

Note: The following information might upset career aerodynamicists because it does not also include explanations of Mean Aerodynamic Center, Decalage, Neutral Point, and more when describing how to achieve optimum CG location and wing incidence. This is a flight training manual, not a manual intended to teach aerodynamics, and my intention when writing was to condense flight dynamics into simple fool proof rules-of-thumb that the average pilot can wrap his head around and result in an optimized airplane setup that ensures pilots using this manual have the greatest opportunity for success. There are plenty of sites online for those wish to get into the details and formulas that are the stock and trade of professional aerodynamicists, such as [http://en.wikipedia.org/wiki/Flight_dynamics_\(aircraft\)#Dynamic_stability_and_control](http://en.wikipedia.org/wiki/Flight_dynamics_(aircraft)#Dynamic_stability_and_control)

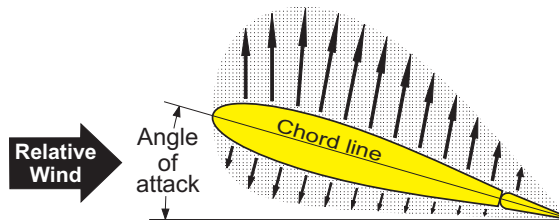
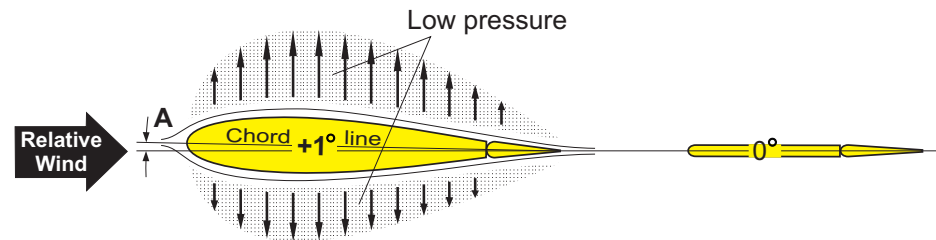
Airplane Guidelines

Basic terminology primer

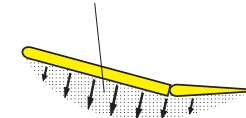
Aero Basics: Air flowing over a curved surface creates a low pressure vacuum. A symmetrical-wing creates low pressure both top and bottom. Not to be confused with “*angle of attack*” affected by a pilot in flight, wing “*incidence*” or “*decalage*” is the angle (**A**) of the wing’s chord line positioned on the fuselage relative to the horizontal stabilizer. Ideally, a slightly positive angle is built-in to induce the upward low pressure *lift* needed to support an airplane’s weight.

Angle of attack is the angle of the wing’s chord line relative to the wind. Generally, wing lift (low pressure) increases with increased angle of attack—up to the point where the angle of attack is (critical) too great for the airflow to remain smooth over the wing (separates), and the wing loses lift or *stalls*.

Critical angle of attack is the point when the wing stalls.

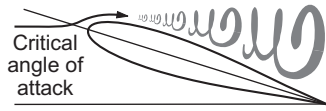


Up elevator changes the airfoil shape of the tail, generating low pressure *down force*.



Advanced Aerobatic Airplane Features: A Tapered Wing

The primary feature of an advanced aerobatic airplane is the tapered wing for its inherent tip stall characteristic that gives the airplane good *snap roll* performance. Of course, this also makes the plane less forgiving to over-controlling and getting it too slow during landing.



Stall: Airflow separation and loss of wing lift occurring when the wing exceeds its critical angle of attack.

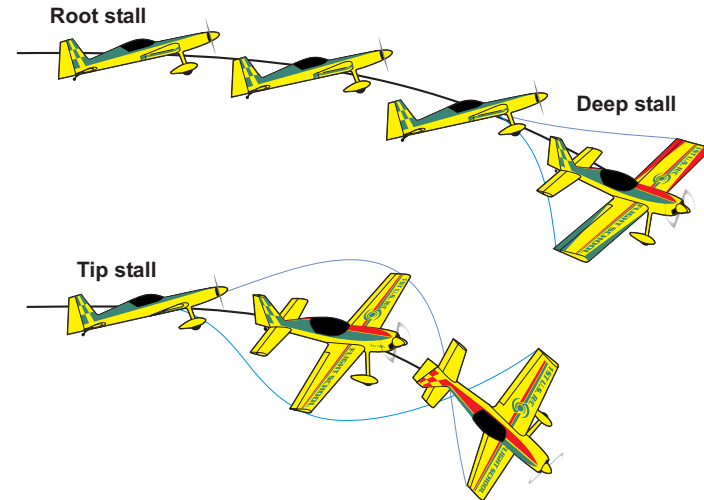
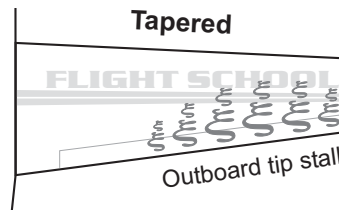
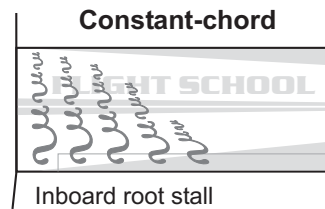
Constant-chord: The first sign of a stall will be a higher sink rate and sluggish elevator response.

Tapered: The first sign of a stall will usually be a wing dropping, followed by a snap roll into a spin if the elevator is not reduced.

A *constant-chord* wing inherently stalls at the wing root first, while the tips continue to provide lift. While forgiving, this wing's aversion to tip stalling tends to produce less than dramatic snap roll results.

A *tapered* wing inherently stalls toward the tips first. Since seldom do both wings stall exactly the same, one wing will typically drop ahead of the other. When a large amount of elevator is applied to intentionally exceed the wing's critical angle of attack, and a yaw force is also introduced, the tip stall can be exploited to produce spectacular snap roll performance.

Note: If caught quickly, all one has to do to halt an inadvertent tip stall is reduce the wing's angle of attack by reducing or neutralizing the elevator. Pilots transitioning into tapered wing planes should consider that the most common inadvertent stalls are preceded by the pilot pulling an increasing amount of elevator in an attempt to keep a steep or slow turn level, or stretch a glide. So, if you ever find yourself steadily increasing the elevator on final approach, or in a turn, with little apparent effect, and are urged to pull more, don't! You are on the verge of stalling and need to reduce elevator and/or add power to keep from spinning into the ground.



Once you have graduated to a tapered wing plane like a Cap, Extra, Edge, Sukhoi, Yak, there are virtually no limits to what you can do. They are all equally capable, and any differences that are not setup related are so minor as to be undetectable to all but the most expert flyers. All that remains is how far will you take it, and will yours be set up to promote rapid advancement?



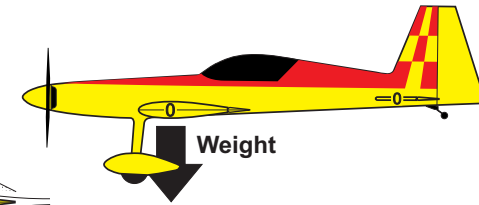
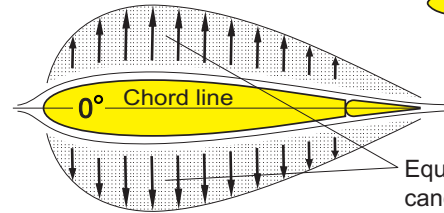
Wing Incidence: Neutral Pitch Characteristics

The omission of positive *wing incidence* on many models today, due in part to the notion that this will improve inverted performance, makes those planes more demanding to fly and therefore inhibits advancement.

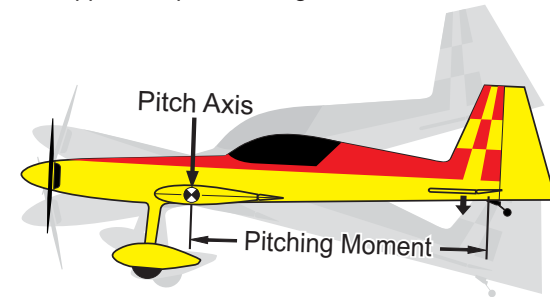
A wing set at zero angle of incidence relative to the stab at zero produces no upward lift to support an airplane's weight. To produce the lift needed to hold altitude, the plane will have to be flown at a positive angle of attack by means of UP elevator trim. However, that only works consistently when the airplane's speed remains constant. But, since airspeed is always changing while maneuvering, the effect of the elevator trim will always be changing as well. The result therefore of flying an airplane with zero wing incidence is that it continually goes in and out of trim. Because it is not feasible to re-trim the entire flight, the pilot ends up having to make continuous pitch corrections to hold the plane level. Expo promises to tame the consequences of making a lot of inputs, but it does not address the cause!

Building a $\frac{1}{2}^\circ$ to $\frac{3}{4}^\circ$ positive wing incidence or decalage into a plane relative to the stab at zero, provides the upward lift needed to support a plane in flight. And since the lift is being generated by means of incidence at the airplane's *pitch axis* (as opposed to using elevator trim), speed changes while maneuvering do not result in undue pitch changes. The result is a less demanding airplane to fly that is just as capable and much more favorable to rapid advancement.

Ironically, attempts to improve inverted performance by omitting wing incidence are negated by the UP elevator trim that's put in to maintain level flight when upright. (Achieving inverted flight requiring little or no forward elevator is not a function of incidence anyhow, but of balance!)

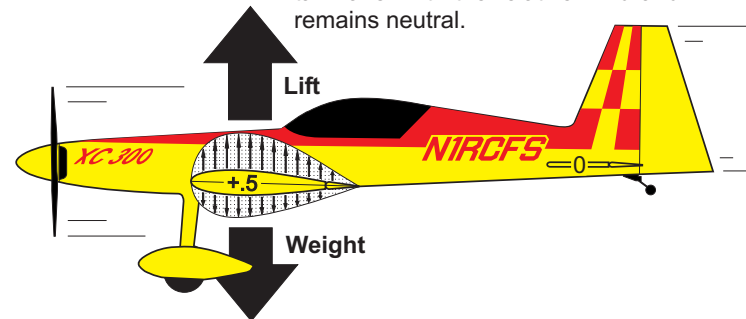


Equal areas of low pressure @ 0° wing incidence cancel each other out—providing no upward lift to support the plane's weight.



The effect of using trim to sustain level flight only works at a constant speed. Changes in speed cause the trim to become more or less effective, causing the tail to pitch up or down.

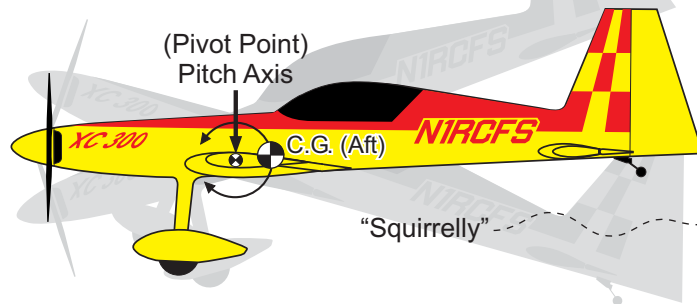
$\frac{1}{2}^\circ$ positive wing incidence built into an airplane generates upward lift to support the plane's weight, while the tail "fairs" with the relative wind and remains neutral.



Neutral Balance Characteristics

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 a great handling plane into a chore. The C.G. location favorable to advanced aerobatics is a compromise of handling and maneuverability.

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



An aft C.G. (tail heavy) makes a plane:

1. Unstable
2. More maneuverable
3. More demanding to fly

A forward C.G. (nose heavy) makes a plane:

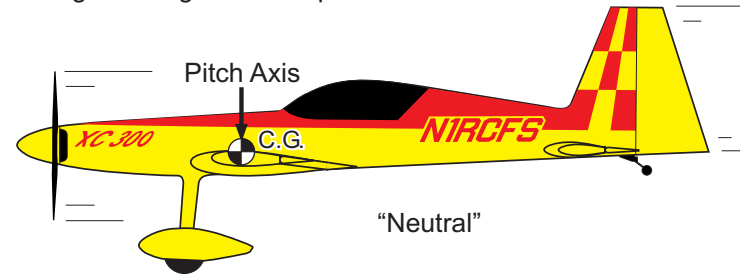
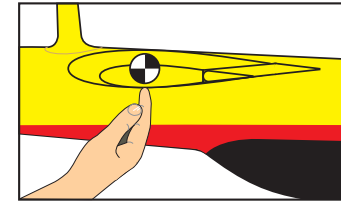
1. Stable
2. Less maneuverable
3. Less demanding to fly

Tail heavy planes tend to snap roll and spin very well, but stopping them precisely on a heading is more difficult.

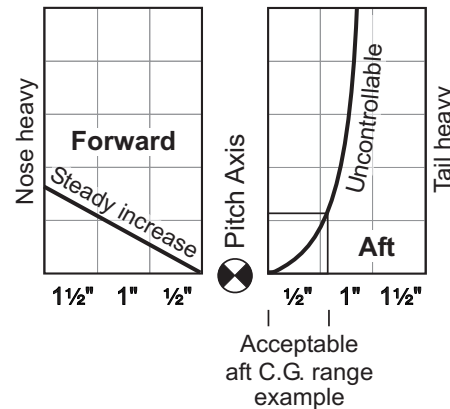
Nose heavy planes tend to snap and spin not as well, but loop and roll like they are on rails.

Since advanced aerobatics involve all the components of snaps, spins, loops, and rolls, the best C.G. location is one that is *neutral*, i.e., neither forward nor aft of the pitch axis.

With few exceptions, the pitch axis and therefore the neutral balance point is located along the wing's thickest point.



C.G. Effects Curves

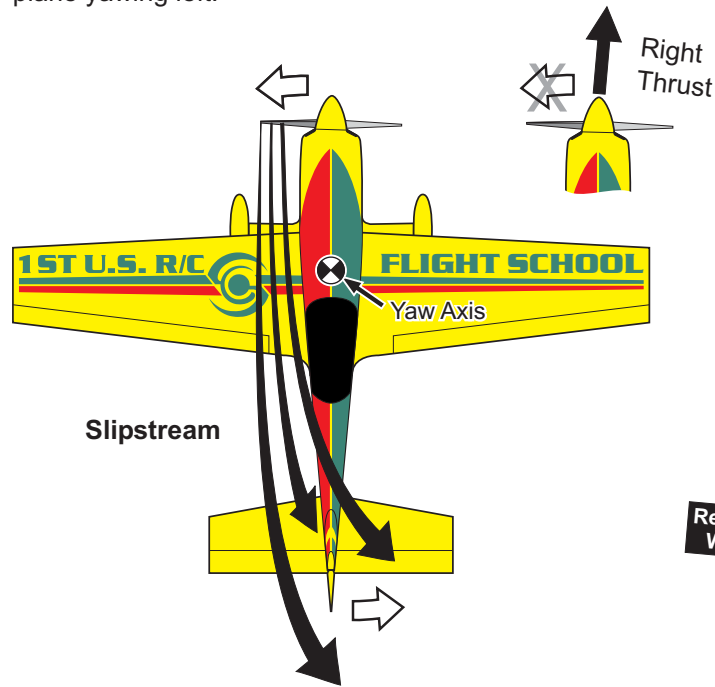


Anyone tempted to experiment with an aft C.G. to enhance snap roll and spin performance has to be very careful! While the effects of being nose heavy tend to increase evenly the more nose heavy a plane becomes, tail heavy effects increase sharply and exponentially to even small aft C.G. changes: Whereas a significant nose heavy condition might cause sluggish snap rolls and may prevent the plane from spinning, a moderately tail heavy plane may perform unintentional snap rolls and be unrecoverable from a spin. That is, at a certain point, control and recovery become impossible regardless of skill.

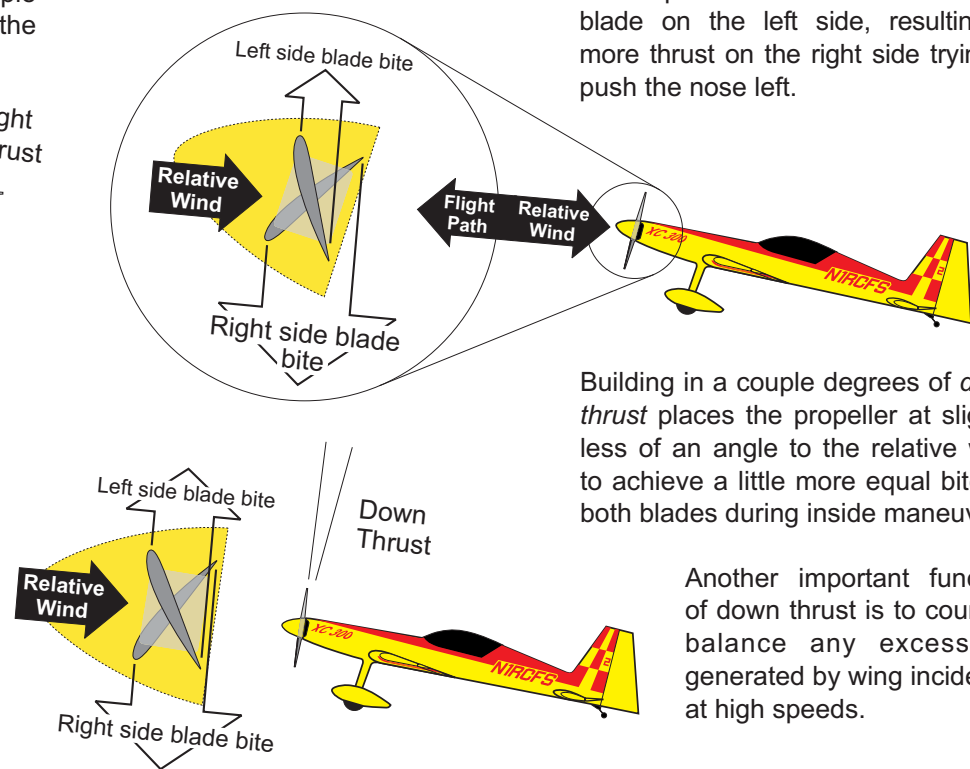
Right and Down Thrust: Reducing Slipstream and P-factor

A couple left turning tendencies associated with propeller thrust, namely *slipstream* and *P-factor*, manifest themselves regularly during advanced aerobatics. At higher airspeeds those tendencies are held mostly in check by the faster airflow over the tail. However, at lower airspeeds with high power, such as nearing the top of loops and vertical lines (e.g., hammerheads), those tendencies can demand a lot of the pilot's attention, unless steps are taken with the airplane setup to reduce their effects.

Slipstream: A spinning propeller sets off a spiraling column of air rearward that strikes the tail and tries to push it to the right, and yaw the airplane to the left. Building in a couple degrees of right engine thrust provides a force against the plane yawing left.



P-(pitch)-factor
(Asymmetric propeller thrust)



P-factor: At positive angles of attack during inside (up elevator) maneuvers, the propeller blade on the right side of the plane bites more air than the blade on the left side, resulting in more thrust on the right side trying to push the nose left.

Building in a couple degrees of *down thrust* places the propeller at slightly less of an angle to the relative wind to achieve a little more equal bite on both blades during inside maneuvers.

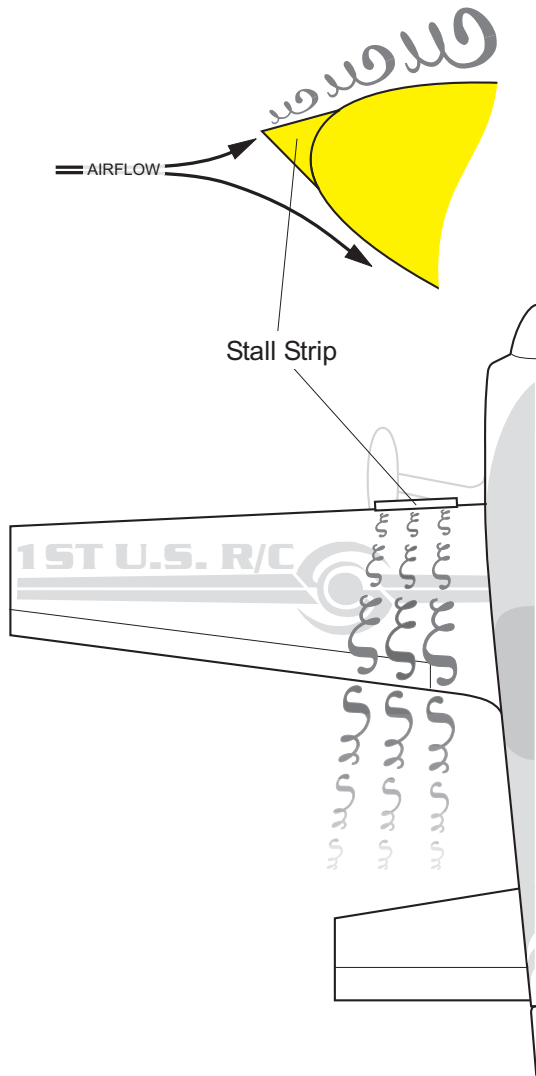
Another important function of down thrust is to counter-balance any excess lift generated by wing incidence at high speeds.

Applying the logic that the “best” airplane setup is one that compliments the type of flying a person does most often, a little right and down thrust is ideal to reduce the demands on the pilot during the inside and vertical segments that make up the greater share of advanced maneuvers.

KPTR: Right and down thrust grant a pilot more time to think about correcting slipstream and P-factor before actually needing to!

Stall Strips: Taming the Tapered Wing During Landing

Certain airplanes, for various reasons, exhibit a tendency to stall during landing with no warning: Say a pilot has just leveled out inches above the ground, he's waiting for the plane to start settling to begin pulling more elevator to grease the landing, and a wing abruptly drops! This can be remedied using the common full-scale technique of placing stall strips on the inboard leading edge of the wing to reduce the abruptness of the stall.



Stall strips, with their sharp leading edge, cause the airflow to trip and separate (stall) at an angle of attack somewhat below the wing's normal stall angle.

Stall strips positioned inboard on a tapered wing will cause the root to stall first and therefore effect a sink rate that remains manageable during landing—before achieving critical angle of attack and experiencing a tip stall.

Also note that inducing an inboard stall means that the ailerons remain in smooth air and thus effective even after the wing has entered a stall.

Side note: While inboard stall strips tame the landing, they shouldn't impact snap roll performance since the tip stall at critical angle of attack occurs irrespective of what is happening at the root.

When the need for stall strips on a model airplane has been determined, they can be generally patterned after the examples seen on most 4-seat tapered wing planes at your local airport—since the size and behavior of air particles remains generally the same irrespective of the plane's size.

Approx. 5" to 6" long,
1/4" to 3/8" triangle balsa,
positioned approx. 3" from
the side of the fuselage.

