11 Slips, Skids, and Snap Rolls

11.1 A Lesson on Snap Rolls

One fine spring day I was instructing a student who had about 5 hours experience. This was her first lesson in slow flight, but she was doing really well: she was maintaining the assigned altitude, the assigned heading, and the assigned airspeed (a couple of knots above the stalling speed). She was also doing a good job of keeping the inclinometer ball in the center, which required considerable pressure on the right rudder pedal because of the high power and low airspeed. I was really enjoying the flight, but suddenly I developed a feeling that there was something wrong. Gradually it dawned on me what the problem was. The problem was that the airplane was upside down.

Here's what had happened: her right foot had gotten tired, so she just removed it from the pedal --- all at once. This produced a sudden yaw to the left. Naturally the left wing dropped, so she applied full right aileron. The nose was dropping, too, so she pulled back sharply on the yoke. The next thing anybody knew, we were upside down.

I took the controls and rolled the plane right-side-up. (See section 16.21 for more about this.) We lost about 500 feet of altitude during the maneuver. The student asked "What was THAT?" and I said "That was a pretty nice snap roll".

This is indeed the recipe for a snap roll: starting from a speed slightly above the stall, apply a sudden yaw with the rudder, apply opposite aileron, and pull back on the yoke. SNAP! --- One wing stalls and the plane rolls over. In our case, we didn't roll exactly 180 degrees --- "only" about 135 degrees --- but that's upside down enough for most people. It took a fraction of a second.

In due course the student completed her training and got her license. She's even still speaking to me. There are a number of points to be learned from this adventure:

- Although the airplane we were flying (a Cessna 152) has a reputation for being a docile aircraft, you should remember that even pussycats can bite. It is all too easy to picture the same thing happening just after takeoff, with insufficient altitude available for a recovery. This is the classic stall/spin accident that figures so prominently in the accident statistics. Don't get complacent --- it could happen to *you.*
- This is why we practice slow flight and stalls a few thousand feet above the ground, and make sure there are no other aircraft nearby.
- This is why we make sure that fire extinguishers, chocks, tow bars, etc. are secure, not floating around in the back of the plane. I don't want to be picking them out of my ear during the snap-roll recovery.
- This is why we insist on maintaining coordinated flight (except for intentional slips, which are a special case). Keep the ball in its house. Don't apply right aileron without also applying right rudder. Don't apply left aileron without applying left rudder.

Let me reiterate: Piloting an airplane at low speeds requires using the rudder pedals. If you don't know how to do this correctly, you have no business trying to land, take off, or anything else.

11.2 Intentional Slips

Slips are used for crosswind landings. They are also used when you want to create extra drag, for instance to steepen an approach.

By definition a *slip* is any condition where the airflow is misaligned left or right relative to the fuselage.

Normally, an intentional slip should always be a proper slip (as opposed to a skid, for reasons discussed in section 11.3).

A proper slip is performed by lowering one wing with the ailerons, and then applying opposite rudder. We say a proper slip uses "top rudder" because you are pressing the rudder pedal on the same side as the raised wing.

Because the rudder is deflected, the air will be flowing somewhat *across* the fuselage. This creates much more drag than the usual streamlined flow *along* the fuselage. This is often useful for dissipating energy, e.g. for making the aircraft descend more rapidly on approach (section 7.7.1). Make sure you have plenty of airspeed when doing this; an uncoordinated stall is a good way to produce a snap roll or a spin.

The crosswise flow not only creates drag (a rearward force) but also creates a sideways force that tends to change the direction of flight, as discussed in section 8.10. A slip, therefore, can be viewed as a boat turn in one direction (because of the crosswise flow), possibly combined with an ordinary turn in the other direction (because of the bank angle).

If you match the rudder deflection to the bank angle just right, no net turn results. This is called a *nonturning slip*.

Nonturning slips are used during crosswind landings, as discussed in section 12.9. The upwind wing is lowered using the ailerons and the opposite rudder is used to prevent the aircraft from turning. The idea is that the bank determines the direction the airplane is *going*, while the rudder determines the direction the airplane is *pointing*. The idea is to make sure, despite the crosswind, that the direction of flight *and* the axis of the airplane are both aligned with the runway.

The definition of a slip "to the left" versus a slip "to the right" is a bit arbitrary and hard to remember. The following table may help. In a slip to the left:

"left" slip, matching statement	mismatching statement
the airplane is moving toward a point that is somewhere to the left of the nose	the nose is pointing to the right of the direction of flight
the air is hitting the left side of the fuselage	you are applying right rudder
the inclinometer ball is displaced to the left	the slip string is displaced to the right
if this is a nonturning slip, you are banked to the left	if you are not banked, you are making a boat turn to the right

Because of the potential for confusion, I try to avoid the term "slip to the left" entirely. Instead, I might say "let's make a boat turn to the right" or "let's lower the left wing and perform a nonturning slip".

Some folks try to define the terms *side slip* and *forward slip*, but any such distinction is unhelpful. In figure 11.1, depending on your intentions, you could be making a side slip to runway 11 or a forward slip to runway 9. But you could change your intentions at any point before the flare.

The right way to think about it is simple: During the approach, you are performing a nonturning slip toward the runway intersection, and that's all that need be said. Aerodynamically speaking, there is no meaningful difference between forward slip and side slip. Both are synonymous with nonturning slip.

Figure 11.1: Side Slip Indistinguishable From Forward Slip

In some aircraft the airspeed indicator is grossly perturbed by a slip, as mentioned in section 2.12.7.

In a typical Cessna 152/172/182, depending on the amount of slip, the airspeed can easily be off by 20%, which means the energy is off by 40%. This is enough to cause real trouble. In some less-common aircraft, you can send the airspeed needle below zero.

Suppose the static port is on the left side of the fuselage, and suppose you are in a slip to the left (the kind that requires pressing on the right rudder pedal). In this situation, the left (upwind) side of the fuselage is a high-pressure point. This high pressure cancels some of the dynamic pressure in the Pitot tube, so the airspeed indicator will lose airspeed.

Now suppose you are in a slip to the right. The static port is now on the downwind side. This will *not* be a low-pressure point. In fact, it could have almost as much high pressure as the other side, because of pressure recovery, as indicated in figure 4.10. More likely, there will be will be relatively little pressure recovery, as illustrated figure 4.9, and the static port will measure something rather close to the real static pressure.

Therefore: In a slip toward the side with the static port, expect the airspeed indicator to lose a lot of airspeed. In a slip toward the other side, expect a smaller loss.

Better yet, ignore the airspeed indicator and determine the angle of attack by looking out the window. Observe the pitch attitude relative to the direction of flight. Don't forget that because of drag caused by the slip, the new direction of flight will be angled more downward. Find a new landmark that remains a fixed angle below the horizon.

11.3 Skids

The term *skid* denotes a particular type of slip that occurs when the airplane is in a bank and the uncoordinated airflow is coming from the side with the raised wing. Typically this happens because you have tried to speed up a turn using "bottom rudder", that is, pressing the rudder pedal on the same side as the lowered wing.

We use the term *proper slip* to denote a slip that is not a skid.

If you have plenty of airspeed, the aerodynamics of a skid is the same as the aerodynamics of a proper slip. In both cases there is air flowing crosswise over the fuselage. However, you should form the habit of not skidding the airplane, for the following reason.

If the aircraft stalls, any slight crosswise flow will cause one wing to stall before the other. In particular, having the rudder deflected to the right means the aircraft will suddenly roll to the right. If the aircraft is in a 45 degree bank to the right and rolls another 45 degrees in the same direction (because you were applying right rudder pressure), it will reach the knife-edge attitude (wings vertical). If on the other hand you were holding top rudder (still holding right rudder but banking to the left this time), a sudden roll of 45 degrees would leave you with wings level (which is a big improvement over wings vertical).

If the wings are level, you can make a proper slip to the left or to the right; a skid is impossible by definition.

* Bottom Rudder: Right vs. Wrong

It is appallingly easy to set up a situation that leads to an unintentional skid. Suppose you are ready to make a left turn from base to final. You start the turn improperly, by applying a little left rudder. The crosswise airflow pattern acting on the dihedral of the wings will cause the airplane to bank to the left and make a relatively normal turn in the desired direction. You absent-mindedly maintain the left rudder pressure, so the bank continues to steepen. You decide to apply right aileron to prevent further steepening of the turn. That's all you need: you are in a skidding left turn, holding left rudder and right aileron, at low altitude. If you stall, you'll never be heard from again. Seriously, folks, this could happen to *you*.

> Never apply more bottom rudder
> than is needed to center the inclinometer ball.

There are only a few cases where bottom rudder is appropriate, for example:

1. If you are already turning to the left and use left aileron deflection to steepen the turn, you will need left rudder deflection in proportion to the aileron deflection, because of adverse yaw and yaw-wise inertia, as discussed in section 8.8.
2. In a steady bank to the right during a low-airspeed, high-power climb, you may need some right rudder deflection to compensate for engine torque effects (mainly the effect of the helical propwash hitting the vertical fin and rudder, as discussed in section 8.4).
3. In a long-winged airplane in a steep turn at low airspeed, the long-tail slip effect will require you to hold bottom rudder to maintain coordination, as discussed in section 8.9.
4. In a multi-engine airplane with one engine inoperative, you need to bank the airplane toward the side with the working engine, and deflect the rudder toward the same side, as discussed in section 17.1.5.

Note that in all these cases you apply only enough bottom rudder to maintain coordinated flight. Do not skid!

11.4 Anticipate Correct Rudder Usage

As discussed in chapter 8, there are four or five things that can cause the airplane to yaw. Your job is to use the rudders to eliminate the unwanted yaw, so that the airplane is always pointing the way it is going.

The objective is to *anticipate* how much rudder is required in various circumstances, so you aren't constantly correcting for errors.

The hardest thing to deal with is yaw-wise inertia. The rule is: rolling to the left requires left rudder; rolling to the right requires right rudder. The amount of rudder pressure should be proportional to the rate of roll. Adverse yaw complicates the situation, and requires rudder deflection whenever the roll rate does not match the aileron deflection. To a fair approximation the two effects can be covered by the rule: “rudder deflection proportional to aileron deflection”.

Note that (unlike yaw-wise inertia) adverse yaw occurs even if you aren’t turning. Suppose that a wind gust causes the left wing to drop. You immediately use right aileron to raise the wing. Right rudder is required. Don’t get the idea that rudder is only required when you intend to turn.

Another tricky case arises when you make your first left turn after takeoff. You are holding a large amount of right rudder pressure because of the helical propwash, and you need to apply left aileron. Rather than using actual left rudder pressure, it probably suffices to use a reduction in right rudder pressure. This is harder to learn than it sounds. You may find it more convenient to *maintain* whatever right-rudder pressure is required to compensate for the helical propwash, and to make left turns by applying countervailing force on the left rudder pedal.

If you have a rudder trim control, by all means use it to compensate for the helical propwash effect.

11.5 Perceiving Slip, Perceiving Coordination

11.5.1 Looking Out the Side

To learn good coordination, first practice looking out the side. When you roll into a turn, you should see the wing go up or down like a flyswatter. If it slices down-and-forward, or up-and-backward, you are not using enough rudder.

You can control the airplane quite nicely while looking out the side. You can judge pitch attitude by the angle the wing chord makes with the lateral horizon. You can judge bank angle by the height of the wingtip above or below the horizon. And, as just mentioned, you can judge coordination by watching for forward or backward slicing motions when you roll into or out of a turn.

It is really important to be able to do this. Just for starters, there is no way you can do a decent job of scanning for traffic if you can’t control the airplane precisely while looking out the side.

I even have my students do fancy things like stalls (and stall recoveries) while looking out the side.

Don’t be a “gauge junkie” --- the sort of pilot who can’t even fly a rectangular traffic pattern except by reference to the directional gyro. When making a 90 degree turn, identify a landmark 90 degrees from your original heading and turn toward it. No gauges are required.

11.5.2 Looking Out the Front

The next step is to learn how to perceive correct coordination while looking out the front. This requires having a precise visual reference. There are several ways to arrange this.

Start by getting the airplane trimmed for straight and level flight at a reasonable airspeed, headed toward a definite point. In the figure, the plane is headed toward a point a couple of degrees to the right of the mountains.

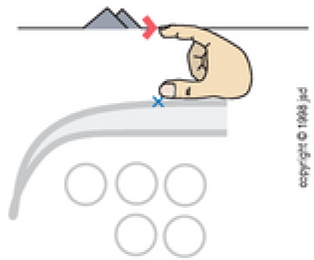

Figure 11.2: Finger Used as Heads-Up Display

You can now use your finger as a reference, as shown in figure 11.2. Rest your hand on the top of the instrument panel and align your finger with the straight-ahead point on the horizon.

Another option is to use a mark on the windshield, as shown by the red wedge in the figure. It really helps to have a mark that falls very close to the line from your dominant eye to the aim point on the horizon, so if you can't find a scratch or a bug-corpse in just the right point, you should *make* a mark. You can use a grease pencil, a washable marking pen, a bit of tape, or whatever.

A single reference of this sort only works if your head is in the right position --- wherever it was when you established the reference. Since you need to move around to look for traffic, be careful to move back into position before using the reference.

If you want to get really fancy, you can use *both* a finger and a mark on the windshield. That makes it easy to detect if your head is out of position. This also helps rule out the image from your non-dominant eye (although the easiest thing is to close that eye if it is confusing you).

Figure 11.3 shows how the situation should look after rolling smoothly into a turn to the right with 30 degrees of bank.

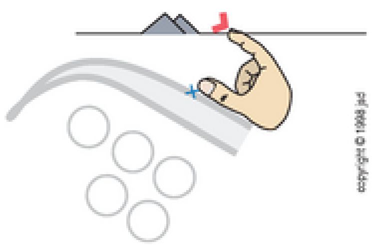

Figure 11.3: Heads-Up Display, Starting a Turn

You should use the visual reference as your primary indicator of pitch attitude and heading. Throughout the roll-in, turn, and roll-out, the rate of turn (i.e. the rate of heading change) should be proportional to the amount of bank. As the bank increases, the rate of turn should increase.

The rate of turn should be proportional to the amount of bank.

It is common mistake to think that the airplane should simply pivot on its axis (roll-wise) and *then* start turning (horizontal-wise). If you look closely, you will see in figure 11.3 that the sight line has already moved to the right a little. This represents the amount of turn that occurred during the roll-in. (If you roll in more slowly, this amount will increase.) Remember: The rate of turn should be proportional to the amount of bank. If the sight mark initially stands still (or backtracks!) and only later starts turning in the proper direction, it means you aren't applying enough rudder to compensate for yaw-wise inertia (and adverse yaw).

During the roll-out, the same rule still applies: the rate of turn should be proportional to the amount of bank. As the bank goes away, the rate of turn should go away. (Of course, the proportionality factor always depends on airspeed, but at each airspeed there is a definite proportionality between bank and rate of turn.) If you neglect to compensate for yaw-wise inertia, the nose will overshoot (yawing toward the continuation of the turn).

Summary: Don't let the nose backtrack on roll-in. Don't let the nose overshoot on roll-out. The rate of turn should be proportional to the amount of bank. The yaw-wise inertia and adverse yaw lead to the rule: rudder deflection should be proportional to aileron deflection.

You can see in figure 11.3 why we went to the trouble of putting a mark on the windshield, rather than using, say a bolt on the cowling at the location marked by the cross in the figure (near the end of your thumb). Such an off-axis reference will not exhibit a rate of turn proportional to the amount of bank. As you can see, the problem is that the cross necessarily rotates a little ways to the outside of the properly-coordinated turn. If you tried to prevent this reference from swinging to the outside of the turn, you would be applying too much rudder during the roll-in. The amount of the error would depend on the angle between the bogus sight line and the actual roll axis --- which depends on the shape of the airplane and the height of the pilot.

Once you have learned to make really good turns using the roll-axis sight mark, you should gradually learn to do without it. Make a point of imagining where the mark *would be* relative to other visual references such as the cowling, the window-frame, et cetera.

Later (after making a few hundred coordinated turns) you should be able to do it with your eyes closed, just by knowing how the controls should feel.

By the way: as you may have noticed, the sight line in figure 11.3 is slightly above the horizon. This is because you need to pitch up a little bit to deal with the load factor in the turn.

Notes: (1) If you make a mark on the windshield, use a bright color, since black is too hard to distinguish from traffic. (2) The best time to make the mark is before takeoff. Taxi into position at the end of a long taxiway, and make a mark that lines up with the horizon at the far end. Even if the pre-flight mark is not perfect, it will facilitate making a better mark later.

11.5.3 Using the Inclinometer Ball

The inclinometer ball will remain almost centered throughout the roll-in, turn, and roll-out if everything is done correctly. There are several reasons why you should not over-emphasize this instrument: (1) The response of the ball to coordination errors is sluggish and complex, so you have to be quite an expert to get useful feedback from it. In particular, I see lots of pilots who apply approximately the right amount of rudder, but apply it too late or too early. Diagnosing such errors using just the ball is nearly impossible; other references are more informative. (2) In general, anything that can be done by outside references should be done by outside references. (3) When rolling into or rolling out of a turn, there will be a force on the rudder which must be balanced by a horizontal component of lift (i.e. a slight bank) in order to maintain zero slip. See section 17.1.4 for an explanation of why having the ball in the center is not exactly what you want (but nearly so).

The inclinometer ball definitely is helpful for providing information about a long-term slip --- in particular, for telling you how much rudder trim to dial in during a high-power / low-speed climb.

Especially in an unfamiliar airplane, it can be hard to tell whether one wing is down a little bit, without referring to the ball.

11.5.4 Using the Seat of Your Pants

The phrase “flying by the seat of your pants” has become such a common cliché that people forget its real meaning: you can use the sense of touch in your rear end to determine whether or not your control usage is properly coordinated.[1]

The idea of using your rear end as an inclinometer might sound trivial or obvious; after all, even non-pilots can notice immediately if they sit down on a park bench that is inclined. But the non-pilots are probably cheating, using their sense of sight (referring to the horizon) and their sense of which way is up (based on the acceleration-detecting organs in the inner ear). In the airplane, as you roll into a turn, the situation is much more challenging. First of all, you want the load vector (gravity plus centrifugal force) to be directed straight down into your seat (perpendicular to the wings, not to the horizon) --- so visual reference to the horizon doesn’t tell you what you need to know about inclination. Secondly, the organs of your inner ear are sensitive not only to the load vector but also to the rate of roll --- so they don’t tell you what you need to know, either.

This is a good illustration of why learning to fly an airplane is hard: the airplane is inclined (relative to the horizon) but it is not inclined (relative to the load vector). One sense (sight) conflicts with two others (inner ear and seat of pants).

Because the sense of sight is so dominant, the visual references discussed in section 11.5.1 and section 11.5.2 are the typically the easiest way to learn proper coordination. But you should also pay attention to what the seat of your pants is telling you. If you are being sloshed side to side as you roll into a turn, there is something wrong. It may help to close your eyes while the instructor makes a series of coordinated and uncoordinated turns.

While we are on the subject of the sense of touch: as you get experience with a particular airplane, you will learn how much force is required on the rudder to go with a certain amount of force on the ailerons (depending on airspeed, of course). Once you’ve got the feel of the controls, you should be able to make a decent turn without much thought or effort.

Flying by the seat of your pants may sound like a throwback to the days when airmail was carried in fabric-covered biplanes, but it is a useful technique even in modern instrument flying. Proper coordination is still important, and modern airplanes still suffer from yaw-wise inertia and adverse yaw, especially at approach speeds. As you maneuver to stay on the localizer, you don’t want to be looking at the inclinometer ball --- you’ve got too many other things competing for your visual attention.

11.5.5 Intentional Slips

The previous sections concentrated on how to maintain coordinated flight. Sometimes, though, you want to perform a slip. You might want to get rid of some energy, or to align the airplane for a crosswind landing. The procedure is straightforward.

1. Make a note of the pitch attitude and direction of flight, since in some aircraft the airspeed indicator is perturbed by a slip, as discussed in section 11.2. You will have to maintain angle of attack by looking at the angles themselves.

2. Make a note of which way the airplane is *going*. For a crosswind landing, maneuver so that the motion is aligned with the runway.
3. Make a note of which way the airplane is *pointing*. Call this heading *A*.
4. Using the rudder, yaw the nose to a new direction. Call this heading *B*. For a crosswind landing, choose this to be aligned with the runway.
5. Bank the airplane as required to keep it going the same direction as before.

The difference between heading *A* and heading *B* is the slip angle.

11.5.6 Slip Angle versus Bank Angle

Do not confuse slip angle with bank angle. In fact, they are perpendicular. That is, slip involves a yaw-wise rotation, while bank involves a roll-wise rotation, as defined in section 19.6.1.

Although in a non-turning slip you can perhaps judge the amount of slip by the amount of bank, in general perceiving the bank angle is a rather poor substitute for perceiving the slip angle.

If you don't use the rudder, then

- A roll, i.e. a *change* in bank, can be a major cause of slip, because of adverse yaw and yaw-wise inertia, as discussed in section 8.8.
- In contrast, a *steady* bank produces a relatively minor amount of slip, via the long-tail slip effect, as discussed in section 8.9.

Using the rudder and ailerons, you can perform a wings-level boat turn, which involves a slip angle with zero bank. See section 8.10.

In a twin with an engine out, you can have a turn with no bank and no slip, or a slip with no bank and no turn, or (preferably) a bank with no turn and no slip. See section 17.1.

Causes of slip include:

- rudder deflection,
- aileron deflection and roll rate,
- asymmetric thrust, and
- tight turns (via the long-tail slip effect)

Causes of turn include:

- bank, and
- slip (via the boat-turn effect)

11.6 Summary

- A proper slip results from applying more top rudder (or less bottom rudder) than required for coordinated flight.
- A skid results from applying more bottom rudder (or less top rudder) than required for coordinated flight.

A skid is more dangerous than a proper slip, because it is more likely to flip you upside down if anything goes wrong. Therefore, never apply excess bottom rudder (no exceptions). To say it another way, never try to speed up a turn with the rudder (no exceptions). Never try to roll out of a turn without applying coordinated rudder (no exceptions). Right aileron deflection requires right rudder deflection; left aileron deflection requires left rudder deflection.

Section 16.6 discusses some good coordination exercises.

1

In common usage, the phrase is a metaphor for any situation where the practitioner has such a good feel for the situation that quantitative information is superfluous --- or where the practitioner is forced to rely on imprecise indications because quantitative information is unavailable.

12 Landing

> Pilots spend a lot of time doing “traffic pattern work” --- a series of touch-and-goes. Non-pilots imagine this as being analogous to driving into a parallel-parking space, then immediately pulling out, driving around the block, and repeating the process --- over and over again.

Landings involve procedures and perceptions that are just a little bit different from those involved in other phases of flight. A few of them are discussed in this chapter. (Special procedures for forced landings are discussed in section 15.1.)

12.1 Planning the Approach

The approach checklist should cover *three* things: approach, landing, and go-around. At the point where you decide to perform a go-around, you will be in no mood to go looking for a checklist.

By the same logic, by the time you are established on downwind in preparation for landing, it is already too late to be reading the approach checklist. Therefore, the practical way to use the approach checklist is to review it *before* entering the traffic pattern. A few miles from the airport, read the checklist, think about it, and commit it to memory. Say it aloud several times if you like.[1] Short-term memory is considerably more reliable than long-term memory. Remember that the checklist is not a “do-list”; you don’t have to do each item at the moment you read it on the checklist.

You probably want to make a pocket checklist, as discussed in section 21.6. Make sure you use a written checklist that applies to the airplane you are actually flying. That is, don’t bother trying to memorize some “universal” checklist. Different airplanes have different checklists.

12.1.1 Other Planning Issues

In flight, you know you have to land sooner or later, but you should never allow yourself to get into a situation where you think you have to land on *this* runway *right now*. If you are approaching a soft, narrow, short runway with gusty crosswinds and the setting sun in your eyes, it might be a lot safer to land somewhere else. You might have to get a ride from the second airport back to the first, or you might just wait on the ground until conditions improve.

12.1.2 Traffic

On approach and in the traffic pattern, be extra-careful to see and avoid other traffic. This is discussed in section 16.2.

12.1.3 Obstacle Clearance

A particularly risky combination is night VFR at an unfamiliar field. I recommend you don't attempt this, unless you remove at least one of the risk factors.

- If you are planning night VFR, stick to fields that you have visited in the daytime often enough to know the tricks for avoiding the local obstacles, if any.
- If you are going to an unfamiliar field at night, follow the IFR procedures. Don't try to invent your own procedure, because non-IFR sources such as the A/FD and sectional charts simply do not give you enough information to do this safely.
- If you are going to an unfamiliar field VFR, go in the daytime, in good weather, so you can see the terrain and obstructions.

See section 13.7.5 and section 21.4 for more discussion of these points. Don't get complacent. You may know of dozens or hundreds of airports where obstacles are easy to avoid ... but sooner or later you will visit an airport where obstacles are a real threat, and you don't want to run even a small-percentage chance of finding this out the hard way.

If the approach procedure says "no circling southeast of the field" you should take the hint.

Don't descend below a safe circling altitude until you have a nice view of the green threshold lights. They should *not* be blinking or twinkling, as discussed in section 12.3.

12.2 Judging Left or Right

Let's consider how things are supposed to look on final approach. One important ingredient is to be correctly lined up left/right. The task of getting lined up with a far-away object, without any intermediate guideposts, is unfamiliar to most people.

Figure 12.1, figure 12.2, and figure 12.3 show how the runway looks if you are lined up too far to the left, perfectly on the runway centerline, or too far to the right (respectively).

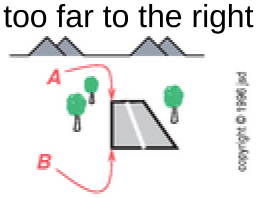

Figure 12.1: Lined Up Too Far Left

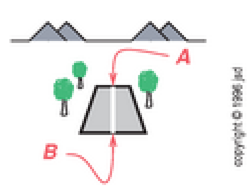

Figure 12.2: Lined up On The Centerline

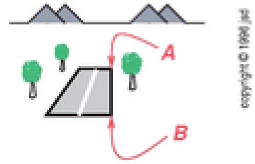

Figure 12.3: Lined Up Too Far Right

The distinctions are easy enough to perceive, once you learn how. In all cases, one of the key ideas is to notice that point *A* lies directly above point *B*. That means you are lined up on the line from *B* to *A*. In particular, we see that in figure 12.1 and figure 12.3, you are exactly half a runway-width to one side. That is, you are lined up on one of the runway edge lines. If you continue with such an approach, you will mow down all the runway edge lights.

If while on final you perceive that you are lined up left or right of the extended centerline, you should *not* just fly directly toward the point of intended landing. Instead, you should fly over to the extended centerline *now* and then follow it to the runway. The objective is to be *traveling in the right direction* when you arrive at the runway.

As discussed in section 12.6.2 and section 12.11.1, you will not be able to see the runway centerline during critical parts of the flare, touchdown, and initial rollout. You need to maneuver to reference to the runway *edge*. You should start applying this skill on short final. If the runway is 40 feet wide, you should say to yourself "I'm lined up 20 feet this side of the edge line.... I'm lined up 20 feet this side of the edge line...".

Land on the center line
by reference to the edge line.

Don't fixate on the centerline --- it will disappear during the flare.

12.3 Judging High or Low; Rule of Thumb

Even more important than having the left-or-right alignment is having the proper up-or-down alignment of the approach path. There are several ways to do this.

One of the worst ways is to use "*local tricks*", such as passing over the pond at 1500 MSL and then passing over the old red barn at 1000 MSL. Such an approach procedure doesn't work too well when you visit other airports.

The smart way to control the slope of the glide is to observe and control the slope angle directly. On an instrument approach, the electronic glideslope needle defines a 3 degree angle for you. At some airports there is a visual aid such as a VASI to define the angle for you. At most airports, though, there is no such guidance, so you simply must learn to perceive angles accurately.

Most people are terrible at judging angles using the unaided eye. Therefore I recommend the following rule of thumb:

A thumb at arm's length subtends four degrees.

Specifically, the rule of thumb refers to the distance between the last joint and the end of the thumb, as shown in figure 12.4.

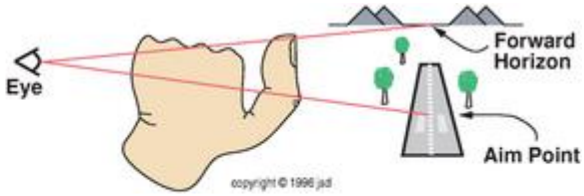

Figure 12.4: Rule of Thumb --- 4 Degree Glideslope Angle

To use this rule, hold your thumb at arm's length, and arrange it so your sight line over the end of the thumb extends to the forward horizon, as shown in the figure. Then the sight line over the last joint of the thumb will be four degrees below the horizon. If this sight line extends to your chosen aim point, you know you are on a nice 4 degree glideslope.

In order to make clear the geometry of the situation, figure 12.4 shows how your eye, your thumb, etc. will appear as viewed by your copilot. Figure 12.5 shows how it looks from your own point of view.

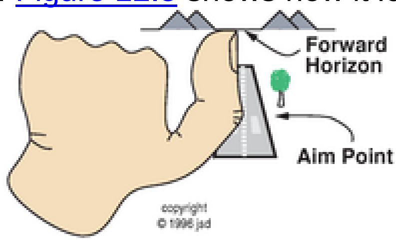

Figure 12.5: Rule of Thumb, Pilot's View

Note that for reasons discussed in section 12.7.3, the aim point is generally not the runway threshold.

Your thumb may not be exactly the same size as mine, but if your thumb is smaller your arm is probably shorter and the angle is probably close to four degrees. In any case, you should learn what angle is subtended by your own thumb[2] --- it comes in really handy.

Another application of this "rule of thumb" is to help perceive the destination of a power-off glide, as described in section 15.1.4.

The next question is, how do you know you are actually *following* the 4 degree glideslope, as opposed to merely passing through it? Answer: as long as you remain on that glideslope, the aim point will *remain* four degrees below the horizon.

This is the correct strategy: throughout the final approach segment, your chosen aim point should remain below the horizon by the desired number of degrees.[3] To say it the other way, if the angle between the horizon and your aim point is changing, then your *intended* destination is not your *actual* destination.

If the angle from the horizon to the aim point is increasing, you are going to land long; if the angle is decreasing, you are going to land short --- unless you somehow change what you're doing. The logic of this is shown in figure 12.6.

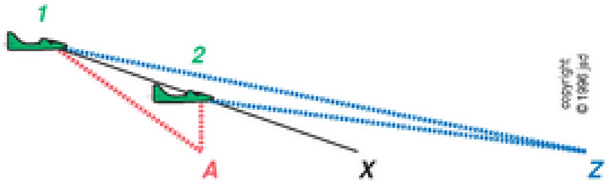

Figure 12.6: Landing Long or Short

The airplane in the figure is flying directly toward point *X*. It will overfly point *A* but land short of point *Z*. As the airplane moves from position 1 to position 2, the angle of *A* below the horizon increases to 90 degrees and beyond. The angle to point *X* remains constant, while point *Z* appears to move closer to the horizon.

If you are on final and perceive the aim point shrinking up toward the horizon, you probably need to add power. Conversely, if you see the angle growing (3 degrees... 3.5 degrees... 4 degrees...), you probably need to reduce power and/or increase drag.

Given that the angle shouldn't change, what sort of angle is suitable? Within the reasonable range (three to six degrees) it usually isn't critical which angle you choose. Here are the main considerations:

If you make a too-steep approach, it makes the flare maneuver more difficult and more critical. Also, some aircraft have so little drag (even in the landing configuration) that they have a hard time staying on a steep glideslope, unless they get help from a headwind.

Conversely, if you fly a too-shallow approach, you need to worry about running into obstructions. It also leaves you with fewer options in the event of an engine failure on final.

Generally, if the angle from the horizon to the aim point is less than three-quarters of a thumb (less than three degrees), you are flying a too-shallow approach. Conversely, if the angle is more than a thumb and a half (more than 6 degrees), you are flying an abnormally steep approach.

In all cases you should be extremely sensitive to *changes* in the angle, since that tells you whether you are going to land long or land short.

12.4 Judging Pitch Attitude and Angle of Attack

Now we come to the most critical task of all: you must control the angle of attack. This is important in all phases of flight, but especially so on final approach when you are intentionally rather low and slow.

12.4.1 Use Outside References and Trim

One way to maintain a definite angle of attack is to carefully perceive and control both the pitch angle and glideslope angle, as shown in figure 12.7.

As discussed in chapter 2, for any given flap setting the angle of attack depends on the difference between the pitch attitude and the direction of flight. Therefore if you maintain a definite value for those two angles, you are also maintaining a definite value for the angle of attack.

Trimming the airplane for the desired angle of attack and flying with a light touch on the controls is also exceedingly helpful in maintaining a definite value for angle of attack; see section 12.12.

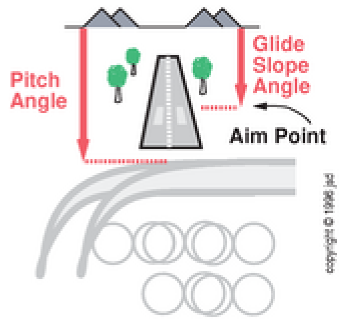

Figure 12.7: Perception of Pitch and Glideslope Angles

To make sure the value in question is the *correct* value, you should look at the airspeed: indicator every so often, but that should constitute only 10% of your looking. The other nine looks out of ten should be directed toward the outside, such as the angles in figure 12.7.

Controlling angle of attack is even more important than controlling the left-or-right and up-or-down alignment of the flight path. If you show up at the runway slightly misaligned, or slightly long, it is usually not tragic and it is usually obvious how to solve the problem (perhaps by going around). On the other hand, if you lose control of the angle of attack, your flying career could end quite suddenly.

12.4.2 Observe and Control More Than One Thing

For any given flap setting, there are three vertical angles of interest:

- the glideslope angle, i.e. the angle of the aim point below the horizon,
- the pitch attitude, i.e. the angle of the nose below the horizon, and
- the angle of attack, which depends on the angle of the nose relative to the aim point.

As discussed below, if you perceive and control any two of these angles, you automatically control the third.

Some pilots (especially students) try to oversimplify the situation by worrying about only *one* of the three angles. This leaves the other two angles completely uncontrolled. Figure 12.8 shows three examples of what can happen if you control only one angle, namely the aim point relative to nose:

1. The lowest airplane has the aim point in the right place on the windscreen. However another angle, namely the glide slope angle, is wrong, so you hit the obstruction.
2. The middle airplane is just right. All three angles have their correct values. You got lucky.
3. The highest airplane once again starts out with the aim point just the right angle above the nose, but this does *not* mean that the angle of attack is correct, because the airplane is not actually moving toward the aim point. Another angle, namely the angle between the aim point and the horizon, is too big and (what's worse) it's changing. To keep the aim point the "right" angle above the nose, you foolishly keep pushing harder and harder on the yoke. At every point along this curved path you've got too much energy, but you don't know it because you are only watching one angle.

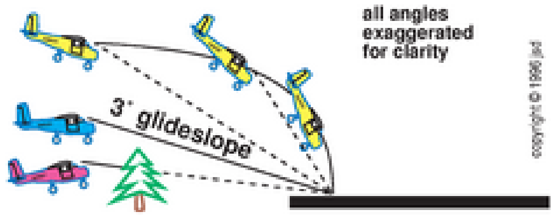

Figure 12.8: Controlling Only One Angle

For a typical person in a typical airplane, on final approach you can easily see the aim point over the nose. If one day the nose of the airplane comes up and blocks your view of the aim point, you should notice immediately and be at least somewhat alarmed.

There are several possibilities. The most alarming ones are:

1. Possibly your pitch attitude is too high (meaning you might be about to stall).
2. Possibly you are not really moving toward your chosen aim point (meaning you are about to land long).
3. Possibly you have both problems (long and slow).

Less-disastrous possibilities include the following:

1. If you ever find yourself on approach with too much airspeed and too little altitude, it is OK to raise the nose and zoom back up to the correct glideslope. During this correction maneuver, the nose will (temporarily!) block your view of the aim point. Still, it remains a topic of concern: if the nose comes up like this, you should have a special reason, and it must be very temporary.
2. If you switch to an airplane with a longer, wider, and higher snout, it might block your view during a normal approach.
3. If you have a short torso, you might have trouble seeing the aim point even if your copilot can see it easily.[4]
4. If you use less than full flaps, it will make the problem worse.
5. An unusually large headwind will make the problem worse.

Note that the converse does not hold; maintaining a proper view of the aim point does not solve all the world's problems, as was illustrated by figure 12.8. To control the airplane properly, you absolutely must perceive and control more than one angle.

In theory, you could concentrate on any two of these angles and let the third one take care of itself. On the other hand, it's not really any extra work to keep track of all three, and each one is interesting for its own special reason:

1. I watch very closely the angle between the horizon and the aim point, because this one is related to energy. Since energy problems cannot be solved quickly, it really pays to notice small changes in this angle as early as possible.
2. As my second angle, I watch the nose relative to the horizon. This is a strong habit. I *always* watch the nose relative to the horizon, whether I am climbing, descending, or flying level.
3. The third angle (the position of the aim point on the windshield) is particularly interesting because it is related to angle of attack. It has the nice property of remaining more-or-less[5] constant from one approach to the next, whereas the other two angles will change quite a bit depending on whether it is a steep approach or a shallow approach. Committing this angle to memory makes it possible to land without using the airspeed indicator.

Additional discussion of too-steep or too-shallow approaches can be found in section 12.3.

12.4.3 Correct for Wind

There is one more ingredient in this recipe: the wind. As we shall see, in the presence of wind your direction of flight relative to the ground is not the same as your direction of flight through the air. You need to be able to perceive both.

Suppose you are on a nice 3 degree glideslope, doing 90 knots in no-wind conditions. Your direction of flight is 3 degrees below the horizon and the relative wind is therefore originating 3 degrees below the horizon. Now suppose a headwind of 30 knots springs up. You add power to remain on the 3 degree glideslope. Your flight path relative to the ground is still three degrees below the horizon, but the flight path through the windy air is only *two* degrees below the horizon.

Figure 12.9 may clarify the situation. The approach commences from a point 1 mile from the runway and 300 feet up; this constitutes a 3 degree glideslope. In the absence of wind, the approach is flown as shown in figure 12.10. You have 90 knots of true airspeed (90 K_{TAS}) and 450 fpm of descent rate. You will reach the runway in 40 seconds.

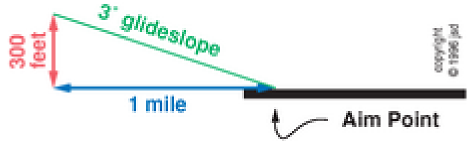

Figure 12.9: Three Degree Glide Slope

As shown in figure 12.11, in the presence of wind you have only 60 knots of groundspeed --- two thirds as much as in the no-wind case. In order to stay on the 3 degree glideslope, you must descend at two thirds of the rate. This is why you had to add power.

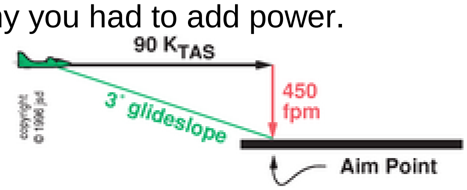

Figure 12.10: Approach Without Wind (Ground View)

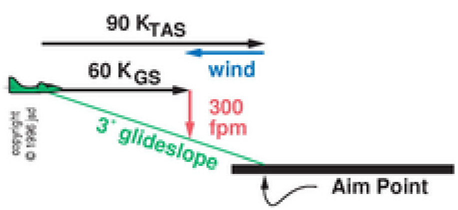

Figure 12.11: Approach With Wind (Ground View)

At the reduced groundspeed, it will take you an entire minute to reach the runway. At the end of that minute, the small hot-air balloon that is in the middle of the runway in figure 12.12 will have been blown a half mile, and will meet you right at the runway threshold. Therefore your path through the air is not aimed toward the threshold, but is aimed toward the balloon. Your direction of flight through the air is only two degrees (not three degrees) below the horizon.

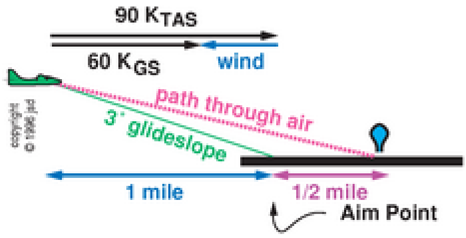

Figure 12.12: Approach With Wind; Path Through the Air

The relative wind is the reciprocal of the direction of flight through the air. The wing doesn't care about your groundspeed; it only cares about the angle of attack, which depends on the relative wind. To maintain the proper angle of attack the pitch attitude will be one degree higher than in the no-wind case.

Conclusion: First, you need to perceive your direction of flight relative to the ground, so you can be sure you will arrive at the aim point as intended. Second, you need to perceive your direction of flight through the air, so you can know what pitch attitude is required to give the desired angle of attack. If you are descending into a headwind, you will need less rate of descent; in any situation where you have less descent you will need less nose-down attitude.

Note that the scheme of estimating the relative wind using the ratio of vertical speed to airspeed gives the correct answer even when nature's wind is blowing. As shown in figure 12.13, you have a normal airspeed and a reduced VSI indication while plodding down the glideslope into the wind. See section 2.11, including figure 2.12, for some discussion of how this looks on the instruments.

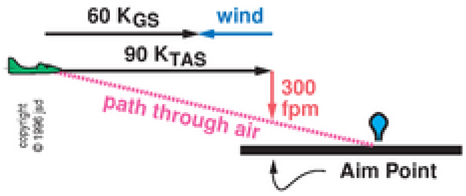

Figure 12.13: Vertical, Horizontal Speeds Determine Angle (Side View)

12.5 Other Perceptions

Instruments: About one look out of ten, you should look at the airspeed: indicator on final approach. The other nine looks out of ten, you should look outside, judging the angles as described above. During the flare, you should definitely be looking outside, not at the gauges. You want to land the airplane at a very high angle of attack. You will have to perceive the angle of attack using outside visual cues. During the flare, the airspeed indicator doesn't tell you anything about angle of attack (as discussed in section 2.12) or anything else you need to know. I once asked an experienced airline captain to tell me at what airspeed his airliner touched down. He said "I don't know; I never looked. I always have more important things to look at". That was a good pilot's honest answer.

Wind drift: On the base leg, you should make it a habit to check your wind drift. Normally you are being blown away from the airport, meaning that after you turn onto final you will have a headwind. If you are being blown toward the airport, watch out!

Groundspeed: Obviously you should choose a runway that is headed into the wind, so you can land with a low groundspeed. However, beyond the choice of runway, you have little control over groundspeed. Your primary duty is to control airspeed, so you are pretty much stuck with whatever groundspeed results.

Also, it is hard to perceive groundspeed accurately. The perceptions will change according to

- the amount of headwind
- day versus night landing
- the model of airplane
- density altitude

See section 12.7.4 for a long list of perceptions you can use to make sure you are landing into the wind at the right speed.

12.6 Basic “Normal” Landing

Your Pilot’s Operating Handbook should specify a “normal” landing procedure. It would probably be more accurate to rename it the “basic” landing procedure, for a simple reason: Many pilots are based at short, unpaved, or crosswindy airports. For them, the basic procedure is definitely not their “normal” procedure. The basic procedure should be thought of as the basis, the foundation on which other techniques are built.

In any case, here are the elements of the basic landing procedure: (1) the final approach, (2) the flare, and (3) the rollout.

12.6.1 Short Final

The main aspects of the final approach were discussed in previous sections.

12.6.2 Flare

The term *flare* refers to the part of the flight where you are raising the nose, from the nose-down attitude on final approach to the nose-high attitude at touchdown.

Throughout the flare process, raise the nose smoothly. It is a common mistake to raise the nose stepwise, that is, to raise the nose a little bit, see what happens, and then raise it a little bit more, and so forth. You should not ask yourself “How much should I raise the nose?” It is much better to ask yourself “At what rate should I be raising the nose?”

At each point in this process, you need to worry about three timescales: how long is it until ...

1. ... your flight path becomes horizontal
2. ... you reach the proper airspeed for touchdown
3. ... you reach ground level

Those are the three main dependent variables that are the result of the maneuver.

Correspondingly, the three key independent variables that you use to control the maneuver are

1. ... the airspeed you have before starting the flare
2. ... the height at which you begin the flare
3. ... the rate at which you raise the nose

Typically you make the decisions in that order: First you pick an airspeed. That determines the height at which you must flare (the faster the speed the higher the flare). Then you adjust the rate accordingly.

In ideal conditions, you can schedule it so that all three things happen at the same time. For any given airspeed, if you start your flare at the right height and raise the nose at the right rate, you can arrange that by the time you reach ground level, you are just beginning to fly horizontally, and your attitude is just right for touchdown.

If the altitude, direction of flight, and attitude are just right, they imply that your angle of attack, airspeed, and energy are just right, too.

In less-than-ideal conditions, you should not attempt this ideal three-way timing. This is because in the real world you need to worry about wind gusts. You don't want a wind gust to come along and rob you of your airspeed while you are still several feet above the ground, in the round part of your roundout.

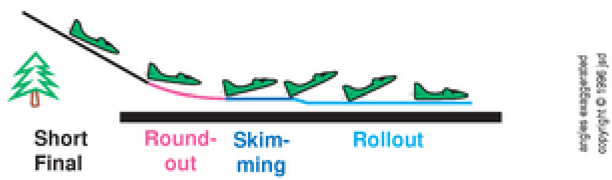

Figure 12.14: Basic Landing Procedure

Therefore, in real-world conditions you should arrange that items (a) and (b) happen at the same time, and item (c) happens later, as shown in figure 12.14. That is, the flare really has two parts:

- During the first part, called the *roundout*, you are making the transition from steadily descending flight to horizontal flight.
- During the second part, called *skimming*, you are moving along horizontally, a foot or less above the ground, waiting for the airspeed to bleed off so you can touch down at the proper airspeed.

Continue skimming, gradually raising the nose, until the angle of attack has increased to the point where you can land on the main wheels, with the nose wheel definitely in the air.[6] To say it the other way, a flat, "three-point" landing, with all three wheels making contact at the same time, is proof that your angle of attack is much too low and your airspeed is much too high.

If you find that the skimming phase lasts longer than necessary, then you started with too much airspeed and/or you began the flare too late. If you had too much airspeed on final, next time get rid of it earlier.

Every so often I get a student who thinks it is a good idea to wait until the last possible moment and then raise the nose all at once. I call this a "square flare". Even though you can get away with this under some circumstances, it is a bad idea for the following reasons:

- There is no margin for error. If you misjudge, and wait a little too long to perform the square flare, you will make an airplane-shaped hole in the runway.
- It puts the instructor in an unpleasant situation. If you don't start the flare at the proper time, I can't just sit there, hoping you will do the square flare at the last moment. I have to take control of the airplane, which will hurt your feelings if you think it wasn't necessary.

- The square flare doesn't work in all circumstances. Yes, you can get away with it in certain light trainers when your airspeed is much faster than your stalling speed, but in an airplane with a higher stall speed, the wing can't develop enough lift to force such a sudden change in direction of flight.
- You can't reliably know how much to pull back. If you move to a different brand of plane, or if your plane isunusually lightly loaded, or if you fly the approach at an unusual airspeed, the square flare will go awry and you'll have no time to compensate.

There is no point in learning the square-flare technique (which will work in just a few airplanes, some of the time), when with the same amount of effort you can learn a technique that works in all sorts of airplanes, and gives a much greater margin of safety.

Remember, good pilots are judged on their smoothness, not their quickness.

In the proper touchdown attitude (in most airplanes), the nose will block your forward view. You will not be able to see the runway centerline. Therefore, during the latter part of the flare, during the touchdown, and during the initial parts of the rollout, you will have to guide the plane by reference to the runway *edge*. Otherwise, one of two things will happen: (1) If you manage to keep the centerline in view, you will touch down with much too low a pitch attitude and much too high a speed. (2) If you raise the nose anywhere near enough, you will lose sight of your reference and become an unguided missile.

If the stall warning horn comes on during the skimming phase, when you are flying horizontally a few inches above the runway, it is a good sign. You will be touching down shortly.

Conversely, if the stall warning horn comes on early in the roundout, when you are still several feet above the runway and descending, it is a bad sign. You should add power immediately. Adding power helps in two ways: (1) The power-on stalling speed is lower than the power-off stalling speed (because of the propwash over the wings). This might give you enough lift to arrest the descent. (2) The added power contributes to the energy budget, so you can rebuild your airspeed.

12.6.3 Timing the Flare

How do you recognize when it is time to begin the flare?

Let us begin by mentioning a few *unhelpful* answers to this question.

1. You could wait until you see the hair on the instructor's neck stand on end, then begin the flare. This is not good preparation for flying solo.
2. Many books suggest beginning the flare at about the height of a typical hangar. This doesn't work very well if you visit some place that has bigger hangars, smaller hangars, or no hangars at all. It also isn't very reliable at night.
3. Some people like to flare at about half the height of a typical tree. Alas, trees work even worse than hangars, for similar reasons.
4. You could wait until the width of the runway subtends a certain angle in your field of vision. This will get you into trouble if you visit some place with a wider or narrower runway.
5. You might think of using the perception of the ground rushing past, which does depend on height. Alas, this is hard to perceive, and is unacceptably sensitive to the amount of headwind.
6. You could try to use the depth perception that comes from having two eyes. However, human binocular stereopsis is absolutely useless at distances of 20 feet or greater. By the time this

depth perception comes into play, it’s too late. Wiley Post was blind in one eye, but that didn’t prevent him from making good landings.

Here is something that actually helps: Use your sense of *timing*. At each moment on short final, ask yourself how much time t remains until you would, at the current rate, reach zero AGL. When this time t reaches the special value t_F (about two seconds), start your flare. (The exact value of t_F will depend on what sort of airplane you’re flying, and other factors.)

Of course the actual flare will take longer than t_F --- roughly twice as long. That’s because t_F refers to what *would* happen if you forgot to flare. During the actual flare, your descent rate is reduced, so you take longer to descend.

This timing technique has some nice properties. It works on wide and narrow runways both. It works during daytime and nighttime both. It causes you to flare at a greater-than-usual height if you have a greater-than-usual vertical speed.

Now all you need is some way to perceive how much time t remains. You don’t need to know the height in feet or the descent rate in feet per second; all you need is *some* quantity that perceptibly changes as you approach zero AGL. Figure 12.15 shows one such quantity. The left side of the figure is what you should see when you are on final, at a definitely nonzero height. The letters *ABCD* and *WXYZ* represent landmarks along the side of the runway. In particular, for night landings you would use the runway lights as landmarks.

Figure 12.15: Perceiving Zero Height

The important thing to notice is that the landmarks are not all colinear. In particular, *BDZ* is a triangle that covers nonzero area in your field of view.

Now, in contrast, imagine that you are on your hands and knees on the runway, so that your eye is just at the same height as the runway lights, about 12 inches AGL. Suppose that landmarks *A* and *W* are behind you, but you can still see the others. As shown in the right side of the figure, all the landmarks have become colinear. The erstwhile triangle *BDZ* has flattened out and now has zero area.

Of course you never actually fly with your eyes at zero AGL. Therefore you need to observe the *rate* at which triangle *BDZ* is gradually flattening out. By combining this rate perception with a sense of timing, you can decide when to begin the flare.

You can practice this perception indoors: Put a book on a table, then lower your head until the corners of the book-cover all line up.

12.6.4 Touchdown and Rollout

Don’t land with the brakes applied. Of course your feet must be on the rudder pedals; just make sure you aren’t accidentally depressing the brake pedals even a little bit. Wait until there is plenty of weight on the wheels (i.e., after the nosewheel is on the ground) before applying the brakes.

At touchdown and thereafter, the airplane should be sufficiently well centered that the centerline is between the main wheels. On a narrow runway you have no choice, but on a wide runway you should land on the centerline anyway. See how close you can come. Make it a matter of self-discipline and pride.

The touchdown should be gentle enough that the nosewheel *stays* in the air during touchdown and during the first 50 feet of the rollout. This is a good way of proving to yourself (and to all the kibitzers in the airport lounge) that you were in complete control of the landing. To say it the other way, if you hit with a lot of vertical momentum, it will force the nosewheel down like a mouse trap. See also section 12.11.7.

Stay in control during the rollout. Remember, the flight isn't over until the aircraft is tied down. The NTSB files are full of reports of pilots who made a decent touchdown and then (a quarter mile later) stopped paying attention and had an accident.

After you have taxied clear of the runway, perform the after-landing checklist. This will include items such as carburetor heat off, flaps retract, cowl flaps open, strobes off (for night taxiing, so you don't blind everybody), boost pumps off, et cetera.

12.7 High-Performance Landing

This section discusses the tradeoffs you must make when the field is short, obstructed, and/or plagued by gusty winds.

The key elements of a high-performance landing are:

1. choose the right runway,
2. use the right configuration,
3. touch down at the right point,
4. touch down at an appropriately low airspeed, and
5. use the brakes effectively.

12.7.1 Choose the Right Runway

Consult your Pilot's Operating Handbook to see how much runway you will need, as a function of headwind, density, and other variables. Make sure your chosen runway is long enough. Include a safety margin, because the numbers in the book are based on perfect pilot technique, and you don't want to put yourself in a situation where perfection is required. Also, for reasons discussed in section 12.7.4, even if you have a headwind, make sure you could safely land on the chosen runway *without* a headwind. And avoid landing with a tailwind!

While you're at it, plan ahead. Do your short-field *takeoff* planning before landing at an unfamiliar short field, since in many airplanes it is quite possible to get into a field that you can't get out of. Usually any runway that is good enough for takeoff is more than good enough for landing, for reasons discussed in section 13.7.2.

12.7.2 Use the Right Configuration

As discussed in section 5.5, extending the flaps has six main effects:

1. Flaps decrease the stalling speed.
2. Flaps increase drag.

3. Flaps increase the incidence.
4. Flaps increase the washout.
5. Flaps perturb the trim speed.
6. Flaps lower the permissible top speed.

These influence the landing in various ways:

1)

Having a low stalling speed is always good.

2a)

The typical short field is not just short, it's obstructed. Because of the obstructions, you want to make a relatively steep approach. Because of the steep approach, you might need the drag that comes with full flaps.

2b)

Your aim point will be not very far down the runway, so a steep approach helps keep you within power-off gliding range. If you lose power and need to glide a long ways, retract the flaps.

3)

Increased incidence means that (other things being equal) the pitch will be lower. (Remember: pitch + incidence = angle of attack + angle of climb.) Extending the flaps makes it easier to see over the nose but makes it harder to have the nosewheel in the air at touchdown.

4)

Increased washout increases roll damping so the airplane handles more nicely near the stall.

5)

In an ideal airplane, you would be able to make power changes and configuration changes without perturbing the trim speed. But in most airplanes, when the flaps are extended (and not otherwise), every power change affects the trim. One of my students pointed out to me that when I was flying with the flaps extended, every time I moved the throttle I simultaneously nudged the trim wheel with my thumb. I had been unaware that I was doing it, but it seems like a very sensible habit. You know compensation is going to be needed, so why wait?

6)

Always glance at the airspeed indicator before reaching for the flap handle. Make sure you are within the permissible speed range.

Also note that in many light aircraft, the last notch of flaps produces its full share of incidence and its full share of drag, but has only a small effect on the stalling speed. Therefore if you didn't need the last notch for energy management on final, you've got very little reason to extend the last notch at all, unless the field is very short and you need to get rid of every last knot of stalling speed.[7]

A gusty wind or a strong crosswind is a good reason using less than full flaps. Compared to full flaps, reduced flaps has the following consequences:

- For any given airspeed[8] you will touch down at a higher pitch attitude. This means that if a gust during the "skimming" phase (after the roundout) causes you to touch down a little sooner than you intended, you will still touch down on the main wheels. This is good, because the main wheels can take a much bigger load than the nosewheel.
- By the same token: For any given pitch attitude you will touch down at a higher airspeed. In most respects, touching down at a higher airspeed is bad, but one might make the following argument: Since the sideways force of the crosswind on the fuselage is largely independent of your forward airspeed, and since your rudder authority etc. are proportional to airspeed squared, touching down at a higher airspeed gives you more authority to combat the crosswind. Therefore, if you are worried about running out of control authority, you might consider using less flaps, maybe even no flaps. The tradeoff is that even a modest increase in

touchdown speed means you will use up significantly more runway. You must take this into account.
- As mentioned above, the stall speed increases. This is 100% bad. Even if you want a higher touchdown airspeed, you still would like it to be as far as possible above the stall. Remember that the effect of the flaps on the *incidence* (retract = nose-high = usually good) is different from the effect of the flaps on the *stall* (retract = bad).

Finally, while we are discussing configuration: extending the landing gear is an important part of the landing configuration. Please don’t forget this. Double-check it on short final.

12.7.3 Touch Down at the Right Point

In the presence of obstructions, a relatively steep approach will make more of the runway available to you: Consider for example a 50-foot tree quite close to the beginning of the runway. If you use a six-degree approach slope, it will block you from using the first 500 feet of the runway. If you were to use a three-degree glide slope instead, it would block twice as much of the runway. You can get information about obstructions from the Airport/Facility Directory and other sources. Also, whenever a runway has a displaced threshold you should suspect it is displaced because of obstructions.

If your airplane requires a 1000-foot landing roll, and you are landing on a 2000-foot runway, you should arrange things so that you use the *middle* two quarters of the runway. That gives you a safety margin at each end. It doesn’t make sense to put all your margin at one end or the other.

For an extreme short-field landing, your margins will be much smaller. In this case, your touchdown point will be beyond, but only very slightly beyond, the runway threshold. You must allow for the fact that your aim point will not be the same as your touchdown point, since the flare carries you forward several hundred feet beyond where the a straight-line extrapolation of your approach path would go. The correct procedure is to aim your approach path a corresponding distance *short* of the intended touchdown point. In extreme cases, the aim point may even be ahead of the runway threshold, as shown in figure 12.16.

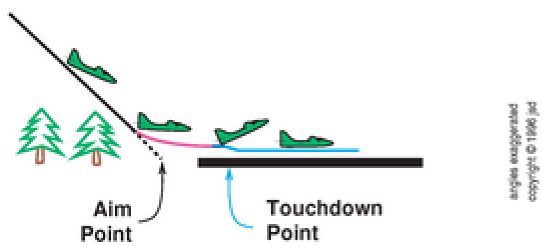

Figure 12.16: Extreme Short-Field Landing Procedure

On any runway, long or short, pick a definite touchdown zone and hit it as accurately as you can; don’t just land “somewhere” down the runway. This shouldn’t be any extra work; it should be a natural consequence of good aim-point control and good airspeed control, which you need for other reasons.

Every landing should be a spot landing.

Pick a definite spot on the runway and land in the zone that begins at this spot and extends 100 feet or so beyond, in normal conditions. If you have unfavorable conditions (such as gusts, wind shear, and/or an inexperienced pilot), the zone will be larger. Make sure the far end of the zone leaves enough room for the rollout, plus a safety margin.

If the field is so horribly short that you need to choose an aim point that is near the threshold, or ahead of it, choose a glide slope that is steep enough that you can fly it without engine power. (Or, better yet, go find a more reasonable runway somewhere else. At any field where you can *depart* with reasonable safety margins, you should be able to land with considerable margin at each end. See section 13.7.2.)

At any field that is not horribly short, including any field where you make a normal power-on approach, you should *not* locate your chosen touchdown zone at the very beginning of the runway. There are a couple of reasons for choosing a zone farther down the runway: (a) it gives you more obstacle clearance, and (b) if you should ever have engine trouble on final, you would have a much better chance of being able to make a power-off approach to the very beginning of the runway.

I often fly at a rather short, obstructed field: 1700 feet after the displaced threshold. That's short but not too horrible; with some skill and some headwind, you can land a Skyhawk using only half of the runway. Some people are overly worried about running off the far end. If you over-react to the possibility of an over-run, you might be tempted to make an extreme short-field approach, so you would have the largest possible amount of runway "left over" in front of you. But that would be a bad idea, for the following reasons.

Much of flight safety depends on margins and on backup plans. At every phase of flight you should ask yourself how many things would have to go wrong at this point before you would run out of options.

So why put all the safety margin at the far end? What about the near end? Among other things, remember that hitting the ditch at the far end when you're almost stopped is better than hitting the ditch at the near end at full flying speed.

So, a few years ago I decided that rather than using the first half of the runway, I would use the *middle* half of the runway. This reduced by half my margin against over-runs, but gave me vastly greater margin against under-runs.

Sure enough, a few months after making that decision, I was with a student who incapacitated the engine[9] on half-mile final. At that point we were close enough and high enough that I could glide toward the weeds as shown in figure 12.16, flare, and land on the runway with several inches to spare.

12.7.4 Touch Down at a Low Speed

If you land with too much groundspeed, you are in danger of running off the end of the runway. I've seen this done on several occasions. It tends to be embarrassing and expensive.

Excessive groundspeed can be due to a tailwind and/or excessive airspeed. Sometimes the one can lead to the other, if you don't understand the basic principles of flight (chapter 7). Here's the scenario: Suppose you have a tailwind on final, and you don't realize it. Because the tailwind is carrying you along, if you don't do something, you are going to land too far down the runway. To fix this, you unwisely push on the yoke and dive towards the aim point. You may think this solves the problem, but in fact it makes it worse. Now you've got too much airspeed (which contributes to a too-high groundspeed) and the tailwind is still there (further contributing to a too-high groundspeed).

Remember, it is OK to use the yoke as the up/down control *provided* you are on the front side of the power curve *and* you are willing to accept an airspeed excursion. On final approach, neither of those provisos is true. Using the yoke as the up/down control in such a situation is horribly improper pilot technique. See section 7.3 for more on this.

Nobody intentionally lands with a tailwind. Nobody intentionally lands with excessive airspeed. The problem is, all too often they just don't notice. Here is a list of things you can notice so you can stay out of trouble. [AS] indicates airspeed cues, and [TW] indicates tailwind cues.

1. [TW] As you approach the airport, listen on the radio and make a note of which runway other airplanes are using. You can also get wind information from ATIS, AWOS, and/or the Tower controller. As you get closer, you can see which runway the other airplanes are using. But remember that winds can shift, so the runway that had a headwind a few minutes ago might have a tailwind now.
2. [TW] Try to look at the windsock when you are on the "downwind" leg of the traffic pattern. If your so-called downwind leg actually has a headwind component, you've got a problem. (Alas, it is often rather hard to see the windsock from traffic pattern altitude, so don't drive yourself crazy trying.)
3. [TW] On the base leg, notice whatever wind-drift is occurring. This is a really good source of information. Think about this every time you fly the pattern. If you are being blown toward the airport, that's bad. Usually it means there will be a tailwind on the runway. (In the rare cases where there is a headwind on the runway but the base-leg wind is blowing you toward the airport, it means there will be a tremendous windshear on final, which is a bad thing unto itself, as discussed in section 16.17.3.)
4. [TW] Every landing should be a spot landing. Even if you've got a 7000 foot runway, don't just land "somewhere" on the runway. Pick an aim point, and keep that point a constant angle below the horizon the whole time you are on final. This disciplined approach gives you valuable information. In particular, you can observe how hard it is to stick to the glideslope. If you've using the usual configuration and the usual power setting, but the airplane keeps floating above the glideslope, either you've got a tailwind, or you've chosen an unreasonably steep glideslope. At this point you should commit to not landing. Make a low pass down the runway so you can get a good look at the windsock.
5. [TW] Similarly, if you see an unusually large reading on the Vertical Speed Indicator, it means you've got too much airspeed, or a tailwind, or a too-steep glideslope angle, or some combination of the above.
6. [AS] Even more importantly, maintain a righteous airspeed on final. Watch the crucial angles, as well as the airspeed indicator, as discussed in section 12.5.
7. [AS] If you touch down three-point, it is another sign that you have too much airspeed.[10] In a proper landing, the nose wheel should be in the air. If you are afraid that raising the nose would make you fly up into the air, go around (unless you are near some huge obstructions). Since you have so much airspeed, the go-around performance will be excellent: the airplane will leap into the air.
8. [AS] If you apply the brakes and get lots of squealing with relatively little braking action, it is yet another sign that you've landed with vastly too much airspeed. The problem is that the wings are still producing lift, so there's not enough weight on the wheels. (See section 12.7.5.) You have got no business being on the ground at this airspeed. Do not tolerate this. If you find flat spots on your tires, it means a dangerously unskillful pilot has been flying your plane.
9. [TW] As you approach the runway for landing, you get another chance to look at the windsock. If it is pointing the wrong way, go around. Similarly, at a tower airport, if you say "wind check" the Tower controller will tell you the current winds.
10. [AS+TW] You might be able to perceive groundspeed directly. If you think you've got an unusually high groundspeed, make a low pass down the runway to double-check the windsock and other factors, then return for landing. Perceiving groundspeed is hard. The perception depends on altitude and other factors. I don't know any good rules to help you distinguish a

good groundspeed from a bad groundspeed. It may help to fly a downwind approach every so often, just so you can see the difference. (Don't land! And watch out for opposite-direction traffic.)

In an airplane that normally touches down at 50 knots, you will use up *more than twice* as much runway with a ten-knot tailwind than with a ten-knot headwind. Roughly speaking, the amount of runway consumed during rollout depends on the *square* of your groundspeed at touchdown.

If the wind is so variable that it might switch from headwind to tailwind at the last moment, make sure you have plenty of available runway.

* Compensate for Density and Weight

Suppose you are flying at less than standard weight. For reasons discussed in section 2.12.4, the angle of attack will be the same but the indicated airspeed will be less. The percentage change in speed should be half the percentage change in weight. If you fly at the correct (lower) airspeed, you will use less runway. If you use the uncorrected POH airspeed, you will use *more* runway than POH tables indicate. The aircraft will tend to "float" more than it should, because you arrived with the wrong angle of attack.

Now suppose you are landing at a high-altitude airport, where the air density is less. For reasons discussed in section 2.12.3, the angle of attack will be the same and the indicated airspeed will be the same --- but the true airspeed will be greater, the vertical speed will be greater, and the ground speed will be greater, by about 2% per thousand feet of density altitude. Because of the groundspeed, you will consume more runway, about 4% per thousand feet of density altitude. Your POH should contain a chart or table with more accurate information.

Note that in all cases, being able to accurately perceive the angles is a big help.

* Compensate for Windshear and Gusts

Proper management of your airspeed during a short-field approach is complicated and tricky. You have some difficult compromises to make. A low airspeed gives you the best short-field performance, but a higher airspeed gives you highly desirable protection against stalling if there is a gust or a windshear (or a lapse in pilot technique).

Your Pilot's Operating Handbook should specify the speed to use for short-field landing. This is the indicated airspeed you want to have when you begin your flare. In ideal conditions, you could trim for this speed early in the final approach leg, and maintain this speed all the way to the flare. In real-world conditions, however, the wind makes speed management much trickier.

Therefore, you need to include the following steps when planning your approach:

- Obtain an up-to-date estimate of the surface winds at the airport. This could come from the ATIS, AWOS, windsock, tower controller, other pilots, or whatever.
- Resolve the total wind into components, so you know what headwind and crosswind to expect during landing. You can use the methods of section 14.2.2, but rotate your point of view so that you measure relative to runway heading, which usually differs from your current heading (since you usually plan the approach before turning onto final).
- Figure out what is the largest possible amount of airspeed that you could lose to a sudden gust or windshear on short final. (Gradual losses are no problem, and even sudden losses on long final are a relatively minor problem.) Call this amount the "gust allowance". If it is larger than

the headwind component, it means you are faced with the possibility that the headwind could shear to a tailwind, and therefore you should divert to a longer runway; you don't want to make a short-field landing with a tailwind.

- Your airspeed on short final should be equal to the short-field approach speed given in the POH *minus* a correction for below-standard weight *plus* the gust allowance.

On final (as always!) trim for the appropriate speed and fly with a light touch; this will greatly help you recognize when a windshear occurs, as discussed in section 12.12.

If your approach speed includes a gust allowance and the expected gust does occur, then you are in good shape. Assuming you are at the right altitude and assuming you are not expecting any further windshear, you can just raise the nose and retrim. You are now flying at the handbook approach speed just as if there had been no gust and no gust allowance. The rest of the approach should be straightforward. (You typically need to make a slight power reduction, because in the absence of the headwind you will arrive at the runway sooner, so staying on the glideslope requires less power.)

On the other hand, if the gust does not occur, you will arrive at the runway with too much airspeed. Fortunately, though, if you have followed all the steps above, the gust allowance is less than the headwind component, so your *groundspeed* is less than the calm-wind short-field groundspeed, and you if you proceed to land your rollout shouldn't consume any more runway than it would in the calm-wind case.

The foregoing describes the correct procedure, in which you anticipated the windshear. Let's now consider various situations that could arise if you have forgotten to include a gust allowance in your approach speed.

1) Suppose you are flying at the handbook's short-field approach speed when a gust or windshear robs you of ten knots. If this happens on long final, several hundred feet above the ground, it is no big deal. You have lots of altitude and lots of time. You can regain your airspeed by diving about 60 feet, according to the law of the roller coaster (section 1.2.1). At this point you are on a new glide path which is 60 feet lower than the old one. This will take you to a point about 600 feet short of where the old one would have (assuming a 6 degree glide slope), but you can correct for this by increasing the power, re-intercepting the desired glide path, and then reducing the power.[11]

2) Now suppose you suffer a similar unanticipated loss of airspeed when you are only 50 feet above the ground. In this case you have a definite problem. At this point you are on (or below) the desired glidepath and below the desired airspeed. You have a critical energy shortage. You have nothing to gain by pulling back on the yoke; if you try it you are likely to wind up as a statistic --- one more "unexplained" stall/spin accident. The proper way to deal with it is to apply full power, as discussed in section 1.4. Simultaneously, dive to regain airspeed. Dive as much as you can without hitting anything, and then proceed with a go-around. Do not attempt to salvage this approach. Instead, go around and set up a proper approach, including an allowance for the windshear.

Beware decreasing headwind on final.

12.7.5 Use the Brakes

To stop in the shortest possible distance, the procedure is as follows:

- Touch down on the main wheels as always,
- lower the nose wheel fairly soon thereafter,
- retract the flaps,
- apply the brakes, firmly but not skidding, and then
- pull back on the yoke a little.

The reasons for these steps are as follows:

The amount of braking force that a tire can provide is directly proportional to how much weight is on the tire. As a consequence, you want to make sure there is as much weight as possible on the wheels before applying the brakes. If the nose is in the air, the wings are still supporting part of the weight of the airplane. Lowering the nose reduces the angle of attack. Retracting the flaps also reduces the angle of attack, since it reduces the angle of incidence.[12]

A skidding tire provides much less braking force than a non-skidding tire. You never have anything to gain by allowing the tire to skid. Furthermore, skidding can very quickly lead to loss of directional control. If you think the tires might be skidding, release the brakes so they stop skidding, re-establish directional control, then reapply the brakes.

In addition to the loss of braking effectiveness, skidding is very destructive to the tires --- it quickly grinds away one part of the tire. The loss of rubber shortens the life of the tire, and the loss *all from one place* throws the tire out of balance. An out-of-balance tire tends to hop off the pavement, reducing braking and steering effectiveness.

The idea of pulling back on the yoke during braking is simple: it increases the weight on the main wheels (which is where the brakes are). The main wheels are now supporting their normal share of the weight of the airplane, plus whatever down-force is being developed by the elevator, plus whatever share was previously being supported by the nosewheel. The idea is not to lift the nosewheel off the ground, just to bring its share of the weight *almost* to zero.

See section 12.6.4 for additional discussion of the rollout, including the case of a not-very-short runway.

12.7.6 Summary: High-Performance Landing

For a short-field landing (compared to the basic landing described in the previous section) ...

- the aim point is short of the touchdown point.
- the approach is steeper.
- the airspeed is less (at corresponding points throughout the approach and roundout).
- the skimming phase is shorter or nonexistent.
- you lower the nose wheel sooner.
- you apply the brakes sooner and harder.

These points can be seen by comparing figure 12.16 to figure 12.14.

12.8 Soft-field Landing

If the field is soft, it is important to touch down (1) as gently as possible, with the smallest possible vertical speed, and (2) with the lowest possible groundspeed. (In gusty-wind conditions, these two objectives are somewhat in conflict, and the first one should get priority. That is, it is better to touch down with a tiny bit of extra horizontal speed, rather than to risk “dropping” the airplane into the mire with any appreciable vertical speed.) If the field is bumpy but not soft, the priority goes to touching down at a low airspeed.

The key element of soft-field technique is to use engine power during the flare and touchdown. This helps in two ways: first of all, the propwash over the wings lowers the stalling speed, meaning you can touch down at a lower speed, and secondly, the power allows you to fly horizontally over the runway for an extended time, descending very slowly, gently “feeling for the runway”.

The approach to a soft-field is basically the same as a normal approach. The only differences are as follows:

On short final, after you are assured of reaching the field, you should extend the flaps to get the lowest possible stalling speed.

Fairly late in the flare maneuver, you should add a little bit of power, just enough to maintain level flight, or a little bit less. The required amount of power is remarkably small. You are in ground effect, so there is very little induced drag, and you are moving slowly, so there is very little parasite drag. If you add too much power, the airplane will speed up or climb, which is not what you want. You will be much too busy to look at the engine gauges during this maneuver, so use your ears: you can learn to recognize the right amount of power by its sound.

When the main wheels make contact with the ground, friction will cause the airplane to slow down, possibly quite rapidly. This friction will also create a torque that tends to slam the nosewheel into the ground, so you generally have to pull back on the yoke to prevent this. Also, you can anticipate that the speed-change will drive your body forward (relative to the plane) at just the moment where you want to be pulling back, so tighten your shoulder harness and brace yourself.

As soon as possible after touchdown, reduce the power to idle.

As always, when taxiing on a soft surface, keep the airplane moving. If you stop, the airplane might sink in, and you will be unable to get it moving again.

During the rollout, and during taxiing on rough surfaces, it is usually a good idea to pull the yoke all the way back. The remaining airspeed and/or the propeller blast acting on the tail helps to reduce the weight on the nosewheel. This is important because (1) the nosewheel is usually more vulnerable to damage than the main wheels, and (2) more importantly, if the nosewheel drops too heavily into a pothole it could result in a prop strike.

Here’s an advanced technique: if you are taxiing toward an abrupt bump, such as the edge of a piece of pavement, keep the yoke all the way back and apply a blast of power during the few feet leading up to the bump. If you do it right, in some aircraft the propwash hitting the tail will allow you to “pop a wheelie”, lifting the nosewheel almost (or perhaps entirely) off the ground. As soon as the nosewheel is over the bump, reduce the power back to idle.

If you are based at a paved airport, the ideal way to learn soft-field procedure is to fly somewhere that has a paved runway *and* an unpaved runway. Land on the paved runway, then practice soft-field taxiing and takeoffs before trying soft-field landings. This way your first experience with a soft bumpy runway comes at the lowest speeds rather than the highest speeds.

12.9 Crosswind Landing

12.9.1 Basics

Immediately before landing, the airplane is moving through the air, and is hardly affected by the ground. During the landing process and afterward, the airplane is moving along the ground --- and is still affected by the air.

During the landing process and afterward, we want the airplane to be *moving* straight down the runway, and we also want the axis of the airplane to be *pointing* straight down the runway. These are two separate requirements; especially in the presence of a crosswind it is all too easy to have the airplane moving in one direction and pointing in another.

The usual way to meet all the requirements is to land in a slip. (An unusual alternative is discussed in section 12.9.5.)

Suppose for sake of discussion that the crosswind is coming from the right. Early on final approach you observe that in order to keep the airplane's *motion* aligned with the runway, the airplane's *heading* is pointed a few degrees to the right. This is normal, coordinated flight; the airplane's heading is aligned with the relative wind, i.e. aligned with the airflow. (For a general discussion of how wind affects groundspeed and direction of travel, see section 14.2.4.)

It is a very bad idea to touch down with the heading not aligned with the runway. It will create a huge sideways force on the landing gear, and could knock the tires right off their rims. If the tires survive, they will create a sudden large force in the direction you are pointing. This will cause the airplane to scoot off the upwind side of the runway.[13]

12.9.2 Heading Control

You need to change the direction you are pointing so that it is aligned with the runway, not the relative wind --- and you need to do it *without* changing the direction you are going. Use the pedals (the left pedal in this case) to aim the nose at a point on the centerline at the far end of the runway. Keep it pointing there. This yaw task is simple, because it is almost independent of what you are doing with the bank angle and the pitch angle. If you see a nonzero yaw angle (relative to runway centerline), fix it right away, using the rudder.

12.9.3 Drift Control

Using rudder alone might work for a moment, but it won't work for long, because the wind is now striking the side of the fuselage and blowing the airplane off course --- an undesired boat turn (as discussed in section 8.10). To solve this problem, lower the upwind wing. This tilts the lift vector toward the upwind side, providing a force that counteracts the wind on the fuselage. The rule here is fairly simple: You use the bank angle to get rid of left/right drifting motion.

If the crosswind suddenly increases (as it so often does), or if you have selected not quite enough bank angle, the airplane will start drifting to downwind. By the time you notice this, you've got three different problems that need to be dealt with separately. (1) Obviously part of the task is to increase the bank to correspond with the actual amount of crosswind. That is, in the long run you want to have zero sideways force on the airplane. (2) However, in the short run that doesn't suffice. With zero force, the airplane will continue to drift, in accordance with Newton's first law (section 19.1). So temporarily you need even more bank. Later, after you have brought the drift velocity to zero, remove this extra bank. To summarize: you need some bank in proportion to the crosswind (whether you're drifting or not) and you need some bank to arrest the drift rate (no matter what the actual crosswind is).

The timescale during which left/right momentum builds up is, alas, comparable to a student pilot's reaction time, which can lead to wild oscillations. If you find yourself overcontrolling left/right, get away from the airport and practice slipping along a road (section 16.9) until you get a feel for how the airplane responds.

(3) You care about left/right position, not just velocity. If you have drifted off to one side, you should set up a slight drift back toward the centerline. Don't be in a big hurry; the smoothest correction is better than the quickest correction. (If you are so far off that a radical correction seems necessary, go around.) Also remember that the airplane has lots of inertia, so it will take a bit of effort to get the corrective drift started, and it will take a bit of effort to get it stopped as you approach the centerline. (See section 16.9 for more on this.)

12.9.4 Flare and Touchdown

You are now ready to touch down. Land on the upwind wheel. Land on the upwind wheel![14] You should keep the ailerons and rudder deflected even after touchdown. Keep rolling along on one wheel for a while; as the airplane slows down you will need to apply more and more aileron deflection in order to maintain the bank angle. Remember, you need that bank angle to provide the force that resists the wind.

Land on the upwind wheel.

Only after the upwind wheel has considerable weight on it should you allow the downwind wing to settle. At this point the aircraft is no longer banked. The friction of the wheels on the runway is the only force resisting the sideways force of the wind. The amount of sideways friction a tire can produce is proportional to the weight on it, which is why you must not level the wings until there is plenty of weight on the wheel(s).

Do not neutralize the ailerons. The crosswind is constantly trying to flip the airplane over onto the downwind side. Keep the ailerons deflected to combat this. It doesn't hurt to slightly overdo it, keeping a little extra weight on the upwind wheel. As airspeed decreases, you will need progressively more aileron deflection to create the required amount of force.

To reiterate, the overall sequence should be:

1. Lower the upwind wing and apply downwind rudder.
2. Land on the upwind wheel.
3. As the lift dies away, the weight of the airplane will force the other main wheel onto the ground.
4. Then you can let the nosewheel come down.

During this whole process you need to maintain pressure on the downwind rudder pedal, to counteract the weathervaning tendency (section 8.11). As soon as there is weight on the nosewheel, the nosewheel steering becomes effective, adding to whatever steering the aerodynamic forces on the rudder have been providing. Therefore at this point you can expect to suddenly need somewhat less pedal deflection.

Maintain appropriate aileron and rudder deflection during the rest of the rollout, and during taxiing as well. Remember, the flight isn't over until the airplane is tied down.

The question arises: at what point should you make the transition from coordinated flight (on final) to slipping flight (for touchdown)? Some pilots prefer to establish the slip on short final or even earlier; the idea is to have time to get the "feel" of the slip. My recommendation, though, is to begin the slip at the same time you are beginning the flare, not much earlier. The rationale is: (1) A strong crosswind is usually accompanied by a considerable headwind component, delaying your arrival at the runway, in which case an early slip is the last thing you need. It just creates drag which steals energy and aggravates the tendency to land short.[15] (2) The winds near the ground are never the same as the winds aloft, so any slip established on final will have to be changed during the flare anyway.

Be sure to correct for whatever crosswind is *actually* there at each point, not the crosswind you were expecting. Crosswinds are notoriously variable. As you descend and as you travel down the runway, you move in and out of the lee of trees and buildings.

If the crosswind is really strong and/or variable, you might consider using less than full flaps, as discussed in section 12.7.2.

12.9.5 737 Scheme

There are some exceptional cases where landing on the upwind wheel is not recommended. An example is a late-model Boeing 737, which has a relatively narrow wheelbase, and huge engines mounted below the wing. You have to land with the wings level; otherwise one engine would hit the ground. A similar situation arises with certain amphibian aircraft that have outrigger-type floats or sponsons far from the centerline.

You begin by maintaining coordinated flight as long as possible. The direction of motion will be aligned with the runway, but the heading will not, until the very last moment. Then, use the rudder to align the heading with the direction of motion. Deft aileron usage is needed to maintain wings level during the yaw maneuver, because of the unequal wingip velocity. The remaining few seconds of flight will be a wings-level slip. This will begin a wings-level boat turn, but you hope not to turn very much. The idea is to touch down before the sideways force imparts any significant sideways velocity. This technique is not recommended for typical general-aviation aircraft. It's more work than necessary, and in a light aircraft the sideways velocity builds up too quickly.

12.10 Going Around

Before you begin the approach, at the time you review the landing checklist, be sure to review the go-around checklist.

> If you're not prepared for the go-around, you're not prepared for the approach.

There are many situations that call for a go-around. You should think about this in advance and establish guidelines for yourself so that you can begin a go-around *immediately* when the need arises.

If you need to go around, don't wait until the last moment. If you are rolling toward the end of the runway and are worried about running off the end into the trees, attempting a go-around will only make it worse. It is better to hit the trees when you are almost stopped than to hit the trees with almost enough energy for a go-around. An early go-around is good, but a late go-around is worse than nothing.

Here are some guidelines. You can imagine exceptions; for instance if you are flying a glider it is hard to perform a go-around. So you should come up with guidelines adapted to your situation. The point is that you should think about the go-around decision in advance. The accident records contain many examples of people who got into trouble because they spent too long deciding whether or not to go around.

- If you think you might be too high and/or too fast to land within the predetermined zone as mentioned section 12.7.3, go around. Do not try to "salvage" the approach by using extra runway.
- If your attempted landing results in a bounce, go around. Many accidents start with a harmless bounce; the salvage attempt results in running off the runway or making a disastrously hard landing.
- If there is a possibility of tailwind, make a low pass to check out the windsock, then return for landing.
- If there is a possibility of wildlife on the runway, make a low pass to scare them off, and another to make sure they are gone, then return for landing.
- If the crosswind is so strong and/or gusty that you have doubts about being able to keep the airplane on the runway, go around. Indeed, don't just go around, go away. Find another runway that is wider and/or more aligned with the wind.
- If another airplane pulls onto the runway when you are on short final,[16] break to one side and go around. Do not stay on the centerline; break to one side so you can keep an eye on the situation, since the other airplane remains a collision threat even while you are going around. Do not try to land farther down the runway (hoping that the other pilot will hold in position). Do not try to land short (hoping that the other pilot will take off and get out of your way).
- On an instrument approach, if you can't see the runway at certain predetermined points, a go-around is mandatory.
- If you find yourself on final with the landing gear not down and locked, or otherwise find yourself not in the correct landing configuration, go around. This is usually a sign that you didn't follow the landing checklist, and you need to take the time to re-run the *whole* checklist, to see what other things you may have missed.
- Do not wait until you are sure you need a go-around; that's the wrong question. The right question is whether you are sure things are OK for landing. If you are unsure, go around.
- If ATC says go around, go around. If your copilot or instructor says go around, go around. If you disagree, go around and argue about it later. (There are exceptions; don't let yourself get talked into attempting a dangerously late go-around.)

If ATC clears you to land, that does not prohibit you from going around. For instance, if your gear is not down, ATC would prefer to see you go around rather than land gear-up. Similarly, if ATC clears you to "land and hold short" of a runway intersection, they would prefer see you go around early rather than skid through the intersection at the last moment.

Energy mismanagement is the most-common reason for go-arounds. This is a good reason for evaluating your energy situation early and often. Ask yourself: are we high and fast, or low and slow? Fixing an energy problem is easy if you start early, but it is hard or impossible if you start late. Also remember:

> An early go-around is good, but
> a late go-around is worse than nothing.

When you begin the go-around, do it right. Don't add "some" power; add full takeoff power.

In a Cessna 152, 172, or 182 with flaps extended, an increase in engine power will magically re-trim the airplane for a lower airspeed, as mentioned in section 2.3. This is annoying when you make small power adjustments on final approach, and downright dangerous when you apply full power for a go-around. Your first defense (which works in all airplanes) is to watch the pitch attitude; if the nose wants to pitch up, don't let it. Push on the yoke as necessary to keep the pitch where you want it. This is sometimes quite a hefty push. (Practice simulated go-arounds at a safe altitude every so often, so you won't be surprised.)

Take a look at the airspeed indicator. Raise or lower the nose as necessary to establish the proper airspeed for the go-around.

After you have done the right thing with the power and the angle of attack, start working on the configuration. If you are carrying full flaps, remember that the last notch contributes a lot of drag but doesn't contribute much to the stalling speed, so you want to retract that notch fairly early in the process. Also, retracting the flaps part way will help with the trim problems. Don't retract the rest of the flaps until you have a reasonable airspeed margin above the stall. To the extent possible, use the trim wheel to take the pressure off the yoke. (A yoke-mounted electric trim switch comes in very handy for this.)

Make sure you have established a positive rate of climb before retracting the gear. This rule arises because in some situations you may need to perform a "bounce and go" --- that is, to touch down on the runway briefly before going around. It is much nicer to bounce on the wheels.

12.11 Learning to Land the Airplane

12.11.1 Maneuver by Reference to the Edge

As mentioned in section 12.6.2 and section 12.2, in most airplanes, the pilot cannot see the runway centerline when the airplane is the proper attitude for touchdown. This comes as a shock to many student pilots.

Therefore, we want to *land on the center line by reference to the edge line*.

There are several good ways to learn to do this. Repeated out-of-control attempts to land the airplane are not the recommended way.

A trick that works beautifully in typical light Cessnas (150/152/172/182)[17] is the following: taxi down to the end of a disused runway (e.g. the crosswind runway) or a long taxiway that resembles a runway. Taxi into "takeoff position" and shut down the engine. You remain in the left seat, while your instructor sits on the tail, raising the nose to touchdown attitude. You should sit there for several minutes contemplating the perceptions. Compare level attitude with touchdown attitude. You will note that in touchdown attitude, you will not be able to see the centerline or the right-hand edge of the runway, but you will be able to see the left-hand edge. Especially if you move your head a little toward your side of the airplane, you should be able to see the whole sideline --- from the point abeam your position all the way to the far end.

You can study these perceptions during taxi. Fortunately, all landings are preceded by takeoffs. Especially in an unfamiliar airplane, you should consciously use the pre-takeoff taxi to practice taxiing on the centerline *without looking at the centerline.* That has a certain Zen ring to it, doesn't it? The trick is to taxi by reference to the taxiway edge line on your side. If the taxiway is 40 feet wide, you should concentrate on taxiing 20 feet in from the left edge. The instructor may help by holding a chart in front of your nose, forcing you to control the airplane by reference to the sideline.[18] Every ten seconds or so the chart will be moved aside so you can recalibrate your perceptions.

During taxi, you should also practice perceiving height. Ask yourself, "how far below me are the wheels?" You will need to know that when it comes time for landing.

12.11.2 Hesitation Takeoff

Make sure you have an instructor with you, especially the first time you try this. At an airport with a nice long runway, taxi into position for take-off. Pull the yoke all the way back, as you would for a soft-field takeoff. Using full power temporarily, speed up until the nose comes up to the attitude that corresponds to stalling angle of attack or slightly less. Then retard the throttle almost to idle so that your airspeed does not increase any more. Do not let the pitch attitude or the airspeed get so high that you actually become airborne. Do not raise the nose so much that the tail hits the runway. Then just taxi down the runway in this configuration. Make a careful note of the perceptions of height, pitch, heading, and left/right position relative to the edge line.

Make sure you don't run out of runway. One option is to close the throttle, stop, and taxi back. Another option is to add power and fly away. Be careful to maintain constant pitch attitude as you increase the power. This will require releasing some of the back pressure on the yoke, since the increased propwash increases the effectiveness of the tail.

12.11.3 Practice Maneuvering at Altitude

The traditional (but not the best) way to learn about landing the airplane is try it again and again until it comes out right.

Landing practice has its place, of course --- but it is not the only thing, or the first thing, you should do. Especially if you are learning landings for the first time, or are learning to fly a new type of airplane, there is no point in practicing defective landings over and over. That just reinforces bad habits. Also, as Langewiesche (reference 1) pointed out, landings happen so quickly that there is very little time to learn anything.

Therefore, you should leave the traffic pattern. Go somewhere where you have more altitude and fewer other aircraft. Perform the familiarization exercises as described in section 16.10.

You want to spend a fair amount of time practicing slow flight. This is the sort of thing you really want to learn in the practice area, not during an attempted landing. Landing involves flying very slowly, right next to the ground. You've got no business trying to fly slowly at three feet above ground level (AGL) if you don't know how to do so at three *thousand* feet AGL.

In slow flight, in the landing configuration, make a note of the angle of attack. This is the angle of attack you want to have when you touch down on the runway. Remember the pitch attitude that goes with this angle of attack. Observe the angle the cowling makes relative to the forward horizon, and observe the angle the wingtip makes relative to the lateral horizon. Since at touchdown you will be (I hope) flying purely horizontally (i.e. negligible vertical velocity), the pitch attitude tells you everything you need to know about the angle of attack (at any given flap setting).

You will probably discover that the angle of attack you want to have on final approach is halfway between the cruise angle of attack and the stalling angle of attack. This rule of thumb is related to the more widely known rule of thumb that approach speed should be about 1.3 times the stalling speed.[19]

This little fact (approach angle of attack is halfway between cruise angle of attack and stalling angle of attack) is more useful than it might seem. It means you can land the airplane --- and I mean an on-the-numbers, short-field landing if necessary --- even if your airspeed indicator has failed (or you just can't see it because your lights have failed at night). You should not consider yourself properly "checked out" in an airplane until you know how to do this.

Table 12.1 shows some airspeeds and angles for a typical general-aviation aircraft.[20]

	Airspeed (K_{CAS})	Pitch Attitude	Incidence	Angle of Climb	Angle of Attack
cruise (clean)	115	0.0°	4.5°	0.0°	4.5°
level V_Y (clean)	76	4.0°	4.5°	0.0°	8.5°
level (flaps)	76	0.0°	8.5°	0.0°	8.5°
slower (flaps)	70	2.0°	8.5°	0.0°	10.5°
descent (flaps)	70	-2.0°	8.5°	-4.0°	10.5°
flare (flaps)	decr.	incr.	8.5°	incr.	incr.
stall (flaps)	53	12.0°	8.5°	0.0°	20.5°

Table 12.1: Landing --- Airspeeds and Angles

On approach, the angle of attack is distinctly not the same as the pitch attitude. Don't be fooled; bear in mind that you probably have ten or a hundred times more experience in level flight than you do in descending flight. You're not flying toward the horizon any more; you're flying toward a point several degrees below the horizon. As you transition from level flight to a four degree descent, you need to lower the nose by several degrees in order to maintain the same angle of attack.

12.11.4 Practice Flaring and Stalling at Altitude

The following is a great way to learn some of the skills that you need for landing the airplane.

Choose a safe altitude (3000 feet AGL or thereabouts) and designate it as the altitude of a "virtual runway". Starting at an altitude 500 feet or more above the virtual runway, set up a power-off glide in the landing configuration (gear and flaps extended) at the normal approach speed. Then, about 10 feet above the virtual runway, begin a flare, so that you wind up flying level, power off, at the virtual runway altitude. As the airplane slows down, keep pulling back, cashing in airspeed to pay for drag, maintaining altitude. Continue pulling back until the airplane stalls. Then make a normal stall recovery.

The point of this maneuver is to learn at what rate you need to raise the nose during the flare to maintain level flight.

As a variation of the above procedure, you can practice "soft field" landings on the virtual runway. After you have flown horizontally at the virtual runway altitude for a second or two with zero power, add enough power to sustain steady level flight. See also next section.

Practice recovering from evil zooms (section 12.11.8) and other types of defective flare (section 12.11.9).

12.11.5 Practice Flying in the Runway Environment

As mentioned above, the landing flare lasts only a few seconds, and if you do a hundred landings you still have only a few minutes of experience handling a flaring airplane. Practicing slow flight at altitude is a tremendous help. Practice this. However, don't expect it to do the whole job, because (a) the airplane handles slightly differently in ground effect, and (b) you need to learn to perceive alignment with the runway, altitude, descent rate, etc. very precisely, based on visual cues in the runway environment.

Before actually trying to land the airplane, go to an airport with a nice long runway and make a few low passes at a safe airspeed.

1) Make the first pass about 10 feet above the runway at approach speed.

2) Then try it about 5 feet above the runway, at approach speed.

3) As you gain skill and confidence, try it about 2 feet above the runway, at approach speed.

4) Then try it about 1 foot above the runway, at approach speed.

During these maneuvers, you will learn to judge your height above the runway, learn to maneuver the plane so that it is centered on the runway, and learn to use the rudder (and *opposite* aileron) to get the fuselage aligned with the direction of motion even in the presence of a crosswind.

Finally, after you know how to perceive and control what is happening in the runway environment:

5) Fly down the runway one foot or less above the surface, at a low airspeed. This will be discussed at length in the next section.

Note that it is a *very, very bad idea* to fly 10 feet or even 5 feet above the runway at a low airspeed. It is OK to stall the airplane at 3000 feet AGL, and it is OK to stall it at 0.5 feet AGL, but it is definitely not OK to drop it in from 10 feet AGL.

12.11.6 Learn Soft-Field Procedure First

After you are comfortable with high-speed flight in the runway environment, and with flaring the airplane at altitude, and handling it in the touchdown attitude, it is time for the most important exercise.

Fly the approach to a nice long runway. As you flare, advance the throttle a tiny amount. The idea is to generate enough power to allow you to fly down the runway in ground effect, a small distance above the ground. This is the soft-field landing procedure, but it works just fine on paved runways, too.[21] Strive to maintain one foot of altitude. You should be able to hold this altitude within a few inches. As you become more proficient, try maintaining ever-lower altitudes with ever-finer precision.

The amount of power required is very small, perhaps only 100 RPM above idle. Because the airplane is in ground effect, induced drag is greatly reduced. Because the airplane is moving so slowly, parasite drag is very small.

Gradually raise the nose to the proper touchdown attitude, and keep flying down the runway at "zero point five AGL". If a gust comes along and drops you the last six inches, it will be a perfect landing.

Remember to keep a careful watch on the runway edge; in the proper touchdown attitude you won't be able to see the centerline and if you persist in trying to look out the front you will wander off to one side and mow down the runway lights.

Also, keep your wits about you --- don't fly the whole length of the runway and run into the trees at the end. Make a timely decision to add power and go around, or chop the power and land.

Take the time to look down at the runway, to double check your perception of height. Look at the lateral wingtip against the horizon. Get rid of the notion that the landing is something that happens at a point in time. Landing is a process that lasts a goodly amount of time.

12.11.7 Nose-High Rollout

After landing, the nosewheel is supposed to stay in the air for a while. For practice, you can make it stay in the air quite a bit longer by adding a tiny amount of power. That creates a situation analogous to the hesitation takeoff described in section 12.11.2.

Even if you don't add power, try to keep the nosewheel off the ground for as long as you can (provided you've got enough runway). This has two advantages.

1. When the nose is up in the air, the airplane produces relatively high drag. This called *aerodynamic braking*. It allows you to slow down without wearing out the brakes. On the other hand, aerodynamic braking is not as effective as real brakes, so if you are approaching the end of the runway, lower the nose and retract the flaps. This puts more weight on the wheels, and therefore allows you to apply the brakes more heavily without skidding.
2. This provides additional practice handling the plane in the proper touchdown attitude. You should try to learn from every landing.

Another suggestion: You will sometimes (alas) touch down with a too-low nose attitude, so that the nosewheel hits almost immediately. If this happens, gently raise the nose to the proper attitude. Again, the purpose of this is twofold: aerodynamic braking plus a reminder of what proper touchdown attitude looks like. If this causes you to become airborne again, it means that your touchdown speed was much too high, which is a valuable lesson. Just stop raising the nose, wait half a second, and the airplane will re-land.

12.11.8 Recovering from an Evil Zoom

Consider the situation where you flare too much, too late. That is, you fly down quite near the ground and, while your airspeed is still several knots above the stall, you pull back on the stick quite a lot. The pitch attitude will become very much nose-up. If you allow this pitch attitude to persist, the airplane will zoom up a few feet and then stall. At this point, there is no way to prevent a crash. The usual stall-recovery procedure (diving to regain airspeed) will not work. You won't be able to dive enough, because the ground gets in the way.

This is a common and very serious mistake. It is a particularly evil type of zoom. (Some other books call it "ballooning" but that seems like an insult to all the beautiful hot-air balloons and helium balloons in the world.)

Obviously you want to stay out of situations from which no recovery is possible. The solution in this case is simple: you absolutely must observe the pitch attitude. If you see a large nose-up pitch attitude, begin a recovery immediately. Do not wait to hear the stall warning horn. Do not wait to feel aerodynamic indications of a stall. Push the nose back down to the attitude that corresponds to slow flight (roughly 15 degrees nose up in typical airplanes) and apply full power immediately. You know that the airplane can fly level at full power in this attitude, so if achieve that attitude and that power setting soon enough (before you have lost too much airspeed) you will be fine. It is important to practice this procedure, as discussed in section 16.20.6.

Do not try to salvage the landing. Go around!

You cannot recover from an evil zoom simply by reversing the process that got you into trouble. During the upward zoom and the downward "reverse zoom", the airplane loses so much energy due to drag that you will not be able to arrest the descent in time for touchdown. To say it again: If you see a bad nose-up situation and try to recover just by pushing the nose way down, the airplane will dive right into the runway nose-first. This is an example of a pilot-induced oscillation, as discussed in section 16.4.

You can reduce your chance of falling prey to an evil zoom by thinking about the pitch attitude at all times. You need to control attitude in the short term, as a means of controlling altitude in the long term.

12.11.9 Salvaging an Imperfect Flare

Nothing is perfect. Sometimes the flare is noticeably imperfect, yet not so bad that a go-around is required. The number of possible imperfections is enormous, so we can't discuss them all, but it is worth discussing how to handle the most-common cases.

Remember that for any given airspeed on short final, there will be exactly one ideal altitude at which to begin the roundout, and one ideal rate at which to raise the nose.

Scenario #1: Suppose you begin the roundout a little bit too late, and/or raise the nose too slowly during the initial moments of the roundout. You can detect this by noticing that the ground is rushing up toward you and will reach you too soon.

Solution: Raise the nose at a slightly higher rate than usual, fast enough to arrest the descent in the available time. This results in an almost-nice roundout, just a little bit squared-off. At best, this salvaged flare will end at a point where you have the right altitude (a few inches) and the right vertical speed (zero), at the cost of having too much airspeed. If there is enough runway available, just skim along until the airspeed bleeds off, then touch down. On a short runway, don't attempt to salvage this scenario. Go around --- the sooner the better.

Scenario #2: Suppose you begin the flare at about the right time, but you raise the nose at too great a rate during the first part of the roundout. (This can be considered a very mild version of the evil zoom discussed in the previous section.)

Solution: If you notice this early enough, you can salvage the situation. You should temporarily stop raising the nose. Hold a constant pitch attitude for a few moments. This constant pitch attitude will *not* correspond to a constant airspeed, nor a constant angle of attack, nor a constant vertical speed. The airplane will lose energy, lose airspeed, and develop an ever-increasing rate of descent. You may think that lowering the nose is the "obvious" way to undo the error, but you should resist the temptation; by the time you have manage to lower it, you will be at too low an altitude with too great a descent rate. Therefore, just hold a constant pitch attitude. Adding a smidge of power (a) will keep things from happening too fast, and (b) means you will have more energy at the end of the roundout. (If you add *too* much power, then at the end of the roundout you'll have more energy than you need, causing prolonged skimming as discussed in the previous scenario.) As you fly along at constant pitch attitude, at some point you will see a combination of airspeed and descent rate that you recognize from your previous normal landings. At that point, resume raising the nose at an appropriate rate.

Scenario #3: Suppose you begin the flare too early. Your first indication that something is wrong might be the following: You are flying a nice circular looping path that will be tangent to the ground; that is, you will reach zero altitude at just the time you reach zero vertical speed. However, alas, you notice that in order to do that, you are raising the nose at a rate that will lead to a stall before the roundout is completed.

Solution: Add a little bit of power. During the rest of the maneuver, raise the nose at a reduced rate. (Once again, if you add *too* much power, it could eat up a lot of runway.)

12.12 Fly with a Light Touch

As discussed in section 2.7, it is vitally important to be aware of how much force you are putting on the yoke. This is good practice in all regimes of flight, but it is particularly important on approach. In particular, imagine you are conducting a short-field approach, which means you've got no excess airspeed. Suppose on long final everything is just right: the right direction of flight, the right pitch attitude, the right angle of attack, the right airspeed --- and in particular, the right trim.

You can --- and should --- confirm that you've got the right trim by letting go of the yoke.[22]

Now suppose that on half mile final the airplane spontaneously pitches down.

The airplane is trying to tell you something! It is trying to tell you that it lost some airspeed --- presumably because of a windshear. This is a very, very common thing to happen on final. You are presumably landing into the wind, and the headwind is almost certainly stronger at pattern altitude than it is on the ground. Therefore you are virtually guaranteed to encounter a decreasing headwind during the final descent. This will rob you of some airspeed. If you are lucky, it will happen so gradually that nobody notices. If you are not lucky, it will happen suddenly. A few knots will suddenly disappear from the airspeed indicator (which you may not notice) and the airplane will want to pitch down (which it is your duty to notice).

The all-too-common temptation is to pull back on the yoke, trying to maintain pitch attitude and (vainly) hoping to maintain constant angle of descent. This is not smart.

Remember: the airplane is trimmed for a definite angle of attack. If you pull back on the yoke, you are forcing the airplane to a higher angle of attack (and a lower airspeed). Since you were already trimmed for short-field approach speed, this is definitely not a good idea.

To reiterate: the yoke is not just a control carrying commands from you to the airplane --- it is also a valuable sensor carrying information from the airplane to you.

With rare, brief exceptions, you should keep the airplane trimmed for the desired airspeed (or, rather, angle of attack). You should be aware of (and wary of) any force you apply to the yoke, forcing the airplane off its trim speed.

Additional discussion of airspeed management, including compensation for windshear, can be found in in section 12.7.

12.13 Critique Your Own Landings

Some of my students learn faster than others. The ones that learn the fastest are the ones who have internalized a set of high standards (and even higher goals) and who have learned to critique their own performance. These folks give me a good feeling. I know that they will continue to get better even when I'm not in the plane --- a pleasant contrast to those who get gradually worse when left to themselves, and depend on the instructor to get them back in shape.

The standards for a good approach and landing are reasonably easy to remember:

- Review the checklist before the approach. Make sure you are prepared for the approach, the landing, *and the go-around*.
- Use the right configuration (flaps, landing gear, carburetor heat, cowl flaps, et cetera).
- On final, track the extended centerline. (That is, don't just fly toward the threshold at some cockeyed angle.)
- On final, maintain the correct angle of attack. Flying with a light touch will help you with this.
- On final, maintain a constant angle of descent. That is, keep the aim point a constant angle below the horizon.
- Pick a definite spot along the runway. Pretend it is the beginning of a very short runway, and try to land beyond, but less than 100 feet beyond, that spot.[23]
- At touchdown, the nosewheel should definitely be in the air.
- The touchdown should be gentle enough that the nosewheel *stays* in the air during touchdown and during the first 50 feet of the rollout.
- At touchdown and thereafter, the axis of the airplane *and* its direction of motion should be aligned with the runway. In a crosswind, this means landing on the upwind wheel.
- At touchdown and thereafter, the airplane should be sufficiently well centered that the centerline is between the main wheels.
- Don't (accidentally or otherwise) apply the brakes until there is plenty of weight on the wheels.
- Stay in control during the rollout.

If you can do all those things, you don't need an instructor to tell you it was a good landing.

1

If you are staying in the traffic pattern, doing touch-and-goes, you must brief the landing checklist before takeoff.

2

To calibrate your thumb, you can use the following rather specialized facts: The standard face-plate on a household light switch is 4.5 inches tall. At a distance of 5 feet, 4 inches, it subtends four degrees. Therefore, measure the switch (just to make sure) and then stand with your eye 5'4" away and see how your thumb compares.

3

By the way, you should make sure your line of sight to the threshold is unobstructed. At night, if the green threshold lights are blinking or can't be seen at all, it tells you there is an obstruction between them and the airplane. Add power!

4

Extending the flaps will help. A booster-cushion on the seat may help. A modest slip might help you see past the side of the nose. A landmark *abeam* the aim point often comes in handy. If the problem is severe, you might want to choose a different model of airplane.

5

Of course this angle is not exactly constant; it depends on flap setting, it depends on whether your seat is adjusted extra-high or extra-low, and it depends on the amount of headwind.

6

Obviously this discussion does not apply to tail-wheel type airplanes.

7

A student pilot might be tempted to always extend full flaps so that all landings would have the same incidence and would therefore look the same, but a sophisticated pilot should be able to deal with the difference between full-flap and partial-flap touchdown attitudes.

8

This applies to airspeeds that you can actually achieve, without stalling, at the reduced flap setting.

9

In a Cessna, if you pull the throttle all the way out and then *bend* it down, it's stuck at idle and you can't fix it without tools.

10

This applies to ordinary nose-wheel aircraft, not taildraggers.

11

If your previous aim point was halfway down a long runway, you could just choose a new aim point 600 feet ahead of the old one, but you should feel guilty about doing so. If you ever have to choose a new aim point, you should take it as a warning of poor pilot technique.

12

On some airplanes, the flap handle is distressingly close to the landing gear handle. Make sure you grab the right one. You don't want to retract the landing gear by mistake.

13

You might think the wind would always blow airplanes off the downwind side of the runway, but more often than not they end up on the upwind side.

14

It is a common mistake among beginners to roll the wings level just before touchdown (even though they had been maintaining the correct slip up to that point) --- perhaps in the effort to make it "look like" a normal no-crosswind touchdown.

15

Also: Heaven help you if try to “stretch the glide” by pulling back on the yoke. If you stall out of a slip you will enter a spin, and there will not be enough altitude for a recovery.

16

If that happens on long final, don’t over-react.

17

It doesn’t work as easily on Pipers, because they require much more force on the tail to raise the nose.

18

While you are looking out the side, make a note of how the wingtip looks against the lateral horizon. That is provides very useful pitch and bank information.

19

As discussed in section 2.12.6, you must multiply the calibrated (not indicated) stalling speed by 1.3, and then convert the product to an indicated airspeed.

20

For other, similar aircraft, the numbers will be similar. In a radically different type of airplane (e.g. a jet interceptor with short, highly-swept wings) the numbers will be radically different.

21

As discussed in the previous section, do not attempt this maneuver until you are proficient at judging altitude and maneuvering in the runway environment. Do not do anything that puts you at risk of a low-altitude stall until you are within a foot or so of the runway.

22

Don’t take your hand away and start scratching your ankle; just open your grip to the point where you are not quite touching the yoke.

23

On a long runway, on a day with gusty crosswinds, this is the least important of the criteria. I’m willing to compromise a little on spot-landing performance if necessary to get a soft, slow, well-aligned touchdown.