To: Team Water Stakeholders

From: Amira Malik

Subject: Main Wing Memo

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Driving Constraints and Design of the Main Wing

1 Executive Summary

We will find that the wing area that has equal power required to fly it as power it can genereate, being 25.5 m^2.The subsequent design shall characterize the wing to produce enough power to stay aloft in sunlight, have good flying characteristics, and be easy to build; however, it is not final pending other memos being released. The tools used can acommodate any changes in information. We will not talk about stability or control surfaces.

2 Wing Analysis Method

2.1 Governing Relations

At cruise:

$$L = \frac{1}{2} C_L \rho S V^2 \tag{1}$$

$$D = \frac{1}{2} C_D \rho S V^2 \tag{2}$$

$$P_{required} = \frac{S}{\eta_P} \sqrt{\frac{2}{\rho}} \left(\frac{C_D}{C_L^{\frac{3}{2}}} \right) \left(\frac{W}{S} \right)^{3/2} \tag{3}$$

$$P_{generated} = \eta_p \eta_m \eta_s \eta_a S Q \tag{4}$$

$$\frac{T}{W} = q C_D \left(\frac{1}{\frac{W}{S}} \right) + k \left(\frac{1}{q} \right) \left(\frac{W}{S} \right) \tag{5}$$

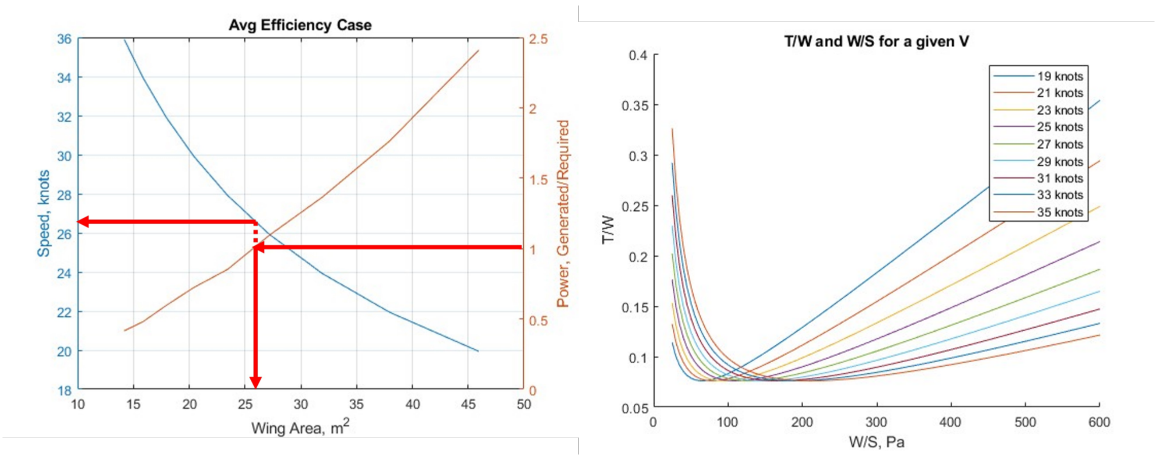
Speed drives each equation, so we can parametrize them by it. Then, we know with confidence:

Variable	Status	Value (SI units)
L, W	Weight-Force at Cruise [6]	2510 N
ρ	Density Altitude [6]	.91 kg/m^3
Q	Determined Value [2]	800 W/m^2
η_s	Determined Value [3]	22.4%
η_p	Determined Value [4]	76.5%
η_m	Determined Value [4]	96.22%
η_a	Determined Range [5]	[75%, 85%]
airfoil	Assumed from Old Design	Eppler 603
L/D, aircraft	Assumed from Old Design	22
L/D, wing	Assumed from Old Design	36
Æ	Assumed from Old Design	15
e	Assumed from Old Design	.8
c_L	Assumed from Old Design	1.2

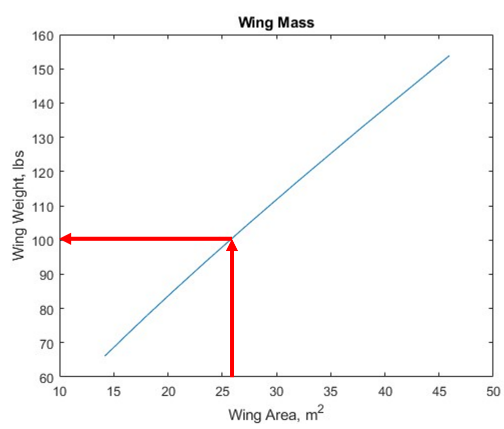
The power efficiencies, lift, irradiance, and altitude alone can not "solve" the governing relationships for a wing area. Therefore, the assumed variables are needed and come from the starting aircraft's drag build up, from which we saw that the major drag contribution comes from the wing. If we keep a similar Æ and wing efficiency, that our L/D will remain mostly unchanged. Also we have a 25% cushion from the L/D of 29, giving us 22. For this analysis, we will not explore different airfoils. The Eppler 603 is a purpose built low speed high lift soaring airfoil with generous internal volume. Different airfoils are welcome in future analysis.

3 Analysis and Final Design

We can perform a fixed lift analysis to find combinations of wing areas and cruise speeds that correspond to particular ratios of power generated over power required. We pick a P ratio of 1 to be as low weight as possible; however, team water can agree on a higher ratio pending accurate wing weight model. At this ratio, we are just under 100 lbs, which is our budget and drives why we picked 1 for this. The power generated here is about 3000 W.



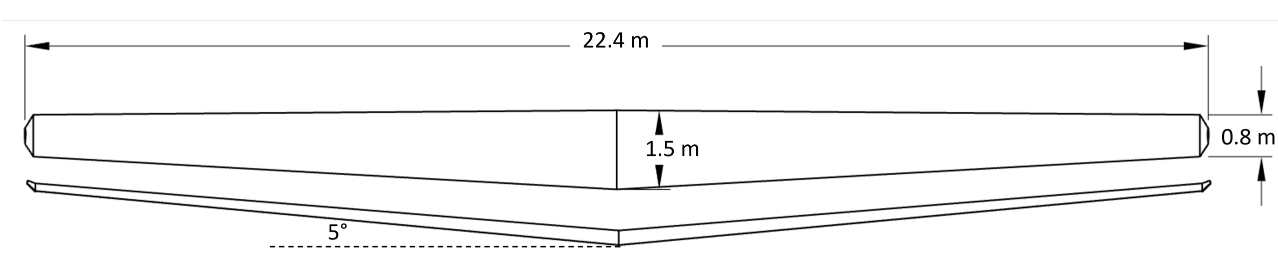
Getting a Low Speed Wing Area



Variable	Value	Units
S	25.5	m^2
Æ	15	-
b	19.8	m
c	1.3	m
V_{cruise}	27	knots
V_{stall}	23	knots
Reynolds #	1,100,000	-
Airfoil	Eppler 603	-

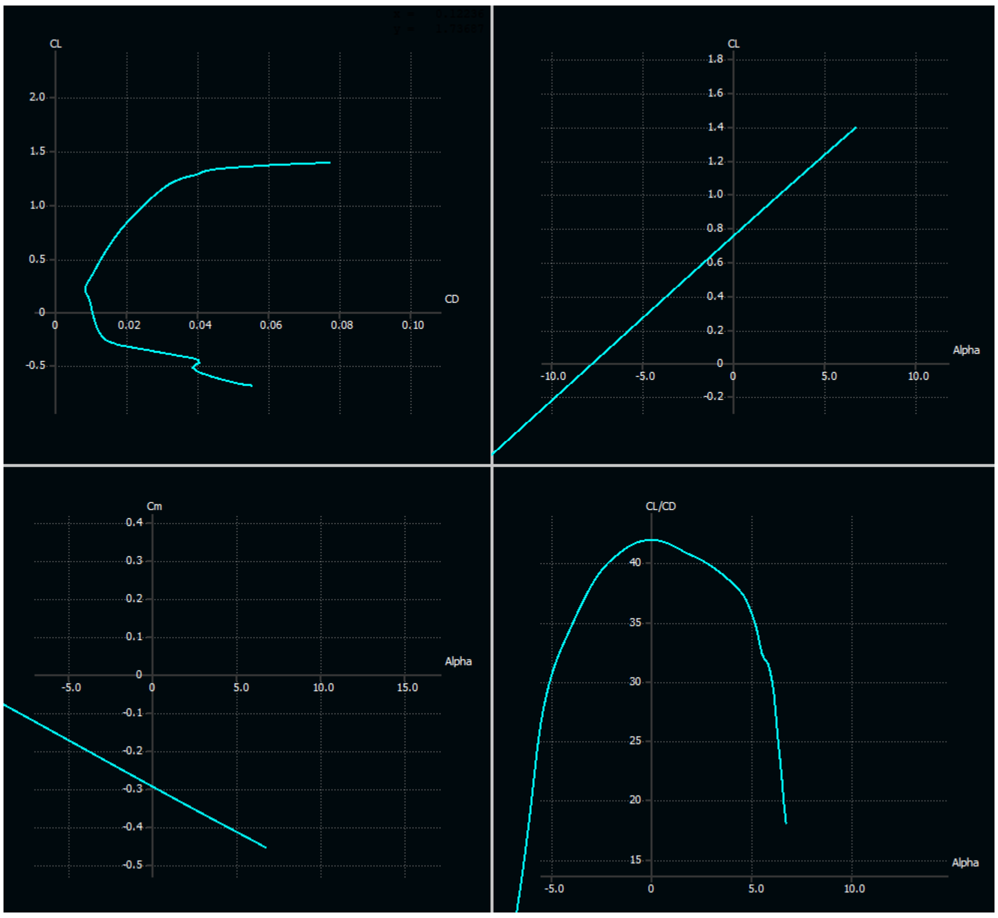
The weight is roughly linear, and shown are the associated variables

The wing's geometry, however, is not determined with this analysis but by iteratively tapering and modifying the wing until it meets the assumptions of the analysis, namely that the wing L/D is >36, Æ 15, $C_L = 1.2$, and the e is > .8. There is no end to how we exceed these variables, so modifying stops once we satisfy these assumptions. We also keep the 1/4 chord straight to ease the integration of structures, and we apply an incidence to keep max cl/cd at zero AOA. And, we have a preliminary twist, fleshed out in the ailerons control sizing memo. And there are wingtips, fleshed out with the pylon design. Applying the minimal amount of modification to a baseline rectangular wing, and after a dozen or so iterations, we get a final OML of:

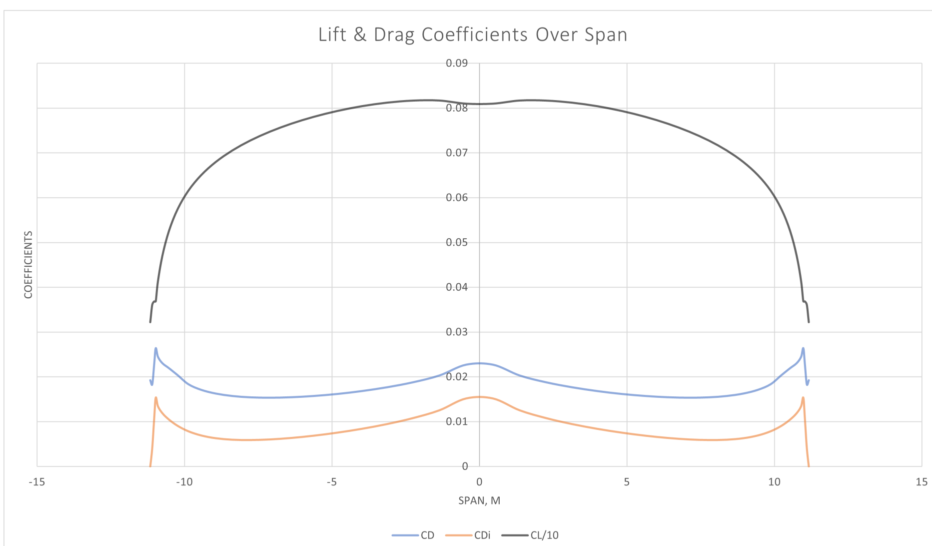


The final wing dimensions

Whose characteristics are:



Wing Polars



Lift & Drag Coefficients

4 Implications for Future Design

At worst, the wing is ready for an optimization of the airfoil to widen the speed range and to increase area to get a higher than 1 power ration. At best, the wing OML is ready to be broken down into its structural components and start to be built immediately, and it will result in a flying aircraft that meets or exceeds the intended operation. With this wing, SEAWAY will be "the new way to see new sights." (10).