The Effect of Twisting Helicopter Blades at an Angle On Duration

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2015 R&D - NARAM 57

NAR 88840

B-Division

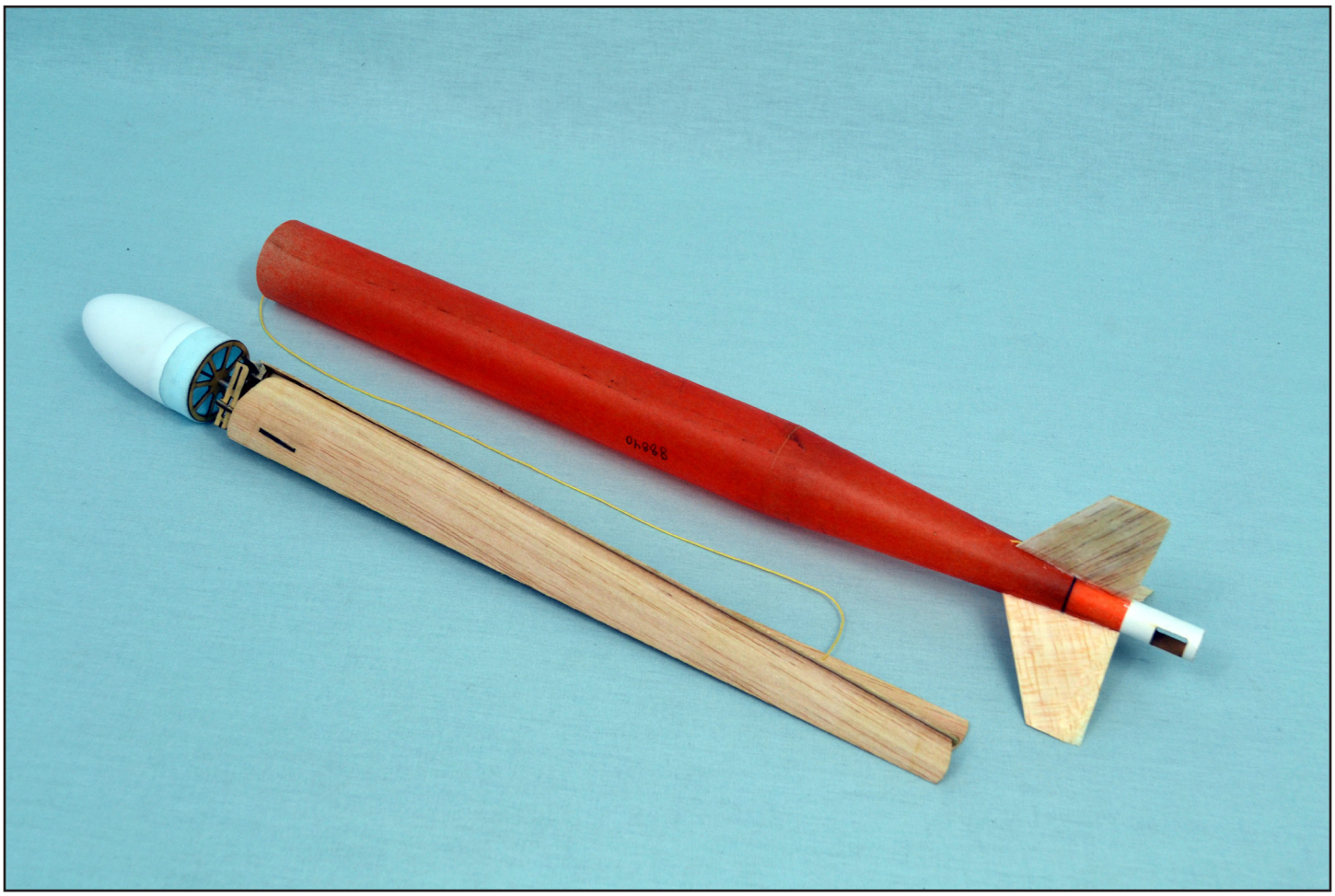
Summary

My R&D this year was a continuation of last year: To make the most effective helicopter blade possible. This year I tested if twisting the helicopter blade increases the descent time. I decided that I was going to test 3 different blade shapes and test both a twisted and non twisted version of each. I was going to test a rectangular blade to have a baseline, this blade did NOT fit in a 40mm FAI body tube, a tapered blade which is the same as the rectangular except the ends are tapered to fit in a FAI body tube, and my optimum blade shape that I created last year.

I cut out each blade set on my dad's laser cutter and then sprayed them with an ammonia water mix to make the flexible. Then I taped the non twisted blades straight down a 4.5in PVC pipe. For the twisted blades my Dad and I figured out how to twist the blades 5° on the PVC pipe by angling it slightly on the pipe. I put these on too and let them dry. After they were dry I glued Skyloft over the slot holes.

To test the blades I did drop tests off a bridge with the help of my Dad. I would drop the blades from the top and he would retrieve them from the bottom. I tested all 6 sets 3 times each.

My results were that the only way a rectangular blade shape spins is without a twist. But the other two shapes spun better with a twist. My optimum blade still tested to be the best shape overall. For the FAI tryouts I will be using my optimum with a 5° twist.



The Objectives of the Work

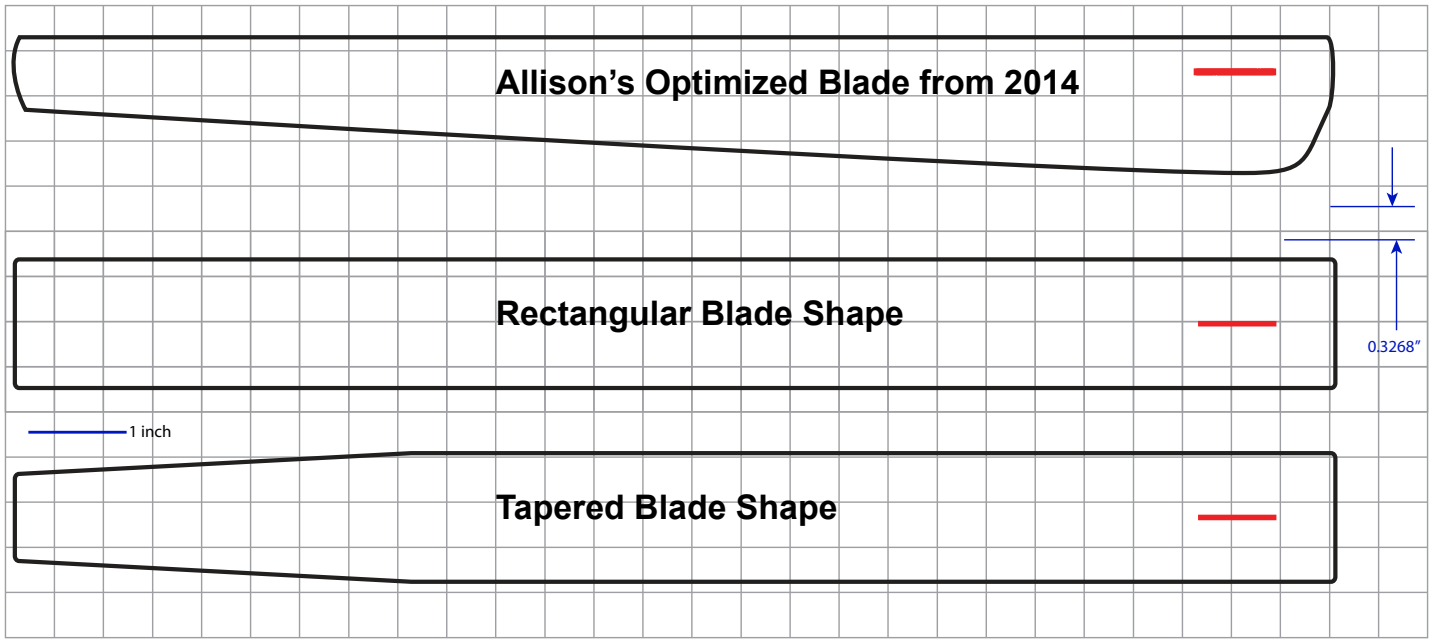
I am trying to create the most effective helicopter blades possible.
I will use data from my sisters R&D report and then conduct my experiment.
I will be evaluating blade twist to see if that increases the descent time.

The Approach Taken

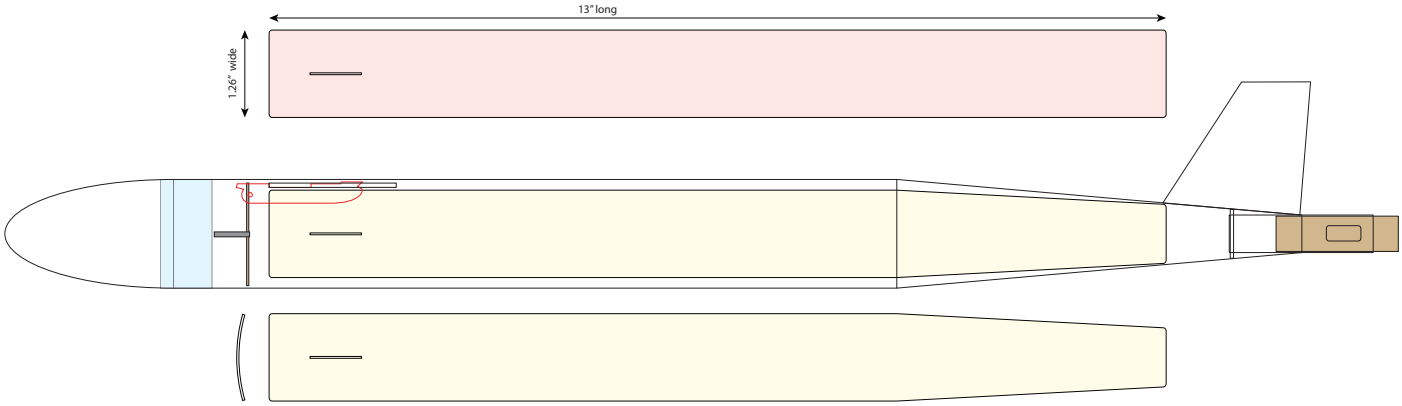
Step 1: I decided all the different helicopter blade shapes and angles I was going to test. Based on my sister Ashley's R&D project, I decided to test the best three blade shapes. I would test a twisted and non-twisted version of each shape.

The shapes I used were the optimum blade that created last year, a blade that was rectangular and finally a rectangular shape with a tapered end. I tested all three of these shapes twisted and not twist.

The different blade shapes used in this experiment



The rectangular blade was just a rectangle. I used this blade to create a baseline so that I would have something to compare the other blades to. The only problem with this blade is it does not fit into a 40mm FAI body tube.



Tapered shape chosen that would fit into a FAI style body tube.

I created a tapered blade because I wanted to have a rectangular blade that would fit in a FAI body tube. The only difference with this blade compared to the rectangular blade is it tapered on both the leading and trailing edge of the blade to fit inside the tube.

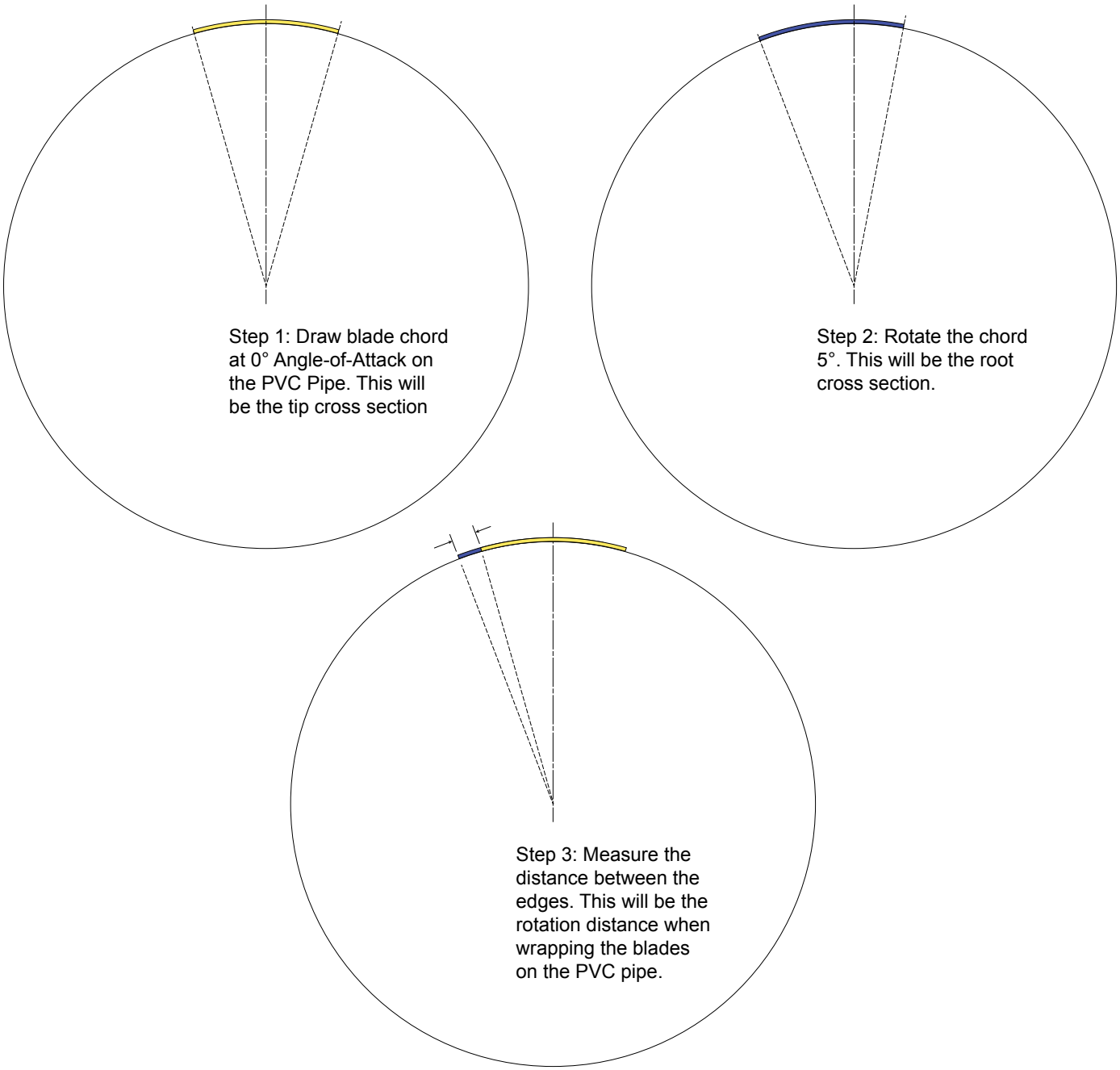
The blade that I created last year had a wider point at the root and then it got thinner more steadily as it went to the tip of the blade. This is the blade I found to be the most effective shape last year.

Step 2: I had to figure out how I was going to twist the blades.

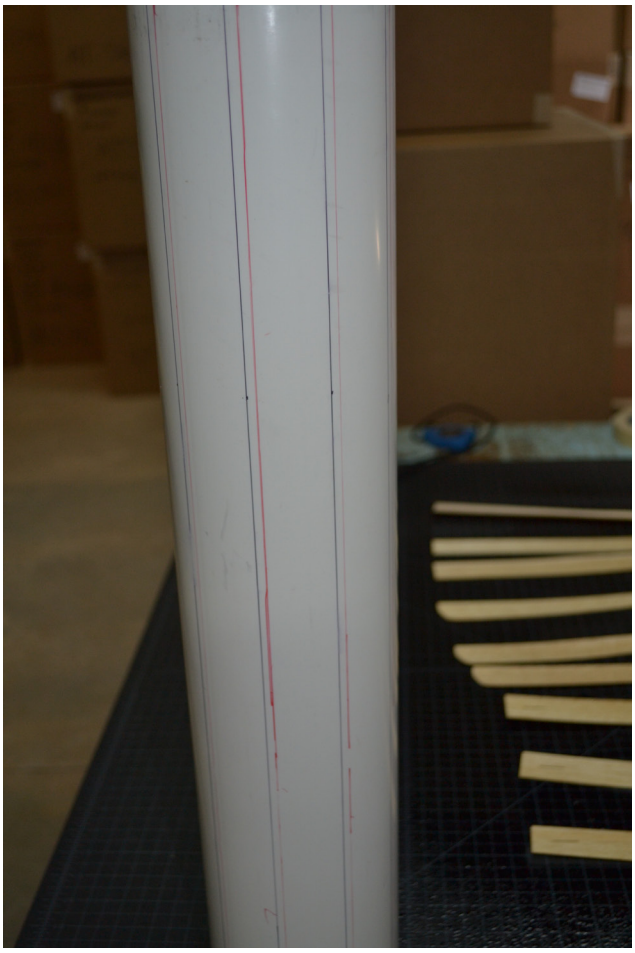
My sister Ashley Van Milligan tested all these blades for her R&D to find the best angle of attack. And I was going to use her results and find out if a twist made it better. She built them the same way as I, and I tested them the same way she did.

I was going to make the blades twist at 5 degrees starting from the root of the blade and then curving out. The objective was to make the tip at 0° angle of attack and the root at -5° angle of attack.

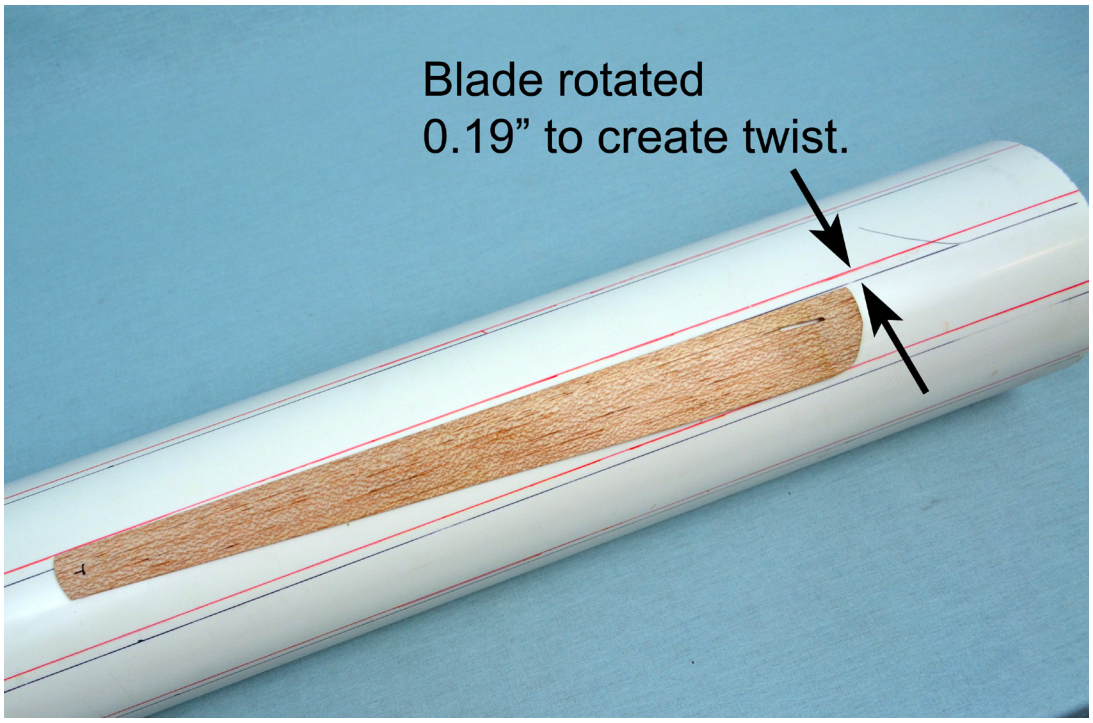
I started the process by drawing straight black lines down a 4 inch PVC pipe that actually has an outside diameter of 4.5 inches. Then my Dad and I did the math to figure out how much 5° measured.



We found out that each blade needed to be rotated 0.19 inches from the trailing edge. Along side of each black line on the PVC pipe. I drew a straight red line to the left of each blade .19 inches away.



To create the curvature and twist each blade I had to wrap them around the PVC pipe at the angle of .19 inches.



Because the wood is brittle, I sprayed each blade with an ammonia water mix to make the wood flexible.

Spraying the wood with ammonia and water mix.

Then I taped the root trailing edge corner of the blade on the red line and the tip trailing edge corner along on the black line. I did this for the 3 shapes that were twisted. I also had 3 sets of the same shapes that were untwisted. For the untwisted blades, they were oriented so the trailing edge was along the black line.

After all the blades were taped on the PVC pipe I wrapped an old sheet around them so it would hold the blades to the curvature of the tube while they were drying.

Wrapped tightly with cloth, and allowed to dry.

I set the blades out in the sun for about 4 hours to dry.

Step 3: Reinforcing the blade attachment slots

Once the blades were curved I had to put a mesh-like material (called skyloft) over the slot hole on the blade. I needed to do this because this prevents the slot hole from tearing and I needed to create these blades like I would for my actual rockets.

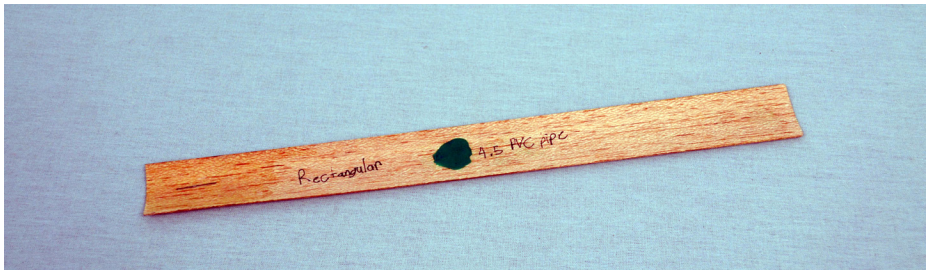
To put the Skyloft mesh on, I cut pieces about 1 inch wide and 2 inches long. They weren't always the exact same they just needed to be big enough to cover the slot holes. I then set the Skyloft over the hole and then put thin super glue over all of it.

Once it was dry if any mesh went over the edge of the blade I cut it off with a hobby knife and I cut out the piece in the slot hole.

Step 4: Preparing the blades to drop

I needed all the blades to be the exact same when I dropped them.

In each different set of blades I weighed each of the three blades and found the one which had the greatest mass. Then I added enough clay to the other two blades of the set so that all three blades had the same mass. Then I found the balancing spot of the heaviest blade and used it to mark where the other blades needed to balance. I balanced these blades in the same spot by adjusting the spot the clay was placed on the blade. I repeated this step for each blade set.



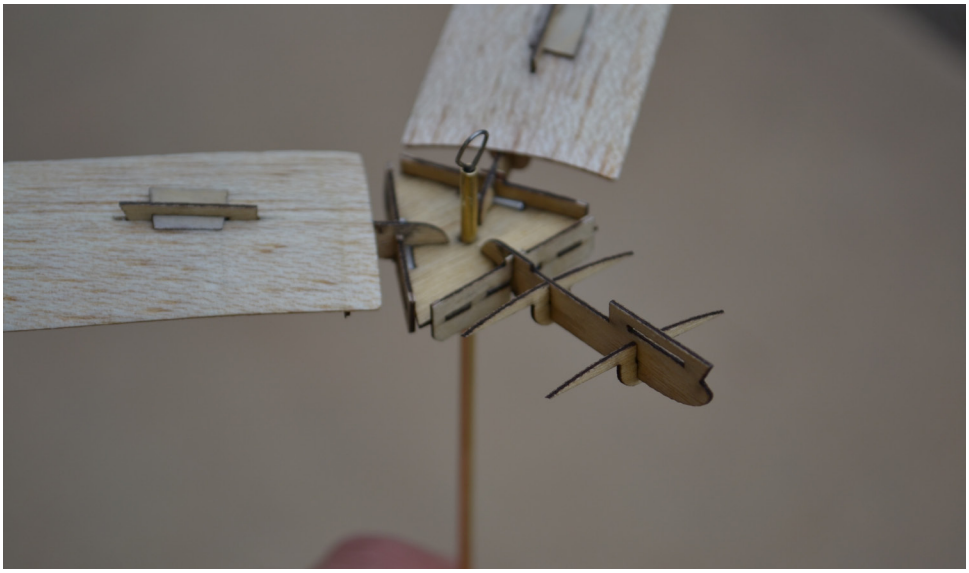
Each blade is balanced so both the weight and the CG position are the same for the entire 3-blade set.

Then I need all three of the blades and the drop test fixture to have a mass of 20g.

They need to be 20g because each blade set has to have the same mass and 20g is about how much a typical FAI helicopter weighs.

Once that was done I had to balance the hub with the blades. I did this by putting a string through the hub a pulling it straight. I spun the blade and marked the blade that landed on the bottom. I spun it again and if it was the same blade I moved some of the clay around to make that side lighter. I did this until it was perfectly balanced.

The drop fixture (right). After the blades are attached, clay is added or removed from the bucket so that it weighs 20 grams.



Close-up view of the hub used on the drop fixture.

Step 5: Drop tests

Now it was time to test the blades. My Dad and I went to this "historic" bridge that was 32 feet and 2 inches above the ground. We had to go at dusk since it was illegal to be on the bridge since it was under construction. I went to the top of the bridge and my Dad went down underneath it.

I counted down 3..2..1..Drop and then I dropped the blades while my Dad was timing it. Once the blade got to the bottom my Dad would pick it up while I threw a string with a paper clip on the end over the bridge. My Dad attached the blade set to it so I could pull the blades back up and drop them again. My Dad recorded the times for each test. I repeated this 3 times for each set of blades.

Once it was time to change blade sets I would duck down on the bridge so nobody could see me while my dad put the next blades on the hubs and added the extra weight if needed.

My Dad and I repeated this until all 6 blade sets had been tested.

List of Any R&D Reports Previously Entered By Me and References to Previous Work Done on Subject Used for Research

"The Effect of Blade Curvature and Angle-of-Attack on Helicopter Descent" NARAM-57 R&D report By: Ashley Van Milligan, 2015

"Finding the Best Gyrocopter Blade Shape and Best Place to Attach the Blade" NARAM-56 R&D report By: Allison Van Milligan, 2014

The Equipment Used

My Dad's Laptop
Laser Cutter
Building Supplies
Scale in Grams
Stopwatch

The Facilities Used

Apogee Components
Cottonwood Creek Bridge

The Money Spent On Project(Budget)

Most of the objects I needed to do this project my sister had already bought so I just reused hers.

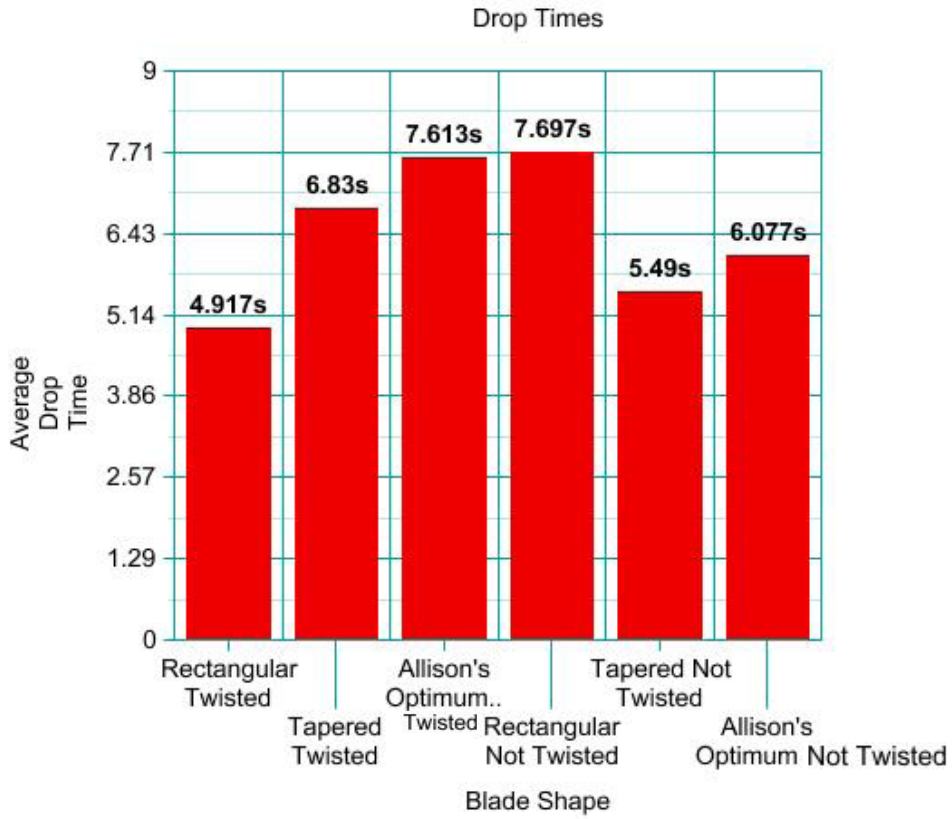
What	Where	Price	How Many	Total Cost
1/32in Balsa	National Balsa	$0.50	9	$4.50
Brass Tube		$3.00	1	$3.00
RoseArt Non Dry Clay	Amazon	$5.98	1	$5.98
		Total Cost		$13.48

The Data Collected

The chart below shows my data collected.

Blade Shape	Twisted Y or N	Drop Height	Drop Weight	Drop Time 1	Drop Time 2	Drop Time 3	Notes	Avg. Drop Time
Rectangular	Yes	32ft 2in	20g	3.47s	5.94s	5.34s	None to Slow Rotation	4.917s
Tapered	Yes	32ft 2in	20g	7.22s	5.13s	5.9s	Worked Okay	6.83s
Allison's Optimum	Yes	32ft 2in	20g	8.22s	8.25s	6.37s	Worked Good	7.613s
Rectangular	No	32ft 2in	20g	9.78s	5.12s	8.19s	First Test hit Bridge; Inconsistent	7.697s
Tapered	No	32ft 2in	20g	6.28s	4.25s	5.94s	First & Second Test Slow to Start Rotating; Third Hit Bridge	5.49s
Allison's Optimum	No	32ft 2in	20g	6.29s	5.56s	6.38s	Unbalanced	6.077s

The Graph Below Shows the Average Drop Times of Each Blade.



The Results Obtained

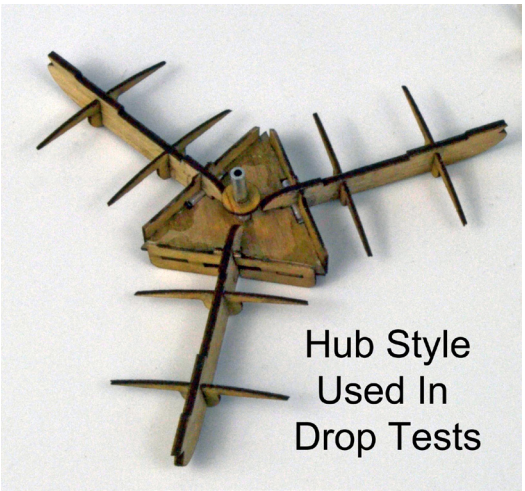
As my chart shows the order from best to worst:

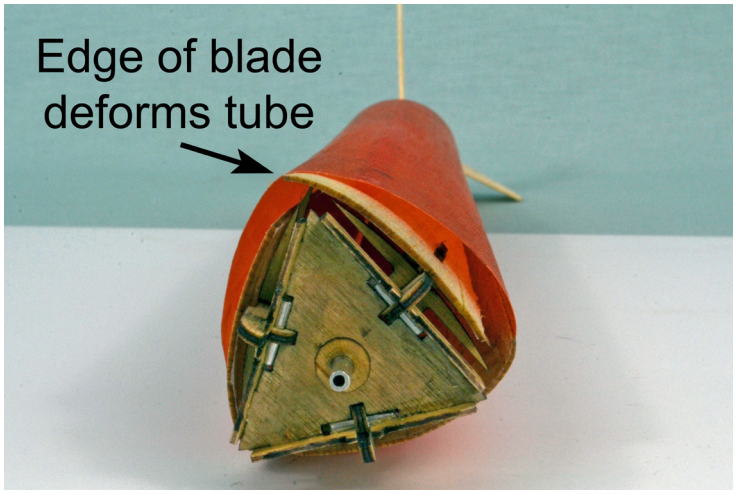
1. Rectangular Not Twisted
2. Allison's Optimum Twisted
3. Tapered Twisted
4. Allison's Optimum Not Twisted
5. Tapered Not Twisted
6. Rectangular Twisted

My data shows that the only way to have a rectangular blade work is to have it not twisted. I'm not a 100% sure this is accurate because my sister found it to perform poorly. Either way it doesn't affect me that much because I cannot use this blade anyway since it won't fit in the tube.

The optimum I created last year still showed to be the best blade shape overall. And it is even better when the blade is twisted.

I did discover when actually building the rockets that the new configuration of blades would not fit into the body tube.



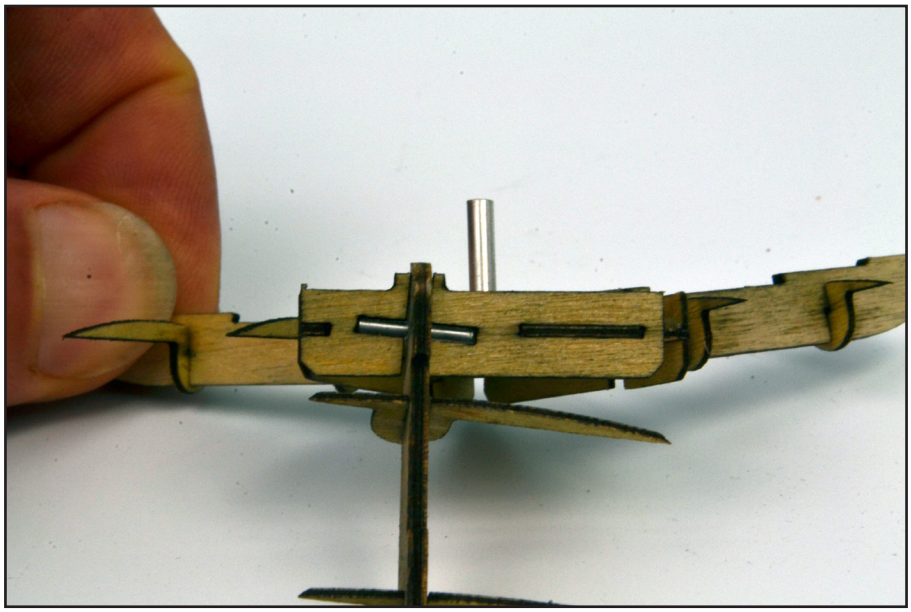


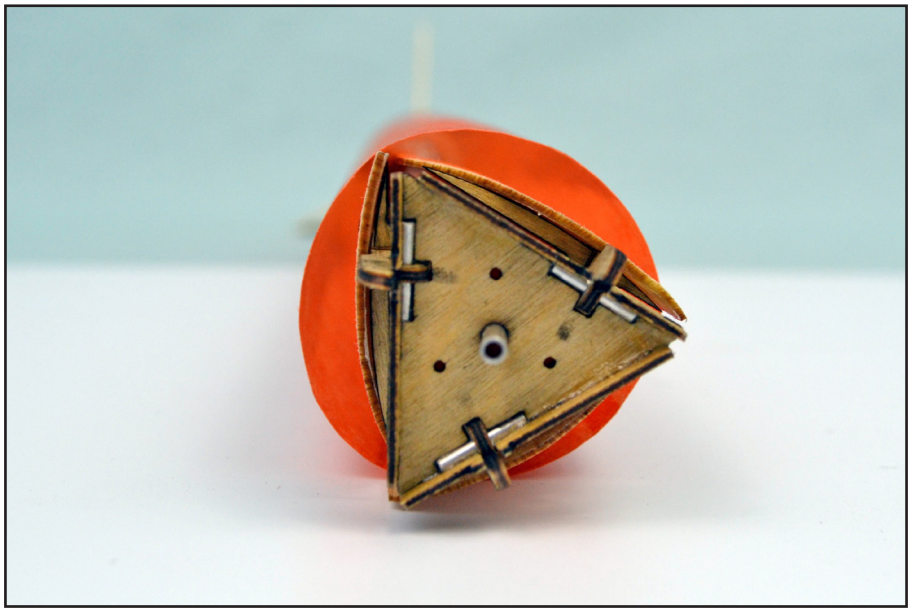
Since the blade is not centered on the mounting arm (it is attached at a point .3268" from the trailing edge), it would deform the tube. And then the nose cone would not fit on the rocket.

I tried to move the blade attachment point two the middle of the blade, like it was for the rectangular and the tapered blades. But when I did a drop test to see how well it spun, it didn't spin at all. It was just like the rectangular blade.

My dad came up with the solution to move the mounting arm on the hub so that it was off-center (see photo on the next page). This way the blade could be centered in the tube, and it would still be mounted at the correct angle.

Flight tests performed on July 19, showed that the blades and the new hub configuration performed well. The second flight thermaled away after 2 minutes on an A3-4T motor.





The Conclusions Drawn

My conclusions are that twisting helicopter blades increases the descent time unless it is a straight rectangular blade. The optimum blade that I created last year still has proven to be one of the best shapes.

For my FAI gyrocopter rockets I will twist my optimum shape. I will be testing out how well they work in competition on Saturday at the FAI tryouts.

Further Work that Would Clarify or Extend Results

If I had had more time and money I would've like to of done more drop tests, more actual flight tests, and tried testing different degrees of twisting the blades.