Australian Government
Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Aviation Occurrence Report – 200505311

Final

Crosswind Landing Event
Melbourne Airport, Vic. - 26 October 2005
HS-TNA
Airbus A340-642

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Figure 3 – sourced from the Airbus A340 Aircraft Maintenance Manual

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Abstract

At 1200 Eastern Standard Time on 26 October 2005, the outboard bead heel of the number-1 wheel tyre on the left main landing gear (MLG) of an Airbus A340-642 (A340) aircraft, registered HS-TNA, separated from the outboard rim of the wheel assembly during a landing on runway 16 at Melbourne Airport, Vic. The landing was conducted during gusting crosswind conditions.

The number-1 wheel tyre deflated immediately after the bead heel separated from the wheel rim. The tyre then partially disintegrated during the remainder of the landing roll, and the tyre tread detached from the tyre casing. Following the number-1 wheel tyre deflation, the crew maintained control of the aircraft and, apart from some minor deviations to the left and right of the runway centreline, tracked along the centreline.

The aircraft touched down with 15-degrees of yaw as a result of its handling by the flight crew. That yaw angle was greater than recommended by the aircraft manufacturer, and increased the risk of damage to the MLG at touchdown. It also increased the risk that the resultant groundslip angle of the MLG tyres would exceed the ‘saturation’ point at which they entered a fully-skidded state.

The pilot in command made dual side stick inputs during the latter stages of the approach intending to assist the copilot to maintain the attitude and trajectory of the aircraft. Those dual inputs compounded the handling difficulties being experienced by the copilot and increased the associated risks. Those risks could have been mitigated by the pilot in command taking control of the aircraft and pressing the side stick priority pushbutton at the point where he appeared to have become concerned about its attitude and trajectory, instead of making dual side stick inputs.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Transport and Regional Services. ATSB investigations are independent of regulatory, operator or other external bodies.

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. Accordingly, the ATSB also conducts investigations and studies of the transport system to identify underlying factors and trends that have the potential to adversely affect safety.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and, where applicable, relevant international agreements. The object of a safety investigation is to determine the circumstances in order to prevent other similar events. The results of these determinations form the basis for safety action, including recommendations where necessary. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations.

It is not the object of an investigation to determine blame or liability. However, it should be recognised that an investigation report must include factual material of sufficient weight to support the analysis and findings. That material will at times contain information reflecting on the performance of individuals and organisations, and how their actions may have contributed to the outcomes of the matter under investigation. 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.

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. While the Bureau issues recommendations to regulatory authorities, industry, or other agencies in order to address safety issues, its preference is for organisations to make safety enhancements during the course of an investigation. The Bureau prefers to report positive safety action in its final reports rather than make formal recommendations. Recommendations may be issued in conjunction with ATSB reports or independently. A safety issue may lead to a number of similar recommendations, each issued to a different agency.

The ATSB does not have the resources to carry out a full cost-benefit analysis of each safety recommendation. The cost of a recommendation must be balanced against its benefits to safety, and transport safety involves the whole community. Such analysis is a matter for the body to which the recommendation is addressed (for example, the relevant regulatory authority in aviation, marine or rail in consultation with the industry).

FACTUAL INFORMATION

Occurrence sequence

At 1200 Eastern Standard Time[1] on 26 October 2005, the outboard bead heel of the number-1 wheel tyre on the left main landing gear (MLG) of an Airbus A340-642 (A340) aircraft, registered HS-TNA, separated from the outboard rim of the wheel assembly during a landing on runway 16 at Melbourne Airport, Vic. The landing was conducted during gusting crosswind conditions.

The aircraft was on a scheduled passenger service from Bangkok, Thailand, with a crew of 20 and 253 passengers on board. The copilot was the handling pilot for the flight. There were no reported injuries to any of the aircraft occupants.

The number-1 wheel tyre (figure 1) deflated immediately after the bead heel separated from the wheel rim. The tyre then partially disintegrated during the remainder of the landing roll, and the tyre tread detached from the tyre casing (see Appendix A).

Following the number-1 wheel tyre deflation, the crew maintained control of the aircraft and, apart from some minor deviations, tracked along the centreline (see Appendix B).

Figure 1: Number-1 wheel tyre

Source: http://www.airbus.com/store/photolibrary/AIRCRAFT/AIRBUS/A330_340/att00000832/media_object_image_lowres_709X473_A340-600.jpg
airbus/cassian koshorst
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[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.

Damage to the aircraft

Contact with the runway surface scored and scratched the outboard rim of the number-1 wheel assembly after the tyre deflated (figure 2).

Figure 2: Damaged number-1 wheel assembly

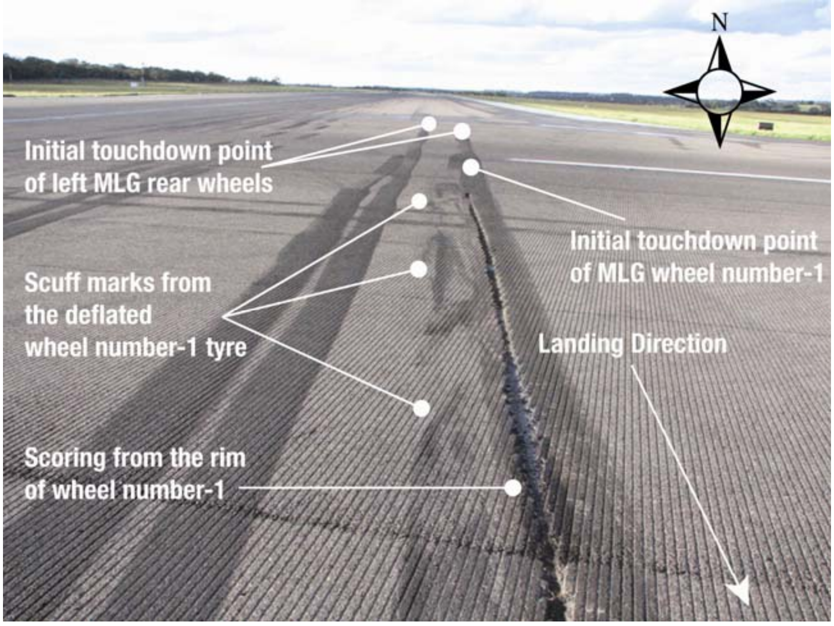
Fragments of rubber that dislodged from the disintegrating tyre impacted the underside of the left wing and the left underside of the fuselage near the left MLG and resulted in some minor skin damage. Rubber fragments also broke off a small portion of the left MLG fairing door, and dislodged a small inspection panel on the inboard side of the number-2 engine pylon.

The disintegrating tyre also damaged a hydraulic brake line on the left MLG. The heat from the left MLG wheel-brake assemblies ignited hydraulic fluid which leaked from the damaged brake line. The airport rescue and fire fighting service (RFFS) rapidly extinguished the fire.

Other damage

The number-1 wheel rim damaged the surface of runway 16 after the tyre separated from the wheel rim (figure 3). Appendix B depicts the extent of the markings and gouging to the surface of runway 16/34 as a result of the occurrence.

Figure 3: Markings and damage to the surface of runway 16



Personnel information

Flight crew

The flight deck crew was an augmented crew consisting of the pilot in command and three copilots.

The pilot in command held an appropriate flight crew licence, was type-rated on A340 aircraft, held a current medical certificate, and had 18,013 hours total flight experience. Of that experience, 17,913 hours were on multi-engine aircraft types, and 630 hours were on the A340 aircraft.

The handling copilot also held an appropriate flight crew licence, was type-rated on A340 aircraft, held a current medical certificate, and had 3,547 hours total flight experience, of which 3,355 hours were on multi-engine aircraft, and 43 hours were on A340 aircraft. Before commencing operations on the A340, the handling copilot had been operating as a copilot on Airbus A330 aircraft.

Both handling crew members reported having taken a period of inflight rest during the flight from Bangkok to Melbourne. Following that rest period, both handling crew members had been at the controls for 3 hours and 15 minutes at the time of the occurrence.

Air traffic services

Airservices Australia reported that all air traffic services (ATS) controllers involved in the control of the aircraft as it approached Melbourne Airport were licensed and rated for the relevant controller positions. The controller acting as the Melbourne Flow Controller was not endorsed to operate in that position, but was under the supervision of an appropriately-endorsed flow controller at the time.

Airservices Australia reported it had identified no unusual work conditions or distractions within the ATS environment that may have contributed to the incident. Also, none of the controllers reported having been fatigued while they were involved in managing the aircraft's approach to Melbourne.

The investigation concluded that the licensing, qualifications and experience of the ATS personnel and the work environment were not factors in the occurrence.

Aircraft information

General

Aircraft model	Airbus A340-642
Serial Number	677
Date of Manufacture	29 June 2005
Certificate of Registration	Valid, issued 29 June 2005
Certificate of Airworthiness	Valid, issued 29 June 2005
Total airframe hours & cycles	1,506 hours, 180 cycles
Left MLG number-1 tyre landing cycles	180
Landing weight	245,300 kgs
Maximum permitted landing weight	256,000 kgs
Maximum demonstrated landing crosswind limit (gust included)	37 kts

The certification requirements for the aircraft included that the '90-degree cross component of wind velocity', or crosswind component[2] demonstrated to be safe for takeoff and landing operations on dry runways 'need not exceed 25 kts'.

Aircraft tyres

The aircraft was fitted with Michelin NZG tyres, which were the certified tyres for the aircraft type. The operator reported that the number-1 tyre, serial number 4191A183, was new when fitted to the wheel rim on 29 June 2005, and had subsequently done 180 landing cycles.

After the occurrence, the remaining MLG tyres showed some evidence of sidewall 'scuffing' and lateral scuff marks on the tyre treads.

Wheel brakes

Each MLG had four wheels, and each wheel was fitted with a multi-disc-type brake. No effective wheel braking would have been available on the number-1 wheel following the partial disintegration of the tyre and detachment of the tyre tread. The resulting 25 per cent reduction of the total left MLG wheel braking effectiveness

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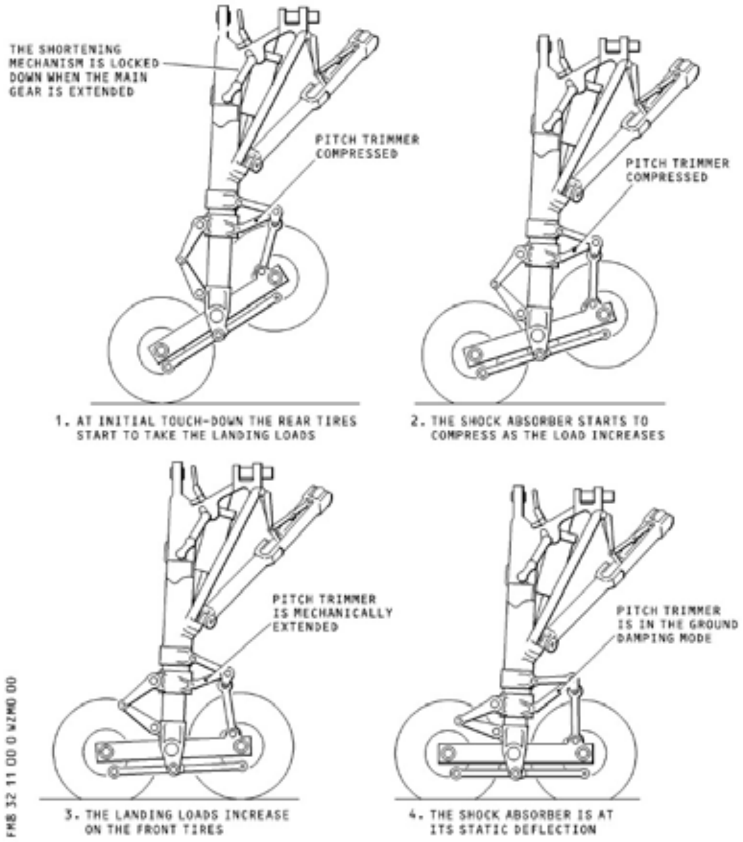
[2] Velocity of the wind component at 90-degrees to the runway.

would have led to an asymmetry in the braking effect between the left and right MLG wheel brakes during the landing roll.

Main landing gear bogey

The main landing gear bogeys of the A340 tilted rearwards when the aircraft was airborne with the landing gear extended. During landing, the rear tyres on the MLG contacted the ground first. As the aircraft weight settled onto the MLGs, the MLG bogey arms 'derotated', and the front tyres lowered onto the ground (figure 4).

Figure 4: Main landing gear bogey alignment – direction of travel left to right



Flight warning system

The aircraft was fitted with a flight warning system (FWS) that provided the flight crew with aural and visual alerts as 'attention getters' for certain configuration, failure, and flight condition situations. The aural alerting function of the FWS provided a variety of specific sound and synthetic voice warnings. The synthetic voice warnings included:

- reporting of significant radio altitudes
- 'HUNDRED ABOVE' and 'MINIMUM' for landing approach decision heights
- 'WINDSHEAR', 'STALL', and 'SPEED, SPEED, SPEED'
- thrust 'RETARD' during the landing flare
- side stick controller 'DUAL INPUT'.

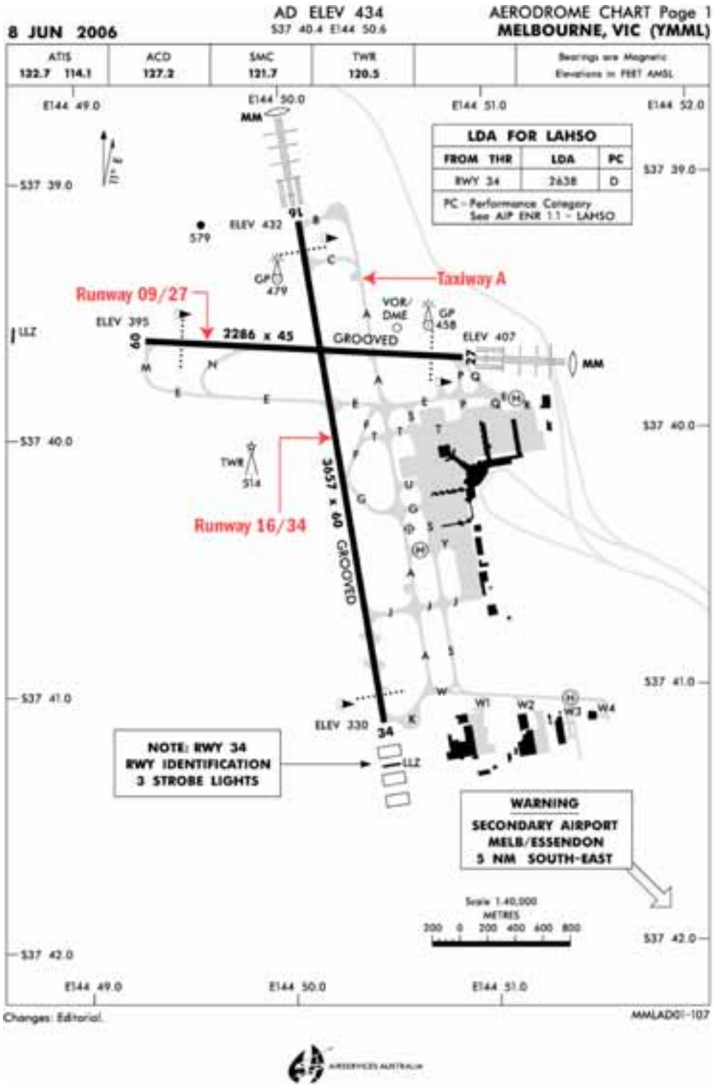
Meteorological information

Before the flight departed Bangkok, the flight crew obtained the Melbourne aerodrome forecast (TAF), valid for their arrival at Melbourne. The TAF contained information that gusty northerly wind conditions were expected at Melbourne between 0600 and 1100. It also contained information that a westerly wind of 15 kts was expected after 1100.

The Bureau of Meteorology weather radar data indicated that a cold front passed through Melbourne Airport at about 1130. The 1200 aerodrome routine meteorological report for Melbourne Airport included information that the wind direction and speed were 260 degrees true (T) at 23 kts, gusting to 29 kts. Melbourne Airport automatic terminal information service (ATIS) ‘Yankee’, issued at 1130, included information that the wind direction and speed were 230 to 280 degrees magnetic at 18 to 30 kts, with a maximum crosswind of 14 kts. The visibility at Melbourne was greater than 10 km, and there had been no recent rain at Melbourne.

Melbourne Airport was equipped with five anemometers that recorded wind speed and direction in 1-minute intervals. The MLW1 anemometer was located to the north-west of the intersection of runways 16/34 and 09/27. The MLW2 anemometer was located on the northern side of runway 09/27, east of taxiway A (figure 5). The wind speed and direction data recorded by the MLW1 and MLW2 anemometers confirmed that gusty wind conditions existed in the touchdown zone of runway 16 before, during, and after the occurrence. The 1-minute recorded data for the MLW1 and MLW2 anemometers at 1200 is included at table 1.

Figure 5: Melbourne airport[3]



The recorded data from the MLW1 anemometer revealed that, during the period between 1100 and 1200, the mean wind direction ranged from between 245 to 352 degrees true. During that same period, the maximum wind speed ranged from 6 kts to 27 kts, and was greater than 15 kts for a total of 34 minutes.

Table 1: Melbourne airport anemometer data at 1200

Anemometer	Wind speed, (Mean)	Wind speed, (Min.)	Wind speed, (Max.)	Wind direction (Mean)	Wind direction (Min.)	Wind direction (Max.)
MLW1	20 kts	15 kts	27 kts	260 True	247 True	273 True
MLW2	21 kts	18 kts	25 kts	258 True	260 True	266 True

A wind rose providing information about the 1-minute distribution of maximum wind speeds and the frequency of the varying wind directions that were recorded by the MLW1 anemometer between 1100 and 1200 is depicted at figure 6.

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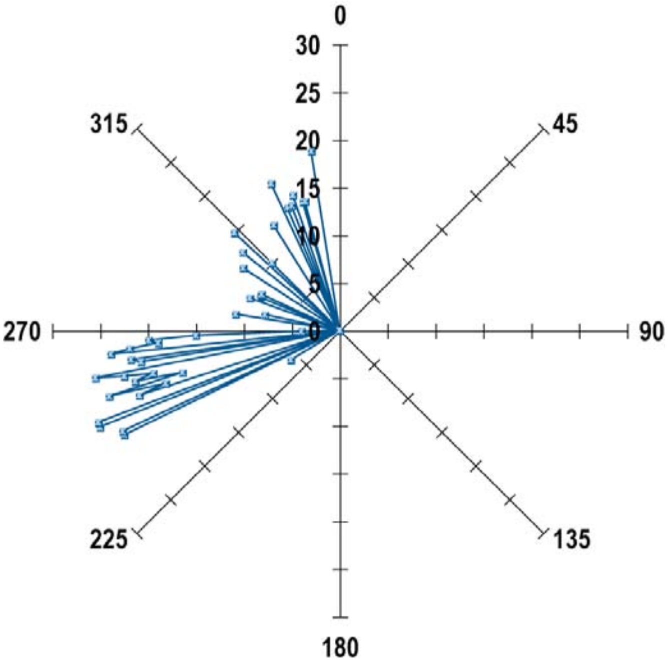
[3] © Airservices Australia 2006. Reproduced with the permission of Airservices Australia.

Figure 6: MLW1 anemometer wind rose for period 1100 to 1200



The wind displays in the control tower at Melbourne Airport showed a graphical depiction of wind direction, accompanied by a digital representation of the actual wind strength. The displays were selectable to display actual wind strength, or crosswind component for the runway selected.

During the investigation, Airservices Australia reported that, during typical tower operations, it was normal practice to have the wind display in front of the aerodrome controller selected to display the threshold wind for the duty runway. A second wind display on the controller's console was normally selected for a second duty runway, if in operation, or for a non-duty runway when one was being used. Airservices reported that the aerodrome controller on duty at the time of the occurrence believed that the first wind display on the controller's console had been selected to display the threshold wind for runway 27, and that the second wind display had been set to display the threshold wind for runway 16.

Airservices Australia also reported that it was possible that, in the strong westerly wind conditions that existed at the time of the occurrence, lee turbulence may have been present in the latter area of the approach onto runway 16. If present, that turbulence had probably been generated by the passage of the strong westerly winds over an area known as the Box Forest that was located in the north-west quadrant of Melbourne Airport, and which was to the west of the runway 16 touchdown zone.

The crew subsequently reported that they were aware of the risk of an engine 'podstrike' during crosswind landings on the A340. They also reported that, when the aircraft was on short final for the landing on runway 16 at Melbourne, they could see that strong and gusty crosswind conditions existed.

Aids to navigation

Ground-based aids

A windsock was located to the east of the touchdown zone of runway 16. It provided aircraft crews with a visual indication of the direction of the surface wind and a general indication of the prevailing wind speed for a landing on runway 16.

Ground-based navigation aids, onboard navigation aids, and aerodrome visual ground aids, and their serviceability, were not a factor in this occurrence.

Equipment on board the aircraft

Presentation of wind speed and direction data to the crew

The aircraft was fitted with an electronic flight instrument system, comprising of primary flight display and navigation display (ND) units installed on the flight instrument panels in front of each crew member. The top left portion of each ND provided the crew with an inertial reference system (IRS)-derived presentation of wind speed and direction data in both digital and analogue format. Additionally, the aircraft's true airspeed (TAS) and groundspeed (GS) were presented above the wind speed and direction data.

The inertial reference system (IRS) wind was derived from the aircraft's TAS and GS vectors. The IRS wind was computed about 10 times per second, and was displayed on the crew's NDs. The displayed IRS wind was therefore, in practical terms, the real-time wind being encountered by the aircraft.

Air data inertial reference units

The aircraft's Air Data Inertial Reference System (ADIRS) included three air data/inertial reference units (ADIRUs). Each unit provided inertial reference information, and an indication of the aircraft's attitude (pitch, roll and yaw), heading, ground speed and present position. Acceleration signals from the attitude and heading information provided by the ADIRUs were resolved into earth-related acceleration rates to provide horizontal and vertical navigation information.

The IRS-derived wind speed and direction that was displayed to the crew was computed by the aircraft's ADIRUs as follows:

- **Wind speed.** The wind speed was computed from the difference between the aircraft's GS and TAS. For a computed wind speed of greater than 50 kts, the accuracy of those parameters was:
  - wind speed, ± 12 kts
  - wind direction, ± 10 degrees.
- **Wind direction.** The wind direction was computed from the difference in the aircraft's track (TRK) and heading (HDG).

  That wind was computed about 10 times per second, and was displayed on the crew's NDs.

In addition, the aircraft manufacturer advised that the true track accuracy was ±2.3 degrees with a GS of 200 kts, and that the true heading accuracy was ±0.4 degrees.

The aircraft manufacturer cautioned that, as a result of the accuracy of the various parameters used to compute the wind speed and direction, crews should use the displayed wind speed and direction 'with care'.

The ADIRUs were located in the aircraft electrical and electronic compartment beneath the cockpit. Because of their location forward of the aircraft centre of gravity (CG), transient yaw accelerations could affect the derived wind speed and direction data presented to the crew. However, once any transient yaw stabilised, the value of the derived wind speed and direction would equal that experienced at the aircraft's CG.

Communications

The internal communications between the ATS controllers and transmissions between ATS and the crew during the aircraft's descent and approach to Melbourne Airport were recorded by ground-based automatic voice-recording equipment. The quality of those recorded transmissions was good. A chronology of the relevant ATS communications is included at table 2.

Table 2: Chronology of relevant ATS communications

Time	Event
1128:00	The crew established contact with the Melbourne Centre CANTY Sector Controller (CANTY Sector Controller). The controller informed the crew that the duty runway at Melbourne was runway 27 and that the wind direction and speed at Melbourne was 290 (M), between 8 and 18 kts. The controller asked the crew if runway 27 would be suitable for the landing and, in response, the crew requested runway 34.
1128:52	The CANTY Sector Controller discussed the crew's request for runway 34 with the controller acting as the Melbourne Flow Controller , who advised 'There is up to 23 knots of crosswind.' The CANTY Sector Controller then advised the crew that there was 23 kts crosswind on that runway. The crew informed the controller that runway 34 would be acceptable under those conditions.[4]
1131:04	The acting Flow Controller advised the Melbourne Tower Co-ordinator that the crew required runway 34 for landing.
1131:16	The Tower Co-ordinator advised the acting Flow Controller that runway 16 would be the preferred runway because '…it's getting up to 9 kts downwind on 34…'
1132:20	The acting Flow Controller advised the CANTY Sector Controller 'There's 9 knots of crosswind now on runway 34 so if Thai requires the long runway it'll be 16.' [5]

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[4] During the investigation, Airservices Australia reported that it was common practice for crews of wide-body international aircraft to request the longer of the two Melbourne runways (runway 16/34) when crosswind on that runway was not a significant factor.

[5] The acting Flow Controller inadvertently transposed the 9 kts reported downwind component on runway 34 as a 9 kts crosswind on runway 34. The controller supervising the Acting Flow controller did not identify that transposition.

1132:31	The CANTY Sector Controller advised the crew '…from the Flow, there is 9 knots of crosswind on runway 34, if you still require a long runway it will be runway 16, advise.' The crew responded that they would accept runway 16.
1134:48	The CANTY Sector Controller advised the crew that Melbourne ATIS 'Yankee' was current, and that the duty runway at Melbourne was runway 27. The controller advised the crew that the surface wind at the aerodrome was '…230 degrees to 280 degrees 18 to 30 knots…'
1149:17	On instruction from the CANTY Sector Controller, the crew contacted the Melbourne Departures Controller. They did not inform the controller, and nor were they queried by the controller, that they were in receipt of ATIS 'Yankee'.
1155:52	The aircraft was 10 NM north of Melbourne, and the Departures Controller instructed the crew to contact Melbourne Tower.
1156:05	The crew contacted the Melbourne Tower Aerodrome Controller.
1158:24	The Aerodrome Controller issued the crew with a clearance to land on runway 16. The controller did not provide the crew with information about the crosswind conditions, and the crew did not request that information.

Recorded information

Flight data recorder

The aircraft was equipped with a Honeywell Intl. Inc. Solid State Flight Data Recorder (SSFDR). The flight path derived from the SSFDR was examined during the investigation. Refer to Appendix C for the relevant SSFDR data plots for the occurrence sequence. The SSFDR parameters examined by the Australian Transport Safety Bureau (ATSB) included:

- wind speed (kts) and direction (degrees T)
- radar altimeter (RALT) in absolute altitude in feet above ground level
- autopilot engaged/disengaged status
- aircraft heading (degrees M)
- aircraft nose-up/down pitch angle
- sidestick lateral (roll) and longitudinal (pitch) 'orders'[6] from both crew members' side sticks[7]
- rudder pedal orders
- aircraft roll (degrees)
- drift angle
- localiser and glideslope deviation[8]

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[6] In fly-by-wire aircraft, pilots provide 'orders' to the flight control computers. In turn, those computers provide signals to transducers/servos/etc that then make 'inputs' to the aircraft's respective control surfaces.

[7] The A340 was fitted with two cockpit-mounted side stick controllers which the crew used to control the aircraft in pitch and roll.

- aircraft landing gear AIR/GROUND status
- vertical, lateral and longitudinal accelerometer ‘g’ loadings.[9]

The data revealed that no aircraft system anomalies had occurred that may have contributed to the occurrence.

The data also revealed that the wind direction during the landing approach from 850 ft RALT was about 250 degrees T, allowing for some minor variations. Wind speed from between 850 ft and 400 ft RALT was about 23 kts, with a maximum 27 kts occurring at 500 ft RALT. From 400 ft RALT, the wind speed reduced to about 20 kts. About 6 seconds before touchdown, the recorded wind speed began to increase, and reached a peak recorded speed of 40 kts about one half second before the right MLG parameter transitioned from AIR to GROUND.

The aircraft’s heading remained relatively constant at about 168 degrees M from 850 ft RALT, then increased to 175 degrees M, coincident with the 40 kt wind gust recorded by the SSFDR at touchdown. The aircraft touched down with 15 degrees right yaw (‘crab’), on a heading of 175 degrees M, and rolled in a 5-degree right wing low attitude.

The drift angle indicated that the aircraft experienced about 8-degrees of left drift during the final stages of the approach below 100 ft RALT. At about 20 ft RALT, the left drift increased steadily until just prior to the aircraft touchdown.

The aircraft deviated to the right of the centreline of the runway 16 localiser, and above the runway 16 glide slope between 250 ft and 100 ft RALT. Dual sidestick inputs in roll occurred (Appendix C.2). They were mainly to the left, in what appeared to be an attempt to bring the aircraft back on the runway centreline. Dual sidestick inputs also occurred in pitch. Those dual pitch inputs were mainly nose down, and commenced at about 90 ft RALT. Dual sidestick pitch inputs also occurred during the flare, and were respectively full back stick on one side stick controller, and two-thirds full forward stick on the other side stick controller.

During the landing flare, two-thirds full right rudder was applied, and the aircraft heading began to deviate to the right. At 15 ft RALT, the right rudder pedal ‘order’ was released. Dual right sidestick was then applied, which resulted in a ‘global’[10] roll ‘order’ of one-half full right stick, and was then immediately countered by application of full left sidestick.

The aircraft was in an about 5-degree right roll angle at 5 ft RADALT, and the right MLG parameter was the first to transition from AIR to GROUND at touchdown. That was followed by the left MLG and the centre MLG both transitioning from AIR to GROUND. The centre MLG then transitioned back from GROUND to AIR, followed by the right MLG, as the aircraft rolled to an attitude of 5-degrees left wing down, coincident with the touchdown. The left roll then reduced and the right MLG

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[8] The localiser and glideslope formed part of the Melbourne runway 16 instrument landing system (ILS) radio navigation aid.

[9] A 3-axis linear accelerometer located close to the aircraft’s empty aircraft centre of gravity provided the ‘g’ loading parameters.

[10] In the case of dual sidestick inputs, the demand ‘orders’ from both pilots’ side sticks are algebraically-summed as a ‘global’ electronic demand ‘order’ to the flight control computers.

transitioned back to GROUND one half second later. The left MLG remained in the GROUND parameter after the initial touchdown.

Successive full left and right rudder pedal inputs were recorded following the second transition of the right MLG parameter back to GROUND.

The dual sidestick inputs during the landing approach resulted in ‘global’ flight control ‘orders’ that exceeded the single stick ‘orders’ of either pilot. While both pilots’ roll inputs during the latter stages of the approach were in the same direction, the magnitude of the pilot in command’s inputs was less than that of the copilot until the landing flare, at which stage they exceeded those of the copilot. The magnitude of the pilot in command’s pitch inputs was less than those of the copilot until the landing flare, at which stage they almost equalled those of the copilot (Appendix C.3).

Touchdown vertical 'g' loading was about 1.7 ‘g’, and lateral 'g' loading was about 0.4 'g' to the left, indicating that the aircraft was in a right sideslip but sliding (skidding) to the left (see Appendix C.4).[11]

The global acceleration data provided by the 3-axis linear accelerometer provided information about the aircraft and landing gear ground loads during the occurrence landing sequence. The aircraft manufacturer reported that the aircraft and landing gear loads had remained below the design limit loads during the landing. The manufacturer reported that, while it was not possible to accurately assess how the total ground loads were shared between the four wheels of the left MLG, the tyre burst was not as a consequence of the landing gear design limit loads having been exceeded.

Cockpit voice recorder

The aircraft was equipped with a Honeywell Inc. Cockpit Voice Recorder (CVR). The CVR data revealed that the side stick ‘DUAL INPUT’ synthetic voice warning was triggered by the flight warning system (FWS) shortly after the aircraft passed through an absolute altitude of 100 ft during the final stages of the landing approach. The warning was triggered twice more prior to touchdown, again at touchdown, and then about seven seconds after touchdown.

In addition, in the latter stages of the landing approach, the FWS activated ‘HUNDRED ABOVE’ and ‘MINIMUM’ radio altitude callouts during the approach, and a ‘THRUST RETARD’ callout was recorded during the flare.

Air traffic system radar data

The Melbourne ATS radar data was examined to correlate the aircraft ground track and speed with the SSFDR data to calculate the wind speed and direction at the threshold of runway 16 during the aircraft landing flare.

A plot of the calculated wind speed and direction is included at Appendix C.5.

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[11] Sideslip – flight manoeuvre in which controls are deliberately crossed, for example, an aircraft banked to the right with left rudder applied. Skidding is the opposite of slip where an aircraft slides outwards because of insufficient bank or excess rudder application.

Organisational information

Operator's A340 Flight Crew Operating Manual

Crosswind landings

The operator's A340 Flight Crew Operating Manual (FCOM) contained information about the crosswind landing technique for the aircraft as follows:

> The preferred technique is to use the rudder to align the aircraft with the runway heading during the flare, while using lateral control to maintain the aircraft on the runway centerline.
>
> Routine use of into wind aileron is not recommended, because sidestick deflection commands the roll rate until touchdown.
>
> In strong crosswind conditions, small amounts of lateral control may be used to maintain the wings level. This lateral stick input must be reduced to zero at first main landing gear touchdown.

The FCOM included information that an engine podstrike or wingtip strike would occur if the aircraft roll angle exceeded 10 degrees.

Landing distance

The FCOM contained information on the actual landing distance required for the A340. Based on the actual landing weight of 245 tonnes, the autoland landing distances required for each autobrake mode with CONFIGURATION FULL[12] at Melbourne (elevation 434 ft above mean sea level) on a dry runway surface are included at table 3.

Table 3: A340 Required landing distances (nil tailwind/headwind)

Autobrake Mode	FCOM Landing Distance @ 245.3 tonnes (metres)	Elevation correction (3% /1,000')[13] (metres)	Correction for 4 operative thrust reversers (metres)	Actual Landing Distance Required (metres)
HI	1,912	24.85	- 76.48 (- 4%)	1,860.37
4	2,031	26.40	- 81.24 (- 4%)	1,976.16
3	2,164	28.13	- 64.92 (- 3%)	2,127.21
2	2,347	30.51	- 70.41 (- 3%)	2,307.10
LO	2,625	34.12	- 52.50 (- 2%)	2,606.62

The landing distance available at Melbourne was 2,286 m on runway 09/27, and 3,657 m on runway 16/34. The landing was carried out using autobrake mode 2.

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[12] CONFIGURATION FULL was a term used to describe the aircraft configured with wing flaps and slats fully extended.

[13] The elevation of Melbourne International Airport resulted in a 1.3% elevation correction.

Aeronautical Information Publication

Requirements relating to ATIS information

The Australian Aeronautical Information Publication (AIP) required pilots to advise ATS that they were in receipt of the current ATIS information when making first contact with ATS Approach Control.[14] The CANTY Sector Controller passed ATIS 'Yankee' to the crew, and at 1149:17 instructed the crew to contact the Melbourne Departures Controller, who was acting as the ATS Approach Control. The crew did not advise the Departures Controller that they were in receipt of ATIS 'Yankee', and the controller did not ascertain whether that was the case. However, the crew recorded the details of ATIS 'Yankee' on the flight plan that they used during the flight from Bangkok to Melbourne.

ATIS 'Yankee' provided information that runway 27 was the duty runway at Melbourne. The crew had elected to use runway 16 for the landing after being offered the alternative of landing on 16 by the CANTY Sector Controller. The Departures Controller should therefore have provided the crew with advice and an update of the landing information applicable for runway 16 as specified in the AIP.[15]

Provision of wind information to flight crews by ATS

The AIP detailed the requirements relating to the provision of wind speed and direction information by ATS to pilots of landing aircraft. In addition to wind speed and direction, pilots of multi-engine aircraft were to be provided with information about the crosswind component on the runway to be used if it equalled or exceeded 12 kts.[16]

Manual of Air Traffic Services

The Manual of Air Traffic Services (MATS) contained the objectives and requirements of ATS. Included was the provision of advice and information useful for the safe and efficient conduct of flights.

The MATS also contained information that crosswind was considered significant if it equalled or exceeded 12 kts for civil multi-engine aircraft.

A wind rose providing information about the 1-minute distribution of maximum wind speeds and the frequency of the varying wind directions that were recorded by the MLW1 anemometer between 1156, when the aircraft contacted the tower controller, and 1200, when the aircraft landed, is depicted at figure 7.

During that period, the maximum wind speed and direction recorded by the anemometer confirmed that the crosswind conditions on runway 16 exceeded 12 kts. However, the Melbourne Tower Aerodrome Controller did not pass information to the crew about the significant crosswind conditions.

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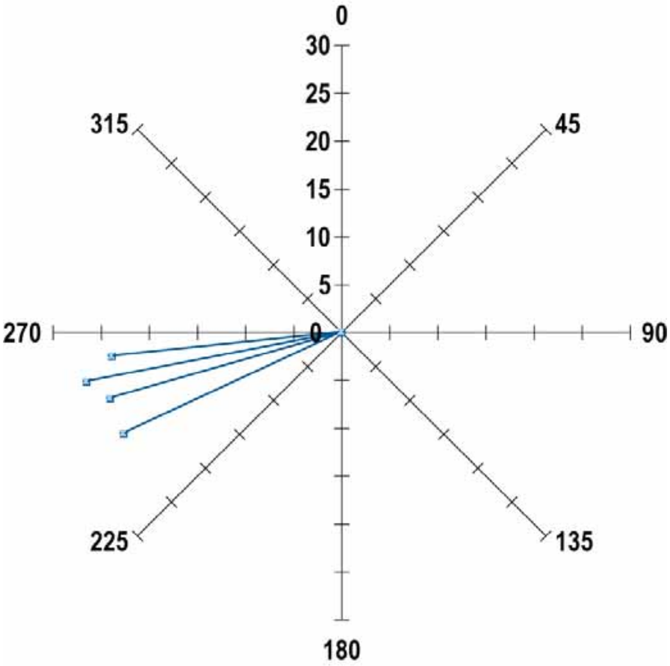
[14] AIP ENR (EN ROUTE) 11.1.6.

[15] AIP ENR (EN ROUTE) 11.1.8.

[16] AIP ENR (EN ROUTE) 13.1.e.

Figure 7: MLW1 anemometer wind rose for period 1156 to 1200



Air traffic services

As a result of this occurrence, Airservices Australia conducted an investigation into the ATS aspects that it considered may have contributed to the occurrence. That investigation identified the need for clarification on which control position should take responsibility for the interpretation of new or revised weather information for approach and landing for inbound aircraft, where information specific to the landing runway was not available from the ATIS.

Additional information

A340 electronic flight control system

Side stick controllers

The A340 is a fly-by-wire aircraft. Each pilot has a side stick, which is used to manually control the aircraft in pitch and roll. The left seat pilot uses the side stick on the left, and the right seat pilot uses the side stick on the right. The side sticks are not mechanically-linked, are able to be moved independently and are spring-loaded to the neutral position when not being moved by a pilot.

When a pilot operates the relevant side stick, the movement of that side stick provides an electronic demand ‘order’ to the aircraft’s flight control computers. The flight control computers respond by providing the necessary outputs to the relevant flight control surfaces to achieve the desired states of pitch and/or roll. When the second pilot simultaneously operates the other side stick in the same or opposite direction, the demand ‘orders’ from both side sticks are algebraically-summed as a ‘global’ electronic demand ‘order’ to the flight control computers. The total ‘global’ demand ‘order’ is limited to the maximum deflection demand ‘order’ able to be provided by the movement of a single side stick controller.

On the A340, one pilot is able to deactivate the other pilot’s side stick controller to take full lateral and longitudinal control of the aircraft. That is accomplished by the pilot activating the side stick priority button on the relevant side stick controller. The operator’s FCOM contained information that, if a take-over became necessary during flight, the pilot not flying (PNF) was to clearly call ‘I have control’, and to press the side stick priority pushbutton, keeping it pressed until the transfer of control was clearly established.

Side stick operation – dual inputs

The operator’s A340 FCOM also contained information that the PNF should not make control inputs to correct the handling of the aircraft by the PF. The lack of a direct mechanical linkage between the side stick controllers meant that there was no tactile feedback provided to the PF if the PNF was making concurrent or dual side stick inputs.[17]

The aircraft was, however, fitted with a warning system to alert the crew of simultaneous inputs on both side sticks in the event that the side stick priority system was not activated. A 2-degree deflection of the PNF’s side stick in any direction from the neutral position resulted in the illumination of the green SIDE STICK PRIORITY warning lights on the glareshield in front of each crew member. In addition, the ‘DUAL INPUT’ synthetic voice message was activated by the flight warning system.

The aircraft manufacturer has examined the reasons for dual sidestick inputs during line operations. Advice received from the manufacturer included that, in normal flight conditions, the practice should not occur if ‘…proper airmanship and CRM [crew resource management] applied.’[18]

An analysis by the manufacturer of reported instances of dual sidestick inputs has revealed they may be ‘spurious’, ‘comfort’, or ‘instinctive’ interventions on the part of the PNF. Those inputs can be defined as follows:

- **Spurious dual inputs.** Spurious dual inputs are unintentional, are of short-term duration and small in magnitude, and result in only marginal effects on an aircraft’s pitch and roll.
- **Comfort dual inputs.** Comfort dual inputs are intentional, short-term interventions by the PNF. The intention of the PNF is to correct or improve the aircraft’s attitude or trajectory during a precision manoeuvre, such as a landing approach or landing flare. Comfort inputs are normally small deflections, and may be the same as, or opposite to the PF’s sidestick inputs. They usually result in only minor effects on an aircraft’s altitude and/or trajectory, and are ‘…thus in most cases unnecessary.’ In most cases, the PF was unaware of any ‘comfort’ inputs by the PNF.
- **Instinctive dual inputs.** Instinctive dual inputs are ‘reflex’ interventions by the PNF, acting out of surprise at some unexpected event that may occur during a

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[17] The aircraft manufacturer indicated that the interconnection of the aircraft’s side sticks ‘would be operationally not beneficial and technically not efficient’.

[18] Airbus ‘*Operational Liaison Meeting A320 family, A330, A340’* - 2002.

dynamic flight manoeuvre, such as the landing flare. Those interventions are significant in terms of stick deflection, and are usually initially in the same direction as the PF's stick inputs. They have the potential to affect an aircraft's behaviour, and may lead to over-control of an aircraft. As with comfort dual inputs, in most cases the PF is unaware of any 'instinctive' dual inputs by the PNF.

Previous incidents involving dual sidestick inputs on 'fly-by-wire' aircraft

The investigation examined three reports on previous dual sidestick input occurrences involving Airbus fly-by-wire aircraft types. Those reports revealed that, because neither crew member is provided tactile feedback of any sidestick inputs made by the other, dual sidestick inputs are problematic.

On 21 June 1996, the crew of an Airbus A340 aircraft enroute from Dallas/Fort Worth Airport to Houston Intercontinental Airport received a "descend" resolution advisory from the aircraft traffic collision avoidance system. The copilot was the PF. The US National Transportation Safety Board (NTSB) factual report[19] on the incident revealed that:

> The Captain initiated an immediate descent. The Captain did not make a verbal announcement that he was taking command of the left side stick control.

In that incident, the dual inputs from the pilot in command's and copilot's side stick controllers continued until the copilot noticed that the pilot in command was providing sidestick input, and returned the right side stick controller to the neutral position.

At the time of that occurrence, the 'DUAL INPUT' side stick warning system was not available on A340 aircraft.

On 21 June 2000, an Airbus A321 aircraft was involved in a tailstrike accident during a landing at London Heathrow. The copilot was the PF. The UK Air Accidents Investigation Branch (AAIB) investigation report[20] included information that:

> The aircraft touched down at an airspeed of 130 kt CAS, with a pitch attitude of 7.4° nose-up and a normal acceleration of 2.0g. The FO's sidestick position was 92.5% nose-up demand with an upelevator angle of 12.3°. The FO's sidestick demand then reduced, towards 46.8% nose-up demand.
>
> The ground spoilers deployed automatically; this is designed to occur when both the main landing gear oleo switches are compressed. The FDR showed that these switches then 'unmade' indicating that the aircraft had rebounded into the air. The pitch attitude continued to increase to a maximum of 9.8° nose-up, which was reached just as the aircraft mainwheels touched the ground again. The tailscrape occurred at this point. The second touchdown recorded a normal acceleration of 1.6g at which time the commander's sidestick moved forward to a 56.3% nose-down demand.

The analysis section of the AAIB investigation included information that:

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[19] NTSB report FTW96LA269

[20] AAIB Bulletin Ref: EW/C2000/6/8

> The commander did not anticipate a problem until after the aircraft's initial touchdown. He could not have been aware of the control inputs applied by the FO[21], in particular the continued aft sidestick input late in the landing, because his own sidestick showed no movement.

and that:

> The sidestick control authority logic requires a different method of intervention by commanders from that which they may have experienced on other aircraft types. Because of the difficulty of detecting the inputs made by the other pilot early takeover of control based on flight characteristics is required.

On 9 October, 2000, another Airbus A321 aircraft was involved in another tailstrike accident during a landing at London Heathrow. The copilot was the PF. The AAIB investigation revealed that, during the latter stages of the landing approach, the pilot in command became concerned at the high rate of descent. The pilot in command then applied aft sidestick, which ‘progressed to nearly full aft sidestick by a height of 10 feet, in order to arrest the rate of descent but he did not activate his sidestick takeover push button.’

The AAIB investigation report[22] included a conclusion that:

> As with other such incidents the commander could not see the control inputs of the FO and his first indication was a high rate of descent at about 40 feet shortly after the flare was initiated. He did not activate his sidestick takeover button and, given the circumstances, this action would not have prevented the tail of the aircraft contacting the runway. This occurred following the bounce on the second touch down when the commander was using aft sidestick to prevent the nose wheel coming down heavily.

Maximum demonstrated crosswind

The Flight Safety Foundation (FSF) published information regarding maximum demonstrated crosswind in Briefing Note 8.6 of its Approach-and-Landing Accident Reduction (ALAR) Toolkit.

The FSF reported that the information published in an aircraft’s flight manual and operating handbook regarding maximum demonstrated crosswind related to the maximum crosswind component encountered during the certification process of the aircraft. The FSF also reported that the maximum demonstrated crosswind for a particular aircraft type was not an operating limitation unless otherwise stated, and that it was not necessarily the aircraft’s maximum crosswind capability.

The information about maximum demonstrated landing crosswind published in the operator’s A340 FCOM did not specify that it was an operating limitation for the aircraft.

Crosswind landings

Crosswind landings are a routine occurrence. During crosswind conditions, a crew must compensate for the drift caused by the crosswind to maintain the aircraft

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[21] FO is the abbreviation used by the AAIB for First Officer (copilot).

[22] AAIB Bulletin Ref: EW/C2000/10/04.

aligned with the centreline of the runway during the landing approach. The factors that limit an aircraft's controllability in crosswind conditions include the aerodynamic forces able to be exerted by the aircraft's flight controls, and the side-force capability of its tyres.

Various handling techniques are used for crosswind landing approaches, including:

- sideslip (wing low)
- crabbed-approach to touchdown, with decrab during the landing flare
- combination sideslip and crabbed-approach.

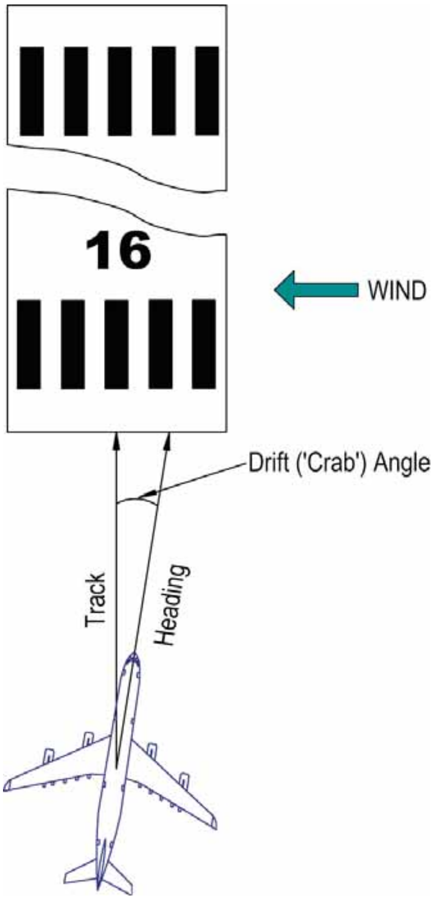
Sideslip (wing low) approach

The sideslip (wing low) technique requires the crew to lower the upwind wing into wind and to use opposite rudder to maintain the aircraft aligned with the runway during the approach. During strong crosswind conditions, the control inputs required to maintain the aircraft's alignment with the runway may reduce the ground clearance of the into-wind wing to the point where an engine podstrike or wingtip strike may occur. Over-control of an aircraft about its roll axis by the use of ailerons increases the risk of a podstrike or wingtip strike. That risk is a particular problem on aircraft with wide-span wings fitted with underwing engines, such as the A340.

Crabbed-approach to touchdown, with decarb during the flare

The crabbed-approach to touchdown technique is flown in a wing-level attitude, with the nose of the aircraft held slightly into wind to track the aircraft towards the runway on the extended runway centreline. The angular displacement between the aircraft heading and its track over the ground is the drift or 'crab' angle (figure 8).

Figure 8: Crabbed crosswind landing approach



Depending on the magnitude of the crosswind, during the landing flare, the aircraft cockpit may be over the upwind side of the runway, with the aircraft's MLG straddling the runway centreline.

The 'decrab' during the flare is effected by the pilot applying rudder to align the aircraft with the runway centreline, and opposite aileron to maintain the wings level. The aim of this manoeuvre is to end up with the resultant aircraft momentum vector along the runway centreline. The 'decrab' during the flare manoeuvre, however, requires precise piloting skills, and the flare height must be correctly judged to perform the manoeuvre successfully. In ideal conditions, the aircraft will generally touchdown with little or no lateral drift. However, in strong crosswind conditions, when the aircraft's bank angle becomes the limiting factor in engine podstrike or wingtip strike avoidance, an aircraft may land with a noticeable residual lateral drift.

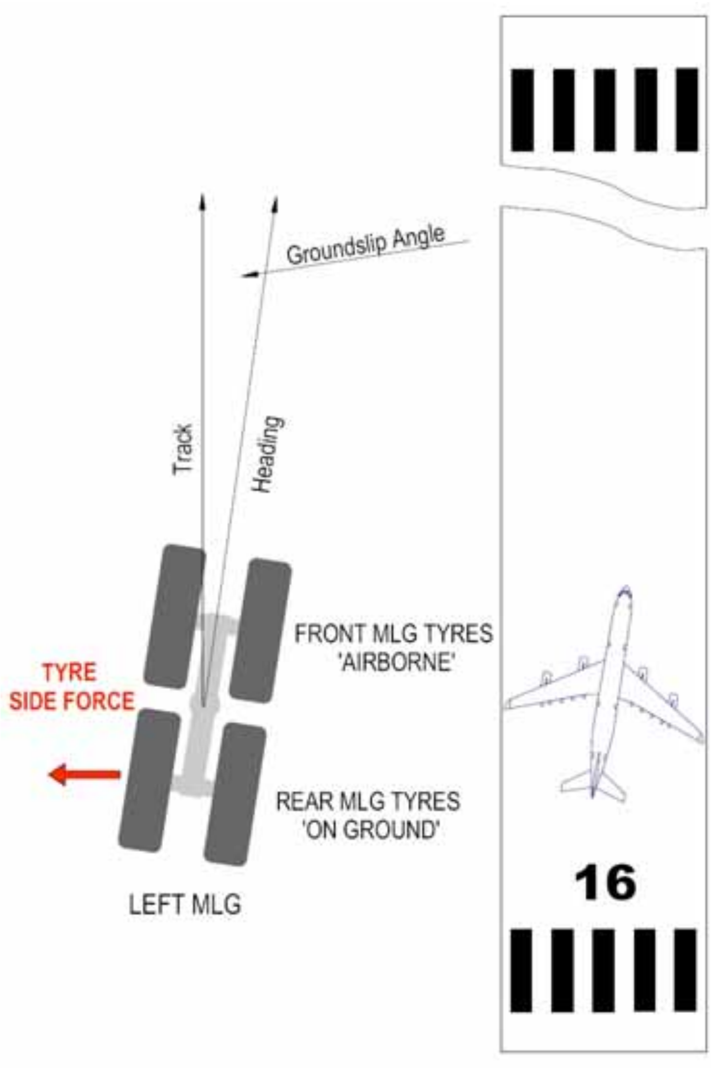
Combination sideslip and crabbed-approach

In strong crosswind conditions, a combination of the sideslip and crabbed approaches is normally the preferred handling technique, because it reduces the amount of 'decrab' required during the landing flare.

An aircraft crew maintains directional control of an aircraft with rudder after an aircraft has landed. The maintenance of runway centreline tracking in crosswind conditions, however, requires equilibrium between the aerodynamic forces from the rudder, and from the mechanical forces generated by the aircraft landing gear and tyres. The side force on an aircraft tyre depends on the groundslip angle of the tyre.

That angle is the angular displacement between the plane of rotation of the tyre (generally approximating the aircraft heading), and the tyre's direction of motion or track over the ground (figure 9).

Figure 9: Touchdown MLG groundslip angle

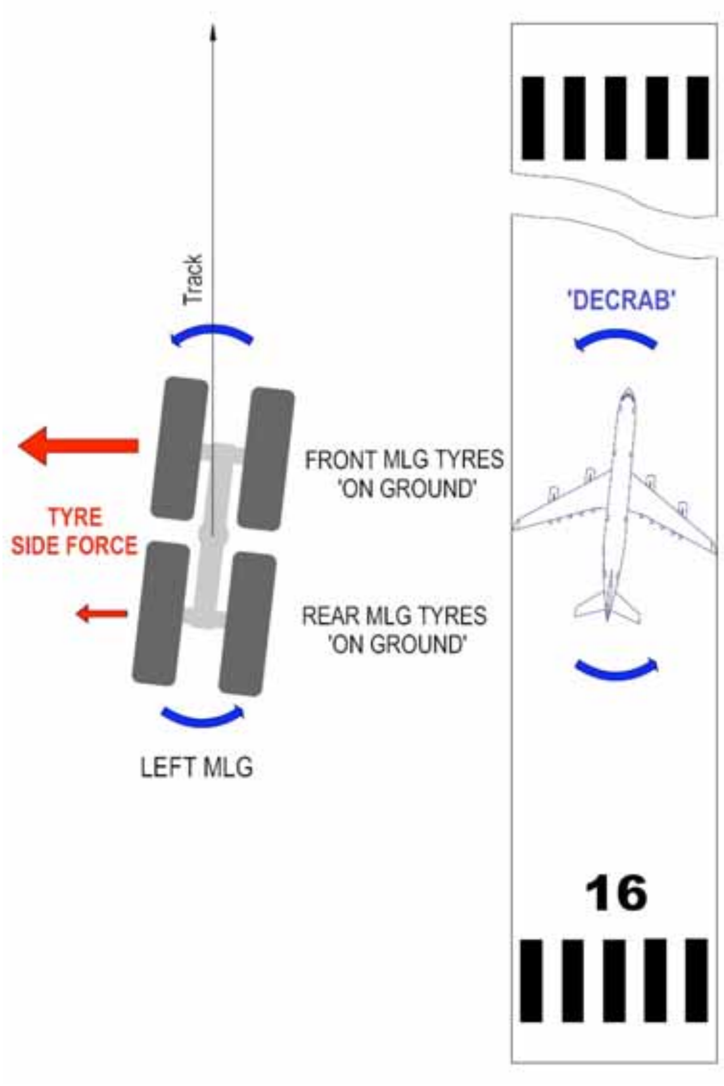


Large groundslip angles result if an aircraft lands with a large drift or 'crab' angle in strong crosswind conditions. Under those conditions, tyre side forces may reach a 'saturation' point at which stage the tyre will enter a fully-skidded state.

On dry runways, where good grip exists between the tyre and the runway surface, a fully-skidded condition will normally occur at a groundslip angle of about 15-degrees. On icy runways, a fully-skidded condition may occur at a groundslip angle of only 5-degrees. It is for that reason that crosswind landings on contaminated runways pose greater risk than on dry runways.

The MLG on an aircraft fitted with a conventional tricycle undercarriage is located aft of the aircraft centre of gravity. During a crabbed landing in crosswind conditions, the MLG tyre side forces tend to 'decrab' the aircraft into alignment with the vector of its forward momentum as depicted in figure 10.

Figure 10: MLG tyre side forces during 'decrab' after touchdown



Angle of bank and 'crab' angle requirements

The aircraft manufacturer published a series of Flight Operations Briefing Notes (FOBNs) that provided:

> an overview the applicable standards, flying techniques and best practices, operational and human factors, suggested company prevention strategies and personal lines-of-defense related to major threats and hazards to flight operations safety.

The FOBN affecting crosswind landing techniques included advice that higher crosswind conditions were typically those where the crosswind component exceeded 15 to 20 kts and that, under those conditions. *'…a safe crosswind landing…'* would require a crabbed-approach with a partial 'decrab' before touchdown. The FOBN included information that on most Airbus models that would require a *'maximum'* of 5-degrees 'crab' angle and 5-degrees of bank angle at touchdown.

The FSF ALAR Toolkit[23] also provided information on bank angle and ‘crab’ angle requirements for crosswind landings.

The FSF briefing note included information that, with a steady 30 kt crosswind, a sideslip approach would require about 9-degrees of into wind bank, and that such a bank angle would place an aircraft close to its geometry limits at which an engine podstrike or wingtip strike could occur. Additionally, that bank angle would place an aircraft closer to its rudder/aileron authority limits.

Under the same crosswind conditions, a crabbed-approach to touchdown (without ‘decrab’ at touchdown) would require a 13-degree drift or ‘crab’ angle, and would possibly result in MLG damage at touchdown.

If a combination sideslip/crabbed approach was flown, it would require only 5-degrees of bank angle and 5-degrees of drift or ‘crab’, increasing safety margins relative to geometry limits and also rudder/aileron authority limits.

The FSF concluded that for most transport-category aircraft:

> …touching down with a five-degree crab angle (with an associated five-degree bank angle) is a typical technique in strong crosswinds.

Aircraft tyre loads

Centrifugal forces

A combination of heavy loads and high operating speeds results in strong centrifugal forces acting on an aircraft’s tyres. In that case, the peripheral shape of the aircraft’s pneumatic tyre(s) is deflected by loading from the tyre’s contact with the ground. That deflection can occur during landing and takeoff.

During rotation for takeoff, the portion of the tyre leaving the ground tries to resume its normal unloaded shape. However, centrifugal forces acting on the tyre, along with inertia, mean that the tyre tread does not stop at the normal peripheral position, but overshoots that position and so distorts the tyre’s natural shape. That distortion continues around the circumference of the tyre tread as it rotates, in what is termed a ‘traction wave’. The traction wave becomes more pronounced as tyre rotation-speed increases.

The Goodyear Tire and Rubber Company have published figures to help explain the magnitude of forces acting on an aircraft tyre at rotation.[24] Goodyear calculated that the traction wave deflection of a tyre rotating at 4,200 RPM was 4.82 cm. The 4.82 cm outward radial deflection was equivalent to an average radial acceleration of 60,960 m/sec^2, which was in excess of 6,000 G. Therefore, the tyre tread was experiencing between 200 to 266 oscillations per second.

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[23] Flight Safety Foundation Approach-and landing Accident Reduction (ALAR) Toolkit – Briefing Note 8.7 – Crosswind Landings.

[24] *Aircraft Tire Care and Maintenance*, (2002) Goodyear Tire and Rubber Company.

Tensile, compression, and shear forces

In normal operating conditions, aircraft tyres are also subjected to high tensile, compression, and shear forces. In an unloaded tyre, the internal tensile forces acting on each layer of fabric in the tyre are uniform. However, when a tyre becomes deflected under load, the tensile forces on the outer plies become higher than those affecting the inner plies. Shear forces then develop between the various layers in the tyre because of the force gradient that exists between the inner and outer plies of the tyre.

Crosswind landing forces

As stated previously, large groundslip angles result if an aircraft lands with a large drift or 'crab' angle in strong crosswind conditions. Additional forces are imparted on an aircraft's tyres on their initial contact with the ground under those conditions. If an aircraft is drifting across the runway at the point of touchdown, the resultant vector from the aircraft's forward and lateral momentum will impart a rearwards, and inwards force on the downwind-facing tyre sidewalls. Additional upwards forces will be applied on the tread portion of the tyre in contact with the runway because of the landing vertical 'g' loading[25]. On a dual bogey landing gear assembly, such as that on the A340 MLG, the bogey derotation will impart additional vertical 'g' loading on the front MLG tyres. Ground contact vertical 'g' loading on the front MLG tyres will therefore be greater than the SSFDR-recorded vertical accelerometer 'g' loading at the touchdown point.

During the investigation, the ATSB provided the French BEA with photographic evidence of the partially disintegrated tyre and of the separated tyre tread. The BEA's assistance was sought in order to obtain an analysis from the French tyre manufacturer of the tyre forces encountered during the touchdown, and which appeared to have resulted in the separation of the tyre tread from the number-1 wheel tyre on the left MLG. Based on its assessment of the photographic evidence, the tyre manufacturer reported that yaw forces had been significant.[26] However, the tyre manufacturer reported that, without physical access to the tyre debris, it was unable to establish the '…most probable origin of the tyre separation and damage…'.

Crosswind hazard and risk

A hazard is a source of potential harm, or a situation with a potential to cause loss or damage. If not correctly managed, a crosswind may represent a hazard to a landing aircraft as a result of its potential to cause damage to the aircraft, and possibly to its occupants.

Risk is related to the potential for an event to occur that will have an impact upon objectives.[27] It is measured in terms of the consequences of the event and of the

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[25] Stress applied to a structure as a multiple of that in 1 'g' flight.

[26] Those yaw forces would have included as a result of the 15-degree touchdown drift or 'crab' angle, and the 'decrab' forces after touchdown that acted to bring the aircraft into alignment with the vector of its forward momentum along the runway.

[27] Australian/New Zealand Standard RISK MANAGEMENT AS/NZS 4360:2004 1.3.13.

likelihood that the event might occur. The likelihood or probability of an event can be expressed in either qualitative or quantitative terms

If crosswind affects a landing area, the residual risk posed by that crosswind will depend on the intensity of the crosswind, and the existing risk controls. Those controls may include factors such as: an operator's standard operating procedures; the crew's awareness of the prevailing wind speed and direction, training and experience and aircraft handling technique; the condition of the runway surface; and the prevailing ambient light and visibility.

In terms of the consequences of a crosswind landing event, relevant risk controls might include the availability of an aerodrome RFFS and of appropriate aerodrome emergency plans.

Following the publication of the ATSB Preliminary Report into this occurrence, the International Federation of Air Line Pilots' Associations (IFALPA) published information about the occurrence in the June 2006 issue of IFALPA News.

The IFALPA article noted that the crosswind landing risks in this event were 'mitigated by the fact that, despite the wind, [the meteorological] conditions were otherwise good…'. The IFALPA also reported that it was developing a Safety Bulletin to address the following safety issues relative to crosswind operations:

- lessons to be drawn from the Melbourne occurrence
- crosswind landing techniques
- the impact of a crosswind landing on a wet or contaminated runway on a crew's ability to maintain directional control of an aircraft, and whether that was a factor to be taken into account when planning or continuing an approach
- whether a review of the utility of published 'maximum demonstrated crosswind' limits was required, because those limits were 'for guidance only'
- whether crosswind limits should take into account runway surface conditions.

ANALYSIS

Introduction

Crosswind landings are routinely encountered in day-to-day flying operations. The existence of a crosswind at a particular location will depend on the prevailing meteorological conditions at that location. The level of risk posed by a crosswind to a landing aircraft depends on the intensity of the crosswind and the existing risk controls.

In ideal circumstances, those risk controls could include factors such as: an operator's standard operating procedures; a crew's awareness of the prevailing wind speed and direction, training and experience and aircraft handling technique; the condition of the runway surface; and the prevailing ambient light and visibility.

This occurrence highlights that, even on a dry runway, when the prevailing weather conditions result in a wind speed and direction that are within the maximum demonstrated landing crosswind limits of an aircraft, compromises to the safety of flight can occur if crews do not maintain their situational awareness about those crosswind conditions. That situational awareness relies on crews seeking, being provided with, and using all available information on the prevailing wind conditions that may affect their aircraft during dynamic flight manoeuvres, such as the landing flare, and on crews employing recommended aircraft handling procedures during those manoeuvres.

Pre-existing conditions related to the operation of the aircraft

Airworthiness

The maximum demonstrated landing crosswind limit (gust included) for the A340 of 37 kts was greater than that required under the certification requirements for that aircraft. The aircraft was therefore capable of operating in crosswind conditions that were greater than those specified in the relevant certification requirements.

There was no evidence that any pre-existing wear or deteriorated condition of the number-1 tyre resulted in its failure during the landing sequence. Additionally, the investigation identified no aircraft systems malfunctions that occurred during the flight from Bangkok to Melbourne that may have contributed to the development of the occurrence.

Flight crew

The flight crew were properly licensed and rated to operate the aircraft. The copilot's experience on the A340 was limited, however, before transferring to the A340, the copilot had been a crew member on Airbus A330 aircraft. On that basis, the copilot had previous handling experience on aircraft of similar size and handling characteristics as the A340.

Both crew members were aware of the possibility of an engine ‘podstrike’ during crosswind landings on the A340. The investigation was, however, unable to determine how much previous operational experience either crew member had in landing during similar gusting crosswind conditions as those experienced at the time of the occurrence.

The crew’s decision to land on runway 16 at Melbourne

The crew departed Bangkok with the knowledge that gusty northerly wind conditions were expected at Melbourne between 0600 and 1100, and that a westerly wind of 15 kts was expected after 1100. That information was contained in the Melbourne aerodrome forecast that formed part of the crew pre-flight briefing.

The changed advice from the CANTY Sector Controller that the 23 kts crosswind affecting runway 34, which had been acceptable for the crew’s planned landing on that runway, had reduced to 9 kts resulted from an unintentional error by the acting Flow Controller.

The subsequent offer by the CANTY Sector Controller of runway 16 as an alternative to runway 34 on the basis that ‘…, there is 9 knots of crosswind on runway 34…’, contributed to the crew’s decision to accept runway 16. That advice by the controller was, however, illogical. As the reciprocal of runway 34, the magnitude of the crosswind affecting runway 16 should have been expected by the controller and crew to have equalled the 9 kts reported as affecting runway 34. In that case, the crew’s initial plan to land on runway 34 would have remained operationally acceptable to the crew.

The landing information contained in Melbourne automatic terminal information service (ATIS) ‘Yankee’, including advice of the wind speed and direction at Melbourne, should have indicated to the crew that tailwind conditions existed on runway 34, and that gusting crosswind conditions existed on runway 16 (and runway 34). That, and the crew’s high experience levels could have been expected to have caused the crew to query the logic of the CANTY Sector Controller’s changed crosswind advice.

Had the crew queried the reported changed crosswind affecting runway 34, and requested an indication of the prevailing wind speed and direction at Melbourne, it could have become evident to the crew and/or CANTY Sector Controller that the controller had unintentionally passed on an incorrect wind report, and that there was actually a 9 kts downwind component affecting runway 34, rather than the reported 9 kts crosswind.

Although shorter than runway 16/34, the length of duty runway 27 was suitable for a landing at the aircraft’s landing weight of 245 tonnes. However, a landing on runway 27 would have required additional flight time and distance to position the A340 to the east of Melbourne Airport and onto the final approach for runway 27, and to then conduct the landing approach onto that runway. Moreover, the ground taxi distance and time following a landing on runway 27 would have been longer than required following a landing in either direction on runway 16/34.

Even though significant crosswind conditions existed on runway 16/34, the crew’s decision to use runway 16 as the non-duty runway was understandable from an operational point of view, particularly as the notified crosswind conditions were within the A340's demonstrated crosswind limits.

Crew handling of the aircraft during the approach and landing sequence at Melbourne

During the latter stages of the landing approach, the pilot in command, who was the pilot not flying (PNF), commenced dual sidestick control inputs. Those dual sidestick inputs contravened the instructions relating to the operation of the aircraft's fly-by-wire and side stick systems, which were contained in the operator's A340 Flight Crew Operating Manual (FCOM).

The passage of the strong westerly winds over the Box Forest area to the north-west of Melbourne Airport would probably also have resulted in lee turbulence in the vicinity of the touchdown zone of runway 16. That turbulence was likely to have contributed to the aircraft's unexpected roll deviations, including the recorded sudden roll to the left shortly after the aircraft passed through a height of about 70 ft. The pilot in command's dual sidestick input at that point seemed to have been a 'comfort' intervention to correct the aircraft's attitude or trajectory at that stage of the approach.

The pilot in command's dual sidestick interventions became more significant in terms of stick deflection as the aircraft neared the ground, and were in mostly the same direction as the copilot's stick inputs. Those dual sidestick would have provided 'global' electronic demand 'orders' to the flight control computers that were greater than those 'ordered' by the copilot. Consequently, the aircraft's response to those 'global' demand 'orders' would likely have been greater-than-expected by the copilot. Moreover, the unexpected magnitude of aircraft's response seemed to result in both crew members applying opposite sidestick inputs to counteract that unexpected response, leading to an over-control of the aircraft.

The investigation was unable to determine whether the copilot was aware of the pilot in command's dual sidestick inputs, even though they resulted in aural 'DUAL INPUT' synthetic voice messages from the flight warning system (FWS). It was likely that, during the latter stages of the approach, the copilot's attention was focussed on the external visual cues in order to maintain the aircraft tracking on the extended centreline of the runway in the gusting crosswind conditions. In addition, the copilot's attention seemed also to have been focused on countering the unexpected magnitude of the aircraft's roll and pitch that resulted from the 'global' demand 'orders'. The copilot's focus on correcting the aircraft's attitude and trajectory, together with the numerous FWS synthetic voice messages, may have resulted in the copilot not comprehending the significance of the aural 'DUAL INPUT' warnings, and that they were a cue to the reason for the aircraft's unexpected handling response.

The application of two-thirds full right rudder during the landing flare increased the yaw angle to more than that recommended by the manufacturer for a '…a safe crosswind landing…' where the crosswind component exceeded 15 to 20 kts. The right yaw resulting from the application of that rudder would have increased the aircraft roll to the right, and therefore increased the risk of a right wingtip or wing-mounted engine pod strike. The right roll was countered by rapid and large left sidestick inputs by both crew members that resulted in an effective full left sidestick input in what appeared to be an instinctive ‘reflex’ response by both crew members to prevent that risk.

There was no attempt by either crew member to partially ‘decrab’ the aircraft during the landing flare. That was contrary to the advice provided by the manufacturer for the performance of ‘…*a safe crosswind landing…*’ in higher crosswind conditions. The lack of any ‘decrab’ therefore decreased safety margins and increased the risk of main landing gear (MLG) damage at touchdown. It also increased the risk that the resultant groundslip angle at touchdown would be of sufficient magnitude that the MLG tyre side forces exceeded the ‘saturation’ point at which they entered a fully-skidded state.

Air traffic services handling of the aircraft’s approach to Melbourne

After discussing the crew’s intention to land on runway 34 with the acting Flow Controller, the CANTY Sector Controller advised the crew that there was 23 kts crosswind on that runway. The crew’s response that the crosswind was acceptable for the proposed landing was consistent with that controller’s experience with other international wide-body aircraft operations at Melbourne.

The acting Flow Controller’s unintended error of advising the CANTY Sector Controller that there was 9 kts of crosswind on runway 34 was not a factor in the occurrence, as the crew were already aware that the crosswind was 23 kts. However, the acting Flow Controller used that (incorrect) information as justification to change the landing runway for the aircraft from runway 34 to runway 16. Although the change in runway was not justified from the operational aspect in terms of the incorrectly reported 9 kts crosswind, it was operationally justified on the basis of the 9 kts of downwind affecting runway 34.

At 1134, the CANTY Sector Controller advised the crew that Melbourne automatic terminal information service (ATIS) ‘Yankee’ was current, that the duty runway at Melbourne was runway 27 and of the surface wind at the aerodrome. While the controller did not provide the crew with specific information about the crosswind affecting runway 16, if the crew had correctly interpreted the wind information provided to them by the controller, it would have been evident that they could expect 30 kts of crosswind on runway 16.

As the crew sought no clarification or advice from the controller about the crosswind conditions affecting runway 16, it was likely that they did not evaluate the crosswind conditions from the information that they had been provided or, if they did, that they considered the crosswind on runway 16 was acceptable for the landing.

Accurate information on the crosswind affecting runway 16 was available to the Aerodrome Controller (ADC) from the controller’s second wind display during the aircraft’s landing approach. Had the ADC provided the crew with the current wind speed and direction, and advice of the greater than 12 kts crosswind affecting runway 16 in accordance with the Aeronautical Information Publication (AIP), the crew would have been aware that the crosswind affecting their landing was about 25 kts. In any case, the crew should have been aware of the wind speed and direction during the approach as a result of the information available from the aircraft’s navigation display units. That awareness should have provided the crew with a reminder that they could probably expect a degree of lee turbulence in the vicinity of the touchdown zone on runway 16, due to the passage of the surface wind over the treed area to the north-west of the airport.

Calculated actual wind direction and speed

The 40 kt wind gust recorded at touchdown by the SSFDR was derived by the ADIRUs that were located in the aircraft's electrical and electronic compartment beneath the cockpit. Because of their location forward of the aircraft centre of gravity, the transient yaw accelerations during the landing flare would have affected the accuracy of the recorded wind speed and direction data.

The recorded 40 kt wind gust was not consistent with the 1-minute interval data recorded by the MLW1 anemometer that was located to the north-west of the intersection of runways 16/34 and 09/27. That data revealed that it was likely that the wind speed and direction encountered by the aircraft just prior to the landing was about 27 kts from 247 degrees true (T).

The calculated wind speed and direction over the runway 16 threshold during the aircraft landing flare was 27 kts from 240 degrees (T). That calculated wind speed was derived from the correlation of the aircraft's ground track and speed from the Melbourne ATS radar data with the SSFDR data.

Landing tyre loads

The landing gear loads remained below their design limits during the landing, and the investigation concluded that tyre burst was not as a consequence of the actual landing gear loads encountered during the landing.

The right MLG parameter was the first to transition from AIR to GROUND at touchdown. That was followed by the left MLG and the centre MLG both transitioning from AIR to GROUND. The centre MLG then transitioned back from GROUND to AIR, followed by the right MLG, as a result of the aircraft rolling to an attitude of 5-degrees left wing down, coincident with the touchdown. The left roll then reduced, and the right MLG transitioned back to GROUND one half second later. The left MLG remained in the GROUND parameter after the initial touchdown.

Because of the MLG rearward bogey tilt, the rear tyres on the MLGs would have contacted the runway first, with the front tyres making contact following derotation of the bogeys. The 15-degree touchdown 'crab' angle would initially have subjected the rear tyres to a large groundslip angle. Under those conditions, the resultant vector from the aircraft's forward and lateral momentum would have imparted a rearwards, and inwards force on the downwind-facing tyre sidewalls. Additionally, the tyre side forces acting on the left MLG rear tyres probably reached a 'saturation' point at which stage those tyres initially entered a fully-skidded state.

The short distance between the marks showing where the rear and front tyres of the left MLG had first contacted runway 16 provided evidence of rapid derotation of the left MLG bogey. That rapid derotation was probably the result of high touchdown loads, and would have imparted additional vertical 'g' loading on the left MLG front tyres.

Following touchdown, the MLG tyre side forces would have tended to 'decrab' the aircraft into alignment with its forward momentum along runway 16. When the left

MLG front tyres contacted the runway, the ‘decrab’ forces would have considerably increased the tyre side forces acting on those tyres.

Once in contact with the runway surface, the heavy loads and high operating speed during the initial stages of the landing roll would have imposed strong centrifugal loads on all MLG tyres. Those loads would have resulted in circumferential distortion of the tyres, causing a traction wave outward radial deflection of the tyres.

Additionally, the high landing loads would have subjected all MLG tyres to high tensile, compression, and shear forces due to the deflection of the tyres under load. Those forces would probably have been greater on the front tyres of the left MLG due to the high tyre side forces acting on those tyres, as well as the additional vertical ‘g’ loading on those tyres that resulted from the rapid derotation of the left MLG bogey at touchdown.

The investigation concluded that the failure of the number-1 wheel tyre on the left MLG resulted from a combination of high side forces, centrifugal loads, tensile compression, and shear forces that had acted on that tyre during the landing touchdown in the prevailing crosswind conditions.

Crosswind risk

A combination of factors increased the risk that ‘*…a safe crosswind landing…*’ would not be accomplished by the flight crew in the crosswind conditions that existed at Melbourne at the time, even though they were less than the maximum demonstrated landing crosswind limit (gust included) of 37 kts for the A340, and the runway was dry.

The aircraft touched down with 15 degrees right ‘crab’, on a heading of 175 degrees M, and was rolled in a 5-degree right wing low attitude. As such, the touchdown was technically a combination of a sideslip and a crabbed landing. However, the aircraft’s 15-degree touchdown ‘crab’ angle was greater than the ‘*maximum*’ 5-degrees recommended by the aircraft manufacturer, and therefore increased the risk of damage to the MLG at touchdown. It also increased the risk that the resultant groundslip would be of sufficient magnitude that the MLG tyre side forces would exceed the ‘saturation’ point, at which they would enter a fully-skidded state.

The pilot in command’s dual sidestick inputs, although intended to assist the copilot, compounded the handling difficulties experienced by the copilot during the latter stages of the approach. The pilot in command’s inputs seemed to be in reaction to concerns about the aircraft’s attitude and trajectory during the latter stages of the approach. However, in so doing, those inputs increased the risk of the over-control of the aircraft when in close proximity to the ground.

Had the pilot in command taken control of the aircraft in the manner specified in the operator’s FCOM, by stating ‘I have control’ and pressing the side stick priority pushbutton when he became concerned, the dual sidestick inputs would most likely have been discontinued at that stage. Single-stick demand inputs to achieve the desired aircraft attitude in terms of its pitch and/or roll would then have been restored, and the risk of the over-control of the aircraft in close proximity with the ground would have been reduced.

Under those circumstances, both the touchdown ‘crab’ angle and vertical 'g' loading of 1.7 ‘g’ would probably have been less than actually occurred. As such, the MLG tyre side forces during the ‘decrab’ after touchdown and the rate of MLG bogey derotation would both have been reduced. The reduced MLG tyre groundslip angle and loadings at touchdown would have lessened the likelihood of the resultant tyre and aircraft damage that occurred.

FINDINGS

Contributing safety factors

- The A340 landed on runway 16 in significant crosswind conditions.
- The failure of the number-1 wheel tyre on the left main landing gear resulted from a combination of high side forces, centrifugal loads, tensile compression, and shear forces that acted on that tyre during the landing touchdown in the prevailing crosswind conditions.
- The pilot in command, as pilot not flying (PNF), and without announcing that he was taking control and pressing the side stick priority pushbutton, made dual sidestick inputs during the latter stages of the landing approach to runway 16, and continued to make those inputs after the aircraft touched down.
- The dual sidestick inputs by the pilot in command resulted in 'global' demand 'orders' that were greater than those 'ordered' by the copilot's sidestick input.
- The aircraft response to the 'global' demand 'orders' was likely to have been greater-than-expected by the copilot.
- The unexpected magnitude of the aircraft's response to the dual pilot sidestick inputs resulted in both crew members applying opposite stick inputs to reduce that response, leading to an over-control of the aircraft.

Other safety factors

- The crew did not seek clarification of the wind speed and direction for their intended landing on runway 16 which, at the time, was not the duty runway at Melbourne Airport.
- The Melbourne Tower Aerodrome Controller (ADC) did not provide the crew with landing information specific to runway 16.
- The Melbourne Tower ADC did not provide the crew with information about the significant crosswind on runway 16, in accordance with the requirements of the Aeronautical Information Publication (AIP) or Manual of Air Traffic Services (MATS).

Other key findings

- The CANTY Sector Controller did not identify and/or query the inconsistency in the wind information provided by the acting Flow Controller regarding the 9 kts crosswind affecting runway 34.
- The crew did not identify and/or query the inconsistency in the wind information that was passed to them by the CANTY Sector Controller regarding the 9 kts crosswind affecting runway 34.
- The air traffic services system did not have procedures in place to ensure that crews using a non-duty runway were provided with appropriate operational information to assist in their timely decision-making.

- The crosswind encountered during the landing was less than the maximum demonstrated landing crosswind for the A340.
- The landing gear loads remained below their design limit during the landing.
- The number-1 wheel tyre burst was not as a consequence of the actual landing gear loads encountered during the landing.
- The flight warning system functioned correctly and activated the ‘DUAL INPUT’ synthetic voice message when the PNF made dual sidestick inputs during the latter stages of the approach.

SAFETY ACTION

Operator

As a result of this occurrence, the operator reported that it had issued the following safety recommendations to its flight crews:

1. Pilots should give increased attention to and consideration of the suitability of the active runway for take off or landing.
2. Pilots should be on alert for unusual winds at MEL (and elsewhere) by continuously monitoring the wind data and information, especially during the take off and approach briefings.

In addition, the operator has:

- Reviewed its pilot training to include the cues to the requirement to execute a go around in the case of abrupt changes in an aircraft's attitude as a result of increased wind gusts and/or other severe meteorological conditions.
- Included this incident in its Flight Operation Trend Analysis and Flight Operations Risk Assessment programs.

Air traffic services

As a result of this occurrence, Airservices Australia reported that it was taking the following safety actions:

1. Developing ATC procedures to ensure responsibilities for passing of amended weather information to landing aircraft are clearly identified.
2. Reinforcement of supervision processes for on-the-job training.
3. Incorporation of behavioural training into ATC awareness training in regard to challenging of information believed to be incorrect or where information provided is not fully understood.
4. Undertaking a review of current ATC training and awareness in respect of ATS behaviours in the provision of weather related information to pilots.
5. Developing procedures to capture [that] the updated information has been passed to an aircraft.
6. Provided information to Melbourne Tower controllers in relation to aircraft utilising runway 16 in strong westerly wind conditions.

In addition, the introduction of amendment 12 to the second edition of the Manual of Air Traffic Services in June 2007 included the requirement for aerodrome controllers to advise the relevant threshold wind to pilots of jet aircraft.

Aircraft manufacturer

In its safety publication *Safety First – The Airbus Safety Magazine # 03 December 2006*, the aircraft manufacturer published an article that highlighted the risks associated with dual sidestick inputs by flight crews in Airbus aircraft. That article is reproduced at Appendix D, with the permission of the aircraft manufacturer.

International Federation of Air Line Pilot's Associations

Following the publication of the ATSB Preliminary Report into this occurrence, the International Federation of Air Line Pilots' Associations (IFALPA):[28]

- Published an article in the June 2006 issue of its IFALFA News. That article reviewed the risks affecting the landing at Melbourne Airport.
- Reported that it was developing a Safety Bulletin for its members to address a number of safety issues affecting crosswind operations in high capacity aircraft.

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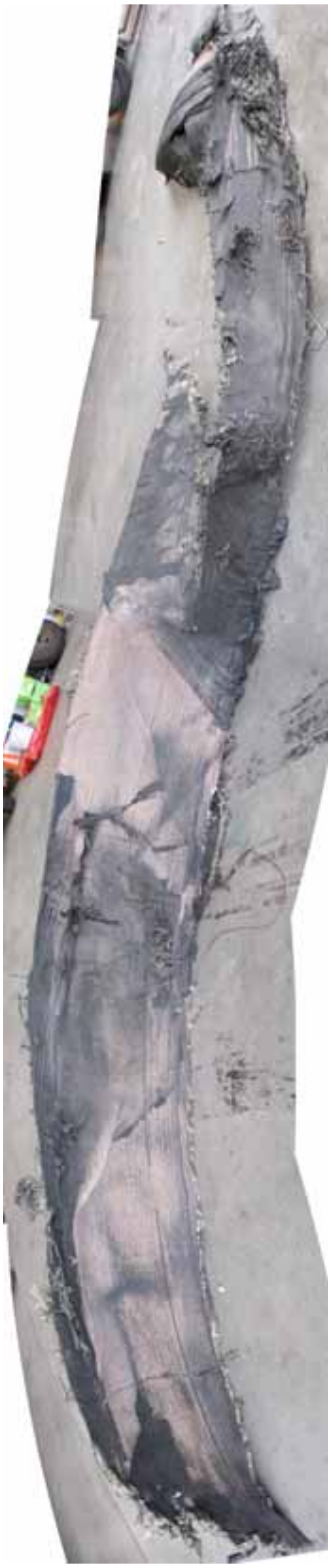
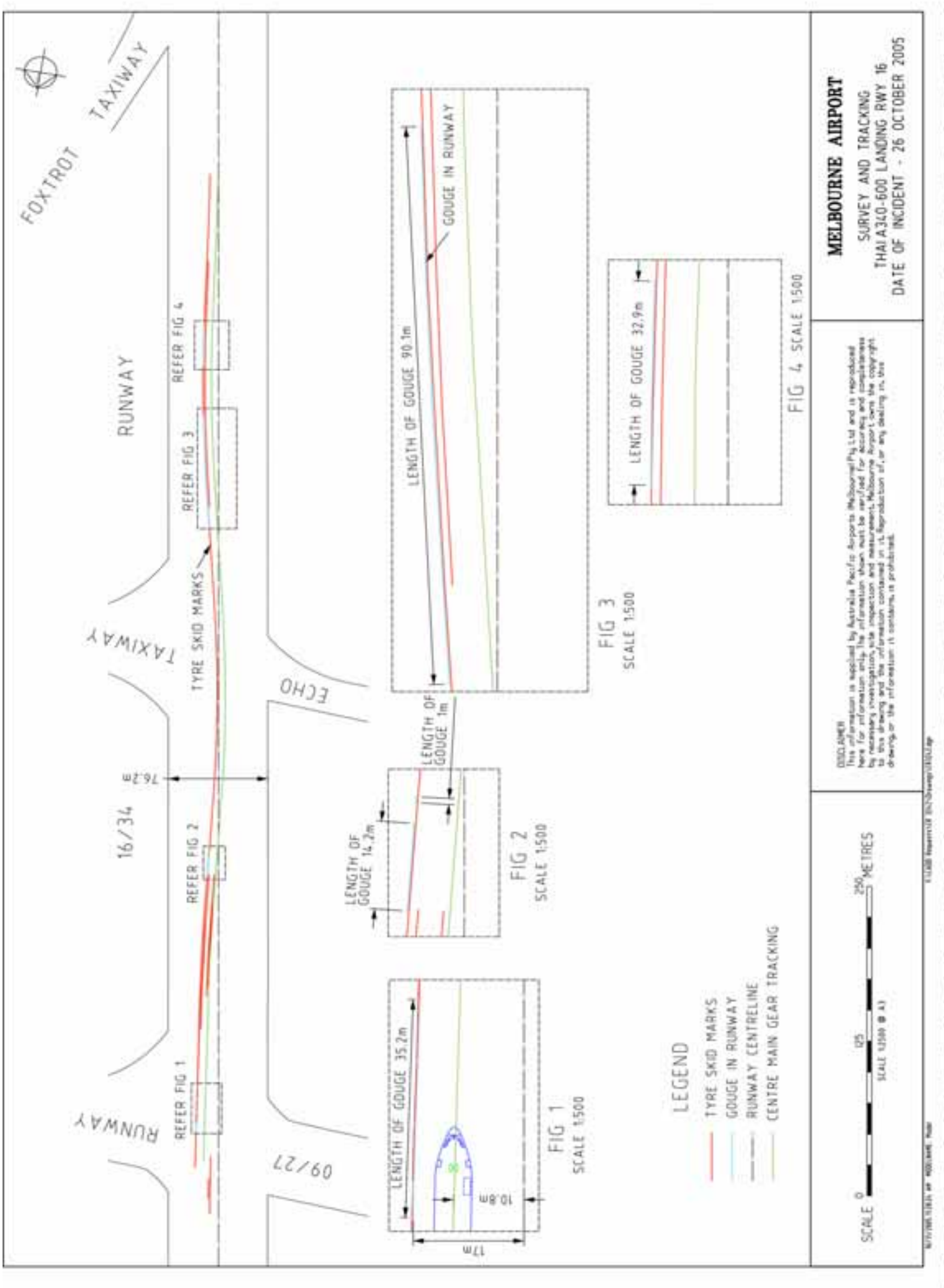
[28] Also see discussion at page 26 to this investigation report.

APPENDIXES

Appendix A. Detached tyre tread



Appendix B. Aircraft tracking on runway 16 after touchdown[29]



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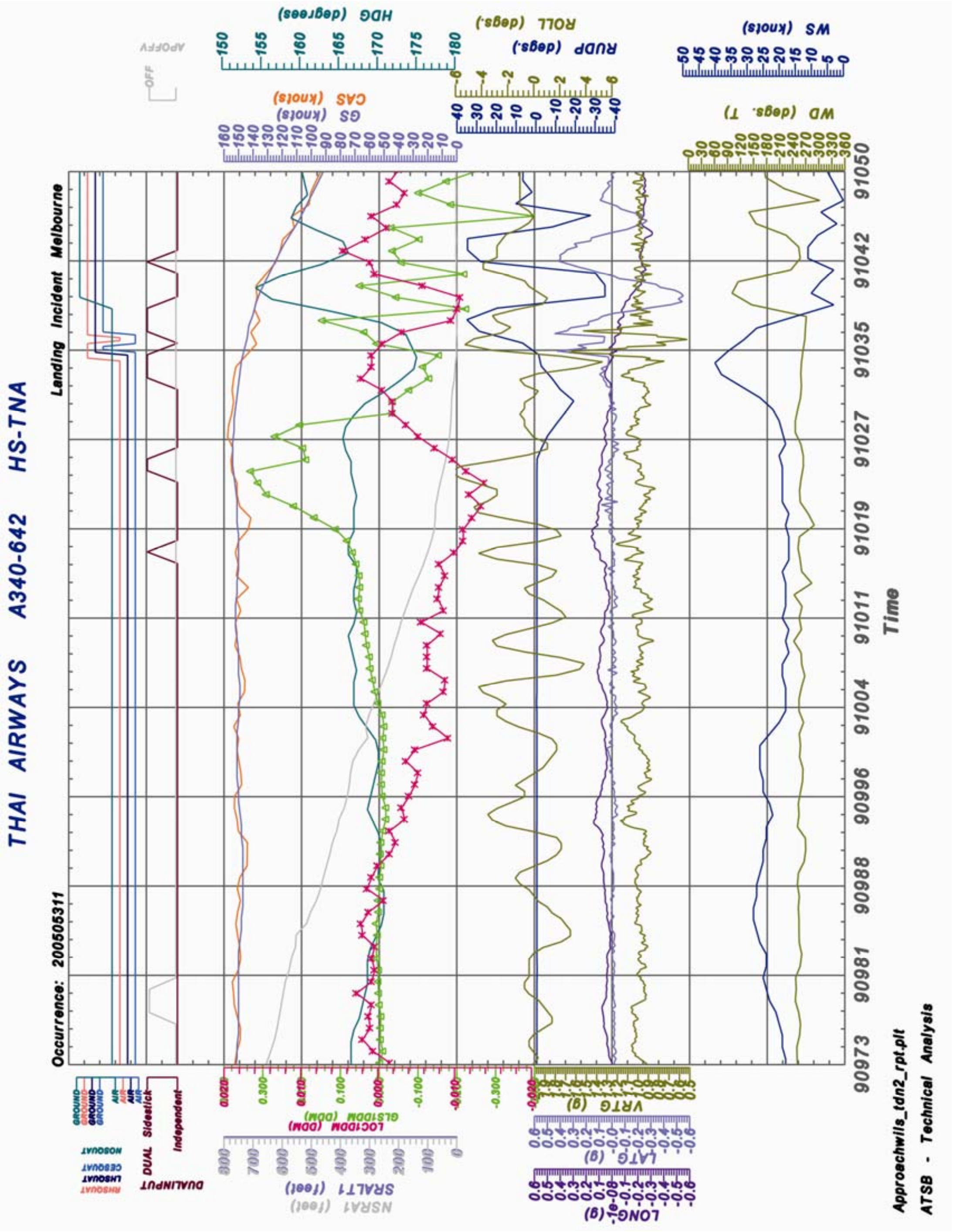
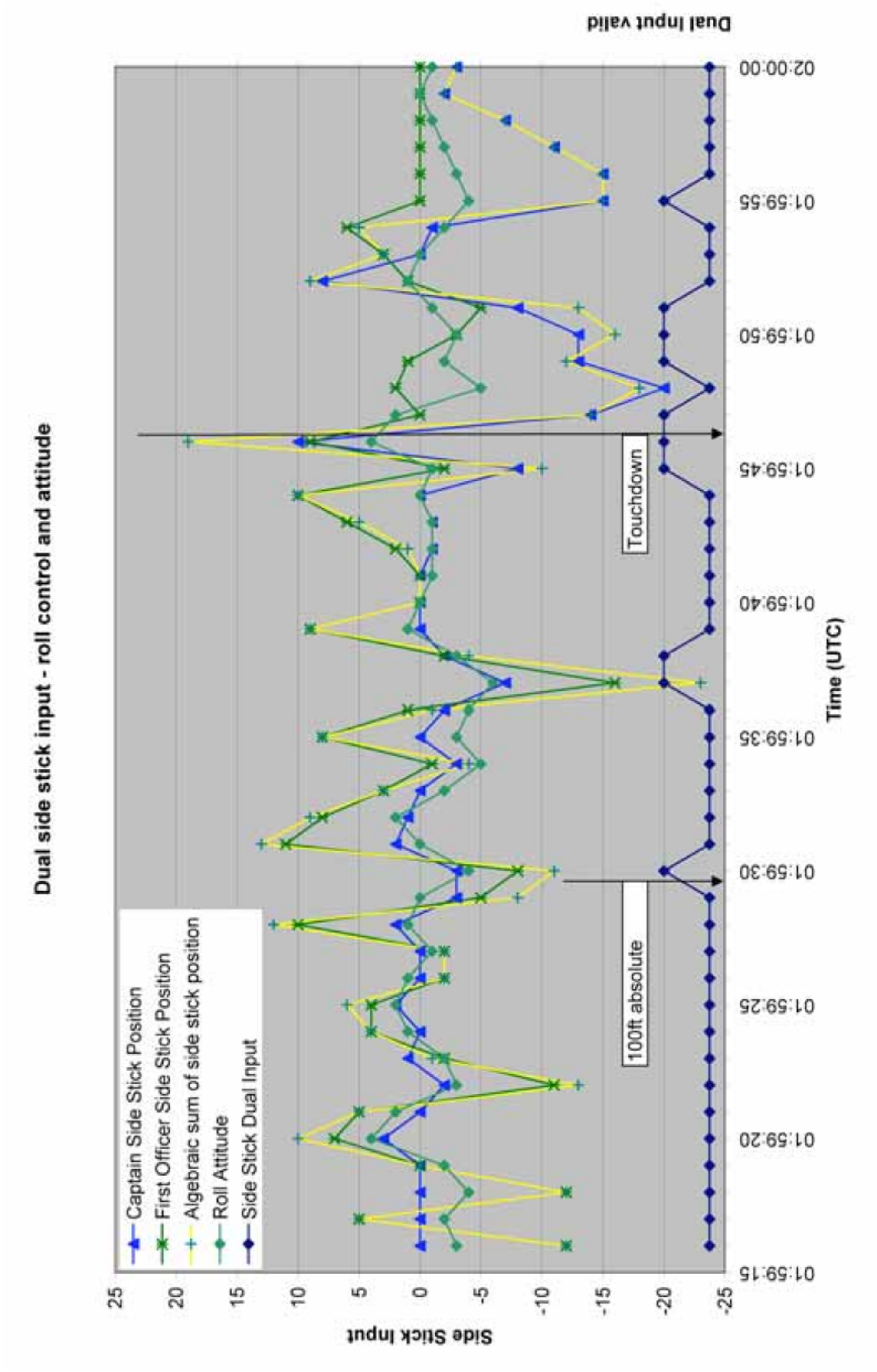
[29] Source: Australia Pacific Airports (Melbourne) Pty Ltd – Reproduced with permission.

Appendix C. Solid state flight data recorder (SSFDR) data plots

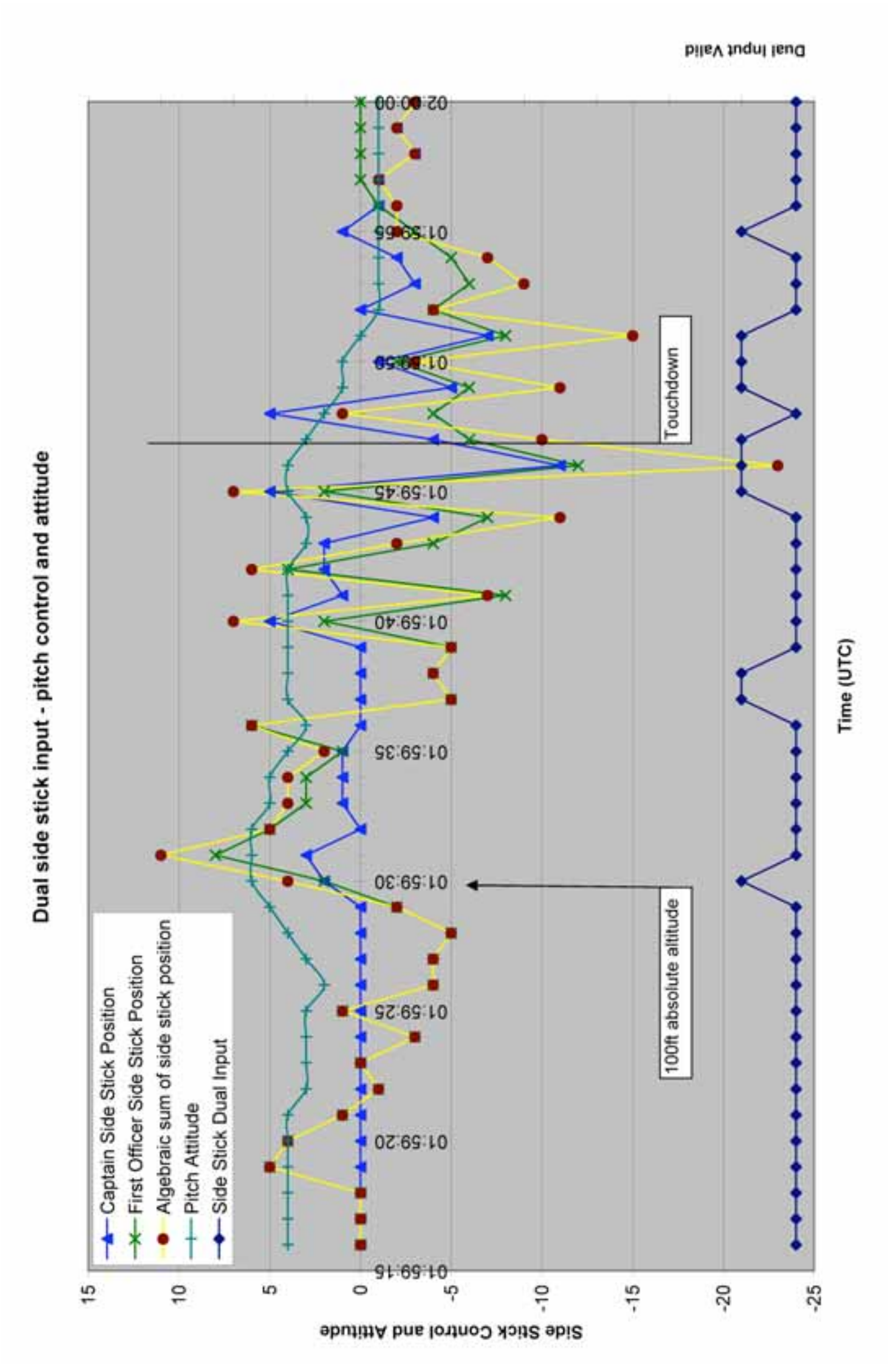
C.1 Consolidated SSFDR Plot



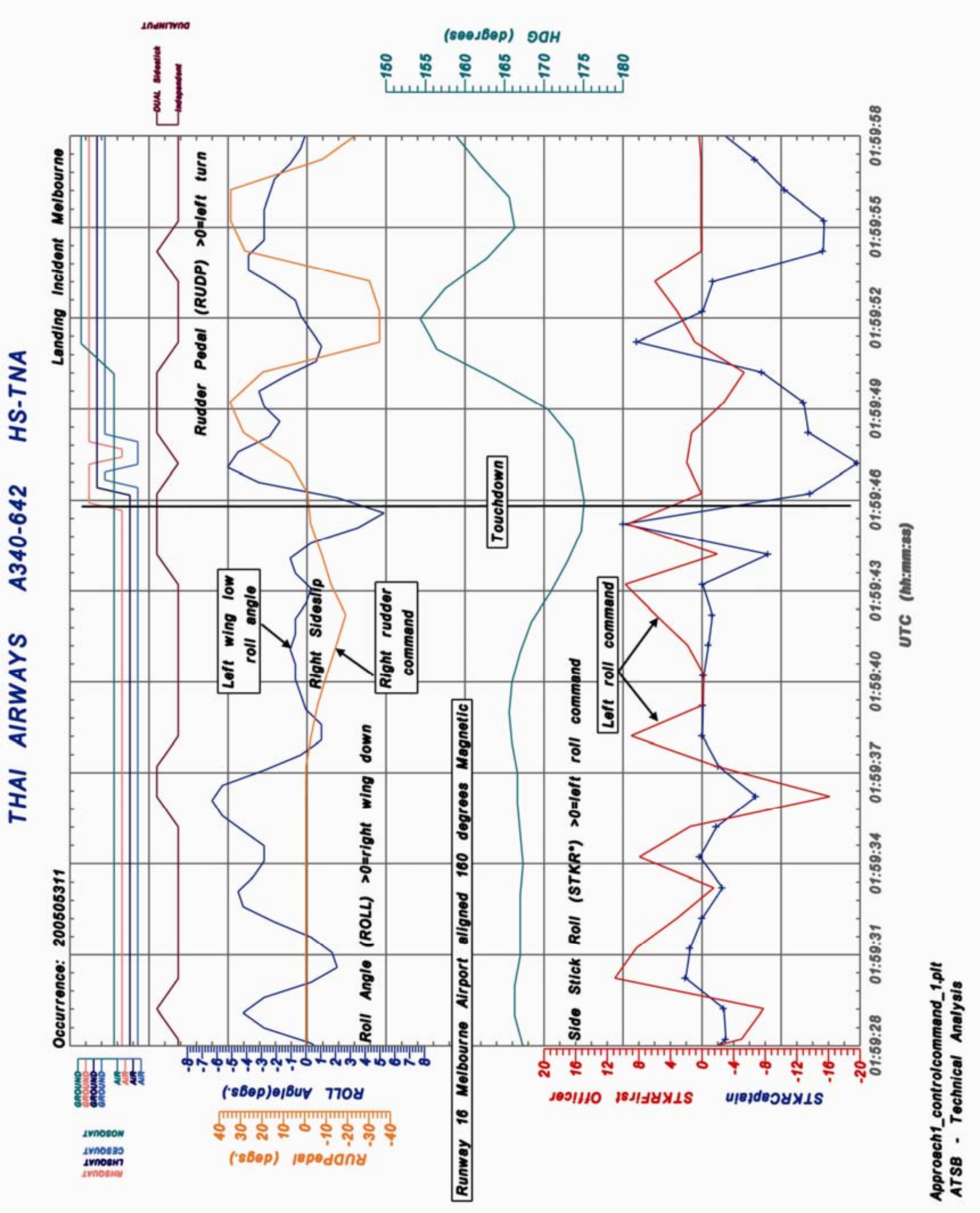
C.2 Dual side stick input – roll control and attitude



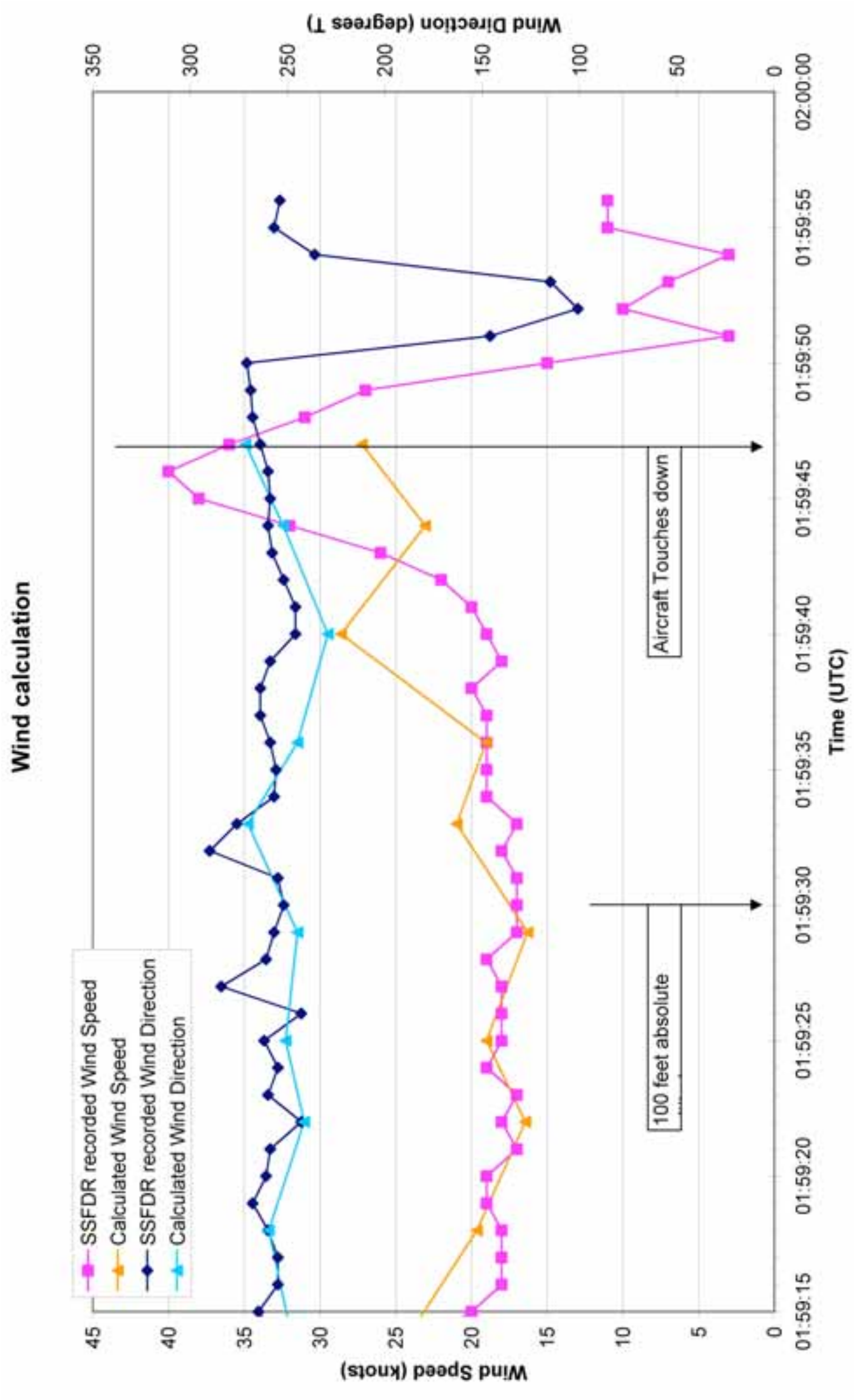
C.3 Dual side stick input – pitch control and attitude



C.4 Sideslip and skid during the landing flare



C.5 Wind calculation



Appendix D Aircraft manufacturer’s article - risks associated with dual sidestick inputs by flight crews[30]

Safety First
The Airbus Safety Magazine
3
#03 December 2006

Dual Side Stick Inputs

By: Frédéric COMBES
Flight Safety Manager

1 | Introduction

One of the basic task sharing principle for any aircraft operation is that one pilot is Pilot Flying at a time. Therefore, if the Pilot Not Flying disagrees with the Pilot Flying inputs, he/she has to verbally request corrective actions or, if deemed necessary, to take over the controls by clearly announcing "I have controls".

This will mean that he/she becomes Pilot Flying from that moment and the other Pilot Not Flying. Nevertheless, the feedback gained from line operations monitoring indicates that dual inputs still occur and are also sometimes involved in operational incidents analyzed by Airbus.

This was the case for the below described event, experienced on an A320 during turbulence

2 | Summary of the event

While climbing to FL 320 at about Mach 0.78, an A320-200 encountered significant turbulence that led roll to increase up to 40°.

The Pilots reacted to this roll departure by various dual sticks inputs in pitch and roll. The Auto Pilot disconnected consequently to stick input.

Before the event the aircraft was in climb to FL 320. The airplane had a weight of 61,2t. and was in the following configuration:

- Clean with AP 2 engaged (CLIMB / NAV) and ATHR Engaged & Active in Thrust mode.
- Managed Mach target was 0,78
- Both ND CPT & FO were selected in ARC Mode with a range of 160NM

The aircraft began an uncommanded roll to the right, which was initially counteracted by the Auto Pilot. However, at a speed above 250 kts, Auto Pilot orders on ailerons are limited at 8°. Therefore, due to the high turbulence the roll reached a value of 40° to the right.

Both pilots reacted with full LH stick orders and 10° LH rudder pedals.

This induced the disengagement of the Auto Pilot. During the next 20 seconds, the Captain and First Officer applied dual stick inputs, which lead to roll values oscillating between 33° to the left and 49° to the right, as well as to a loss of 2400 feet altitude. The Captain then re-engaged the Auto Pilot, selected Flight Level 310, and the flight resumed without noticeable event.

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[30] Reproduced with the permission of the Flight Safety Manager, Flight Safety – GSE, AIRBUS Central Entity.

3 | Types of dual stick input

Analysis of reported dual side stick inputs events, reveals that there are three types of occurrences:

The "Spurious" Dual Stick inputs

Typically due to an inadvertent movement of the stick by the PNF.
For example when grabbing the FCOM or when pressing the R/T.
A spurious dual stick input only marginally affects the aircraft behavior due to only time limited & small inputs.

The "Comfort" Dual Stick inputs

Typically due to short interventions from the PNF who wants to improve the aircraft's attitude or trajectory:
These are generally experienced in approach, during a capture (altitude localizer), or in flare, and have minor effects on the aircraft's altitude/trajectory.
However, as the PF is not aware of the PNF's interventions, he may be disturbed and may counteract the PNF's inputs.

The "Instinctive" Dual Stick Inputs

Typically due to a "reflex" action on the part of the PNF on the stick. This instinctive reaction may come about when an unexpected event occurs, like for example an AP disengagement, an overspeed situation or a dangerous maneuver.
Such interventions are more significant in terms of stick deflection and duration. Usually in such situations, both pilots push the stick in the same direction, which may lead to over control, a situation illustrated by the above occurrence.

4 | Operation of the sidestick

The two sidesticks are not mechanically linked as they are on older types of aircraft.
This means that both sticks may be operated independently one of the other.
When one sidestick is operated it sends an electrical signal to the Fly By Wire computers. When both sticks are moved simultaneously, the system adds the signals of both pilots algebraically.

The total is limited to the signal that would result from the maximum deflection of a single sidestick.

To avoid both signals being added by the system, a priority P/B is provided on each stick. By pressing this button, a pilot may cancel the inputs of the other pilot.

An audio signal will indicate which sidestick has priority,

and a red light comes on in front of the pilot whose stick is deactivated

A green light will come on in front of the pilot who has taken control if the other stick is not in neutral position.

With autopilot (AP) engaged, the sidesticks are kept in the neutral position, with no possibility of simultaneous inputs from either pilot.

Indeed, when the A/P is engaged, it is normally disconnected by pressing the priority P/B (the pilot takes priority over the A/P) or instinctively at any time by a firm action on the stick: typically 5kg in pitch, 3.6kg in roll.

5 | Operational procedures

Simultaneous inputs by both PF and PNF on the sidesticks must be avoided. Thus, if the PNF feels he must intervene, he must do so by pressing the Priority P/B while saying "I have controls".

These rules are reminded in the Flight Crew Training Manual 01.020 – Flight Controls and Flight Crew Operating Manual 1.27.40 – Flight Controls: Controls and Indicators"

6 | Dual Sidestick inputs warning system

In order to warn the crew in case of dual sidestick operations, Airbus has designed a package of dual input indicators and audio warning.
These operate when both side sticks are deflected simultaneously by more than 2°.
These visual and aural warnings have proved to be efficient means to inform the pilot of dual inputs.

Visual indication

When a dual input situation is detected, the two green priority lights located on the cockpit front panel flash simultaneously.

The visual indication is an **ADVISORY** of a dual input situation

Aural Indication

After the visual indication has been triggered, a synthetic voice "DUAL INPUT" comes up every 5 sec, as long as the dual input condition persists.

The synthetic voice is a **WARNING** of a dual input situation

Note: This audio has the lowest priority among the synthetic voice audio alerts.

The visual and audio indications are designed to provide the crew with a progressive alert.

Experience has shown, that these warnings are very effective to:
- "Educate" the pilots to respect the basic task sharing principle;
- Reduce drastically the number of dual input occurrences.

The activation of these dual input warnings has no repercussion in term of :
- Crew training;
- Mixed fleet flying.

HOW TO UPGRADE YOUR SA AND LR AIRCRAFT ?

- The light and aural indicators are basic, and free of charge on retrofit, on the A320 family and A330/A340.
- It requires **FCDC** and **FWC** to be at a given standard already available on production line:
  - A320: FWC E2 Standard - FCDC 53 Standard
  - A330/A340: FWC K3/L7 Standard - FCDC M11/L14 Standard
- **Pin programs are activated on Operator request**