

Model Rocket Helicopter (Gyrocopter) Duration

Trip Barber

NAR 4322

Competition Rules

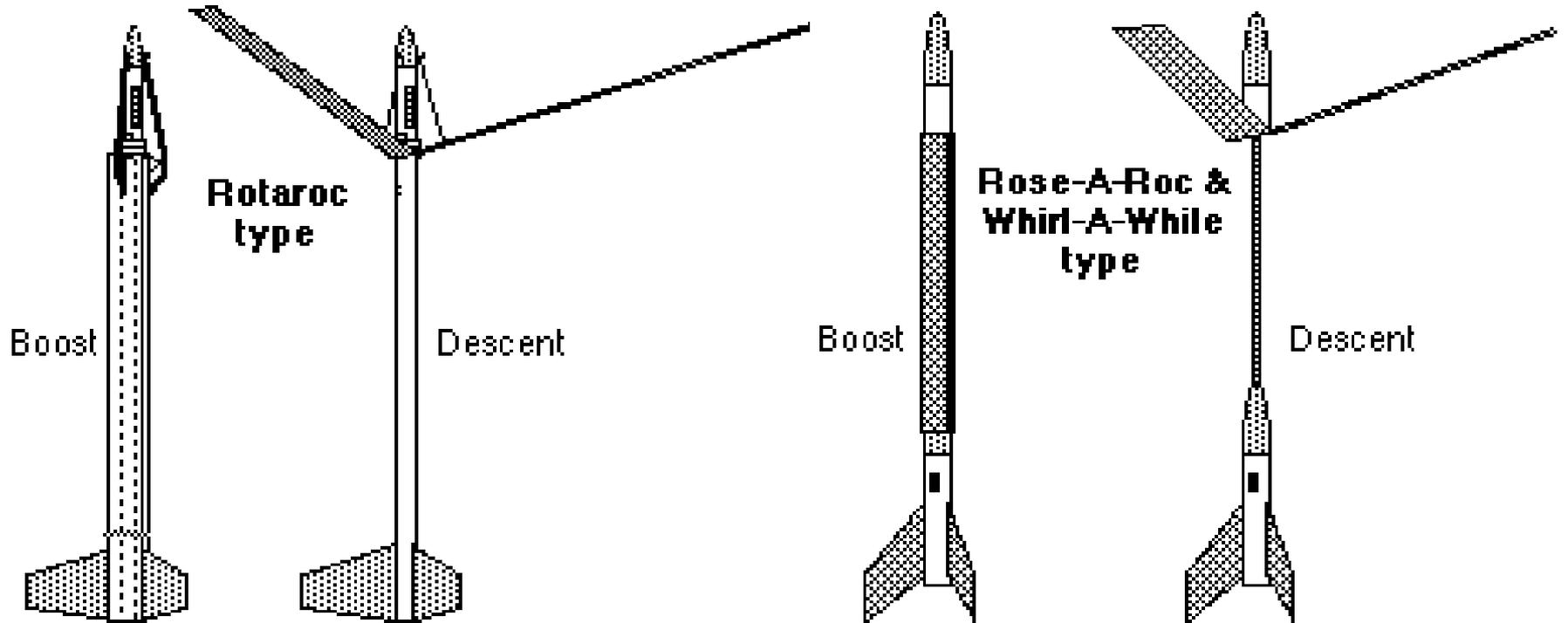
NAR and FAI

- 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
 - Lengthwise-folding blades a structural challenge for heavy models

External Blade NAR Designs

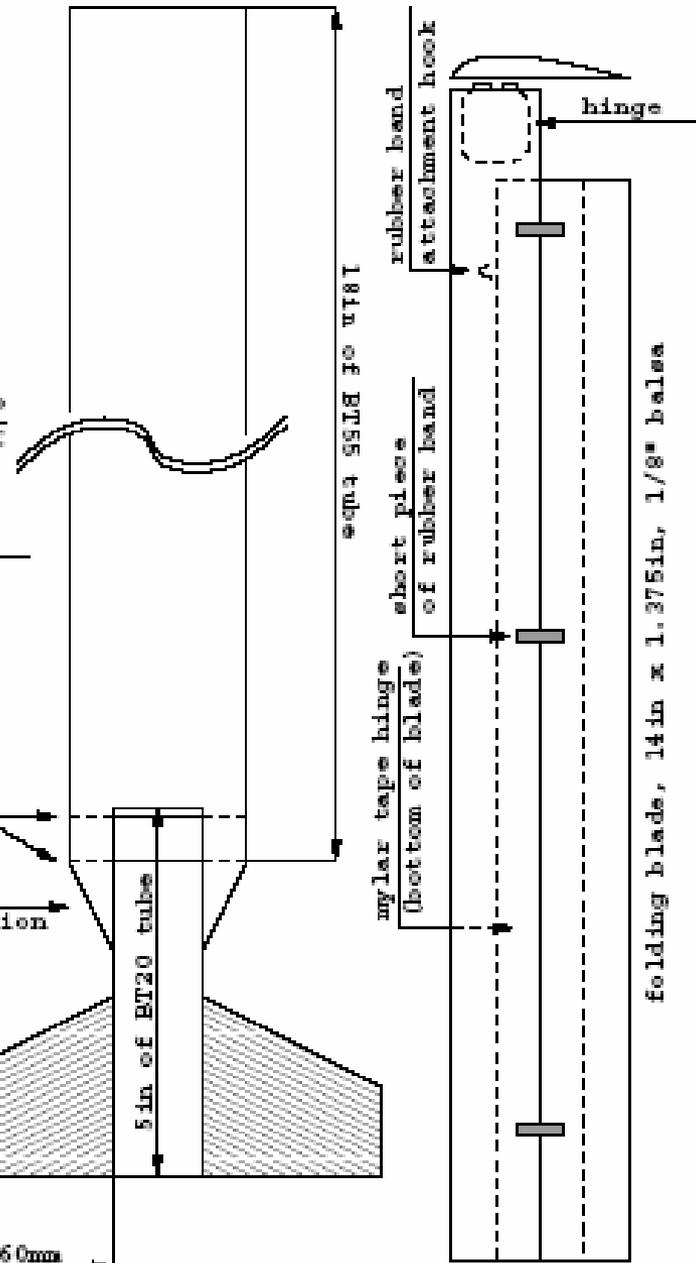
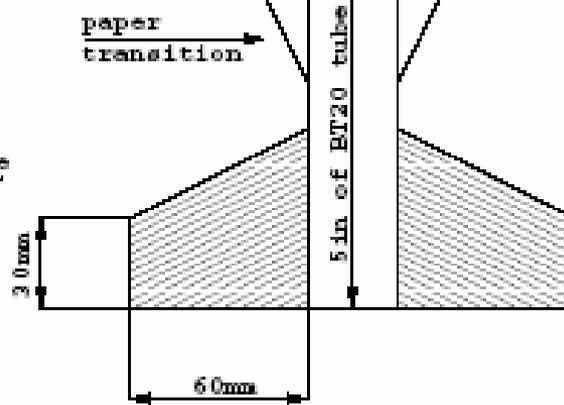
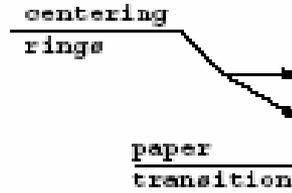
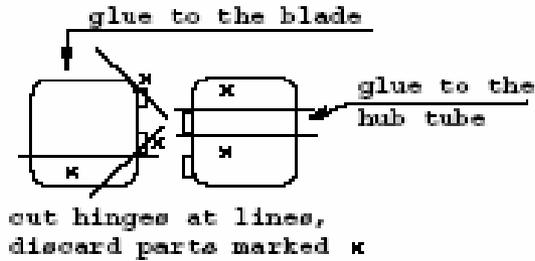
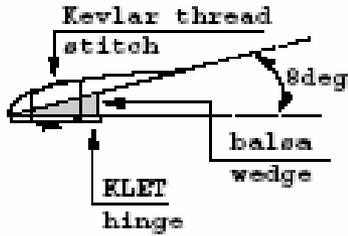
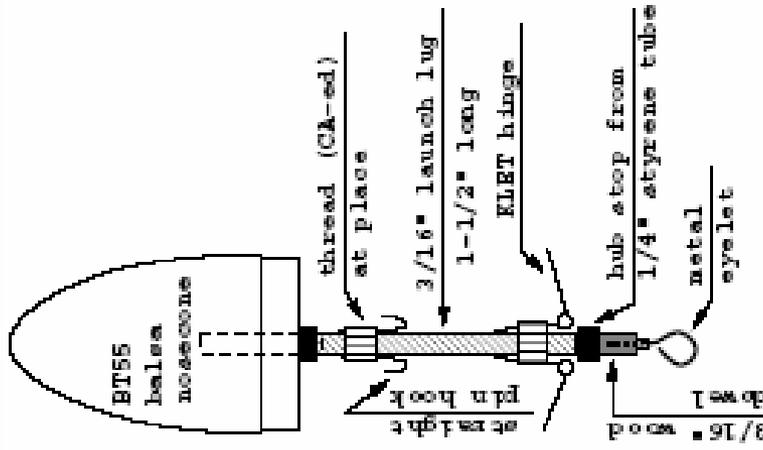


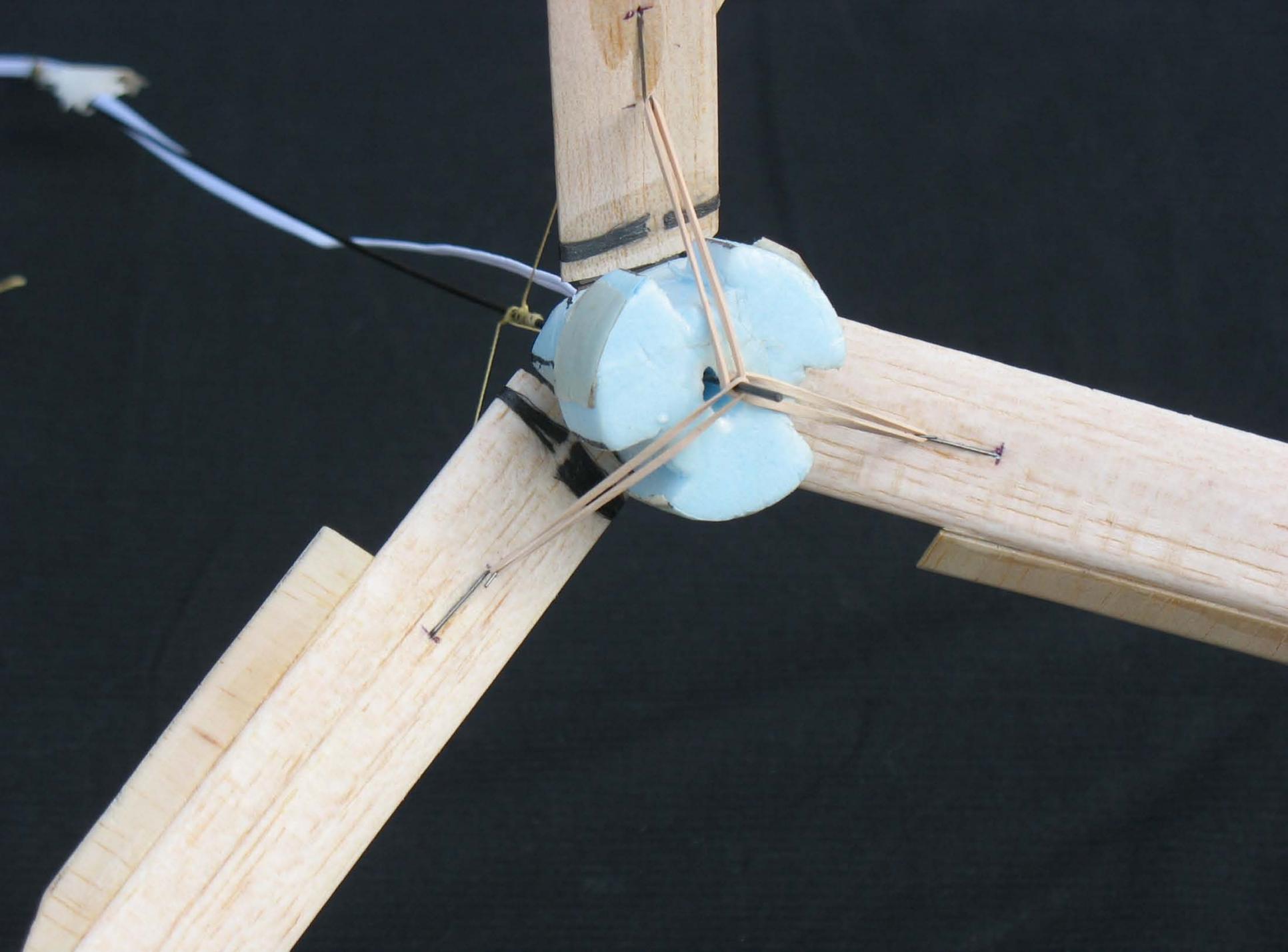
**Good NAR external blade competition kits on the market:
Apogee Heli-Roc and QCR High Rotor series**

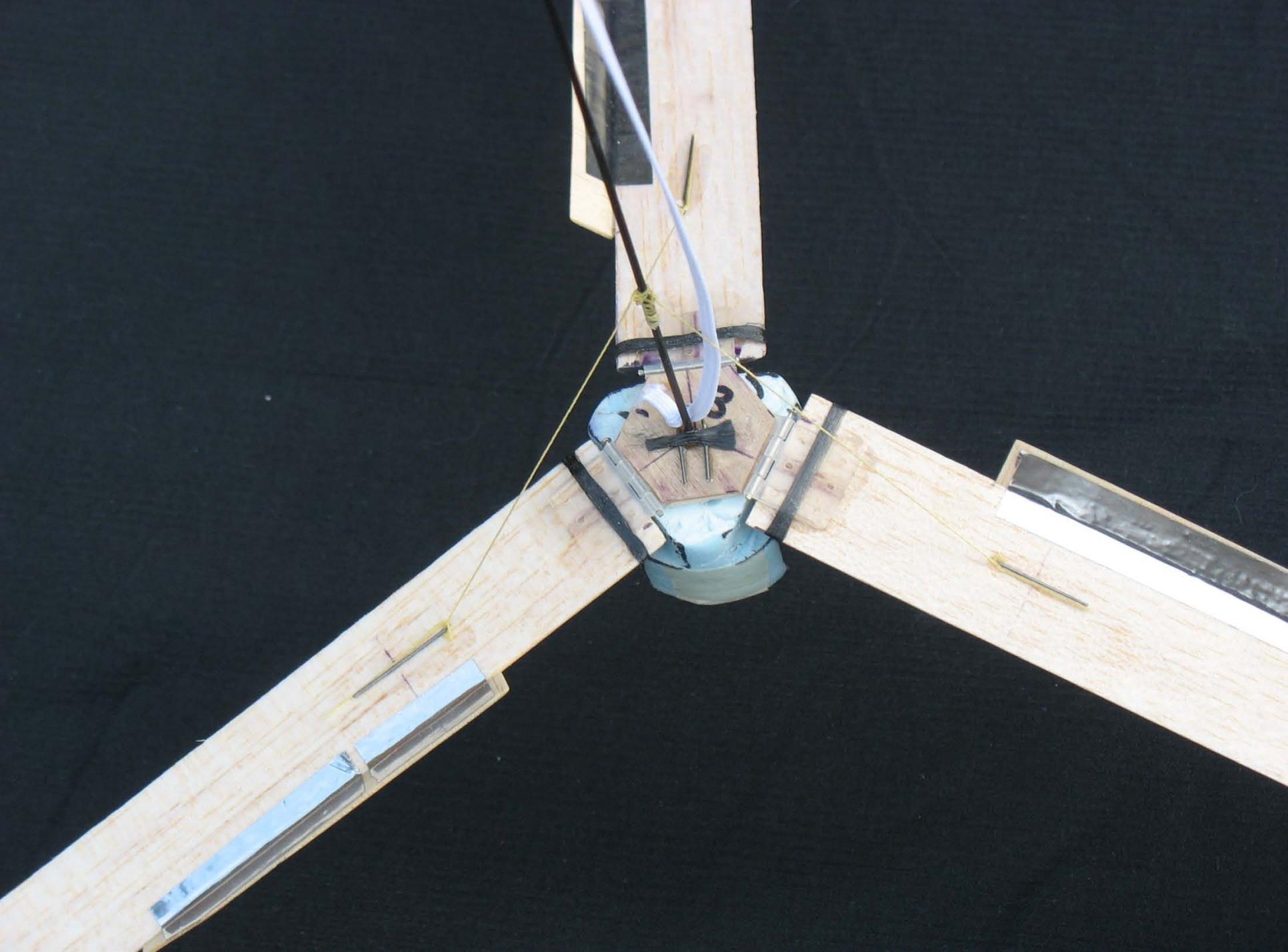
The Midwest WeedWhacker

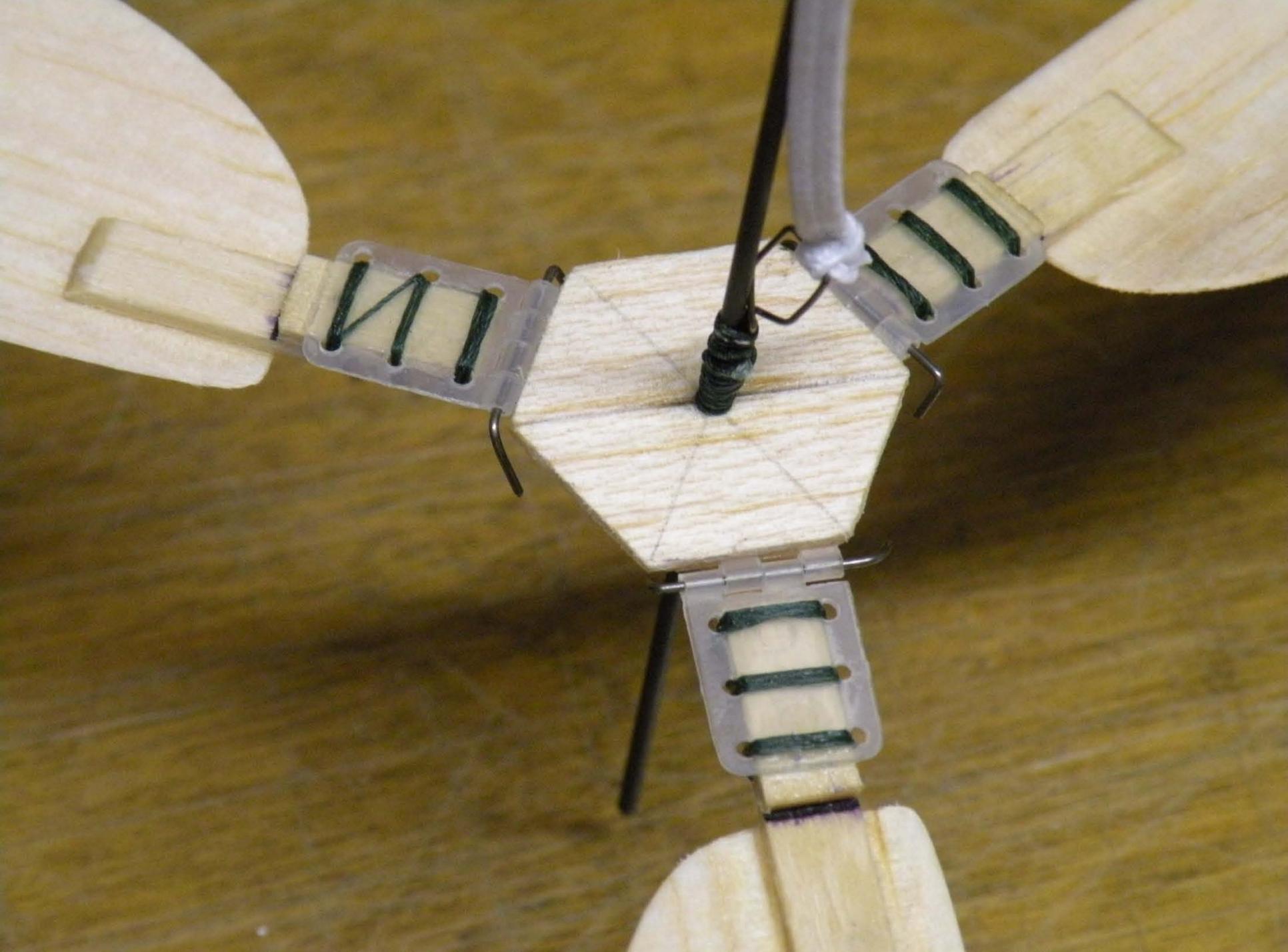
C Internal Rotor Helicopter

Drawing by Thomas & Pavel Pinkas and Kevin Wickart



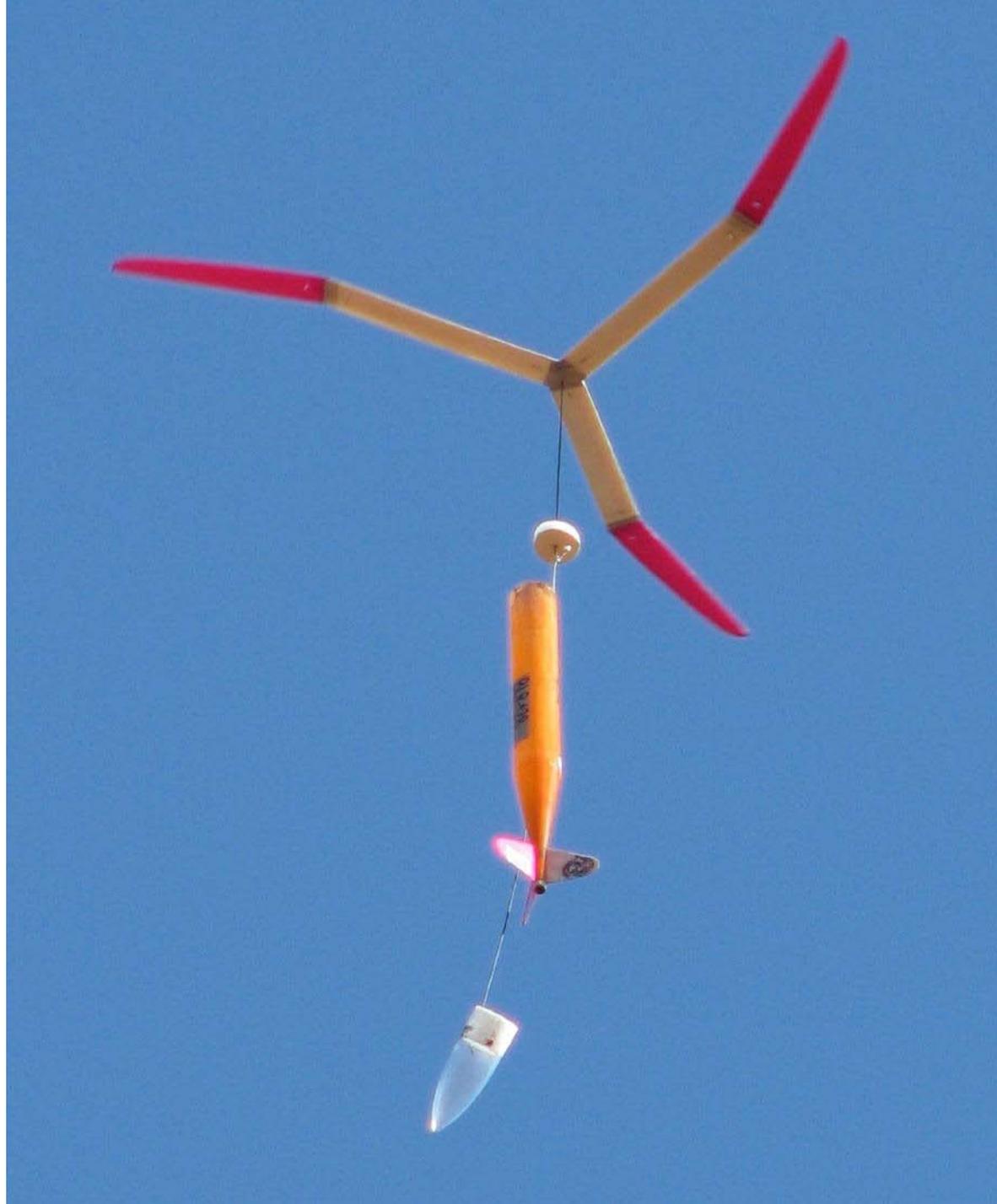








Space Modelling World Championships
GBR
2008
Mike Francis



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

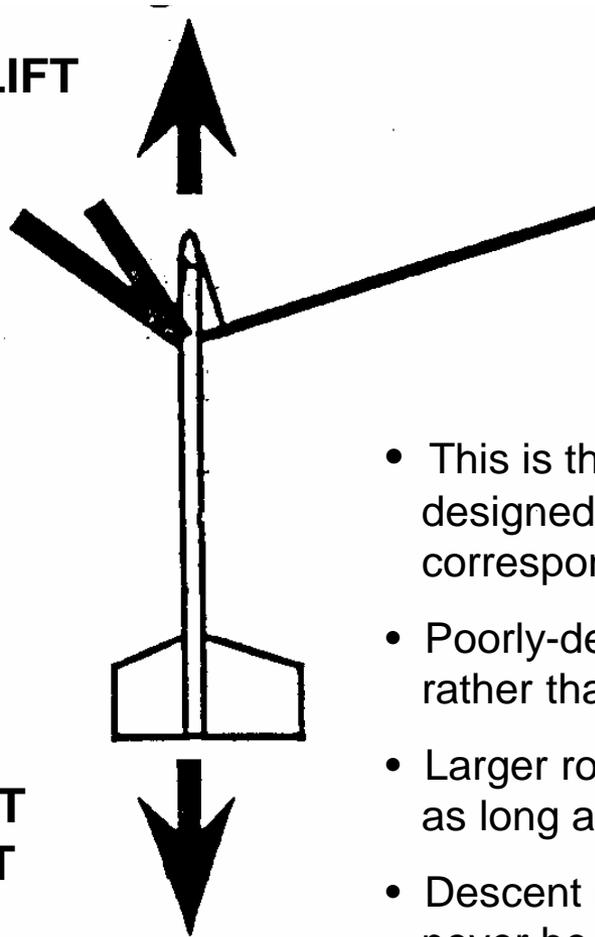
Descent Rate

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

W = rocket mass (kg) : minimize

S = rotor disc area (m²) : maximize

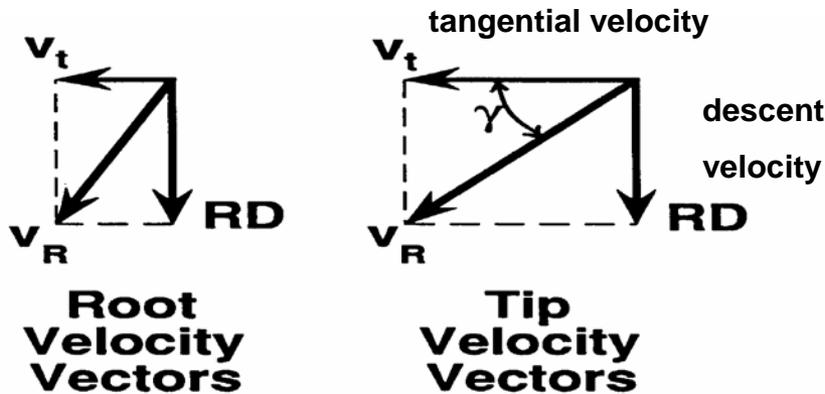
ROTOR LIFT



ROCKET
WEIGHT

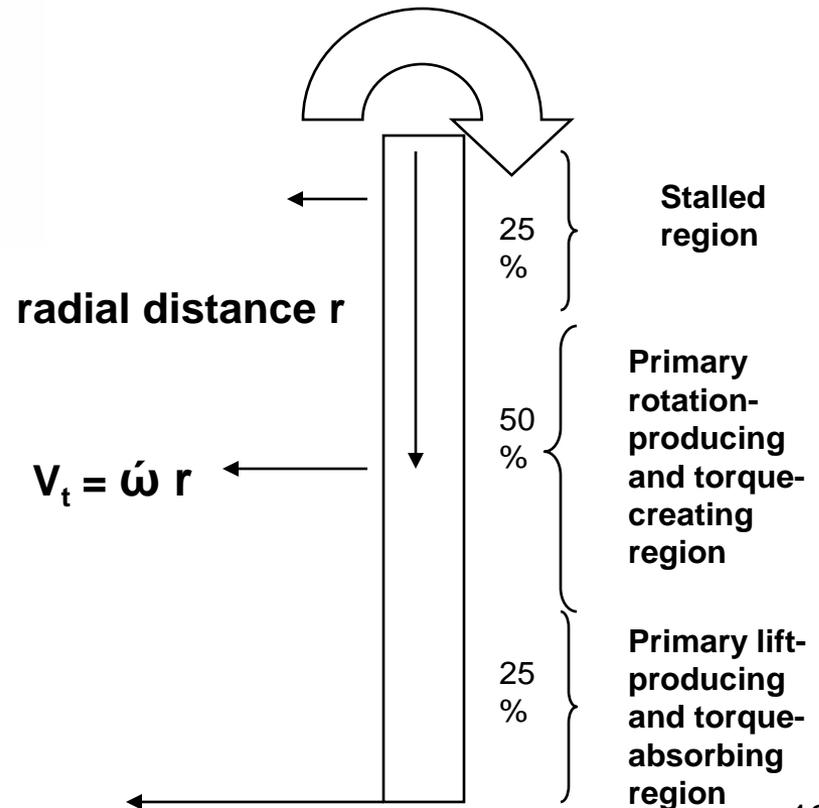
- This is the lowest possible descent rate for a well-designed rotor stably spinning at high speed; it corresponds to ~85% of the C_D of a spherical parachute
- Poorly-designed rotors behave as 3 individual blades rather than a disc and cannot match this descent rate
- Larger rotor disc areas (blade 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



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

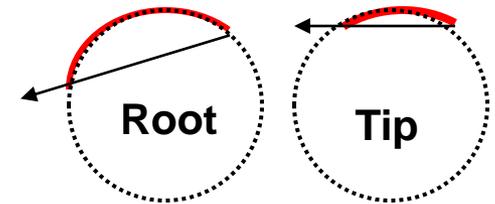
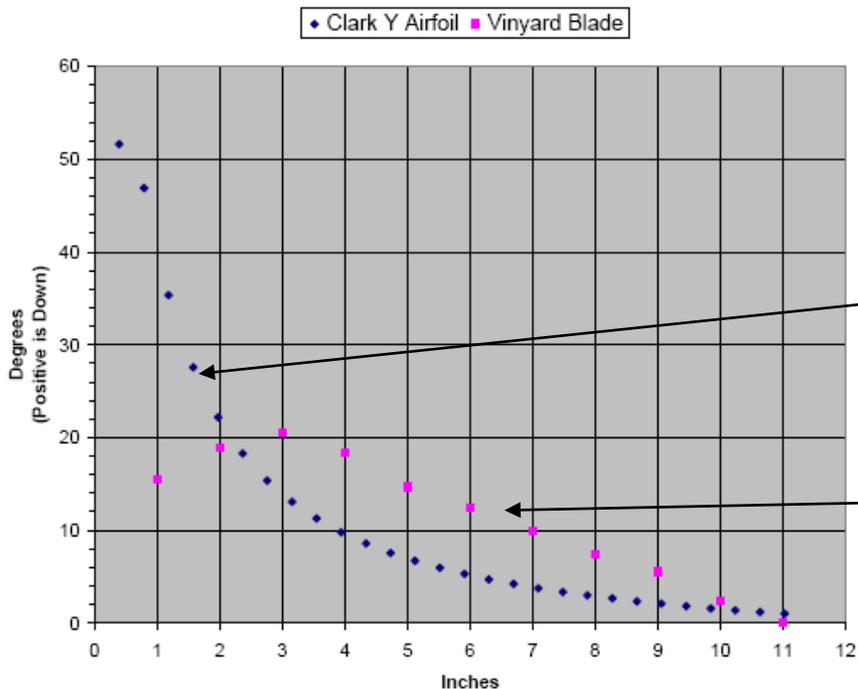
blade rotation rate $\dot{\omega}$



- 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 $\sim 5-8^\circ$
- Twists of 30 degrees between hub (most pitch) and tip (least) are typical

Building a Twisted Blade

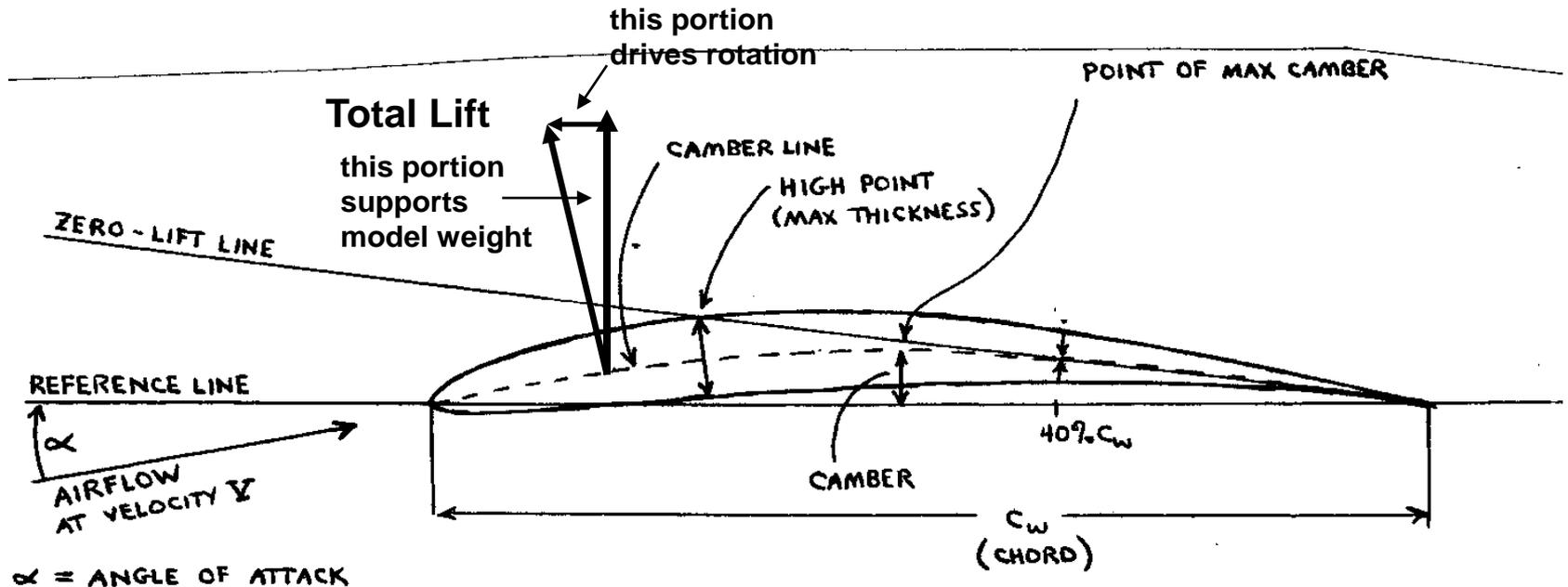
- 3 non-folding balsa blades with curved airfoil generated by forming chord around 40mm diameter cylindrical mandrel
- Change in blade pitch vs span along the blade is created by change in blade chord with span
- Semi-circular airfoil produces lift over a very wide range of angle of attack (+ or - 20 degrees) so it spins up quickly and handles both calm and wind



Clark-Y airfoil produces lift over limited range of “negative” angle of attack, so the twist angle must carefully follow effective air stream direction

Curved plate produces lift from -20 to +20 degree angle of attack, so optimization of twist angle with respect to air stream is not as critical

Blade Lift



α = ANGLE OF ATTACK

←
Direction of blade rotation

$$\text{Blade Lift} = 0.5 \rho V^2 C_L S$$

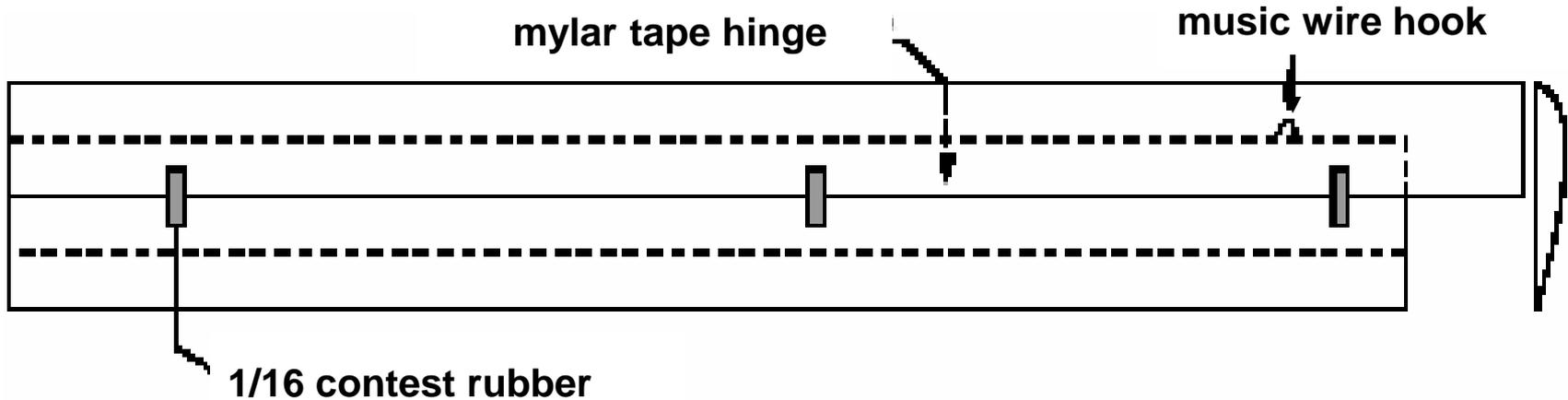
Increases with the square of distance outward from the hub

- 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

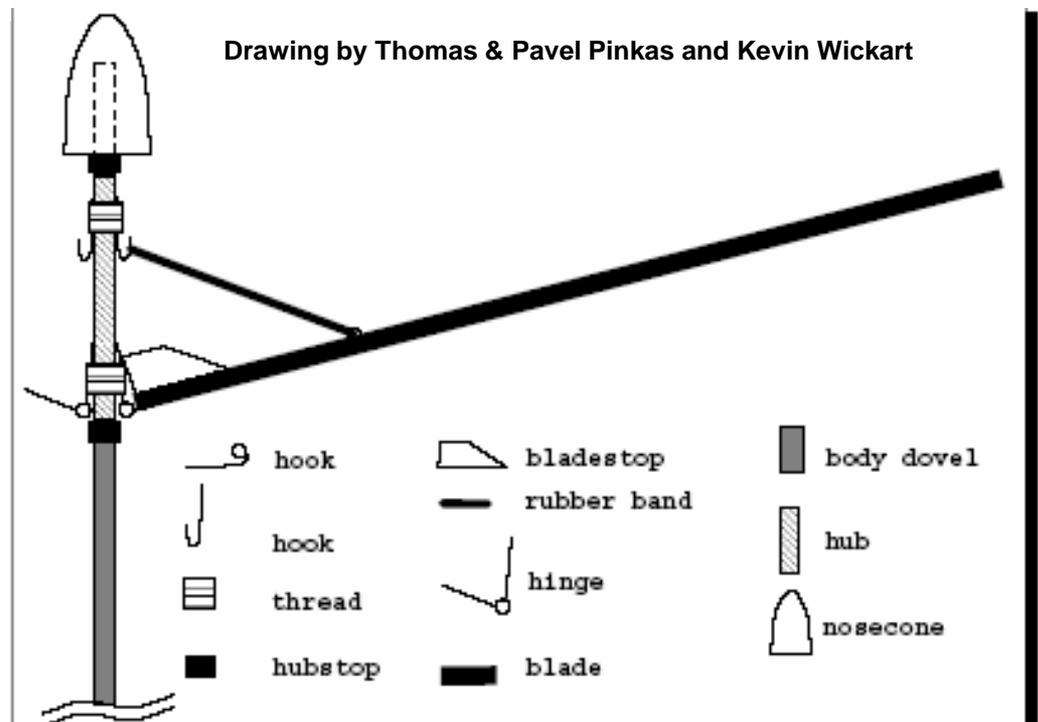
Blade Rotation

- 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 15° 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 or above power classes