A Calculator Program Useful for the Design of North American Fighter Kites
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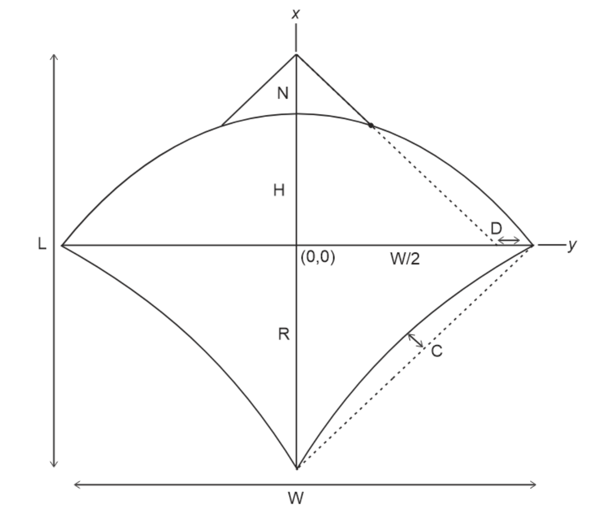
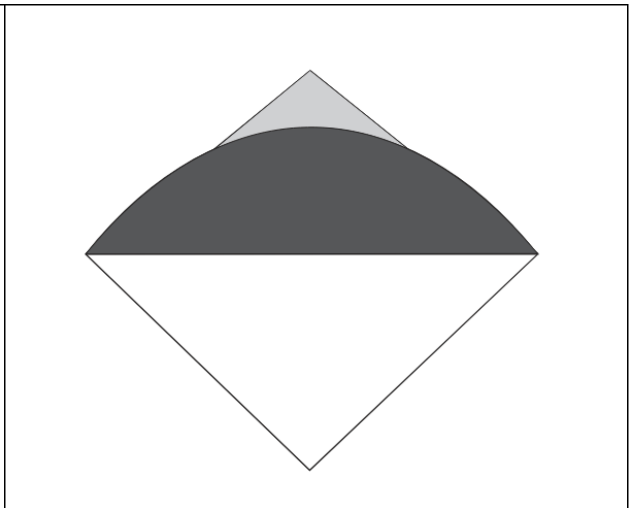
1. Fighter kite shape

The left figure below shows the measurements that define the shape of a basic North American fighter kite of length L and width W.

	
Geometry of a North American fighter kite sail.	Three parts of a fighter kite sail.

The length of the spine L=N+H+R, where N (Nose) is the part of the sail above the bow, H (Height of the bow) is the part between the bow and the line connecting the wingtips, and R (Rear) is the part below the wingtip line. The nose leading edge may project straight to the wingtip or to a point inside of it. The amount of "droop" of the nose leading edge can be measured with D, the distance along the wingtip line where the projection of the nose leading edge intercepts the wingtip line. The amount of a curved sidecut in the trailing edge can be measured with C.

Following Ed Alden's notation (https://fighterkites-na.com/wp-content/uploads/2021/08/1-vari-fighter-ed-alden.pdf), the following ratios describe the shape of the kite:

- The aspect ratio of the kite ***A***=*W/(N+H+R) = W/L* (Typical values are 1.10 < A < 1.30)
- The height (distance from the tail) of the wingtips ***W***=*R/L* (Typical values are 0.49 < W < 0.57)
- The height of the point where the bow crosses the spine ***B***=*(R+H)/L* (Typical values are 0.80< B < 0.90)

The area of sail is approximately ***S***=*LW/2*   (A typical 17"x19" kite has an S of 162 in^2 or 0.105 m^2.)

As illustrated in the right side of the figure above, the sail of fighter kite divides into three parts that correspond to the N, H, and R sections of the spine. Under wind pressure, the base of the nose section (light gray) is supported by the bow but the rest of it only by the spine, which can bend. As a result, the nose section will usually be less square to the wind than the rest of the sail. Partly because the bend in fighter kite spines is typically concentrated in the upper half of its length, the wingtip line (or something close to it) also separated parts of the sail that act differently. Relatively static wrinkles that form as the bow deforms under wind pressure tend to locate above the wingtip line (dark gray). The lower part of the sail (white) is supported only by the spine and becomes scooped with air spilling off the trailing edge. Most of the noisy sail rippling that occurs when the kite is pulled hard occurs tailward the wingtip line, both near the spine and along the trailing edge.

The points where the leading edges of the nose intersect the bow are often referred to as the "shoulders" of the kite. They divide the leading edge of the kite into a part that is secured to the bow (outside the shoulders) from the part that is not (inside the shoulders, the base of the nose). Many fighter kite builders have found that having more of the leading edge secured to bow makes a kite faster. On the other hand, a kite's ability to turn or spin predictably suffers if the nose is eliminated so that the entire leading edge is supported by the bow. Apparently, the presence of the nose section – either the small patch of sail there, the **V**-shape of the leading edge at the shoulders, or both – is essential to making a fighter kite controllable.

If the bow is a reasonably uniform carbon fiber rod, then the shape of a fighter kite bow is close to that of a parabola if the sail is not under wind pressure. This approximation works well for a typical North American style fighter where the height of the bow (H) is not much more than 1/3 the width of the kite. With increasing bend (including that which occurs when the sail is deformed by the wind), the shape becomes less parabolic. Bamboo bows, standard on almost all fighter kites other than the North American variety, typically taper toward the wingtips and so have a more complex curved shape.

2. Calculating bow length, shoulder position, and sail area

In order to learn more about how changes in aspects of fighter kite design affect each other, I wrote a program ("FK") for my indefatigable, 30+ year old HP42S calculator (or really, for the even better emulator of the HP42s that is freely available for phone or laptop- "Free 42"). It uses the equations you can find in the Appendix to calculate bow length, the position of the shoulders, the actual sail area, and a few other values. The program takes as input the following parameters:

A: Sail aspect ratio T: Wingtip height B: Bow crossing height S: Sail area (m^2) D: Leading edge droop (mm) C: Side cut depth (mm)	

The program calculates:

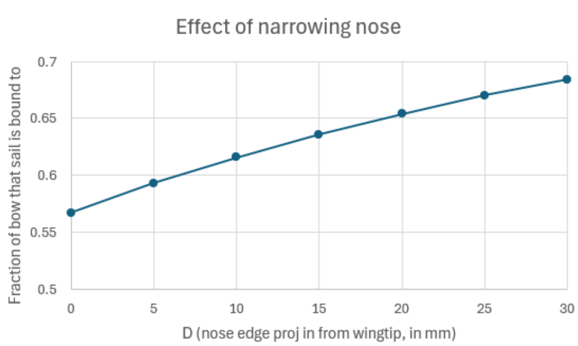
The length and width of the kite and the length of the bow (all in mm)	L W BOW: 441 512 607 x: 3.E-1
The length of the three parts of the spine (N, H, and R, in mm)	SPINE: 71 146 225 x: 3.E-1
The length and width of the kite and the length of the bow, but now in inches	LWB": 17.4 20.2 23.9 x: 23.9
The nose height and width and the % of the sail's leading edge that is bound to the bow	NH NW BB% 94 205 65 x: 65
The ratio (True Sail Area)/S, and the % of sail area that is above the bow (i.e., the nose)	TS/S: 0.979 TN% 5.8 x: 5.8

The "True Sail Area" involves calculating the shape of the nose (whose base is part of a parabola), the rest of sail below the leading edge (whose top is a parabola) and the area missing because of the side cut (which I have assumed is shaped like a circular segment).

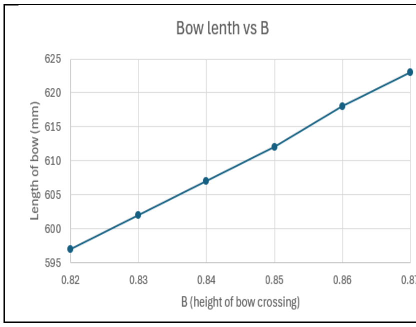
3. Using the calculator program

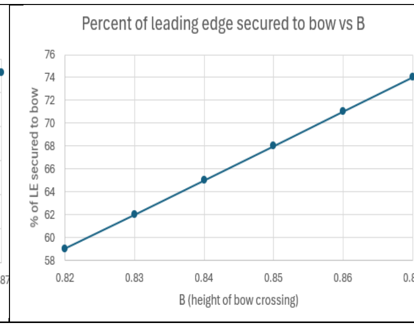
When using Free42 to help design a kite, I set A, T, and B to define the basic shape of the sail, and then adjust S to set the overall size of kite. Usually, I am trying to find a value of S that gives a bow of certain length (because I want to use a CF rod of that length) or a sail of a certain width (because I I am lazy and want the bow to fit in a pre-existing notch in my Bruce-Lambert-style bow setter).

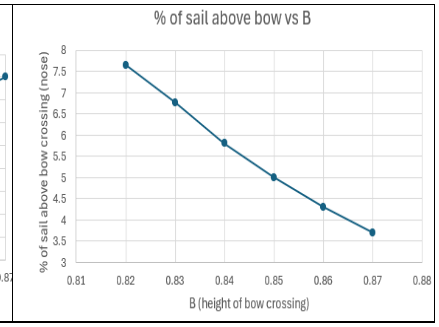
The other output from the calculator lets you see how changes in sail design parameters work. For example, how does narrowing the nose (i.e., increasing the value of D) affect a kite's leading edge? With a fairly standard (441 x 511, A=1.16 T=0.51 B=0.84) sail plan, I found that that increasing D from 0 to 30 mm increases the portion of the leading edge that bound to the bow by almost 20% (from 57% to 68%). The increase is not quite linear, so you get a bigger increase in bound leading edge at low values of D than at higher ones.



Adjusting the bow crossing height has a big effect. Lowering the crossing point from 87% of the spine length to 82% of the spine length (all else remaining constant) will shorten the bow by over 4%, decrease the fraction of sail secured to the bow by 20%, and more than double the fraction of sail area above the bow (i.e., the relative size of the nose).





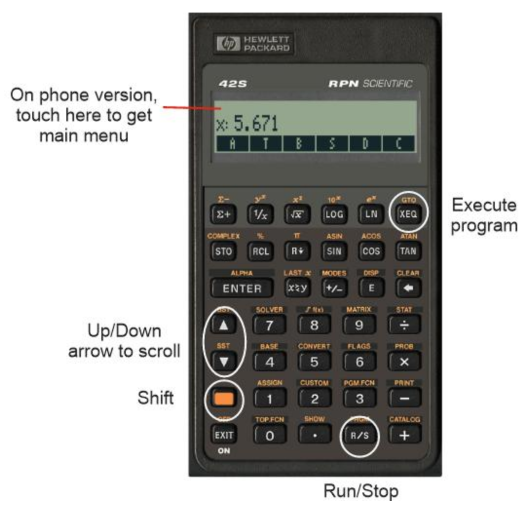


Finally, I was surprised how closely the sail area is approximated with S=LW/2. With D=0 (no droop) and C=0 (straight trailing edge), the true sail area is just 1.5% greater than S. With a much smaller and narrower nose (D=30), the approximation is even better: within 0.4%. On the other hand, adding just a little side cut to the trailing edge reduces sail area considerably. With D=20, a 5 mm sidecut reduces the true sail area to 98.7% of S; with a 15 mm sidecut the true sail area is 94.7% of S. So, if you are tweaking a sail design to reduce sail area, a little sidecut goes a long way compared to narrowing the nose.

3. Using FK with the Free42 emulator

1. Get and install the Free42 emulator for your phone or laptop. I have an Android phone and found Free42 at the Google Play store. For the laptop version, go to https://thomasokken.com/free42/ Two versions will download -either one works just fine. I have the “decimal” running on my Windows laptop. Then, use this link https://tinyurl.com/yc5t8snx to grab the calculator program “FK.raw” from Google Drive.

2. Fire up Free42 and, on the phone version, touch in the upper left corner of the simulated LCD screen to bring up the Main Menu. On the laptop version, the menus are at the top of the frame.

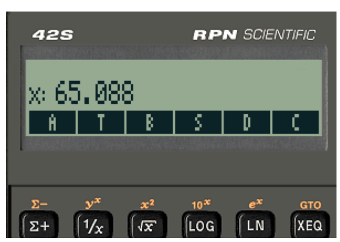


3. Look for “Program Import & Export” and then “Import programs”. Select FK.raw from where you saved it. After you do that and hit the “XEQ” key (upper right) on the simulated keyboard, you should see something like this:

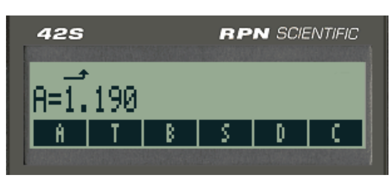
The two black triangles in the upper left of the lcd display are a cue that you can scroll to see more options. To do that, use the up/down arrow keys (middle left on the keyboard). If you hit the down arrow, you will see something like this:

The labels in the black rectangles are names of the programs and subroutines that you imported into the Free42. Scroll back up so that “GO” is showing. On a touchscreen, you can touch the rectangle with “GO” in it OR the button(1/x) directly below it. On a laptop without a touchscreen, use the mouse pointer to hit “GO”.

4. After hitting GO, the screen you see will look like this, but with a different number showing after “x:”



A, T, B etc. are the values that Free42 will use in its calculations. To set A (sail aspect ratio, width/length) to 1.19, type the number in and then hit the box with A in it or the key right below it. That sets A=1.19. To see if it worked, first hit the orange shift button (lower left of the keyboard) then the box with A or key below it. The current value of A will be displayed for a few seconds:

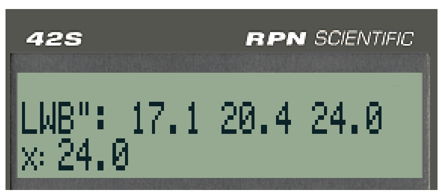


Load in values for T, B, S, D and C in a similar fashion.

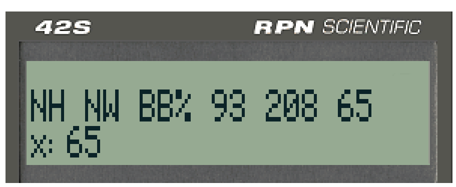
Once all the input parameters are loaded in, hit the R/S key (“Run/Stop” - lower right part of the keyboard) to see the L, W and bow length (in mm). Ignore the number after “x:”

Hitting the R/S key again shows you the lengths of the N, H, and R parts of the spine. They should total to L (though may miss by 1 because the output values are rounded) :

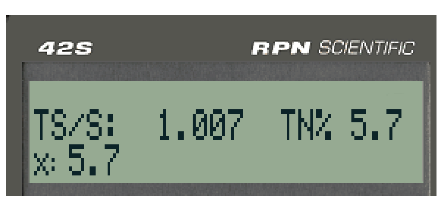
Hit R/S again to see the L, W, and bow measurements in inches:



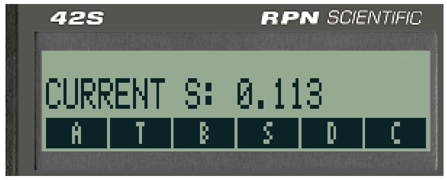
Hit R/S again to see the height and width of the kite nose (NH and NW), and the percentage of the bow that it is outside the shoulders and secured to the sail (BB%):



Hit R/S again to see how the true area of the sail compares to the estimate S (TS/S), and the percentage of the sail that lies above the bow (TN, the true area of the nose)



Hitting R/S again takes you back to the first screen where you set the input parameters. It helpfully shows you the current value of S in case you are tweaking it to get a fighter kite size that is just exactly perfect:



After adjusting any of the input values, just keep hitting R/S to see the new results.

If you are tired of running the program, hit the Exit key (lower left) to get the emulator back into its default calculator mode.

Appendix: Calculation details

With 0,0 at point where wingtips cross the spine, the shape of a fighter kite bow made of uniform carbon fiber is close to a parabola of height H and width W:

$$y = -\frac{4H}{W^2}x^2 + H$$

(Note well! - A bow that tapers towards the ends, as is typical in bamboo bows, will have a shape that is quite different!)

A very good approximation for the length S of a parabolic fighter kite bow is

$$S = 0.5 * \sqrt{W^2 + 16H^2} + \frac{W^2}{8H} * \ln\left(\frac{4H + \sqrt{W^2 + 16H^2}}{W}\right)$$

The (right side) nose leading edge and its projection toward the wingtip is described mathematically by

$$y = \frac{-2(H+N)}{W'}x + (H+N)$$

where *W'=W* if the nose leading edge projects to the wingtip or *W'=(W-2D)* if projected to a point a distance D from the wingtip.

The point (x,y) that satisfies both the equation for the bow and the leading edge of the nose will be intersection point – the shoulder of the kite. Finding that point boils down to solving the following quadratic equation

$$\frac{4H^2}{W^2}x^2 + \frac{-2(H+N)}{W'}x + N = 0$$

and then plugging the value found for x back into the previous equation to get y.

The area of the sidecut is assumed to be a circular segment of height C. The width of the segment is the length of the trailing edge (if straight):

$$TE = \sqrt{R^2 + \frac{W^2}{4}}$$

The radius of the circular segment is:

$$Rc = \frac{TE}{2} + \frac{TE^2}{8C}$$

In case you were curious, a shallow (10 mm) sidecut on a typical sail plan produces a circular segment with a radius of about 1.5 m.

The interior angle of the circular segment is:

$$\theta = 2\sin^{-1}\left(\frac{TE}{2R}\right)$$

And finally, the area of the circular segment is:

$$Ac = \frac{R^2}{2}\left(\frac{\pi}{180}\theta - \sin\theta\right)$$