MORE THAN MATH

Understanding Performance Limits

DAVE SWARTZ

I hate it when you complete the takeoff run hanging upside down from the seat belts. A few years ago, that happened to me, and I really should have known better. You see, I'm an aeronautical engineer and I occasionally do performance calculations for a living, so I have no excuse. That fateful day the conditions looked marginal, so I looked at "the book." It said I could make it. One of my mistakes was taking the book numbers too seriously. They didn't take into account the tailwind I didn't know I had.

Since that day, I have been thinking and learning a lot about what went wrong. I hope you find my mistakes useful in avoiding some of your own. According to the 2006 Nall Report, published by the Aircraft Owners and Pilots Association's Air Safety Foundation (AOPA/ASF), about one out of six takeoff accidents is fatal. It's sobering to realize that you have the same odds in Russian roulette.

I am one of the lucky ones.

Where Do Performance Numbers Come From?

Honestly, it's really a mixed bag. In the case of many older airplanes, the Pilot's Operating Handbook (POH) contains limited information at best. Yet, you can still be confident that most airplanes have been tested by steely-eyed test pilots to determine what the airplane can, and will, do under specific conditions. Then, engineers try to replicate what they think an average pilot will do. Engineers start with the takeoff distances that the test pilots achieve and correct them for things like density altitude and runway conditions.

Next, they fill out the tables that eventually get published in the POH. These tables give you numbers like 2,479 feet over a 50-foot obstacle at 32°F with a nine-knot headwind at 6,000 feet on the first Monday after a full moon. Okay, the last part is a stretch, but the point is that this level of precision is pretty silly in view of the assumptions involved. I am quite confident that a test pilot can replicate those numbers in the factory airplane 50 percent of the time. I can also tell you that with my level of experience, in a 60-year-old airplane, there was a day I couldn't do it. That day, I learned that the engineers didn't put a safety factor into their takeoff performance numbers. AOPA/ASF recommends adding 50 percent to published takeoff and landing distances. If I had paid attention, my insurance company would be a lot happier today.

The next time you are out practicing on a nice VFR day, consider seeing if you can get the "book numbers." Here's a simple way to test your skills and aircraft performance for takeoff and landing distances. Typically, runway lights are spaced 200 feet apart, so you can count them as they go by. Have a friend or fellow pilot ride along with you and count the lights as you roll by. You, of course, should be focused completely on the business of flying the airplane! Have your helper write the numbers down, and later you can compare them with the POH. You can also use these numbers to start making your own, more realistic, takeoff and landing performance tables.

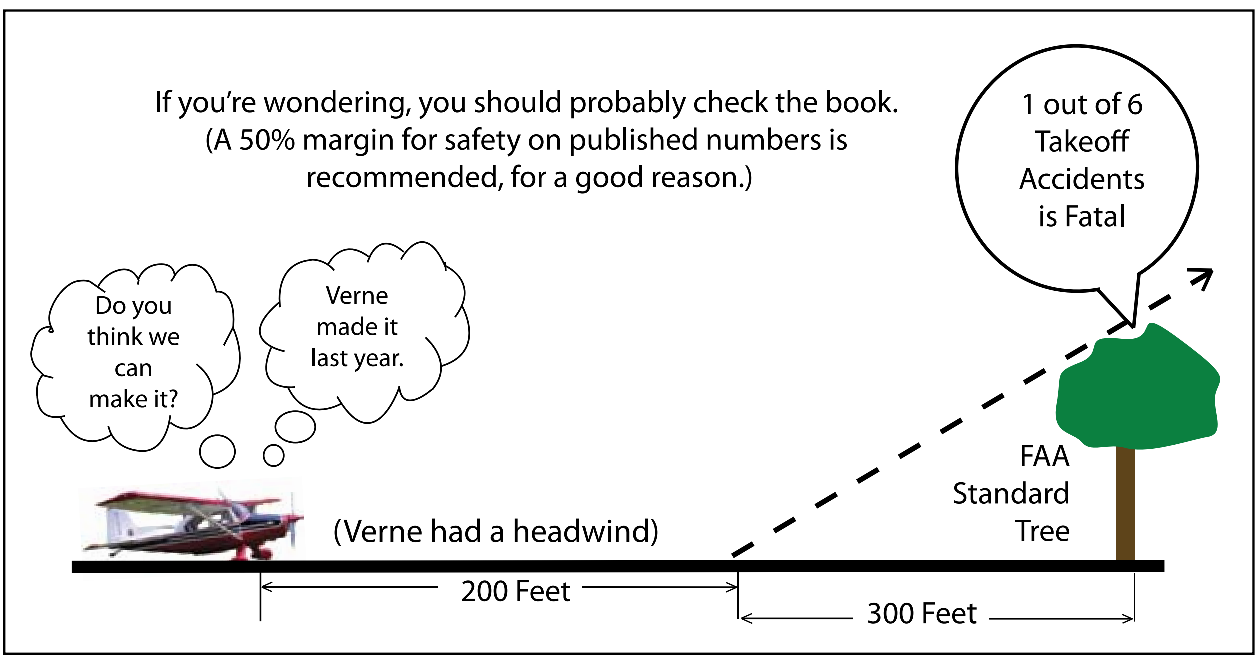
As you work on this project, keep in mind some of the conditions that will affect your takeoff distance. Before I list them, though, please bear this caution in mind: I use some rules of thumb from *The Axioms of Flight* by James Embree, as well as other sources. All rules of thumb are necessarily based on assumptions whose accuracy may be suspect in certain circumstances. These particular rules of thumb are intended for typical light, normally-aspirated, reciprocating single-engine airplanes. When you have good data for your specific airplane, it's usually more accurate.

"Experience is the best teacher; unfortunately, she has been known to kill her students."

For several reasons, higher-density altitude increases your takeoff distances.

1. Normally-aspirated engines make less power. At some point, you may need to lean even for takeoff to get all the power that is available.
2. The propeller is less efficient (not as much thrust for the same power).
3. Your liftoff airspeed is in indicated airspeed, but tire friction depends on ground speed, which will be greater at higher-density altitudes.

Several publications on mountain flying estimate that your takeoff distance will increase by 10 percent for each 1,000 feet in density altitude. While this rule of thumb works for limited differences in density altitude (about 4,000 feet), extrapolations



Just because someone else made it over an obstacle doesn't mean you will. Check your performance numbers and remember to add a proper safety margin. Illustration courtesy of Dave Swartz.

beyond that can become dangerous because power then starts to fall off more quickly than 10 percent per thousand feet.

Is That Really a 50-Foot Tree?

We generally focus on required takeoff distance. But, given that small airplane climb angles are typically pretty flat, it's much more important to be aware of what obstacles exist beyond the runway and to have a good idea of their height. In the event described at the beginning of this article, I hit a tree that was only about 10 feet tall. Ironically, I then hit the wind sock that was lying in the weeds. The height of the obstacle was undeniably a factor in my rationalization. Even though "the book" said it would be tight, I thought that I could make it because the trees weren't that tall.

The number is not really the most important element: The key is your individual training, proficiency, and comfort level.

Do you know how to estimate obstacle heights? Here's an easy method for getting a ballpark idea on the height of a tree.

- Fold a piece of paper into a 45-degree triangle.
- Sight along the diagonal edge as you walk toward the tree.
- When you see the tree top along the diagonal edge of the paper, the tree height is equal to your distance from it, plus your height.

After you practice this technique a few times, you will have honed your ability to judge how high obstacles are. You may be surprised by what you learn.

Once you know how high the tree is, the next step is to determine whether you can clear it. For this purpose, look at the POH numbers and get the difference between the ground-run distance and the takeoff over a 50-foot obstacle distance. Here's an example: A Piper *Super Cub* POH has a published 200-foot ground roll, with a total takeoff distance of 500 feet to get over a 50-foot obstacle. So, it takes 300 feet from liftoff to clear the obstacle. This means that over a 100-foot obstacle, you would need about 800 feet (500 feet for the first 50 feet, plus an additional 300 for the next 50).

If you are using an "unimproved surface," most POHs have a correction factor. That number usually adds about 15 percent to the ground run. What the correction factor does not necessarily cover is the fact that mud, snow, or tall wet grass can make the ground run much longer. In the case of a ski plane, taking off on clear ice can be very short, but takeoff

The photos in this article are of Dave Swartz's own aircraft after the accident that inspired this article.

distances in deep snow can seem infinite. Landing in deep snow is very short, but landing on ice can also seem infinite unless you shut the engine off completely and throw out an anchor. Seaplane pilots have similarly variable conditions and are especially sensitive to weight.

What about Wind?

We all know that a tailwind hurts you on takeoff, but it is also important to know how much. If your airplane's POH contains correction factors, use them. If not, a good rule of thumb is that for every 10 percent of the takeoff speed, a tailwind will increase the ground run by about 21 percent. For example, with a liftoff speed of 51 knots and a zero-wind takeoff ground roll of 980 feet, the rule of thumb would tell you that a five-knot tailwind will increase your ground roll by about 210 feet. The book for a Cessna 172 shows these same conditions resulting in a published increase of 245 feet (25 percent). The Cessna manual is based on actual flight test information instead of a rule of thumb. (Remember, there is still no margin of safety in these numbers!)

Although headwinds will reduce your takeoff distance by a similar factor, it's important to remember that a headwind can change quickly with altitude, and it can disappear altogether with a gust. If your life depends on the extra performance expected from a headwind, reconsider the takeoff.

Crosswinds negatively affect takeoff performance. That's because they require you to introduce aerodynamic drag with the control surface deflections that keep the airplane on the runway. In addition, performance is affected by drag from the tires scrubbing on the runway.

The Medallion Foundation, an organization committed to reducing aviation accidents in Alaska, has effectively incorporated the concept of personal minimums into its safety seminars. My own personal limit is a five-knot crosswind component. That's because I fly a tail dragger with a fairly strong tendency to weather vane on landing, and that works for me. The number is not really the most important element here: The key is your individual training, proficiency, and comfort level. Think about that before committing to the landing, and take action if it looks like you are over your limit. (Editor's note: Please see the May/June 2006 issue of *FAA Aviation News* for an article on developing your individual personal minimums.)

Propellers

When reviewing takeoff performance numbers, make sure you have the same prop that the chart assumes you have. If your POH numbers are based on a climb prop when your airplane actually has a cruise prop installed, you won't make the book numbers. As an aside, please remember that you can also run out of fuel if you have a climb prop when POH numbers for cruise speed are based on having a cruise prop.

Propellers are routinely filed to remove rock dings. Though necessary, this process compromises the airfoil to some extent. POH numbers are established in an airplane with a new prop. They do not include adjustments for a prop that has been filed down to limits.

Pay Attention!

If you don't remember anything else from this article, please note these four short points:

1. Take it from me: It's better to figure out if you are going to make it before you are airborne. When in doubt, do the math.
2. Establish your own personal limits and stick to them.
3. Incorporate a safety factor into the numbers; AOPA/ASF's 50 percent is a good one.
4. Keep learning, and incorporate what you learn into how you fly.

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