FINAL REPORT

RUNWAY EXCURSION INVOLVING
BOEING 777-200, REGISTRATION 9V-SRN
SINGAPORE CHANGI AIRPORT
28 Feb 2009

AIB/AAI/CAS.057

Air Accident Investigation Bureau of Singapore
Ministry of Transport
Singapore

29 October 2010

The Air Accident Investigation Bureau of Singapore

The Air Accident Investigation Bureau (AAIB) is the air accidents and incidents investigation authority in Singapore responsible to the Ministry of Transport. Its mission is to promote aviation safety through the conduct of independent and objective investigations into air accidents and incidents.

The AAIB conducts the investigations in accordance with the Singapore Air Navigation (Investigation of Accidents and Incidents) Order 2003 and Annex 13 to the Convention on International Civil Aviation, which governs how member States of the International Civil Aviation Organization (ICAO) conduct aircraft accident investigations internationally.

In carrying out the investigations, the AAIB will adhere to ICAO's stated objective, which is as follows:

> *"The sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability."*

CONTENTS

GLOSSARY OF ABBREVIATION

AIS	:	Aeronautical Information Service
ATCO	:	Air Traffic Control Officer
ATIS	:	Automated Terminal Information Service
CAAS	:	Civil Aviation Authority of Singapore
COP	:	Crew Operating Pattern
CVR	:	Cockpit Voice Recorder
DME	:	Distance Measuring Equipment
FDR	:	Flight Data Recorder
FO	:	First Officer
GTOW	:	Gross Take-off Weight
ILS	:	Instrument Landing System
mb	:	millibars (atmospheric pressure)
NOTAM	:	Notice To Airmen
OAT	:	Outside Air Temperature
PF	:	Pilot Flying
PIC	:	Pilot-in-Command
PNF	:	Pilot not flying
QAR	:	Quick Access Recorder
QNH	:	Altitude above mean sea level based on local station pressure
SO	:	Second Officer
SUC	:	Supervisory Captain
UTC	:	Universal Time Coordinate
VHF	:	Very High Frequency
VOR	:	VHF Omni-directional Range

SYNOPSIS

At about 8.54 pm on 28 February 2009, a Boeing B777-200 aircraft landing on Runway 02L at Singapore Changi Airport veered to the right side of the runway after touchdown. The right main landing gear departed the paved runway surface momentarily during the landing roll. The Pilot-in-Command immediately took over control from the Second Officer who had performed the landing and steered the aircraft back to the centre of the runway. Two runway edge lights were damaged. The aircraft sustained cuts on two of the wheels on the right main gear. There were minor damages to the electrical harness underneath the landing gear. No passengers or crew were injured.

The Air Accident investigation Bureau of Singapore classified this occurrence as an incident.

AIRCRAFT DETAILS

Aircraft type:	Boeing B777-200
Aircraft registration:	9V-SRN
Numbers and type of engines:	2 Rolls Royce Trent 800
Type of flight:	Scheduled passenger flight
Date and time of incident:	28 February 2009, 2058 hours local time
Place of accident:	Singapore Changi Airport
Runway in use:	02L
Phase of flight:	Landing
Persons on board:	289

1 FACTUAL INFORMATION

Unless otherwise stated, all times quoted in this report are based on Singapore local time, which is 8 hours ahead of Coordinated Universal Time (UTC).

1.1 History of the flight

1.1.1 The flight crew had operated to Perth the day before and had a short layover of 24 hours before reporting for this flight. They reached the airport at 1545 hours Perth local time and prepared for the flight. The Second Officer (SO) occupied the right hand seat and was the pilot flying (PF). The Pilot-in-Command (PIC) was the pilot monitoring. The SO was on line training under the supervision of the PIC who was also a Supervisory Captain (SUC). The PIC and SO had flown together for a few sectors prior to this incident and were familiar and comfortable working with each other. (The SO said to the investigation team that he had no qualms voicing his views during the flight.) With them in the cockpit was a First Officer (FO) acting as a safety pilot. The FO was occupying an observer seat.

1.1.2 The flight took off from Perth at 1658 hours local time and flew to Singapore without any incident. At about 90 minutes before the estimated arrival time of 2100 hours, the crew tuned into the Singapore Automated Terminal Information System (ATIS) and noted ATIS "S" at 1930 hours advising of thunderstorm observed in the north of the airport and moving in a south-easterly direction. The validity period of the thunderstorm warning was from 1910 to 2010 hours. Prior to descent, the crew again listened to the ATIS and noted ATIS "U" at 2000 hours advising that the thunderstorm was still moving in a south-easterly direction and that there were light showers around Changi Airport. The runway in use for landing was 02L.

1.1.3 During the descent, the crew listened to the ATIS again and noted ATIS "Y" broadcasting thunderstorm with heavy rain over Changi Airport. The validity period of the thunderstorm warning was from 2030 to 2115 hours. The SO noted that their arrival time was within that thunderstorm forecast period. The PIC highlighted that there could be windshear during approach and that they would react according to the windshear discussion that they had earlier[1]. The PIC also highlighted the weather located in the northwest area of Changi Airport.

1.1.4 During the final approach at 2,500 ft, Approach Control advised the crew that a preceding aircraft had reported a tailwind of 15 knots on landing at runway 02L and that the current wind was 240° at 10 knots. Approach Control asked if they could accept that for landing. The PIC accepted it as the aircraft's allowable tailwind limit for landing was 15 knots.

1.1.5 The PIC interpreted the wind speed change from 15 knots tailwind to 10 knots wind at 240° (i.e. about 8 knots tailwind) as an indication that the wind was subsiding. And since the aircraft was still a distance away from

[1] The PIC had briefed on the crew actions required on encountering windshear. The crew actions cover four areas: avoidance, precaution, recognition and recovery.

landing, he decided to let the SO proceed with the approach. He monitored the situation as the aircraft descended and waited for the weather update from ATC during the landing clearance before deciding whether to take over, to let the SO land, or to conduct a missed approach. The PIC had also overheard on the radio that one other flight did not accept the 15 knots tailwind for landing and had discontinued its approach. The PIC did not let the decision of this other flight affect his decision to proceed with the approach as he was aware that it was a different aircraft type.

1.1.6 According to the Singapore Air Traffic Service Manual (ATSM), tailwind limit for any selected runway in use shall not be more than 5 knots. Runway direction change was initiated at 2048 hours. At that time, there were three aircraft that were in queue to land on Runway 02L (the incident aircraft followed by two A320s) and Approach Controller advised them of the 15 knots tailwind experienced by a preceding landing. Approach Control also advised them that the wind speed was 10 knots at 240°. The two A320 aircraft[2] behind the incident aircraft did not accept the wind speed for landing and discontinued their approach and were subsequently re-vectored to land on runway 20C.

1.1.7 At 2,000 ft, landing clearance was given by Changi Tower with mention of wind speed of 8 knots at 230° (i.e. about 7 knots tailwind) with rain over the airfield and with mention of wet runway surface. The PIC continued to let the SO fly the aircraft as the SO was flying well and the wind condition had improved. The PIC stated that he had flown five sectors with the SO over the last eight days. The SO had landed in similar wind condition and the PIC was comfortable with letting the SO handle that landing.

1.1.8 The PIC had observed from his weather radar display that there was no weather cell on the aircraft's approach path but there were weather cells to the north of Changi Airport and in the aircraft's missed approach path. He highlighted this to the SO.

1.1.9 At 1,000 ft, the aircraft began to drift slightly right of the localiser and was slightly below glideslope. The PIC immediately shouted to verbalise the situation and manoeuvre instruction to the SO: "centreline, centreline, follow your flight director". The SO made corrections and regained the localiser and glideslope. The approach was flown with no further deviations from the localiser and glideslope until the flare.

1.1.10 The flare occurred at about 50 feet. The wind speed at 40 feet was 6 knots at 268° (crosswind of 5.4 knots and tailwind of 2.5 knots) and at 31 feet was 8 knots at 267° (crosswind of 7.2 knots and tailwind of 3.5 knots). At touchdown, the wind was 16 knots at 266° (crosswind of 14.3 knots and a tailwind of 7.3 knots). The aircraft took seven seconds to descend from 31 feet to touchdown during which the crosswind increased from 7.2 knots to 14.3 knots. Both the PIC and SO stated that at 40 feet, the left wing started to rise as the aircraft began to drift towards the right.

1.1.11 The PIC tried to arrest the drift by banking the aircraft to the left but felt a

[2] A320's allowable tailwind limit is 10 knots.

resistance on his control wheel. The PIC subsequently applied a stronger control wheel force. He had wanted to initiate a go around, but the aircraft had already touched down firmly and continued to deviate to the right of the runway[3]. The right main gear exited the runway pavement and the PIC immediately steered the aircraft back to the centreline with a left rudder pedal input. The PIC suspected that the right main gear might have hit some of the runway edge lights when it exited the runway pavement.

1.1.12 The SO was aware of the three crosswind techniques presented in the operator's Flight Crew Training Manual. They are the touchdown in crab technique, the de-crab technique (removal of crab in flare) and the sideslip technique. During the landing, the SO used the touchdown in crab technique.

1.1.13 From the FDR data, the aircraft landed in the crab position (18° to the left of runway heading). When the aircraft started to drift to the right during the flare, the SO tried to arrest the drift and did not execute the de-crab manoeuvre on touchdown. From the Quick Access Recorder (QAR) data that was analysed by Boeing, there appeared to be dual inputs from both the PIC and SO during the entire landing phase. The control column and rudder pedal forces[4] recorded by the FDR indicated that the PIC exerted most of the forces during the entire phase of the landing. As the force data of only the captain's control wheel was recorded, the control wheel force applied by the SO, if any, cannot be determined.

1.1.14 When asked if he intended to take over control during the onset of the drift, the PIC stated that he did not intend to take over. His intention was to assist the SO and so he did not verbalise "I have control". The PIC felt that this was more expedient in arresting the situation under the circumstances than taking over the control.

1.1.15 The aircraft landed with its longitudinal axis at about 18° to the left of runway heading due to correction for the left crosswind component. The aircraft touched down at about 518 m (1750 feet) from Runway 02L's threshold. The right main gear touched down near the right runway edge. The tyre marks corresponding to the right main gear ran from the right runway edge line to the runway pavement edge and then exited onto the grass area owing to the momentum of the aircraft's drift.

1.1.16 The right main gear hit and damaged one runway elevated edge light as the aircraft exited the runway (**Figures 1** and **2**) and rolled on the grass patch for about 92 m before re-entering the runway at the intersection of Taxiway W7 and Runway 02L.

[3] The PIC's reaction was to bring the aircraft back to the centreline. He believed that it would be a safer option to steer the aircraft back to the centreline since it had already touched down.

[4] Both the left and right hand control column and rudder pedal forces were measured and recorded in the FDR. The control wheel forces were only measured and recorded from the left control wheel, thus it is not possible to determine which pilot was applying the lateral input during the flare.

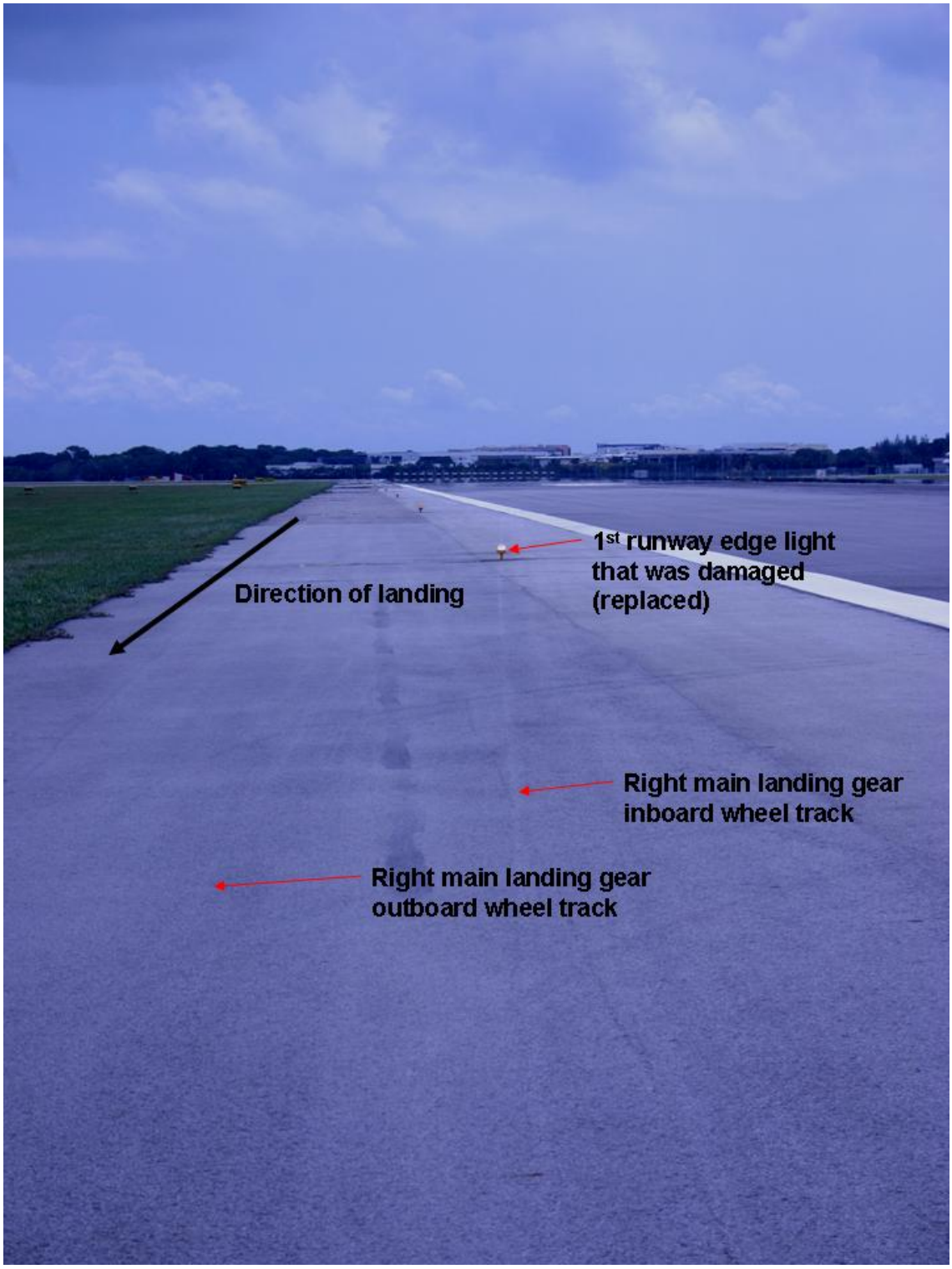

Figure 1: Wheel track of right main landing gear (looking against the direction of landing)

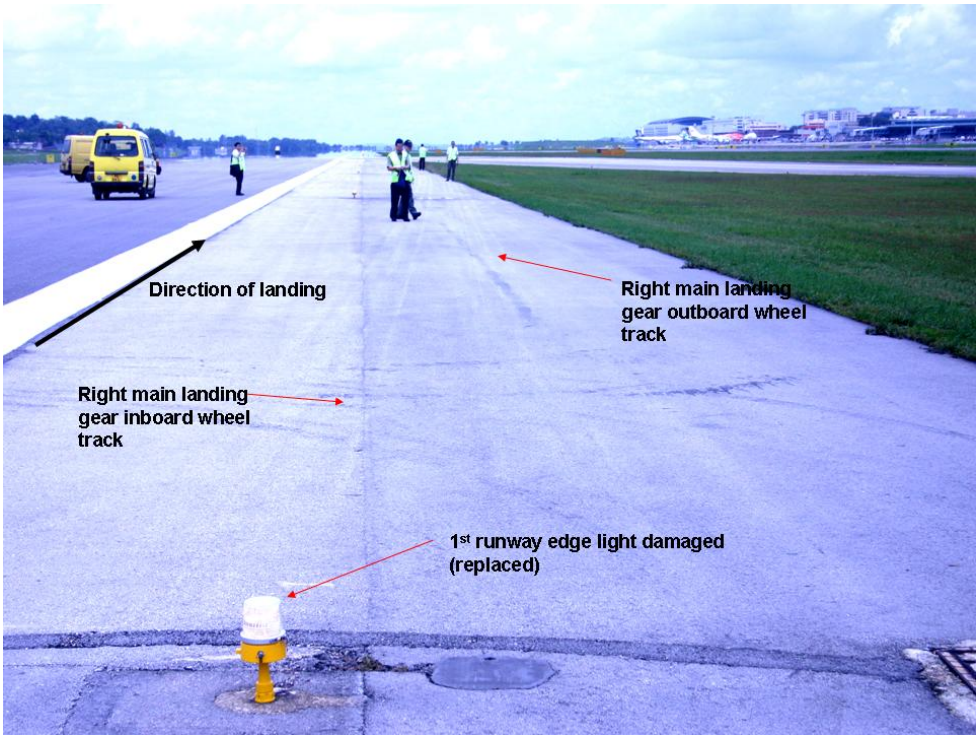

Figure 2: Wheel track of right main landing gear (looking in the direction of landing)

1.1.17 The maximum displacement of the right main gear from the runway pavement edge is 2.1 m (**Figure 3**). As the aircraft returned to the runway centreline, the right main gear's inboard wheels hit and damaged a second elevated runway edge light (**Figure 4**).

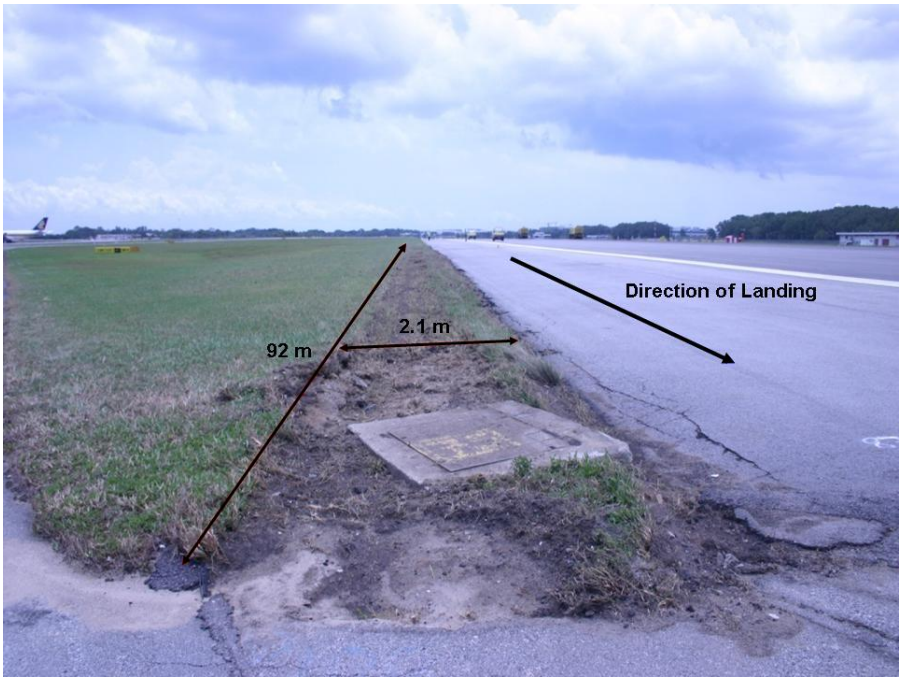

Figure 3: Wheel track on grass patch adjacent to runway edge (looking against the direction of landing)

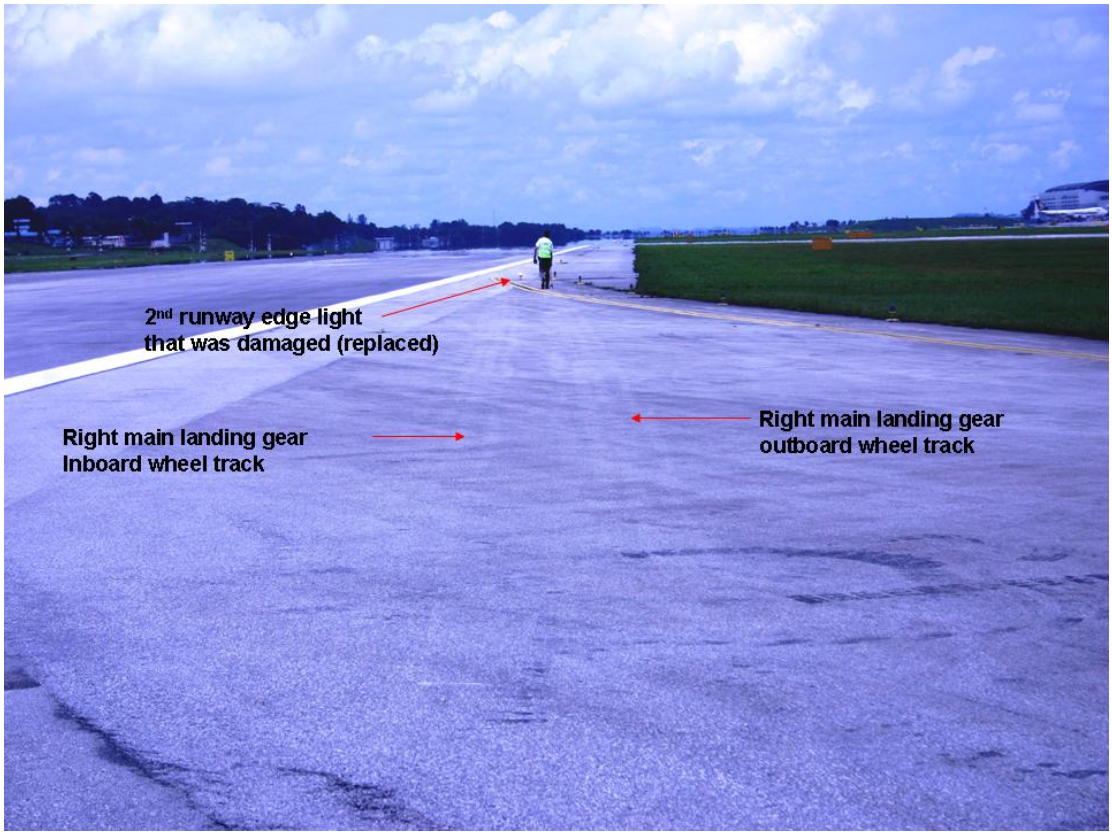

Figure 4: Wheel track of right landing gear on intersection of W7 Taxiway and runway (looking in the direction of landing)

1.1.18 The SO stated that prior to touching down, a sudden gust of wind caused the right wing to dip low and the PIC immediately took over the control. The SO did not consider going around. All three flight crew members recalled that the PIC shouted "I have control" as he took over the control. After the PIC had taken over, the SO stated that he had continued to keep two fingers (right hand) lightly on the control wheel to feel the PIC's manoeuvre and learn his manoeuvre techniques. However, the cockpit voice recording shows that the PIC only announced that he was taking over control (to steer the aircraft back to the runway centreline) after the aircraft had landed.

1.1.19 After turning off from the runway, the PIC immediately instructed the SO to contact the tower to advise that they had landed to the right side of the runway and might have damaged some runway edge lights.

1.2 Injuries to persons

1.2.1 There was no injury to any person in this incident.

1.3 Damage to aircraft

1.3.1 Wheel tyres # 4 and # 11 sustained deep cuts (**Figures 5**, **6** and **7**). There was no deflation of any tyre. There was no sign aquaplaning.

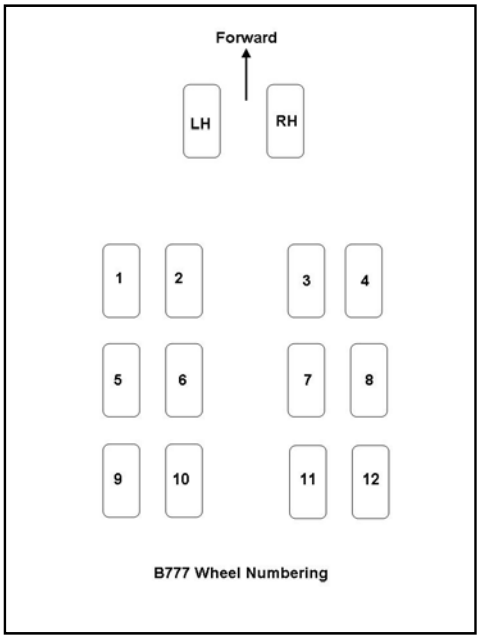

Figure 5: B777 wheel numbering system

Figure 6: Number 4 tyre cuts

Figure 7: Number 11 tyre cuts

1.3.2 The right main landing gear's left hand brake temperature wire harness support bracket was found distorted and # 7 brake temperature harness damaged (**Figure 8**).

Figure 8: Damaged brake temperature harness

1.4 **Personnel information**

1.4.1 Pilot-in-Command

Gender:	Male
Age:	35
Nationality:	Malaysian
Licence:	Airline Transport Pilot Licence issued by the Civil Aviation Authority of Singapore
Aircraft rating:	Beechcraft Baron 58/ Learjet 31/ Airbus A310/ Boeing 747-400/ Boeing 777
Medical certificate:	Date of examination -12 September 2008 Class 1 Medical certificate Nil limitation
Last base check:	3 January 2009
Last line Check:	14 January 2009
Rest period before flight:	24 hours layover in Perth
Duty time before incident:	6 hours 9 minutes
Flight time before incident:	4 hours 52 minutes
Total flying experience:	9,371 hours (3,185 hours on B777 as Pilot-in-Command)
Flying in last 24 hours:	4 hours 52 minutes
Flying in last 28 days:	63 hours 15 minutes
Flying in last 90 days:	211 hours 18 minutes

1.4.2 First Officer

Gender:	Male
Age:	26
Nationality:	Malaysian
Licence:	Commercial Pilot Licence issued by the Civil Aviation Authority of Singapore
Aircraft rating:	Beechcraft Baron 58/ Boeing 777
Medical certificate:	Date of examination - 3 June 2008 Class 1 Medical certification Nil limitation
Last base check:	14 December 2008
Last line check:	25 December 2008
Rest period before flight:	24 hours layover in Perth
Duty time before incident:	6 hours 9 minutes
Flight time before incident:	4 hours 52 minutes
Total flying experience:	753 hours 34 minutes (528 hours 41 minutes on B777)
Flying in last 24 hours:	4 hours 52 minutes
Flying in last 30 days:	61 hours 31 minutes
Flying in last 90 days:	146 hours 11minutes

1.4.3 Second Officer

Gender:	Male
Age:	28
Nationality:	Singaporean
License:	Commercial Pilot License issued by the Civil Aviation Authority of Singapore
Aircraft rating:	Beechcraft Baron 58/ Boeing 777
Medical certificate:	Date of examination - 13 August 2008 Class 1 Medical certificate Nil limitation
Last base check:	23 January 2009
Last line check:	14 January 2009
Rest period before flight:	24 hours layover in Perth
Duty time before incident:	6 hours 9 minutes
Flight time before incident:	4 hours 52 minutes
Total flying experience:	616 hours 12 minutes (268 hours 41 minutes on B777)
Flying in last 24 hours:	4 hours 52 minutes
Flying in last 30 days:	59 hours 28 minutes
Flying in last 90 days:	139 hours 50 minutes

1.5 **Aircraft Information**

1.5.1 The aircraft was serviceable and had a valid certificate of airworthiness.

1.5.2 Maintenance records of the aircraft shows no pre-existing fault in antiskid system or the autobrake system.

1.6 **Meteorological information**

1.6.1 The flight crew tuned in to the ATIS to update themselves of the weather situation on three occasions (ATIS “S”, “U” and “Y”).

1.6.2 ATIS “S” contained the following:

- SINGAPORE CHANGI AIRPORT ATIS INFO SIERRA METAR 1130 HOUR
- WIND 090 DEGREES 03 KNOTS DIRECTION VARIABLE BETWEEN 010 AND 170 DEGREES
- MODERATE THUNDERSTORM
- FEW TOWERING CUMULUS 1500 FEET
- TEMPERATURE 27
- DEW POINT 25
- QNH 1007
- BECOMING TILL 1200 NIL SIGNIFICANT WEATHER
- WSSS AERODROME WARNING 7 VALID FROM 1110 TILL 1210
- THUNDERSTORM OBSERVED IN NORTH APCH
- FORECAST MOVING SSE AT 8 KNOTS AND AFFECT AERODROME NO CHANGE

1.6.3 ATIS “U” contained the following:

- SINGAPORE CHANGI AIRPORT ATIS INFO UNIFORM METAR 1200 HOUR
- WIND CALM
- THUNDERSTORM WITH LIGHT RAIN
- FEW TOWERING CUMULUS 1500 FEET
- TEMPERATURE 27
- DEW POINT 25
- QNH 1007
- BECOMING TILL 1230 LIGHT SHOWERS OF RAIN
- WSSS AERODROME WARNING 7 VALID FROM 1110 TILL 1210
- THUNDERSTORM OBSERVED IN NORTH APCH
- FORECAST MOVING SSE AT 8 KNOTS AND AFFECT AERODROME NO CHANGE

1.6.4 ATIS “Y” contained the following:

- SINGAPORE CHANGI AIRPORT ATIS INFO YANKEE METAR 1230 HOUR
- RAIN OVER AIRFIELD RUNWAY SURFACE WET
- WIND VARIABLE 02 KNOTS
- FEW TOWERING CUMULUS 1800 FEET
- TEMPERATURE 27
- DEW POINT 24
- QNH 1007
- RECENT THUNDERSTORM
- TEMPO TILL 1330 WIND 300 DEGREES 15 KNOTS GUSTING TO 25 KNOTS

- THUNDERSTORM WITH HEAVY RAIN
- FEW 800 FEET
- SCATTERED CB 1000 FEET
- WSSS AERODROME WARNING 9 VALID FROM 1230 TILL 1315
- THUNDERSTORM FORECAST OVER AERODROME
- FORECAST MOVING SOUTH EAST AT 8 KNOTS AND AFFECT NORTH AND SOUTH APCH INTENSIFYING

1.6.5 At the time of the incident, ATIS "A" was active and contained the following:

- SINGAPORE CHANGI AIRPORT ATIS INFO ALPHA SPECI 1245 HOUR
- RAIN OVER AIRFIELD RUNWAY SURFACE WET
- WIND VARIABLE 04 KNOTS
- THUNDERSTORM WITH HEAVY RAIN
- BROKEN TOWERING CUMULUS 1600 FEET
- TEMPERATURE 26
- DEW POINT 25
- QNH 1008
- TEMPO TILL 1330 WIND 300 DEGREES 15 KNOTS GUSTING TO 25 KNOTS
- BECOMING FROM 1430 NIL SIGNIFICANT WEATHER
- WSSS AERODROME WARNING 9 VALID FROM 1230 TILL 1315
- THUNDERSTORM FORECAST OVER AERODROME
- FORECAST MOVING SOUTH EAST AT 8 KNOTS AND AFFECT NORTH AND SOUTH APCH INTENSIFYING

1.7 Aids to navigation

1.7.1 All navigation aids at Changi Airport required for aircraft operations were working normally at the time of the incident.

1.8 Communications

1.8.1 Communications between the flight crew and ATC were normal.

1.9 Aerodrome information

1.9.1 Runway 02L of Changi Airport has a length of 4,000 m and a width of 60 m. The surface of the runway is paved with bituminous concrete and is constructed with traverse slope of 1.5 percent to permit rapid drainage of water. The 3 m shoulders on both sides of the runway were extended to 7.5 m to meet the requirement for Airbus A380, and are sloped at 2.5 percent. On both sides of the runway are flat grass areas sloped at 2.5 percent that drain into a large drainage system at about 130 m away from the edge of Runway 02L. In addition, there are sub-soil drains in place beneath the runway edge to speed up the flow of water seeping into the soil.

1.10 Flight recorders

1.10.1 The Digital Flight Data Recorder (DFDR) and the Cockpit Voice Recorder (CVR) were removed intact by the operator and sent to the AAIB for readout.

1.10.2 The Honeywell solid state memory DFDR (part number: 980-4700-042 serial number: SSFDR 09579) was downloaded and the data were useful for investigation.

1.10.3 The L3 FA2100 CVR (part number: 2100-1020-00/ serial number: 000217003) with a recording duration of two hours was downloaded. The quality of the recording was good and the data were useful for the investigation.

1.11 Medical and pathological information

1.11.1 Both the PIC and the SO were sent for medical/toxicological examination following the incident. The examination results were normal.

1.12 Additional Information

1.12.1 Threat assessment and error management

1.12.1.1 The PIC carried out the descent briefing. The Risk Awareness Tool in the B777 Quick Reference Handbook (QRH) was reviewed by all crew members. ATIS weather information was updated three times during descent. The PIC also included windshear in his briefing and highlighted the location of the weather cells along the missed approach path as indicated on the aircraft's weather radar display. The PIC also reminded the SO of the prevailing wind condition and to expect possible wind direction shifts. Even though the PIC had identified during the descent that the weather and changing wind condition could pose a threat, he did not consider them as a factor requiring him to take over the flying from the SO.

1.12.2 Flight crew training

1.12.2.1 The PIC stated that he was trained by the operator to always guard the control even when flying with qualified FOs. During training flights with SO assuming PF duty, the PIC would keep his hand on the control wheel lightly to guide and assist the SO[5]. The placement of hands should be so light as not to cause any hindrance to the pilot flying. In this way, the SO under training could then have the exposure to develop confidence in handling the aircraft in difficult weather condition. The operator's flight crew training department stated that instructor pilots are trained to guard the control by keeping their hands close to the control wheel but not by

[5] The purpose for the PIC to keep his hands on the control is to have a tactile feel of what the SO is doing, thus enabling him to take over control of the aircraft more quickly should the need arise.

keeping their fingers on the control wheel when trainee pilots were flying. The operator did not capture this in any documentation because it deemed this to be a basic skill on the part of the instructor pilot.

1.12.2.2 Anecdotal accounts suggest that it is not an uncommon practice for instructor pilots to keep their hands lightly on the control when trainee pilots are flying the aircraft. In this incident, instead of keeping his hand lightly on the control, the PIC had exerted input throughout the landing phase to assist the SO in flying. When the drift occurred, the PIC tried to assist the SO in arresting the drift by providing a control input. However, the input was not effective because the SO was also controlling.

1.12.2.3 When asked what the weather limits for allowing a line training SO to act as a PF were, the PIC indicated that the operator did not set any limits for SO, but he would apply the same limits for FO to the SO as he believed this was consistent with the aim of training SO to be competent FO. However, he would let a SO handle the aircraft in difficult conditions only if he felt that the SO was competent enough. The operator requires SUCs to carry out risk assessment in deciding whether to allow an SO to perform PF duty, taking into account factors such as the SO's experience level, aircraft technical status, airport services and equipment, airport environment such as visibility, cloud level, prevailing weather, wind and runway condition, etc.

1.12.2.4 The PIC had been a captain for three and a half years and had been appointed a SUC for 11 months. The operator's flight instruction manual indicated that trainee SUCs will have to undergo the Flight Instructor Development Programme (FIDP) course to equip them with necessary teaching skill. A copy of flight instruction manual was provided to SUC trainees as guidance material for training.

1.12.2.5 The FIDP course involves classroom training, one simulator training detail with an Assistant Chief Pilot (ACP) and two training sectors. In the simulator, trainee SUC will be trained to recognise potentially unsafe situation or deviation from an intended flight path during critical flight phases. The ACP will assume the role of a trainee pilot and the trainee SUC will be required to take corrective action or recovery action from situations. Trainee SUCs are trained to identify and recover from:

- Unstable take-off run
- Fast rotation, early rotation and over rotation for take-off at R.T.O.W.[6]
- Very light weight take-off
- Off centreline and high/low glideslope approaches
- Fast or early retardation of thrust during flare
- Bounced landing
- Maximum crosswind take-off and landing

1.12.2.6 The trainee SUC will fly two sectors under the supervision of an ACP. The first sector is for the ACP to observe the trainee SUC when a FO or SO performs pilot-not-flying (PNF) duties and the second sector when a FO or

[6] Regulated Take-Off Weight - max permissible take-off weight (below MTOW), varying according to flaps setting, altitude, air temperature, length of runway and other factors.

SO performs the PF duties.

1.12.2.7 The operator's flight Instruction manual described the duties of a SUC as follows:

- Conduct line training for FOs and SOs
- Assist in the development of FOs and SOs
- Submit Confidential Command Qualities Assessment (CCQA) reports on the operating co-pilots in line flights

1.12.2.8 According to the operator's B777 Deputy Chief Pilot, the safety of the flight is of paramount importance and training of pilots will only be a secondary priority. SUCs are instructed to take over the flying whenever there is any doubt or slightest indication that a SO may have difficulty executing any manoeuvre or when flying condition deteriorates.

2 Analysis

The analysis by the investigation team covered the following areas:

a) Weather and decision to land
b) Pilots' action
c) Guarding of controls

2.1 Weather and decision to land

2.1.1 During the aircraft's descent at about 2,500 ft, Approach Control advised the flight crew of the incident aircraft and two other flights that a preceding flight that had landed on Runway 02L reported a tailwind of 15 knots[7]. Approach Control asked if they could accept the tailwind condition for landing. The PIC decided to continue with the approach to land on 02L because 15 knots was within his aircraft type's tailwind limit. The other two flights chose to discontinue the approach and were re-vectored to Runway 20R.

2.1.2 The PIC overheard on the radio that one of the flights declined to land on 02L. The PIC did not let the decision of this other flight affect him as he was aware that it was a different aircraft type. The reported wind condition appeared to have improved and as it was still a distance away from landing, the PIC decided to proceed with the approach and would conduct a missed approach should the condition deteriorate.

2.1.2.1 The PIC had in his earlier descent briefing identified that the weather and changing wind condition could pose a threat. At 2,000 ft, the landing clearance was given by Changi Tower with updates of wind speed of 8 knots at 230°, rain over the airfield and wet runway surface. Based on this updated wind condition, the PIC felt that the wind condition had improved and that the SO could handle the landing.

2.1.3 The operator provides guidelines for PICs on weather limits for allowing FO to act as PF. However, there are no guidelines provided to the PICs on weather limits for SOs to act as PF. In the absence of guidelines, the PIC exercised his discretion in letting the SO continue flying after considering the reported wind condition (which appeared to be improving) and his assessment of the SO's competency. However, the decision made may vary from one PIC to another due to individual PIC's experience level and confidence in letting SOs act as PF. Published guidelines on weather limits for SOs would have provided guidance to the PICs in making consistent decision on

[7] At that time tower had already decided to change the runway to 20R and was repositioning aircraft.

when to let SOs perform PF duties or when to take over control of the aircraft.

2.2 Pilots' action

2.2.1 Throughout the landing phase, both pilots' hands were on their respective control wheels and the PIC was assisting the SO in the flying. When the drift occurred at 31 feet, the PIC reacted quickly with the intention to help the SO bring the aircraft back to the runway centreline but he did not verbalise the taking over of control from the SO. The PIC also did not exercise assertiveness in verbalising the situation and correction manoeuvre to the SO (he did verbalise the situation and manoeuvre instruction to the SO at 1000 ft when the aircraft drifted out of centreline). Both pilots reacted to the drift, with the PIC exerting most of the forces on the control as recorded by the FDR. However, the PIC's input was impeded by resistance due to the input of the SO and the drift was not arrested.

2.2.2 The aircraft took seven seconds to descend from 31 feet to touchdown during which the aircraft drifted to the right and exited the runway shortly after touchdown. The onset of the drift was not arrested and it developed into an unstable situation. In their preoccupation to arrest the drift, both pilots did not recognise the development of the unstable situation and did not activate the go-around option.

2.3 Guarding of control

2.3.1 According to the operator, instructor pilots were trained to guard the control by keeping their hands close to the control wheel but not touching it. But according to the PIC in this case, he was trained to guard the control by keeping his fingers lightly on the control wheel when trainee pilots were flying. There is a difference between what the operator expected its instructor pilots to do and what the PIC did.

3 FINDINGS

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

3.1 The flight crew was properly rested and fatigue was not a factor.

3.2 The airport approach lights, lighting facilities and runway condition did not contribute to the incident.

3.3 There was forecast of thunderstorm and rain over the airport and the runway was wet.

3.4 The PIC interpreted that wind condition had improved following update by tower that wind speed had dropped to 8 knots at 230° and he allowed the SO to continue the approach to land even though there was a forecast of thunderstorm with heavy rain over the aerodrome.

3.5 The operator did not publish weather limits for SO as pilot flying.

3.6 The increase in crosswind component of the wind caused the aircraft to drift off the runway centreline when it was over the threshold.

3.7 The flight crew did not react effectively to the crosswind which was increasing progressively as the aircraft crossed over the threshold.

3.8 The PIC tried to assist the SO during the flare by applying corrections on the aircraft controls when the aircraft started to drift to the right but the PIC did not intend to take over.

3.9 The PIC's practice in guarding the control was different from what the operator expected its instructor pilots to do.

3.10 Neither the PIC nor the SO initiated a go-around when the aircraft began to drift to the right of the runway at about 40 feet above ground.

4 SAFETY ACTIONS

During the course of the investigation, the following safety actions were initiated by the operator.

4.1 The operator has established and implemented weather limits for SOs on take-off, approach and landing. The range of the weather limits within which the SOs may operate will be progressively increased in the course of training as SOs gain more operational experience.

4.2 The operator has issued a Technical Crew Circular to all its flight crews to:

- re-iterate the need to be assertive and to comply with all Standard Operating Procedures (SOP) for taking and handing over of control for all phases of flight; and to
- re-emphasise its go-around policy.

4.3 The operator has required its flight crews to brief on taking and handing over of controls during approach or landing (as is done for take-off) as part of the descent and approach briefing.

4.4 The operator has included this incident as a case study in its Crew Resource Management/ Threat and Error Management (CRM/TEM) programme during flight crew recurrent training sessions to highlight the dynamic situation of unstabilised approach.

4.5 The operator has required the flight crew concern to undergo reinforcement training programme as recommended by the Civil Aviation Authority of Singapore. The reinforcement training programme included the following:

- Approach and landing accident reduction principles
- Crosswind landing techniques
- Adherence to the operator's SOP in taking and handing over of aircraft

5 SAFETY RECOMMENDATION

It is recommended that:

5.1 The operator review its requirements concerning the guarding of controls and ensure that its requirements are understood by its instructor pilots. [AAIB Recommendation R-2010-001]