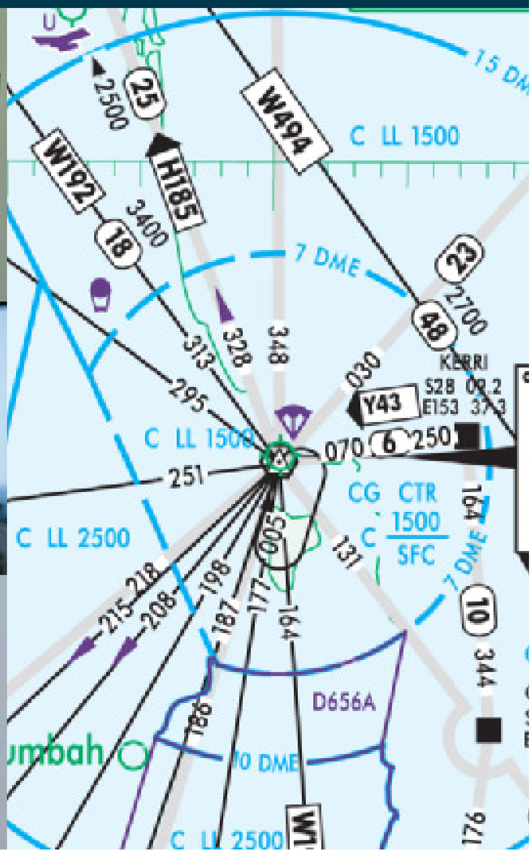
Australian Government
Australian Transport Safety Bureau

Loss of separation between aircraft in Australian airspace

January 2008 to June 2012



Research

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Safety summary

Why the ATSB is doing this research

One of the main objectives of air traffic services (ATS) is to prevent the collision of aircraft. Aircraft separation standards are set to ensure that the chance of a mid-air collision is very remote. When they are infringed, there are fewer defences left to guard against a mid-air collision. This ATSB research investigation looks at loss of separation (LOS) incidents in Australian airspace to understand how often they occur and in what contexts, how and why they are occurring, and whether there are any wider implications that the air traffic system is not functioning appropriately.

What the ATSB found

Although there had been an increase in the number of occurrences reported to the ATSB over the 2 years ending in June 2012, there were fewer LOS occurrences during that period than during 2005 to 2008. Traffic levels have generally increased during the same period. A LOS between aircraft under air traffic control jurisdiction happens on average about once every 3 days. In almost 90 per cent of LOS occurrences, there was no or minimal risk of aircraft colliding. On average, however, there are six occurrences per year where an elevated risk of collision exists. There have been no mid-air collisions in Australia between two aircraft under ATS control.

The investigation found that military controlled terminal area airspace in general, and all airspace around Darwin and Williamtown in particular, had a disproportionate rate of LOS (for civilian aircraft). Most of these LOS occurrences were contributed to by air traffic controller actions. This may be a result of the nature of aircraft operations and airspace constraints at some military airports, leading to reduced use and effectiveness of strategic separation defences, thereby placing more responsibility for separating aircraft directly onto the controllers. Furthermore, as military ATS are not subject to safety oversight by the Civil Aviation Safety Authority (CASA), there is no independent assessment and assurance as to the safety of civilian aircraft operations at military airports.

In civil airspace, LOS occurrences attributable to pilot actions are not monitored as a measure of airspace safety nor actively investigated for insight into possible improvements to air traffic service provision. As about half of all LOS incidents are from pilot actions, not all available information is being fully used to assure the safety of civilian airspace.

What's been done as a result

The ATSB has issued recommendations to the Department of Defence to review all processes and controls in place for aircraft separation in military ATS and to CASA to review whether its current level of involvement with military ATS is sufficient to assure the safety of civil aircraft operations. The ATSB also recommends using all available information, including pilot attributable LOS occurrences, to assure the safety of civilian airspace, and will itself investigate all serious LOS incidents.

Safety message

Aircraft separation is a complex operation with many levels of defences to avoid errors and to safely manage the results of the errors that will inevitably be made from time to time by air traffic controllers and pilots. The defences ensure that even if a LOS does occur, the chance of an aircraft collision is still very remote. Safety could be enhanced through understanding and addressing the reasons for the disproportionate rate of LOS occurrences involving civil aircraft in military airspace, and through the ongoing monitoring and investigation of all LOS incidents in civil airspace.

Executive summary

Context

One of the main objectives of air traffic services (ATS) is the prevention of collisions between aircraft. In controlled airspace, aircraft separation standards are one element of a defences-in-depth approach to avoid collisions between aircraft. There are several controls that take effect before the physical application of a separation standard, such as airspace designed to keep aircraft apart, air traffic flow and capacity management procedures and traffic synchronisation including multi-sector planning for arrival and departure sequences. Air traffic controllers then apply pre-defined separation standards to keep aircraft apart by actively instructing aircraft when, where and at what speed they can operate. If the separation standard is infringed, several controls normally remain in place before a collision can occur. This includes computerised alerts such as short-term conflict alerts and monitoring and detection by controllers in the ATS environment, traffic collision avoidance systems in the aircraft and visual 'see and avoid' by pilots. Arguably, the most important defence against a mid-air collision when a separation standard is lost is the air traffic controller, who is trained and experienced at resolving such situations.

This ATSB research investigation reviewed and analysed loss of separation (LOS) occurrences between aircraft in controlled airspace between 2008 and June 2012 with the objectives to:

- understand how often they occur and in what contexts, and whether their frequency is changing
- understand how and why they are occurring, and whether there are any wider implications that the air traffic system is not functioning appropriately.

This was achieved through understanding how LOS occurrences are recorded and reviewed by Australia's two air navigation service providers (ANSPs), Airservices Australia (civil airspace) and Department of Defence (military airspace), and a review of occurrence data from reports to the ATSB, the contributing factors coded for all reported occurrences, ATSB investigations, and confidential reports to the ATSB of concerns about air traffic services.

Background

The majority of controlled airspace is under the jurisdiction of Airservices Australia. Airservices controls virtually all of the en route airspace, and tower and terminal area (approach and departures) control at most major and regional, and all metropolitan airports. The Department of Defence provides tower and terminal area control services at a number of military controlled aerodromes that permit civilian aircraft movements (for example Williamtown). Military controllers also provide air traffic services at the 'Joint User' airports of Darwin and Townsville which mostly cater for civil aircraft movements.

The Civil Aviation Safety Regulation (CASR) Part 172 (Air Traffic Service Providers) sets out the rules for ATS providers in Australia, but does not apply to any air traffic service provided by the Defence Force. Part 172, and the associated Manual of Standards, requires ANSPs to maintain and operate in accordance with an operations manual that complies with the Manual of Standards. Airservices and the Department of Defence share ownership of this operations manual, the Manual of Air Traffic Services (MATS).

MATS specifies policy and procedures for keeping aircraft separated and avoiding collisions. Although controller procedures should be equivalent in the two organisations, the Department of Defence reported that, due to the degree of flexibility required for military operations, and the nature of the traffic flows and mix in military airspace, military ATS does not normally employ strategic separation mechanisms, and when it does, their efficiency is limited. It is therefore probable that there is a greater reliance on controller initiated tactical separation decisions in military controlled airspace than in civil airspace. In addition, although the Civil Aviation Safety

Authority (CASA) has an oversight of Airservices' compliance with MATS and CASR Part 172, CASA does not have a regulatory oversight role of ATS provided by the Department of Defence. The Department of Defence has an internal 'Defence Aviation Safety Program' that formally assesses operational and technical airworthiness. This program includes consideration of 'Aviation Support Systems', which include air traffic control., CASA and Department of Defence have an agreement that aims to align regulatory outcomes and allows for the invitation of CASA staff to participate and provide guidance in internal, routine operational evaluations of the individual ATC units conducted by military air traffic control headquarters staff.

Both the air traffic controller and the pilots of aircraft under the controller's jurisdiction have responsibilities for maintaining separation, and errors by either or both can lead to a loss of the separation standard. However, through the ATS system, it is the controller that is provided with the bigger picture of the positions and proximity between all aircraft in their airspace, and who therefore has accountability for keeping those aircraft apart. Although *ATS safety performance* is often measured by counting only those LOS occurrences deemed to be attributable to ATC, this approach gives only part of the story, as occurrences that were triggered by a pilot error or violation are not counted. In many cases, they may have been avoided or their consequences (how much separation remained) made less serious through better monitoring, detection and action by ATC.

Both Airservices Australia and the Department of Defence keep their own occurrence databases and conduct data analysis for internal safety management purposes. Each organisation also conducts internal investigations of either all LOS occurrences (Department of Defence) or some of the ATS-attributable LOS occurrences (Airservices).

Airservices Australia shares and benchmarks with civil ANSPs in other countries key performance indicators of ATS-attributable LOS occurrences as a rate per hours flown and movements. The ATSB was not made aware of any similar benchmarking conducted by the Department of Defence. Data produced by CANSO (Civil Air Navigation Services Organisation) shows that loss of separation occurrence rates attributable to Australia's civil ATS are among the lowest in the comparison groups. Internal analysis and monitoring of LOS occurrences by Airservices for itself and the aviation regulator also only measure ATS-attributable LOS occurrences.

Occurrences

A loss of separation (LOS) between aircraft under air traffic control jurisdiction happens about once every 3 days. Although standards are designed to ensure aircraft remain separated, a LOS does not normally indicate that there was a near-collision between aircraft – in almost 90 per cent of LOS occurrences, there was no or a low risk of aircraft colliding. There have been no mid-air collisions in Australia between two aircraft under ATS control receiving a separation service. On average, there are 6 occurrences per year where an elevated risk of collision existed (where an evasive manoeuvre was taken, or where the aircraft passed but evasive action should have been taken to ensure there was no chance of a collision).

Aircraft separation is a complex operation with many levels of defences to ensure that even if a LOS occurs, the chance of a collision remains very remote. The analyses in this report have shown that losses of separation occur across all controlled airspace types and types of separation standards, involve mostly aeroplanes (but of all types of operations, from large jet airliners to general aviation aircraft), and involve errors by both controllers and pilots. Although there are some areas, set out below, where future attention may be focussed to enhance safety, the evidence available from a range of sources does not indicate fundamental deficiencies in the safety management of aircraft separation in Australia.

The number of LOS occurrences has varied across recent years. Although there was an increase in the number of occurrences reported to the ATSB over the 2 years to the end of 2012, there were fewer LOS occurrences happening in that period than there were 5 years previously, while traffic levels generally increased over the period considered in this report. While continuation of an upward trend would give increasing cause for concern, the numbers of occurrences reported at the time of writing are within the range of historical experience and comparable with those of the best-performing international counterparts[1].

The civil ANSP, Airservices Australia, controls most of Australia's controlled airspace, including nearly all of the en route airspace. This explains the fact that most (80%) LOS occurrences occur in airspace managed by Airservices Australia. Although the number of aircraft movements at military aerodromes is relatively low (compared with aerodromes of similar size and airspace class), the 20 per cent of reported LOS occurrences (involving civilian aircraft) that occurred under military ATS control is relatively high considering the overall number of movements. The Department of Defence have reported that they believe this is because the military does not normally employ strategic separation mechanisms such as long range flow control or traffic management plans, as these mechanisms do not allow the required degree of flexibility in service provision that military operations and training require. They also reported that some military airspace is confined and adds to the complexity of operations, and that there is a greater diversity of aircraft using military aerodromes, which in combination severely limit opportunities to segregate incompatible traffic flows. This places more of the responsibility for separation on individual controllers. That said, the factors behind these occurrences suggest that this is an area where efforts could be focused to reduce LOS occurrences, noting in particular that the number of military aircraft movements at the joint-user airports (Darwin and Townsville) are very low (6% and 12% respectively), and that most LOS occurrences at these airports are between two civil aircraft.

Of the three areas of air traffic control (en route, terminal control area (approach and departures), and tower environment), the terminal control area poses the largest risk to safety taking into account the overall number of occurrences, aircraft capacity of the aircraft involved, and the risk of collision. Military ATS are responsible for about 25 per cent of the aircraft movements in terminal areas, but were involved in 36 per cent of LOS occurrences in terminal areas. En route air traffic control (ATC), despite having lower numbers of LOS occurrences than the tower environment, poses the next highest risk.

Terminal control area

The capital city airports have the highest number of occurrences, especially Sydney and Darwin. The highest total risk (in terms of both number of occurrences, and the collision risk and capacity of the aircraft for those occurrences) lies with Sydney and Melbourne due to the high volume of airline traffic, but military-controlled terminal areas were over-represented in occurrences per aircraft movement, especially Darwin, Williamtown, Amberley, and Townsville. While these locations mostly involved minimal or nil collision risk occurrences (Darwin, Townsville, Williamtown), or low numbers of occurrences or movements (Amberley), 5 of the 11 elevated collision risk occurrences in the terminal area involved military ATS controlling general aviation aircraft (Amberley, East Sale, Edinburgh) or high capacity air transport aircraft (Williamtown).

Most occurrences in the terminal control area involved an infringement of surveillance standards as most terminal control areas are covered by radar. In about a third of occurrences, ATC had not detected the compromised separation before the LOS occurred. Aircraft on crossing tracks accounted for most of the LOS occurrences where the distance remaining between the aircraft was smallest. Six occurrences in the terminal area were rated as very high risk due to an elevated collision risk involving large passenger transport aircraft, two in Sydney, two in Melbourne/Essendon, one in Brisbane, and one in Williamtown.

En route airspace

In the en route environment, more occurrences (64%) related to procedural separation loss. Procedural LOS occurrences, relative to surveillance-based losses, were more likely not to have

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1 A provisional analysis of the data from January to June 2013 indicates that the upward trend has ceased and may now be decreasing.

been previously detected (nearly half), and more of these resulted in an elevated or some collision risk. This may be related, in part, to the lack of a short term conflict alert (STCA) for controllers in the procedural environment to help detect aircraft separation issues both before and after a LOS has occurred. For losses of procedural separation, aircraft on crossing and converging tracks were more likely to have an elevated collision risk. Also notable was the large number of procedural losses that occurred between aircraft flying at the same level.

The upper airspace in en route procedural control is changing more towards surveillance-based separation as more aircraft are equipped with automatic dependent surveillance (ADS-B and ADS-C) avionics equipment, and this will be mandatory for all aircraft flying above FL 290 from 12 December 2013.[2] However, although only 36 per cent of LOS occurrences involved surveillance based standards, three of the five elevated collision risk occurrences in en route airspace were surveillance-based losses. Four occurrences in the en route environment were rated as very high risk due to an elevated collision risk involving large passenger transport aircraft (two involving procedural separation, two involving surveillance-based separation).

Tower environment

Losses of separation involving aircraft under ATC tower jurisdiction were equally prevalent in class C and class D airspace[3]. About a third happened at capital city airports, mostly involving a conflict between two high capacity aircraft or a high capacity and a general aviation aircraft. Another third were at metropolitan class D airports, in particular, Moorabbin and Bankstown Airports. Separation losses at these airports usually involved only general aviation aircraft, were a loss of runway separation, and were due to pilot actions alone. These two airports also accounted for most of the LOS occurrences with elevated or some collision risk that happened under tower control, and Moorabbin posed the greatest overall risk of any towered airport (due to the combination of the large number of occurrences, a large number of movements, and numerous occurrences with elevated or some collision risk).

Non-capital city class C airports accounted for one-sixth of tower LOS occurrences, while regional class D airports accounted for the remaining sixth. Both had a significant proportion of occurrences involving general aviation and/or high capacity aircraft. Regional airports generally had relatively higher rates of occurrences per aircraft movement, as did Darwin and Williamtown (both class C airports).

Apart from Moorabbin (which was by far the highest risk aerodrome for tower ATS separation losses), other towered airports with a high overall risk (in terms of both number of occurrences, and the collision risk and capacity of the aircraft for those occurrences) were Melbourne, Darwin and Bankstown, and to a lesser extent, Williamtown and Mackay.

While 60 per cent of occurrences under tower control involved a loss of runway separation, this increased to 91 per cent at the metropolitan class D airports where most aircraft are general aviation and operating under visual flight rules (VFR). Half of all tower-controlled LOS occurrences were a loss of runway separation at a class C airport, but only a quarter were at regional class D airports. In runway LOS occurrences, aircraft separation was reduced to the smallest margins when the aircraft were on crossing tracks, usually while one aircraft was taxiing. More than half of those 'close calls' were not detected before the LOS.

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2 See http://www.airservicesaustralia.com/projects/ads-b/upper-airspace-mandate-2013.

3 While instrument flight rules (IFR) aircraft receive a separation service in both class C and D airspace, visual flight rules (VFR) aircraft only receive separation from IFR aircraft in class C airspace. All aircraft receive runway separation. See *Separation service provided by airspace class* in the main report on page 10.

Contributing factors and issues

About half of the LOS occurrences in this study were related to actions by the air traffic controller, and about half were related to pilot actions. In 9 per cent of cases, actions by both the controller and pilot contributed to the LOS.

Controllers contributed to fewer occurrences in en route airspace. At class C airports, controller actions were more likely to precede the LOS, but occurrences happening under civil ATC jurisdiction were twice more likely to be associated with pilot actions than those under a military ATS, where three quarters of occurrences were related to controller actions. In class D terminal area and tower environments (controlled by the civil ANSP, Airservices Australia), pilot actions contributed to nearly three quarters of all LOS occurrences. For metropolitan class D airports, most occurrences were due to pilot actions only (100 per cent of LOS occurrences reported at Moorabbin). At regional class D airports, it was about half and half.

Of all the standard types, controller and pilot actions were equally likely to have contributed to the LOS, except for wake turbulence separation losses, where most occurrences were a result of controller actions.

The contribution of air traffic services actions, as a rate per aircraft movement, were disproportionally high for some terminal areas where the military ANSP (Department of Defence) provides ATS, especially Darwin and Williamtown, and with lower overall numbers at Tindal and Amberley. As noted above, the Department of Defence have reported that this is reflective of military ATS employing reduced strategic separation measures and having an increased reliance on controllers to assure separation through tactical measures. Terminal area occurrences with contributing controller actions were also high at Adelaide Airport. Under tower control, LOS occurrences due to controller actions were disproportionately higher at the military controlled Darwin and Williamtown Airports, and at the civil controlled Karratha and Broome Airports (although the number of occurrences reported at the latter two was low).

Common occurrence events preceding a LOS were pilots failing to comply with ATS instructions (especially while under en route control), violations of controlled airspace in the terminal area, missed approaches, and runway incursions. Most pilot errors identified involved inadequate monitoring and checking, and to a lesser extent, inadequate communication.

Controller actions and conditions

Contributing controller actions were most commonly assessing and planning errors (50% of these occurrences) or monitoring and checking errors (50% of these occurrences). In a quarter of occurrences, poor communication of information to pilots was a factor. High workload was by far the most common factor contributing to controller errors found. This was the case in all ATC environments, but was especially prevalent in the tower environment. Other conditions preceding controller errors to a lesser extent included (in decreasing order) distractions, poor procedures, insufficient knowledge, skills or experience, issues with training, fatigue, and display issues.

High workload conditions and related issues were also discovered through a review of ATSB investigations of occurrences where separation was lost, or was not assured. The review of ATSB investigations also found a number of cases where a combination of staff resourcing issues and low controller experience resulted in high workload due to controlling combined sectors or issues with on the job training. While a number of these investigations are ongoing at the time of writing this report, and more detailed findings and associated safety actions will be included in those reports when published, most of these issues are consistent with some of those identified in the Civil Aviation Safety Authority's *Review of CASR Part 172 Air Traffic Service Approval of Airservices Australia,* which was finalised in January 2013. To that end, noting that Airservices has responded to the review with what CASA considers a 'responsive and appropriate' action plan, it is likely that resolution of the ATSB identified issues will either be in place or in progress by the time of publication of the ATSB investigation reports. However, any additional or specific safety action relating to the ATSB identified issues will be included in those reports.

The review of confidential reports to the ATSB through the REPCON scheme also uncovered similar themes to occurrences and investigations in the contributing factors to a LOS – poor communication with pilots, procedures, training, and fatigue. It also uncovered reported concerns that were not evident in the occurrence data or across investigations. These included cases where instructions to pilots from ATS were considered inadequate or challenging. As most occurrence reports come from air traffic controllers and not from the pilots involved, such instructions are unlikely to have been reported to the ATSB with individual occurrence records. However, it is possible that such instructions contribute to pilots failing to comply with ATC instructions and not meeting performance expectations – both of which were found to precede many losses of separation. Other issues reported through REPCON involved a lack of risk assessments and staff shortages impacting on the quality and safety perception of civil ATS.

Safety analysis & findings

Although maintaining aircraft separation is an important defence against collisions, losses of separation are expected to occur from time to time, and the detection and correction of these losses form an important control against aircraft collisions. However, although it is desirable to reduce the frequency and resultant collision risk of *all* LOS occurrences across Australia, the above analysis suggests there are some specific areas where future attention should be focussed to enhance safety.

Military ATS were involved in a disproportionate number of loss of separation occurrences involving civilian aircraft in terminal area airspace relative to the amount of traffic they control. This was the case with both the number of occurrences in total and with elevated collision risk. Darwin and Williamtown in particular were over-represented in both the terminal area and tower environment. Air traffic controller actions contributed to more of these occurrences than was the case for occurrences at civil ATS locations. Confined airspace and more general aviation traffic may account for some of the increased risk seen in some military airspace. However, it was also reported that military ATS do not normally employ strategic separation mechanisms such as long range flow control or traffic management plans and as a result, military ATS has an increased reliance on controllers to assure separation through tactical measures. It is probable that this increased reliance on military air traffic controllers at all locations, in addition to confined airspace and variation of traffic mix at some locations, has led to the disproportionate risk of loss of separation seen in this investigation.

The Department of Defence and Airservices Australia both have internal processes for auditing and safety oversight of their ATS functions. Unlike Airservices Australia, the ATS provided by the Department of Defence does not have an independent and external regulatory scrutiny of its compliance with MATS or a general monitoring of safety in relation to civilian aircraft navigation services provided. The Department of Defence has an internal ‘Defence Aviation Safety Program’ that formally assesses operational and technical airworthiness. This program includes consideration of ‘Aviation Support Systems’, which include air traffic control. Under an agreement with CASA, CASA can and does participate by invitation and provide guidance and advice in internal Defence operational evaluations of individual units by ATC headquarters staff. The findings of this ATSB research investigation suggest that a reliance on Defence sharing the same ATS operations manual as Airservices and internal auditing and oversight, including involvement, guidance and advice by CASA, will not guarantee an equivalent level of safety is provided to civilian aircraft operating into and out of Defence operated aerodromes as for civilian aerodromes. Some military aerodromes, such as Darwin and Townsville, are primarily used for civilian traffic and some, such as Williamtown (Newcastle), act as an important regional airport for regular public transport and the evidence indicates that those civil aircraft are exposed to a higher level of risk compared with equivalent civilian-operated airports. At present, there is no comprehensive and independent assessment of the levels of safety and compliance with respect to civil aircraft operations at these airports and no transparency for industry with respect to any differences in the levels of service provided or safety afforded. Given that the safety of the travelling public is a primary function of CASA, it would seem that some level of independent assessment and assurance as to the safety of civil aircraft operations at DoD airports by CASA is warranted.

Both Australian ANSPs have a responsibility for monitoring the level of safety associated with managing the airspace they are responsible for. To measure aircraft separation safety risk, all loss of separation incidents are relevant, including those which occurred solely through the actions of pilots. However, Airservices Australia does not routinely investigate any LOS occurrences that were not deemed to be attributable to ATS. Broad consideration of pilot-attributable LOS incidents is undertaken to each day for the preceding 24 hours with a view to identifying whether the ATS system was potentially causal or contributory. In addition, Airservices undertakes a number of collaborative activities with industry to share safety information and to discuss and evaluate safety performance of the ATS system. However, public monitoring of air traffic management performance, the international benchmarking with the Civil Air Navigation Services Organisation, internal safety monitoring for the Airservices Board, and LOS trend monitoring provided to the Civil Aviation Safety Authority, do not include LOS incidents that were pilot attributable. As such, while Airservices Australia puts considerable effort into monitoring and investigating ATS-attributable losses of separation, they are not fully using all available information to assure the overall risk associated with aircraft separation is appropriately being managed in civilian airspace. Furthermore, as Airservices trend monitoring and investigation findings form a major source of intelligence gathered by CASA to monitor the safety of civil airspace, opportunities for potential improvements to the aviation system that could be acted upon at the regulator level may be lost.

Several ATSB investigations (including some on-going investigations) have found resourcing of staff and rostering problems leading to ATS procedures such as combining sectors and multiple on the job instructors. In turn, these have resulted in inexperienced controllers being exposed to very high workload and complexity early in their endorsed period of employment on a particular sector/group. High workload was also found to be the most common factor contributing to controller errors across all LOS occurrences, and issues with procedures and training were also evident. Although the evidence reviewed in this research investigation suggests that the effect of resourcing issues on inexperienced controller workload is an emerging safety issue, the preliminary nature of much of this evidence (since some of the relevant ATSB occurrence investigations are not yet complete) means that firm conclusions cannot yet be drawn. These matters may be raised as safety issues in ATSB occurrence investigations scheduled for completion and release in 2013 and 2014.

Safety issues and actions

Military ATS risk and use of strategic separation

There was a disproportionate rate of loss of separation incidents which leads to a higher risk of collision in military terminal area airspace in general and all airspace around Darwin and Williamtown in particular. Furthermore, loss of separation incidents in military airspace more commonly involved contributing air traffic controller actions relative to equivalent civil airspace occurrences.

The Department of Defence advised the ATSB that:

> The Department of Defence takes all losses of separation and losses of separation assurance seriously and investigates all incidents to identify causes and areas that can be improved in order to mitigate against further occurrences. To reduce the potential for separation occurrences, Defence are reviewing the implementation of the traffic management plans at Darwin, Townsville, and Williamtown to improve the effect of strategic separation techniques. These reviews will also be used to highlight any current airspace constructs that inhibit the controller’s ability to provide optimum separation assurance. Defence has also recently published an internal capability improvement plan that focuses on increasing experience levels at Defence air traffic locations. To improve our ability to respond to potential losses of separation, Defence has enhanced the School of Air Traffic Control simulator packages to provide greater exposure to compromised separation occurrences, with the trainee being assessed on their ability to apply compromised separation recovery. Defence has also added both

> theoretical and practical assessment to local training packages regarding scanning for possible losses of separation and applying compromised separation recovery techniques when required.

The ATSB acknowledges the intended action by the Department of Defence, but considers that a broader review of Defence ATC processes and risk controls should be undertaken, including analysis of ATS-related occurrence data, training, staffing and ATS infrastructure to ensure the reasons for the disproportionate risk of loss of separation incidents, and the relative higher level of controller actions contributing to these occurrences, are well understood and any additional appropriate action can be taken to minimise future risk.

As such, the ATSB is issuing the following recommendation to the Department of Defence.

- AR-2012-034-SR-014: The Australian Transport Safety Bureau recommends that the Department of Defence undertake a review of all processes and risk controls in place to reduce both the disproportionate risk of loss of separation in military terminal area airspace in general and all airspace around Darwin and Williamtown in particular, and the relatively more common contributing air traffic controller actions.

Regulatory oversight of military air traffic services

Regulatory oversight processes for military air traffic services do not provide independent assessment and assurance as to the safety of civilian aircraft operations.

The Civil Aviation Safety Authority advised the ATSB:

> The Report appears to predicate on the assumption that CASA should have oversight authority in respect of military air traffic services when civil traffic is present. However, no evidence or arguments are presented to support this as the most appropriate option.
>
> In the past, CASA has participated in Defence surveillance of military air traffic services. We have every intention of continuing to do so in the future. The Report fails to acknowledge that activity or the effective benefits it has produced.
>
> The ATSB [draft] recommendation …. does not appear to take into consideration the benefit of joint work (such as that described in the bullet point above) that Airservices Australia (AsA), the Department of Defence (DoD) and CASA could undertake, without the need for CASA to assume formal oversight of DoD air traffic services.

The ATSB acknowledges that CASA does have a standing invitation to attend operational evaluations of military ATC units conducted by the military ANSP's auditors, and have participated and plan to continue to participate in these. Such cooperation is important, but CASA remains limited in the level of influence it has over military ATS in relation to the safety of civilian aircraft using military airspace. This ATSB investigation concluded that civilian aircraft have a disproportionate rate of loss of separation incidents which leads to a higher risk of collision in military terminal area airspace in general and all airspace around Darwin and Williamtown in particular. As the function of CASA is that of maintaining, enhancing and promoting civil aviation safety in Australia, the results of this investigation suggest that CASA’s influence is not as effective as it could be when it comes to the safety of civilian aircraft, including passenger transport aircraft, in military controlled airspace and some level of independent assessment and assurance as to the safety of civil aircraft operations at DoD airports by CASA is warranted.

As a result, the ATSB is issuing the following recommendation.

- AR-2012-034-SR-015: The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority should review the results of this report and determine whether its current level of involvement with Military air traffic services (ATS) is sufficient to assure itself that the safety of civil aircraft operations while under Military ATS control is adequate.

Using all information to monitor separation risk

Loss of separation (LOS) incidents attributable to pilot actions in civil airspace are not monitored as a measure of airspace safety nor actively investigated for insight into possible improvements to air traffic service provision. As about half of all LOS incidents are from pilot actions, not all available information is being fully used to assure the safety of civilian airspace. Airservices Australia advised the ATSB that:

> In response to the report's observation that Airservices does not actively investigate or monitor pilot-attributable LOS incidents Airservices would like to clarify that our primary focus on the investigation of ATS-attributable occurrences is to effectively prioritise our internal resources and learning effort on Airservices systems, processes and people. Airservices also actively monitors LOS incidents deemed attributable to pilot actions through the daily safety review of all incidents occurred in the last 24 hours. Consideration is given to whether the air traffic services (ATS) system was potentially causal or contributory in those incidents identified as pilot attributable.
>
> Airservices notes that non-ATS-attributable LOS occurrences are subject to the investigations by aircraft operators and the ATSB which is the lead agency responsible for conducting independent investigations of safety occurrences. Whilst Airservices is committed to continuing our existing support of the ATSB's investigations, Airservices does not have the direct legal authority for investigating non-ATS-attributable LOS occurrences.
>
> However to promote the safety of air traffic, Airservices engages in collaborative activities with industry to share safety information regarding all LOS occurrences and participate in joint investigations. Airservices has initiated a workshop with the major domestic and regional airlines to develop a protocol to enable joint Airservices I airline investigations to be conducted. This workshop is planned for 22 August 2013 in Canberra. This in effect will achieve the same outcome.
>
> Further, Airservices conducts the annual Airline Safety Forum and hosts Heads of Safety Meetings to engage industry in discussing and evaluating the safety performance of the air traffic management network. These forums include the exchange of safety performance information and data based on errors and occurrences reported under both our and the airlines' safety management system (SMS). They also inform the publication of our internal quarterly external threat assessment report on LOS occurrence trends, key systemic safety issues and actions for safety improvement.
>
> In addition an action from the most recent Airline Safety Forum is underway to conduct formal hazard/risk workshops focusing on the interfaces between the air traffic and aircraft operations. This will assist in identifying opportunities to improve the management of internal and external threats (e.g. pilot attributable factors).

The ATSB acknowledges the actions already taken by Airservices Australia and future action planned. The ATSB understands that Airservices does not have legal authority to compel pilots to be involved in investigations, but has other mechanisms available to obtain information from pilots involved in loss of separation occurrences such as voluntary and confidential surveys. In addition, the ATSB believes that the safety of civil airspace in terms of aircraft separation is not fully being monitored by current processes either within Airservices or by the Civil Aviation Safety Authority. CASA requires Airservices to regularly report trends in and internal investigations of LOS occurrences, but only those that are air traffic services-attributable.

As such, the ATSB is issuing the following recommendation.

- AR-2012-034-SR-016: The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority, in consultation with Airservices Australia and major aircraft operators, use all available information to assure the safety of civilian airspace through actively monitoring and investigating loss of separation incidents attributable to pilot actions in addition to the current focus on air traffic services-attributable occurrences.

In addition, the ATSB acknowledges that as Australia’s independent transport safety investigation agency, it has a role to investigate serious incidents, including serious LOS incidents resulting from pilot actions. Such investigations provide an opportunity to learn from others’ errors and correct any system issue identified, both in the ATS environment and in the aircraft operation environment.

Therefore, the ATSB has committed to undertaking investigations into all LOS occurrences classified as serious incidents, including those that appear to be a result of only pilot actions.

Other on-going safety action from Airservices Australia

Airservices Australia advised the ATSB that:

> Airservices continually strives to identify and mitigate the potential for loss of separation occurrences. The organisation continually examines its incident base in efforts to better understand hazards, the performance of risk controls and mitigators and then make improvements. In 2012, the organisation undertook a Normal Operating Safety Survey in its en route operations in efforts to better understand the errors and threats which controllers encounter, and how these are managed. The results were very encouraging, but also presented some opportunities for improvement which are now being actioned. Strategic interventions, such as the implementation of Automatic Dependent Surveillance-Broadcast (ADS-B), aim to both improve and expand the number of risk controls which are in place to reduce the incidence and severity of occurrence.

Contents

Context

Aircraft separation by air traffic control

The main objectives of air traffic services (ATS) include:[4]

- prevention of collisions between aircraft
- prevention of collisions between aircraft on the manoeuvring area and obstructions on that area
- to expedite and maintain an orderly flow of air traffic
- to provide advice and information useful for the safe and efficient conduct of flights.

The level of service provided by air traffic control (ATC) varies depending on airspace classifications, which are generally designated as ‘controlled’ or ‘uncontrolled’. Controlled airspace is actively monitored by air traffic controllers to ensure the safety of aircraft operating within it while allowing for an efficient flow of the generally high volume of traffic.

When providing a separation service, air traffic controllers apply separation standards to keep aircraft apart to reduce collision risk and prevent adverse effects from wake turbulence.

Typically, ATC will maintain appropriate separation between aircraft in controlled airspace by actively instructing aircraft when, where and at what speed they can operate. This includes both when aircraft are flying, and when on the ground using runways.

The responsibility for separation is shared between air traffic controllers and pilots. Generally, larger and faster aircraft flying under instrument flight rules (IFR) and operating in controlled airspace to and from major airports are subject to full ATC separation services. In contrast, more responsibility for maintaining separation lies with pilots when operating at metropolitan and regional towered airports and general aviation aircraft flying under visual flight rules (VFR). ATC may provide a traffic information service, to alert pilots that another aircraft may be in close proximity to their position or route. Although not covered in this report, separation between aircraft operating in uncontrolled airspace (non-towered aerodromes and lower level (class G) airspace) is completely the responsibility of pilots.

Separation standards exist so that air traffic services can work within defined parameters which allow efficient traffic flow while providing a safe buffer between aircraft positions. Various separation standards are used depending on the operating environment (ground or air) and level of real-time surveillance that the controller has access to. Some of these standards are based on a minimum distance between aircraft, while others are based on the flying time between two aircraft passing the same location. When the separation between two or more aircraft is less than the standard, there is a *loss of separation*.

The common element in all separation standards, however, is that while each controller will actively control aircraft to maintain the appropriate standard, there is a significant buffer between the limits of the standard and a collision to ensure the chance of a mid-air collision or a near collision between aircraft is very remote.

ATS as an error tolerant system

In all complex systems such as aviation, nuclear power, oil and gas platforms, chemical manufacturing, maritime and rail transport, the basic safety philosophy driving the design of these systems is *defences in depth*. That is, a single mistake or violation by someone operating at the ‘coal face’ should never alone lead to a high-consequence accident.

Since James Reason’s influential 1990 book *Human Error*[5], it has been widely accepted that all

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[4] From the *Manual of Air Traffic Services.*

people make errors every day. This concept of error normalisation applies equally to office workers as it does to highly trained and skilled professionals like surgeons, pilots and air traffic controllers. For pilots, on-board *line operation safety audits* run by the University of Texas[6] across several airlines have shown that, on average, 2.6 errors are made by flight crew on every flight. Similar over-the-shoulder observations of air traffic controllers during normal shifts, or *normal operations safety surveys* find similar results. Research conducted up to 2005[7] using two Australasian ATS organisations showed controllers made, on average, 2.6 errors per observation/shift.

It is widely accepted that human error can never be totally eliminated, so complex systems are built to be *error resistant*. Systems must be in place (such as cross-checks and warning systems) that capture and mitigate errors before they lead to a consequence. Although pilots and controllers may make errors while at work, most of those errors should be captured and corrected by these systems, and very few errors, even when not corrected, should lead to negative consequences.

Aircraft separation standards are just one layer in the defences in depth approach to avoiding collisions between aircraft. There are several layers of controls that take effect in place before the physical application of a separation standard, such as airspace designed to keep aircraft apart (including standard instrument departures (SIDs) and standard arrival routes (STARs) for airports), air traffic flow and capacity management, and traffic synchronisation including multi-sector planning for arrival and departure sequences. If there is a loss of separation, several controls normally remain in place before a collision can occur. In the ATS environment, computerised alerts such as short-term conflict alerts (STCA) and monitoring and detection by the controller responsible, and sometimes even their supervisor or other controllers monitoring adjacent sectors, are the most common ways in which a loss of separation is identified. On the aircraft, technology such as airborne/traffic collision avoidance systems (ACAS/TCAS), and visual 'see and avoid' by pilots are other defences against aircraft colliding if ATS defences have been ineffective.[8]

Arguably, the most important defence against a mid-air collision when a separation standard is lost is the air traffic controller. Computers are very good at monitoring and detecting (STCA and TCAS) and even giving de-conflicting instructions (TCAS). Unlike computers, however, people are apt at troubleshooting and resolving complex but novel situations. The air traffic controller is trained in and routinely uses these skills to maintain separation standards and resolve situations where standards have been inadvertently lost.

Typical scenarios

A LOS between aircraft in controlled airspace generally occurs either because of an ATC error, pilot error, a combination of controller and pilot errors, or more rarely, other issues not directly related to the controller or pilot (such as weather or a technical problem with an aircraft). There are many reasons why a LOS can occur.

Typical scenarios where ATC does not provide adequate aircraft separation are:[9]

- controller is aware of both aircraft, but makes a misjudgement
- controller is unaware of one or more aircraft
- a trainee controller is under instruction and the instructor fails to intervene appropriately when the trainee allows a potentially hazardous situation to develop

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5 Reason, J. (1990). *Human Error*. Cambridge Education Press: Cambridge, UK.

6 Eg. Merritt, A. (2006). Archie Tells All! Surprising Statistics from the LOSA Archive. From *7th International Symposium of the Australian Aviation Psychology Association*, 9-12 November 2006.

7 Henry, C. (2005) *NOSS: The Methodology and Early Findings*. Presentation given to the Third International Civil Aviation Organization (ICAO) - International Air Transport Association (IATA) LOSA &TEM conference, Kuala Lumpur, Malaysia, 13 to 14 September 2005. (Available at http://legacy.icao.int/anb/humanfactors/).

8 Skybrary (2012). *Mid-air collision*. http://www.skybrary.aero/index.php/Mid-Air_Collision.

9 Skybrary (2012) *Loss of Separation.* http://www.skybrary.aero/index.php/Loss_of_Separation.

- failure in co-ordination between airspace sectors managed by different controllers.

Pilot actions can lead to a LOS when a flight in controlled airspace deviates from a cleared track or level without clearance. This can be due to flight crew:[9]

- allowing their aircraft to enter controlled or restricted airspace without an ATC clearance
- failure to act in accordance with an ATC clearance (such as from mis-hearing a clearance)
- not maintaining the expected aircraft performance (not flying instructed or expected speeds, or rates of climb and descent) which has been the basis of a controller's flight sequence management
- equipment malfunction
- mis-setting of aircraft equipment such as altimeter barometric pressure
- mis-management of flight management system inputs, such as controlling descents, climbs, speeds, and altitudes
- avoiding a perceived (visual) loss of separation with another aircraft
- avoiding weather that could potentially be hazardous and unable to make timely contact with ATC
- failure to properly follow a TCAS resolution advisory (RA)[10], including failure to terminate the flight path or altitude deviation in a prompt manner when the RA ceases
- ineffective visual 'see and avoid' when operating VFR.

Does it matter who causes a LOS? Attributable versus contributing

Both the air traffic controller and the pilots of aircraft under the controller's jurisdiction have responsibilities for maintaining separation. However, through the ATS system, it is the controller that is provided with the bigger picture of the positions and proximity between all aircraft in their airspace, and has accountability for keeping those aircraft apart.

ATC is reliant on pilots complying with instructions given to them and not entering controlled airspace without permission. However, all complex transport operations need to be error tolerant. No matter how much effort is put into reducing pilot error, pilot error and violations will occur and can be expected to continue to occur into the future. The ATS system therefore needs to be prepared for and actively control these circumstances so that pilot error or violation does not lead to a loss of separation or worse, a mid-air collision.

A common world-wide benchmark of ATS safety performance is the rate of LOS occurrences per aircraft movement or hours flown, *counting only those occurrences deemed to be attributable to air traffic control* (see *Performance measures for LOS* below). This approach gives only part of the story, as occurrences that were triggered by a pilot error or violation (and therefore are not ATC-attributable) are not counted. In some cases, they may have been avoided or their consequences (how much separation remained) made less serious through better monitoring, detection and action by ATC.

For example, a pilot failing to comply with an ATC-issued altitude restriction (for any reason, such as avoiding sudden weather, setting the autopilot incorrectly, lack of monitoring, or a wilful violation) can lead to a separation conflict with another aircraft. Although this will often lead to a loss of separation with little or no warning, sometimes there is an opportunity for the controller to notice or be alerted to this situation with sufficient time to take remedial action. Controllers frequently intervene in these situations to provide instructions to the pilot, or manoeuvre other traffic away from the area. As a result, these errors and violations by pilots are often appropriately managed and no loss of separation occurs. These non-events are not always reported, but when

10 ACAS/TCAS is equipment fitted to an aircraft which provides the pilot with a warning of the proximity of other aircraft. A resolution advisory (RA) is a verbal and visual advisory from the TCAS system about action to be taken to avoid a collision.

a conflict resulting from a pilot action is not identified by ATC (due to insufficient monitoring from a distraction or high workload for example), and there was an opportunity for the controller to intervene, then it can be said that controller (in)action *contributed* to the loss of separation in addition to the pilot error/violation.

It is for this reason that all LOS occurrences are an important measure of ATC's ability to maintain separation standards, and not just those LOS occurrences that were a result of controller error. As such, this research investigation will look at *all* LOS occurrences – including those primarily from pilot actions, and those primarily from controller actions – and use the total occurrence rate as a measure of ATS effectiveness of controlling aircraft separation in Australia. When looking at pilot and controller actions involved in LOS occurrences, this research investigation will use the measure of *(in)actions contributing to the loss of separation*, rather than apportioning responsibility to either pilot or controller action alone.

Mid-air collisions while controlled by ATC

Although there have been 84 mid-air collisions recorded in Australia since 1969, there have been no mid-air collisions between aircraft in Australia which were being separated by ATC.

Worldwide, the commercial jet fleet has experienced two fatal mid-air collisions for the 10 years 2002 to 2011.[11] Both of these accidents involved high capacity air transport aircraft flying at cruise altitudes. While both involved a complex but unique chain of events leading to the accident, each also involved issues with a last line of defence for a mid-air collision – the TCAS warning.[12]

Objectives

This research investigation will document loss of separation occurrences under the control of Australian Air Navigation Services Providers (ANSPs). One objective is to understand how often they occur and in what contexts, and whether their frequency is changing. Another objective is to understand how and why they are occurring, and whether there are any wider implications that the air traffic system is not functioning appropriately.

To achieve these objectives, this research investigation will document how LOS occurrences are recorded and reviewed by Australia's two ANSPs (Airservices Australia and Department of Defence), and will analyse and present data from a number of sources. These include:

- occurrence data from reports to the ATSB
- contributing factors coded for all reported occurrences
- ATSB investigations
- confidential reports to the ATSB of concerns about air traffic services.

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11 Boeing (2012). *Statistical Summary of Commercial Jet Airplane Accidents Worldwide Operations 1959 – 2011*.

12 In the 29 September 2006 collision in Brazil between an Embraer Legacy 600 business jet and a Boeing 737, the TCAS did not activate due to the transponder on one of the aircraft inadvertently not being activated. In the collision above Überlingen, Germany on 1 July 2002 between a Tupolev Tu-154M and a Boeing 757, the crew of one aircraft continued to follow an ATS instruction to descend when their TCAS system instructed them to climb.

Background

ATS in Australia

In Australia, there are two main Air Navigation Services Providers (ANSPs). The majority of controlled airspace is under the jurisdiction of Australia's civil ANSP, Airservices Australia. Airservices controls virtually all of the en route airspace, most major and regional, and all metropolitan, terminal area airspace and tower controlled airspace in and over Australia.

The other ANSP is the Department of Defence. The Department of Defence provides tower and approach control services at a number of Australian Defence Force bases with aerodrome facilities. They also control many Restricted Areas of airspace. Although their prime function is to provide a capability for controlling military aircraft, some military controlled aerodromes permit civilian aircraft movements (for example Williamtown). Military controllers provide air traffic services at the 'Joint User' airports of Darwin and Townsville for all civil and military aircraft movements. Civilian aircraft in en route airspace also transit Restricted Areas under military control.

Authority to be an air traffic service provider

The *Civil Aviation Act 1988* states that the Governor-General may make regulations, consistent with the Act, for '…the planning, construction, establishment, maintenance, operation and use of air route and airway facilities [including air traffic control services and facilities]…'.

One of those regulations is the Civil Aviation Safety Regulation (CASR) Part 172 (Air Traffic Service Providers), which applies to any Australian ATS provider and sets out certain administrative rules. However, Part 172 does not apply to any air traffic service provided by the Defence Force.

CASR Part 172 includes provision for CASA to issue a Manual of Standards (MOS) for Part 172 that provides:

> (a) standards, including procedures, systems and documents used to provide an air traffic service;
>
> (b) standards for facilities and equipment used to provide an air traffic service;
>
> (c) standards for the training and checking of an ATS provider's personnel;
>
> (d) any matter required or permitted by these Regulations to be provided for by the Manual of Standards;
>
> (e) any matter necessary or convenient to be provided for the effective operation of this Part

Part 172 also requires ANSPs to maintain an operations manual that complies with the MOS, and ensure that air traffic services provided are in accordance with the MOS.

For both Airservices Australia and the Department of Defence, this operations manual is the *Manual of Air Traffic Services* (MATS). The MATS is a joint publication between Airservices Australia and the Department of Defence. This provides a single operations manual for both ANSPs. Therefore, each ANSP should provide the same air traffic service and level of safety to civil aircraft.

Both Airservices Australia and the Department of Defence have internal auditing processes and safety oversight of their ATS functions that are independent of their operational units. These processes are designed to ensure that the organisations are operating as per their procedures and safety management systems, and are also used to identify areas for improvement.

Australia's independent aviation regulator, the Civil Aviation Safety Authority (CASA), has the function of maintaining, enhancing and promoting civil aviation safety.[13] As part of its oversight of

[13] Australian Government (2011) *Australia's state aviation safety program*. Available from http://www.infrastructure.gov.au/aviation/safety/ssp/index.aspx.

Australian ATS, CASA ensures that Airservices Australia maintains and operates its ATS functions according to the MATS and complies with the Manual of Standards for CASR Part 172. However, as CASR Part 172 does not apply to air traffic services provided by the Defence Force, CASA does not play an oversight role of ATS provided by the Department of Defence in the same way it does for Airservices Australia. The Department of Defence has an internal 'Defence Aviation Safety Program' that formally assesses operational and technical airworthiness. This program includes consideration of 'Aviation Support Systems', which include air traffic control.

That is not to say that there is no interaction between Defence and CASA with respect to air traffic management. The Department of Defence have reported that:

> In 2010 (updated in 2012), a formal agreement between CASA and Department of Defence titled *Agreement on the Promotion of Aviation Safety and Airworthiness between the Civil Aviation Safety Authority and the Department of Defence,* was established to promote aviation safety and airworthiness regulation …. The purpose of this agreement is to provide a high level basis for future cooperation to harmonise, where possible, regulatory system outcomes to support improved aviation safety, efficiency, consistency of service and capacity. The agreement considered Defence adopting CASA's system for regulating the safety of military ATC services in Australia. It found that 'this was not feasible as it would fragment Defence's overarching aeronautical regulatory system, require some Defence agencies to comply with two aeronautical regulatory systems, and require significant effort by Defence agencies to change.

The agreement established regulatory requirements and a method for reporting/certifying between CASA and Department of Defence by:

> a. Participating in joint projects with respect to equipment acquisition;
> b. Shared maintenance agreements;
> c. On-going commitments and arrangements regarding flexible use of airspace, and
> d. By the military ANSP working closely with Air Traffic Services Integrity, where possible, aligning Defence regulations with those of CASR [172].

Defence and CASA have also reported that CASA have participated in internal Defence surveillance of military ATS. The Department of Defence have reported that:

> Since 2010 and under the above agreement, CASA has had a standing invitation to attend Operational Evaluations conducted by the military ANSP's auditors. Members of both CASA and the ADF report that this type of relationship has been in effect since the early-1990s and at one time included Airservices Australia involvement. Most recently, CASA attended both Darwin and Townville 2012 Operational Evaluations. Whilst CASA has no regulatory powers over Defence, CASA provided guidance and advice that was accepted by the military ANSP. Further to this, military staff are also included in the CASA Office of Airspace Regulation.

Air traffic levels

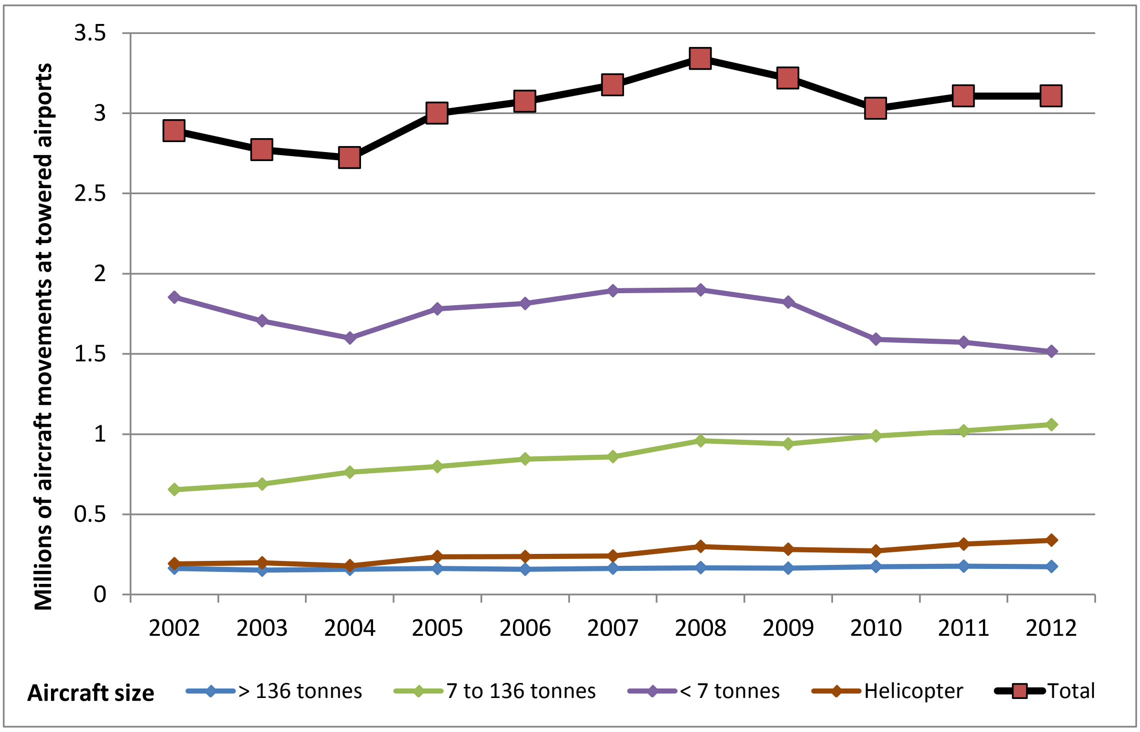
Air traffic levels to and from controlled aerodromes have fluctuated somewhat over the past decade. Light aircraft (less than 7 tonnes and mostly general aviation operations), accounted for more than half of all movements at controlled aerodromes in all years up to 2011, and about half in 2012.

Figure 1 shows an overall 20 per cent increase in movements from 2004 (2.7 million movements) to 2008 (3.3 million movements). This has since declined to about 3.1 million movements. The decline after 2008 was driven by a reduction in activity of smaller aircraft.

Activity for medium aircraft (7 to 136 tonnes and typically domestic air transport) has grown by 60 per cent from 654,000 movements[14] in 2002 to 1.1 million movements in 2012.

[14] Movements refer to the number of departures plus the number of arrivals at aerodromes.

Figure 1: Aircraft movements at controlled aerodromes[15]



Main air traffic control categories

In Australia, there are three broad categories of air traffic control: en route, tower, and terminal.

En route

En route airspace covers the majority of the Australian mainland and the oceanic airspace within the Australian Flight Information Region (FIR) and generally comprises of classes A, C, E and G airspace[16]. The Australian FIR consists of the Brisbane and Melbourne FIRs and en route services are provided for each FIR from two main ATS Centres located in Brisbane and Melbourne.

Tower

Airport and aerodrome control tower personnel are responsible for all aircraft and vehicle movements on the taxiways, runways and in the immediate vicinity of the airport/aerodrome. Tower control services are usually provided in class C airspace at major airports and class D airspace at busier regional and metropolitan airports.

Terminal control

A Terminal Control Area (terminal area) is normally established in the vicinity of one or more major airports in which air traffic services are provided by Approach and Departures control. Controllers working in a Terminal Control Unit provide air traffic services within that area (which is usually class C airspace). For some civilian controlled terminal areas, controllers may be remotely located in one of the ATS Centres.

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15 Includes all aerodromes controlled by Airservices Australia, plus Darwin and Townsville.

16 For an explanation of Australian airspace classes, see Aeronautical Information Package (AIP), Part 2 – En Route, Section 1.4 ATS Airspace Classification, available at http://www.airservicesaustralia.com.

Separation assurance

To achieve the main ATS objective in the *Manual of Air Traffic Services* (MATS) of avoiding collisions between aircraft, ATS have both preventative defences in place to assure aircraft remain separated, and recovery defences when separation is comprised or lost (see *ATS as an error tolerant system* in the *Context* above).

MATS, which is a joint Airservices Australia and Department of Defence publication, describes the responsibilities for aircraft separation for ATS as follows:

> Provide separation using approved separation standards and procedures ensuring spacing between aircraft is never less than a prescribed minimum.

The standard may vary depending on a number of factors, including the type of airspace in which the aircraft are operating, and may specify horizontal or vertical distances, or separation based on a flying time between two aircraft passing the same location. Sometimes ATS planning, or ATS or flight crew execution of those plans, may not ensure that separation can continue to be guaranteed. When such a situation occurs, it constitutes a loss of separation assurance (LOSA). If a LOSA is not rectified, it is possible that aircraft will not maintain the required separation. That constitutes a loss of separation (LOS).

The *Manual of Air Traffic Services* requires *separation assurance* to be applied in both the strategic and tactical environments. According to MATS, strategic separation assurance:

> … is the designing of airspace, air routes, air traffic management plans and air traffic control practices, to reduce the likelihood that aircraft will come into conflict, particularly where traffic frequency congestion or system performance, amongst other considerations, may impair control actions.

At the individual air traffic controller level, MATS describes tactical separation *assurance* as the preferred way to approach the task of separating aircraft. This means that controllers proactively plan to avoid conflict between aircraft, rather than to wait for or allow a conflict to develop before its resolution.

In order to assure separation, MATS requires controllers to:

1. be proactive in applying separation to avoid rather than resolve conflicts
2. plan traffic to guarantee rather than achieve separation
3. execute the plan so as to guarantee separation
4. monitor the situation to ensure that plan and execution are effective.

Separation standards

Separation is defined in MATS as:

> … the concept of ensuring aircraft maintain a prescribed minimum from another aircraft or object, whilst meeting the associated condition(s), and requirements of the standard, as specified in MATS.

Separation standards are specified in the Manual of Standards Part 172[17] and outlined in MATS, and based on the provisions documented by the International Civil Aviation Organization (ICAO).[18] Standards are a means to ensure separation between aircraft, the ground and protected airspace using longitudinal, lateral, vertical and visual criteria and minima.

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17 Manual of Standards (MOS) Part 172 (Air Traffic Services) outlines the requirements and standards for ATS compliance with in the Civil Aviation Safety Regulation 1998 Part 172, including aircraft separation.

18 ICAO document 4444 (Procedures for Air Traffic Management).

Surveillance separation

An Air Traffic Services (ATS) surveillance system can be a Primary Surveillance Radar, Secondary Surveillance Radar, Automatic Dependent Surveillance - Broadcast (ADS-B), or any comparable ground-based system that enables ATC to identify aircraft. Within the en route ATC environment, the horizontal surveillance separation minimum is 5 NM (9.26 km), except under certain conditions, including when greater wake turbulence distance separation is required. The 5 NM standard may be reduced to 3 NM (5.56 km) when aircraft are in communication with and under control of either a Terminal Control Unit[19] or a Control Tower providing class C or class D services, and are within certain specified distances from radar sensors.

Procedural separation

Procedural separation is required when the information derived from an ATS surveillance system (for example radar or ADS-B) is not used or is not available for the provision of air traffic control services. Procedural separation involves the use of vertical, time, distance or lateral separation standards, and is based on the reported positions of aircraft, as advised to ATC by pilots through radio contact or Controller Pilot Data Link Communications.[20] As a controller's knowledge of exact aircraft positions in the procedural control environment is less precise than if ATS surveillance systems are available, procedural separation standards, other than vertical, are considerably larger than separation standards applied in the surveillance environment to provide a conservative safety buffer.

Vertical standards (for procedural and surveillance separation)

Vertical separation is achieved through aircraft operating at a prescribed altimeter pressure setting within designated airspace, at vertically spaced levels. The vertical separation standard for two instrument flight rules (IFR) aircraft operating below FL 290[21] is 1,000 ft (300 m), and 2,000 ft (600 m) at and above FL 290. Between IFR aircraft that are both approved for Reduced Vertical Separation Minimum (RVSM) operations[22], separation at and above FL 290 to FL 410 can be reduced to 1,000 ft. In severe turbulence, and operations above FL 410, a vertical standard of 2,000 ft between IFR flights is applied.

The vertical separation standard between IFR and visual flight rules (VFR) flights, where both aircraft are 7,000 kg maximum take-off weight or less, operating at or below 10,000 ft (3,000 m), is 500 ft (150 m).

Visual separation

Visual separation is a means of spacing aircraft through the use of visual observation by a tower controller, or a pilot when assigned separation responsibility. Visual separation by ATS is reliant on the establishment of positive identification of aircraft. The assignment of responsibility for separation to pilots requires ATS to consider the performance characteristics of the aircraft involved and limitations on a pilot's ability to comply with ATS instructions, including their field of vision from the cockpit and glare from the sun.

A controller may assign responsibility for visual separation to a pilot when aircraft are operating below 10,000 ft (3,000 m) and the pilot reports sighting the other aircraft. In these cases, ATS instructs the pilot to maintain visual separation with, pass behind or follow that aircraft.

In the ATS tower environment, visual separation can be used if the aircraft are continuously visible to the controllers. The use of visual separation allows a reduction in separation from that required when using a procedural or surveillance standard.

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[19] An ATS unit providing services in a control area in the vicinity of a major aerodrome.

[20] A means of communications between controller and pilot, using text-based messages via an ATS data link.

[21] At altitudes above 10,000 ft in Australia, an aircraft's height above mean sea level is referred to as a flight level (FL). FL 290 equates to 29,000 ft.

[22] Approved aircraft fitted with transponders, specially certified altimeters and autopilot systems.

Runway separation

Runway separation standards ensure that the runway area is not occupied by another aircraft or obstruction when ATS clear an aircraft for take-off or landing. It also prevents two aircraft from being cleared to use the same runway simultaneously, except under specific conditions, such as for military formation flights.

The standards outline the requirements for separation of aircraft operating to and from runways and the required distances, expressed in units of time or distance, between departures and arrivals in a number of configurations, on the same, crossing or parallel runways. For landing or take-off behind a preceding aircraft, the general runway separation standard does not permit ATS to issue a clearance or allow a landing aircraft to cross the runway threshold[23] until the preceding aircraft has vacated and is taxiing away from the runway or has crossed the upwind threshold on departure (or a specified distance in certain circumstances).

Wake turbulence separation

Wake turbulence separation standards specify the amount of time or distance required between aircraft that are departing or arriving, or are following en route. The minima vary between 2 and 4 minutes or between 4 NM (7.4 km) and 8 NM (14.8 km) depending on aircraft weight categories[24] (light, medium, heavy, or Airbus A380) of the leading and following aircraft. The standard applies to all aircraft in controlled airspace (including metropolitan and regional airports with small VFR traffic) when an aircraft is operating within ½ NM (0.93 km) laterally or is crossing behind another aircraft's flight path at the same level or less than 1,000 ft below. It also applies when a lighter category aircraft is following a heavier category aircraft and their projected flight paths are expected to cross. Under some circumstances, such as when separation has been assigned to the pilot and the pilot is then responsible for wake turbulence separation, or the pilot waives a departure wake turbulence separation minimum, wake turbulence separation is not required.

Separation service provided by airspace class[25]

In upper en route (class A) airspace (above FL 180 within radar coverage and above FL 245 outside of radar coverage), only IFR flights are permitted. All aircraft are separated from each other by ATC. In lower en route (class E) airspace, both IFR and VFR aircraft are permitted. ATC provides IFR aircraft with separation from other IFR aircraft, and traffic information on VFR flights as far as practicable. VFR flights only receive a *surveillance information service* on request and where ATC surveillance coverage exists.

Class C airspace covers some mid-level en route (between class A and E) airspace and in the control area steps to, and the control zones around, major airports (capital city and larger non-capital city). Both IFR and VFR flights are permitted. IFR aircraft are separated from all other aircraft. VFR aircraft are separated from IFR aircraft and receive traffic information about other VFR flights. In addition, Special VFR flights and separated from other Special VFR flights when visibility conditions are less than visual meteorological conditions (VMC)[26]. Runway separation is generally provided for all aircraft.[27]

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23 The beginning of that portion of the runway used for landing.

24 The weight categories in which aircraft are divided to determine the impact of wake turbulence on other aircraft operations.

25 See Aeronautical Information Publication ENR 1.4 published by Airservices Australia (http://www.airservicesaustralia.com/aip/current/aip/enroute.pdf)

26 See Aeronautical Information Publication ENR 1.2.

27 Except at Essendon airport outside of Essendon tower hours when this area is part of the Melbourne class C control zone.

Civil aircraft operating in military restricted areas or airspace in which a military service is provided will receive a service equivalent to that of class C airspace unless specified in the En Route Supplement Australia.[28]

Class D airspace covers control area steps to, and control zones around, controlled metropolitan and regional airports. Both IFR and VFR flights are permitted. IFR aircraft are provided with a separation service only from other IFR aircraft and Special VFR aircraft. IFR aircraft only receive traffic information about VFR aircraft. VFR aircraft receive traffic information about all other aircraft. Special VFR flights are separated from other Special VFR flights when visibility conditions are less than VMC. Runway separation is generally provided for all aircraft.[29]

Class G airspace is non-controlled. It is generally airspace between the ground and controlled airspace above, outside of the control zones and control areas surrounding controlled aerodromes. There is no air traffic separation service provided for any aircraft. Workload permitting, ATC may provide a flight information service. In addition, ATC will provide an inflight emergency response to pilots requesting assistance, both in controlled and uncontrolled airspace.

Separation defences available by location and ANSP

In the *Context* above, several layers of defence were identified that help prevent collisions between aircraft. These included:

- airspace design, including standard arrival routes (STARs) and standard instrument departures (SIDs) for airports
- air traffic flow and capacity management
- traffic synchronisation including multi-sector planning for arrival and departure sequences
- separation standards
- computerised alerts to ATC such as short-term conflict alerts (STCA)
- monitoring and detection by the controller responsible or other controllers
- airborne collision avoidance systems (ACAS) such as TCAS[30] on medium to large commercial aeroplanes[31]
- visual ‘see and avoid’ by pilots.

Not all of these defences are available in all levels of airspace or airports, often varying with the levels and types of aircraft activity and the need for flexibility at military airports. Figure 2 shows the number of aircraft movements at airports involved in this analysis of LOS occurrences, separated into airspace class and airport type. Airservices Australia operate the separation services in en route airspace, and in the terminal area and tower environment at all locations in Figure 2 except Darwin, Pearce, Townsville, Williamtown (Newcastle), Oakey, Amberley, Richmond (tower only), Tindal, East Sale, and Edinburgh (tower only), which are operated by the Department of Defence.

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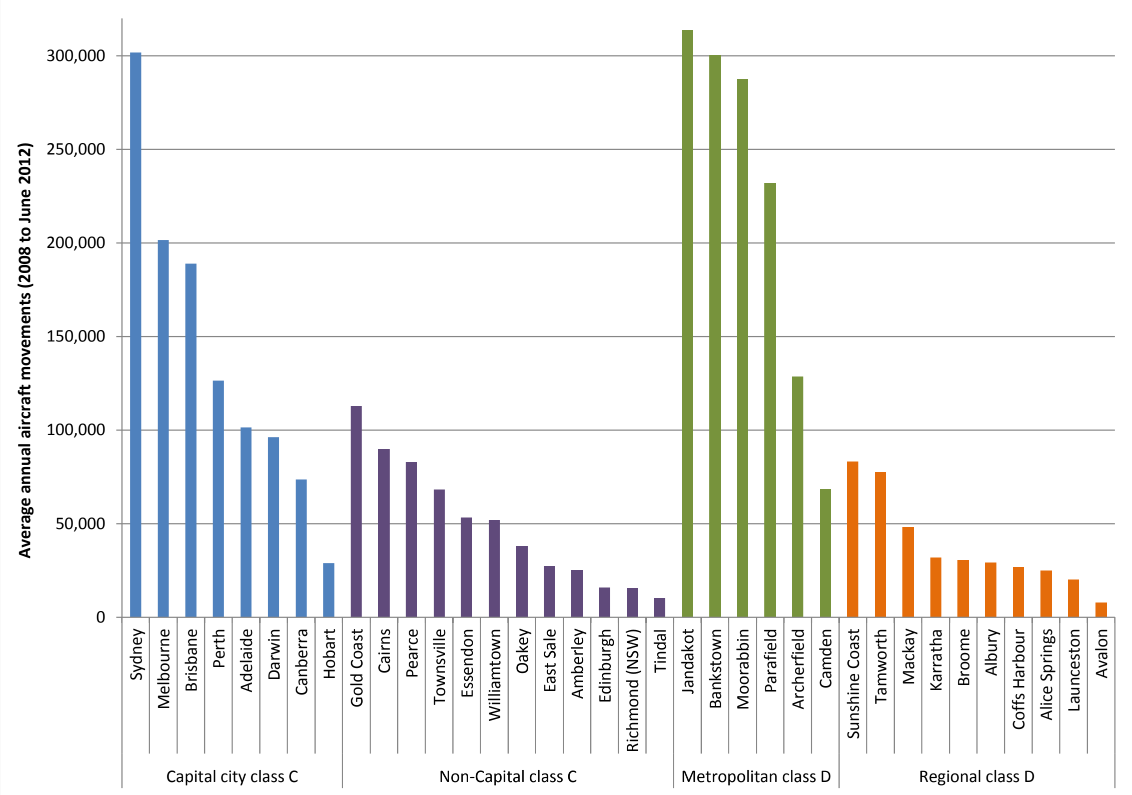
[28] See Aeronautical Information Publication ENR 1.4.

[29] Except at Cambridge airport, Tasmania, which is part of the Hobart control zone.

[30] ACAS is equipment fitted to an aircraft which provides the pilot with a warning of the proximity of other aircraft. ACAS II (such as the Traffic Alert and Collision Avoidance System II or TCAS II), also provide the pilot with information about action which can be taken to avoid a collision.

[31] Civil Aviation Regulation 262 requires all turbine powered commercial transport aeroplanes certified to carry more than 30 passengers or with a maximum take-off weight in excess of 15,000 kg, to be fitted with ACAS/TCAS when operating in Australian airspace. From 1 January 2014, this requirement will change to ACAS II version 7.1 for the above aircraft (and newly registered smaller aircraft certified to carry between 19 and 30 passengers, or with a maximum take-off weight between 5,700 and 15,000 kg).

Figure 2: Aircraft movements at aerodromes with at least one loss of separation occurrence between January 2008 and June 2012



Generally, more levels of separation defences are provided for airports with more air transport aircraft movements rather than just more movements overall. For capital city airports, the high movement airports (Sydney, Melbourne, Brisbane, Perth) have mostly air transport movements, while lower movement airports have more general aviation (Adelaide (23%), Darwin (58%), Canberra (38%), Hobart (48%)). Military aircraft movements are insignificant in capital city airports except Darwin (about 6%) and Canberra (about 3%).[32]

While non-capital city class C airports[33] have a substantially lower number of total aircraft movements than capital city airports, they also generally have a higher proportion of general aviation movements (Gold Coast (67%), Cairns (48%), Townsville (48%), Essendon (92%)). About 7 per cent of movements at Townsville were military aircraft.[32] (Data for the breakdown of aircraft operation types or weights for movements at other military airports was not available.)

Most metropolitan class D airports have a high number of aircraft movements (Figure 2) but are virtually all general aviation. Regional class D airports had generally lower numbers of aircraft movements with between 60 and 90 per cent of all movements being general aviation aircraft.

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[32] The proportion of military movements at airports was calculated using aircraft movement data published by Airservices Australia (available from www.airservicesaustralia.com/publications/reports-and-statistics/movements-at-australian-airports). Military movements in these publications are based on flight plans provided to air traffic control which have a Flight Type of ‘M’ (Military). While based on this data, military movements at Darwin and Townsville are 2% and 7% respectively, advice from the Department of Defence was that the military movements were 6% and 12% respectively. The difference is possibly the result of non-flight planned military traffic at each of those locations

[33] It should be noted that some military operated airspace is not formally designated as class C, but have been grouped with class C airspace around civilian airports for purposes of comparison throughout this report. The Department of Defence have advised that ‘with the exception of Darwin and Townsville, the majority of military controlled airspace is Restricted airspace or a Control Zone surrounded by Restricted airspace, where civil aircraft 'will receive a service equivalent to that of class C airspace unless specified otherwise in ERSA FAC'. Richmond and Pearce do not have a Control Zone or class C airspace.’

The Department of Defence have reported that ATC at some military operated aerodromes, such as Amberley, Darwin, Williamtown, and Townsville, operate:

> with a far greater level of dissimilar aircraft operations and a far greater level of general aviation traffic, most of which are prevented from operating in the civil terminal areas.

Apart from Darwin having a higher proportion of general aviation operations than other capital city airports, data is not available to confirm that military aerodromes deal with a greater diversity of civil aircraft operations, although the non-joint user military aerodromes are more commonly exposed to diverse military operations including fast jet and helicopter operations.

Table 1 shows the availability of published[34] STARs and SIDs at the aerodromes in Figure 2.

Table 1: Published standard instrument departures (STARs) and standard arrival routes (SIDs) for airports with LOS occurrences

Airport type	STAR(s)	SID(s)
Capital city class C	All Exception: Hobart	All
Non-capital city class C	None Exceptions: Gold Coast, Cairns, Pearce	All Exception: Pearce, Edinburgh
Metropolitan class D	None Exceptions: Jandakot, Bankstown	All Exceptions: Moorabbin, Camden
Regional class D	None	None Exceptions: Launceston, Alice Springs, Avalon

Although published STARs and SIDs are available to a similar extent within the four groups of airports (Table 1), the civil and military ANSPs can apply the various defences available to ATS to different levels. The Department of Defence have indicated that:

> The military does not normally employ strategic separation mechanisms such as long range flow control or traffic management plans (including deconflicted STARs and SIDs). At Defence locations where traffic management plans are employed, the efficiency of the strategic separation measures are limited in nature. These strategic separation measures are not normally employed by Defence because they do not allow the required degree of flexibility in service provision that military operations and training requires. Therefore, the vast majority of traffic that the military controls are not on deconflicted flight paths, which means that the military has a greater reliance on controller initiated tactical separation decisions.

The Department of Defence have also noted that some military airspace has not been designed for effective processing of arrivals and departures. In particular, Williamtown, Townsville, Pearce and Amberley have constrained airspace environments that add to the complexity of the operations at these locations.

[34] As published in the *Aeronautical Information Package, Departure and Approach Procedures*, available from http://www.airservicesaustralia.com/aip/aip.asp.

Performance measures for LOS

Airservices measures and reports[35] its performance against LOS occurrences by calculating the rate of LOS each quarter, separately for en route, terminal area (TMA), and tower. Airservices only includes LOS occurrences attributable to errors made by air traffic controllers. As such, rates reported by Airservices can be seen more as a measure of the ATS performance than as a general measure of aviation safety.

Below are the Airservices key performance indicators for LOS:

KPI	Methodology	Target
ATS-attributable en route LOS rate	Air traffic Service attributed number of en route loss of separation per 100,000 flight hours[36]	<1.25
ATS-attributable terminal area LOS rate	Air traffic Service attributed number of terminal area breakdowns of separation per 100,000 flight movements37	<1.50
ATS-attributable tower LOS rate	Air traffic Service attributed number of tower breakdowns of separation per 100,000 flight movements[37]	<1.50

Rates of LOS occurrences against each of the above key performance indicators (KPIs) were published on the Airservices website from December 2010 to September 2011 and are replicated below.

KPI	Target	Actual rates (as reported by Airservices)			
		2010-2011 Q2	2010-2011 Q3	2010-2011 Q4	2011-2012 Q1
ATS-attributable en route LOS rate	<1.25	1.07	1.37	1.27	0.96
ATS-attributable terminal LOS BOS rate	<1.50	1.69	1.44	1.31	1.62
ATS-attributable tower LOS rate	<1.50	0.14	0.58	0	0.54

Airservices Australia also benchmarks the above key performance indicators with other civil ANSPs from around the world through the Civil Air Navigation Services Organisation (CANSO). ATS-attributable LOS occurrences are benchmarked as a rate per hours flown and movements. Another 19 ANSPs from North America, Europe and Asia have been involved in this benchmarking, with data supplied confidentially so that each ANSP can only recognise their own performance relative to other countries.

Data produced by CANSO shows that Australia's civil ATS-attributable loss of separation occurrence rates are among the lowest in the comparison groups, with rates of about one third that from many other ANSPs.

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35 KPIs and data are from Airservices *Quarterly reports to industry* published at http://www.airservicesaustralia.com/publications/corporate-publications/quarterly-reports-to-industry/

36 Flight hours used by Airservices include IFR flight hours as measured by the Airservices TAATS system.

37 Movements refer to the number of IFR departures plus the number of arrivals at aerodromes controlled by Airservices.

Recording and investigation of LOS

All losses of separation in Australian airspace are reportable to the ATSB by responsible persons (air traffic control, and if not already reported, pilots) under the Transport Safety Investigation Regulations 2003. The ATSB maintains an occurrence database of all reported aviation safety matters, including LOS occurrences. Each occurrence is independently assessed by the ATSB, classified, coded, and details entered into the database. Some of these occurrences are investigated by the ATSB.

Most LOS occurrences are reported by one of the two Australian ANSPs, Airservices Australia and the Department of Defence. Both of these organisations keep their own occurrence databases and conduct data analysis for internal safety management purposes. Each organisation also conducts internal investigations either all LOS occurrences (Department of Defence) or some of the ATS-attributable LOS occurrences (Airservices). Investigation findings of ATS-attributable LOS occurrences from Airservices are also used as part of CASAs monitoring of Airservices compliance with CASR Part 172.

Airservices Australia regularly analyses LOS occurrences in civil airspace for both its own internal monitoring processes and for CASA. The latter is used as part of CASA's monitoring of Airservices' compliance with CASR Part 172. These analyses measure ATS-attributable LOS occurrences only.

The ATSB also has a voluntary reporting scheme (REPCON) which allows any person who has an aviation safety concern to report confidentially. The de-identified reports and resultant safety actions are maintained in a database by the ATSB.

This report will now document all losses of separation in Australia between January 2008 and June 2012 using information drawn from occurrences reported to the ATSB, coding of contributing factors behind these occurrences, ATSB investigations, and confidential reports of safety concerns.

Review of reported occurrences

Methodology

All loss of separation (LOS) occurrences in Australian airspace and involving (at least one) civilian aircraft are reportable to the ATSB through the Transport Safety Investigation Regulations 2003. This includes occurrences that happen under the control of the civil or military air navigation service providers (ANSPs) (or both).

The ATSB has conducted a detailed analysis of LOS occurrence data across four and a half years from January 2008 to June 2012. There were 531 occurrences reported to the ATSB in this time. The details of each occurrence were individually reviewed for this analysis. A longer 10-year trend has also been included to give a broader picture of how LOS reporting has changed over time.

Data used in the analysis has been reported to the ATSB by ANSPs and pilots/operators following each LOS occurrence. Based on the information provided, the ATSB has independently decided which occurrences constituted a loss of the separation standard (and therefore were included in this analysis), and coded the specific aspects of each occurrence.

Collision risk assessments

The ATSB assigns a collision risk to all LOS occurrences. In this study, the collision risk assessment was calculated based on several elements that may have contributed to the LOS. For airborne LOS events, these elements were:

- the closure rate between the aircraft, and the proximity of the aircraft to each other
- any evasive action that was taken by the controller or by the flight crews, as well as considering situations where evasive action was warranted but neither aircraft sighted the other until they passed
- the relative tracks of the aircraft involved
- the awareness and communication of each aircraft by the controller, and by each flight crew.

For LOS events that occurred on runways, the elements were slightly different:

- whether evasive action was taken (or should have been taken) by the flight crew, or was instructed by the controller
- the relative positions of one aircraft in relation to another aircraft, vehicle, or a person
- the closing speed of one aircraft in relation to another aircraft, vehicle, or person
- the awareness and communication of each aircraft by the controller and by each flight crew

Each of these elements was given a severity weighting and the combination provided the total risk score. The collision risk scores fell into one of four categories:

- Elevated - an evasive manoeuvre was performed or should have been taken to ensure a collision would not result.
- Some - no positive separation existed as the result a loss of situational awareness by the controller or the flight crew(s). While a near collision did not occur, separation was severely compromised.
- Minimal - required the re-establishment of a separation standard, however, little risk of a collision existed. This is generally the case in situations where a LOS occurs, but the aircraft tracks are not directly on a collision course.
- Nil - the aircraft tracks and distances were such that a collision risk never existed.

Appendix A gives further information on how each element is scored to determine a collision risk for airborne and runway LOS events.

Event risk classification

The ATSB assesses the probable level of safety risk associated with each reported safety occurrence (not just LOS occurrences), considering the circumstances of the occurrence at the time it happened. The safety risk of occurrences is assessed using a modified version of the Aviation Risk Management Solutions (ARMS) event risk classification framework.[38] This framework bases the safety risk on the most credible potential accident outcome that could have eventuated, and the effectiveness of the remaining defences that stood between the occurrence and that outcome. The intention of this assessment is to determine if there was a credible risk of injury or loss to passengers, crew, the public, and property.

For LOS occurrences, the event risk classification considers the combined seating capacity of the aircraft involved as a measure of the potential loss of life (and hence worst credible outcome) if a mid-air collision occurred (or in the case where a wake turbulence standard was not maintained, severe turbulence that could result in a loss of aircraft control). For non-wake turbulence-related losses of separation, the collision risk assessment (described above) provides an assessment of the effectiveness of the defences that still existed to prevent a mid-air collision – such as avoiding action, ATC verbal traffic alerts, or on-aircraft traffic advisory systems – and the ability of the controller to re-establish the separation standard.

The event risk classification provides an indication of the safety risk posed by a LOS occurrence to the traveling public. A LOS involving two large passenger transport aeroplanes where there was some collision risk poses a high risk to safety, whereas a LOS with the same collision risk but involving a light aircraft and a vehicle only poses a medium safety risk. See Appendix B for more details on how the event risk classification is calculated.

Normalising data

Frequency counts (for intervals of time and at locations) were divided by either total aircraft hours flown or aircraft movements to normalise the data. This was done to show the LOS risk as an occurrence rate per unit of exposure (hours flown or movements) to supplement the total LOS risk as shown by the frequency counts.

Normalising data included in this analysis included aircraft hours flown for en route LOS occurrences, which were obtained from Airservices Australia. These data were recorded automatically and include all IFR and VFR flight hours in en route airspace that involved interaction by Airservices Australia's air traffic controllers.

For terminal airspace and tower related LOS occurrences, aircraft movements[39] were used at the relevant airports. Movement data for civilian airports was collected from data published by Airservices Australia[40]. For all military airports (including those which Airservices Australia publishes movement data for), movements data was obtained directly from the Department of Defence.

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38 The Event Risk Classification (ERC) methodology is from the report *The ARMS Methodology for Operational Risk Assessment in Aviation Organisations* (version 4.1, March 2010). ARMS is an industry working group set up 2007 in order to develop a new and better methodology for Operational Risk Assessments. The methodology is freely available from http://www.skybrary.aero/index.php/ARMS_Methodology_for_Risk_Assessment.

39 Movements are the sum of arrival and circuits multiplied by 2, and are used to estimate the combination of all take-offs and landings.

40 http://www.airservicesaustralia.com/publications/reports-and-statistics/movements-at-australian-airports.

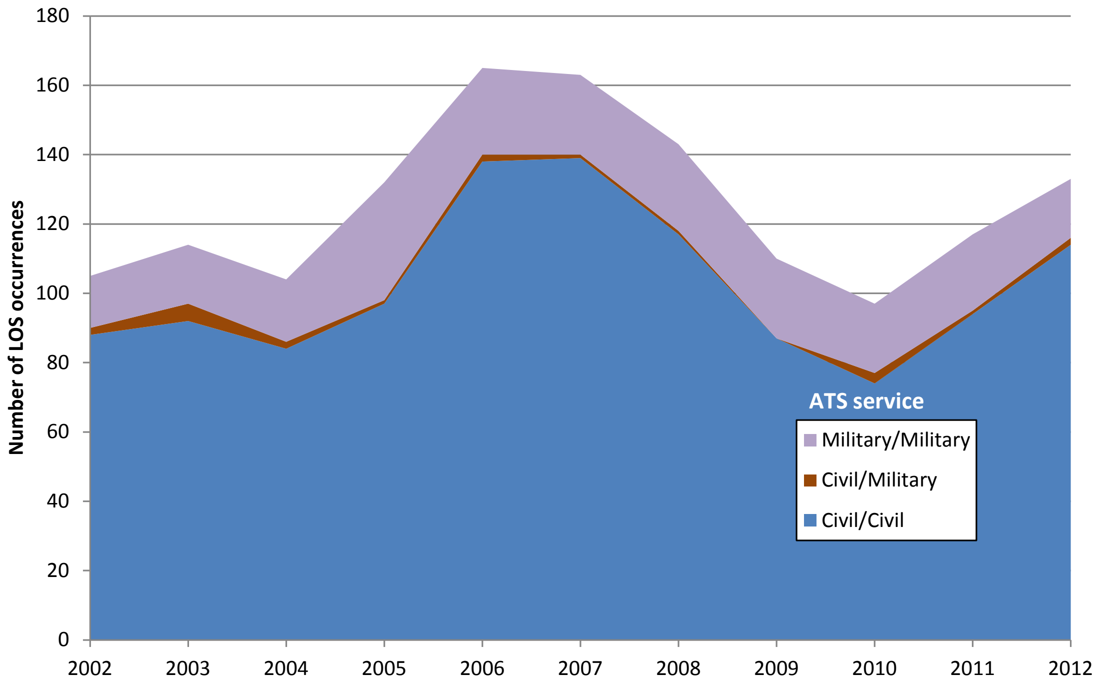
Overall trends

Ten year trend

Across the last 10 years, there were, on average 126 loss of separation (LOS) occurrences per year. In 2012, there were 133. Slightly less than 20 per cent of all LOS occurrences involved military air traffic services (ATS).

As can be seen in Figure 3, the number of LOS occurrences involving military ATS has remained fairly constant across the decade at an average of 23 per year. In comparison, the 80 per cent involving civil ATS (provided by Airservices Australia) have varied significantly across the decade, growing from about 90 per year to 140 per year in 2006 and 2007, before declining to 77 in 2010. In the past two years, LOS occurrences involving civil ATS have increased, with 2012 recording 116. However, this is still well below the 2006-2007 peak.[41]

Figure 3: Total loss of separation occurrences by controlling agency, 2002 to 2012



When compared to aircraft movement data in Figure 1 on page 7, the increase in LOS occurrences after 2004 corresponded with a rapid growth in aircraft movements. Similarly, the decline in movements after 2008, and then slight increase in movements again after 2010, may account for some of the variation in LOS occurrences involving civil ATS after 2008.

January 2008 to June 2012

The remainder of the analysis presented is for LOS occurrences from January 2008 to June 2012. In those four and a half years, there were 531 LOS occurrences (average of 118 per year).

Nearly every occurrence was reported to the ATSB by an ATS provider. Only 149 (28%) were reported by pilots or airlines. Most occurrences reported by pilots were also reported by ATS, with only two occurrences reported to the ATSB by pilots without a subsequent report from an ATS provider.

[41] A provisional analysis of the data from January to June 2013 indicates that the upward trend has ceased and may now be decreasing.

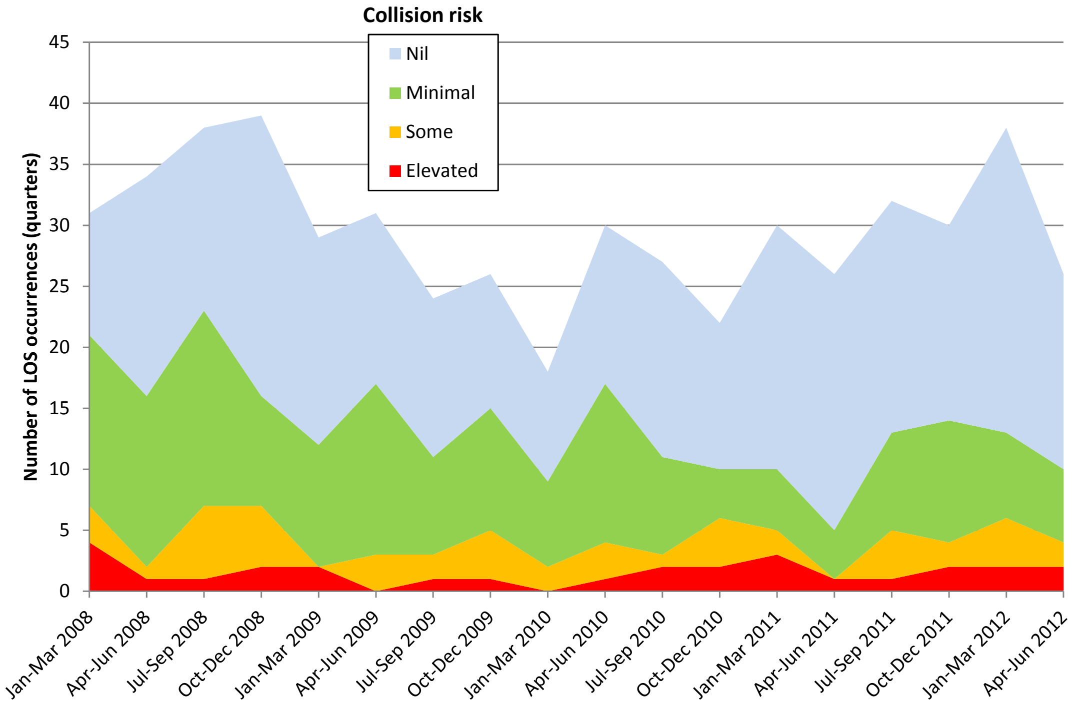
Collision risk

While it is an undesired situation, a loss of separation between two or more aircraft does not mean that the aircraft were about to collide. In many cases, there was no chance of the aircraft colliding, even though separation standards were infringed. This is especially the case where aircraft were on diverging tracks, breached a wake turbulence separation standard, or where the flight paths were laterally converging or crossed but at different flight levels (see *Methodology* above).

As can be seen in Figure 4, 86 per cent of LOS occurrences involved either minimal or no collision risk.

Of the 531 LOS occurrences reported in the last 4.5 years, 28 (5%) were considered as having an elevated collision risk, and 48 some collision risk (9%). There has been minimal variation in the number of LOS occurrences with elevated or some collision risk over this time, and most of the variation in the trend is accounted for by nil and minimal collision risk occurrences.

Figure 4: Overall collision risk trend, January 2008-June 2012

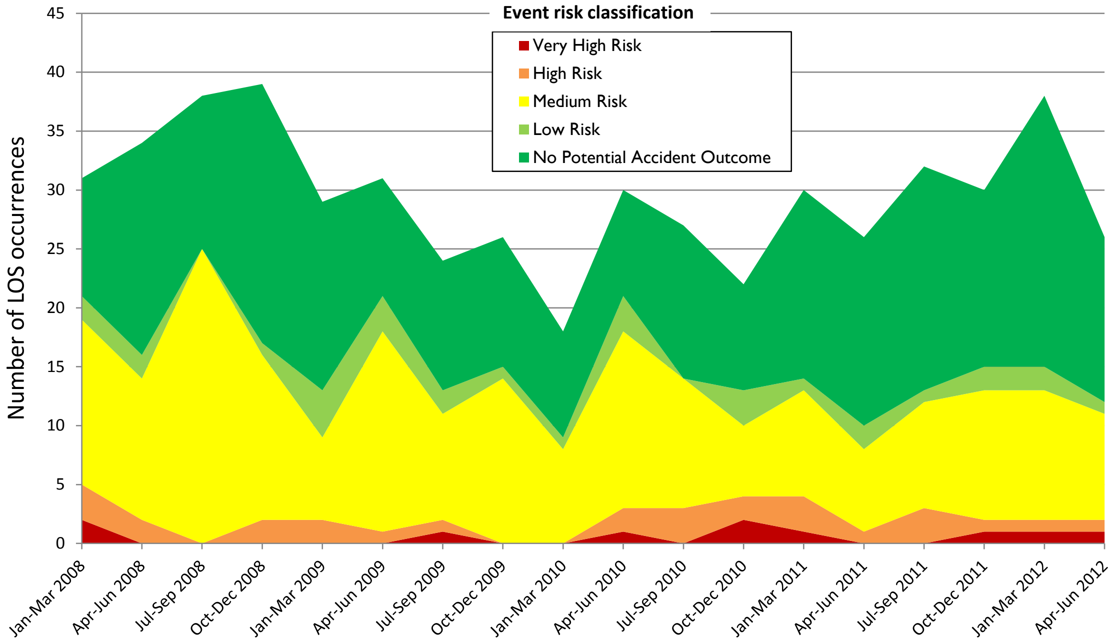


Event risk

As described in the *Methodology* above, the event risk classification provides an indication of the safety risk posed by a LOS occurrence to the traveling public by taking into account both the collision risk and the capacity (in terms of people carried) of the aircraft involved in the occurrence.

The number of LOS occurrences by event risk shown in Figure 5 indicates a slightly decreasing trend for medium risk and higher occurrences across the 4.5 years. However, 7 of the 10 very high risk LOS occurrences have occurred since 2010.

Figure 5: Overall event risk classification trend, January 2008-June 2012



The 10 occurrences with a very high risk rating all involved high capacity aircraft[42] as follows:

- On 4 January 2008, a Cessna 441 flying under instrument flight rules (IFR) was climbing outbound from Essendon while a Boeing 767 was inbound to Melbourne and descending through terminal airspace. Under radar surveillance, the controller was distracted by other traffic and did not notice the Cessna was 1NM (1.85 km) north of the expected track, resulting in the two aircraft passing with 1.5 NM (2.78 km) of horizontal and 700 ft of vertical separation.
- On 24 February 2008, while passing 8,700 ft on descent into Sydney Airport through terminal area control, the crew of a Boeing 737 reported passing a glider a few hundred feet below. The glider had made an airspace incursion which was undetected by ATC.
- On 3 September 2009, a domestic Boeing 737 and international Boeing 777 aircraft were on crossing tracks while cruising at FL 300 in en route airspace, 3.6 NM (6.67 km) apart. The air traffic controller responsible for separation of the aircraft had recently completed the air navigation service provider’s approved training, but had not recognised the potential conflict between the two aircraft. See ATSB investigation AO-2009-056.
- On 11 May 2010, on departure from Sydney Airport, a Jetstream 32 was cleared to 5,000 ft but was subsequently observed by ATS to have climbed to 5,400 ft without a clearance due to an autopilot anomaly. This resulted in a converging track towards an inbound Boeing 737 in the terminal area. Separation was reduced to1.6 NM (2.96 km) horizontally and 600 ft vertically.
- On 5 December 2010, on departure from Melbourne Airport, the flight crew of a Boeing 737 had reduced their aircraft's speed in order to meet a height requirement of the Standard Instrument Departure. A following Boeing 767 aircraft climbed at a faster speed. When the aircraft were transferred from the aerodrome controller to a departures controller, there was 3.4 NM (6.3 km) separation between them. The departures controller expected them to climb at a similar speed, and did not recognise the loss of separation assurance. The controller's actions to manage the compromised separation were not fully effective, with horizontal separation reduced to 1.9 NM (3.52 km) and vertical to 500 ft. See ATSB investigation AO-2010-104.

[42] High capacity aircraft refer to larger air transport aircraft (more than 38 passengers).

- On 17 December 2010, after holding prior to approach into Brisbane Airport due to thunderstorms, separation was reduced to 2.9 NM (5.37 km) and 500 ft vertically in the terminal area between a Boeing 737 and an Airbus A320 after aircrafts' crews were unable to comply with ATS instructions to alter heading due to thunderstorm in the vicinity.
- On 1 February 2011, separation between a Boeing B737 departing Williamtown and maintaining 5,000 ft and a charter Westwind 1124 on descent was reduced to 0.7 NM (1.3 km) and 400 ft vertically. The terminal area controller instructed the Boeing 737 to turn towards the Westwind when the crew received a TCAS resolution advisory (RA) to 'descend'. Vertical separation was achieved by the crew following the TCAS RA. See ATSB investigation AO-2011-011.
- On 8 November 2011, procedural separation between two Boeing 737 aircraft cruising at FL 390 on converging tracks reduced to within 2 minutes (6 to 12 NM (11.1 – 22.2 km)). The ATSB investigation AO-2011-144 is continuing.
- On 18 January 2012, procedural separation was reduced to 2 minutes and 1,000 ft vertically between a south-bound Airbus A320 and a west-bound Airbus A340 during cruise. The ATSB investigation AO-2012-012 is continuing.
- On 6 April 2012, a Boeing 737 and an Airbus A330 aircraft were on converging tracks at FL 360 (en route surveillance-based control). As the aircraft approached each other at the same level, the controller received a short term conflict alert (STCA) and noticed the aircraft were 5.2 NM (9.63 km) apart. The controller issued instructions to both aircraft to achieve vertical separation, which was established when the distance between the aircraft reduced to about 3.5 NM (6.48 km). See ATSB investigation AO-2012-048.

ATS area involved

Most LOS occurrences (80%) involved aircraft under the jurisdiction of civil ATS. There were four occurrences in which pilot actions contributed to a LOS situation that involved both civil and defence ATS, and they all occurred in terminal areas surrounding military controlled airfields (Edinburgh, Williamtown, and Townsville). Nineteen per cent of occurrences involved aircraft only under military ATS control.

As can be seen in Figure 6, about 40 per cent of LOS occurrences were in terminal airspace, a third involved the tower environment, and a quarter occurred en route. For LOS occurrences involving aircraft under civil ATS jurisdiction, occurrences were evenly split between terminal area, tower, and en route environments. For occurrences involving aircraft under military ATS jurisdiction, nearly three quarters were in the terminal area, while a quarter were in the tower environment. One occurrence was recorded as involving en route military control which involved a confliction in a prohibited, restricted, or danger (PRD) area.

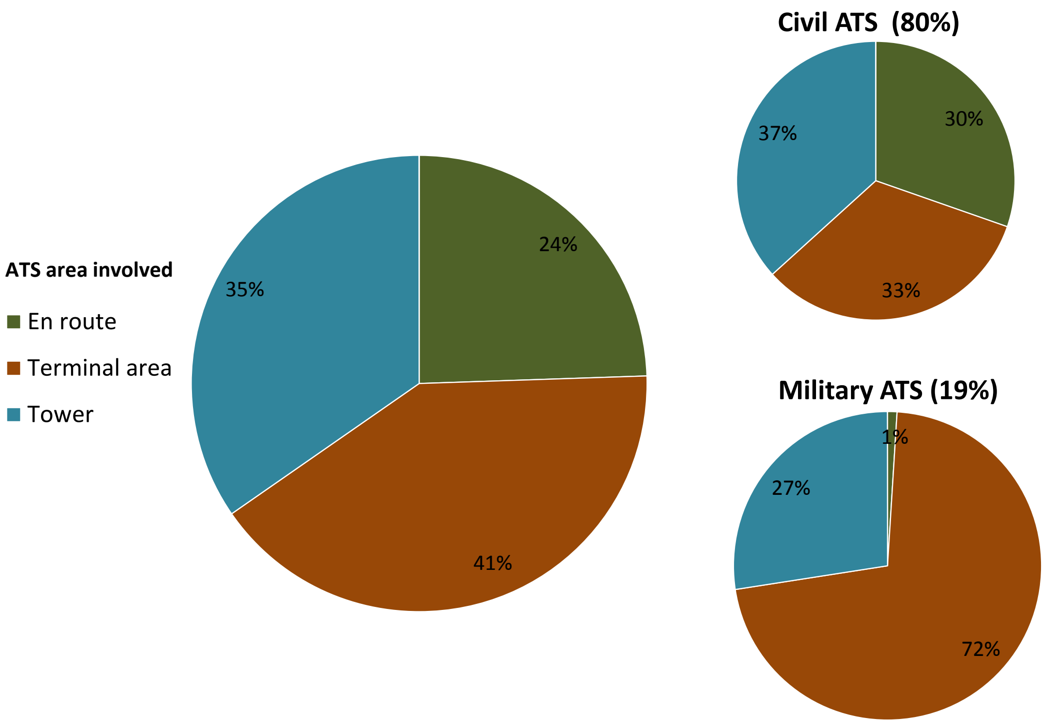
Occurrences with an elevated or some risk of collision showed similar patterns when considering who was controlling the airspace, and what type of airspace it was.

As civil ATS controls virtually all en route airspace (apart from some restricted areas), 99 per cent of en route LOS occurrences involved civil ATS. In terminal areas, civil ATS controls about 75 per cent of IFR traffic movements, with military ATS controlling about 25 per cent.[43] However, civil ATS were only involved in 65 per cent of LOS occurrences, while military ATS were involved in 36 per cent (with 2% involving both ATS).[44] In the tower environment, civil ATS handle about 86 per cent of all traffic movements (including VFR aircraft), and 85 per cent of LOS occurrences involved civil ATS.

43 Note that the proportion of movements in the terminal area and tower environments were calculated using all movements to and from airports with an air traffic service, which included several airports (both civil and military) which did not have any LOS occurrences recorded against them.

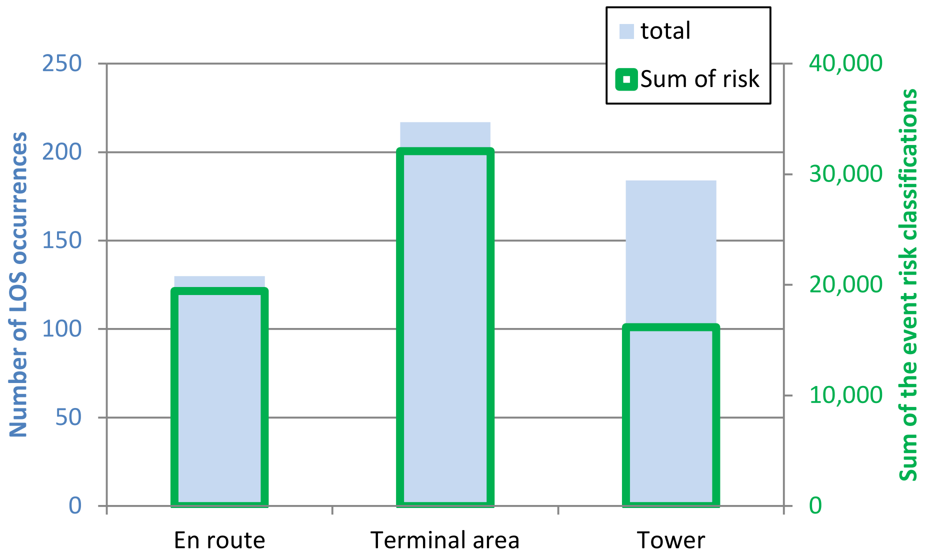
44 This higher proportion of LOS occurrences involving military terminal area ATS, relative to the proportion of IFR traffic controlled by military ATS, was statistically significant (Chi square) $X^2_{(df=1)} = 8.35$, $p < 0.005$.

Figure 6: ANSP and ATS area involved, January 2008-June 2012



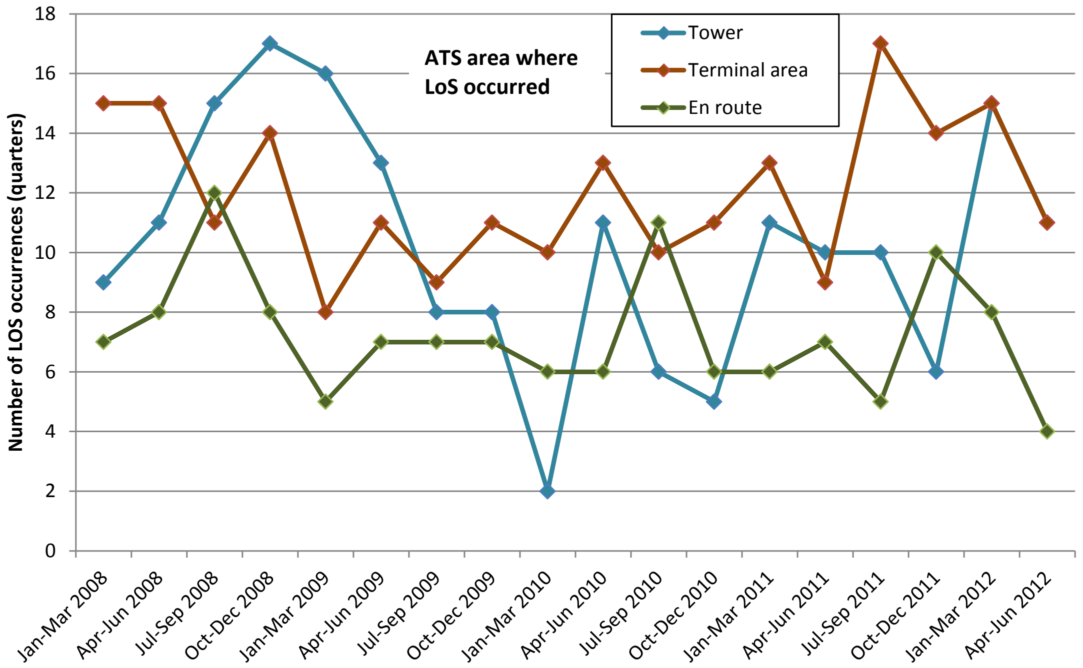
In Figure 7 below, the sum of the event risk classifications (see Appendix B) for each occurrence is shown as the green unfilled bars. The individual event risk classifications for LOS occurrences vary, as they consider a number of factors including the collision risk, the capacity of the aircraft involved, and whether there were any other occurrence events associated with the loss of separation. Compared to the raw number of occurrences (blue filled bars), occurrences in the ATC tower environment posed a relatively lower risk overall. This is because a larger proportion of LOS occurrences involved only smaller general aviation aircraft in the tower environment, whereas a higher proportion of LOS occurrences in en route and terminal areas involved larger aircraft. As such, the largest risk posed by loss of separation is in the terminal area, followed by en route control.

Figure 7: Total risk by ATS area involved, January 2008-June 2012



Occurrences in the tower environment have fluctuated across the 4.5 years, peaking at the end of 2008 before declining by two-thirds and then gradually increasing from 2011. The number of terminal area occurrences in 2012 returned to 2008 levels after reducing by a third in the years in between. En route occurrences have remained fairly consistent across the time period (Figure 8).

Figure 8: ATS area involved trend, January 2008-June 2012

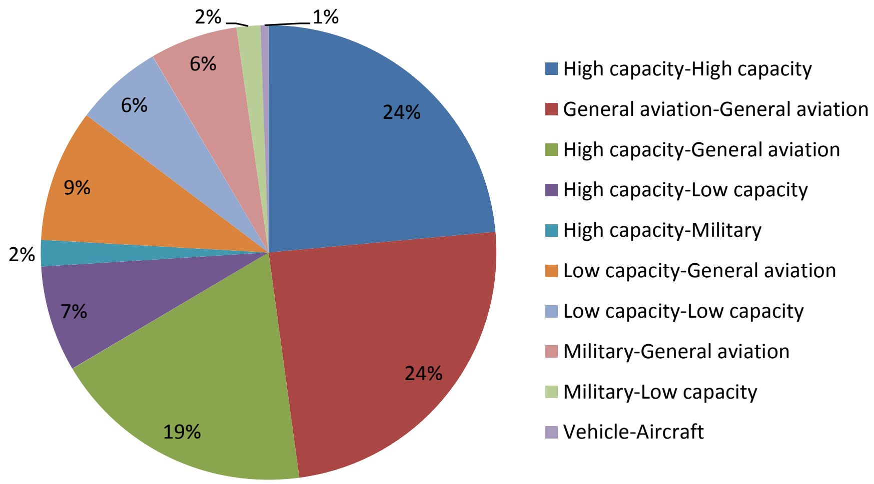


Aircraft involved

Over half of the LOS occurrences involved at least one general aviation aircraft (59%) or high capacity air transport aircraft (52%). Figure 9 shows that a quarter of all occurrences involved only general aviation aircraft or only high capacity aircraft, while a further 19 per cent involved a conflict between a general aviation aircraft and a high capacity aircraft.[45]

Low capacity air transport (incorporating both regular public transport and charter) were involved in a quarter of all occurrences, while military aircraft were involved in 10 per cent.[46] Military aircraft were generally in conflicts with general aviation aircraft.

Figure 9: Aircraft operation conflicts, January 2008-June 2012



General aviation aircraft were mostly involved in LOS occurrences in the terminal area and tower environment, while military aircraft were mostly involved in occurrences in the terminal area. Air transport aircraft were fairly evenly represented in all three ATS environments.

Almost every LOS occurrence from 2008 to June 2012 was between two aeroplanes (92%). Seven per cent involved separation between an aeroplane and a helicopter. Only three occurrences involved separation between an aeroplane and a ground vehicle, while gliders were involved in two occurrences and balloons in one.

Most LOS occurrences (59%) involved only IFR aircraft, while another 29 per cent involved a separation loss between an IFR and VFR aircraft. Occurrences involving a confliction between IFR and VFR aircraft were mostly in the terminal area (91 occurrences), and to a lesser extent, the tower environment (55 occurrences). Occurrences involving VFR aircraft only (applicable to runway separation and wake turbulence separation only, and therefore mostly in the tower environment) accounted for about 10 per cent of all LOS occurrences.

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45 High capacity aircraft refer to larger air transport aircraft (more than 38 passengers). Low capacity refers to smaller air transport aircraft used for both regular public transport and charter.

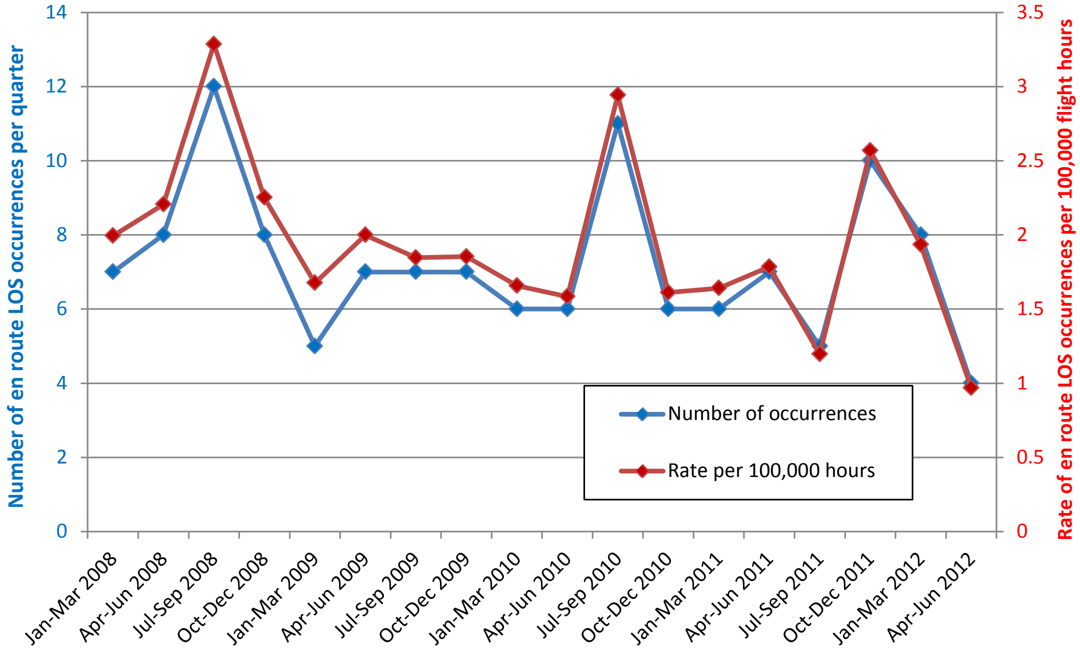
46 Reported data only includes occurrences were military aircraft were in conflict with civilian aircraft.

En route environment

Trends

The number and rate of en route LOS occurrences has reduced since 2008 and, apart from some quarter by quarter variability, has remained steady since. Figure 10 shows that since 2009, the estimated rate of LOS occurrences in en route airspace varied around a mean of about 1.9 occurrences per 100,000 flight hours. The key performance indicators for Airservices Australia (see *Performance measures for LOS* on page 14) for ATS-attributable LOS occurrences is less than 1.25 occurrences per 100,000 occurrences. The data in Figure 10 is for all en route LOS occurrences, not just those that were ATS-attributable. (The following chapter, *Review of safety factors to reported occurrences*, provides an analysis of occurrences as contributed to by ATC and pilot actions.)

Figure 10: Number and rate of en route LOS occurrences, January 2008 - June 2012



Aircraft involved

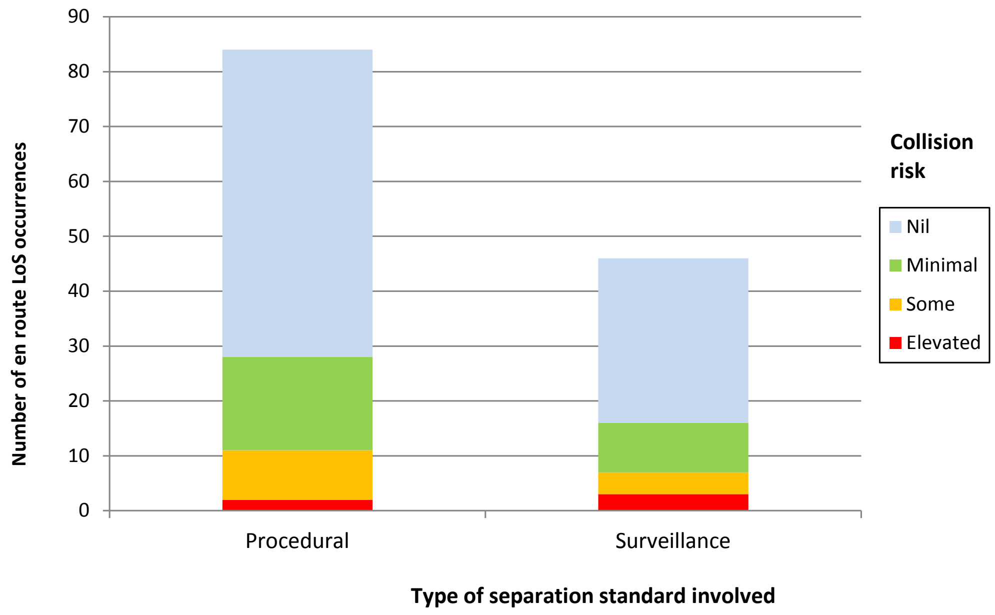
While 71 per cent of en route occurrences involved a confliction with at least one high capacity air transport aircraft, only 45 per cent involved two high capacity aircraft. En route occurrences involving high capacity aircraft also had conflictions with low capacity air transport (14%) and general aviation aircraft (11%). Over a third of en route occurrences involved low capacity air transport aircraft – these were split fairly evenly between conflictions with another low capacity aircraft, high capacity aircraft, or a general aviation aircraft.

Nearly all en route occurrences involved only IFR aircraft, however, there were seven (5%) that involved a combination of IFR and VFR aircraft. One occurrence involved a confliction between an aeroplane and a glider, while the remainder involved aeroplanes.

Type of separation standard involved

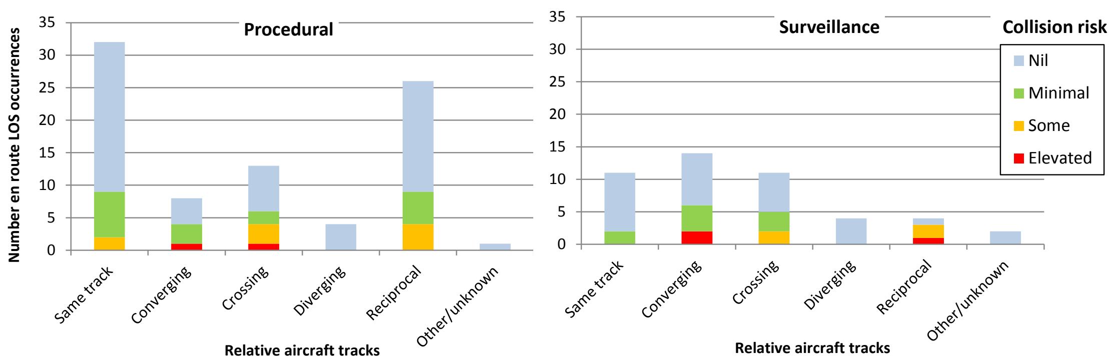
Of the 130 en route LOS occurrences reported in the 4.5 years, 83 involved procedural separation, while 47 involved surveillance (mostly radar-based) separation. Figure 11 shows that the number of elevated collision risk occurrences was very small (two where aircraft were subject to en route ATC procedural services and three in surveillance environments).

Figure 11: Collision risk and applicable separation standards for en route LOS occurrences, January 2008-June 2012



Of the en route loss of *procedural* separation occurrences, most (64%) involved aircraft either on the same track (one aircraft was following the other) or on reciprocal tracks (the aircraft were 'head to head') (Figure 12 left panel). Figure 13 (left panel), which shows how close the aircraft got after the separation standard was lost, also shows this fact in that most of these occurrences involved aircraft travelling at the same flight level. However, the two elevated collision risk occurrences where a procedural standard was lost involved aircraft on converging or crossing tracks[47].

Figure 12: Collision risk and aircraft tracks for en route LOS occurrences, January 2008-June 2012



[47] For separation purposes, crossing tracks are those tracks that intercept at right angles while converging tracks are those that intercept at less than 90 degrees.

The distribution of *surveillance* LOS occurrences was more spread across the types of relative aircraft tracks (Figure 12 right panel) and mostly towards the largest remaining horizontal and vertical distances (Figure 13 right panel). Two of the three elevated collision risk occurrences involved aircraft on converging tracks at the same flight level, while the third involved two aircraft on a reciprocal track with only 400 ft vertical separation when the aircraft passed.

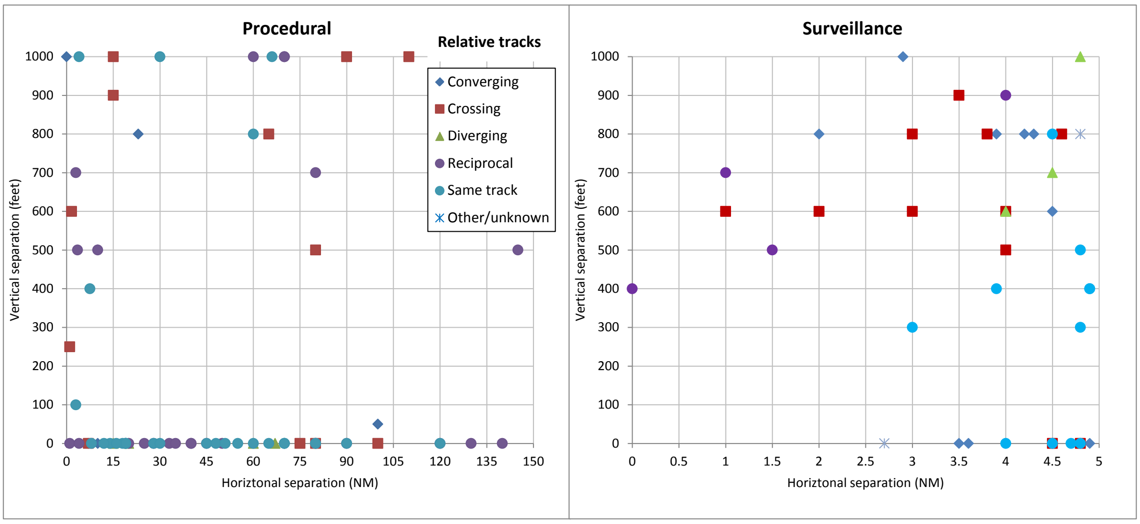
The elevated collision risk occurrences in the en route environment were as follows:

- During manoeuvres in restricted airspace near Williamtown, a Hawk formation climbed to 9,600 ft and came within 400 ft vertically to a Piper PA-31P at 10,000 ft in controlled airspace (surveillance).
- A Boeing 737 en route from Sydney to Adelaide, and a Boeing 777 en route from Melbourne Singapore were on crossing tracks and both were cruising at FL 300. The aircraft came with 3.6 NM (6.67 km) of each other. The air traffic controller responsible for separation of the aircraft had recently completed training, and had not recognised the potential conflict between the two aircraft (surveillance).
- A loss of procedural separation between two Boeing 737 aircraft on crossing tracks abeam Ceduna. The ATSB investigation AO-2011-144 into this occurrence is continuing (procedural).
- The procedural separation standard of 15 minutes was infringed between a south-bound Airbus A320 and a west-bound Airbus A340. The ATSB investigation AO-2012-012 into this occurrence is continuing (procedural).
- A Boeing 737 en route from Sydney to Darwin and an Airbus A330 en route from Melbourne to Shanghai were on converging tracks at FL 360. As the aircraft approached Tindal, a loss of separation occurred when the distance between the aircraft reduced to about 3.5 NM (6.48 km) before vertical separation was established. The incident occurred about 16 minutes after a handover between two air traffic controllers (surveillance).

In addition to the above two procedural occurrences, there was one with some collision risk where the aircraft separation reduced to 1 NM side-by-side on reciprocal tracks at the same level:

- Procedural separation was established between a Dash 8 in bound to Karratha and a Fokker 27 outbound from Karratha based on location reports from the flight crew of each aircraft. However, the inbound aircraft mistakenly reported their location in reference to an IFR waypoint rather than the aerodrome. The planned separation was therefore based on an incorrect location, resulting in the aircraft passing each other at FL200 1 NM apart. The Fokker 27 had been notified of the Dash 8 via a TCAS traffic alert and remained in visual contact with the other aircraft until they passed.

Figure 13: Separation remaining and aircraft tracks for en route LOS occurrences, January 2008-June 2012 (*note different scale for horizontal axes*)

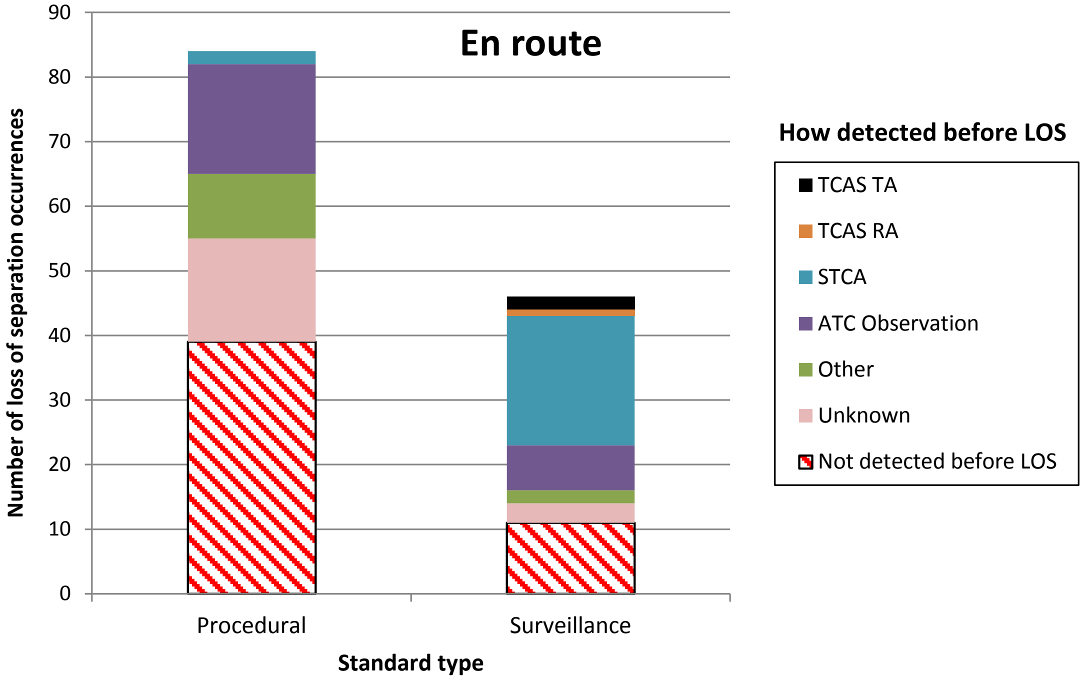


Detection of compromised separation situations

A compromised separation situation can be detected before there is a loss of the separation standard either through controller or pilot observation, or through ATC system alerts (like the short term conflict alert (STCA)[48]) or within the aircraft (like traffic collision avoidance system or TCAS[49]).

For en route LOS occurrences, nearly half (46%) of the procedural separation losses were not detected by either human, ATS and/or aircraft system alert before the separation was already lost (Figure 14). This was the case for a quarter of all en route losses of surveillance separation. For procedural LOS occurrences, about a fifth were identified through the controller detecting the conflict and taking compromised separation recovery actions before the LOS occurred. In contrast, surveillance LOS occurrences were most commonly (43%) detected through the activation of a STCA (which is not available for procedurally controlled aircraft).

Figure 14: How en route loss of separation was detected, January 2008-June 2012



Of the en route LOS occurrences not detected until after separation had already been lost, Figure 15 (left panel) shows that most posed nil collision risk (74% for procedural and 84% for surveillance). However, there was one occurrence with an elevated risk (currently subject to an ATSB investigation, AO-2012-012), and five with some collision risk, involving aircraft under procedural separation where the separation assurance loss was not detected until after separation was lost. No non-detected surveillance LOS occurrence had an elevated collision risk and only

48 The STCA in Airservices Australia's Australian Advanced Air Traffic System (TAAATS) determines all of the possible surveillance track pairs for which, in a predefined period, the minimum separation between each track pair will be less than the minimum safety requirements. A STCA alert is only available when aircraft are able to be monitored through radar or ADS-B.

The Australian Defence Air Traffic System (ADATS) is equipped with conflict alerting functionality for aircraft under radar surveillance, in the form of Predicated Conflict Alert (PCA) and Conflict Alert (CA) functions. The parameters and enablement of these alert functions vary between military ATS locations. The PCA, when enabled, is generally set to activate 30 seconds prior to the proximity between aircraft reducing to within 2.8 NM and/or 750 ft.

49 TCAS/ACAS refers to on-board Traffic/Airborne Collision Avoidance Systems which detect other aircraft with Mode C or Mode S transponders. Traffic advisories (TA) provide crew with information about the location of other nearby aircraft, while resolution advisories (RA) recommend to the flight crew to follow a specific manoeuvre to provide separation or restriction to maintain existing separation.

one had some collision risk.

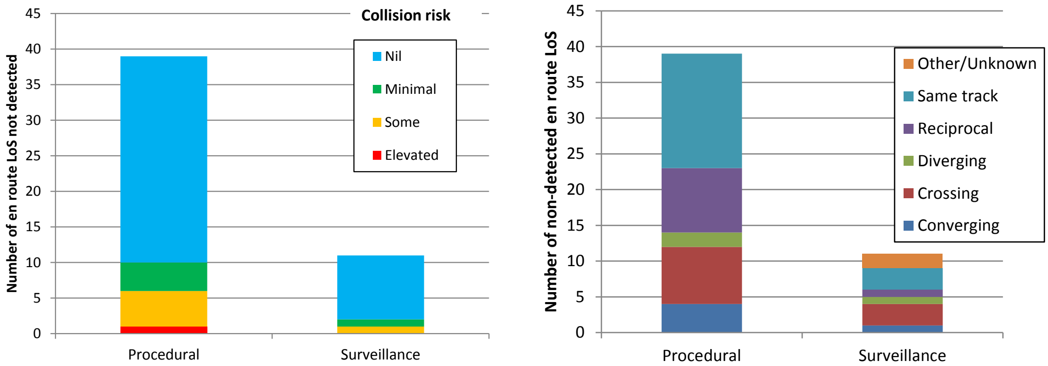
For the 39 procedural separation losses that were undetected, 11 were noticed by ATC after the loss and de-conflicting instructions were given, while 27 were not noticed or de-conflicted, including 16 where the aircraft had already passed and 11 where the spacing between aircraft travelling in the same direction had reduced below the required amount. Given the larger tolerances for procedural separation to account for the inexact positional information provided to ATC, these LOS occurrences did not involve conflicts that were close enough to lead to aircraft TCAS alerts or advisories. However, TCAS was available as a last line of defence against collision if the aircraft did get closer.

For the 11 surveillance based LOS occurrences that were undetected, five were noticed by ATC after the loss and de-conflicting instructions were given, while six involved aircraft travelling in the same direction or on diverging tracks where the distance between the aircraft had reduced below the standard.

Figure 15 (right panel) shows that undetected procedural LOS occurrences more commonly involved aircraft on the same track (one following the other) (41%). Just under a quarter of occurrences involved aircraft operating on reciprocal or crossing tracks. Although the same track and reciprocal track proportions are similar to that for all procedural en route LOS occurrences, the proportion of non-detected occurrences involving aircraft on crossing tracks was over-represented relative to all procedural LOS occurrences.

For undetected surveillance LOS occurrences, 27 per cent involved aircraft on the same track, and 28 per cent involved aircraft on crossing tracks. Although 30 per cent of *all* surveillance-based en route occurrences involved aircraft on converging tracks, cross tracks only represented 9 per cent of those that were not alerted by any means.

Figure 15: En route undetected LOS by collision risk (left) and relative tracks (right), January 2008-June 2012



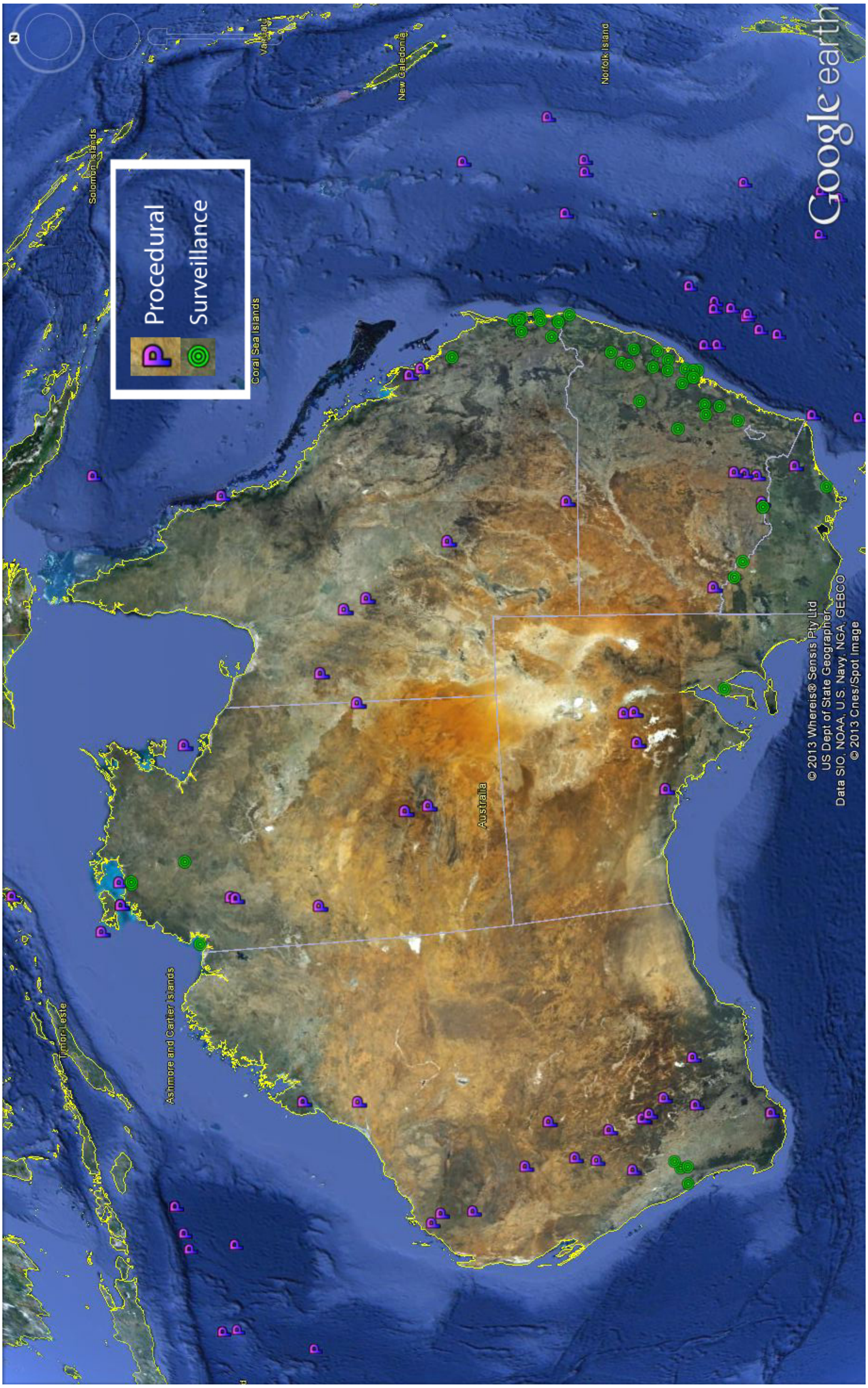
Location of en route LOS

Figure 16 shows the location of the en route LOS occurrences. It can be seen that most of the LOS occurrences involving aircraft subject to ATC surveillance services happened in airspace located in the Eastern half of Australia between Brisbane and Melbourne, with a smaller number around Perth and a few in north Northern Territory.

In contrast, procedural LOS occurrences were most common above the Pacific Ocean and (possibly due to traffic to mining locations) across Western Australia, and to a lesser extent, across inland Queensland and Northern Territory and towards Java.

This pattern seen in Figure 16 is due to the ‘J-curve’ radar coverage on the eastern seaboard between Brisbane and Melbourne compared to the limited surveillance services in the remainder of Australian away from major airports with radar coverage. More recently, the installation of ADS-B sites and uptake by aircraft operators has resulted in surveillance based separation losses elsewhere in Australia.

Figure 16: Location of en route occurrences by separation standard type, 2008-June 2012



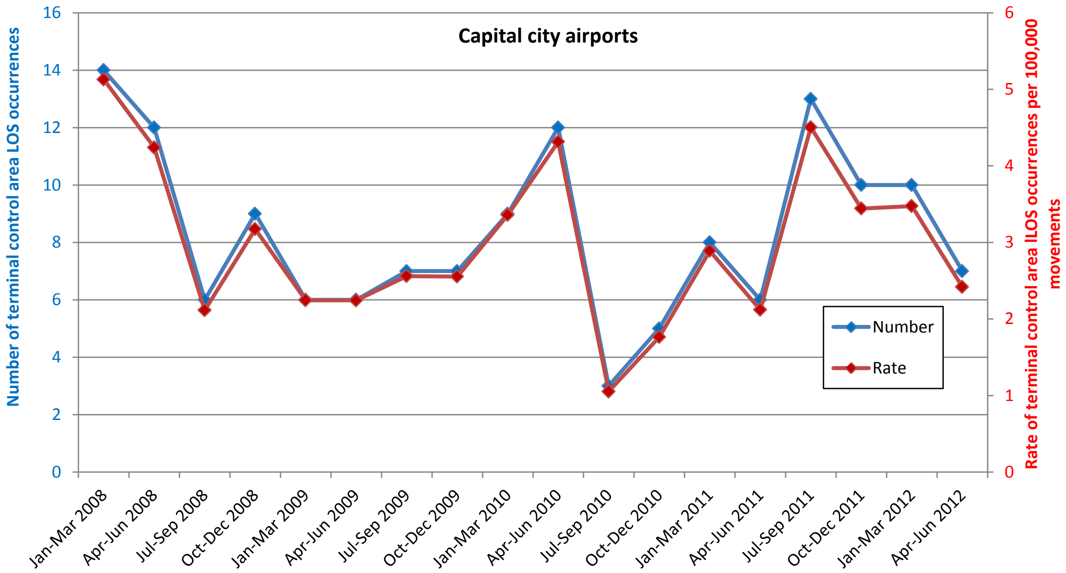
Terminal control area

Rates

Terminal control area LOS rates at capital city airports have varied somewhat across the January 2008 to June 2012 period, ranging from 5.1 per 100,000 movements in the Jan-Mar 2008 quarter, before reducing to 1.0 in Jul-Sep 2010 quarter, than climbing back to 4.5 a year later, reducing to 2.4 by the end of the study period (Figure 17).

Note that all terminal control area LOS occurrences at capital city airports are shown as a rate per 100,000 aircraft movements at those airports. This includes separation losses that are attributable to both controllers and pilots. In contrast, the target terminal control area rate for Airservices Australia explained in *Performance measures for LOS* on page 14, of less than 1.5 occurrences per 100,000 movements, refer to ATS-attributable occurrences only.[50]

Figure 17: Trend for terminal area LOS occurrences at capital city airports, January 2008-June 2012



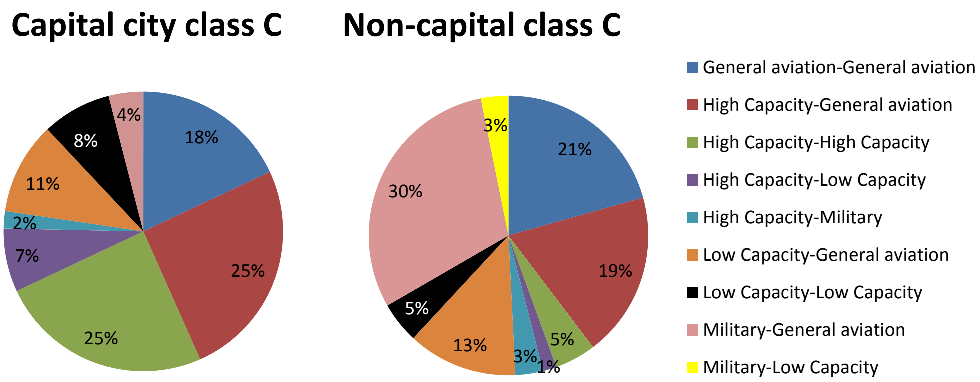
50 The following chapter, *Review of safety factors to reported occurrences*, provides an analysis of occurrences as contributed to by ATC and pilot actions.

Aircraft involved

Terminal area occurrences mostly involved general aviation and/or high capacity aircraft. About a quarter of all terminal area occurrences involved a confliction between a general aviation and high capacity aircraft, while 20 per cent involved only general aviation and 18 per cent involved only high capacity aircraft. Conflictions between military and general aviation aircraft accounted for 11 per cent of terminal area occurrences.

It can be seen in Figure 18 that the types of aircraft conflicts differ somewhat between the capital city and non-capital city terminal airspace. A similar proportion of conflicts were between two general aviation aircraft, or between a general aviation and a high capacity aircraft. However, for capital city airports, a quarter involved two high capacity aircraft, while in non-capital city airports, 30 per cent involved a military aircraft and a general aviation aircraft. The latter result reflects the fact that all military airports apart from Darwin are in the non-capital city class C group. Unlike other capital city airports, over half of the LOS occurrences in Darwin terminal airspace involved low capacity air transport aircraft (10 with general aviation aircraft, 7 with other low capacity aircraft).

Figure 18: Aircraft operation type conflicts in terminal areas, January 2008-June 2012



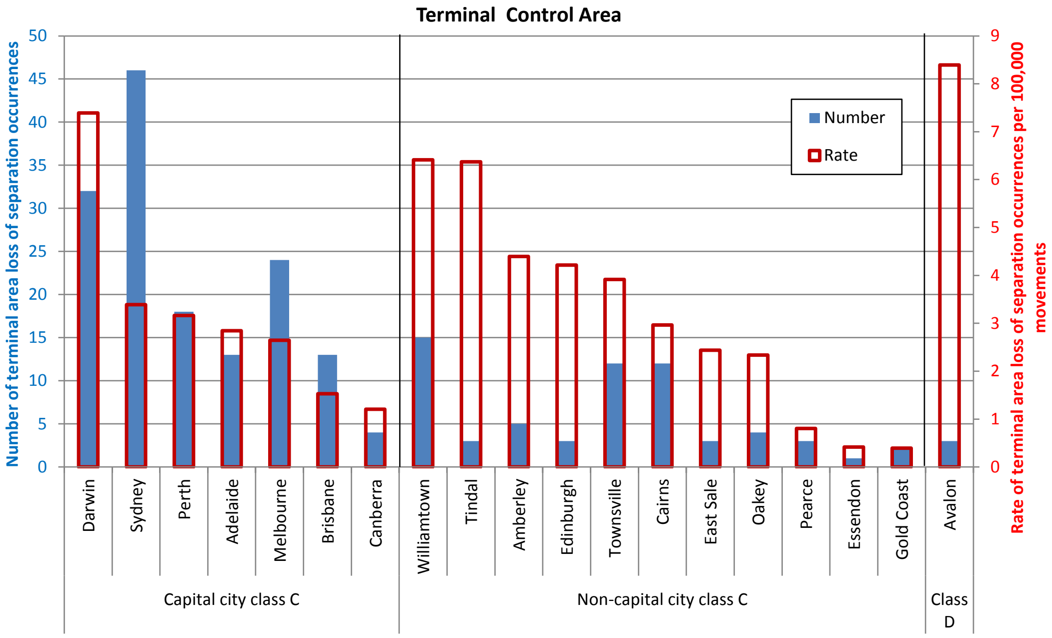
Most (90%) terminal area occurrences involved two aeroplanes, while 9 per cent involved a confliction between an aeroplane and a helicopter. Just over half of the terminal area occurrences involved only IFR aircraft, while 42 per cent involved a loss of separation between an IFR and VFR aircraft.

Locations

Not surprisingly, most terminal area LOS occurrences were at the capital city airports, in particular, Sydney, Melbourne, Darwin, Perth (blue bars in Figure 19). Of the non-capital city airports, with relatively less aircraft movements than capital city airports (see Figure 2 on page 12), Williamtown (Newcastle) (15 occurrences) and Townsville and Cairns (12 occurrences each) were notable.

When looking at the rate of occurrences per 100,000 movements, it becomes clear that many of the military operated aerodromes[51] had considerably higher terminal area LOS rates than most civilian operated aerodromes (red unfilled bars in Figure 19). In particular, Darwin, Williamtown, and Townsville had a high rate and number of terminal area LOS occurrences, as well as (but with very low numbers of occurrences) Tindal, Amberley and Edinburgh[52].

Figure 19: Number and rate of terminal area LOS by aerodrome, 2008-June 2012[53]



Avalon recorded the highest LOS rate of all terminal control areas in Australia, but only had three occurrences in the study period. Avalon is located in class D airspace, meaning that no aircraft (IFR or VFR) are separated from VFR aircraft, and generally only IFR to IFR are separated.[54] As such, there will be other separation issues at Avalon involving VFR traffic that do not involve air traffic control, and are not reported on in this study.

The terminal control area rate was similar across the civil ATS operated major airports, ranging from 3.4 to 2.6 occurrences per 100,000 hours for Sydney, Perth, Cairns, Adelaide and Melbourne. Brisbane and Canberra had lower occurrence rates (1.5 and 1.2 respectively).

The maps in the figures below (Figure 20, Figure 21 and Figure 22) show the locations of terminal area losses of separation around Sydney, Melbourne and Darwin Airports.

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51 Only LOS occurrences involving at least one civilian aircraft are reportable to the ATSB so LOS occurrences between two military aircraft are not included in the data presented. Movements used in the rate calculations at military (and other) aerodromes include all military and civilian aircraft movements.

52 Although Edinburgh terminal area is controlled by Airservices Australia, two of the three LOS occurrences involved a combination of military ATC for one aircraft and civil ATC for the other aircraft.

53 There are other aerodromes that receive terminal area control that are not shown in this figure because they have not had any LOS occurrences in the period of study.

54 Except for ‘Special VFR’ in conditions less than VMC.

Figure 20: Location of terminal control area LOS occurrences in the vicinity of Sydney Airport, January 2008-June 2012

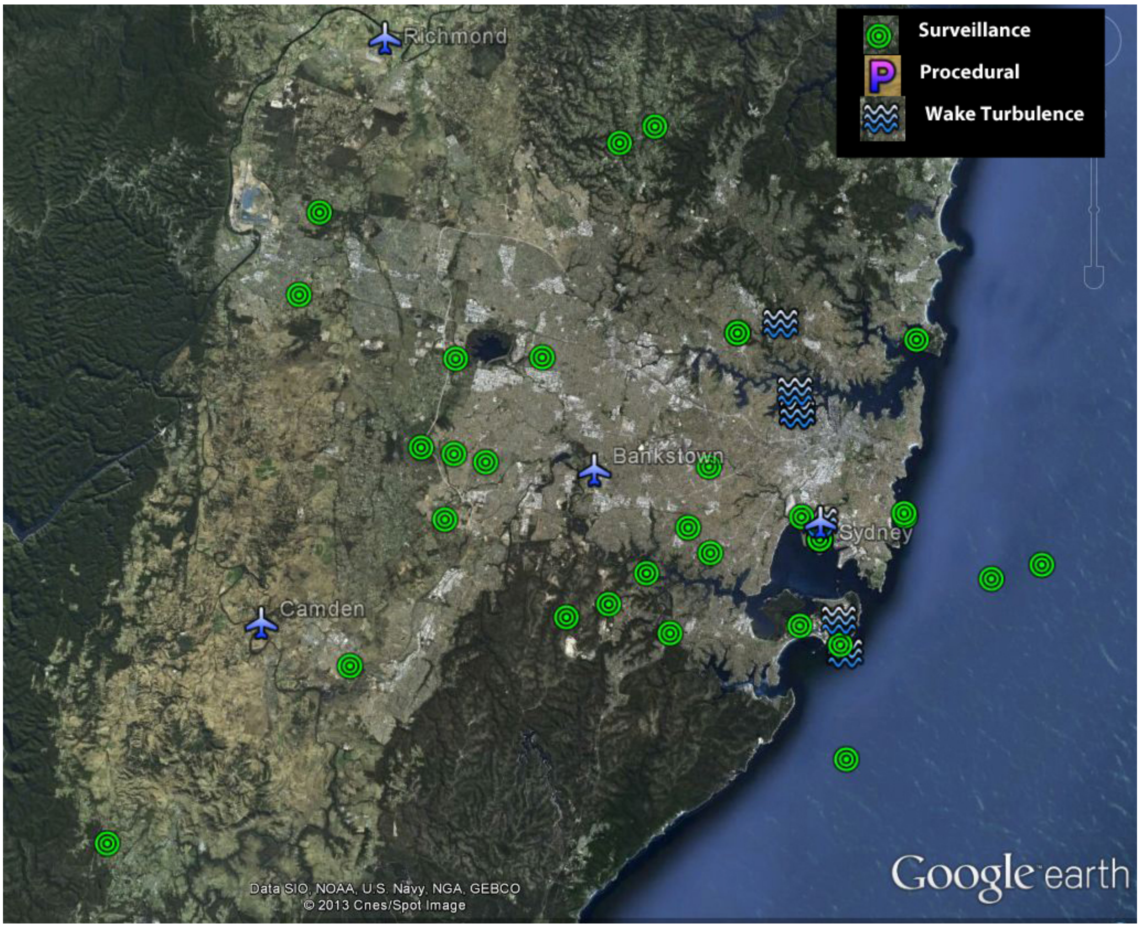


Figure 21: Location of terminal control area LOS occurrences in the vicinity of Melbourne Airport, January 2008-June 2012

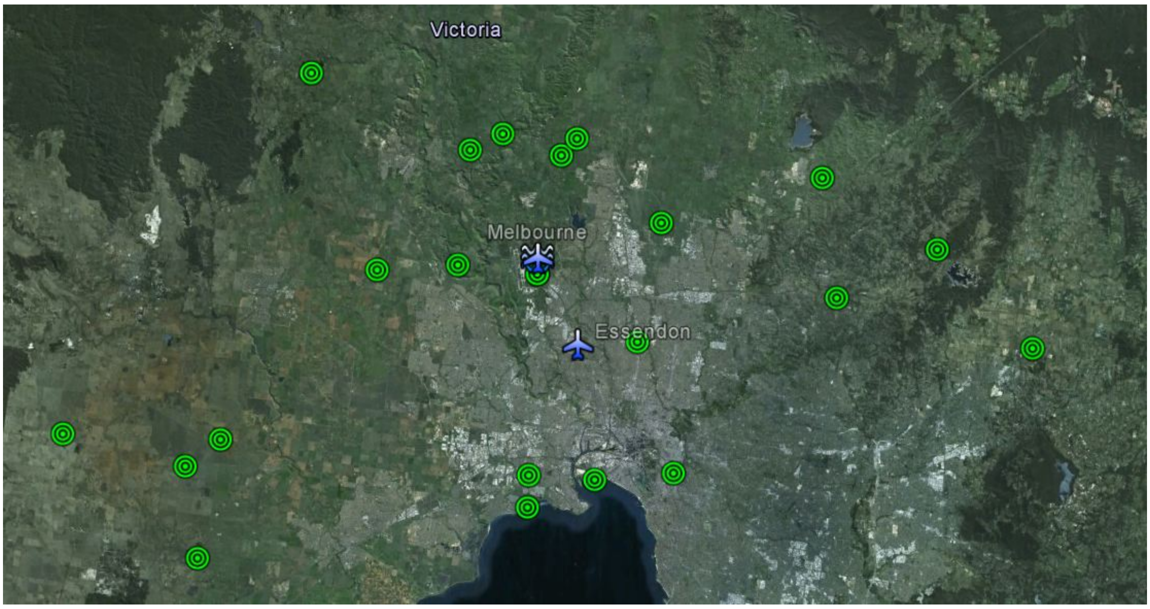
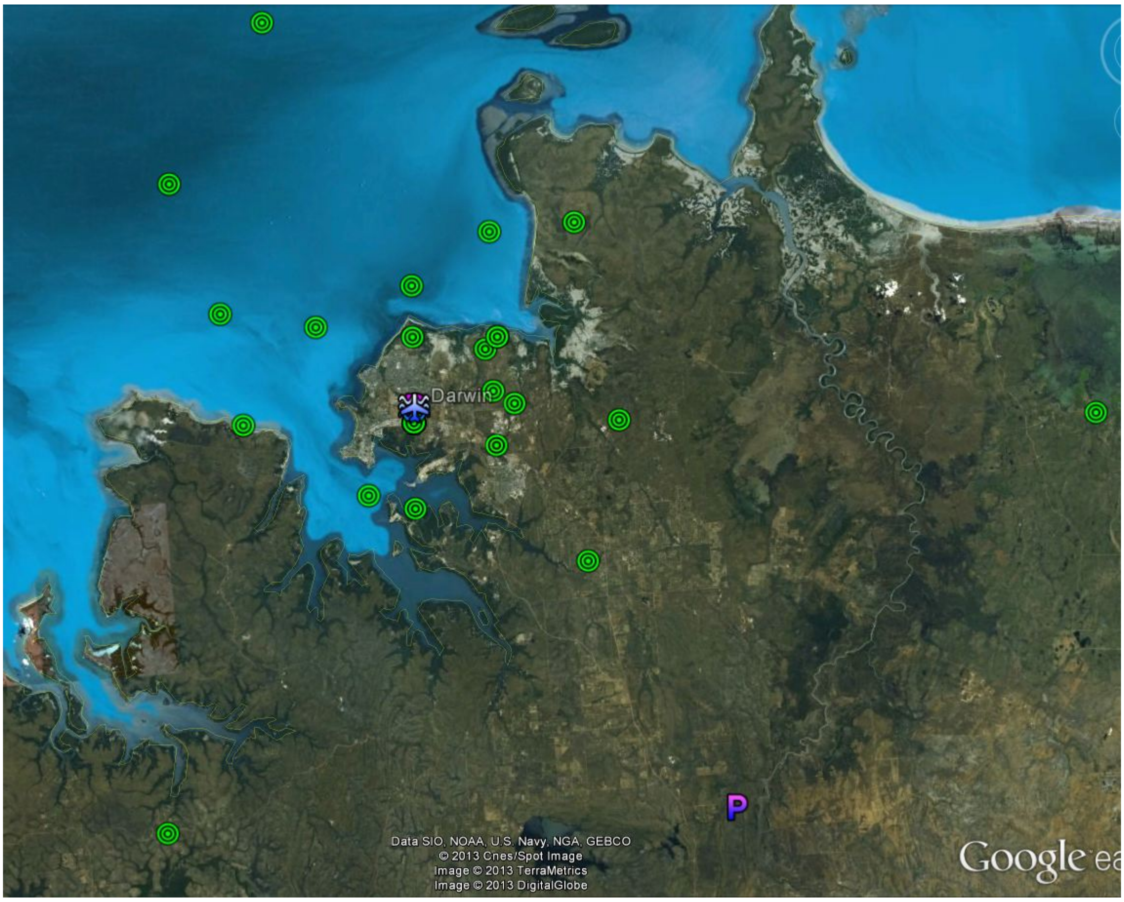


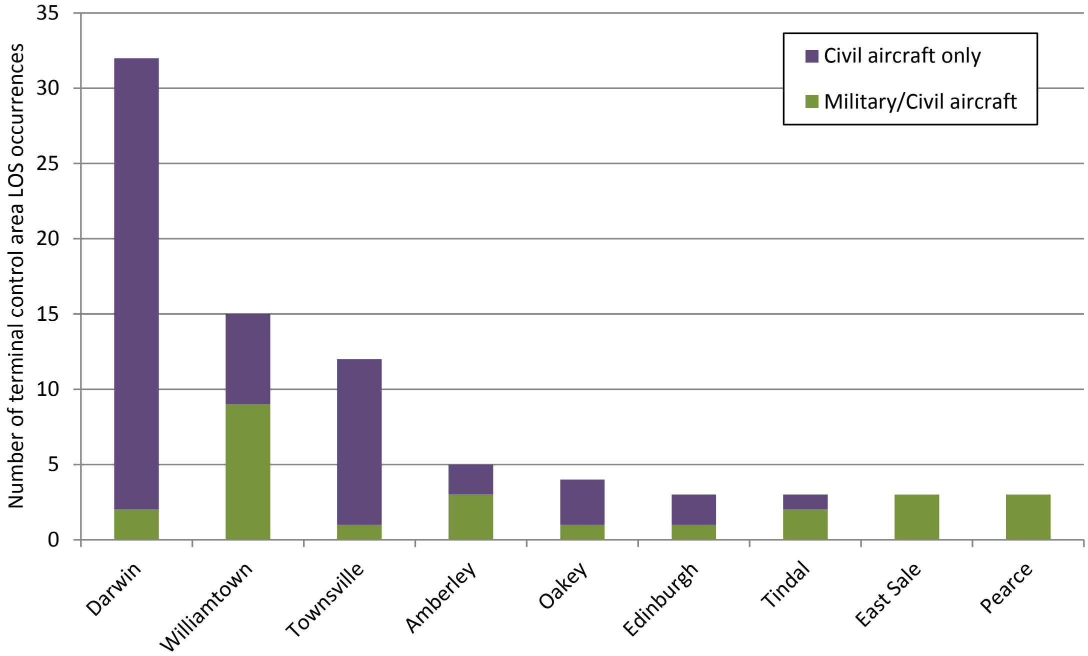
Figure 22: Location of terminal control area LOS occurrences in the vicinity of Darwin Airport, January 2008-June 2012



Civil/Military aircraft

At the two joint civil/military aerodromes where the Department of Defence is the ANSP (Darwin and Townville), most occurrences involved a confliction between two civilian aircraft (Figure 23). This is consistent with the small numbers of military aircraft movements relative to all aircraft movements at these airports (Darwin 6%, Townsville 12%). In contrast, most other military aerodromes, including Williamtown, recorded LOS occurrences that involved both a military and a civil aircraft.

Figure 23: Aircraft involved for terminal control area LOS at military ATS aerodromes, January 2008-June 2012

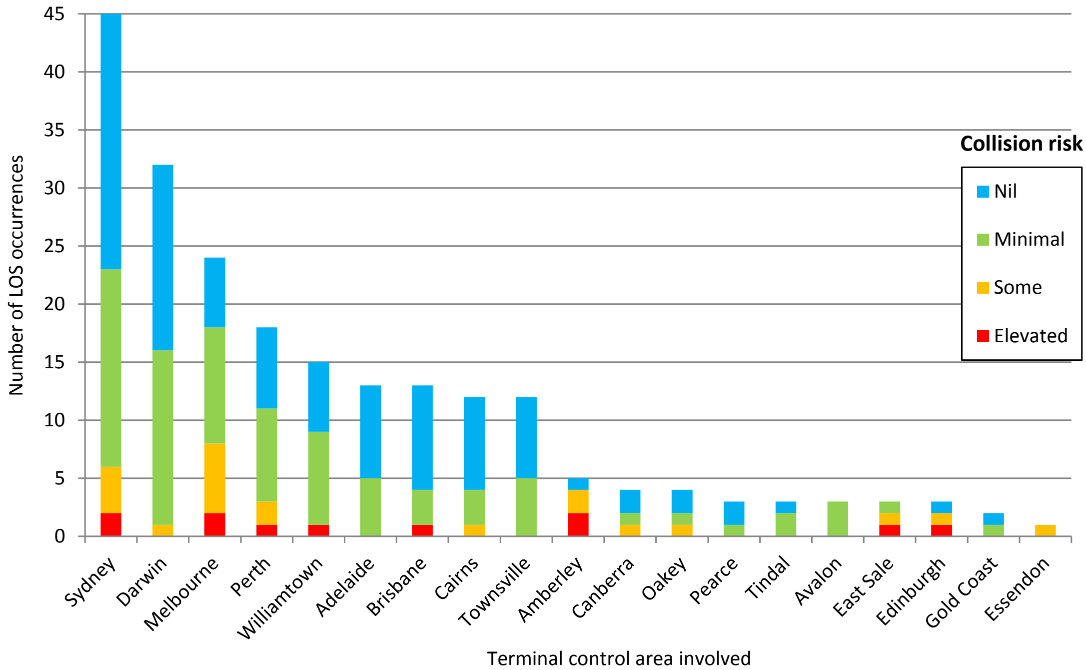


Collision risk

Figure 24 shows that most LOS occurrences in terminal control areas at most aerodromes had minimal or nil collision risk. Melbourne and Sydney had the highest number of occurrences with elevated or some collision risk, as could be expected due to the sheer number of movements at these airports.

However, as a proportion of occurrences at individual aerodromes, it was the smaller military aerodromes which commonly featured occurrences with elevated or some collision risk. In particular, Amberley, Edinburgh[55], and East Sale had a notable proportion of higher risk LOS occurrences, although all of these had a small total number of terminal area occurrences. Despite the high number and rate of occurrences at Darwin, most had minimal or no risk of collision (none were elevated, and only one had some collision risk). Similarly at Williamtown, one occurrence had an elevated collision risk, but all others were minimal or nil risk.

Figure 24: Terminal area LOS at aerodromes by collision risk, January 2008-June 2012



The terminal area occurrences with an elevated collision risk were as follows:

- A Cessna 441 was climbing outbound from Essendon and the Boeing 767 was inbound to Melbourne and descending. For separation, the approach controller instructed the 767 crew to climb. The two aircraft passed with 1.5 NM (2.78 km) of horizontal and 700 ft of vertical separation.
- While passing 8,700 ft on descent into Sydney, the crew of a Boeing 737 reported passing a glider a few hundred feet below that had entered controlled airspace without clearance.
- The crew of a Pilatus PC-9 did not comply with the clearance to remain at or above 4,000 ft and commenced descent to East Sale. A Piper PA-31 was on a reciprocal track to the PC-9 and descending from 3,500 ft.
- The Piper Tomahawk was cleared to conduct non-standard circuits not above 2,500 ft at Amberley. An F-111 was cleared to descend to 2,500 in the circuit area and separation reduced to 0.3 NM (0.56 km) laterally and 300 ft vertically between the two aircraft.

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[55] Although Edinburgh terminal area is controlled by Airservices Australia, the two LOS occurrences with either elevated or some collision risk involved a combination of military ATC for one aircraft and civil ATC for the other aircraft.

- On departure from Sydney, a Jetstream 32 was cleared to 5,000 ft, but was subsequently observed by ATS to have climbed to 5,400 ft without a clearance which brought it into conflict with the inbound Boeing 737.
- A Cessna entered restricted airspace without a clearance, resulting in the aircraft crossing in front of a Blackhawk helicopter at Amberley. Separation reduced to 0.8 NM (1.48 km).
- The two F/A18 aircraft in formation climbed through their assigned altitude to 4,700 ft at Edinburgh. This resulted in a loss of separation standards with the Beech 76 aircraft that was holding at 5,000 ft.
- The flight crew of a Boeing 737, on departure from Melbourne, reduced their aircraft's speed in order to meet a height requirement of the Standard Instrument Departure. A following 767 aircraft climbed at a faster speed. When the aircraft were transferred from the aerodrome controller to a departures controller, there was 3.4 NM (6.3 km) separation between them. The departures controller expected them to climb at a similar speed, and did not recognise the loss of separation assurance. The controller's actions to manage the compromised separation were not fully effective. At one point, radar separation had reduced to 1.9 NM (3.52 km) and vertical separation to 500 ft.
- Separation standards were infringed when, due to thunderstorm in the vicinity at Brisbane, neither the crew of the Boeing 737 or Airbus A320 were able to comply with ATS instructions to alter heading.
- During approach, the crew of a Pilatus PC-12 received a TCAS Traffic Advisory (TA)[56] and took avoiding action in relation to an aircraft that had exceeded its altitude limits resulting in separation of about 100 ft vertically over Perth.
- At Williamtown, separation between a Boeing B737 and a Westwind 1124 reduced to 0.7 NM (1.3 km) on radar and 400 ft. The reduced vertical separation was a result of the 737 flight crew responding in accordance with a resolution advisory provided by their aircraft's traffic alert and collision avoidance system. The ATSB investigation (AO-2011-011) identified a series of errors by the Williamtown Approach controllers involving separation assurance, coordination and communication, and compromised separation recovery.

Overall risk by location

Figure 25 below shows the sum of the total LOS risk in the terminal control area for each airport. This was achieved through the event risk classification of each occurrence which takes into account collision risk, the people carrying capacity of the aircraft involved, and other occurrence events that occurred either immediately prior to or after the LOS. The results for the sum of risk (green unfilled bars) should only be viewed as a relative comparison between the locations. The graph does not take into account the number of movements at each location in order to show where the greatest risks lie. As such, airports with higher numbers of occurrences due to a higher number of movements will feature more prominently, as will those airports which cater for larger aircraft and/or have more severe collision risks.

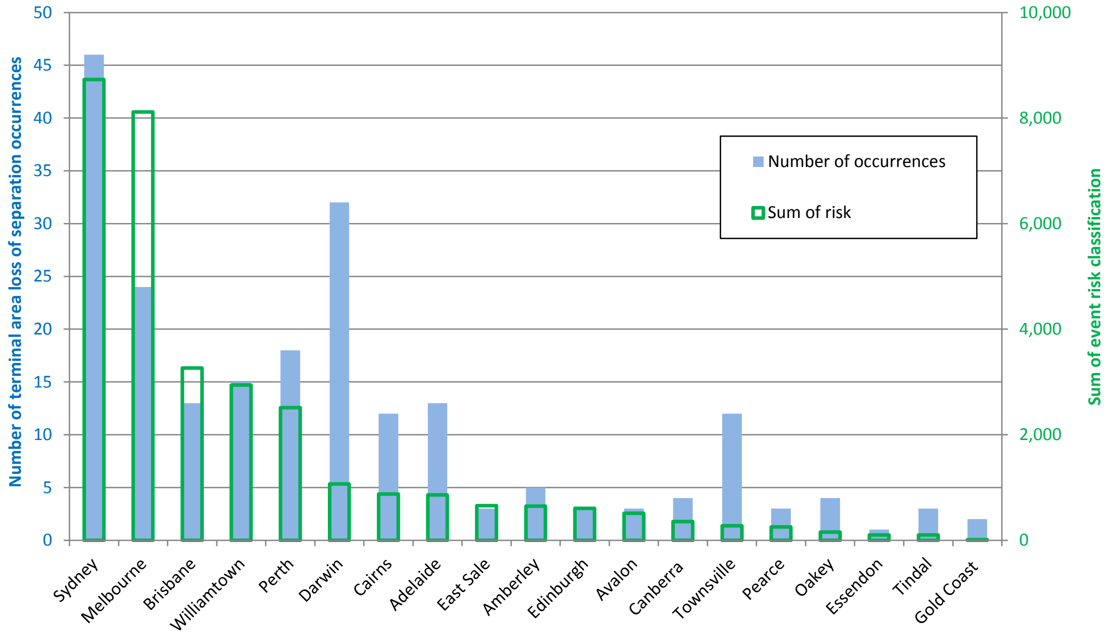
It can be seen in Figure 25 that the sum of the event risk classifications (green unfilled bars) does not necessarily follow the total number of terminal area occurrences (blue filled bars). In particular, LOS occurrences at Darwin and Townsville had a relatively smaller risk than would be expected from the number of occurrences alone. This is because occurrences at Darwin and Townsville Airports nearly always were between smaller, mostly general aviation aircraft, and many had nil collision risk.

Melbourne had a risk similar to Sydney despite far fewer occurrences being recorded at Melbourne. This was due to half of Sydney’s occurrences having no collision risk, while only a quarter at Melbourne had no collision risk.

[56] Traffic Collision Avoidance System Traffic Advisory, when a TA is issued, pilots are instructed to initiate a visual search for the traffic causing the TA.

The other prominent terminal control area risk locations were Brisbane, Williamtown and Perth. A prominent occurrence at Brisbane was a LOS with an elevated risk involving an Airbus A320 and a Boeing 737 aircraft. Williamtown had one occurrence with an elevated collision risk involving a Boeing 737, while Perth had one elevated collision risk involving a Pilatus PC-12 corporate turboprop and an occurrence with some collision risk involving a Boeing 777 aircraft.

Figure 25: Overall terminal control area LOS risk by aerodromes, January 2008-June 2012



Standard type

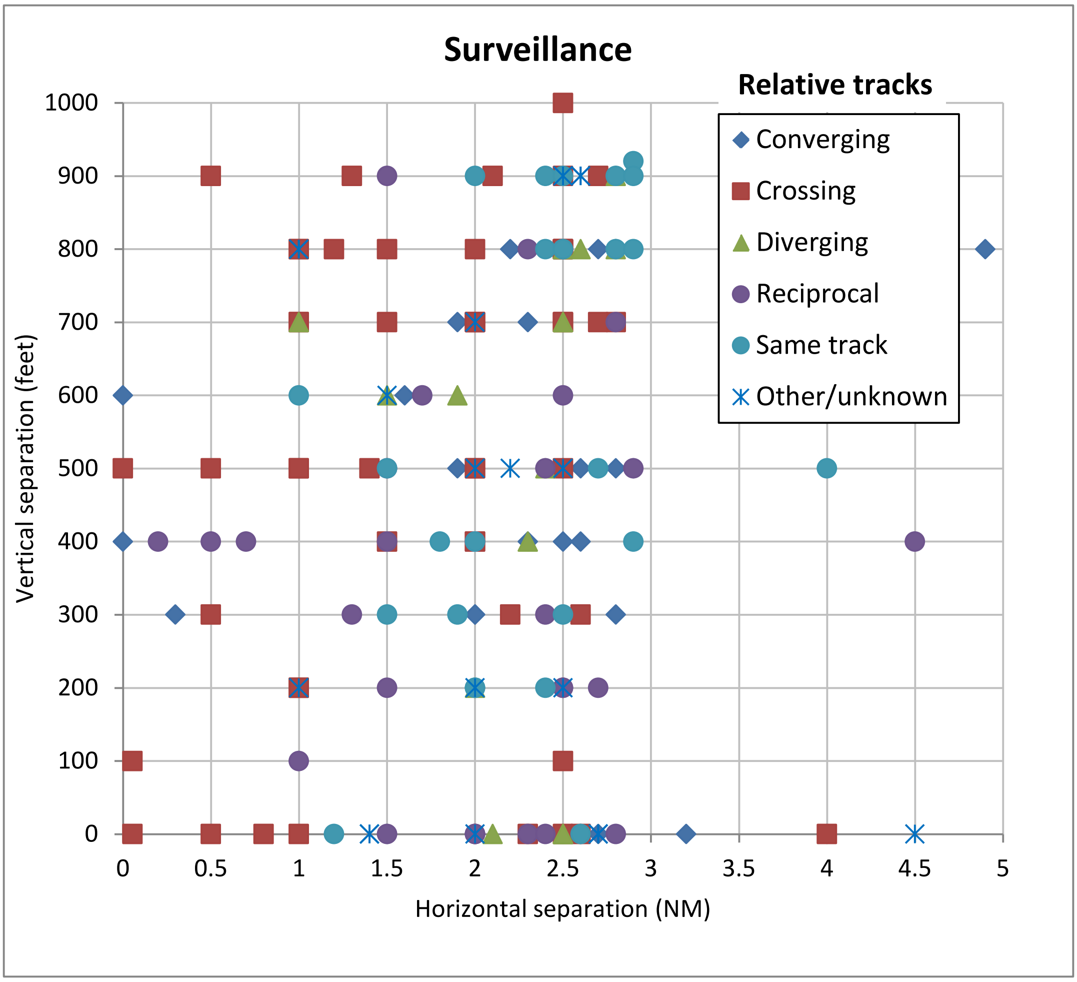
For terminal control area occurrences, most (89%) involved a loss of surveillance-based separation. There were also a small number of wake turbulence separation occurrences (8%), particularly at Sydney and Brisbane Airports. There were four procedural separation losses, two of which were due to a radar failure at Darwin, and two occurrences involving visual separation at other locations.

Separation remaining

Figure 26 shows the distance remaining between the aircraft when the separation standard was lost. In the terminal control area, the proximity of the aircraft involved was closest following a surveillance-based LOS when the two aircraft were on crossing tracks. In particular, there were four occurrences in which crossing aircraft flying at the same level came within 1 NM (1.85 km) of each other. The most extreme case involved the following elevated collision risk occurrence:

- While being positioned for an approach into Jandakot over a danger area involving aerobatic aircraft for an Australia Day display, the Pilatus PC-12 crew received a continuous TCAS TA with an aerobatic aircraft that had exceeded its altitude limits. The crew saw the aircraft and perceived a possible collision would result so took avoiding action by turning steeply to the right. Separation reduced to 100 metres (0.05 NM) horizontally at the same level.

Figure 26: Separation remaining for terminal area surveillance LOS occurrences, January 2008-June 2012



Detection of compromised separation situations

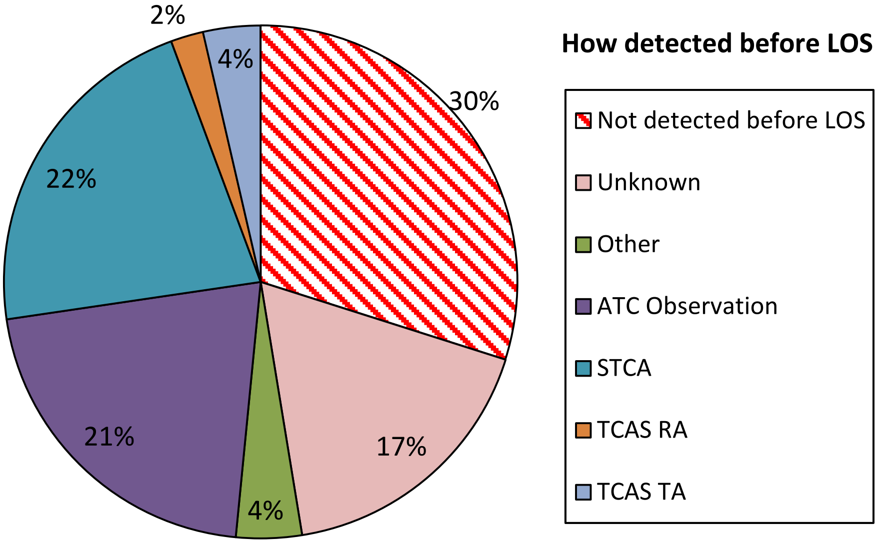
Thirty per cent of surveillance-based LOS occurrences in terminal areas were not detected before separation was lost. Of these, most had either nil (41%) or a minimal (43%) risk of collision between the aircraft. Only four (7%) had an elevated collision risk, and five (9%) had some collision risk. The four undetected occurrences with elevated risk were:

- The crew of a Boeing 737 reported passing a glider a few hundred feet below.
- Under high workload, a controller inadvertently directed a military F-111 towards a Piper aircraft conducting non-standard circuits. The pilot of the Piper descended immediately upon hearing ATC instructions to the F-111.
- The crew of a Boeing 737 and Airbus A320 aircraft that were holding before landing due to thunderstorms were given instructions to alter their heading, but could not comply due to the location of the thunderstorms.
- Following take-off and shortly after transferring aircraft control from the tower environment to the terminal area, the terminal area controller did not notice that a Boeing 767 aircraft was travelling faster than a preceding Boeing 737 aircraft.

About a quarter of the occurrences that were not detected involved aircraft on converging tracks, and another quarter involved aircraft on crossing tracks.

As seen in Figure 27, over half of the terminal area surveillance LOS occurrences were detected, with 22 per cent identified through the controller observation, 22 per cent from a STCA, before taking compromised separation recovery actions. Very few were detected from a pilot reacting to and/or communicating about a TCAS alert.

Figure 27: How compromised separation for terminal area surveillance were detected, January 2008-June 2012

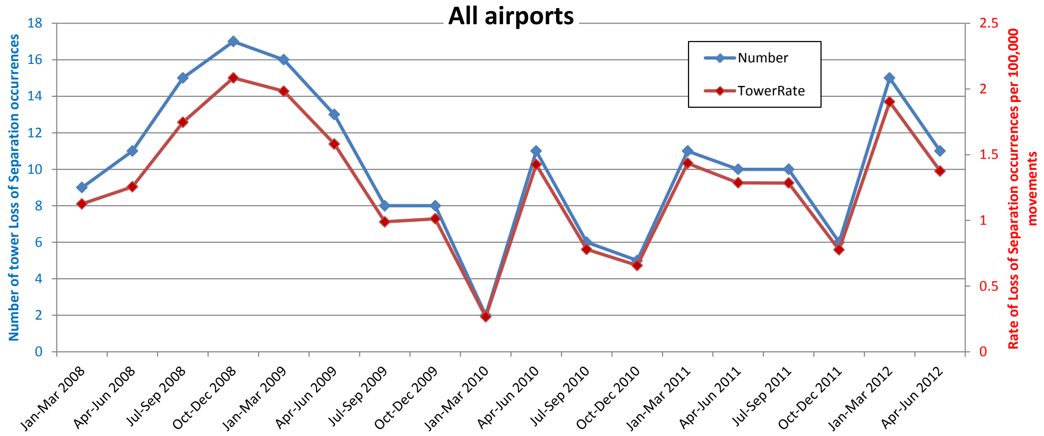


Tower environment

Rates

The total number of LOS occurrences that happened in the tower environment, and the rate per 100,000 movements per quarter, can be seen in Figure 28. The number of occurrences in 2012 reduced from 2008 levels, but has climbed since 2010. The occurrence rate has varied over the study period, from as low as 0.6 to as high as 2.1 tower related LOS occurrences per 100,000 movements.

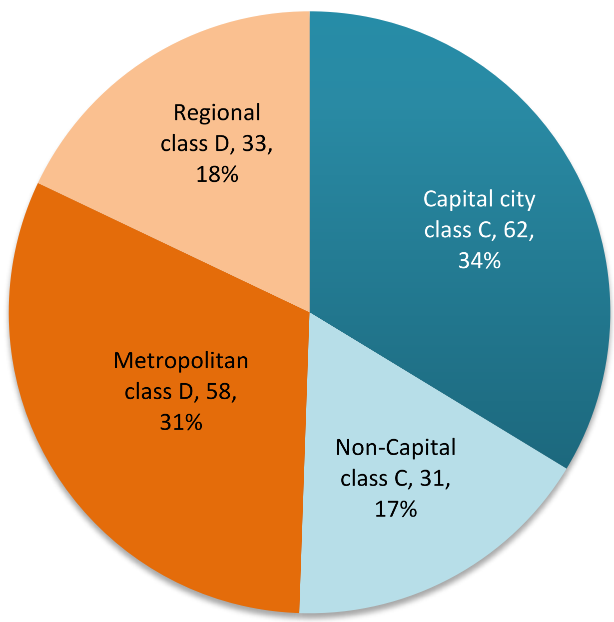
Figure 28: Tower LOS trend, January 2008-June 2012[57]



Locations

For loss of separation occurrences that happened in the tower environment, only about one third were at capital city airports, with another third at metropolitan class D airports. The remaining third were split between other class C airports and regional class D airports (Figure 29). Half were in class C airports and half were in class D airports.

Figure 29: Tower LOS airport type, January 2008-June 2012

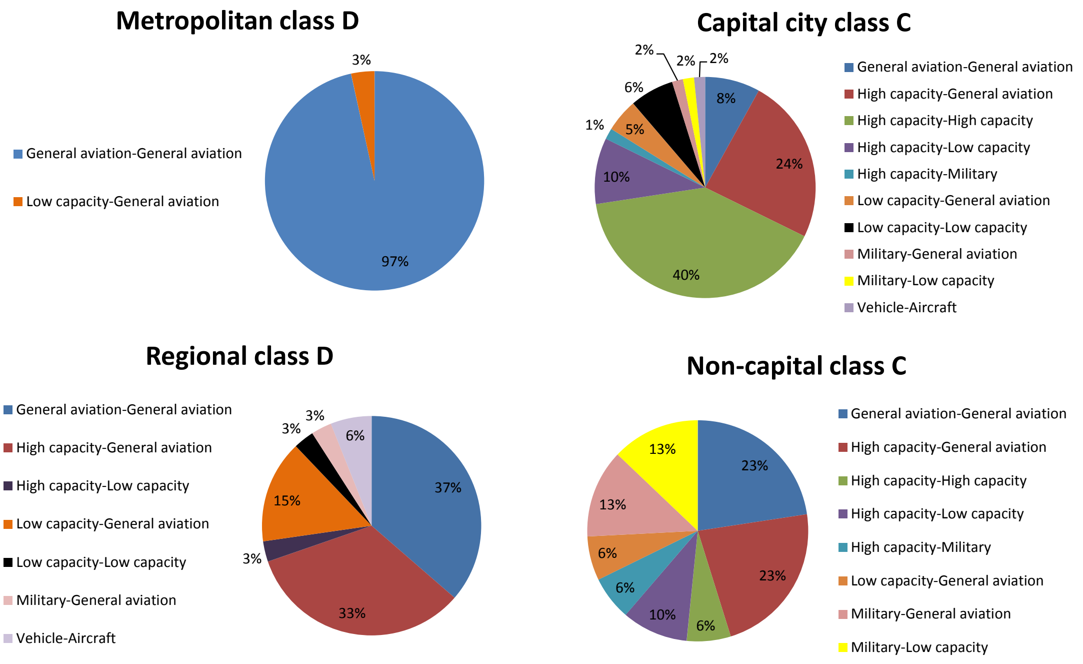


57 Only includes airports with at least one loss of separation occurrence. See Figure 31 for airports included.

Aircraft involved

It can be seen in Figure 30 that the types of aircraft involved in conflicts varied greatly between different types of airports. Metropolitan class D occurrences nearly all involved only general aviation aircraft, as this reflects the majority of traffic flying in and out of these airports. Conflicts only involving high capacity air transport aircraft (shown in green) featured heavily in capital city airports (40%), but were non-existent at other airports. For the other airport types, there was a greater mix in the aircraft types involved in conflicts, with general aviation to general aviation, and general aviation to high capacity featuring prominently.

Figure 30: Aircraft operation type conflicts at Towers by type, January 2008-June 2012

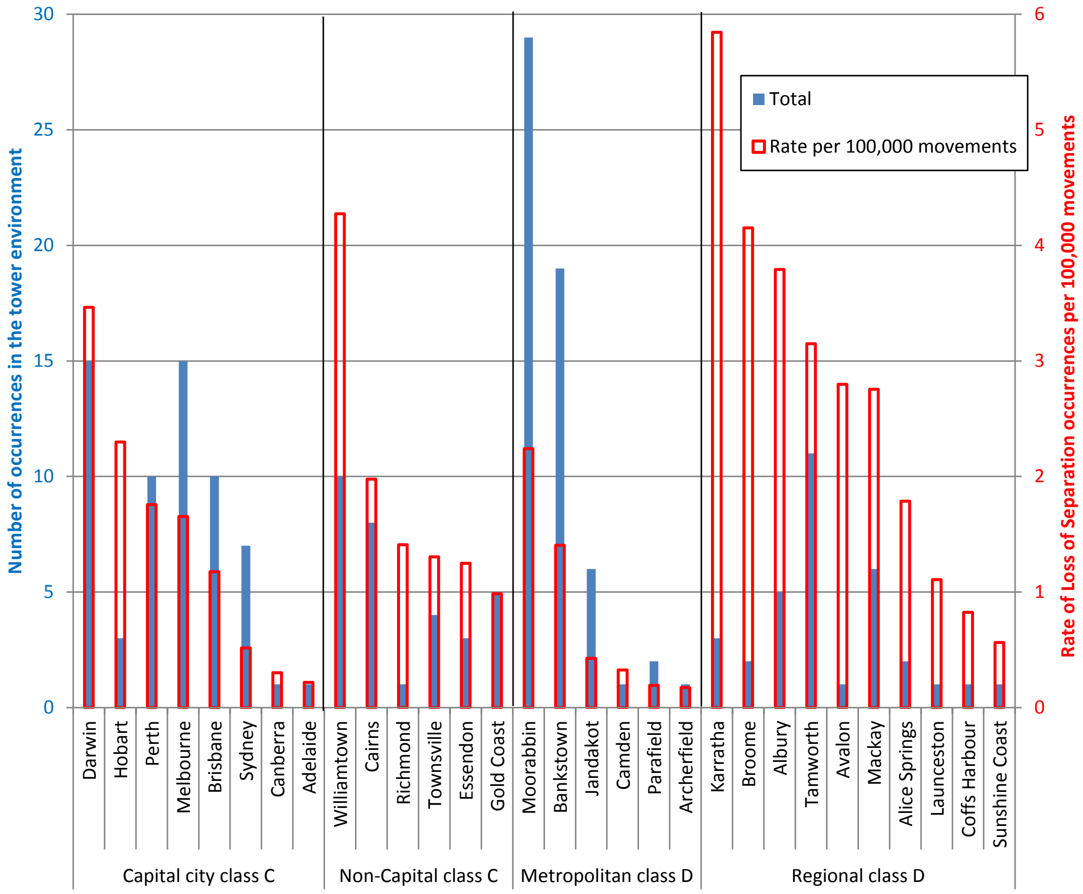


Aerodromes

Occurrences at two metropolitan class D airports, Moorabbin and Bankstown, accounted for a quarter of all tower LOS occurrences. These airports are very busy general aviation hubs (see Figure 2 on page 12) with multiple runways. Jandakot, despite being as busy as Moorabbin and Bankstown, had far fewer occurrences. Other airports shown in Figure 31 generally had a similar proportion of tower LOS occurrences to the number of movements at those airports.

When looking at the rate of tower LOS occurrences per 100,000 movements, it becomes clear that the regional class D airports in general, and the class C airports of Williamtown and Darwin, had relatively higher rates. Karratha and Broome Airports show a low number of tower LOS occurrences (partly because a tower service has only been provided at these airports since late-2010, halfway through the study period), but a high occurrence rate. The rate of occurrences at Metro D airports is relatively low compared to regional class D airports which have far fewer movements.

Figure 31: Tower LOS airport type, January 2008-June 2012



Standard type involved

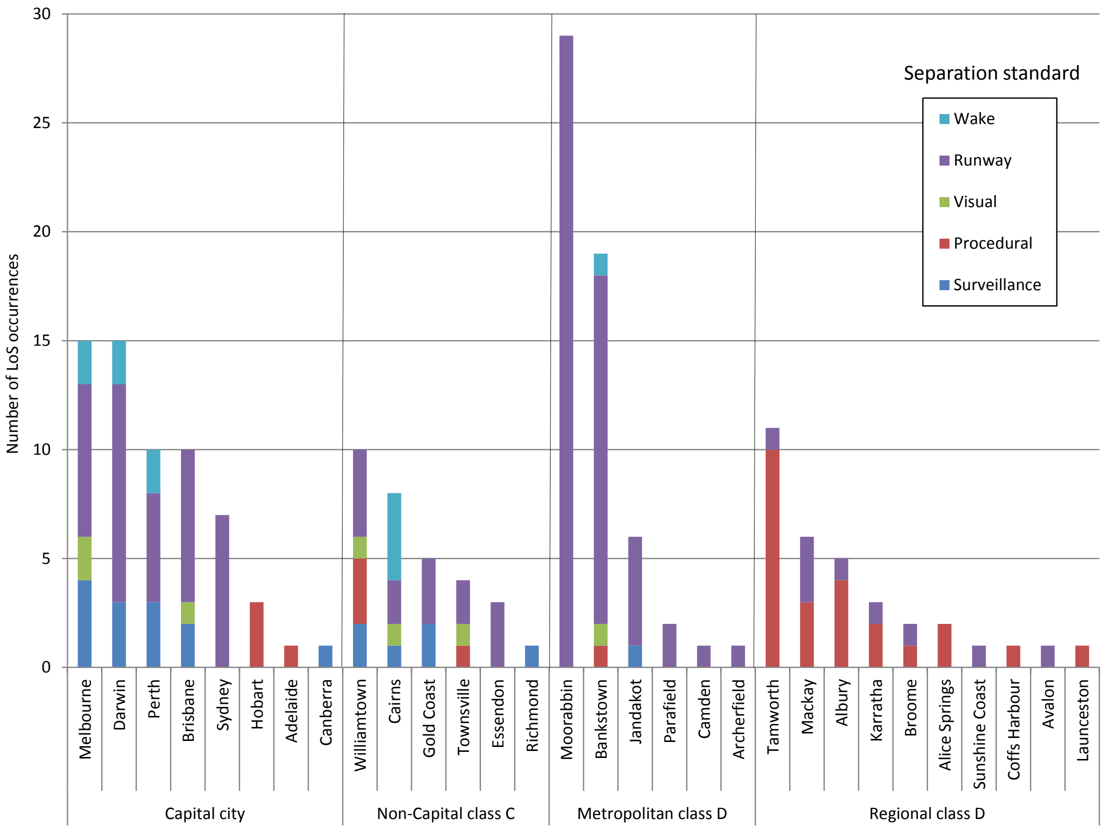
In the tower environment, about 60 per cent of all occurrences were a loss of a runway separation. A loss of a procedural standard made up 18 per cent, while surveillance accounted for only 11 per cent, and wake turbulence standards 6 per cent.

There was a very different pattern in the types of separation standards lost between the different types of airports. For the metropolitan class D airports, most (91%) occurrences involved a loss of runway separation. This was due to the majority of traffic into these airports being VFR, with the only separation being provided for VFR aircraft in class D airspace being runway and wake turbulence separation. Moorabbin, and to a lesser extent Bankstown Airport, accounted for most of these occurrences. In contrast, an occurrence resulting from a reduction in the required runway separation standards made up about half of all occurrences at both class C airport types (capital city and non-capital city), and only a quarter at regional class D airports.

About 10 per cent of occurrences at class C airports involved a compromise of wake turbulence separation standards.

Nearly three quarters (73%) of tower LOS occurrences at regional class D airports involved a loss of procedural separation between IFR aircraft, or between IFR and special VFR aircraft.

Figure 32: Tower LOS at airports by standard, January 2008-June 2012



Considering the phase of flight of the aircraft involved in a runway LOS, about a third involved a conflict between an aircraft on approach to land or landing with an aircraft on take-off. Another third involved a conflict between an aircraft on approach to land, or an aircraft landing conflicting with a taxiing aircraft. Only about 22 per cent involved an aircraft taking off and a taxiing aircraft coming too close.

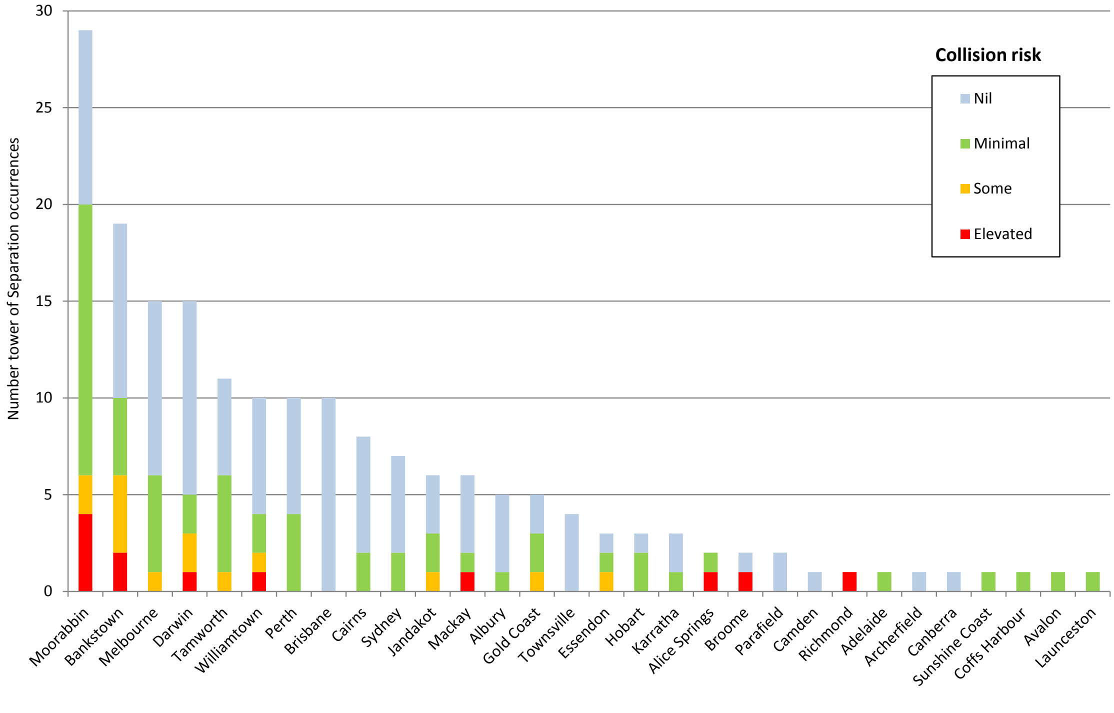
For runway separation occurrences, about half involved aircraft on crossing tracks. These occurrences almost entirely involved one aircraft taxiing. Another 35 per cent involved conflicts between aircraft on the same track. More than three quarters of these were conflicts between an aircraft on approach to land (or landing) and an aircraft taking off.

Collision risk

The most common locations for occurrences with elevated or some collision risk where separation was controlled by the tower were at the metropolitan class D airports of Moorabbin and Bankstown (six occurrences each). For each of these airports, five of the six higher collision risk occurrences involved a loss of runway separation.

Locations with a single tower LOS with an elevated collision risk (Figure 33) were the military operated Darwin, Williamtown and Richmond Airports, and the civil operated Mackay, Alice Springs and Broome Airports. Four of these aerodromes also had tower occurrences with some collision risk: Bankstown with four, Moorabbin and Darwin with two, and Williamtown with one.

Figure 33: Tower LOS at airports by collision risk, January 2008-June 2012



The elevated collision risk tower occurrences were as follows.

- During an approach to Richmond, the pilot of the Beech 76 was assigned a heading of 240 degrees. The aircraft was observed on radar to turn through 240 degrees to a heading of 150 degrees. This put the aircraft in conflict with a Beech 95. The pilot of the Beech 95 was instructed to maintain heading and altitude, however, separation reduced to 300 ft vertically and 0.6 NM (1.11 km) laterally (Richmond, surveillance standard).
- A Cessna 152 was observed by ATC to cross the threshold of runway 11C without a clearance as a Cessna 182 passed directly overhead on short final approach, resulting in an infringement of separation standards. The vertical distance between the aircraft was estimated to be approximately 10 feet. The aerodrome controller had reportedly been busy sighting inbound traffic. (Bankstown Airport, runway standard).
- A Piper PA-31 entered runway 11R without a clearance resulting in a loss of runway separation standards with a Cirrus SR22. The SR22 had crossed the threshold after being cleared for a touch and go landing. The controller instructed the SR22 pilot to conduct a go around. (Bankstown Airport, runway standard).
- During the take-off run, the Cessna 210 pilot observed an aircraft on short final for the crossing runway. The Cessna pilot stopped prior to the runway intersection. The other pilot conducted a missed approach. There was a breakdown of separation standards. (Darwin Airport, runway standard).

- While conducting an airfield runway and lighting inspection, the driver of an airport safety vehicle crossed a runway at the same time as an aircraft was taking off from that runway. The driver was distracted by a telephone call at the time, and did not comply with an air traffic control instruction to hold short of the runway. (Mackay Airport, runway standard)
- A Cessna Cardinal was observed by ATC to have entered the runway 31L strip without a clearance while the Cessna 310 was taking off on runway 31L. The pilot of the Cardinal was not in normal communication with ATS and the crew of the Cessna 310 elected to complete the take-off. The Cardinal passed over the Cessna 310 at about 20 feet (Moorabbin Airport, runway standard).
- The pilot of a Piper PA-28 was issued a take-off clearance for runway 13R. Another aircraft that had recently landed on runway 13R was cleared to cross runways 22, 17L and 17R during taxi. The pilot of the PA-28 became disorientated at the holding point A2 as it was a combined entry to both runway 13R and 17R, and inadvertently began a take-off roll on runway 17R instead of runway 13R. The aircraft came within 100 m of each other before the PA-28 exited at the first taxiway and returned to the apron. (Moorabbin Airport, runway standard).
- While taxiing after landing, a Cessna 152 crossed runway 17R without a clearance. A Piper PA-31 was landing on the runway at the time. (Moorabbin Airport, runway standard).
- A Cessna 172R aircraft landed on runway 13L at Moorabbin Airport with a student and instructor on board. On vacating the runway, the 172R was issued a clearance by ATC to taxi back to base via taxiway C, but to hold short of runway 13R; however, the 172R did not stop at the holding point, but continued across the runway. At the time of the runway incursion, a Cessna 172S had just touched down to land on runway 13R. On seeing the 172R cross the runway, the pilot of the 172S applied full power, commenced a go-around, and passed overhead the 172R. (Moorabbin Airport, runway standard).
- A procedural infringement of separation standards occurred between a Beech 350 conducting navigation aid calibration and an approaching Piper PA-31. The crew of the Beech 350 reported climbing in response to a TCAS Resolution Advisory (RA).[58] (Alice Springs Airport, procedural standard).
- On descent to 6,000 ft, the crew of the inbound Bombardier DHC-8 received a TCAS RA to descend about 17 NM (31.5 km) north east of Broome. The crew then sighted a Pilatus PC-12 about 1 NM (1.85 km) ahead and reported that it passed about 200 to 300 ft to the right and slightly above them. The pilot of the PC-12 had not selected Automatic Direction Finding as one of the active navigation aids in the aircraft's Electronic Flight Instrumentation System (EFIS). As a result, upon programming new information into the EFIS after departure, the PC-12 unintentionally deviated from the desired outbound track and conflicted with the inbound track of the DHC-8. (Broome Airport, procedural standard).
- The pilot of a PA-28 was instructed to maintain runway heading after departure, but was subsequently observed to turn left. This resulted in an infringement of separation standards with a formation of F/A-18s operating in restricted airspace 2 NM (3.7 km) to the north. To avoid further conflict, the pilot of the PA-28 was given a heading away from the airspace, resulting in the aircraft operating below the minimum safe altitude in instrument meteorological conditions (IMC). (Williamtown Airport, surveillance standard).

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58 When a TCAS RA is issued pilots are expected to respond immediately to the RA unless doing so would jeopardise the safe operation of the flight.

Total risk per aerodrome

Figure 34 below shows the sum of the total risk at each towered airport. This was achieved through the event risk classification of each occurrence which takes into account collision risk, the people carrying capacity of the aircraft involved, and other occurrence events that occurred either immediately prior to or after the LOS. The results for the sum of risk (green unfilled bars) should only be viewed as a relative comparison between the locations. The graph does not take into account the number of movements at each location in order to show where the greatest risks lie. As such, airports with higher numbers of occurrences due to a higher number of movements will feature more prominently, as will those airports which cater for larger aircraft and/or have more occurrences with higher collision risks.

It can be seen in Figure 34 that Moorabbin Airport had the highest risk associated with tower LOS occurrences. This is related to the large number of occurrences (due in part to the large number of movements, and a complex arrangement of taxiways to deal with three runways), and the relatively high number of occurrences with an elevated or some collision risk (mostly as a result of runway separation issues). Moorabbin caters for general aviation aircraft, so this result is not due to occurrences involving large transport aircraft.

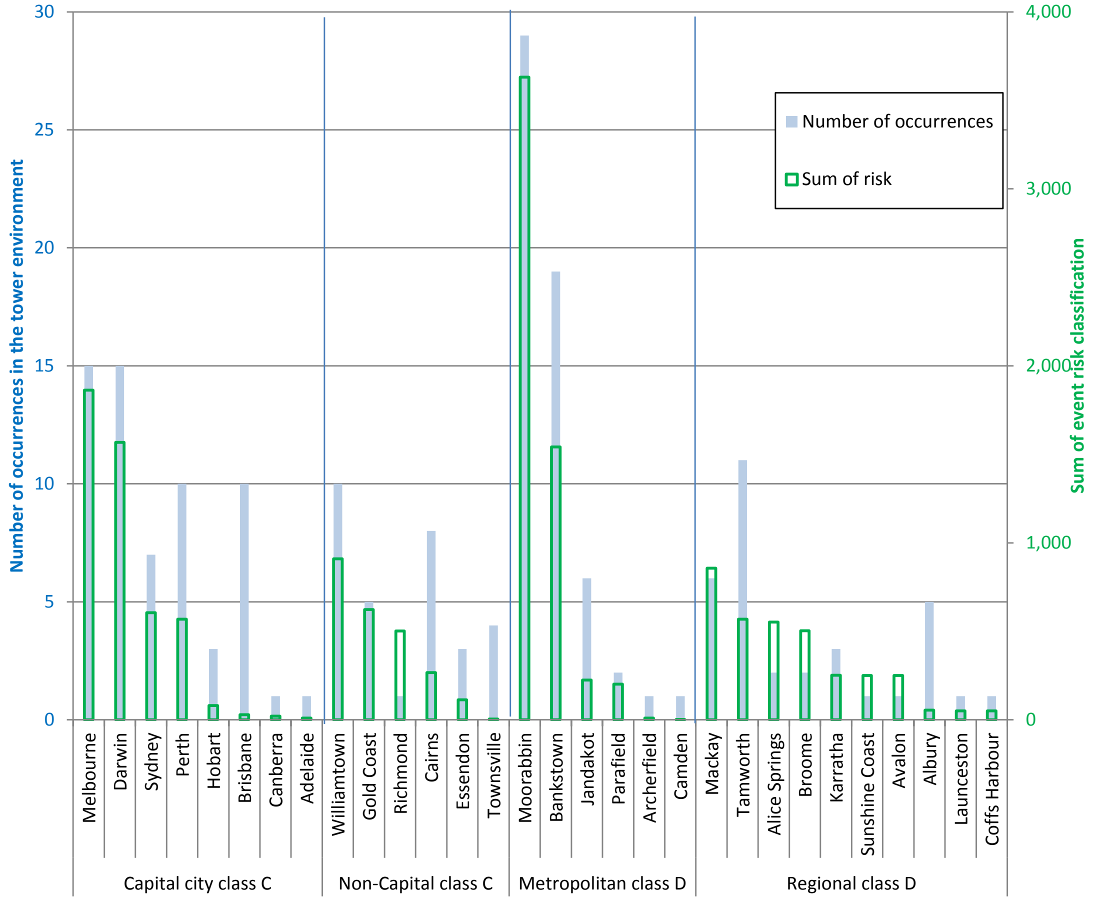
For the capital city towers, more high risk tower LOS occurrences happened at Melbourne and Darwin airports. Melbourne was higher than Darwin despite the same number of occurrences being reported. This was due to some occurrences at Darwin involving only general aviation aircraft, while all at Melbourne involved high capacity air transport aircraft.

For the non-capital city class C airports, Williamtown showed a higher risk than most capital city airports (other than Melbourne and Darwin) due to most occurrences involving high capacity air transport, one elevated collision risk occurrence (listed above), and another occurrence with some collision risk involving low capacity passenger transport. Although Cairns had a higher number of tower LOS occurrences than Gold Coast (formerly Coolangatta), Gold Coast showed a larger risk due to minimal collision risk occurrences involving Boeing 737 aircraft (Cairns also had occurrences with high capacity aircraft, but they were mostly nil collision risk).

For the other metropolitan class D airports, Moorabbin followed Bankstown in terms of the sum of total risk, as would be expected by the large numbers of occurrences. On the other hand, Jandakot had a relatively low risk score compared to the number of tower LOS occurrences as a result of the generally minimal collision risks involved in those occurrences.

For regional class D airports, Mackay showed the highest risk due to a combination of one elevated collision risk occurrence at Mackay Airport, and other minimal collision risk occurrences involving large aircraft (Dash 8, Embraer 190). Despite having twice as many tower LOS occurrences than Mackay, Tamworth had a somewhat lower sum of risk than Mackay. Alice Springs and Broome both only had two occurrences in the study period, but one in each location involved an elevated collision risk. It should be noted though that a tower service has only been provided at Broome Airport since late-2010, halfway through the study period.

Figure 34: Sum of total risk of tower environment LOS occurrences at airports, January 2008-June 2012



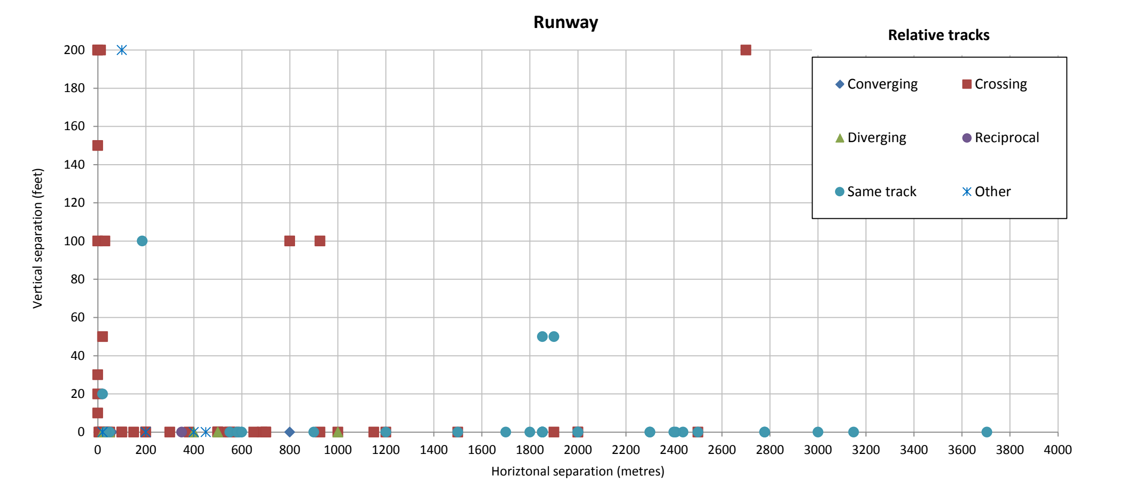
Separation remaining

For runway separation occurrences, aircraft had the least amount of separation remaining most commonly when their tracks were crossing (Figure 35). As previously mentioned, this mostly involved one of the aircraft taxiing; in some of these situations an aircraft overflew the taxiing or standing aircraft with minimal clearance. Conflictions involving aircraft on the same track were more likely to be horizontally positioned, but usually involved aircraft flying at the same level.

Figure 35 indicates that there were quite a number of occurrences where the tower's separation standard was lost, and there was only minimal distance remaining. In fact, there were 21 occurrences where separation reduced to 100 metres or less horizontally and about 20 ft vertically. These all involved aircraft on the runway, and all involved two aircraft, except for one occurrence involving a helicopter. Fourteen occurrences were reported at metropolitan class D aerodromes (nine of which occurred at Moorabbin Airport). Out of these occurrences, in seven incidents ATC had detected the situation before the separation standard was lost. In the majority, however, it was not detected before separation was lost. Only two of the 21 close proximity tower LOS occurrences had an elevated collision risk (listed earlier -both at Moorabbin), and one had some collision risk:

- A Cessna 172 was cleared to land on runway 11R at Bankstown but approached and landed on runway 11C. Another aircraft had been cleared to enter and line up on runway 11C and was within the flight strip when the 172 landed. The aircraft came with 20 metres horizontally and 20 feet vertically.

Figure 35: Separation remaining after loss of runway standard, January 2008-June 2012



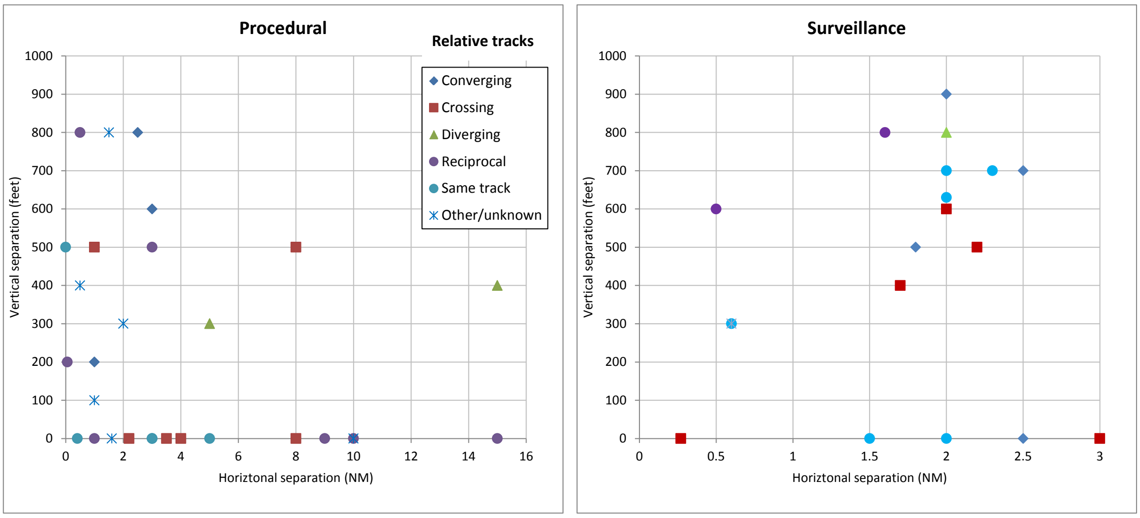
As mentioned above, procedural losses of separation where the tower was providing a separation service occurred mostly at regional class D towers. The left panel of Figure 36 shows that most of these occurrences involved aircraft flying either at the same level, or at different levels but within 3 NM horizontally. The two 'closest' occurrences were as follows:

- At Tamworth Airport, ATC nominated a Piper Chieftain on right downwind for runway 30R as number two to a Piper Twin Comanche on VOR final approach, but the Chieftain pilot lost sight of the Twin Comanche and turned base, causing a confliction. ATC cleared the Chieftain to land and instructed the Twin Comanche to go around. Separation reduced to 750 m at the same level
- A Cessna 172 was instructed to depart from overhead Bankstown at 1,500 ft, but climbed to 2,000 ft inside controlled airspace without a clearance. This resulted in an infringement in separation standards with an approaching Piper PA-31. Separation reduced to 1 NM (1.85 km) at the same level.

Losses of surveillance-based separation (right panel of Figure 36) provided by tower based ATS were generally confined to class C airports, and on the whole had large margins remaining in both horizontal and vertical distances. The two occurrences where aircraft got within 0.6 NM (0.93 km) of each other were as follows:

- During the approach to Melbourne Airport, an Airbus A330 was instructed to turn base for runway 34. The aircraft was subsequently observed to turn downwind which brought the aircraft into conflict with a Piper PA-34. The crew also changed frequency without instruction. The Melbourne tower controller instructed the A330 to turn right and the Essendon tower controller instructed the PA-34 to turn right also, in attempts to resolve the traffic confliction. The aircraft came within 0.5 NM (0.93 km) and 600 ft.
- At Canberra Airport, a Cessna 172 made a wider circuit than ATC expected, resulting in a LOS (500 metres at same level) with an approaching de Havilland DHC-8 (Dash 8). The Dash 8 crew reported receiving a TCAS TA.
- During an approach to Richmond, the pilot of the Beech 76 was assigned a heading of 240 degrees. The aircraft was observed on radar to turn through 240 degrees to a heading of 150 degrees. This put the aircraft in conflict with a Beech 95. The pilot of the Beech 95 was instructed to maintain heading and altitude, however, separation reduced to 300 ft vertically and 0.6 NM (1.11 km) laterally.

Figure 36: Separation remaining for loss of procedural (left) and surveillance (right) standard in the tower environment (note difference horizontal scale), January 2008-June 2012

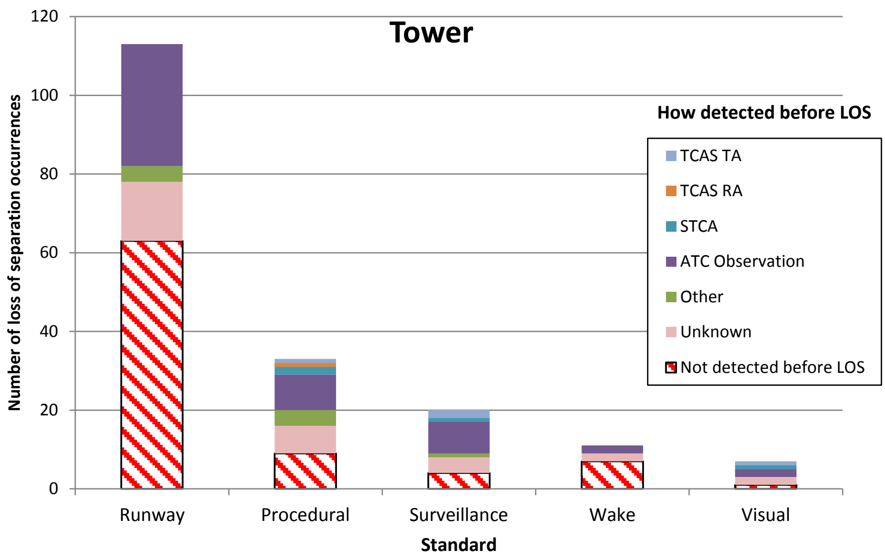


Detection of compromised separation

More than half of the occurrences (56%) involved in runway separation losses were not detected by ATC before the LOS occurred. In a quarter of cases, they were detected through ATC observation and pilots received verbal advice from a controller of the conflict. Of the 62 runway separation losses that were not detected, four resulted in an elevated collision risk and 10 resulted in some collision risk.

For procedural and surveillance standard losses, it was more likely that the compromised separation was detected before it led to a loss of separation in the tower environment (Figure 37) than they were in the terminal area environment (see Figure 27 on page 42 above). For the 11 wake turbulence occurrences that occurred under tower ATS control, at least seven were not detected beforehand.

Figure 37: How pilots were alerted to loss of separation by standard in the tower environment, January 2008-June 2012



For the losses of runway separation, a quarter of those involving crossing tracks led to an avoidance manoeuvre by the pilot (14 of 53), while only one of the 38 occurrences that involved aircraft on the same track led to pilot-initiated avoidance manoeuvres.

Review of safety factors to reported occurrences

Methodology

This chapter analyses the safety factors that contributed to reported loss of separation (LOS) occurrences across the January 2008 to June 2012 period. Safety factors are events and conditions that were present at the time of the occurrence that increased risk.

Safety factors have been coded by the ATSB using information provided by one or more of four sources: reported information from controllers and pilots, ATSB investigations, Department of Defence internal investigations (Aviation Safety Occurrence Reports), and/or investigation factors from Airservices Australia internal investigations of LOS occurrences.

Although many of these factors were identified in investigations (ATSB, Airservices, or Department of Defence), others were coded based on information reported to the ATSB by air traffic service providers and pilots/operators at the time of the occurrence. No distinction has been made between occurrences where there was specific evidence to suggest the factors that directly contributed to the occurrence, and those occurrences where factors may have contributed, but a lack of formal investigation meant that this information was not confirmed. For the purposes of this analysis, all factors will be referred to as contributing factors.

Contributing versus attributable

As mentioned in the *Context* above, safety factors should be interpreted as potentially contributing to an occurrence and are not synonymous with attribution of cause. Safety factors do not attribute blame to one party. Instead, the existence of a safety factor suggests that actions by controllers and pilots, and/or pre-existing conditions, were present and increased the chance of the loss of separation or increased its severity. As such, some occurrences have contributing safety factors from both the ATS environment and the flight deck environment.

All discussion of safety factors below refers to actions and conditions that *contributed* to the LOS occurrence. They should not be read as attributing cause to one of the involved parties.

Safety factor taxonomy

Nearly every accident and incident in aviation has associated with it one or more individual actions that led to the sequence of events resulting in the occurrence. Individual actions are those actions by pilots and controllers conducted in order to achieve an outcome (coordinate and separate aircraft for controllers, or fly safely for pilots) but which have ended up threatening the safe accomplishment of these outcomes.

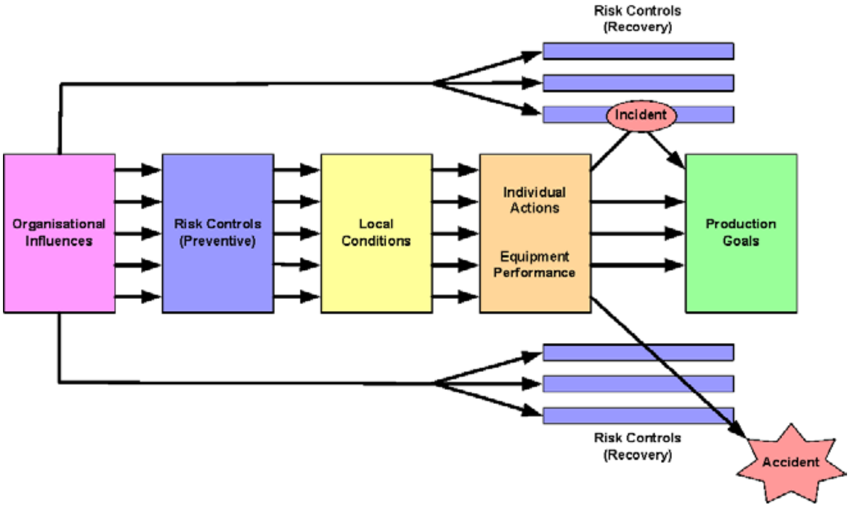
Individual actions can be seen as ‘how’ an occurrence happened. Errors or violations normally do not happen in isolation, and generally other factors lie behind them. These other factors are often the local conditions and inadequate risk controls in place which, when able to be identified, more accurately describe ‘why’ these occurrences happened (see Figure 38).

Local conditions are those conditions which exist in the immediate context or environment and which can have an influence on the individual actions. They include characteristics of the people (such as fatigue or lack of skill) and the equipment involved, as well as the nature of the task (including workload and distractions) and the physical environment (including weather).

Risk controls are the measures put in place by an organisation to facilitate and assure safe performance of operational personnel and equipment. Preventive controls are control measures put in place to minimise the likelihood of undesirable local conditions, individual actions and occurrence events, and include procedures, training, equipment design, and work rosters. Recovery controls are control measures (such as warning systems) put in place to detect, correct, or otherwise minimise the adverse effects of local conditions, individual actions and occurrence events.

Beyond risk controls are the organisational influences that establish, maintain or otherwise influence the effectiveness of an organisation's risk controls.

Figure 38: The ATSB safety factor taxonomy model



Data limitations

Of the 531 occurrences used in this analysis, 529 were reported to the ATSB by an air navigation service provider (ANSP). Only 28 per cent were also reported by the pilots involved. As a result, generally more details were available about occurrences from the air traffic services (ATS) perspective than from the pilots' perspectives. As such, the reasons why controllers made errors are more likely to have been coded than the reasons why pilots made errors.

As the majority of occurrences analysed for this report were not investigated, most safety factors identified have been at the individual action level only as more in-depth information has not been available. As such, analysis below of local conditions and risk controls will understate the true levels of when these conditions were actually present.

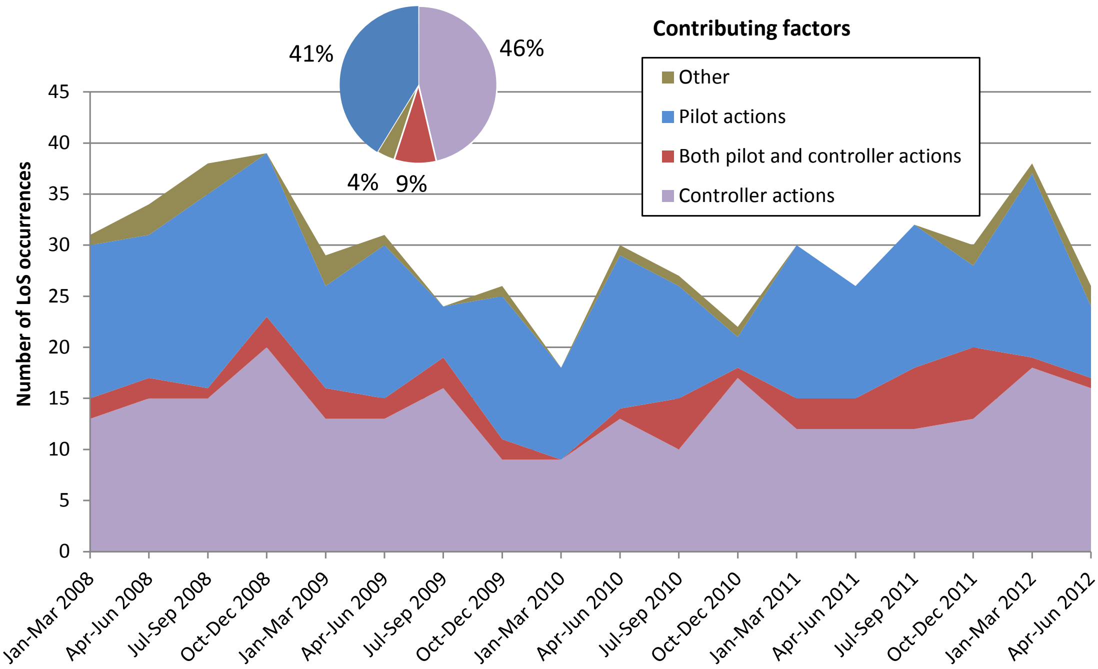
Overall

Controller and pilot contributing actions

About half of the 531 LOS occurrences involved a contributing action from an air traffic controller (55%) or a pilot (50%). Of these, 9 per cent involved contributing actions from both. It can be seen in Figure 39 that the relative contribution from pilots and controllers has remained fairly even across the study period.

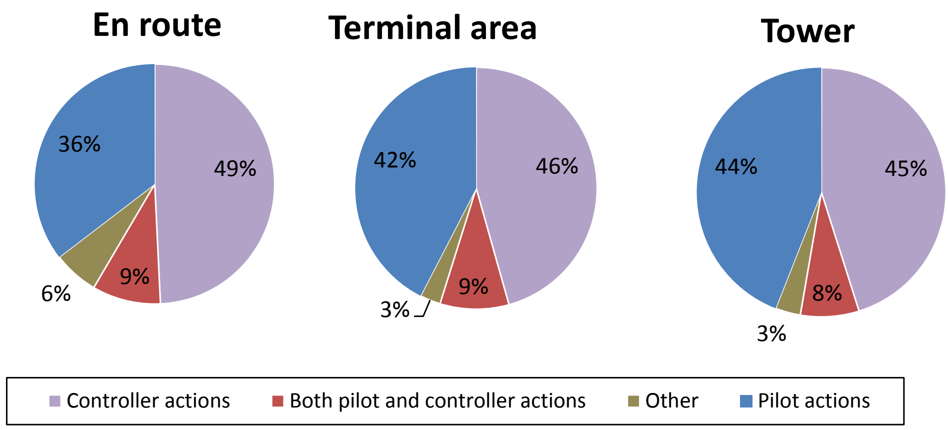
Seventeen occurrences (4%) had no individual actions associated with the occurrence. Many of these LOS occurrences were due to weather-related issues (turbulence, windshear, light conditions). Others were due to unforseen technical issues (flat tyre on the leading landing aircraft preventing it from moving off the runway quickly, momentary radar failure), while others did not have enough reported information available to make a judgement.

Figure 39: Contributing individual actions trend, January 2008-June 2012



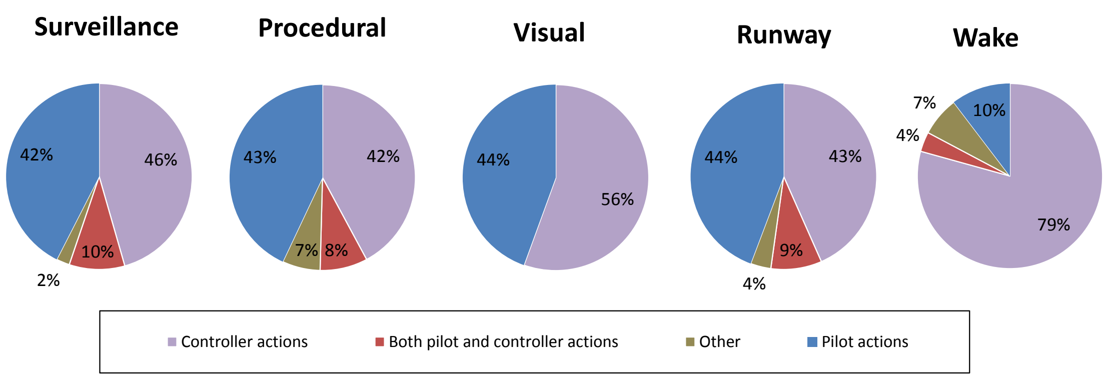
As can be seen in Figure 40, the type of individual action that contributed to the LOS did not vary greatly depending on the ATS environment in which the LOS occurred in. The main difference was that in the en route environment, pilot actions were only involved in 45 per cent of occurrences, less than terminal area (51%) and tower environment (52%).

Figure 40: Contributing individual actions in each ATS environment, January 2008-June 2012



Similarly, the proportions of contributing actions did not vary much between losses of procedural, surveillance and runway standards. However, as can be seen in Figure 41, most (83%) wake turbulence separation losses involved ATS actions, with 79 per cent involving only ATS actions.

Figure 41: Contributing individual actions by standard, 2008-June 2012



Looking at the breakdown between contributing actions from controllers and pilots for the two ANSPs in Australia in the tower and terminal area environments (where both ANSPs provide an air traffic service), Figure 42 shows that in class C airspace (or military controlled equivalent), 76 per cent of LOS events that occurred when the aircraft were under military ATS (Department of Defence) jurisdiction, involved air traffic controller actions. This is in contrast with occurrences involving civil ATS (Airservices Australia) in class C airspace, where only 51 per cent of occurrences involved a controller action.[59, 60]

In class D airspace, air traffic controller actions only contributed to 32 per cent as a result of metropolitan class D airports which made up a high proportion of class D civil LOS occurrences, and most of these LOS occurrences involved only pilot actions.

Figure 42: Contributing individual actions by ANSP (tower and terminal area only), January 2008-June 2012

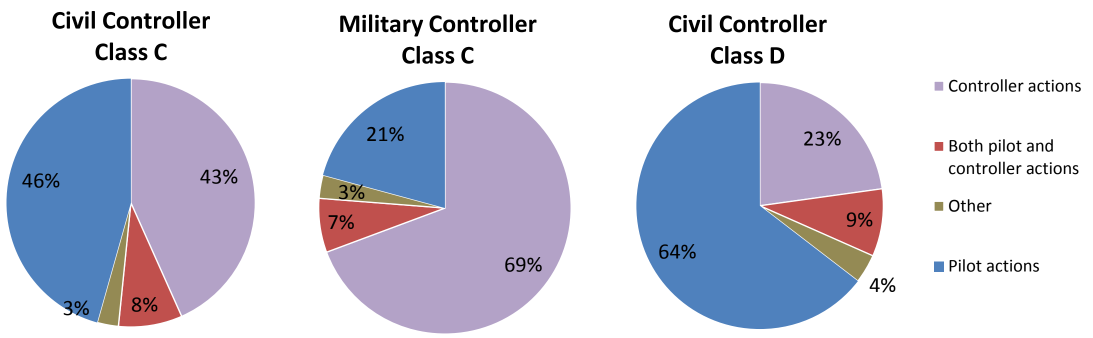


Figure 43 shows that all collision risks were represented across all contributing actions. Occurrences involving only pilot contributing actions more commonly resulted in elevated or some collision risk (19%) than occurrences involving controller actions (11%).

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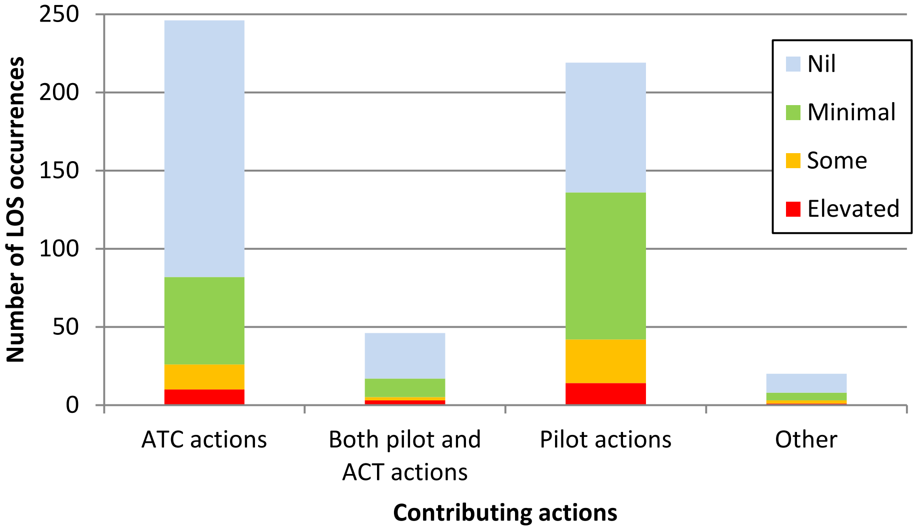
59 It could be suggested that some of this difference is a reflection of the Department of Defence's policy of investigating all LOS occurrences while Airservices only investigate those considered attributable to ATS, providing less opportunity to uncover ATS contributing factors in civil ATS occurrences where pilot actions were the obvious contributing factor. However, if this was the reason behind the difference, the proportion of occurrences where both a pilot and control contributing action would be significantly higher in military ATS occurrences, which is not the case.

60 Difference was statistically significant (chi square) $X^2_{(df=1)} = 17.48$, $p<0.001$.

Figure 43: Collision risk by contributing individual actions, January 2008-June 2012



En route

The average rate of all en route LOS occurrences across January 2008 to June 2011 was 1.9 per 100,000 flight hours[61]. When including only those occurrences where an ATS individual action was involved, it was 1.13 per 100,000 hours (lower than the Airservices target of 1.25 LOS occurrences attributable to ATS per 100,000 hours). The rate of en route occurrences where pilot actions contributed to the LOS was 0.86 per 100,000 hours flown.

Terminal control area locations

Figure 44 shows the rate of LOS occurrences in the terminal control area by location, broken down by the individual actions that contributed to the occurrence. The line indicates Airservices' target of 1.5 LOS occurrences per 100,000 movements attributable to ATS in the terminal area. Although actions contributing to LOS occurrences (as defined in this report) are broader than the Airservices-attributable target, it nevertheless provides a useful indicator.

The graph clearly shows that all civil airports, except Adelaide and Cairns, had a rate of LOS occurrences with ATS contributing actions lower than the target of 1.5 per 100,000 movements. Adelaide had a rate of 2.2, and Cairns a rate of 1.7, occurrences per 100,000 movements with controller actions contributing.

On the other hand, many of the airports where military ATS is provided (Darwin, Williamtown, Tindal, and Amberley) had a considerably higher rate of occurrences with ATS contributing actions – as much as 5 per 100,000 movements at Darwin and Williamtown. It should be noted that Amberley and Tindal had a low number of occurrences reported (5 and 3, respectively), but the low number of movements at these airports makes rates at these airports sensitive to single occurrences.

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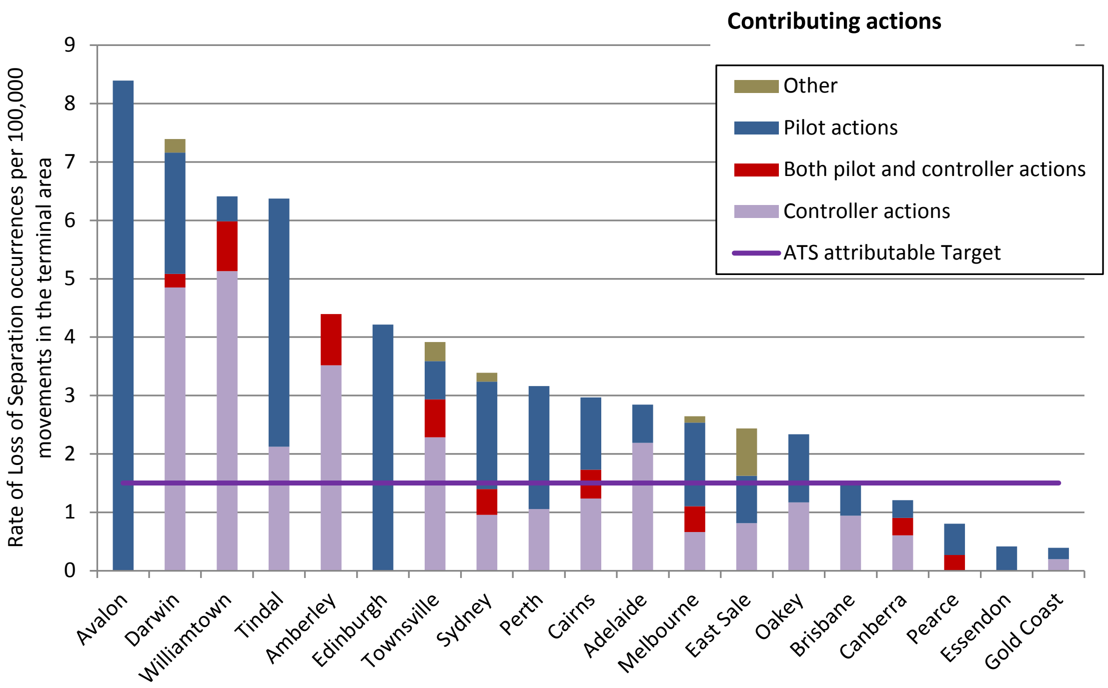
61 See *Normalising data* section on page 17 in the *Methodology* section of the previous chapter for how en route hours flown was estimated.

Figure 44: Contributing individual actions by airport for terminal control area, January 2008-June 2012

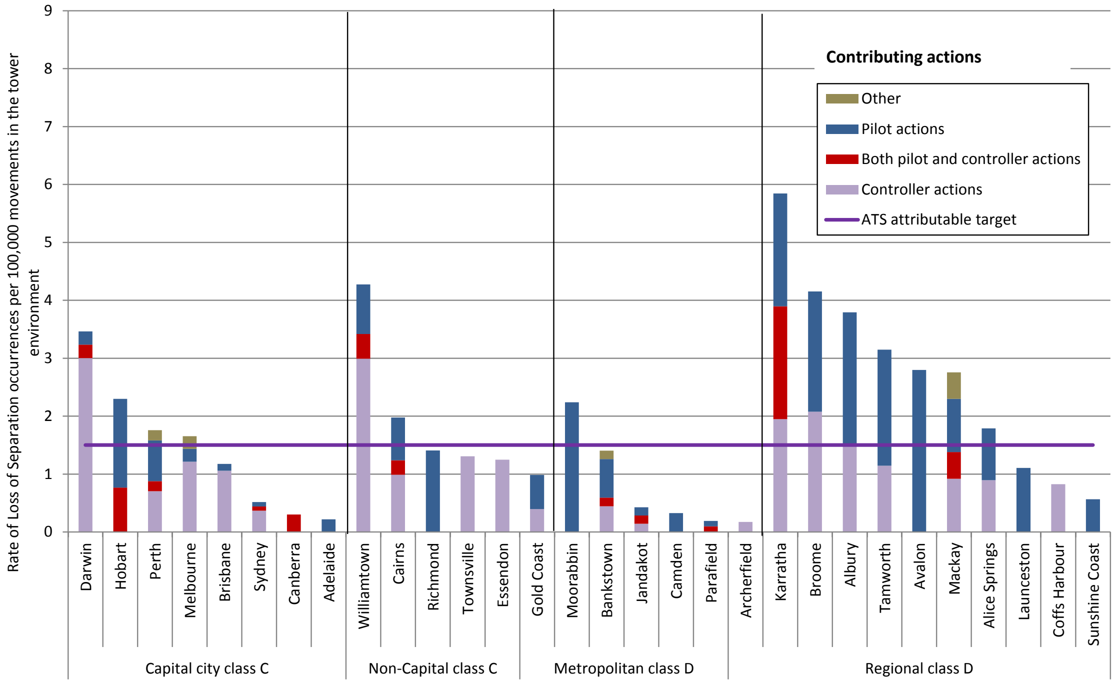


Tower locations

Figure 45 shows that most airports serviced by civil ATS had a lower rate of occurrences that involved controller actions than the Airservices target of 1.5 ATS-attributable losses of separation per 100,000 movements. The main exceptions were Karratha (3.9) and Broome (2.1) though a low number of occurrences were reported at these airports (with a low number of movements making rates at these airports sensitive to single occurrences). For the airports where a Military ATS is provided, Darwin and Williamtown tower environments had relatively high rates of occurrences involving controller actions (3.2 and 3.4 per 100,000 movements, respectively)

Some airports only had reported LOS occurrences that were due to pilot individual actions. Moorabbin is particularly prominent in this regard, despite the high number of LOS occurrences at this airport. Other metropolitan class D airports have relatively high LOS rates where pilot actions were involved. In contrast, class C airports (except Hobart) tended to have more losses of separation where ATS actions were involved, and regional class D airports tended to have LOS occurrences that more evenly involved actions from pilots and controllers.

Figure 45: Contributing individual actions by airport for towers, January 2008-June 2012

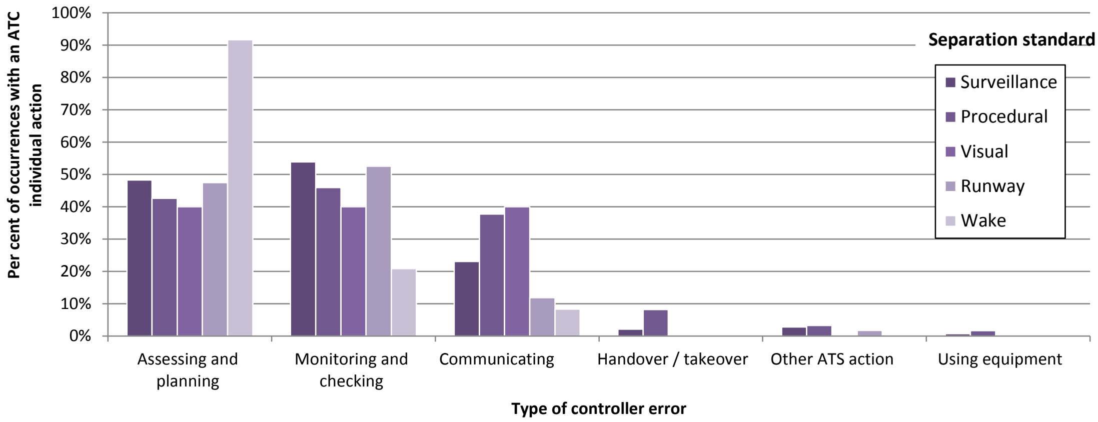


Controller actions and conditions

Most individual actions by controllers that contributed to a LOS occurrence involved either assessing and planning or monitoring and checking errors. These errors were present in about half of all occurrences where a controller action was involved. They were common in all three ATS environments, although monitoring and checking errors were slightly more likely to be involved in occurrences in the en route environment. Losses of surveillance-based separation, where a controller action contributed to the LOS, were slightly more likely to be monitoring and checking issues (54 per cent) than procedural losses (46%). Nearly all losses of wake turbulence separation involving controller actions (92%) involved an assessing and planning problem, with only 21 per cent involving monitoring and checking errors (Figure 46).

About a quarter of LOS occurrences involving ATS actions included communication errors from the controller to flight crew or to other controllers. These were more common in the en route environment (where there were more procedural separation standard losses) than in the terminal control area and tower environments. About 40 per cent of all losses of procedural and visual separation involving an ATS action included communication issues. However, only a small proportion of runway and wake turbulence standard losses involved an ATS communication error (12 and 8 per cent respectively).

Figure 46: Contributing controller individual actions in each standard, January 2008-June 2012



Assessing and planning errors

Problems associated with assessment and planning activities were not all the same and varied somewhat between occurrences. More common issues included:

- inadequate or inappropriate plans for establishing and managing aircraft tracks, altitude or speeds
- wrongly estimating relative aircraft speeds (aircraft performance related, heading-related wind changes)
- using the wrong standard (instrument approach, RVSM related, altitude related)
- incorrect calculations or estimations of time
- not projecting into the future to plan to avoid conflict
- applying the continuation of current conditions (aircraft altitudes, relative distances) after those conditions no longer existed
- ineffective management of a compromised separation before it became a loss of separation
- not anticipating when aircraft would initiate an expected turn
- assessing an aircraft as the wrong category (weight or flight rules)
- incorrectly positioning aircraft to be able to intercept an instrument approach
- (for runway separation losses) issuing a landing clearance based on (incorrect) expectations that other aircraft currently on the runway would be clear in time (take-off, exiting after landing, or taxiing across runway).

Monitoring and checking errors

Monitoring and checking errors are those controller actions associated with maintaining awareness of system states, environmental states and traffic disposition. The more common examples of these errors seen in LOS occurrences were:

- physically scanning displays but not noticing conflicts
- inadequate scan of display for potential conflictions
- not visually inspecting the runway to ensure it was clear before giving a landing clearance
- not monitoring cleared aircraft progress (climb or descent rate, relative speeds or closing speeds, vector track, location on runway), so not identifying when aircraft were not performing as expected
- not observing aircraft displayed on ATC radar, or not detecting aircraft entering prohibited or controlled airspace without clearance (when that information was available)
- the controller’s focus of attention was with other aircraft, so they did not identify a conflict

- not detecting that the pilot of an aircraft was not complying with instructions (when that information was available)
- not identifying an incorrectly read back instruction, or that no read-back was given by a pilot or flight crew
- not detecting, or forgetting, that other aircraft were present before issuing clearances.

Communication errors

Communication safety factors refer to actions associated with communicating relevant operational information to flight crew and other ATS personnel. Such information included operational decisions, uncertainties, intentions, actions, and observations regarding environmental states or facilities. Communication safety factors commonly identified in LOS occurrences included:

- not coordinating appropriately between adjacent ATC sectors, or between the terminal control area and tower (not passing all information, not updating, informal handover/takeover)
- no coordination at all from foreign ATS when aircraft were entering Australian airspace
- not providing clear, timely or urgent instructions to pilots when separation had been lost to ensure that immediate action was taken to avoid other aircraft or re-establish separation
- not passing traffic information to pilots or flight crews once separation was compromised
- providing clearances meant for one aircraft to the pilot or flight crew of another aircraft.

Other occurrence events

Common occurrence events that preceded LOS occurrences involving controller actions included pilot non-compliance with verbal instructions, runway incursions, and missed approaches/go-arounds.

For losses of procedural separation, about 1 in 5 occurrences were preceded by pilot non-compliance with verbal instructions. Of the 11 occurrences, nine involved an altitude deviation either due to avoiding weather, the pilot misunderstanding or mishearing their cleared level (incorrect read-back), not reaching the cleared level by the required time, or descending/climbing without a clearance.

For losses of runway separation, about a third involved a runway incursion (incorrect presence on the runway).

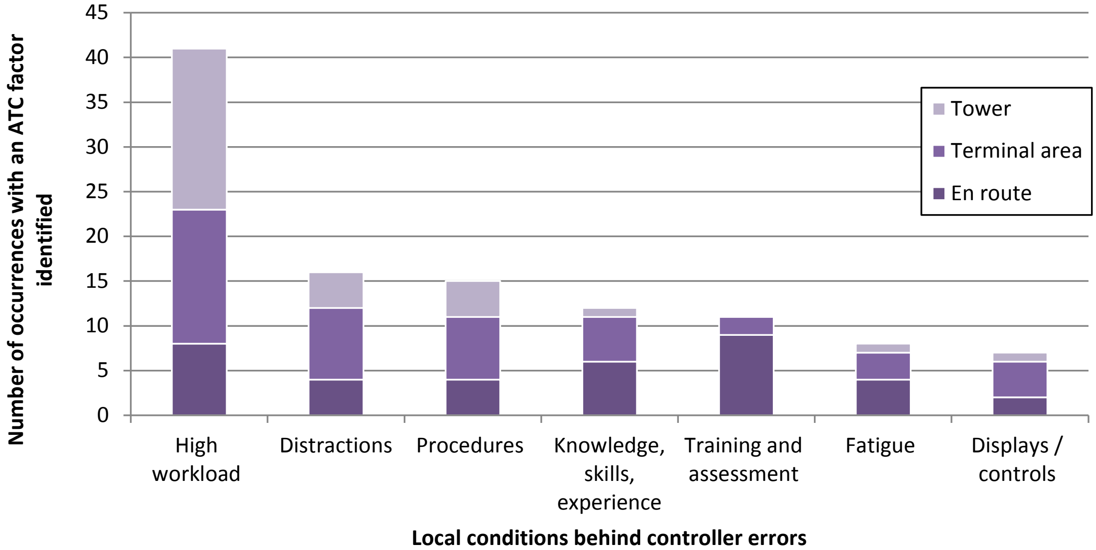
Missed approaches or go-arounds preceded 10 of the 24 wake turbulence separation losses.

Local conditions and risk controls

As mentioned above, due to the limited information about many LOS occurrences (many were not formally investigated at the time), local conditions and risk controls present at the time of the LOS (and which may have contributed to it) are often not known. Of the 292 occurrences involving an ATS action, 82 occurrences had one or more local conditions present at the time of the LOS. A further 37 had one or more risk controls identified as contributing to the controller’s actions.

Task demands were the most common type of local condition identified in LOS occurrences where controller actions were involved – in particular, high workload and distractions. These were common in all ATS environments, but more common for LOS occurrences in the tower environment. Other factors identified in multiple occurrences (see Figure 47) were inadequate procedures, inadequate knowledge skills or experience, insufficient training and assessment (mostly in the en route environment), fatigue, and issues with ATS displays and controls.

Figure 47: Contributing conditions and control factors by ATS area, January 2008-June 2012



High workload was the most common factor identified behind controller errors (41 occurrences). Three quarters of these involved civil ATS and a quarter involved military ATS. High workload can have a number of effects, including allowing performance to degrade (such as through reducing the number of information sources accessed, and the frequency they are accessed), taking short-cuts in performing tasks, or shedding (generally lower priority) tasks altogether.[62] High workload was generally due to a controller having to manage a high number of aircraft at that particular time, but also the combining of ATC sectors or functions, having to manage trainees, and from multiple aircraft diverting due to weather. Of the 41 occurrences:

- 23 involved a monitoring and checking error
- 20 involved an assessing and planning error
- 11 involved a communications error
- 7 also involved a lack of task or equipment knowledge, skill or recency.

Distractions from a person's primary task can change their focus of attention away from that task and may, both mentally and physically, prevent the person from noticing whether the primary task has changed. LOS occurrences where distraction was a factor usually involved controllers' diverting their attention away from the aircraft involved to deal with other traffic. Less commonly, ATS distractions involved assisting other controllers or pilots, adjusting the display screen, or engaging with visitors. Of the 16 occurrences where distraction was known to have been involved:

- 13 involved a monitoring and checking error
- 8 involved an assessing and planning error

There were 15 occurrences involving 22 safety factors concerning inadequate procedures. About three quarters of these involved civil ATS and a quarter involved military ATS. Issues with procedures covered a wide range of areas with no one area appearing on multiple occasions.

Knowledge, skills and experience factors were present in 12 LOS occurrences (16 factors identified). Most of these concerned controllers that were newly endorsed for the sector currently being operated, several of which were coupled with higher workload situations. Less common factors included a lack of knowledge of aircraft performance and a lack of skill or knowledge in operating the air traffic interface system.

Training and assessment was a factor in 11 occurrences (with 16 individual safety factors

[62] Wickens, C. D. (1999). *Engineering psychology and human performance.* Prentice Hall: New Jersey.

identified, all but one of which involved civil ATS). These concerned a range of issues including refresher training not being available, a lack of compromised separation training, and individual weaknesses in controllers' skills not being resolved prior to endorsements.

Fatigue was identified in eight occurrences. Fatigue can affect people in many ways, including reduced vigilance, slower reaction times, increased forgetting, reduced short term memory, and reducing the amount of information considered during decision making. Controllers reported fatigue issues when the occurrence happened at the end of a long shift (8 or 10 hours), at the low point of a controller's circadian rhythm (night, early morning), or due to limited sleep.

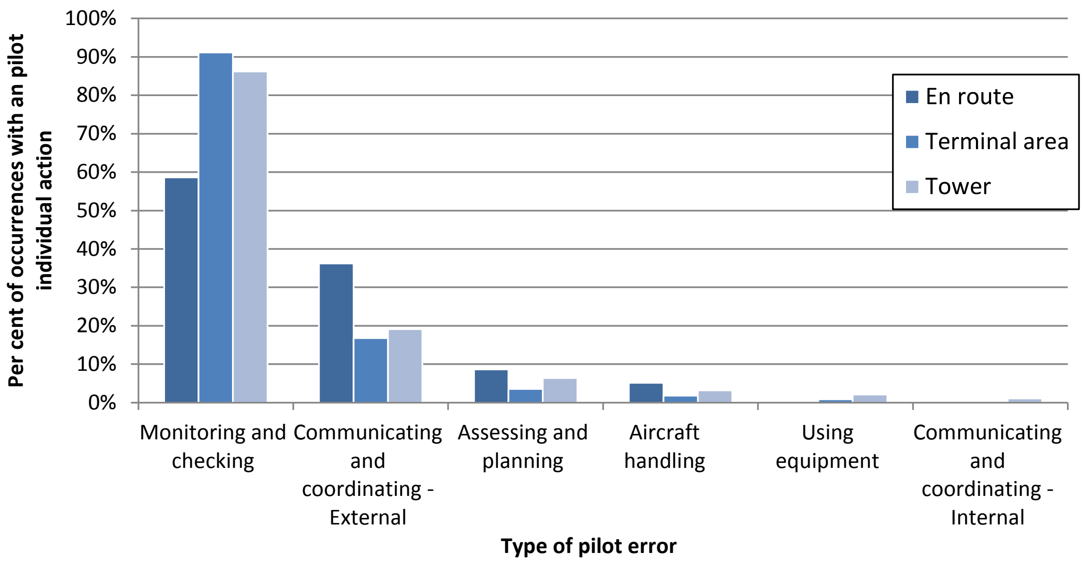
Issues with displays and controls were identified in seven occurrences, mostly concerning difficulty in observing aircraft on radar displays.

Pilot actions

Of the 265 LOS occurrences involving at least one pilot action, the most common contributing pilot actions are shown in Figure 48. Inadequate pilot monitoring and checking was present in most (218 occurrences, 82%) of these occurrences. Monitoring and checking errors made by pilots were less common (but were still present in at least half of occurrences) in en route control than under other ATS environments. Inadequate pilot monitoring and checking was prominent across surveillance and runway standard losses of separation (nearly 90 per cent in each where a pilot action was involved).

The only other pilot action that frequently contributed to LOS occurrences was inadequate external communication (22%), especially in the en route environment, where it was involved in 36 per cent of LOS occurrences involving a pilot action.

Figure 48: Contributing pilot individual actions in each ATS environment, January 2008-June 2012



Other occurrence events

In nearly half (121 occurrences) of the 265 occurrences involving a pilot action, there was also a non-compliance with a verbal ATS instruction.

Many monitoring and checking pilot actions were related to these non-compliances, or, to a lesser extent, with a controlled airspace incursion. Given that most occurrences analysed were reported by ATS providers, the exact reasons for these pilot actions were normally not known. In the en route ATS environment, nearly all monitoring and checking pilot actions were a non-compliance with an ATS requirement (mostly maintaining an assigned altitude). In the terminal area, only about half of pilot actions were related to a non-compliance with an instruction (again mostly altitude instructions), with the other half related to airspace incursions. When aircraft were under ATC tower jurisdiction, only a third of monitoring and checking pilot actions were associated with non-compliance with the tower controller's instructions (predominantly taxiing-related instructions).

In 58 of the 265 LOS occurrences (22%) where a pilot action was involved, an incursion of controlled airspace by the pilot of one of the aircraft preceded the LOS. Throughout 2011-2012, Airservices Australia sent a survey to all pilots that they had identified as being involved in an airspace incursion. In that time, they received 219 responses. As not every pilot responded to this survey, not enough of these survey responses could be matched in this investigation to the 58 LOS occurrences associated with an airspace incursion to make meaningful observations. However, the general results of the survey are likely to be very similar to the subset of these incursions that led to losses of separation. The survey found that:

- About 60 per cent of the pilots were flying private operations and had a private or sport pilot licence
- 60 per cent of pilots only became aware of the incursion after they were contacted by ATS, and 18 per cent were not aware at all
- 73 per cent had intended to remain outside controlled airspace
- 87 per cent were using charts, but only 56 per cent were using electronic aids such as a Global Positioning System (GPS) receiver
- The main contributing factors, indicated as having some influence on the airspace incursion, were:
    - distractions (62%)
    - high workload (60%)
    - mis-read chart (36%)
    - complex airspace (36%)
    - weather (34%).

Local conditions and risk controls

As most LOS occurrences are only reported by ATS, very little information was available to consider why pilots made the above errors. Of the 265 occurrences where a pilot action contributed, only 69 had information available about a local condition that led to the pilot's action, and only seven had information about inadequate risk controls.

The most common known condition that contributed to pilot errors was adverse weather (30 occurrences), and the LOS occurrences that resulted were distributed across all three ATS environments. Adverse weather mostly related to poor visibility, avoidance of adverse weather conditions, and wind or turbulence.

The next most common issue was a lack of knowledge, skills or recency (25 occurrences). All but one of these led to a LOS in the tower or terminal ATS environment, and nearly all related to problems relating to flying students.

The other main condition identified was pilot task demand (14 occurrences). These were divided between issues with high pilot workload and the influence of distractions.

Review of ATSB investigations

The ATSB has conducted a number of safety investigations into particular loss of separation (LOS) and loss of separation assurance (LOSA) occurrences. A retrospective review of relevant investigations was conducted to identify any common themes across these investigations. These investigations are not necessarily representative of all LOS occurrences, representing less than one-fifth of annual reported LOS occurrences.

All ATSB complex investigations[63] of LOS and LOSA incidents from 2011 and 2012 were analysed. This comprised 12 investigations (9 LOS and 3 LOSA). Of the 12 investigations, 10 involved civil ATS, and two involved military ATS. Although not all of these investigations have been finalised with a published report, any facts already established with evidence were included in the analysis below. A list of these 12 investigations can be found in Appendix C on page 93.

Methodology

An initial review of the investigation reports was done to identify overarching themes in LOS and LOSA occurrence investigations, focusing on issues with a potential to have systemic causes. Each of the 12 reports was reviewed for the presence of these issues.

The identification of issues in investigations below does not necessarily indicate that the issue contributed to each occurrence. This is because ATSB investigations analyse many sources of evidence surrounding an incident, and do not limit the investigation analysis to only those factors where there is positive evidence of a contribution to the occurrence. Analysis is also undertaken of other factors that increased risk and were considered important due to the potential for an ongoing influence on safety.[64]

Common issues across investigations outlined below were not necessarily identified as formal safety issues in individual occurrence investigations, but have been/will be raised in the investigation report. In individual investigations, there may not have been sufficient evidence from a single occurrence to conclude that an issue has an ongoing influence on safety to the extent required to make a formal investigation finding. In contrast, common issues identified across several investigations, as in the analysis below, provide some evidence that they have systemic roots and are not necessarily one-off events.

Results

The review of selected ATSB investigations into LOS and LOSA occurrences indicated that there was a broad spread of safety factors that contributed to these occurrences. Those issues which featured in multiple LOS or LOSA investigations are shown in Figure 49.

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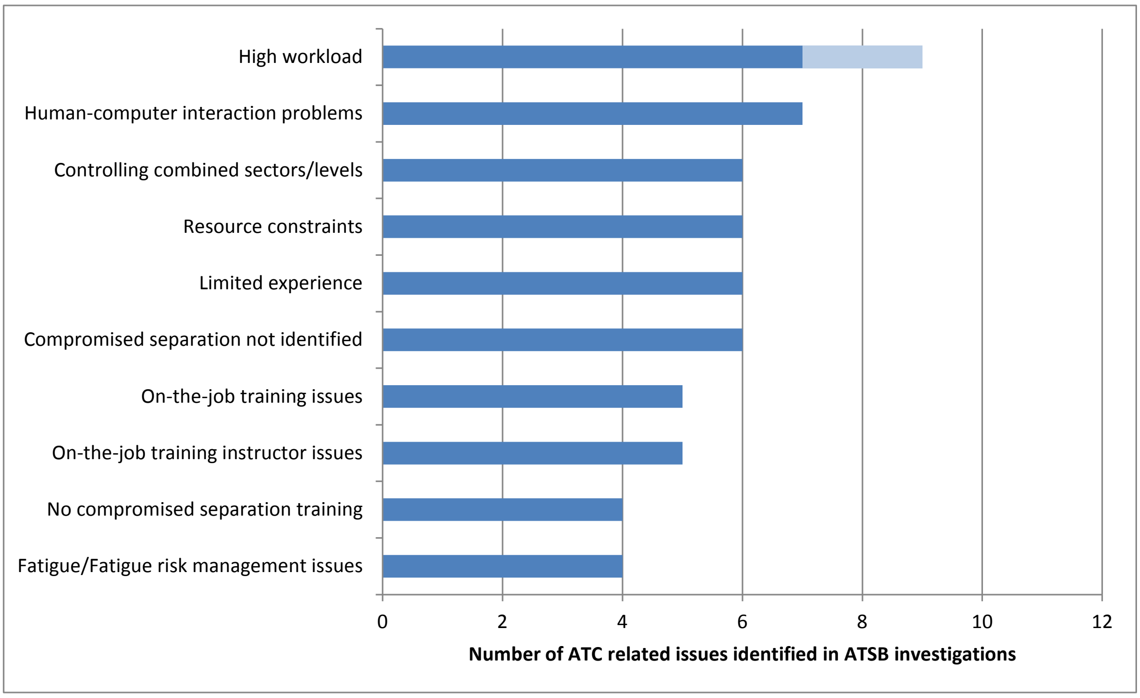
63 Complex investigations refer to those ATSB investigations involving the independent collection of evidence by the ATSB, analysis using the ATSB investigation analysis framework, and formal findings including the identification of ongoing safety issues. The analysis of ATSB investigations in this chapter does *not* include less-complex factual investigations (which are based on information supplied by organisations or individuals involved in the occurrence and only detail the facts behind the event). There were 16 less-complex factual only investigations in 2011 and 2012.

64 For more information on the ATSB investigation analysis framework model, see: Walker, M. B. & Bills, K.M. (2008). *Analysis, Causality and Proof in Safety Investigations*. (Aviation Research and Analysis Report AR-2007-053). Canberra: ATSB.

Figure 49: Issues identified in 12 selected ATSB LOS and LOSA occurrence investigations



Common issues identified

Key points from the review were as follows:

- There was no single issue identified across all 12 investigations
- In seven of the 12 investigations, the controller was experiencing high workload at the time of the LOS. In another two, the controller had just finished a period of high workload when the LOS occurred
- Seven had human-computer interaction issues, related to either the controller not knowing how something worked, complex human-computer interaction requirements which increased the controller's workload, or the systems not having conflict alerting either available or activated to alert controllers to conflictions
- The controllers had limited experience on the sector or ATS environment in six investigations. Of these six, four involved controllers with less than two years of total experience as a controller
- Six involved the controller operating combined sectors
- Six involved resource constraints: that is, staffing issues resulting in not having a full complement of controllers for a shift
- Of the 12 LOS/LOSA incidents, six were initially undetected by the controller. In these cases, compromised separation action was prompted as a result of system alerts received by either the controller or flight crew
- In five investigations, there were issues with on the job training. These included reduced training time due to assumed prior knowledge, inconsistency between trainers in the technique trained, and the controller receiving training without being informed training was to be provided
- In five investigations, the limited-experience controller was allocated multiple on the job instructors or no instructor at the time of the incident.

Co-existing issues

From the issues discussed above, there were some which tended to be found together in the same investigations as follows:

- In six of the 12 investigations, there was a combination of high workload from combined sectors and lower-experience controllers
- The five investigations that involved a limited experience controller with multiple on the job instructors or no instructor at the time of the incident were indicative of resource limitations
- Five investigations identified human-computer interaction issues combined with the controller having limited experience on the sector/environment
- In four investigations, resource issues were present when the controller involved in the LOS was operating multiple sectors.

Summary

This review of selected ATSB investigations into separation-related events did not identify any distinct factor which prevailed over all of the LOS and LOSA occurrences. The broad range of results tends to support the assertion that LOS occurrences are complex and occur as a result of a number of interacting factors.

Several issues tended to co-exist across several investigations. The most common involved resourcing of staff and rostering problems leading to procedures such as combining sectors, multiple on the job instructors. In turn, these have resulted in inexperienced controllers being exposed to very high workload and complexity early in their endorsed period of employment on a particular sector/group.

The relationship between combined sector tasking and experience level is an area requiring further examination. For example, as airway traffic density changes with time, it may be prudent to conduct a workload analysis to identify which sector combinations represent an unacceptable level of risk to controllers who may still be in a ’consolidation’ phase following endorsement.

Review of confidential reporting of safety concerns

Methodology

REPCON (REPort CONfidential) is a voluntary reporting scheme which allows any person who has an aviation safety concern to report it to the ATSB confidentially. Protection of the reporter's identity and any individual referred to in the report is a primary element of the scheme.

The ATSB analysed all reported safety concerns through the REPCON scheme from 2010 to June 2012. Of the 294 reports made during this time, 40 were related to the provision of air traffic control services. All of these reports concerned services provided by, or activities at, Airservices Australia, and none concerned the Department of Defence.

Of the 40 reports, 23 were submitted by air traffic controllers, 14 by flight crew, and three from others.

Safety actions initiated by Airservices Australia in response to the concerns documented below are shown in the *Safety issues* and actions chapter on page 85.

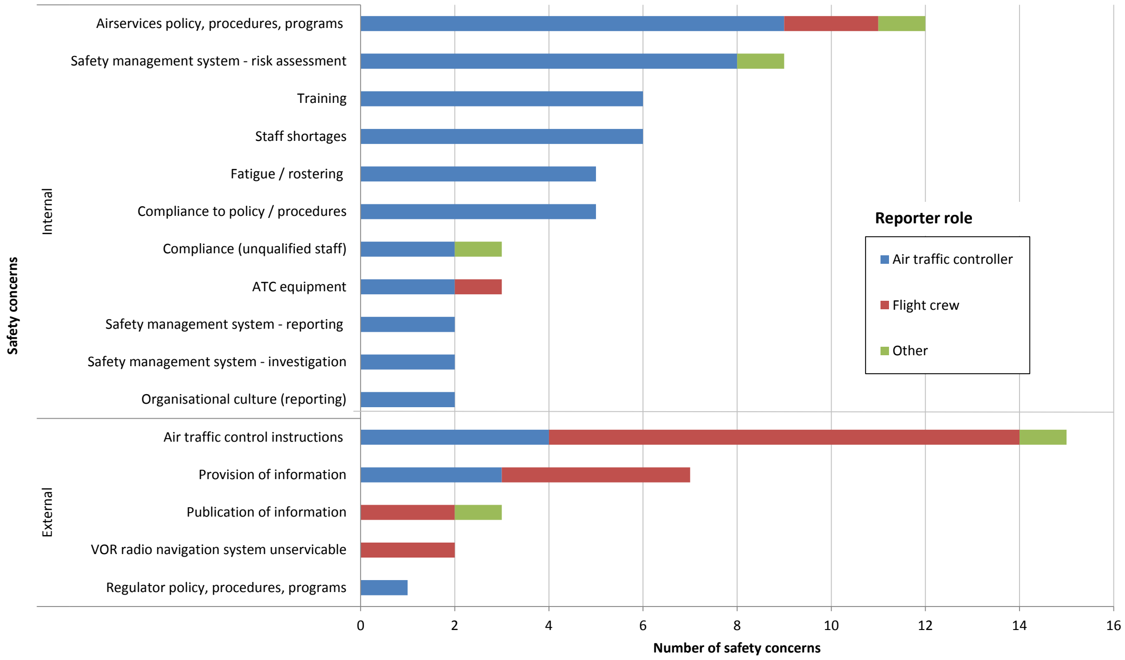
Reported safety concerns

The 40 reports identified involving the safety of air traffic control services described 83 safety concerns.[65] These related to air traffic services in general and not specifically to separation of aircraft. The most common concern was related to the communication of ATS instructions (15 reports), and these were mainly reported by flight crew (Figure 50). The next most common areas of concern were Airservices Australia's policies, procedures and programs (12 reports) and the frequency of risk assessments carried out by Airservices Australia (9 reports). Concerns regarding provision of information by controllers (7 reports) and training and staff shortages (6 reports each) were also raised by REPCON reporters.

As seen in Figure 50, most safety concerns regarding internal issues with civil ATS (Airservices Australia) were reported by air traffic controllers. In contrast, 64 per cent of external safety concerns with civil ATS were reported by flight crew, although air traffic controllers reported 14 per cent of these external issues.

[65] Note that a reporter can raise more than one safety concern, so the number of safety concerns is greater than the number of RECPON reports.

Figure 50: Reported safety concerns involving civil air traffic services



The following section summarises the seven most commonly reported safety concerns involving civil ATS.

Air traffic control instructions

Where ATC instructions are unclear, inconsistent or lacking, flight crew may not have the guidance they require to maintain separation.

Flight crew were concerned about the holding patterns that were applied to their flight – often with little justification provided by air traffic controllers. Pilots were also concerned about unsafe runway procedures, the lack of standardised or consistent instructions from controllers (see case study below), and the lack of sequencing in situations where there were multiple inbound aircraft to an aerodrome.

Air traffic controllers were concerned about the re-introduction of Converging Runway Operations (CROPS) at Brisbane Airport at night, which would allow for simultaneous approaches, arrivals and departures for certain runway configurations in visual meteorological conditions (VMC). Controllers were also concerned about the use of intersection departures at Brisbane Airport where there were no formal procedures for the co-ordination of the intersection departures between the surface movement controller and the airways clearance delivery controller. One reporter was concerned about the lack of separation assurance at Avalon Airport where aircraft operating under visual flight rules (VFR) can descend and climb without a clearance from ATC. Another concern raised regarded runway crossing procedures at Adelaide Airport, where aircraft are required to hold short at the runway holding point, change frequency to be cleared to cross a runway, and are then required to change back to the original frequency. This all happens while the crew are completing their post-landing checklists.

Case study

The reporter expressed a safety concern about the lack of ATS standardisation for landing helicopters outside controlled movement areas at Bankstown Airport. The reporter believed that the landing procedure used by ATS was inconsistently applied in that some controllers required a clearance to land request while others did not.

AIP ENR 1.1-110, Para 67.5.2 states "At locations within controlled airspace, helicopters may be granted a landing clearance or be instructed to report on the ground, as appropriate, at any area nominated by ATS or the pilot, and assessed by the pilot as being suitable as a HLS [Helicopter Landing Site]." The reporter believes that because the helipad at this aerodrome is outside the controlled movement area, a clearance to land is misleading and inappropriate.

The reporter was concerned that this lack of consistency might increase the risk of collision, as it might mislead the helicopter pilot to think, for instance, that an outbound taxiing aircraft knows that the helicopter is landing and is required to hold short, when in fact the outbound taxiing aircraft is completely unaware of the landing helicopter and may not even have been in contact with ATS.

Safety action

Bankstown Airport has informed AIP about the need to place the secondary HLS in the north/west sector in the ERSA. The En Route Supplement Australia (ERSA) entry for Bankstown Airport, which did not depict the western helipad which is shown on the Departure and Approach Procedures East Aerodrome Chart, was corrected.

Airservices policy, procedures, programs

Programs and policies that may increase a controller's workload or fatigue levels may affect a controller's ability to detect and manage a potential LOS. Also, where programs are rushed to meet a deadline, controllers may not be ready to adapt to new separation procedures, may not have been adequately trained and familiarised with these new programs and procedures, and risks may not be well considered.

Reporters were concerned about the short break procedures, the grey (standby) day/night shift[66] policy and other 'contingency procedures' for staff shortages at Airservices Australia, as well as runway crossing procedures at Adelaide Airport which were reported to increase controller workload (see case study below). Also of concern to REPCON reporters were the following programs:

- The ground delay programs at Perth Airport where Airservices Australia can change an aircraft's departure time and, thus, changing the required fuel carried without issuing a notice to airmen (NOTAM)[67] in enough time for the operator to rectify the difference in fuel quantity.
- The Integrated Tower Automation Suite (INTAS), where it was reported that when faults were identified in the system which may have affected a controller's interpretation of the display, Airservices Australia was reluctant to roll back the INTAS project.
- The reintroduction of CROPS at Brisbane Airport in VMC conditions at night (discussed previously).

Air traffic controllers also reported feeling uncomfortable in their knowledge of the procedures for the Surveillance Approach for Regional Airports (SAFRA) program for the standard approaches into Hobart and Launceston Airports. The SAFRA program introduces air traffic services to

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66 It was reported that Airservices Australia would apply a fatigue score to the standby night shift when the controller roster is initially published. If a controller was not called in for the standby night shift then it was disregarded that the controller actually prepared for the shift. A new fatigue score was then calculated for the ensuing morning shift with the assumption that the controller had had a night's rest instead of preparing for the standby shift.

67 A Notice to Airmen advises personnel concerned with flight operations of information concerning the establishment, condition or change in any aeronautical facility, service, procedure, or hazard, the timely knowledge of which is essential to safe flight.

regional aerodromes using surveillance, including the use of new and existing surveillance technologies that have been developed over recent years. There was also a concern about the delays to the introduction of the Aerodrome Surface-Movement Guidance and Control System (A-SMGCS). The A-SMGCS is an air traffic surveillance system that enables aircraft and vehicles on the airport surface to be accurately identified and tracked in all visibility conditions by ATS.

Safety management system – risk assessment

Where risk assessments into programs or procedures are inadequate, the factors that could lead to a separation loss, whether they be organisational, procedural or human factors, may not be fully appreciated or managed.

Air traffic controllers reporting through REPCON were concerned about the lack of risk assessments given to the re-introduction of CROPS (including the use of intersection departures at Brisbane Airport), and the change in sector boundaries between Armidale and Mudgee sectors. Concerns were also raised about whether controllers were all working to an appropriate standard once the new SAFRA training had been completed, consideration of the risk of Air Show Ground (ASG) being the only operator of a surface movement control (SMC) service during an airshow, and the roll out of the INTAS project despite known faults and concerns. Reports also flagged concerns about the way the grey (standby) day/night shift was assessed in Airservices Australia's fatigue risk management system, and the increase in the number of handovers conducted during a shift despite an internal LOS review advising that handovers should be minimised.

Case study

The reporter expressed safety concerns regarding the use of intersection departures at Brisbane Airport. It was reported that the intersection of runway 19/01 and taxiway A4 is often used for departures by aircraft, both in the day and at night. The reporter stated that the aerodrome controller (ADC) position's view of this intersection is significantly obscured by a large tower support pole. The reporter also stated that there were no formal procedures for coordination of the intersection departures between the surface movement controller (SMC) and the ADC, except for the marking on the departure strip used within the tower. An error by SMC can result in this marking being omitted, meaning that the ADC would be unaware of the presence of an aircraft or vehicle at that intersection. It is reported that at night, observation of this critical intersection is particularly difficult from the ADC position, especially if being used by poorly lit corporate or propeller driven general aviation aircraft. The reporter was concerned that an aircraft at taxiway A4 may be lined up behind a departure aircraft, in the misbelief that it is at taxiway A1 or A9.

Safety action

Airservices intends to update national procedures to formalise this process.

Providing and communicating information

Where there is a lack of information being communicated by controllers, pilots may not have the full situational awareness to make informed decisions in order to maintain separation standards.

Most REPCON reports submitted by pilots and related to civil ATS concerned the lack of information provided to them by Airservices Australia. Reports included concerns about aerodrome weather information services (AWIS) being unavailable at class D aerodromes when a tower service was not being provided, and in one report, an unserviceable very high frequency (VHF) omnidirectional radio range (VOR) navigation system was not highlighted as such in a NOTAM (see case study). Another pilot reported that a controller could not provide a time for onwards clearance, an expected approach time, or a number in the queue for approach and landing. That communication would allow the pilot to make an informed decision about whether to continue to hold, divert, or to declare a fuel emergency with sufficient time to land with minimum fuel reserves. One pilot was concerned about the misinterpretation of height requirements given in clearances.

On the other hand, air traffic controllers were concerned about the lack of information Airservices Australia provides to pilots to warn them of a reduction of the provision of published ATC services. In one instance, the reclassification of controlled airspace into class G (uncontrolled) airspace was not communicated to pilots through a NOTAM. Another controller was concerned that there was no indication to pilots when ATS contingency procedures were being used during times of reduced service (which, reportedly at that time, were used more and more to maintain 'service continuity') and that pilots were not receiving a full air traffic control service in accordance with the published and expected levels of service.

Case study

The reporter expressed safety concerns that the Tailem Bend VOR was unserviceable on 27 January 2010 and had not been reported to pilots as being unserviceable via a NOTAM. It was also reported that the VOR had been unserviceable on and off for approximately 5 months. It was reported that if the Tailem Bend VOR was not in operation, high volumes of training aircraft were concentrating on the Ardrossan VOR instead, resulting in multiple near misses.

Safety action

CASA reported that the Tailem Bend VOR has been returned to service. CASA is investigating issues associated with CASR P171, P172 and Airspace Regulation.

Staff shortages

Staff shortages may result in pressure from management to maintain the level of service, but lead to higher levels of fatigue and pressure on staff. Fatigue and pressure can lead to short cuts being taken, or rushing the completion of safety critical tasks such as a handover / takeover or missing a potential traffic confliction during a scan.

Air traffic controllers voiced their concerns over ATS staff shortages through REPCON, and described instances where this has been a factor in reduced safety margins. For example, a trend towards the increasing number of handovers (see case study below), airspace being controlled by controllers who do not have the correct endorsements, and contingency procedures not being followed in order to conceal staffing issues were all cited as symptoms of staff shortages. Other reports concerned the inadequate training for CROPS provided to controllers in order to maintain 'service continuity', and instances where controllers who had not met recency requirements were not provided with the required familiarisation shift in order to maintain staffing levels. The lack of transparent risk assessments (regarding staffing issues) and the unwillingness of management to report instances of reduced staffing levels affecting the provision of ATS were also raised.

Case study

The reporter expressed concerns about a trend towards the large number of handovers being conducted during a shift. This trend is occurring despite an internal Airservices Australia LOS review that identified handovers as an area of concern and found that handovers should be minimised. The reporter believes that this trend is becoming more commonplace due to financial constraints and staff shortages.

Training

Inadequate training (such as lack of on-the-job training), or training that is rushed can lead to a situation where controllers do not have the full skill set to prioritise air traffic situations and anticipate potential conflicts, particularly in periods of high stress or workload, or in complex environments.

Reports to REPCON concerning civil ATS training were mainly about inadequate training for air traffic controllers. For instance, some tower controllers reported that they were not provided with high definition tower simulator exercises, but only a computer presentation prior to the implementation of CROPS. It was also reported that training for new operators of SAFRA was being rushed through to cover personnel taking leave. The training was reported to be inadequate in terms of realistic scenarios, completed training manuals, and procedures for dealing with missed approaches. Other examples of reported training safety concerns were courses for ‘restricted endorsements’ being reduced from several months in length to a couple of days, and limited only to theory and simulation because on-the-job training was eliminated. Controllers were also concerned that a change in sector boundaries was not supplemented by training.

Case study

The reporter expressed a safety concern regarding the training of the controllers operating SAFRA (Hobart and Launceston approaches). The reporter stated that the next training course was being rushed through to cover a period of extended personnel sick leave. The reporter also stated that the current SAFRA-rated controllers already felt uncomfortable in their knowledge of the procedures, and that to rush someone through the training just for the sake of being able to say that there are no airspace closures was a real safety concern.

Safety analysis

On average, a LOS between aircraft under air traffic control jurisdiction happens about once every 3 days. In almost 90 per cent of LOS occurrences, there was no or minimal risk of aircraft colliding, although on average, there are six occurrences per year where an elevated risk of collision exists. There have been no mid-air collisions in Australia between two aircraft receiving an ATS separation service. Although there has been an increase in occurrences reported to the ATSB over the past 2 years, there are fewer LOS occurrences happening than there were 5 years ago.

The evidence available from a range of sources does not indicate fundamental deficiencies in the safety management of aircraft separation in Australia. Although maintaining aircraft separation is an important defence against collisions, losses of separation are expected to occur from time to time, and the detection and correction of these losses form an important control against aircraft collisions. However, although it is desirable to reduce the frequency and resultant collision risk of *all* LOS occurrences across Australia, the above analysis suggests there are some specific areas where future attention should be focussed to further enhance safety, as follows.

Aircraft separation safety levels in military controlled airspace

The military ANSP, Department of Defence (DoD), provides air traffic control services to all civil and military aircraft at two joint user airports (Darwin and Townsville) and several other airports where civilian aircraft, including high capacity passenger transport, are allowed to land such as Williamtown (Newcastle). Most aircraft activity at the joint user airports is civilian.

Military ATS are responsible for about 25 per cent of the aircraft movements in terminal areas, but were involved in 36 per cent of loss of separation occurrences. Relative to civil ATS controlled terminal airspace, military controlled terminal areas were over-represented in occurrences per aircraft movement, especially Darwin, Williamtown, and Amberley. In addition, 5 of the 11 elevated collision risk occurrences in the terminal area involved military ATS controlling (including one occurrence at Williamtown with an elevated collision risk involving a Boeing 737).

In the tower environment, although across all military airports the proportion of occurrences was relative to the proportion of traffic, Darwin and Williamtown were considerably over-represented by the rate of occurrences per aircraft movement compared to similar class and type airports, and both included occurrences with elevated or some risk of collision. While the occurrences at Darwin mostly involved general aviation aircraft, Williamtown showed a higher risk than most capital city airports (other than Melbourne and Darwin) due to most occurrences involving high capacity air transport.

When comparing occurrences across all class C terminal area and tower environments, three quarters of those under military ATS control had an associated contributing controller action, while only half did so when under civil control. In addition, relative to civil ATS controlled class C terminal areas, the proportion of occurrences where air traffic controller actions contributed to the loss of separation (as opposed to pilot actions), as a rate per aircraft movement, were disproportionally high for some military ATS terminal areas, especially Darwin and Williamtown.

The combination of the number of occurrences, the rate of occurrences per movement, the risk of collision, the aircraft involved, and the proportion of occurrences with controller contributing actions, suggests that separation involving civilian aircraft when under military ATS control, particularly at Darwin and Williamtown, represents a disproportionate risk relative to locations under civil ATS control.

The DoD has indicated that the above results are understandable given that:

> Darwin is unique in its poor civil airport design (no parallel taxiway on the civil side of the main runway), complex traffic mix, weather and isolation relative to other airfields. Similarly, Williamtown's constrained airspace and mix of fast jets, large RPT and general aviation is also unique.

Darwin caters for a large proportion of general aviation traffic, similar to other large non-capital city airports and smaller capital city airports. In contrast, the large capital city airports have significantly more aircraft movements than Darwin but mostly cater for airline movements which can be more consistent in their operations than are general aviation aircraft. The DoD has also noted that some military airspace has not been designed for effective processing of arrivals and departures. Together, these factors probably add some complexity to the operations at some military airports, and may account for some of the higher risk found in military airspace found in this investigation.

For each ANSP to achieve its objective of preventing collisions between aircraft, they implement a range of defences in depth. This starts with airspace design, including the design and use of standard arrival routes (STARs) and standard instrument departures (SIDs) for airports, air traffic flow and capacity management, traffic synchronisation including multi-sector planning for arrival and departure sequences, separation standards themselves, computerised conflict alerts to ATC, monitoring and detection by the controller responsible or other controllers, and on aircraft, TCAS systems and use of visual 'see and avoid' by pilots.

Military operated airports have STARs and SIDs published in a similar manner to other airports of the same airspace class and type of airport. However, it is possible they are used to a lesser extent than in civilian airports. It was reported by the DoD that military ATS do not normally employ strategic separation mechanisms such as long range flow control or traffic management plans because they do not allow the required degree of flexibility in service provision that military operations and training requires. As a result, the DoD advised that the military ATS has an increased reliance on controllers to assure separation through tactical measures.

However, at the two joint user locations (the only military airports where the proportion of civilian aircraft is known), most aircraft movements are civilian (88% at Townville, 94% at Darwin). Most LOS occurrences at these two locations involved two civilian aircraft. These two facts suggest that issues leading to most LOS occurrences at these locations are not related to military operation and training requirements.

At other locations, such as Williamtown, a higher proportion of aircraft movements are military aircraft and this is reflected in the fact that more LOS occurrences (60%) involve military aircraft in conflict with a civilian aircraft (the number of military to military aircraft LOS occurrences are unknown), so it is possible that reduced strategic separation is part of the reason. However, like Darwin and Townville, large and small civilian passenger aircraft operate to and from Williamtown.

The DoD have advised that military ATS are required to manage a high LOS risk due to the combination of needing to integrate civil general aviation, military operations, and civil airline traffic at the same time, often in constrained airspace. They further advise that 'whereas most controlled airspace environments facilitate layers of defences such that a[n air traffic controller] lapse/error will rarely cause a loss of separation, the diversity of military airspace users (including a diverse range of civil aircraft) and or constrained airspace severely limit opportunities to segregate incompatible traffic flows and increase the risk of lapses resulting in a loss of separation.'

However, although the reasons for the high LOS risk in military airspace may be understood by the Department of Defence, there is still a reasonable assumption that civilian aircraft and passengers of both small and large air transport both expect and should be afforded the same level of safety operating to any major controlled airport, independent of what other types of aircraft operate in the same location and regardless of ANSP. The data presented in this report suggests that this assumption may not fully hold for airports operated by military ATS.

Oversight of Australian air navigation service providers

The Civil Aviation Safety Authority (CASA) provides a safety oversight function for all civilian aircraft operations in Australia. In terms of ATS, this extends to ensuring that Airservices Australia complies with its own operations manual (the Manual of Air Traffic Services or MATS) and CASA's Manual of Standards (MOS) for Civil Aviation Safety Regulation (CASR) Part 172. This is achieved through the setting of standards for procedures, equipment and training, and ensuring compliance with these standards through audits, investigations, and monitoring safety incidents and other activities. However, Part 172 as currently written prevents CASA from exercising responsibility for the safety of civilian aircraft operations in terms of ATS once the aircraft comes under control of military ATC.

Although the *Civil Aviation Act 1988* allows for the making of regulations for the operation of air traffic services, currently, CASR Part 172 does not apply to air traffic services provided by the Defence Force. As a result, CASA does not have an oversight function of Defence operated ATS, including Defence ATS dealing with civilian aircraft. The DoD does have the same ATS operations manual (MATS) as Airservices Australia, so theoretically, should provide the same level of air traffic service to civilian aircraft and should, therefore, also be compliant with the MOS for CASR Part 172.

The existence of an operations manual by itself, however, does not guarantee the extent to which it is complied with at the operational level. For example, the DoD reported that due to the required degree of flexibility required for military operations, military ATS does not normally employ strategic separation mechanisms as required in MATS. Further, as detailed in the previous section of this analysis, the DoD advised the ATSB that the nature of their operations and environments 'severely limit opportunities to segregate incompatible traffic flows and increase the risk of lapses resulting in a Loss of Separation'.

The DoD, like Airservices, does have internal processes for auditing and safety oversight of its ATS functions. However, unlike Airservices, it does not have an independent and external regulatory scrutiny of its compliance with MATS or a general monitoring of safety in relation to civilian aircraft navigation services provided. Since 2010, CASA and the DoD have had an agreement for future cooperation to harmonise regulatory system outcomes to support improved aviation safety. This agreement did not extend to giving CASA any regulatory-type authority over civil aviation under military ATS control, but does allow for CASA to be invited to participate and provide guidance and advice in internal Defence auditing processes.

The findings of this ATSB research investigation suggest that a reliance on Defence sharing the same ATS operations manual as Airservices and internal auditing and oversight, including involvement, guidance and advice by CASA, will not guarantee an equivalent level of safety is provided to civilian aircraft operating into and out of Defence operated aerodromes as for civilian aerodromes.

Cooperative interactions between CASA and DoD have only formally been in place since half way through the present study and may not have had time to result in enhanced safety outcomes, but may well have longer-term benefits.

Many military aerodromes are primarily operated for military purposes, but allow some, mostly general aviation, aircraft to take off, land, or transit through the airspace. However, other military controlled aerodromes such as Darwin, Townsville, and Williamtown (Newcastle Airport) are primarily used for civilian traffic and/or form an important regional airport for regular public transport. It is these airports in particular, as well as any other military airport that conducts or plans to conduct regular public transport operations, where the evidence indicates that civil aircraft operations are exposed to a higher level of risk compared with equivalent civilian-operated airports. At present, there is no comprehensive and independent assessment of the levels of safety and compliance with respect to civil aircraft operations at these airports and no transparency for industry with respect to any differences, if any, in the levels of service provided or safety afforded. Given that the safety of the travelling public is a primary function of CASA, it would seem that some level of independent assessment and assurance as to the safety of civil aircraft operations at DoD airports by CASA is warranted.

Responsibility for monitoring collision risk

Both Australian ANSPs have a responsibility for monitoring the level of safety associated with managing the airspace they are responsible for. In the context of aircraft separation, this essentially relates to monitoring the likelihood of a collision (mid-air or on the runway), or a loss of control accident related to wake turbulence, based on the recent history of loss of separation incidents. This needs to take into account both the number of incidents and the level of accident risk each incident posed. It also needs to look at areas for potential improvement in the system to reduce the likelihood and/or consequences of future events. This is done through the investigation of individual incidents as well as through trend analysis of occurrences and their contributing factors.

To measure safety risk, all loss of separation incidents are relevant, including those which occurred solely through the actions of pilots. Although separation is a shared responsibility between ATS and pilots, ATS is responsible for the 'bigger picture' from initial strategic separation to the final control of multiple aircraft interacting in airspace and on the ground. The aircraft separation system needs to be tolerant of pilot error, designed to both minimise such error and to maximise the chance that the controller will notice or be alerted to these errors and positive action is taken to avoid a near or actual collision.

Through a policy of investigating all LOS incidents, the Department of Defence explores whether there are lessons to be learned for ATS from all occurrences. This is important as even some LOS occurrences where only pilot actions were involved provided an opportunity for ATC to predict, detect and/or correct either a potential LOS or an actual LOS earlier. ATSB examination of Department of Defence *Aviation Safety Occurrence Reports* into LOS incidents has identified multiple cases of ATS system improvements being identified in Defence investigation reports into pilot error-related losses of separation.

In contrast, Airservices Australia does not routinely investigate any LOS occurrences that were not deemed to be attributable to ATS. Public monitoring of air traffic management performance, the international benchmarking with CANSO, internal safety monitoring for the Airservices Board, and LOS trend monitoring provided to CASA, do not include LOS incidents that were considered pilot attributable. As such, while Airservices Australia puts considerable effort into monitoring and investigating ATS-attributable losses of separation, they are not monitoring the overall risk associated with managing aircraft separation in civilian airspace.

Furthermore, as LOS trend monitoring and investigation findings provided to CASA as part of CASA's monitoring of CASR Part 172 do not include LOS incidents that were considered pilot attributable, a major source of intelligence gathered by CASA to monitor the safety of civil airspace is also limited to ATS-attributable occurrences. As a result, opportunities for potential improvements to the aviation system that could be acted upon at the regulator level may be lost.

If a collision occurred in controlled airspace due to the actions of pilots, there is no doubt that the subsequent investigation will scrutinise any opportunity that the ATS system had to avoid that collision, including actions by the controller(s) involved. More importantly, it would also look at whether the potential for any such collision should have been able to be predicted through monitoring of related incidents. More importantly, the investigation would need to consider whether that collision could have been prevented by implementing safety actions that addressed short comings in the ATS system that could be identified through examination of such incidents. By not regularly investigating LOS occurrences related to pilot actions and by not regularly monitoring trends across all LOS occurrences, including those relating to pilot actions, Airservices is not fully using all available information to assist in meeting the number one objective of ATS, to avoid collisions between aircraft.

The first objective of air traffic services is the prevention of collisions between aircraft. This objective can only carry as far as the ATS has any control, which is mostly for IFR aircraft in controlled airspace. Although ATS does not have full control over individual pilot actions to conform to instructions or procedures, there are often opportunities to predict, prevent, and/or correct such actions to prevent a LOS or the chance of a collision. Given that more than half of all LOS incidents in civilian airspace are from pilot actions, by not investigating and monitoring all LOS occurrences, Airservices is not fully using all available information to assure the safety of civilian airspace.

Emerging issues from ATSB investigations

Several ATSB investigations have found resourcing of staff and rostering problems leading to ATS procedures such as combining sectors and multiple on the job instructors. In turn, these have resulted in inexperienced controllers being exposed to very high workload and complexity early in their endorsed period of employment on a particular sector/group.

High workload was by far the most common factor contributing to controller errors across LOS occurrences. Issues with ATC procedures and training were also evident in some LOS occurrences and some confidential reports.

Although the evidence reviewed in this research investigation suggests that resourcing issues effect on inexperienced controller workload is an emerging safety issue, the preliminary nature of much of this evidence (due to incomplete ATSB occurrence investigations) means that firm conclusions cannot yet be made. These matters may be raised as safety issues in several ATSB occurrence investigations scheduled to be completed and released in 2013 and 2014.

While a number of the above investigations are ongoing at the time of writing this report, and more detailed findings and associated safety actions will be included in those reports when published, most of the issues are consistent with some of those identified in the Civil Aviation Safety Authority's *Review of CASR Part 172 Air Traffic Service Approval of Airservices Australia,* which was finalised in January 2013. To that end, noting that Airservices has responded to the review with what CASA considers a 'responsive and appropriate' action plan, it is likely that resolution of the ATSB identified issues will either be in place or in progress by the time of publication of the ATSB investigation reports. However, any additional or specific safety action relating to the ATSB identified issues will be included in those reports.

Findings

From the evidence available, the following findings are made with respect to the loss of separation incidents in Australia. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

Safety issues, or system problems, are highlighted in bold to emphasise their importance. A safety issue is an event or condition that increases safety risk and (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operating environment at a specific point in time.

Factors that increase risk

- **There was a disproportionate rate of loss of separation incidents which leads to a higher risk of collision in military terminal area airspace in general and all airspace around Darwin and Williamtown in particular. Furthermore, loss of separation incidents in military airspace more commonly involved contributing air traffic controller actions relative to equivalent civil airspace occurrences (Safety issue).**
- **Regulatory oversight processes for military air traffic services do not provide independent assessment and assurance as to the safety of civilian aircraft operations (Safety issue).**
- **Loss of separation (LOS) incidents attributable to pilot actions in civil airspace are not monitored as a measure of airspace safety nor actively investigated for insight into possible improvements to air traffic service provision. As about half of all LOS incidents are from pilot actions, not all available information is being fully used to assure the safety of civilian airspace (Safety issue).**

Other findings

- Although LOS occurrences are common (about once every 3 days), most pose no or a low risk of aircraft colliding, and there have been no mid-air collisions in Australia between two aircraft under air traffic services control. However, on average, there are 6 LOS occurrences per year resulting in an elevated risk of collision.
- The number of LOS occurrences reported to the ATSB has increased over 2011-2012, although there were fewer LOS occurrences in that period than there were in 2007, while traffic levels have generally increased since 2007. While continuation of an upward trend would give increasing cause for concern, the present numbers of occurrences are within the range of historical experience and comparable with those of the best-performing international counterparts.
- Moorabbin Airport had the highest number of LOS occurrences and had the highest risk associated with tower environment LOS occurrences. All occurrences were due to pilot actions.
- Sydney and Melbourne posed the highest risk of any terminal area as a result of the high number of aircraft movements which are predominantly high capacity aircraft
- ATSB investigations have found indications of resourcing of staff and rostering problems that have led to procedures such as combining sectors and multiple on the job instructors. In turn, these have resulted in some inexperienced controllers being exposed to very high workload and complexity early in their endorsed period of employment on a particular sector/group.

Safety issues and actions

All of the directly involved parties were provided with a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to the conclusions of this report relevant to their organisation.

Military ATS risk

Number:	AR-2012-034-SI-01
Issue owner:	Department of Defence
Operation affected:	Aviation – Air traffic control
Who it affects:	All civilian aircraft operations into military controlled airspace

Safety issue description:

There was a disproportionate rate of loss of separation incidents which leads to a higher risk of collision in military terminal area airspace in general and all airspace around Darwin and Williamtown in particular. Furthermore, loss of separation incidents in military airspace more commonly involved contributing air traffic controller actions relative to equivalent civil airspace occurrences.

Response to safety issue by Department of Defence

> The Department of Defence takes all losses of separation and losses of separation assurance seriously and investigates all incidents to identify causes and areas that can be improved in order to mitigate against further occurrences. To reduce the potential for separation occurrences, Defence are reviewing the implementation of the traffic management plans at Darwin, Townsville, and Williamtown to improve the effect of strategic separation techniques. These reviews will also be used to highlight any current airspace constructs that inhibit the controller's ability to provide optimum separation assurance. Defence has also recently published an internal capability improvement plan that focuses on increasing experience levels at Defence air traffic locations. To improve our ability to respond to potential losses of separation, Defence has enhanced the School of Air Traffic Control simulator packages to provide greater exposure to compromised separation occurrences, with the trainee being assessed on their ability to apply compromised separation recovery. Defence has also added both theoretical and practical assessment to local training packages regarding scanning for possible losses of separation and applying compromised separation recovery techniques when required.

ATSB comment in response

The ATSB acknowledges the intended action by the Department of Defence, but considers that a broader review of Defence ATC processes and risk controls should be undertaken, including analysis of ATS related occurrence data, training, staffing and ATS infrastructure to ensure the reasons for the disproportionate risk of loss of separation incidents, and the relative higher level of controller actions contributing to these occurrences, are well understood and any additional appropriate action can be taken to minimise future risk. As such, the ATSB is issuing the following recommendation.

ATSB safety recommendation to Department of Defence

Action number: AR-2012-034-SR-014

Action status: Released

The Australian Transport Safety Bureau recommends that the Department of Defence undertake a review of all processes and risk controls in place to reduce both the disproportionate risk of loss of separation incidents in military terminal area airspace in general and all airspace around Darwin and Williamtown in particular, and the relatively more common contributing air traffic controller actions.

Regulatory oversight of military air traffic services

Number:	AR-2012-034-SI-02
Issue owner:	Civil Aviation Safety Authority
Operation affected:	Aviation – Air traffic control
Who it affects:	All civilian aircraft operations into military controlled airspace

Safety issue description:

Regulatory oversight processes for military air traffic services do not provide independent assessment and assurance as to the safety of civilian aircraft operations.

Response to safety issue by Civil Aviation Safety Authority

> The Report appears to predicate on the assumption that CASA should have oversight authority in respect of military air traffic services when civil traffic is present. However, no evidence or arguments are presented to support this as the most appropriate option.
>
> In the past, CASA has participated in Defence surveillance of military air traffic services. We have every intention of continuing to do so in the future. The Report fails to acknowledge that activity or the effective benefits it has produced.
>
> The ATSB [draft] recommendation …. does not appear to take into consideration the benefit of joint work (such as that described in the bullet point above) that Airservices Australia (AsA), the Department of Defence (DoD) and CASA could undertake, without the need for CASA to assume formal oversight of DoD air traffic services.

ATSB comment in response

The ATSB acknowledges that CASA does have a standing invitation to attend operational evaluations of military ATC units conducted by the military ANSP's auditors, and have participated and plan to continue to participate in these. Such cooperation is important, but CASA remains limited in the level of influence it has over military ATS in relation to the safety of civilian aircraft using military airspace. This ATSB investigation concluded that civilian aircraft have a disproportionate rate of loss of separation incidents which leads to a higher risk of collision in military terminal area airspace in general and all airspace around Darwin and Williamtown in particular. As the function of CASA is that of maintaining, enhancing and promoting civil aviation safety in Australia, the results of this investigation suggest that CASA's influence is not as effective as it could be when it comes to the safety of civilian aircraft, including passenger transport aircraft, in military controlled airspace and some level of independent assessment and assurance as to the safety of civil aircraft operations at DoD airports by CASA is warranted. As a result, the ATSB is issuing the following recommendation.

ATSB safety recommendation to Civil Aviation Safety Authority

Action number: AR-2012-034-SR-015

Action status: Released

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority should review the results of this report and determine whether its current level of involvement with Military air traffic services (ATS) is sufficient to assure itself that the safety of civil aircraft operations while under Military ATS control is adequate.

Using all information to monitor separation risk

Number:	AR-2012-034-SI-03
Issue owner:	Airservices Australia
Operation affected:	Aviation – Air traffic control
Who it affects:	All aircraft operations in civilian controlled airspace

Safety issue description:

Loss of separation (LOS) incidents attributable to pilot actions in civil airspace are not monitored as a measure of airspace safety nor actively investigated for insight into possible improvements to air traffic service provision. As about half of all LOS incidents are from pilot actions, not all available information is being fully used to assure the safety of civilian airspace.

Response to safety issue by: Airservices Australia

> In response to the report's observation that Airservices does not actively investigate or monitor pilot-attributable LOS incidents Airservices would like to clarify that our primary focus on the investigation of ATS-attributable occurrences is to effectively prioritise our internal resources and learning effort on Airservices systems, processes and people. Airservices also actively monitors LOS incidents deemed attributable to pilot actions through the daily safety review of all incidents occurred in the last 24 hours. Consideration is given to whether the air traffic services (ATS) system was potentially causal or contributory in those incidents identified as pilot attributable.
>
> Airservices notes that non-ATS-attributable LOS occurrences are subject to the investigations by aircraft operators and the ATSB which is the lead agency responsible for conducting independent investigations of safety occurrences. Whilst Airservices is committed to continuing our existing support of the ATSB's investigations, Airservices does not have the direct legal authority for investigating non-A TS-attributable LOS occurrences.
>
> However to promote the safety of air traffic, Airservices engages in collaborative activities with industry to share safety information regarding all LOS occurrences and participate in joint investigations. Airservices has initiated a workshop with the major domestic and regional airlines to develop a protocol to enable joint Airservices / airline investigations to be conducted. This workshop is planned for 22 August 2013 in Canberra. This in effect will achieve the same outcome.
>
> Further, Airservices conducts the annual Airline Safety Forum and hosts Heads of Safety Meetings to engage industry in discussing and evaluating the safety performance of the air traffic management network. These forums include the exchange of safety performance information and data based on errors and occurrences reported under both our and the airlines' safety management system (SMS). They also inform the publication of our internal quarterly external threat assessment report on LOS occurrence trends, key systemic safety issues and actions for safety improvement.
>
> In addition an action from the most recent Airline Safety Forum is underway to conduct formal hazard/risk workshops focusing on the interfaces between the air traffic and aircraft operations. This will assist in identifying opportunities to improve the management of internal and external threats (e.g. pilot attributable factors).

ATSB comment in response:

The ATSB acknowledges the actions already taken by Airservices Australia and future action planned. The ATSB understands that Airservices does not have legal authority to compel pilots to be involved in investigations, but has other mechanisms available to obtain information from pilots involved in loss of separation occurrences such as voluntary and confidential surveys. In addition, the ATSB believes that the *safety* of civil airspace in terms of aircraft separation is not fully being monitored by current processes either within Airservices or by the Civil Aviation Safety Authority which requires Airservices to regularly report trends and internal investigations of air traffic services-attributable LOS occurrences only. As such, the ATSB is issuing the following recommendation.

ATSB safety recommendation to: Civil Aviation Safety Authority

Action number: AR-2012-034-SR-016

Action status: Released

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority, in consultation with Airservices Australia and major aircraft operators, use all available information to assure the safety of civilian airspace through actively monitoring and investigating loss of separation incidents attributable to pilot actions in addition to the current focus on air traffic services-attributable occurrences.

ATSB action in response:

The ATSB acknowledges that as Australia's independent transport safety investigation agency, it has a role to investigate serious incidents, including serious LOS incidents resulting from pilot actions. Such investigations provide an opportunity to learn from others' errors and correct any system issue identified, both in the ATS environment and in the aircraft operation environment.

Therefore, the ATSB is committed to undertaking investigations into all LOS occurrences classified as serious incidents, including those that appear to be a result only of pilot actions.

Other on-going safety action from Airservices Australia

Airservices Australia advised the ATSB that:

> Airservices continually strives to identify and mitigate the potential for loss of separation occurrences. The organisation continually examines its incident base in efforts to better understand hazards, the performance of risk controls and mitigators and then make improvements. In 2012, the organisation undertook a Normal Operating Safety Survey in its en route operations in efforts to better understand the errors and threats which controllers encounter, and how these are managed. The results were very encouraging, but also presented some opportunities for improvement which are now being actioned. Strategic interventions, such as the implementation of Automatic Dependent Surveillance-Broadcast (ADS-B), aim to both improve and expand the number of risk controls which are in place to reduce the incidence and severity of occurrence.

Actions initiated through confidential reporting

A number of safety actions were taken in response to the reports submitted to the ATSB via the REPCON confidential reporting scheme. While not taken in response to this research investigation, these safety actions may have reduced the number or severity of loss of separation occurrences at some locations during 2008 to 2012 period. They are discussed below.

The 40 REPCON reports submitted to the ATSB relating to ATS from 2010 to June 2012 resulted in 22 safety actions being taken to improve the safety of Australia's civil air traffic system. Not surprisingly, Airservices Australia carried out the majority of the safety actions (65 per cent) while the Civil Aviation Safety Authority (CASA) was involved with a third of safety actions.

The most common form of safety action, organisational surveillance, was conducted by Airservices Australia. For example, Airservices undertook an overall review of the CROPS procedure involving industry consultation, statistical analysis and hazard assessments. Airservices Australia informed the ATSB that the planned reintroduction of the CROPS procedure at Brisbane Airport was cancelled as a result. In response to concerns about the short break procedure, Airservices advised that they were in the process of conducting a review in regards to the application of the short break procedure in certain circumstances to assure that it meets the design intent.

The Australian aviation safety regulator, CASA, changed documentation or created additional documentation in response to several of the safety concerns reported through REPCON. For example, safety concerns with regards to the potential for misinterpretation of missed approach procedures in the Aeronautical Information Publication (AIP) led CASA to generate a request for change to the AIP. The regulator informed the ATSB that this should ensure that pilots are provided with a greater level of information regarding a missed approach, and that the AIP change would be coordinated with Airservices. The regulator also investigated issues raised with Civil Aviation Safety Regulation (CASR) Part 171 and Part 172 and with airspace regulation.

One aerodrome operator updated the En Route Supplement Australia (ERSA) in response to a REPCON report to reflect a second helicopter landing site.

Appendices

Appendix A: LOS collision risk assessment elements

For both airborne and runway LOS events, there are four elements that were considered to assess the collision risk. Each element is scored based on the severity of the factor—that is, how much it suggested that there was no control over the separation loss. An element can be scored as elevated risk (15), some risk (10), minimal risk (5), or nil risk (1).

When all elements are assessed, the collision risk is calculated by summing the element scores:

- Elevated risk of collision – score of 41 to 60
- Some risk of collision – score of 26 to 40
- Minimal risk of collision – score of 9 to 25
- Nil risk of collision – score of 8 or less

The tables below show how each element is scored.

Airborne LOS

	Elements			
Score	**Closure rate & proximity**	**Evasive action**	**Relative tracks**	**Awareness & communication**
15	Considering relative aircraft performance, <20 seconds to imminent collision Altitude +/- 250ft vertically between aircraft Laterally separated by <400m	Necessary, or should have been taken, to avoid an imminent collision	Aircraft tracks are crossing, reciprocal or converging (critical)	No awareness by ATS or flight crews of imminent collision Traffic alert (STCA or TCAS RA) as last line of defence
10	>20 seconds but <60 seconds to potential collision Altitude >250ft but <500ft vertically between aircraft Laterally separated by >400m but <1,000m	Close conflict necessitating pilot or ATS action	Aircraft tracks are crossing, reciprocal or converging (critical but not imminent)	Loss of situational awareness by ATS or Flight Crews Ground based or aircraft traffic alert activation preventing potential collision High traffic, frequency congestion
5	>60 seconds to potential collision Vertical separation >500ft Lateral separation >1,000m	Action required to re-establish separation standard (non-critical) or should have been taken	Aircraft tracks are crossing, reciprocal or converging (non-critical)	One aircraft aware of the other or ATS aware of both aircraft
1	Closure rate and proximity not a factor (aircraft were never going to collide)	Evasive action not required ATS action not required to re-establish standard	Diverging, parallel or same track Tracks did not cross	ATS and all associated aircraft had situation awareness (technical LOS)

Runway LOS

Elements

Score	Evasive action	Relative positions	Speed	Awareness & communication
15	Collision impending where evasive action is taken or should have been taken	Aircraft positioning is such that a collision with another aircraft, vehicle or person is imminent	Aircraft speed dictates a high closure rate with another aircraft, vehicle or person	No awareness by ATS or flight crew(s) of imminent collision Traffic alert (STCA or TCAS RA) as last line of defence Loss of communications (such as use of wrong frequency or frequency congestion)
10	No positive runway separation Critical conflict necessitating ATS or flight crew action	Paths are crossing, reciprocal or converging (collision not imminent but deemed critical)	One aircraft high speed the other at taxi speed (collision not imminent but deemed critical)	Loss of situational awareness by ATS or flight crew(s) Ground based or aircraft traffic alert activation preventing potential collision High traffic, frequency congestion
5	Action required to re-establish separation standard (non-critical) or collision risk deemed non-threatening	Paths are crossing, reciprocal or converging (collision risk deemed non-threatening)	One aircraft high/medium speed with the other party stopped or slowing	One party is aware of the other either visually and/or through external communication
1	No risk of a collision occurring	Paths are diverging, parallel or same track	Both aircraft/vehicles travelling at low speed or one stopped (actual runway surface not infringed by one party)	ATS and ground parties aware of each other

Appendix B: Event risk classification matrix

A three-step method is used to assess the risk that each occurrence poses to aviation safety, and determine the ERC risk classification for that occurrence.[68]

Step 1

If this event had escalated into an accident, what would have been the most credible accident outcome?

a. First, identify the accident outcome that is of most concern when this type of incident occurs, or put another way, 'what is the accident we are trying to avoid by having these incidents reported?'
b. These judgements are based on 'potential accident outcomes', which may not be the same as the outcome in a particular occurrence.
c. Potential accident outcomes are solely based on injury outcome.
d. It is important to remember when making risk assessments that the occurrence has already occurred. It now carries no risk. The ERC model is based on the risk that the event carried at the time but was (most of the time) not realised as an accident.

The answer to this question takes the form of one of the choices from the list below:

Outcome score	Accident outcome	Outcome description	Typical aircraft in these categories
125	High capacity catastrophic	More than 38 fatalities	Q400, Boeing 737, Airbus A330
25	Catastrophic accident	Multiple fatalities (7 to 38)	DHC-8-100/200, Saab 340, EMB-110, larger Cessna/Piper twin piston/turboprops, Beech King Air
5	Major accident	1 to 6 fatalities	Beech Baron, Turbo Commander, R44, most Cessna/Piper single pistons and turboprops and light twins below 6 seats, Bell 206
1	Injury accident	1 or more injuries (no fatalities), minor damage to aircraft	Any aircraft
0	No accident outcome	No potential for aircraft damage or injuries	Any aircraft

Step 2

What was the effectiveness of the remaining barriers between this event and the most credible accident outcome?

a. When determining the answer to this question, only the barriers/defences that remained in place at the point of the occurrence are considered.
b. These could be mechanical/aircraft system-based, pilot training or knowledge, procedure-based, or related to ATC systems and procedures.
c. The aim is to estimate the probability that the occurrence outcome would further escalate from the actual outcome into the most credible accident outcome (determined in Step 1). The barrier which stopped the escalation is counted (because it was still in place), along with any others that are believed to still remain. The already failed barriers are ignored.

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68 The Event Risk Classification (ERC) methodology is from the report *The ARMS Methodology for Operational Risk Assessment in Aviation Organisations* (version 4.1, March 2010). ARMS is an industry working group set up 2007 in order to develop a new and better methodology for Operational Risk Assessments. The methodology is freely available from http://www.skybrary.aero/index.php/ARMS_Methodology_for_Risk_Assessment.

The answer to this question takes the form of one of the choices from the list below:

Effectiveness score	Effectiveness rating	Definition	Example
2	Effective	The safety margin was 'effective', typically consisting of several good barriers.	A passenger smoking in the lavatory, which would be highly unlikely to result in an in-flight fire accident.
4	Limited	Typically, this is an abnormal situation, more demanding to manage, but with still a considerable remaining safety margin.	A moderate error in a load sheet or loading which might result in slight rotation problems at take-off, however, the crew are able to safely continue flight or conduct a rejected take-off.
20	Minimal	Some barrier(s) were still in place, but their total effectiveness was 'minimal'.	A GPWS 'terrain' warning just before an imminent CFIT.
100	Not effective	The only thing separating the event from an accident was pure luck or exceptional skill, which is not trained nor required.	An unrecovered loss of control and collision with terrain where the aircraft occupants are not seriously injured.

Step 3

The credible accident outcome is combined with the effectiveness rating for each occurrence. Usually, this takes the form of the credible accident outcome score multiplied by the effectiveness score.

This step gives the ERC risk classification for each occurrence, and its risk rating score. The risk rating score is a dimensionless, relative value only. It is only useful in comparing the risk of one occurrence to that of other occurrences, and does not constitute an amount of risk in itself.

The ARMS risk analysis matrix (below) shows the possible risk classifications that can be applied to occurrences (based on the answers to the questions in Step 1 and Step 2), and the corresponding risk rating scores:

	Effective	Limited	Minimal	Not effective
High capacity catastrophic accident	250	503	2,503	12,500
Catastrophic accident	50	102	502	2,500
Major accident	10	21	101	500
Injury accident or minor aircraft damage	2	4	20	100
No accident outcome	1			

Appendix C: ATSB Investigations used for analysis of common themes

Investigation Number	Investigation title	Released
AO-2011-011	Breakdown of separation - 22 km S Williamtown (Newcastle Airport), NSW- 1-Feb 2011	07/03/2012
AO-2011-090	Loss of separation - BLAKA (IFR Reporting Point) 29 July 2011 - VH-VZC, Boeing Company 737-838 / VH-VOT, Boeing Company 737-8FE	06/03/2013
AO-2011-127	Breakdown of separation, VH-YVA/VH-CGF, 59 km NE Armidale, New South Wales, 8 October 2011	31/07/2012
AO-2011-142	Loss of separation involving parachuting area, CASA C212-CC, VH-MQD, and Boeing 737-7BX, VH-VBP, near Richmond Aerodrome, New South Wales - 5-November 2011	Still to be published
AO-2011-144	Loss of separation - VH-VXM / VH-VUV, near Ceduna, SA - 08-Nov-11	Still to be published
AO-2011-147	Loss of separation, VH-TFK/VH-PDP, 6 km N of Cairns, Queensland, 23 November 2011	04/02/2013
AO-2012-012	Loss of separation between 9V-TAZ and A6-EHH, 656 km NW of Karratha, Western Australia, 18 January 2012	Still to be published
AO-2012-029	Loss of separation between VH-ATO and VH-VZA followed by a loss of separation between VH-ATO and VH-TJY - 19 km NE of Melbourne Airport, Victoria, 16 February 2012	Still to be published
AO-2012-047	Loss of separation assurance - PK-GPO/PK-GPA, AIRBUS A330-243/AIRBUS A330-343X, near Curtin Aerodrome WA - 30-Mar-12	Still to be published
AO-2012-132	Procedural error - 41 km SSW Williamtown, New South Wales - 28 September 2012	Still to be published
AO-2012-131	Airways facility event - Darwin Aerodrome, 150° M 33Km - 02-Oct-12	Still to be published
AO-2012-161	Loss of separation - VH-EBM/VH-QPC, Airbus A330, 148 km E of Narrogin (ALA) (BURGU IFR), WA, 28 November 2012	Still to be published

Sources and submissions

Sources of information

The sources of information during the investigation included the:

- Occurrence reports submitted to the ATSB
- Department of Defence Aviation Safety Occurrence Reports
- Airservices Australia investigation factors
- ATSB occurrence investigation reports
- Confidential (REPCON) reports submitted to the ATSB.

Google Earth was used to produce to following maps:

- Figure 16: Location of en route occurrences by separation standard type, 2008-June 2012
- Figure 20: Location of terminal control area LOS occurrences in the vicinity of Sydney Airport, January 2008-June 2012
- Figure 21: Location of terminal control area LOS occurrences in the vicinity of Melbourne Airport, January 2008-June 2012
- Figure 22: Location of terminal control area LOS occurrences in the vicinity of Darwin Airport, January 2008-June 2012

Submissions

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

A draft of this report was provided to Airservices Australia, Department of Defence, the Civil Aviation Safety Authority, and the Department of Infrastructure and Transport.

Submissions were received from Airservices Australia, Department of Defence, and the Civil Aviation Safety Authority. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

Australian Transport Safety Bureau

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The ATSB is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

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

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

Purpose of safety investigations

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

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

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

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

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

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

Glossary

ACAS	Airborne Collision Avoidance System
ADC	Aerodrome controller
ADS-B	Automatic Dependent Surveillance - Broadcast
ANSP	Air Navigation Service Provider
ATC	Air traffic control
ATS	Air traffic services
ATSB	Australian Transport Safety Bureau
AWIS	Aerodrome weather information services
CANSO	Civil Air Navigation Services Organisation
CROPS	Converging Runway Operations
EFIS	Electronic Flight Instrumentation System
FIR	Flight Information Region
FL	Flight level
ICAO	International Civil Aviation Organization
IFR	Instrument flight rules
LOS	Loss of separation
LOSA	Loss of separation assurance
MATS	Manual of Air Traffic Services
NOTAM	Notice to airmen
REPCON	REPort CONfidential (voluntary reporting scheme)
RVSM	Reduced Vertical Separation Minimum
SID	Standard instrument departure
SMC	Surface movement control
STAR	Standard arrival route
STCA	Short-term conflict alerts
TCAS	Traffic Alert and Collision Avoidance System
VFR	visual flight rules
VMC	Visual meteorological conditions
VOR	VHF (very high frequency) Omnidirectional radio range instrument approach

Australian Transport Safety Bureau

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Research

ATSB Transport Safety Report
Aviation Research Investigation
Loss of separation between aircraft in Australian airspace,
January 2008 to June 2012

AR-2012-034
Final – 18 October 2013