COLLISION AVOIDANCE PROCESSES for SPORT and RECREATIONAL AVIATION and the APPLICATION of ADS-B

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SUMMARY

Strongly held views expressed by a number of members of ASTRA and the ABIT sub-group indicate a lack of understanding of the realities of collision avoidance processes used by sport and recreational aviation[1]. If ASTRA and its sub-groups are to make appropriate and logical recommendations regarding airspace regulation involving sport aviation these views need to be addressed and the realities of collision avoidance by sport and recreational pilots understood.

This analysis shows that current collision avoidance processes used by sport aviation which depend on see-and-avoid are capable of delivering good safety outcomes and that the common failure leading to an accident is not a failure of visual acquisition but a failure of pilot lookout (vigilance). The factors leading to the success of visual acquisition under the conditions applying in sport aviation are presented.

Hazard analysis and the accident record show that the hazard to other airspace users in Classes E and G is limited to the terminal area of uncontrolled airfields. The use of ADS-B in the terminal area by sport pilots is inappropriate and is likely to lead to an increase not a reduction in accidents. Analysis and the accident and incident record show that current and proposed collision avoidance process used by sport aircraft in Classes E and G are appropriate and installation of ADS-B in these aircraft for protection of other airspace users cannot be justified.

Potential exists to improve the protection of RPT operations using conventional means and I have addressed this matter elsewhere.

Because of the nature of sport aviation operations, the avoidance of collision between sport aircraft depends on an ongoing visual scan which can be assisted by an alert process – but, in the situations where significant hazard exists, the time available between the action leading to a potential collision and any necessary avoidance action is so short that this scan must be essentially continuous. Any alert process used must not interrupt the ongoing external visual scan and accordingly, the alert must preferably be aural.

It is concluded that, while ADS-B may provide some assistance, particularly by providing an alert at a greater distance than is now available, this technology will add little if anything to safety outcomes within sport aviation. The technology has the potential for inappropriate use which, if allowed, would lead to increased not reduced accident rates.

An alternate technology related to ADS-B known as FLARM has been developed specifically for use in gliders in Europe particularly when mountain flying. While this technology is subject to the same reservations regarding the applicability of cockpit displays, this device is purpose designed for gliders, includes an audio alarm and does not suffer from the disadvantages inherent in ADS-B in sport aircraft and it is currently under evaluation by the GFA.

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[1] Sport aviation refers to the ASAC organisations – the GFA, HGFA, ABF – balloons – and APF – parachuting. Recreational aviation refers to operations under the RAA

COLLISION AVOIDANCE PROCESS USED BY SPORT AIRCRAFT

It needs to be clearly understood that:

See-and-avoid, both alerted and unalerted, is the central process involved in collision avoidance in sport and recreational aviation.

See-and-avoid is enhanced where ever possible by radio alert, but direct visual acquisition remains an essential step in this process and radio alert is used to enhance, not replace, see-and-avoid.

See-and-avoid is supported where appropriate by a number of procedures, typified by circuit procedures, designed to create standard traffic patterns which:

a) Where possible, keep aircraft separate without the pilots having to be aware of the presence of the other aircraft.
b) When it is necessary to bring aircraft together, to do so in a standardised pattern so that pilots know where to look for traffic with or without radio alert.
c) Avoid head to head conflicts.

See-and-avoid is the central process in collision avoidance for sport aircraft because, at the traffic densities at which these aircraft operate, self-arranged separation is less reliable and frequently impractical.

EFFECTIVENESS OF COLLISION AVOIDANCE PROCESSES

It is a matter of record that the above processes, in the context of sport and recreational aviation, combine to produce an effective means of collision avoidance.

The primary evidence for this is 50 plus years of experience.

Gliders and, more recently, other sport aircraft have operated uncontrolled aerodromes at very high traffic levels. Movement rates of 15 per hour or more are common at sites such as Camden, Bacchus March, Temora, Narromine, Jondaryan, Piper's Airfield (Bathurst Gliding Club) and others[2]. At sites where much of this traffic is gliding, the glider training area is necessarily the same as the circuit area so traffic densities in this airspace are very high. Until the 90s such sites were run on unalerted see-and-avoid with no accidents. None of the accidents involving sport aircraft – gliders – occurred at these very high density aerodromes.

Gliders also go cross-country in gaggles of up to 6-8 glider or more. This involves thermalling and cruising within a few to a few tens of seconds of potential conflict for considerable periods of time.

Consequently, gliders in particular and sport and recreational aircraft to a lesser extent, frequently fly under conditions where see-and-avoid, both alerted and unalerted, will be relied on several times in each flight to avoid actual conflicts. If this process did not work we would have many collision each year.

FACTORS AFFECTING the EFFECTIVENESS of SEE-AND-AVOID

[2] For comparison Broom A/P has 150 movements per day. It is a common misconception that the MBZ aerodromes are the uncontrolled aerodromes with most traffic. This is not the case – a number of sport and recreational aerodromes which are now uncontrolled CTAF aerodromes have much higher traffic levels than MBZ airfields including aircraft up to bank runner size and speeds.

A number of factors combine to render see-and-avoid effective in sport aviation operations, including at least:

a) **Pilot expectation and training**. Vision is a very subjective process. What we see is constructed in the visual cortex largely from memory and assumption updated selectively with input from the eye. As a result no pilot will see anything which he is not actively looking for or does not expect to see. Sport aviation pilot training and experience leads to an expectation of success. Glider pilot training starts with lookout training and this is emphasised at every stage throughout training. Well before going solo our student pilots are aware of the limitations of see-and-avoid and how these are overcome under the circumstances of sport aviation operations and, accordingly, how to apply an ongoing, appropriate, effective, targeted scan.

b) **Moving visual target triggers acquisition**. Because sport aviation aircraft in general and gliders in particular, do not cruise at a fixed height, speed and direction, the visual target which must be acquired will always have some apparent motion triggering the peripheral vision close around the point of focus. This applies whether the target aeroplane is another glider or a cruising powered aeroplane.

c) **Visual target size**. The high manoeuvrability and lower speeds allow a much closer minimum detection time resulting in a much increased visual target size, significantly enhancing the effectiveness of visual acquisition.

d) **Lower closing speeds**

e) **Excellent cockpit visibility**

These factors combine to make see-and-avoid applied with vigilance an effective means of collision avoidance in the context of sport aviation – glider – operations.

Many of these factors also apply to recreational aviation and to a lesser extent to GA operations.

More detail and specific justification of these conclusions is provided in Note 1.

EXAMINATION of the COLLISION ACCIDENT RECORD.

Nevertheless, it is also clearly a matter of record that gliders are involved in too many collision accidents. This matter has been the subject of ongoing examination by the GFA including a number of specific intensive examinations and pilot T&E programmes. This is a world wide problem and this analysis shows that, while this outcomes must not be simply accepted, it is a result of the type of exposure.

In examining the collision accident record it has become accepted and it is important to separate collision accidents which occurred between aircraft which chose to fly close to each other from those in "normal Operations"

Attached in Appendix 1 is an analysis by CASA of collision accidents between 1969 and 2000. Accidents since the period covered by this analysis show similar trends for gliding and a worrying trend involving accidents for GA at controlled airfields and MBZ. Also an extract of an analysis by the GFA of glider accidents is provided in Appendix 2.

ACCIDENTS in 'NORMAL' OPERATIONS

Considering firstly accidents involving aircraft which did not chose to fly close to each other – normal ops.

These show that all but 2 accidents occurred at aerodromes with about half in controlled airspace and half at uncontrolled airfields. The two remaining accidents occurred at holding points prior to entry into controlled airspace. There have been no *en route* accidents confirming a long recognised fact that the collision hazard in Classes E and G is limited to points of concentration – mostly aerodromes.

Of the 22 accidents in this category only 2 involved sport aircraft and the last involving a glider was in 1990.

ACCIDENTS INVOLVING AIRCRAFT WHICH CHOOSE TO FLY TOGETHER – GLIDERS

The CASA analysis includes 36 accidents of which 22 were glider to glider and another 6 were glider to tug.

Accidents involving GFA aircraft were analysed in more detail by the GFA. An extract of this analysis is shown in Appendix 2, (covering the period up to 2002)

This analysis shows that about one quarter of these accidents – 9 in total – occurred in the terminal area. 6 of the 9 were glider to tug, 2 glider to GA (included in 'normal' ops in the CASA analysis) and only 1 was glider to glider.

Gliding alone has *en route* accidents. A simple overview shows immediately why this is so. These "*en route"* accidents all occurred at "points of concentration" – mostly while thermalling or cruising in gaggles. 2 occurred at turn points.

To assist in understanding the conclusions drawn, typical scenarios are provided in Note 2.

All or almost all gliding accidents occurred under conditions where pilots chose or were effectively required, for operational reasons, to fly in close proximity with other aircraft – gliders or tugs. In the terminal area traffic levels are frequently very high. *En route* accidents occur largely during thermalling in gaggles where aircraft not only fly close together but where actions which result in the creation of a potential conflict occur a few to, at most, a few 10 of seconds from the point of potential conflict. Under both these circumstances the pilot is normally aware that other aircraft are present. The size and apparent motion of the visual target combine to make visual acquisition reliable and rapid. The primary difficulty with the application of see-and-avoid under these circumstances is the very short time between the action which created the conflict and any required avoidance action. This requires an ongoing targeted external visual scan. Any interruption to this external scan at such times is hazardous.

Note: It should be made clear that glider flight is not perpetually in this situation of very close contact with other gliders – however, analysis shows that these accidents occur essentially exclusively under circumstances where these conditions do apply. Processes which attempt to deal with these glider to glider accidents must deal with these circumstances.

The significant conclusions reached from detailed analysis of this accident record were:

1. Collision accidents appear to be a failure of lookout or vigilance not visual acquisition. As above, the circumstances of these accidents mean that visual acquisition is reliable and rapid. However the time available between the action leading to the conflict and required avoidance action is short.

2. Improved cockpit displays have increased the likelihood that pilots will concentrate inside the cockpit. Audio input is considerably preferable to an internal visual scan and audio varios are considered essential.
3. Cockpit workload has been implicated in a number of cases.
4. Radio alert is a useful assistance to see-and-avoid in the terminal area but of limited but not zero value *en route.* The difficulty *en route* is the lack of triggers to identify appropriate times to make a call combined with the difficulty of succinctly identifying the position of the calling glider.
5. Tug to glider conflicts were high but a statistical analysis suggested that this could be accounted for by exposure. Nevertheless action has been taken to address this problem by improved local procedures. Additional radio calls introduced in the NAS 2c changes may well further assist.
6. A glider circuit/training area is a very high intensity area and is not suitable for RPT operations. Most areas where RPT operations come close to such a glider training area have evolved local procedures promulgated in ERSA to ensure either separation or at least radio alert.

APPLICATION of ADS-B TO COLLISION AVOIDANCE PROCESS USED BY SPORT AIRCRAFT

Because the requirements and opportunities are very different, this report will consider the application of ADS-B as an assistance to collision avoidance within sport aviation – ie between sport aircraft and then separately for the protection of other airspace users – ie between sport aircraft and other airspace users.

APPLICATION WITHIN SPORT AVIATION – GLIDERS

The above analysis shows that, under the circumstances applying in glider to glider accidents, the closeness of approach means that visual acquisition is reliable and the primary difficulty is the short time between the action creating the conflict and the required avoidance action. Any factor which interrupts the ongoing external scan has the potential to cause accidents.

Again, under these circumstances, a visual display, such as provided by ADS-B IN, will normally show more than one target all of which move apparently randomly, allowing only a few seconds to a few tens of seconds between the action leading to a potential conflict and any avoidance action required.

Clearly, total replacement of the external visual scan relying on the ADS-B visual display would not be functional.

Any attempt to augment the external scan using the internal visual display would require the pilot to interrupt this external scan and scan a visual cockpit display and then resume the external visual scan applying information derived from the cockpit display. To be successful this switch in scan would have to be made at a frequency which would deal with the timing of actions likely to alter the source of potential threat. As the scenarios in Note 2 show, in glider operations in general, and for all in a busy circuit area, this would be every few minutes at least. This would require a VFR pilot to make rapid decisions requiring good spatial awareness and rapid adjustment from a visual scan within the cockpit requiring a close visual focus to an external scan requiring a distant focus.

The suggestion that the average VFR pilot would have the spatial awareness and ability to switch rapidly from an internal cockpit display to an external scan at this frequency and achieve improved visual acquisition is not credible.

For this reason ADS-B has limited application under these circumstances and if used inappropriately has the potential to encourage concentration inside the cockpit and may well cause an increased number of accidents.

ADS-B or similar technology has the potential to provide alert at a greater distance and provide early warning of the approach of an additional aircraft. Where it is operationally impractical to avoid that aircraft at a distance, eventual visual acquisition is required. Under some circumstances this early alert would have some advantages but it is not the revolutionary outcomes expected by many. Application of the technology then becomes a cost benefit situation.

The essential conclusion from this analysis is that collision avoidance by sport and recreational aircraft depends on an ongoing visual scan which can be assisted by an alert process – but in the situations where a significant hazard exists, the time available between the action leading to a potential conflict and the point of conflict means that this scan must be essentially continuous and any alert process must not interfere with the ongoing external visual scan essential to acceptable safety outcomes.

In this context a cockpit display such as can be provided by ADS-B has the problem that it must interrupt this external scan.

APPLICATION OF FLARM

FLARM (**FL**ight al**ARM**) is essentially a proximity detector based on GPS which operates between aircraft (only) in a manner similar to ADS-B. This device was purpose developed in Europe for gliders in an attempt to address the serious collision hazard encountered in glider mountain flying at the traffic densities encountered in Europe. This device is in current use in Europe and is under examination by the GFA for use in Australia.

The device is purpose designed for gliders. It has an audio alarm and a simple visual display. The device determines which of any potential conflicts is significant and the audio alarm increases in volume as the target approaches. The audio alarm can be muted for periods when one or more glider is close for significant periods of time. The audio alarm automatically comes back on after 5 minutes. The device costs less than $1000 and has a battery drain which is manageable in a glider cockpit.

This device still suffers from the potential to encourage pilot concentration inside the cockpit but it is designed for use in gliders and the audio alarm is intended to minimises this downside. Experience in Europe shows that, under the conditions applying in Europe, the device has significant advantages but all emphasise that it is only an aid, providing an alert at a greater distance than unalerted see-and-avoid. The strong advice is that pilots must be briefed not to rely on the device and vigilant effective lookout is still required if the device is to have a positive effect on safety outcomes. Used in this fashion the device has good acceptance in Europe.

PROTECTION OF OTHER AIRSPACE USERS

The hazard to other airspace users is limited to the terminal area of uncontrolled airfields.

The *en route* hazard in Classes E and G is well down in the trivial region. Analysis by CASA of the ATSB database (attached Note 1) shows that there has never been a legitimate *en route* accident involving aircraft which did not chose to fly close to each other. (The record shows two accidents, but these occurred at holding points prior to entry into controlled airspace.) Analysis by Airservices[3], sport

[3] In the lead up to the LLAMP project David Anderson examined the collision hazard across Australia down to squares 10 NM on a side and this work demonstrated that the hazard in Classes E and G was far from uniform

aviation (Bob Hall) and the RAAF shows that the en route hazard in the remaining Classes E and G is less than the design standard for major structural failure. Sport aircraft, particularly unpowered aircraft, do not cruise on tracks and hence this traffic is random to traffic involving other airspace users. The RAAF[4] and the sport aviation risk study (Bob Hall) both concluded that this random traffic contributes a minor – negligible – amount to this already trivial hazard.

Radio alert and the new CTAF procedures are a more appropriate risk mitigator in the terminal area of uncontrolled airfields because this process enhances rather than attempting to replace see-and-avoid. Replacement of see-and-avoid with another process is inconsistent with the NAS 2c changes.

Overall the accident record and risk assessment show that fitment of ADS-B to sport aviation aircraft cannot be justified based on the protection of other airspace users.

Note 1 SEE-AND-AVOID for SPORT AIRCRAFT

A number of factors combine to make see-and-avoid considerably more effective particularly for sport aircraft, gliders in particular but to a lesser extent recreational and some GA aircraft, than for other segments of aviation.

These are:

1. Pilot expectation and training.

It is well known that vision is a very subjective process. What we ‘see’ is a construct created in the visual cortex largely from memory and assumption updated only by selective input from the eye. Recent evidence adds support to the view that the same process in the visual cortex is used to remember a scene (the mind’s eye) as is used in current ‘live’ vision. What this means is that no pilot will see anything he/she is not actively looking for nor believes he/she can see. Accordingly, the view that see-and-avoid does not work is a self fulfilling assumption.

Pilots, especially glider pilots who frequently choose to fly very close to other aircraft for considerable periods of time, need to be specifically trained in appropriate scanning processes and to be continually urged to apply them all the time. In this context the comments by some regarding the lack of success in this process make our job of convincing our pilots more difficult. Glider pilot training starts with lookout training and this continues to be emphasised at all stages throughout the syllabus. Well before this training is finished even our student pilots are aware of the limitations of see-and-avoid and how to apply this overcoming these limitation to achieve good safety outcomes. Glider pilots are checked at least annually independent of experience and any failure in lookout processes is a mandatory failure. Failure of this check automatically removes solo privileges until retraining achieves a passing grade.

The frequency of conflicts is such that lookout can be and is taught as a self checking process. Pilots are told to note the apparent visual size at first detection. This is frequently defined as the apparent image size at 1 metre – arms length – from the eye. Under normal circumstances this apparent image size at one metre should give an apparent wing span of 1 cm. Smaller than this is good, larger is late. For a 15 m glider this is a detection distance of about 1.5 km.

2. Apparent motion of visual target.

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with very few spots containing a hazard level above the trivial range.

[4] During the LLAMP project the RAAF examined the hazard to ‘pop up’ operations in Classes E and G after removal of DTI (directed traffic information) and this analysis concluded that the hazard created by random operations in this airspace was negligible.)

Because sport aviation aircraft in general and gliders in particular, do not cruise at a fixed height, speed and direction, the visual target which must be acquired will have sufficient apparent motion to trigger acquisition via the peripheral vision surrounding the point of focus. This effect allows a successful scan to be abbreviated and greatly increases the reliability of visual acquisition. This is essential to the success of the abbreviated, targeted scan which is relied on during gaggle flying by gliders.

This effect still successfully applies to visual acquisition by a glider pilot of powered aircraft which are cruising on a fixed course at fixed altitude because the variable path of the glider means that the visual target subtended by such an aircraft does not remain stationary for long even if the two aircraft are eventually going to come into close conflict.

The combination of 1) and 2) above means that most target aircraft – whether sport or other aircraft are normally detected at a an apparent visual size at one metre from the eye of 1 – 2 cm.

3. Visual target size.

A critical factor in visual acquisition is the minimum approach distance by which visual acquisition must be achieved to allow time for avoidance action. Risk assessment studies carried out by CASA and Airservices have used the time by which visual acquisition must be achieved to define this minimum detection distance and CASA has assumed 10 sec, whereas Airservices used 12 sec. The high maneuverability and lower speeds in sport aircraft allows a much closer minimum approach at last point of detection. Frequently, at 10 to 12 sec, gliders are still flying towards the already detected aircraft. Expert opinion puts this last time for collision avoidance action for gliders at ca 5 sec. Perhaps GA aircraft would be somewhere in between and recreational aircraft may be similar to gliders.

Because the visual target size is inversely proportional to the square of the separation distance – this minimum detection distance has a very big effect on the final probability of visual acquisition. This factor has a larger effect than is commonly realised.

The definitive work on visual acquisition is that by Andrews. The following figures are taken from his data and model. Shown is the visual acquisition of a Dash 8 flying at 200 kts from a glider flying at 80 kts. Included are acquisition probabilities for head to head and 90 degrees to track for unalerted, radio alert and TCAS alert (similar to ADS-B ?) at 5, 10 and 12 sec to the point of conflict.

	Head to head Probability of visual acquisition			90 degree to track Probability of visual acquisition		
Time to Collision	Unalerted	Radio alert	TCAS alert	Unalerted	Radio alert	TCAS alert
5 sec	0.902	0.999	1.000	0.999	1.000	1.000
10 sec	0.612	0.943	0.997	0.958	0.999	1.000
12 sec	0.525	0.893	0.975	0.918	0.999	1.000

These data show that a reduction in the minimum time for visual acquisition from 10 sec to 5 sec makes a similar improvement to visual acquisition as is made by radio alert.

(Compare the visual acquisition probability for a head to head conflict unalerted at 10 sec – 0.612 – with the same situation for alerted see-and-avoid at 10 sec – 0.943 and that for unalerted see-and-avoid at 5 sec – 0.902.

A similar comparison may be made for the same figures for 90 degree to track – ie 0.958 compared to 0.999 for either alerted see-and-avoid at 10 sec and unalerted see-and-avoid for 5 seconds.)

Also that at 10 or 12 sec even radio alerted visual acquisition can be significantly improved by TCAS alert (similar to ADS-B alert ?) but at 5 sec the possible improvement is marginal.

These figures do not include the effect 2) above caused by the fact that this target is not apparently stationary but will have apparent movement triggering visual acquisition. Because the visual target will have apparent motion, visual acquisition will normally be achieved by a glider pilot who is actively looking out well before this last time requirement. However the combination of these two effects makes the probability that a pilot who is actively using an effective scan process will fail to visually acquire a target up to and including this last time of detection very small indeed.

These figures alone explain the difference in outcome for sport and recreational aircraft and some other airspace users.

4. Cockpit Visibility

Sport aircraft and gliders in particular are designed for see-and-avoid. Visibility out of a glider is uninterrupted from above about 12 degrees below horizontal round to as far back as a pilot can turn his head. (I can see my own tailplane out of the cockpit of my glider – this is not uncommon.)

5. Closing speeds are somewhat lower.

Application to recreational and GA aircraft.

Powered aircraft are required to cruise at levels. This results in the loss of the advantage achieved from the fact that the visual target shows apparent motion. However this also eliminates head to head conflicts in cruise. Accordingly, visual acquisition will be as in the table above. The closeness of approach allowed particularly in many GA aircraft will not be as low as for gliders but will be lower than the 10 – 12 sec assumed for large aircraft.

However when the increased effectiveness of radio alert is combined with the recommendation that GA aircraft avoid airspace containing significant IFR aircraft, the use of CTAF procedures at uncontrolled airfields and the very low hazard in the remaining Class E, see-and-avoid, while not being as effective as for gliders, remains an adequate process for collision avoidance in Classes E and G.

Note 2 TYPICAL SCENARIOS

General

A glider cockpit is small with little room for movement or papers, maps etc. Visibility out of the cockpit is largely uninterrupted. The aircraft is light and twitchy to fly and because of this and the need to make best use of the air, the aircraft is actively flown all the time. Concentration should be outside the cockpit with a minimum of instrument scan. The 'feel', airflow noise and motion of the airframe are all important information combined with an audio indication of lift and/or sink. Concentration is divided between lookout for collision avoidance and 'feel' of the air to make maximum use of the available lift and to avoid sink. Other aircraft are frequently seen and must be expected all the time.

1. Busy Circuit.

At an active glider site, training and local flying is coincident with the circuit area. Several gliders and one or more tugs will occupy the airspace near and in the circuit. Flight paths are random and unpredictable. A continuous, targeted scan is required. Near the ground, where most traffic will be encountered, the pilot is also concentrating on flying the aircraft near the ground, flight management, circuit planning (no engine) and lookout combined with radio alert.

Conclusion The record at busier airports shows that provided all pilots are vigilant, outcomes based on see-and-avoid and radio alert are good. Opportunity to monitor a cockpit visual display is limited. Because of the number of aircraft, the fact that it is operationally impossible to fly away from any given target and the random, unpredictable nature of flight paths involved, interpretation of the cockpit display to assist collision avoidance would require extensive monitoring of the display at the expense of the external scan. This would not be practical – and would probably be dangerous.

2. Thermalling in a Gaggle

Again up to several gliders may be involved – either competing or flying cooperatively. Gliders are turning at angles of bank up to 45 degrees and will frequently be modifying the turn to remain centred in the thermal. Gliders are frequently a few seconds from collision with often more than one glider for considerable periods of time. Lookout is all around but is concentrated directly overhead which is where an entering glider will appear. Pilots must monitor speed and lift rate assisted by an audio indication. Routinely, there is not sufficient time for radio alert – and a continuous visual scan is essential.

Conclusion Opportunity to monitor a cockpit visual display would be limited to times where no other aircraft are currently in the vicinity. Outcome is limited to an alert of a single new target. This could then be by audio alarm.

3. Cruising in a Gaggle

Several gliders cruising between thermals at similar heights. Many situations are possible. The following is not perhaps typical, but does graphically illustrate the type of situation which will face glider pilots from time to time.

Glider A is cruising at the same speed (typically 80 – 120 kts) as a target glider 500’ lower and 0.5 km ahead to one side. The target glider is visible to glider A with a visual target size at arms length of ca 3 cm wing span. This target glider should be visually acquired by the pilot of glider A. Target glider cannot see the glider A. The target glider strikes lift and pulls up into a turn towards glider A. If no action is taken, approximately 10 sec later the target glider will pass close to or collide with glider A. Other gliders may be close.

The target glider will be able to see glider A once the initial turn is under way – requiring a lookout scan directly overhead – as for thermalling. The target glider will be visible to glider A throughout. Both gliders will have considerable apparent motion.

Visual acquisition should be achieved by one or both BUT a continuous external scan is required as defence against such scenarios. The opportunity for glider A to be alerted to this turn by the target glider via a cockpit display given the short time between initiation of the turn and conflict is negligible. The target glider may well consult a visual cockpit display before commencing the turn and may derive some advantage from such a device. However, the pilot of the target glider must react quickly or miss the lift and is concentrating on internal and external indications of lift, deciding whether to take this thermal, flying the aircraft in a steep climbing turn and, as it is not appropriate to rely on the cockpit display, a lookout directly overhead. The opportunity for this internal visual scan of the cockpit display and the reliability of such action is at least questionable.

Many similar but normally less critical situations similar to the above occur regularly and, while these would normally leave more time for visual acquisition and avoidance response, ongoing vigilance and external visual scan is required when flying in close proximity with other gliders.

Conclusion: A cockpit visual display may be of some assistance but will not provide more than an alert with many opportunities to cause a problem. Visual acquisition of any target glider remains essential.

In instances where the proximity of other aircraft would allow more time for a scan of an internal display or activation of an aural alarm, early warning – earlier than possible by visual acquisition may well have significant advantages. However, almost by definition such scenarios will normally involve a reduced hazard. Such benefits do not ameliorate the need for current vigilance and an ongoing external scan in regions of more significant hazard.

APPENDIX 1 Analysis by CASA – MID AIR COLLISIONS IN AUSTRALIA – 1969 to 2001

Tony Rothwell, GM Airways & SA, CASA, 4th February 2002

This table is divided into two parts:

The first is those mid-airs where the aircraft have not been deliberately operated in close proximity to each other, and

The second is those where the aircraft have both been deliberately operated in close proximity

The reason for the distinction is that an analysis for the purposes of considering airspace structures needs to determine not only what the risks are but how those risks came about.

Clearly in any mid air collision, two aircraft have operated in close proximity. The distinction for the present purpose is drawn by considering the nature of the operation: Where for example two aircraft have been conducting formation flying together or where a tug aircraft is towing a glider or where two gliders are thermalling together then that kind of operation is regarded as having been conducted knowing or reasonably being expected to know that another aircraft was in close proximity. The mere existence of two aircraft in a common circuit pattern is not considered as coming within the second category.

The base information has been provided by ATSB but the taxonomy into the two distinct classes has been made by myself based only on the short form ATSB (ex BASI) summary data. In one case a pilot has deliberately flown close to another aircraft, misjudged his distance and collided with it however since the second pilot was not deliberately party to operating in this manner the accident has been included in the first group – arguably it should be in the second but that is a judgment.

1st group of aircraft – Those not deliberately flown in same airspace 22 Items

Date:	**Location**	**Aircraft 1**	**Aircraft 2**	**Airspace**	**Details**
06-07-69	Parafield SA	V-100 VH-BWT	PA-32 VH-PPV	GAAP	PA-32 took off, overtook and collided with V-100
08-01-70	Jandakot WA	PA-24 VH-PAR	B-23 VH-RWA	GAAP	Both failed to keep lookout
19-10-70	7nm Moorabbin V	Bell 47 VH-BLM	Beech 50 VH-RCN	OCTA	Converging on MB entry point

13-02-71	Jandakot WA	PA-28 VH-CTP	C-150 VH-RXS	GAAP	CTP overtaking RXS fail see and avoid
14-06-71	Bankstown NSW	C-150 VH-DFD	C-182 VH-GAC	GAAP	Fail see and avoid
12-03-72	Armidale NSW	C-172 VH-AAC	CA-28 VH-SSF	OCTA	
01-06-73	Moorabbin Vic	PA-28 VH-CWJ	PA-28 VH-RVK	GAAP	Pilot 2nd solo failed to go-around until 5' hit a/c on runway
13-03-74	Bankstown NSW	DH-Dove VH-WST	PA-30 VH-WWB	GAAP	Fail see and avoid
23-03-74	Ballarat Vic	PA-28 VH-KMP	C-172 VH-PLO	OCTA	PLO descended on top KMP on final
01-02-76	Parafield SA	C-172 VH-UGC	PA-28 VH-UQN	GAAP	UQN descended on top of UGC on final
08-01-79	Warrnambool Vic	C-150 VH-RAD	C-150 VH-RID	OCTA	Collided on final approach to runway
28-09-80	3NW Moorooduc N	C-172 VH-EAG	Glider VH-GRT	OCTA	
24-04-88	Archerfield Qld	PA-28 VH-RQQ	C-150 VH-TKR	GAAP	Fail see and avoid despite ATC traffic information
20-05-88	Coolangatta Qld	C-172 VH-HIZ	PA-38 VH-MHQ	Pri CTR	ATC Failure to separate and pilot fail see and avoid
07-08-88	30ESE Brisbane Qld	PA-28 VH-DMB	PA-28 VH-WAS	OCTA – GA hold pt	Fail see and avoid
29-05-89	Jandakot WA	C-152 VH-BFT	C-152 VH-TNO	GAAP	Fail comply ATC instruction – ATC and pilot not see and act
25-04-90	Blacksmith Is Qld	PA-31 VH-NDU	C-210 VH-MDU	OCTA	PA-31 pilot deliberately flew close to C-210 – misjudged
02-11-90	Tocumwal NSW	Beech 35 VH-CAG	Glider VH-Gxo	OCTA	CAG fail see/avoid glider, fly conflicting circuit
12-04-91	2NW Mudgee NSW	PA-28 VH-DAF	PA-28 VH-JGG	OCTA	Collide in circuit. Both pilots made required radio calls
15-07-92	Hoxton Pk NSW	Beech 23 VH-AYZ	PA-28 VH-SGF	OCTA	Pilot AYZ taxy onto runway in front of landing SGF
06-06-98	Hoxton Pk NSW	PA-28 VH-UZR	PA-38 VH-FTX	OCTA CTAF	Collision in Circuit
18-09-00	Merredin WA	Grob 115 VH-ZIB	Grob 115 VH-ZIR	OCTA CTAF	Circuit Area fail see and avoid

2nd group of aircraft – Those deliberately flown in same airspace 36 Items

Date:	Location	Aircraft 1	Aircraft 2	Airspace	Details
16-06-75	Laverton Vic	Glider VH-GOM	Glider VH-GPL	OCTA	Fail see and avoid
09-01-77	3 SE Mirrool NSW	Glider VH-GZP	Glider VH-WQM	OCTA	Pilots positioning for photo task collided
10-01-78	24 NW Canberra ACT	PA-28 VH-PIL	PA-28 VH-TVG	OCTA	Formation flight
28-01-79	15SE Eudunda SA	Glider VH-GDQ	Glider VH-KYO	OCTA	Thermalling, failed see and avoid
04-01-80	18SE Cecil Plains Qld	C-188 VH-TKO	C-188 VH-TTG	OCTA	Crop spray training with inadequate co-ordination
04-01-81	Waikerie SA	Glider VH-GDC	Glider VH-GEB	OCTA	Thermalling at championships fail see and avoid
02-07-81	Cranbourne Vic	C-152 VH-UFK	C152 VH-UZE	OCTA	Formation practice

13-09-82	Stanwell Tops NSW	Hang Glider	Hang Glider	OCTA	Both gliding from same site
19-01-83	Leeton NSW	Glider VH-GJG	Glider VH-GZW	OCTA	During competition
04-01-84	5NW Cobram Vic	Glider VH-IID	Glider VH-IZQ	OCTA	Several thermalling together – fail see and avoid
23-01-84	20SW Ararat Vic	Glider VH-GFH	Glider VH-GOP	OCTA	Several thermalling together – fail see and avoid
26-08-84	Cunderdin WA THREE a/c	Glider VH-GQK	Chipmunk VH-RJK	OCTA Glider WUT	GQK collided with WUT under tow by RJK
13-10-84	35NW Dalby Qld	Glider VH-GKN	Glider VH-IZE	OCTA	Both in same thermal – fail see and avoid
27-01-86	50NE Benalla Vic	Glider D-2870	Glider VH-HNZ	OCTA	Thermalling in same thermal – fail see and avoid
10-07-86	Benalla Vic	Glider VH-GVZ	Pawnee VH-PXT	OCTA	Tug collided with glider
12-01-87	3S Benalla Vic	Glider VH-FQS	Glider VH-KYF	OCTA	Competition – same thermal – fail see and avoid
29-01-87	7NE Deniliquin NS	Glider	Glider VH-GSO	OCTA	Same thermal – fail see and avoid
16-01-88	Portsea Vic	Pitts VH-AVM	Pitts VH-WIZ	OCTA	Aerobatic formation – fail see and avoid
06-02-88	14SE Horsham Vic	Glider VH-HDY	Glider VH-KYO	OCTA	
20-01-89	13SSW Yarrawonga	Glider VH-GGV	Glider VH-GXY	OCTA	Same Thermal – fail see and avoid
13-08-89	26S Alice Springs NT	Balloon VH-NMS	Balloon VH-WMS	OCTA	Ascent into basket of balloon above – fail see/communicate
12-11-90	30 E Tocumwal N	Glider VH-GEZ	Glider VH-GGT	OCTA	Both in same thermal – fail avoid
08-02-92	Tocumwal NSW	Glider VH-GQR	Tug - VH-UTK	OCTA	Glider collided with tug
26-08-92	Stanwell Pk NSW	Hang Glider	Hang Glider	OCTA	Two operating from same site fail see and avoid
01-11-92	Jondaryan Qld	Pawnee VH-SCT	Glider VH-WQR	OCTA	Glider collided with tug
26-12-92	8 W Jondaryan Q	Glider VH-GFN	Glider VH-IUR	OCTA	Both left same thermal – fail see and avoid
15-07-93	Mt Emu Vic	Hang Glider	Hang Glider	OCTA	Fail see and avoid
24-11-93	Benalla Vic	Glider VH-GMN	Tug VH-AYB	OCTA	Tug collided with glider in cira – fail see and avoid
15-07-94	13NW Coolangatta Qld	Balloon VH-AJB	Balloon VH-HJA	OCTA	Fail see and avoid
05-01-97	Tocumwal NSW	Glider VH-GVS	Glider VH-GKT	OCTA	Circuit area fail see and avoid
24-01-97	Roseberry Vic	Glider VH-GWX	Glider VH-UKG	OCTA	Competition. Pass on incorrect side – fail see and avoid
25-11-98	7N Narromine N	Glider VH-HDT	Glider D-1003	OCTA	Competition – fail see and avoid
02-03-99	Waikerie SA	Glider VH-GDL	Tug VH-EVZ	OCTA	Glider collided with tug which had just released 2nd glider
13-04-99	Melbourne	Balloon VH-AHU	Balloon VH-BDE	Pri CTR	Balloons 'in formation' touched
24-09-99	Rees Riv Hunter Strm	Heli VH-HHW	Heli ZK-HNE	Unknown	Both engaged in aerial filming when collided

16-01-02	16E Warren NSW	Glider VH-GGF	Glider VH-ZHW	OCTA 'G'	Not yet known

SUMMARY:

By type of airspace:

Of the first group – 22 collisions:

10 occurred in or on the boundary of a GAAP airport control zone
2 occurred in or on the boundary of a (Primary) Class C control zone
10 occurred outside controlled airspace (In class G airspace)

Of the second group – 36 collisions:

All occurred OCTA (In class G airspace) excepting a 'touching' between two hot air balloons flown in formation.

By phase of flight:

Of the first group (22)

19 were in the circuit area of an aerodrome being used by the aircraft
2 were close to nominated reporting points for entry to control zones
1 was in an unknown phase of flight but the proximity was deliberately caused

Of the second group (36)
All were between aircraft operating for an associated purpose
Gliders conducting simultaneous thermalling
Collision between aircraft conducting airwork together etc

By type of aircraft:

Of the first group:

Single engine aircraft to single engine aircraft:	17
Single engine aircraft to glider (not tug)	2
Twin engine aircraft to twin engine aircraft:	1
Twin engine aircraft to helicopter	1
Twin engine aircraft to single engine aircraft	1
(NB – this latter was deliberately close not accidental)	

Of the second group:

Glider to glider	19
Glider to tug aircraft	6
Hang Glider to Hang Glider	3
(Plus another known to CASA not shown by ATSB)	
Formation flight – aircraft	3
Balloon to balloon	3
Agricultural flying – crop spraying aircraft	1

Filming – helicopter to helicopter	1

Conclusion: The purpose has been to provide information useful in the consideration of future airspace design by showing the historical incidence of mid-air collisions, the locations and types involved and thus indicators of risk situations which may or may not be aided by any given new design of airspace.

Any airspace design needs to be tested against these events to consider likely changes to the air safety situation.

Tony Rothwell, GM Airways & SA, CASA, 4th February 2002

Appendix 2 ACCIDENTS INVOLVING GLIDERS – ANALYSIS BY THE GFA

Total 27

3.1 Time Trend

Examination of the time trend shows that the worst period was in the late 80s and early 90s. This prompted a detailed analysis by the GFA Ops panel which culminated in a report in 1992 and a strong push to deal with this problem through the GFA safety systems. The result was a period of nil accidents till the late 90s. A second analysis separately by both Sporting and Ops resulted in further changes and pilot education by both groups and this seems possibly to have arrested the unacceptable trend again – with the exception of one accident in 2002. This accident in 2002 prompted Ops to go to Sports and request a joint investigation which is currently in progress.

3.2 By type

In Terminal Area (within 5 NM) – total 9

Involving Tug A/C	6
Glider to GA	2
Glider to glider	1

En Route – Total 17

Thermalling	13
Streeting	1
Turn point	1
Unknown	2

3.3 Further Analysis

Details of the period leading directly to the actual collision are mostly unknown. Tragically many of these were fatal and in the other cases the trauma of this type of accident makes pilot reports unreliable. In one case only we have data logger evidence and the facts elicited by this hard evidence was at variance with pilot recollection.

Nevertheless the following can be determined:

3.3.1 General

1. In most cases one glider should have had a clear view of the other glider while, often, the other glider was "blind spotted".
2. In almost all collisions at least one glider is turning.
3. Many collisions involved a pull-up by one glider.
4. Tug/glider conflicts were a significant cause.
5. When it comes to experience level it is clear that very experienced pilots are involved. No case of an apparent failure of see-and-avoid involving early solo pilots trained in Australia has been identified.

3.3.2 Terminal Area

The low number of glider to glider collisions in the terminal area is striking

Most accidents in the terminal area occurred at busy aerodromes which now would use CTAF procedures. Despite criticism of radio use by GFA pilots all but one case all CTAF calls were made. In the one case where this was not the case the size of the CTAF was larger than normal and a call at the boundary would not have altered the outcome. No additional radio procedures has every been suggested which might have influenced the outcome. More than one accident resulted in a strong recommendation that where practical, pilots should announce intention to use a runway direction other than the duty runway.

It is a curious fact that our most busy aerodromes have been accident free.

3.3.3 *En Route*

The fact that no aircraft from group 1 (aircraft which did not chose to fly close to each other) has occurred in en route airspace whereas most gliding accidents have occurred in the en route phase – most associated with thermalling turning and pull ups seems very significant.

The categorisation of these accidents simply to ‘while thermalling’ is inadequate and detailed examination of this aspect is required.