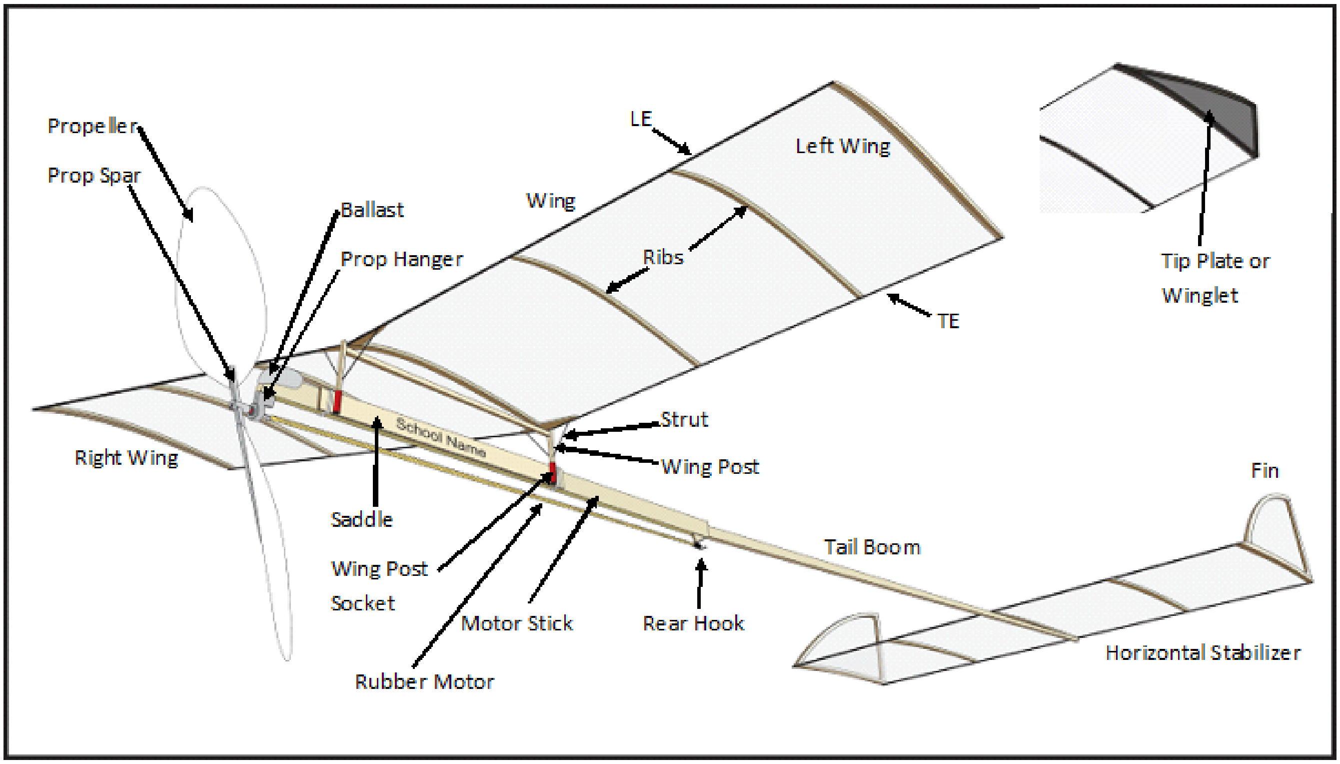
Indoor Free Flight Glossary

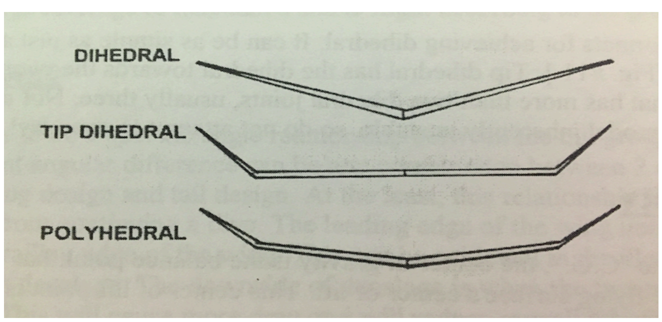
These are terms utilized in construction, initial flying, trimming, and optimizing the flight characteristics of a Science Olympiad indoor free flight plane. It helps to understand these terms when asking for assistance. In addition to defining the term, we explain some of the impact each item has on the flight of the plane.

Airplane Structure



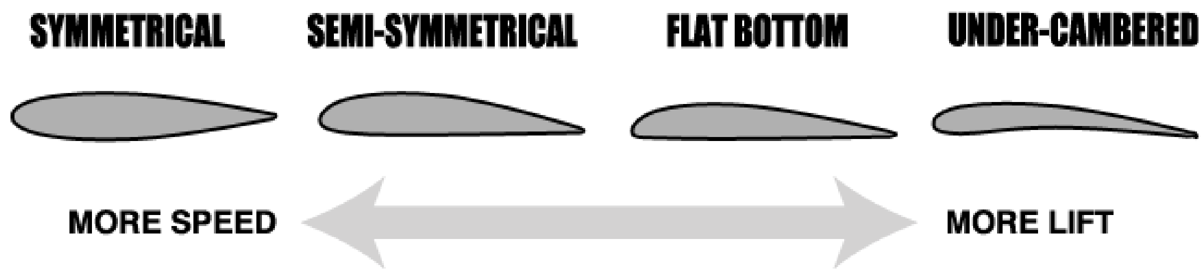
1. **Wing.** The primary lifting surface of the airplane. The wing may have an airfoil (curved ribs, as shown) or may be flat. The wing creates lift as the plane moves forward.
2. **Wing saddle (aka wing mount)** On some planes, the wing posts are connected to a saddle that mounts to the motor stick with rubber bands, allowing easy changes in the wing position, fore and aft on the motor stick. This is not normally done on lighter classes of planes.
3. **Wing post.** The wing posts are a vertical post at the leading and trailing edge of the flying surface, joining the wing to the motor stick. Often the wing is adjustable on each wing post, or the post is adjustable where it attaches to the motor stick
4. **Wing Post Socket.** A small diameter tube that is glued to the wing or the motor stick, and fits over the wing post allowing adjustment of vertical position. Some kits utilize shims under a saddle instead of tube sockets. The tube is traditionally made by wrapping tissue and glue on a music wire form. The tubes may also be made from polyamide tubing (Kapton), nylon tubing, heat shrink tubing, or even balsa. The tube may be attached to the motor stick or saddle, or alternatively to the wing LE and TE.
5. **Wing frame.** The hard structure of the wing, including leading edge, trailing edge, and ribs. These parts may be made from balsa wood, carbon strips, or other suitable materials. The wing frame holds the covering material which creates the lifting surface.
6. **Covering frame.** A rectangular frame, usually from scrap wood, that is used to support the raw covering material for attachment to the wing frame or other parts of the airplane to be covered.

7. **Horizontal stabilizer.** The smaller flying surface, typically in the rear of the plane, which provides pitch stability to the plane. In indoor duration flying, including SO, the horizontal stabilizer is larger than needed for reasons of stability; the extra surface area provides some of the lift for the plane.
8. **Tail Moment.** The distance between the center of gravity of the plane and the center of lift on the horizontal stabilizer, multiplied by the area of the horizontal stabilizer. A larger stabilizer or a longer tail boom create a larger tail moment.
9. **Conventional Wing.** In this configuration, the primary lifting surface (wing) is forward, and the horizontal stabilizer is aft. The plane in the diagram above has this type of wing.
10. **Tandem.** In this configuration, the wing and horizontal stabilizer are identical in size, and both provide similar amounts of lift to the plane. In general, this is most effective with a long tail moment.
11. **Canard.** An airplane configuration where the wing is at the rear and the horizontal stabilizer is at the front.
12. **Rib.** A part of the wing structure that separates the leading and trailing edges and defines the airfoil shape for the wing or stabilizer. Generally, the lifting surface will have multiple ribs to uniformly define the airfoil across the surface.
13. **Leading edge (LE).** The horizontal member of the flight surface that defines the front of the flight surface (wing or stabilizer). On typical SO models this is a straight member of either balsa, basswood, or carbon strip.
14. **Trailing edge (TE).** The horizontal member of the flight surface that defines the back of the flight surface (wing or stabilizer). On typical SO models this is a straight member of either balsa, basswood, or carbon strip.
15. **Spar.** The load-carrying member of the flight surface. In a typical airplane, the spar is at the thickest part of the wing in order to provide the greatest bending strength for the least weight. On indoor duration models such as Science Olympiad, LPP, and F1D, the function of the spar is carried by the leading and trailing edges. This is because the loads are light, and eliminating a spar within the middle of the airfoil makes a less draggy plane.
16. **Span.** The horizontal length of the wing, tip to tip. Generally span is the length of the wing projected onto a flat surface, not the length following the shape of the wing.
17. **Chord.** The horizontal length of the wing from leading edge to the trailing edge, measured in a straight line.
18. **Dihedral.** The flying surface, usually the wing, has an angle upward from the root to the tips.

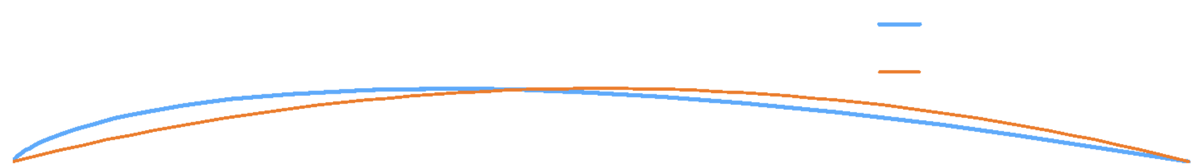


This provides roll stability, and converts yaw imposed by rudder offset into roll to help in turning. (Roll and Yaw defined in the flight characteristics section below). The dihedral is optimally an elliptical shape as viewed from the front of the plane, but this is difficult to construct with preformed carbon and wood strips. An elliptical shape may be approximated using central dihedral (simple dihedral, where the wing is in two pieces, each side angled up uniformly), Tip dihedral (some portion usually a few inches, of the outer end of each wing is angled upward), Polyhedral (a combination of several breaks in the wing shape to more closely simulate an ellipse), or tip plates (an extreme case of tip dihedral)

19. **Tip Plates (aka winglets).** An entirely flat wing may be fitted with tip plates, especially in a case where wing span is limited by rule. These tip plates are essentially vertical tip dihedral, and help to control tip vortices in addition to providing the effect of dihedral.
20. **Fin.** One or more vertical surfaces near the rear of the plane that provides yaw stability and yaw directional control. (yaw is defined in the flight characteristics section) The fin is usually centered on the tail boom, above or below. An alternative is dual tips on the horizontal stabilizer. As tips, they may be installed with dihedral instead of vertically.
21. **Airfoil.** The shape of the cross section of the wing, as defined by the ribs and covering.



The airfoil may be flat, convex on top and concave on bottom (under cambered), Convex on top and flat on bottom (flat bottom airfoil), Convex on top and bottom (symmetric or semi-symmetric airfoil), Most indoor duration planes have only one surface covering (on top), and so the airfoil is either flat or under cambered. The airfoil converts forward motion through the air into lift, and the amount of camber and design of the airfoil determines the lift vs drag profiles at different speeds. On indoor duration models, the airfoil is typically a circular arc (high point at mid chord, shown in red below) or Simplex (a unique shape giving a more forward high point, shown in blue. The Simplex shape is such that a single template works for many different chord lengths by reducing the length of the less curved end of the rib).

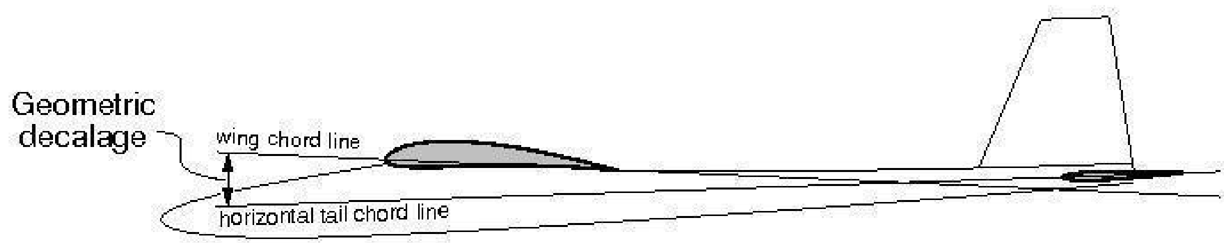


22. **Camber.** The amount of curvature of the airfoil or top of the rib. The camber is usually expressed as a percent height vs chord length. Wing airfoils are typically 4-6%, and stabilizer airfoils are typically 2-4% for many indoor duration planes. Some planes have 0% camber on the stabilizer. The ratio of camber wing to stabilizer will impact the response of the plane in pitch to various speeds.
23. **Airfoil symmetry**. This refers to the symmetry top to bottom. On indoor duration planes, the airfoil is almost never symmetric, as this would require two covered surfaces. Symmetry does NOT refer to the front-to-back symmetry of a circular arc airfoil vs a Simplex airfoil.
24. **Motor Stick.** The fuselage of the model, which provides structure to support the rubber motor. The motor stick generally goes from the prop hanger to the rear hook. On some models, it extends beyond the rear hook as part or all of the tail boom. The motor stick must resist bending side to side, top to bottom, and twisting when the fully wound rubber is mounted.
25. **Tail boom.** The portion of the fuselage behind the rear hook. The tail boom function is to support and position the tail surfaces (fin and stabilizer) relative to the wing. It should be stiff enough to not flop around under normal flight loads. Since it does not support the rubber motor, it is generally a smaller cross section than the motor stick in order to save weight.

26. **Propeller.** The rotating lifting surface, typically at the front of the plane, that converts the torque output of the rubber motor into forward motion of the plane. The prop includes the prop shaft, the prop spar, and one or more blades.
27. **Prop hanger.** A bearing assembly that holds the prop shaft and sets the thrust line. This may be an aluminum or wire pigtail, a plastic assembly, or a piece of tubing. The pigtails and Ikara plastic hangers allow removal and replacement of the prop.
28. **Rear hook.** A wire hook that anchors the rear of the rubber motor to the motor stick.
29. **Ballast.** Weight, usually clay, used to balance the plane. Ideally this also brings the plane up to minimum weight. In the case of a heavy plane that is out of balance, it is more important to set the CG properly than to be at minimum weight, so ballast may be utilized even if the overall weight is high.
30. **Prop shaft.** A wire shaft that is attached to the prop hub and passes through the prop hanger bearing assembly.
31. **Prop spar.** The stick that joins the prop blades to the prop hub or prop shaft. On a flaring prop, some of the flex that changes the pitch of the prop may be the prop spar twisting.
32. **Prop blade.** The lifting surface(s) of the prop. This may have a curvature (camber) to it as an airfoil, and may have a twist to it to have the same pitch at each radius.
33. **Prop blade leading edge.** The portion of the prop blade ahead of the spar. When the leading edge of the prop is larger than the trailing edge, the prop may be “flaring”, in that it will flex to higher pitch at higher torsional load. If the prop only has blade area in front of the spar, with no area behind the spar, it is said to have 100% flaring.
34. **Thrust bearing.** A bead or Teflon disk placed on the prop shaft between the prop spar/hub and the prop hanger. This bearing takes the thrust load of the stretched rubber and reduces friction.
35. **Wing strut.** On some designs a small strut is added diagonally from the wing post to the leading edge or trailing edge of the wing to improve the rotational stiffness of the wig/post joint.
36. **Rubber motor.** One or more strands of rubber, which when wound stores energy that is released to turn the propeller. For typical SO planes, the motor consists of a loop of rubber, to two strands. In SO flying, under current and recent rules, any O-rings or other fixtures permanently attached to the rubber motor are included in the mass of the rubber. In FAI flying such as F1D and F1R, the O-rings are counted as part of the plane weight and not as part of the rubber motor weight.
37. **O-ring.** A small ring, usually Buna-N rubber or nylon, that facilitates installing a wound rubber motor on the airplane. The rubber motor is usually wound on a stooge, or a torque meter, so that failure will not destroy the plane. If no O-rings are utilized, it would be difficult to remove the rubber motor from the winder and stooge and install it on the plane. Usually two O-rings are used, one at the prop shaft and one at the rear hook
38. **Covering.** A thin plastic or tissue membrane that forms the lifting surface of the plane. It is attached to the frame of the lifting surface. The covering may be mylar, veggie bag material, tissue, or other thin plastic or paper material. It may be attached with glue stick, spray adhesive, or thinned spray adhesive brushed on. The covering should not be attached with CA glue as this adds a lot of weight.
39. **Duco/Cellulose Glue.** This “model cement” is solvent based, Duco is one available brand. The advantage is that it is easily dissolved with acetone, allowing repositioning of parts. The bond to carbon fiber structures may be limited. This glue takes longer to set up than CA glues.
40. **CA Cyanoacrylate Glue.** This is “super glue”, and can be used for assembling model airplane parts. It is available in various densities. Only Thin or Medium should be used on SO planes. It is important to apply carefully to prevent excessive weight buildup. The CA cures fast, but is heavier and harder to dissolve than Cellulose glues.

Trim Parameters

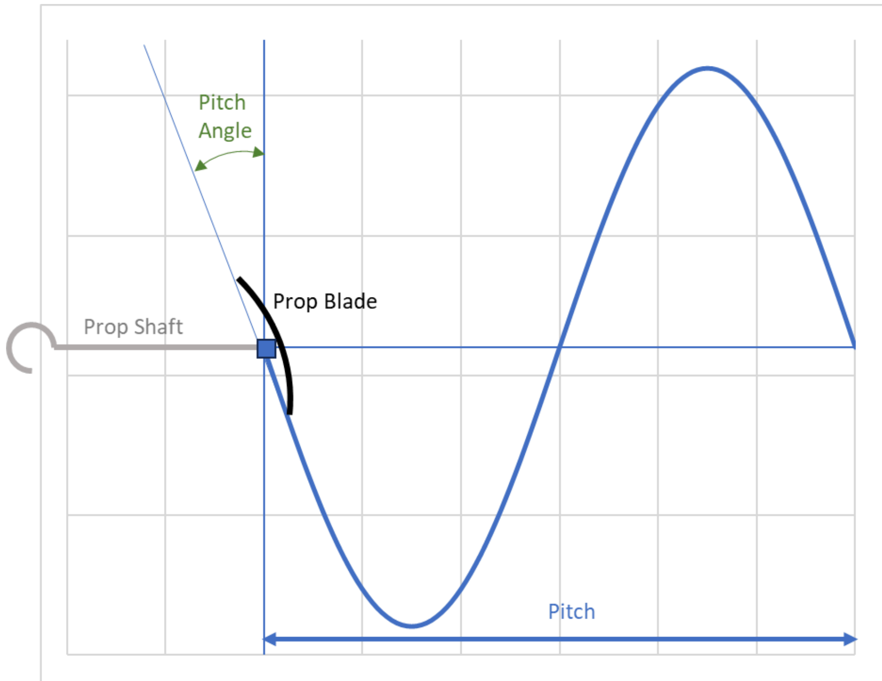
1. **Wing Incidence**. The angle of the wing relative to the motor stick, with positive being the leading edge higher than the trailing edge. Typically 3-6 mm positive difference on SO planes (LE 3-6 mm higher than TE). Add positive incidence to address a dive.
2. **Stabilizer Incidence**. The angle of the horizontal stabilizer relative to the motor stick or tail boom, with positive being the leading edge higher than the trailing edge. Typically not adjustable on SO kits, and set to 0 degrees. Add negative incidence to address a dive.



3. **Decalage**. The difference between the wing incidence and stabilizer incidence. Increasing decalage will address a dive, decreasing will address a stall. Adding positive incidence to both surfaces has the effect of increasing down thrust on the prop shaft without changing decalage.
4. **Center of Gravity (CG)**. This is the fore/aft balance point of the plane in flying condition (with the rubber motor). The CG affects stability. Moving forward relative to the wing increases stability, but requires more decalage, reducing efficiency. Moving back reduces stability, but may increase efficiency. An unstable plane will dive sharply upon disturbance such as hitting a rafter. On planes with sliding wing saddles, moving the wing forward moves the CG back relative to the wing, and vice versa. For most SO planes the CG is measured relative to the rear wing post.
5. **Wing position**. (Nose length). On planes with a sliding wing saddle, the position of the wing on the motor stick can be measured from the front of the prop bearing to the front wing post. However, in most cases the effect of moving the wing is to adjust the CG, so it is generally more important to report CG relative to the rear wing post. However, for repeatability in setup, recording and checking the wing position may be simpler.
6. **Tail boom offset.** The vertical stabilizer is offset to the left at an angle to help induce a left turn. This can be just the vertical fin or the entire tail boom. This tightens up the left turn in all flight phases, but strongest at higher torque
7. **Stabilizer tilt.** The horizontal stabilizer is tilted relative to the wing, with the left tip higher than the right tip. With a lifting stabilizer (if it has an airfoil), the lift is now directed slightly to the right, pushing the tail to the right or the nose to the left. Typically 1-2 cm is plenty of tail tilt. Tail tilt is most effective at slower speeds on cruise and letdown.
8. **Left wing wash-in**. **(aka wing warp or twist).** The leading edge of the left wing is higher than that of the right wing, relative to the trailing edge. The wing essentially has a twist, creating more lift on the left. This is ONLY added to address a plane rolling left and diving at high launch torque. This adjustment adds significant drag so should only be implemented if needed. Generally, the wing should have the LE and TE parallel to each other.
9. **Down thrust.** The propeller shaft can be mounted such that the propeller points downward a few degrees. Generally, this is not needed on SO planes unless called for in the design. Excessive down thrust will make the plane hard to climb, and reduce efficiency. Unless called for, set the thrust line to 0 degrees, parallel to the motor stick.

10. **Left thrust.** On some planes at very high thrust, left thrust may help prevent the plane from rolling left, and help tighten the circle at the beginning of the flight. Generally, this is not needed for the low ceilings seen in SO. Check to be sure your left thrust is set to 0 unless called for in the plan.

<u>Propeller Parameters</u>



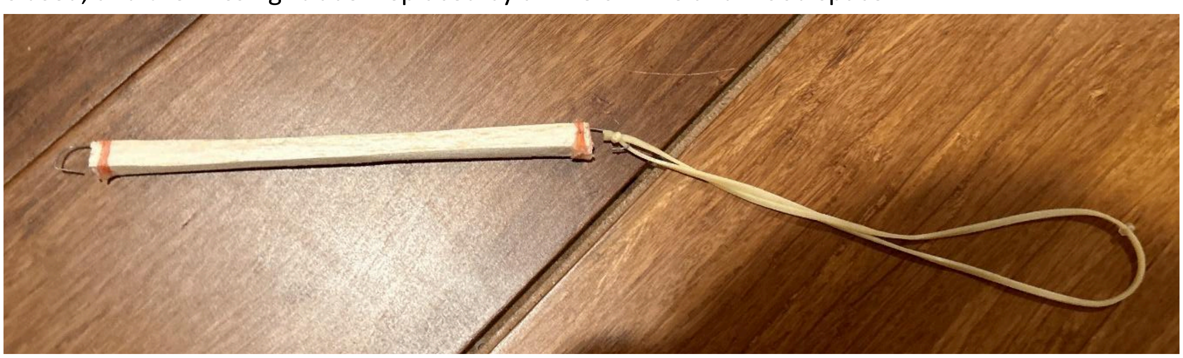
1. **Propeller Pitch.** The pitch is how far a propeller would ideally move the plane forward through the air if there were no slip (like the prop was turning in Jello). If the prop pitch is the same everywhere on the prop it is called “helical”. Some props deviate from this purposely, for example tip wash out of a few inches. Some manufactured props may not have enough twist to have a helical shape.
2. **Propeller Pitch Angle.** The angle of the prop blade relative to the plane of the prop. If the pitch is constant along the prop, the pitch angle is steeper as you get closer to the hub of the prop. The pitch angle is typically measured around the 2/3 to ¾ radius location of the prop. For a Science Olympiad prop of 9.5” diameter, the pitch angle is typically measured at a radius from the shaft of 3.5-4 inches. To convert pitch angle to pitch, Pitch=tan(Pitch Angle)*2*π*R where R is the radius at which the P.A. is measured. To convert pitch to pitch angle, Pitch Angle=atan(Pitch/(2*π*R)).
3. **Propeller Diameter.** The propeller length, measured from tip to tip. Generally the maximum distance tip to tip. If the propeller tip is square, the diameter may be measured to the corners. The propeller diameter may be regarded as the minimum circle that can be circumscribed around the propeller.
4. **Radius of Measurement.** When measuring the pitch angle, it is important to know what radius it is measured at, because while the pitch may be constant on the propeller, the pitch angle varies with radius. Generally it is best to measure between ⅔ and ¾ of the propeller tip radius.
5. **P/D Ratio.** The Pitch to Diameter Ratio is the ratio of the prop pitch to the diameter of the prop (not the diameter of the measurement location). Typically, P/D will be between 1.5 and 2.0.

<u>Rubber Motor Parameters</u>

1. **Rubber Width.** This is the cut width of the rubber motor. The wider the motor the more power or torque it can put to the prop, but the fewer total winds you can fit. The power is more accurately impacted by

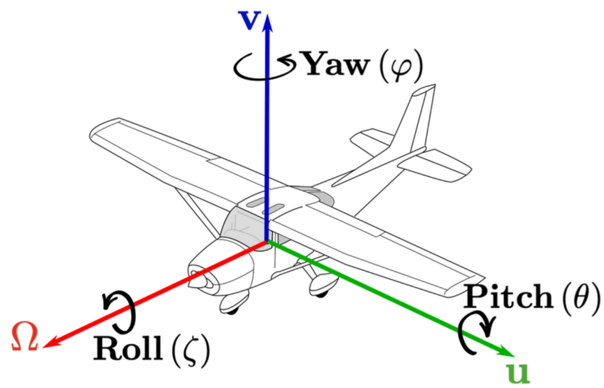
the cross-sectional area of the rubber, and the cut width does not account for the thickness variation from batch to batch or within a batch.

2. **Rubber Thickness.** The stock thickness of the rubber, generally around 1mm (0.040”). This thickness varies due to the manufacturing processes, and is not controllable by the user. Thickness typically can vary 5-6% within a batch of rubber, and can vary more than 10% batch to batch.
3. **Rubber Linear Density.** This is a characterization of the rubber “width” in g/in (typical mixed units), which accounts for variations in thickness and density. The power of the rubber corresponds well to the linear density. This is a preferred method of characterizing a piece of rubber. The actual density (g/in^3) does not vary much, so the linear density is generally proportional to the cross-sectional area of the rubber.
4. **Rubber Loop Length.** Given a fixed mass, 1.5g for current SO rules, a measurement of the loop length, before any stretching or winding, is a simpler method of estimating the performance of the rubber. Measure from the inner end of the knot, and only stretch enough to straighten the rubber
5. **Rubber Lube.** Lubrication helps prevent the rubber from abrading itself as it is wound, allowing significantly more winds and higher torque before breaking. Petrochemicals, such as motor oil and WD40, SHOULD NOT BE USED as they will attack the rubber. Use a silicon-based oil such as R/C car shock oil or Armor-All Original (available at most auto shops)
6. **Partial Motor Testing.** A fraction of the motor, often ½, is replaced with a spacer to limit climb during the testing. The rubber motor is wound and unwound to the max torque and launch torque planned for the full motor. The winds will be ½ (or whatever fraction the motor is), the climb altitude change will be ½, and the time will be ½. This is useful for testing when the test venue has a lower ceiling than the competition venue. It is also useful for limiting the duration of test flights (more testing), limiting the altitude gain of test flights (less risk to the plane), and reducing the amount of rubber needed for testing.
7. **Spacer.** In partial motor testing, a rubber motor that is a fraction of the length of the competition motor is used, and the missing rubber replaced by a wire or wire and wood spacer.



The spacer makes up the missing rubber in both mass and length. For example, with half motor testing, the rubber and spacer each weigh ½ the mass of the allowed rubber motor, and the spacer is ½ the length of the hook-to-hook distance on the plane. The spacer is attached to the rear of the rubber motor, and to the rear hook on the plane. Typically, the partial motor only has one O-ring at the front, as the spacer serves the function of the second O-ring.

Flight Characteristics



1. **Roll.** The plane rotates about its motor stick or fuselage. Typically, due to torque, the plane may roll in to the left (toward the center of the circle). If the roll is excessive, the plane may dive and crash.
2. **Pitch.** The plane rotates about the left-to-right horizontal axis of the plane, with the nose going either up or down relative to the center of the plane.
3. **Yaw.** The plane rotates about a vertical axis, with the nose moving to the right or left relative to the center of the plane.
4. **Lift.** An upward force on the airplane generated by the flying surfaces.
5. **Thrust**. A forward force on the airplane generated by the motor and propeller combination
6. **Drag.** A rearward force on the airplane caused by friction and aerodynamic forces on the plane. Drag increases with speed. Drag is caused by the frontal area and by aerodynamic forces on the lifting surfaces. Generally lift-producing surfaces will also produce drag.
7. **Angle of attack**. The angle of the wing flying surface relative to the direction of travel. Increasing the angle of attack will increase the lift (and drag) of the plane until stall occurs.
8. **Stall.** The wing of the plane reaches a high enough angle of attack that it fails to generate lift, and the nose of the plane drops. The plane recovers (typically) and then repeats the cycle. Some planes, notably the C div plane in 2024 and 2023, tend to “mush” in a nose-high attitude but never drop through in a visible stall. A stall may be induced by too much decalage or in some cases a CG too far to the rear.
9. **Dive.** The nose of the plane pitches downward continuously while the plane picks up speed. A dive may be induced by insufficient decalage, a forward CG. or damaged parts. An unstable plane may dive and not recover after a disturbance.
10. **Stability.** The ability of the plane to recover from a disturbance such as hitting a girder or rough air. An unstable plane will lose a lot or all of the altitude after a disturbance, whereas a very stable plane may only lose a few inches of altitude. An overly stable plane may not be as efficient as a neutrally stable plane. Stability is affected by the CG location relative to the lifting surfaces, and is typically measured from the rear wing post.