

LOOKOUT: HOW THE EYE CAN LIE

PART ONE

"I just didn't see it!" Sound familiar? Paul Sheffield explains why it may not be your fault

MOST of us probably think we carry out a pretty good lookout when flying and we need to, because our vision is not all that it seems. How many times, for example, have you heard people say "I never saw the person, the bike or even the truck"?

In the UK we had TV adverts stating 'Think Once, Think Twice, Think Bike' because drivers were pulling out of junctions into the path of motorbikes. The point wasn't simply about looking, it was about

giving your eyes an opportunity to overcome physical issues with eyesight – the natural blind spot and saccades (quick, simultaneous movement of both eyes between two or more phases of fixation in the same direction).

Just imagine for a moment you're sitting in a car at a 'T' junction as a cyclist rides past on the main road in front. You'll follow their path smoothly and see everything along that path, but try moving your eyes just as smoothly when there's no bike to follow. You can't; it's impossible. Without something to track, your eyes will be moving in sudden jerks, or 'saccades', then pausing for a moment (fixating), before another saccade, and so on.

During this very rapid and short – around 20–200 milliseconds – saccadic eye movement you are effectively blind. This is because the brain suspends vision during the saccade and nothing new is seen for that small duration. If that wasn't the case, the world would whizz past in a very blurred and disconcerting fashion. Our vision is only updated when our eyes have come to rest and had a moment to interpret the image.

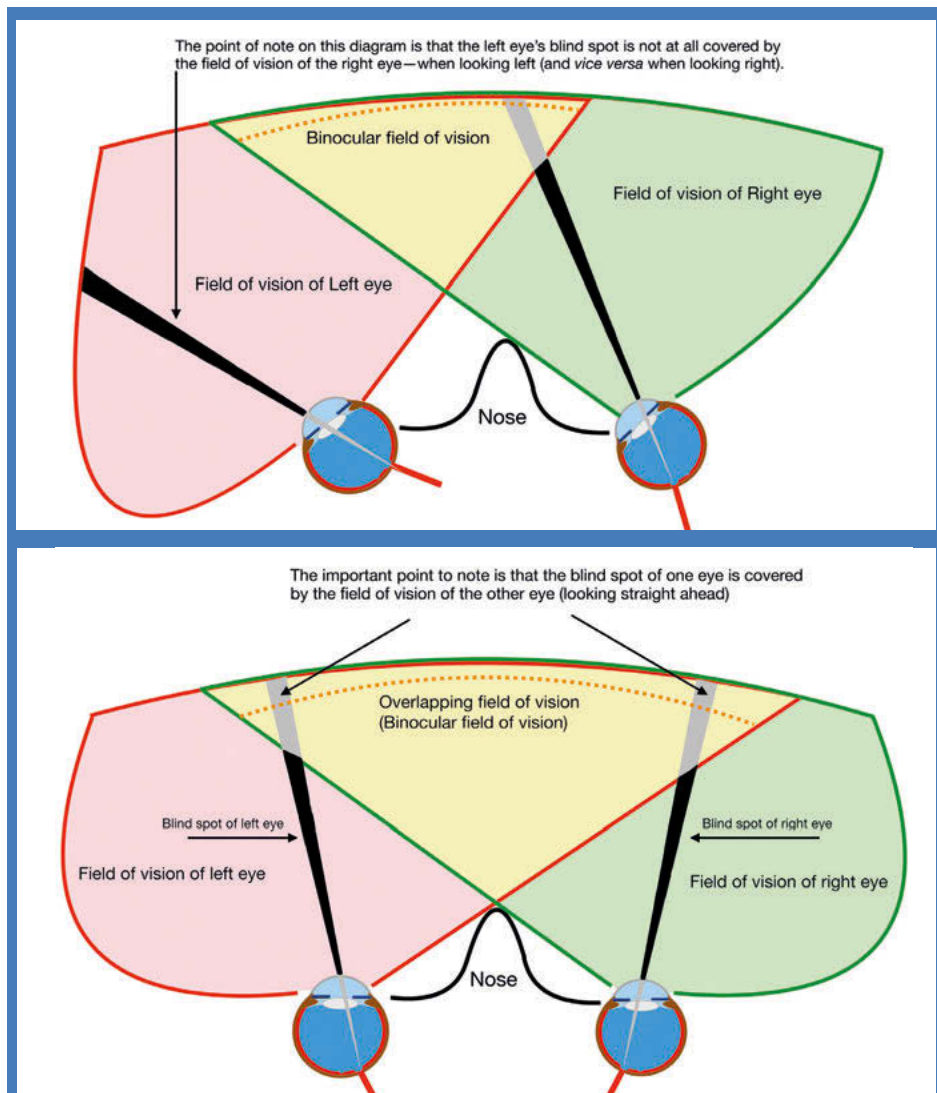
The consequence of this in flying is that with large saccadic eye movements we could easily 'jump-over' any number of aircraft while we are 'blind', and if there are none where our eyes come to rest, or fixate, we will assume there are none anywhere. Even a bright flash of light would not be seen during a saccadic eye movement.

Collision course

If an aircraft is moving relative to us in that jumped-over part of the visual scene, we might see it after the saccade ceases if our peripheral vision detects movement, but if it's on a constant relative bearing (collision course), it's very probable we wouldn't see it until it's alarmingly large in our field of view.

In addition to saccades, we have a natural blind spot, and the eye makes assumptions about what's in that blind spot. These are often the cause of "I just didn't see it...".

Light enters the eye through the cornea, continues through the pupil and adjustable



crystalline lens, and finally falls into focus in the form of an image on the retina. This retinal image is received by more than 100 million light sensitive cells, and additional cells that convert the light (ie the image) to nerve impulses. The result is only superficially analysed in the retina and so is compressed and sent to the brain for further interpretation. Note that this compression of the data means assumptions have to be made by the retina. The main thing it does is to break down the image into edges and contours – a contour map of edges. One of the biggest assumptions is that anything within a given contour is uniform, in other words, nothing else exists within that particular boundary. There are roughly one million nerve fibres leaving the retina (the optic nerve), so clearly there has been at least a 100:1 data compression by the 100 million light sensitive cells.

It's also worth looking at the retina's two types of light sensitive cells in more detail: rods and cones. Cones require a lot more energy (brightness) to work and therefore generally only function in daylight conditions (photopic conditions). Cone cells peak in number in the centre of your retina – the macula (and the macula therefore gives rise to the centre of your field of vision and its peak resolution) – and rapidly decrease in number more peripherally.

Daylight conditions

Rod cells only work in low light (scotopic conditions) and are completely bleached out and functionless in daylight conditions. Rod cells are much less numerous in the very centre of the retina, which is why a faint star appears to fade if directly looked at, and brighter if looking just to one side of it at night-time. Rod cells cannot detect colour, and so the colour of navigation lights is only seen by the cone cells, and they only function when there is sufficient-focused light energy at night to stimulate them. Fortunately, rod cells at night are extremely sensitive and excellent at detecting flashes.

In daylight conditions then, what you might think of as one big clear, detailed picture is far from it; detail is seen very centrally, in an area roughly that of a thumbnail held at arm's length. Not only is this area small, but also an image falling on it has to be stable for a moment for retinal processing, and for the higher brain centres (the pilot's attention) to comprehend. The more peripheral your field of vision, the less resolution. Try reading a car number plate



by moving your eyes (your point of fixation) just one car width to the side.

Meanwhile, the cones in the periphery of the retina are responsible for the peripheral visual field in daytime, and it is now motion detection that comes to dominate. You may have noticed a flickering fluorescent light bulb in your peripheral vision which appears less flickery when looked at directly. Peripheral vision is especially good at detecting motion and flicker. Movement of an object is a very important attention-grabber. This is fine if an object isn't on a constant relative bearing – a collision course.

On top of all this, the nerves from the rods and cones pass through a hole in the retina (the optic disc), which gives rise to a small, circular area called the blindspot about 12.5 degrees from your absolute central vision (your fixation point), about the size of a fingernail at a hand-span's distance, where there is no vision whatsoever.

Visual field

This area of blindness is to the right in the right eye, and to the left in the left eye on the horizontal plane. Each eye simply fills in the blind area with whatever it sees around the edge of the blindspot, so in a blue sky it will be filled in with blue – the retinal data compression assumption. Thankfully, one eye tends to cover for the other blindspot with its visual field when looking ahead. It is possible when just moving your eyes to the left that the right eye doesn't cover the blindspot in the left eye, and vice versa when looking to the right, so it's crucial to turn one's head when looking around to maintain a full field of vision.

Then there is empty field myopia. It is easy, in a younger eye (roughly less

■ Cover your left eye and look at the red cross (above) with your right eye only, from a distance of approx 40cm. The aircraft will disappear, if it doesn't, move your head slightly closer, or further away from the page until it does.

The aircraft is now in the blind spot of your right eye.

Now open your left eye (whilst still looking at the red cross). The aircraft will re-appear, but not that obviously. The left eye's field of vision is now making up for the blind spot in the right.

Now, keep looking at the red cross with both eyes open and slowly turn your head to the left (which is in effect the same as glancing to your right without a head movement), the aircraft will disappear again as your nose cuts off the overlapping field of vision from your left eye. This could be quite a small movement if your nose is larger, or your head held slightly chin high.

This latter demonstration shows that when looking to your right, without moving your head, it is possible that an aircraft further to the right is lost in your blind spot even though your field of vision extends well beyond that point. Turning your head, ideally roughly pointing your nose in the direction you wish to scan, will allow the fellow eye to cover the other's blind spot. The same is true for the other eye if looking the other way – close your right eye and look at the aircraft with your left and the red cross will disappear.



Paul Sheffield went solo at 16, then gave it up, apart from the odd week's gliding holiday around the country. He took it up again and got Silver C 20 years later. Family/work commitments meant that Paul gave up gliding again until in recent years. He now flies from the Gliding Centre and is hoping to try cross-country flying. Paul has been an optometrist for 35 years.

↳ than 50 years of age), in a featureless sky, or poor visibility, with no visual cues to stimulate the eye's focus, to stop actively adjusting the crystalline lens. Focus comes to a rest at a point in space one to two metres away – this is called empty field myopia (effectively a temporary short-sightedness). The result is you won't necessarily see anything that does gradually appear in your field of vision, as it will be out of focus. To counter this, we need to look at an object at a distance, preferably some feature on the ground, the sharp edge of a distant cloud, or even the wingtip.

The focusing crystalline lens of the eye also suffers a significant age-related loss of adjustment after 50 years (presbyopia – this being the reason that that age-group end up with reading spectacles or multifocals), with virtually no focusing adjustment by the age of 55. Beyond this age, the eye's focus will set at a distance dependent on whether you had previously perfect eyesight (rare), myopia – in which case your spectacles should give you good distance vision regardless of your age, or are long-sighted (hyperopia). In the latter case this is not as good as it sounds because when younger the crystalline lens can

compensate for hyperopia (an eyeball that is a fraction short) and your vision can be returned to proper focus. With a hardening crystalline lens due to age your distance vision will become gradually blurred as no compensation can take place.

So, what can we take from all this? I don't own my own glider, so I have to wait for a club single-seater to land. On an excellent day, when the thermals are so strong that even dustbin lids are going up and not coming down, I search the bit of sky 'my' glider was last seen in to see where it's got to, and whether it's coming back! I make lots of small eye movements in the area it's most likely to be, pause, look intently and examine that small bit of sky before moving a little further to the adjacent piece of sky. If on a non-flying day someone had asked me to look for an aircraft in the sky, I would probably make large saccadic eye movements, pausing for as short a time as possible so as to cover as much of the sky as I can.

Attitude of mind

In reality, both these methods have their uses, but in the latter case if I'm looking for a distant aircraft, I'd almost certainly not see one that was there. Here lies the clue on how to look out for other aircraft. The first step is attitude of mind. If I think it's unlikely there's an aircraft there, the temptation is not to look properly. So when looking out, absolutely assume there's something out there. Next, look in the area of sky the threat is most likely to be. Where these are, and how we move our eyes and head depends on the mode of flight we're in, and what we're flying. Gliding and light aircraft typically have very different flight paths. These will be looked at in the second part of this article in the next issue.

Quite apart from the physiological limitations, the eyes are vulnerable to other visual distractions; lighting, illness, fatigue, emotion, the after-effects of alcohol, certain medications, dehydration and age all play their part. There are also additional challenges, such as atmospheric conditions, glare, deterioration of transparencies, aircraft design and cockpit temperature, which all take their toll on your eyes and what you can see.

You'll probably be familiar with the problem of 'constant relative bearing', or 'stationary in the field of view', mentioned earlier where colliding aircraft have a relative bearing constant to each other until impact. The subjective effect of this is that the collision threat remains in the same place



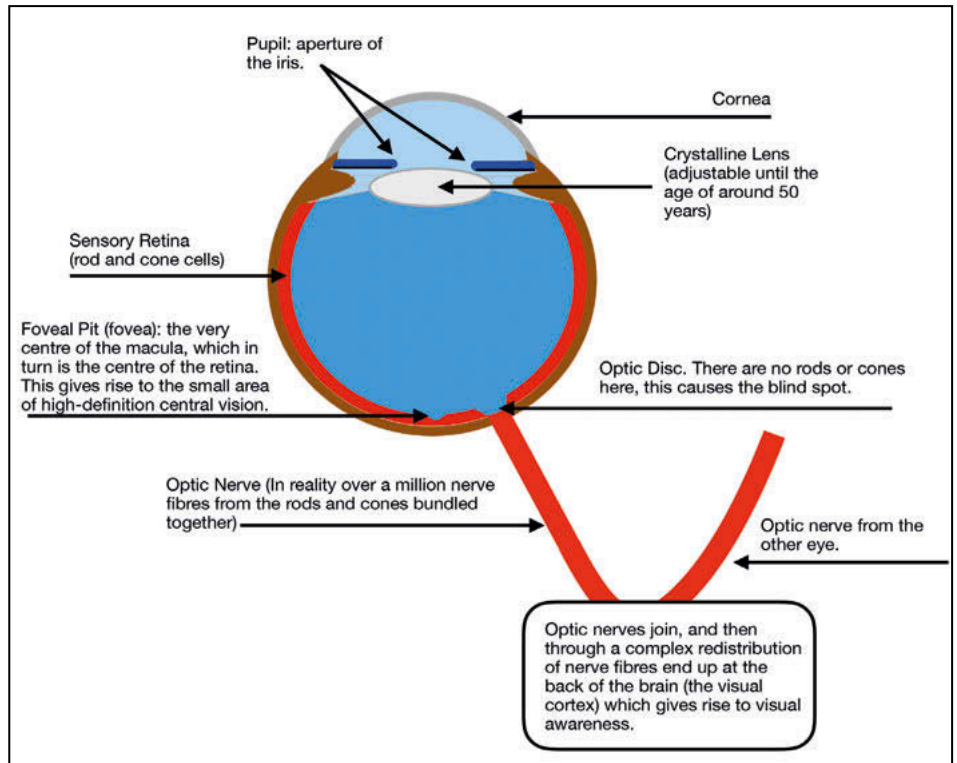
(stationary) on the canopy – so looking intently is key. An unfortunate consequence of ‘constant relative bearing’ is that pilots are most likely to see aircraft that are moving in the field of view and therefore not on a collision course. Frustratingly, it’s the very ones on a collision course that are so hard to see because they don’t move in your field of view.

Collision threat

A quick bit more science shows that as a collision threat approaches, its angular size roughly doubles with each halving of the separation distance, so colliding aircraft stay relatively small until shortly before impact when it all happens rather quickly. This presents a bit of a challenge even if you do perform a good lookout, but it underlines the importance of apportioning the correct amount of time for a systematic and repetitious scan pattern to spot aircraft early.

It’s a curious thing about flying that many pilots believe they keep a good lookout when, in reality, it’s less than effective. Glancing out and scanning with non-stop eye or head movements is unproductive because for the pilot to perceive another aircraft, time is needed for a stable image of it to fall on the retina, up to one second in fact.

Lookout should be performed using a series of eye and head movements with intervening fixations, the latter being the only time when



the outside world is really being interrogated. Carrying out regulated scans may sound a bit formulaic and, let’s be honest, boring, but they do work. That said, there is no one technique that suits all situations or all pilots, so it is important to develop your own comfortable and workable scan.

IN SHORT

- Ensure your eyesight is properly focused in the first place with clean spectacles and canopies, and your eyes focused in the distance.
- Only a small, central area of your vision is high definition.
- The peripheral retina is good at detecting movement, but an aircraft on a collision course, a constant relative bearing, has virtually no movement until the last few seconds.
- You must turn your head as well as your eyes to mitigate the effects of the natural blindspot. Additionally, moving your head relative to the canopy or windscreen helps reduce obscured areas from canopy furniture, pillars, high/low wings etc.

A salutary tale...

IN 2009 two Grob Tutors (a single-engined, two-seat trainer) collided at 2,500ft. The visibility was good with light scattered cloud.

It took on average just 20 seconds for them to impact the ground.

Minimum operating height of the pilots’ parachutes was 500ft and, due to the aircraft flight trajectory, after collision they had 10 seconds to minimum abandon height.

The pilots and students would have been shocked and disorientated, the aircraft rolling and yawing about a new, unfamiliar C of G with increased G loads.

There were no survivors.

Recommendations/Observations by the MoD:

- Get to be thoroughly familiar with the

abandon drill of your aircraft, and know exactly where to find your parachute handle... seconds really do count.

- Conspicuity of aircraft (they were white with blue flashes on the fuselage) was poor against a bright sky, especially against clouds.
- Obscuration of field of view by canopy arch required significant head movements to mitigate.
- Glare from the sun.
- Windscreen zoning — the tendency to look out through the easy, central parts of a canopy, and not to the edges.
- Lookout, although never perfect, must be developed and practised to search in the higher risk areas.

In general, the probability of a pilot seeing a threat until a short time before impact is low.

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PART
TWO

Paul Sheffield continues his article on lookout with advice on where we should be looking

PART one of this article in the last issue dealt with the limitations of our vision, and how to overcome them. Part two tries to take the seemingly random space we fly in and make some sort of sense of where the risks are more likely to be – where we should be looking out as glider pilots.

In a perfect world we would pay equal attention to all areas, and that would be ideal if the threat were truly random. In reality some areas hold more risk: cloud

streets, circuits, ridge flying, nearby ATZs, entering and being established in thermals, etc. So scan patterns have to be adaptable, and thinking ahead is crucial depending on where we are.

How we look out depends on the mode of flight we're in. Clearly, when in a cruise compared with thermalling the threats are quite different.

During cruise, one could imagine lookout is somewhat akin to driving. We look where we're going and our peripheral vision becomes attuned to anything that moves. This isn't good enough however for flying, because it's the objects that don't appear to move (on a constant relative bearing) that are the real threats, whether they be on, or more peripheral to, our track. To spot these aircraft at a distance, we require our acute, central vision, which means looking around the likely threat areas. It's probably true that the faster we fly in cruise the more time should be spent looking where we're going in some band of space around our track, but the word is more, not solely – we still need to look around. The reasoning is as follows.

Threats

Imagine you could cruise on track at Mach 1 in airspace containing gliders flying around at normal speeds, all on their individual tracks. You'd probably leave nearly all the threats behind you; it'd be a narrow band of space around your track that would matter. Now consider you're in a helicopter, hovering in the same airspace. The threat is now equal from all points of the compass. Looking 'ahead' is no more relevant than anywhere else in this instance. Should we now move off in our helicopter at 10 knots, the threat would only slightly increase ahead, and slightly reduce towards the space behind (we're only talking about cruise flight here without turns). Furthermore, if everyone else were hovering, we couldn't hit anything from behind our wing. If we're flying at the same speed as everyone else, this is still

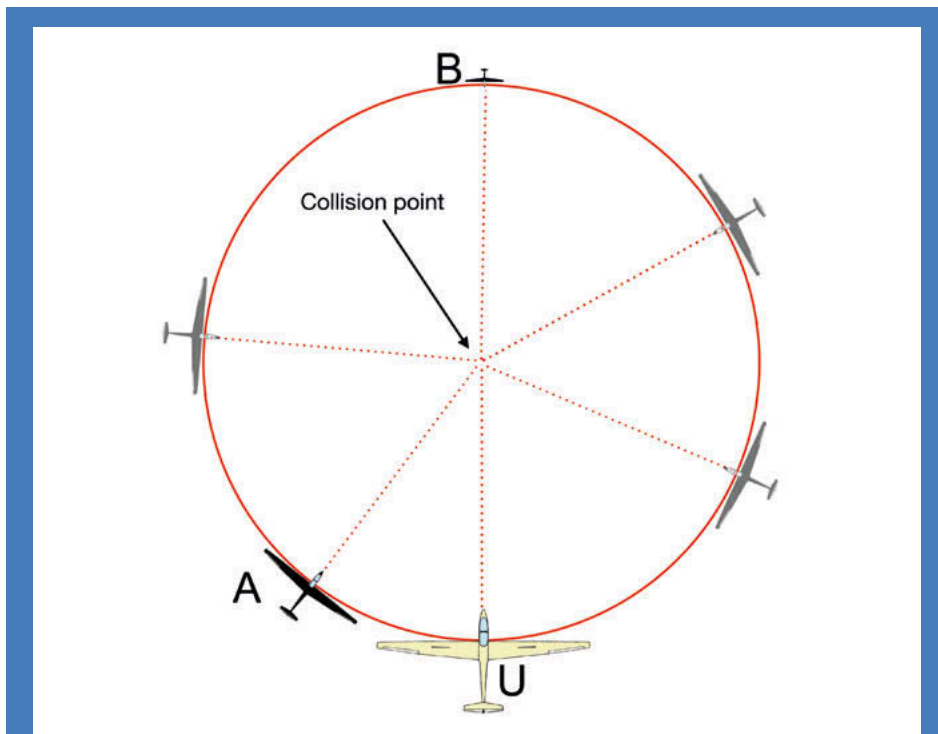


Figure 1: Other aircraft travelling at the same speed as you will cover the same distance as you in any given time. Therefore, those aircraft that happen to be on a constant relative bearing (CRB) will be at the same distance as you from the collision point. They are all on the circumference of a circle of which you (U) are a part. That CRB circle is ahead of you, so all gliders will be in front of your wing. Aircraft on a CRB travelling faster, are on a larger circle, and part of that circle, is behind you. Note that time to impact for glider A and B are the same, but the angular size of B is much smaller as it's further away (only gliders A and B are in relative scale to each other here).

essentially true.

If we all flew at precisely the same speed, the collision threat would be in the forward 180°, even if the converging track angle between the two aircraft was small, even much less than 90° [Fig. 1, glider A]. This is because the converging glider that's going to collide can't be behind you at any time (if it were, and travelling at the same speed, it couldn't catch you up). The other aircraft would still be in front of your wing by some small amount. How far in front of the wing is dependent on how small the converging angle is. The shallower, or more parallel the converging angle of a colliding threat, the closer it would be to the wingtip position.

Think of it as the other glider on a straight course and you converging on it, even by some small amount, your wing must be angled such that the other glider is in front of it. Theoretically, you could ultimately be hit behind your wing, but the point is they would have been visible in front of your wingtip until impact. The CAA consider that the majority of collisions would come from the 120° arc ahead of track in cruise flight.

Time to spot

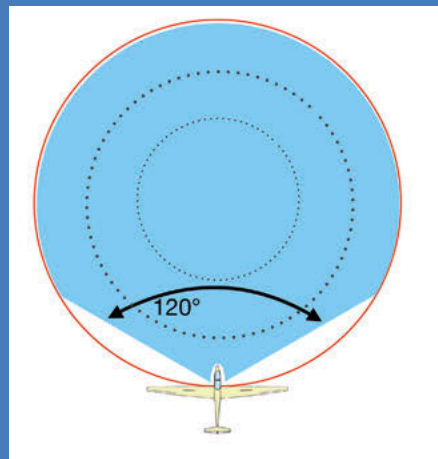
If we were all to fly at the same speed, whether that be 10 knots or Mach 1, the threat would come from the same potential places, just that we'd have more time to spot them at 10 knots!

The faster we fly on cruise relative to everyone else, the more ahead the threat becomes (and with gliders generally the more we descend too). So the threat, hidden from us behind, will be flying faster than us, and the other pilot needs to be looking in their forward sector as just mentioned.

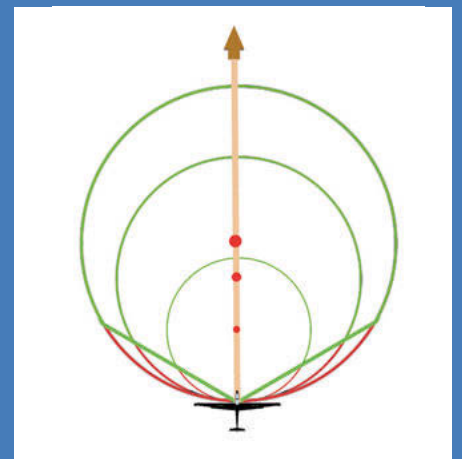
Perhaps all this can be simplified too: the faster you fly relative to everyone else, the closer you begin to look to your track, apportion slightly more time there, and the smaller the eye movements. It's not just the time to the threat as the angular size of the threat [Fig. 1, glider B], but not to the exclusion of everywhere else. When we look off-track, turning our head, we'll probably be using relatively larger saccadic eye movements – pausing for a moment between them to assimilate what we're looking at – to check larger areas of nearby, and therefore slightly more easily seen threats. We also need to constantly update what else is in the sky in general.

Once we start turning, all this threat analysis goes out the window!

In general sport aviation our speeds ↗

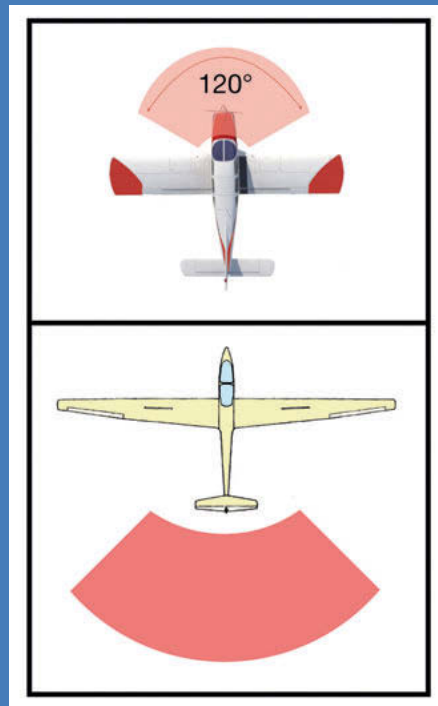


Above: A 120° sector from your viewpoint happens to cover exactly 2/3 of a same-speed-as-you CRB circle, and a larger proportion, up to 100%, of slower moving aircraft on a CRB (dotted smaller circles centred on some notional collision point). Colliding aircraft of slower, but differing speeds, will in effect fill the area of this same speed CRB circle. This all assumes aircraft are maintaining a constant course and speed. In reality, course and speed changes by other aircraft, or you, will either take them off part of a CRB circle, or put them on one.



Above: These CRB circles don't have a specific size (threat distance from you), they are an amalgamation of angles and distance to some collision point, such that a CRB arises from aircraft on a constant course and speed. You are on the circumference of whatever size circle you may consider. The collision point moves further ahead for aircraft further away (red dots at the centre of the circles). The ratio of the field of view not looked at, in red, remains the same to that checked, in green. Looking from wingtip to wingtip will cover 100% of same-speed and slower aircraft on a CRB, and likely the majority of faster aircraft on a CRB.

Aircraft flying faster than you are the only ones that could potentially hit you without you having any chance of seeing them, as they could hit you from behind, just as you could hit someone slower than you from behind, but we would (should... hopefully!) see them in front of us.



Left: The CAA suggests the greatest threat probably comes from 60° either side of track during cruise, with reduced threat beyond 90° either side. Independently, the BGA find that the greatest risk of collision in gliders comes from the rear quarter, and overwhelmingly with other gliders in thermals, ridges or airfield patterns (there is no particular implication that powered aircraft fly into the back of gliders). Airspace4All Ltd found after analysing 43 years of civil aircraft collisions that 13% of glider collisions were with powered aircraft (half of those with tugs), and 87% with other gliders – 17% of that risk occurring in the cruise and 83% over or close to the launch site.

DURING THERMALLING THE THREATS ARE QUITE DIFFERENT TO CRUISE AND COULD BE CONSIDERED TO BE ALMOST THE OPPOSITE

IN SUMMARY:

■ Ensure your eyesight is properly focused in the first place with clean spectacles and canopies.

■ You must turn your head as well as your eyes for an effective lookout to reduce the chance of missing something in one of your natural blindspots, and overcome obscurations from canopy arches and furniture, etc.

■ Develop a methodical scan routine, for example, by searching a broad band centred on the horizon. Perhaps consider that space overlaid with a grid or clock positions to avoid missing large areas. Start by looking in one direction and at each position look above and below the horizon and work your way around (and at the 3 or 9 o'clock position you could check if the wings are still level). Come back and check attitude (which is looking ahead too, so you can search here again) and instruments, and then repeat in the other direction.

■ In cruise mode of flight, in general, the faster you fly compared to other aircraft in your area, the slightly more time should be spent looking ahead, and the closer to track you look use smaller saccadic eye movements as those threats are likely to subtend smaller angles.

■ The vast majority of the threats will be in your field of view in front of the wings.

■ Highest risks of collision appear to be during thermalling, ridge flying and circuits.

Finally, don't forget to enjoy the view!

↻ are largely similar, so the highest risks are probably, but not solely, in that forward 120° centred in a band around 10° to 15° from the horizon above and below. We must also consider that the sum of all the threats from everywhere away from some notional band of space around track will probably be much higher than the risk from that band of space around track alone – the area of space ahead is small compared to everywhere else. Of course, the faster-moving aircraft striking another can come from any direction.

During thermalling the threats are quite different to cruise and could be considered to be almost the opposite, that is, from the rear quarter, and from above and below. Likewise, we shouldn't knowingly put ourselves in the obscured regions of another glider whenever possible. Perhaps then as we thermal and another glider begins to disappear behind us (which requires more head turning than comfortable), we should leave the thermal. There is always that risk/benefit balance, but when you know there's an unseen glider behind you, you are accepting that your life is in their hands. Thermalling then requires virtually continuous lookout in so many areas whilst maintaining correct attitude and bank.

As yet no one really knows the ideal way to apportion the time, or precisely where you should be looking during particular modes of flight, although we should have a good intuitive idea. You can be sure in the meantime that the more time looking out in a regular and routine way, the better.

In the following part of this article are a series of photographs of a winch launch and flight. These are not comprehensive by any means, nor are they the only places we should be looking. These should be considered as starting points.

As fundamental as it is, looking out is only half the story; we have to act on what we see, even if that's only thinking about options. It's all too easy to feel it is OK because we've seen another aircraft, and think maybe it's fine to fly closer. We don't perceive the threat really increasing that much as we get closer, yet in reality it is. The presented area of the other aircraft goes up fourfold with halving

distance (since the dimensions each way double), so something small only really starts to balloon in size when we are much too close. Perhaps we should view the threat of collision going up fourfold as the distance halves on the basis that at any given time in a flight, the potential places you are able to fly to, but mustn't, increases fourfold. One for the mathematicians amongst you to cogitate on, please!

The first of these articles started with a driving soundbite, *Think Once, Think Twice, Think Bike*, and I shall it end with one too: *Keep Your Distance*. Safe flying.



■ **Before launch** – As we wait for the person who's put the cable on to say "All clear above and behind," the implication is that we have checked everywhere. There are four issues in this image: the first is that we wouldn't launch from a position so close to the other cables. Having started from a position more to the left, not only the rope section, but also the chute and as much of the cable as possible should be pulled over in-line with the glider. This reduces the risk of suddenly inducing yaw during the initial acceleration of launch. The second is the vehicle on the field, the third the glider at the top of the launch area, and finally, the area of picture shown isn't wide enough to check if our airspace will remain clear of approaching aircraft – we should check everywhere in this image and further left and right for approaching conflicts.



■ **Above: Winch** - Once in the full climb on a winch launch briefly look along either wing to check you're at a suitable angle of climb, the amount of 'lay-off' to compensate for a cross-wind element if appropriate, and for any other issues!

After launch, threats can come from anywhere so lookout should begin with a broad band centred on the horizon, above and below, and as far back as possible. Gliders too are almost always changing their altitude, course and speed, so a glider that appeared 'safe' some seconds ago may soon become a real and serious threat. Don't forget to look overhead, especially so when entering a thermal. When descending rapidly with airbrakes it's usually safer to do a series of 'S' turns or circling rather than letting down in a straight line and being unable to see what's below.

PERHAPS THEN AS WE THERMAL AND ANOTHER GLIDER BEGINS TO DISAPPEAR BEHIND US, WE SHOULD LEAVE THE THERMAL

■ **Right: Thermal** - It's obviously crucial to monitor the other gliders at a similar altitude in the thermal so as to slot oneself in with the least fuss. Look up too before joining to see who's there. Those gliders may leave the thermal before you, others may join, and you may have missed someone higher up with whom you may catch up.



■ **Above: Before turn/during turn/coming out of turn** - Before initiating a turn look as far round as possible in the opposite direction to the intended turn to look for an approaching aircraft as you may not see it again until turned through nearly 180°, check attitude, then look as far round as you can in the direction of the intended turn.

When rolling into the turn look over the nose to check attitude and coordination. Once in the turn, the scan's datum point should be along the horizon in the direction of travel, NOT down the wing during the turn.

Before initiating roll-out, ideally check ahead as you sweep about 90° of airspace during the turn, and then look under the down-going wing.

CONTINUED ON THE NEXT PAGE

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■ **High key** – Our anticipated circuit in red. We're less likely to collide with anyone ahead of us on a similar circuit, but obviously we need to know whether anyone is there and where they're going – we don't want to catch them up. The higher risk of mid-air collision will come from someone converging on a 'non-standard' approach from outside of our intended path. We have to keep cycling our attention to all the risky areas. Don't forget to check below too as far as you are able. The radio is a valuable tool, assuming it's working!



■ **Base leg** – Look ahead for someone on an opposite base leg, and scan an area in the opposite direction to the final turn for someone coming straight in. Naturally the pilot is constantly judging their position to the landing area and checking for conflicts there – if gliding were easy, we wouldn't do it!

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