Model Rocket Helicopter (Gyrocopter) Duration

Trip Barber
NAR 4322

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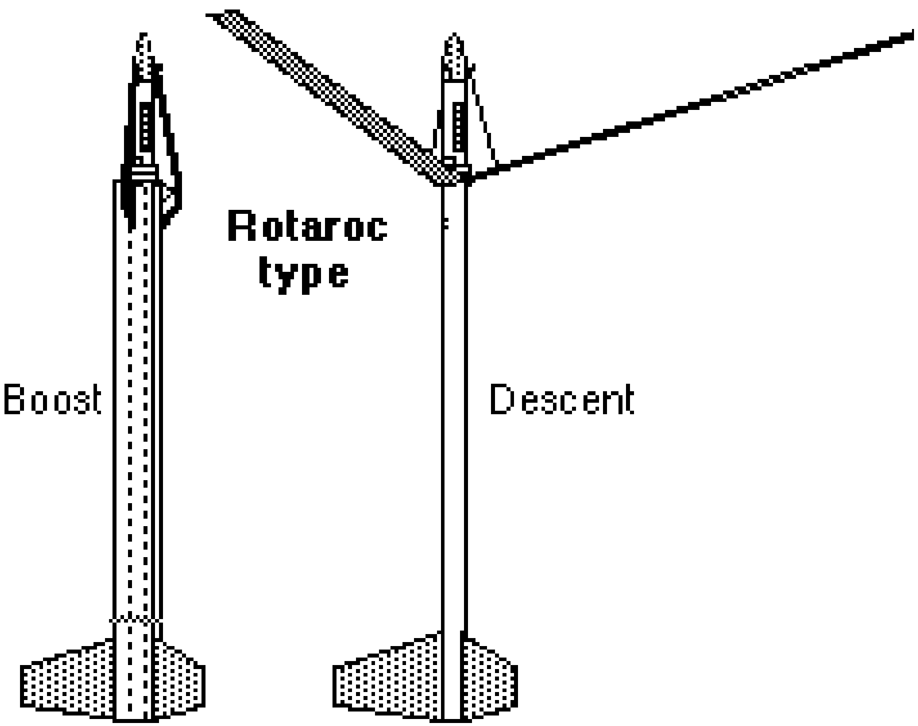
Competition Rules
NAR and FAI

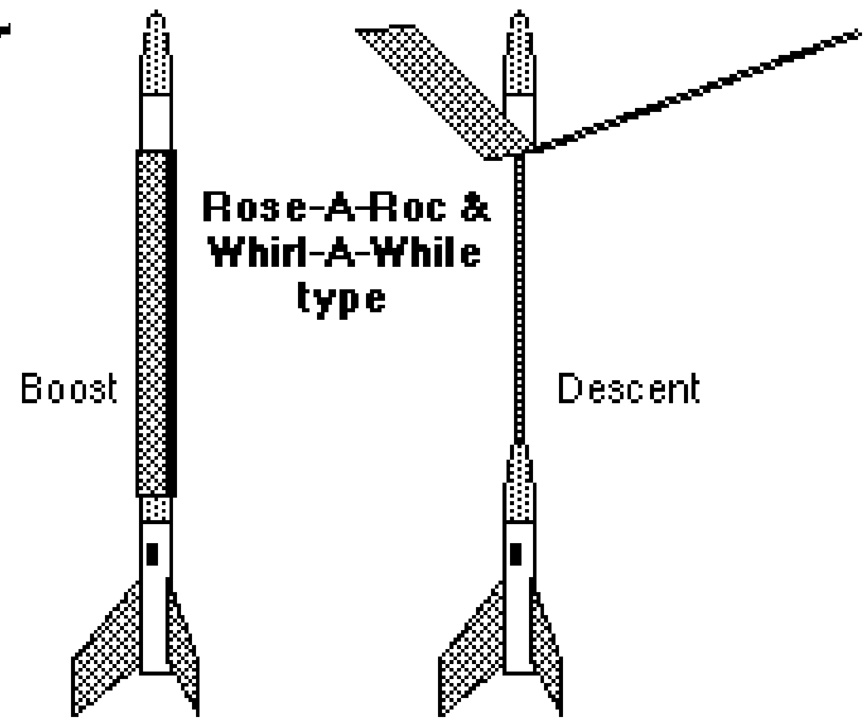
- Each entry must be decelerated during descent by its autorotating recovery device. The resulting autorotation must be around the vertical (roll) axis.
- A model that descends nose first, or flips over during descent is permitted under NAR rules. FAI rules require that "proper deployment and operation of the recovery system".
- The recovery system may not be constructed solely, or in part, of flexible materials and rigging (e.g., a parachute with rigid stringers or folding rotors of flexible materials between rigid stringers).
- Entries using a recovery system that is designed to act (or that actually acts) in a manner similar to a parachute, a rigid inverted bowl, or similar techniques are specifically excluded.
- FAI Gyrocopter (S9) models must be contained in a body that is at least 500 millimeters long, and that is at least 40 mm in diameter for at least half of its length.

Types of Models

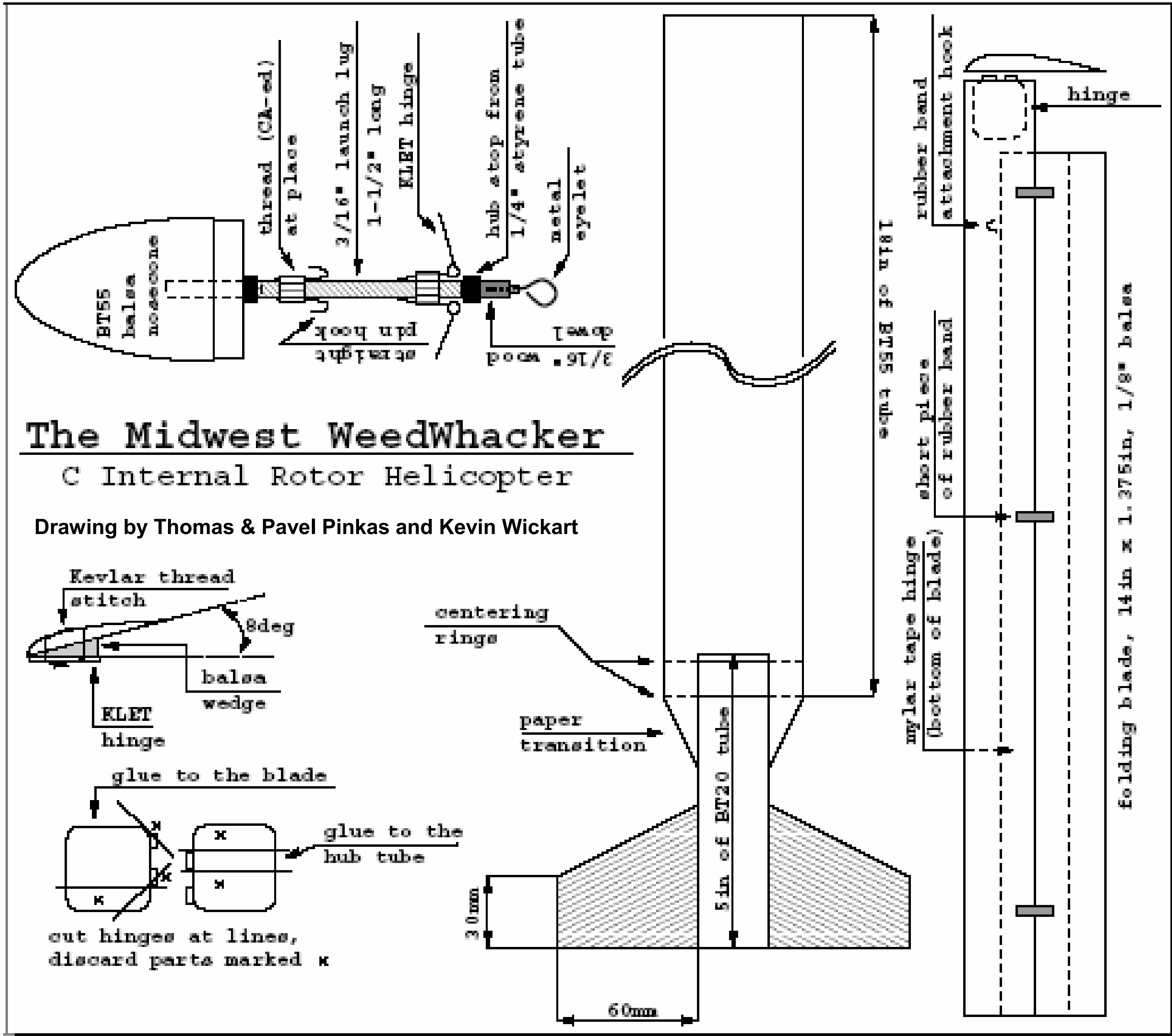
- External blades – blades are attached to and fold along an engine-diameter body
  - Fit between fins during boost
  - Burn-string holds them closed until ejection
  - Easy to build, but high boost drag/low altitude
- Internal blades – blades fold inside a body that is larger than the engine in diameter
  - Piston ejects the blades, which are attached to a hub
  - Blade hub is attached to booster body by a Kevlar cord
  - The only design used in the FAI event
  - Harder to build (complex) and heavier, but higher boost altitude offsets in A and higher power classes
- Folding blades – can be used with either approach
  - Folded part can either lengthen the blade, or can increase its width and add camber with an angled flap

External Blade NAR Designs





Good NAR external blade competition kits on the market: Apogee Heli-Roc and QCR High Rotor series


The Midwest WeedWhacker
C Internal Rotor Helicopter
Drawing by Thomas & Pavel Pinkas and Kevin Wickart
thread (CA-ed) at place
3/16" launch lug 1-1/2" long
KLET hinge
hub stop from 1/4" styrene tube
metal eyelet
BT55 balsa nosecone
straight pin hook
3/16" wood dowel
18in of BT55 tube
rubber band attachment hook
hinge
short piece of rubber band
mylar tape hinge (bottom of blade)
folding blade, 14in x 1.375in, 1/8" balsa
Kevlar thread stitch
8deg
balsa wedge
KLET hinge
centering rings
paper transition
5in of BT20 tube
30mm
60mm
glue to the blade
glue to the hub tube
cut hinges at lines, discard parts marked x

How They Work

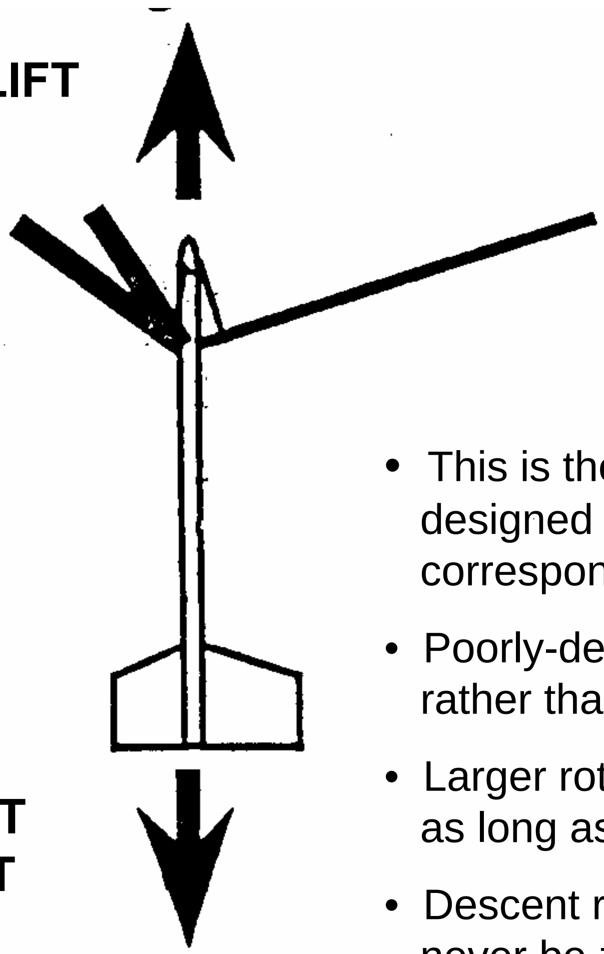
- Multiple blades, symmetrically arranged around the model's roll axis, deploy at apogee.

- The airspeed from the model's initial descent creates airflow over the deployed blades, inducing lift.

- The component of blade lift perpendicular to the long axis of the model causes rotation of the blades.
  - The middle of the blade's span creates most of this torque

- The component of blade lift parallel to the long axis of the model offsets its weight, slowing its descent.
  - The outer part of the blade's span, where airspeed across the blade is highest, creates most of this lift

Descent Rate



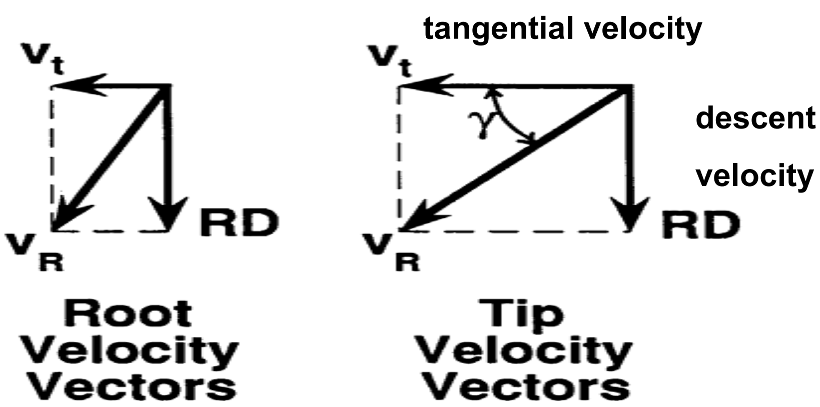
BEST DESCENT RATE (m/sec) = $3.6 \sqrt{W / S}$

W = rocket mass (kg) : minimize

S = rotor disc area (m^2) : maximize

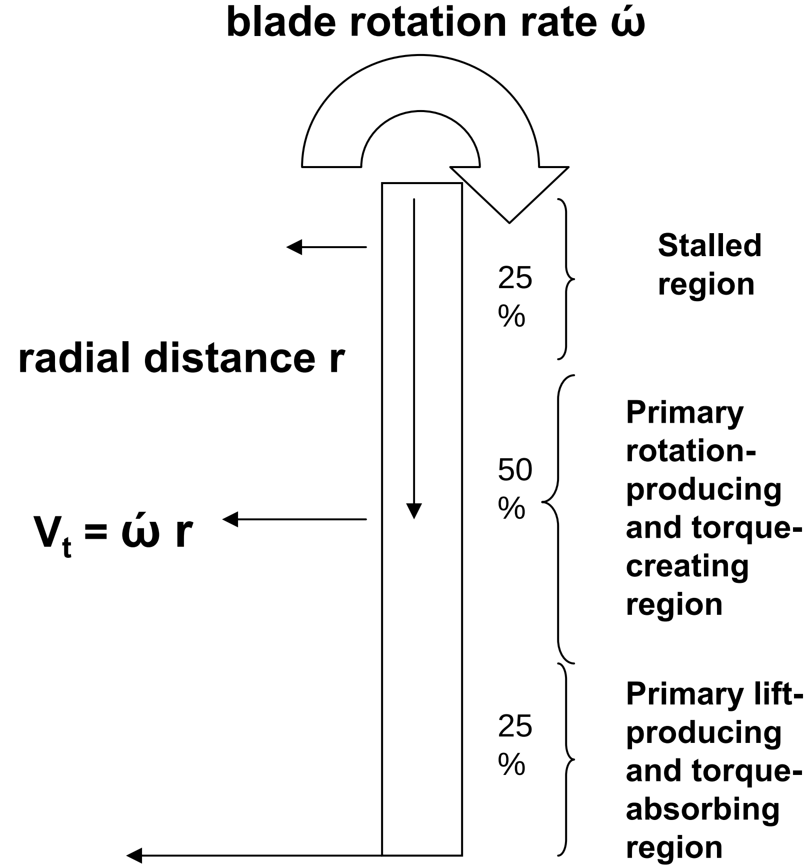
- This is the lowest possible descent rate for a well-designed rotor stably spinning at high speed; it corresponds to ~85% of the C_D of a spherical parachute
- Poorly-designed rotors behave as 3 individual blades rather than a disc and cannot match this descent rate
- Larger rotor disc areas (blade span) descend slower as long as they can reach high rotation rates (100's rpm)
- Descent rate relative to the surrounding air mass can never be zero – then there is no pressure difference across the rotor disc and the blades will stop rotating

Blade Twist

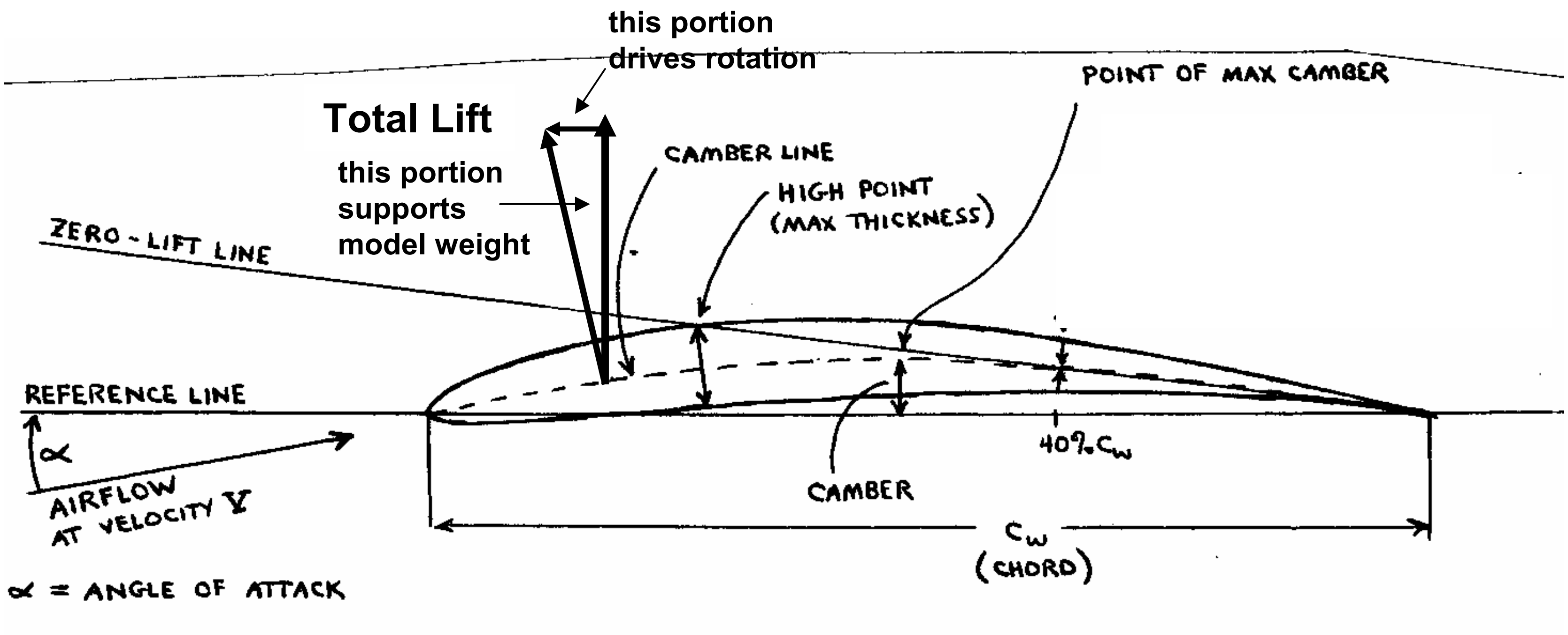


- Blade twist keeps each part of the blade flying at its best angle of attack relative to the blade's net velocity V_R at that local point along its span
- The best local angle of attack is the one that minimizes $C_L^{1.5}$ / C_D, typically ~5-8^o
- Twists of 30 degrees between hub (most pitch) and tip (least) are typical

- Lift increases with the square of the distance r along the blade until the tip area, where it goes to zero



Blade Lift



Direction of blade rotation

Blade Lift = $0.5\ p\ V^2\ C_L\ S$

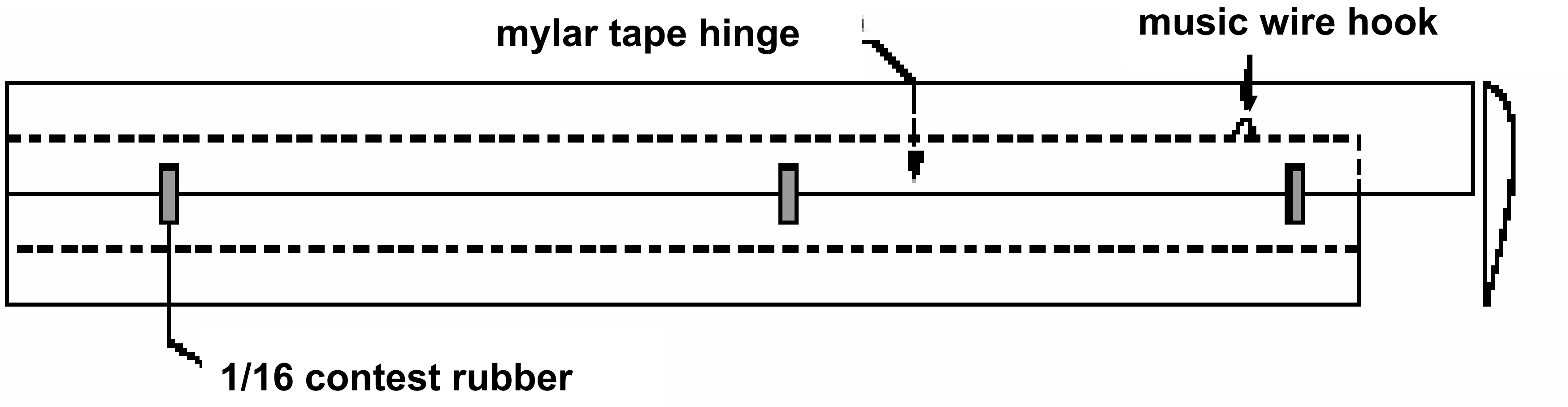
Increases with the square of distance outward from the hub

- At the low Reynolds Numbers of modroc helo flight, blades produce lift by angle of attack, not airfoil – keep them very thin (~1% is ideal) with a few % of camber
- At the blade tip, pitch angle relative to blade plane of rotation should be zero to slightly positive

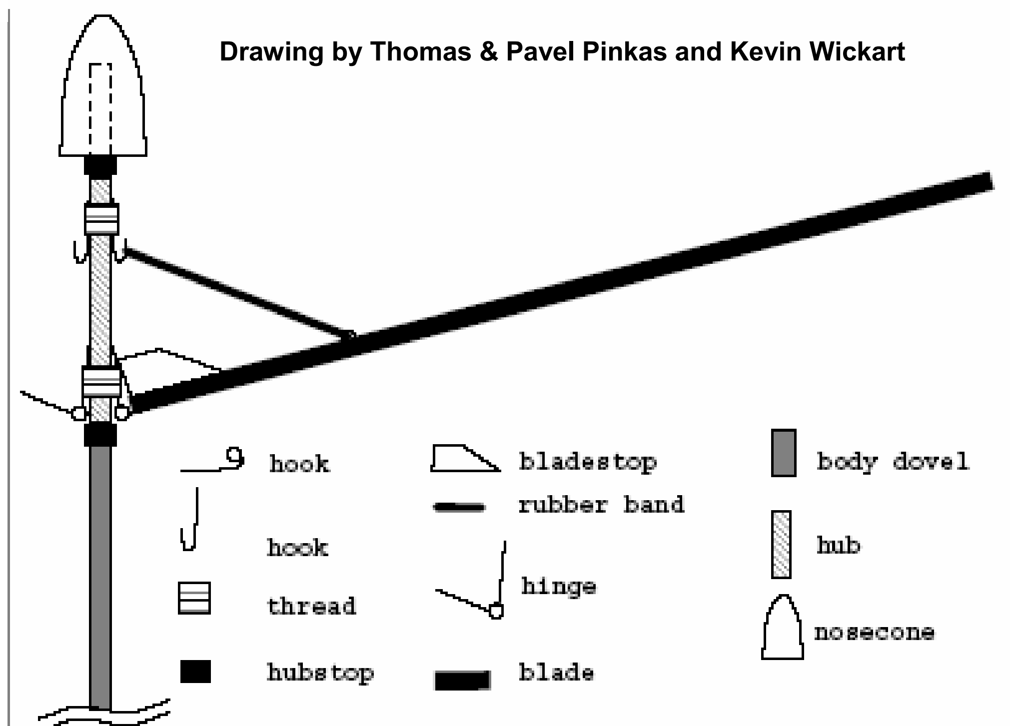
Blade Rotation

- Rotation rate should be as fast as possible to create maximum blade lift
- Impediments to fast rotation include:
  - Blade drag: keep them thin and smooth
  - Body/fin drag: only seen if the blades' rotation makes the body rotate – use a free-spinning hub to avoid
  - Rotational moment of inertia: longer, thicker, and/or heavier-material blades spin up to speed slower
  - Stability: use 15º dihedral angle in mounting the blades to the body or hub, and keep overall model's descent center of gravity low
  - Stalling: result of excessive blade pitch angle

Construction Details



- Dihedral angle can be set either by blade stops on top of the blade, or by “limit lines” underneath the blade
- Rubber bands that open the blades must exert significant force to ensure opening off-apogee
- Hinges are Du-Bro nylon model airplane types



Summary

- Keep the model light and minimize both boost drag and rotation drag/friction
- Get the blade pitch angles right – a twist with more at the root and zero at the tip
- Make the blades long and thin, and put dihedral in them
- Use strong elastic to open the blades
- Internal blades are harder to make but can beat external blades in A - C power classes