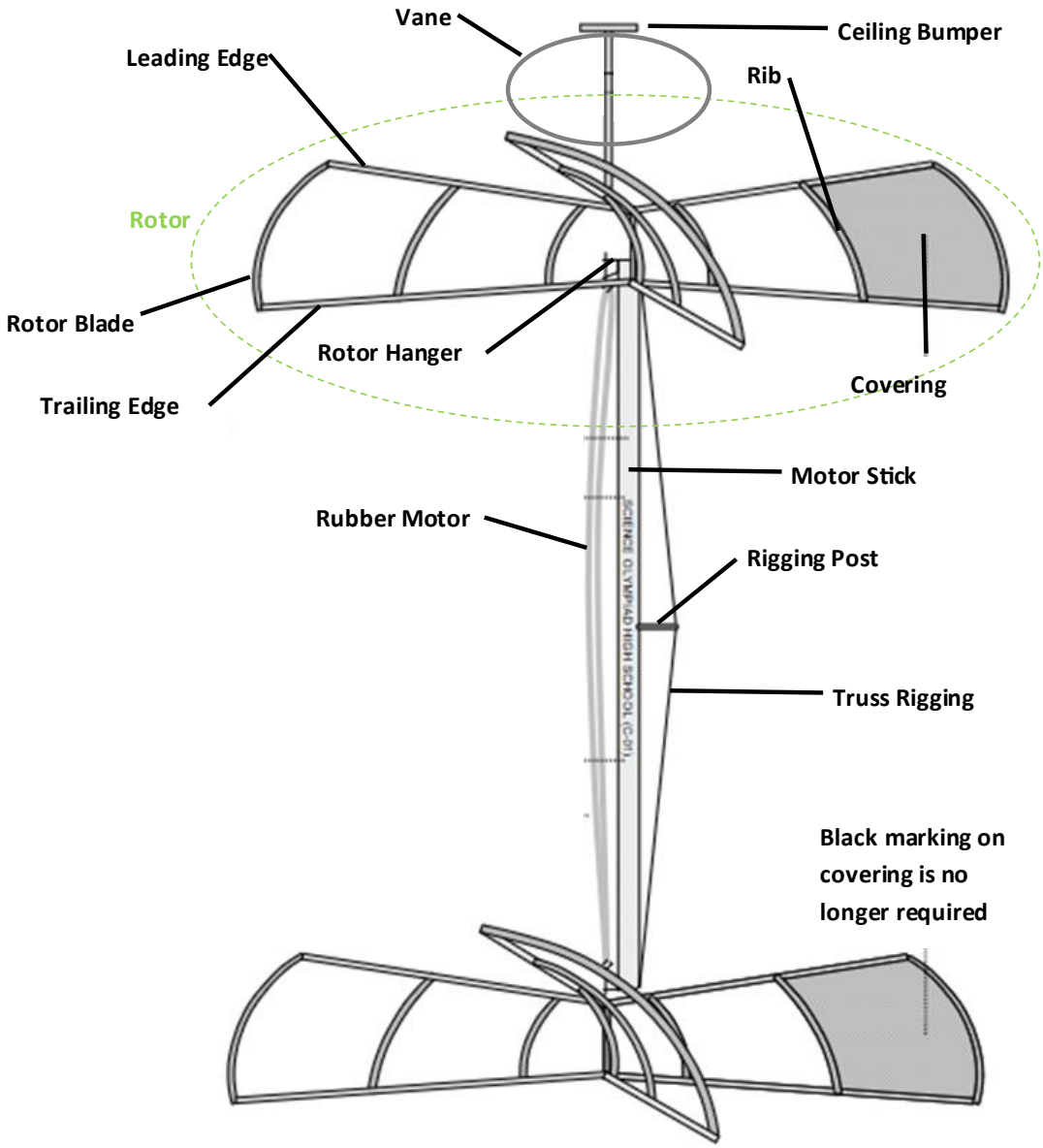
Indoor Free Flight Helicopter Glossary

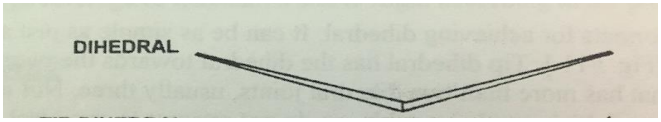
These are terms utilized in construction, initial flying, trimming, and optimizing the flight characteristics of a Science Olympiad indoor free flight helicopter. It helps to understand these terms when asking for assistance. In addition to defining the term, we explain some of the impact each item has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

Helicopter Structure



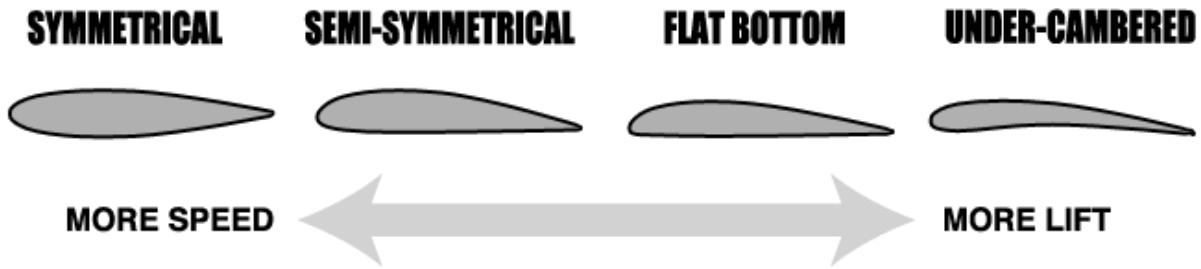
Rotor assembly

1. **Rotor.** The primary lifting surface of the helicopter. The rotor may have an airfoil (curved ribs, as shown) or may be flat. The rotor creates lift as it rotates about the axis. There may be up to 3 rotors on the helicopter, and they may be in any arrangement that fits in the measurement box.
2. **Rotor frame.** The hard structure of the rotor, including leading edge, trailing edge, and ribs. These parts may be made from balsa wood, carbon strips, or other suitable materials. The rotor frame holds the covering material which creates the lifting surface.
3. **Rotor blade.** The lifting surface(s) of the rotor. 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. Each rotor has one or more blades, typically 2-4
4. **Rib.** A part of the rotor structure that separates the leading and trailing edges and defines the airfoil shape for the rotor. Generally, the lifting surface will have multiple ribs to uniformly define the airfoil across the surface.
5. **Leading edge (LE).** The horizontal member of the flight surface that defines the front of the flight surface (rotor). On typical SO models this is a straight member of either balsa, basswood, or carbon strip.
6. **Trailing edge (TE).** The horizontal member of the flight surface that defines the back of the flight surface (rotor). On typical SO models this is a straight member of either balsa, basswood, or carbon strip.
7. **Rotor spar.** The stick that joins the rotor blades to the rotor hub or rotor shaft. The Leading and Trailing edges of the rotor may perform the function of the spar(s)
8. **Rotor shaft.** A wire shaft that is attached to the rotor hub and passes through the rotor hanger bearing assembly.
9. **Rotor Diameter.** The horizontal length of the rotor, tip to tip. Generally span is the length of the rotor projected onto a flat surface, not the length following the shape of the rotor. For rotors with an odd number of blades, the diameter is the minimal circle size that can circumscribe the entire rotor.
10. **Chord.** The horizontal length of the rotor from leading edge to the trailing edge, measured in a straight line. This often varies along the length of the rotor.
11. **Dihedral.** The flying surface (rotor) has an angle upward from the root to the tips.



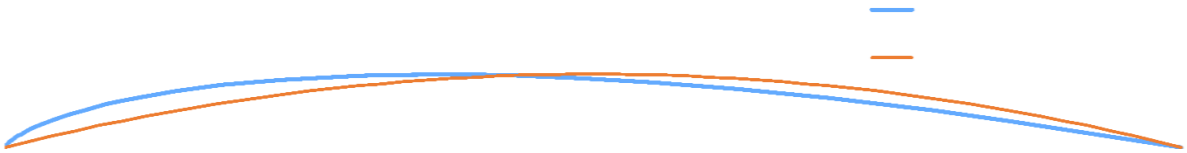
This may provide additional stability. Most SO kits do not incorporate dihedral in the rotor.

12. **Airfoil.** The shape of the cross section of the rotor, 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 aircraft 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).



13. **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 and rotor airfoils are typically 4-6%.
14. **Airfoil symmetry**. This refers to the symmetry top to bottom. On indoor duration aircraft, 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.
15. **Covering.** A thin plastic or tissue membrane that forms the lifting surface of the rotor. 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.
16. **Covering frame.** A frame, usually from scrap wood, that is used to support the raw covering material for attachment to the rotor frame or other parts of the helicopter to be covered. The covering frame is not part of the helicopter, but a fixture used in building. The helicopter covering frame may need to be angular in shape to allow the covering to conform to a twisted blade.

Motor Stick Assembly

1. **Vane.** The vane at the top of the helicopter is free to rotate, and adds stability to a heli with flat rotors. Helis with X-rotors do not typically need a vane, as the higher pitch angle in the middle of the rotor effectively adds vertical surface area.
2. **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.
3. **Truss rigging.** Some designs utilize rigging to stiffen the motor stick against bending. This allows a smaller cross section, or lighter motor stick, but risks tangling a broken rubber motor in the truss rigging. Some designs include three truss wires, one opposite the rubber and one on each side to hold off buckling under load.
4. **Rigging post.** This post supports the truss rigging away form the motor stick to form a tension triangle for motor stick stiffness.
5. **Rotor hanger bearing.** A bearing assembly that holds the rotor 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. The helicopter may have a hanger bearing at each rotor, or may have one at only one rotor while the other rotor is attached firmly to the motor stick, causing the motor stick to rotate with the fixed rotor.
6. **Rear hook.** A wire hook that anchors the rear of the rubber motor to the motor stick, for the case of only one rotor hanger.

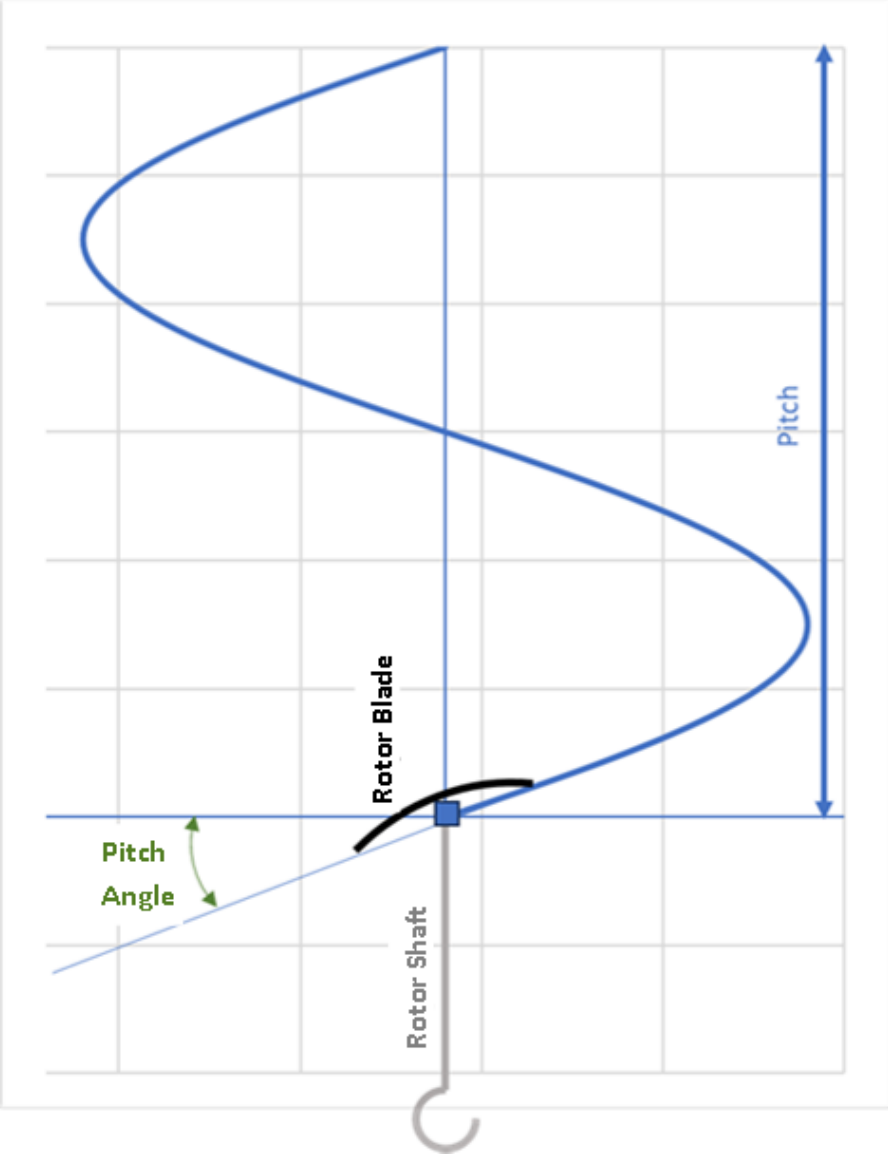
7. **Ballast.** Weight, usually clay, used to balance the helicopter. Ideally this also brings the helicopter up to minimum weight.
8. **Thrust bearing.** A bead or Teflon disk placed on the rotor shaft between the rotor spar/hub and the rotor hanger. This bearing takes the thrust load of the stretched rubber and reduces friction.
9. **Ceiling bumper.** A dime-sized (minimum) balsa disk required by SO rules to be the upper-most part of the helicopter, which contacts the ceiling first. On some designs this disk is free to rotate to limit wandering along the ceiling.
10. **Rubber motor.** One or more strands of rubber, which when wound stores energy that is released to turn the rotor(s). For typical SO aircraft, the motor consists of a loop of rubber, or 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.
11. **O-ring.** A small ring, usually Buna-N rubber or nylon, that facilitates installing a wound rubber motor on the aircraft after winding. 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 rotor shaft and one at the rear hook or second rotor shaft.
12. **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.
13. **CA Cyanoacrylate Glue.** This is “super glue”, and can be used for assembling model aircraft parts. It is available in various viscosities. 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.

Helicopter Trim Parameters

The helicopter has far fewer trim parameters to adjust, when compared to airplanes.

1. **Center of Gravity (CG)**. This is the top/bottom balance point of the helicopter in flying condition (with the rubber motor). The CG may affect stability. Some have reported a “pendulum effect”, where a lower CG is beneficial to stability. Others have reported improved stability with the CG above the centerline. If you see stability issues on the climb, try moving the ballast up or down and see what works for your helicopter.
2. **Thrustline.** The rotor shaft can be mounted such that the propeller points off axis a few degrees. Sometimes a spiral climb can be adjusted by changing the thrustline. However, first be certain that your rotors are symmetric in their construction and pitch.
3. **Motor stick length.** The length of the motor stick may affect stability in the climb. A longer motor stick is generally more stable.

Rotor Parameters



1. **Rotor Pitch.** The pitch is how far a propeller would ideally move the rotor upward through the air if there were no slip (like the rotor was turning in Jello). If the rotor pitch is the same everywhere on the rotor it is called “helical”. Some rotors deviate from this purposely, for example tip wash out of a few inches pitch. Some kits use less twist than helical, or even a flat rotor which would have constant pitch angle rather than constant pitch. In indoor model aircraft, the pitch at 60-75% of the rotor radius is often used as a representative pitch for the whole blade.
2. **Rotor Pitch Angle.** The angle of the rotor blade relative to the plane of the rotor. If the pitch is constant along the rotor, the pitch angle is steeper as you get closer to the hub of the rotor. The pitch angle is typically measured around the 2/3 to ¾ radius location of the rotor, or at the tip. 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. **Rotor Pitch Progression.** The change in the rotor pitch angle along the length of the rotor. In a helical pitch progression, the pitch is constant along the blade, so the pitch angle changes with position. In a flat blade, the pitch angle is constant along the blade, so the pitch changes with position.

4. **Rotor Wash Out.** In some cases a propeller or helicopter rotor may have a small amount of "wash out", where the outermost part of the blade (last 25-35%) has less pitch than the rest of the blade. This may affect blade efficiency, but may not be routinely incorporated on heli kits.
5. **Rotor Diameter.** The horizontal length of the rotor, tip to tip. Generally span is the length of the rotor projected onto a flat surface, not the length following the shape of the rotor. For rotors with an odd number of blades, the diameter is the minimal circle size that can circumscribe the entire rotor.
6. **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 rotor, the pitch angle varies with radius.
7. **P/D Ratio.** The Pitch to Diameter Ratio is the ratio of the rotor pitch to the diameter of the rotor (not the diameter of the measurement location).

Rubber Motor Parameters

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 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. **Rubber "size".** SO rules require you to report rubber size before winding, in your log. Rubber size is intentionally vague, and could be the linear density, the total mass, the loop length, the cut width, or possibly other parameters. It is up to the team to decide what is the important parameter(s) of size. If more than one is beneficial, use one to fulfil the required entry, and then additional size parameters for the user-selected parameters.
7. **Winds on rubber.** SO requires the winds on the motor or torque at launch. This is the number of times the rubber motor has been twisted. This is NOT the winder turns, but the turns in the motor itself, so be sure to multiply by the winder ratio.
8. **Stretch Winding.** When winding, it the rubber is stretched to 5-8 times its natural length, far more winds can be imposed than if the rubber is not stretched. Stretch to 5-8x, then begin winding. When the turns or torque are about 50-60% of the maximum expected, begin to walk in while continuing to wind. NFFS provides several instructional resources on stretch winding.

9. **Backoff Turns.** After winding, the torque, and linear pull, will be very high, near breaking. On helicopter, the only need to back off (unwind) is to reduce the peak forces to the amount the motor stick can handle. This may only be a few turns of the winder.
10. **Max Turns.** The estimated maximum turns can be estimated using a calculator that NFFS has made available on its resource page. This is an estimate only, but can be a good indication as to whether you are accomplishing good winding techniques.

Flight Stages

1. **Launch.** The helicopter is held vertically and released. It may help to release the rotors a moment (one second) before releasing the helicopter to allow the rotor to reach flying speed for a straighter launch.
2. **Climb.** At initial high torque, the helicopter will rapidly ascend to the ceiling. This phase may only take a second or two depending on ceiling height.
3. **Cruise, or Ceiling Stick.** When the helicopter reaches the ceiling, the torque is still more than needed to support the helicopter, so it presses against the ceiling for most of its flight. These helicopters are sometimes called “ceiling stickers” As long as the torque is in excess of that needed to balance the mass, it will stay at the ceiling. The dime-sized disk prevents the helicopter from impaling the ceiling and getting stuck to a ceiling tile.
4. **Letdown.** As the torque gradually reduces during the flight, the force against the ceiling (excess lift) also reduces. When it gets to the point that the lift generated by the rotors equals the mass, the heli will start to come back down. The equilibrium point is momentary because the torque continues to reduce as the rubber motor unwinds.
5. **Landing.** The helicopter lands after a brief descent. At landing, the remaining turns on the motor may help you to decide what changes to make to the rubber motor size. Ideally the helicopter should just about run out of turns at landing, though only the stopwatch will tell you how many turns should remain.

Helicopter Configurations

1. **Coaxial.** A helicopter consisting of two rotors on opposite ends of the motor stick, with the rotor shafts coaxial, or inline, with each other. Generally one rubber motor is used to power such a helicopter. Either one or both rotors are mounted in bearings, or one of the rotors may be affixed to the motor stick. The rotors turn in opposite directions.
2. **Chinook.** Two or more rotors are arranged generally in the same plane, at the top or bottom of the helicopter, with the axes of rotation separated by at least the radius of the rotors. Generally this requires a separate rubber motor for each rotor, and generally the rotation is in opposite direction.
3. **X-rotor blades.** The rotor spars (leading and trailing edges) form an “X” through the center shaft area. IF the spars are straight, the rotors are inherently helically pitched. The spars are separated vertically to provide the pitch of the rotor. The pitch is built into the rotor and may be difficult to adjust. This is a simple-to-build configuration that is very stiff. X-rotors can be applied to co-axial or Chinook style helicopters.
4. **Modified X-Rotor blades.** An X-rotor with a 2-part trailing edge intended to limit the chord at the tip. Generally the outer portion of the trailing edge slopes to continue the helical pitch progression along the

blade. The joint between the inner and outer section of the trailing edge may be adjusted to change the tip pitch angle with minor difficulty.

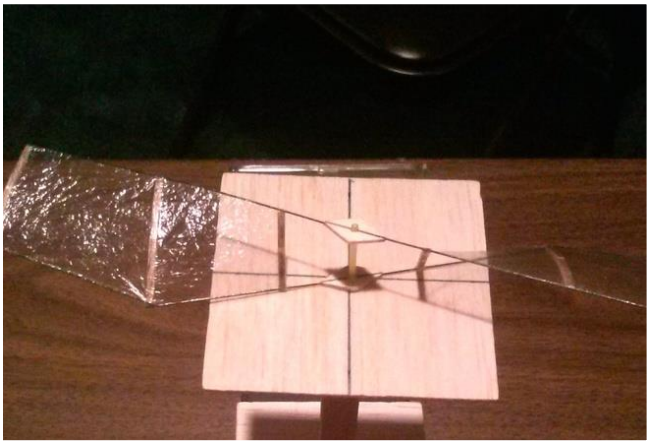
5. **Paddle Rotor blades.** These rotor blades have a single spar attached to the center hub, much like a propeller. The spar may be on the leading edge, trailing edge, or more typically in the middle of the chord or the high point of the airfoil. The blade itself may be twisted (pitch progression) or a constant pitch angle (flat blade). The blade may or may not have camber. This approach may allow pitch angle adjustment depending on the hub design.



A coaxial helicopter with X-rotor blades (Guru)



A coaxial helicopter with paddle blades (J&H)



A modified X-rotor blade (Earlier FFM design)



A Chinook helicopter from2018 (FFM)