FLYING LESSONS for April 24, 2026

FLYING LESSONS uses recent mishap reports to consider what *might* have contributed to accidents, so you can make better decisions if you face similar circumstances. In most cases design characteristics of a specific airplane have little direct bearing on the possible causes of aircraft accidents—but knowing how your airplane's systems respond can make the difference in your success as the scenario unfolds. So apply these *FLYING LESSONS* to the specific airplane you fly. Verify all technical information before applying it to your aircraft or operation, with manufacturers' data and recommendations taking precedence. **You are pilot in command and are ultimately responsible for the decisions you make.**

I apologize for being late with this week's report.

This week's LESSONS

Late last year Australian aviatrix (she uses the archaic term) and well-known aviation author Kreisha Ballantyne asked me **three questions** about **the practical application of weight and balance calculations and performance charts.** Here are my answers.

See https://www.flightsafetyaustralia.com/author/kreisha-ballantyne/

1. *Weight and balance limits are sometimes seen by newer pilots as "paperwork hurdles" rather than safety barriers. How do you explain what these limits actually protect us from, and why they are fundamental to aircraft controllability and performance?*

Weight and balance is all about aircraft ***performance, stability*** **and** ***control***.

First let's look at ***weight***. Clearly, with an engine capable of developing only so much power, and a wing capable of creating only so much lift, there will be an ultimate airplane weight at which even full power and full lifting capability will not be enough for the airplane to fly. So that's an absolute limit.

But you want the airplane to be in a condition that guarantees a certain amount of **predictable performance** in terms of takeoff and landing distance, rate of climb, cruise speed and maximum altitude. A desirable performance envelope will require the airplane's weight to be at or below some maximum that's well less than that absolute limit.

Further, aircraft structure is designed to absorb the additional G forces of turns, turbulence and approved maneuvers. The maximum airplane weight must be such that even under maximum certificated G forces it performs to a certain, known level. **All this together** means there will be a maximum weight approved for an airplane and exceeding that weight means it will not perform or maintain structural integrity as designed.

Now consider ***balance***. Aircraft controls exert a certain amount of force based on the airplane's **design**—wing and tail length, size of control surfaces, whether a surface is exposed to propeller blast, etc.—and its **indicated airspeed**—essentially, the amount of air flowing over control surfaces. The slower the indicated airspeed (the lower the airflow), the less effective controls become. **You need control surfaces to be as effective as possible at the slowest speeds** at which you plan to fly…all the way to aerodynamic stall.

There's another factor in control authority: **stability.** Stability occurs in all three axes but is most noticeable on the lateral axis, that is, airplane pitch. Stability is determined in large part by

the distance between the center of gravity, the point around which all airplane weight as currently loaded revolves, **and the center of pressure** (sometimes called center of lift), which is a generally fixed location about one-third of the distance between the leading edge and trailing edge of the wing where half the lift generated is ahead of that point and half is behind it. Center of pressure usually changes with flap extension, generally moving slightly aft of the location it's at when flaps are up.

As the center of gravity (CG) moves forward the airplane tends to pitch downward. To maintain a given pitch attitude requires a greater amount of "up" elevator control. As airspeed decreases a given amount of up elevator is less effective, meaning at slower speeds a given "nose up" force requires greater control deflection. Ultimately you'll find a forward CG location that requires nearly full up elevator to maintain a given pitch attitude (such as liftoff attitude, or level flight) at just above stall speed. If the CG moves any further forward the nose will continue to drop. The wing might not reach stall angle of attack but the airplane's nose cannot be raised any more.

Conversely, if the CG goes aft beyond some extreme you might not have enough control authority at slow speeds to prevent the nose from pitching up further into a stall.

Additionally, as CG moves forward **stability increases**. It takes more control force to cause changes in pitch than with the CG further aft. On the positive side, the airplane rides better in turbulence and tends to stay at a given pitch and return to that pitch if disturbed; it's a "good instrument platform." **As CG moves rearward stability decreases**. It oscillates more in turbulence and requires more control input to maintain precise tracks such as during an instrument approach. But rearward CG improves control responsiveness, and it also causes an airplane to fly a little faster for a given power setting.

I have not touched on distribution of weight laterally, that is, along the wingspan. I don't know of a single *Pilot's Operating Handbook* that provides information for checking the lateral balance. That said, the closer to balanced the airplane is in the roll axis, the less control deflection is required to keep the wings level and therefore the **less drag** that is created from those deflected controls. There are some limits if you look, most notably wingtip mounted "tip" tanks sometimes having limitations requiring one tank contain no more than some amount of fuel than the other, and some autopilots that stipulate a **maximum fuel imbalance** for using the autopilot.

The balance in weight and balance, then, is more complicated than weight alone. But you can see where there will be a **maximum forward** CG position, and a **maximum rearward** CG position, that assures stability and control, and because of decreased control authority **the loading envelope is most critical at slow speeds**, especially during takeoff and landing.

Put it all together and you'll see how important it is to remain within the airplane's weight and balance limits to assure aircraft **performance, stability and control**.

2. *When an aircraft is loaded outside its limits, pilots lose important safety margins without realizing it. What practical tips do you give students to help them recognize these risks early and build good habits around staying within weight and balance limits on every flight?*

Most pilots are taught how to compute weight and balance to confirm the airplane is within limits for takeoff. Far fewer are taught to compute weight and balance as it will exist ***at landing***. In many light training airplanes there's no significant change in the center of gravity position as fuel burns—the fuel tanks are fairly small, and they do not extend fore and aft along the longitudinal axis. But get beyond simple trainers and CG often does move enough as fuel load changes that stability and control are affected.

In the process of calculating takeoff-condition weight and balance you will have weights and moments for the airplane and everything in it for that flight *except* fuel—the **zero fuel condition**. I teach pilots to see that the weight and moment in **the zero fuel condition** is within the envelope too, not just that takeoff condition.

Unless the airplane has more than just one tank per wing, if you plot both the takeoff and zero fuel conditions in the weight and balance envelope chart there is usually a straight line between them such that any fuel load between takeoff and empty is along that line (read the *Pilot's Operating Handbook* or *Aeroplane Flight Manual* and talk with experts in the airplane type you fly to learn if yours is different). If the airplane indeed does have a straight-line derivation between takeoff fuel load and empty, and both points are within the envelope, then as long as you have gas in the aircraft it will have predictable performance, stability and control. Take off knowing that if you need to divert and burn more fuel than expected that you don't have to worry about center of gravity as long as you have fuel in the tanks.

If the zero fuel condition is outside the envelope, determine how much fuel must be in the tanks to keep it in the envelope, and even if you must delay or divert ensure you are on the ground before the CG goes out of limits.

Short version: ***Confirm the* takeoff*, expected* landing *and* zero fuel *conditions are within the loading envelope***. If zero fuel is out of limits land before reaching the point the center of gravity moves out of the approved envelope.

> ***3.*** *Performance charts are built on worst-case assumptions, yet many pilots treat them as optimistic predictions. How do you teach students to use these charts properly, and why should pilots plan to stay comfortably inside the weight and balance envelope rather than right on the edge?*

Most performance charts have three distinct parts: ***the chart itself***, where you derive the performance expectation; a ***recommended speed*** (or recommended speeds varying by airplane weight or other factors) that serve as targets for flying the maneuver predicted by the chart; and the ***associated conditions*,** which is the technique that, at the recommended speeds, is required to obtain the performance calculated using that chart. You are not usually prohibited from using some other technique or other speeds. But if you deviate from the POH/AFM you won't get the performance that using the chart suggests.

For example, most Takeoff performance charts call for full power before brake release, ***then*** applying positive aft elevator slightly below a recommended liftoff speed (before, so the airplane, responding to the control input, is at liftoff attitude at the liftoff speed), ***then*** maintaining an attitude that results in Vx speed as you pass through 50 feet (15 meters) above ground level. Plus or minus use of flaps, that sounds like a Short Field takeoff even if the POH/AFM chart calls it a "normal" takeoff.

Can you do what most pilots would call a "normal" takeoff, where you smoothly apply power, ease back on the stick and let the airplane lift off "when it's ready to fly," then climb out at Vy or a little faster if you don't have an obstacle to clear? Of course you can. ***But you won't get the performance the chart says you will.*** It will likely take a lot more runway before you lift off and a lot more distance before you're 50 feet/15 meters above the ground.

Another example: Most POH/AFMs don't overtly state such, but cruise performance is usually based on leaning to 25°F rich of peak exhaust gas temperature (EGT). Does it prohibit using some other leaning target? Usually no. But **you won't get the same speeds, fuel burns or endurance** the manual suggests if you use a different technique.

So build a big margin into your planning for using other-than-handbook techniques. **If performance is critical** (such as a real short field, or high density altitude), calculate performance to ensure the airplane is capable of the flight under current conditions, and then review and **use the airspeeds and associated conditions** called for by the performance chart.

Even then give yourself a healthy margin. I use at least 50% beyond the “book” numbers. By (U.S.) certification requirements performance data obtained during factory flight test is adjusted to reflect “average pilot technique” when in actual operation. The “average” pilot, however, is probably assumed to be at least as on top of his/her game as he/she was when passing their most recent Flight Test. So if you’re not ready to prove your worthiness to earn the certificate you hold today, ***give yourself an even greater margin*** beyond the performance chart minimums.

Bringing this back to weight and balance: Do a few comparisons using the same airplane data and the same environmental conditions, but at maximum airplane weight, at 100 pounds or 50 kg less and at 50 kg or 100 pounds less than that. You’ll find that **reducing payload even a little results in a noticeable increase in performance**, especially takeoff and climb—and 100 lb/50 kg can make a vast improvement, especially in single-engine climb rate in a piston twin.

If you need performance for takeoff and climb because of a short runway or hot weather or heavy payload, you might keep the fuel load low and fly a shorter leg to somewhere with a longer runway and/or lower density altitude before topping the tanks for the rest of the flight.

Far from being a paperwork exercise or a matter of technical legality—although knowingly operating out of weight and balance issues is a violation of Federal regulations—aircraft weight and balance and performance calculations are a real-world matter of **performance, stability and control**.

Readers, what can you add?

Questions? Comments? Supportable opinions? Let us know at mastery.flight.training@cox.net.

Debrief

Readers write about recent *LESSONS*:

We’ll get to the backlog in your insights next week.

More to say? Let us learn from you, at **mastery.flight.training@cox.net.**

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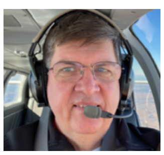

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