AVIATION WEEK NETWORK

A Secret About Landing Flare

James Albright April 21, 2021

Your first flight instructor's first lesson about landing,
Credit: James Albright

Flying aircraft is, for the most part, an exacting science of aerodynamics, physics, meteorology and geometry. We do our best to learn and understand what needs to be understood, but we train and memorize rote procedures to make sure we get it right, every time. There is, however, an exception to this scientific approach to flying: the landing flare. We are told that what happens in the last 20 or 30 ft. of flight is an art. *Magic, really.* We all remember that one day during training when the light clicked on, and we had it, we knew how to land. But then we lost it, and "pranged" one on. These days the same thing happens on the line: One day you have the magic, the next day you don't. It is an art they say.

After a lifetime of research, I am here to tell you that the landing flare can be broken into smaller, achievable steps that can be explained by science. Understand the science, and your landings will become more consistently on speed, in the touchdown zone, and--dare I say it--more pleasing to your passengers.

Most of us intuitively understand that the scribblings of our first flight instructors on the well-worn chalkboards in our first flight schools were the knowledge we needed at the time to progress along our way to becoming professional pilots. But many of those axioms were actually folklore, taught by instructors who were taught by the generation before, and they from the generation before them. We may suspect some of these truisms are false, but we may not be sure why. If you want to take this journey from art to science, you will need to unlearn a few things you have been taught:

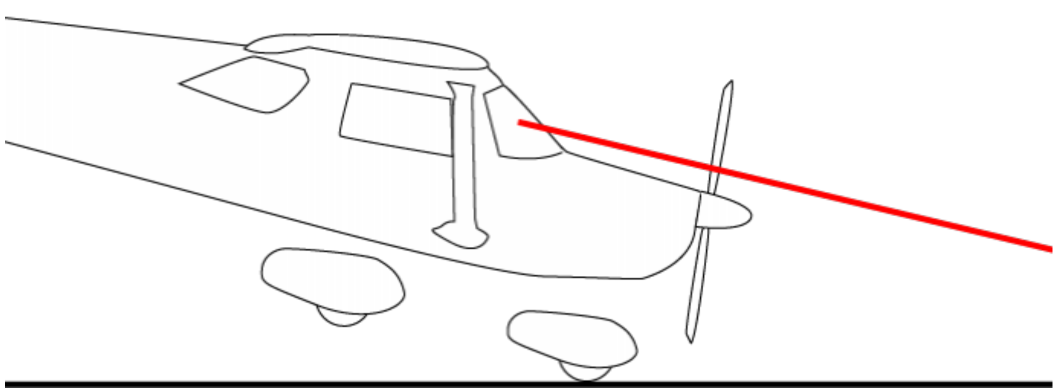
(1) If we keep our aimpoint stationary in the windshield, that is where our wheels will hit the runway.

(2) Once we lose sight of the aimpoint, it is time to flare.

(3) If we shift our aim to the horizon during the flare, we will be able to judge a proper touchdown at our aimpoint.

(4) The flare cannot be taught; it is a matter of feel learned through experience.

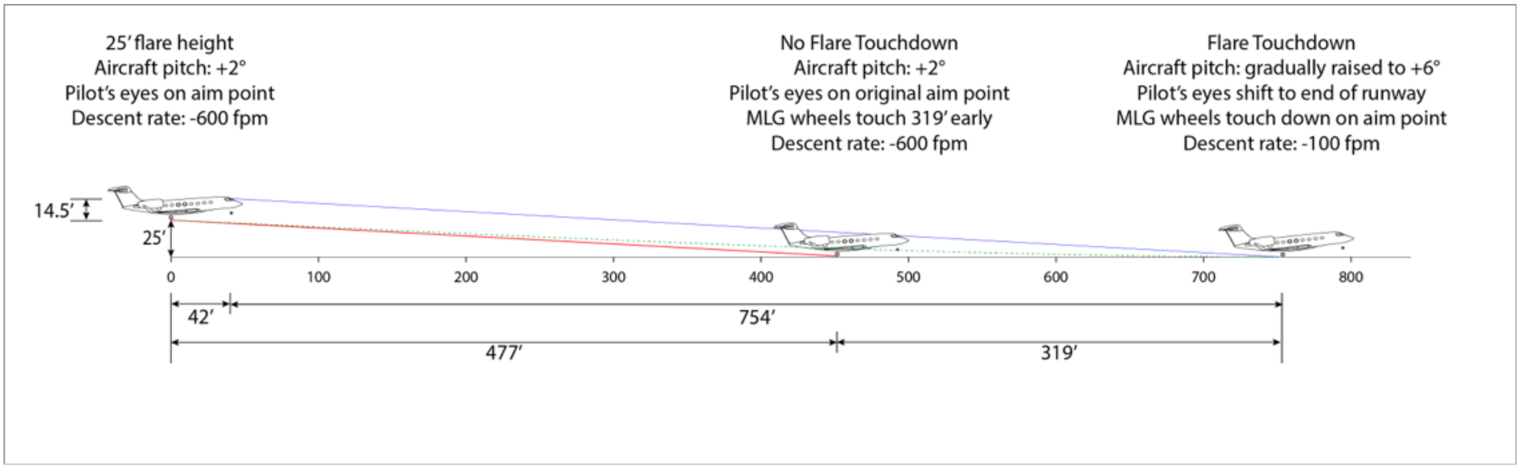
Folklore: If we keep our aimpoint stationary in the windshield, that is where our wheels will hit the runway.



There is airplane below and behind you. Image credit: James Albright

When we started flying, be it in a single-engine Piper Cherokee, a single-engine Cessna 150, or something else, we were told to place a point on the runway on our windshield so it becomes stationary. Everything above it moves higher, everything below it moves lower. “Keep it right there,” we are told, “and that is where your wheels will end up.” This lesson is reinforced by the fact that it seems to work out that way. Left unsaid is that it *sometimes* works out that way because our wheels are actually aimed short and the act of flaring the airplane *sometimes* gets the wheels to where you were aiming. If you really “keep it right there,” what will happen is a part of the airplane will hit the runway (or short of the runway) before your eyes ever get to the aimpoint. “But that doesn't matter,” your flight instructor would say if you brought that up, “the wheels are only a few feet behind you.”

We can examine the idea that the "wheels are only a few feet behind you" and the rest of the folklore with some trigonometry. You don't need a math degree to understand the landing flare, but a short discussion can help cement the concepts and lead to a better grasp of what needs to be done to properly land an airplane. Few manufacturers provide all the numbers needed to do this, but we can pick as an example one that does: Gulfstream and its G650.



Gulfstream G650 landing geometry. Image credit: James Albright

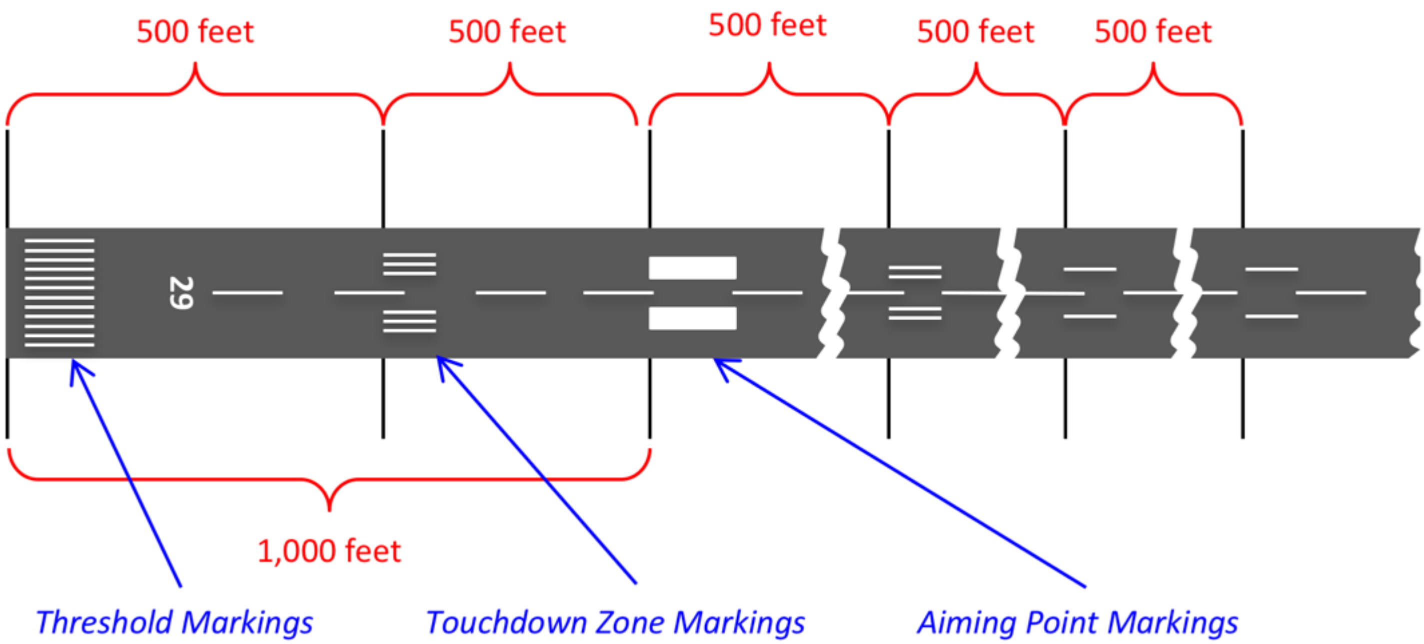
Gulfstream tells us that in the +2-deg. pitch during the approach, the pilot's eyes are 14.5 ft. above and 42 ft. ahead of the main landing gear (MLG). If the aircraft is flying on a 3-deg. glidepath, we can compute the distances using the "tangent" trigonometric function by dividing the height in question by the tangent of 3 deg.. The aimpoint, for example, is found by dividing the pilot's eye height (39.5 ft.) by tan (3 deg.), which equals 754 ft. ahead of the pilot's eyes. We can also determine where the wheels will touch if the pilot forgets to flare: 25 divided by tan (3 deg.) = 477 ft. ahead of where they were at 25 ft. Knowing that the MLG is 42 ft. behind the pilot's eyes, we can compute the distance behind the aimpoint that the MLG will contact the runway if the pilot doesn't flare: 754 + 42 – 477 = 319 ft.

Of course, the G650 is a large business jet; it is nearly 100 ft. long. But this fact holds true for most aircraft: The MLG wheels will touch down hundreds of feet short of your aimpoint. This is a fact lost on many pilots attempting to put their aircraft down on the first inch of pavement. (See "Countering Complacency" in the October 2014 issue of *BCA* for an example where a brand-new Bombardier Global 5000 was destroyed when the pilots arrived just a few feet short of a runway.) The lesson is clear: You need to plan on an adequate threshold crossing height (TCH) that allows for the fact that most of your aircraft is below and behind you.

Editor's Note: There will be two subsequent articles by James Albright about landing gear flare this week in BCA Digest*.*

When Should I Flare?

James Albright April 22, 2021



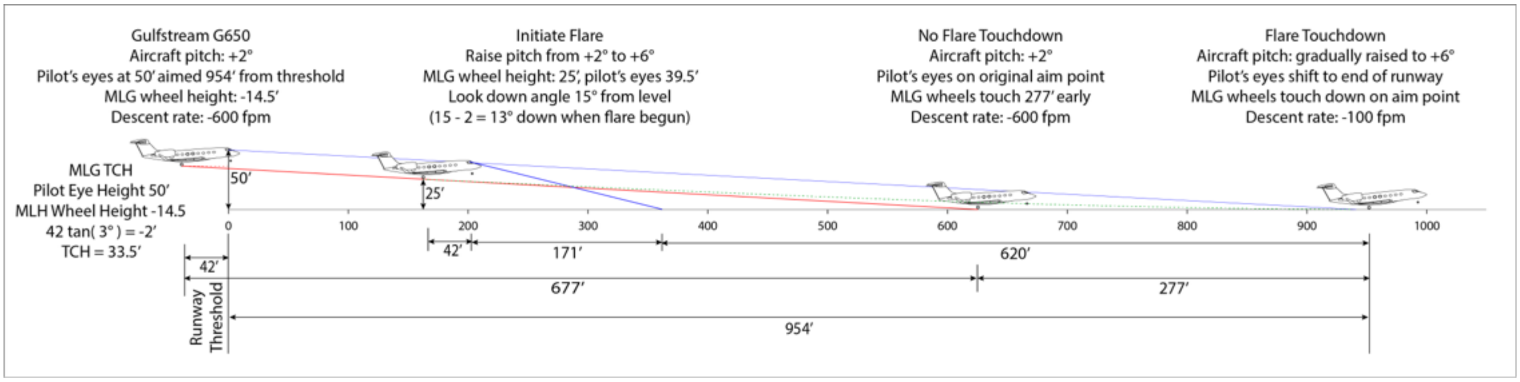
James Albright

I've heard this off and on over the years: "Hold your aimpoint steady in the windshield and once you lose sight of it, flare." Of course, that makes no sense. If you hold the aimpoint stationary you will not lose sight of it until the wheels touch well short of it. So, how do you know when to flare? Few manufacturers quantify the height where the flare begins. In fact, I've only seen this for three aircraft: the Gulfstream G450, the Boeing 747 and the Boeing 777. The published height for the Gulfstream is 20 ft., though I've found 25 ft. to be more comfortable. For the Boeings it is 30 ft. For the rest of us, we tend to figure that out for ourselves.

Let's cut down on the number of variables by making two assumptions. First, we would like to touch down where we are aiming. Second, we want to pitch up to the flare attitude in one smooth and continuous motion. That makes the rotation-to-flare easier to teach and replicate for consistency.

If a Boeing 747 flares at 30-ft. wheel height, we can safely assume our G650 will flare with a little less altitude. I have used 25 ft. in every Gulfstream I've flown but start the thought "flare now" when I hear the radio altimeter announce "30." Have I been cheating in the 5 ft. all this time? I don't think so. On a 600-fpm glidepath, which is what you will be on if you are flying at 120-kt. ground speed, you are descending at 10 fps.

So thinking "flare now" with a half a second warning seems like a reasonable thing to do. Let's see how our flare geometry looks with a 25-ft. wheel height.

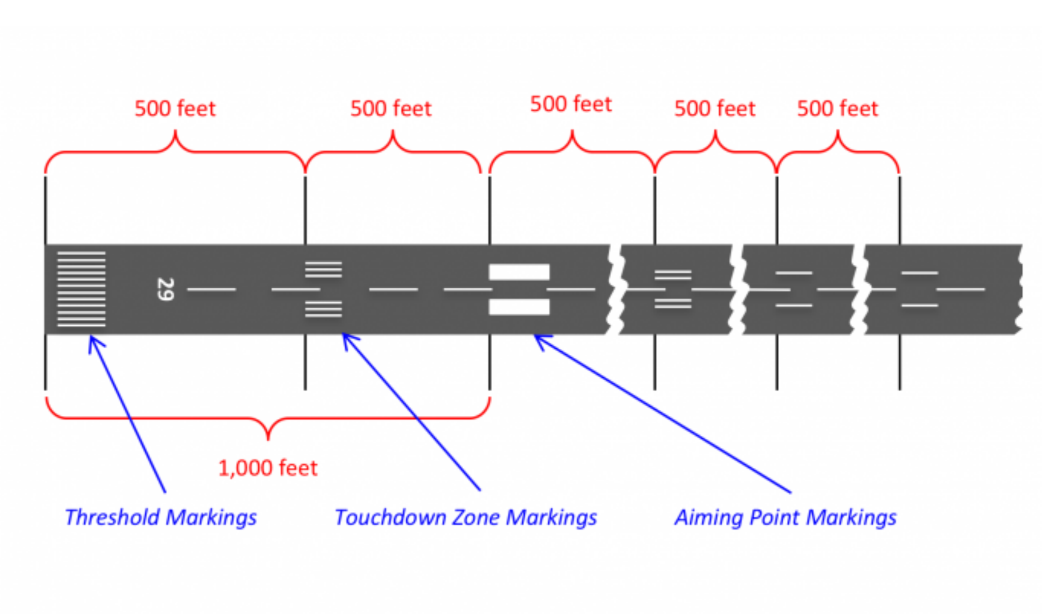


An example Gulfstream G650 from 50 ft. to touchdown. Image credit: James Albright

If we position ourselves visually attempting to place the aircraft on a 3-deg. glidepath to the 1,000-ft. marker, our eyes will cross the threshold at 52 ft. If we manage to place our eyes at precisely 50 ft. TCH, our aimpoint will be 954 ft. from the end of the runway. In the case of our G650, our MLG will be 50–14.5 = 35.5 ft. above the runway. The MLG will continue to descend at 3 deg. and by the time it gets to the threshold, the MLG will be 42 x tan (3 deg.) = 2 ft. lower, for a TCH of 33.5 ft.

As pilots, we condition ourselves to maintain this stable descent rate until it is time to flare. Since the flare is initiated at a height above the ground, we tell ourselves we have an ability to judge the height accurately and pull the nose up when it "feels about right." Over the years I've started to rely on the radio altimeter's aural callout of "30," knowing that in a half second I will be at 25 ft. and it will be time to flare. But what if you don't have this kind of technology or what if the technology is broken? Worse yet, what if the technology fails you without warning? How can you accurately know it is time to flare without the callout?

Once again, trigonometry can be your best friend. Our G650 has a published "look down angle" of 15 deg. below level flight. Restated in English, this means as you look over the nose, your view of the world below you is blocked by the aircraft below an angle of 15 deg. Since you will be approaching the flare with your eyes at 25 ft. + 14.5 ft. = 39.5 ft. at a +2-deg. pitch, you will be unable to see the 39.5 / tan (13 deg.) = 171 ft. directly in front of the aircraft. With a little more math, we can determine that our first point of vision will be 620 ft. short of our aimpoint. In other words, when a point just over 600 ft. short of our aimpoint disappears, our MLG will be 25 ft. above the runway and it will be time to flare.



Typical runway markings. Image credit: James Albright

That is handy knowledge for a G650 pilot wanting to know a good visual cue for when to start the flare. If you are aiming for the 1,000-ft. fixed-distance markers, you can wait for the preceding 500-ft. markers to just about reach your nose before starting to flare. Good for the G650 crowd, but what about the rest of us?

You could of course do the math if you have access to the eye-wheel-height, eye-to-MLG distance, and the look-down angle for your aircraft. Very few manufacturers provide these numbers. This data is not available for the aircraft I am flying now, a Gulfstream GVII-

G500. It is similar in size to the G650 and I would guess the numbers are about the same. But there is an easier way to figure this out.

You could simply ask the other pilot to take note of the first part of the runway viewable over the nose when you arrive at your customary flare height having flown a very steady glidepath to a discernible aimpoint. Do this several times and you will soon see a pattern develop. This distance short of the aimpoint is your visual cue to start the flare.

GoPro view of the author's GVII at 25 ft., showing the cutoff point is 500 ft. short of the aimpoint. Photo credit: James Albright

There is an even easier way. We've mounted a portable video camera at about the pilot's eye level off to the side. We've taken multiple videos and have come to the conclusion that we will be at 25-ft. MLG height when a point 500 ft. short of our aimpoint touches the nose.

Landing An Airplane Essentials

James Albright April 23, 2021

A G450's flight path vector at 10 ft. on a short runway (KBED Runway 23). Photo credit: James Albright

Folklore: If we shift our aim to the horizon during the landing flare, we will be able to judge a proper touchdown at our aimpoint.

The idea behind shifting our eyes from the runway aimpoint to the horizon is to give us the best depth perception to judge when our descent rate has been arrested. There is a truism in the art of riding motorcycles that says the bike goes where your eyes are looking. I find that putting your eyes on the horizon leads you to level off, which many pilots think is the entire goal of the landing. The problem is this: Have we stopped our descent rate an inch above the runway or 10 ft.? Or perhaps we misjudged that and would have stopped it at -10 ft. except there was pavement in the way. Attempting to end the flare right above the runway is difficult and carries a risk of landing short or long.

Most aircraft are designed to land with a descent rate that is only partially arrested. The highest I've seen is in the G550, which is designed to land while descending at 8 fps, which comes to 480 fpm. That is just barely short of that airplane's normal glidepath descent rate of 600 fpm. I don't know anyone who does that with a load of passengers on board. But if you are in the habit of landing on runways within a few hundred feet of the computed landing distance, you need to know what it takes to achieve your flight manual's performance numbers.

I practice these "performance landings" in the simulator, just to make sure I know how. In the real world, I insist on an extra 1,000 ft. of runway over my aircraft manual's requirements. (We've actually written that into our operations manual.) For these conditions, I shoot for a mere 100-fpm descent rate at touchdown. That puts me down at my aimpoint reliably and avoids long landings. This technique produces comfortable landings in all but the most stiff-legged aircraft. You won't be getting applause from the cabin, but you won't be having to explain any excursions beyond the paved landing surface. So your goal should be for a slight descent on touchdown. But how do you do that?

I find that raising my eyes to the end of the runway, but below the horizon, does the trick. The photo shows the flight path vector (symbology that shows the aircraft's trajectory) slightly below the end of the runway because I was looking at the runway's end, not the horizon. If I sense the airplane has leveled off, I'll nudge the stick forward with the thought, "Keep it coming down." This assures the aircraft continues to descend. Even without flight path vector technology, the pilot needs only to shift his or her eyes to the end of the runway to keep the descent rate going. But there is a little more to it than that, and for that we need to look at some timing.

Folklore: The flare cannot be taught; it is a matter of feel learned through experience.

While much of pilot life is taught as science--think of takeoff data, obstacle avoidance, range performance, etc.--the act of landing the airplane is taught as art. You simply do it under instruction, learn from critique, and adjust until you get it. But as we have seen here so far, you can quantify the act of landing an airplane up to the point you need to pull back on the stick or yoke. We know how to get to flare height and we know what to do after the wheels touch. How do we connect the two? How do you flare an airplane?

In its simplest form, you pull back on the stick or yoke from its existing approach pitch angle and end up at a new angle. That is the "flare rotation." To bring this art to science, try to pull back in one smooth, continuous motion that ends just as the wheels touch. It would be helpful to know how long this takes. Let's reexamine our G650's flare path starting at 25 ft.

When we begin the flare, the MLG will be at 25 ft. and the pilot's eyes 14.5 ft. higher. The aimpoint will be 39.5 ft. / tan(3deg.) = 754 ft. away. Since the MLG have to travel an additional 42 ft., we know the distance of the flare will be a total of 796 ft. If we assume a ground speed of 120 kt., the flare will take:

$$t = 796 \text{ ft.} \times \frac{1 \text{ hr.}}{120 \text{ nm}} \times \frac{1 \text{ nm}}{6{,}076 \text{ ft.}} \times \frac{3{,}600 \text{ sec.}}{1 \text{ hr.}} = 3.93 \text{ sec.}$$

Which means you are attempting a smooth, continuous pull on the stick or yoke that takes 4 sec. I think the best flare ends just as you get to the end of your pull while the wheels touch.

The flare can be learned scientifically by instilling the need to begin at a consistent height, pulling back at a consistent rate, and with your eyes pointed at the end of the runway. Each event should be graded looking for a 4-sec. rotation to flare, ending with the wheels touching at the desired aimpoint.

Some of us have been doing this for decades and the thought of grading each landing may seem abhorrent. If you tend to have streaks of good landings and bad landings, this grading approach should help. I find it helpful to write a few sentences describing each landing in retrospect. On a good day: “Stable approach, nice easy pull back, wheels kissed the pavement 4 sec. later right in the touchdown zone, on speed.” On a less than good day: “Crossed the threshold a little low, started the flare too early, ended up over-rotating and landing long.” You will find that after a while a pattern will develop, helping you self-analyze and, more importantly, self-correct.

Remember when grading yourself that the wheels touch behind you and your forward view is obscured by the aircraft’s look-down angle. You will not see the landing in the touchdown zone because your aircraft is blocking the view.

How to Land an Airplane, in Summary

(1) Fly a stable approach, on speed, on the proper glidepath.

(2) Cross the runway threshold at 50 ft. visually or electronically. Remember that if flying visually or on an ILS glideslope, your wheels will be lower than 50 ft. (In our example, that was 35.5 ft. when flying visually.)

(3) Determine the proper flare height based on any flight manual data or on what you have determined by experience. This height can be made evident by electronic means, such as a radio altimeter, but should always be backed up with a point on the runway that you expect to just disappear under the nose. (In our example, a point 600 ft. short of the aimpoint.)

(4) At the proper flare height, shift your eyes to the end of the runway (not the horizon), and using one smooth and continuous motion, pull back to your flare rotation pitch. The pull should take 4 sec. and should end as the wheels touch with the aircraft still in a 100- to 200-fpm descent rate.

Notice that we have not mentioned thrust at all, which will be handled in accordance with aircraft-specific procedures. My technique is to allow the autothrottle “retard” function, if available, to function as designed. This further reduces the number of variables. If operating without autothrottles, I attempt to initiate the reduction at the same time I initiate the pitch rotation, reaching idle as the wheels touch. This has worked on every aircraft I have flown, but I recognize it will not work for others.

One last note for those flying aircraft with unpublished eye-to-wheel and flare heights. The math shown here is for a Gulfstream G650, an aircraft in the 100,000-lb. range that is nearly 100 ft. long. Using a 25-ft. flare height will probably be conservative for smaller aircraft but will give you a starting point. (Remember larger aircraft may have flare heights around 30 ft.) I recommend trying these out in the simulator or seeing what you have been doing in the airplane as a comparison. The first step in any scientific endeavor is observation. I believe you can improve your landings if you approach the landing flare as science, not art.