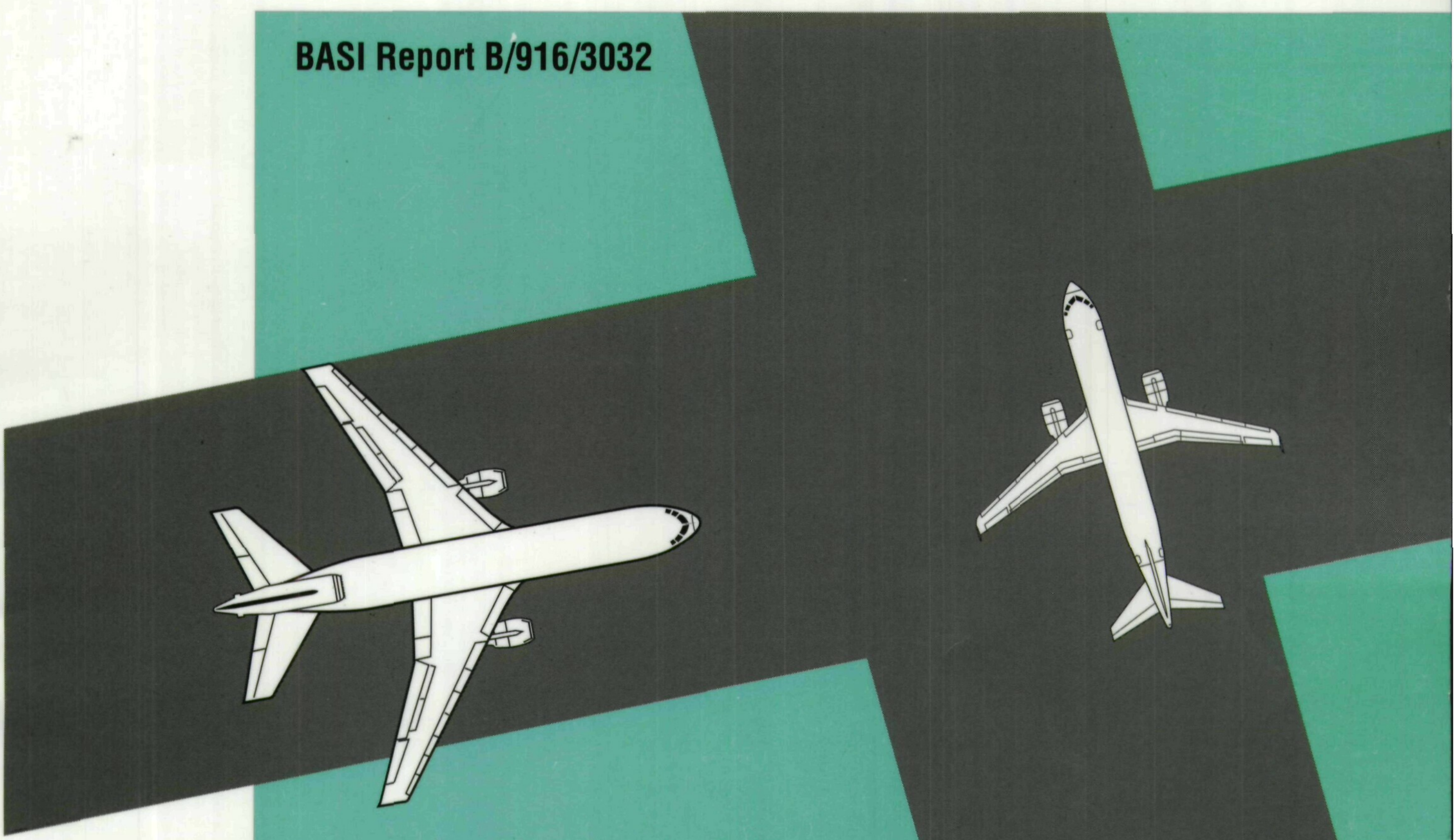
SPECIAL INVESTIGATION REPORT

BUREAU OF AIR SAFETY INVESTIGATION

BASI Report B/916/3032



Near Collision at Sydney (Kingsford Smith) Airport 12 August 1991

BASI

Bureau of Air Safety Investigation

AUSTRALIA

Transport and Communications

Department of Transport and Communications

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SPECIAL INVESTIGATION REPORT
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DC-10 Series 30ER Aircraft HS-TMC
and
A320-211 Aircraft VH-HYC

Near collision at
Sydney (Kingsford Smith) Airport
12 August 1991

BASI
Bureau of Air Safety Investigation

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under the provisions of Air Navigation Regulation 283

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SYNOPSIS

On Monday 12 August 1991, at 1023 hours Eastern Standard Time (EST), a McDonnell Douglas DC-10 Series 30ER aircraft (DC-10) operated by Thai Airways International was landing on runway 34 at Sydney (Kingsford Smith) Airport. The DC-10 was carrying 185 persons. At the same time, an Airbus A320-211 aircraft (A320), operated by Ansett Australia was on a short final approach for landing on runway 25. The A320 was carrying 110 persons.

Runways 34 and 25 intersect, and Simultaneous Runway Operations (SIMOPS) were in progress.

Landing instructions to the crew of the DC-10 included a requirement for the aircraft to be held short of the intersection of runways 34 and 25.

A Qantas Airways Boeing B747 aircraft was holding on taxiway Victor ('V'), north of runway 25 and west of runway 34, awaiting the landing of the A320 and a subsequent clearance to cross runway 07/25. The B747 was carrying 372 persons.

While observing the DC-10's landing roll, the captain of the A320 judged that the DC-10 might not stop before the intersection of the runways. He elected to initiate a go-around from a low height above the runway.

Under heavy braking, the DC-10 slowed to about 2 kts ground speed, at which time the nose of the aircraft was approximately level with the edge of runway 07/25.

During the go-around executed by the crew of the A320, that aircraft passed above the DC-10 on its left and the B747 on the right of its flight path.

1. FACTUAL INFORMATION

1.1 History of the flight

The Thai Airways International DC-10, registration HS-TMC, was operating an international regular public transport (RPT) flight as THA485. The aircraft was making an approach to runway 34 after a scheduled flight from Bangkok, and was carrying 167 passengers and 18 crew.

The Ansett Australia A320 aircraft, registration VH-HYC, was making an approach to runway 25 on completion of a scheduled flight from Brisbane. VH-HYC was carrying 102 passengers and eight crew.

At the time of the incident, SIMOPS were in progress with aircraft landing on the intersecting runways. Traffic had been flowing at a rate of approximately 50 movements per hour but had reduced to approximately 20 movements per hour at the time of the occurrence. The Senior Tower Controller (STWR) stated that he considered these traffic conditions to be 'light'.

The relevant Automatic Terminal Information Service (ATIS) broadcast recording indicated that SIMOPS were in progress and that runway 25 was nominated for departures, while runways 25 and 34 were nominated for arrivals. The ATIS advised aircraft to 'expect traffic on the crossing runways'. Heavy jets were 'to land on runway 34 and international aircraft were to depart on runway 34'.

At 10.23:39 EST, THA485 landed on runway 34. The landing instructions given to the aircraft included a requirement to stop before the 'flight strip' of runway 25, the intersecting runway. With the expectation that THA485 would hold short of the runway intersection as required under SIMOPS procedures, the Aerodrome Controller (ADC 1) had cleared VH-HYC to land on runway 25.

At the same time, a Qantas Airways B747 preparing for an international RPT flight to Nagoya Japan, was holding on taxiway 'V'. The aircraft was being held pending the landing of VH-HYC and receipt of a subsequent clearance to cross runway 07/25 en route to runway 34 for takeoff. The B747 was on the northern side of runway 07/25 approximately 180 m (600 ft) west of the runway intersection. It was carrying 353 passengers and 19 crew.

At 10.23:57 EST, VH-HYC initiated its landing flare. The progress of THA485's landing was being monitored by control tower personnel and by the captain of VH-HYC.

At 10.24:02 EST, ADC 1 assessed that THA485 was approaching the runway intersection at an excessive speed. Believing that the DC-10 would not stop before the intersection, the ADC 1 transmitted the instruction 'Thai 485 stop immediately, stop immediately'. At that time, the captain of THA485 applied heavy braking.

At 10.24:04 EST, the captain of VH-HYC, assessing that THA485 might not stop before the intersection and that there was a possibility of a collision between the two aircraft, initiated a go-around from a height of 2 ft above the runway.

At 10.24:14 EST, VH-HYC passed through the centreline of runway 34 at a radio altitude of 52 ft (15.85 m). At this time THA485 had almost stopped, with the nose of the aircraft approximately 35 m inside the 07/25 runway strip and approximately 40 (± 20) m from the runway centreline.

At their closest point the separation between VH-HYC and THA485 was 11 (± 2) m vertical distance between the left wingtip of the A320 and the top of the DC-10 fuselage. The horizontal separation at this point was 33 (± 20) m between the left wingtip of the A320 and the nose of the DC-10. (This horizontal distance could not be computed as accurately as the vertical due to limitations in the recorded data which required it to be derived. In contrast, the vertical distance is far more precise because it was recorded directly from the aircraft radio altimeter onto the Digital Flight Data Recorder (DFDR).)

1.2 Injuries to persons

No injuries were reported.

1.3 Damage to aircraft

No damage was reported.

1.4 Other damage

No other damage was reported.

1.5 Personnel information

1.5.1 Crew of DC-10 HS-TMC

Captain: The captain was aged 50 years and held an Airline Transport Pilot Licence (ATPL) appropriately endorsed for command of DC-10 Series 30ER aircraft. At the time of the incident, he had a total flying experience of 19,475 h, of which 3,380 h were on DC-10 aircraft, with 78 h in the last 30 days. His last Sydney flight operation prior to 12 August 1991 was in January 1991.

First officer: The first officer was aged 37 years and held an ATPL appropriately endorsed for co-pilot and systems operator (flight engineer duties) of DC-10 Series 30ER aircraft. At the time of the incident, the first officer had a total flying experience of 7,372 h, of which 6,665 h were on DC-10 aircraft, with 83 h in the last 30 days. The first officer was occupying the systems operator position at the time of the incident. His last Sydney flight operation prior to 12 August 1991 was in 1988.

Pilot trainee: The pilot trainee was aged 28 years and held a Commercial Pilot Licence (CPL) appropriately endorsed for systems operator and co-pilot for DC-10 Series 30ER aircraft. At the time of the incident, the pilot trainee was the handling pilot. He had a total flying experience of 1,675 h, of which 1,495 h were on DC-10 aircraft, with 68 h in the last 30 days. The pilot trainee's DC-10 flying experience had been gained as a systems operator. This flight was his first check flight as a co-pilot after commencing co-pilot route training. He had not previously operated into Sydney.

1.5.2 Crew of A320 VH-HYC

Captain: The captain was aged 40 years and held an ATPL appropriately endorsed for command of A320 aircraft. At the time of the incident, he had a total flying experience of 7,731 h, of which 1,023 h were on A320 aircraft including 36 h in the last 30 days. His last Sydney flight operation prior to 12 August 1991, was on 6 August 1991.

First officer: The first officer was aged 42 years and held an ATPL appropriately endorsed for co-pilot of A320 aircraft. At the time of the incident, he was the handling pilot. He had a total flying experience of 10,557 h, of which 1,245 h were on A320 aircraft, including 82 h in the last 30 days. His last Sydney flight operation prior to 12 August 1991 was on 7 August 1991.

1.5.3 Air Traffic Services (ATS) personnel

1.5.4 Tower personnel

ADC 2: The officer occupying the Aerodrome Controller 2 (ADC 2) position was aged 42 years. He held ratings for the Surface Movement Controller (SMC), Co-ordinator (COORD), ADC 1, ADC 2 and STWR positions. His last proficiency check was in August 1991. He had 20 years experience as an air traffic controller.

ADC 1. The officer occupying the ADC 1 position at the time of the incident was aged 41 years. He held ratings for the SMC, COORD, ADC 1 and ADC 2 positions. His last proficiency check was in March 1991. He had 17 years experience as an air traffic controller.

1.5.5 Area Approach Control Centre (AACC)

Airways Data Systems Operator (ADSO): The officer occupying the ADSO position in the AACC at the time the DC-10 flight plan message was processed was aged 25 years. She held a Certificate of Proficiency with valid ratings for the flight data positions in the AACC and control tower. She was rated for the Traffic Entry Co-ordinator position in the Sydney Communications Centre and had also previously held flight data ratings for the Sydney Operational Control Centre. She had approximately 18 months experience as an ADSO at Sydney.

1.6 Aircraft information

HS-TMC, a DC-10 Series 30ER passenger aircraft, owned and operated by Thai Airways International Limited, had the no. 3 (right) engine thrust reverser deactivated prior to the aircraft leaving Bangkok. However, the aircraft was legally serviceable and its serviceability status was appropriately documented.

VH-HYC, an A320-211 passenger aircraft owned and operated by Ansett Australia, was serviceable and its serviceability status was appropriately documented.

1.7 Meteorological information

At the time of the incident the ATIS indicated that the surface wind was from the west at 10–15 kts. The altimeter setting (QNH) was 1,023 hPa and the temperature was 13°C. There was no reported cloud and the visibility was greater than 10 km.

The runways were dry and the crosswind components on runways 25 and 34 were 9 kts and 12 kts respectively. Under these conditions, runway 25 was nominated for departures and runways 25 and 34 were nominated for arrivals.

No problems with visibility were reported by any of the controllers.

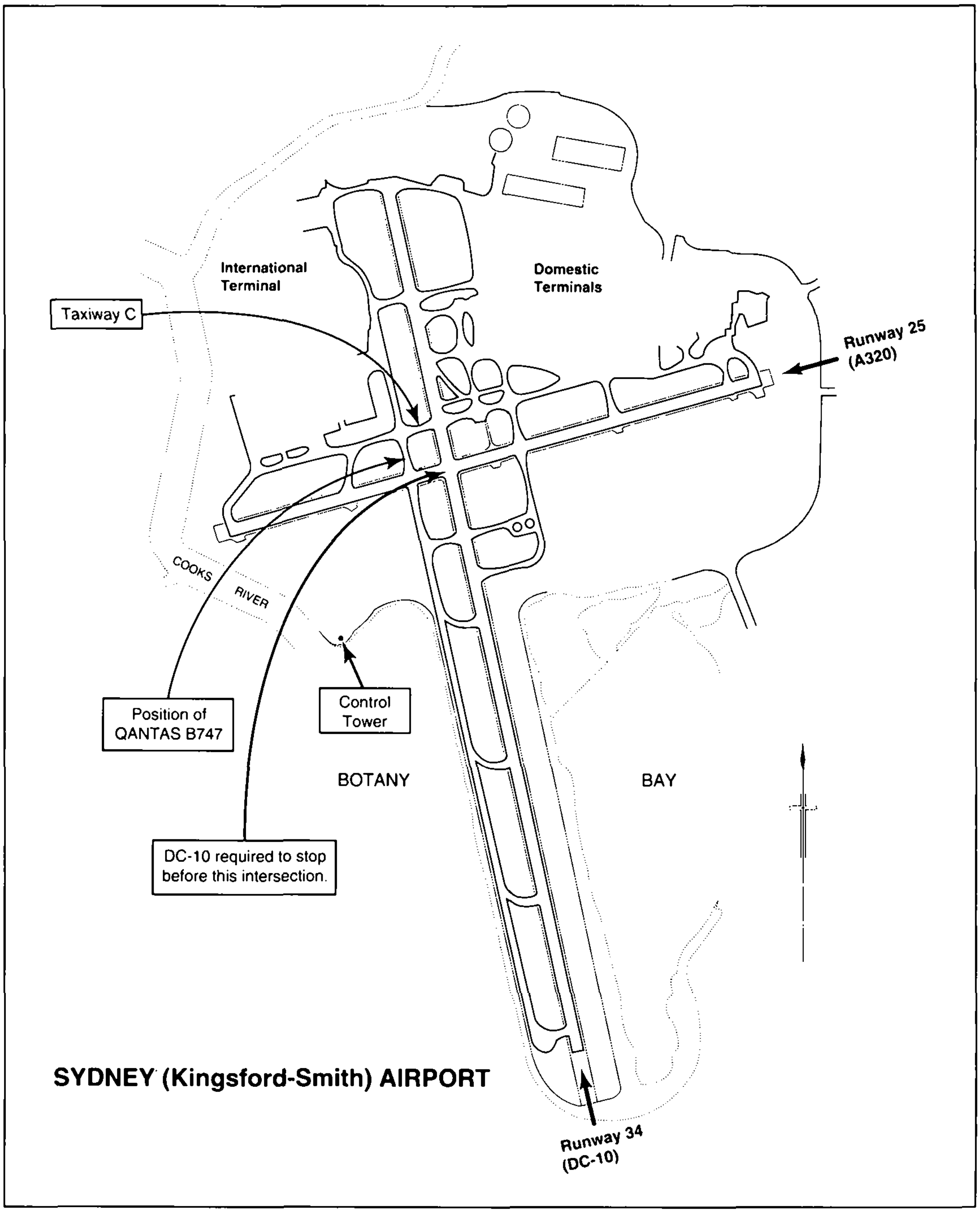
1.8 Aids to navigation

Not applicable.

1.9 Communications equipment

No problems were found with the radio communications facilities at Sydney tower. Examination of the Automatic Voice Recording (AVR) tapes indicated that all transmissions by the ADC 1 and the aircrew were clear.

1.10 Aerodrome information



1.10.1 The aerodrome

The operator of Sydney (Kingsford Smith) Airport is the Federal Airports Corporation. The complex includes two sealed runways, 16/34 and 07/25, which are 3,962 m and 2,529 m in length respectively. Runway 07/25 has a slope of 0.1% down to the west. It is 45 m wide, and crosses runway 16/34 at a point 2,624 m from the threshold of runway 34.

Runway 34 has an overall slope of 0.2% down to the north and is 45 m wide. In side elevation, the runway has a hump which rises to a maximum of 2.33 m above the threshold of runway 34 and approximately 3.0 m above the intersection of runways 25 and 34. The landing distance available (LDA) from the threshold of runway 34 to the intersection is 2,550 m.

1.10.2 The Sydney control tower

The Sydney control tower is configured with a console to accommodate four controller positions facing northwards from an elevated tower cabin located south-west of the intersection of runways 25 and 34. There is also provision for one additional supervisory position, the STWR, and one ADSO position.

Tower floor plan

From left to right, when at the operating workstation, the operators' functions and positions are as follows:

SMC: The occupant of this position is responsible for ground separation by issuing instructions, clearances and information to all aircraft and vehicle traffic operating on the manoeuvring area of the aerodrome, excluding the duty runway(s). This controller also has the use of Surface Movement Radar (SMR) for guidance only.

COORD: The occupant of this position relays procedural messages to and from other airways units, and has various operational and weather information liaison functions, including the alerting of emergency services as required.

ADC 2: The occupant of this position relays Flight Progress Strips (FPS) and departure/arrival sequencing instructions to and from the ADC 1 and other airways units such as the Approach and Departures control cell in the AACC. He was also performing the STWR function at the time of the incident, due to the temporary absence of the STWR and the light traffic density at the time.

ADC 1: The occupant of this position is responsible for maintaining separation between arriving and departing aircraft using the duty runway(s). This officer shares access to the SMR and a 20-NM radius Terminal Area Radar (TAR) display with the ADC 2.

STWR: The occupant of this position is responsible for the oversight of all operations within the control tower cabin. At the time of the incident the officer rostered for the STWR position was taking a short break after a busy period.

ADSO (tower): The occupant of this position sits behind the control console and is responsible for preparing the FPS for use by the tower controllers. The source data for the preparation of the FPS is derived from encoded aircraft flight plans.

1.10.3 AACC

ADSO (AACC): The occupant of this position performs the same duties for the AACC controllers as the ADSO position performs for the tower controllers, that is preparation of the FPS.

1.11 Flight recorders

THA485 was fitted with a Sundstrand 573 DFDR. VH-HYC was fitted with a Sundstrand Universal DFDR.

The data obtained from each aircraft's DFDR was positively identified as originating from the incident flight.

Both aircraft were fitted with Cockpit Voice Recorders (CVR). Information recorded on a CVR is overwritten every 30 min of operation. Since it was not possible for the investigation team to secure the CVRs within the 30 min immediately following the incident, no CVR information pertaining to the incident was available.

1.11.1 DFDR THA485

The DFDR readout showed the aircraft touched down at 10.23:39 EST, approximately 680 m from the runway 34 threshold and 1,930 m from the intersection, with a landing weight of 179,600 kg at an airspeed of 146 kts. After touchdown a nose-up attitude for aerodynamic braking was maintained for 14 s until 10.23:53 EST, when the nosewheel contacted the ground, with the aircraft approximately 970 m from the intersection.

At 10.23.55 EST the thrust reverser for the no. 1 (left) engine was deployed and remained in this condition until 10.24:19 EST. During this period the engine was at idle thrust. As noted earlier, the thrust reverser for the no. 3 (right) engine had been deactivated. Between 10.23:54 and 10.24:09 EST, significant reverse thrust was produced from the no. 2 (centre) engine.

Wheel braking was initiated at 10.24:02 EST at a ground speed of 101 kts and approximately 470 m from the intersection. (The ADC 1 instruction to 'stop immediately' was also transmitted at 10.24:02 EST.) Braking was discontinued at 10.24.16 EST at a ground speed of 4 kts with the aircraft 22 m (±20 m) from the runway 25 centreline. (The A320 overflew at 10.24:14 EST.) During this period, the magnetic heading data varied between 333–340°. The magnetic heading of runway 34 is 336°.

Deceleration had stopped by 10.24:17 EST and the aircraft ground speed remained at 2 kts. At 10.24:23 EST power was applied to increase taxiing speed.

1.11.2 DFDR VH-HYC

The DFDR readout showed that the aircraft passed through a radio altitude of 20 ft (6 m) and entered the flare for runway 25 at 10.23:57 EST, approximately 1,090 m from the intersection, with a landing weight of 56,000 kg at an airspeed of 140 kts. The Auto Thrust System was disengaged and the engine power was being controlled manually. The thrust levers for both engines were retarded to the idle position.

By 10.24:01 EST, the aircraft had descended to a radio altitude of 2 ft (0.6 m) which was maintained for 6 s. The recorded thrust lever angle showed that the go-around was initiated at 10.24:04 EST, with the aircraft 630 m from the intersection. Both engines took approximately 5 s to accelerate from idle to go-around thrust, and the minimum airspeed during the go-around was 131 kts. For approximately 12 s differing attitude command inputs were recorded from both the left and right sidesticks. The maximum nose-up pitch input of 11.9° was recorded at 10.24:06 EST, and the aircraft overflew the intersection at 10.24:14 at a radio altitude of 52 ft (15 m).

1.11.3 Computer graphics

Computer graphics were used to produce an animation of the incident, based on the DFDR readouts from both aircraft. Selected plots from this animation are at appendix C.

1.12 Wreckage and impact information

Not applicable.

1.13 Medical and pathological information

Not applicable.

1.14 Fire

Not applicable.

1.15 Survival aspects

Not applicable.

1.16 Tests and research

1.16.1 A320 simulator trial

An A320 simulator was used in an attempt to duplicate the landing profile flown by VH-HYC during this incident. The simulator was programmed with the incident aircraft's landing conditions and configuration at the time of the incident. The simulator was then operated by the captain of the incident aircraft in an attempt to duplicate as near as possible the approach, landing and go-around profile flown during the occurrence.

The captain was not able to recreate the exact profile flown and recorded on the aircraft's DFDR. Nevertheless, the simulations indicated that had he not initiated the go-around at his nominated decision point, the A320 would not have achieved the altitude required to clear the DC-10 if that aircraft had entered the intersection in front of the A320. The simulations also determined that it was within the A320's performance capabilities to stop short of the runway intersection had it been flown for a touchdown with a preplanned intention of applying emergency braking and stopping before the intersection. However, when the actual incident approach profile was simulated, followed by a landing with an attempt to stop before the intersection, the results indicated that it was possible the A320 may not have stopped before the intersection.

1.17 Additional information

1.17.1 The Reason analytical model

In the course of this investigation a systems analysis model developed by Professor James Reason of the University of Manchester has been used. This model is described at appendix A.

1.17.2 Flight planning/flight data aspects

The flight plan for THA485 originated from the ATS reporting office at Bangkok International Airport, Thailand, at 2133 EST on 11 August. The flight plan was prepared in the International Civil Aviation Organisation (ICAO) format, and was correctly received in the Sydney AACC at 2135 EST.

The aircraft performance category (PANS/OPS designator) is shown on the flight plan and is an indicator of the landing distance required (LDR) by an aircraft. This information is used by controllers at Sydney to determine the landing instructions given to that aircraft. The PANS/OPS designator given to a particular aircraft type or model is largely dependent upon its calculated speed at the runway threshold during an approach to land. For Instrument Flight Rules (IFR) operations, this speed determines the aircraft performance category and is not intended to be a variable based on actual landing weight. This speed is expressed as VAT, i.e. the speed at the threshold, and is equal to 1.3 times the stalling speed in the landing configuration at maximum landing weight. The PANS/OPS category for this model DC-10 was 'Delta' ('D'), that is VAT greater than 141 kts. This information was transmitted in the ICAO flight plan message in Field 18 and received as 'PER/CAT-D'.

The ADSO in the Sydney AACC prepared FPSs incorrectly indicating that the PANS/OPS category of the DC-10 was 'C', i.e. VAT less than 141 kts. However, the ADSO in the control tower prepared the FPS correctly indicating that the PANS/OPS category for the DC-10 was 'D'— as per the flight plan.

The significant difference between the PANS/OPS 'C' and 'D' designators was that category A, B and C aircraft types were not given specific SIMOPS advisory information by Sector or Arrivals controllers, whereas category D aircraft were.

This advisory information was required to be passed to category D aircraft at a distance of approximately 100–150 NM from Sydney when SIMOPS were in progress. All category D aircraft being processed for landing on runway 34 were asked: 'Confirm you are able to comply with SIMOPS procedures. You will be required to hold short of the runway intersection. Landing distance available, 2,550 m'. This call was normally made before the aircraft received the ATIS broadcast, and prior to contacting the tower.

On this occasion, the DC-10 crew were not asked by the Sector or Arrivals controllers to confirm compliance with SIMOPS because the relevant FPS in the AACC was incorrectly displaying the PANS/OPS category as 'C'.

1.17.3 PANS/OPS information (general)

During the on-site phase the investigation team examined the PANS/OPS information on a number of flight plans received at the AACC, and noticed that a seemingly large proportion contained errors. A number of FPS were also seen to contain errors and omissions. A random sample of 60 flight plans was therefore examined in detail. It was found that 15% contained PANS/OPS errors.

1.17.4 Conflict detection

The ADC1 sighted the DC-10 at the time of his initial radio contact with it, when the aircraft was approximately eight miles (16 km) from touchdown. At that stage he instructed the DC-10 to continue its approach. A short time later the DC-10 crew reported on final approach for runway 34. The ADC 1 then instructed the crew to stop the aircraft before the 'flight strip' of runway 25, confirmed that 'simultaneous operations were in use' (spoken in full) and cleared the aircraft to land on runway 34. The crew read back the clearance to land and the designated runway. The crew had not been specifically advised by the Sector or Arrivals controllers that the LDA was 2,550 m. However, ADC 1 had no reason to believe that the DC-10 aircrew were unaware of the relevant LDA.

Shortly after ADC 1 established initial communications and sighted the DC-10, he also sighted and established communications with the inbound A320. After THA485 had been cleared to land on runway 34, ADC 1 then advised the A320 that 'SIMOPS' (spoken in the abbreviated format) were in use, and cleared that aircraft to land on runway 25.

1.17.5 Ground routing

At the time of the incident a Qantas B747 was holding on taxiway 'V' north of runway 25 prior to crossing it for a departure on runway 34.

The planned sequence for the ground routing of the DC-10, the A320 and the B747 was for the DC-10 to land and stop short of runway 25. The A320 was expected to cross runway 34 in front of the DC-10, and the B747 would then be cleared to taxi across runway 25 behind the A320. The DC-10 was then to cross runway 25 via the runway intersection and vacate runway 34 via taxiway 'C', continuing on to a northern bay at the international terminal.

1.17.6 Runway and taxiway markings

At the time of the incident, there were no CAA standards for visual aids to conduct SIMOPS. Temporary runway and taxiway Movement Area Guidance Signs (MAGS) were installed in early 1991 at the request of the CAA, conforming to MAGS standards contained in Rules and Practices for Aerodromes. The MAGS were for aircraft landing on runway 34 and approaching the intersection and were positioned adjacent to the appropriate taxiways and runways. These signs were small and aircrew reported that they were difficult to read from an aircraft during its landing roll. There were no existing requirements for 'distance to run' markers to indicate the proximity of the intersection or the end of the runway.

1.17.7 SIMOPS

SIMOPS, introduced in 1983, allowed the takeoff of an aircraft from one runway while another aircraft landed on a crossing runway within established separation criteria.

In 1985 a trial of modified SIMOPS procedures commenced, allowing simultaneous landings. Intersecting runway procedures were also implemented whenever departing aircraft required the use of a non-duty runway, resulting in dual runways being used for landings and departures.

The primary difference between SIMOPS and intersecting runway procedures is that under SIMOPS procedures aircraft are cleared to land simultaneously on the crossing runways without consideration being given to their relative positions. This procedure is based on the assumption that one aircraft will stop prior to the runway intersection as required under SIMOPS instructions. In contrast, when intersecting runway procedures are in progress, positive separation procedures are used so that one aircraft has to be through, actually stopped short, or clear of, the intersection before the other aircraft can be cleared to land or commence takeoff.

The modification of the initial SIMOPS procedures was intended to increase air traffic movement rates at Sydney. The actual introduction of the procedures expanding the limitations to SIMOPS was effected in December 1989 with the promulgation of Notice to Airmen (NOTAM) C11/89. This followed recommendations made by a Civil Aviation Authority (CAA) sponsored study group of ATC personnel who had earlier visited a number of North American airports.

The CAA has indicated that Australian SIMOPS procedures are based on successful US procedures for Simultaneous Operations on Intersecting Runways (SOIR). While the two procedures are very similar, at the time of the incident there were some significant differences between the formal instructions for the operation of SIMOPS in Australia and those for SOIR in the USA.

Most notably, the US SOIR procedures were laid down in detail in a single document, (the Federal Aviation Administration ATC Handbook) whereas Australian SIMOPS procedures were laid out in a variety of NOTAMS and the Manual of Air Traffic Services (MATS). The major differences between US and Australian simultaneous operations procedures were:

(a) The US ATC Handbook specified that traffic information (traffic that poses a risk of potential conflict) must be issued to both aircraft and acknowledgments must be received. Section 3-123b(3) states: 'Issue traffic information to both aircraft involved and obtain an acknowledgment from each'.

In Australia at the time of the incident, pilots received the general statement 'Expect traffic on crossing runway'.

(b) US procedures required an acknowledgment of hold-short requirements.

In Australia there was no requirement for pilots to confirm specifically that they could hold short of the intersection. Such a requirement was introduced to Australian SIMOPS by NOTAM three days after the incident.

(c) US procedures specified that there must be user briefings 45 days before implementation. Operators must confirm that all their flight crews have been fully briefed on SIMOPS requirements.

At the time of the incident Australian procedures did not include any such requirement. However, they have since been introduced by the CAA.

(d) Under US procedures, aircraft types are placed into one of six SOIR groups from 1 to 5A. The SOIR groupings are used to determine an aircraft's eligibility to land on a shortened runway. They generally correspond to the PANS/OPS categories used at Sydney.

The PANS/OPS categories are an ICAO classification whereas the SOIR groups are not. One of the differences between the two classification systems is that under the US SOIR system, all DC-10 aircraft are categorised as SOIR group 5 (approximately equivalent to the PANS/OPS category 'D'), while under the PANS/OPS system DC10s are classified as either category 'C' or 'D', depending upon the particular model.

1.17.8 US SOIR and Canadian SIRO practices.

At numerous airports in the USA, landing heavy transport aircraft as well as light aircraft are routinely requested to hold short of runway intersections. US airports which employ SOIR are listed in the Airport/Facilities Directory published by the US Department of Commerce in consultation with the FAA. SOIR has not been without incident in the USA. For example, the National Transportation Safety Board (NTSB) has investigated a number of near collisions at Chicago O'Hare Airport. In a letter to the FAA of 16 March 1988, the Chairman of the NTSB wrote:

The Safety Board acknowledges the fact that O'Hare is one of the busiest airports in the United States. Additionally, unique to this airport are the concurrent flight operations using several or more intersecting runways. The Safety Board believes that these two factors create a more demanding work environment which can increase the potential for human performance deficiencies.

The US FAA has recognised the seriousness of the runway incursion problem and in January 1991 set up a Runway Incursion Working Group to co-ordinate 45 projects aimed at reducing the frequency of runway incursions.

Canadian procedures for Simultaneous Intersecting Runway Operations (SIRO) are broadly similar to US SOIR procedures. The major difference is that the Canadians permit simultaneous operations on wet runways, whereas SOIR procedures are presently restricted to dry runways. However, wet runway trials are currently underway at O'Hare.

Both the Canadian and US systems require pilots to read back the hold-short requirement to controllers. They also specify consultations with operators before they are permitted to participate in SIRO/SOIR procedures.

Significant additional aspects of the Canadian system are: (1) that the LDA on a shortened runway is measured from the threshold to a point 200 ft short of the nearest edge of the runway being intersected; and (2) that visual cues at the runway intersection must be evaluated before commencing SIRO to ensure that there are appropriate runway signs and lights before the intersection. Aircraft are required to receive a clearance before crossing the hold-short lines.

1.17.9 Previous similar incidents

There had been a number of incidents related to SIMOPS at Sydney during the previous two years. Five of the more serious reported incidents are as follows:

1. 2 August 1990, a Boeing 747 failed to hold short of runway 07 after landing on runway 34.
2. 11 August 1990, a McDonnell Douglas DC-10 failed to hold short of runway 07 after landing on runway 34.
3. 18 March 1991, a Boeing 747 landing on runway 34 appeared that it would not stop before the intersection, and a Falcon 900 on runway 25 was instructed to abort its takeoff.
4. 26 June 1991, a McDonnell Douglas DC-10 failed to hold short of runway 25 after landing on runway 34.
5. 25 July 1991, a McDonnell Douglas DC-10 attempted to take off on runway 34 without clearance. There was crossing traffic on runway 25 at the time.

1.17.10 Other recorded information

SMR is used by controllers to determine the location of aircraft on the aerodrome complex, but is not used for separation purposes. Because the SMR is not a facility for separation or control there is no operational need to record the display. There were video cameras and recorders at the international terminal building which provided Department of Customs officers with a facility to observe the taxiway complex and intersection of the runways. The video recorders are required to be manually selected and were not activated at the time of the incident.

1.18 Summary of interviews

1.18.1 DC-10 crew

It had not been possible to hold detailed interviews with the crew members before they left Australia. The interviews were subsequently conducted at Thai Airways International headquarters in Bangkok some weeks after the incident.

The captain advised that the DC-10 was not usually operated into Sydney as the service was normally operated with a B747. On this occasion, the DC-10 had been substituted for the B747 which was unserviceable. The captain conducted the flight planning briefing in accordance with company policy, as he had operated into Sydney within the last year. During the flight planning briefing in Bangkok, he briefed the crew on SIMOPS at Sydney. He was in possession of the Australian CAA NOTAM C11/89 and it was his understanding that when landing on runway 34, if SIMOPS were in progress, it was a requirement to stop before the intersection.

On descent into Sydney the first advice received by the crew that SIMOPS were in progress was on receipt of the ATIS. After being told by the Sector Controller that the duty runway was 34, the captain conducted the crew landing brief which included the requirement to stop before the intersection. The captain's SIMOPS crew briefing was verified by the other DC-10 flight crew members.

The trainee pilot was the handling pilot for the landing. A visual approach was flown with minimum auto brake selected for landing. The captain considered that the aircraft achieved a normal touchdown approximately 500 m from the threshold, whereupon idle reverse thrust was selected on nos. 1 and 2 engines. As noted earlier, no. 3 reverser was deactivated.

The pilot maintained aerodynamic braking by holding the nose of the aircraft high and clear of the runway. During this time it was observed that the auto brake system was malfunctioning. As a result, the captain took control of the aircraft and applied manual brakes. Just after the captain assumed control, he heard the instruction 'Thai 485 stop immediately, stop immediately' on the ADC 1 frequency. The captain immediately applied hard braking and reverse thrust, bringing the aircraft almost to a stop approximately 40 m from the runway 07/25 centreline, but within the runway strip.

The crew reported that they did not hear the SIMOPS instructions issued in the landing clearance, nor were they aware of the presence of the A320 until the aircraft passed over them in the go-around. They saw the B747 holding on the taxiway adjacent to the intersection just before they reached the intersection.

The captain advised that the crew had been concentrating on the landing and subsequently on the brake system malfunction. Both he and the handling pilot were unaware of the presence of the MAGS, and had difficulty in actually identifying the runway intersection. They also experienced difficulty in assessing their closure rate on what they thought was the intersection, which was probably taxiway 'C'. The call from the tower alerted the captain to the urgent need to stop, and to the proximity of his DC-10 to the intersection of runways 34 and 25.

After the incident, the captain made a radio transmission to the ADC 1 indicating that the aircraft had experienced a problem with the brakes. The reported brake problem was not recorded in the maintenance log, but ground maintenance personnel did cool the brakes. The captain of the DC-10 did not ask for the brakes to be cooled as he stated that they did not need it as the brake temperatures had only reached 150°C (within normal limits).

The captain advised that he had observed that the auto brake system light was illuminated on the glare shield panel after he commenced manual braking. He was unaware of the presence of the light prior to his taking control of the aircraft as he was concentrating on the progress of the landing and the handling of the aircraft by his co-pilot. The captain also advised that he was aware of previous occurrences where the system had failed without a failure light or a fault being found with the system.

The captain advised that the DC-10 was capable of landing and stopping within the LDA, using aerodynamic and conventional braking only. Idle reverse thrust was selected as a backup only.

1.18.2 A320 crew

The crew reported that, approaching Sydney, the aircraft was radar vectored onto a right circuit for runway 25. The first officer was the handling pilot with the captain as the support pilot.

The captain heard the landing clearance for THA485 and observed the DC-10 on base for runway 34. He judged that the two aircraft were about the same distance from touchdown and was concerned about the potential for collision should anything go wrong. He discussed the possibility of confliction with the first officer. The first officer continued the approach whilst the captain observed the DC-10. The captain kept monitoring the position of the DC-10, keeping the first officer advised by calling the progress of the DC-10 landing, the fact that the nose was still in the air and finally that the DC-10 was approaching the intersection too fast.

Having advised the first officer that the DC-10 was approaching too fast and believing that a collision would be inevitable if the A320 continued its landing, the captain took control and initiated the go-around. At the start of this sequence, the captain said to the first officer, 'Going around'.

The conditions under which the go-around was executed were extraordinary in that whilst watching the DC-10 approaching the intersection at a rapid closing rate, the captain initiated the go-around with the A320 only 2 ft from the runway with both engines at idle power.

During the go-around, the captain was alternating his attention between the engine instruments, nose attitude (visually), and the position of the DC-10. He was also concerned about the performance of the aircraft, particularly during the time required for the engines to accelerate from idle to go-around thrust. However, once the engines had attained full power, the captain was in no doubt that the A320 would clear the DC-10 and that it was not necessary to utilise the full capabilities of the aircraft.

Both flight directors had been selected 'OFF' (i.e. visual approach), hence the captain did not have pitch command information available to him on the primary flight display. By not having pitch command information displayed, the task of setting the attitude was complicated by the need to ensure the aircraft was not over-rotated, a situation which could result in a tail strike.

As his aircraft climbed away, the A320 captain observed the DC-10 inside the runway 07/25 strip with smoke coming from the tyres. As the A320 passed above the intersection, the crew believed they had overflown the DC-10.

1.18.3 Qantas B747 crew

The Qantas B747 was holding on taxiway 'V' adjacent to the intersection of the runways.

The captain reported observing that while the A320 was going around, the DC-10 was 'fish-tailing' under heavy braking as it came to a stop with the nose protruding into the runway strip of runway 25. He estimated that the A320 overflew the DC-10 with a maximum clearance of 30 m. The captain stated that he had no doubt that had the A320 touched down and been committed to stop, a collision would have occurred involving the A320, the DC-10 and his B747.

1.18.4 ADSO (AACC)

The AACC ADSO had prepared the FPS for the DC-10 in the early hours of the morning of 12 August 1991. In preparing the FPS she changed the aircraft's PANS/OPS category from 'D' to 'C'.

The ADSO indicated that in her experience the operation of PANS/OPS category D DC-10 aircraft into Sydney was relatively uncommon.

In the 72 h leading up to the morning of the incident, the ADSO had worked a series of staggered shifts. On Friday 9 August 1991 the officer worked from 1300 EST to 2000 EST. On Saturday 10 August she worked from 0600 EST to 1300 EST. On Sunday 11 August she worked two shifts from 0600 EST to 1100 EST and then from 2230 EST to 0600 EST Monday 12 August. The officer had 3 h sleep in the 24 h from 0600 EST 11 August to 0600 EST 12 August. She also reported experiencing a medical condition which from time to time left her feeling physically ill.

The officer was not on duty at the time of the incident.

1.18.5 Air Traffic Control (ATC)

Tower personnel on duty at the time of the incident other than the ADSO (tower), witnessed the incident. Their general observations of the incident were consistent with those of other observers.

When the DC-10 landed, the STWR was on the control tower balcony observing airport activity. As the traffic density was light, he considered that his presence in the tower was not essential at that time. He monitored the progress of the landing of both the DC-10 and the A320, assessing that it was going to be a 'dead heat' at the intersection. At that point, he returned to the control cabin taking up a position behind ADC 1, as the A320 was entering the landing flare. The STWR stated that after the A320 had passed over the intersection and the DC-10 cleared the runway, he had to relieve the ADC 1 to allow him to regain his composure.

Both ADC 1 and ADC 2 were monitoring the landing roll of the DC-10 and while initially they observed nothing unusual, they subsequently started to become concerned about the aircraft's lack of deceleration. ADC 1, observing that the DC-10 was rapidly approaching a position which raised doubts in his mind about its ability to stop before the intersection, gave the instruction 'Thai 485 stop immediately, stop immediately'. Before that instruction was transmitted, both ADCs had judged that the A320 had touched down and that it was therefore too late to instruct it to go around.

Despite observing the heavy braking of the DC-10, the tower controllers considered that a collision was inevitable as they believed that the two aircraft would not stop before the intersection. They observed the DC-10 come almost to a stop with the nose of the aircraft adjacent to the paved edge of runway with smoke coming from the wheels. ADC1 stated that he 'could not believe' that the A320 had executed a successful go-around, above and clear of the DC-10.

At the time of the incident, traffic movement rates had reduced to about 20 per hour from a peak of 50 per hour. SIMOPS were still in progress as the controllers felt there was an operator expectation regardless of traffic movement rates.

The controllers stated that they had experienced many similar situations where a heavy aircraft had successfully landed with wheels smoking from heavy braking, even though its landing speed had initially caused them to doubt its ability to stop prior to the intersection.

1.18.6 Fire control centre

The fireman on duty in the new fire control centre tower observed the DC-10 rapidly approaching the intersection, as though it had a clearance to use the full length of the runway. He heard the radio call for THA485 to stop, and then saw the A320 landing. As he considered a collision was inevitable, he activated the crash alarm. He observed the DC-10 enter the runway 25 runway strip with the tyres smoking and was surprised to see the A320 go around and clear the DC-10.

1.18.7 Other observers

Statements from passengers on the DC-10 who were aware of the developing incident were consistent with other observers' statements on the landing and stopping sequence, culminating in the go-around of the A320.

1.19 Aircraft systems information.

During the course of the investigation it became apparent that anomalies existed with regard to the attitude control inputs on the A320, and in the braking system of the DC-10.

1.19.1 Sidestick controllers—A320.

The first officer indicated that he was in no doubt that the captain was taking control of the aircraft. He relaxed his grip on the right sidestick, but did not remove his hand. He stated that he was not aware of making any subsequent intentional control inputs through his sidestick. However, the DFDR readout indicated that neutral and nose-down inputs were made for some 12 s. The inputs from the first officer's side stick did not detract from the captain being able to achieve the desired aircraft attitude.

The two sidesticks of the A320 are essentially independent insofar as the pilots are concerned, in contrast to the 'traditional' system in which the two control columns in the cockpit are mechanically interconnected. In other words, while the A320's computer systems co-ordinate the inputs from both sidesticks and base the control response on the algebraic sum of the inputs, there is no linkage between the two with regard to control feel. As a result, the inputs being made by each pilot on his sidestick cannot be sensed through his sidestick by the other. Had there been such a sense of movement between the two sidestick controllers, the co-pilot could have sensed the captain's input as he initiated the go-around, and released any pressure on his sidestick.

The A320 design makes provision for either pilot to take full control with his sidestick, e.g. in the event that one pilot should become incapacitated. To assume priority for his sidestick, i.e. to direct the computers to ignore inputs from the other sidestick, the pilot who wishes to assume priority must activate the 'instinctive autopilot disconnect button', more commonly referred to as the 'take-over button'. As soon as this button is activated, control authority is immediately transferred to that sidestick. However, the button has to be held down continuously for 30 s before control priority is permanently reallocated to that sidestick. Activation of the take-over button on a go-around was not part of Ansett Australia's standard operational procedures.

Ansett Australia's procedures for activation of the take-over button (viz. to do so when it is believed that the response from the side stick is not normal), follow the recommendations and standard operating procedures laid down in the aircraft manufacturer's manual. As the aircraft was achieving the attitude required by the captain, he saw no requirement to activate the button.

1.19.2 Auto brake system—DC-10.

The captain of the aircraft indicated that the auto brake system was set to 'MIN' (minimum) for the landing, but that a malfunction of the system occurred.

Information provided by McDonnell-Douglas and Thai Airways International indicated that, provided the MIN landing mode had been selected by the crew, the auto brake system fitted to this DC-10 should have commenced to function 4 s after the deployment of the aircraft's ground spoilers. These are activated with main gear spin-up when the flaps are in the landing range (more than 30°). The DFDR readout showed that wheel braking did not actually commence until 10.24.02 EST, some 23 s after the mainwheels had touched down. This delay is consistent with the auto brake malfunction reported by the crew. However, the auto brake system is designed so that if a malfunction does occur, the system will automatically disarm, the arm-disarm switch will move to DISARM, and indicating lights will come on. These lights consist of an amber ABS light on each side of the glareshield and an AUTO BRAKE FAIL light on the overhead annunciator panel. These three warning lights also come on if the pilot overrides the system by depressing the brake pedals beyond 40% of travel. The ABS lights should therefore have been activated in any case when maximum braking was applied following the controller's instruction to stop immediately, provided that the auto brake system had been selected prior to landing.

No record of a system malfunction was entered in the maintenance log following the incident, and no fault was found in the system when the aircraft returned to Bangkok.

2. ANALYSIS

2.1 Introduction

The analysis of this incident has been undertaken within the general principles of the Reason analytical model outlined at appendix A.

SIMOPS, described in detail in section 1.17.6 of this report, is an ATC procedure designed to maximise the aircraft movement rate at airports with intersecting or converging runways. As in all complex systems both human operators, such as pilots and air traffic controllers, and to a lesser degree, the machine elements of the system, are subject to largely random failures. In other words, people make errors and machines fail in ways which are unpredictable. Such deficiencies are normal, albeit undesirable events. As a consequence, the aviation industry has over many years developed sophisticated technologies and procedures to minimise the probability of such failures, and to reduce as far as possible their effects on system performance when they do occur. These constitute the defences within the system, also referred to as the 'safety net'.

Much of the safety effort in aviation has traditionally concentrated on active failures; only relatively recently has the critical need also to identify systemic deficiencies—in particular, latent failures—been fully appreciated.

Systems involving risk that are designed to reduce or eliminate the potential consequences of error or failure are known as 'fail safe' systems.

To achieve maximum safety, systems that involve risk should be designed as far as possible to be 'fail safe' rather than 'fail unsafe'. This is particularly the case when the consequences of system failure could be catastrophic.

However, in any complex sociotechnical system which involves risk, safety must be balanced against economic and practical realities, together with the costs and consequences of a failure of the system. Quantitative risk analysis is therefore an integral element of risk management, and is a technique in widespread use throughout the aviation industry worldwide.

Typically, these analyses use empirical data such as numbers of accidents, incidents, and aircraft movements, together with appropriate mathematical or computer modelling, and simulation techniques to provide quantitative estimates of the probability of certain categories of system failure, e.g. the loss of an aircraft or a mid- air collision.

The circumstances surrounding the present incident indicate that a full systems safety analysis should have been carried out prior to the operational introduction of the SIMOPS procedures in use at the time of the incident to identify any possible areas of excessive risk.

Such an approach is used by Transport Canada, the US FAA, and the UK CAA, all of which have groups of personnel dedicated to this task.

2.2 Analysis of the incident

2.2.1 DC-10 crew

The handling pilot was an inexperienced DC-10 co-pilot who had never before flown into Sydney. The incident flight was his first route check flight on the DC-10. The captain stated that he conducted the pre-landing brief which included the requirement to stop before the intersection. This requirement was in accordance with his understanding of the requirements of NOTAM C11/89. The crew advised that at no time did they hear any ATC SIMOPS instruction to hold short of the intersection, nor were they aware of the A320 conducting its approach to land on runway 25.

The investigation team considers it possible that the DC-10 crew failed to perceive the SIMOPS transmission because it was embedded in the landing clearance. In addition, the relevant radio transmissions occurred as the DC-10 was on its final landing approach, when the crew workload was at its peak. During this period the captain also had the task of supervising and monitoring the performance of the inexperienced handling pilot. However, the captain of the DC-10 stated that even though he did not hear the SIMOPS transmission, he was aware that the aircraft was required to hold short of the intersection, and this was his intention. It is also possible that the handling pilot (co-pilot) did not have the same perception of the requirement of SIMOPS as did the captain. Both pilots stated that they experienced difficulty in identifying the intersection.

The crew also reported that they had an auto brake system malfunction on landing, as a result of which the captain took control from the co-pilot during the landing roll. The captain did not state the nature of the fault, either to the ADC1 or to the investigation team. No fault was entered into the maintenance log, no maintenance on the auto brake system was requested or undertaken in Sydney, and the system was checked as serviceable when the aircraft returned to Bangkok.

The crew also advised that they were unaware of the taxiway and intersection MAGS. However, these signs were small and would have been very difficult to read from an aircraft during the landing roll. The crew appear, at least initially, to have mistaken the intersection of taxiway 'C' and runway 16/34 for the intersection of runways 25/34. Taxiway 'C' is approximately 180 m (600 ft) beyond the runway 25/34 intersection.

The investigation team believes that the combination of an inexperienced co-pilot flying the aircraft, the captain's distraction by circumstances on the flight deck, and a misperception of the true location of the runway 34/25 intersection led to the aircraft not being stopped before the runway 07/25 flight strip.

From the system safety perspective, the primary focus of concern is that, whatever may have been the specific factors involved, the DC-10 did not come to a stop as expected. There was a latent failure in the design of the SIMOPS procedures in use at that time, in that they did not preclude the possibility of two aircraft arriving at the runway 34/25 intersection simultaneously, should the aircraft landing on runway 34 fail to stop as required. The active failure of the DC-10 to stop as expected, in combination with the latent failure in the SIMOPS procedures, resulted in a near collision between the two aircraft at the runway 34/25 intersection.

2.2.2 ATS personnel (tower)

The relevant ATS personnel on duty at Sydney tower were all suitably qualified and licensed for the tasks they were performing. All the tower controllers were operating correctly in accordance with the information they had, and on the assumption that both aircraft involved in this incident had been correctly processed and handled by the other components of the ATS system.

2.2.3 ATC use of SIMOPS

At the time of the incident traffic conditions were light (see para. 1.1). Yet SIMOPS procedures were still in progress in a situation where the movement rate did not warrant their use.

Given that use of SIMOPS added an increment of risk (even though this risk has been deemed acceptable when balanced against the economic imperative of improving traffic flow), its use at a time when it was not needed served only to reduce the safety net unnecessarily.

2.2.4 FPS preparation

The ADSO function is to prepare the FPSs for the relevant controllers. The tower ADSO prepares the FPS for the tower controllers, while the AACC ADSO prepares the FPS for the Approach and Sector controllers. In preparing the FPS both ADSO officers use copies of the same source data i.e. the original flight plan. Part of the information transmitted from the original flight plan and displayed on the FPS is the aircraft performance category, i.e. the PANS/OPS designator. In the case of SIMOPS the PANS/OPS designator determines what and when information is passed to the aircraft. The PANS/OPS designator code is determined by a formula explained in section 1.17.1 of this report.

The flight plan received at Sydney correctly indicated the long-range DC-10 aircraft as PANS/OPS category 'D'. Other models of the DC-10 are PANS/OPS category C.

When completing the FPS, the tower ADSO correctly recorded the DC-10 as a category 'D' aircraft, but the AACC FPS PANS/OPS designator was transcribed by the AACC ADSO from code 'D' to code 'C'. This change resulted in the Arrivals Sector controllers not giving the crew of the DC-10 the SIMOPS information appropriate to its real category of operation. However, the tower controllers were operating in the belief that the crew of the DC-10 had been given the correct information.

The AACC ADSO who made the transcription error stated that she was not familiar with DC-10 aircraft used by this operator. In her experience, most DC-10 aircraft had been PANS/OPS category C. She read the DC-10 flight plan and saw that it displayed the PANS/OPS category as 'D', and transcribed it as category 'C'.

Flight plan errors are not uncommon. As noted earlier, the investigation team found that of a sample of 60 flight plans, approximately 15% contained PANS/OPS information errors or omissions. When the ADSO read the category on the flight plan, she may have assumed it was just another flight plan error and automatically transcribed it as the category with which she was familiar.

Another factor that may have influenced this action was that this ADSO had processed another DC-10 flight plan just prior to dealing with the Thai DC-10 flight plan. On the preceding flight plan, the DC-10 involved had a correct PANS/OPS category code of 'C'. It had not been the long range version of the aircraft.

Other factors which may have been affecting the AACC ADSO's performance when she incorrectly transcribed the Thai DC-10 as PANS/OPS category 'C', were the time at which she processed the flight plan and her physical condition. The FPS was prepared at approximately 0030 hours on 12 August, at which time the officer was feeling fatigued and physically ill.

The AACC ADSO's active failure in transcribing the correct flight plan PANS/OPS category 'D' to the incorrect FPS PANS/OPS category 'C' was a token of a latent failure in the ADSO training requirements which is considered by the investigation team to be a safety deficiency. Under particular combinations of circumstances, errors of this type might have serious consequences.

The task of the ADSO in preparing the FPS is solely to transcribe information from the flight plans received. ADSOs are required to check the plans for omissions, but they are not required, and nor are they trained, to interpret or validate flight plan data. However, some ADSOs have understandably developed the practice of making changes on their own initiative on the basis of their personal experience, to assist in ensuring the accuracy of the FPS information. Because they receive no training to do this, such changes could be incorrect, as in the present instance. The issue should therefore be addressed as a systemic problem. Appropriately trained and motivated ADSOs could add an effective element of quality control to the information transfer process.

However, in relation to the development of the specific incident which is the subject of this report, the evidence indicates that the active and latent failures involving the ADSO were not relevant.

This is so because, regardless of the incorrect categorising of his aircraft, the DC-10 captain stated that he knew he was required to stop before the runway intersection, that he had every intention of doing so, and that he had briefed his crew accordingly. The other flight crew members of the DC-10 verified that the captain had briefed them of the requirement to stop before the runway intersection.

2.2.5 A320 crew

As part of Ansett Australia Airlines' procedures for one pilot to take control of an aircraft from the other pilot, the pilot taking control is required to say 'Taking over' or 'I've got it'. This procedure is designed to ensure that the pilot relinquishing control of the aircraft does so in a positive and timely manner. In this incident the captain of the A320 said 'Going around' and not 'Taking over', or 'I've got it'.

While the first officer reported that he was not aware of any delay or confusion in the hand-over/take-over process resulting from the captain's use of non-standard terminology, it is possible that the sequence was imperceptibly delayed for a short period of time.

2.2.6 Aircraft performance—A320

Although the A320 successfully avoided the DC-10, under different circumstances the cross controlling between the pilots (see para. 1.18.2) could have jeopardised a safe go-around.

The DFDR readout indicated that as the A320 commenced its go-around, both crew members were manipulating their sidestick controllers. Approximately 12 s of dual control inputs were recorded. The captain was making pitch-up inputs while the FO was alternating between neutral and pitch-down inputs. However, the FO stated that he was not consciously aware of having made any control inputs following the captain's call of 'Going around'. As described earlier, the aircraft's computer systems based the control response on the algebraic sum of the two sidestick inputs, as neither had priority.

It is evident that crew co-ordination broke down somewhat as the go-around was initiated, because the company standard hand-over/take-over procedure was not employed. This may have contributed to the short period of control inputs from both pilots. This simultaneous input situation would almost certainly have been immediately apparent, and corrected rapidly had there been a sense of movement between the two sidesticks.

Whilst the engines were accelerating, the captain applied sufficient back stick to keep the aircraft in the air. He was concerned about the aircraft's performance, particularly during the time required for the engines to accelerate as he judiciously managed the aircraft energy balance, gaining altitude whilst minimising the reduction in aircraft performance. As engine power increased, the aircraft nose attitude was adjusted to ensure that the A320 tail would not strike the ground and to ensure that the two aircraft would not collide.

The characteristics of the A320 and the crew behaviour described in the preceding paragraphs highlight the need to address cockpit resource management, procedures, communication and design issues in the operation of such advanced technology aircraft. US studies, for example, have suggested that 'traditional' CRM training may not be appropriate to the demands of the new generation of highly computerised and automated 'glass cockpit' aircraft.

2.3 SIMOPS

Under SIMOPS, the crews of both the DC-10 and the A320 flew their respective approaches and were cleared to land without any positive interdependent sequencing of the aircraft. That is, the timing of the landing sequence and the separation of the aircraft were random, based on the assumption that the DC-10 would hold short of the runway strip for 07/25 as required.

It was noted that the procedures in place at the time of the incident were such that no further positive separation safeguards formally applied once the controllers had assumed that inbound aircraft had received SIMOPS information from all three available sources, these being:

(a) at 100–150 NM (containing the LDA information);

(b) on the ATIS (advising of crossing traffic); and

(c) with the landing clearance (the requirement to stop short).

On this occasion, only information from the latter two sources had been available to the DC-10 aircrew.

Although the DC-10 crew did not receive it because of the error in the PANS/OPS classification of their aircraft, the investigation team was also concerned about the content of the call normally made to PANS/OPS category D aircraft at approximately 100–150 NM from Sydney when SIMOPS were in progress, viz. 'Confirm you are able to comply with SIMOPS procedures; you will be required to hold short of the runway intersection. Landing distance available 2,550 m'. The particular way in which the request was framed could have elicited an affirmative answer, even though the aircrew might not have fully understood it. This is because the request begins with a command ('Confirm') which is biased towards a positive response that the desired state of affairs does exist. This is in contrast to an objective instruction, or request, which requires a crew to state what the situation actually is without influencing their reply.

2.3.1 Communications and phraseology

It was significant that although arriving aircraft received SIMOPS instructions on the ATIS and with their landing clearance, the crews of A, B and C category aircraft were not required to give a separate acknowledgment of the SIMOPS instructions. In each case, the SIMOPS information was embedded in other messages. As a consequence, a flight crew which was not expecting this message was less likely to hear it. In the case of the ATIS, the abbreviation 'SIMOPS' was used, a local expression which may not have been familiar to foreign crews.

The delivery of the SIMOPS hold-short instruction embedded in the landing clearance was not only poor from a human factors point of view, but may have been inconsistent with the spirit of ICAO PANS-RAC 9-2 2.7 which specifies that 'clearances or instructions, including conditional clearances, shall be read back or acknowledged in a manner to clearly indicate that they have been understood and will be complied with' (*ICAO Rules of the Air and Air Traffic Services*, Part IX 2.7).

The crew of the DC-10 reported that they could not recall hearing SIMOPS instructions in their landing clearance. It is probable that this was because the SIMOPS transmission was embedded in the other information.

The investigation noted that the ADC 1 instructed the DC-10 to 'stop before the *flight strip* of runway 25' [emphasis ours]. This was not procedurally correct, as per AIP/RAC-34, which states that 'instructions are used to restrict the landing aeroplanes from entering the intersecting *runway strip*' [emphasis ours]. The term 'flight strip' was used in Australia until replaced by the ICAO term 'runway strip'. The two expressions refer to the same physical dimensions. Because he may not have been familiar with the non-standard term 'flight strip', the pilot could have been presented with a mental picture of a different stopping reference point from the one actually intended and assumed by the controllers.

2.3.2 System design and evaluation

Although the CAA has indicated that Australian SIMOPS procedures are based on SOIR procedures used in the USA, they appear to have evolved gradually to meet demands for increased traffic flow. Moreover, they incorporate some significant differences and/or omissions when compared with SOIR (see para. 1.17.7). The picture that emerges is one of a system that evolved by 'patching on' features in response to outside pressures, rather than a system that was carefully designed and evaluated before it was put in place.

If careful system design was a feature of the introduction of the Australian SIMOPS system, then one of the features of such a system would have been a plan and procedures for monitoring a number of indicators of its efficiency, effectiveness and safety after introduction. The previous roll-throughs (and potential roll-throughs) associated with SIMOPS (see paras 1.17.9 and 1.18.5) do not appear to have resulted in any wide-ranging or structured review by the CAA of SIMOPS procedures and the risks involved. Consequently, some deficiencies appear to have existed in system design and evaluation relating to the introduction and ongoing management of SIMOPS.

2.3.3 Risk management

Mechanical failures, pilot errors of skill and/or judgement, non-compliance with ATC instructions and ATC errors each occur from time to time, with the potential to jeopardise the safety of SIMOPS. The investigation team found that the CAA had not estimated the numerical probability of collisions between aircraft on the ground or in the air under SIMOPS procedures.The CAA has, however, carried out comprehensive risk studies in relation to the need for control towers at various airports. These studies include, among other things, mathematical calculations of estimated midair collision probabilities and probabilities of aircraft collisions on the ground. An assessment is made as to the significance of these collision probabilities, i.e. whether or not they are acceptable, and the data is then used together with other parameters to make decisions regarding the need for control towers at the airports concerned.

In addition to such quantitative estimates of the actual levels of risk, effective risk management strategies require, firstly, the reduction of the probability of failures, and secondly, the minimisation of the consequences should such failures nonetheless occur.

As a result of this incident the CAA has taken a number of steps to reduce the risks of SIMOPS procedures.

2.3.4 Summary

The SIMOPS procedures in use at the time of this incident suffered from a number of fundamental weaknesses. They relied heavily on near perfect human performance, despite the history of active failures and variability of performance which human operators in the system have demonstrated, and which are normal characteristics of human performance. The evidence available indicated that FPSs were sometimes incorrect, flight crews did not always comply with hold-short instructions, and the task of sighting the runway intersection was sometimes difficult for flight crews.

A major weakness of the SIMOPS procedures then in use was that all participants may not have fully understood them. Whereas the American FAA requires confirmation of user briefings before operators are permitted to participate in SOIR, there had been no such requirement in Australia.

The SIMOPS procedures in use at the time of this incident were fail unsafe and harboured latent failures within their design. These latent failures predisposed the ATS system towards a breakdown should there have occurred a particular combination of active failures or unusual events, such as that which happened on 12 August 1991.

The most potentially dangerous latent failure in SIMOPS was that there was no formal provision in the system to prevent two landing aircraft from arriving at the intersection at the same time, should the aircraft landing on one runway fail to stop, or should both have to execute simultaneous go-arounds.

Although measures such as signs or lighting will considerably reduce the probability that an aircraft will fail to stop by the intersection as required, sooner or later it will happen, as long as that probability is greater than zero. It is important to emphasise that even though the probability of an event may be extremely small, it can occur at any time.

Consequently, because there was no positive sequencing and co-ordination of aircraft landing on the two runways, purely by chance an aircraft could have been in the intersection at the time another aircraft failed to stop or initiated a go-around.

This is a serious generic deficiency in any ATC procedure in which aircraft are landing simultaneously on intersecting runways.

Airports with converging runways (where the extended centrelines intersect), risk a potential collision if two aircraft conduct simultaneous go-arounds. Recognising this latent failure, the FAA in the USA has developed the Converging Runway Display Aid (CRDA) which is currently undergoing trials at St Louis. CRDA was designed to be used for a new procedure known as Dependant Converging Instrument Approaches (DCIA). The DCIA procedure will allow the use of two converging runways during IFR conditions by calling for the staggering of arrivals to those runways in order to provide safe separation in the event of a dual missed approach situation. Under this system, radar returns from the stream of aircraft approaching one runway are 'ghosted' onto the radar returns of the aircraft on approach to the converging runway. Thus, a controller will have a single stream of real and 'ghost' images on his screen. Because the real and 'ghost' returns are based on a common reference point, the CRDA assists the controller to sequence the stream of aircraft on both runways so that there is no possibility of conflict should both aircraft have to go around.

The FAA's CRDA project manager has advised that CRDA is expected to be of assistance at airports that conduct concurrent approaches to intersecting runways for both VFR and IFR conditions.

It is understood by BASI that application of this US system is not presently possible at Sydney airport because it is incompatible with the technology of the Sydney radar.

However, the central point to be made in relation to the present investigation is that CRDA represents an attempt to address the same kind of latent failure in SIMOPS identified in BASI's interim recommendation to the CAA shortly after the incident (see page 31). The generic problem has been clearly recognised in the USA, and the FAA has invested very considerable resources towards its solution.

BASI suggests that it may be worthwhile for the CAA to explore an interim solution to achieve the objective of the CRDA radar system by procedural means.

3. CONCLUSIONS

3.1 Findings

The investigation revealed that:

1. The relevant ATS personnel and the flight crews of the aircraft involved in the incident were suitably qualified and licensed for the tasks they were performing.

2. There was no evidence that any of the persons involved in the incident suffered any sudden illness or incapacity which may have affected their ability to undertake their respective tasks.

3. There were no meteorological conditions that might have contributed to the incident.

4. Aircraft traffic movements were light at the time, but aircraft were still being processed in accordance with SIMOPS procedures.

5. The thrust reverser for one of the engines of the DC-10 was not available. No other defects had been identified and the aircraft was serviceable. No defects had been identified on the A320 and this aircraft was also serviceable.

6. The captain of the DC-10 was familiar with SIMOPS procedures and was aware of the requirement to stop his aircraft before the runway 34/25 intersection.

7. Instructions to ATS personnel included a requirement for aircraft of the DC-10's performance category to be informed of SIMOPS procedures and the LDA before the crew contacted the tower controller. This information was normally provided by the relevant controller in the AACC.

8. When the flight plan for the DC-10 was received, the ADSO in the AACC incorrectly transcribed the flight details to indicate that the aircraft was of a different performance category. As a result, the pertinent (see para. 1.17.2) SIMOPS information and LDA, which are important to category D aircraft, were not passed to the crew.

9. The last opportunity to reinforce the requirement for the DC-10 to stop before the intersection occurred when that aircraft was cleared to land. At this time crew workload was high and the message was evidently not assimilated by the crew. As a result, at no stage did the crew positively acknowledge the hold-short requirement, nor were they required to.

10. The lack of positive acknowledgment of SIMOPS requirements was considered to indicate a deficiency in the relevant procedures.

11. The captain of the DC-10 was supervising an inexperienced co-pilot who was making his first approach to Sydney. It is likely that he was devoting considerable attention to this monitoring task.

12. Neither of the flight crews involved had received specific traffic information on the other aircraft. However, the captain of the A320 was maintaining visual surveillance of the progress of the DC-10.

13. After touchdown, the DC-10 did not decelerate as expected by the tower controllers. This lack of retardation was probably the result of either the crew forgetting about the

hold-short requirement, or a misperception of the location of the intersection, and the auto brake system having suffered a transient fault.

14. When the unsatisfactory deceleration profile was recognised by the tower controller, it was considered to be too late to instruct the A320 to go around. An instruction to stop immediately was therefore passed to the DC-10.

15. Under heavy braking the DC-10 came almost to a stop with the nose of the aircraft approximately 40 m from the runway 07/25 centreline.

16. The captain of the A320 had not been convinced that the DC-10 would stop before the intersection, and initiated a go-around from a low height above the runway.

17. The height of the A320 as it crossed the intersection was not optimum, as the aircraft had achieved the climb-out attitude required by the captain and he did not believe that it was necessary to fully utilise the capabilities of the aircraft. Deficiencies were identified in crew and company procedures relating to go-around manoeuvres.

18. The design of the A320 control system provided no tactile feedback to one pilot to alert him to the control inputs of the other. However, in this instance the inputs from the first officer's sidestick did not detract from the captain's ability to achieve the desired climb attitude.

19. The captain of the A320 exercised the final failsafe mechanism when he executed the go-around manoeuvre in a most difficult situation.

3.2 Significant factors

1. There was a deficiency in SIMOPS procedures in that aircraft being processed for landing on runway 34 were not specifically required to acknowledge or read back the requirement to stop before the runway intersection.

2. The captain of the DC-10 did not devote sufficient attention to the landing roll, probably because of the additional workload required in his supervision of an inexperienced co-pilot.

3. The temporary Movement Area Guidance Signs (MAGS) which were installed to provide pilots landing on runway 34 with additional visual information as to the proximity of the intersection with runway 07/25 were inadequate.

4. After touchdown, the deceleration profile of the DC-10 was insufficient to allow compliance with the stop-short requirement.

5. The DC-10 crew had not been informed of the A320 landing simultaneously on runway 25.

6. The SIMOPS procedures in use at the time did not allow for the situation where an aircraft landing on runway 34 did not, or could not, stop before the runway 25 intersection.

4. RECOMMENDATIONS

4.1 Interim recommendation

On completion of the preliminary investigation BASI made an interim recommendation (on 16 August) that the CAA:

'... immediately review the SIMOPS system, at all airports where the procedure is in use, and make appropriate changes to ensure that, in the event of a human or aircraft system failure, the probability of two aircraft arriving at or near the runway intersection at the same time be insignificant.'

4.1.1 CAA responses to interim recommendation

Three days after the incident, the CAA advised BASI that a NOTAM had been issued which addressed the interim recommendation. The CAA considered that appropriate remedial steps had been taken to modify the SIMOPS procedures in that the NOTAM detailed specific requirements to:

(a) require pilots of landing aircraft to confirm their ability to hold short of a crossing runway and monitor traffic on crossing runways;
(b) obtain read-back of the hold-short instruction; and
(c) provide pilots using the other runway with notification of the aircraft which had been instructed to hold short.

In addition, the CAA issued local instructions to ATS personnel at Sydney which excluded international aircraft from participation in any form of SIMOPS until individual international operators:

(a) signed letters of agreement stating that full SIMOPS documentation was held; and
(b) full briefings on SIMOPS procedures had been given to aircrews.

To enable Sydney ATS personnel to identify which international aircraft were permitted to conduct SIMOPS, the CAA also introduced a procedure where personnel responsible for the preparation of flight data were required to annotate the registration markings of all inbound international aircraft on flight strips for:

(a) the last en-route sector
(b) the Arrivals Sector and
(c) the sequence strip.

4.2 Related safety action

At the time of discovering the problem with the errors in FPS preparation, the investigation team advised the CAA at Sydney who took immediate action to address the situation.

Since the commencement of this investigation a US consulting firm, Ratner and Associates, has completed a comprehensive review of the Australian ATS system. The review was jointly funded by BASI and the CAA. Recommendations from that review, which impinge on some of the systemic safety issues identified during this investigation, are discussed at appendix B.

4.3 Final recommendations

The Bureau of Air Safety Investigation recommends that the CAA:

1. Ensure that, prior to the implementation of any significant change in operational procedures or regulations, a comprehensive systems safety analysis is carried out. The purpose of such analyses is to identify and rectify any latent factors associated with the proposed changes which could adversely affect the safety of operations.

2. Carry out further development of the current SIMOPS procedures with a view to ensuring that pilots landing on intersecting runways can:

   (i) pass through the intersection without risk of collision should their aircraft fail to stop before the intersection as required; and

   (ii) safely exercise their prerogative to conduct an overshoot or missed approach from any point prior to crossing the intersection.

APPENDIX A:

The Reason analytical model

The Bureau's primary objectives in investigating an occurrence are to establish what, how and why the occurrence took place, and to determine what the occurrence reveals about the safety of the aviation system. That information is used to make recommendations aimed at reducing or eliminating the probability of a repetition of the same type of occurrence, and, where appropriate, to increase the safety of the overall system.

To produce effective recommendations, the information collected and the conclusions reached must be analysed in a way that reveals the relationships between the individuals involved in the occurrence, and the design of the systems within which those individuals operate.

For the purposes of broad analysis, the Bureau uses an analytical model developed by Professor James Reason of the University of Manchester. The principles of the Reason model are outlined in detail in his book *Human Error* (1990).

Reason explains the basic elements of his model as follows:

> Like many other high-hazard, low-risk systems, modern aircraft have acquired such a high degree of technical and procedural protection that they are largely proof against single failures, either human or mechanical. They are much more likely to fall prey to an 'organisational' accident. That is, a situation in which latent failures, arising mainly in the managerial and organisational spheres, combine adversely with local triggering events (weather, location etc.) and with the active failures of individuals at the sharp end (errors and procedural violations).
>
> — Paper presented to the International Society of Air Safety Investigators 22nd Annual Seminar (1991).

Reason describes two kinds of failures in complex systems—'active' and 'latent':

> Active failures [are defined as] those errors or violations having an immediate adverse effect. These are generally associated with the activities of 'front line' operators: control room personnel, ships' crews, train drivers, signalmen, pilots, air traffic controllers, etc.
>
> Latent failures: these are decisions or actions, the damaging consequences of which may lie dormant for a long time, only becoming evident when they combine with local triggering factors (that is, active failures, technical faults, atypical system conditions, etc.) to breach the system's defences. Their defining feature is that they were present within the system well before the onset of a recognisable accident sequence. They are most likely to be spawned by those whose activities are removed in both time and space from the direct human-machine interface: designers, high-level decision makers, regulators, managers and maintenance staff.
>
> — *BASI Journal* 9 (1991) p. 4

APPENDIX B

The Ratner review of ATS

SIMOPS

Ratner found that, in practice 'controllers experienced in SIMOPS procedures do in fact attempt to ensure sufficient stagger between aircraft on interceding flight paths so that, if an aircraft does not hold short as cleared, the two aircraft will not enter the intersection simultaneously'.

In his final report Ratner made a specific recommendation regarding the use of SIMOPS procedures, viz:

> (S-45) Limit use of SIMOPS procedures to times and locations where accumulating delays are predicted without use of SIMOPS. Require signing and lighting as currently specified with any necessary waivers limited to a maximum of 90 days. Require controllers to complete appropriate training on SIMOPS procedures before conducting them and to maintain currency acording to an appropriate standard. Continue to evaluate additional backup aids.

BASI, the CAA and the Civil Air Operations Officers Association of Australia agreed with this recommendation, and the CAA has undertaken to implement it.

Risk analysis

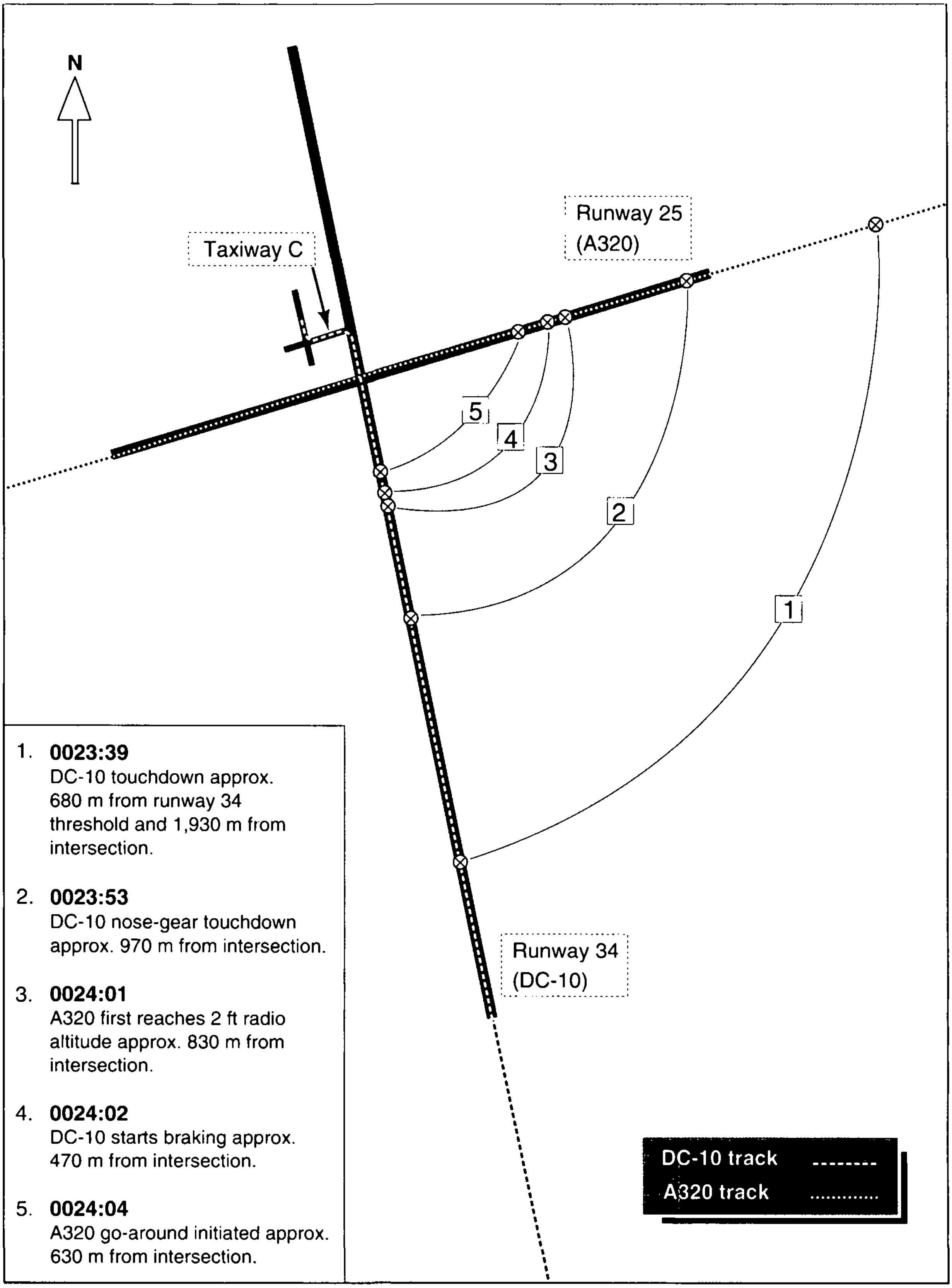
The Ratner review also suggested that increased use of quantitative risk analysis techniques could provide benefits to the CAA. The reasons were that:

- The analysis process itself ensures that the critical dimensions of the issue are identified, and that subsequent discussion is based on a common and comprehensive frame of reference. In particular, the benefits of the operation are fully identified and assessed against the associated risks.
- The quantitative analysis of data, particularly data based on experience (for example, incident rates from US experience with SOIR), removes debate based purely upon strongly held opinions.

The Ratner recommendations, together with the relevant findings of this investigation, suggest that it would be beneficial for the CAA to carry out a quantitative risk analysis of the present SIMOPS procedures. Such an analysis would be similar in nature to those carried out by the Authority regarding the need for control towers (section 2.3.2).

Source: Ratner Associates Inc., *Report of the 1992 Review of the Australian Air Traffic Services System Prepared for Bureau of Air Safety Investigation, Department of Transport and Communications, Commonwealth of Australia and Civil Aviation Authority of Australia* (April 1992).

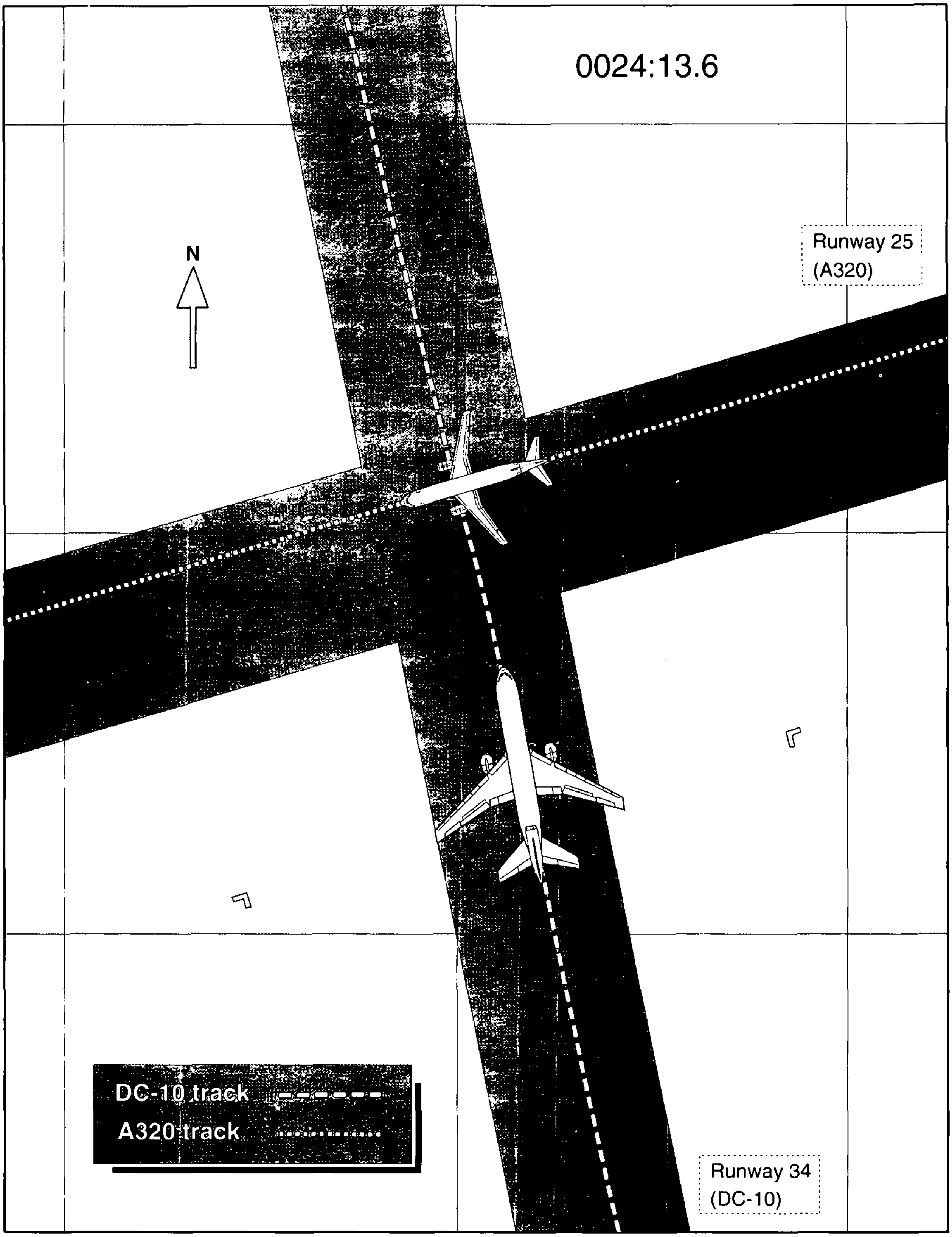
APPENDIX C



Relative positions of A320 and DC-10 at five instances during sequence.

Positions estimated from aircrafts' flight data recorders

Grid size 100 m and aligned to true north.



A320 passing through intersection at radio altitude of 52 ft.

Positions estimated from flight data recorder information.

Gable markers indicate runway 07/25 flight strip and are 75 m from runway 07/25 centreline.

Aircraft drawn to scale.

Grid size 100 m and aligned to true north.

BASI Publications

At the time of publication of this report the Bureau of Air Safety Investigation had a number of other safety-related publications available including:

Aircraft accident reports:

- ★ Beech King Air E 90 VH-LFH Wondai Qld 26 July 1990
- ★ Gulfstream Aerospace AC 681 VH-NYG Tamworth NSW 14 February 1991

Research reports:

- ★ Wire Strikes – a Technical Analysis
- ★ Limitations of the See-and-Avoid Principle

Other reports:

- ★ MU-2 Accident Investigation and Research Report incorporating MU-2 accidents VH-BBA near Leonora WA 16 December 1988 and VH-MUA at Meekatharra WA 26 January 1990
- ★ Survey of Accidents to Australian Civil Aircraft 1988
- ★ Survey of Accidents to Australian Civil Aircraft 1989
- ★ Survey of Accidents to Australian Civil Aircraft 1990
- ★ Near collision on Runway 34 Sydney (Kingsford Smith) Airport 11 September 1990

Periodicals

- ★ BASI Journal Nos. 8–12
- ★ Asia-Pacific AIR SAFETY Issues 1–3

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