Runway Incursions

A review based on Transport Accident Investigation Commission Report 07-005

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Presented at the
Australia & New Zealand Societies of Air Safety Investigators Annual Seminar
Adelaide, 1 June 2008

Introduction

The threat of runway incursions continues to be at the top of the list of major air safety concerns for those countries and regions with the highest air traffic densities, such as the USA and Europe. There have been some serious incidents down under – two at Sydney spring to mind - but in New Zealand, apart from an occasional pedestrian taking a short cut across Milford Sound's airstrip, there have been few incidents to recall.

So, two serious incursions at Auckland International Airport (AKL) in the space of two months caused quite a stir. In both incidents, the pilots of the aircraft that were already on the runway saw the other traffic enter the runway, but the pilots of all of the involved aircraft took avoiding action. There were no injuries or damage.

The Transport Accident Investigation Commission (TAIC) began an investigation of the first event, in May 2007, without delay. The contributing factors were soon apparent. When the second incident was notified on 1 August, similar circumstances and factors were recognised, so that incident was added to the existing investigation. TAIC does not have a specialist air traffic control (ATC) investigator, as does the Civil Aviation Authority of NZ (CAA), but the investigation was straight forward due to the excellent cooperation of all parties.

This paper illustrates the value of investigating serious incidents, shows how multiple factors are likely to be involved in a runway incursion, and that regulators and operators alike must be aware of the true scope of the problem for their efforts to reduce the incursion rate to be successful.

The paper is based on TAIC Report 07-005, which is available at www.taic.org.nz, but as it also includes personal opinions of the author, it is not the official view of the TAIC.

Auckland International Airport

The layout of AKL is shown in Figure 1. International and domestic aprons are marked. The runway rapid exit taxiways, for example A3 and A5, which are, of course, also used for runway entry, played a key part in these events.

The ATC services involved in these incidents were aerodrome control and ground control.

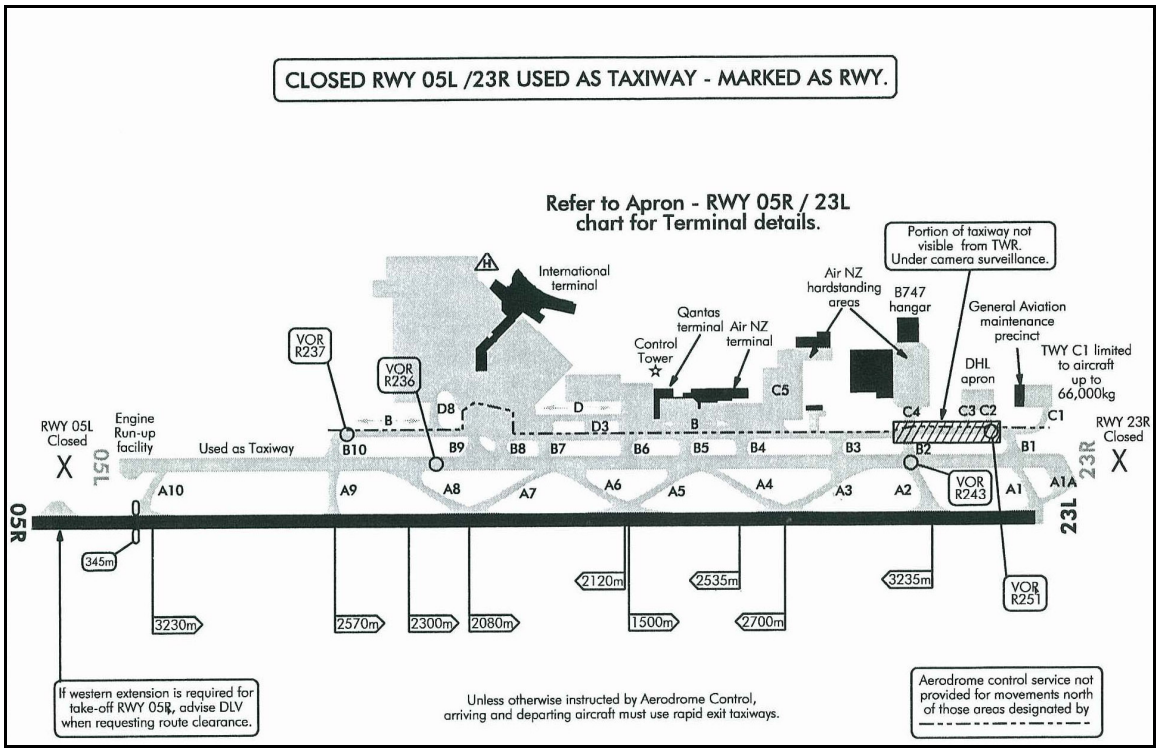

Figure 1
Auckland International Airport plan
(Diagram adapted from Aeronautical Information Publication of New Zealand, courtesy of CAA.)

"Runway Incursion"

At the time of these events, there was no standard definition of *runway incursion* in New Zealand. The ICAO definition is:

> 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.

Note that an aircraft does not have to be involved for an incursion to occur. Other questions of interpretation of this definition have been raised. For example, what is the *protected area*? Does the protected area include the obstacle clearance surface? Does an ATC service have to be in use?

The incidents

The relevant traffic in the first incident at AKL is shown in Figure 2. The movement rate was busy, but not overly so. The weather was good, CAVOK. The aerodrome controller mentioned that she might be able to get an aircraft departed after the landing Beech and before a following Beech on approach. The ground controller suggested the Link aircraft holding at taxiway A5, referring to that aircraft's call sign only. At that instant, the aerodrome controller was looking at, and probably intended to line up, the Link Q300 that was approaching the holding point on taxiway A3, but after the ground controller's suggestion, she inadvertently used the call sign of the aircraft at A5 and cleared that aircraft to line up.

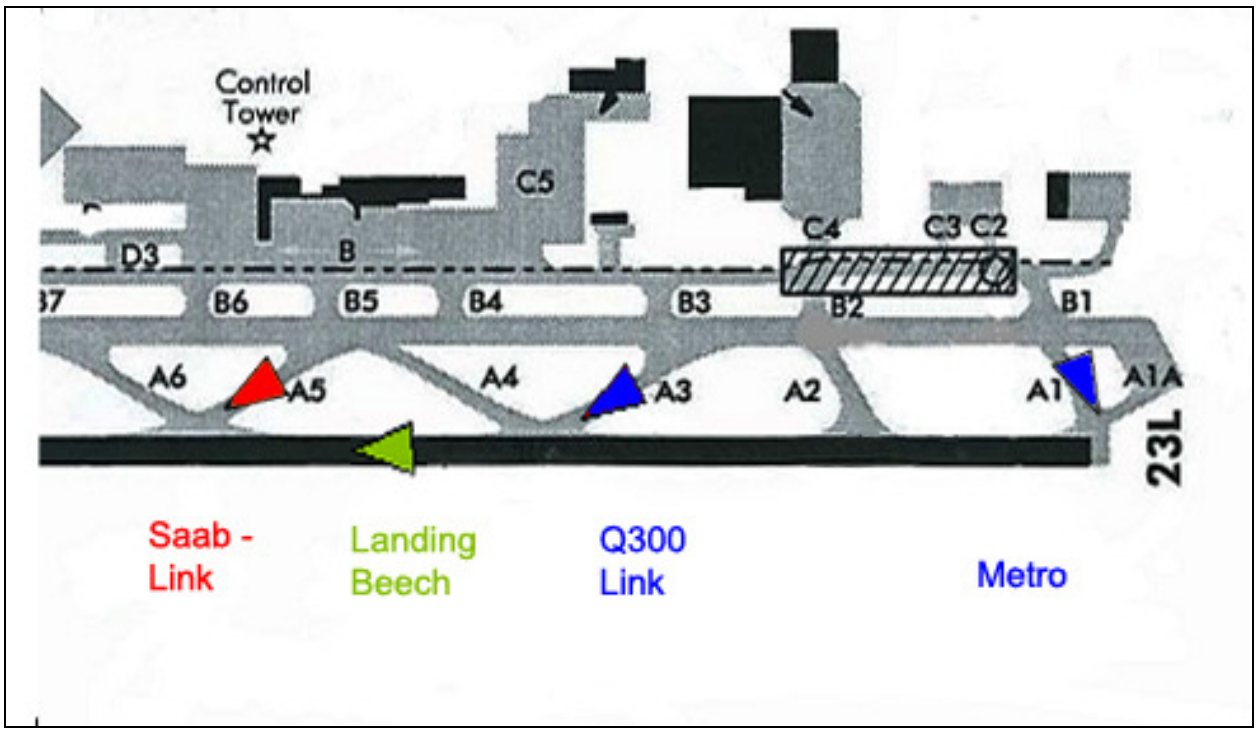

Figure 2
First incident

The line-up clearance was not conditional - that is, it was not of the form “after the landing Beech, line up behind”, but the phase “if you can take an immediate [take off], line up” was interpreted by the Saab captain as “don’t muck about”. The ground controller sitting next to the aerodrome controller immediately pointed out that the cleared aircraft was at A5. The aerodrome controller immediately transmitted an amended clearance, but it crossed with the read back from the Saab crew who were already taxiing towards the runway, in front of the Beech rolling out after landing.

The Commission identified the following contributory factors, which will be expanded on below:

- the ATC procedure for the handling of flight progress strips for departing traffic
- the use of multiple taxiways, including angled taxiways, for runway entry
- the captain of the Saab not seeing the landing traffic.

The traffic situation in the second incident is shown in Figure 3. In this case, there was little traffic, but the aerodrome controller was distracted by a band of low cloud and fog that was quickly approaching from the northwest, from behind the controller.

A Beech holding on taxiway A3 called “ready”. Without acknowledging that call, the controller immediately cleared a company Beech, already lined up, to take off. The take off clearance was read back by both aircraft. The read backs crossed, and although the controller heard a hash, he did not react to that incomplete read back as he was already looking back to the threatening weather. The aircraft on A3 entered the runway in front of the cleared aircraft, which had commenced its take-off roll.

Contributory factors identified in this case were as follows:

- the non-adherence to standard procedures for radiotelephony (RTF) use
- the non-adherence to standard procedures for the issue of an air traffic clearance
- the use of an angled taxiway for runway entry
- the captain of the aircraft at A3 not seeing the aircraft already lined up.

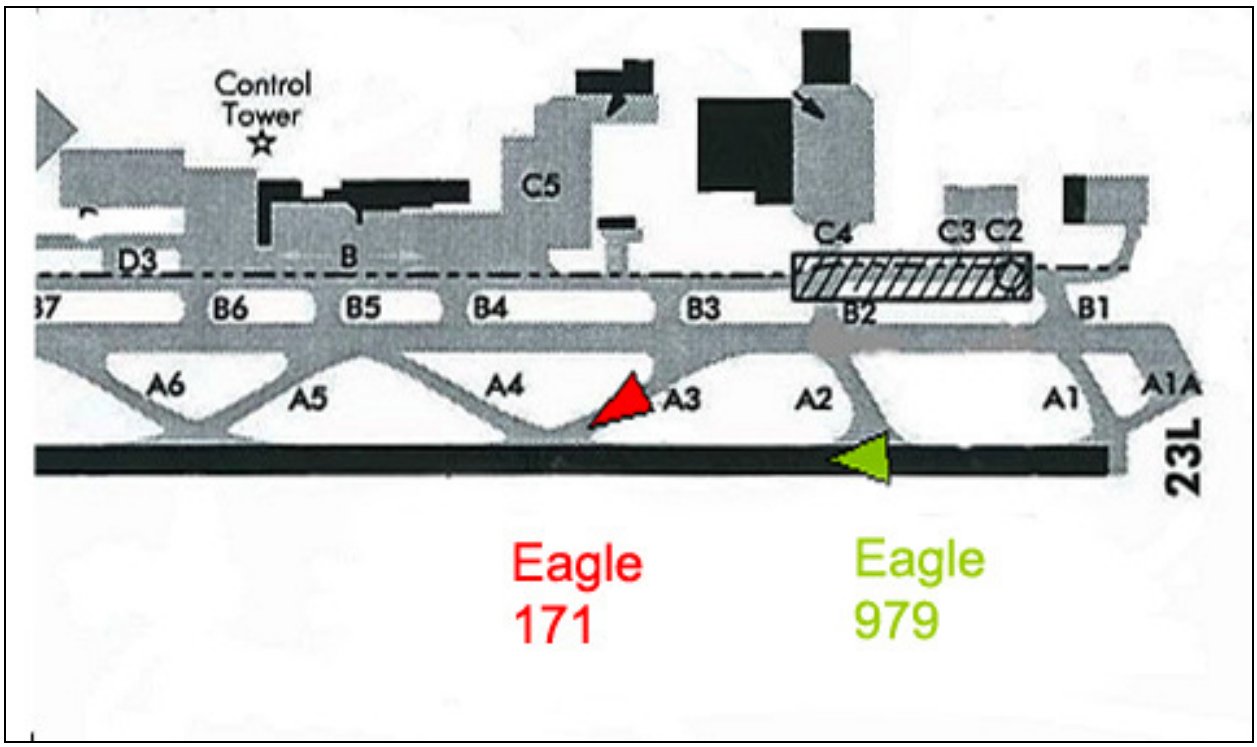

Figure 3
Second incident

Other findings of the investigation were that because the CAA had not defined *runway incursion*, earlier notified aerodrome and airspace incidents could have been runway incursions. These had not been recorded or investigated in a consistent manner, so the true nature and scale of the runway incursion problem in New Zealand was not known.

The restricted vision from the cockpit of some aircraft types, such as the Saab 340, when holding on an angled taxiway brought into question the use of conditional clearances for runway entry.

Investigation findings

- The use of multiple runway entry points increased the risk of runway incursions by creating more points for potential traffic conflict and an increased workload for aerodrome controllers.
- The use of angled taxiways for runway entry further increased the risk by limiting pilots' view of the runway threshold and of other aircraft.
- Crossed radio transmissions remain a risk to aerodrome operations and contributed to both of these incidents.
- Hastily delivered runway line-up and take-off clearances by controllers and too quick compliance by pilots increased the risk of incursions. Pressure to minimise runway occupancy times was probably an underlying factor.
- The practice of not transferring control of a departing aircraft from the ground controller to the aerodrome controller until the aircraft was near the runway holding point reduced the situational awareness: of controllers, because less time was available to review aircraft details; and of pilots, because they had less time to listen on Tower frequency before entering the runway.

- The issue of a conditional clearance without confirmation that the pilot had positively identified the conflicting traffic was a significant risk when angled taxiways were used for runway entry.

- The rate of runway incursion incidents at AKL and elsewhere was not known by the CAA or the relevant parties because accurate data was not maintained and analysed. There was no standard definition for runway incursion.

Discussion

Multiple and angled taxiways

The use of multiple runway entry points tends to suggest a possible increased controller workload and the potential for misidentifying aircraft or taxiway. If procedures are in place to control that, for example a maximum number of entry points and specific bays on the controller's flight progress board corresponding to the holding points, then the risk can be mitigated. At the time of these incidents, such procedures were not in place.

Apart from strict conditions for the use of angled taxiways when used in the reverse sense (for example, using taxiway A4 to enter runway 23L), the only restrictions on their use were for protection of the ILS signal in poor weather. There were no restrictions on the use of angled taxiways during rain or at night.

ICAO, Eurocontrol and the FAA have all recognised the danger inherent in using angled taxiways. An accident at Paris Charles de Gaulle and a serious incident at Munich involved use of angled taxiways, at night in both cases.

Immediately following the August 2007 incident at AKL, the use of the angled taxiways for runway entry was stopped until a new procedure was promulgated 2 months later. Contrary to expectations, the withdrawal of the angled taxiways for runway entry did not attract criticism from operators, did not cause delays, and did not create traffic management issues for controllers.

Airways also amended the flight progress board layout at AKL to include a specific bay for each runway holding point.

Situational awareness

In each incident, the final defence against a runway incursion should have been the captain of the aircraft entering the runway seeing – before he crossed the holding point – that there was an aircraft already on the runway. A check that the runway and approach are clear before entering the runway is universally considered a fundamental and critical action. In each case, the check was made but nothing was seen. Why not?

The actual causes may not be known, but the possibilities include the following:

- The pilot didn't look before crossing the holding point, by which time an incursion had already occurred.
- The pilot gave a cursory look, perhaps limited by the taxiway angle to the runway.
- The pilot was unable to see the pertinent area of runway at all, because of the external vision angle from the cockpit.

The psychologist Sidney Dekker has criticised[1] the unqualified use of the expression "loss of situational awareness" to explain some facet of an incident. But the Federal Aviation Administration, in one of its periodic reviews, stated:[2]

> 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.

Having a correct appreciation of a situation informs us prior to taking subsequent action. For example, if you hear an aircraft being cleared to land while you are holding for take off from that runway, you would likely look for and monitor the progress of the landing aircraft. Such awareness allows you to fit in other small tasks or crew conversation while you wait, with less risk of interrupting pertinent radio calls.

When the aerodrome controller indicated that she would depart an aircraft in the gap between the landing Beech and the next arrival, the ground controller suggested "Link 659" and pointed to the Saab at A5. However, taxiway A5 was 70° right of where the aerodrome controller was looking, towards a Link Q300, call sign Link 383.

Neither of the Saab pilots recalled hearing an aircraft being cleared to land while they were holding. Perhaps the pilots were talking at the relevant time; however, this was not determined because the Commission chose to rely on interview evidence and did not to down load the CVRs (for either incident).

The Saab captain did have a visual problem though, because the external vision angle from his cockpit was only 122° in azimuth (see Figure 4), and up to 140° if he leaned forward and turned in the seat. Although the angled taxiways at AKL joined the runway at 30°, the ICAO standard, the runway end might not be visible from an angled taxiway.

The published external vision angle from a Beech cockpit was 137°, which Beech pilots said allowed them to see the threshold, but the amount of runway seen was dependent on the location of the holding point from the approach end of the runway.

Interestingly, Airways had some years earlier published a circular that referred to the many contributory factors usually found in runway 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 …
>
> and
>
> A pilot holding on a rapid exit taxiway 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 [traffic] misidentification.

[1] Sidney Dekker, The Field Guide to Understanding Human Error, Ashgate, Aldershot, 2006.
[2] Federal Aviation Administration, Runway Safety Blueprint, 2002-2004, July 2002.

So the problem had been recognised, but had it been addressed?

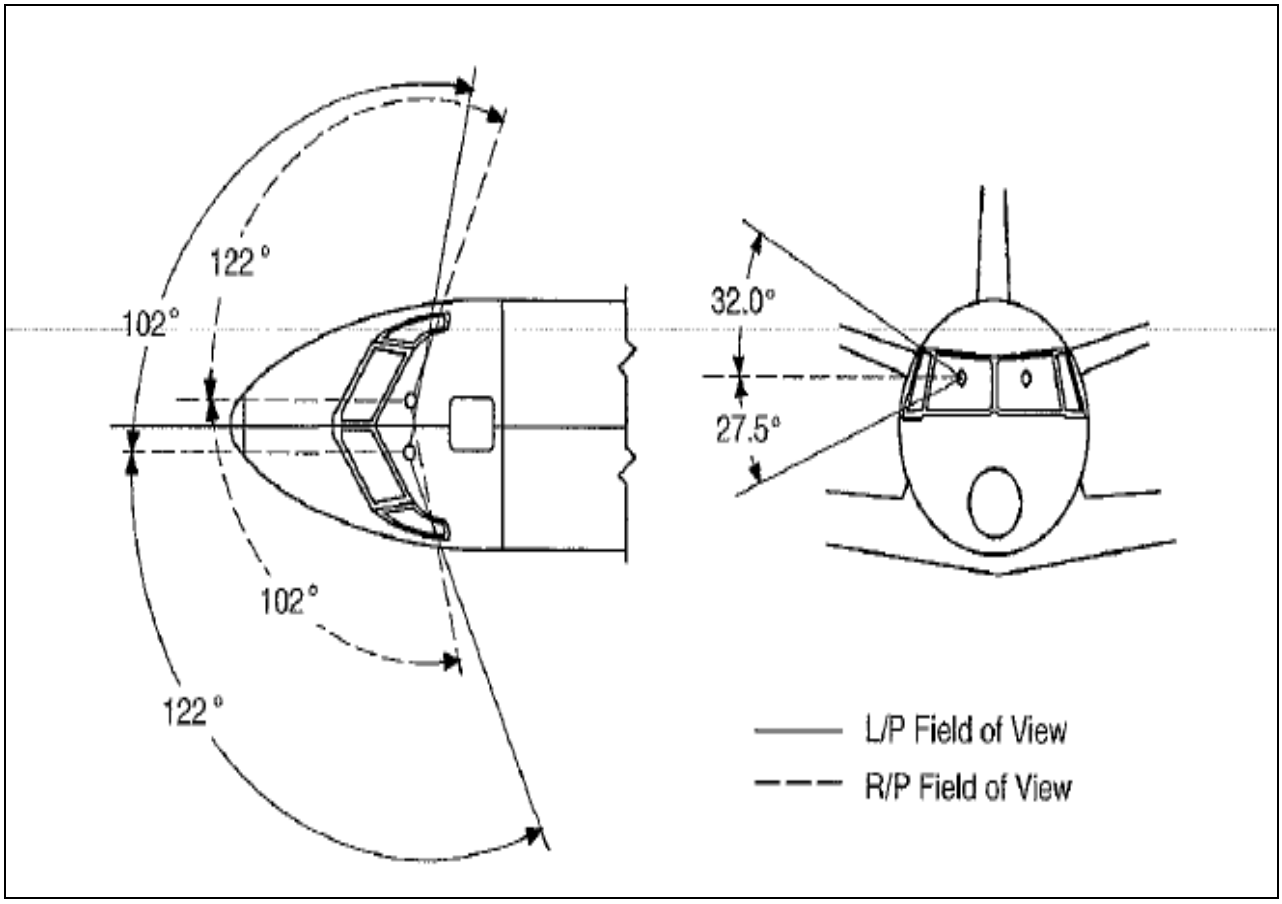

Figure 4
External vision angles from Saab pilots' seats

Radiotelephony procedures

Call sign errors are common enough, but they are usually recognised and corrected before there is an adverse result. Crossed transmissions too, are not uncommon. In the first incident, the controller attempted to correct the clearance but was blocked by the Saab crew's read-back. Including the controller's attempted correction of the clearance, there were 3 crossed transmissions during that incident. Controllers have no reliable means of intervening to stop crossed transmissions.

Do you think that the call signs Eagle 171 and Eagle 979, from the second incident, sound similar? If you knew the first one and had no prior warning of the other which was quickly transmitted, you might mistake the second for the first. The aerodrome controller did not make strict use of phonetic pronunciation of numerals. The controller listened 3 times to a replay of the recorded transmissions on the day of the incident before being sure that "979", and not "171", had been cleared to take off.

There was a crossed transmission in the second incident too, when pilots from both crews read back the take off clearance. Part of the process for the issue of an ATC clearance is for the controller to listen to the pilot's read-back so that the controller is assured that the clearance was correctly issued and received. A controller has to actively attend to a pilot's read-back and, if necessary, correct or repeat the clearance.

In this case, the controller heard the hash of a crossed transmission but did not take action to ensure the clearance had been correctly issued and received.

Data from the United Kingdom[3] 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 UK runway incursions. I am not aware of a similar study in New Zealand, but it is not surprising that the same factors were present in these AKL incidents.

Haste

The AIP had a section entitled "Minimum runway occupancy – controlled aerodromes" that 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.

This was good guidance, except perhaps for the admonition that "every second counts". Because some form of communication precedes pilots' actions on an airport, care is needed with the communication: hasty communications can be hazardous.

In the first incident at AKL, the aerodrome controller was making a normal decision in trying to fit in another departure after the landing Beech and before a following Beech. However, in haste the call sign of the aircraft that was intended to be cleared was mistaken. The wording of the line up clearance implied haste. The captain of the cleared aircraft picked up on that tone and acted accordingly. Haste led him to cross the holding point before ensuring that the runway was clear.

In the second incident, the first officer of the infringing aircraft possibly showed some impatience after the longer than usual wait before he could get in his "ready" call. Who hasn't felt that during a busy traffic situation? In rushing his transmission, he clipped the operator prefix. Haste preceded a communication error.

The controller, aware that Eagle 979 had been lined up for over 2 minutes, probably thought it was that aircraft which had called and immediately cleared it to take off. The rapidly delivered clearance was responded to by both aircraft in a similar quick fashion: by Eagle 979, because they had been waiting for more than 2 minutes and were explicitly cleared; and by Eagle 171, because, unaware that Eagle 979 was already lined up, they assumed the clearance was in response to their "ready" call and the call sign was heard by them as 171. Haste, together with poor phonetic pronunciation that is quite commonplace in New Zealand, led them to hear what they expected to hear.

Use of flight progress strips

When an aircraft is instructed to call Tower, control of the aircraft passes from the ground controller to the aerodrome controller. At the same time, the ground controller passes the flight progress strip for that aircraft to the aerodrome controller. Because there was only one strip per flight, an aerodrome controller could get little advance notice of departures, compared with a minimum of 10 minutes' notice for an arrival.

[3] 2005 data from United Kingdom National Air Traffic Services, DVD "Communication Error" (2006).

As the transfer usually was not made until the aircraft was approaching the holding point, the aerodrome controller might have little time to assimilate the flight details and pilots too could have little time to listen on Tower frequency and build a picture of what was going on. The available time would depend on the movement rate. Not all controllers would agree with this finding. They could point to the frequent verbal information sharing that takes place between controllers and which offsets any reduced time to peruse the strips.

Airways have developed an electronic flight strip system presently undergoing operational trial. 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.

Conditional ATC clearances

Although neither of the AKL incidents involved a conditional line-up clearance, they pointed to a safety issue with such clearances when angled taxiways are involved.

The Manual of Air Traffic Services states[4] 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

and the Aeronautical Information Publication New Zealand[5] similarly states:

> 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]
> Conditional clearances require the pilot of the aircraft receiving the clearance to identify the aircraft … causing the condition.

Neither publication explicitly states that a pilot has to positively identify the conditional traffic before accepting the conditional clearance. Incidents have occurred where pilots accepted a conditional clearance before they had identified the subject traffic but had an expectation of confirming the identification before entering the runway. When they then misidentified the subject traffic, a runway incursion resulted.

Airways had advised its controllers, in regard to conditional clearances, that:

> … 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.

In 2004 at Munich airport, there was a night time incursion almost identical to one that occurred during day time at AKL 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

[4] MATS, chapter RAC4, section 7.1.1.
[5] Aeronautical Information Publication, page AD 1.5-11 and 13.

conditional line-up clearance. The Munich investigation[6] noted that the crew of the infringing aircraft could not see the final approach sector from their holding position on an angled taxiway and could not identify the arriving aircraft.

Subsequently, the German ATC provider banned conditional clearances in conjunction with angled taxiway departures. Their procedures for conditional clearances were amended to require controllers to instruct pilots to report "traffic in sight" before issuing the clearance.

Since these incidents, some controllers have suggested that the May 2007 incursion would have been prevented if a conditional line up clearance had been issued. That belief discounts the risk of misidentification that is present when angled taxiways and multiple runway entry points are used, as was demonstrated at AKL in 2003 and Munich in 2004. Unless the subject traffic is identified prior to accepting the conditional clearance, misidentification remains a risk and a runway incursion is a real possibility.

Appreciation of the threat

The CAA had no definition for *runway incursion* and did not show it as an incident type on its incident reporting form, yet the CAA safety database did have *runway incursion* as a specific type of aerodrome incident.

It was probably not surprising that there was a lack of consistency in the logging of incidents as runway incursions, and that the CAA did not routinely produce data on runway incursions. A search of their database found over 500 airspace incidents over the 15 years prior to August 2007 that, judging from the text or event descriptor, met the ICAO definition. Of those, 54 had occurred at AKL. Because they had been recorded as airspace incidents rather than aerodrome incidents, none had been encoded *runway incursion*. In the same 15-year period, there were another 2 aerodrome incidents (not those that were the subject of TAIC report 07-005) that also met the ICAO definition.

This number of runway incursions was a surprise. Because the descriptive text of those incidents was of variable quality, their severity was not assessed, but the majority did not involve a risk of aircraft collision.

The report 07-005, by the way, although recommending that the CAA adopt the ICAO Runway Incursion Severity Classification model, did not determine the severity of the 2 incidents. It was later determined that there had been one each of severities A and B.

Investigation of incursions

One reason for the lack of awareness of the incidence of runway incursions in New Zealand was the Civil Aviation Rules requirement for certificated organisations 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". This rule can lead to the involved parties conducting separate investigations, if they do investigate, from isolated standpoints.

For example, Airways has an internal procedure to consider their involvement in an incident. If it is determined that the incident was primarily due to another party, Airways advises the CAA of that finding, and Airways might not actively pursue further understanding of other contributory factors. The other parties in the incident may or may not provide accurate findings to the CAA regarding their involvement.

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

At airports where Airways is contracted to provide air traffic services, a runway incident would likely be seen as an airspace incident rather than an aerodrome issue and would be notified by ATC staff to the CAA. In many cases, the airport operator may not be aware that an incident has occurred, which means little or no consideration would be given to whether airport factors, such as taxiway layout, were involved.

Fortunately, in many of the more significant incidents, airlines and the air traffic services provider cooperate to produce satisfactory findings. Otherwise, determination of the true facts and causes, and identifying appropriate corrective action, is left to the CAA that must meld the separate investigation reports. Effective corrective action could be unlikely if a party responsible for mitigating a particular risk was not aware of other relevant incidents or related contributing factors. Even so, in some cases, one party, often the air traffic services provider, will be best placed to take effective corrective or preventative action.

To avoid such deficiencies, serious incidents and accidents should be investigated by the national independent investigation agency, such as TAIC. Lesser incidents should be referred to a local runway safety team, as ICAO advocates, for resolution.

Interaction of contributory factors

Although the final defence, that of the pilot seeing that the runway was occupied, failed in each of these AKL incidents, they were not simply cases of poor lookout. Any one of the factors above could have led to an incursion, or it may have taken some to be present in combination. The interactions between factors were important to consider.

Some were obvious: for example, the taxiway layout and the reduced vision from the Saab cockpit. That observation led to the investigation examining the acceptability of conditional clearances under such conditions.

Consider RTF procedures. Crossed transmissions and similar call signs are persistent and significant threats to air safety. If RTF procedures are lax, the risk of an incident is raised considerably if any other factor is present; and another one usually is.

If a controller misidentifies the aircraft that is intended to be cleared, an incident can be avoided if the clearance is correctly read back (by the unintended aircraft) and heard by the controller (to give an opportunity to cancel the clearance). As long as the pilot ensures the runway and approach are clear before crossing the holding point, and there is no rush to move, an incorrectly issued clearance should be a non-event. To eliminate the initial error though, none of the other factors can be present.

Technological solutions for the runway incursion problem

There is no technological tool available today that can recognise and reverse the sort of communication error or misidentification of traffic that often precedes an incursion. Good RTF discipline remains essential, and adherence to basic airmanship (definition?) and actively building situational awareness go a long way to preventing incursions.

The types of tools that are now available, and used in the USA especially, were summarized in the paper prepared by John Guselli and the ISASI air traffic services group and presented at the ISASI annual seminar in Singapore in 2007. Those tools include specialized taxiway and PAPI lighting systems and various radar and transponder-based systems. ADS-B has been demonstrated to provide adequate

warning of an impending runway incursion, regardless of which aircraft precipitated the situation.[7]

Aircraft on-board systems, such as the Electronic Flight Bag, utilised GNSS to help pilots confirm their position on an airport. Getting lost close to the active runway was an occasional problem at Sydney, but had not been an issue to date in New Zealand.

What safety action was taken?

The TAIC investigation into the AKL runway incursions in 2007 made safety recommendations to the Director of Civil Aviation of New Zealand 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.

Conclusion

This was an investigation of serious incidents that contained the seeds of accidents. As ICAO envisaged, the investigation provided a cheap lesson. It confirmed that multiple factors are likely to be present in any incursion, and showed that those factors need to be identified and their interactions considered.

We are often reminded that data is needed if we are to understand what is really happening with any particular issue. Participants in the aviation safety system have to use common and well-specified definitions for the various issues, and report and investigate to the same standards. In regard to the runway incursion threat, under the current rules in New Zealand, investigation findings sent to the CAA should be analysed in a consistent manner, if the threat factors are to be properly identified and eliminated.

[7] Reported in Aviation Week and Space Technology magazine, 6 November 2006. http://www.l-3com.com/supportfiles/1-18728457Eprint.pdf.