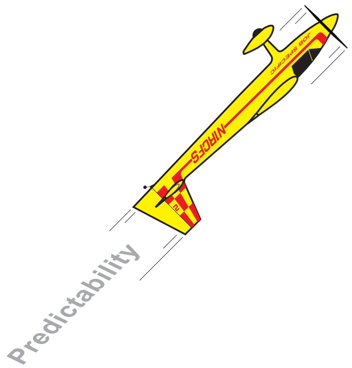
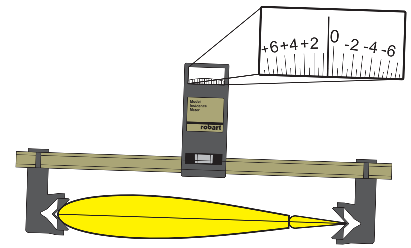
Note: The following information might upset career aerodynamicists because it does not also include explanations of Mean Aerodynamic Center, Decalage, Neutral Point, and more when describing how to achieve optimum CG location and wing incidence. This is a flight training manual, not a manual intended 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

DAS PHASE II

Improving Airplane Performance

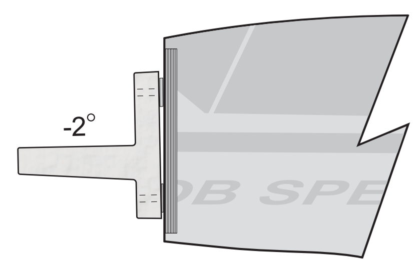




Wing Incidence

Neutral Pitch Stability

Right and Down Engine Thrust



Propwash and P-factor

(Left Turning Tendencies)

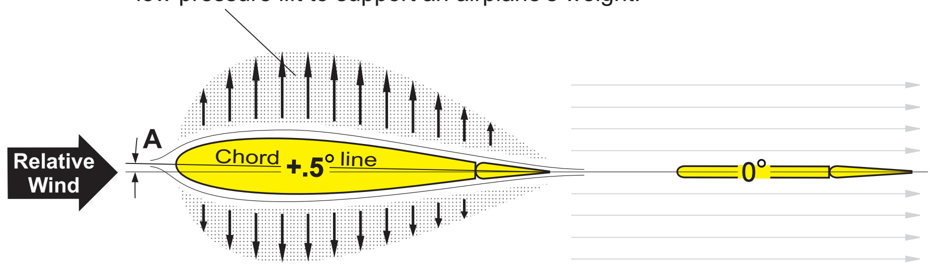
Neutralizing Pitch Stability and Engine Torque

In this section: A-6 profiles the effect positive wing *incidence* has on ensuring a high degree of *neutral* pitch stability, i.e., an airplane's tendency to stay in the pitch attitude it is placed in until changed by the pilot. The absence of positive wing incidence on many models designed since the mid 1990's has made it necessary to cover this crucial subject, which for most of our sport's history could be entrusted to the airplane designers:

BASIC

The horizontal stabilizer or stab will, like the feathers of an arrow, always try to align or *fair* with the relative wind (direction of flight). The optimal engine and wing layouts for specified performance are then determined using the stab as the chief reference.

[Not to be confused with *"angle of attack"* affected by the pilot in flight.] Wing *"incidence"* or *"decalage"* is the angle (**A**) of the wing's chord line positioned on the fuselage relative to the stab. Ideally, a slightly positive angle is built-in to induce the upward lift needed to support an airplane's weight.



The steady disappearance of wing incidence in radio control aviation is due to the persistent theory that the best airplane setup for maneuvering in any attitude is to have everything set at zero! The problem with that theory is gravity isn't zero, and until that is eliminated, wing incidence will continue to be necessary and beneficial.

A-7 illustrates the predictable tendencies of an airplane with positive wing incidence when performing aerobatics that leads to maximum learning from each maneuver attempt.

A-8 illustrates how to check an airplane's wing incidence, and if it turns out to be zero (or neg.), how to take steps to place in the standard ½° positive relative to the stab.

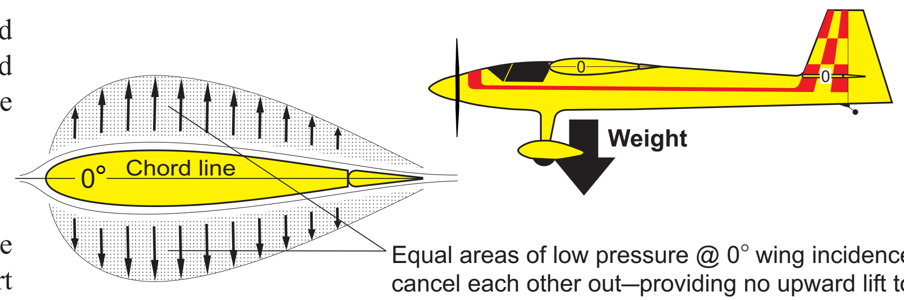
A-9 answers some common questions pertaining to wing incidence. (The more one looks into it, the more one finds that the superiority of wing incidence is as fundamentally certain as "the wheel works best when it's round!")

A-10 through A-13 illustrate the effects that engine right and down thrust have on neutralizing the *left turning tendencies* caused by an engine turning a propeller — concluding with a summary list of the incidence, engine thrust, and balance standards that provide maximum in-flight predictability.

 KPTR: To effectively take your skills to the next level, it becomes necessary to ensure that you won't be fighting your plane.

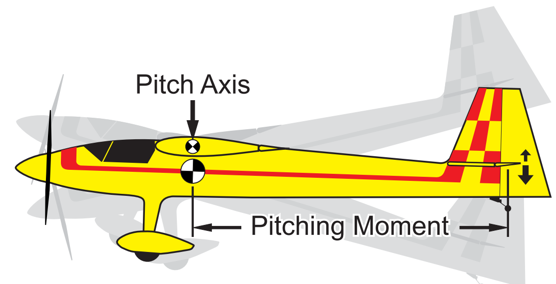
Wing Incidence: Neutral Pitch Stability

With the objective of efficiently adding refinements and flying more precisely, the importance of an honest and predictable airplane can not be overstated. For these conditions to exist, positive wing incidence is a must!



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

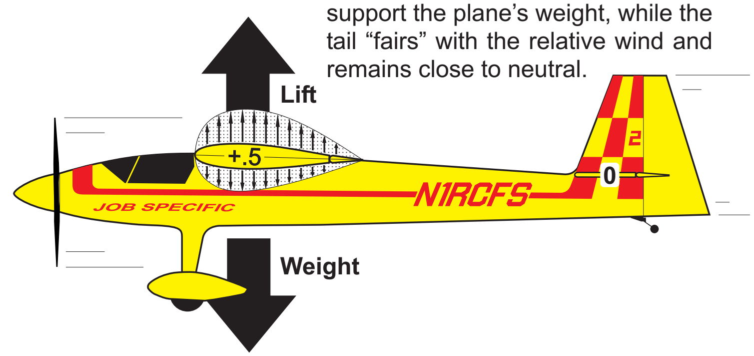
A wing set at zero angle of incidence relative to the stab also at zero produces no upward lift to support an airplane's weight. Attempts to trim the nose UP to generate upward lift would only work consistently if the airplane's airspeed remained constant, but since the airspeed is always changing in flight, the effect of the elevator trim would always be changing as well.



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.

Note that elevator trim exerts a force on the tail a distance from an airplane's *pitch axis* (the point about the wing very near the C.G. that the airplane pivots around). As airspeed increases, the increased effectiveness of the trim will leverage or cause an airplane to pitch up (inside). As the airplane slows and the effect of the trim becomes less, it will pitch down (outside). Knowing that even a turn causes a change in airspeed, planes with zero wing incidence are continually going in and out of trim, if not acting unstable. Because it's not practical to re-trim the entire flight, a pilot flying an airplane without wing incidence ends up having to make continuous pitch corrections just to hold the plane level.

½° 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 close to neutral.

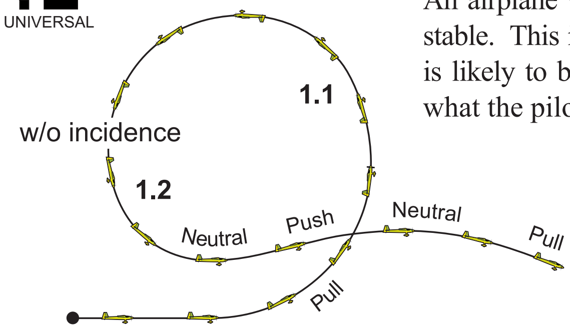


On the other hand, when a wing is set at approximately ½-¾° positive angle of incidence or decalage relative to the stab at zero, the wing will generate a balance of upward lift to support the airplane's weight And since the lift is provided by means of incidence at the airplane's *pitch axis* (as opposed to using elevator trim), changes in airspeed while maneuvering do not result in undue pitch changes—ensuring a *neutral* plane in pitch, just as capable, but requiring less effort to fly—and therefore freeing up more time for other things.

KPTR: Wing incidence helps turn what would otherwise be an unstable airplane, into a neutral, honest, and predictable one!

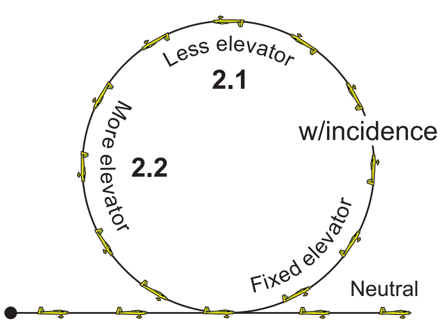
Wing Incidence: Increasing Practice Effectiveness

An airplane without positive wing incidence is actually *negatively* stable. This is to say that while performing maneuvers the airplane is likely to both deviate from established patterns, and exaggerate what the pilot does, even if he's not doing it anymore!

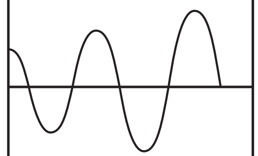


Example: 1.1. In a loop, a *negatively* stable airplane may actually begin to straighten out as it slows towards the top, requiring more elevator to keep it looping. **1.2.** Then, as it comes back down picking up speed, the loop will begin to tighten up, despite reducing the elevator, and may even balloon up after fully neutralizing the elevator!

In contrast: 2.1. A *neutral* plane will attempt to drop out of a loop as it slows down toward the top, as one would expect, requiring less elevator over the top. **2.2.** Then, as the plane picks up speed coming down, more elevator is needed to overcome the pull of gravity, as one would also expect.



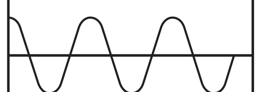
Negative Pitch Stability



Magnified effects

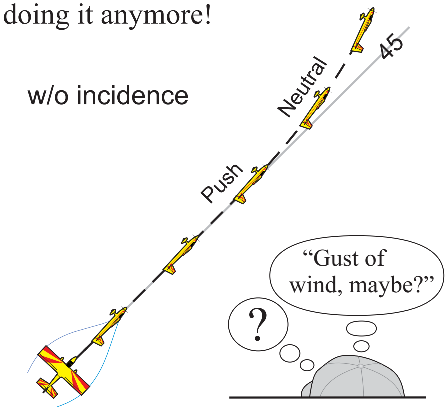
Difficult to anticipate and defying just about all the physical laws one would expect.

Neutral Pitch Stability



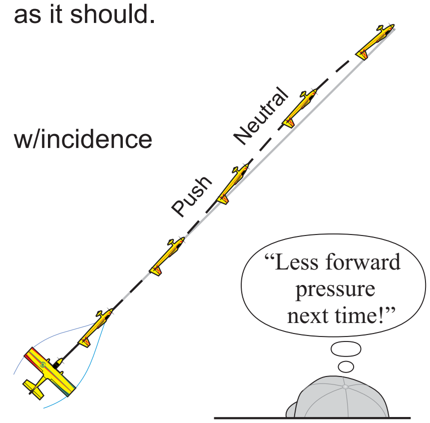
Steady predictable effects

Essentially the plane does only what it's told to do in pitch, except for the effects of gravity, but even those are predictable.



Example: While applying forward pressure to hold the 45 during a reverse Cuban, a *negatively* stable airplane may continue to pitch outside, despite neutralizing the elevator and being inverted—requiring back pressure to try to stop it!

In contrast: If too much forward elevator pressure is applied on the 45 with a *neutral* airplane, when it is released, the airplane will predictably start coming back down toward the 45 as it should.



Side note: Models designed without wing incidence have led to the use of large amounts of computerized *exponential* as people attempt to find ways to make their negatively stable airplanes easier to control. But expo. does not address the true source of the instability, nor does a lot of practice. What large amounts of exponential does do is remove the direct 1-to-1 correlation between control inputs made and the actual in-flight results to effectively inhibit learning.

Side note: Airplanes with wing incidence reduce the need for significant programming and promote *controlling* the airplane with small inputs when intending lesser results, and larger inputs when intending more—thus maintaining a direct correlation between one's intentions, inputs, and the actual in-flight results that leads to peak learning from each attempt.

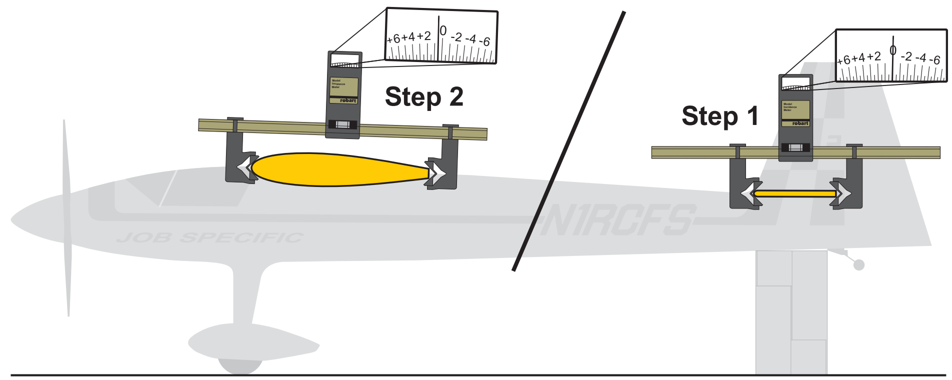
 KPTR: Countless issues occur without wing incidence. To avoid wondering, "Was that me, or the plane?" your plane needs incidence.

Checking and Installing Positive Wing Incidence

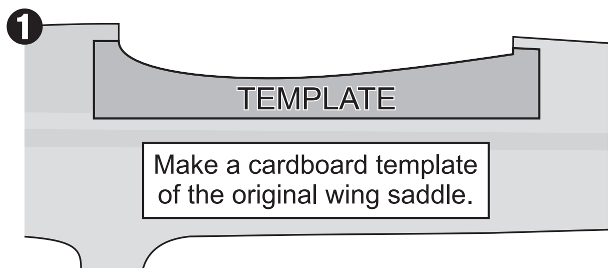
The wing incidence rule-of-thumb is ½° positive relative to the stab. Frankly, you would have to pilot hundreds of models over thousands of hours to detect whether some planes would be slightly better off with .4° or .7°. The ½° rule will always be within 95 to 100% of optimum, no less.

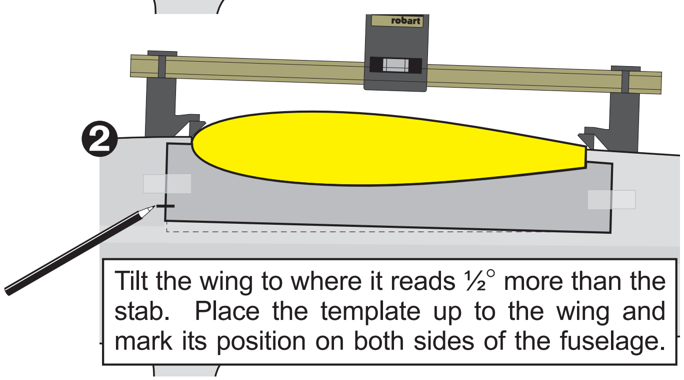
Step 1: Acquire an incidence meter. Slide it onto the stab and note the reading.

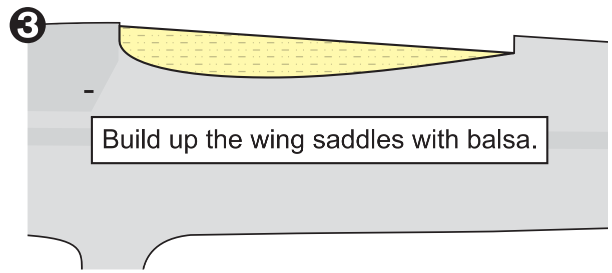
Step 2: Check the wing, and whatever the stab read, the wing should be ½° more. (Ideally, the incidence would be checked before gluing on the control surfaces. But, if already assembled, take your readings with the control surfaces as neutral as possible.)

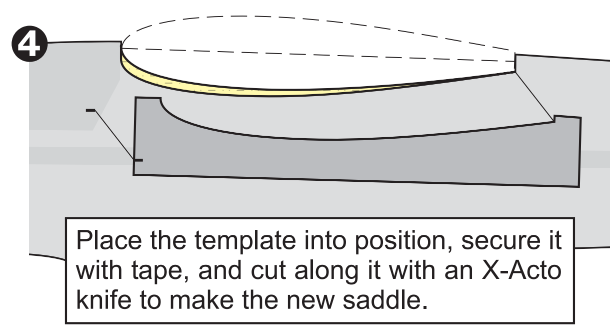


In the event your model does not have positive wing incidence, the wing saddle needs to be changed:

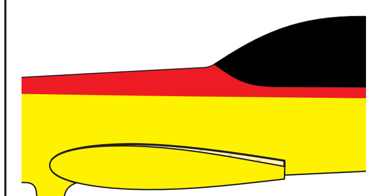








The process is the same for low wing airplanes, but the trailing edge of the wing will be lowered instead.



Obviously then cover that area. If the airplane is one of the ARF's that will not accept iron-on covering, adhesive vinyl from a sign shop works very well.

KPTR: The standard for wing incidence is ½° positive relative to the stab.

Common Wing Incidence Questions

Q. Will wing incidence make it tougher to fly inverted? A. No, but forward elevator pressure will be required. Ironically, attempts to get airplanes to fly inverted with very little forward pressure by placing the wing at zero incidence are negated by the UP elevator trim that's required to maintain level flight when upright, so about the same amount of forward elevator pressure is needed with or without wing incidence. In fact, having to hold in some forward elevator pressure inverted has its advantages: That way the pilot has more *feel* for what he's doing, and a person will seldom get confused about which way to apply the elevator if he is already holding some in.

Q. Won't less (zero) wing incidence make an airplane more maneuverable? A. Not necessarily. Wing shape and position relative to the C.G., moments, tail size, control throws, weight, and balance primarily dictate an airplane's maneuverability. The only increase in maneuverability an unstable airplane provides is the erratic kind—which some obviously prefer. Airplanes with wing incidence are just as maneuverable as those without in the realm of controlled precision aerobatics.

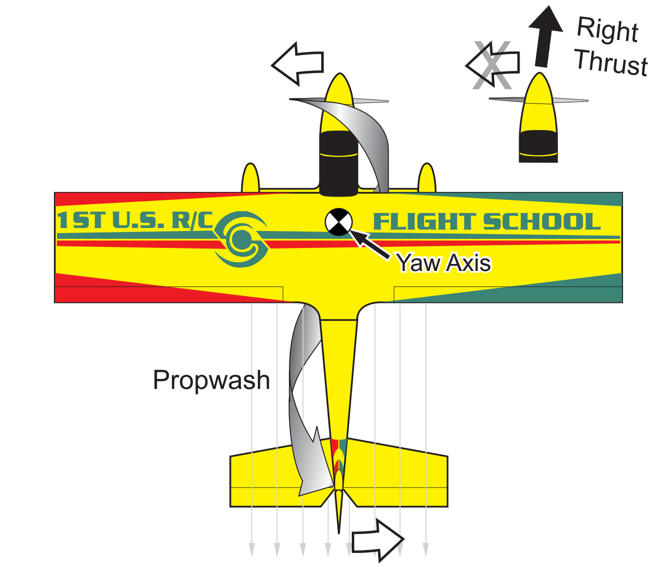
Q. What would happen with 2° incidence? A. The wing would generate too much lift, requiring more trim. Too much positive incidence would require down trim to keep from climbing, creating the same instability issues during speed changes that zero incidence causes, but reversed: Decelerate = pitch inside. Accelerate = pitch outside. Ultimately, the neutral pitch stability achieved using the ½° rule <u>results in the pilot thinking less about how the airplane is behaving, and more about what he wants to do with it!</u>

Q. Does the airplane's size make any difference? A. Yes, larger planes have more inertia helping to steady faulty aerodynamics. While larger planes overcome some aero-defects when up to speed, erratic instability issues can still pop up and even dominate when slower with less inertia (e.g., landing). *Sound aerodynamic principles are sound principles, regardless of whether it's a NASA wind tunnel model, R/C, or man-carrying*.

Q. Why don't the designers put wing incidence back into their plane's? A. Flyers have assumed the burden. Lack of wing incidence is seldom identified as a source of trouble, since it is so natural to assume that inconsistencies during maneuvers and flying higher performance airplanes is simply the need for more practice, additional programming, or wind gusts, radio glitches, etc..

Q. My plane came from a company that's designed a lot of planes, so wouldn't they know if incidence was needed or not? We have attempted here to stress that with wing incidence a pilot won't have to make any more inputs than what is essential to performing the maneuvers. Wing incidence principles are common knowledge in full-scale aviation. Therefore, if you are interested in learning more about the dynamics and importance of wing incidence—since this is not the place to delve deep into aerodynamic principles—visit a library and start by researching Dynamic Stability, Centers of Pressure, Mean Aerodynamic Center, and Pitching Moments, and you will understand more than most in our sport.

Right Thrust: Neutralizing Propwash (Spiraling Slipstream)

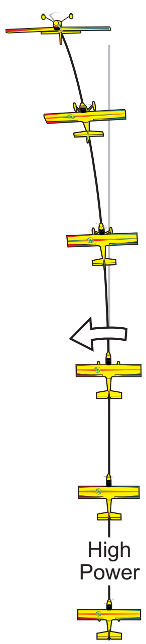


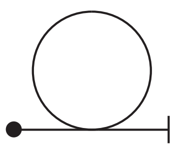
Engine "torque" is an often used term actually made up of several factors that all contribute to an airplane's tendency to turn left, esp. while maneuvering. The primary engine/propeller force that will have to be dealt with in order to free up attention for adding maneuver refinements is *propwash*.

Propwash: The turning propeller sends a spiraling column of air rearward that strikes the left side of the tail and tries to push the tail to the right and yaw the nose to the left. Building in a couple degrees of right engine thrust provides a force against the propwash trying to turn the nose left.

Note: An airplane is most susceptible to the effects of propwash at slower airspeeds (e.g., taking off and approaching the tops of loops). At higher airspeeds the faster air moving over the tail should hold it in place and keep the plane tracking straight.

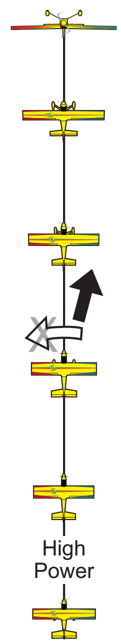
Side note: Right rudder trim or mixing is unsuitable to counter propwash, for it would only work at the power setting and speed that it was trimmed for! Upon reducing power, any trim that is in to counter a powerful propwash—now reduced—would cause a deviation. On the other hand, while built-in right thrust provides a force against the propwash at higher power settings, the right thrust does not cause a deviation when the power is reduced, because the effect of the right thrust is also reduced.





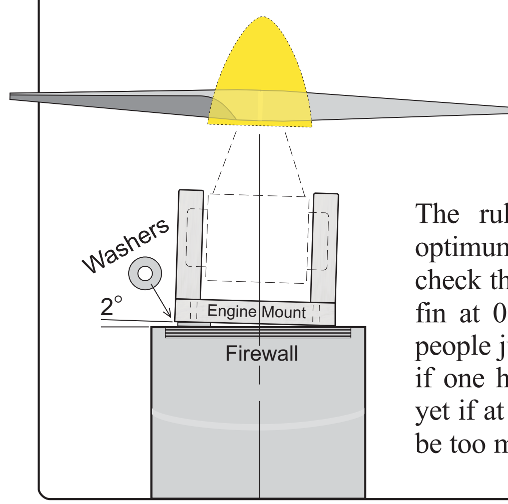
Inside loop example

Lacking right thrust, propwash will turn the airplane left as it slows down toward the top of a loop.



Right thrust provides a force against the nose turning left as the plane slows toward the top of a loop.

Now instead of correcting propwash, the pilot's time can be better spent keeping the loop round, corrected for wind, etc..



In the likely event your firewall is square to the overall centerline of the fuselage (and fin), the standard method for placing in right thrust is to install washers behind the mount. The rule-of-thumb within 95 to 100% of optimum is 2° right. It can be a little tricky to check the 2° angle of the engine relative to the fin at 0° using an incidence meter, so many people just put in "a little bit". In other words, if one has to strain to see it, it's not enough, yet if at a glance it is quite obvious, there may be too much. 2° is visibly just a little bit.

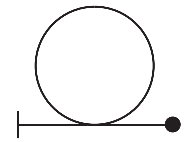
KPTR: Right engine thrust correcting for propwash frees up the pilot to focus on practicing other refinements.

DAS

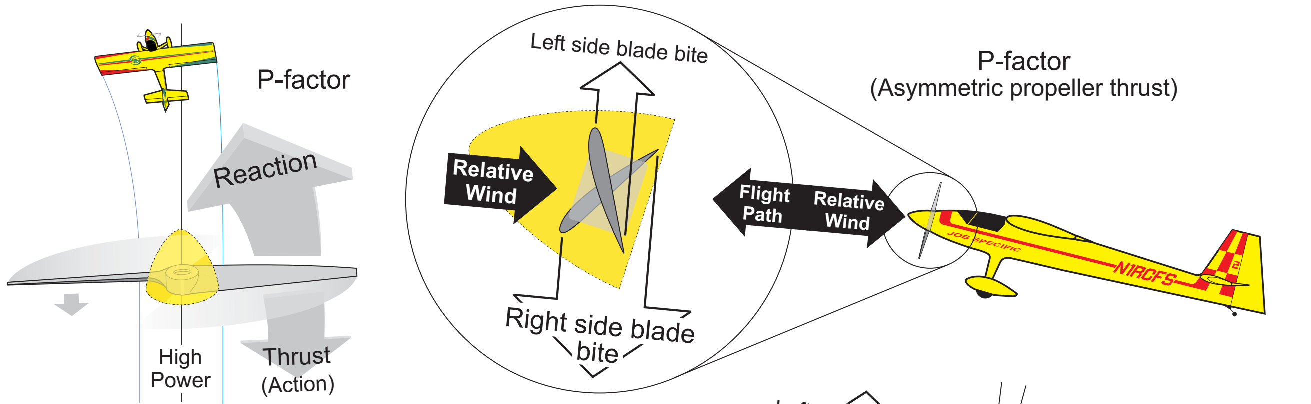
PHASE II

Down Thrust: Reducing P-factor (Asymmetric Propeller Thrust)

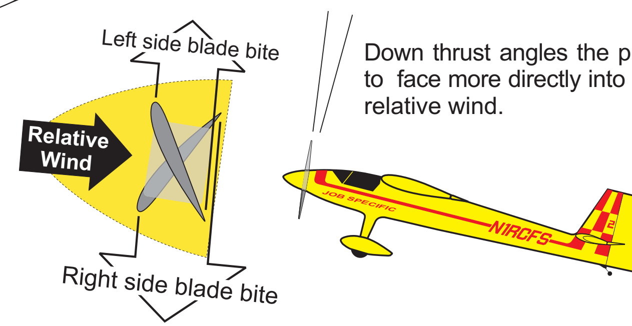
While maneuvering, the propeller blades are seldom taking equal bites of air, known as “P-factor.” At this stage, our primary concern is the left turning tendency of P-factor during inside maneuvers.



When a plane is pitched up into a climb or loop, the *angle of attack* is made greater than the actual flight path or arc that the airplane is flying (which is what makes it climb or loop). At positive angles of attack, 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. (Every little bit helps—esp. when you consider that it’s enough just to take on a whole new set of rudder wind corrections almost every day!) Another important function of down thrust is to counter-balance any excess lift generated by wing incidence at high airspeeds.

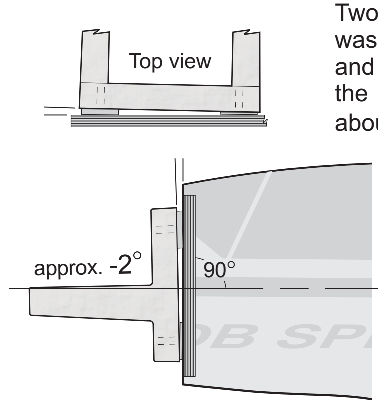


Down thrust angles the prop to face more directly into the relative wind.

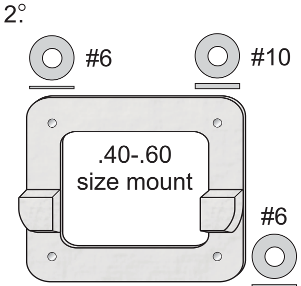
Note: Like propwash, P-factor is held mostly in check at higher airspeeds. Where down thrust is most helpful is in reducing or at least delaying the need for P-factor rudder corrections during the slower parts of loops, Immelmanns, Cubans, etc..

Post script: P-factor can be anticipated and easily corrected with Right rudder—with the understanding that it will only need correcting at lower airspeeds with a high power setting and increased angle of attack. This explains why those who attempt to mix (substitute) rudder corrections through their radio will never get them right, since the rudder is <u>not</u> always needed, or at least not always right away!

P-factor is an inevitable part of maneuvering. To eliminate it during inside maneuvers would require so much down thrust that other aspects of flight would be affected. So, the engine thrust rule-of-thumb that reduces P-factor without otherwise being noticed is 2° down <u>relative to the stab</u> at 0.



Two #6 and one #10 thickness washers (i.e., two thin washers and one twice as thick) will *shim* the engine both down and right about 2°.

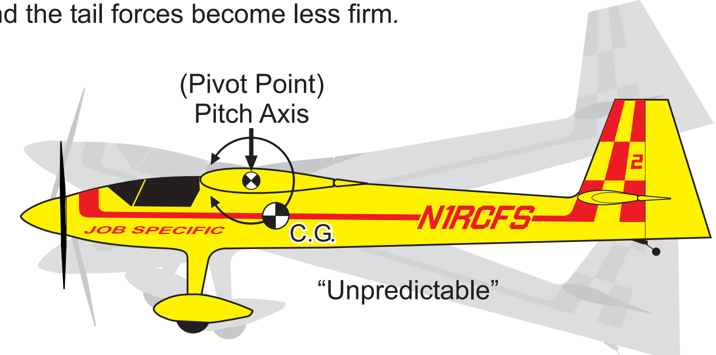


KPTR: Down thrust delaying the left turning tendency of P-factor grants a pilot time to think about his correction before needing it!

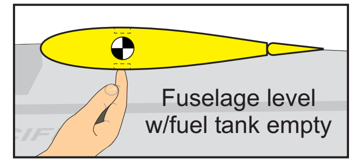
Balancing for Neutral Stability - and - Closing Setup Remarks

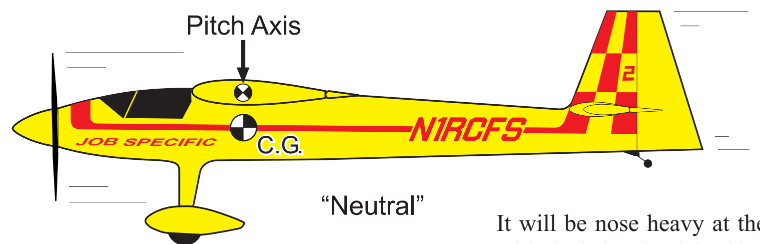
Balancing an airplane for neutral flight performance is achieved by ensuring that the C.G. is in-line with the airplane's pitch axis (pivot point). With very few exceptions (canards, reflex-airfoil aircraft, and alike), the pitch axis and therefore neutral balance point is located along the wing's thickest point.

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! While manageable at higher speeds, a plane with an aft C.G. becomes unpredictable and harder to control as soon as it is slowed down and the tail forces become less firm.



With the C.G. neither forward nor aft of the wing's thickest point, an airplane has no tendency to change its state, nor resists or exaggerates what it is told to do, and behaves basically the same at any speed.





It will be nose heavy at the start with fuel, but lend itself, as the flight continues, to a great finish!

Contrast: While a significantly nose heavy airplane won't attempt to swap ends, it will tend to behave differently at different speeds. Since aerobatics involve constant speed changes, it's well worth it to relocate the battery and/or add weight to properly balance your plane in return for the neutral flight performance that leads to staying ahead of the airplane and faster more effective learning.

In closing: Logic dictates the "best" airplane setup is the one that best compliments the type of flying a person does most often. Intermediate flying primarily consist of inside maneuvers and correcting for wind and engine forces. A lofty goal for most in the sport. Too often though, flyers break away from the cardinal setup standards that would compliment the majority of flying they do, for setups suited to the sensational stunts they attempt less frequently (e.g., tail heavy, huge control throws, etc.). Analogous to putting off-road tires on a car that is driven in the city most of the time!

The setup rules-of-thumb presented in this section have proved countless times to provide the best overall results in the least amount of time, giving a huge psychological boost to the flyer. Confidence is, after all, one of the most important aspects of learning aerobatics, and knowledge breeds confidence. So, hopefully you will not go the route of sacrificing the ease and quality of most of your flight—as so many others do—since you now have the knowledge to set up your plane to achieve a higher level of precise flying like not so many others do!

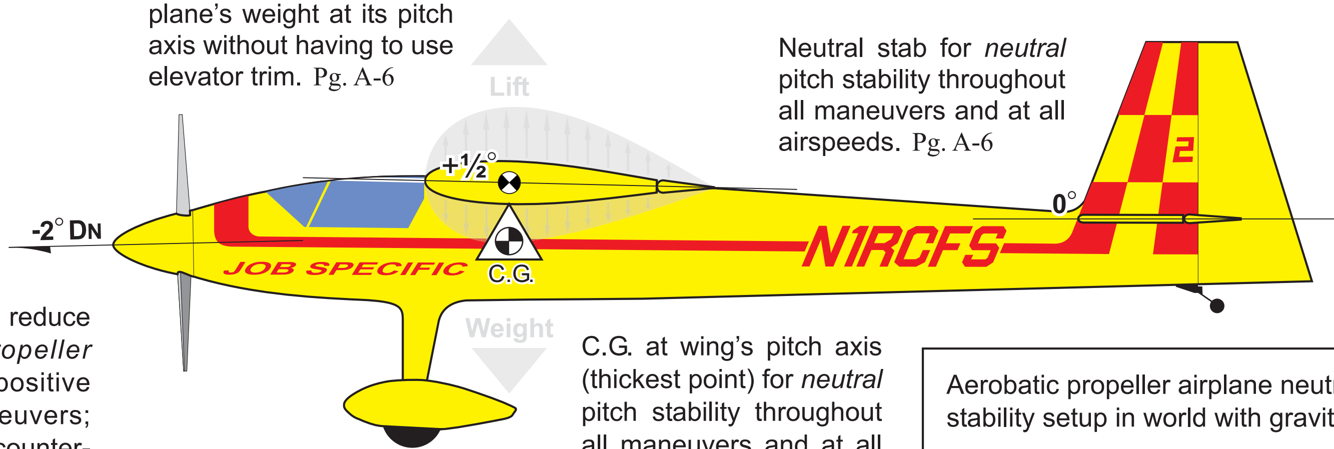
KPTR: A neutrally balanced plane neither resists nor exaggerates what it is told to do, and behaves the same at any speed.

DAS
PHASE II

All Neutral Airplane Rules-of-thumb

Positive wing incidence to produce lift to support the plane's weight at its pitch axis without having to use elevator trim. Pg. A-6

Neutral stab for *neutral* pitch stability throughout all maneuvers and at all airspeeds. Pg. A-6



Down thrust to reduce *asymmetric propeller thrust* during positive or inside maneuvers; To provide a counter-balance against climbing at higher airspeeds. (Assists inverted flight.) Pg. A-11

C.G. at wing's pitch axis (thickest point) for *neutral* pitch stability throughout all maneuvers and at all airspeeds. Pg. A-12

Aerobatic propeller airplane neutral-stability setup in world with gravity:

- 0° Stab Incidence
- ½° Pos. Wing Incidence
- 2° Right Thrust
- 2° Down Thrust

C.G. @ Wing's Thickest Point

Right thrust to counter the force of *propwash* at slower maneuvering airspeeds with higher power settings. (Assists in reducing P-factor.) Pg. A-10

Neutral fin for *neutral* directional stability maneuvering at higher airspeeds.

KPTR: Logically, the "best" airplane setup is the one that compliments the things you do the greatest percentage of the time.