Report 07-005	**Raytheon 1900D, ZK-EAN and Saab-Scania SF340A, ZK-FXA, critical runway incursion, Auckland International Airport**	**29 May 2007**
INCORPORATING		
Report 07-009	**Raytheon 1900D, ZK-EAH and Raytheon 1900D, ZK-EAG, critical runway incursion, Auckland International Airport**	**1 August 2007**

The Transport Accident Investigation Commission is an independent Crown entity established to determine the circumstances and causes of accidents and incidents with a view to avoiding similar occurrences in the future. Accordingly it is inappropriate that reports should be used to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

The Commission may make recommendations to improve transport safety. The cost of implementing any recommendation must always be balanced against its benefits. Such analysis is a matter for the regulator and the industry.

Report 07-005

incorporating

occurrence 07-005

Raytheon 1900D, ZK-EAN and Saab-Scania SF340A, ZK-FXA

critical runway incursion

Auckland International Airport, 29 May 2007

and

occurrence 07-009

Raytheon 1900D, ZK-EAH and Raytheon 1900D, ZK-EAG

critical runway incursion

Auckland International Airport, 1 August 2007

A Raytheon (Beech) 1900D aircraft
Photograph courtesy of Eagle Airways Limited

A Saab-Scania SF340A aircraft
Photograph courtesy of Air Nelson Limited

Abstract

On 29 May 2007, a Saab SF340A aircraft that was holding on an angled taxiway at Auckland International Airport was inadvertently cleared to line up in front of a landing Raytheon 1900D. The aerodrome controller transmitted an amended clearance, but the transmission crossed with that of the Saab crew reading back the line-up clearance. The pilots of both aircraft took action to avoid a collision and stopped on the runway without any damage or injury.

Contributory factors were the local procedure for the handling of flight progress strips for departing traffic; the use of multiple taxiways, including angled taxiways, for runway entry; and the captain of the aircraft entering the runway not seeing the landing traffic.

On 1 August 2007, the crew of a Raytheon 1900D aircraft holding on an angled taxiway at Auckland International Airport mistakenly accepted the take-off clearance for another Raytheon 1900D aircraft that was waiting on the runway and which had a somewhat similar call sign. The pilots of both aircraft read back the clearance. The aerodrome controller heard, but did not react to, the crossed transmissions. The holding aircraft entered the runway in front of the cleared aircraft, which had commenced its take-off. The pilots of both aircraft took avoiding action and stopped on the runway without any damage or injury.

Contributory factors were the non-adherence to standard procedures for radiotelephony (RTF) use and the issue of an air traffic clearance, the use of an angled taxiway for runway entry, and the captain of the aircraft entering the runway not seeing the aircraft already lined up on the runway.

The Civil Aviation Authority of New Zealand (CAA) had not previously assessed the nature and scale of the runway incursion problem in New Zealand and had not defined "runway incursion", and aerodrome and airspace incidents that were probably runway incursions had not been recorded or investigated in a consistent manner.

The restricted vision from the cockpit of some aircraft types when holding on an angled taxiway drew attention to the procedures for the issue and acceptance of conditional clearances for runway entry.

Safety recommendations were made to the Director of Civil Aviation regarding:

- conditions for the use of multiple and angled taxiways for runway entry
- the recording and investigation of runway incursion incidents
- the handling of air traffic control (ATC) flight progress strips
- the promulgation of safety-related information to air traffic controllers
- the issue and acceptance of ATC conditional clearances
- compliance with published RTF techniques
- situational awareness in the runway environment, and
- the use of technology to complement procedural defences against runway incursions.

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Abbreviations

ADS-B	Automatic Dependent Surveillance – Broadcast
AIAL	Auckland International Airport Limited
Airways	Airways New Zealand
ATC	air traffic control
CAA	Civil Aviation Authority of New Zealand
CAR	Civil Aviation Rules
ft	feet
ICAO	International Civil Aviation Organisation
m	metre(s)
MATS	(Airways) Manual of Air Traffic Services
RTF	radiotelephony
TCAS	traffic alert and collision avoidance system
UTC	coordinated universal time

Glossary

apron	a defined area on an aerodrome intended to accommodate aircraft for purposes of loading or unloading passengers or cargo, refuelling, parking or maintenance
conditional clearance	an ATC clearance that was dependent on the recipient complying with the accompanying condition(s)
electronic flight bag	an electronic display system that gave pilots information about a variety of aviation data. Systems varied from laptop-like devices independent of the aircraft to displays fully integrated into the aircraft cockpit
flight progress strip	a printed card that showed essential information relating to a flight
movement	one landing or one take-off
threshold	the beginning of that portion of the runway usable for landing

Data Summary

29 May 2007 incident	Landing aircraft	Departing aircraft
Aircraft registration and call sign:	ZK-EAN, Eagle 766	ZK-FXA, Link 659
Type:	Raytheon 1900D	Saab-Scania SF340A
Operator:	Eagle Airways Limited	Air Nelson Limited
Type of flight:	scheduled air transport	scheduled air transport
Persons on board:	2 crew, 19 passengers	3 crew, 19 passengers
Pilots' flying experience:	captain – 3339 hours total, 1627 hours on type first officer – 1764 hours total, 850 hours on type	captain – 4960 hours total, 2401 hours on type first officer – 2143 hours total, 805 hours on type
Date and time:	29 May 2007, 1333[1]	
Location:	Auckland International Airport, runway 23L	
Controller's experience:	17 years	

1 August 2007	Aircraft on runway	Aircraft on taxiway
Aircraft registration and call sign:	ZK-EAG Eagle 979	ZK-EAH Eagle 171
Type:	Raytheon 1900D	Raytheon 1900D
Operator:	Eagle Airways Limited	Eagle Airways Limited
Type of flight:	scheduled air transport	scheduled air transport
Persons on board:	2 crew, 13 passengers	2 crew, 19 passengers
Pilots' flying experience:	captain – 4980 hours total, 2434 hours on type first officer – 2267 hours total, 294 hours on type	captain – 12 442 hours total, 2740 hours on type first officer – 1516 hours total, 278 hours on type
Date and time:	1 August 2007, 0758	
Location:	Auckland International Airport, runway 23L	
Controller's experience:	26 years	

Investigator-in-charge: Mr P R Williams

[1] All times in this report are in New Zealand Standard Time (UTC + 12 hours) and expressed in the 24-hour mode.

Factual Information

1.1 29 May 2007 incident

1.1.1 On the afternoon of 29 May 2007, runway 23 left (23L)[2] was in use at Auckland International Airport (see Figure 1). The 4 ATC staff in the tower, employees of Airways New Zealand (Airways), included an aerodrome controller responsible for aircraft on the runway and in the air within the control zone, and a ground controller responsible for aircraft movements on the rest of the manoeuvring area.[3]

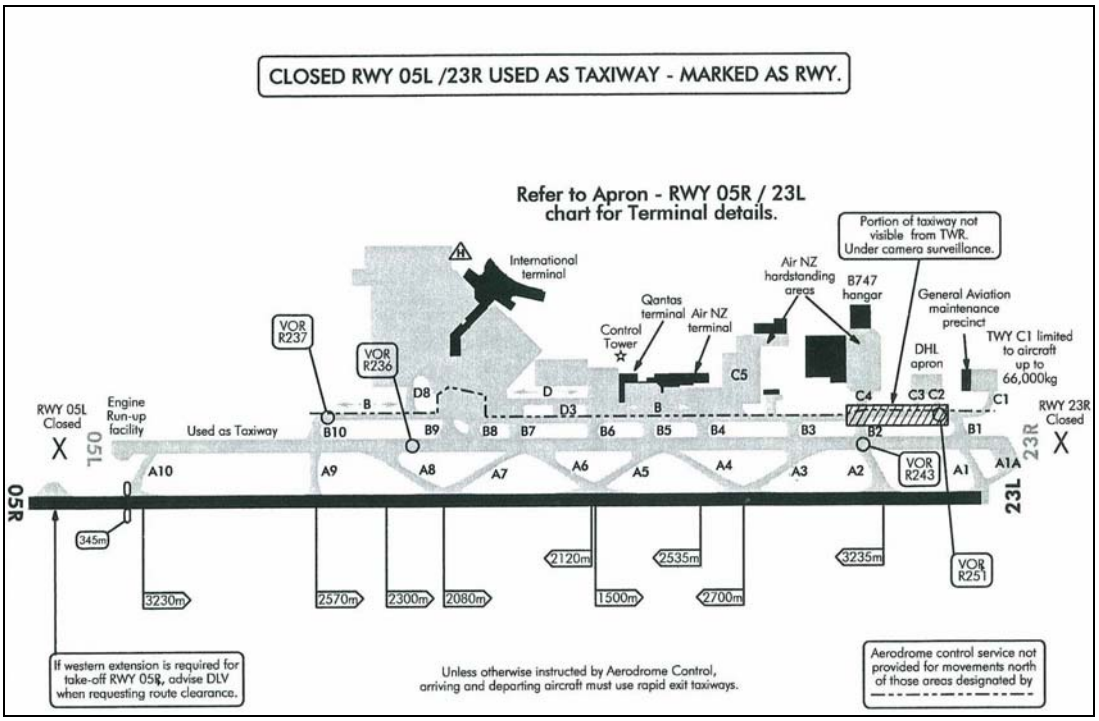

Figure 1
Auckland International Airport plan
(Diagram adapted from Aeronautical Information Publication of New Zealand, courtesy of CAA.)

1.1.2 At 1329:52, an Air Nelson Saab-Scania SF340A (Saab) aircraft, call sign Link 659, was cleared by the ground controller to taxi from the apron via taxiway B5 to the runway holding point on taxiway A5 (said "alpha 5"). On the Saab were 19 passengers and a crew of 2 pilots and a flight attendant.

1.1.3 The Saab captain said that when they taxied across parallel runway 23R, he saw 2 aircraft on approach to runway 23L, but they seemed to be some distance away. He identified one as a Raytheon 1900D (Beech).[4] The Saab pilots had completed their pre-take-off checks and had changed to the aerodrome controller's radio frequency (Tower) as they approached the holding point. The pilots of the Saab were not under any schedule-keeping pressure.

1.1.4 At 1331:56, after a landing Air Nelson Bombardier Q300 (Dash) had passed taxiway A5, the aerodrome controller cleared a Beech holding ahead of the Saab for "immediate take-off". For

[2] The numeral was the runway direction, in this case 231° magnetic, abbreviated to tens of degrees. Parallel runways were distinguished as left and right when viewed in the direction of landing and take-off.
[3] Airways was, at the time, the only certificated provider of air traffic services in New Zealand.
[4] In March 2007, Hawker acquired Beechcraft from the Raytheon Aircraft Company. The Eagle Airways aircraft were registered under the type name Raytheon, but are still commonly known as Beech. The model 1900D was no longer in production.

separation purposes, the Beech crew were instructed to remain on Tower frequency. The Saab captain recalled hearing that clearance before the Saab crew called Tower, saying, "Link 659 is ready in turn alpha 5." The aerodrome controller acknowledged this by repeating the Saab's call sign.

1.1.5 At that time, including the Beech cleared for take-off, there were 7 aircraft on Tower frequency: 4 were arriving, led by a Beech, call sign Eagle 766; the Saab was holding on taxiway A5; and there was a Metro holding on taxiway A1.

1.1.6 Another Air Nelson Dash, call sign Link 383, was taxiing towards the holding point on taxiway A3. The ground controller had instructed its pilots to call Tower when ready but they had not yet changed frequency (see Figure 2).

1.1.7 The instruction to call Tower meant that control of the aircraft had passed from the ground controller to the aerodrome controller. Airways procedures required the ground controller to pass the flight progress strip[5] for the Dash to the aerodrome controller at the same time.

1.1.8 At 1332:44, the aerodrome controller transmitted to the Beech on final approach "Eagle 766, [Beech] 1900 departing, runway 23L, cleared to land". Neither of the Saab pilots recalled hearing an aircraft being cleared to land.

1.1.9 The aerodrome controller discussed with the ground controller whether to depart an aircraft in the gap between Eagle 766 and the next arrival. The ground controller suggested Link 659 and pointed towards the Saab. However, the aerodrome controller was looking towards the approach area and touchdown zone, beyond taxiway A3. Taxiway A5 was about 70° right of where the aerodrome controller was looking.

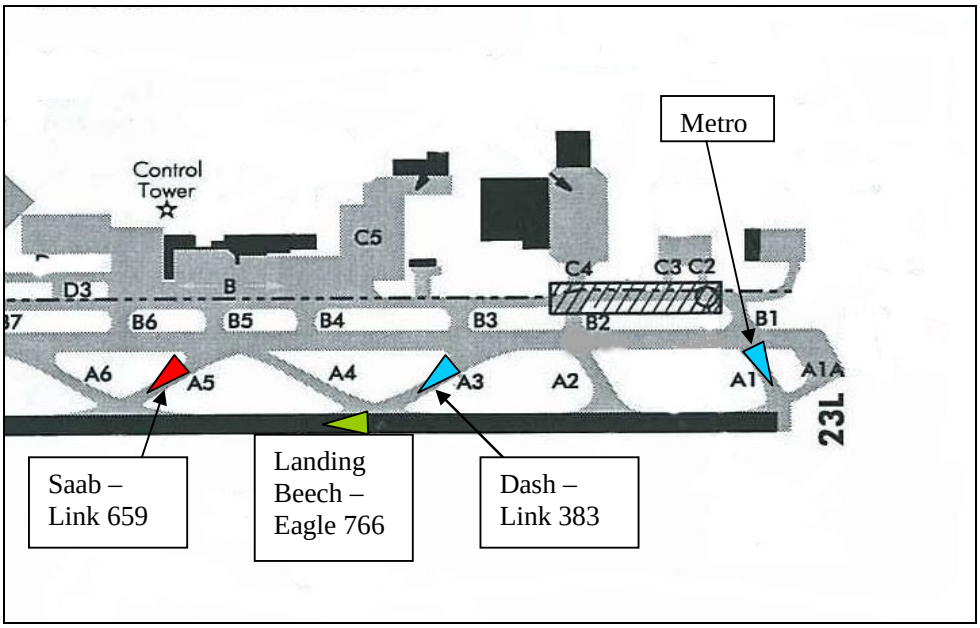

Figure 2
Relevant traffic at 1333 on 29 May 2007

1.1.10 The aerodrome controller decided to depart the Dash in the gap and at 1333:11, after Eagle 766 had passed taxiway A3, transmitted: "659, if you can take an immediate, line up runway 23L". The ground controller saw that the aerodrome controller was looking towards the Dash when the clearance was given and immediately reminded the aerodrome controller that Link 659 was

[5] A flight progress strip was a printed card that showed essential information relating to a flight. See paragraph 1.9.4.

the Saab at taxiway A5. As the Saab began to move, the aerodrome controller transmitted an amended clearance for it to line up behind the landing Beech, but the transmission crossed with the Saab first officer's read-back of the prior clearance.

1.1.11 The Saab captain said that he thought the aerodrome controller sounded busy and the tone of the line-up instruction meant "don't muck around". As the first officer read back the clearance, the captain looked left and saw no aircraft on the runway, but he noted that it was "difficult to see [down the] runway due to [the] angle of A5 to the runway". The captain said that if you could not actually see the traffic, you had "to rely on controllers getting it right". The captain called for the line-up checks, which included selecting the traffic alert and collision avoidance system (TCAS)[6] to On.

1.1.12 The aerodrome controller tried again to clarify the line-up instruction to the Saab with "sorry, that's behind the [Beech] 1900", but the transmission crossed with "Tower 383 is ready A3". The Saab captain, after hearing "nineteen hundred" at the end of the crossed transmission, looked left again and saw the landing Beech bearing down as it turned off the runway towards taxiway A6. Both aircraft were braked hard and came to a stop, each captain estimated, about 10-15 metres (m) apart.

1.1.13 A review of closed-circuit television tapes provided by the airport operator showed that about 30 seconds elapsed from when the Beech, Eagle 766, touched down until it stopped on the painted runway edge marking near taxiway A5. About 16 seconds before the Beech came to a stop, the Saab, Link 659, had begun to move from the holding point on taxiway A5 and had stopped before it had crossed the runway edge. The 2 aircraft were estimated, from the camera tapes, to have stopped 25-30 m apart.

1.1.14 There were no injuries and no damage.

1.2 Personnel information (29 May 2007)

Note: None of the air traffic controllers and pilots referred to in the 29 May 2007 incident was involved in the 1 August 2007 incident.

Air traffic controllers

1.2.1 The aerodrome controller was qualified for all positions in the Auckland Tower and was an ATC examiner. Her last proficiency check had been completed satisfactorily on 18 October 2006.

1.2.2 The incident occurred on the second day of the aerodrome controller's roster pattern, following 3 days off. She began duty on 29 May 2007 at 1145 and was due to take a break at 1345. Her prior duty had ended at 2100 the night before. She said that she was fit and had no distracting work or personal issues at the time.

1.2.3 Between 1325 and 1335, the aerodrome controller managed 11 aircraft. The recording of transmissions made on Tower frequency was reviewed and the aerodrome controller was heard giving clear instructions and information until the incident occurred.

1.2.4 The ground controller was qualified in all positions in the Auckland Tower. Her last proficiency check had been completed satisfactorily on 1 November 2006.

1.2.5 The incident was on the second day of the roster pattern for the ground controller, following 2 days off. On 29 May 2007, she began duty at 0815 and had returned from a break 20 minutes prior to the incident. Her prior duty had ended at 2015 the night before.

[6] TCAS gave commands to a pilot to avoid an aircraft that was calculated to be a collision risk, but the system was not designed to provide any safety benefit for an aircraft on the ground. The collision avoidance function was inactive until airborne, and the traffic display was not designed to depict aircraft on the ground.

1.2.6 Around the time of the incident, an electrician was working on the lighting control panel situated between the aerodrome controller and ground controller positions. The ground controller had to stand away from her normal position and almost behind the aerodrome controller.

Pilots of Saab, Link 659

1.2.7 The Saab captain was issued with an airline transport pilot licence in November 2005. He had been employed by Air Nelson since January 2004, obtained a Saab type rating on 13 February 2004 and was promoted to captain in May 2006.

1.2.8 The captain's medical certificate was endorsed "spectacles (distance vision) must be worn". He stated that he was wearing the prescribed spectacles at the time of the incident.

1.2.9 The first officer was issued with a commercial pilot licence in October 2001 and had been employed by Air Nelson since March 2006. He obtained a Saab type rating on 18 April 2006.

1.2.10 The 2 pilots had flown together previously. The incident occurred during the first sector of the duty. They both said that they felt fit for flying, and were rested and in good health prior to the flight. Their total and recent experience as at 29 May 2007 was as follows:

Pilot	Captain	First Officer
Licence	airline transport pilot licence (aeroplane)	commercial pilot licence (aeroplane)
Medical certificate	class 1, issued 8 February 2007	class 1, issued 21 May 2007
Last competency check	20 February 2007	14 March 2007
Last route check	20 February 2007	14 March 2007
Flying experience	4960 hours total, 2401 hours on type	2143 hours total, 805 hours on type
Duty time	1 hour	1 hour
Time since last duty	45 hours	4 days

1.3 Saab aircraft information (29 May 2007)

1.3.1 The Saab aircraft operations manual showed that the external vision angle for a pilot was 122^{o} in azimuth when looking out the same side of the aircraft (see Figure 3). During the investigation, it was found that nearly 140^{o} could be seen if a pilot leaned forward and turned in the seat. Both Saab pilots said that when holding on angled taxiways such as A3 at Auckland they could not see the active runway threshold.

1.3.2 Pilots usually did the line-up checks as the aircraft was taxied onto the runway.

1.3.3 The operator retired its Saab fleet on 24 September 2007.

1.4 Meteorological information (29 May 2007)

1.4.1 The incident occurred during daylight on a dry runway with the weather reported to be suitable for visual approaches.

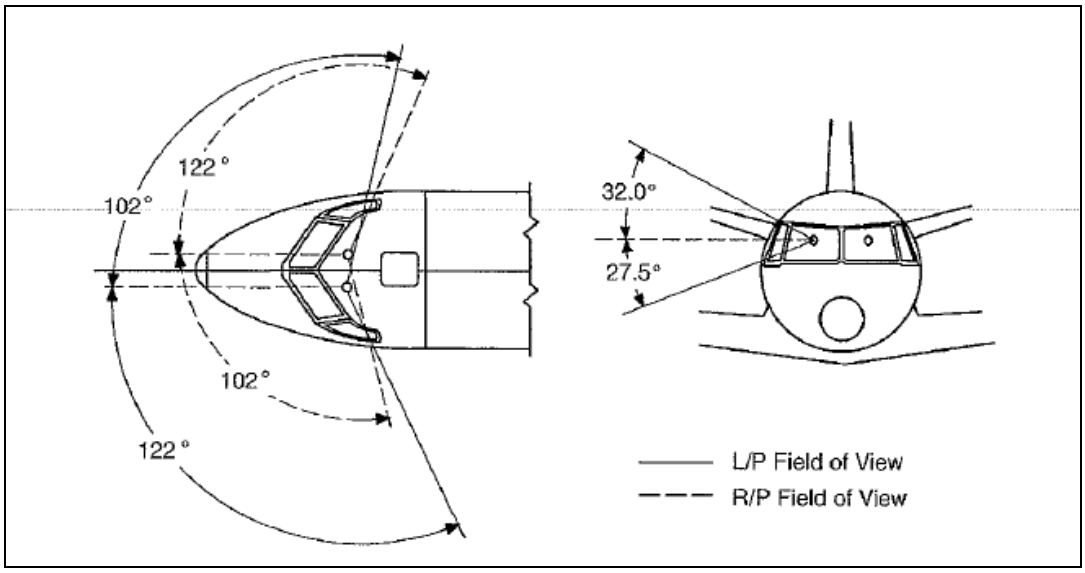

Figure 3
External vision angles from Saab pilots' seats
(Source: Saab SF340A aircraft operations manual.)

1.5 1 August 2007 incident

1.5.1 At 0756 on 1 August 2007, the aerodrome controller cleared a Beech, call sign Eagle 979, to line up on runway 23L from taxiway A2. At the time, the aerodrome controller was also managing 2 other aircraft: a light aircraft that had departed a few minutes earlier on a visual flight rules plan and an arriving flight that had not yet joined final approach.

1.5.2 The aerodrome controller then asked the light aircraft pilot to report the cloud base and visibility in the vicinity of the airport. The controller was concerned that fog was approaching the airport and he was considering whether to implement newly introduced low visibility procedures.

1.5.3 At about 0757, another departing Beech, registered ZK-EAH and with call sign Eagle 171, entered taxiway A3 and the crew were instructed to change to Tower. The pilots of Eagle 171 were not under any schedule-keeping pressure. The flight progress strips for the 2 Eagle flights were annotated with the cleared holding positions (see Figure 4).

1.5.4 Eagle 171 waited at the holding point for more than 30 seconds before the aerodrome controller finished discussing the weather with the light aircraft pilot. The first officer then transmitted "Eagle 171 ready [for take-off]".

1.5.5 The recorded transmissions on Tower frequency were reviewed. The operator prefix "Eagle" was partly clipped from the pilot's ready call, and the flight number – even knowing that another aircraft had a slightly similar call sign – was not unmistakably "one seven one".

1.5.6 The aerodrome controller heard a flight call ready, but he did not identify the call sign. He said the non-identification was not an issue, as flights had to wait until positively cleared. He said that sometimes a controller might choose not to respond to a call if there was a more urgent transmission to be made, although that had not been the case here. He intended to next clear the Beech waiting on the runway and so, at 0758, he transmitted "Eagle 979, 23L, cleared take off".

1.5.7 The first officers of both Eagle 979 and Eagle 171 read back the take-off clearance at the same time. The format for a clearance read-back ends with the aircraft call sign, and both "seven one" and "seven nine", in that order, could be heard on the Tower recording. The first officer of Eagle 979 said that he heard "seven one" after he had finished his read-back, which he thought was strange, but he did not suspect crossed transmissions.

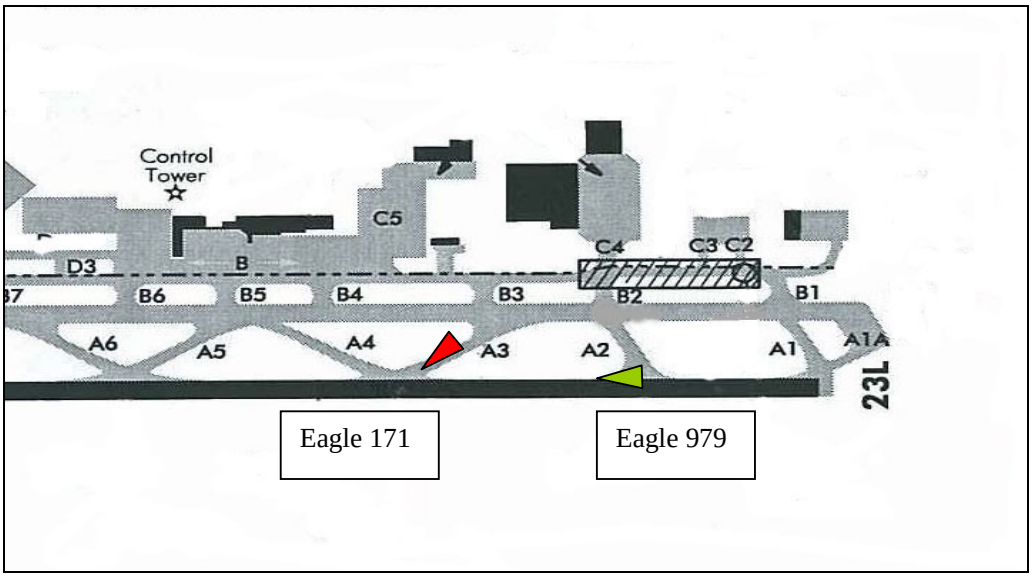

Figure 4
Relevant traffic at 0758 on 1 August 2007

1.5.8 The aerodrome controller said that he heard the crossed transmissions, but he did not associate them with either Eagle flight. He had looked away from the runway to assess the weather, and then instructed the light aircraft to change frequency. He did not see Eagle 979 start its take-off or Eagle 171 move towards the runway. The aerodrome controller's attention was brought back to the runway when he heard someone transmit "Eagle alpha hotel, hold!"

1.5.9 The pilots of Eagle 171 had seen Eagle 979 taxi ahead of them from the terminal apron, but when the captain looked left before crossing the taxiway A3 holding point he saw only one aircraft, some miles away and on a wide base leg for the runway. On a closed-circuit television recording supplied by the airport company, the flashing strobe lights on Eagle 979 could be seen operating while the aircraft was waiting on the runway.

1.5.10 About 10 seconds after Eagle 979 began its take-off roll, Eagle 171 entered the runway. The first officer of Eagle 979 was unsure of the call sign of the infringing Beech, but could read its registration mark so transmitted "Eagle alpha hotel, hold!" followed by "Hold! Hold! Hold!"

1.5.11 The captain of Eagle 979 had already initiated a rejected take-off from a speed of about 60 knots. He swerved left almost to the runway edge, while the captain of Eagle 171 veered his aircraft to the right. Each aircraft was stopped on its respective half of the runway.

1.5.12 Airport company closed-circuit television records were used to estimate that the distance between the aircraft wing tips, looking in the runway direction, was approximately 8 m.

1.5.13 There were no injuries and no damage.

1.6 Personnel information (1 August 2007)

Note: None of the air traffic controllers and pilots referred to in the 1 August 2007 incident was involved in the 29 May 2007 incident.

Air traffic controller

1.6.1 The aerodrome controller, an employee of Airways, was qualified for all positions in the Auckland Tower. His last proficiency check had been completed satisfactorily on 13 October 2006.

1.6.2 The incident occurred on the fourth day of the aerodrome controller's roster pattern. He began the duty on 1 August 2007 at 0630 and took a break after the incident. His prior duty had ended at 0600 the previous day. He said that he was fit and had no distracting work or personal issues at the time.

1.6.3 The aerodrome controller said that he did not make strict use of phonetic pronunciation of numerals.[7] He said he listened 3 times to a replay of the recorded transmissions the same day before he was sure that he had cleared "979" and not "171" to take off.

Pilots of Eagle 171

1.6.4 The captain of Eagle 171 was issued with an airline transport pilot licence in October 1993. He had been employed by Eagle Airways since September 1997, was appointed a captain in December 2000 and had obtained a Beech type rating on 21 September 2001. His medical certificate required him to carry half-spectacles for close reading only.

1.6.5 The first officer obtained his commercial pilot licence in April 2003 and had been employed by Eagle Airways since February 2007. He obtained a Beech type rating on 4 March 2007.

1.6.6 The 2 pilots of Eagle 171 had flown together previously. The incident occurred during the second sector of their duty, which began at 0605. They both said that they felt fit for flying, and were rested and in good health prior to the flight. Their total and recent experience, as at 1 August 2007, was as follows:

Pilot	Captain	First Officer
Licence	airline transport pilot licence (aeroplane)	commercial plot licence (aeroplane)
Medical certificate	class 1, issued 14 September 2006	class 1, issued 25 July 2007
Last competency check	12 September 2006	23 May 2007
Last route check	12 January 2007	23 May 2007
Flying experience	12 442 hours total, 2740 hours on type	1516 hours total, 278 hours on type
Duty time	2 hours	2 hours
Time since last duty	10 hours	10 hours

1.7 Beech aircraft information (1 August 2007)

1.7.1 The published external vision angle from the Beech cockpit was 137^{o} in the horizontal plane. Both Beech pilots said they could see the approach area and runway touchdown zone when holding on angled taxiways.

[7] Phonetic pronunciation is further described in section 1.10.

1.8 Meteorological information (1 August 2007)

1.8.1 The weather reported on the automatic terminal information service was as follows:[8]

Version, time	Wind	Visibility	Weather	Cloud
F, 0747	340/06	30 kilometres	haze	few 2000 feet (ft), scattered 3000 ft
G, 0802	320/06	30 kilometres, reducing 10 kilometres	haze	broken 500 ft
H, 0817	310/10	3000 m, reducing 1000 m	mist and fog patches	broken 300 ft

1.8.2 The pilot of the departing light aircraft told the aerodrome controller at 0757 that the cloud base was about 600 ft (180 m) to the north-west of the airport.

1.9 Air traffic control

1.9.1 The ATC objective was the provision of a safe, orderly and expeditious flow of air traffic and the prevention of collisions.

1.9.2 The primary document for Airways personnel was the Manual of Air Traffic Services (MATS), which was based on International Civil Aviation Organisation (ICAO) documents and the New Zealand Civil Aviation Rules (CAR). At Auckland, MATS was supplemented and amplified by the Auckland Tower Main Trunk Procedures.

1.9.3 MATS stated in part[9] that:

> Aerodrome controllers shall, as far as is practicable, maintain a continuous watch on all flight operations on and in the vicinity of the aerodrome …
> Watch shall be maintained by visual observation augmented by radar as appropriate.
>
> Identification shall be established by correlation of observation with:
> - aircraft type and distinctive markings
> - position reports.

1.9.4 A "flight progress system" was used for displaying information on flights to assist controllers to predict and resolve conflict between aircraft. Essential information relevant to a flight – such as aircraft type and call sign – were usually pre-printed on a card or paper strip, and clearances and actual times were added by hand, as required.

1.9.5 One flight progress strip was prepared per flight and the strip's movement between controllers matched the transfer of control of the aircraft – for example, from the ground controller to the aerodrome controller as the aircraft approached the runway for take-off. Because there was only one strip per flight, an aerodrome controller did not normally get advance notice of departures, whereas a minimum of 10 minutes' notice was required by MATS for an arrival.

[8] Wind direction was given in degrees magnetic and wind speed in knots. Cloud layers were reported as the proportion of the sky that was covered: few = 1-2/8, scattered = 3-4/8, broken = 5-7/8.
[9] MATS, chapter RAC4, section 1.1.2.

1.9.6 The procedure[10] for transferring control of an aircraft was as follows:

> **Transfer of control** — As taxiing aircraft approach the departure holding point, [the ground controller]:
> - Instructs the aircraft to contact [the aerodrome controller], and
> - Passes the flight progress strip to [the aerodrome controller].

1.9.7 At Wellington, aircraft taxied from the apron on Tower frequency, and at Christchurch, pilots changed to Tower automatically as they neared the holding point and were ready for take-off.

1.9.8 On 29 May 2007, the strips for the Saab, Link 659, and the Dash, Link 383, were correctly prepared, but the distinction between the handwritten holding points, A5 and A3 respectively, was not clear. The aerodrome controller said that her normal practice was to read the strips for each aircraft that she controlled, rather than rely on memorising call signs and types, but whether she had read the strips before issuing the clearance to Link 659 was not determined.

1.9.9 MATS procedures for line-up clearances stated in part:

> Once an arriving aircraft has been cleared to land, a departing aircraft shall not be permitted to enter the runway … being used by the landing aircraft until:
>
> - the landing aircraft has passed the point of intended holding or entry to the runway …

1.9.10 An Aeronautical Information Publication section entitled "Minimum runway occupancy – controlled aerodromes" explained the ATC goal of maximum capacity use of runways. Pilots were given the following guidance to help them contribute to that goal:

- … plan ahead, be prepared for the controller's instructions, and carry out these instructions without delay
- listen to instructions to other aircraft in the immediate vicinity, because when it is busy it is important that pilots have situational awareness of other aircraft …
- always remember that every second counts.

1.9.11 Airways, the airport operator, Auckland International Airport Limited (AIAL) and airlines had cooperated in a project intended to achieve incremental improvements in the operating efficiency of the airport. The actual performance was dependent on controller and pilot procedures, the taxiway and runway configuration, the mix of departures and arrivals, aircraft types and the weather.

1.9.12 Airways advised that a 1997 review had found that 40 movements an hour were possible under visual conditions for the traffic mix at Auckland at that time. A 2007 review indicated that 46 movements an hour could be safely achieved. Gatwick airport in England, which had a similar layout, had a declared rate in excess of 50 movements an hour. After consideration of software modelling data, an optimum rate of 44 movements an hour had been set for Auckland.

1.9.13 Anecdotal evidence suggested rates in excess of 50 movements an hour could sometimes be achieved for short periods of time. On 29 May 2007, in the 10 minutes leading up to the incident there were 5 movements, but 11 different aircraft on Tower frequency.

1.9.14 The MATS included runway separation standards that were essentially ICAO standards, and which provided practical constraints to the movement rate. Aerodrome controllers were trained how to issue landing and take-off clearances without breaching the standards. If a standard was likely to be breached, a controller could instruct a landing aircraft to go round or an aircraft that was taking off to reject the take-off. Airways was confident that the incidence of such events, which were notified to the CAA in accordance with CAR Part 12, was low.

[10] Auckland Tower Main Trunk Procedures, Taxi Clearances, page 3-C-6.

1.9.15 Routine CAA audits of control tower operations were primarily to assess compliance with the Airways exposition and CAR. Although controllers' practices were observed for short periods during audits, auditors did not expect to evaluate the suitability or risk potential of established procedures. There was provision for controllers or other persons to report deficiencies or operational concerns through Airways' internal quality assurance system or directly to the CAA.

Runway incursions

1.9.16 Runway incursions were acknowledged by aviation accident investigation authorities and civil aviation regulators worldwide to be a major threat to the safety of airport operations. ICAO defined[11] a runway incursion as:

> Any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle or person on the protected area of a surface designated for the landing and take off of aircraft.

The definition did not require that an aircraft be involved for an incursion to occur.

1.9.17 The CAA did not define the term "runway incursion" and did not show it as an incident type on its incident reporting form, CA005. However, the CAA safety database taxonomy had "runway incursion" as a specific type of aerodrome incident.

1.9.18 CAR Part 12 defined an aerodrome incident as:

> an incident involving an aircraft operation and –
>
> (1) an obstruction either on the aerodrome operational area or protruding into the aerodrome obstacle limitation surfaces; or …

and an airspace incident as:

> an incident involving deviation from, or shortcomings of, the procedures or rules for –
>
> (1) avoiding a collision between aircraft, or
> (2) avoiding a collision between aircraft and other obstacles when an aircraft is being provided with an Air Traffic Service.

1.9.19 The CAA did not routinely produce data on runway incursions. A review of the CAA database for the period 1 August 1992 to 16 October 2007 found over 500 airspace incidents that, judging from the text or event descriptor, possibly met the ICAO definition of "runway incursion". Of those, 54 had occurred at Auckland. The data was assessed with a CAA analyst who agreed that 30 of the 54 incidents probably met the ICAO definition. Because they had been recorded as airspace incidents rather than aerodrome incidents, none had been encoded "runway incursion".

1.9.20 The CAA database had 16 aerodrome incidents in that period that may have been runway incursions, including 8 that were so coded. Three of the 16 had occurred at Auckland, and 2 of those (not the 2 incidents that are the subject of this report) did meet the ICAO definition.

1.9.21 No attempt was made as part of this investigation to categorise the severity of the 30 airspace and 2 aerodrome incidents that were runway incursions, or consider their causal factors, because the descriptive text in the CAA database was of variable quality. However, events that involved one aircraft only, or no aircraft, probably could not have resulted in an incident or accident.

1.9.22 In the 13 years to June 2007, there were over 1.87 million aircraft movements at Auckland. Using the CAA incident data, the nominal runway incursion rate at Auckland for that period was 15.8 per million movements. The annual rate varied from 7.1 to 28.1 per million movements, with the highest rates occurring in 2001-2005, years during which (apart from 2003) major runway works took place. There were major runway works in 2006 also, but in spite of the number of instrument flight rules movements being 30% higher, the incursion rate was less than half that for 2005.

[11] ICAO Procedures for Air Navigation Services – Air Traffic Management (Doc 4444), amendment 3, 2004.

1.9.23 CAR Part 12 required an air traffic service provider and the operator or pilot involved in an airspace incident to provide the details to the CAA. Similarly, the holder of an aerodrome operating certificate was required to notify the CAA of an aerodrome incident. Certificate holders were required to "conduct an investigation to identify the facts relating to [their] involvement in the incident and establish, so far as those facts allow, the cause or causes of the incident".

1.9.24 In the absence of a CAA definition, it was likely that incidents which met the ICAO definition had not been recognised as incursions by some certificate holders – perhaps because there had been no loss of separation or real risk of collision – and therefore may not have been investigated.

1.9.25 A further difficulty for analysis of the CAA data was that occurrences could be encoded according to outcome (for example, "loss of separation") and/or according to assigned cause (for example, "breach of clearance").

1.9.26 AIAL advised that Airways, as its ATC provider, notified the CAA of runway incursions at Auckland that involved aircraft only, or which were airspace incidents. The airport company was primarily concerned with, and had only notified and investigated, vehicle incursions: it was not aware of most incidents that were notified to the CAA by Airways.

1.9.27 Airways advised that their occurrence database prior to year 2000 had not been configured to reliably identify runway incursion events, especially those without a direct ATC input. However, concurrent with this investigation, Airways identified 30 incursion events at Auckland since 2000. Their analysis concluded that approximately 93% had no risk of collision, but all had been notified to the CAA.

1.9.28 Occasionally, Airways published MATS Advisory Circulars in operational notice books that contained new or important information which controllers were required to read prior to each shift. On 2 September 2004, Airways issued Advisory Circular 14, "Runway Incursions", "to provide guidance to tower controllers to guard against the threat of runway incursions". Neither of the aerodrome controllers involved in the 29 May and 1 August 2007 incidents recalled the specific content of that circular.

1.9.29 The Airways circular defined a runway incursion as:

> A potential or actual breakdown of separation standards when an aircraft, vehicle, person or animal ventures onto a runway without authorisation, or is cleared onto a runway creating an unsafe situation.

1.9.30 The circular referred to contributory factors present in many runway incursions, such as call sign confusion, and noted that air traffic controllers, pilots and airport operators had a joint role in reducing the threat of incursions. The circular included a pilot's perspective of the threat and stated, in part:

> Consider the field of view from the cockpit. Before asking a pilot to see and manoeuvre relative to other aircraft … be reasonably sure that it is possible …
>
> A pilot holding on a rapid exit taxiway[12] may be unable to see traffic on final approach or on the runway behind him. This may restrict situational awareness and increase the risk of misidentification.

1.9.31 Air traffic service providers and airport operators relied primarily on their own, separate, procedural defences against runway incursions, and secondly on pilots knowing, and complying with, those procedures.

[12] Rapid exit taxiways are explained in paragraph 1.11.3.

1.9.32 The following recommendations from the ICAO Manual on the Prevention of Runway Incursions,[13] further excerpts from which are given in Appendix A, illustrated that prevention was dependent on many parties:

> Conduct all communications associated with runway operations in accordance with ICAO air-ground radiotelephony communications language requirements.
>
> Pilots should not accept an ATC clearance which would otherwise require them to enter or cross a runway from an obliquely angled taxiway.
>
> If lined up on the runway and held more than 90 seconds beyond anticipated departure time, pilots should contact ATC and advise that they are holding on the runway.
>
> [Addressed to air traffic service providers and air traffic controllers] Identify any hazards and evaluate any risks of runway capacity enhancing procedures (intersection departures, multiple line up, conditional clearances etc) when used either individually or in combination. If necessary develop appropriate mitigation strategies.
>
> When using multiple or intersection departures, do not use oblique or angled taxiways that limit the ability of the flight crew to see the landing runway threshold or final approach area.

1.9.33 The United States had considered runway incursions to be a serious problem for many years and had an established reporting and classification system. The Federal Aviation Administration, in one of its periodic reviews, stated:[14]

> The overwhelming category of both pilot and controller errors can be classified as a loss of "situational awareness." Specifically, when tower controllers are involved in an operational error, it is typically due to one or more of the following:
>
> - Forgetting about an aircraft, a closed runway, a vehicle on the runway, or a clearance that the controller issued;
> - Miscalculation of the impending separation;
> - Communication error – hear-back errors (i.e. failing to catch a read-back error);
> - Misidentifying an aircraft or its location (and issuing an instruction to the "wrong" aircraft); and
> - Incomplete or inadequate coordination among controllers.

1.9.34 Data from the Federal Aviation Administration[15] showed that the United States national rate for all categories of runway incursion at airports with ATC (more than 500 airports) was steady over the period 2003-2007 at about 5.2 runway incursions for every one million movements. The worst individual airport rate[16] exceeded 50; the best would be zero. No attempt was made to identify a United States airport with similar characteristics to Auckland for comparison.

1.9.35 On 1 October 2007, the Federal Aviation Administration adopted the ICAO definition of "runway incursion". The broader ICAO definition resulted in the United States national rate being higher and trending upwards from an estimated 5.2 incursions per million movements to 14.5 incursions per million movements over the period 2003-2007.

[13] ICAO Manual on the Prevention of Runway Incursions (Doc 9870), 2007. ICAO manuals do not have the status of Standards, but are published to provide "guidance and information concerning selected aspects of aeronautical activity or intended to facilitate the uniform application of international Standards and Recommended Practices".
[14] Federal Aviation Administration, Runway Safety Blueprint, 2002-2004, July 2002.
[15] Federal Aviation Administration, Runway Safety Report, September 2007.
[16] Federal Aviation Administrator's Fact Book, April 2007.

1.9.36 Over 90% of the United States events involved little or no risk of collision. The incident rate for the 2 most serious categories, where there was an actual or potential risk of collision, was less than 0.5 per million movements in the year ending 30 September 2007.[17]

1.9.37 The Runway Incursion Severity Classification model was developed by ICAO to minimise the variability in categorising the outcomes of runway incursions. The model was an automated system that had been offered by ICAO to member states as a tool for standardisation.

1.9.38 In 2003, the European Organisation for the Safety of Air Navigation, Eurocontrol – an organisation of air traffic service providers – published the European Action Plan for the Prevention of Runway Incursions. The plan stated that intersection departures, use of angled taxiways and conditional clearances were common factors in runway incursions.

1.9.39 Appendix B provides a selection of runway incursion incidents that have occurred at Auckland and overseas to illustrate how a mixture of pilot, controller, procedure, aircraft and airport factors is typically involved in runway incursions. Some corrective and preventive actions are included to show that one party, such as the air traffic service provider, might be best placed to effect the desired safety outcome.

1.10 Communication

1.10.1 Voice communication between air traffic controllers and pilots was by very high frequency RTF. Such transmissions were typically clear, but misunderstandings could arise due to speakers' accents or RTF technique. Standard phraseology and phonetic pronunciation helped to avoid such misunderstandings.

1.10.2 The common RTF training resource for pilots and air traffic controllers was Advisory Circular 91-9 & 172-1, Radiotelephony Manual. The manual included the following guidance to pronunciation, with the syllables to be emphasised shown in upper case:

Numeral or numeral element	Pronunciation
0	ZE-RO
1	WUN
2	TOO
3	TREE
4	FOWer
5	FIFE
6	SIX
7	SEVen
8	AIT
9	NINer
decimal	DAY SEE MAL

1.10.3 The CAA required an applicant for a pilot or air traffic controller licence to demonstrate an understanding and the correct use of standard phraseology, but correct pronunciation was not specifically tested. There was no ICAO or national requirement for ongoing compliance to be tested or demonstrated.

1.10.4 CAR Part 172, Air Traffic Service Organisations – Certification, stated in part:

> **172.105 Radio and telephone procedures**
>
> (a) Each applicant for the grant of an air traffic service certificate shall establish systems and procedures to ensure that –
>
> (1) the standard telephony and radiotelephony phraseology prescribed in paragraph (b) is used; and …

[17] http://www.faa.gov/news/press_releases, 31 October 2007.

(b) The applicant shall establish procedures to ensure that, for the purposes of paragraph (a), the standard phraseology, and the circumstances in which it is used, is that published in –

(1) Subpart F, or
(2) Annex 10, or …

1.10.5 The CAA Advisory Circular 91-9 & 172-1 complied with Annex 10.[18]

1.10.6 When 2 stations transmitted at once, neither could hear the overlapping transmissions but other stations on the frequency would hear either a largely unintelligible "hash" or the higher-powered transmitter. A not uncommon practice was for an air traffic controller or pilot who was aware of a crossed transmission to transmit "Two at once" to invite clarification of the transmissions.

1.10.7 The problem of crossed transmissions was international and long-standing, and no effective preventive solution had yet been found.

1.10.8 Controllers had no reliable means of intervening to stop crossed transmissions, other than to rely on the greater power output of ATC transmitters and the likelihood that a longer transmission could allow them to regain control of the frequency. An internal Airways investigation of the 29 May 2007 incident recommended that controllers faced with crossed transmissions by other stations should transmit repeatedly an overriding urgency message until the controller had control of the frequency.

1.10.9 Part of the process for the issue of an ATC clearance was for the controller to listen to the pilot's read-back so that the controller got assurance that the clearance was correctly issued and received as intended. A controller had to actively attend to a pilot's read-back and, if necessary, correct or repeat the clearance.

1.10.10 Neither the CAA nor Airways had conducted any examination of the role of RTF errors in airspace incidents in New Zealand. The CAA had stressed correct phraseology, but phonetic pronunciation did not appear to have been a concern. Airways analyses had been limited to investigation of individual events and the recommendation of specific corrective or preventive actions.

1.10.11 Data from the United Kingdom[19] suggested that the 3 main types of communication error were read-back and hear-back errors (30%), call sign confusion and non-adherence to RTF standards. Communication errors were present in 40% of United Kingdom runway incursions.

1.11 Aerodrome information

1.11.1 The airport operator, AIAL, contracted Airways to provide an aerodrome control service. CAR 139.53, Aerodrome limitations, required the airport operator to establish, when necessary for the safety of aircraft operations, any necessary limitations on the use of the aerodrome that arose from the aerodrome design. In practice, that responsibility linked with that of Airways to provide for the safe, orderly and expeditious flow of traffic and the prevention of collisions.

1.11.2 The main runway at Auckland was designated 23L, with the reciprocal direction being 05R. The runway was 45 m wide between the edge markings, and there was an additional 15 m of paved shoulder on each side.

1.11.3 Six of the 10 taxiways joined the runway at an angle of 30° to the runway centreline to form rapid exit taxiways for landing aircraft.[20] For example, taxiways A4 and A6 were rapid exit taxiways for runway 23L. The Auckland ground movements chart published in the

[18] Annex 10 (Aeronautical Telecommunications) to the Convention on International Civil Aviation.
[19] 2005 data from United Kingdom National Air Traffic Services, DVD "Communication Error" (2006).
[20] Thirty degrees was the angle recommended by ICAO in Annex 14, Aerodromes, Volume 1.

Aeronautical Information Publication stated, "Unless otherwise instructed by Aerodrome Control, arriving and departing aircraft must use rapid exit taxiways" (see Figure 1).

1.11.4 An aircraft that did not require the full runway length for take-off was usually cleared to depart from an inset take-off position, which was usually reached via a rapid exit taxiway for the opposite direction runway. For example, when runway 23L was in use, taxiways A3 and A5, which were rapid exit taxiways for runway 05R, could be used to enter runway 23L for take-off. Aircraft up to Boeing 737 size often used taxiway A3, and smaller aircraft – which typically needed a shorter take-off distance – could use taxiway A5 also.

1.11.5 Inset take-off positions offered shorter taxi routes, increased spacing ahead of an arriving aircraft and, if from a rapid exit or angled taxiway, faster runway entry. These benefits aided more efficient use of a runway.

1.11.6 The availability of inset take-off positions meant that multiple taxiways could be used for runway entry. The use of multiple taxiways and angled taxiways for runway entry had been identified as a factor in only a small number of incidents notified to the CAA, and had not been considered a safety issue by the CAA, Airways or AIAL.

1.11.7 In 1974, the main runway at Auckland was extended west of taxiway A9.[21] Some aircraft that had been able to line up from taxiway A3 for take-off from runway 23L could then take advantage of the extra runway distance and line up from taxiway A5. AIAL could not confirm whether the provision of the additional runway entry had been evaluated for its operational risk.

1.11.8 The main runway at Auckland was constructed in 1965 and the need for major rehabilitation work was evident by the early 1990s. To enable the work to proceed without having to close the airport, the parallel taxiway was converted into a runway, now designated 05L/23R.

1.11.9 By the late 1990s, the concept of risk management was well established and was incorporated into the AIAL plans for each year's work programme. Risk mitigation measures included, but were not limited to, the use of safety officers to observe works and movements for hazards, strict vehicle control, lighting systems, special purpose radar monitoring and pilot education. Representatives of the main participants met at least monthly to discuss operational incidents, such as runway incursions, that had occurred.

1.11.10 The Airways local procedures for Auckland had strict conditions for the use of angled taxiways when used in the reverse sense (for example, using taxiway A4 to enter runway 23L). In addition, in order to protect the instrument landing system signal propagation when the cloud base or visibility reduced below 300 ft (100 m) or 800 m respectively, aircraft were not permitted to hold on taxiways A1 to A9. There were no restrictions specified for the use of angled taxiways during rain or at night.

1.11.11 AIAL and Airways planned to commission a category 3B[22] instrument landing system for runway 23L in November 2007. As the airport was not equipped with a surface movement radar, only one aircraft would be permitted on the manoeuvring area if it was obscured by fog or the runway visual range was 550 m or less, in part to remove the risk of a runway incursion.

1.11.12 Pilots seated on the left side of aircraft holding on taxiway A3 or A5 had to look back over their shoulders through almost 150° in order to see the runway threshold, and could see less of the runway and approach area when holding on taxiway A5 than when holding on taxiway A3. Right seat pilots were similarly hindered if on an angled taxiway when runway 05R was in use.

[21] In 1974, the runway and taxiway designators were different.
[22] A category 3B instrument landing system permitted a suitably equipped aircraft and trained crew to land with a runway visual range of not less than 75 m.

1.11.13 The ATC tower was located about 500 m north of the intersection of runway 23L and taxiway A5. Controllers had an unobstructed view of all the taxiway holding points for runway 23L/05R.

1.11.14 Christchurch and Queenstown were the only other international airports in New Zealand that had angled taxiways, one in each case. The CAA incident database was reviewed and no evidence found of any runway incursion at either of these airports in which the taxiway configuration was a factor. No analysis was attempted to explain the absence of similar incidents at these 2 aerodromes.

1.12 Flight recorders

1.12.1 All of the involved aircraft were fitted with the prescribed flight data and cockpit voice recorders. Data from the recorders was not recovered because the cockpit voice recorders were overwritten on the subsequent flights and sufficient flight data was available from the crewmembers, air traffic controllers and other sources.

1.13 Additional information

External vision from aircraft cockpits

1.13.1 Most western-built aircraft, including the Saab and the Beech, were designed to the United States Federal Aviation Regulation Part 25, "Airworthiness standards: transport category airplanes". Sub-part D, Design and Construction, of the standard read, in part:[23]

> 25.773 Pilot compartment view
>
> (a) *Nonprecipitation conditions.* For nonprecipitation conditions, the following apply:
>
> (1) Each pilot compartment must be arranged to give the pilots a sufficiently extensive, clear, and undistorted view, to enable them to safely perform any maneuvers within the operating limitations of the airplane, including taxiing takeoff, approach, and landing …
>
> (b) *Precipitation conditions.* For precipitation conditions, the following apply:
>
> (1) The airplane must have a means to maintain a clear portion of the windshield, during precipitation conditions, sufficient for both pilots to have a sufficiently extensive view along the flight path in normal flight attitudes of the airplane …
>
> (d) Fixed markers or other guides must be installed at each pilot station to enable the pilots to position themselves in their seats for an optimum combination of outside visibility and instrument scan …

1.13.2 Federal Aviation Administration Advisory Circular 25.773-1, "Pilots Compartment View – Design Considerations", issued on 8 January 1993, provided window dimensions that would demonstrate compliance with regulation 25.773. The criteria were primarily concerned with providing the minimum vision necessary for the avoidance of mid-air collisions.

1.13.3 The published external vision angle in the horizontal plane was less than 128^{o} for most turboprop aircraft using Auckland. The vision angle was up to 139^{o} for larger, faster jet aircraft.

Conditional ATC clearances

1.13.4 Link 659 was not issued with a conditional line-up clearance on 29 May 2007, but, because the pilots could not see the landing traffic from the angled taxiway, and the sighting of the subject

[23] Source: Electronic Code of Federal Regulations, http://ecfr.gpoaccess.gov, as at 14 June 2007.

traffic was a prerequisite for use of a conditional clearance, the appropriateness of conditional clearances for aircraft holding on angled taxiways was examined.

1.13.5 A conditional clearance was an ATC clearance[24] that was dependent on the recipient complying with the accompanying condition(s) – for example, to line up on the runway after a particular aircraft had landed. A pilot's read-back of a conditional clearance had to assure the controller that the pilot understood the associated condition.

1.13.6 MATS stated,[25] in part, that:

> Conditional clearances to line up on the active runway shall only be used when:
> - the tower controller and pilot have the conflicting traffic in sight, and
> - the tower controller can monitor the situation, and
> - the conditional aircraft is identified by type and position and any other information necessary to ensure correct identification, and
> - the preceding departing aircraft has been cleared to line up or take off, or
> - the conditional arriving aircraft is number one to land.

1.13.7 Similar information was available to pilots in the Aeronautical Information Publication New Zealand,[26] which stated in part:

> The pilot of a departing aircraft must:
> … if having received a conditional clearance to line up behind a departing or landing aircraft, ensure correct identification of the aircraft and enter the runway immediately after the other aircraft has passed …
>
> Conditional clearances require the pilot of the aircraft receiving the clearance to identify the aircraft … causing the condition.

1.13.8 Neither MATS nor the Aeronautical Information Publication explicitly stated that a pilot had to positively identify the conditional traffic before accepting the conditional clearance. Incidents had occurred where pilots had accepted a conditional clearance before they had identified the subject traffic and, although they expected to confirm identification before entering the runway, had misidentified the traffic and precipitated a runway incursion.

1.13.9 The Airways MATS Advisory Circular 14, referred to earlier, reiterated the MATS requirements in regard to conditional clearances and noted:[27]

> … use of conditional clearances requires that both the controller and the pilot have the conflicting traffic in sight. The tower controller must be reasonably sure that the pilot will be able to see the traffic.
>
> **Will the pilot be able to see and correctly identify the conflicting traffic?**
> **If in doubt – ask.**
> **If not, do not issue a conditional clearance.**
>
> If there is room for doubt, do not use conditional clearances.

Pilots must be able to sight the correct aircraft to comply with conditional clearances.

Technological solutions for the runway incursion problem

1.13.10 There was no technological tool available in 2007 that could recognise and reverse an error in communication or visual identification of traffic, which often preceded an incursion. Unless an additional warning system was in place, there was usually insufficient time to prevent some

[24] MATS, chapter RAC1, definitions.
[25] MATS, chapter RAC4, section 7.1.1.
[26] Aeronautical Information Publication, page AD 1.5-11 and 13.
[27] Emphasis and boxed comment in original.

degree of runway incursion, although a serious incident in New Zealand had normally been avoided by aerodrome controller intervention or appropriate pilot action.

1.13.11 The Federal Aviation Administration's Runway Safety Report, September 2007, gave examples of technological tools and improvements to airport infrastructure that could help aerodrome controllers and pilots to correctly locate an aircraft or vehicle and thereby minimise runway incursions. Highly developed ATC systems typically used surface movement radar and transponder systems, and many airports also used controller-selectable stop bars at taxiway holding points. Stop bars required an aerodrome controller to choose the correct taxiway holding point before changing the stop bar from red to green (or Off) when clearing an aircraft to enter the runway.

1.13.12 Research was being conducted into ground-based lighting systems that would automatically warn pilots not to land on or enter a runway, or commence take-off, because a runway incursion risk had been detected.

1.13.13 Aircraft on-board systems, such as the Electronic Flight Bag, used global navigation satellite systems combined with a geographical database to help pilots confirm their position on an airport. The Electronic Flight Bag was especially suited for operations conducted in low visibility or at airports with complex layouts or high traffic density.

1.13.14 Automatic Dependent Surveillance – Broadcast (ADS-B) was a transponder-based system that allowed a suitably equipped aircraft to automatically broadcast its precise position, combined with other flight data, to ATC. A cockpit display of traffic information could be installed to show the position of similarly equipped aircraft. ATC radar data from aircraft not equipped with ADS-B could also be broadcast by ATC and also shown on the cockpit display. ADS-B, with additional software, had been demonstrated to provide adequate warning of an impending runway incursion, regardless of which aircraft precipitated the situation.[28]

1.13.15 In 2005, the United States selected ADS-B to be the basis of its future ATC system. Australia had started to supplement traditional radar coverage with ADS-B ground stations and had indicated[29] that ADS-B would replace most en route radar facilities in Australia by 2009.

1.13.16 Airways advised that development of an electronic flight strip system was well advanced and the first installation was planned to be in operational trial by November 2007. Expected operational benefits for aerodrome controllers included earlier notice of departing traffic and reduced data management workload. The system would record all data inputs and changes, which would assist incident investigations.

2 Analysis

2.1 The incidents on 29 May and 1 August 2007 were runway incursions that were resolved primarily by the pilots of the aircraft on the runway seeing the infringing traffic. Each of the 4 involved aircraft had to take evasive action.

2.2 On 29 May 2007, the aerodrome controller misidentified the aircraft that the controller intended to depart next, but which was not yet on Tower frequency, and incorrectly used the call sign of a Saab, of the same operator, that was ready for take-off. The Saab then taxied onto the runway in front of the Beech, which had just landed. A call sign error was not an uncommon event, but one that was usually recognised and corrected before there was an adverse result. The aerodrome controller attempted to correct the clearance but was blocked by the Saab crew's read-back. The error would have been inconsequential had the Saab pilots seen the landing traffic before they entered the runway. These factors are examined below.

[28] Reported in Aviation Week and Space Technology magazine, 6 November 2006. http://www.l-3com.com/supportfiles/1-18728457Eprint.pdf.
[29] http://www.casa.gov.au/newrules/airspace/AS0403.asp.

2.3 The 1 August 2007 incursion was another case of mistaken identity, this time by the pilots of the infringing aircraft, and missed opportunities by pilots and the controller to recognise and correct the error. Non-standard radio techniques were involved. These factors are examined further below.

2.4 The following factors were common to both incidents and are considered further below:

- the use of multiple runway entry points
- the use of an angled taxiway for runway entry by the infringing aircraft
- hasty clearance delivery and line-up
- the pilots of the infringing aircraft not seeing the conflicting traffic before crossing the holding point
- crossed radio transmissions at a critical time.

29 May 2007 incident

2.5 In the 10 minutes before the incident there were 5 movements. At the time of the incident, there were 2 aircraft ready for take-off, and 3 others in the arrival sequence and also on Tower frequency. The aerodrome controller saw the Dash, Link 383, approaching the taxiway A3 holding point, although its crew had not yet changed to Tower. The aerodrome controller was probably anticipating a busier period and a need to keep up the movement rate.

2.6 The actual movement rate was well below the airport's optimum rate of 44 an hour. A review of the record of Tower frequency transmissions showed that the aerodrome controller appeared to be confidently managing the workload, although the Saab captain said she sounded busy. As the controller said there were no distractions or concerns that might have affected her performance, it was unlikely that she was overloaded.

2.7 After clearing the Beech, Eagle 766, to land, the aerodrome controller considered whether to depart an aircraft in the gap between the Beech and the next aircraft to land. Ordinarily, the aircraft at taxiway A1 should have been next, as it was ready first. It was not determined why the aerodrome controller had not already decided to depart that aircraft next.

2.8 As the aerodrome controller monitored the final approach of the Beech, she saw a Dash taxiing towards the taxiway A3 holding point. The Dash crew had been instructed to call Tower when ready; therefore, its flight progress strip should have been with the aerodrome controller. However, the aerodrome controller could not have assimilated the strip details before deciding which aircraft to next depart, because the strip showed that the Dash going to taxiway A3 had the call sign Link 383.

2.9 The aerodrome controller might have decided that the Dash should depart after the Beech had landed because the Dash was still taxiing at the time, and would have been able to line up, once cleared, without stopping at the holding point. An expeditious line-up by the Dash would have made good use of the available gap before the next landing aircraft.

2.10 The aerodrome controller was looking at the Dash when the ground controller suggested that Link 659 could line up. The aerodrome controller appeared to have correlated her observation of "aircraft type and distinctive markings", as required by MATS, with the operator call sign "Link", even though the Dash crew had not yet called on Tower frequency. The erroneous correlation led to the aircraft being misidentified and the wrong call sign being used. Prior reference to the flight progress strip for the Dash would probably have prevented that error.

2.11 The correlation of aircraft type and operator call sign could have been reinforced by the aerodrome controller's recalling the "Link" Dash that had landed about 2 minutes earlier, but

that was unlikely as, since then, the aerodrome controller had acknowledged Link 659, the Saab, and she was used to managing over short periods many aircraft with the same operator call sign.

2.12 The aerodrome controller was also unlikely to have forgotten the Saab or that taxiway A5 was in use, because the preceding aircraft to take off had left from taxiway A5 and the Saab crew had then reported ready there. Even so, having up to 5 taxiways available for runway entry increased the likelihood of an aerodrome controller misidentifying aircraft or taxiways. Having adequate time to assimilate the contents of flight progress strips would help to mitigate that risk.

2.13 The maintenance work in the tower cab was probably a minor nuisance, because it forced the ground controller to stand behind the aerodrome controller. When the ground controller pointed at the Saab and taxiway A5, the ground controller was in the peripheral vision of the aerodrome controller, who was then looking at the Dash.

2.14 After the aerodrome controller had used the incorrect call sign when intending that the Dash line up, the ground controller immediately pointed out that Link 659 was the Saab at taxiway A5. At that point, there were still at least 2 potential defences against a runway incursion:

- the aerodrome controller could have corrected the clearance before the Saab moved
- the Saab pilots could have seen the landing Beech on the runway and questioned the instruction.

2.15 The aerodrome controller attempted to correct the clearance for Link 659 immediately, but was prevented by 3 crossed transmissions that were determined to be:

- the crew of Saab, Link 659, reading back the line-up instruction, followed by
- the crew of the Dash, Link 383, on Tower frequency for the first time, reporting that they were ready at taxiway A3, then
- the crew of the Beech that had just taken off, but who were still on Tower frequency, asking to transfer to radar frequency.

2.16 The local procedure of not transferring departing aircraft to the Tower frequency until they were close to the holding point benefited aerodrome controllers by minimising the number of aircraft on Tower frequency, but also reduced the time that controllers and pilots had to assimilate the traffic situation. The effect could be worse for a pilot of an aircraft holding on an angled taxiway, or taxing to a mid-field angled taxiway such as A5, who would have a shorter time to see relevant traffic.

2.17 The different procedures for the change from Ground to Tower frequency at other New Zealand airports were probably justified by the different configurations and traffic densities at those airports, and appeared to not have the same potential disadvantage as the late frequency change procedure at Auckland.

2.18 Pending implementation of the proposed Airways electronic flight strip system that should give all aerodrome controllers earlier advice of impending departures, a safety recommendation was made to the Director of Civil Aviation that he require Airways to enhance its procedure for handling flight progress strips, with the aim of increasing the time given to aerodrome controllers to assimilate the details of departing traffic.

2.19 When the Saab pilots got to the holding point, they heard the Beech ahead of them being cleared for “immediate take-off”. That might have suggested to them that an aircraft was on final approach to land, but they did not recall hearing the subsequent qualified landing clearance, “nineteen hundred departing, cleared to land”, given to Eagle 766, the landing Beech.

2.20 The Saab pilots could not have suspected that the aerodrome controller had made a call sign error. Although they had an incomplete knowledge of the traffic situation because of the taxi

route and late change to Tower frequency, they probably determined that it was safe to enter the runway for the following reasons:

- they had called ready, the clearance was addressed to them, and it was not conditional
- the controller had indicated that an immediate take-off clearance would follow, so the runway should have been clear
- they had confidence, while they had a reduced view of the runway from the angled taxiway, that the controller would "get it right".

2.21 Confidence in the performance of controllers was not necessarily misplaced, but it was not a substitute for self-preservation. A check for conflicting traffic before crossing the holding point was a universal defence against a runway collision and should always be done.

2.22 Because of the restricted external view from the cockpit, combined with the taxiway angle, the Saab captain could not see if the runway was clear. Although he might have been able to see up to 140^{o} behind by twisting in his seat, even that was probably insufficient for him to see if the approach was clear. If the captain had heard Eagle 766 being cleared to land, he could have concluded that he could not see the Beech because it had exited the runway at taxiway A4.

2.23 The operator considered that the view from the Saab cockpit, although restricted, was superior to that of the aircraft type that it replaced and was not a shortcoming. Many years of apparently safe operation had probably led pilots to not consider the restricted view to be a hazard and also meant that aerodrome controllers were unaware of the condition.

2.24 When entering a runway from an angled taxiway, pilots will often taxi slightly off the taxiway centreline towards the landing threshold to enable them to check the runway and approach area. However, if told to expect an immediate take-off clearance, most pilots would stay on the centreline to expedite the line-up, as the Aeronautical Information Publication encouraged. That was what the Saab captain did, and as a result, his look up the runway, already limited by the cockpit window design, was probably less searching than normal.

2.25 Although the Saab fleet has been retired, there were possibly other aircraft types whose cockpit view was limited. The airworthiness criteria for cockpit visibility were primarily aimed at the minimum vision necessary to avoid mid-air collisions. The rule required adequate visibility during ground operations under non-precipitation conditions, but under precipitation conditions only required a clear view "along the flight path" – that is, straight ahead. Because cockpit side windows were not equipped with wipers, external vision during rain would likely be further reduced. Therefore, when it was raining, even without haste and limited cockpit external vision, the use of angled taxiways for runway entry could increase the risk to runway safety.

2.26 A safety recommendation was made to the Director of Civil Aviation that he require operators of aerodromes with angled taxiways to prescribe the procedures and conditions, including the environmental conditions, under which those taxiways may be used to enter the runway.

1 August 2007 incident

2.27 At the time of this incident, the aerodrome controller had few aircraft movements but was concerned about the deteriorating weather. His discussion with the light aircraft pilot probably took longer than anticipated, but it was necessary for the controller to decide whether to implement low visibility procedures. The crew of Eagle 171, who were taxiing towards taxiway A3, changed to Tower frequency part-way through this discussion.

2.28 Although the aerodrome controller did not identify the call sign of the aircraft that called ready, he was aware that Eagle 979 had been lined up on the runway for almost 2 minutes and could have subconsciously thought the ready call was a prompt from the Eagle 979 pilots for a take-off clearance.

2.29 If the aerodrome controller had asked the unknown station to repeat its call sign, he would have known that it was Eagle 171 and been more likely to emphasise that the take-off clearance was for Eagle 979. By responding immediately to an unknown station, and by not using phonetic pronunciation, the aerodrome controller unintentionally misled the pilots of Eagle 171 into thinking the clearance was for them.

2.30 Whether the aerodrome controller had read the flight progress strip for Eagle 171 before its crew called ready was not determined, but the strip should have alerted the controller to the somewhat similar call signs. "Eagle 979" and "Eagle 171" had a similar structure, but if spoken phonetically, "niner seven niner" should have been easily distinguished from "wun seven wun".

2.31 While a listen-out on any ATC frequency in New Zealand might suggest that phonetic pronunciation was not widely practised, the CAA had no current concern that it was a safety issue. However, laxity in phonetic pronunciation meant that RTF users could become accustomed to not hearing the distinctions and be liable to make a hearing error as a result.

2.32 A safety recommendation was made to the Director of Civil Aviation that he remind pilots and air traffic controllers to comply strictly with the phonetic pronunciation of letters and numerals in RTF communications.

2.33 The use of the unique registration mark for an aircraft as its call sign (for example, EAG) would not eliminate the problem of similar call signs, because alphabetical similarities could also occur. The present operator-flight number format had the advantage of associating the operator name with a recognisable paint scheme to help visual identification, although misidentification of the Dash in the 29 May 2007 incident showed that format, too, could lead to errors.

2.34 The Eagle 171 pilots were not sure of the location of Eagle 979, although there should have been an opportunity while taxiing to A3 to see that aircraft. Eagle 171 was not on Tower frequency when the other Beech was cleared to line up. Therefore, the pilots of Eagle 171 lacked some necessary visual or aural information that would have enabled them to have a complete mental picture of the traffic situation.

2.35 In general, pilots did not like waiting on runways for extended periods because they could not see the approach area and there was a risk that another aircraft could be mistakenly cleared to land. The Eagle 979 pilots should have been acutely aware of what was happening around them while lined up on the runway. They probably saw a Beech approaching taxiway A3, but if their attention had wandered, perhaps because of the extended weather discussion, they may not have heard the crew of Eagle 171 call ready.

2.36 The pilots of both aircraft were primed to expect a take-off clearance: Eagle 979 because it had been lined up for 2 minutes, and Eagle 171 because a line-up or take-off clearance following a ready call was not unusual. These expectations, combined with the aerodrome controller's clearance to Eagle 979 immediately after a ready call from Eagle 171 and the controller's lack of phonetic pronunciation, led to both flights accepting and reading back the take-off clearance.

2.37 As in the 29 May 2007 incident, there were then a number of potential defences against a runway incursion:

- the aerodrome controller would recognise and react to the crossed transmissions during the read-back
- the pilots of either Eagle aircraft would recognise and react to the crossed transmissions
- the pilots of Eagle 171 would see the other Beech on the runway.

2.38 The controller, having issued the take-off clearance, was required to listen for a correct read-back, but his attention had already been diverted to the weather behind him. Having heard only crossed transmissions, he should have reacted by observing the runway environment and repeating the clearance clearly and precisely. By not actively listening to the read-back to

ensure the intended pilot had copied it correctly, the aerodrome controller did not complete the clearance process.

2.39 Airways advised that controllers were taught that attention to read-backs was an important part of the clearance process. However, that aspect would be reinforced in initial and continuation training and in documentation, and be monitored in performance and standards assessments of controllers.

2.40 One of the Eagle 979 pilots heard a "seven one" after he had read back the take-off clearance, which he thought was strange, but he took no action. If the Eagle 979 pilots had seen Eagle 171 taxing to the holding point and heard its ready call, they might have realised that the "seven one" was the other aircraft also accepting the clearance.

2.41 A recognised crossed transmission immediately after an instruction or clearance was a potential threat that controllers and pilots should be alert for and react to. A safety recommendation was made to the Director of Civil Aviation that he remind pilots and air traffic controllers to seek immediate clarification of any clearance or read-back that was affected by a crossed transmission.

2.42 The first officer of Eagle 171, being on the upwind side of the aircraft on angled taxiway A3, could not see if the runway was clear. The captain said later that he could easily see the runway end while holding on taxiway A3. Therefore, as he did not see the other Beech, the captain must have made a cursory look before crossing the holding point. His haste might have been due in part to his interpreting the aerodrome controller's immediate (if misunderstood) take-off clearance as requiring a prompt reaction.

2.43 The 3 potential defences listed at paragraph 2.37 failed to prevent the runway incursion because the procedures upon which they relied were not followed.

Common factors

2.44 The factors that were common to both incidents are listed at paragraph 2.4. The presence of any one or all of them did not mean a runway incursion was inevitable, but did increase the probability of a runway incursion.

Multiple runway entry points and angled taxiways

2.45 The airport operator was responsible for the taxiway configuration and any limitations on its use. In practice, such decisions required joint consideration by the airport operator and aerodrome control service provider. The use of multiple taxiways for runway entry gave controllers the flexibility to optimise runway capacity.

2.46 When multiple runway entry points were available, there was an increased probability of an aerodrome controller making an error when identifying or issuing a clearance to an aircraft. Although the location of the cleared holding point was shown on the flight progress strip for each aircraft, a controller had to see and remember, or cross-check, that detail before clearing an aircraft to enter the runway.

2.47 Controllers and Airways were generally not in favour of the earlier transfer of departing aircraft to the aerodrome controller, citing implied pressure on movements and congestion on the tower radio frequency. However, Airways subsequently amended the flight progress board layout at Auckland to provide clear identification of runway holding positions, which would assist controllers to correctly identify aircraft when multiple taxiways were in use for runway entry.

2.48 Angled taxiways were obviously beneficial when used as rapid exit taxiways, but their use for runway entry required careful consideration by airport operators and ATC. Incidents that illustrated the hazard had occurred previously at Auckland, as shown in Appendix B. The

recommendations of ICAO and the French accident investigation authority concerning angled taxiways were likely to be equally applicable to New Zealand airports.

2.49 Pilots of smaller aircraft could make allowance for cockpit visibility restrictions by positioning on an angled taxiway centreline so that the runway end and approach area could be seen.

2.50 Airways had recognised that ATC procedures, pilot behaviour, and aircraft and airport design could interact to increase the risk of runway incursions, as shown by the content of the MATS Advisory Circular 14, but had not formalised the MATS procedures to account for those risks. Furthermore, because the aerodrome controllers involved in these incidents could not recall the circular, its promulgation was ineffective.

2.51 A safety recommendation was made to the Director of Civil Aviation that he require Airways to improve its method of promulgation to controllers of safety-related information so that the content was understood and applied.

2.52 In addition to the safety recommendation concerning angled taxiways, referred to at paragraph 2.26, it was recommended that the Director of Civil Aviation require operators of aerodromes where an air traffic service was provided, and that have more than one taxiway available for runway entry, to prescribe the conditions under which multiple taxiways may be used to enter the runway.

Hasty clearances and line-ups

2.53 In the 2 incidents central to this report, the attempted expediency in air traffic management was detrimental to safety. Increased movement rates and increased pressure on pilots to minimise runway occupancy increased the risk of errors by aerodrome controllers or pilots that could result in runway incursions.

2.54 On 29 May 2007, the aerodrome controller sought to get the Dash away in the arrivals gap, but through haste misidentified the aircraft. On 1 August 2007, the aerodrome controller did not identify which aircraft crew had called ready nor acknowledge that call. The immediate issue of a take-off clearance was a factor in the wrong crew accepting it.

2.55 Pilots noticed when a controller's speech rate and choice of words reflected a high tempo of movements, and would typically cooperate promptly with instructions, for their mutual benefit. However, if the movement rate was too busy or pilots or controllers acted too hastily, adverse consequences could result, such as clipped and rushed transmissions, lack of cross-checking, errors due to expectation and misinterpreted messages.

2.56 The Aeronautical Information Publication advice regarding runway occupancy was generally appropriate, particularly in regard to having the correct situational awareness. However, it was perhaps inappropriate to insist that "every second counts", as undue haste removed what might be the last defence against an incident: a few seconds for someone to see and correct an error.

2.57 Rushed clearance delivery and read-back, and pilots starting to enter the runway before completing the clearance read-back, minimised the opportunity for an aerodrome controller to intervene and rescind or correct a clearance before a runway incursion had taken place.

Incorrect situational awareness

2.58 The pilots of the Saab, Link 659, and of the Beech, Eagle 171, were either unaware or unsure of the position of the respective conflicting traffic immediately before they entered the runway. Incorrect situational awareness was a factor in most of the incidents referred to in Appendix B.

2.59 The situational awareness of the Saab pilots might have been better if the captain had positioned the aircraft at the holding point so that he could see the approach area. However, in the absence of any guidance from the operator on how to mitigate the external vision restriction, the captain probably held and entered the runway as other Saab pilots would have done.

2.60 The external vision angle was not limiting for the pilots of the Beech, Eagle 171. The captain should have seen Eagle 979 waiting on the runway before he crossed the holding point, even though he had not heard the other Beech being cleared to line up. He probably did not see the other aircraft because of his haste to comply with the immediately delivered take-off clearance.

2.61 The aerodrome controllers in both incidents had incomplete situational awareness at the crucial times. On 29 May, the flight progress strip for the Dash had been passed to the aerodrome controller about the time that she was looking at the Dash and thinking to clear it to line up, but she had not yet read the strip and its crew had not called on Tower frequency. The controller on 1 August did not seem sufficiently aware of the details of Eagle 171 to recognise its somewhat similar call sign.

2.62 Several of the incidents in Appendix B refer to flight crew using TCAS to help locate or identify traffic in the aerodrome environment. Eurocontrol did not recommend that practice because TCAS was not designed to display aircraft that were on the ground, nor provide collision avoidance advisories for aircraft on the ground. The recommended procedure was for TCAS to remain off until an aircraft was approaching the holding position, at which time the traffic display could be useful to confirm the location of an aircraft on final approach. However, the absence of a displayed target was not a guarantee that there was no airborne traffic, and the display did not replace the essential visual scan before entering a runway.

2.63 Although most pilots spoken to had a high level of confidence in controllers, they must actively seek and confirm for themselves evidence of the traffic situation, especially when near or on runways.

2.64 Because the time spent taxiing and holding prior to take-off are critical for pilots to establish a correct situational awareness, a safety recommendation was made to the Director of Civil Aviation that he remind pilots that an active listen-out and lookout were required around the runway environment.

Conditional clearances

2.65 If an effective lookout was not possible from a certain aircraft type when on an angled taxiway, then that type probably should not use angled taxiways for runway entry. By extension, the offer of a conditional line-up clearance to that aircraft type when holding on an angled taxiway would not be appropriate.

2.66 The MATS requirements for a conditional clearance made it clear that the subject traffic had to be seen by both the controller and the pilot, and both MATS and the Aeronautical Information Publication stressed the need for pilots to identify the traffic before entering the runway. Airways had previously recognised these risks, as shown by guidance given in Advisory Circular 14, but appeared to have not amended its procedures to fully account for those risks.

2.67 The circumstances of some of the runway incursions included at Appendix B suggested that, if the subject traffic could not be seen because of the taxiway geometry, pilots would rely upon the correctness of a controller's instructions. In some of those incidents, conditional clearances were accepted before the subject traffic was identified or, where an aircraft had been holding on an angled taxiway, before the traffic was even seen.

2.68 Airways and controllers commented that conditional clearances were generally safe and effective, and to always require controllers to confirm that the subject traffic had been correctly identified before issuing a conditional clearance would usually be unnecessary and could be counterproductive. However, the current requirements for the issue of conditional clearances had been amended as recently as 2003 because of misidentification of traffic by a crew holding on an angled taxiway. Unless a controller was assured that the subject traffic should be positively identified by the pilot to be cleared, a conditional clearance could entail the risk of traffic misidentification and a runway incursion.

2.69 Two safety recommendations were made to the Director of Civil Aviation regarding the issue and acceptance of conditional clearances.

The scale of the runway incursion problem

2.70 The CAA appeared to have taken no specific action in response to developments by ICAO and other agencies in regard to the runway incursion problem. Until requested to provide data for this investigation, the CAA had not interrogated its incident database specifically to determine the scale of the problem in New Zealand.

2.71 The CAA database contained more records of potential runway incursions at New Zealand aerodromes than was anticipated, given the moderate number of movements. The total number of incidents at Auckland that were found to meet the ICAO definition of "runway incursion", and the resultant incursion rate, surprised the CAA, AIAL and Airways. However, because the ICAO definition covered a wide range of incursion types, not just those involving aircraft, and the occurrences had not all been investigated to the same degree, the nominal incursion rate could not be used as a measure of the level of runway safety at Auckland International Airport.

2.72 The recurring runway rehabilitation programme at Auckland heightened awareness of the potential for airport works and changes to taxiway layout to increase the risk of runway incursions. Successful action was taken to mitigate new risks associated with the works, but those hazards were a specific subset of the wide range of factors that contributed to incursions, and to some extent displaced the existing, largely unrecognised, risks.

2.73 For example, while runway 05R/23L was closed for works, no angled taxiways were available for runway entry and that risk was temporarily eliminated. However, new hazards were created by the reduced separation between runway 05L/23R and the parallel taxiway, and the placing of holding points on that taxiway. At the completion of the works and reinstatement of runway 05R/23L, the previous risks associated with angled taxiways returned.

2.74 The number of incursions at Auckland during the period 2001-2006 probably illustrated the higher risk during periods of airport works and changes. However, the halved incidence during 2006 compared with 2005, even though major runway works took place in both years, could indicate the success of targeted risk mitigation efforts.

2.75 The size of the national runway incursion problem was probably masked by the lack of a common definition for "runway incursion" and the conducting of separate investigations that had not had access to all of the relevant facts. For example, except when there was increased scrutiny of incursions during the runway works periods, AIAL had not been aware of all reported incursions and therefore had not always had the opportunity to investigate whether airport factors, such as the aerodrome layout, were involved.

2.76 The requirement of CAR Part 12 for each certificate holder to "conduct an investigation to identify the facts relating to [their] involvement in the incident", and the process used by the CAA for melding those separate investigation reports, had not identified that runway incursions were a safety issue. The process itself could have misled the CAA and the other parties as to the correct identification of causes, and the relevance of safety action taken. Effective corrective action was unlikely if a party responsible for mitigating a particular risk was not aware of relevant incidents.

2.77 Apart from no accident having occurred to draw attention to runway incursions, other reasons for their being obscured were probably the CAA listing them as aerodrome incidents, of which only 8 were coded as runway incursions, and the encoding of occurrences according to both outcome and cause, which could confound a search and analysis of the data.

2.78 Comparison of the incursion rate at a particular airport with those at other airports and countries required careful consideration because of dissimilar movement rates, mixes of traffic and environmental conditions, and airport designs. However, unless some consistent measurement

and analysis was adopted, the involved parties would remain unaware of the actual situation and trends at specific airports.

2.79 A safety recommendation was made to the Director of Civil Aviation that he adopt the ICAO definition of "runway incursion" and the ICAO Runway Incursion Severity Classification model, that he apply a consistent investigation process for runway incursions and ensure that likely parties are promptly advised of a notified incursion, and that he calculate annual runway incursion rates for certified aerodromes.

2.80 Strict compliance with existing standards and procedures might have prevented many of the incidents reviewed in this investigation. Adoption of the ICAO recommendations for the prevention of runway incursions, which were based on the extensive experience of the world's foremost aviation economies, would probably reduce the risk further.

2.81 A broad range of technological solutions existed to mitigate the risk of runway incursions. A safety recommendation was made to the Director of Civil Aviation that he encourage operators of aerodromes to apply suitable technological measures to complement procedural defences against runway incursions.

3 Findings

Findings are listed in order of development and not in order of priority.

Specific to the 29 May 2007 incident

3.1 The aerodrome controller and Saab pilots were appropriately qualified and fit for their duties.

3.2 The aircraft movement rate and weather were favourable and did not create an onerous workload for the aerodrome controller.

3.3 This runway incursion was initiated when the aerodrome controller mistook the call sign of the aircraft she intended to line up for take-off and thereby inadvertently instructed another aircraft to line up in front of the aircraft that was landing.

Specific to the 1 August 2007 incident

3.4 The aerodrome controller and pilots of Eagle 171 were appropriately qualified and fit for their duties.

3.5 The aircraft movement rate was low and did not create an onerous workload for the aerodrome controller, but he was distracted by the deteriorating weather conditions at the aerodrome.

3.6 This runway incursion was initiated when the pilots of the aircraft holding on a taxiway mistook the clearance for another aircraft to take off as being for them, and entered the runway in front of the aircraft that was taking off.

3.7 The aerodrome controller contributed to the holding pilots mistaking the call sign by issuing the take-off clearance immediately after the pilots of the holding aircraft had called ready, and by not using phonetic pronunciation for the call sign numbers.

3.8 Had the aerodrome controller attended fully to the read-back, he would probably have reacted to the crossed transmission and might have prevented the runway incursion.

Common to the runway incursion problem

3.9 The use of multiple runway entry points increased the risk of runway incursions by creating more points for potential traffic conflict and a potentially higher workload for aerodrome controllers, and contributed to both of these incidents.

3.10 The use of angled taxiways for runway entry increased the risk to aerodrome operations by further limiting pilots' view of the runway threshold and of other aircraft, and contributed to both of these incidents.

3.11 Because they did not, or could not, check that the runway was clear before crossing the holding point, the captains of the infringing aircraft contributed to both of these incidents.

3.12 Crossed radio transmissions remained a risk to aerodrome operations and contributed to both of these incidents.

3.13 Pressure to minimise runway occupancy times occasionally led to hastily delivered runway line-up and take-off clearances by controllers and too quick compliance by pilots, as in both of these incidents, which increased the risk to aerodrome operations.

3.14 The practice of not transferring control of aircraft from the ground controller to the aerodrome controller until they were near the runway holding point contributed to these incidents because the practice reduced the situational awareness:

- of controllers, as less time was available to review aircraft details; and
- of pilots, because they had less time to listen on the Tower frequency before entering the runway.

3.15 A conditional clearance was not a factor in either of these 2 incidents, but the issue of a conditional clearance without confirmation that the pilot had positively identified the conflicting traffic was identified as a significant risk when angled taxiways were used for runway entry.

3.16 The Airways procedure for the dissemination of new information and guidance for air traffic controllers was not effective in ensuring new material was learned, applied and, where necessary, incorporated into standard operating procedures.

3.17 The rate of runway incursion incidents at Auckland International Airport was unknown by the airport operator, Airways and the CAA because accurate data on runway incursions was not maintained or analysed by any of those organisations.

3.18 The lack of a common definition of "runway incursion" and the non-adoption of ICAO recommended practices for the prevention of runway incursions contributed to the lack of appreciation of the scale of the issue at Auckland International Airport.

4 Safety Actions

Safety actions are listed in order of development and not in order of priority.

4.1 On 2 August 2007, Airways issued Notice to Airmen B3237/07, which precluded the use of rapid exit taxiways at Auckland for departing aircraft. The action was described as a traffic management trial with an expected duration of 3 months.

4.2 On 30 August 2007, Air Nelson issued a memo to flight crew reminding them of the requirements for acceptance of a conditional clearance and drawing their attention to the likely unsuitability of a conditional clearance if lining up from an angled taxiway.

4.3 On 17 October 2007, Airways advised that it had amended its occurrence database so that future airspace incidents which resulted in runway incursions were identified as such.

4.4 On 19 October 2007, Airways issued Auckland Tower Temporary Order 07/33, which introduced a standard layout for the aerodrome control tower flight progress board and a standard method for the handling of flight progress strips. In the revised layout, the strip for a departing aircraft was put in a bay corresponding to the holding point the aircraft had been cleared to by the ground controller. The temporary order was effective 24 October 2007 until 24 April 2008 or until the content was incorporated into the Auckland Tower Main Trunk Procedures manual.

4.5 On 19 October 2007, Airways issued Auckland Tower Temporary Order 07/35, which introduced an amended traffic management trial to replace that notified in Notice to Airmen B3237/07. The revised traffic management plan limited all departures off runway 23L to using taxiway A1A, A1 or A2; and all jet aircraft departing off runway 05R to using taxiways A9 and A10. Non-jet aircraft departing off runway 05R could use taxiways A7-A10, but restrictions – including a prohibition on conditional line-up clearances – were placed on the use of A7 and A8. The temporary order was effective 24 October 2007 until 24 April 2008 or until the content was incorporated into the Auckland Tower Main Trunk Procedures manual.

4.6 On 29 October 2007, the CAA advised that it had amended its procedure for encoding occurrences in order to provide clearer identification of runway incursion events.

4.7 On 22 November 2007, Airways amended the relevant part of the Manual of Air Traffic Services to read:

> Any critical instruction required to be passed in a congested radio environment must be repeated as required to ensure receipt. This ensures that at the first break in aircraft transmissions the controller's transmission will dominate.

4.8 On 19 December 2007, Airways advised that the following actions had been taken or were intended:

> Readback/hearback issues in the clearance process will be strongly reinforced across the board through training, documentation and continuation training. This will be monitored and targeted through ongoing performance and standards assessments.
> An Airways Improvement review will be carried out to scope the risks and issues about the current "see and sign" information change system. Following this work, airways will effect any necessary changes to improve the system. Close out 30 April 2008.
> Controllers would be reminded in training programs throughout 2008 to comply strictly with the rules for phonetic pronunciation, particularly of numerals, and to seek immediate clarification of any clearance or read-back affected by a crossed transmission.

4.9 On 21 December 2007, Airways advised the following, in respect of the handling of flight progress strips:

> As a result of the Rapid Exit Taxiway management system that has now been put in place for departing flights and adjustments to how the flight progress board is managed [see paragraphs 4.4 and 4.5 of this report], the aerodrome controller now has more time to assimilate the information on the flight progress strips for departing flights prior to their reaching the departure point. Accordingly, [safety recommendation 046/07 addressed to the Director of Civil Aviation; see paragraph 5.1.4 of this report] … in effect has been implemented. Airways will consider this recommendation when designing the operational requirements for electronic flight strips in 2008.

4.10 On 5 February 2008, after an internal investigation of the 1 August 2007 incident, Airways advised that a working group had been formed at Auckland to review the procedure for

transferring aircraft between the ground controller and the aerodrome controller. Tower staff had been reminded of the need to employ robust RTF procedures and standard RTF phraseologies. Regular audits of the tower voice recorder were to be conducted to check compliance.

5 Safety Recommendations

Safety recommendations are listed in order of development and not in order of priority.

5.1 On 21 February 2008, the Commission recommended to the Director of Civil Aviation that he:

5.1.1 require operators of aerodromes that have taxiways joining a runway at an oblique angle to prescribe the procedures and conditions, including the environmental conditions, under which the taxiways may be used to enter the runway (043/07).

5.1.2 require operators of aerodromes where an air traffic service is provided and that have more than one taxiway available for entry to any runway to prescribe the procedures and conditions, including the environmental conditions, under which multiple taxiways may be used to enter the runway (044/07).

5.1.3 adopt the ICAO definition of "runway incursion" and the ICAO Runway Incursion Severity Classification model, use a consistent process to investigate runway incursions and to ensure that other involved parties are promptly advised of an incursion notified by any one of them, and calculate annual runway incursion rates for certified aerodromes (045/07).

5.1.4 require Airways New Zealand to enhance its procedure for handling flight progress strips, with the aim of increasing the time given to aerodrome controllers to assimilate the details of departing traffic (046/07).

5.1.5 require Airways New Zealand to improve its method of promulgation to controllers of safety-related information and to demonstrate that the content was understood and applied by controllers (048/07).

5.1.6 investigate, in conjunction with Airways New Zealand, whether aerodrome controllers, before issuing a conditional clearance, should obtain confirmation from the pilot concerned that the subject traffic has been positively identified (049/07).

5.1.7 remind pilots that a conditional clearance cannot be accepted unless the conflicting traffic that is the subject of the clearance has been positively identified (050/07).

5.1.8 remind pilots and air traffic controllers to comply strictly with the rules for phonetic pronunciation, particularly of numerals, and to seek immediate clarification of any clearance or read-back affected by a crossed transmission (051/07).

5.1.9 remind pilots that an active listen-out and lookout are critical requirements around the runway environment (052/07).

5.1.10 encourage operators of aerodromes to apply suitable technological measures to complement procedural defences against runway incursions (055/07).

Approved on 21 February 2008 for publication

Hon W P Jeffries
Chief Commissioner

Appendix A Excerpts from ICAO Manual on the Prevention of Runway Incursions

2.3 PILOT FACTORS THAT MAY RESULT IN RUNWAY INCURSIONS

2.3.1 Pilot factors that may result in a runway incursion include inadvertent non-compliance with ATC clearances. Often these cases result from a breakdown in communication or a loss of situational awareness in which a pilot thinks that he/she is at one location on the aerodrome (such as a specific taxiway or intersection) when they are actually elsewhere, or they believe that the clearance issued was to enter the runway, while in fact it was not.

2.4 AIR TRAFFIC CONTROL FACTORS THAT MAY RESULT IN RUNWAY INCURSIONS

2.4.1 The most common controller-related actions identified in several studies are:

a) momentarily forgetting about:
    1) an aircraft;
    2) the closure of a runway;
    3) a vehicle on the runway, or
    4) a clearance that had been issued;

b) failure to anticipate the required separation or miscalculation of the impending separation;
c) inadequate coordination between controllers;
d) crossing clearance issued by a ground controller instead of air/tower controller;
e) misidentifying an aircraft or its location;
f) failure by the controller to provide a correct read-back of another controller's instruction;
g) failure by the controller to ensure that read-back by the pilot or the vehicle driver conforms with the clearance issued;
h) communication errors;
i) overlong or complex instructions;
j) use of non-standard phraseologies; and
k) reduced reaction time due to on the job training.

2.6 AERODROME DESIGN FACTORS

2.6.1 Complex or inadequate aerodrome design significantly increases the probability of a runway incursion. The frequency of runway incursions has been shown in many studies to be related to the number of runway crossings and the characteristics of the aerodrome layout.

2.6.2 Common factors include:

a) complexity of airport layout including roads and taxiways adjacent to the runway;
b) not enough spacing between parallel runways;
c) departure taxiways that fail to intersect active runways at right angles; and
d) no end loop perimeter taxiways to avoid runway crossings.

4.2 RECOMMENDATIONS TO ENHANCE COMMUNICATIONS

4.2.5 Conduct all communications associated with runway operations in accordance with ICAO air-ground radiotelephony communications language requirements (Annex 10 – *Aeronautical Telecommunications*).

4.4 RECOMMENDATIONS TO PILOTS

4.4.1 Pilots should never cross illuminated red stop bars when lining up or crossing a runway unless contingency procedures are in use that specifically allow this.

4.4.2 Pilots should not accept an ATC clearance which would otherwise require them to enter or cross a runway from an obliquely angled taxiway.

4.4.3 If lined up on the runway and held more than 90 seconds beyond anticipated departure time, pilots should contact ATC and advise that they are holding on the runway.
4.4.4 Pilots should turn on aircraft landing lights when take-off or landing clearance is received, and when on approach.
Note.— A globally acceptable procedure is to be defined.
4.4.5 Pilots should turn on strobe lights when crossing a runway.
Note.— A globally acceptable procedure is to be defined.
4.4.6 If there is any doubt, when receiving a clearance or instruction, clarification should be immediately requested from ATC before the clearance or instruction is enacted.
4.4.7 If there is any doubt as to exact position on the surface of an aerodrome, pilots should contact ATC and follow the associated ICAO procedure (PANS-ATM, Doc 4444).
4.4.8 Pilots should be “Head up” for a continuous watch during aerodrome surface operations.

4.5 RECOMMENDATIONS FOR AIR TRAFFIC SERVICES PROVIDERS AND AIR TRAFFIC CONTROLLERS

4.5.13 Identify any hazards and evaluate any risks of runway capacity enhancing procedures (intersection departures, multiple line up, conditional clearances etc) when used either individually or in combination. If necessary develop appropriate mitigation strategies.
4.5.14 Do not issue line up clearance to an aircraft if this aircraft will be required to hold on the runway for more than 90 seconds beyond the time it would normally be expected to depart.
4.5.15 When conditional clearances are used, specific training should be provided to ensure that they are used strictly according to ICAO provisions.
4.5.16 When using multiple or intersection departures, do not use oblique or angled taxiways that limit the ability of the flight crew to see the landing runway threshold or final approach area.

Appendix B Selected runway incursions

Auckland International Airport

October 2001

The crew of a Boeing 737 was held for nearly 5 minutes on taxiway A9 before being cleared to line up after a Boeing 737 that was number 2 to land but which the aerodrome controller had said was "on final [approach]". Conditions were hazy.

The captain of the departing 737 lined up after the first landing aircraft, a Saab that neither 737 pilot identified. As they entered the runway, the 737 pilots observed visually and on TCAS that there was only a small gap before the next landing aircraft, which was the 737 they had been cleared to follow.

Airways subsequently amended its conditional line-up procedures to require the conditional traffic to be number one in sequence.

August 2003

The aerodrome controller cleared a Boeing 737 crew, holding at taxiway A1, for immediate take-off on runway 23L, ahead of a 737 of the same airline that was on approach. Immediately after giving that clearance, the aerodrome controller gave a conditional clearance to an aircraft, holding on angled taxiway A3, to line up behind the landing 737.

When the pilots of the aircraft given the conditional clearance saw the 737 that was taking off pass them, they mistook it for the landing 737 and taxied forward to the runway. The pilot in the left seat looked left and saw an aircraft on approach (the 737 that was the subject of the conditional line-up clearance), and said, "This'll be tight", but did not realise he had misidentified the traffic. The controller did not see the incursion and cleared the arriving aircraft to land. On hearing the landing clearance, the pilot of the infringing aircraft immediately exited the runway.

The pilots of the infringing aircraft did not recall hearing the aerodrome controller instruct the arriving 737 to "continue approach, company 737 departing ahead", nor did they hear the 737 at taxiway A1 then being cleared for "immediate take-off". The pilots also incorrectly interpreted the TCAS display of a target on the runway (the 737 on take-off) as the landing 737.

After that incident, Airways amended its procedures to require the conditional traffic to have received its landing clearance before a conditional line-up clearance could be issued. Airways also issued MATS Advisory Circular 14 (see paragraph 1.9.28) to give controllers an understanding of a pilot's perspective of runway operations and risks, such as the reduced visibility from cockpits when on angled taxiways.

August 2006

A Jetstream had been cleared to land and was on short final approach when the aerodrome controller cleared a commuter aircraft holding on angled taxiway A6 to take off on runway 05R, and then instructed a Boeing 737 to line up from taxiway A9. The Boeing pilot saw the Jetstream and questioned the clearance, after which the Jetstream pilot initiated a go-around. The aerodrome controller cancelled the take-off clearance for the commuter aircraft. The weather at the time was suitable for visual approaches.

The aerodrome controller's incident report stated that the ground controller had reported that the commuter aircraft was ready for an immediate departure. The internal investigation found that the experienced aerodrome controller had been reactive in controlling and had not used the flight progress board and strips properly.

April 2007

A Bombardier business jet taxied the short distance from the general aviation maintenance precinct at the east end of the airport and the crew called "ready" on Tower frequency as they entered taxiway B1. The aerodrome controller was not expecting the Bombardier and did not have its flight progress strip because

the ground controller had not instructed the crew to change to Tower. The aerodrome controller checked the radar display, "made a snap decision" to depart the Bombardier in a perceived arrival gap and cleared it to line up on runway 23L.

At the time, a Boeing 737 was on short final for a visual approach but had not been cleared to land. The Bombardier crew reported seeing the Boeing and the aerodrome controller cancelled the line-up clearance. The Bombardier did not cross the holding point.

Early morning sun had interfered with the aerodrome controller's view of the approach area, so greater use was being made of the radar than normal. However, a processor fault had removed the Boeing target from the radar display. The aerodrome controller assumed the first target was the Boeing when it was actually a following ATR72. The aerodrome controller had been standing back from his desk to look for the Bombardier and to avoid glare, and had not checked the flight progress board for other traffic.

Elsewhere

Paris Charles de Gaulle

Paris Charles de Gaulle airport has a complex runway and taxiway configuration, with many angled taxiways. In May 2000, after a Boeing 737 had landed, the aerodrome controller cleared a DC9 holding near the runway end to take off and then cleared a Shorts SD330 freight aircraft to line up "number 2". The aerodrome controller believed the Shorts had been holding behind the DC9, when it had been cleared by the ground controller to hold at an angled taxiway halfway down the runway.

The Shorts crew mistook the landing B737 that passed them, still at high speed, to be "number one" and started to taxi towards the runway. The DC9 had just rotated for take-off when the left wing tip of the DC9 sliced through the cockpit of the Shorts, killing the first officer. The DC9 crew successfully rejected their take-off. The accident happened at night.

The investigation[30] found that the external vision angle from the Shorts cockpit was 120^{o} and the angled taxiways were at 20^{o} to the runway,[31] and concluded that the Shorts crew would not have seen the DC9 until just before the impact.

The investigation noted that 20 runway incursions had been reported at Paris Charles de Gaulle between January and June 2000. Causal factors often included line-up from an angled taxiway, similar or mistaken call signs, misidentified conditional traffic, and controllers forgetting or confusing the location of aircraft.

The investigation made 7 safety recommendations specifically to the airport operator and the French civil aviation regulator, including the following:

> [that they] together study all of the procedures and associated means for the simultaneous use of two different parts of a runway so as to guarantee, in all circumstances, the same level of safety as when the runway is used by only one aircraft;
>
> and in particular that:
>
> terminology used in practice by the aerodrome air traffic control include the systematic identification of the taxiway from which the aircraft must line up;
>
> the use of high speed exits for line-ups be subject to the existence of arrangements which guarantee a level of safety equivalent to visual checks performed by the crew.

[30] Bureau Enquête d'Accident, F-GHED/G-SSWN–25 Mai 2000, report number f-ed000525.
[31] ICAO recommended, in Annex 14, a minimum angle of 25^{o}.

Munich

In 2004 at Munich airport, in an event similar to that at Auckland in August 2003, the infringing aircraft lined up after a departing aircraft and in front of the landing aircraft that was the subject of the conditional line-up clearance. The investigation[32] noted that the crew of the infringing aircraft could not see the approach sector from their holding position on an angled taxiway and could not identify the arriving aircraft. The incident occurred at night. The conditional clearance and the use of the angled taxiway were determined to be contributing factors.

Following the investigation into that incident, the German ATC provider amended its procedures for the use of conditional clearances to require controllers to instruct the pilot to report "traffic in sight". The ATC provider said that conditional clearances would not be used in conjunction with angled taxiway departures, but did not expect that change to result in significant additional delays or controller workload.

[32] As described in Eurocontrol Runway Safety Letter, February 2007; http://www.eurocontrol.int/runwaysafety.

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06-006	ZK-MYF, Partenavia P68B, loss of engine power, Takapau, 2 December 2006
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05-008	Cessna U206G, ZK-WWH, loss of control on take-off, Queenstown Aerodrome, 10 August 2005
01-005R	Bell UH-1H Iroquois ZK-HJH, in-flight break-up, Taumarunui, 4 June 2001
05-010	Aerospatiale-Alenia ATR 72-500, ZK-MCJ, runway excursion, Queenstown Aerodrome, 5 October 2005
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05-009	Eurocopter AS350 BA Squirrel, ZK-HGI, roll over on landing, Franz Josef Glacier, 17 August 2005
05-007	Piper PA-34-200T Seneca II, ZK-MSL, Wheels-up landing, Napier Aerodrome, 7 July 2005
05-001	Gulfstream G-IV ZK-KFB and Piper PA 28 ZK-FTR , loss of separation, near Taupo 7 January 2005
04-009	Hughes 360D, ZK-HHT, heavy landing, Wanganui River, South Westland, 21 December 2004
04-007	PA-34-200T Sceneca 11, ZK-JAN, collision with terrain, Mount Taranaki, 20 November 2004

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