Center of Gravity (C.G.) Considerations and Neutral Pitch Stability

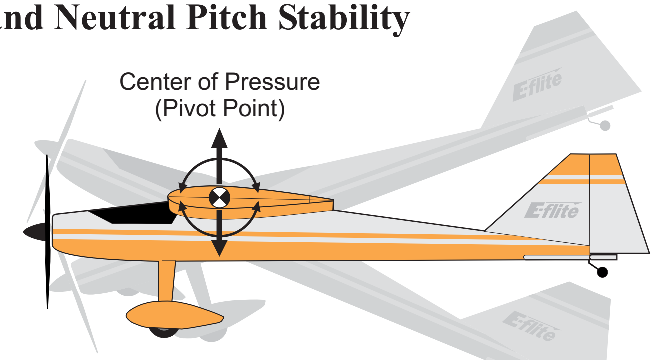
Center of Gravity (C.G.) location can have the single greatest influence on how an airplane handles in the air. Changing the C.G. can make a previously poor handling plane fly great, or turn an otherwise great airplane into a chore to fly. The C.G. location favorable to precision aerobatics is a compromise between "flying on rails" handling and unrestricted maneuverability, that is, neither tail heavy nor nose heavy, a.k.a., "neutral".

Explained: As the air flows around a symmetrical airfoil wing, the areas of greatest low pressure are located near the wing's thickest point. Between the top and bottom centers of pressure is the wing's aerodynamic pivot point (pitch axis). With very few exceptions, when the C.G. is in-line with the wing's thickest point (pivot point) the airplane will be balanced neutral.

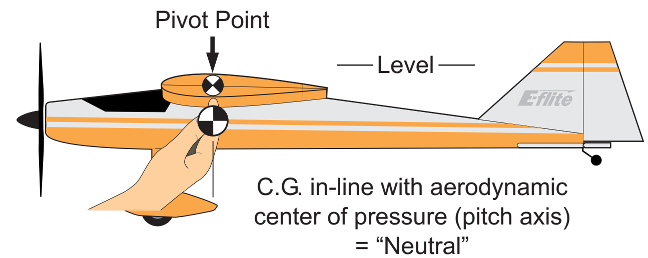
On 99% of aerobatic models the wing's thickest point and neutral C.G. location is between 30-33% of the wing chord. When the C.G. is neither forward nor aft of the wing's thickest point, an airplane neither resists nor exaggerates what it is told to do, has almost no tendency to change its state, and behaves basically the same at nearly any speed.

On the other hand, when the center of gravity is aft of the wing's center of pressure, an airplane becomes unstable and would be inclined to swap ends in flight (similar to shooting an arrow backwards) if it were not for the tail and corrective inputs. While sometimes manageable at higher speeds, a plane with an aft C.G. becomes especially unpredictable and hard to control when the tail becomes less effective at lower airspeeds (e.g., landing)!

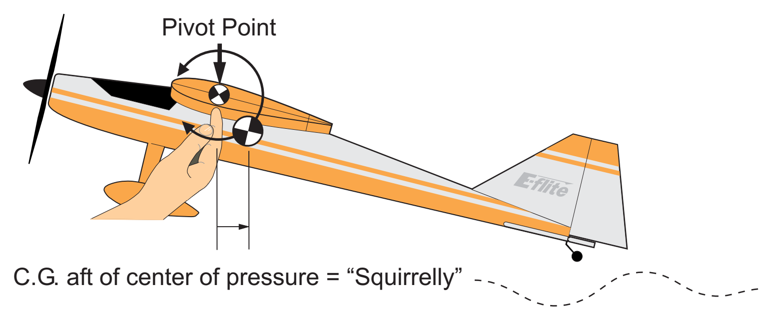
While a significantly nose heavy airplane won't attempt to swap ends, it will tend to behave differently at different speeds, e.g., becoming a lawn dart when slowed and/or rolled upside down. Since the airspeed is constantly changing during aerobatics, it's well worth the effort to relocate the batteries and/or add weight to achieve a C.G. that is neither forward nor aft in order to achieve the "neutral" flying qualities and predictable handling that enable pilots to practice more effectively and ultimately remain ahead of the airplane.



Whenever a symmetrical wing airplane is pitched up or down, it's aerodynamically inclined to pivot around the wings thickest point (center of pressure). When the C.G. is neither forward nor aft of the wing's thickest point (pivot point) the airplane tends to be the most neutral/predictable.



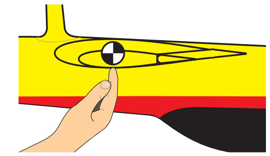
When the C.G. is aft of the wing's thickest point (pivot point), the airplane becomes unstable – similar to shooting an arrow backwards – and would be inclined to swap ends in flight if not for the tail and corrective inputs!

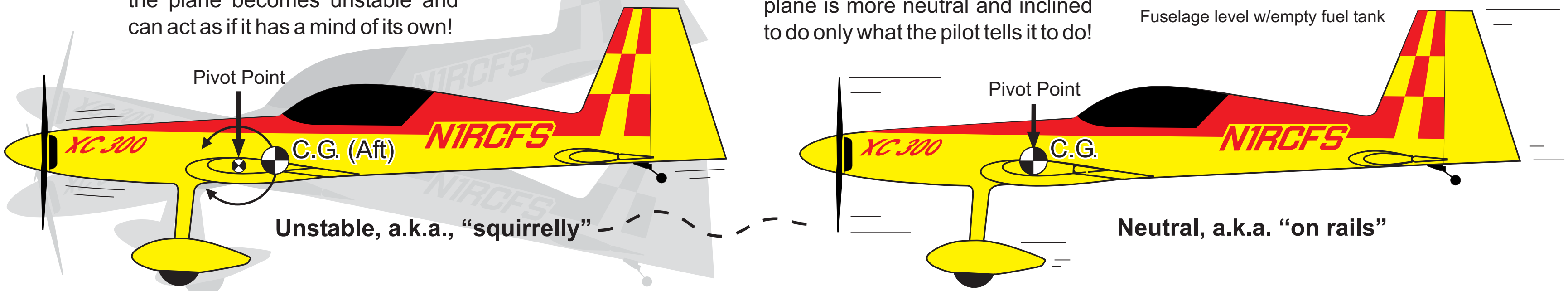


C.G. aft of center of pressure = "Squirrelly"

KPTR: A neutrally balanced plane favors rapid advancement because it does mostly only what the pilot tells it to do.

C.G. Considerations Continued

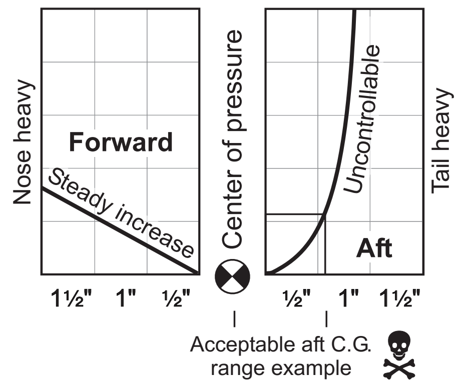

Fuselage level w/empty fuel tank



Page through any R/C magazine today and it's obvious that "3D" flying has taken over the sport. As a result, many airplane manufacturers recommend C.G. ranges that are tail heavy, in part to help inverted flight, but primarily to compliment the extreme 3D maneuvers that benefit from an aft C.G.. (You can be fairly certain that this is the case whenever the airplane has references to "3D" in its name or advertising.) While it's true that a tail heavy condition may help certain 3D maneuvers, it comes at the cost of making the airplane unstable, difficult to trim, exponentially more challenging/demanding to fly, and therefore unsuitable for precision flying.

Indeed, all too often pilots and manufacturers abandon a neutral C.G. that would compliment the majority of flying pilots do (including takeoff and landing), in favor of a C.G. aimed at helping an isolated flight condition or stunts that most pilots seldom attempt. However, logic dictates that the "best" C.G. setup is the one that compliments the type of flying a person does most often!

C.G. Effects Curves



An aft C.G. (tail heavy) makes a plane 1. Unstable in all axis, but esp. pitch. 2. More maneuverable, i.e., "snappier". 3. More demanding to fly and less forgiving.

A forward C.G. (nose heavy) makes a plane 1. More stable. 2. Less maneuverable. 3. Less demanding to fly and more forgiving.

In short, tail heavy planes tend to snap roll, spin, and 3D very well, but are more difficult to fly (and land) with precision. Nose heavy planes tend not to snap and spin as well, but maneuver like they are on rails. Since precision aerobatics involve all the components of snaps, spins, loops, rolls, etc., the best C.G. location is neutral, i.e., near the wing's thickest point, to provide the best overall handling without restricting maneuverability.

Note: Anyone tempted to experiment with an aft C.G. to enhance snap roll and spin performance does so at great risk! While the effects caused by a nose heavy condition tend to increase evenly as the plane becomes more nose heavy, the effects of a tail heavy condition increase sharply and exponentially to even small aft C.G. changes. Thus, whereas a significantly nose heavy condition might cause snap rolls and spins to be a bit sluggish, a moderately tail heavy plane may snap roll unintentionally, and prove unrecoverable from a spin and almost impossible to land. Hence, if the C.G. isn't neutral, it's usually better to err on the side of nose heavy rather than tail heavy!

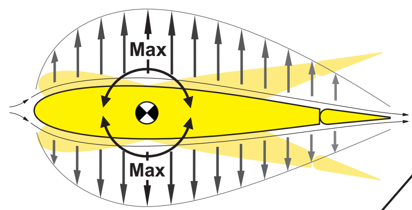
KPTR: A neutral C.G. provides the most predictable performance throughout all maneuvers and airspeeds.

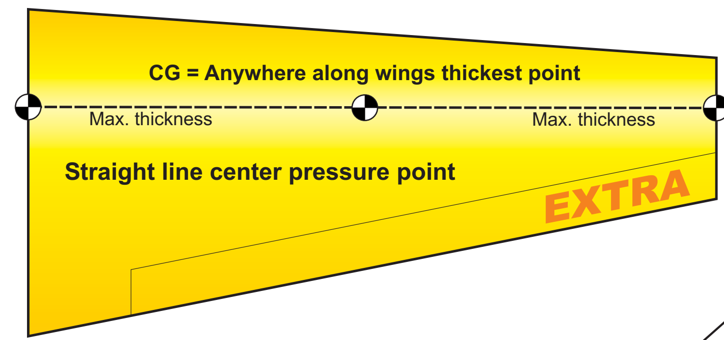
DAS
SETUP

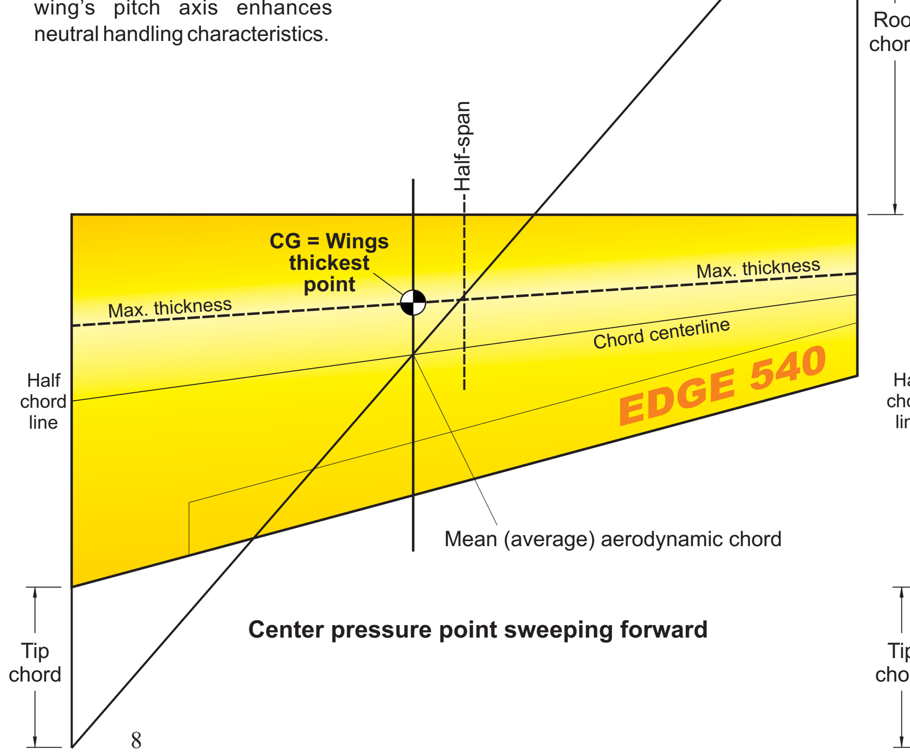
Locating the “Neutral” C.G. (neither nose heavy nor tail heavy)

On 99% of symmetrical wing aerobatic airplanes, neutral flight performance is achieved by ensuring that the C.G. is in-line with the wing’s mean (average) aerodynamic center of pressure located along the wing’s thickest point. Locating the neutral C.G. point is simple when the wing’s thickest point is a straight line from tip to tip as it is with all Extra airplanes. Yet, a different method is required when the wing’s thickest point angles forward as it does on an Edge 540, or sweeps to the rear as it does on most precision pattern airplanes. While you can try to use the formula to determine the neutral C.G. location on these airplanes, the easiest method is to locate the wing’s thickest point at the half-span, and then to account for the greater wing area inboard, move in along the wing’s thickest point a few inches closer to the fuselage -- realizing that an inch or two one way or the other amounts to only a small difference fore or aft, and thus won’t have too much impact.

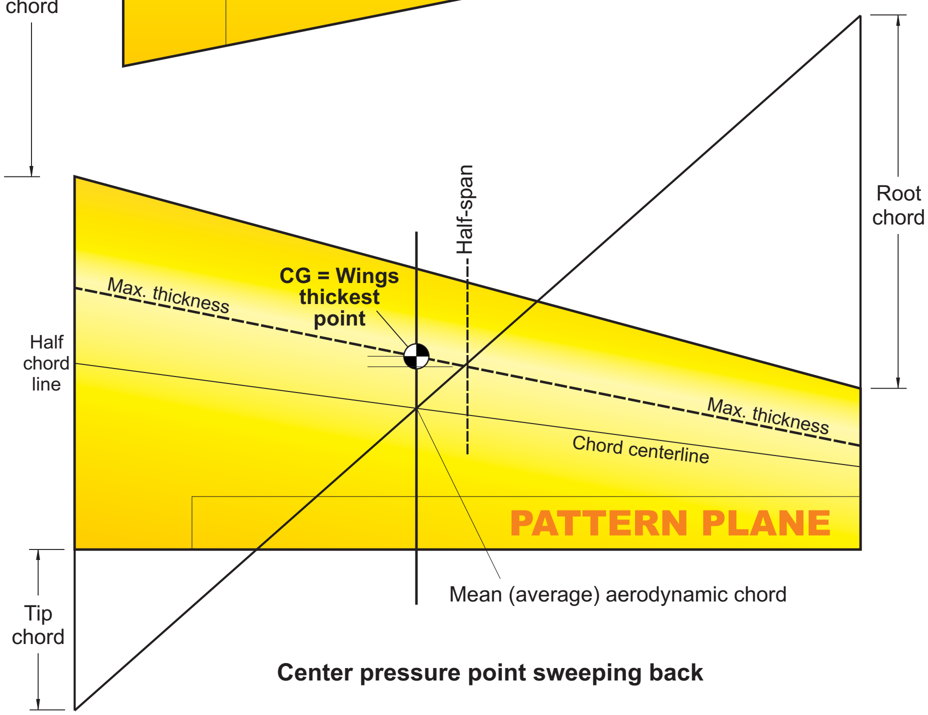
Areas of maximum low pressure occur near the wing’s thickest point. Acting like tethers pulling on the top and bottom of the wing, where the centers of pressure intersect determines the wing’s aerodynamic pitch axis. Locating the C.G. near the wing’s pitch axis enhances neutral handling characteristics.







Center pressure point sweeping forward



Center pressure point sweeping back