Rod Machado's Instrument Pilot's Survival Manual

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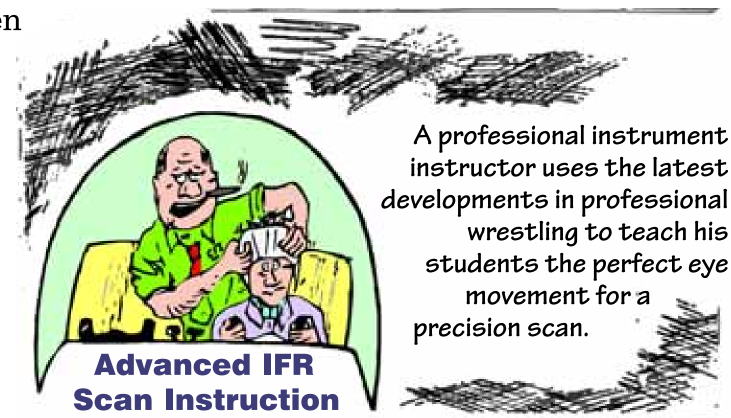
Chapter 2
The Art of the Instrument Scan

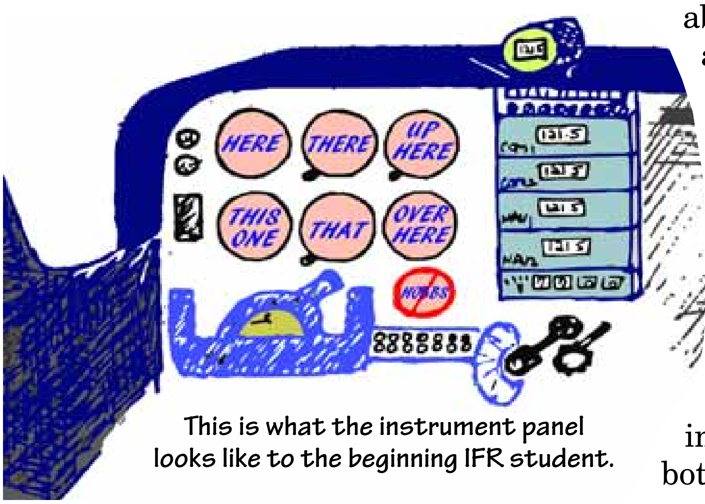
Flying instruments is one of the most challenging and rewarding achievements you’ll attain in aviation. It satisfies and gratifies a pilot’s inherent need to be a master of the machine, environment, and universe while offering its own form of entertainment along the way. In fact, instrument flying is analogous to a video game in three dimensions, except you don’t get to shoot down any Klingons with your joystick. Your next flight is the free game you receive for a satisfactory score or performance. Developing a good instrument scan is the foundation for meeting the challenge instrument flying offers. We are, in the end, measured by the span of our scan. Yet it’s in this area that we as instrument pilots are most often deficient.



A professional instrument instructor uses the latest developments in professional wrestling to teach his students the perfect eye movement for a precision scan.

My initial instrument instructor would insist on tapping the instruments with his metal pointer, his baton leading my eyes in scan while looking like the conductor of a runaway orchestra. This was about as educational as being at an Amish science fair. He would say, “OK, look here (airspeed); look there (attitude indicator), don’t look at that (heading indicator), look at this one (turn coordinator)...” For a long while, I thought that’s what the instruments were called: HERE, THERE, THAT and THIS ONE. He had fun and I got a headache.

Many pilots end up having survived, rather than mastered, every IFR flight. For them, it’s a victory, but it’s rarely a comfort. Too bad, because there *is* a realisitc method to the madness of scanning instruments (one that doesn’t involve a pointer). Mastering the art of instrument flying means acquiring the scanning skills that allow you to become a good in-flight manager. The proper scan gives you time to think, plan, anticipate, plot, scheme, and stay at least one step ahead of the airplane. This is what instrument flying is all about, mastering the mechanics of flying, and freeing up your imaginative capacity to be aware of your position and anticipate what’s next.



This is what the instrument panel looks like to the beginning IFR student.

In this chapter I’ll show you a very simple method for scanning your instruments. At first, we’ll discuss scanning the typical *six pack* of analog instruments, then we’ll apply this scan to the electronic instruments of a PFD or primary flight display. It’s absolutely imperative that you read and understand both methods if you’re flying technically advanced airplanes equipped with PFDs. Why? Because the loss of your PFD, or one of its essential instruments, often leaves you with only your backup analog instruments on which to fly (most technically advanced airplanes have backup analog instruments). Additionally, flight instruments are flight instruments, so what you learn on a traditional panel directly applies to a PFD.

There are two fundamental conditions in instrument flying—steady state, and change. Either the airplane is straight and level with everything set, or you are in some kind of transition. In the steady state condition, you are primarily monitoring to make certain everything *stays* steady. Transitions, on the other hand, involve a very active role. Once something is disturbed, as it must be to climb, descend, or turn, everything changes and you then have the job of putting it right again after making that climb, descent, or turn. Executing these transitions well is the defining skill for a competent instrument pilot. All it takes is three specific steps, performed consistently.

The Three Steps

There are three essential steps in the effective instrument scanning process. These steps are to be executed *every time a major attitude change is made*. In other words, when you make any *major attitude change*, you'll go through three steps, one right after the other, until the airplane is established in its new attitude. It should take approximately 10 to 15 seconds to accomplish all three steps. Here are the three steps of the scan, in the order they should be done:

Step 1: Select attitude and power. Trim and confirm.
Step 2: Radial scan the primary instruments.
Step 3: Trim using the VSI and monitor scan the 6-Pack

Essentially, the airplane is put in the desired attitude, power is adjusted, and an initial twist of trim is applied to hold the airplane in this attitude. The correct operation of the most critical instruments is checked by a confirmation process. The primary instruments are then scanned in an organized fashion, and small corrections are made to fine tune the airplane to the proper attitude. The final trim adjustment is made, and the airplane's new attitude is monitored on the six main flight instruments. This is the big picture of how the instruments are scanned in this three-step process. Let's take a more detailed look at how it works.

Step One of the Scan

The first step in the three-step scan is to select the attitude, power and trim conditions for the new flight attitude. This first step is executed by focusing on the attitude indicator and selecting, from experience, the attitude that educated approximation says will provide the desired flight conditions. If you're ever going to have an attitude, now is the time to do it. The implication here is that you have or are acquiring knowledge of the predetermined attitudes necessary to make the airplane climb, turn, and descend as commanded.

After the first few hours of instrument flying, you should decide on an array of specific power settings and flight attitudes that will cause the airplane to do exactly what you wish. These power settings and flight attitudes are values or reference points on the tachometer or manifold pressure gauge and attitude indicator. In a light general aviation trainer, climbs are typically done with full power (or nearly so) and a 5 to 10 degree nose-up pitch attitude. This will consistently result in a good climb rate and speed. Most turns are accomplished with a 15 to 20 degree bank. This is close to the bank necessary for a standard rate turn at normal cruising conditions.

Remember, a standard rate turn simply means that the nose of the airplane changes direction at three degrees per second. The easiest way to figure out what bank is required for a standard rate turn is to drop the last number off the airspeed and add the number 5. If the airspeed is 125 knots, then the bank required for standard rate is 12 + 5 or 17 degrees. If the airspeed is 90, then the standard rate bank is 9 + 5 or 14 degrees. If the airspeed is 600 knots, then the bank required is 65 degrees. This could be real interesting for the passengers! There is a good chance some of the older passengers will experience a dislodging of their uppers. The general rule is never to exceed 30 degrees of bank under IFR conditions even if something steeper is required for a standard rate turn.

After thousands of hours of exposure to g-forces caused by steep turns and turbulence, a pilot's body is subtly altered. One of the unique benefits of this condition is the tendency of the pilot to always remain upright if he topples off the seat in a fit of vertigo.

Someone once suggested that most airline pilots avoid steep turns because of the debilitating effects of G-forces on posture. After spending many years in a flight crew seat, professional pilots have been known to take on the shape of a Lazy-boy recliner. I suppose the critical stage is reached when pilots start to look like they have just graduated from the Quasimodo posture school.

No VFR pilot worth his or her weight in slow Hobbs meters would deny that looking outside at the horizon is a good thing. The earth's horizon is what allows you to keep your airplane in the correct attitude for flight. In fact, most pilots flying VFR spend well over 90% of their time referencing the visible horizon. Why should this be any different during instrument flight? When the earth's horizon is no longer visible, the airplane's attitude indicator (artificial horizon) is a most welcome substitute.

Step one of the instrument scan suggests that the attitude indicator be exclusively observed during major attitude changes. This is certainly contradictory to what you may have been told about instrument flying. It's always been considered a punishable offense to stare at any one instrument. For the most part, this is a good rule—except when it comes to step one of the scan.

The *Air Force Instrument Flying Manual* (AFM 51-37) states:

"The attitude indicator is the only instrument which you should observe continuously for any appreciable length of time. Several seconds may be needed to accomplish an attitude change required for a normal turn. During this period you may need to devote your attention almost exclusively to the attitude indicator to ensure good attitude control."

Since the USAF pretty much knows which side of an airplane is up, it's a sure bet that they have given this statement a great deal of thought. Problems with instrument scan often occur when you spend too little rather than too much time observing the attitude indicator.

Many years ago, a military study of professional pilots discovered something educationally interesting. When cameras were targeted on the eyes of these professional pilots during their instrument scan, it was discovered they spent 85% of their time looking at the attitude indicator. The only reasonable conclusion that can be drawn is that this behavior has evolved because it is imminently useful and efficient. The pros know, and the rest of us will do well to follow.

The attitude indicator is a complete instrument. Unlike other instruments, it contains both pitch and bank information, so it's reasonable to focus on this instrument when changing attitude. If attitude indicators never failed, there would be no concern with them being the center of your attention. As an entry instrument, it is the core of the scan. But you cannot be obsessed with its presence nor crippled by its absence. These instruments do fail, often with disastrous consequences for anyone who is addicted to the attitude indicator but who rejects all other injections of information. Knowing how to detect instrument failure and correct for it is the defensive countermeasure that balances the emphasis on the attitude indicator.

In the first step of this scan, you will compare and validate the result of control input to the response of the attitude indicator. This is the confirmation process, which ensures that the attitude indicator is working properly. In other words, the attitude indicator should respond in a manner consistent with how the controls are moved. It's kind of like using an unseen instrument—the nonsense detector.

If control pressure is applied to make a right turn, the attitude indicator should show (brace yourself) a right turn deflection in proportion to the amount and rate of control input. Who said instrument flying is difficult? A slight amount of back pressure on the controls should show a gradually increasing pitch on the attitude indicator. Any discrepancy between control input and attitude response should be checked by consulting the turn or pitch "triangle of agreement. Keep in mind that you only need to check the turn or pitch triangle of agreement if you suspect the attitude indi-

Mind Twister

I was cleared for an immediate departure. I went through the final checklist: time, instruments, transponder and strobe. When checking the directional gyro with the compass and runway heading, I noticed it was 20 degrees off and made a mental note to keep track of precession.

After passing through about 500 feet, I was told to contact Departure. I acknowledged and hit the flip-flop button on the #1 com and called. I got no response, so I tuned the #2 com to Departure to try again. In my airplane, the radios are located beneath the yokes, with #2 on the bottom. This requires a large movement of the head in two axes. When I raised my head, I noted the attitude indicator was way off to the right, and I started to follow it. It became clear, almost immediately, that something was wrong, as the airspeed was building and the rate-of-climb was descending. I caught a glimpse of the approaching ground before I got back under control with the turn-and-bank and started to resume a climb. I simultaneously called Departure and declared a no-gyro emergency...The controllers acted with aplomb and reassurance, and a successful no-gyro ILS was accomplished.

What happened? The A.I. had a leak in the case (discovered by the instrument shop the next week) causing it to slow down and tilt and the D.G. to precess. The rapid head movement of returning the radio caused vertigo, and I started to follow the tumbling A.I. My instrument crosscheck located the defective gyros in time to prevent disaster. Partial panel ability with excellent assistance from ATC assured a successful landing.

How to prevent similar occurrences? I have raised my personal minimums for instrument takeoff in controlled airspace...

ASRS Report

cator or any other flight instrument of error. In other words, it's not necessary to check the triangle of agreement every time a major attitude change is made. Of course, if you're going to *check* the triangle of agreement, we'd better take a look and see what it is.

Making Three Agree

A *triangle of agreement* is an attempt to solve a vexing instrument aviation problem. Sometimes instruments fail. When they do, how do you know for sure what's right and what's wrong? If you compare any two instruments showing the same kind of information, the best you can get is an unresolved disagreement. Instrument pilots inherently dislike ambiguity. So, we add the word from a third, with point, game, and match going to the two instruments that agree.

To take part in a triangle, the three participating instruments must show the same type of information (turn, climb, etc.) but be independent in terms of their power source. If the vacuum system fails, obviously *everything* that's vacuum powered will fail, so having two vacuum powered instruments in a triangle would create problems rather than solving them.

When you look at the instruments in a triangle of agreement, at least two of the three should agree, and should be consistent with the quality and quantity of control input.

The Turn Triangle of Agreement

For example, the *turn triangle of agreement* (Figure 1) consists of the attitude indicator, turn coordinator and magnetic compass. All three of these instruments respond to a turn. When turning, these instruments should reflect similar rates and similar directions of turn.

If the three don't agree, you have a problem *somewhere*. In the context of this discussion, *problem* is a nice way of saying something has gone belly up, and you now have an urgent need to know what's talking trash and what's giving you good information. If the lead suspect is the attitude indicator, the other two instruments of the triangle should be consulted, starting with the turn coordinator. If the turn coordinator does not reflect the attitude indicator's expected direction and rate of turn, the magnetic compass should be checked for movement. The instrument in disagreement with the other two is the one most likely to have failed.

Figure 1. The turn triangle of agreement.

For instance, if the attitude indicator reflects a turn and the compass shows a heading change, but the turn coordinator indicates a constant heading, this says that the turn coordinator is in error. The majority wins. It's just like professional wrestling,