LIMITATIONS OF THE SEE & AVOID PRINCIPLE

Original idea from BASI

In 1991, BASI (The Bureau of Air Safety Investigation) published a research report titled, *Limitations of the See-and-Avoid Principle.* This report concluded that *"the see-and-avoid principle, In the absence of traffic alerts, is subject to serious limitations"*. Unalerted see-and-avoid has a *"limited place as a last resort means of traffic separation at low closing speeds, and is completely unsuitable as primary traffic separation for scheduled services".* This report highlighted the fact that *"many of the limitations of see-and avoid are associated with physical limits and human perception"*, and encouraged pilots to be, *"made aware of the limitations of the see-and-avoid procedure, particularly the factors which can reduce a pilot's effective visual field"*.

HISTORY

If two aircraft are on a collision course and these aircraft are flying on constant headings at constant horizontal and vertical speeds, then each aircraft has a constant relative bearing to the other right up unti 'I the moment of impact. Even though one aircraft may be going twice as fast as the other, if their relative bearings are constant, the aircraft will collide (see figure *1). From the pilot's point of view, if the approaching aircraft has no apparent motion with respect to his or her aircraft and stays at exactly the same point on the windscreen, a collision is inevitable.* This absence of any relative motion is important from the point of view of detecting the other aircraft because the retina is especially sensitive to the detection of small movements. Also, most of us would use motion of another aircraft as a good cue to detection.

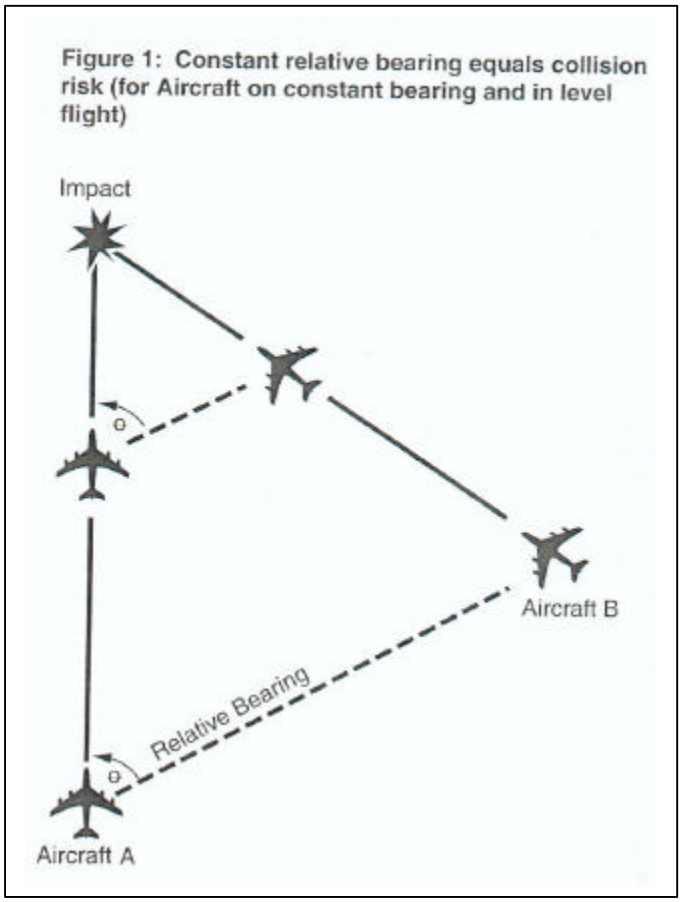

Figure 1: Constant relative bearing equals collision risk (for Aircraft on constant bearing and in level flight)

While aircraft on converging tracks will, of course, appear larger as they get closer, it is roughly true to say that the apparent size of an on-coming aircraft doubles with each halving of that aircraft's range. Imagine the case in which a general aviation aircraft and a military jet are approaching each other head-on at speeds of 150 knots and 450 knots respectively, a closing speed of 600 knots. At about 20 seconds before impact, the two aircraft might be about 6,000 metres apart and reach will present a target to the other of only around one-sixteenth of a degree. Ten seconds from impact, the distance will have halved and the target size will have increased to all of one-eighth of a degree; at 5 seconds, the size will have again

doubled, but will still be only about one-quarter of a degree. In other words, ,the oncoming aircraft remains extremely small until very, very late, and then it suddenly expands into something that fills the windscreen. Figure 2 illustrates this concept.

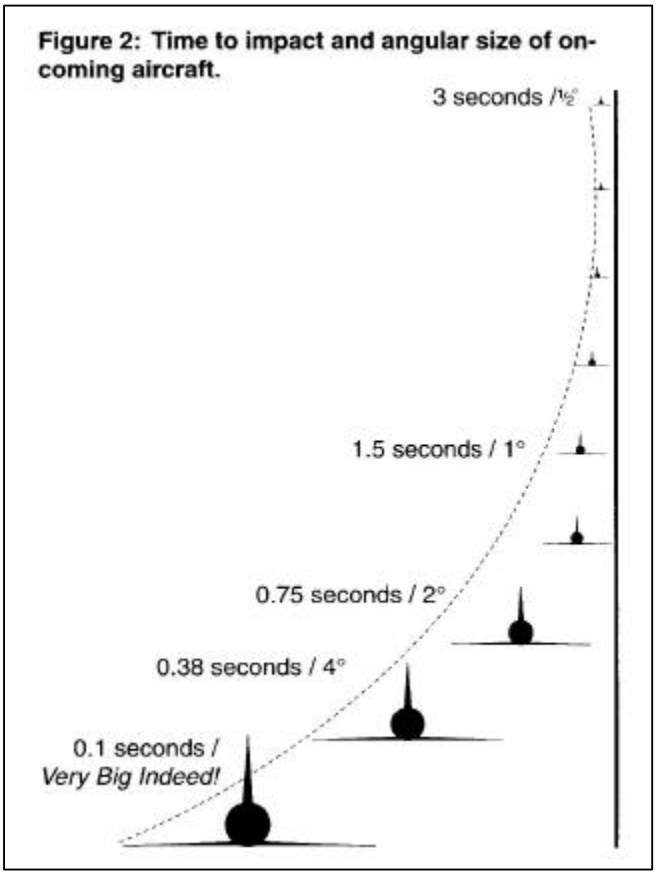

Figure 2: Time to impact and angular size of on-coming aircraft.

The calculations in the previous paragraph match up ,with the accounts of many pilots who have had midairs or near-collisions. Typically they maintained a good lookout and then diverted their attention inside the cockpit for 2 or 3 seconds to complete some checks, only to look up in horror to find the windscreen full of aircraft. An added complication is that reaction time is usually 2 seconds or more.

The retina of the eye is not equally sensitive over its ,whole surface. In fact, it is only in a small, central area of the retina (the fovea) that visual acuity is good. Even at very small angular departures from this central area, acuity drops off alarmingly to a small fraction of the central acuity (see figure 3). This does not cause any problems in everyday life because we can always use the central part of the retina to investigate anything that we are interested in and use the rest of the retina to fill in the rest of the world. But it does mean that if we are conducting a visual search for a small target and the object of our search does not happen ever to fall on the foveal area, then we are extremely unlikely to see it. This is particularly true if the target has no relative movement. Many pilots will have spotted another aircraft, looked away for a Few moments, and then been unable to see it again because this time the aircraft's image bust does not happen to land on the right bit of the retina.

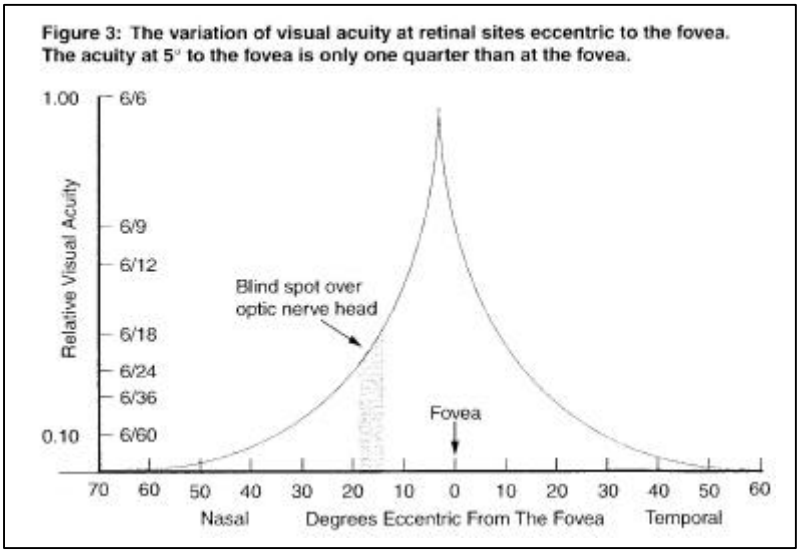

Figure 3: The variation of visual acuity at retinal sites eccentric to the fovea. The acuity at 5° to the fovea is only one quarter than at the fovea.

What is the best way to scan an empty sky in order to maximize the chances of detecting an aircraft? Some pilots believe they should move the eyes in a smooth, continuous action. But unless there is something out in the world also moving smoothly which the eye can track, the eye will move only in fast jerks ("saccades") with interposed rests. There is some good evidence to suggest that if you are conducting a search, it wastes time to prolong the rests because, if the aircraft is going to be spotted, it will become visible immediately.

Another point to make about visual searches regards the problem of where to look. It is possible that you could collide with an aircraft that was descending (in which case you should have seen it silhouetted against the sky) or climbing (in which case it should have been seen against the ground).

In the first case it probably would not matter much what color the aircraft was painted, but in the latter case it might be an important issue. The most likely threat, however, is another aircraft that is at the same level. In this case, the other aircraft will (at low to moderate altitudes) be between yourself and the horizon and will present its least conspicuous aspect.

Pilots should understand what they are actually doing when they search the sky. Here are some tips that may be worth remembering:

- Remember that the aircraft you are going to collide with is the one that appears to be stuck in the same pace on the windscreen. If you are both in cruise and it moves, you will miss it, but take positive avoidance action to miss it by a safe distance.

- Remember that you are looking for a small target that gets bigger only when it is too late to be avoided. It can easily take 2 seconds or more to appreciate the situation, make a response and get your aircraft to change course, so minimize the time with your head in the cockpit.

- Concentrate your search in the area of most likely conflict, which in many situations will mean along the horizon, looking for those aircraft at the same levels.

- Do not imagine that you can make a smooth, continuous search. Keep your eyes scanning the world 'in quick movements.