the occurrence Boeing 727 autopilot did not have the SB modification.

The Boeing 727 is not certified for a Category II landing with an SP-150 autopilot when the middle marker is not available, unless a modification has been made to provide approach gain change via the Low Range Radio Altimeter system. The occurrence aircraft did not have this modification.

The United States National Transportation Safety Board (NTSB), while investigating a 1998 accident at Chicago O'Hare International Airport, Illinois, determined that in some instances 150 seconds is too long to provide the desired autopilot sensitivity reduction. Pitch oscillations

close to the ground can then occur. On 01 June 2000, the NTSB issued five recommendations (A-00-41 through A-00-45) to deal with the problem of the Sperry SP-150 (and SP-50) autopilot sensitivity. The NTSB recommendations are contained in Appendix A.

Analysis

The approach into Calgary came at the end of a long duty day. The scheduled duty day was more than 11 hours, and the weather delay in Salt Lake City, because of the low visibility in Calgary, extended the duty day. By the time the crew had disembarked at the gate in Calgary, the duty day was slightly longer than 13 hours. The scheduled and actual duty day were within the time allowed by company procedures.

The captain and the second officer commuted by air to Atlanta. Both pilots chose to arrive in Atlanta on the morning of the flight and, as a result, were subjected to a long day of activities related to their flight. The captain's work day essentially commenced at about 0700 when he reported to the Charlotte airport for his commute flight. His actions did not contravene any regulation and were consistent with company policy and normal commuting practice.

The crew schedule is designed to reduce the possibility of fatigue. If this work period is exceeded, the likelihood of fatigue increases. The crew day does not legally include the time required to commute; however, the level of fatigue is affected by the extra time commuting. In the United States, as in Canada, the regulations do not specifically address crew commuting times. Commuting times are not included in airline calculations of time on duty for the purposes of determining the duty day.

The approach into Calgary was proceeding without difficulty. The crew had chosen to use the autopilot for a coupled ILS approach to runway 34. They had intended to keep the approach coupled until just above the minimum disconnect height of 50 feet agl. This normally has the benefits of keeping the aircraft stabilized longer and allowing pilots to concentrate more on acquiring visual cues for the transition to landing. As the aircraft descended through about 350 feet, the pitch angle increased and pitch oscillations commenced.

At this point, about 84 seconds after the aircraft descended below 1 500 feet agl, the approach became unstable. The aircraft was likely displaced slightly from the glide path, but, because of the proximity of the ILS land-based equipment, this slight displacement would appear to the autopilot as a relatively large angular deviation from the glide path. The autopilot thus made an aggressive attempt to return the aircraft to the glide path. Because the timing from the descent through 1 500 feet agl had not yet reached 150 seconds, and the runway was not equipped with a middle marker, the autopilot had not fully desensitized. The corrective action was therefore too aggressive, resulting in the pitch oscillations.

The autopilot did not desensitize in time because the aircraft ground speed was higher than the assumed ground speed of the autopilot design. The ground speed was high because of light tailwinds, the relatively high-altitude airport, and a high approach speed. The approach speed, based on V_{ref}, was higher than normal because of the increased landing weight. The use of 30 degrees of flap, which is now a normal landing configuration, was not accounted for in the original autopilot design. Had the SB 21-1132-122 modifications been made on this aircraft, the autopilot pitch control would likely have remained stable, because the desensitizing would have been complete or near completion.

The captain did not detect the pitch oscillations until the aircraft was below the decision height and a 5-degree pitch down occurred. The captain's reaction was to disconnect the autopilot. However, while attempting the visual transition to landing at night, with few visual cues available, the aircraft drifted to the left of the runway centreline. The captain's attempt to return the aircraft back to the right at low altitude resulted in bank angles that caused the wing to contact the runway as the aircraft touched down firmly. Because of its flap geometry and swept wing design, the Boeing 727 is prone to wing strikes when landed with only relatively small amounts of bank. The transition to the landing in low visibility, with the autopilot oscillations, required a heightened amount of pilot skill and alertness. The captain's long work day may have affected his performance and ability to manage the situation.

Findings as to Causes and Contributing Factors

1. The aircraft drifted left of the centreline during the low-visibility landing. While attempting to return the aircraft to the centre of the runway, the captain applied too much right bank, resulting in the wing strike.

2. The autopilot sensitivity did not fully reduce during the approach into Calgary, leading to pitch oscillations. The captain disconnected the autopilot earlier than planned to try to control the oscillations.

3. The original design of the SP-150 autopilot assumed that approaches would be flown at a flap setting of 40 degrees. The occurrence crew used a flap setting of 30 degrees, which is current standard practice.

4. The autopilot was designed to desensitize, based on an assumed ground speed for a 3-degree glide slope, within 150 seconds of descending through a radio height of 1 500 feet above ground level (agl). The occurrence aircraft took about 110 seconds to pass from 1 500 feet agl to 50 feet agl, the minimum altitude for autopilot operation.

5. The ground speed during the approach was higher than normal because of light tailwinds, the relatively high-altitude airport, and a high approach speed. The approach speed, based on V_{ref}, was higher than normal because of the increased landing weight.

6. The scheduled crew day was slightly more than 11 hours 30 minutes, which was less than the normal maximum scheduled crew day. The crew day was extended because of the delay in Salt Lake City while waiting for the Calgary weather to improve.

Other Findings

1. The captain and the second officer were subjected to a long work day because, in addition to the duty day required to operate the flights, they had commuted to their base of operation by air early on the morning of the flight. Long work days may contribute to fatigue.

2. A service bulletin (SB) for the SP-150 autopilot was issued to reduce the time of autopilot desensitization to 105 seconds from 150 seconds. Compliance with the SB was not mandatory, and the occurrence aircraft autopilot did not have the SB modification.

3. The Calgary instrument landing system to runway 34 was serviceable at the time of the occurrence.

4. Aircraft equipped with the SP-150 and SP-50 autopilots with the same sensitivity reduction logic as the occurrence aircraft will never reach minimum sensitivity value for runways not served with a middle marker.

5. Most airports in Canada are not equipped with middle markers.

Safety Action

Safety deficiencies identified in this investigation related to Boeing 727 autopilot sensitivity and gain have been addressed by recommendations issued by the US National Transportation Safety Board (NTSB). The US Federal Aviation Administration (FAA) indicated, in a 30 January 2001 letter to the NTSB, that it planned to issue a notice of proposed rulemaking (NPRM) proposing to perform the modifications described in Sperry Service Bulletin (SB) 21-1132-121 for SP-50 autopilots and SB 21-1132-122 for SP-150 autopilots. The FAA also reports that the aircraft flight manual will be changed to limit the approved flap setting to less than 40 degrees for coupled instrument landing system Category II approaches.

Crew fatigue has been identified by the NTSB and the FAA as a safety issue. As a result of long-standing discussions between the NTSB and the FAA, based on NTSB recommendations, the FAA indicated that, in the spring of 2001, it planned to issue a Supplemental NPRM addressing elements of crew fatigue. The FAA was provided with information regarding this occurrence.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 29 March 2001.

Appendix A—NTSB Recommendations Re: SP-150 Autopilots

On 01 June 2000, the US National Transportation Safety Board issued five recommendations (A-00-41 through A-00-45) concerning the problem of the Sperry SP-150 (and SP-50) autopilot sensitivity:

> Require operators of Boeing 727 aircraft equipped with Sperry Aerospace SP-50 and SP-150 autopilots to perform the modifications described in Sperry Service Bulletin (SB) 21-1132-121 (for SP-50 autopilots) and SB 21-1132-122 (for SP-150 autopilots) if these 727 aircraft are used for coupled instrument landing system category II approaches at flap settings less than 40°. (A-00-41)
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> Develop sets of operating limitations for Sperry Aerospace SP-50 and SP-150 autopilots on coupled instrument landing system approaches that are appropriate for the desensitization schedules used by these autopilots so that every possible desensitization schedule has a corresponding set of operating limitations. The limitations should also address approach flap settings and airspeeds specifically, and should also consider tolerances on winds, capture altitudes, glide slope angles and/or other parameters that could adversely affect autopilot performance and safety of flight. (A-00-42)
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> Advise all operators of Boeing 727 aircraft equipped with Sperry Aerospace SP-50 and SP-150 autopilots to inform their pilots, maintenance, and engineering personnel of the dangers of conducting coupled instrument landing system approaches at airspeeds that are not consistent with the desensitization schedule of the autopilots, and notify the operators that the Federal Aviation Administration has been asked to develop operating limitations for the use of these autopilots on coupled approaches that will ensure that the approaches are conducted in a manner consistent with the autopilot design. (A-00-43)
>
> Review the certification of all autopilot systems that use time-based desensitization schedules and develop operating limitations, as necessary, for the use of these autopilots on coupled instrument landing system approaches. The limitations should address approach flap settings, and airspeeds specifically, and should also consider tolerances on winds, capture altitude, glide slope angles, and/or other parameters that could adversely affect autopilot performance and safety of flight. (A-00-44)
>
> Advise all operators of aircraft equipped with autopilot systems that use time-based desensitization schedules to inform their pilots, maintenance, and engineering personnel of the dangers of conducting coupled instrument landing system approaches at airspeeds that are not consistent with the autopilot desensitization schedule, and notify the operators that the Federal Aviation Administration had been asked to develop operating limitations for the use of these autopilots on coupled approaches that will ensure that the approaches are conducted in a manner consistent with the design of the autopilot. (A-00-45)