Dragons of the Downwind Turn

TEXT, DIAGRAMS AND PHOTOGRAPHS BY JIM DAVIS

EVER WONDERED why the mention a low-level turn after takeoff causes the club greybeard to blanch and start twitching the corner of one eye? Jim Davis looks at the dragons that lurk around this seemingly benign manoeuvre.

I was reading a British flying magazine when I spotted this thing about an airshow accident. The pilot had finished an aerobatic sequence and was about to go home. He did a beat-up into a 25 knot wind, followed by a steep, climbing 180 to the right. Halfway through the turn he lost airspeed, spun in and was killed. The CAA's finding was that during the turn the headwind became a tailwind – causing him to run out of airspeed.

In making this judgement the CAA were grievously in error.

I e-mailed them to say that there are many who would disagree with their thinking. They responded with a blushing admission that they should have their wrists slapped for saying such a stupid thing.

I tell this story, not as a criticism of the CAA, but to show that the downwind turn is indeed a thorny problem. Not only did it humble the regulatory powers in their ivory tower, but it squished an experienced pilot.

Everyone who has put their mind to the downwind turn has strong views on it. Those who understand physics point out that there is no danger. They tell you that once airborne the aircraft flies in a block of air. Whether this block is stationary, or moving relative to the ground, makes no difference to the aircraft's flight within it. They explain that you can do steep turns 20 feet off the ground or at 2 000 feet, with no ill effects, regardless of wind strength (to keep it simple, we assume no turbulence). Pilots who support this thinking are aerodynamically 100-percent correct. Unfortunately their scientific fervour may blind them to some dangerous practicalities.

Then an old-timer, possibly a crop-sprayer, will say, "To hell with science – I have scared myself often enough – I know it's bloody dangerous". And of course he is also 100-percent right; but seldom knows why.

The largest group of experts, including the CAA's blunderer, believe it is dangerous because your inertia causes you to lose airspeed when you turn down wind. They ask you to imagine you are indicating, say 80kts, while climbing into a 30kt headwind - giving you a groundspeed of only 50kts. They point out that if you suddenly turn round so the wind is behind you, the aircraft will not instantly accelerate to a groundspeed of 110kts (80 + 30). It is a heavy chunk of metal, which has inertia, so it will take time to accelerate from 50 to 110 knots, and during this time the tailwind will cause it to lose airspeed and lift.

Although this explanation seems logical it has a major flaw. It is based on the belief that groundspeed plays a part in the aerodynamics of a body that is totally supported by the air.

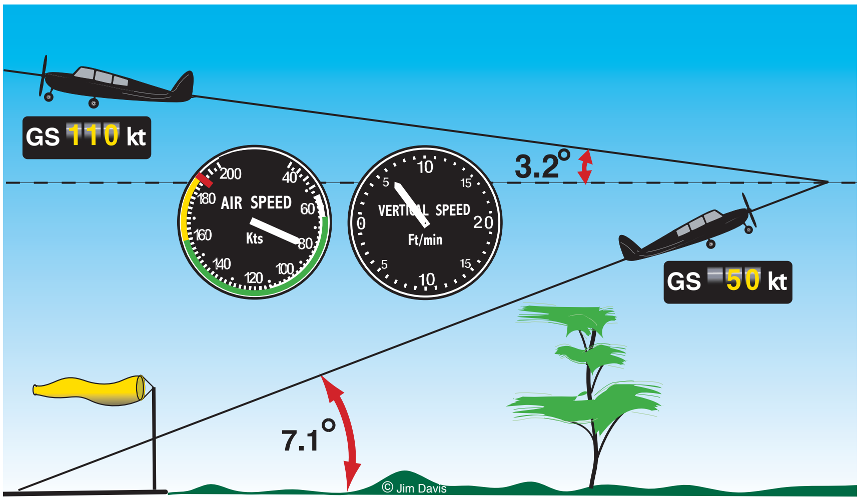
To find out what really happens in a low level downwind turn you need to get your mind around to four different things:

- some basic aerodynamics
- a little schoolboy physics
- an understanding of windshear caused by surface friction
- and the illusions that betray you when flying near the ground

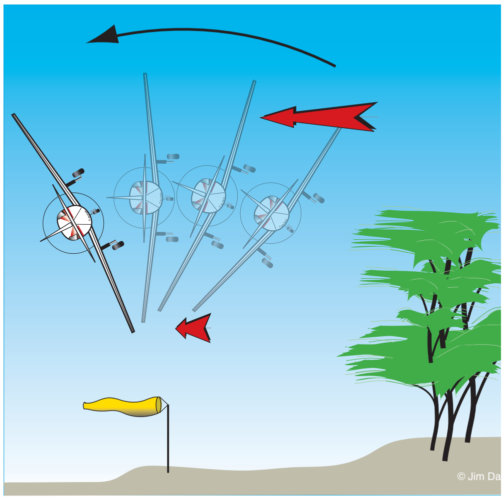
We are really looking at two schools of thought - those who believe it's dangerous because the sudden tailwind causes a loss of airspeed and lift; and those who say it is not dangerous because lift is a function of airspeed, and not groundspeed.

The bottom line is that a low level downwind turn is indeed dangerous. It is even more dangerous if it's a climbing turn affected by windshear – which it often is, because it normally happens soon after takeoff.

To clear the air we need some cold, realities – facts that will dethrone the misunderstandings and half-truths that surround the problem. So here are the brute



Both ways airspeed and rate of climb are the same. But climbing into wind you have a tree-clearing angle of climb, while downwind it is scarily poor


When windshear causes you to overbank, the next step is often a spin.

facts:

Brute Fact No.1. A downwind turn is not dangerous – aerodynamically.

Once the aircraft leaves the ground and is flying in a steady wind, its aerodynamics relate only to its movement through the air in which it is flying.

Its geographical position is dependent on the wind's speed and direction – but that is a navigational matter – not an aerodynamic one.

Let's say you take off, climb to 2000 feet overhead the field and level off indicating 90kts. You know the wind is from the north at 30kts. You put on a hood and start doing rate 1 turns to the left (about 16-degrees of bank). One hour later, when you lift the hood, you will find yourself exactly 30 nautical miles south of the airfield. So that's what the wind does to your navigation – it has 100-percent effect – it carries you 30 nautical miles downwind in one hour, regardless of your heading or airspeed. If a butterfly and a Boeing had been circling nearby, they would also wind up 30 miles south.

But how does it affect your aerodynamics? During this flight you will notice that the airspeed doesn't twitch even the slightest fraction as you turn into wind or down wind. This, despite the fact that your groundspeed continually alternates between 60kts while turning through north, and 120kts when heading south. The VSI and altimeter also remain rock steady.

Once the aircraft is in this block of moving air that we call wind, its aerodynamics are identical to those in a no wind. This rule applies to all objects supported by the air. Boeings, balloons and butterflies all conform to this physical imperative.

Since this argument attacks the very foundations of what many people believe, perhaps another illustration will help. Imagine a bee in a railway carriage. The train is covering ground at 100kts. The bee is doing 360s with her little airspeed indicator showing 3kts. One moment she has a groundspeed of 103kts and the next she is going backwards at 97kts. No problem - her aerodynamics are unaffected by the speed that the sleepers are galloping past just feet below her wee striped tummy. She is in a block of moving air and her flying is just fine. She can even practice little stalls, spins and loops while travelling sideways over the ground.

Still not sure? Here is a final mind-experiment. Let's go back to flying those 360s. This time you are above a layer of solid cloud, and not using a hood. Remember your groundspeed is continually changing between 60kts and 120ts. But the ASI is solidly on 90 knots.

Now, imagine that while you are doing your 360s, God sneaks up and quietly removes the world. Because you are above cloud you don't notice this curious deficiency. Does it make any difference to how the aircraft flies? Of course not. (We assume that She kindly leaves gravity and your block of air in place). She could even twiddle the world around, representing mighty wind changes and unbelievable surges in groundspeed. But you will keep flying just fine – like the bee in the train.

So Brute Fact No.1 says that groundspeed has nothing to do with the way the aeroplane flies – nothing – full stop.

Brute Fact No.2. As you turn downwind your angle of climb gets less.

If you take off into a 30kt wind and climb at an indicated 80kts, with your VSI steady on say 600 ft/min, your groundspeed will be 50kts (80-30) and you will have an angle of climb of 7.1 degrees (see diagram). This means you will travel 422ft horizontally to clear a 50ft obstacle. After you turn downwind your rate of climb will still be 600'/min (from Brute Fact No.1). Your groundspeed will more than double to 110kts. Your angle of climb will be less than half at only 3.2 degrees, and you will travel more than twice as far – 930ft – to clear a 50ft obstacle. This means that your ability to climb above looming power-lines becomes terribly disappointing.

So, while the turn has its own perils, which we will look at shortly, the completed turn leaves you in a miserable position. Obstacles surge into the windscreen and you have scant ability to clear them.

Brute Fact No.3. Windshear is a grave problem.

Windshear is a rapid change in wind speed or direction.

As we climb above the trees and obstacles that reduce the surface wind, the wind speed increases rapidly. This means we generally climb through windshear soon after takeoff.

Now let's look at a turn during this windshear phase. We start with say a 10kt headwind as the wheels leave the runway, but by the time we are above the trees and have completed the turn we might have a 20kt tailwind.

So as not to confuse the turning with what's happening aerodynamically, we'll ignore the turn for the moment (don't panic, I'll come back to it) and just assume a straight climb during which the wind rapidly changes from a 10kt headwind to a 20kt tailwind.

Now we do indeed have a serious problem – the medium that supports us is moving relative to us. This is like God not moving the earth (as She did previously) but suddenly moving our block of air. So now our inertia within that block becomes important.

Any sudden increase in headwind will cause a temporary increase in airspeed and lift. While a sudden tailwind, or loss of headwind, causes a temporary loss of airspeed and lift. (This is why your airspeed fluctuates during a gusty approach.)

So a change of wind speed is all about inertia.

Spinning (above) can be a disorientating experience for many students. However, it can provide a fascinating insight into basic aerodynamics. The marble and cotton wool concept (right) demonstrates inertia in relation to wind speed.

To understand this more clearly here is another mind-experiment. Imagine a marble and a ball of cotton-wool, sitting side-by-side on a smooth, flat table (see photo). If you try to blow them along the surface, the cotton-wool will shoot off, attaining blow-speed in a millisecond, due to its lack of weight (actually 'mass'). The marble, being heavier, will suffer a tailwind for quite a while before it accelerates to blow-speed. This shows that the weight of the object is important when you have a sudden change of wind speed. In this case it changed from zero to blowspeed.

So the aerodynamics of Boeing and butterfly are both unaffected by a steady wind. But they have hugely different reactions to a change of wind speed. A sudden tailwind causes a Boeing to lose airspeed and lift, while a butterfly is almost instantly carried along by the new wind and hardly notices the change.

With a Cherokee or Cessna a sudden increase in tailwind robs you of airspeed and lift for a few seconds. If you are low it only takes a few seconds to kill you.

Now let's think what windshear does to the turn itself. Imagine you are halfway through your left-hand climbing turn. The left wing is in a 20kt wind and the right one is in a 30kt wind. This often happens when the wind is blanketed by a hangar or row of trees. The diagram gives you an idea of what to expect. Your airspeed is low, the bank increases dramatically and the nose drops. You yank the stick to the right and pull back. When a spin dragon attacks you near the ground you stay attacked.

So Brute Fact No.3 tells us that windshear, rather than actual wind, is a major killer.

Brute Fact No. 4. You lose climb performance in any turn.

During a turn, drag increases, and airspeed decreases. If you lower the nose to maintain airspeed, your climb suffers, and if you don't your airspeed suffers. Either is bad for the climb. Obviously the steeper your turn the poorer the climb.

Brute Fact No.5. The reason for the turn may be a problem.

If you do the turn to avoid an obstacle, such as a line of trees, buildings or a koppie, then that obstacle may, apart from causing windshear, produce health-ruining down-draughts on your side.

And if the reason for the turn is that you want to come back and dazzle the admiring onlookers with your skill, as did our perished airshow pilot – then you are the problem.

Brute Fact No.6. Flying downwind you cannot turn quickly.

We saw earlier (from Brute Fact No.2) that once flying downwind you have limited ability to climb over the powerlines. But you also have equally limited capacity to turn away from whatever is filling your windscreen. The problem is that the tailwind gives you a massive radius of turn which carries you into the jaws of the dragon.

These six Brute Facts explain the raw physics and aerodynamics of the problem. But wait – there's more, the downwind turn also produces three illusional dragons, which lurk waiting to swat you into the ground.

Illusion No.1. The aircraft appears to slip into the turn.

Let's say you are half way through your left hand climbing turn. You are 90-degrees to the wind and travelling sideways over the ground at 30kts. This is very noticeable because the ground is so close. The scenery moves across your windscreen from left to right. It gives you the sensation that the aircraft is slipping to the left - into the turn. It's only an illusion - if you glance at the ball it's pretty much in the middle. But the deception is so strong you find yourself feeding in left rudder.

Whoa! Let's look at what's happening. You are doing a left turn and using too much left rudder. This increases the bank, and pulls the nose down. How do you react? You use right aileron to fight off the scary bank, and you move the stick back to keep the nose up. Now you have got crossed controls, low airspeed and the stick coming back. Swat. This is what happened to the airshow guy – and a thousand others.

Illusion No. 2. The airspeed seems to increase.

As you turn downwind your increasing groundspeed makes you think that your airspeed is running away (in our example the groundspeed more than doubled). It feels as if you have too much airspeed for the climb. There is a huge temptation to raise the nose. Some people even reduce power. Both deadly reactions sound silly – but they are intuitive and they happen all the time.

Illusion No. 3. There is an apparent decrease in rate of climb.

The increased groundspeed causes a flat angle of climb (see diagram). Of course the rate of climb is unchanged, but what you see is a frighteningly flat angle relative to the ground, and this makes you squirm. So what do you do? You ease the stick back.

Actually, it is a good idea to reduce airspeed slightly to the best angle of climb speed. But the illusion tempts you to ease back too much, which further erodes the climb. Also sounds stupid, but dragons feed on stupidity.

But perhaps the greatest danger of a downwind turn is that it lures you into a whole herd of hidden hazards. There are no signposts in the sky to say; "Don't do it – it looks safe but dragons lurk herein".

To misquote someone whose name I have forgotten. There is no reason to do a downwind turn in peacetime. But if you absolutely must, then understand the dangers, don't do it for the wrong reasons, don't overbank, and remember that a glance at the ball and the ASI may save your life.

A buzzing bee's airspeed indicator is showing three knots, whilst the train's is showing 100.

Summary of Dragons

A downwind turn holds no aerodynamic problems, but a climbing, low level downwind turn is a whole lot more dangerous than we imagine:

- The shallow climb reduces your ability to clear the power lines. It may also cause you to ease back and lose airspeed and lift.
- The increased groundspeed limits your ability to turn away from obstacles. It can also fool you into throttling back. Or easing back and running out of airspeed and lift.
- You can get dragged down by downdraughts caused by trees, hills or buildings.
- Windshear causes a loss of airspeed and lift. It can also make you overbank at a time when you are already in trouble.
- All turns cause a loss of climb performance.
- Apparent slip can cause you to use too much rudder then opposite aileron and up elevator – inducing a spin.
- Your reason for doing the turn may contain its own dragons.