Big Sky Redefined

The Theory: The sky is so vast and your aircraft so small, there's almost no chance of a "midair" encounter

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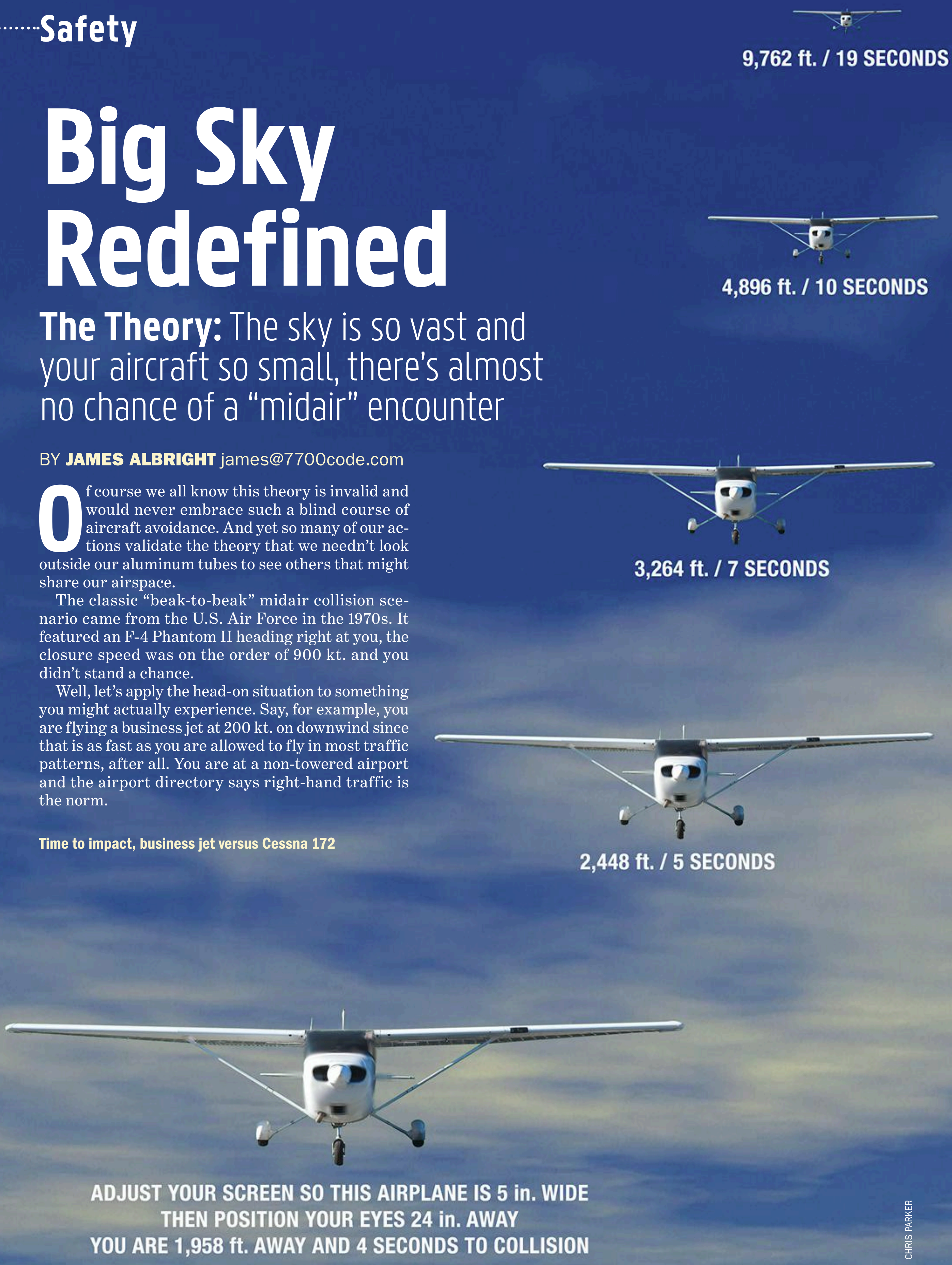
Of course we all know this theory is invalid and would never embrace such a blind course of aircraft avoidance. And yet so many of our actions validate the theory that we needn't look outside our aluminum tubes to see others that might share our airspace.

The classic "beak-to-beak" midair collision scenario came from the U.S. Air Force in the 1970s. It featured an F-4 Phantom II heading right at you, the closure speed was on the order of 900 kt. and you didn't stand a chance.

Well, let's apply the head-on situation to something you might actually experience. Say, for example, you are flying a business jet at 200 kt. on downwind since that is as fast as you are allowed to fly in most traffic patterns, after all. You are at a non-towered airport and the airport directory says right-hand traffic is the norm.



Time to impact, business jet versus Cessna 172

CHRIS PARKER

Now let's say a Cessna 172 pilot thinks it's a left-hand pattern and that flying at your pattern altitude is the thing to do. The two of you are flying "beak-to-beak," one at 200 knots and the other at 100 knots. This 300-knot closure speed is a third of F-4 scenario. So, does that give you triple the time to impact?

It does indeed. But maybe not enough. Studies show it takes 12 seconds to acquire an aircraft visually, make a decision, and then take evasive action. At 300 knots, that means an object one mile distant will be upon you before you can jink. Let's examine the in-flight collision problem, starting with the very first.

The threat surfaced not all that long after the Wrights' first powered flight on Dec. 17, 1903. It happened just seven years later at the "Milano Circuito Aereo Internazionale" meeting in Milan, Italy. French pilot René Thomas, flying an Antoinette IV monoplane, descended steeply and hit British Army Capt. Bertram Dickson flying a Henry Farman III biplane. Both were aware of each other's aircraft, but Thomas lost sight of Dickson, shattering the Big Sky Theory forevermore. Pilots, it would seem, need to look outside the airplane.

The 'See and Avoid' Void

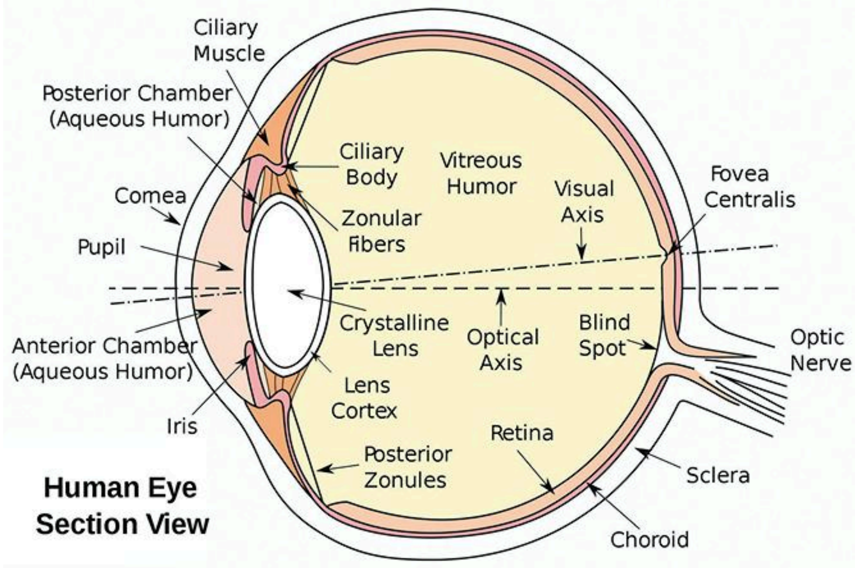
The idea that pilots can simply look outside to avoid hitting other aircraft is codified by regulation, 14 CFR 91.113(b) to be exact: "When weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft."

But the hardest part about that dictum is the requirement to see in the first place. Our eyes are not well suited to the task of tracking distant objects, especially those that appear to be stationary against a blank, featureless sky. In fact, our eyes have some noteworthy limitations.

Eye anatomy. Our eyes take in light through a lens that is adjusted by fibers and muscles to ensure that focused images are seen by the retina on the back of the eye. The retina contains millions of light-sensitive receptor cells that send this information through an optic nerve to our brains for reaction. The central part of the retina contains receptors shaped like cones that are highly receptive to bright lights and colors. These cones are concentrated on the fovea, a small depression in the retina where we have our greatest visual acuity. These cones, however, are not as receptive to darkness, faint light, shape, and movement. For handling these, we have receptors shaped like rods, located on the outer part of the retina.

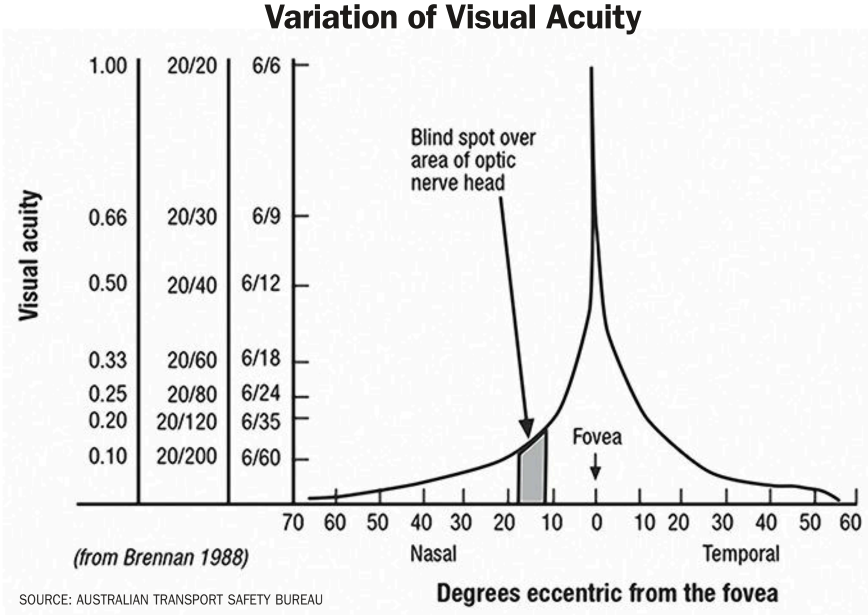
Blind spot. Together the rods and cones take in all the visual information we will ever perceive, but they are not spread throughout the entire retina. There is a small area where the optic nerve resides and this creates a "blind spot" where we don't see anything at all. Our binocular vision can make up for the 5- to 10-deg. blind zone in each eye, but vision obstructions, such as a window post, could render us monocular.

Field of view. Because our eyes are located on the front of our skulls, it would seem obvious that we can take in visual information from roughly 180 deg. in front. The average person has an actual field of view closer to 190 deg., but that angle decreases with age. More importantly, the field of view of the fovea is significantly less. The fovea, which is where our ability to focus resides, is relatively narrow, about 15 deg. at the most. (Some studies suggest it can be as small as 2 deg.) If you want to see something and be able to identify it precisely, you need



STARDUST DRAWING/PUBLIC DOMAIN

Variation of Visual Acuity



SOURCE: AUSTRALIAN TRANSPORT SAFETY BUREAU to be looking right at it. (You may have 20/20 vision, but the farther your visual target from the fovea, the weaker your vision acuity.)

Empty field myopia. An "empty field" can be a featureless sky, and myopia is simply nearsightedness. Our eyes cannot focus properly on empty space. Left on their own, our eyes tend to focus on space near to us, between 3 and 30 ft. Without something distant on which to focus, anything beyond this normal range will be blurry or even invisible.

Saccadic eye movement. Our eyes are able to track moving objects smoothly but cannot move smoothly with nothing to track. The result is jerky moves called saccades, which significantly reduce distant acuity.

Event	Seconds
See Object	0.1
Recognize Aircraft	1.0
Become Aware of Collision Course	5.0
Decision to Turn Left or Right	4.0
Muscular Reaction	0.4
Aircraft Lag Time	2.0
TOTAL	12.5

Accommodation. This is the ability of our eyes to change focus from near to far, like when reading a book and then looking up to watch TV. Our eyes automatically accommodate for near and far objects, but they usually take 1 to 2 sec. to do so. That may not seem brief, but given the time required to see, recognize and act, it can be crucial. As noted, according to a study cited in FAA Advisory Circular 90-48D, the average person has a reaction time of 12 sec.

Night Vision. Seeing things becomes much more challenging once the sun sets. The fovea is far less sensitive in low light conditions, so it becomes a second blind spot. And because a dark sky gives us even less to focus upon, empty field myopia becomes an even greater obstacle to scanning the distant sky.

Considering the forgoing, as pilots we need a significant amount of help to see and avoid other traffic. This, of course, is the charter of air traffic control.

Farman-Goliath, 1937 (Polska lotnicza)

DeHavilland DH-18 (United Kingdom)

Not All Traffic Is Easily Controlled

Air traffic control was first introduced in 1920 at Croydon Airport in London. In an ironic twist of fate, the first inflight collision of commercial aircraft involved airplanes departing from and arriving at that same facility.

The two airplanes were flying in opposite directions on a regular route between Croydon and Paris-Le Bourget Airport. The arriving aircraft was a Farman F-60 Goliath, operated by the Compagnie des Grands Express Aériens, flown by a crew of two with three passengers aboard. The outbound aircraft was a de Havilland DH-18, operated by Daimler Hire Ltd., flown by a crew of two and carrying mail with no passengers. The weather was marginal and both aircraft were flying just under the clouds, which means they were at the same altitude.

Back then, IFR truly meant "I follow roads," and the normal practice among aviators at the time was to fly as you drive, so the arriving French pilot offset to the right while sighting the road on the left. The departing British pilot, however, was used to right-hand drive automobiles. He would normally fly to the left while sighting the road to the right. All but one person on board both airplanes were killed in the collision.

A New York Times story at the time stated, "chances of its recurrence seem so infinitely small that it is not likely to affect civilian flying on a route which daily transports many passengers and mails." Fortunately, aviation authorities realized otherwise and instituted standardized "priority rules."

By 1956, air traffic control in many parts of the world had become much more sophisticated. In the U.S., high-altitude aircraft were deconflicted with other traffic through specific routing and altitude assignments, unless operating in visual conditions at least 1,000 ft. "on top" of any weather. In visual conditions, some operators were allowed to fly off airways on direct courses to take advantage of the most favorable weather and winds. Civil Air Regulations of the day allowed these operations but required that the pilots assume the responsibility for aircraft separation.

That was the situation on June 30, 1956, when a Lockheed 1049A Super Constellation operated by Trans World Airlines collided with a Douglas DC-7 operated by United Air Lines. Air traffic control was aware of both flights but did not inform either aircraft because the TWA flight was operating "on top" and was responsible for its own separation with other traffic. But, as the accident report noted, "seeing other aircraft in flight is difficult." The planes collided over the Grand Canyon and all 128 people onboard both aircraft were killed.

That catastrophe led to the development of active federal oversight of "controlled airspace" in which air traffic controllers were employed to separate aircraft in the en route, approach and departure sectors of their airspace. Controlled airspace implies that someone has control of the airspace, which is probably true. Radar control implies that the controllers have radar contact with all aircraft, which is not always true.

On Aug. 31, 1986, the frailty of the air traffic control system was brought to light again over the skies of Southern California. An Aeroméxico Douglas DC-9, on approach to Los Angeles International Airport, was struck by a Piper PA-28 Cherokee that had inadvertently entered the Los Angeles Terminal Control Area (TCA). The DC-9 was under radar control, but the controller was busy admonishing another airplane for blundering into the same TCA and did not notice the Piper's "skin paint" radar return. Of the 69 persons airborne, only six survived. Another 15 on the ground were also killed.

Seventy-six years after the first midair collision, it became obvious that "see and avoid," even when combined with air traffic control, isn't enough to defeat

JAMES ALBRIGHT/BCA

TCAS display on a Gulfstream 450 on approach to Chicago O'Hare International Airport, Illinois

the shortcomings of the Big Sky Theory. The answer, we were told, rested with technology.

Technology Isn't Perfect

Perhaps the single most important innovation in the science of avoiding midair collisions is the Traffic Alert and Collision Avoidance System (TCAS), also known as the Airborne Collision Avoidance System (ACAS) internationally. This airborne equipment uses another aircraft's altitude and position data from transponder signals to extrapolate and predict future values. The system, in effect, allows pilots to "see" other aircraft electronically even without visual cues.

TCAS has evolved from an advisory system that merely pointed out a traffic conflict into a system that is able to theoretically resolve that conflict. The Traffic Advisory (TA) can be thought of as passive; it tells the pilot there is a problem and provides clues about where in the sky to look. Newer systems provide Resolution Advisory (RA) guidance; they give pilots specific actions to follow, such as "Climb; climb now." Even though an RA can be thought of as an active system, it still requires the pilot to take the necessary action.

On Jan. 31, 2001, two Japan Airlines Boeing 747s nearly collided over Japan when an air traffic controller trainee gave one of the airplanes instructions that conflicted with the TCAS RA. The airplanes came within 35 ft. of each other and several passengers and crewmembers were injured during the evasive maneuvering that followed. The Japanese government asked the International Civil Aviation Organization (ICAO) to answer the question: Should pilots follow the RA or air traffic control? ICAO decided it was a matter best decided by individual countries.

A year and a half later a Bashkirian Airlines Tupolev 154M found itself on a collision course with a DHL Aviation Boeing 757 over the skies of Germany. The controller at an undermanned Swiss Air Navigation Services facility issued descend instructions to the Tupolev 14 sec. before its TCAS issued climb instructions. The Boeing's TCAS issued complementary descend instructions.

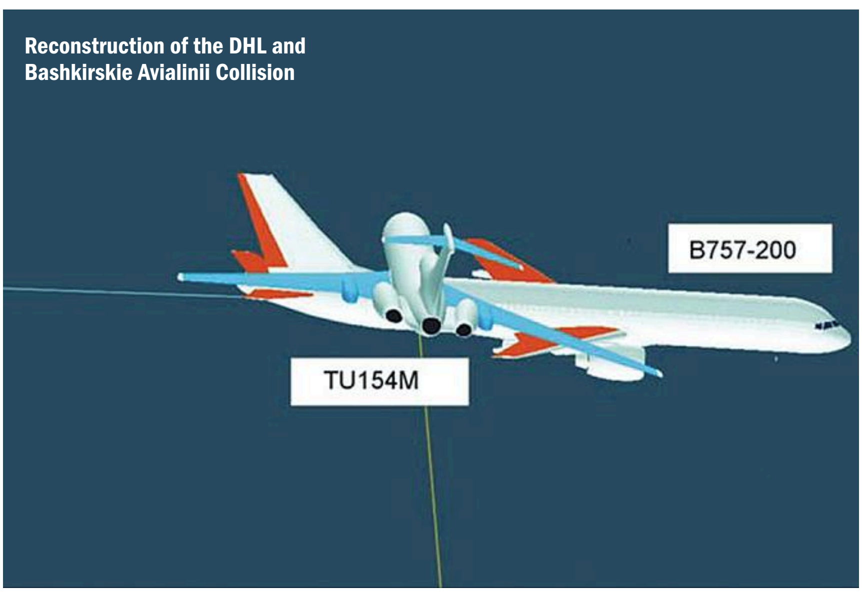
The Tupolev crew's manual stated, "For the avoidance of inflight collisions is [sic] the visual control of the situation in the airspace by the crew and the correct execution of all instructions issued by ATC to be viewed as the most important tool." This ran contrary to the DHL crew's procedures and those used by most countries in the world. But the discontinuity was permitted under ICAO rules. All 71 occupants aboard both aircraft were killed in the collision that followed.

The ICAO rules have since changed: The TCAS RA takes precedence over air traffic control instructions. But not everyone has TCAS and there are times you can operate without it. You might argue that the only time TCAS is necessary is for those long en route portions of flight where it would be impractical and ineffective to stare outside the window for hours on end. But what about during a visual traffic pattern?

We Are at Risk, Even When We Think We Are Paying Attention

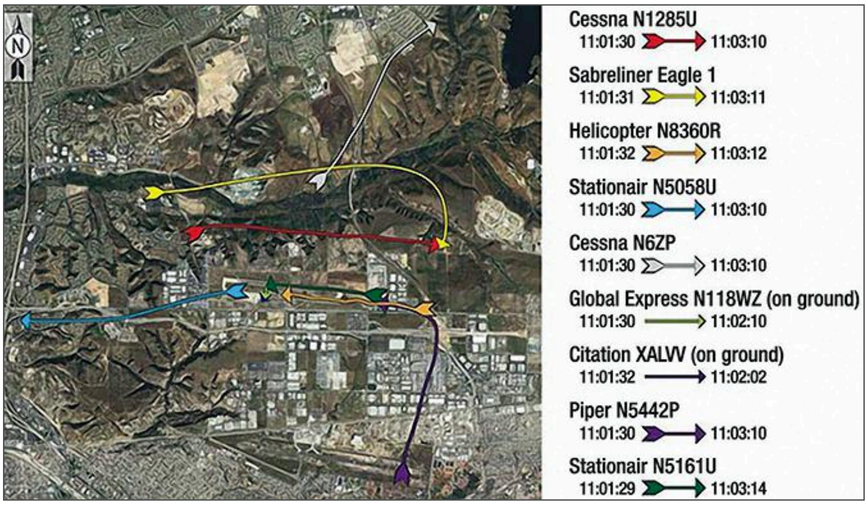
The visual traffic pattern should provide pilots the greatest opportunity to

Reconstruction of the DHL and Bashkirskie Avialinii Collision



GERMAN FEDERAL BUREAU OF AIRCRAFT ACCIDENT INVESTIGATION

NTSB



Air traffic situation at San Diego Brown Field Municipal Airport

see and avoid other traffic. Here, airplanes are flying at slower speeds and flying predictable routes and altitudes. Pilots expect traffic conflicts and are on guard to avoid them. So what can possibly go wrong?

Please read the *Cause & Circumstance* that immediately follows this article. The events of Aug. 16, 2015, at San Diego's Brown Field Municipal Airport answer that question dramatically and tragically.

The NTSB rightfully cites the tower controller's failures as causal to the in-flight collision, but if any of the pilots in any of the several aircraft involved had better situational awareness, the midair and four deaths could have been avoided, despite the visual challenges that prevailed that morning.

Improving Your SA

One of your best tools for enhancing situational awareness (SA) is to listen to the air traffic control instructions going on around you, not just the radio traffic directed at you. This works at every altitude and is especially useful when down low.

Even while cruising along in Class A airspace where everyone is operating under instrument flight rules (IFR), controllers and pilots alike can make mistakes. You can save the day by paying attention to instructions for close-by or potentially conflicting traffic. Be especially aware of "wrong way" traffic that could end up in a "beak-to-beak" situation with you.

It would be self-defeating to be on visual watch at all times below FL 180, but there are times when your eyes need to be outside. Just because you filed an IFR flight plan doesn't mean you have positive separation from everyone; you still have to climb through the aerial domain where visual flight rules (VFR) rule to get to altitude and then return. Beware of the VFR pilot cruising along at a 500-ft. altitude with the autopilot engaged and a good book or DVD player perched above the yoke. (It does happen!)

The traffic pattern is an especially vulnerable area; you are busy inside the cockpit and your sleek jet isn't designed with external visibility in mind. Knowing how the pattern is constructed and how others will be flying it will be key to improving your SA. If you started your aviation journey in light aircraft flying at a non-towered airport you may have had this mastered early on. But do you fly as "defensively" as you once did? If you started in a fast mover, like many of us from the military, the world of the segmented circle may be a foreign place to you. In either case, it may pay dividends to your future SA to brush up on Chapter 4, Section 3 of the *Aeronautical Information Manual (AIM)*. Knowing where to look is half the battle.

Improving Their SA

Of course your situational awareness only addresses half of the collision threat. You can help improve the other pilot's SA by being predictable.

You should attempt to fly departure and arrival procedures as depicted when you have that option. Most VFR pilots expect the jets to be 500 ft. above them in the traffic pattern and to fly a bit wider; that's what you should do. If the non-towered rules tell them to fly left-hand traffic, that's what you should do too. Best practices dictate a stable approach no later than 500 ft. above the landing surface and tracking a 3-deg. glidepath; that takes about a 2-mi. final to achieve. Resist the urge for that "fighter base turn" that impresses the fans but surprises the single-engine pilot trying to fly so as to always be in a position to land if an engine quits.

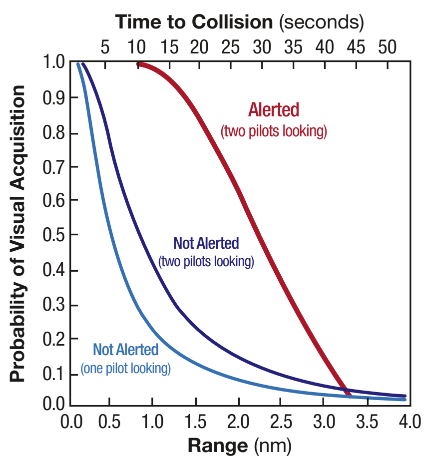
But you must always remember that the other pilot may not see you and it may be up to you to prevent the collision. It is true that "see and avoid" doesn't always work, but there are ways to improve the likelihood of actually seeing so you can avoid.

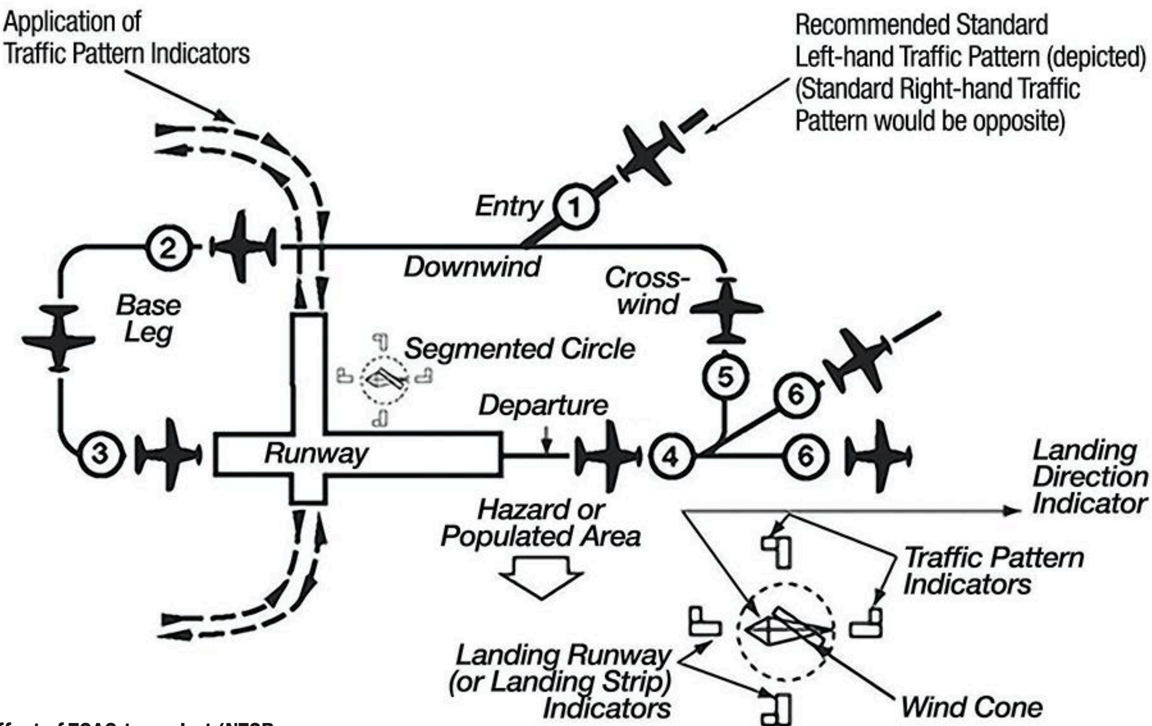
Improving Your Scanning Abilities

Scanning for distant aircraft in a featureless sky is not a natural act and it should be no surprise that we are all naturally disposed to doing it poorly. We tend to look straight ahead when scanning for traffic and if that doesn't yield results, we check the outer edges of the windows thinking that covers our viewable airspace.

But because our foveal focus area is so narrow, that misses a great deal of area. We also tend to start our eyes on a blank spot, but with nothing to focus on, our eyes focus far too close. Finally, we tend to spend just a second or two on each spot in our scan before moving to the next; that is too quick a movement to allow the eyes to compensate for the reduction in visual acuity due to saccades.

Most texts about visual scanning techniques include side-to-side and front-to-side patterns that include the entire viewable windscreen in 10 to 15 blocks of space. If you spend 3 to 5 sec. between eye movements to allow your





The effect of TCAS-type alert (NTSB Aircraft Accident Report 87/07, Figure 4)

saccadic acuity to restore, then 2 sec. actually looking, it will take you between 50 and 105 sec. to complete your scan. Do you have the time to do that while still attending to your other cockpit duties? Probably not.

Consequently, consider "targeted scans" that concentrate your search in the most likely area, based on your SA. A study by aviation safety research consultant Shari Stamford Krause, Ph.D, chair of the Aircraft Operations Technical Committee, American Institute of Aeronautics and Astronautics, published in the May 1997 edition of the *Flight Safety Digest*, suggests the following:

▶ Anticipate the target in the location and ranges you are searching.

▶ Locate a sizable, distant object (*e.g.,* a cloud formation, mountain peak, prominent landmark, building or pier) that is within the range of the anticipated target, and focus your eyes on it as you begin each scan pattern.

▶ Refocus frequently on a distant point as you begin each new scan.

▶ Allow 3 to 5 sec. for your saccadic eye movement to suppress before shifting your search to the block of airspace around the object.

▶ Vary distances to ensure a thorough scan and to reduce visual fatigue.

The best way to anticipate the target's location is to cheat, and that's what technology does best.

Adding Technology

Having TCAS or Automatic Dependent Surveillance-Broadcast In (ADS-B In) will narrow your search efforts enough to make a difference on whether you can fulfill the second edict in the "see and avoid" imperative.

Following the 1986 Aeroméxico midair, researchers at the Lincoln Laboratories of the Massachusetts Institute of Technology studied the impact of having an alert prior to a potential collision on the time it took to visually acquire another aircraft. The results were dramatic. If the probability of seeing the other aircraft is on the order of 50%, two pilots without an alert were unable to acquire the aircraft until less than 10 sec. remained before impact. If given an alert, they were able to acquire the aircraft with almost 30 sec. to spare, more than enough time to take evasive action.

Improving Your Odds

Finally, you can further stack the odds in your favor with a few housekeeping items:

(1) Make sure your eyes are up to the task. Get regular checkups. If you need glasses, wear them.

(2) Reduce glare by using sunglasses, sun visors, or the visor on a hat or baseball cap.

(3) Make sure cockpit windows are clean. A bug spot can be just the right size to cover a large airplane on a collision course at a distance inside your reaction time.

(4) Keep cockpit lights dim at night to allow your eyes to remain night adjusted. Don't forget the impact of cabin lights on your cockpit lighting.

(5) Keep your head on a swivel. Look around aircraft blind spots, such as window posts.

(6) Maximize the use of exterior aircraft lighting.

(7) Always squawk. Even if a transponder code is not assigned, squawking 1200 (or 2000 in some areas) lets you see and be seen on TCAS.

(8) Talk and listen. Announce yourself at key points on your arrival into a non-towered airport's pattern and listen for others, even at airports with an operating control tower.

(9) Make everyone in the cockpit responsible for detecting other aircraft.

It Is a Big Sky After All

Our original premise stated that the sky is so big and your aircraft is so small that you do not have to worry about hitting other aircraft.

As it turns out, only the first part of that statement belongs in the Big Sky Theory. It is time to amend the theory. The sky is indeed big, but it takes a pilot with excellent situational awareness using all the tools available to scan it effectively, so as to avoid an inflight collision. **BCA**