SOARING Rx

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Seeing, yet Blind

Pete was enjoying a lovely day at the gliderport, happy in the back seat behind a good student, basking in the simple pleasures of good camaraderie, good-enough weather, and the joy of teaching. Their excitement became his own.

"I want to see you handle getting out of position in the pattern," he said. "There's lots of reasons you might not be able fly a standard pattern. Make a little wider entry here, and fly a little away from the field on downwind. Then let's see how you adjust for the difference in position and altitude."

There was a muffled "OK" from the front seat. Jerry, a high-school senior who seemed to have the knack, flew diagonally away from the downwind line until Pete felt they were comfortably a little low. Then he said, "Now adjust your pattern and land."

Jerry did fine. Pete was pleased with his ability to adjust appropriately. They landed smoothly on the grass. Jerry's grandfather Al, whose gift was funding the lessons, trotted over. All was well in the world. A Cessna landed on the other half of the broad runway and taxiied to the office area.

Pete lifted the canopy, grinning ear to ear. "That was good, Jerry! I think you'll be ready to solo pretty soon!"

Al arrived, puffing. He exploded, "You idiot! You nearly hit that Cessna! You could have killed my grandson! We're going to have a talk with the safety officer! What kind of a strange pattern was that? Why didn't you call it?"

Pete said, "I'm sorry! I have to confess that I didn't see the Cessna at all. And I didn't hear him call downwind, if he did. Jerry, did you see him?"

Jerry, crestfallen, muttered, "No."

They walked over to the flight office. The Cessna driver hadn't seen the glider, was surprised and chagrined to hear about his own near-death experience.

See and avoid.

We think it's a rule of life in aviation except within clouds, but it's actually a *non sequitur*. (Footnote: *Non sequitur*, Latin, "does not follow.")

You disagree? Let me ask, How do we manage to *see* and then accomplish *avoid*? Analyze your thinking for a moment: Why does there seem to be an actual connection between the goal of avoiding, and the facts that we have vision, that we do see things, and that the visibility is good?

I'm here to argue that the goal is much more elusive than we realize; that our perceptual systems are geared toward *not seeing*. I contend that what actually saves us is the big sky, not our keen vision and fast reflexes.

Consider some facts about collisions: FAA research on mid-airs (Footnote: http://hf.tc.faa.gov/technotes/dot_faa_ct_05_14.pdf) has revealed some key points for us recreational pilots:

• Nearly all accidents occur at or near uncontrolled airports and at altitudes below 1000 ft.

• Most mid-air collisions occur under conditions of good visibility.

• Mid-air collisions generally occur during weekend daylight hours, 56% in the afternoon, and 32% in the morning.

Hello? Anybody here operate out of an uncontrolled field, on weekends, during the daytime? With other pilots flying around?

On the topic of "traffic area," let's ask, "Why do we fly a pattern, anyway?" Is it so that we can coax a reluctant aircraft, that wants to keep flying, onto a runway with precision? Has the traffic pattern been designed because a rectangular pattern is the best way to judge angles and distance?

No! There are many ways to safely judge landing angles, distance, and speed while approaching the ground. The traffic pattern exists to reduce collision risk:

• The pattern causes us to fly alongside the runway we're going to land on, so we can look for detritus like large wildlife, cars and trucks, airplanes or gliders, that might crumple us and our ship if we fail to discover them.

• The pattern is a *routine* that puts our aircraft in an *expected* position, so that others know roughly where to look for it.

• This means that when we announce position, we really should be where others expect to look! Or if we're out of position we should explain it succinctly, using referents others will understand.

• This means also that if there's activity at an airport, it makes a lot of safety sense to fly and announce upwind and crosswind legs in order to give everyone a chance to see and avoid.

Example: We were enjoying an afternoon of autotow ground launching, occasionally pausing for VFR traffic. We were ready for launch – tow rope laid out, tow truck ready for the launch signal, pilot and passenger done with the prelaunch checklist, pattern clear. The safety officer raised his hand to signal 'ready'. Abruptly everyone's handheld crackled: "Podunk traffic, Baron 777 whiskey 10-mile final runway 27." We stood down for ten minutes while the FBO owner flew and cleared the area.

What is wrong with this picture? Well, one is the simple rudeness of declaring "final" seven minutes out, thus claiming right-of-way over everyone in the pattern and on the ground. However, more important is that it's unsafe to fly a straight-in approach to an uncontrolled field on a VFR weekend afternoon (56% of mid-airs are in the traffic area on weekend days, if I may repeat myself). Final-glide worm burners, sit up and pay attention here.

Physiological limitations to see and avoid.

We think we see well because the fovea (Footnote: The *fovea* is the tiny spot on the retina that gives us vision for tiny details.) resolves very tiny spots, and the brain does an amazing job of integrating this and our scan into the image provided by peripheral vision. But, there are some terrific limitations to acute vision:

• The fovea is only about 5% of the retinal surface! Think about this for ten seconds: we are surrounded by a sphere.

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In the best circumstances our peripheral vision includes less than half this sphere (more to the sides than above and below, especially if we have bushy eyebrows). The fovea must be rapidly maneuvered around the area of this sphere in order to build an accurate picture of the details. (The eye normally does this automatically with tiny movements called *saccades* and we supplement this with a systematic *scan*.

• Visual acuity decreases rapidly away from the fovea, and is really pretty vague at the edges of vision. Remember, there are pretty considerable differences in visual acuity among individuals. What do these differences mean for see-and-avoid? (See the sidebar, "Sharpness of Vision versus Distance from Visual Center", page 19)

• What do we really see? The retina and visual perception are designed to detect *change*, not status. Peripheral visual perception is good at detecting *movement*, and tends to *blank out* still images. Yes, our retina and our brain both "extinguish" images that don't move. (This is why our eyes continually jitter in our heads – "saccadic" movement – to maintain a textured image.)

• The image of the airplane that will collide with you is *not moving* across the canopy.

• If it *is* moving, you're not going to collide!

OK, so, in this scenario, what's the difference between a mosquito carcass stuck to the plexiglass and a collision-course C152 10 seconds (1 mile) away? None! Except that the C152-speck will *grow*. Guys and girls, I hate to disappoint your confidence in your sharp vision, but you are simply not designed to notice a growing speck off to the side.

The only way you and I are going to notice a growing speck on the canopy is if we look straight at it (foveal vision). And the only way we are going to see that speck is if we know it is probably there, and if the color and background texture permit it to stand out.

There is some help here, for the cognizant: the airplane we're about to collide with will be on or near the horizon (if it's climbing, slightly below, if it's descending, slightly above). Therefore, we don't have to waste our time scanning anywhere but near the horizon, with special attention to just below, because it's a lot harder to see specks against ground clutter.

Yet, wait a minute! How much of that horizon can you see? *Nothing* behind you; *nothing* below you; hardly anything off to the side or above.

Think about the obstructions to your vision in the cockpit.

• The bill of your cap. (We're told to wear them, to protect from sunburn and glare, yes?)

• The frames of your glasses. (You *are* wearing shades, to protect your corneas and retinas from sunburn, aren't you?)

• The aircraft structure, especially the part below and behind you, and the panel, struts, wings, and posts.

• The head and hat of the person in front.

Let's talk about the sorry fate of the instructor. "I was giving a ride one afternoon," said the man, "And at one moment I realized that my passenger's head was sprouting wings. This was vaguely interesting for a split second, and then I realized what it meant and mashed the stick forward as hard as I could. A Cessna 172 roared by overhead. I thought my passenger would have been terrified, but when I asked her about it, she didn't even know there had been an airplane."

The failure of the passenger to notice the huge overhead roaring speck says something important about our perceptual limitations, especially regarding see-and-avoid. How could she *not* notice? It has nothing to do with gender or hair color – it's normal!

• First, our cognitive systems are strongly designed to *filter noise* and to assemble recognizable important patterns from minimal information.

• Second, we have to be *attending* to the source of the perception.

For the pilot, the wings she sprouted were the opposite of noise: a life-or-death threat, a tiger in the bushes, a snake under the bed. For the *non*-pilot passenger, the clouds, the ground objects, other airplanes, were merely miscellaneous scenery of no particular significance. For the pilot, the minimal information the wings represented was instantly assembled into accurate recognition. For the passenger, the plane was simply visual and aural noise, to be filtered out and discarded.

It's important also that we have put the person most responsible for see-and-avoid safety in the tandem seat having the worse visibility. I do this too: the pax go in the front seat because it's more wonderful. The Happiness Quotient seems greater. We don't *expect* a head-on collision.

I was cheerfully circling near cloud base one day in a 2-33, on a weekday afternoon, at a near-deserted gliderport, enjoying a day off work. There wasn't another airplane in sight, nothing on the radio. I turned in the circle from east to north, and suddenly a light twin zoomed beneath me, perhaps 200 feet below.

I had been keeping my eyes on the horizon, carefully scanning. He had gone from invisible to "collide-able" in the time it took me to make one turn. This was a sobering lesson! How can this happen?

Let's look at the physics. It's a 2-33, so let's make a best-case calculation. Assuming we turn at 45 mph at a bank angle of 45 degrees, we complete one turn about every 13 seconds. He might have been less than a mile away one turn earlier, two miles away three turns earlier. Clearly, there was a hypothetical chance to see him, and for him to see me, in time to avoid fright.

But, what would he have looked like? A speck, seen head-on, just below the horizon. What would I have looked like? A variable speck, alternating between a tiny vertical line and a tinier head-on or tail-first speck, just below a dark cloud on a hazy day.

In addition, it was not a best-case scenario. I was probably flying faster than 45, with a bank angle more like 30 degrees – the turn rate would then be 25 seconds, meaning I would have had a chance to pick up his speck at 1.3 miles, 2.6 miles. Beyond that I can't pick up specks. Moreover, the vario's battery had died, and I was a nervous new pilot, spending at least as much time glancing at the ASI and vario as I was studying the horizon.

Most importantly, we cannot see what we cannot see, yet our perceptual system is very good at making us feel as though we can see very completely, for it always paints a complete picture by filling in the gaps.

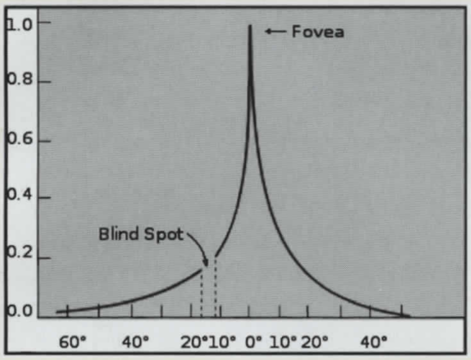
And there is always the impossible, such as the friends who were flying identical ships over the Sierras years ago, in a race, each wondering how the other was doing, not having seen his buddy for a long time. Then came a thermal, and Bill pulled up sharply, not knowing Hank was immediately above and behind him. Neither could possibly have seen the other, though they could talk and know their approximate positions. Bill was killed when Hank's wing sliced through his cockpit. One friend dead, the other grieving. What a terrible way to end a wonderful soaring flight, an exciting race, a delightful competition.

There really is a need for FLARM when gliders are together, and for ADS-B when we mix with air traffic. The big sky protects only while we don't clog it up very much. We see much less than we think we do. See and avoid is the blind avoiding the blind.

[1]Calculate turn rates at http://www.csgnetwork.com/aircraftturninfocalc.html.

Sharpness of Vision versus Distance from Visual Center

Our vision is sharpest in the center (in the *fovea centralis*), about 1.2 degrees of our total visual field. Here's a commonly-reproduced figure showing the relative acuity of vision versus the angular distance from the fovea centralis. (Footnote: From Hans-Werner Hunziker, (2006) Im Auge des Lesers: foveale und periphere Wahrnehmung – vom Buchstabieren zur LesefreudeTransmedia Stäubli Verlag Zürich 2006, and other sources.)



Let's look at this another way. The chart below shows how acuity decreases rapidly with distance from the fovea. If the center of the chart is fixated at a normal reading distance, all the letters should be equally legible. (Footnote: Anstis, S. (1974). A chart demonstrating variation in acuity with retinal position, Vision Research, 14, 589-92.)

Now, let's project our sharpest vision out into the distance, like the beam of a flashlight in the night. Several "beams" are worth thinking about.

- First, the smallest theoretically-resolvable spot, given an optically perfect eye, is 0.4 minutes of arc. This is about equivalent to a tested visual acuity of 20/8.
- Second, what can an imperfect eye detect, and what can its owner *recognize*? The smallest detectable spot is emulated on an eye chart by the gaps in the letters, recognition by discerning which letter is which. The gaps in the letters of the standard eye chart are 1 minute of arc; the letters subtend 5 minutes of arc. So, for practical purposes, 1 minute is the smallest visible spot and 5 minutes is the smallest *recognizable* object. What sizes do these represent at 1, 2 and 5 NM?
- Third, what are the standards? For 3rd-class medical certification, only 20/40 distance-vision acuity is required. With 20/40 acuity, a person can just barely resolve a grating whose bars (or gaps) subtend a 2-minute arc. This means that person can just barely detect a clear image of [size] = [tan(2/60) * distance]. The limit of acuity with perfect eyes is 20/8 vision, able to resolve 0.4 minutes of arc.> For glider pilots, there is no standard. Next time you get an eye check, just for fun have the examiner deliberately degrade your vision to 20/40, and put this "correction" in a set of trial frames so that you can look around the room. Now imagine that you are in the sky with someone else who thinks he can "see" (and avoid!) with this level of visual acuity.

The sharpest vision is in the kernel of the fovea, the *foveola*, or *fovea centralis*. It subtends 1.2 degrees (72 min). The fovea subtends about 6.2 degrees (372 min). What size is the circle – the beam of the searchlight – for each of these, assuming sharp vision, at 1, 2, and 5 NM?

Here's a chart that shows this :

Size of visually detectable objects or sharp vision in feet, versus distance:

Circumstance	Angle in min.	Size at 1 NM, ft	Size at 2 NM, ft	Size at 5 nm, ft
Optical perfection	0.4	0.7	1.4	3.5
Best 20/20 vis.	1	1.8	3.5	8.8
Best 20/40 vis.	2	3.5	7.1	17.7
Recognizable	5	8.8	17.7	44.2
Foveola – 1.2 deg.	72	127	255	637
Fovea – 6.2 deg.	372	661	1321	3303

"Recognizable" is meant to mean "smallest recognizable object" based on sub-texture, using the size of the letters of the eye chart. This would imply that a glider or small aircraft, seen head-on, might be detectable but possibly not recognizable at 1 NM, assuming we are looking *directly* at it, and have 20/20 vision.

The pilot's Scan:

Remember: in order to detect and recognize small important objects such as airplanes, we have to move this circle of best vision around, systematically putting it against the various parts of the sky or ground that might contain a target. We call this the "scan", the idea of focusing our vision on parts of the sky sequentially. Pretend that we need to use our best vision (the fovea centralis, 1.2 degrees of arc), and only scan through 1/3 of the horizon – 120 degrees – as representing the most important threat. Then we must fixate **100** times in succession, while precisely placing each foveal projection in a non-overlapping, adjacent sequence on the horizon.

And that's only to scan the horizon! Were you, like me, feeling a bit un-talented because we keep failing to see traffic that's called or announced? Just maybe, many of these targets are actually *invisible* to us! After doing this analysis, I am understanding why I can't see the traffic at 3 or 5 miles that Center is calling out for me.

So we can see that the "scan" is not very useful for fast-moving aircraft on a collision course with us, or for any aircraft that is very far away.