TECH TOPICS

Dave Register
Bartlesville, Oklahoma
regdave@aol.com

2 METER DESIGN ANALYSIS

Designing a 2 Meter sailplane for thermal duration performance can be challenging. The trade-off in wing loading, aspect ratio and airfoil is much more constrained than for an open class design.

People have many opinions on this topic, but for me Mark LeVoe's Super-V (2 Meter) is still the best of this class. The combination of airfoil, planform and generous V-stab surfaces make a pleasing appearance and a very stable, high performance design.

Although you can find 2M Super-Vs out there, Mark stopped production of this ship several years ago. The planes that Mark designed, from the Albatross to the Super-V, are excellent flying machines.

Everyone has his or her favorite plane or design trend, so I won't try and defend everything we're going to discuss. The approach I'll use is just one of several ways to look at the whole problem.

There are a number of good 2 Meter ships out there. Three that appear to have promise are the Starling Pro (assuming the spar quality improves), the Mini-Graphite from Kennedy Composites and the Laser 2M from NE Sailplane Products (sorry, Sal but V-tails are just sexier). The Organic is a beautifully crafted airplane but too fragile for the way I hammer my planes. And so on.

To address the 2 Meter design challenge, there are several issues to be reviewed:

1) Wing loading and airfoil selection,
2) Wing planform – which depends a great deal on #1,
3) Pitch and yaw stability analysis, and
4) Fuselage/stabilizer design, which depends a great deal on #3.

To look at trade-offs with the wing loading, airfoil and planform selection, we'll use (you guessed it) a polar analysis. We'll first evaluate the estimated flight profile for the things we can conveniently change and then see how that plays into the choice of the airfoil and wing planform.

To provide input to the polar program, we need estimates for scaling the weight of our designs. To do that, I'll work from measured values for planes I've been flying that use composite construction techniques. After measuring everything I've got in the shop, I come up with the following average numbers:

Wing ~ 4.75 oz./sq.ft.
Stabs ~ 2.50 oz./sq.ft.
Fuselage ~ 1.77 oz./ft.

These are all 'dry' weights - as received in the box. Note that the fuselage scaling is based on the overall length of the fuselage and not its wetted area. This is a reasonably consistent number for the 2 Meter and Open class ships used to come up with these averages.

Weights for other components can be measured directly. I'm assuming a six-servo design with a 500maH NiCd pack. The additional weight from the

Figure 1: Polar Plots For 2 Meter Design Estimates

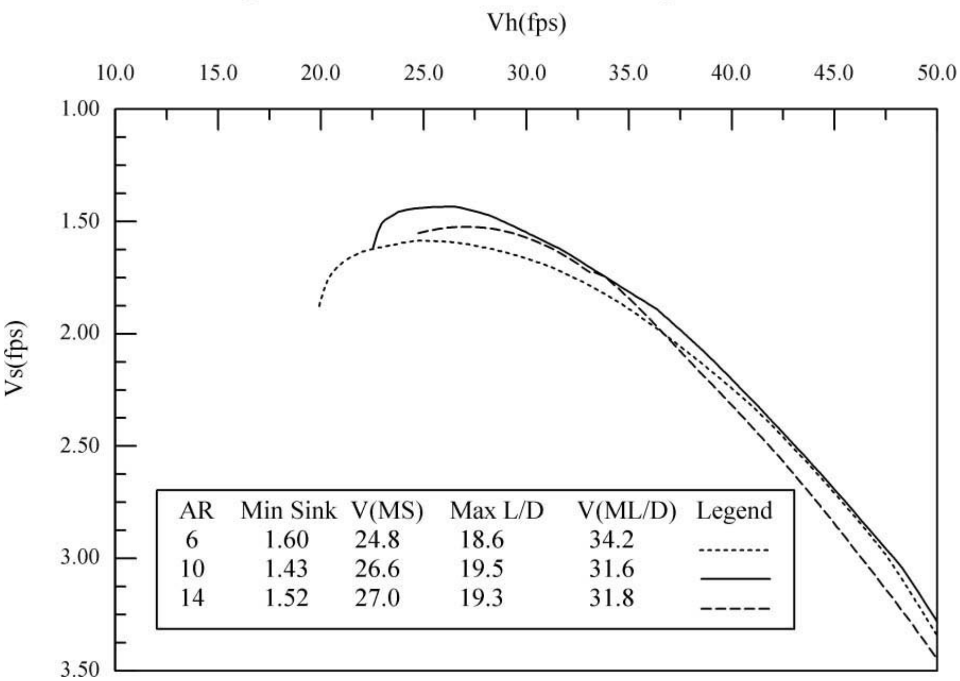


Table 1: 2 Meter Design Values

Aspect Ratio	6	8	10	12	14
Wing Area (si)	1027	770	616	514	440
Stab Area (si)	305	184	125	92.5	72
Weight (oz)	62	52	46	42	40
Loading (oz/sf)	8.8	9.7	10.8	11.8	12.9

flight gear comes to about 17-19 oz.:

6 Servos: 1 oz. each
Receiver: 1.5 oz.
Battery/Harness: 3.0 oz.
Wing Wiring Harnesses: 1.0 oz.
Wing Rod: 3.5 oz.
Misc.: 5.0 oz.

(Servo Mount/switch/plugs/linkage/control horns/tow hook/skid/skeg/etc.)

Total ~ 20.0 oz.

There are lighter weight components available but these values are typical of equipment normally used to run a 6-servo ship. You can use a NiMh battery and save some weight but you'll probably add it back as lead in the nose. If you have numbers that represent your equipment better, go for it.

Right away I think you can see the problem. The weight of the ancillary equipment is proportionally higher for a 2 Meter ship than for open class. That 20 oz. number is real. It includes the wing rod, skid, skeg, linkage, wing wiring harness and then ALL of the components of your radio gear. If you don't come up with at least 18 oz. for a typical setup, I'll be surprised.

A 2M ship typically weighs ~ 44 oz. while an open class comes in ~ 76 oz. Using the above numbers we find that your hardware contributes about 45% of the flying weight of a 2 Meter plane whereas that same value is about 30% of the weight of an open class ship. This really affects the wing loading and the subsequent performance envelope of the 2 Meter class.

Assuming values for the stabilizer volume coefficients (RVC ~ 0.045 and TVC ~ 0.50) and the fuselage moment arm (distance from 25% wing average chord to 25% horizontal stabilizer chord), we can come up with estimated wing loadings as a function of wing aspect ratio. Table 1 provides the scaling information to be used for our first cut at a 2 Meter design.

Aspect ratio is an important criterion. High aspect ratio is good for low induced drag but bad for wing loading. One can compensate with a high lift airfoil but then profile drag becomes a problem at higher speeds.

Plugging this all into a polar analysis helps sort out the trade-offs.

First, let's zero in on the aspect ratio/wing loading trade-off using data for the SA7035. What I'm looking for is a minimum sink velocity ~ 1 ft/sec, a max L/D of ~ 18. Based on my personal preferences, I'd also like a flying speed of ~ 25 ft/sec in the min sink to max L/D part of the flight profile. An added bonus would be a fairly broad polar at higher speeds to allow good cruising efficiency when you have to bring it back in a modest breeze.

Figure 1 shows the result of this analysis for the aspect ratios and wing loadings summarized in Table 1. One of the first things we see is that the wing loading for a 2-meter design makes it difficult to make that 1 ft/sec minimum sink velocity.

It's tough getting down to the cruising range I'd like with the SA7035. However, we do see a reasonable optimization of things around an AR of 8 - 10.

The velocity near minimum sink is ~ 25 ft/sec but the sink rate is a little high and I'd like to bring that down a bit if possible.

Before looking at airfoil responses, it's useful to compare this same analysis to an open class ship. Table 2 contains the same type of estimates but using a 124 inch span (~ 3 meter). As a reality check, my Laser 3MC has an AR ~ 15 and weighs in at 74 oz.

Figure 2 presents the polar calculation for the data in Table 2. Note that the minimum sink, max L/D and velocity in the min sink range are all more favorable than the 2-meter case. So 'yes' is the quick answer to 'does bigger fly better'?

If we take a close look at Reynolds number (Re) for these two configurations we find Re has very little to do with the performance difference. It's almost exclusively aspect ratio and wing loading. Since the radio, servo and ancillary equipment weight is

Figure 2: Polar Plots For Open Class Design Estimates

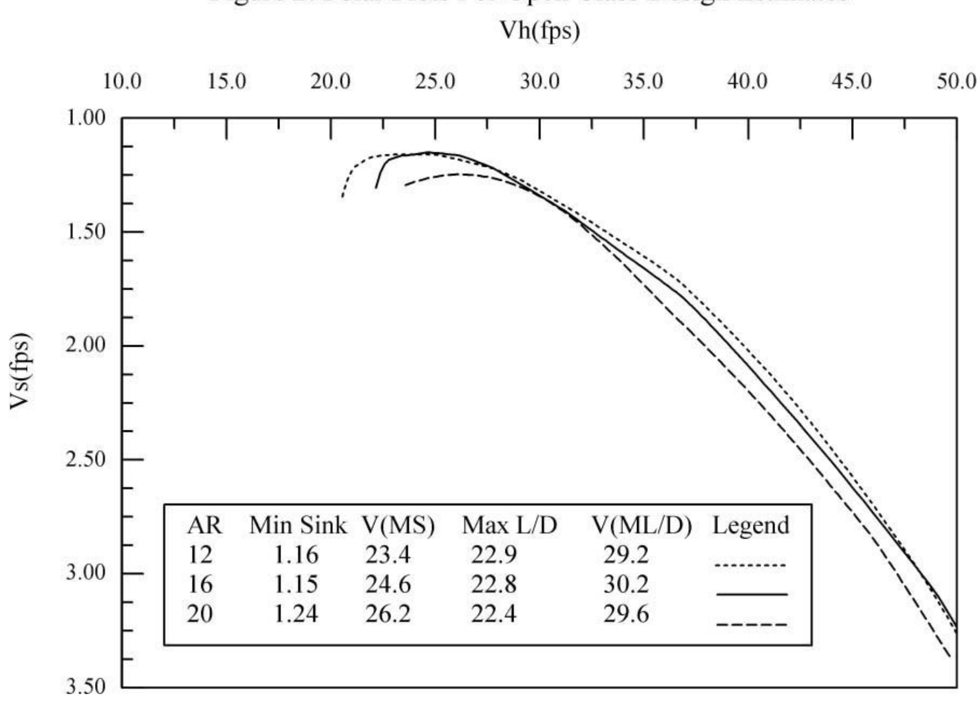


Table 2: Open Class Design Values

Aspect Ratio	12	14	16	18	20
Wing Area (si)	1281	1098	961	854	769
Stab Area (si)	300	233	188	157	133
Weight (oz)	82	75	69	65	62
Loading (oz/sf)	9.2	9.8	10.4	11.0	11.6

about the same for both sailplane classes, we can add more wing area at a higher aspect ratio in open class and still come out ahead on wing loading.

The next variable we can push around is airfoil selection. Since we're flying at typically higher wing loadings in 2-meter class, we should probably look at higher lift sections. The SA7038 and S3021 are worth a look. I had excellent performance with the S3021 on a standard Duck a few years ago. Other good airfoils are certainly available but these three give a reasonable look at the responses.

Using an aspect ratio of 10 (2 Meter case), Figure 3 compares these four airfoils using the same planform considerations. The SA7038 appears to give the best benefit for the selected AR and wing loading.

Finally, in Figure 4, we compare the suggested 2-meter configuration (SA7038 airfoil, AR ~ 10) with an optimized open class ship (AR ~ 14) using the SA7035. Although the Open class ship is still the better overall performer, we've closed the gap quite a bit.

Figure 3: Polar Plots For 2 Meter Airfoils (AR = 10)

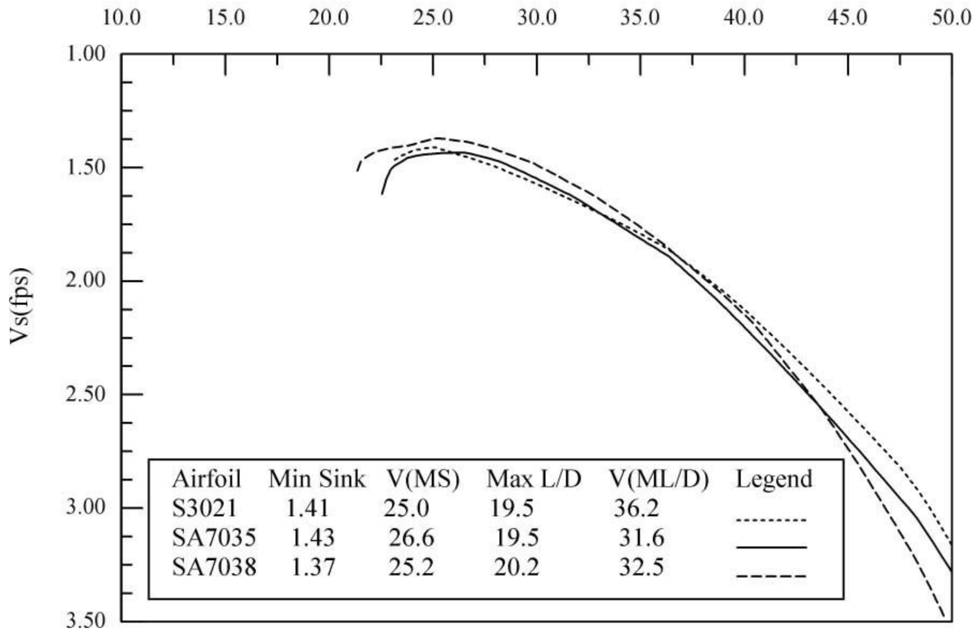
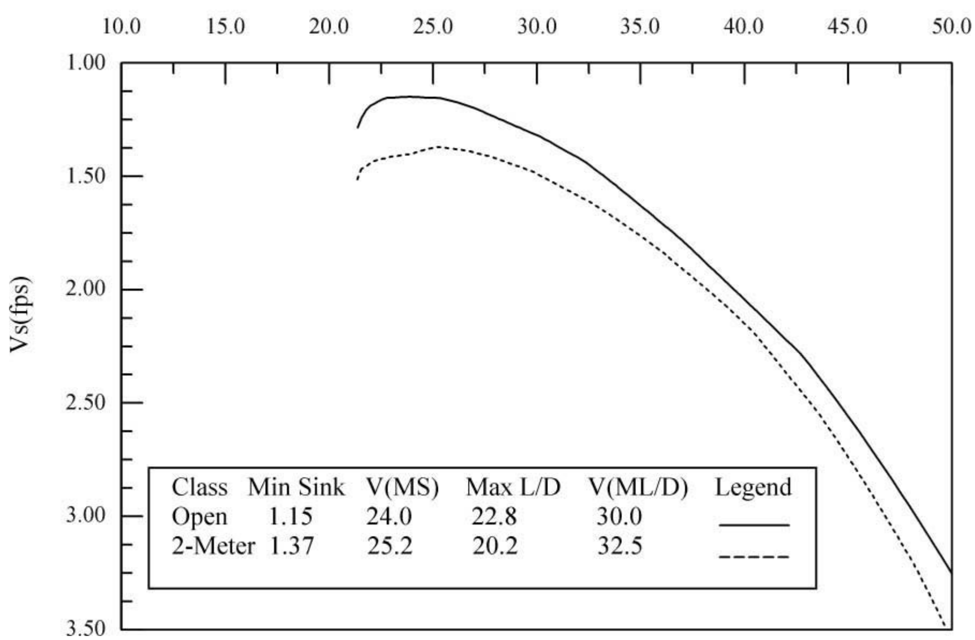


Figure 4: 2 Meter (AR=10) and Open (AR=14) Optimization



To summarize what we've learned so far:

Bigger does fly better,
Re is not the dominant effect in the 2 meter and larger classes,
Wing loading and aspect ratio flexibility favors the open class design, and
To approach open class performance, a 2-meter design will need to use a lower aspect ratio wing and a higher lift airfoil section.

Clearly, if we can change the construction and equipment weight parameters to the low side, you'll also come out ahead. But the numbers used are typical of the planes out there in production. When you start using exotic materials and construction techniques to lighten the load, the cost usually goes up and the durability goes down – at least for a ham-handed guy like me.

In the next several installments, we'll do the same calculations for some two meter designs with which I have personal experience. Then we'll look in more detail at optimizing the wing planform for lift distribution and wash-out. Finally, we'll wrap up by taking a look at some stability criteria which will help properly size the horizontal and vertical stabilizers.

• • •