Final Report

Boeing B747-400F, REGISTRATION 9V-SFO
ENGINE GROUND STRIKE
AT AUCKLAND AIRPORT, NEW ZEALAND

10 DECEMBER 2019

AIB/AAI/CAS.189

Transport Safety Investigation Bureau
Ministry of Transport
Singapore

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The Transport Safety Investigation Bureau of Singapore

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SYNOPSIS

On 10 December 2019, while landing at Auckland Airport in New Zealand in a crosswind of about six to seven knots, the flight crew of a Boeing B747-400 freighter aircraft executed a rejected landing followed by a go-around. During the rejected landing manoeuvre, the aircraft banked to the left and the left engine scraped the runway. The aircraft continued with the go-around and subsequently landed at the airport without further incident. A post-flight inspection of the aircraft revealed damage to the underside of the leftmost engine on the left wing.

The Transport Safety Investigation Bureau classified this occurrence as a serious incident.

AIRCRAFT DETAILS

Aircraft type	:	Boeing B747-400 Freighter
Operator	:	Singapore Airlines
Aircraft registration	:	9V-SFO
Numbers and type of engines	:	Four x Pratt and Whitney 4056
Date and time of incident	:	10 December 2019, 1435 UTC
Location of occurrence	:	Auckland Airport, New Zealand
Type of flight	:	Scheduled
Persons on board	:	Five

1 FACTUAL INFORMATION

All times used in this report are New Zealand Local Time (LT) unless otherwise stated. At the time of the incident, New Zealand Local Time was 13 hours ahead of Coordinated Universal Time (UTC).

1.1 History of the flight

1.1.1 On 10 December 2019, a Boeing 747-400 freighter aircraft flew from Sydney, Australia, to Auckland, New Zealand. Prior to operating this flight, the flight crew had rested for 48 hours and stated that they were well rested.

1.1.2 During the flight from Sydney to Auckland, which took 2hr 50min, the flight crew did not experience any flight control anomalies, nor observe any abnormal engine parameters.

1.1.3 At about 0332LT, during the approach to Runway 05R at Auckland Airport, when the aircraft was at a height of about 2,400ft, the Pilot-in-Command (PIC), who was performing Pilot Flying (PF) duties, disengaged the auto-pilot and flew the Instrument Landing System (ILS) approach manually.

1.1.4 There was a right crosswind of about six to seven knots at Auckland Airport. The PIC employed the 'touchdown-in-a-crab[1]' technique for the approach, which entailed in this instance pointing the aircraft about 5° to the right of the runway centreline. The PIC planned to touch down on the runway slightly to the right of the runway centreline instead of on the centre of the runway[2]. His consideration was that this would allow a greater margin of safety from an excursion off the left edge of the runway should the aircraft be forced downwind during touchdown.

1.1.5 According to the PIC, he executed the flare[3] at about 30ft. The aircraft touched down on the runway at about 0335LT, the speedbrakes were automatically deployed and the aircraft pitched up shortly after touchdown. The PIC said that he lost sight of the runway end lights when the aircraft pitched up and sensed that the aircraft bounced[4]. He then sensed that the aircraft was moving towards the right edge of the runway and so he called for a go-around and manually

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[1] The crab is a flight profile that enables an aircraft to align its track (i.e. movement of the aircraft) with the runway by pointing the aircraft's nose (i.e. heading) off the runway heading in order to create a component of its movement in the direction of the crosswind to counter the effect of the crosswind.

[2] The operator's Flight Crew Training Manual (FCTM) stipulated that pilots should aim at touching down on the centre of the runway. More details in paragraph 1.11.1.

[3] A manoeuvre executed during the approach to land where the nose of the aircraft is raised, i.e. pitched up, to reduce the rate of descent.

[4] However, data from the aircraft's Flight Data Recorder (FDR) revealed that the aircraft did not bounce.

increased the throttles. At about the same time, the PIC also applied left aileron to roll the aircraft towards the left to align the aircraft with the runway centreline. Subsequently the aircraft got airborne.

1.1.6 The Air Traffic Control (ATC) observed what looked like sparks coming from the left wing of the aircraft and informed the flight crew that some part of the aircraft might have contacted the runway during the go-around. The flight crew acknowledged the ATC and subsequently landed at the airport at 0350LT without further incident.

1.2 Injuries to persons

1.2.1 There was no injury to any persons.

1.3 Damage to aircraft

1.3.1 The fan cowl panel, thrust reverser panel, thrust reverser lower track fairing and louvered exhaust door assembly at the underside of the No. 1[5] engine sustained gouge and tear damage (see **Figure 1**).

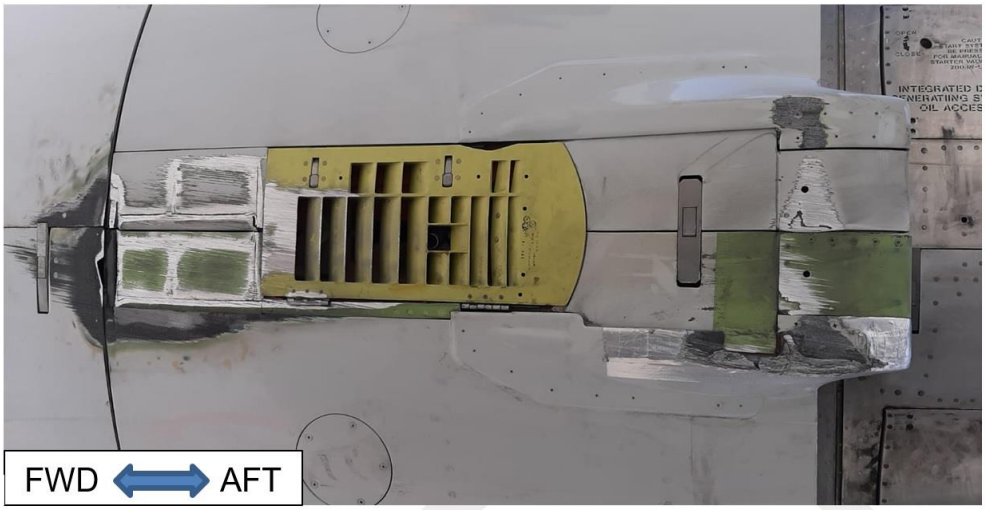

Figure 1: Damage to underside of No. 1 engine

[5] The four engines of the incident aircraft were numbered 1, 2, 3 and 4 from left to right (as viewed from the rear). The No. 1 engine was the leftmost engine.

1.4 Other damage

1.4.1 Two scrape marks were observed on the runway about 1,040m from the Runway 05R threshold (see **Figure 2**), each measuring about 1m by 0.3m.

Figure 2: Scrape marks (circled in blue) on runway

1.5 Personnel information

1.5.1 Pilot-in-Command (PIC)

Gender	Male
Age	63
Licence	Airline Transport Pilot Licence (ATPL)
Issuing Authority	Civil Aviation Authority of Singapore
Licence validity	30 June 2020
Medical certificate	Class 1
Total flying experience	22,637 hours
Total hours on type	4,586 hours
Flying in last 24 hours	Nil
Flying in last 7 days	23 hours 28 minutes
Flying in last 28 days	56 hours 01 minute

Flying in last 90 days	93 hours 18 minutes
Duty time in past 48 hours	Nil

1.5.2 First Officer (FO)

Gender	Male
Age	40
Licence	Airline Transport Pilot Licence (ATPL)
Issuing Authority	Civil Aviation Authority of Singapore
Licence validity	31 August 2020
Medical certificate	Class 1
Total flying experience	6,067 hours
Total hours on type	5,837 hours
Flying in last 24 hours	Nil
Flying in last 7 days	10 hours 46 minutes
Flying in last 28 days	20 hours 30 minutes
Flying in last 90 days	126 hours 17 minutes
Duty time in past 48 hours	Nil

1.6 Aircraft information

1.6.1 After the aircraft had flown back to Singapore on 13 December 2019, a check on the operation, rigging[6] and travel limits of the aircraft flight controls were performed. There was no evidence to suggest that the aileron, rudder, elevator, leading/trailing flaps and spoilers could have contributed to the approach incident in Auckland.

1.7 Meteorological information

1.7.1 At the time of the approach incident, the wind at Auckland Airport was about six to seven knots from the southeast, a direction almost perpendicular to Runway 05R.

1.7.2 The runway surface condition was dry during the approach incident.

[6] The B747-400 is not a fly-by-wire aircraft and still uses cables pullies, and linkages for some control surface movement. The cables were checked for alignment of aircraft flight control surfaces and correct tension to obtain proper flight characteristics.

1.8 Aids to navigation

1.8.1 During the time of the approach incident, the Instrument Landing System at Auckland Airport was operating normally and no fault was reported.

1.9 Aerodrome information

1.9.1 According to Auckland Airport's airfield lighting reports, the runway lightings were operating normally during the approach incident.

1.9.2 The landing distance available for Runway 05R was 3,292m and the runway width was 45m.

1.10 Flight recorders

1.10.1 The aircraft's Cockpit Voice Recorder (CVR), Flight Data Recorder (FDR) and Quick Access Recorder (QAR) data were available to the investigation team for analysis.

1.11 Additional information

1.11.1 'Touchdown-in-a-crab' crosswind landing technique

1.11.1.1 The 'touchdown-in-a-crab' technique was one of three crosswind landing techniques recommended by the aircraft manufacturer in its Flight Crew Training Manual (FCTM). The other two techniques were the de-crab (with removal of crab in flare) technique and the sideslip technique. This FCTM had been adopted by the operator.

1.11.1.2 According to the FCTM, when using this technique:

- Pilots should maintain approaching the runway at a crabbed angle all the way until the touchdown;
- Pilots should aim at having the main landing gears touch down on the centre of the runway; and
- Once the aircraft had touched down, the force dynamics would be such as to de-crab the aircraft and make it aligned with the runway direction.

1.11.2 Training in crosswind landing techniques

1.11.2.1 According to the operator, it had adopted a competency-based training and assessment system in which the training programme was structured to ensure that, at the completion of training, pilot trainees would be able to execute safe crosswind landings. The operator expected that pilot trainees would have had some exposure to the three crosswind landing techniques during their training and flying career and that most instructors would use any available opportunity to teach the three techniques.

1.11.2.2 The operator expected all its pilots to be competent in the three crosswind landing techniques recommended by the FCTM. According to the PIC, he had learnt all the three techniques during his training days and he was conversant with all the three landing techniques. However, he had never been assessed during simulator checks on the 'touchdown-in-a-crab' technique. This was because during simulator checks, pilots were given a crosswind scenario and it was up to the pilots to use whichever technique they liked to show to the check instructor that they could land the aircraft successfully. In the PIC's case, he had never used the 'touchdown-in-a-crab' technique during a simulator check. The incident approach was the first time the PIC chose to use the 'touchdown-in-a-crab' technique in line flying but he said he was confident he could execute it without difficulty.

1.11.3 Operator's Flight Data Analysis Programme

1.11.3.1 The aircraft operator had a Flight Data Analysis Programme (FDAP) to monitor and analyse flight data from its fleet of aircraft. The FDAP aimed at improving safety through the regular and routine analysis of flight data to ensure that the operator's standard operating procedures (SOPs) were being adhered to in flight operations and at detecting operational deviations which could be precursors to a more significant safety event such as an accident.

1.11.3.2 A parameter that the FDAP was monitoring was the aircraft bank angle during landing. At the time of the approach incident, a flight would be flagged out for FDAP analysis if the aircraft had banked more than 9° when it was within 10ft from ground and within 10sec from touchdown.

1.11.3.3 Prior to this approach incident, the FDAP had captured only one other similar event of aircraft banking more than 9° when it was within 10ft from ground and within 10sec from touchdown[7].

[7] An engine pod strike event by the same aircraft in Sydney, Australia on 28 November 2019 which was being investigated by the Australian Transport Safety Bureau. Between these two events, the aircraft operated nine flights, with no aircraft handling issue reported.

1.11.4 Aircraft's tendency to pitch up upon landing

1.11.4.1 According to the FCTM:

(a) the pitch attitude of the aircraft would increase slightly during landing even if the control column input (i.e. the pull force on the control column) was kept constant;

(b) there could be a tail strike if the pitch attitude was maintained or increased after landing; and

(c) the speedbrakes would induce further pitching up of the aircraft if they were deployed upon landing while the aircraft was pitching up.

1.11.4.2 The FDR data showed that, upon touchdown, the control column input (i.e. the pull force on the control column) was relatively constant and that the speedbrakes were deployed soon after touchdown.

2 ANALYSIS

The investigation team looked into the following:

a. Cause of the engine ground strike

b. Crosswind landing techniques

c. Assessment of pilot competency in crosswind landing techniques

d. Flight data analysis programme

2.1 Cause of the engine ground strike

2.1.1 As mentioned in paragraph 1.1.5, the aircraft pitched up shortly after touchdown. The FDR data showed that, upon touchdown, the control column input (i.e. the pull force on the control column) was relatively constant and that the speedbrakes were deployed soon after touchdown. As identified in the FCTM (see paragraph 1.11.4.1), the constancy of the column control input and the deployment of the speedbrakes would result in pitching up of the aircraft.

2.1.2 The PIC said that he lost sight of the runway end lights when the aircraft pitched up and sensed that the aircraft bounced (even though the aircraft did not bounce). The disappearing of the runway end lights made him believe that the aircraft was momentarily airborne.

2.1.3 Believing that the aircraft was airborne and sensing that the aircraft was moving towards the right edge of the runway (FDR data showed that the aircraft was tracking towards the right after touchdown), the PIC called for a go-around and manually increased the throttles, while applying at the same time left aileron to roll the aircraft towards the left to align the aircraft with the runway heading.

2.1.4 The investigation team believed that it was at this moment that the No. 1 engine struck the runway because of the aircraft's bank angle (which the FDR data showed to be about 7°), resulting in what appeared to ATC to be sparks coming from the left wing of the aircraft.

2.1.5 The investigation considered whether the Blackhole Effect[8] could possibly explain why the PIC sensed that the aircraft had bounced but concluded that it was unlikely as the aircraft had already touched down on the runway. Moreover, the flight recorder data showed that the aircraft remained on the

[8] The Blackhole Effect, which affects pilots during the approach phase of the flight, is a visual illusion that may cause pilots flying a visual approach to think that they are above the ideal approach path, i.e. higher than they actually are. This results in pilots typically flying the aircraft below the intended glideslope. Typically, the Black Effect is associated with a lack of visual cues in the vicinity of the runway while approaching the runway.

ideal glidepath from 2,000ft until it touched down. The lack of visual cues in the vicinity of the runway, even if it had been the case in this approach incident, would not have had an effect to the PIC when the aircraft was on the runway.

2.2 Crosswind landing

2.2.1 To deal with the crosswind, the PIC opted to use the 'touchdown-in-a-crab' technique. However, while he was aware that the FCTM had stipulated that pilots should aim at having the main landing gears touch down on the centre of the runway, he decided that he should aim at having the main landing gears touch down slightly to the right of the runway centreline. He believed this would allow a greater margin of safety from an excursion off the left edge of the runway should the aircraft be forced downwind during touchdown.

2.2.2 While this consideration of the PIC seemed plausible, touching down with the main landing gears to the right of the runway centreline would mean that there was a reduced margin of safety from an excursion off the right edge of the runway. It would appear prudent to adhere to the FCTM's guidance of having the main landing gears touch down on the centre of the runway.

2.3 Assessment of pilot's handling skills in crosswind landing

2.3.1 The operator expected all its pilots to be competent in the three crosswind landing techniques recommended by the FCTM. Pilots were trained on all the three techniques, but when it came to crosswind technique assessment during simulator checks, the operator would provide a crosswind scenario and let pilots use whichever technique they liked to show to the check instructor that they could land the aircraft successfully. The incident approach was the first time the PIC chose to use the 'touchdown-in-a-crab' technique in line flying and he had never used this technique during simulator checks. It seemed desirable that the operator require all its pilots to demonstrate that they can apply all the three crosswind landing techniques during simulator checks to ensure that pilots are competent in the three crosswind landing techniques[9].

2.4 Flight Data Analysis Programme (FDAP)

2.4.1 A parameter that the FDAP was monitoring was the aircraft bank angle during landing. At the time of the approach incident, a flight would be flagged out for

[9] The operator's internal investigation has also identified that crosswind landing training can be further refined.

FDAP analysis if the aircraft had banked more than 9° when it was within 10ft from ground and within 10sec from touchdown.

2.4.2 The operator considered that since a typical flare phase lasts between 5sec and 7sec, monitoring the roll of the aircraft 10sec from touchdown was sufficient to identify any abnormal aircraft rolls during landings. However, if an aircraft was below 10ft and had rolled more than 9° but thereafter maintained wings level and landed more than 10sec later, the event would not be captured by the FDAP.

2.4.3 Prior to this approach incident, the FDAP had captured only one other similar event of aircraft banking more than 9° when it was within 10ft from ground and within 10sec from touchdown. It is not known whether there were marginal cases (e.g. involving a bank angle of 7° or 8°, or more than 9° but with aircraft landing more than 10sec later). It may be desirable for the operator to modify the data capture criteria in order to have a bigger data pool of this parameter for analysis.

3 CONCLUSIONS

From the information gathered, the following findings are made. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

3.1 While the operator indicated that it had adopted a competency-based training and assessment system to ensure that, at the completion of training, pilot trainees would be able to execute safe crosswind landings, the investigation team noted that, during simulator checks, it was up to the pilot trainees to use whichever technique they liked to land the aircraft successfully in a crosswind scenario. They were not required to demonstrate during simulator checks that they are able to apply all the three crosswind landing techniques.

3.2 The incident approach was the first time the PIC chose to use the 'touchdown-in-a-crab' technique in line flying.

3.3 The aircraft pitched up shortly after touchdown. This was probably the result of the constancy of the column control input and the deployment of the speedbrakes, as identified in the Flight Crew Training Manual.

3.4 The PIC lost sight of the runway end lights and believed that the aircraft had momentarily become airborne even though the aircraft had remained on ground.

3.5 As the aircraft tracked towards the right after touchdown and believing that the aircraft was airborne, the PIC applied left aileron to align the aircraft with the runway centreline. This caused the left wing to bank to the left and the No. 1 engine to scrape the runway.

3.6 The operator was aware of the hazard of banking an aircraft when the aircraft was very close to the ground and had in place a Flight Data Analysis Programme (FDAP) which looked for abnormal aircraft roll during landing. The FDAP would capture abnormal aircraft roll during landing events only if it occurred within 10sec from touchdown. Other than this approach incident and another engine pod strike occurrence on 28 Nov 2019, there had been no other abnormal aircraft roll events captured.

4 SAFETY ACTIONS

Arising from discussions with the investigation team, the aircraft operator has taken the following safety action.

4.1 From 6 May 2020, the operator reduced the roll angle threshold to capture abnormal roll during landing in the Flight Data Analysis Programme from 9^{o} to 7^{o} when the aircraft was below 10ft, regardless of whether this occurs within 10sec from touchdown or not.

4.2 The operator will implement a requirement in December 2020 whereby pilots will be asked to demonstrate during simulator checks that they are able to apply all the three crosswind landing techniques recommended in the aircraft manufacturer's Flight Crew Training Manual.

5 SAFETY RECOMMENDATION

A safety recommendation is for the purpose of preventive action and shall in no case create a presumption of blame or liability.

5.1 It is recommended that the operator remind its pilots that:

(a) the pitch attitude of the aircraft will increase slightly during landing;

(b) the speedbrakes would induce further pitching up of the aircraft if they are deployed upon landing while the aircraft was pitching up; and

(c) any excessive aileron input when the aircraft is close to the runway may result in a roll exceedance and engine contacting the runway.

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