Australian Government
Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT
Occurrence Investigation Report AO-2007-001
Final

Microburst event
Sydney Airport, NSW
15 April 2007
VH-OJR
Boeing Company 747-438

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Abstract

On 15 April 2007, a Boeing Company 747-438 aircraft, registered VH-OJR, was being operated on a scheduled passenger flight from Singapore to Sydney, NSW. On board the aircraft were 19 crew and 355 passengers. At 1923 Eastern Standard Time, the aircraft was about 100 ft above ground level prior to landing on runway 16 Right (16R) when it encountered a significant and rapid change in wind conditions. The aircraft touched down heavily and the windshear warning sounded in the cockpit. The crew conducted the windshear escape manoeuvre and made a second approach and landing.

The airport was under the influence a line of high-based thunderstorms associated with light, intermittent rain. Investigation revealed that the aircraft was influenced by outflow descending from a high-based storm cell that developed into a microburst. The airport did not have a windshear warning system. Pilots of aircraft operating on the reciprocal runway had previously reported moderate windshear to air traffic control, and the surface wind conditions had changed rapidly. However, that information was not communicated to the occurrence aircraft by air traffic control.

In response to this occurrence, the Bureau of Meteorology commenced a Sydney Airport Wind Shear Study to assess options for providing the aviation industry with low altitude windshear alerts. That study is scheduled for completion in April 2010.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory Agency. The Bureau is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not a function of the ATSB to apportion blame or determine liability. However, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

When safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation, the person, organisation or agency must provide a written response within 90 days. That response must indicate whether the person, organisation or agency accepts the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

TERMINOLOGY USED IN THIS REPORT

Occurrence: accident or incident.

Safety factor: an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include the occurrence events (e.g. engine failure, signal passed at danger, grounding), individual actions (e.g. errors and violations), local conditions, risk controls and organisational influences.

Contributing safety factor: a safety factor that, if it had not occurred or existed at the relevant time, then either: (a) the occurrence would probably not have occurred; or (b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or (c) another contributing safety factor would probably not have occurred or existed.

Other safety factor: a safety factor identified during an occurrence investigation which did not meet the definition of contributing safety factor but was still considered to be important to communicate in an investigation report.

Other key finding: any finding, other than that associated with safety factors, considered important to include in an investigation report. Such findings may resolve ambiguity or controversy, describe possible scenarios or safety factors when firm safety factor findings were not able to be made, or note events or conditions which 'saved the day' or played an important role in reducing the risk associated with an occurrence.

Safety issue: a safety factor that (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a specific point in time.

Safety issues can broadly be classified in terms of their level of risk as follows:

- Critical safety issue: associated with an intolerable level of risk.
- Significant safety issue: associated with a risk level regarded as acceptable only if it is kept as low as reasonably practicable.
- Minor safety issue: associated with a broadly acceptable level of risk.

1 FACTUAL INFORMATION

1.1 History of the flight

On 15 April 2007, a Boeing Company 747-438 (747) aircraft, registered VH-OJR, was being operated on a scheduled passenger flight from Singapore to Sydney, NSW. On board the aircraft were 19 crew and 355 passengers. The flight crew consisted of a pilot in command (PIC), a copilot, and two relief pilots. The copilot was the flying pilot. At 1923 Eastern Standard Time[1], the aircraft was about 100 ft above ground level (AGL) prior to landing on runway 16 Right (16R), when it encountered a significant and rapid change in wind conditions. The aircraft touched down heavily and the windshear warning sounded in the cockpit. The crew conducted a windshear escape manoeuvre[2] and made a second approach and landing.

At the time of the aircraft's departure from Singapore, there were no weather-related operational requirements in effect for the estimated arrival time at Sydney. Around the time that the aircraft crossed the coastline of north-west Australia, company operations personnel advised the flight crew that there would be a 30-minute weather-related holding requirement for their arrival at Sydney.

Shortly before commencing descent, the crew reviewed the 1830 METAR[3] for Sydney. That report indicated that the wind at Sydney was 030^{o} True (T) at 17 kts and that there were thunderstorms 18 NM (33 km) south-west, which were moving east-north-east at 15 kts. The associated trend type forecast (TTF) indicated that between 1830 and 2000[4], there would be 30-minute periods during which thunderstorms, rain, and associated low visibility and cloud would be present.

Table 1 chronicles the aircraft's arrival into Sydney, along with related events and information during that period, including:

- information about other arriving and departing aircraft
- weather information
- weather and operational information that was provided to pilots by air traffic control (ATC) agencies
- weather and operational information that was not provided to pilots by ATC agencies.

1 The 24-hour clock is used in this report to describe the local time of day, Eastern Standard Time (EST), as particular events occurred. Eastern Standard Time was Coordinated Universal Time (UTC) + 10 hours.

2 A maximum-rate manoeuvre by a flight crew in order for the aircraft to achieve a speed and flightpath that maintained terrain clearance.

3 Routine weather report.

4 Last light was at 1759.

Table 1: Sequence of events

Local time	Event
1829:40	The aircraft was radar identified at 178 NM (330 km) north-west of Parkes, NSW.
1837.00	Sydney Automatic Terminal Information Service (ATIS) PAPA was issued and stated: Expect [an] instrument landing system (ILS) approach then independent visual approach when visual. Runways 34 Left (34L) and Right (34R) for arrivals and departures. Wind direction 030° at 15 kts, crosswind 12 kts. Visibility greater than 10 km. Showers in the area. Cloud one to two oktas[5] at 4,000 ft. Temperature 23° [C] and QNH[6] 1015 [hectapascals]. *Comment: No significant weather was included on ATIS PAPA.*
1857.28	The aircraft was cleared for descent by ATC and assigned the arrival procedure for runway 34 Left.
1902.04	The pilot of an aircraft that landed on runway 34 L, reported overshoot windshear between 1,500 and 700 ft above mean sea level (AMSL) and moderate turbulence above 1,500 ft. The aerodrome controller west (ADC WEST) passed that information to the aerodrome controller east (ADC EAST[7]). The ADC EAST subsequently provided directed information regarding the windshear to a number of arriving and pre-departure aircraft.
1904.14	The ADC WEST controller reported to the traffic director controller (DIR) that the wind at Kurnell was indicating a southerly, but at the airport the wind was still indicating a northerly.
1904:19	The pilot of an aircraft that landed on runway 34R reported experiencing moderate overshoot windshear during the approach.
1905.42	An aircraft on approach for runway 34R went around due to a windshear warning.
1906:22	The wind conditions caused the flight crew of the aircraft that went around on runway 34R at 1905:42 to require a higher level as the aircraft was experiencing difficulties maintaining 3,000 ft. In addition, the pilot reported '...that wind is pushing us up'. *Comment: These windshear reports were not passed to the Bureau of Meteorology (BoM) by ATC. The crew of VH-OJR were on a*

5 Unit of visible sky area representing one-eighth of the total area visible to the celestial horizon.

6 The QNH barometric setting is referenced to mean sea level so that an aircraft altimeter will indicate the height above mean sea level.

7 The ADC EAST was the aerodrome controller responsible for controlling aircraft using runway 34R/16 Left (16L). ADC WEST was the aerodrome controller responsible for controlling aircraft using runway 34 Left/16R.

different radio frequency at the time of those reports, and were unaware that an aircraft had conducted a go-around due to windshear.

1907.18 The pilot of an aircraft on final approach for runway 34L reported the wind as 230° at 5 kts.

1907.25 The crew of VH-OJR transferred to the approach control (APP) frequency and reported descending through flight level (FL) 160 and in receipt of ATIS PAPA. APP informed the crew to expect a visual approach and a visual left circuit for runway 34L.

1907.58 The ADC WEST controller passed information regarding the reported windshear and variability of the surface wind to the pilot of an aircraft taxiing for takeoff.

Comment: VH-OJR was on APP frequency at that time.

1908.00 ATIS QUEBEC was issued and stated:

> Expect ILS [instrument landing system] approach then independent visual approach when visual. Runways 34L and 34R for arrivals and departures. Wind 030° at 15 kts, crosswind 12 kts. Visibility greater than 10 km. Showers in the area. Cloud one to two oktas at 4,000 ft. Temperature 23° [C] and QNH 1016. Significant weather - [a] Boeing 737 reports moderate overshoot shear on final at 1,000 ft.

1908.20 The crew of VH-OJR asked APP for an appreciation of the weather in the terminal area. APP responded 'Standby'.

1908.48 The DIR broadcast that ATIS QUEBEC was now current and advised the differences to the previous ATIS. Those changes were: QNH 1016 and that a Boeing 737 had reported moderate overshoot shear on final at 1,000 ft.

Comment: The crew of VH-OJR were on the APP frequency at that time.

1909:14 When provided with the wind and shear conditions by ADC EAST, the crew of a departing aircraft elected not to take off from runway 34R and taxied off the runway.

Comment: VH-OJR was on the APP frequency on that time.

1909.25 The ADC WEST controller advised the crew of an aircraft taxiing for takeoff from runway 34L that the surface wind indication at the runway 34R threshold had just changed from a light northerly to a southerly at up to 20 kts. That crew accepted the downwind conditions and subsequently took off from runway 34L.

Comment: VH-OJR was on the APP frequency at that time.

1910.25 The crew of an aircraft on final for runway 34R reported going around to ADC East. Approaches for runway 34 were then cancelled by ATC.

Comment: VH-OJR was on the APP frequency at that time.

1910.32 The APP controller made a general broadcast that there were cumulo-nimbus clouds (thunderstorms) in the area, there was 20 kts downwind on all runways, and that the duty runway would be advised shortly.

Comment: VH-OJR was on the APP frequency at that time.

1911.30 The APP controller instructed the crew of VH-OJR to descend to 7,000 ft.

1911.30 The crew of VH-OJR asked whether approaches were still being processed.

1911.33 The duty runway was changed to runway 16.

Comment: There were no runway arrivals or departures to or from runways 34 and 16 between 1911:00 and 1915:38.

1911.36 The APP controller advised the crew of VH-OJR that the duty runway was being changed to runway 16.

1911.47 The APP controller advised the crew VH-OJR to expect to track via right downwind for runway 16R.

1912:10 The crew of VH-OJR requested a turn onto 330° within the next 3 to 4 NM. APP approved the turn.

1913.00 New ATIS ROMEO was issued and stated that:

> Runways 16R and 16L, wind was 190° at 10 to 20 kts, visibility greater than 10 km, showers in the area, cloud one to two oktas at 4,000 ft, temperature 23° C and QNH 1017.

Comment: No significant weather was included in ATIS ROMEO.

1914.10 The APP controller instructed the crew of VH-OJR to descend to 6,000 ft.

1914.22 The APP controller advised that ATIS ROMEO was current, and broadcast the differences to the previous ATIS, including: Expect independent visual approach runway 16L and 16R for arrivals and departures, the wind was 190° at 10 to 20 kts and QNH 1017.

1916.35 The crew of VH-OJR transferred to the DIR frequency.

1916.43 The DIR instructed the crew of VH-OJR to descend to 5,000 ft.

1917:18 The pilot of the first aircraft to arrive using runway 16L contacted ADC EAST and was advised that:

> ...there's a southerly moving through the field, it's to the 16R threshold at the moment...aloft, you may still have a northerly breeze...request a wind readout at 1,000 thanks...lightning at the field...threshold wind is showing 190° at 20 kts, crosswind 12 kts, runway 16L cleared to land.

Comment: That pilot advised there was nil wind at 1,000 ft.

1917.28	The DIR instructed the crew of VH-OJR to descend to 3,000 ft and to advise when they were visual.
1917.50	The first aircraft, after the change to runway 16, reported ready for takeoff on runway 16R. *Comment: Only one aircraft departed from runway 16R prior to the arrival of VH-OJR. VH-OJR was the first arrival to runway 16R following the runway change from runway 34.*
1918.00	ATIS SIERRA was issued and stated: Expect independent visual approach when visual. Runways 16L and 16R for arrivals and departures. Wind 190° at 10 to 20 kts, visibility greater than 10 km, showers in the area, cumulonimbus clouds in the area, cloud one to two oktas at 4,000 ft, temperature 22° C, QNH 1017. Significant weather - expect windshear below 3,000 ft. *Comment: Significant weather (the windshear hazard) was mentioned in the ATIS.*
1918.20	ADC WEST advised the crew of a taxiing aircraft that the wind at the runway 16 threshold was 220° at 15 kts and 190° at 6 kts at the southern end. *Comment: VH-OJR was on the DIR frequency at that time*
1919.00	VH-OJR was instructed to intercept the localiser runway 16R.
1919.10	The DIR advised all aircraft that information SIERRA was now current and that it was the same as ATIS ROMEO, with the addition of advice that there were cumulonimbus clouds in the area, and that pilots should expect windshear below 3,000 ft. *Comment: VH-OJR was on DIR frequency*
1919.44	The DIR instructed the flight crew of VH-OJR to descend to 2,100 ft and cleared the pilots for an ILS approach to runway 16R.
1919.50	The ADC WEST advised the crew of an aircraft about to depart Sydney that the wind at the runway 16R threshold was 100° at 8 kts. *Comment: VH-OJR was on DIR and was at 3,000 ft.*
1920:17	The crew of the first aircraft to land on runway 16L, after the runway change, reported to ADC-EAST that they experienced 'quite a bit of shear' on final approach. The crew did not specify the type or severity of the shear. *Comment: VH-OJR was on DIR frequency and was at 2,700 ft altitude at that time.*
1920:20	The ADC EAST advised ADC WEST of the windshear report he had received at 1920:17 from the pilot on the ADC EAST frequency. *Comment: VH-OJR was on DIR frequency at that time.*

1920:25	The ADC WEST advised a pilot of an aircraft about to depart runway 16R that the wind direction was varying from south-westerly to south-easterly at up to 15 kts.
	Comment: VH-OJR was on DIR frequency.
1920.51	The crew of VH-OJR reported to the DIR that they were visual.
1920.55	The DIR re-cleared VH-OJR for a visual approach to runway 16R, and advised that the aircraft was number one in the landing sequence and instructed the crew to call Sydney Tower [ADC WEST].
1921:04	*Comment: VH-OJR was passing 1,900 ft altitude and was 2 minutes 12 seconds from touchdown*.
1921:27	*Comment: VH-OJR was passing 1,540 ft and was 1 minute 49 seconds from touchdown.*
1921:34	The crew of a departing aircraft advised ADC WEST that there was a thunderstorm cell about 8 NM (15 km) south of the airport.
1921:38	Following a request by ADC EAST for additional information, the crew that reported at 1920:17 that they had experienced windshear on final approach, advised there was initially overshoot and then undershoot windshear at 100 ft when landing on runway 16L .
	Comment: This information was not notified to ADC WEST. The Tower Traffic Management Coordinator did not pass the information to BoM.
1921:54	The crew of an arriving aircraft for runway 16L contacted ADC EAST and was advised that the wind was 100° at 5 kts and warned about the overshoot and undershoot shear.
	Comment: The crew of VH-OJR were transferring from the DIR frequency to ADC WEST at that time.
1922:06	The crew of VH-OJR contacted ADC WEST and reported on final approach for runway 16R (at about 3 NM (6 km) from touchdown).
1922:10	The ADC WEST advised the crew that the wind at the landing threshold was 180° at 22 kts, issued a clearance for the aircraft to land, and requested a wind readout from the aircraft.
1922:15	The crew reported that the wind at 1,000 ft was a 20 kt tailwind.
1922:18	The pilots of VH-OJR disconnected the autopilot. The copilot requested a continuous call-out of the wind and the PIC advised that the wind was calm.
	Comment: VH-OJR was passing 780 ft and was 58 seconds from touchdown at that time.
1922:28	The PIC advised the crew that there was a 10 kt headwind.
1922:35	The aircraft passed 500 ft radio altitude on descent and the PIC called that the approach was stable. The pilots later recalled hearing on the ATIS that the pilot of a preceding aircraft had reported moderate overshoot windshear at 1,000 ft. They experienced a 15 to

20 kt tailwind at 1,000 ft, which then subsided and, by the time the aircraft descended through 500 ft, there was a 15 kt headwind. They considered that VH-OJR had transitioned through the reported overshoot windshear by that stage. The crew reported that the approach was stable and that there was no indication of any unusual conditions ahead.

1922:43 The PIC advised the crew that the crosswind from the right was increasing.

1922:58 The PIC advised the crew that they still had a headwind, which was slightly from the right.

1923:10 The aircraft descended through 120 ft radio altitude.

1923:14 The aircraft descended through 50 ft radio altitude.

1923:15 The ADC-WEST advised the pilot of the aircraft that was on final approach behind VH-OJR that:

> ...the wind at the upwind end of [runway 25] two five is indicating 030° at 16 kts...now er it's all over the place at the moment but that will give you [at] the upwind end at 10 kts or 11 kts downwind'

1923:15 The PIC advised the crew that the airspeed was reducing. As the copilot initiated the flare for landing, the PIC had the sensation of the aircraft being pushed down and sideways. The copilot recalled a similar sensation at about 50 ft altitude, and hearing the windshear alert at the same time.

1923:16 The rate of descent did not diminish despite an increase in aircraft pitch and thrust, and the aircraft touched down firmly on the main landing gear. Just after the touchdown, the aircraft's enhanced ground proximity warning system (EGPWS) (see Section 1.6.1 - EGPWS) sounded a windshear alert and the PIC took control of the aircraft and initiated a go-around. The crew thought that the PIC took control of the aircraft at about the time of the initial touchdown and initiated the windshear escape manoeuvre. Recorded flight data showed a rapid forward movement of the engine thrust levers within 2 seconds of the initial touchdown. The PIC said that he did not select the TOGA[8] switches but adopted the quicker method of manually advancing the thrust levers to achieve go-around thrust. The crew recalled that the aircraft touched down heavily, left wing low. They were unanimous in the view that a go-around was the appropriate response to the situation. During a later interview, the PIC could not recall hearing the windshear alert, but the two relief pilots did recall hearing the windshear alert.

1923:20 The ADC EAST advised the crew of an arriving aircraft that the wind was 060° at 5 kts with a 2 kt downwind component, and issued a clearance to land. That pilot later reported experiencing about 20 kts of overshoot shear at between 1,500 and 2,000 ft.

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8 Takeoff and go round thrust setting. The maximum thrust that the engines will supply.

1923:36	The crew of an aircraft that had reported ready for takeoff cancelled the ready report to ADC WEST and advised that he would hold '...until the wind settles down a bit.'
1925:13	The aircraft on final approach following VH-OJR conducted a missed approach from 300 ft. The crew advised that there was a 13 kt tailwind and a windshear on the approach.
1929:00	New ATIS SIERRA was issued and stated:

> Expect ILS approach then independent visual approach when visual. Runways 34L and 34R for arrivals and departures. Surface condition wet, wind variable at 10 downwind 5 kts, visibility greater than 10 km, showers in the area.

1940:00	VH-OJR landed on runway 34L.

1.2 Injuries to persons

There were no reported injuries to passengers or crew.

1.3 Damage to the aircraft

During the event, ceiling panels above seat rows 34, 35, and 50 in the aircraft cabin were dislodged, and those above seat rows 51 and 52 were partly dislodged. The emergency lights in the ceiling panels above rows 48 and 51 were also dislodged. None of those fittings were damaged and they were able to be resecured via their normal attachments.

The recorded rate of descent immediately prior to touchdown, was about 820 feet per minute (fpm). The maximum acceleration value recorded at the initial touchdown was 2.34 g[9]. The aircraft manufacturer's hard landing inspection criteria[10] required that a structural inspection be performed when the vertical acceleration exceeded 1.8 g (for a vertical acceleration sampling rate of 16 samples/second).

The operator advised that a *Heavy Landing Phase One* inspection of the aircraft was conducted following the event in accordance with the manufacturer's aircraft maintenance manual. That inspection did not reveal any abnormalities.

1.4 Personnel information

The PIC had 18,666 hours total flying experience, and had been flying 747-400 aircraft for 8 years. The copilot had 16,972 hours total flying experience and had been flying 747 aircraft for 9 years.

The operator advised that, in the previous 8 months, both the PIC and the copilot had completed three recurrent simulator training exercises. Two of those simulator exercises included sequences involving windshear/microburst training. Windshear

9 Acceleration due to the earth's gravity. In smooth, level flight, an aircraft is affected by 1 g.

10 Boeing document B-YB70-All-M00-001 dated 31 October 2000.

avoidance, precautions, and recovery were among the discussion items in one of the exercises. Both the PIC and the copilot had successfully completed that training.

1.5 On-board windshear alert systems

There were two systems that could be fitted to 747 aircraft to provide windshear warning advice. One was incorporated into the 747's enhanced ground proximity warning system (EGPWS) and was reactive, while the other was associated with the 747's weather radar system and was predictive.

1.5.1 Enhanced Ground Proximity Windshear Alert system

The aircraft was equipped with an EGPWS that incorporated a windshear alert system.

The EGPWS incorporated an alert system that reacted to changes in the aircraft's speed and acceleration. Windshear alerts were enabled below 1,500 ft radio altitude, and were triggered if an increasing headwind (or decreasing tailwind) and/or downdraft exceeded defined thresholds.

A Windshear Caution triggered the illumination of amber Windshear Caution lights on the cockpit instrument panel and was accompanied by an aural message **'CAUTION, WINDSHEAR'**. The lights remained on for as long as the aircraft was exposed to conditions in excess of the caution alert threshold.

A Windshear Warning triggered the illumination of red Windshear Warning lights on the cockpit instrument panel and an aural siren followed by the message '**WINDSHEAR, WINDSHEAR, WINDSHEAR**'. The lights remained on for as long as the aircraft was exposed to conditions in excess of the warning alert threshold. The aural message was not repeated unless another separate windshear event was encountered.

1.5.2 Predictive windshear warning system

The aircraft did not have a predictive windshear warning system fitted.

The weather radar system fitted to 747 aircraft has the capacity to incorporate predictive warning of windshear. The radar measures changes in the velocity of air moisture or particulate matter ahead of the aircraft and could detect windshear up to about 2.5 km ahead of the aircraft. Of the operator's thirty three 747 aircraft, 12 were equipped with the system.

The operator's 747-400 Flight Crew Operating Manual (FCOM) included the following note regarding the system:

> Weather radar detects microbursts and other windshears with similar characteristics. Weather radar does not provide alerting for all types of windshear. The Flight Crew must continue to rely on traditional windshear avoidance methods.

1.6 Meteorological information

1.6.1 Meteorological forecasts and reports

The Bureau of Meteorology (BoM) issued forecasts and reports of expected weather conditions at aerodromes.

Aviation weather forecasts included aerodrome forecasts (TAFs), and trend type forecasts (TTFs). A TAF was a statement of expected weather conditions within a radius of 5 NM (9 km) of the centre of the aerodrome runway complex for the duration of the specified period. A TTF was an aerodrome weather report to which a statement of the expected weather trend over the subsequent 3 hrs was appended.

Aerodrome weather reports were observations of actual meteorological conditions at aerodromes. Routine reports (METARs) at Sydney Airport were issued half hourly and were broadcast on the very high frequency (VHF) Automatic En Route Information Service. Special reports (SPECIs)[11] were issued whenever weather conditions fluctuated about or were below, specified criteria.

1.6.2 Information from Bureau of Meteorology

A detailed report was provided by BoM (Appendix A) on the meteorological situation and weather forecasts associated with the occurrence, along with a comprehensive analysis of the recorded weather information in the vicinity of Sydney Airport, and the wind data recorded by the aircraft's Quick Access Recorder[12]. That report included the following text:

> Wind Shear Warnings were not issued for the Airport because the risk of wind shear, which is a potential hazard associated with all thunderstorms, is implied when a forecast or warning of thunderstorms is issued. On this occasion, there were no real-time reports or observations of wind shear. And, apart from thunderstorms, there were no expectations of wind shear associated with any other phenomena.
>
> The Terminal Forecasts (TAF and TTF) issued after 0545Z indicated the potential for thunderstorms at Sydney Airport between 06Z and 10Z. However, because the thunderstorms were not anticipated to bring a significant increase in wind speed, the forecasts didn't indicate any significant wind variation with the thunderstorm change groups in the TAF or TTF. The weather observations, however, indicated that at times the thunderstorms did cause temporary fluctuations in the wind direction of up to 180º in variance with the forecast wind (see Appendix 1 and Appendix 3, between 09Z and 10Z). Although no significant increase (above the forecast) in wind speed was recorded, a forecast including a variable wind direction with the thunderstorms would have better represented the actual conditions that occurred at the Airport.

11 Special reports (SPECIs) were issued whenever weather conditions fluctuated about or were below, specified criteria.

12 See Section 1.10.

The report also included details of the changing weather pattern in the Sydney Airport area between 1900 and 2000 as a line of showers and thunderstorms moved across the airport. The report noted the following regarding that weather pattern:

- the line of showers and thunderstorms moved across the aerodrome from the south-west at 22 kts
- the showers and thunderstorms had a cloud base of around 12,000 ft
- there was only light intermittent precipitation, and no reduction in visibility
- at 1920, the leading edge of the line of showers and storms was over the aerodrome, and the anemometer data showed an intensifying divergent flow over the threshold of runway 16R, which was associated with a developing microburst[13]
- the microburst over the threshold of runway 16R was most intense between 1921:31 and 1922:00
- at 1923:01, the wind at the threshold had changed to a westerly at 12 kts, suggesting that the microburst had moved to the west of the runway 16R threshold (VH-OJR descended through 100 ft radio altitude at 1923.10 and landed at 1923.16).

1.6.3 Information from the flight crew

The flight crew provided the following information regarding their assessment and understanding of the weather situation during the approach:

- As the aircraft descended towards Sydney, the crew manipulated the weather radar to assess the vertical extent of the storms. The only significant build-up was south of Bundeena (greater than 15 km south of the airport). The radar showed no significant cells in the terminal area.
- As they were vectored on to the final approach, they were informed by ATC that a preceding aircraft had reported moderate overshoot windshear at 1,000 ft. The same information was on the ATIS.
- As the aircraft descended on final approach, they experienced a headwind of 15 to 20 kts at about 1,000 ft, but the wind then changed to calm and by 500 ft they were in conditions of a steady headwind.
- Nothing the crew had heard or seen indicated that they should expect anything abnormal during the remainder of the approach.

1.6.4 Microbursts

The US Federal Aviation Administration published the Aeronautical Information Manual (AIM) to provide the aviation community with general flight information.

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13 A very strong form of vertical wind gust, in which a vertical core of up to 2.5 km diameter forms a vertical 'jet' of air below convective cloud. That jet can have a downward velocity of up to 4,000 ft/min (20 m per second), or an almost instantaneous velocity difference of 80 kt, that acts down to the very low levels.

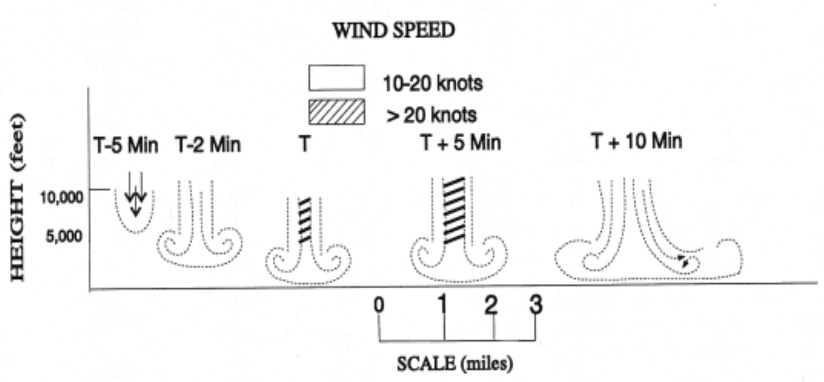
Chapter 7, Safety of Flight, Section 1-26[14]of that manual was titled Meteorology. It included the following information regarding microbursts:

7-1-26. Microbursts

a. Relatively recent meteorological studies have confirmed the existence of microburst phenomenon. Microbursts are small scale intense downdrafts which, on reaching the surface, spread outward in all directions from the downdraft center. This causes the presence of both vertical and horizontal wind shears that can be extremely hazardous to all types and categories of aircraft, especially at low altitudes. Due to their small size, short life span, and the fact that they can occur over areas without surface precipitation, microbursts are not easily detectable using conventional weather radar or wind shear alert systems.

b. Parent clouds producing microburst activity can be any of the low or middle layer convective cloud types. Note, however, that microbursts commonly occur within the heavy rain portion of thunderstorms, and in much weaker, benign appearing convective cells that have little or no precipitation reaching the ground.

FIG 7-1-13
Evolution of a Microburst



Vertical cross section of the evolution of a microburst wind field. T is the time of initial divergence at the surface. The shading refers to the vector wind speeds. Figure adapted from Wilson et al., 1984, Microburst Wind Structure and Evaluation of Doppler Radar for Wind Shear Detection, DOT/FAA Report No. DOT/FAA/PM-84/29, National Technical Information Service, Springfield, VA 37 pp.

c. The life cycle of a microburst as it descends in a convective rain shaft is seen in FIG 7-1-13. An important consideration for pilots is the fact that the microburst intensifies for about 5 minutes after it strikes the ground.

d. Characteristics of microbursts include:

1. Size. The microburst downdraft is typically less than 1 mile in diameter as it descends from the cloud base to about 1,000-3,000 feet above the ground. In the transition zone near the ground, the downdraft changes to a horizontal outflow that can extend to approximately 2 $^{1}/_{2}$ miles in diameter.

2. Intensity. The downdrafts can be as strong as 6,000 feet per minute. Horizontal winds near the surface can be as strong as 45 knots resulting in a 90 knot shear (headwind to tailwind change for a traversing aircraft) across the microburst. These strong horizontal winds occur within a few hundred feet of the ground.

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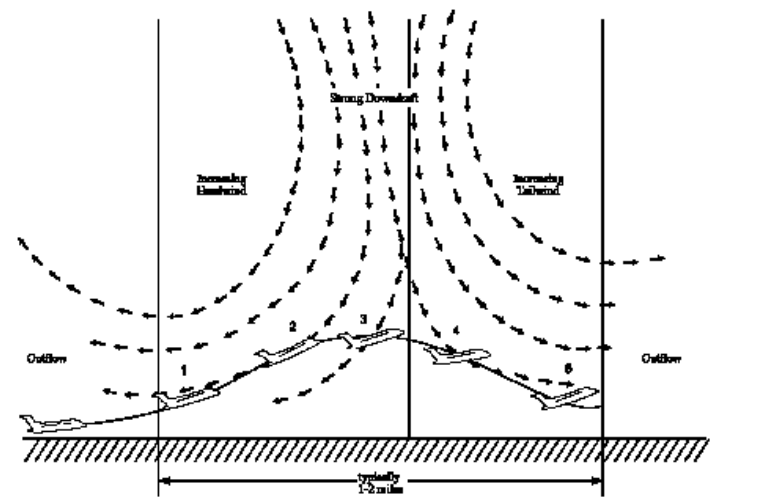
[14] Edition dated February 14, 2008.

3. Visual Signs. Microbursts can be found almost anywhere that there is convective activity. They may be embedded in heavy rain associated with a thunderstorm or in light rain in benign appearing virga. When there is little or no precipitation at the surface accompanying the microburst, a ring of blowing dust may be the only visual clue of its existence.

4. Duration. An individual microburst will seldom last longer than 15 minutes from the time it strikes the ground until dissipation. The horizontal winds continue to increase during the first 5 minutes with the maximum intensity winds lasting approximately 2-4 minutes. Sometimes microbursts are concentrated into a line structure, and under these conditions, activity may continue for as long as an hour. Once microburst activity starts, multiple microbursts in the same general area are not uncommon and should be expected.

FIG 7-1-14

Microburst Encounter During Takeoff



A microburst encounter during takeoff. The airplane first encounters a headwind and experiences increasing performance (1), this is followed in short succession by a decreasing headwind component (2), a downdraft (3), and finally a strong tailwind (4), where 2 through 5 all result in decreasing performance of the airplane. Position (5) represents an extreme situation just prior to impact. Figure courtesy of Walter Frost, FWG Associates, Inc., Tullahoma, Tennessee.

e. Microburst wind shear may create a severe hazard for aircraft within 1,000 feet of the ground, particularly during the approach to landing and landing and take-off phases. The impact of a microburst on aircraft which have the unfortunate experience of penetrating one is characterized in FIG 7-1-14. The aircraft may encounter a headwind (performance increasing) followed by a downdraft and tailwind (both performance decreasing), possibly resulting in terrain impact.

1.7 Communications

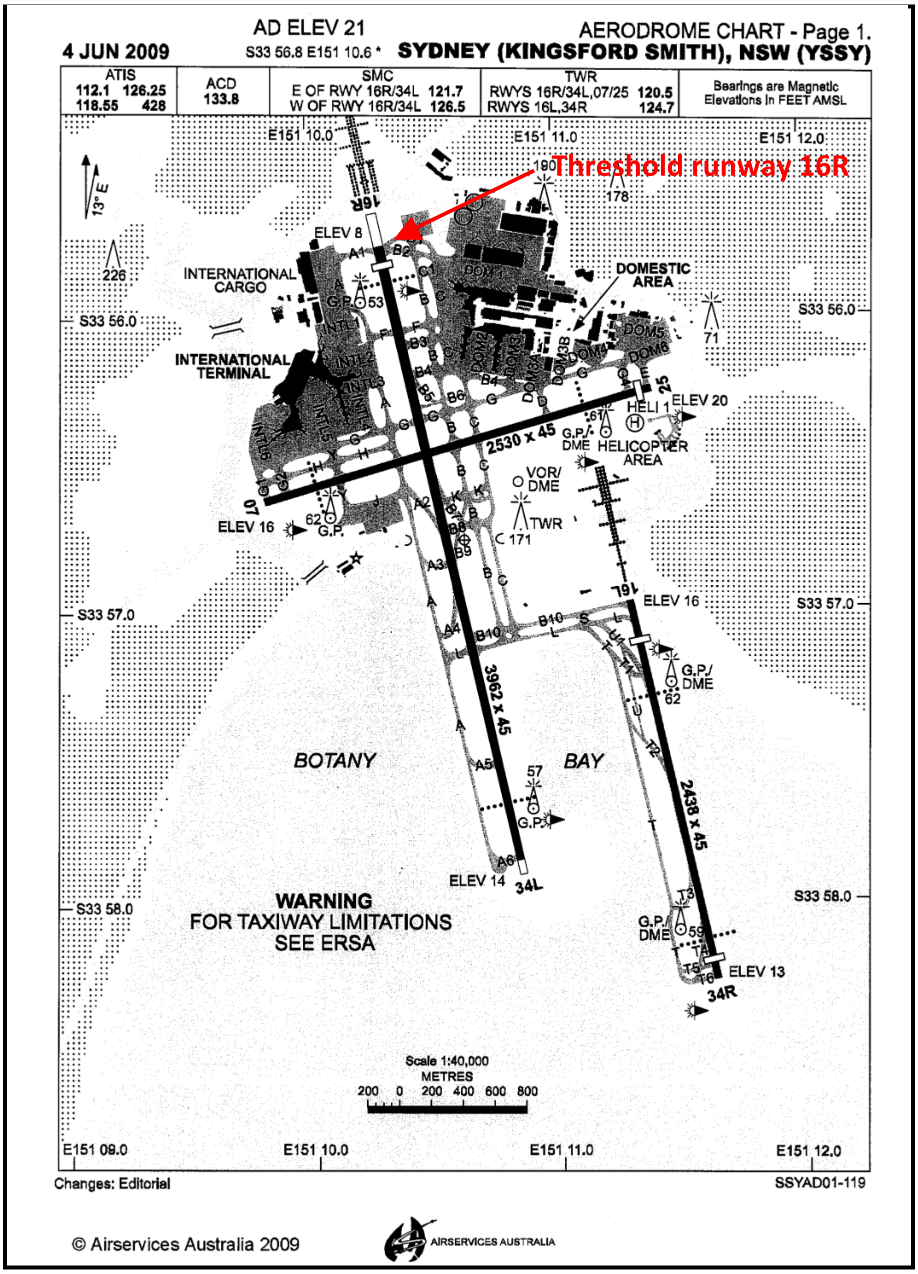
1.7.1 Air Traffic Services recorded information

Communications between pilots and air traffic controllers were recorded by ground-based automatic voice recording equipment. The aircraft's radar position and transponder-broadcast altitude was also recorded by ground-based recording equipment.

1.8 Aerodrome information

The layout of Sydney Airport is shown at Figure 1. Anemometers were positioned adjacent to the threshold of each runway. Wind direction and speed information from those anemometers was displayed in the air traffic control tower console. The information was also recorded.

Figure 1: Sydney Aerodrome Chart



1.8.1 Surface wind display in Sydney Control Tower

The equipment in Sydney Control Tower included a surface wind display that provided airport wind information. A photograph of the screen taken during normal airport operations is shown at Figure 2. The display included:

- a schematic diagram of the airport's runways
- a display of the active runway(s)
- a display of runway threshold wind speed and direction information
- the display of wind speed and direction information from the Wattamolla (MOL) and Wanda (WDA) anemometers which were located to the south of Sydney Airport
- the ability to nominate a specific anemometer for display on the left section of the display (In Figure2, the runway 34L anemometer)
- the display of time, temperature and QNH information.

The wind information could be selected as either **Inst** (instantaneous – the average wind over the previous 3 seconds), **Avg** (the average wind over the previous 2 minutes) or **Peak** (the peak wind over the previous 10 minutes). The red background colour of the runway 25 sensor indicated that a warning condition applied to that sensor.

Figure 2: Sydney Control Tower surface wind display

1.9 Flight recorders

The aircraft was fitted with a flight data recorder (FDR), a cockpit voice recorder (CVR), and a quick access recorder (QAR). High quality data was obtained from each recorder. The FDR recorded 381 parameters at a rate of 64 words per second, whereas the QAR recorded 512 parameters at a rate of 256 words per second. On that basis, the QAR data was used by the Australian Transport Safety Bureau (ATSB) as the primary data for its analysis of the event. Principal events from the data included:

- The autopilot and autothrottle were disconnected by 760 ft above airfield level (AAL) and the aircraft was subsequently flown manually during the approach to runway 16R.
- At 120 ft AAL, 9 seconds before touchdown, the aircraft's CAS[15] increased to 159 kts (v_{ref}[16] + 15 kts).
- Three seconds later, at 90 ft altitude, the aircraft's CAS began to decrease at a fairly steady rate, reducing through v_{ref} (144 kts) at 30 ft AAL, and reaching 131 kts (v_{ref} -13 kts) at touchdown. That corresponded to an airspeed loss of 28 kts over 6 seconds, or 4.7 kts/sec, and exceeded the acceleration capability of a large jet aircraft in the landing configuration.
- The variations in CAS corresponded with the recorded wind changing from a headwind to a tailwind.
- The increase in CAS (to 159 kts) and the subsequent decrease (to 131 kts) was typical of overshoot shear then undershoot shear produced by a microburst.
- The maximum vertical acceleration recorded at the initial touchdown was 2.34 g and the roll attitude was 0.9° left.
- A windshear warning first became evident in the recorded QAR data 2 seconds after the initial touchdown.
- The go-around was initiated (indicated by rapid forward movement of the engine thrust levers) within 2 seconds of the initial touchdown.
- Three seconds after the initial touchdown, the aircraft touched down again and the maximum vertical acceleration recorded at the second touchdown was 1.53 g and the roll attitude was 0.7° left**.**
- After the second touchdown, the aircraft began to roll to the left, reaching a maximum roll attitude of 6.0° (i.e. left wing low).
- The aircraft was airborne and climbing away within 7 seconds of the first touchdown.

1.9.1 Wind speed and direction during the final approach

The recorded flight data for the aircraft's radar altitude and wind speed and direction for its final approach from 2,000 ft is shown in Figure 3.

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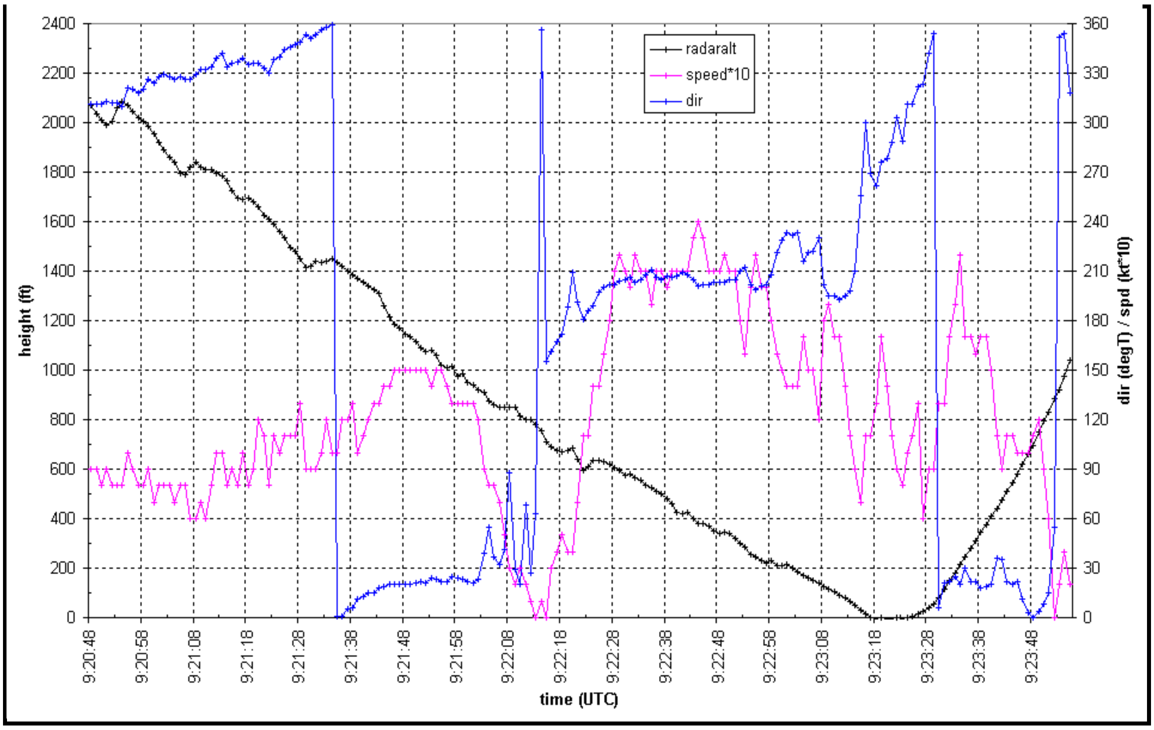
15 Calibrated, or computed, airspeed.

16 Reference speed for the approach.

Figure 3: Recorded flight data showing aircraft altitude, wind speed and wind direction



The Bureau of Meteorology provided the following analysis of the recorded data:

> As the aircraft descended through 2000 ft it experienced NW winds around 10 kt that shifted NE and increased to 15 kt. At around 092213 UTC when the aircraft was at 800 ft the wind shifted from NE to S and increased to around 20 kt. At this time the aircraft was around 4 km north of the threshold for Rwy 16R and the observed wind change is consistent with the aircraft descending through the upper boundary of the gust front that passed across the airport earlier. The observed winds are also consistent with those observed at the threshold of Rwy 16R at this time.
>
> In the period 092311-092316 UTC when the aircraft was at less than 100 ft altitude the wind rapidly shifted from 190/18 kt to 280/12 kt. This is a significant wind change at such a critical stage of landing. The along-track wind component changed from an 18 kt headwind to a 5 kt tailwind with an airspeed loss of 23 kt and there was a rapid increase in the cross wind component. The observed wind change reported by the aircraft is again consistent with the wind observed at the threshold of Rwy 16R where the wind shifted from S to W in the period 092220-092250 UTC.
>
> As the aircraft climbed the observed wind is reported as 020/18 kt consistent with the presence of the divergent outflow.

1.9.2 Aircraft manufacturer's analysis of recorded flight data

The ATSB forwarded the FDR and QAR data to the aircraft manufacturer for analysis. The company's report concluded:

> Analysis of the FDR data indicates that a headwind which shifted to a crosswind caused a loss in airspeed. This loss in airspeed (primary effect), combined with an 8 ft/sec downdraft and a large right [control] wheel input (secondary effects), combined to [induce] a high rate of sink just before touchdown. The flare and the commanded increase in thrust were unable to arrest the high sink rate and the aircraft touched down with a normal acceleration of 1.84g's and a calculated sink rate of approximately 720 ft/min (12 ft/sec).

A copy of the complete report is at Appendix B.

1.9.3 Analysis of recorded EGPWS data

Data recorded by the EGPWS was forwarded to the manufacturer of that system for analysis. That analysis showed that the windshear event was triggered by a significant horizontal windshear, with little vertical shear present. The recorded true airspeed of the aircraft increased from 150 to 163 kts, and then rapidly fell to 135 kts over the following 7 seconds. That loss of true airspeed commenced when the aircraft was 111 ft above the runway, some 8 seconds before touchdown.

A copy of the complete report is at Appendix C.

1.10 Aircraft operating procedures

The aircraft operator's 747-400 FCOM included procedures and guidance for flight crew regarding windshear precautions and windshear recovery procedures. Those procedures and guidance formed part of the windshear awareness program that the operator had in place for all of its 747-400 flight crew at the time of the occurrence.

1.10.1 Windshear precautions

The FCOM contained the following information regarding windshear precautions:

'If windshear is suspected, be especially alert to any of the danger signals and be prepared for the possibility of an inadvertent encounter. The following precautionary actions are recommended if windshear is suspected:

….<u>Approach and Landing</u>

- *Establish a stabilised approach no lower than 1,000 feet above the airport to improve windshear recognition capability.*
- *Use the most suitable runway that avoids the areas of suspected windshear and is compatible with crosswind or tailwind limitations. Use ILS G/S, VNAV path or VASI/PAPI indications to detect flight path deviations and help with timely detection of windshear.*
- *If the autothrottle is disengaged, or is planned to be disengaged prior to landing, add an appropriate airspeed correction to maintain Reference Ground Speed, up to a maximum of 20 knots.*
- *Avoid large thrust reductions or trim changes in response to sudden airspeed increases as these may by followed by airspeed decreases.*
- *Crosscheck flight director commands using vertical flight instruments.*
- *Crew coordination and awareness are very important, particularly at night or in marginal weather conditions. Closely monitor the vertical flight path instruments such as vertical speed, altimeters and glide slope displacement. The PNF should call out any deviations from normal. Use of the autopilot and autothrottle for the approach may provide more monitoring and recognition time.'*

1.10.2 Windshear recovery procedures

The FCOM contained the following procedure for recovery if windshear was encountered:

Windshear encountered in flight:
• perform Windshear Escape Manoeuvre.
Note: Unacceptable flight path deviations are recognized as uncontrolled changes from normal steady state flight conditions below 1,000 feet AGL, in excess of any of the following:
• 15 knots indicated airspeed
• 500 FPM vertical speed
• 5 degrees pitch attitude
• 1 dot displacement from the glideslope
• unusual thrust lever position for a significant period of time.

Windshear Escape Manoeuvre

Pilot Flying	Pilot Not Flying
MANUAL FLIGHT: Disengage autopilot. Push either TO/GA switch. Aggressively apply maximum* thrust. Disconnect autothrottle. Simultaneously roll wings level and rotate toward an initial pitch attitude of 15°. Retract speedbrakes. Follow flight director TO/GA guidance (if available). AUTOMATIC FLIGHT: Press either TO/GA switch.** Verify TO/GA mode annunciation. Verify thrust advances to GA power. Retract speedbrakes. Monitor system performance***.	Assure maximum* thrust. Verify all required actions have been completed and call out any omissions.
Do not change gear or flap configuration until windshear is no longer a factor. Monitor vertical speed and altitude. Do not attempt to regain lost airspeed until windshear is no longer a factor.	Monitor vertical speed and altitude. Call out any trend toward terrain contact, descending flight path, or significant airspeed changes.

Note: Aft control column force increases as the airspeed decreases. In all cases, the pitch attitude that results in intermittent stick shaker or initial buffet is the upper pitch attitude limit. Flight at intermittent stick shaker may be required to obtain positive terrain separation. Smooth, steady control will avoid a pitch attitude overshoot and stall.
Note: * Maximum thrust can be obtained by advancing the Thrust levers full forward when the EECs are in the normal mode. If terrain contact is imminent, advance Thrust levers full forward.
Note: ** If TO/GA is not available, disengage autopilot and disconnect autothrottle and fly manually.
WARNING: *** Severe windshear may exceed the performance capability of the AFDS. The pilot flying must be prepared to disengage the autopilot and disconnect the autothrottle and fly manually.

1.11 Air traffic control procedures

1.11.1 Communication of meteorological information between air traffic service (ATS) units and pilots

The Manual of Air Traffic Services (MATS), Part -10-500 – Meteorological to/from Pilots, described the requirements for communicating windshear advice as follows:

Meteorological Information to/from Pilots Part 3: Meteorology
3-10-500

3-10-500

Wind Shear Advice - Controlled Aerodromes

3-10-510
ATIS requirement

Include on the ATIS:

a. reports of moderate, strong or severe wind shear on the approach or take-off paths
b. forecasted but unreported windshear greater than intensity Light.

3-10-520
- Example WIND SHEAR WARNING

ATC: "WIND SHEAR WARNING – B737 (MEDIUM CATEGORY AIRCRAFT *if military* CATIS) REPORTED MODERATE UNDERSHOOT WING SHEAR AT 200 FEET ON FINAL RUNWAY 34 AT TIME 0640"

3-10-530
- Forecast example

ATC: "PROBABLE VERTICAL WIND SHEAR FROM 0510 TO 0530 - FORECAST WIND AT 400 FEET ABOVE GROUND LEVEL 120 DEGREES 50 KNOTS."

3-10-540
Low level wind shear – controlled aerodrome

Pass pilot reports of moderate, strong or severe wind shear and changes in intensity or cessation to the MET or ATS unit responsible for the origination of special aerodrome weather reports for the aerodrome, as prescribed in Local Instructions. If such a unit is not established, disseminate the reports by AIREP Special message.

3-10-550
Aircraft not in receipt of ATIS

Upon receipt of a pilot report and/or a forecast of wind shear of intensity greater than Light, alert subsequent aircraft by ATIS broadcast and directed transmission, where the aircraft is not in receipt of the ATIS information.

3-10-560
More favourable runway

When aware of the presence of significant wind shear, nominate a more favourable runway, if available, and provide the appropriate flight information.

P 190 MATS General

The MATS also required controllers to notify the BoM of unforecast conditions; specifically, '...ATC observed or pilot reported weather that may warrant forecast amendment'.

The MATS also provided guidance to controllers in relation to when reports of significant weather no longer needed to be reported on the Automatic Terminal Information Service (ATIS); including that two successive reports from pilots of aircraft not experiencing shear conditions were necessary before a windshear report was removed from an ATIS recording. No such reports had been received at the time of the approach and landing of VH-OJR.

1.11.2 Local instructions

The *ATS Operations Manual Volume 2 (Local Instructions) – Sydney Tower, Meteorology* stated:

> TMC (Traffic Manager Coordinator) shall relay reports of significant weather to the Sydney Airport Met [Meteorological] Unit (SAMU). Example: Pilot reports of moderate, strong and severe windshear or changes in intensity or cessation.

A review of the recorded voice communications from the period including the arrival of VH-OJR, revealed that the TMC did not relay any of the pilot reports of moderate windshear received prior to the arrival of VH-OJR to the SAMU[17].

1.11.3 Automatic Terminal Information Service

The Sydney ATIS provided a continuous and repetitive broadcast of pre-recorded information about the operational and meteorological conditions at Sydney on a designated frequency. It included an identifying phonetic code letter, which was changed to the next code letter whenever the ATIS information was amended. The ATIS information was required to be revised whenever operational information changed, or when meteorological information varied or exceeded specified values and was expected to remain that way for at least 15 minutes. Details of the ATIS information that was current during the aircraft's approach into Sydney were included in Section 1 *History of Flight*. During normal operations, pilots check ATIS information before top of descent and monitor the ATIS frequency for the remainder of the flight.

Pilots of aircraft on descent towards destination airports are normally advised by air traffic control of any changes to the ATIS. In circumstances where weather conditions are changing rapidly, it may not be possible for tower controllers to maintain up-to-date ATIS information. Tower controllers are responsible for ensuring that pilots of aircraft under their control, and adjoining air traffic control units, are advised of any sudden and unexpected changes to aerodrome information, pending the issue of an amended ATIS.

1.11.4 Sydney control tower

At the time of the occurrence, the tower was fully staffed, with the following positions occupied:

- Traffic Manager Coordinator (TMC)/Shift Manager

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17 Since the occurrence Sydney Tower has installed 'speed dial' access to the Sydney Airport Meteorological Unit (SAMU).

- Aerodrome Controller East (ADC EAST)
- Aerodrome Controller West (ADC WEST)
- Surface Movement Controller East (SMC EAST)
- Surface Movement Controller West (SMC WEST
- Airways Clearance Deliverer (ACD).

The TMC held overall responsibility for the provision of air traffic services in the tower. The specific responsibilities of the position included:

- exercising operational command authority
- traffic management and runway mode selection in accordance with procedures and directives
- maintaining a weather watch and assisting with the identification and distribution of Hazard Alert information.

The responsibilities of the ADC EAST included all operations on runway 16L/34R and in the airspace on/east of those runways and their extended centrelines.

The responsibilities of ADC WEST included all operations on runway 16R/34L and in the airspace on/west of runway 16L/34R and its extended centreline.

None of the responsibilities of the other tower positions concerned the circumstances of the occurrence.

1.12 Low-level windshear alert systems

Low-level windshear alert systems (LLWAS) are ground-based systems that measure wind speed and direction at remote locations around an airport, with the aim of detecting low-level windshear in runway corridors. The remote sensor information is automatically analysed and when pre-determined threshold values are exceeded, warnings are displayed to control tower and approach controller positions. Controllers relay windshear information to aircraft, including runway-specific alerts.

There were no operational LLWAS in Australia at the time of the occurrence.

In October 2008, the Bureau of Meteorology provided the following comparison between manual windshear warning products and LLWAS:

> There's a fundamental difference between the manual wind shear warning product (currently provided by the Bureau at Sydney Airport) and the automated wind shear alert systems discussed above. The wind shear warning product is prepared and issued by a Bureau forecaster and provides concise information of observed, reported or expected wind shear – giving specific advice such as the expected cause of the wind shear hazard and its start and end times. The focus of the wind shear warning is primarily to provide advance notice, as much as possible, of weather conditions expected to produce hazardous wind shear. However, because of the often small time and space scales associated with hazardous wind shear events, the manual wind shear warning service is generally not suitable for providing specific alerts to aircraft in a timely manner for each and every wind shear occurrence detected at an aerodrome. A wind shear alert system, on the other hand, is fully automated and generates an alert when significant wind shear (based on predefined criteria) is detected by an array of instruments. The alert is automatically transmitted to pilots and provides realtime, detailed information on wind shear conditions detected at an aerodrome. An effective combination of the two levels of service (wind shear warning and wind shear alert) should complement each other and provide both predictions and detailed observations of hazardous wind shear at an aerodrome.

In its report on the occurrence (Appendix A), the Bureau of Meteorology stated (page 27 of that report):

> The analysis presented here also shows there can be very complex wind flows associated with the passage of thunderstorms and the time scales associated with these events can be very short. This applies in particular to the period that associated wind shear might affect the flight corridor on the approach or departure path for any given operational runway. In these situations only automated systems can be used to detect the wind shear and provide appropriate warnings.

1.13 Windshear case study

The investigation sourced information regarding flight crew response to windshear encounters from a number of sources. The following extract was from a 1988 windshear case study[18].

> On April 18, 1993, a Douglas DC-9-41 experienced a hard landing when it encountered windshear while crossing the runway threshold during the landing approach. Following the occurrence, the Japan Federation of Flight Crew Unions established a project to obtain objective and quantitative data on flight crews' reactions to windshear. The project was supported by the Air Line Pilots Association of the United States, and was conducted on a DC-9 flight simulator at Northwest Aerospace Training Corporation near Minneapolis, USA.

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[18] Schlickenmaier, H. (1988). *Windshear case stud: Denver, Colorado, July 11, 1988 (DOT/FAA/DA-89/19)*. Washington, DC; Federal Aviation Administration.

The results demonstrated that nearly 90 percent of crews' recovery attempts were successful when windshear encounters were triggered at a height of 200 ft or above. However, when triggered below 200 ft, about 67 percent of recoveries resulted in ground contact. Accordingly, the height of 200 ft was regarded as the "critical height" for a safe recovery from a windshear encounter. The results also demonstrated that the average recognition time for a windshear encounter was about 5.5 seconds amongst the crews sampled, and the average reaction time was also about 5.5 seconds. Additionally, the average height losses during recognition and reaction were about 93 feet and about 97 feet respectively.

The research concluded that an average pilot would therefore need about 11 seconds of time and about 200 ft of height above the ground to recognise and react to a severe windshear encounter.

An incident involving four transport-category aircraft at Denver, Colorado on 11 July 1988 highlighted problems on how air traffic controllers and flight crews manage weather information. The aircraft consecutively entered active microbursts' during the landing approach, despite each crew being provided with warning of their presence.

A study of the Denver incident was conducted to determine crew awareness and decision-making behaviour in a microburst/windshear environment. The study found that the elapsed time from the microburst alert to the announced go-around decision by the captain was reduced by nearly one minute when the crew were provided with a visual presentation of the microburst event in real time. That potential time saving was operationally significant, because it provided crews with an expanded manoeuvre time. Manoeuvre time was defined as the elapsed time between the announced go-around decision and an aircrew control action associated with the go-around, such as a change in aircraft configuration. The one-minute margin could provide a distance advantage of up to 3 NM at typical approach speeds of transport-category jet aircraft. It could also provide an additional altitude advantage of between 700 ft to 800 ft.

1.14 Reported windshear events within Australia, 1 July 1998 to 30 June 2008

The ATSB database included 194 reported occurrences of high capacity aircraft encountering windshear during the approach or take-off phases of flight at Australian capital city airports between 1 July 1998 and 30 June 2008 (Table 2). It is possible that some windshear events were not reported to the ATSB.

Table 2: Reported windshear occurrences by flight phase for Australian capital city airports

Location	Takeoff	Approach	Total
Brisbane	1	29	30
Sydney	7	58	65
Canberra	0	7	7
Melbourne	9	42	51
Hobart	1	5	6
Adelaide	1	9	10

Perth	1	20	21
Darwin	1	4	5
Total	21	174	195

The reported occurrences, per year, for each location are at Table 3.

Table 3: Reported windshear occurrences by year for capital city airports

Location	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
Brisbane	0	0	2	5	3	4	5	11	0	30
Sydney	2	0	7	11	7	12	9	11	6	65
Canberra	0	0	0	1	3	2	1	0	0	7
Melbourne	1	2	3	8	3	6	9	15	4	51
Hobart	0	1	2	0	0	2	0	1	0	6
Adelaide	2	0	0	0	2	2	2	1	1	10
Perth	3	0	3	1	1	1	4	4	4	21
Darwin	0	1	0	1	0	1	1	0	1	5
Total	8	4	17	27	19	30	31	43	16	195

Previous investigation

The ATSB investigated a microburst incident that occurred on 18 January 2001 in which a Boeing 737-476 aircraft encountered microburst windshear while conducting a go-around from runway 19 at Brisbane Airport, Qld during an intense thunderstorm. The aircraft was operating a scheduled fare-paying passenger service from Sydney to Brisbane.[19]

That investigation found that there was no effective mutual exchange of information between air traffic controllers and the crew during that occurrence. Also, the incident highlighted that, without extensive Doppler weather radar capabilities, and in the absence of appropriate systems designed to detect hazardous windshear in Australia, there was a need for collaborative decision making among forecasters, controllers, pilots and operators during periods of intense or severe convective weather.

An aspect not highlighted in that report, but that needs to be understood, is that there may be significant differences in the information displayed on ground-based and airborne radar systems for the same observed weather.

[19] The complete report is available from the ATSB at http://www.atsb.gov.au/publications/investigation_reports/2001/AAIR/pdf/aair200100213_001.pdf

2 ANALYSIS

2.1 Overview

From the various analyses of the recorded data from the aircraft, and land-based sensors, it was clear that the aircraft encountered windshear immediately before touchdown on runway 16 Right (16R) at Sydney Airport. The windshear was associated with a thunderstorm formed in an environment that suited high-based convective activity, but that did not favour frequent or long-lasting thunderstorms; and exhibited characteristics typical of microburst activity associated with such weather conditions. The windshear caused a significant loss of aircraft performance, resulting in a heavy landing, and triggering a windshear warning alert in the cockpit. The crew's response of flying the windshear escape manoeuvre was appropriate and in accordance with the company procedures and training. There was no evidence of any equipment or system malfunction on board the aircraft.

Crew preparedness for countering the effects of the windshear depended upon the effectiveness of the following defences in providing sufficient and timely information to allow the crew to respond appropriately:

- the windshear warning equipment on board the aircraft
- wind information that was obtained from ground-based systems and provided to the crew by air traffic control.

2.2 The windshear warning equipment on board the aircraft

The enhanced ground proximity warning system (EGPWS) windshear warning system that was fitted to the aircraft functioned normally during the event and alerted the crew. However, because the system was reactive, and because the windshear developed so quickly and occurred when the aircraft was at a very low altitude, the aircraft contacted the runway before the warning was triggered.

The circumstances of the incident are consistent with previous research which indicated that, with the aircraft below 200 ft above ground level, the EGPWS was not capable of providing an alert in sufficient time to enable a pilot to respond to prevent the heavy landing. Some other form of advanced warning or advice offered the best prospect of avoiding the windshear or escaping from it.

The predictive windshear warning system that was fitted to some of the operator's 747 aircraft (but not the occurrence aircraft) depended upon the movement of moisture or particulate material in the air ahead of the aircraft. However, as the microburst was 'dry' in this instance, the windshear was unlikely to have been detected by this predictive system, even if it had been fitted to the aircraft.

In this occurrence, information from system(s) external to the aircraft were likely to have offered the best prospect of preventing or limiting the effect of the windshear on the aircraft.

2.3 Wind information received by the crew from ground-based systems

There was no automatic windshear warning system at Sydney Airport. The provision of wind and windshear information to the crew in this instance brought with it the limitations outlined in the Bureau of Meteorology's (BoM) October 2008 comments regarding manual windshear warning products compared with automated windshear warning systems (see Section 1.15). Those comments emphasised that:

> ...because of the often small time and space scales associated with hazardous wind shear events, the manual wind shear warning service is generally not suitable for providing specific alerts to aircraft in a timely manner for each and every wind shear occurrence detected at an aerodrome.

The available manual windshear warning products included:

- forecast weather information
- special aerodrome weather reports
- reports by other pilots
- automatic terminal information system (ATIS) information
- directed transmissions by air traffic controllers.

2.3.1 Forecast weather information

The forecast weather information that was received by the crew included the potential for thunderstorms at Sydney Airport between 1800 and 2000, but did not include specific windshear warnings. The BoM advised that specific windshear warnings were not included in the forecast because the risk of windshear was implicit whenever a forecast included thunderstorms or thunderstorm warnings.

2.3.2 Special aerodrome weather reports

From 1900 until the time the aircraft landed, the reported and observed wind variability and windshear conditions met the criteria for the issuance of a special report (SPECI) at Sydney airport. However, no SPECI was issued until 4 minutes prior to the heavy landing and go-around. In addition, the flight crew did not receive that SPECI. It is unlikely that the provision of the SPECI to the flight crew would have assisted them as it did not report windshear.

The Air Traffic Management Coordinator was required by the Manual of Air Traffic Services (MATS) and the local instructions, to have passed the windshear information to the Sydney Airport Meteorological Unit (SAMU). The provision of that information to the staff of the SAMU would have assisted them in their assessment of any appropriate changes to the forecast, or of the need for a SPECI. Had the SAMU received details of the earlier pilot reports of windshear, it is likely that a SPECI, highlighting the likelihood of windshear, would have been issued prior to the arrival of VH-OJR. The availability of that information would have allowed the flight crew to better prepare for the likely conditions affecting their approach.

2.3.3 Automatic terminal information service

The 1902:04 windshear information provided by the crew of a landing aircraft formed part of automatic terminal information system (ATIS) Quebec, issued at 1908:58. That information contributed to the pilots' expectation that, after the aircraft descended through the reported windshear between 1,000 and 500 ft, they were unlikely to experience further windshear during the approach.

There was no reference to the possibility of windshear in ATIS Romeo, which was issued about 10 minutes before VH-OJR landed, and related to the change from runway 34 to 16.

The effect of the runway change was to alter the relative location of the reported windshear from the approach path to runway 34 to the take-off path for runway 16. In that context, the windshear still met the conditions in the MATS of 'reports of moderate, strong or severe windshear on the approach or take-off paths' for inclusion in the ATIS. Also, the condition required by the MATS for removing a windshear warning from the ATIS had not been met. Therefore, the windshear information should have been included in ATIS Romeo. That information was very relevant to the pilots of VH-OJR in endeavouring to conduct a safe approach and landing.

2.3.4 Directed transmissions from air traffic control

The differences in the quantity and quality of wind and windshear information that was provided to the flight crew by the aerodrome controllers, revealed the limitations of human information processing and decision making in a rapidly changing situation. It also reinforced the Australian Transport Safety Bureau's finding from the 18 January 2001 microburst incident investigation, in that:

> ...without extensive Doppler weather radar capabilities, and in the absence of appropriate systems designed to detect hazardous wind shear in Australia, there is a need for collaborative decision making among forecasters, controllers, pilots and operators during periods of intense or severe convective weather.

It was possible that the provision of immediate advice by the controllers to the pilots regarding the types of aircraft that were conducting go-around manoeuvres, would have provided a more salient notification of the variable conditions, compared with the notification of the changing wind direction and speed.

2.3.5 Flight crew actions

The pilots had been monitoring the weather conditions at Sydney and acted to avoid obvious weather to the south of the airport when on the Approach (APP) frequency. The non-inclusion on the ATIS of the presence of previously notified windshear at the southern end of the airport probably reduced their situational awareness regarding the possible weather conditions and hazards. Their awareness was further reduced because the report from the pilot of another aircraft to the aerodrome controller east (ADC-EAST) of overshoot then undershoot shear at 100 ft altitude, when VH-OJR was about 2 minutes from touchdown (and descending through about 1,700 ft altitude), was not broadcast on the aerodrome controller west (ADC-WEST) frequency. If the information had been provided at that stage of the approach, there would have been sufficient time for the crew to evaluate that information and to decide whether to continue the approach.

The recorded flight data showed that the pilot in command initiated the go-around within 2 seconds of the initial touchdown, and very close to the same time as the EGPWS warning occurred. However, the extent to which the speed and direction of the wind changed, and the low altitude at which that change occurred, gave the crew no prospect of responding to the situation in time to prevent the heavy landing.

3 FINDINGS

From the evidence available, the following findings are made with respect to the microburst event involving Boeing Company 747-438 aircraft, registered VH-OJR, which occurred at Sydney Airport, NSW on 15 April 2007 and should not be read as apportioning blame or liability to any particular organisation or individual.

3.1 Contributing safety factors

- Weather conditions in the Sydney Airport area were conducive to the development of low-level windshear associated with dry microbursts.
- There was no ground-based automatic low-level windshear warning system at Sydney Airport. *[Safety issue]*
- The handling of wind and windshear-related information by air traffic controllers was inconsistent and resulted in the crew not receiving information that was relevant to the conditions they were likely to encounter during the landing approach.
- The aircraft encountered significant horizontal windshear associated with a dry microburst that commenced at about 120 ft radio altitude as the flying pilot began to flare the aircraft for landing.

3.2 Other safety factors

- A dry microburst was unlikely to have been detected by an airborne predictive windshear warning system, even if one had been fitted to the aircraft.

3.3 Other key findings

- The timing, location and characteristics of the windshear were such that a heavy landing was unavoidable.

4 SAFETY ACTION

The safety issues identified during this investigation are listed in the Findings and Safety Actions sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

All of the responsible organisations for the safety issues identified during this investigation were given a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

4.1 Bureau of Meteorology

4.1.1 Availability of a ground-based automatic low-level windshear warning system at Sydney Airport

Safety issue

There was no ground-based automatic low-level windshear warning system at Sydney Airport.

Action taken by the Bureau of Meteorology

On 5 November 2009, the Bureau of Meteorology (BoM) provided the following information regarding the Sydney Airport WindshearStudy:

> The Bureau of Meteorology has advised that it is undertaking the Sydney Airport Wind Shear Scoping Study.
>
> The objective of the Scoping Study is to assess the options for providing the aviation industry with low altitude wind shear alerts, focusing on Sydney Airport.
>
> A planned outcome from the Scoping Study is that the aviation industry, including airlines, Airservices Australia (AsA), Civil Aviation Safety Authority (CASA), Sydney Airport Corporation Limited (SACL) and the Bureau of Meteorology, has sufficient information (scientific, technical, performance, costs, infrastructure requirements) to make an informed decision on the requirement for and selection of a wind shear alert system for Sydney Airport with some consideration for other airports across Australia.
>
> This Scoping Study was initiated in 2008 following discussions between aviation industry representatives and the Bureau of Meteorology.
>
> In these negotiations it was noted that the Bureau of Meteorology has limited capacity to undertake all components of the Scoping Study in the time requested and employment of a consultant was recommended.
> The USA National Center for Atmospheric Research (NCAR) was selected as

the consultant to assist in undertaking this Scoping Study. NCAR scientists have considerable expertise and experience in the scientific investigation of wind shear, the impacts of wind shear on aviation, development of wind shear detection systems and the implementation of these systems. They also have extensive international experience in assisting with the procurement and implementation of wind shear detection systems. The contract with NCAR for the Consultancy was finalised in Jan 2009 and target dates for the remaining tasks and deliverables from the Scoping Study are set between April 2009 and April 2010.

Deliverables from the Scoping Study include:

- An assessment of the meteorological risk factors associated with wind shear for operations at Sydney Airport, including the factors that may influence the choice of a wind shear alert system;
- A report on available technologies, including system performance, limitations and costs, for providing low altitude wind shear alerts for aviation;
- A procurement options report based on international experience that includes discussion on the installation, integration and acceptance process;
- A functional requirements document that provides details on specific technology options taking account of factors specific to Sydney Airport; and
- Workshops and seminars on wind shear and the impacts on aviation.

The technology report "Preliminary Assessment of Wind Shear Events, Detection System Options and Issues, and Applicability of Existing Sensors" was completed in March 2009 and circulated to industry stakeholders.

A site visit to Sydney Airport to assess potential sites for sensors for wind shear alert systems was conducted in the week 22-26 June 2009. During this period a meeting with industry stakeholders was held to provide a detailed briefing on the technology report and discuss technology options, instrument site issues and implementation issues. The meeting was attended by representatives from NCAR, SACL, Qantas, Virgin Blue, AsA, CASA and the Bureau of Meteorology.

Outstanding deliverables include the procurement options report, functional requirements document and the conduct of workshops.

ATSB assessment of action taken

The ATSB is satisfied that the assessment being undertaken by the Bureau of Meteorology is an important step in the consideration of the options for providing the aviation industry with low altitude wind shear alerts, focusing on Sydney Airport. The ATSB will monitor the progress of action to address this safety issue.

Microburst event Sydney Airport, NSW, 15 April 2007
VH-OJR, Boeing Company 747-438

File: 70/13/24, 70/150

Australian Government

Bureau of Meteorology

Air Safety Incident Report

Sydney Airport

15 April 2007
0923 UTC

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1 August 2007

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Executive Summary

At approximately 0923 UTC, on 15 April 2007, a Boeing 747 encountered low-altitude wind shear when attempting to land on runway 16R at Sydney Airport. The wind shear was (in all likelihood) associated with a thunderstorm microburst, which briefly occurred over the airfield as the aircraft attempted to land. This report examines the meteorological setting and the weather forecasts associated with the event. A separate report (Appendix 3) examines, in detail, the microburst and wind shear encounter. Wind shear events of this nature (associated with the downdrafts of individual thunderstorm cells) are considered to be an inherent risk with all thunderstorms.

Meteorological data shows that a thunderstorm, which produced the microburst, formed in an environment that suited high-based convective activity, but did not favour frequent or long-lasting thunderstorms. Initially, because the environment was not particularly favourable for thunderstorms, the meteorologists at Sydney Airport assessed that the probability of thunderstorms occurring the Airport would be low, so thunderstorms were not included in initial forecasts for Sydney Airport. As the situation evolved, the forecasts were revised during the afternoon and thunderstorms were then forecast at the Airport for the late afternoon to evening period. When thunderstorms eventually did occur at the Airport (in the evening), a post-analysis of high-resolution meteorological data showed that a microburst briefly resulted over the northern end of the airfield – at the time of the reported wind shear encounter. The microburst, which in all likelihood caused the wind shear, was present for just a few minutes and then dissipated. A detailed account of the wind shear and microburst event – analysing both the data in the vicinity of the Airport and the Flight Data Recorder – is attached separately in Appendix 3.

Forecasts (TAF and TTF), Aerodrome Warnings and Thunderstorm Alerts were issued by the Sydney Airport Meteorological Unit to indicate the potential for thunderstorms at the Airport, up to 3 ½ hours before the wind shear encounter.

Post-analysis of Airservices anemometer data revealed the classic signature of a microburst at the time of the incident. The Bureau is currently looking at ways to improve the integrity of the Wind Shear Warning product on a national basis through improved training resources, better use of available data and improved communication with Air Traffic Control. In addition to this, the Bureau conducted a low level wind shear alert system (LLWAS) trial at Darwin in 1997 and, since 2002, has archived high-resolution wind data from the Airservices anemometer network at Sydney Airport. Following further analysis of these data, the Bureau will present a paper on the frequency of wind shear events at Sydney Airport and will hold discussions with industry, the Civil Aviation Safety Authority, Airservices Australia and Sydney Airport Corporation Limited on the findings.

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1. Synoptic Situation

On 15 April 2007, a trough of low-pressure was approaching Sydney from the west (see Figure 1.1). The trough lay in a southeast to northwest orientation, across NSW, and extended beyond its southern and northern borders, and marked the convergent region in-between two high-pressure systems: one centred over the Tasman Sea, and the other, to the west, near Adelaide. The trough's motion was from west towards east – not uncommon for broad-scale weather patterns.

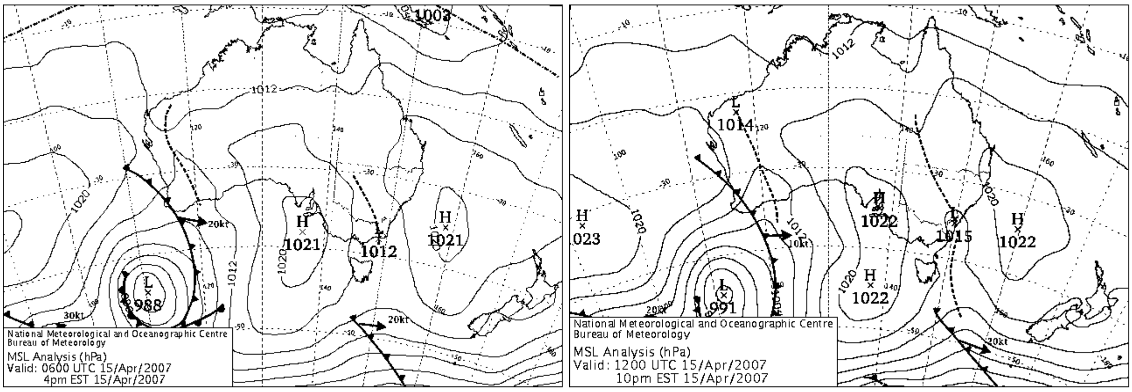

Figure 1.1 Synoptic weather charts show a trough lying across NSW, and it's eastward progression between 06Z and 12Z on 15 April 2007.

When the trough eventually passed through Sydney, early the next morning, it brought a southerly wind change. During the period before the change, when the high in the Tasman Sea generated northeast winds and the trough was still west of Sydney (on the afternoon and early evening on 15 April), a scattered field of clouds developed across NSW in the zone ahead of the approaching trough (see Figure 1.2).

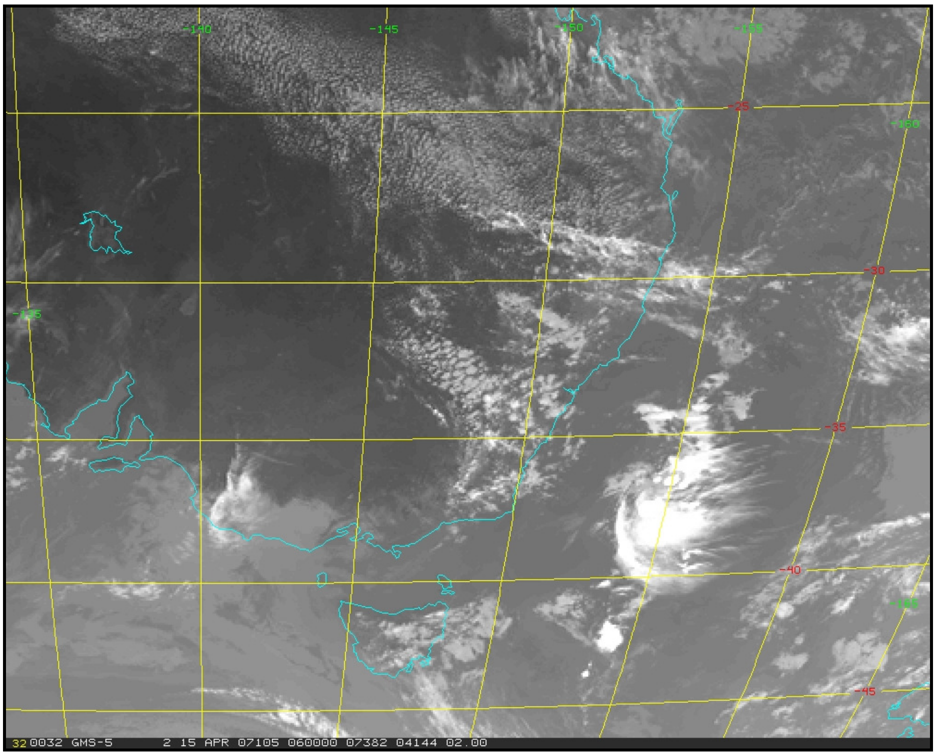

Figure 1.2 Satellite image shows convective clouds (speckled grey and white) east of the trough position, at 06Z on 15 April 2007 (Satellite image originally processed by the Bureau of Meteorology from the geostationary satellite MTSAT-1R operated by the Japan Meteorological Agency).

2. The Weather

A detailed analysis and discussion of the microburst that caused the wind shear encounter is attached in Appendix 3. The discussion below is a broader summary of the weather events leading up to, and around the incident.

In the afternoon, before the incident occurred, the weather in Sydney started out fine with northeast winds around 15 knots and little, if any, significant cloud (see Aerodrome Weather Reports in Appendix 1). The vertical profile of the atmosphere (Figure 2.1) shows that it was potentially unstable at the time, with conditions suitable for high-based convective clouds to develop (if the necessary atmospheric forcing was present). The steep lapse rate in air temperature, especially in the lowest several thousand feet, shows an environment suitable for convective clouds to grow to a significant height. The moisture profile also shows that the air was relatively dry in the layers below about 8000 feet (apart from the relatively shallow and moist layer at the surface). Overall, the atmospheric profile shows conditions favourable for the development of moderately high-based convective clouds, with relatively dry air below the cloud base: i.e. conditions not unfavourable for the formation of a microburst.

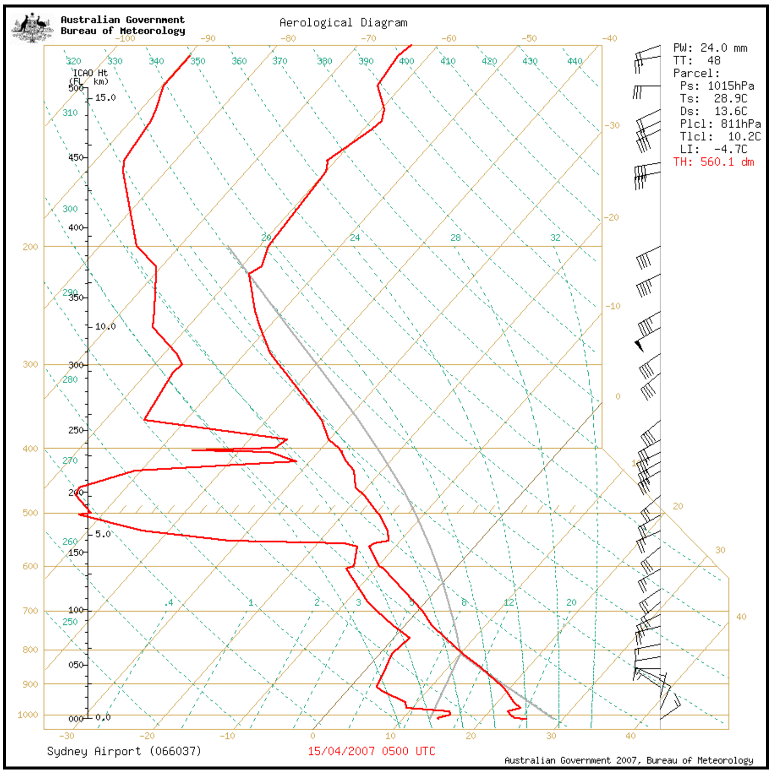

Figure 2.1 Vertical profile of air temperature (right) and moisture (left) at Sydney Airport (05Z, 15 April 2007) shows a steep temperature lapse rate (between 1000ft-15000ft) and dry air (between 1000ft-8000ft). The vertical wind profile is shown on the far right.

A temperature inversion, in the lowest thousand feet near the surface, would have trapped the upward motion of air from the surface and inhibited the formation of convective clouds around the Airport. This explains how, despite the potentially unstable situation aloft, the weather remained fine at the Airport for much the afternoon.

The wind data show that the low-level temperature inversion was caused by northeast winds blowing in off the sea, underneath the (relatively warmer) northwest winds a thousand feet, or more, above.

While the sky above the Airport remained mostly free from cloud during the afternoon, cumulus clouds built up in the regions surrounding the Sydney Basin – to the north, west and south – where the low-level inversion was weaker, or non-existent, and failed to trap convection. High-based showers, and isolated thunderstorms, were generated inland and were driven towards the coast at a rate of about 20 knots by the winds above 10000 feet in the atmosphere, which were blowing from the west or southwest. At first, the showers and thunderstorms that approached the coast dissipated over the Sydney Basin as the convective cells were inhibited by the low-level inversion near the coast (see Figure 2.2).

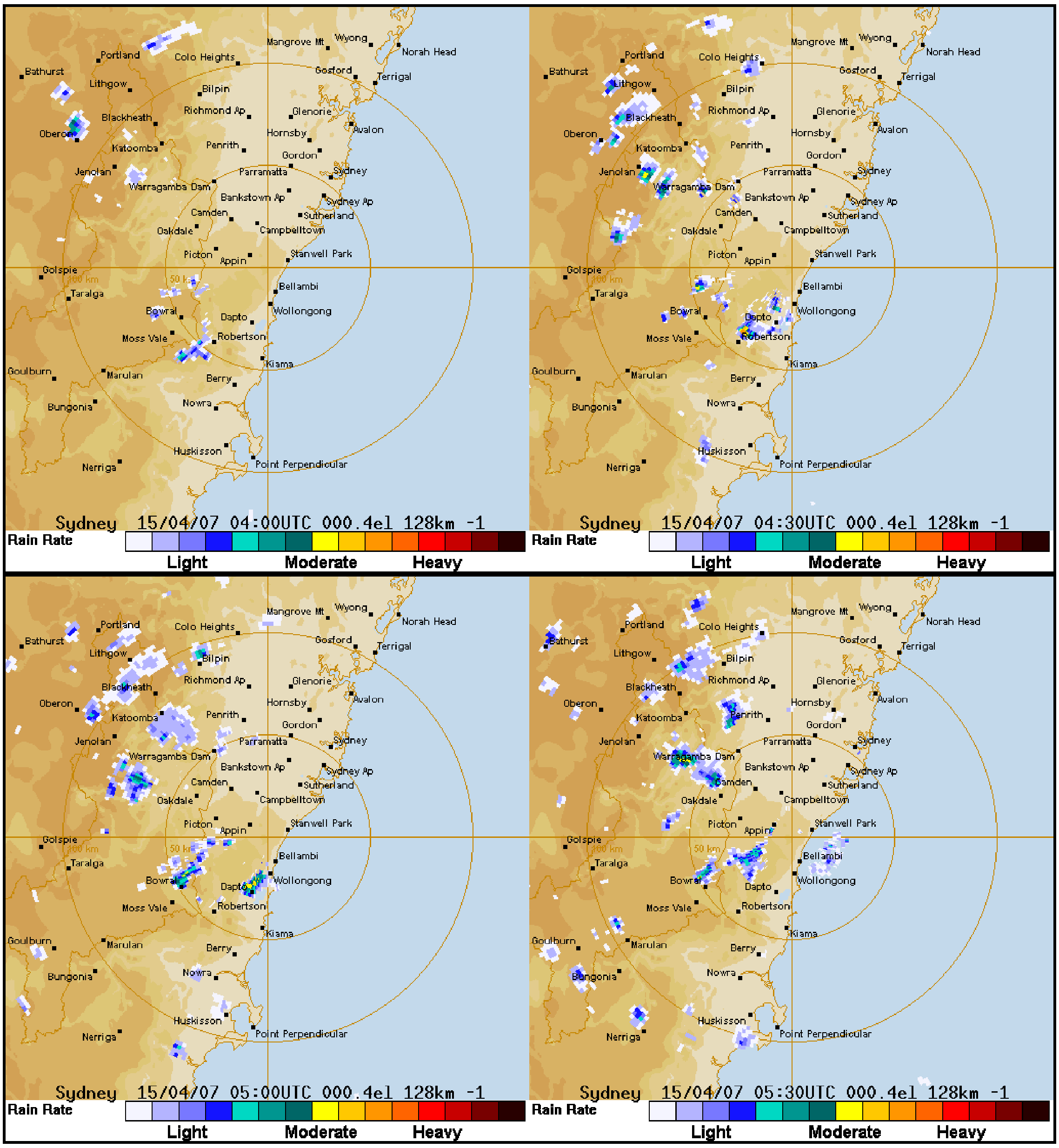

Figure 2.2 Radar images show showers and thunderstorms over elevated terrain between 0400Z and 0530Z, with little or no development over the Sydney Basin.

But later, after 06Z, some showers and thunderstorms, which developed to the west of Sydney, continued moving east over the Sydney Basin without dissipating as they moved closer to the coast (see Figure 2.3).

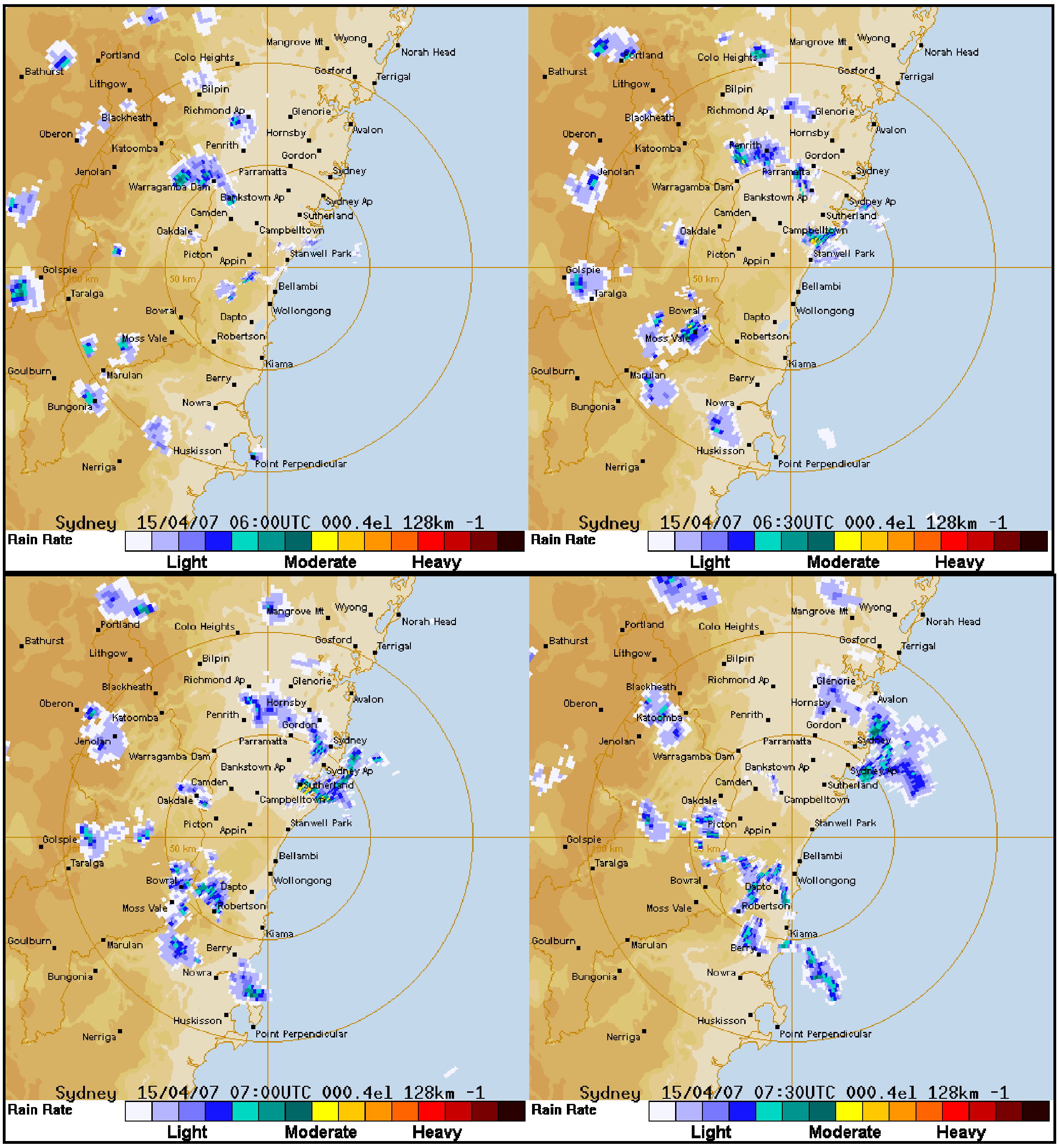

Figure 2.3 Radar images show showers and thunderstorms drifting over the Sydney Basin from west to east between 0600Z and 0730Z.

The cluster of showers and thunderstorms, which caused the thunderstorm and microburst at the Airport, first appeared on radar to the southwest of Sydney (before 0830Z), then moved over the Airport between 0920Z – 0930Z and cleared to the east by 1000Z (see Figure 2.4).

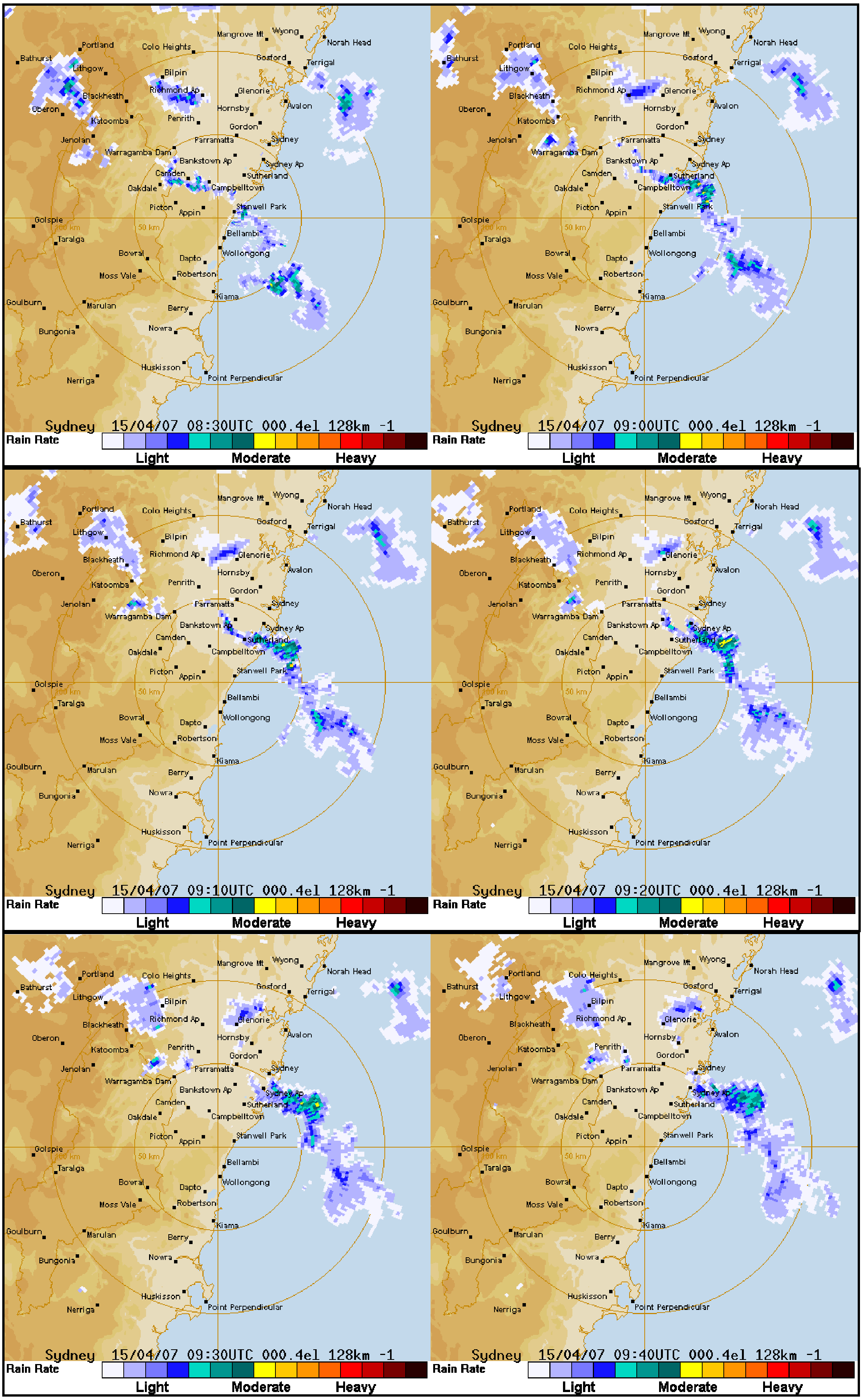

Figure 2.4 Radar images show storms moving over the Airport around 0920UTC.

These storms generated a gust-front of southwest winds, which spread out ahead of the advancing line of storms. At the Airport, the gust-front was first recorded with a southwest wind-change of 15 to 20 knots between 0910Z and 0920Z (see Appendix 1 and Appendix 3 for wind recordings).

Then, at 0920Z, the leading cells from the approaching storm complex were detected overhead (at the Airport), by radar. Visual observations (see Aerodrome Weather Reports in Appendix 1) confirm that the clouds were predominantly high-based (12 000 feet), as expected from the weather balloon sounding. Relatively weak radar reflectivity indicated low to moderate precipitation rates. The post analysis of wind data shows that, from this time, winds measured at the thresholds of runways 16R and 07 began to spread out in a divergent pattern – indicating that the outflow descending from a high-based storm cell was spreading out and developing into a microburst over the airfield (see Appendix 3).

Over the next few minutes, the wind measurements indicate that the microburst intensified over the northern end of the airfield (with a horizontal shear equivalent to 43 knots recorded across a distance of 1.7 km at 0921Z). During this period, the observer at the Airport reported a thunderstorm with light rain.

By 0925Z, the storm cell's core had moved to the east of the Airport, and the microburst had weakened. A few minutes later, another storm's outflow moved across the Airport, but this time with weaker winds.

By 1000Z, the entire storm complex had cleared to the east of the Airport and winds had returned to the prevailing, northeast, direction.

3. Aviation Forecasts Issued

On 15 April 2007, the Terminal Forecasts for Sydney (TAF and TTF), which were issued before 0545Z, indicated northeast winds at 15 knots and no significant weather. The forecaster's assessment was that the probability of thunderstorms, or showers (which were expected to develop over the tablelands to the west and southwest of Sydney), was less than 30% (mainly because of the low-level inversion that was inhibiting convection near the coast). The Airport Weather Briefing issued in the morning indicated only a 10% chance of showers affecting the Airport, and a 20% chance of thunderstorms occurring seaward of the Airport.

By late afternoon, when showers and thunderstorms had developed within 50 nautical miles to the west of Sydney and were moving closer, the forecast was reassessed: it had become less certain that the convection would be inhibited as it approached Sydney; the TAF was amended at 0548Z and indicated showers plus a 30% probability of thunderstorms (for periods less than 30 minutes) at the Airport between 06Z and 10Z.

When showers and thunderstorms developed within approximately 30 nm to the west of the Airport, the TTF (issued at 0600Z) indicated thunderstorms at the Airport from 0630Z. Subsequent issues of the TTF continued to forecast thunderstorms at the Airport up until 1000Z (after which the probability of further storms was assessed to be below 30%).

An Aerodrome Warning (of thunderstorms) and a Thunderstorm Alert were issued at 0650Z, when a thunderstorm was detected within 10 nm of the Airport. The Aerodrome Warning, which was valid up until 1000Z, warned Aerodrome users of the high likelihood of thunderstorms. The Thunderstorm Alert advised ground staff that thunderstorms had been detected within 10 nm of the Airport. The Thunderstorm Alert was cancelled an hour later, when thunderstorms were no longer detected within 10 nm of the Airport.

A subsequent Thunderstorm Alert was issued at 0857Z, when thunderstorms were again detected within 10 nm of the Airport. Again, it was cancelled about an hour later, when storms were no longer within 10 nm.

Wind Shear Warnings were not issued for the Airport because the risk of wind shear, which is a potential hazard associated with all thunderstorms, is implied when a forecast or warning of thunderstorms is issued. On this occasion, there were no real-time reports or observations of wind shear. And, apart from thunderstorms, there were no expectations of wind shear associated with any other phenomena.

The Terminal Forecasts (TAF and TTF) issued after 0545Z indicated the potential for thunderstorms at Sydney Airport between 06Z and 10Z. However, because the thunderstorms were not anticipated to bring a significant increase in wind speed, the forecasts didn’t indicate any significant wind variation with the thunderstorm change groups in the TAF or TTF. The weather observations, however, indicated that at times the thunderstorms did cause temporary fluctuations in the wind direction of up to 180º in variance with the forecast wind (see Appendix 1 and Appendix 3, between 09Z and 10Z). Although no significant increase (above the forecast) in wind speed was recorded, a forecast including a variable wind direction with the thunderstorms would have better represented the actual conditions that occurred at the Airport.

Copies of relevant forecasts and warnings issued before, and around, the time of the incident are contained in Appendix 2. TTFs are in Appendix 1.

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Appendix 1: OBSERVATIONS

Aerodrome Weather Reports and Trend Type Forecasts

Sydney Airport, 0400Z – 1100Z on 15/04/2007

```
TTF METAR YSSY 150400 07013/15KT CAVOK 27.0/13.9 1015.8
RMK RF00.0/000.0
NOSIG

TTF METAR YSSY 150430 08014/16KT CAVOK 26.4/15.0 1015.5
RMK RF00.0/000.0
NOSIG

TTF METAR YSSY 150500 05013/15KT CAVOK 25.6/14.8 1015.2
RMK RF00.0/000.0
TS 33NM TO SW MOVING NE AT 18KT
NOSIG

TTF METAR YSSY 150530 06012/15KT CAVOK 25.7/14.5 1015.0
RMK RF00.0/000.0 TS 38NM TO SW AND 45NM TO W MOVING ESE AT 20KT
NOSIG

TTF METAR YSSY 150600 04014/16KT 9999 VCSH 1CU050 3AC100 25.6/14.3 1015.1
RMK RF00.0/000.0 TS 32NM TO SW AND WNW MOVING NE AT 22KT
INTER 0630/0900 4000 TSRA SCT030 SCT060CB

TTF METAR YSSY 150630 05012/15KT 9999 VCSH 1CU050 4AC100 24.2/14.6 1015.2
RMK RF00.0/000.0 TS 11NM TO SW AND 23NM TO WNW MOVING ENE AT 15KT LIGHTNINGS TO SW
INTER 0700/0930 4000 TSRA SCT030 SCT060CB

TTF SPECI YSSY 150652 08011/13KT 9999 VCTS 1ST025 6AC100 1CB050 23.4/15.8 1015.5
RMK RF00.0/000.0 TS 8NM TO NW AND SSW MOVING NE AT 12KT
INTER 0700/0952 4000 TSRA SCT030 SCT060CB

TTF SPECI YSSY 150700 07009/12KT 9999 VCTS 1CU040 6AC100 1CB060 23.2/15.2 1015.7
RMK RF00.0/000.0 TS 5NM TO S MOVING NE AT 12KT
INTER 0700/1000 4000 TSRA SCT030 SCT060CB

TTF SPECI YSSY 150730 07008/12KT 9999 VCSH 1CU050 4AC090 22.9/16.3 1016.0
RMK RF00.0/000.0 TS 5NM TO SSE AND 8NM TO NNE MOVING ESE AT 15KT TCU TO EAST
INTER 0730/1000 4000 TSRA SCT030 SCT060CB

TTF SPECI YSSY 150754 03018/22KT CAVOK 23.4/16.2 1015.2
RMK RF00.0/000.0 LIGHTNING NE
INTER 0754/1000 4000 TSRA SCT030 SCT060CB

TTF METAR YSSY 150800 04018/22KT CAVOK 23.1/16.3 1015.3
RMK RF00.0/000.0 LIGHTNING NE/S
INTER 0800/1000 4000 TSRA SCT030 SCT060CB

TTF METAR YSSY 150830 03017/19KT 9999 1CU045 3CI250 23.1/12.4 1015.4
RMK RF00.0/000.0 TS 18NM TO SW MOVING ENE AT 15KT
INTER 0830/1000 4000 TSRA SCT030 SCT060CB

TTF METAR YSSY 150900 03015/18KT 9999 1CU045 3AC120 23.1/11.6 1015.6
RMK RF00.0/000.0 TS 7NM TO SSW MOVING ENE AT 15KT
FM0910 18015KT 9999 -SHRA FEW040 SCT100
FM1000 02015KT 9999 -SHRA FEW040 SCT080
INTER 0900/1000 4000 TSRA SCT030 SCT060CB

TTF SPECI YSSY 150919 20015/21KT 9999 VCSH 1CU025 6AC120 22.3/13.6 1017.6
RMK RF00.0/000.0 LIGHTNING SE
FM1000 02015KT 9999 -SHRA FEW040 SCT080
INTER 0919/1000 4000 TSRA SCT030 SCT060CB

TTF SPECI YSSY 150924 13007/09KT 9999 -TSRA 1ST018 6AC120 1CB050 23.5/12.2 1017.0
RMK RF00.0/000.0 TS 3NM TO S MOVING ENE AT 15KT
FM1000 02015KT 9999 -SHRA FEW040 SCT080
INTER 0924/1000 4000 TSRA SCT030 SCT060CB

TTF METAR YSSY 150930 15007/10KT 9999 -SHRA 1ST020 7AC120 23.2/13.4 1017.7
RMK RF00.0/000.0
FM1000 02015KT 9999 -SHRA FEW040 SCT080
INTER 0930/1000 4000 TSRA SCT030 SCT060CB

TTF SPECI YSSY 150950 03020/23KT 9999 VCSH 1ST020 5AC100 21.7/14.6 1016.1
```

```
RMK RF00.0/000.0
FM1000 02015KT 9999 -SHRA FEW040 SCT080
INTER 0950/1000 4000 TSRA SCT030 SCT060CB

TTF METAR YSSY 151000 02019/22KT 9999 1CU035 3AC120 22.1/12.7 1016.2
RMK RF00.0/000.0
NOSIG

TTF METAR YSSY 151030 01011/15KT 9999 1CU035 22.5/12.9 1016.5
RMK RF00.0/000.0 TS 20NM TO NE, MOVING TO ENE AT 17 KNOTS
TTF:NOSIG

TTF METAR YSSY 151100 01011/14KT CAVOK 22.5/14.8 1016.6
RMK RF00.0/000.0
NOSIG
```

Appendix 2: FORECASTS

Terminal Aerodrome Forecasts

Sydney Airport, covering 0923Z on 15/05/2007

```
TAF YSSY 141042Z 141212
30007KT CAVOK
FM02 02015KT 9999 FEW040
RMK
T 20 18 16 16 Q 1022 1021 1020 1020

TAF YSSY 141648Z 141818
32007KT CAVOK
FM02 02015KT 9999 FEW040 SCT080
FM12 29008KT 9999 FEW040
RMK
T 17 17 24 26 Q 1020 1020 1019 1016

TAF YSSY 142218Z 150024
32007KT CAVOK
FM02 02015KT 9999 FEW040 SCT080
FM12 29008KT 9999 SCT080
FM18 22012KT 9999 SCT080
RMK
T 23 27 25 23 Q 1020 1017 1015 1015

TAF YSSY 150419Z 150606
02015KT 9999 FEW040 SCT080
FM13 29008KT 9999 SCT080
FM18 22012KT 9999 SCT080
FM02 17015KT 9999 -SHRA SCT035 SCT060
RMK
T 25 23 22 19 Q 1015 1015 1015 1015

TAF AMD YSSY 150548Z 150606
02015KT 9999 -SHRA FEW040 SCT080
FM13 29008KT 9999 SCT080
FM18 22012KT 9999 SCT080
FM02 17015KT 9999 -SHRA SCT035 SCT060
PROB30 INTER 0610 4000 TSRA SCT030 SCT060CB
RMK
T 25 23 22 19 Q 1015 1015 1015 1015

TAF YSSY 151045Z 151212
02012KT 9999 FEW035 SCT120
FM13 29008KT 9999 FEW030 SCT080
FM18 22012KT 9999 FEW030
FM02 17015KT 9999 -SHRA SCT035 SCT060
RMK
T 22 19 17 17 Q 1016 1015 1015 1016
```

Airport Weather Briefings

Sydney Airport, covering 0923Z on 15/05/2007

```
Sydney Airport Weather Briefing
Issued at 1202Z on 14/04/07

Sydney TAF
TAF YSSY 141042Z 14 1212
30007KT CAVOK
FM02 02015KT 9999 FEW040
RMK
T 20 18 16 16 Q 1022 1021 1020 1020

TAF Summary
A high in the west Tasman is directing a northerly over Sydney. Winds
at the airport will tend light northwest overnight, and then return
to the northeast tomorrow afternoon. Mist and fog patches are
expected to develop in the western suburbs overnight , and there is a
slight chance that the airport may be affected. See code grey. Fine
conditions are expected tomorrow.

Thunderstorm Potential
Nil chance within 20nm of Sydney Airport.

Other Possibilities
10% chance of fog 18/23Z.
20% chance of N/NE winds delayed until 04Z tomorrow.

Sydney Outlook
Monday       Chance showers.  City Max:  25
Tuesday      Fine. Partly cloudy City Max:  25

CODE GREY
Yes, 10% chance of fog 18/23Z.

Regards Tad till 7am, then Dmitriy.

Sydney Airport Meteorological Unit

NOTES:

1. This briefing note is issued four times per day and is not amended
between issues. For operational planning reference should be made to
the latest TAF YSSY and TTF YSSY.

2. Code Grey provides early advice of a possible later TAF amendment.
It is used if there is a small but realistic chance of a thunderstorm
or below special alternate conditions between 1400Z and 2400Z. Special
alternate conditions for YSSY are BKN or OVC cloud below 400ft and/or
visibility less than 2000m.northwest
```

```
Sydney Airport Weather Briefing
Issued at 1733Z on 14/04/07

Sydney TAF
TAF YSSY 141648Z 14 1818 32007KT CAVOK
FM02 02015KT 9999 FEW040 SCT080
FM12 29008KT 9999 FEW040
RMK
T 17 17 24 26 Q 1020 1020 1019 1016

TAF Summary
A high in the Tasman is directing a northerly flow over Sydney. Winds
at the airport will be light northwest this morning, tending moderate
to fresh northeast in the afternoon. Some mist and isolated fog
patches have formed in the western suburbs, but visibility should not
be significantly affected at the airport. Fine conditions are
expected with cloud at times during the day. A trough moving through
Victoria will bring a southerly change Monday morning.

Thunderstorm Potential
Slight chance within 20nm seawards of Sydney Airport from late
morning.

Other Possibilities
20% chance of haze reducing visibility to 7000m 19/23Z.
10% chance of a shower this afternoon.
10% chance of a S change around 16Z Monday morning.

Sydney Outlook
Monday     City Max:  25  Chance showers.
Tuesday    City Max:  25  Fine. Partly cloudy

Regards Tad till 7am, then Dmitriy.

Sydney Airport Meteorological Unit
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```
Sydney Airport Weather Briefing
Issued at 2218Z on 14/04/07

Sydney TAF
TAF YSSY 142218Z 15 0024 32007KT CAVOK
FM02 02015KT 9999 FEW040 SCT080
FM12 29008KT 9999 SCT080
FM18 22012KT 9999 SCT080
RMK
T 23 27 25 23 Q 1020 1017 1015 1015

TAF Summary
A high in the Tasman is directing a northerly flow over Sydney. Winds
at the airport will be light northwest at first, tending moderate to
fresh northeast in the afternoon. Fine conditions are expected with
middle level cloud at times. A prefrontal trough moving through
Victoria will bring a shift to southwesterlies early tomorrow.

Thunderstorm Potential
Small chance within 20nm seawards of Sydney Airport in the afternoon.

Other Possibilities
20% chance of haze reducing visibility to 7000m 19/23Z tomorrow
morning.
10% chance of a shower this afternoon and from 16Z.
10% chance of winds shifting SW as early as 16Z.

Sydney Outlook
Monday     City Max:  25  Chance showers.
Tuesday    City Max:  25  Fine. Partly cloudy

Regards Dmitriy till 7pm, then Tad.

Sydney Airport Meteorological Unit
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SYDNEY AIRPORT METEOROLOGY UNIT
Department of the Environment
Sydney Airport Weather Briefing
Issued at 0626Z on 15/04/07

Sydney TAF
TAF YSSY 150548Z 15 0606
02015KT 9999 -SHRA FEW040 SCT080
FM13 29008KT 9999 SCT080
FM18 22012KT 9999 SCT080
FM02 17015KT 9999 -SHRA SCT035 SCT060
PROB30 INTER 0610 4000 TSRA SCT030 SCT060CB
RMK
T 25 23 22 19 Q 1015 1015 1015 1015

TAF Summary
NE/NW airstream prevails over Sydney ahead of approaching prefrontal
trough currently in the eastern Bass Strait. Moderate N/NE winds will
become light NW tonight before shifting SW early tomorrow with the
trough passage. Winds are expected to freshen and become S/SE around
midday tomorrow. Possible shower or thunderstorm could affect Sydney
airport tonight. There is small chance of fog early tomorrow. Light
showers are likely tomorrow afternoon, but no significant
deterioration in cloud or visibility is expected.

Thunderstorm Potential
30% chance within 20nm of Sydney Airport till 10Z, 10% chance till
12Z and small chance seawards tomorrow afternoon.

Other Possibilities
10% chance of fog 18/23Z tomorrow morning.
10% chance of a thunderstorm till 12Z and tomorrow afternoon.
10% chance of winds shifting SW as early as 16Z.
20% chance of S/SE wind developing +/-1 hour of time indicated.

Sydney Outlook
Tuesday     Fine. Partly cloudy City Max:  24
Wednesday   Fine. Mostly sunny. City Max:  25

CODE GREY
Yes, 10% chance of fog 18/23Z.

Regards Dmitriy till 7pm, then Lily.

Sydney Airport Meteorological Unit

NOTES:

1. This briefing note is issued four times per day and is not amended
between issues. For operational planning reference should be made to
the latest TAF YSSY and TTF YSSY.

2. Code Grey provides early advice of a possible later TAF
amendment. It is used if there is a small but realistic chance of a
thunderstorm or below special alternate conditions between 1400Z and
2400Z. Special alternate conditions for YSSY are BKN or OVC cloud
below 400ft and/or visibility less than 2000m.northwest
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Aerodrome Warnings

Sydney Airport, issued on 15/05/2007

```
YSSY AD WRNG 1 VALID 150650/151000Z
AERODROME WARNING NUMBER 1 FOR SYDNEY VALID 041650/042000 LOCAL
THUNDERSTORMS
```

Thunderstorm Alerts for Ground Staff

Sydney Airport, issued on 15/05/2007

10 nm Thunderstorm Alert for Airport Ground Staff Sydney
Issued at 1650 on Sunday the 15th of April 2007

Thunderstorms have been observed within 10 nm of Sydney Aerodrome and are forecast to cross the aerodrome.

Note: This service has been designed to cope with discrete thunderstorms that move over the aerodrome by using weather radar rainfall echoes as the primary tool for identification and tracking. The position of lightning activity associated with thunderstorms cannot be accurately stated, however users should be aware that all thunderstorms have the potential to produce lightning that strikes the ground. Indeed in some cases lightning can strike the ground several nautical miles away from the radar location of the thunderstorm, which is identified by its areas of maximum rainfall.

Duty Forecaster
Sydney Airport Meteorological Unit

Cancellation of Thunderstorm Alert for Airport Ground Staff Sydney
Issued at 1751 on Sunday the 15th of April 2007

New alerts will be issued if further thunderstorms are expected within 10 nm of Sydney Aerodrome and forecast to cross the aerodrome.

Note: This service …

Duty Forecaster
Sydney Airport Meteorological Unit

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10 nm Thunderstorm Alert for Airport Ground Staff Sydney
Issued at 1857 on Sunday the 15th of April 2007

Thunderstorms have been observed within 10 nm of Sydney Aerodrome and are forecast to cross the aerodrome.

Note: This service …

Duty Forecaster
Sydney Airport Meteorological Unit

Cancellation of Thunderstorm Alert for Airport Ground Staff Sydney
Issued at 1953 on Sunday the 15th of April 2007

New alerts will be issued if further thunderstorms are expected within 10 nm of Sydney Aerodrome and forecast to cross the aerodrome.

Note: This service …

Duty Forecaster
Sydney Airport Meteorological Unit

Area Forecasts

Area 20 & 21, issued prior to 0923Z on 15/05/2007

```
AMEND  AREA FORECAST 150600 TO 151700 AREA 20

OVERVIEW:
ISOLATED SHOWERS WITHIN AREA YSDU/YBIA//YGFN/YWLM, EXTENDING TO
COAST/SEA N OF YWLM BY 09Z. ISOLATED THUNDERSTORMS WITHIN SAME AREA
TILL 11Z.

WIND:
 2000     5000     7000       10000         14000         18500
330/15   290/15   270/15   250/20 PS01   240/20 MS06   240/25 MS15

CLOUD:
ISOL CB 6000/30000 TILL 11Z WITHIN AREA YSDU/YBIA/YGFN/YWLM,
CONTRACTING TO SEA/COAST N OF YWLM AFTER 09Z.
SCT ST 3000/4500 RANGES IN PRECIPITATION.
SCT CU/SC 3500/9000 SEA/COAST, ISOL TOPS TO 15000 N OF YTRE AFTER
09Z.
SCT CU 6000/12000 RANGES, ISOL TOPS TO 18000 BEFORE 11Z.
SCT AC/AS ABOVE 12000.

WEATHER
TS, SH.

VISIBILITY:
3000M TS, 5000M SH.

FREEZING LEVEL:
11000.

ICING:
MOD IN AC/AS.

TURBULENCE:
MOD IN CU.

AMD CRITICAL LOCATIONS [HEIGHTS ABOVE MSL]:
AMD MT VICTORIA [3700FT]: 9999 -SHRA SCT CU 6000 SCT AC/AS 10000
                      PROB30 INTER 0610 3000 TSRA FEW CB 6000
AMD MURRURUNDI [2300FT]:  9999 -SHRA SCT CU 6000 SCT AC/AS 10000
                     PROB30 INTER 0610 3000 TSRA FEW CB 6000
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AMEND AREA FORECAST 150600 TO 151700 AREA 21

OVERVIEW:
TROUGH APPROACHING FROM W, NEAR SW CORNER AT 06Z, YFBS/YMRY BY 11Z
AND FAR NE BY 17Z. ISOLATED SHOWERS AND THUNDERSTORMS E OF YORG/YTMU.
LOCALLY BROKEN LOW CLOUD IN PRECIPITATION. AREAS OF SMOKE HAZE IN SE.
MODERATE TURBULENCE BELOW 7000FT LEE OF RANGES, DECREASING BEHIND
TROUGH.

SUBDIVISIONS:
A: E OF TROUGH
B: W OF TROUGH

WIND:
    2000     5000     7000      10000         14000         18500
A: 330/20   310/25   290/25   280/25 MS01   260/30 MS08   260/35 MS17
B: 230/20   250/20   260/20   260/20 MS02   250/25 MS09   250/30 MS18

CLOUD:
ISOL CB 5000/28000 AS PER OVERVIEW.
BKN ST 1000/2000 SEA/COAST, 3000/4500 RANGES IN SH/TS.
SCT CU/SC 3500/9000 SEA/COAST, 5000/9000 RANGES/W SLOPES, TENDING BKN
RANGES/COAST/SEA IN FAR S WITH ISOL CU TOPS TO 18000.
SCT AC/AS ABOVE 10000.

WEATHER:
TS, SH, SMOKE, HAZE.

VISIBILITY:
3000M TS, 5000M SMOKE/SHRA, 8KM HAZE.

FREEZING LEVEL:
11000.

ICING:
MOD IN LARGE CU TOPS AND IN AC/AS.

TURBULENCE:
MOD BLW 7000FT LEE RANGES IN S, DECREASING BEHIND TROUGH.
MOD IN CU/AC.

AMD CRITICAL LOCATIONS [HEIGHTS ABOVE MSL]:
AMD MT VICTORIA [3700FT]: 9999 -SHRA SCT CU 6000 SCT AC/AS 10000
                          PROB30 INTER 0610 3000 TSRA FEW CB 6000
AMD BOWRAL [2200FT]: 9999 -SHRA FEW CU 5500 SCT AC/AS 10000
                        PROB30 INTER 0610 3000 TSRA FEW CB 6000

FOR MORE INFORMATION RING 02 9296 1527
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AMEND AREA FORECAST 150900 TO 152300 AREA 21

AMD OVERVIEW:
TROUGH APPROACHING IN W, EXPECTED IN NE BY 23Z. ISOLATED SHOWERS AND
THUNDERSTORMS E OF YORG/YTMU, CONTRACTING TO SEA/COAST BY 17Z.
LOCALLY BROKEN LOW CLOUD IN PRECIPITATION. AREAS OF SMOKE HAZE IN SE.
MODERATE TURBULENCE BELOW 7000FT LEE OF RANGES, DECREASING BEHIND
TROUGH.

SUBDIVISIONS:
A: E OF TROUGH
B: W OF TROUGH

WIND:
    2000     5000     7000      10000         14000         18500
A: 330/20   310/25   290/25   280/25 MS01   260/30 MS08   260/35 MS17
B: 230/20   250/20   260/20   260/20 MS02   250/25 MS09   250/30 MS18

CLOUD:
ISOL CB 5000/28000 AS PER OVERVIEW.
BKN ST 1000/2000 SEA/COAST, 3000/4500 RANGES IN SH/TS.
SCT CU/SC 3500/9000 SEA/COAST, 5000/9000 RANGES/W SLOPES, TENDING BKN
RANGES/COAST/SEA IN FAR S WITH ISOL CU TOPS TO 18000.
SCT AC/AS ABOVE 10000.

WEATHER:
TS, SH, SMOKE, HAZE.

VISIBILITY:
3000M TS, 5000M SMOKE/SHRA, 8KM HAZE.

FREEZING LEVEL:
11000.

ICING:
MOD IN LARGE CU TOPS AND IN AC/AS.

TURBULENCE:
MOD BLW 7000FT LEE RANGES IN S, DECREASING BEHIND TROUGH.
MOD IN CU/AC.

CRITICAL LOCATIONS [HEIGHTS ABOVE MSL]:
MT VICTORIA [3700FT]: 9999 -SHRA SCT CU 6000 SCT AC/AS 10000
                      PROB30 INTER 0910 3000 TSRA FEW CB 6000
BOWRAL [2200FT]: 9999 -SHRA FEW CU 5500 SCT AC/AS 10000
                 PROB30 INTER 0910 3000 TSRA FEW CB 6000

FOR MORE INFORMATION RING 02 9296 1527
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Appendix 3: Other Relevant Information

Sydney Airport Wind Shear encounter 15 April 2007

Rodney Potts
Bureau of Meteorology Research Centre
16 May 2007

Introduction

At approximately 0923 UTC, 15 April 2007 a Boeing 747 encountered wind shear when attempting to land on Rwy 16R at Sydney Airport. In this report we focus on a detailed analysis of the evolution of the weather in the vicinity of Sydney Airport and the wind data recorded by the aircraft Flight Data Recorder. A separate Aviation Safety Incident Report will be prepared that presents broader details of the weather on the day.

Data

The data used in this study includes radar data from the Bureau of Meteorology's Sydney weather radar and Kurnell weather radar, automatic weather station (AWS) data from stations around the Sydney Basin and high resolution wind data from the anemometer network at Sydney Airport and the Kurnell AWS located on a shipping wharf in the southeast of Botany Bay. The Kurnell radar records volumetric Doppler radar data with an update rate of 5 minutes. The start time for each volume is exactly on the hour and each 5 minute interval thereafter. The high resolution anemometer data is available at 10 second intervals and provides 10 second averages of the wind at each location.

Flight Recorder Data from the aircraft concerned is also examined in the context of the meteorological observational data indicated above.

Meteorological analysis

In this analysis we focus on the period 0900-1000UTC during which a line of showers and thunderstorms moved across the airport from the southwest at around 22 knots. It is important to note that in this period the showers/storms were high based with a reported base generally around 12000ft. There was only light intermittent precipitation reported at the airport during this period and there was no associated reduction in visibility.
The evolution of the weather in the Sydney Airport area is described below and this relates to Fig.1 that shows a sequence of images of Kurnell radar data and wind data over Sydney Airport for corresponding times.

0900 UTC: At this time the radar data shows the line of showers/storms approximately 5 NM to the southwest of the airport. The wind data shows a NE airflow 10-15 kts over the airport and Botany Bay.

0905 UTC: Wind data shows NNE airflow 10-15 kts over the airport. The wind at the Kurnell anemometer has shifted SW 15 kt following the passage of a gust front ahead of the line of showers/storms.

0910 UTC: At this time the radar data shows the leading edge of the showers/storms around 3 NM to the southwest of the airport. The gust front ahead of this lies across the airport with the SW winds 10-15 kt evident at the thresholds of runways 34L, 34R and 07. The wind at the thresholds of runways 16R, 16L and 25 is northeasterly around 10 kt.

0915 UTC: At this time the gust front has moved to the northeast of the airport with SW winds 15-20 kt across the airport. The Kurnell anemometer has shifted Nly 15-20 kt (change occurred at 0913 UTC) and this is associated with the presence of a convective cell over the anemometer that is evident in the radar data. The Kurnell wind data suggests the presence of a strong divergent outflow associated with the cell.

092000 UTC: The leading edge of the showers/storms is now over the airport. The associated radar reflectivity over the airport is 20-30 dBZ which is relatively weak. There are more intense cells over the south of Botany Bay and the Kurnell Peninsula. The airport anemometer data shows an intensifying divergence flow over the northern end of Rwy 16R that is associated with a developing microburst.
The wind at the Kurnell anemometer has shifted westerly ahead of the cell immediately to the west.

092131 – 092201 UTC: The microburst is clearly evident in the anemometer data over the north end of Rwy 16R and was most intense in this period. The maximum divergence observed between the anemometers at the thresholds of runways 16R and 07, a distance of around 1700m, was 12.9×10^{-3} sec^{-1} at 092151 UTC. The approach speed for the B747 was around 149 kt and at 092201 UTC the aircraft was around 5 km from the threshold of Rwy 16R.

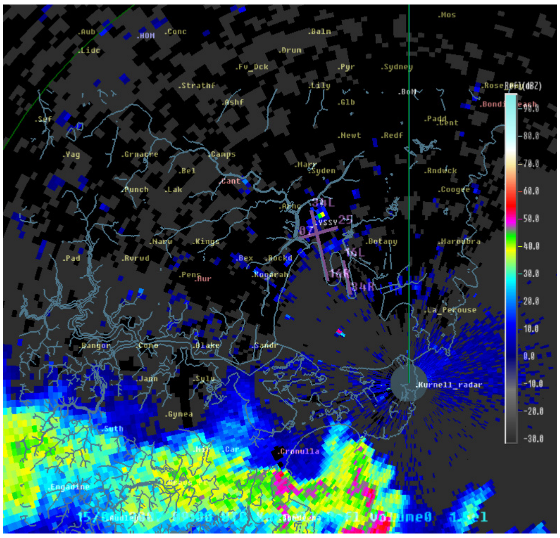
092301 UTC: At this time the wind at the threshold of Rwy 16R has shifted Wly 12 kt and the anemometer data suggests the microburst is centred to the west of the threshold of Rwy 16R.

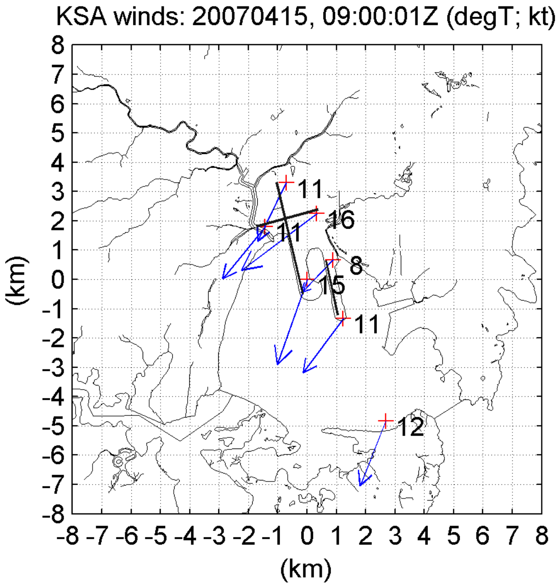
0925 UTC: At this time the radar shows reflectivities of 30-40 dBZ over the airport with the cell core just to the east. There are northeasterly winds around 10 kt at the northern anemometers (07, 25, 16R and 16L) and this is consistent with the presence of a divergent outflow to the northeast of the airport. The presence of the divergent outflow is evident in the Kurnell Doppler velocity data.

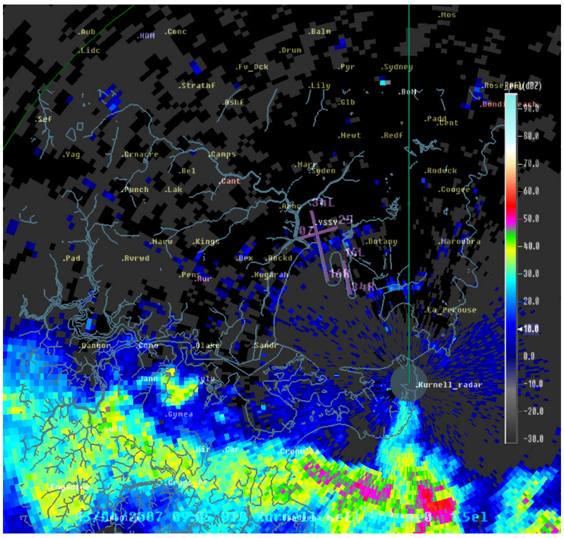
0930 UTC: The radar shows the leading edge of a second line of showers/storms approximately 1 NM to the southwest of the airport. The gust front ahead of this is evident in the anemometer data with 5-10 kt SW winds at southern anemometers (runways 34L, 34R, 07, 16L) and N/NE 5-10 kt winds at northern anemometers runways 16R and 25).

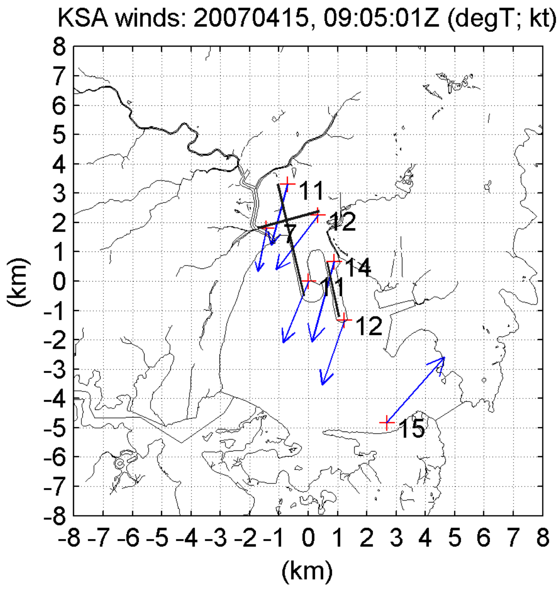
0935 UTC: The radar data shows the second line of showers/storms lying across the airport at this time. The anemometer data clearly shows a divergent outflow with wind speeds of 5-10 kt, indicative of a weak downdraft.

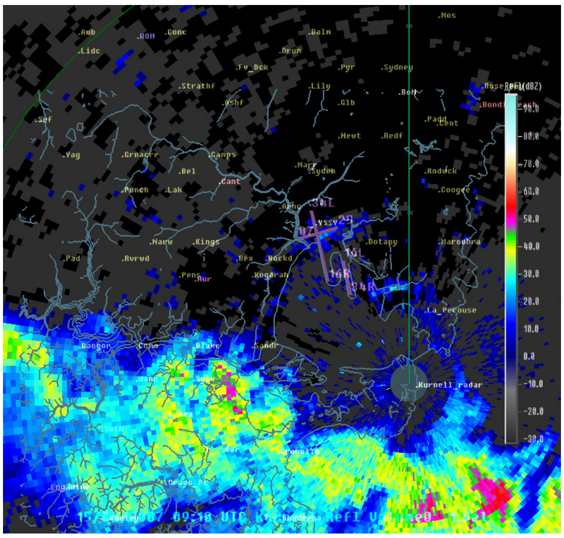
0940 UTC: The radar data shows the most intense line of showers/storms to the east of the Airport with trailing stratiform echoes over the airport. At this time an E/NE airflow of 15-20 kt is evident over the airport. The E/NE winds persisted until around 1030UTC when the strength decreased to 10-15 kt.

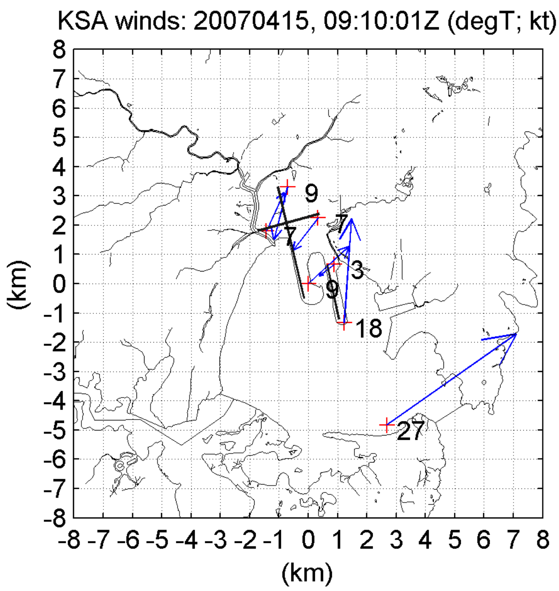



KSA winds: 20070415, 09:00:01Z (degT; kt)
(km)
(km)




KSA winds: 20070415, 09:05:01Z (degT; kt)
(km)
(km)

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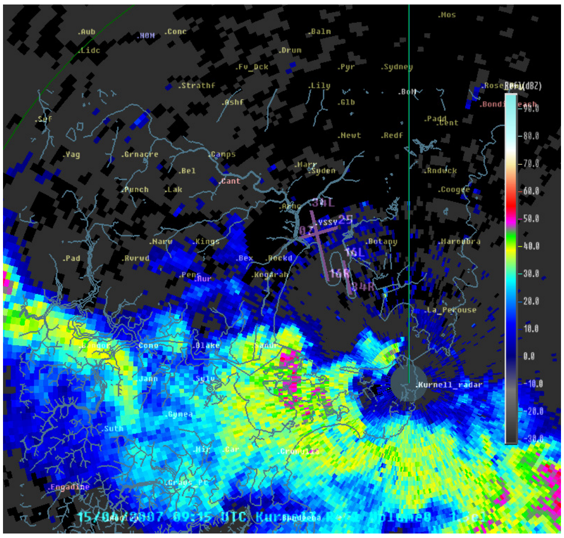
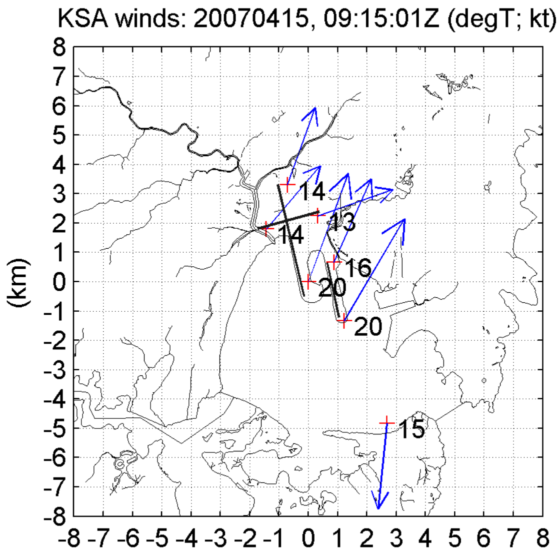
(km)
(km)

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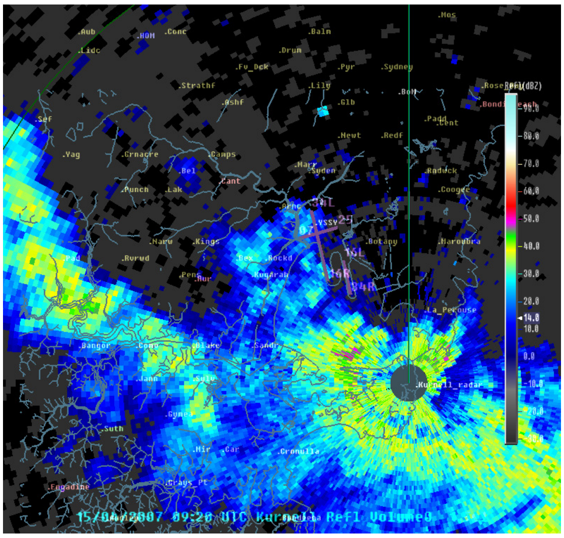
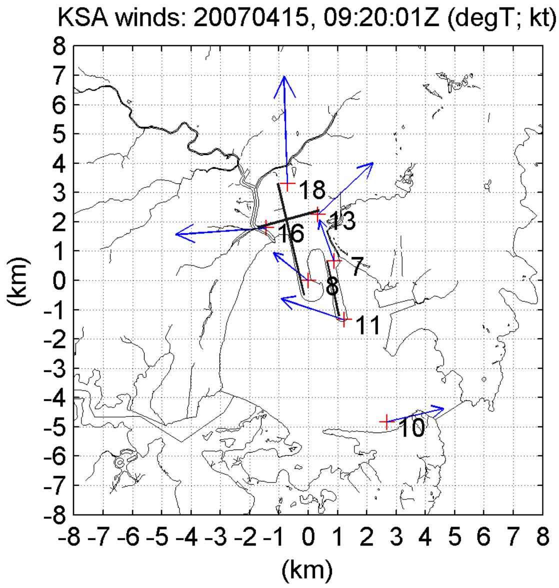
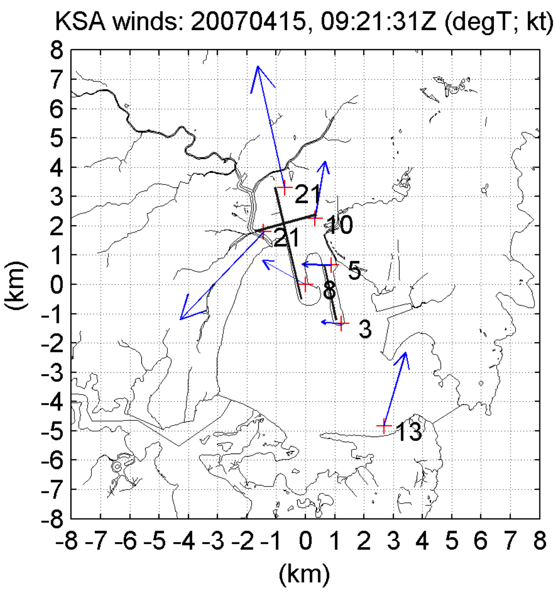
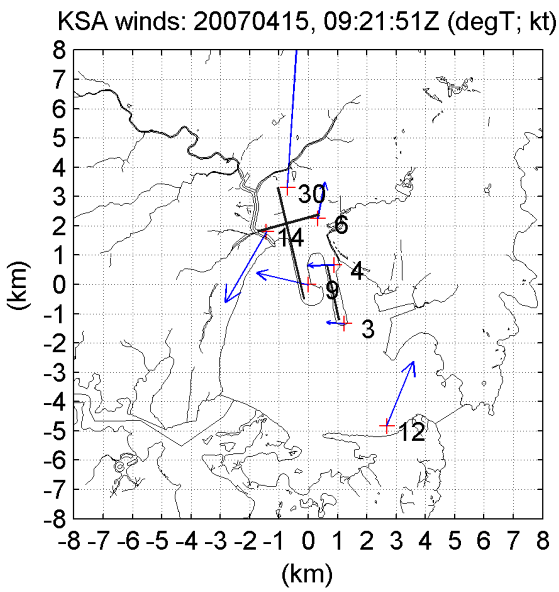
(km)




KSA winds: 20070415, 09:20:01Z (degT; kt)
(km)
(km)


KSA winds: 20070415, 09:21:31Z (degT; kt)
(km)
(km)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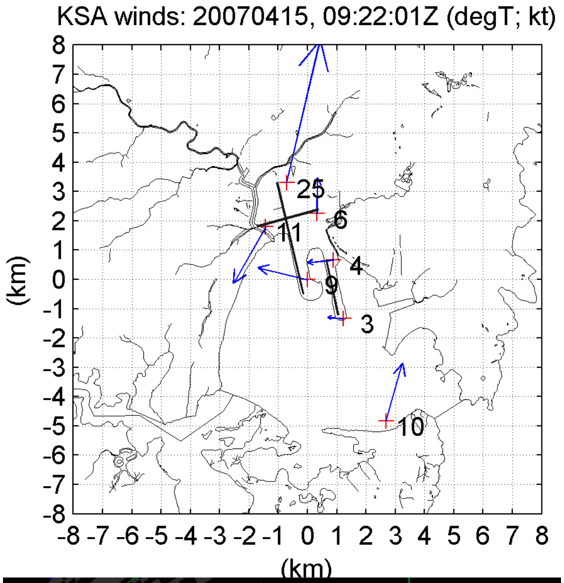
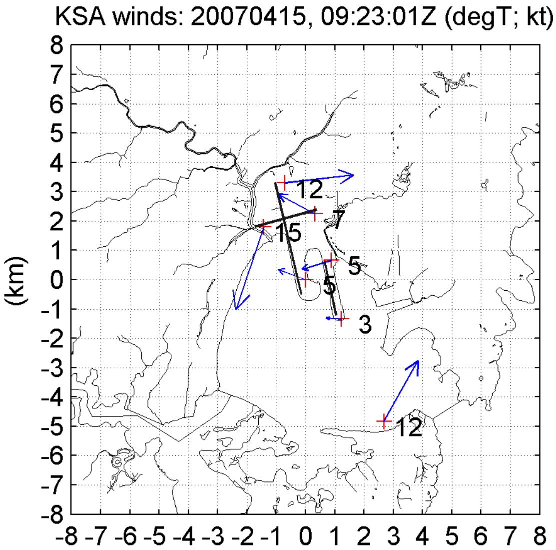
(km)
(km)


KSA winds: 20070415, 09:22:01Z (degT; kt)
(km)
(km)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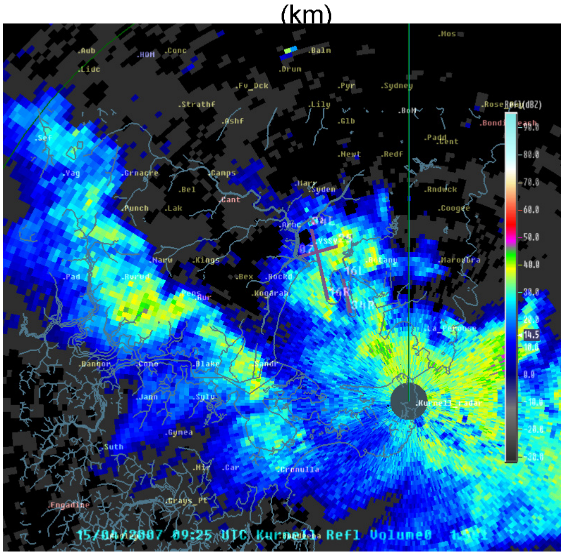
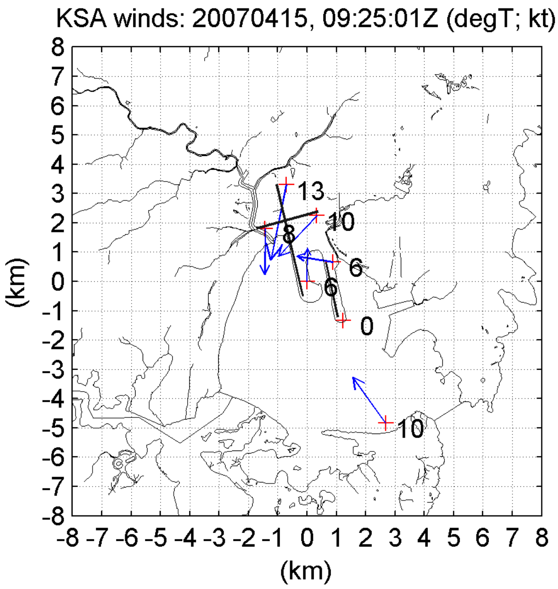
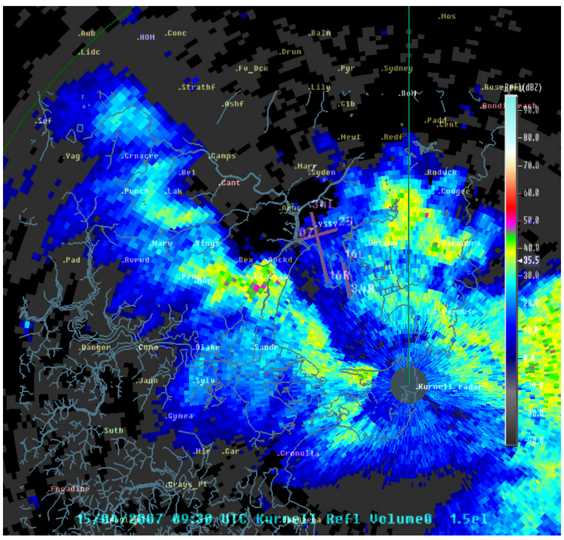
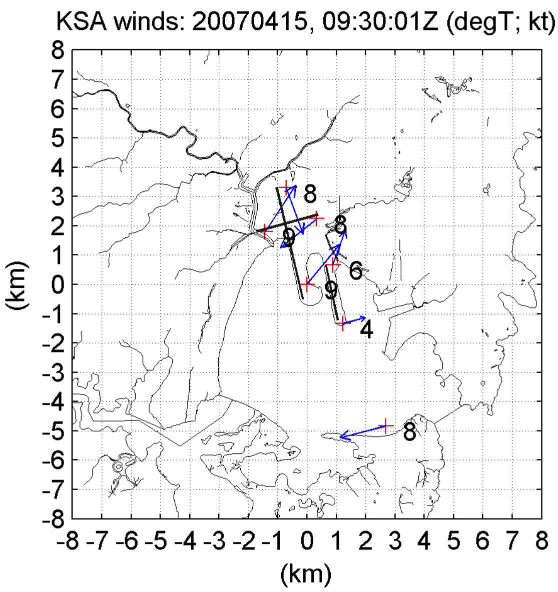
(km)


15/04/2007 09:25 UTC Kurnell Refl Volume0


KSA winds: 20070415, 09:25:01Z (degT; kt)
(km)
(km)


15/04/2007 09:30 UTC Kurnell Refl Volume0 1.5el


KSA winds: 20070415, 09:30:01Z (degT; kt)
(km)
(km)

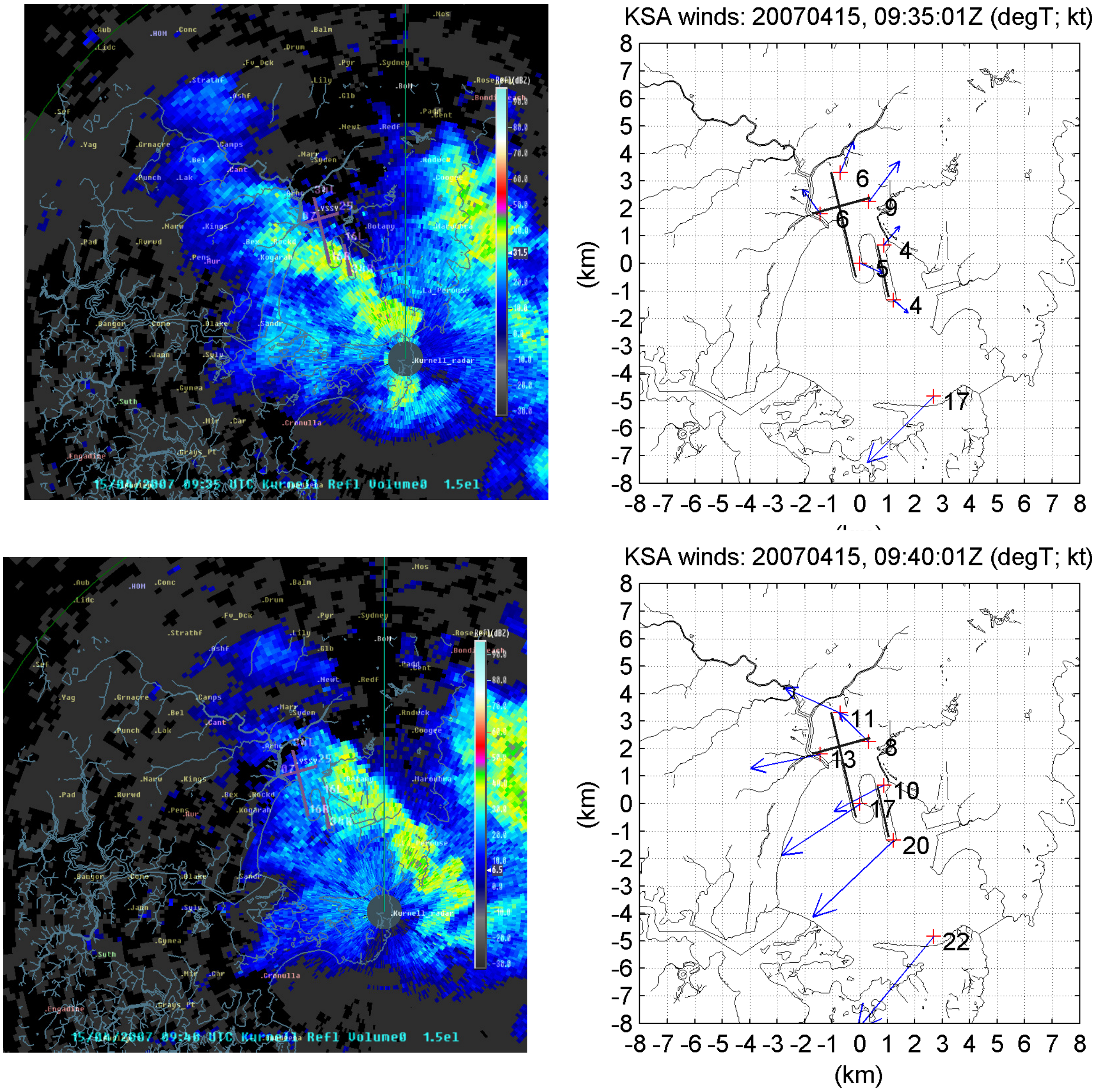


Figure 1. Radar and anemometer data across the Sydney Airport / Botany Bay area in the period 0900-0940 UTC, 15 April 2007. The anemometer data shows wind speeds in knots.

Flight Recorder Data

Fig. 2 shows Flight Recorder Data from the aircraft concerned as it approached Rwy 16R, touched down at 092318 UTC and then climbed as it aborted the landing. This covers the 3 minute period 092048 – 092348 UTC and shows the radar altitude (ft), the wind direction (degT) and the wind speed (x 10 kt) as the aircraft approached.

As the aircraft descended through 2000 ft it experienced NW winds around 10 kt that shifted NE and increased to 15 kt. At around 092213 UTC when the aircraft was at 800

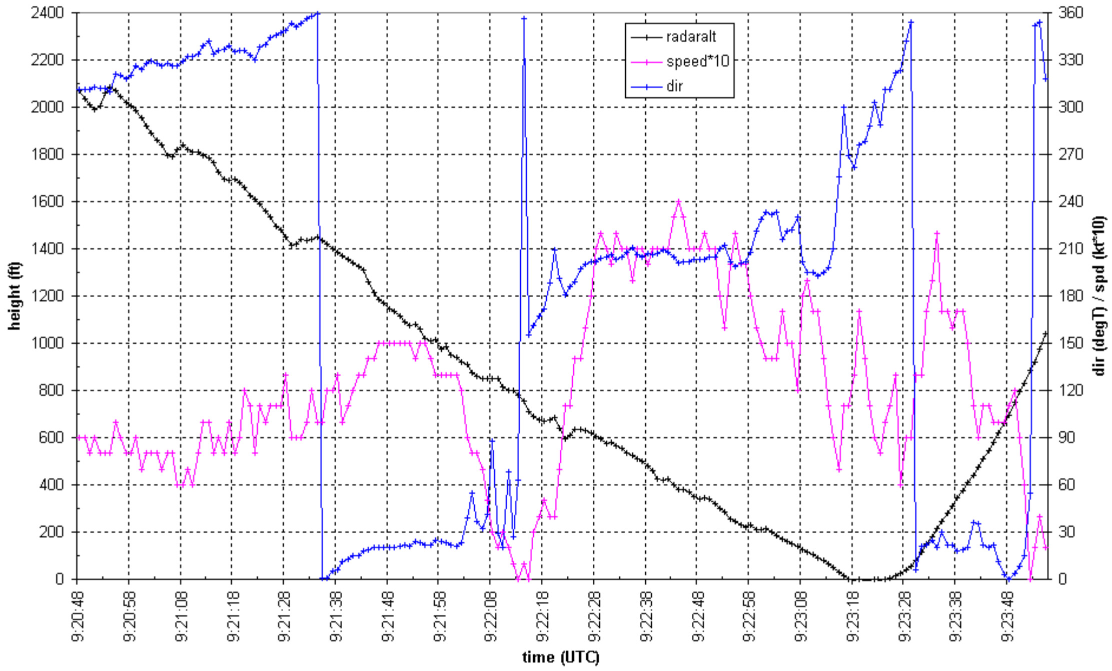


Figure 2. Flight recorder data for period 092048-092348 UTC.

ft the wind shifted from NE to S and increased to around 20 kt. At this time the aircraft was around 4 km north of the threshold for Rwy 16R and the observed wind change is consistent with the aircraft descending through the upper boundary of the gust front that passed across the airport earlier. The observed winds are also consistent with those observed at the threshold of Rwy 16R at this time.

In the period 092311-092316 UTC when the aircraft was at less than 100 ft altitude the wind rapidly shifted from 190/18 kt to 280/12 kt. This is a significant wind change at such a critical stage of landing. The along-track wind component changed from an 18 kt headwind to a 5 kt tailwind with an airspeed loss of 23 kt and there was a rapid increase in the cross wind component. The observed wind change reported by the aircraft is again consistent with the wind observed at the threshold of Rwy 16R where the wind shifted from S to W in the period 092220-092250 UTC.

As the aircraft climbed the observed wind is reported as 020/18 kt consistent with the presence of the divergent outflow.

Discussion

Wind shear is defined in the ICAO Manual on Low-level Wind Shear (ICAO 2005) as "a change in wind speed and/or direction in space, including updrafts and downdrafts". It can result from a number of meteorological factors and at low altitudes this includes sea breezes, cold fronts, strong low level winds, terrain, gust fronts and convective downdrafts.

Experience has shown that low-altitude wind shear presents a significant risk to aviation during the landing/take-off phase when the airspeed and ground clearance are near critical. Furthermore, wind shear associated with convective activity, and particularly microbursts, present the greatest threat to aircraft operations and these phenomena have been the cause of a number of major aircraft accidents involving passenger aircraft (National Research Council, 1983). There have been detailed investigations of these events and a number of scientific studies aimed at gaining a better understanding of their characteristics and the factors that cause them (Wilson et al 1984, Hjelmfelt 1988).

As a convective cloud or thunderstorm develops, and precipitation begins to fall, an associated downdraft will develop and descend towards the surface. In some situations the downdraft can cause damaging winds at the surface. Fujita 1981 defined a microburst as a downdraft associated with a sudden outflow of damaging horizontal winds at the surface with a horizontal extent less than 4.0 km. In a study of microburst characteristics using Doppler radar Wilson et al (1984) refined this by classifying a

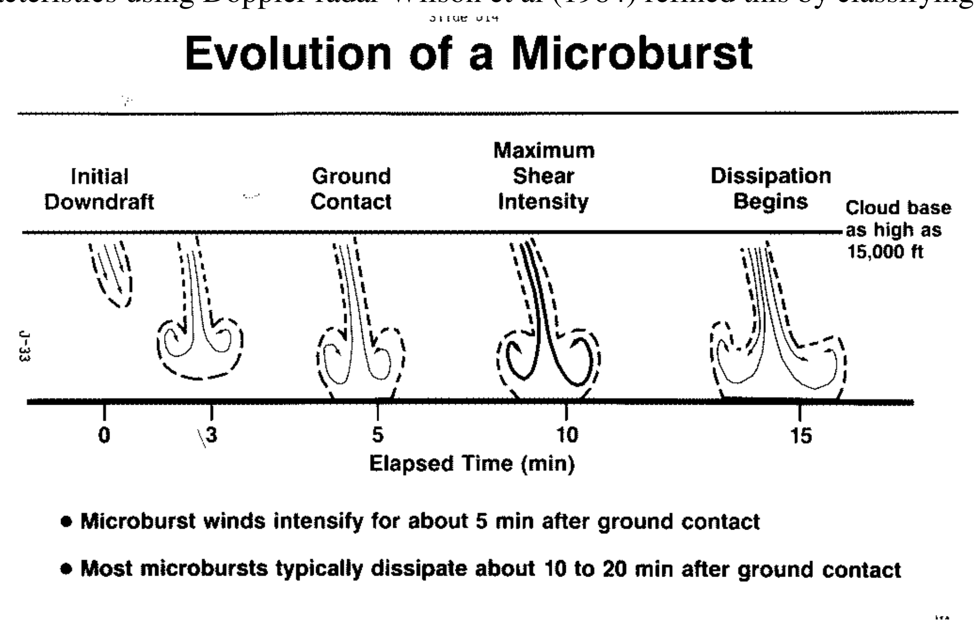


Figure 3. Evolution of typical microburst. (Adapted from Wilson etal 1984)

convective downdraft as a microburst when the distance between the maximum radial outflow regions in the initial stages is ≤ 4km and the velocity differential is ≥ 10 m/s (20 kt). They described the evolution of a typical microburst as illustrated in Fig.3 and found the lifetime of a microburst is of the order of 5-15 minutes. A further finding was that in many cases there may be little or no rain at the surface associated with a microburst.

Based on these criteria, the divergent outflow evident in the anemometer data over the north end of Rwy 16R in the period 091951-092300 UTC can be defined as a microburst. Furthermore since there was very little associated rain we can define it as a 'dry' microburst. Based on the anemometer data the lifetime of the event was at least 3:10 minutes. It is possible the lifetime was a little longer but after 092300 UTC the centre of the microburst was outside the anemometer network and the divergent outflow was not so clearly evident. The wind observations recorded by the aircraft Flight Data Recorder are consistent with the surface observations and with a microburst encounter. The observations suggest that at the time the aircraft touched down on the runway at 092318 UTC the microburst was weakening.

A simple analysis of the vector difference between the observed winds at two anemometers showed the maximum divergence occurred at 092151 UTC when the wind at the thresholds of 16R and 07 was 190/30 kt and 040/14 kt respectively. This corresponds to a vector difference of 43 kt (22 $m.s^{-1}$) over a distance of 1.7 km and equates to a divergence of $12.9x10^{-3}$ s^{-1}. This is significantly greater than the threshold of 10 $m.s^{-1}$ at ≤4 km used by Wilson et al (1984) to define a microburst (equating to a divergence of $2.5x10^{-3}$ s^{-1}), and the mean velocity difference reported by Hjelmfelt (1988) of 24 $m.s^{-1}$ over 3.1 km (equating to a divergence of $7.74x10^{-3}$ s^{-1}).

The analysis presented here also shows there can be very complex wind flows associated with the passage of thunderstorms and the time scales associated with these events can be very short. This applies in particular to the period that associated wind shear might affect the flight corridor on the approach or departure path for any given operational runway. In these situations only automated systems can be used to detect the wind shear and provide appropriate warnings.

The high resolution wind data at Sydney Airport has been archived for several years as part of an effort to better quantify the level of risk to aviation that is associated with wind shear. The rapid changes that can occur in the wind flow during convective weather events as shown for this event demonstrate the utility of these data for analysis of air safety incidents.

The impact of wind shear on aviation

The impact of low-altitude wind shear on aircraft are well understood and the ICAO 'Manual on Low-level Wind Shear' presents considerable detail on the characteristics of wind shear, the impacts on aviation, detection and warning methodologies and training. There are a number of well known issues that must be recognized in relation to the impact of wind shear on aviation:

- The characteristics of wind shear are complex and the phenomena can be caused by a wide range of factors.
- During take-off or landing the available ground clearance may be insufficient for an aircraft to maintain control or recover from some wind shear encounters in time to prevent an accident.
- There is a need to provide appropriate training for meteorologists, ATC personnel and pilots to enable them to recognize the risk of wind shear and provide appropriate warnings or respond in timely and appropriate ways.
- For some wind shear events, including wind shear associated with convection, it is not feasible to provide forecasts due to the small time and space scale of the events. For these events automated detection and warning systems may be required. The cost of installing such systems is significant and the cost effectiveness needs to be determined.

- There is a need for a good understanding of the phenomena that can cause wind shear at any given airport and the level of risk to aviation.

In Australia there have been several studies and several aviation safety incidents associated with wind shear. Potts (2002) provides some background on these and presents details on two recent air safety incidents where aircraft encountered wind shear. The wind shear encounter discussed here supports the conclusion in Potts (2002) that “wind shear associated with convection, namely gust fronts and microbursts, present a risk to aircraft operations in Australia”.

Conclusions

At approximately 0923 UTC, 15 April 2007 a Boeing 747 encountered wind shear when attempting to land on Rwy 16R at Sydney Airport. In this report we provide a preliminary analysis of meteorological observations in the vicinity of Sydney Airport. This includes Flight Recorder Data from the aircraft,. A separate Air Safety Incident Report will be prepared that presents broader details of the weather on the day.

In the period of interest a line of high based convective cells / thunderstorms moved across the airport. A ‘dry’ microburst developed over the north end of Rwy 16R at approximately 091951 UTC and this was most intense in the period 092131-092200 UTC with a maximum velocity difference around 40 kt. The B747 encountered the wind shear associated with this microburst in the final stage of landing and aborted the approach. In this process the aircraft touched down at 092318 UTC before climbing. At this time the available observations suggest the microburst was weakening.

References

Fujita, T.T., 1981: Tornadoes and downbursts in the context of generalized planetary scales. J.Atmos.Sci., 38, 1511-1534.

Hjelmfelt M.R., 1988: Structure and life cycle of microburst outflows observed in Colorado. J.Appl.Meteor. 27, 900-927.

ICAO, 2005: Manual on Low-level Wind Shear. ICAO Doc 9817-AN/449., pp219.

National Research Council, 1983: Low altitude wind shear and its hazard to aviation. National Academy Press, Washington DC., 161pp.

Potts R.J., 2002: Low altitude wind shear at major Australian airports and the risks to aviation. Preprints 10th Conf. on Aviation Range and Aerospace Meteorology, 13-16 May 2002, Portland, Oregon. Amer. Met. Soc.

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APPENDIX B: ANALYSIS BY AIRCRAFT MANUFACTURER

Performance Analysis – Qantas 747-400 VH-OJR
Windshear Encounter during Approach to Sydney – 15 April 2007

ATSB Preliminary Occurrence Report AO-2007-001 contains the following abstract:

> *On 15 April 2007, a Boeing Company 747-438 aircraft, registered VH-OJR, was being operating on a scheduled passenger flight from Singapore to Sydney, NSW. At 1923 Eastern Standard Time, the aircraft was positioned on a short final approach for a landing on runway 16R when it encountered rapidly changing wind conditions. The aircraft touched down firmly and the crew conducted a go around.*

The ATSB provide FDR/QAR data from the event aircraft and asked that Boeing analyze the event. The results of our analysis follow.

<u>FDR Data Analysis</u>
The FDR data for the event landing are plotted on Figures 1 through 4. Figures 1 and 2 show the longitudinal and lateral-directional parameters respectively for the approach and touchdown. Figures 3 and 4 show the longitudinal and lateral-directional parameters respectively for the aircraft right before and during touchdown. Figure 4 includes kinematically calculated winds and vertical speed. Parameter sign conventions were validated using previous on-ground and in-flight maneuvers available in the data.

The FDR data show the aircraft on a flaps 30 approach at a calibrated airspeed of approximately 154 knots. A comparison of the airspeed and ground speed shows a 15 knot headwind that diminished just before touchdown. The recorded gross weight of the aircraft at this time was 555,000 lbs. The appropriate Vref speed for this aircraft configuration is 144 knots. The approach speed would then be calculated as follows: Vref + ½ headwind component + full gust increment (above the steady wind). The winds during the final approach were reported to be 180 degrees at 22 knots. The gust information was not reported to Boeing. Therefore, this would give an approach speed of at least 154 knots and a touchdown speed of at least 144 knots. These speeds would increase if the gust magnitude was reported to the crew as well.

At time 27029 seconds, the vertical speed began to increase (altitude reduction) as the throttles were reduced. At this same time, a vertical wind occurs, resulting in an 8 ft/sec downdraft just before touchdown. At time 27031 seconds, the thrust was then slightly increased at the same time the flare was initiated. This reduced the sink rate slightly. At time 27032 seconds, the wind direction shifted from a right quartering headwind with a magnitude of 15 knots, to a left crosswind. This shift in headwind caused a 15 knot loss in airspeed just before touchdown. A master warning triggered at time 27035 seconds, just after the aircraft experienced this loss in airspeed. The FDR Windshear caution discrete did not toggle at this time. The master warning light will be set if there is a windshear alert displayed on the primary flight display indicating that there is a windshear. It is unclear why the FDR windshear caution discrete did not toggle, however the master warning triggered near the time the crew reported seeing the windshear alert.

A 35 degree right wheel input was commanded to control the sudden left crosswind. This resulted in a lift loss from the raised spoiler panels causing the sink rate to increase. As a result of this lift and airspeed loss, the aircraft touched down with a calibrated airspeed of 141 knots, a recorded normal acceleration of 1.84 g's and a calculated sink rate of 720 ft/min (12 ft/sec). QAN reported a touchdown normal acceleration of 2.3 g's as recorded in the QAR data. The differences seen between the QAR peak value and FDR peak value may be attributed to the sample being recorded at different times within the second. If the FDR data had a higher sample rate, it may have recorded the 2.3 g's seen in the QAR data.

The thrust levers were above idle thrust at the time of touchdown, therefore the speedbrakes did not automatically deploy. A go-around was commanded as the thrust levers were increased at time 27038.5 seconds.

Simulation

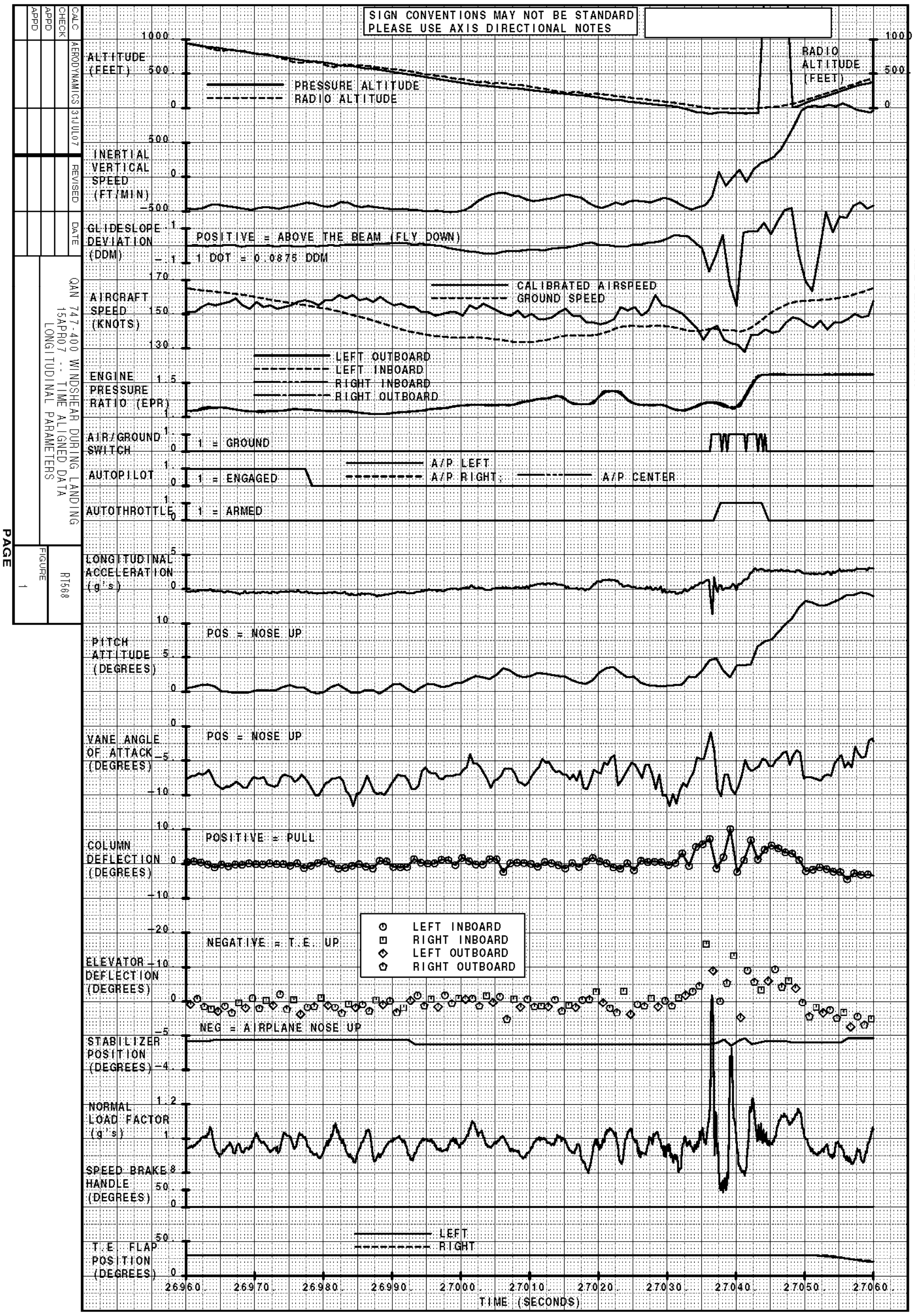
A simulation analysis of the approach portion of the event was performed comparing the recorded data to an engineering model of the aerodynamic performance of the 747-400. This analysis identified the horizontal wind shift with resulting airspeed loss as the primary contributor to the large touchdown sink rate. The vertical wind component and large wheel inputs experienced on final approach were identified as significant but secondary contributors to the large sink rate at touchdown.

Kinematic Analysis

The FDR wind information is a good indication of longitudinal and lateral atmospheric conditions. However, it is recorded at a low sample rate. To better determine the wind conditions, the wind information was predicted kinematically using higher sampled FDR data parameters, 747-400 airplane information, and the equations of motion. This process derives longitudinal, lateral, and vertical wind information that is both at a high sample rate and is consistent with the FDR acceleration information. Figure 4 shows that the kinematic wind calculation agrees closely with the wind data recorded in the FDR data.

Conclusions

QAN reported a windshear event on approach on a 747-400 (RT568) aircraft at the Sydney International Airport (SYD) on 15 April 2007. Analysis of the FDR data indicates that a headwind which shifted to a crosswind caused a loss in airspeed. This loss in airspeed (primary effect), combined with an 8 ft/sec downdraft and a large right wheel input (secondary effects), contributed to a high rate of sink just before touchdown. The flare and the commanded increase in thrust were unable to arrest the high sink rate and the aircraft touched down with a normal acceleration of 1.84 g's and a calculated sink rate of approximately 720 ft/min (12 ft/sec).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AERODYNAMICS
31JUL07
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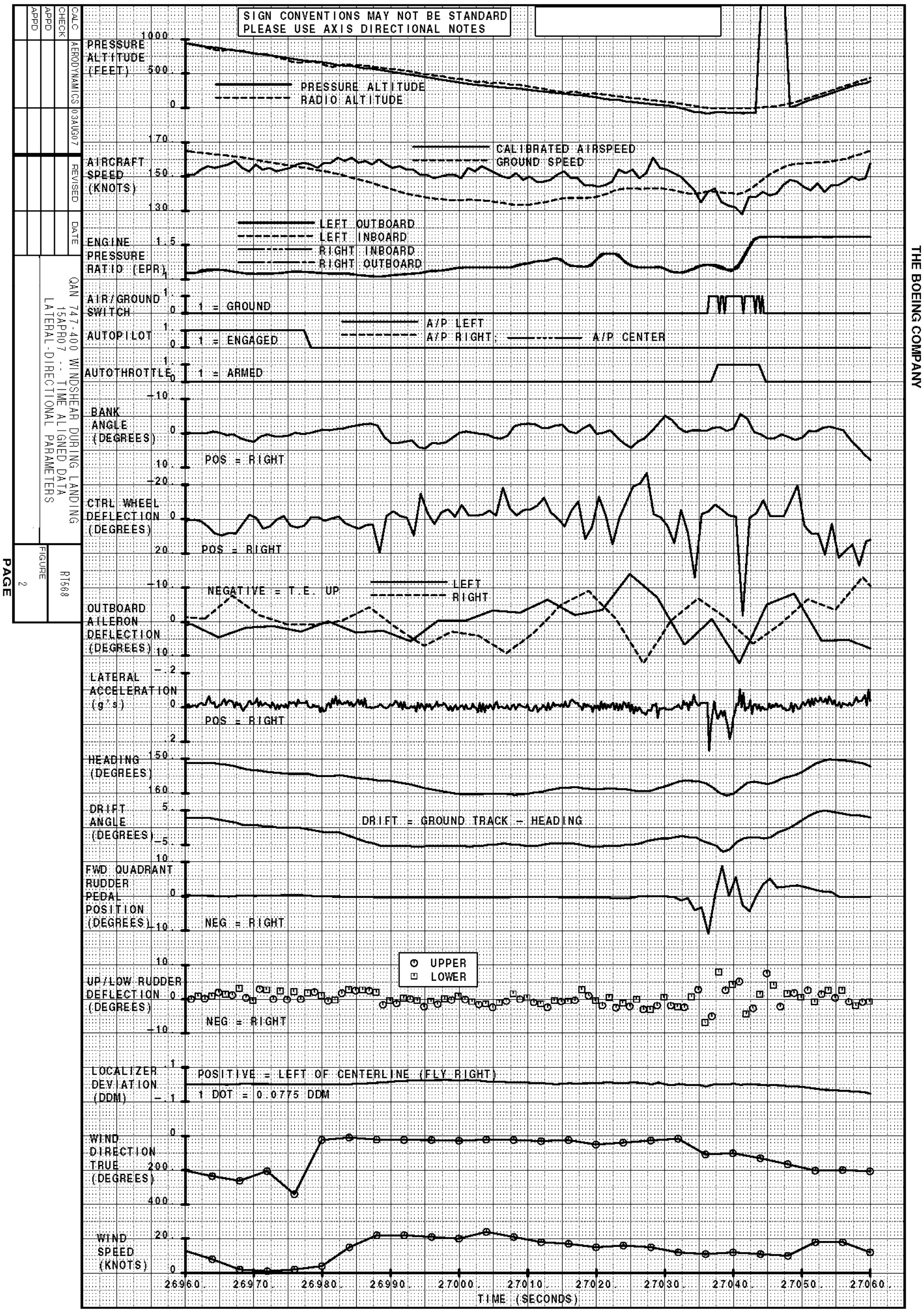
DATE
QAN 747-400 WINDSHEAR DURING LANDING
15APR07 .. TIME ALIGNED DATA
LONGITUDINAL PARAMETERS
RT568
FIGURE
1
PAGE
THE BOEING COMPANY
ALTITUDE (FEET)
PRESSURE ALTITUDE
RADIO ALTITUDE
RADIO ALTITUDE (FEET)
INERTIAL VERTICAL SPEED (FT/MIN)
GLIDESLOPE DEVIATION (DDM)
POSITIVE = ABOVE THE BEAM (FLY DOWN)
1 DOT = 0.0875 DDM
AIRCRAFT SPEED (KNOTS)
CALIBRATED AIRSPEED
GROUND SPEED
ENGINE PRESSURE RATIO (EPR)
LEFT OUTBOARD
LEFT INBOARD
RIGHT INBOARD
RIGHT OUTBOARD
AIR/GROUND SWITCH
1 = GROUND
AUTOPILOT
1 = ENGAGED
A/P LEFT
A/P RIGHT
A/P CENTER
AUTOTHROTTLE
1 = ARMED
LONGITUDINAL ACCELERATION (g's)
PITCH ATTITUDE (DEGREES)
POS = NOSE UP
VANE ANGLE OF ATTACK (DEGREES)
POS = NOSE UP
COLUMN DEFLECTION (DEGREES)
POSITIVE = PULL
ELEVATOR DEFLECTION (DEGREES)
NEGATIVE = T.E. UP
LEFT INBOARD
RIGHT INBOARD
LEFT OUTBOARD
RIGHT OUTBOARD
STABILIZER POSITION (DEGREES)
NEG = AIRPLANE NOSE UP
NORMAL LOAD FACTOR (g's)
SPEED BRAKE HANDLE (DEGREES)
T.E. FLAP POSITION (DEGREES)
LEFT
RIGHT
26960.
26970.
26980.
26990.
27000.
27010.
27020.
27030.
27040.
27050.
27060.
TIME (SECONDS)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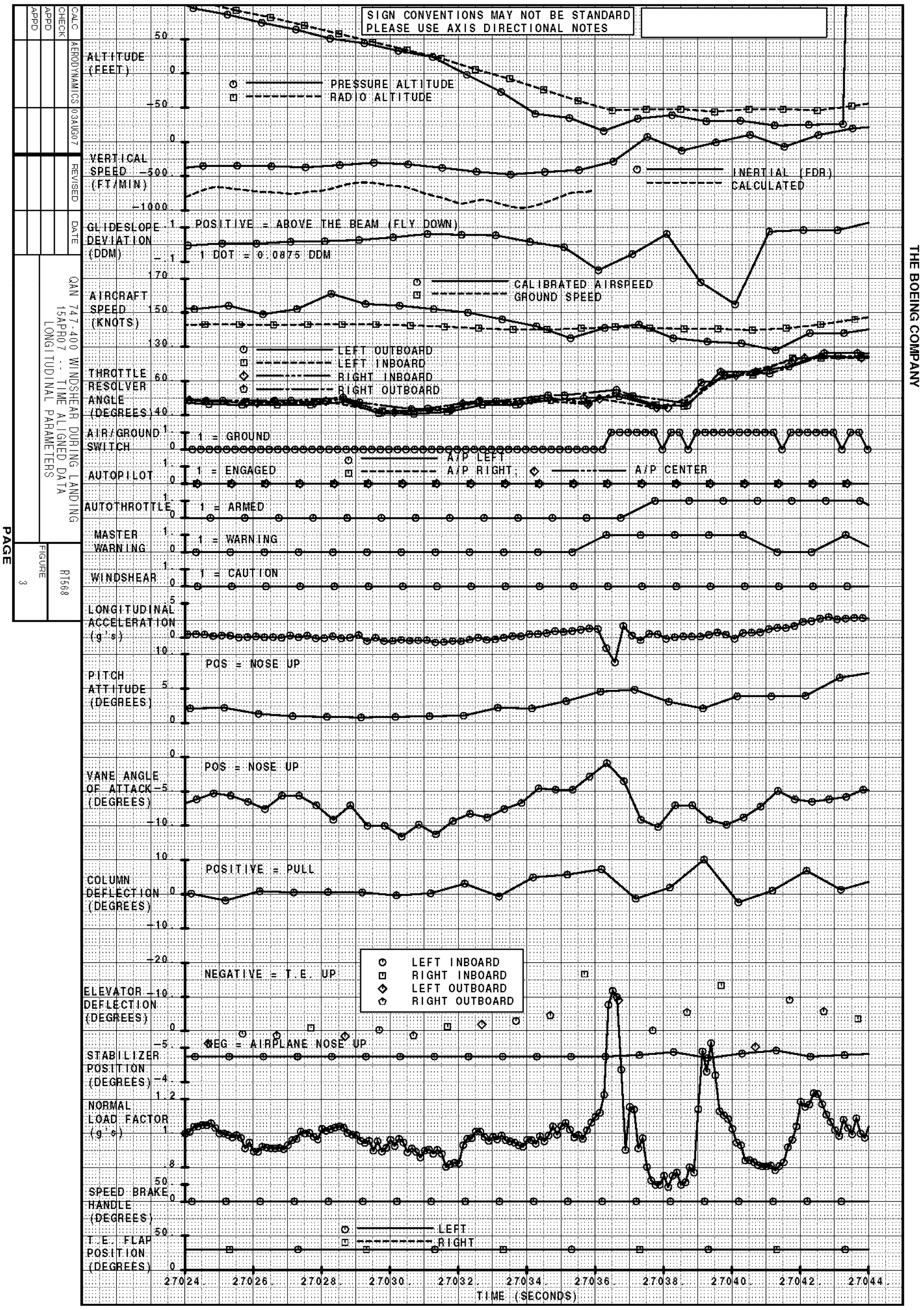
PRESSURE ALTITUDE
RADIO ALTITUDE
AIRCRAFT SPEED (KNOTS)
CALIBRATED AIRSPEED
GROUND SPEED
ENGINE PRESSURE RATIO (EPR)
LEFT OUTBOARD
LEFT INBOARD
RIGHT INBOARD
RIGHT OUTBOARD
AIR/GROUND SWITCH
1 = GROUND
AUTOPILOT
1 = ENGAGED
A/P LEFT
A/P RIGHT
A/P CENTER
AUTOTHROTTLE
1 = ARMED
BANK ANGLE (DEGREES)
POS = RIGHT
CTRL WHEEL DEFLECTION (DEGREES)
POS = RIGHT
OUTBOARD AILERON DEFLECTION (DEGREES)
NEGATIVE = T.E. UP
LEFT
RIGHT
LATERAL ACCELERATION (g's)
POS = RIGHT
HEADING (DEGREES)
DRIFT ANGLE (DEGREES)
DRIFT = GROUND TRACK - HEADING
FWD QUADRANT RUDDER PEDAL POSITION (DEGREES)
NEG = RIGHT
UP/LOW RUDDER DEFLECTION (DEGREES)
UPPER
LOWER
NEG = RIGHT
LOCALIZER DEVIATION (DDM)
POSITIVE = LEFT OF CENTERLINE (FLY RIGHT)
1 DOT = 0.0775 DDM
WIND DIRECTION TRUE (DEGREES)
WIND SPEED (KNOTS)
TIME (SECONDS)
26960. 26970. 26980. 26990. 27000. 27010. 27020. 27030. 27040. 27050. 27060.
CALC CHECK APPD APPD
AERODYNAMICS 03AUG07
REVISED DATE
QAN 747-400 WINDSHEAR DURING LANDING
15APR07 -- TIME ALIGNED DATA
LATERAL-DIRECTIONAL PARAMETERS
RT568
FIGURE 2
PAGE
THE BOEING COMPANY


SIGN CONVENTIONS MAY NOT BE STANDARD
PLEASE USE AXIS DIRECTIONAL NOTES
CALC
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03AUG07
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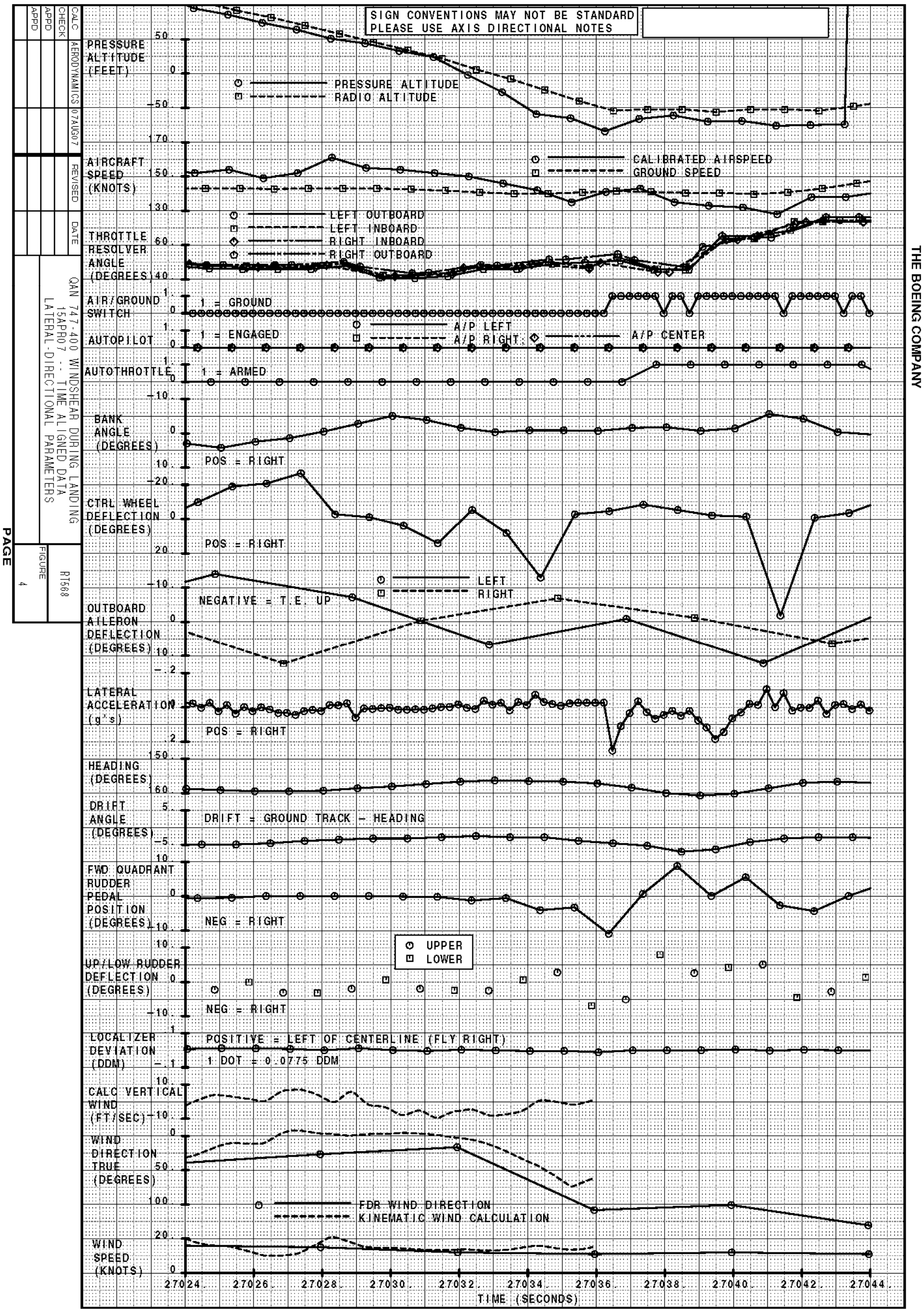
DATE
QAN 747-400 WINDSHEAR DURING LANDING
15APR07 .. TIME ALIGNED DATA
LONGITUDINAL PARAMETERS
RT568
FIGURE
3
PAGE
THE BOEING COMPANY
ALTITUDE (FEET)
PRESSURE ALTITUDE
RADIO ALTITUDE
VERTICAL SPEED (FT/MIN)
INERTIAL (FDR)
CALCULATED
GLIDESLOPE DEVIATION (DDM)
POSITIVE = ABOVE THE BEAM (FLY DOWN)
1 DOT = 0.0875 DDM
AIRCRAFT SPEED (KNOTS)
CALIBRATED AIRSPEED
GROUND SPEED
THROTTLE RESOLVER ANGLE (DEGREES)
LEFT OUTBOARD
LEFT INBOARD
RIGHT INBOARD
RIGHT OUTBOARD
AIR/GROUND SWITCH
1 = GROUND
AUTOPILOT
1 = ENGAGED
A/P LEFT
A/P RIGHT
A/P CENTER
AUTOTHROTTLE
1 = ARMED
MASTER WARNING
1 = WARNING
WINDSHEAR
1 = CAUTION
LONGITUDINAL ACCELERATION (g's)
PITCH ATTITUDE (DEGREES)
POS = NOSE UP
VANE ANGLE OF ATTACK (DEGREES)
POS = NOSE UP
COLUMN DEFLECTION (DEGREES)
POSITIVE = PULL
ELEVATOR DEFLECTION (DEGREES)
NEGATIVE = T.E. UP
LEFT INBOARD
RIGHT INBOARD
LEFT OUTBOARD
RIGHT OUTBOARD
STABILIZER POSITION (DEGREES)
NEG = AIRPLANE NOSE UP
NORMAL LOAD FACTOR (g's)
SPEED BRAKE HANDLE (DEGREES)
T.E. FLAP POSITION (DEGREES)
LEFT
RIGHT
27024
27026
27028
27030
27032
27034
27036
27038
27040
27042
27044
TIME (SECONDS)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AERODYNAMICS 07AUG07
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DATE
QAN 747-400 WINDSHEAR DURING LANDING
15APR07 -- TIME ALIGNED DATA
LATERAL-DIRECTIONAL PARAMETERS
FIGURE 4
RT568
PAGE
THE BOEING COMPANY
PRESSURE ALTITUDE (FEET)
PRESSURE ALTITUDE
RADIO ALTITUDE
AIRCRAFT SPEED (KNOTS)
CALIBRATED AIRSPEED
GROUND SPEED
THROTTLE RESOLVER ANGLE (DEGREES)
LEFT OUTBOARD
LEFT INBOARD
RIGHT INBOARD
RIGHT OUTBOARD
AIR/GROUND SWITCH
1 = GROUND
AUTOPILOT
1 = ENGAGED
A/P LEFT
A/P RIGHT
A/P CENTER
AUTOTHROTTLE
1 = ARMED
BANK ANGLE (DEGREES)
POS = RIGHT
CTRL WHEEL DEFLECTION (DEGREES)
POS = RIGHT
OUTBOARD AILERON DEFLECTION (DEGREES)
NEGATIVE = T.E. UP
LEFT
RIGHT
LATERAL ACCELERATION (g's)
POS = RIGHT
HEADING (DEGREES)
DRIFT ANGLE (DEGREES)
DRIFT = GROUND TRACK - HEADING
FWD QUADRANT RUDDER PEDAL POSITION (DEGREES)
NEG = RIGHT
UP/LOW RUDDER DEFLECTION (DEGREES)
UPPER
LOWER
NEG = RIGHT
LOCALIZER DEVIATION (DDM)
POSITIVE = LEFT OF CENTERLINE (FLY RIGHT)
1 DOT = 0.0775 DDM
CALC VERTICAL WIND (FT/SEC)
WIND DIRECTION TRUE (DEGREES)
FDR WIND DIRECTION
KINEMATIC WIND CALCULATION
WIND SPEED (KNOTS)
27024 27026 27028 27030 27032 27034 27036 27038 27040 27042 27044
TIME (SECONDS)

APPENDIX C: ANALYSIS BY EGPWS MANUFACTURER

Analysis of B747-400 Windshear event
Rev: New 5-14-2007

Warning history download data taken from EGPWS P/N 965-0976-003-216-216 S/N 14557 with Terrain database 433. Aircraft type is B747-400.

Windshear Warning event is found at EPGWS flight leg #1647 and occurred on approach into Sydney, Australia at a radio altitude of 12 feet.

The recorded data was formatted and then run through a simulation of the EGPWS Windshear computation as done on the B747-400 aircraft. The recorded data matched very closely the simulated data.

Note the recorded data is provided at a 1 second sample rate. The simulation used data interpolation to provide a 10 hertz simulation rate to match the computation rate of the EGPWS.

Figure 1 below shows a graph of the EGPWS calculated windshear value (total shear) versus the threshold values. The Windshear Caution threshold is set a +0.09 g's, and the Windshear Warning threshold is set to -0.11 g's. The graph also shows separate values for the horizontal and vertical Windshear components as calculated by the EGPWS.

As can be seen from the graph the Windshear Warning threshold was exceeded at time 19 seconds. The Windshear event is triggered by a large horizontal Windshear. Very little vertical shear (downdraft) is detected.

Figure #2 shows the recorded speeds. True Airspeed first increases from 150 knots to a maximum of 163 knots starting at time 10 seconds. Then True Airspeed rapidly decreases from the 163 knot maximum to a minimum of 135 knots (-28 knots) over the next 7 seconds. Ground speed is fairly steady during this time. This rapid decrease in True Airspeed (shear) started at a radio height of 111 feet. This is about 8 seconds before touchdown.

Figure 1 – Shear value

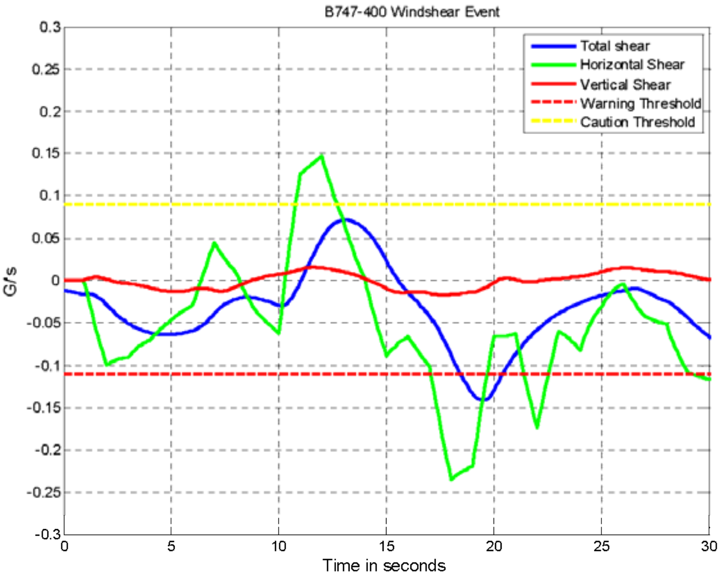
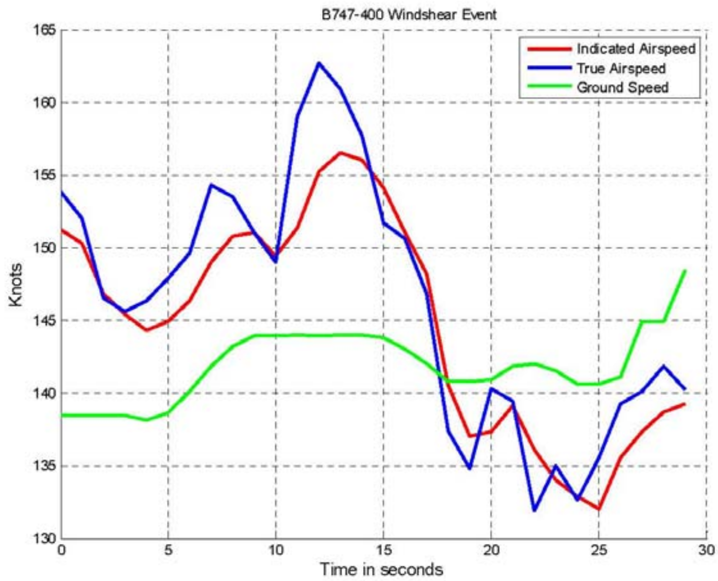


Figure 2 -


B747-400 Windshear Event
Indicated Airspeed
True Airspeed
Ground Speed
Knots
165
160
155
150
145
140
135
130
0
5
10
15
20
25
30
Time in seconds

APPENDIX D: SOURCES AND SUBMISSIONS

Sources of Information

The main sources of information during the investigation included:

- the pilots of VH-OJR
- the aircraft operator
- Airservices Australia
- the Bureau of Meteorology
- the aircraft manufacturer
- the manufacturer of the flight data recorder
- the manufacturer of the enhanced ground proximity warning system.

References

Schlickenmaier, H. (1988). *Windshear case stud: Denver, Colorado, July 11, 1988 (DOT/FAA/DA-89/19)*. Washington, DC; Federal Aviation Administration.

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the Transport Safety Investigation Act 2003, the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the:

- members of the flight crew
- affected air traffic controllers
- aircraft operator
- aircraft manufacturer
- airport operator
- relevant avionics manufacturers
- Civil Aviation Safety Authority
- Airservices Australia
- Bureau of Meteorology
- US National Transportation Safety Board.

Submissions were received from the pilot in command, the aerodrome controller – east, the aerodrome controller – west, the airport operator, Airservices Australia and the aircraft manufacturer. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.