Aircraft Performance

Certification versus **the real world**

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On April 2, 2011, a Gulfstream 650 test crew perished while completing steps along that airplane's road to certification under Title 14 of the U.S. Code of Federal Regulations, Part 25 (14 CFR 25). They had been hard at work, proving the aircraft could fly the very low takeoff safety speeds predicted by its designers. A lower V_2, after all, meant the aircraft would be capable of using shorter runways. Their last attempt resulted in an asymmetric stall below the predicted in-ground-effect stall angle of attack (AOA). Modern certification test standards are remarkably safe and these types of accidents have become rare, making this mishap all the more tragic.

The G650 crash points out the diametrically opposed forces in aircraft certification. The certification authority and the manufacturer want to produce a safe aircraft. But a safe aircraft is of no use if nobody is willing to buy it. They must walk a fine line getting the most performance possible from the jet while still keeping it safe for everyday operations. The result of their handiwork is an airplane the manufacturer and certification authority can stand behind, and airplane flight manuals we line pilots rely on to predict aircraft performance. But how relevant is that performance data to real world operations?

Many professional pilots are skeptical and misinformation is rampant: "The numbers in the manual are obtainable only by highly qualified test pilots flying factory-new aircraft!" On the opposite end of the spectrum: "Those numbers are padded by 50%! Everyone knows that!" Why so much confusion? Try these phrases on for size: "demonstrated crosswind," "minimum control speed — ground," "accelerate-stop," "gross versus net climb," "maneuvering speed" and "landing distance available." There are more, of course, but each of these serves to illustrate a different aspect of aircraft certification and the line pilot.

Crosswinds — Demonstrated Versus Limiting

How would you define an aircraft's limiting crosswind? Would it be just a knot

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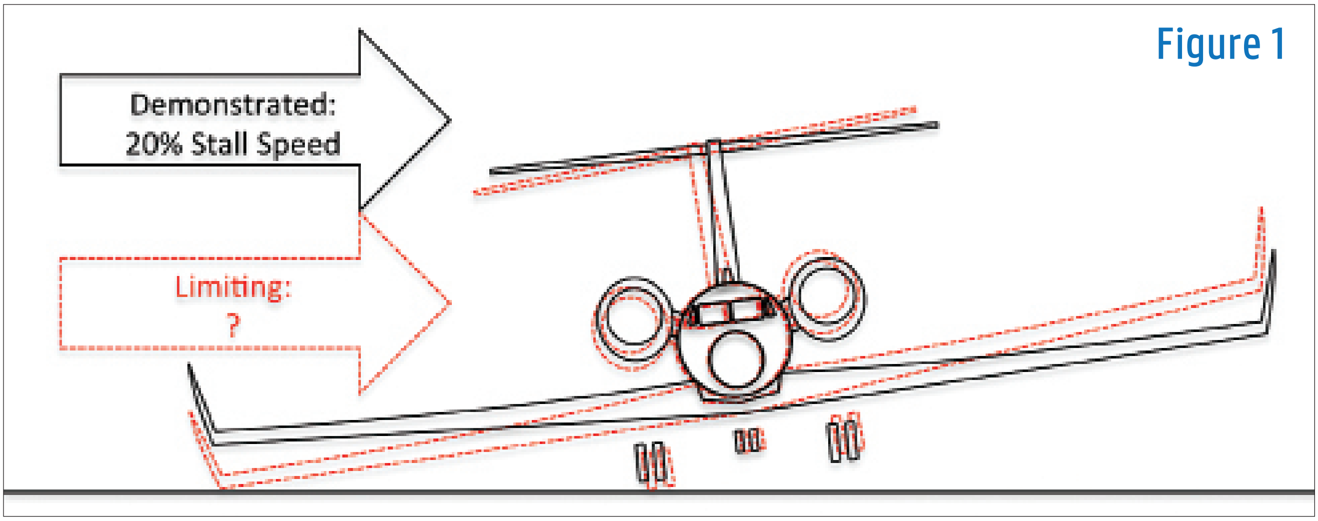
NTSB



less than the point a wing-low landing scrapes a wingtip or engine pod? We can all agree that is taking things too far. But how close to limiting should the manufacturer go?

Let's say your aircraft has a "maximum demonstrated crosswind component" of 24 kt., but you've witnessed the airplane landing at twice that with no problem. What gives? The first reaction many pilots give to these debates is to blame the lawyers. That is only partially true. An aircraft certified in the U.S. must satisfy 14 CFR 25.237: An aircraft must demonstrate the ability to take off and land on a dry runway with a crosswind of at least 20 kt. or 20% of its reference stall speed in the landing configuration, whichever is greater, except that it need not exceed 25 kt. In the case of a Gulfstream 450, which stalls at 119 kt. at maximum gross weight at sea level, 24 kt. is the smallest number the manufacturer is supposed to demonstrate and that's exactly the number they cite. Will the airplane do more? Sure. But that is all they were required to demonstrate.

The crosswind math comes out the same for the bigger and heavier Gulfstream 550, but the manufacturer posts a 28-kt. demonstrated crosswind. Why? Some say that on the day the FAA observed the demonstration the winds happened to be 28 kt. so Gulfstream signed up to it. Others say an important customer insisted on it. Whatever the reason, pilots are left with two possible answers to the crosswind problem. They can say, with some degree of accuracy, that their aircraft might be capable of more. Or, more cautiously, that if the people who built the airplane won't defend more than "X" knots of crosswind, why should they? (See Figure 1)

Reality Check: The manufacturer had to demonstrate a minimum value but not a limit. You have no idea of where the limit is: It could be double the demonstrated value or just 1 kt. higher. In fact, it could very well be the limit — you just don't know. If you decide to exceed what the manufacturer has demonstrated, you become the test pilot and will have a solo seat at the inquiry if you break something as a result.

Ground Minimum Control Speed — A Hidden Limitation

While it can be said that 14 CFR 25 outlines a crosswind limit that isn't a limit, there are other limits that disguise other limits, such as the Ground Minimum Control Speed, VMCG. (See Figure 2)

We plan our takeoffs assuming we are going to lose an engine at the worst possible time without losing directional control. All that is well and good if you have a wide runway, but what does it really mean to your trip planning? Under 14 CFR 25.149(e), manufacturers must establish a minimum control speed on the ground, VMCG, after which the aircraft will not deviate more than 30 ft. from runway centerline using rudder alone, following an engine failure with the aircraft at its most unfavorable center of gravity.

Reality Check: While few manufacturers post a minimum runway width, the VMCG certification rule gives you a de facto limitation. A "classic" Gulfstream V, for example, has a main gear footprint of about 15 ft. If the aircraft moves 30 ft. either side of centerline, the outboard tire will be 37.5 ft. from centerline. That puts it right on the edge of a 75-ft.-wide runway, establishing a bare minimum width of runway for the GV. If your airplane flight manual does not list a minimum runway width, it is up to you to do the math: two times the sum of 30 ft. and half your main gear footprint.

If VMCG can be said to disguise an aircraft limitation, V_1 can be said to completely obscure another. How much time do you have to recognize and react to an engine failure?

V_1 — Decision or Action?

A fundamental concept in multiengine aircraft is the idea of a decision speed, V_1. This suggests the pilot is making a decision at this point, but nothing could be further from the truth. At V_1, the aircraft is either continuing its takeoff, possibly with one less operating engine, or the pilot is in the process of aborting the takeoff. Decision speed is really an "action speed." (See Figure 3)

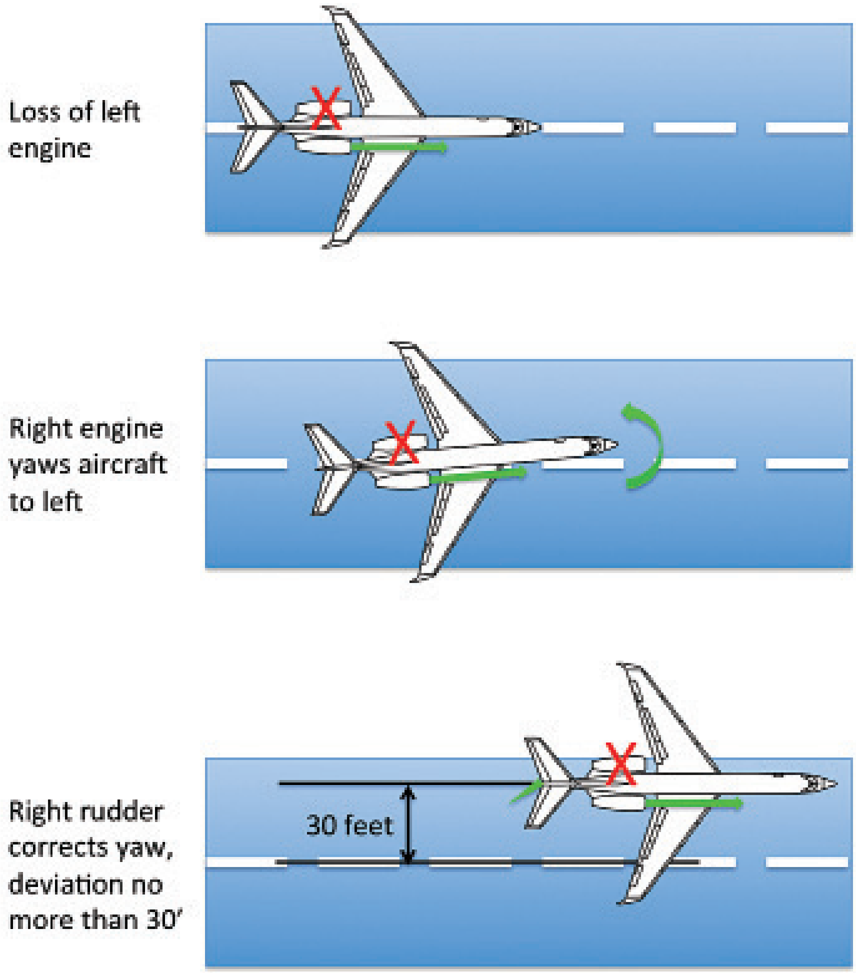
Under 14 CFR 25.107(a)(2), the manufacturer is allowed to select V_1 so long as it occurs after the critical engine fails, and it allows for the pilot's decision and reaction time. But no matter how V_1 is chosen, 14 CFR 25.109(a) mandates that a safety margin be added to the accelerate-stop distance. This distance is equivalent to 2 sec. at V_1 speed.

There is no mandated decision time between engine failure and the time an abort must be initiated; that is up to the manufacturer. A Bombardier Global Express, for example, uses 2.0 sec., but that is 2 sec. prior to V_1 and has nothing to do with the 2-sec. distance added to accelerate-stop distance. Most Gulfstreams use between 1.0 and 1.25 sec. Some manufacturers do not specify an interval.

The braking effort itself is left to the discretion of the manufacturer, but the tests must be made using brakes worn to the point that they have not more than 10% of their allowable brake wear range remaining.

Reality Check: When taking off on a balanced field, one where you have just enough runway to continue or abort the takeoff after losing the critical engine at what is more properly known as V_{EF}, it is absolutely critical that an abort be initiated prior to V_1. To make this happen, the pilot monitoring has to call the speed in time for the pilot flying to recognize the callout and react. Calling the speed too early also poses risks. If you attempt to continue the takeoff without adequate all-engine acceleration time, you may not get off the ground in the remaining runway with an engine out. The 2-sec. pad for a V_1 of 120 kt. is just 405 ft. If you are planning a takeoff where the balanced field length equals the runway length, you need to have your act together.

Figure 2



Climb Gradient — Net or Gross?

The constraints on the pilot at V_1 are considerable and the rules for certification do not provide much room for error. Climb gradient safety margins, on the other hand, are adequate but confusing. (See Figure 4)

Very few aircraft manufacturers provide climb gradient charts based on all-engine climb performance because the regulations assume a failure of the critical engine. They must produce engine-out numbers and in many cases that's all they provide. Actual aircraft performance is further reduced under 14 CFR 25.115(b) by what can be considered a safety factor but is only given the name "net flight path."

The "net versus gross" climb gradient debate is misunderstood by many pilots. There are those that say gross climb gradient is what the test pilot gets from a brand new airplane and net is what we mortal pilots get from our "seasoned" jets. They are wrong on both counts. U.S. certification rules state, "No takeoff made to determine the data required by this section may require exceptional piloting skill or alertness." The net takeoff flight path data is simply the actual flight path reduced by a safety factor of 0.8% for two-engine aircraft, 0.9% for three-engine aircraft, and 1.0% for four-engine aircraft. The actual flight path has come to be known as "gross flight path," though the regulation does not use this term. Why does this matter? Commercial operators are told their engine-out performance will clear all obstacles by 35 ft., period. In a two-engine aircraft, they will actually clear all obstacles by 35 ft. plus an additional 48 ft. (0.008 x 6,076) for every nautical mile from the departure end of the runway.

Reality Check: The airplane flight manual climb gradients are derived from multiple test runs using normal piloting procedures on what can be considered "normal" aircraft. The resulting numbers are reduced by a safety factor. A line pilot with average skills should be able to outperform the numbers provided in the flight manual.

Maneuvering Speed — Not What You Think

Design maneuvering speed, V_A, is a valuable tool in any fighter pilot's arsenal. Knowing how to extract the last bit of aerodynamic maneuverability can be a lifesaver in air-to-air combat. It is, however, a subject best left in the classroom for most transport category pilots. It is defined in 14 CFR 25.335 as simply the clean stall speed of an aircraft times the square root of its positive maneuvering load factor limit. Aircraft designers must consider it, but manufacturers are not constrained on how they present it. While the layman's translation of V_A is the speed at which you cannot stall or over-stress an aircraft, manufacturers do not have to specify an altitude or weight at which they figured VA. Pilots are either left with a single number without the weight and altitude specified, or a chart that is hardly usable when the pilot wants to know a speed to fly. (See photo below.)

In November 2001, an American Airlines Airbus A300 crashed after departure from New York's JFK International Airport in what many assumed was a wake turbulence encounter. The aircraft had actually survived the wake turbulence behind a Boeing 747 but suffered inflight separation of the vertical stabilizer due to overly aggressive rudder inputs. The NTSB "learned that many pilots might have an incorrect understanding of the meaning of the design maneuvering speed (VA) and the extent of structural protection that exists when the airplane is operated below this speed." Certification tests to determine design maneuvering speeds do not consider combinations of sideslip or rapid rudder reversal. If the situation calls for full rudder, by all means use it. But VA does not protect you from structural failure under all conditions.

Reality Check: Design maneuvering speed (VA) for transport category aircraft is primarily a number used in the certification process. It can be presented as a single number based on conditions of the manufacturer's choosing, or as a complete chart that covers a wide range of conditions. There is limited benefit to a transport category pilot knowing a specific VA, and there is a real danger if pilots don't understand the true meaning of VA. The old maxim that you can "yank and bank to your heart's content at VA" is false. Pilots should understand that an aircraft's aerodynamic stall speed goes up with increased load factor and that it is easier to reach a limiting load factor as the airspeed goes up.

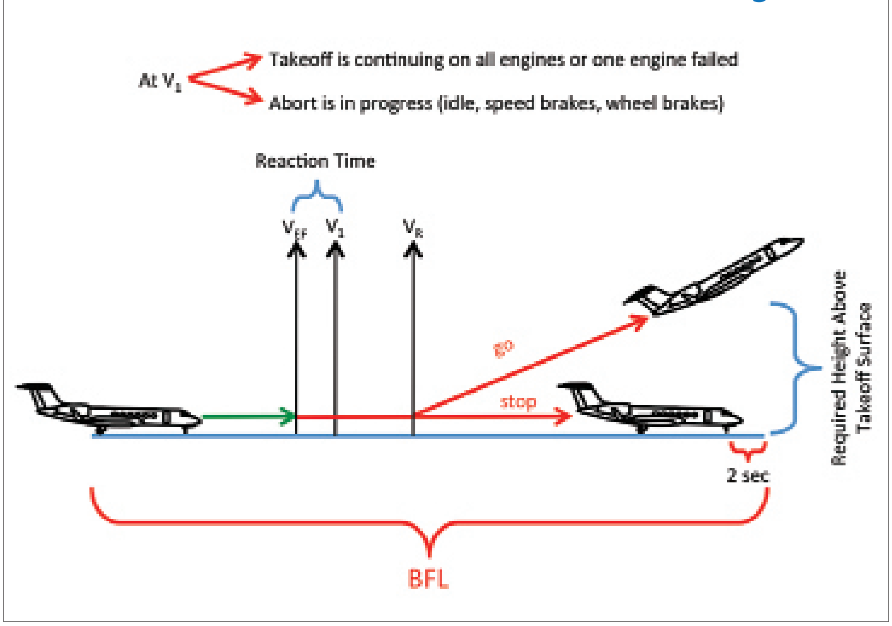
Landing Distance — An Exact Number With Inexact Procedures

The certification rules for landing are specific in many areas and silent in others. Under 14 CFR 25.125 landing distances are required to be based on a stabilized approach with a calibrated airspeed of not less than VREF maintained to a 50-ft. height, without excessive vertical acceleration or tendency to bounce, nose over, ground loop or porpoise. The landing may not require exceptional piloting skill or alertness. Here too is where you will find the oft-repeated rule about winds: not more than 50% of a headwind or 150% of a tailwind. Nowhere in this section, however, is there a mention of the biggest landing variable of them all: the flare. (See Figure 5)

Some manufacturers get around this lack of flare guidance by mandating specific touchdown rates. The Gulfstream 450 Airplane Flight Manual, for example, specifies that the aircraft will cross the threshold at VREF and that landing distances are based on a 3-deg. glidepath and a 6-ft.-per-sec. touchdown. That's 360-ft. per min., about half the normal ILS glidepath descent rate. To achieve the stated landing distances, you will need a very minimal flare, a firm touchdown and aggressive braking.

Most aircraft manuals do not provide this level of detail on the landing techniques required to achieve flight manual landing distances. The Cessna Citation X, for example, only notes the aircraft

Figure 3



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should arrive on a 3-deg. angle at 50 ft., at which time the throttles are brought to idle, speed brakes deployed on main wheel contact and maximum braking applied.

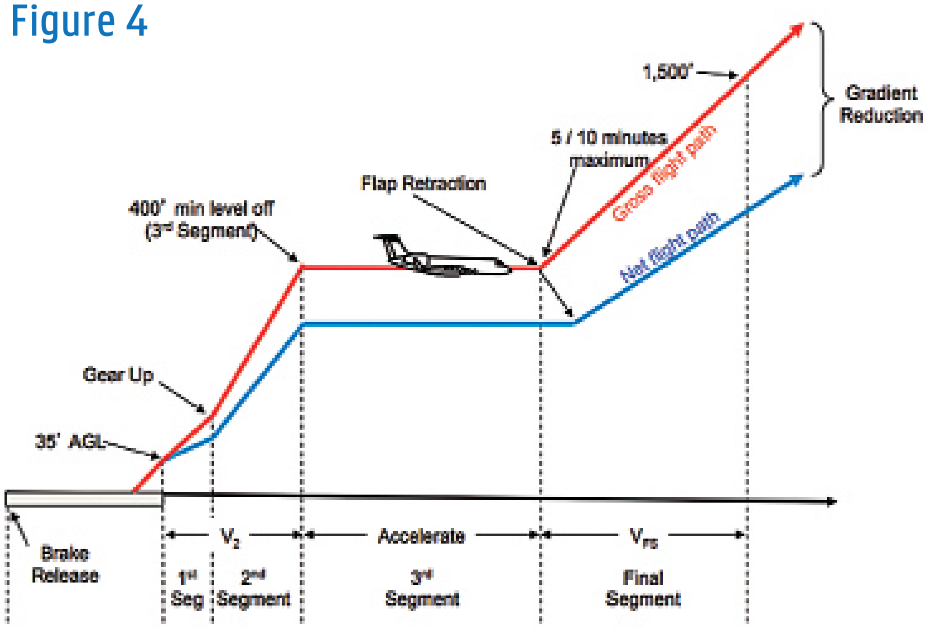
Reality Check: Aircraft manufacturers use very specific techniques to achieve landing distances for publication in flight manuals but are not always explicit on the techniques needed. Pilots are left in an uncomfortable position, having to get the airplane into and out of runways the airplane was advertised as capable of, and providing a comfortable ride to those who are paying the bills. Here are two techniques:

(1) Fly the aircraft as the flight manual dictates and become proficient at getting the advertised performance. Educate your fellow pilots and your passengers that a safe landing is one that is flown off a stable approach, on speed, ends up on centerline and in the touchdown zone, and vacates the runway with an ample margin of distance left over. The touchdown will be firm.

(2) Compute 14 CFR 135 landing factors (aircraft cannot depart an airport unless conditions would allow them to land at their destination on 60% of the available runway) for every landing and grade your normal landing and braking technique against this margin. If, for example, the AFM performance predicts a landing distance of 2,500 ft., you would find a factored distance by multiplying the distance by 1.667 (or dividing it by 0.60, the 60% factor) to arrive at 4,167 ft. If you can routinely land inside of this factored number, you will know how to adjust your AFM numbers to predict landing distances with you at the controls.

Most of us, subconsciously, adjust our landing distance numbers and have a general feel for how much extra runway our flare and comfortable braking will take. There is a real danger in doing this, however. Who is to say our internal adjustment factors will work for all conditions? If we don't routinely use the same techniques used to produce the numbers in the flight manual, will we be able to do so when we really have to?

Figure 4



The Pilot's Role — Making Sense of It All

Your aircraft was certified as airworthy using precise procedures designed to extract as much performance as possible, while leaving a margin for error. In most cases that margin is quite small. If you understand the origin of many of your flight procedures you will be better prepared to know where additional caution is needed. Yes, a demonstrated crosswind component might as well be a limit. No, you cannot yank and bank to your heart's content just because the airspeed indicator sits on a magic number of the manufacturer's choosing. And if you really need to get the airplane stopped in its advertised landing distance, you need to practice doing it by the book. **B&CA**

Figure 5