Slips – Good; Skids – BAD!

Daniel Sullivan November 15, 2021

A Slip by Any Other Name is Still Sweet

First, to dispense with the nomenclature – Forward Slip vs. Side Slip.
They are, aerodynamically, the same. Just like that little static electricity spark that you use to annoy your spouse, cat, dog, sibling or your significant other is the same as lightning. Although neither of those things are very useful to most normal people (Mr. Franklin notwithstanding). On the other hand slips are very useful tools (and something that gets tested at your Private Pilot check ride).

Forward slip is when the nose of the aircraft is sideways to the direction of travel.
Side slip is when the nose of the aircraft is pointing in the same direction as the line of travel.

Confusing nomenclature, to be sure. If I forward slip I point the nose to the side, if I side slip I point the nose forward. I read somewhere that it's the British to blame because they call a crosswind a 'side wind' and when you are landing in a crosswind you keep the wing down into the wind but want the nose to point in the direction of travel (down the centerline). So this is a side (wind) slip. I can't say that is where the term actually came from, just something I read. I suspect that the FAA is somehow involved in this confusing terminology (you know – like maneuverability vs. controllability).

As alluded to above, a side slip is useful when performing a crosswind landing. A forward slip is useful when you when you want to lose altitude without gaining airspeed. Handy when flying an airplane without flaps or one with flaps when terrain and buildings make for dicey winds at low levels where a steep approach may be more favorable, or when a steep approach is necessary just because of the terrain or buildings themselves.

I contend that a forward slip and a side slip are ***exactly*** the same – both have their nose pointing to the side of the (oncoming) relative wind. They differ only by: 1) the degree to which the nose points to the side of the oncoming wind and 2) the frame of reference that defines the relative wind direction.

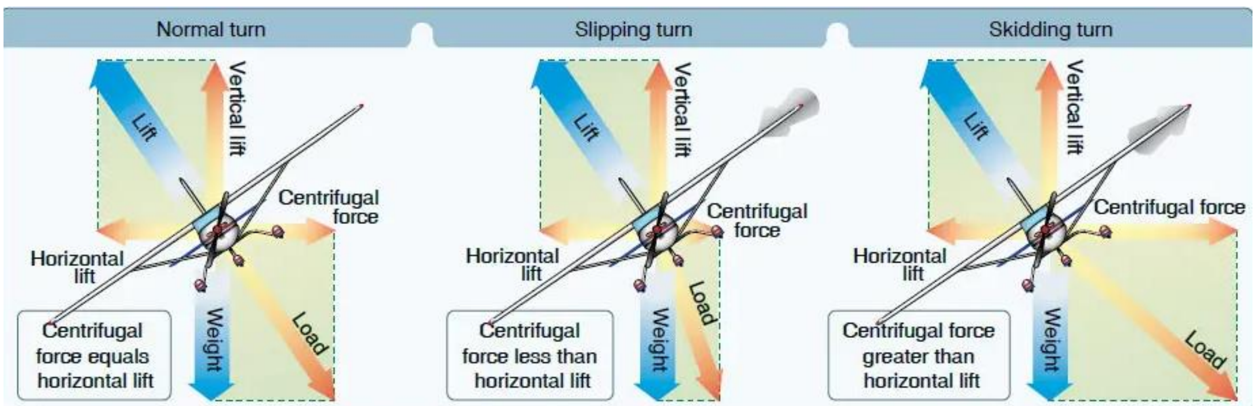
Slips can also happen if the aircraft is turning or not turning. You side slip for a crosswind landing, clearly with no desire to turn at all, unless you are yearning for a runway excursion. You forward slip to lose altitude without gaining airspeed on final approach – with no turn because you want to keep the aircraft on the extended centerline (or on the localizer). But, you can also forward slip to lose altitude during your base-to-final turn, with the advantage of possibly getting a better view of the runway without that nose-thing sticking out in front getting in your way.

And turbulence can induce roll without any aileron input – a slip by definition. This is also a useful slip because slip is why dihedral works. Read more about that in the cleverly named article *Dihedral – How it Works* in the **Supplemental Reading** section of the Academy Curriculum Contents page.

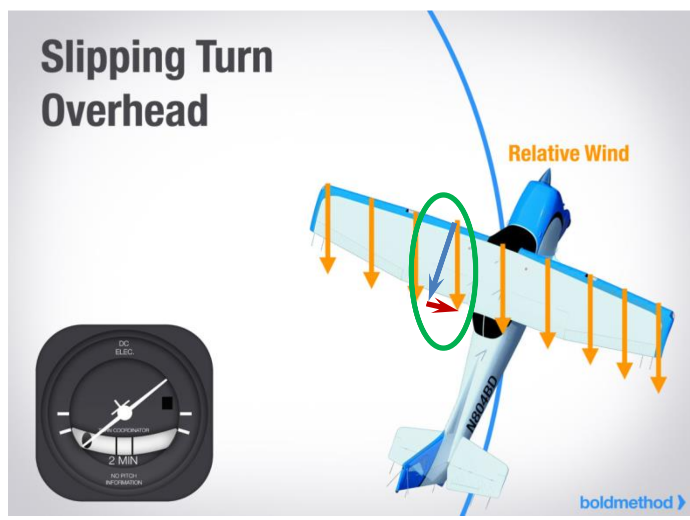
So, What is a Slip?

You can describe it a few different ways (and probably more than the ones I am giving):

1. A slip is an uncoordinated maneuver where the amount of rudder applied is inadequate for the amount of bank of the wing compared to the amount of rudder required for a coordinated turn.
2. A slip is an uncoordinated maneuver where the rudder is applied in the direction opposite the direction the wings are banked.
3. A slip is an uncoordinated turn where the horizontal component of lift (the force that causes an aircraft to turn – see *Turns and the Over-banking Tendency* in the **Supplemental Reading** section of the Academy Curriculum Contents page) is greater than the centrifugal force resulting from the turn radius. The FAA seems to like this definition, or at least they have an illustration for it.



4. A slip is an uncoordinated turn where the nose of the aircraft points in a direction that is towards the outside of the turn (or is outside the turn arc the aircraft makes).
5. A slip is an uncoordinated turn where the nose of the aircraft points at an angle to the relative wind and the angle to the oncoming relative wind (orange arrows) is in a direction opposite the direction of bank (or if you prefer, the nose is to the same side as the raised wing). The nose is "outside" the turn.



Those smart folks at **Boldmethod** (if you don't frequent their web site you should!) have an illustration that covers both #4 and #5.

I use a combination of #3 and #5. Number 3 gives me a picture of the net force – in a slip the horizontal component of lift (towards the center of the turn) is greater than the centrifugal force (away from the center of the turn) resulting in a net force that causes the aircraft to move towards the center of the turn. Number 5 helps describe the aerodynamics that result from the net force pushing the aircraft towards the center of the turn. Added to Boldmethod's illustration (in the green circle) are the component of relative wind due to forward motion of the aircraft (blue arrow) and component due to slip towards the center of the turn (red arrow). Together these two result in the relative wind velocity and direction.

Side Slip and Forward Slip Are the Same

We'll borrow the **[Boldmethod]** Illustration again, this time with the curve representing a turn replaced by a dashed line representing the centerline of a runway. Here the blue arrow in the green oval again represents the wind component due to the forward motion of the aircraft traveling straight down the runway centerline. But now the red arrow is the crosswind so the relative wind across the aircraft is angled in the same direction as it would be in a forward slip (magnitude of the crosswind dictates how much the relative wind angles). The aerodynamics of a side slip are the same as the aerodynamics of a forward slip. The nose of the aircraft is angled with respect to the relative wind and in a direction opposite the direction of wing banking (the nose in the direction of the raised wing - definition #5 of a slip). Here the wings are banked to the left, into the crosswind while the nose is angled to the right of the oncoming relative wind (the orange arrows).

Stalls when Slipping – Relatively Benign

Relatively benign – but like any stall they still deserve respect and awareness (and a knowledge of recognizing an impending stall and avoiding a fully developed stall). At least relative to a *skidding* stall they are more benign. Some have characterized a slipping stall as not too different from a stall in level flight or in a coordinated turn, at least from the standpoint of stall recognition and avoidance. But keep in mind that there is a greater risk of a stall progressing to a spin in an uncoordinated attitude vs. coordinated flight so it would be fair to argue that even a slipping stall is riskier than a coordinated stall.

In a slip, it is the raised wing that loses lift (stalls, if you will but read on) first.

I will confess that I had a hard time wrapping my head around this statement that is not hard to find:

In a slip, it is the raised wing that stalls first *because it has a greater angle of attack*.

Another chance to get you to take a look at: *Dihedral – How it Works* in the **Supplemental Reading** section of the Academy Curriculum Contents page.

You will see in the explanation of how dihedral works that the raised wing experiences (because of dihedral) a lesser angle of attack and you would think that would make it less prone to stalling. And, limiting the analysis to the influence of the lateral movement in a slip combined with wing dihedral, the raised wing's relative wind (vs. the lowered wing) does create a lesser angle of attack, so lesser lift, which creates a rolling moment that causes the aircraft to return to level flight. For the relatively small bank angle usually experienced even in moderate turbulence the reduction of lift due to the *reduction* of the angle of attack is probably the primary aerodynamic phenomenon that occurs.

The Honest Truth is it's Not That Simple

The FAA came painfully close to giving what I think is the best definition of *aerodynamic stall*:

> *A stall is an aerodynamic condition which occurs when smooth airflow over the airplane's wings is disrupted, resulting in loss of lift.*

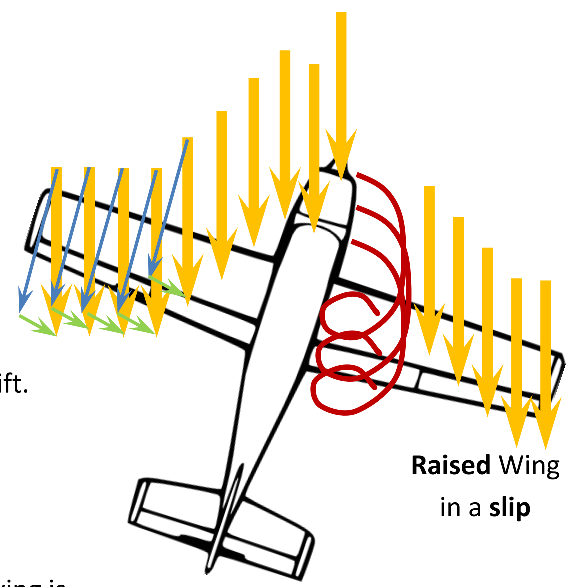
And granted what follows is a worthwhile and probably the most common reason that a stall occurs, but for the sake of understanding stalls in slipping and skidding situations what they continue to say muddies the water:

> *Specifically, a stall occurs when the AOA—the angle between the chord line of the wing and the relative wind—exceeds the wing's critical AOA. It is possible to exceed the critical AOA at any airspeed, at any attitude, and at any power setting.*

The first part is exactly why a stall occurs – the disruption of smooth airflow results in a loss of lift. The second part is just one reason (admittedly, almost always *the* reason) there is a disruption of airflow but anything that disturbs the airflow over the wing can result in a stall (which as the FAA states results in a loss of lift, which may be the more accurate characterization). So I believe that a more complete description is required to explain why the raised wing "stalls" first in a slipping turn.

First let's get a picture of the airflow in a slipping turn. This is a simplification of airflow over an airfoil because even in straight and level flight airflow over an airfoil is a very complex thing. This just helps show the effect of the 'slipping' part of things.

A slip viewed from the top – slipping with the nose pointed to the right so the slip (and turn, if any) is to the left and so the right wing would be raised. You can see that the left (lowered) wing has clean air flowing over it and lift is provided by the chord-wise flow (blue arrows) where the green arrows show the span-wise flow due to slip which provides no lift. So, even the wing that is fully in clean air potentially has a certain amount of disadvantage because only the chord-wise component produces lift.



Raised Wing in a **slip**

But –

The opposite wing is partially in the "shadow" of the fuselage. This blocks airflow and what air does reach the inner part of the wing is turbulent (disturbed), allowing this part of the wing to stall earlier than the outer portion. Even if not stalled the swirling airflow reduces the chord-wise flow effectively decreasing the area of the raised wing (or wing opposite the direction of slip).

Slipping – The Raised Wing Stalls First or Loses Lift First?

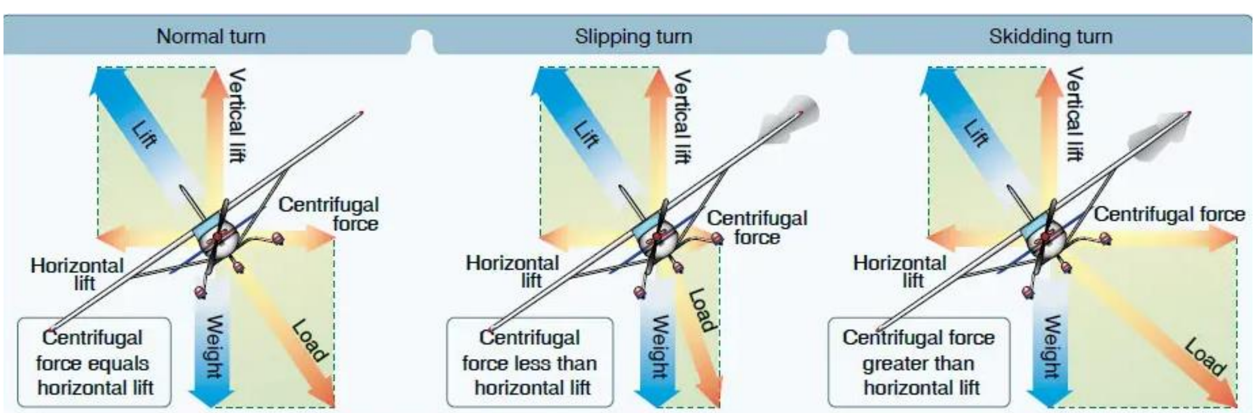
I believe the answer is – both. Or, potentially some combination of both, for the reasons I list below (and maybe some that I did not list). You may not agree with my analysis but to quote the poet Camila in her work *Havana*: “Hey sweetie. If you don’t like my story, go write you own!”

1. Loses lift – the disorganized flow that does reach the inner portion of the raised wing effectively removes the area provided by this part of the wing from lift production. Since
   Lift (L) = $\frac{1}{2}$ $(\rho/g_c)\ V^2\ A\ C_L$
   where ρ is the density of air, V the airspeed, A the area of the wing, C_L the coefficient of lift and g_c the gravitational constant, (effectively) reducing the area A of the raised wing reduces the total lift produced by the wing.
2. Stalls – the disorganized flow over the inner portion of the raised wing allows it to stall earlier than the remainder of the wing.
3. Loses lift – what air does reach the inner portion of the wing is less than the amount of air that passes around the remainder of the wing so this portion, pumping a lesser mass of air downward (in the conservation of momentum principle of lift) or developing a lesser pressure difference across the wing (in the conservation of energy principle of lift) and therefore less total lift.
4. Stalls – Here you, the pilot, plays a role. As the raised wing loses lift you want to maintain the bank you apply aileron, which deflects downward on the raised wing, increasing the camber of that section of wing, increasing angle of attack thereby increasing the risk of (or inducing a) stall.
5. Loses lift and stalls – All that air banging against the side of your aircraft slows you down so reduces lift (the V^2 term in the lift equation). So if you do not want to lose altitude or do not want to lose altitude too fast then you pull back on the stick, increasing the angle of attack and bringing the wings closer to the critical angle of attack. Yes, this affects both wings but with all the other things degrading the lift of the raised wing this is the one that is more likely to drop first.

What is a Skid?

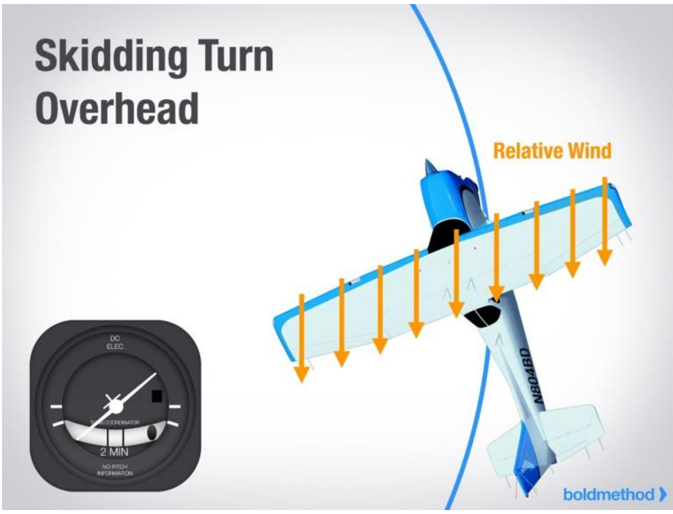
Like a slip you can describe it a few different ways.

1. A skid is an uncoordinated maneuver where the amount of rudder applied is more than what is needed for the amount of bank of the wing compared to that required for a coordinated turn.
2. A skid is an uncoordinated maneuver where the rudder is applied in either direction when the wings are not banked (a “boat turn”).
3. A skid is an uncoordinated turn where the horizontal component of lift (the force that causes an aircraft to turn – see *Turns and the Over-banking Tendency* in the **Supplemental Reading** section of



the Academy Curriculum Contents page) is *__less__* than the centrifugal force resulting from the turn radius. The FAA seems to like this definition too as this one also is included in their illustration.

4. A skid is an uncoordinated turn where the nose of the aircraft points in a direction that is towards the inside of the turn.
5. A skid is an uncoordinated turn where the nose of the aircraft points at an angle to the relative wind and that angle to the oncoming relative wind (orange arrows) in the same direction as the bank (or if you prefer, nose to the same side as the lowered wing). The nose is "inside" the turn.



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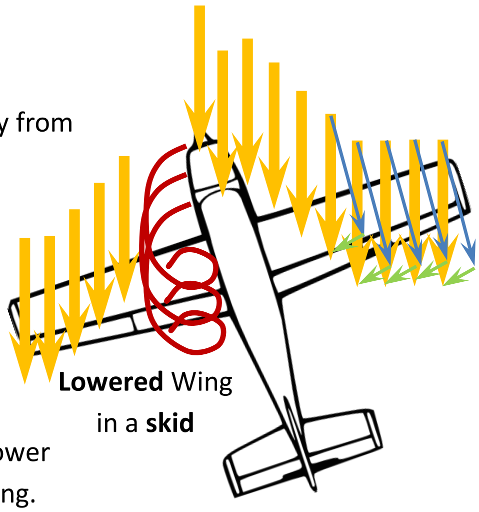
Like slips I use a combination of #3 and #5 when I am thinking about a skid. Number 3 gives me a picture of the net force – in a skid the horizontal component of lift (towards the center of the turn) is less than the centrifugal force (away from the center of the turn) resulting in a net force that causes the aircraft to move away from the center of the turn. Number 5 helps describe the aerodynamics that result from the net force pushing the aircraft away from the center of the turn (outwards from the turn).

Skidding – The Lowered Wing Stalls / Loses Lift First

All the same things happen in a slip as in a skid except it is the lowered wing that is affected so that is the wing that stalls / loses lift first.



Here the turn is to the left. The nose is "inside" the turn and the skid is away from the center of the turn. The skid is what causes the component of the relative wind which points towards the center of the turn (the short green arrow). And, as you can see all the "bad air" is on the inside wing. So in this case you might add a sixth reason to the list:

6. Stalls – In a steep enough skidding turn the higher speed of the outer wing (and cleaner air) may produce an overbanking tendency.
   To counteract this, the pilot may apply opposite aileron increasing the lower wing's angle of attack subsequently increasing the risk of stalling that wing.

If it's the Same, Why 'Stalls Good, Skids BAD'?

The simple answer is that if you lose lift from the raised wing of a slipping airplane the wing drops and becomes level. Within certain limits (which generally are governed by aircraft design) loss of lift in a skid is self-correcting. Even if the wing actually stalls it falls to a more favorable attitude and has a roll rate that allows more time to recognize and correct the stall vs. a skidding stall. Likewise an impending stall can be recognized and a stall avoided altogether if the loss of lift in the impending stall and leveling of the wings does not prevent the stall by itself. But DON'T BE FOOLED – a slipping stall can also result in a spin (sometimes termed an ‘over-the-top’ spin) which can be dangerous if you are at a low above-ground level or do not have experience in spin recovery. A slip performed for the purpose of altitude loss or to compensate for a crosswind is safe if you do it in a controlled manner, remain keenly aware of signs of incipient stall and maintain proficiency at performing slip maneuvers. I would venture to say that stalls while slipping occur predominantly because the pilot is unaware of the poorly coordinated turn configuration and is startled (with resulting further delay in recovery measures) by the over-the-top rolling in the opposite direction of the turn.

In a skid the aerodynamics (including the disrupted airflow) are the same but it is the lowered wing that is affected by the adverse airflow – so it drops even further, and does so quickly. Before you know it you’ve done a snap roll, and maybe not a full roll to level again and that would be the problem. As the lowered wing begins to drop further a lot of pilot-aircraft coupling comes into play. The nose also drops, so you pull back on the yoke but your elevator (due to the steepening bank) starts acting in part like a rudder, further increasing the skid. And, you of course try to counteract the dropping wing by adding aileron, which causes the aileron of the lowered wing to move down, increasing the chord and thereby the angle of attack which worsens the stall. All of this happens very quickly and is, in fact, how a snap roll is performed. But unless you are doing this intentionally with adequate altitude and are a trained aerobatics pilot you probably will not complete the roll which will lead to you having a very bad day. And if done at low absolute altitude you may not have time to complete the roll. Skilled pilots demonstrating the skidding stall-spin require several hundred feet to recover. Not usually the available height AGL in the pattern. And that’s for a pilot with aerobatic training and practice.

Any time you are close to the ground the outcome of a skidding or slipping stall gets worse. The classic high-risk time is the base-to-final turn where there is temptation to add more rudder to correct for overshooting the extended centerline of the runway. Low altitude, low speed on approach, sometimes banking that is too steep (so, overbanking tendency) – add more rudder to try to get back to the centerline and … snap roll. And in a decent, *even in a coordinated turn* it is the lowered wing (inside wing) that stalls first.

A time when you could experience a stall in a slip is on departure if you have sloppy (or no) rudder use and are doing a departure turn. Relatively low speed, high angle of attack, high weight (all that fuel because you’ve just taken off) and lack of awareness that you are slipping at all can catch you by surprise. And here, *even in a coordinated turn* it is the raised wing that stalls first in a climb which adds to the possibility of that raised wing developing a stall resulting in an over-the-top spin.

And possibly the most dangerous move the FAA has made to date – requiring CFIs to instruct student pilots on turning back to the departure airport in the event of engine failure. Do you think they’ll be thinking “Now easy on the rudder and let the plane turn smoothly. Plenty of time to get turned around. No worries just because the engine is not running”. I believe what they will be thinking is that they want to do everything they can to swing that nose around quickly. And if the pilot is not the one thinking those thoughts I’ll bet their spouse, kids, friends and other passengers with them will be doing all they can to convince them to ‘stand on that rudder’. But that’s just my opinion, I could be wrong. But if you want to read more about this from my perspective please see the article *The Impossible Turn* in the **Supplemental Reading** section of the Academy Curriculum Contents page.