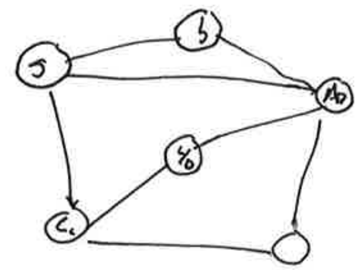
Primary Design Variables?

Wing span = b
Wing Area = S
Aspect Ratio = AR
Flight Velocity = V
Taper Ratio = λ
Tail Length = l_t
Tail Area = S_h
Airfoil {thickness =, Camber, ... } = ?
Dihedral = Γ
Wing Sweep = Λ
Configuration = {monoplane, biplane, canard, ?}
Flight C_L
Balsa {Weight, Thickness} = ?

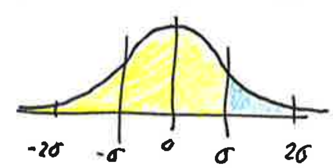


Pareto's Law

80% of results determined by 20% of actions

$(.80^2 = 0.64$ by $.20^2 = 0.04)$

Think of standard deviations



Simplify

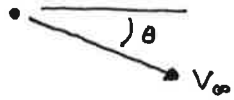
$AR \equiv \frac{b^2}{S}$, so track $\begin{cases} b, S \\ b, AR \\ S, AR \end{cases}$ pick one

~~b, S, AR~~

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

$R_e \approx 6350 \cdot V \cdot \bar{c}$ unless $\lambda \neq 1$

Endurance



$\Rightarrow \quad \downarrow V_v = \dot{h} = \frac{dh}{dt}$

From AEM 368, the vertical velocity is

$$\dot{h} = V_\infty \left(\underbrace{\frac{T}{W}}_{\text{thrust}} - \underbrace{\frac{1}{2}\rho V_\infty^2 \left(\frac{W}{S}\right)^{-1} C_{D_0}}_{\text{profile drag}} - \underbrace{\frac{W}{S}\frac{2k\cos^2\theta}{\rho V_\infty^2}}_{\text{induced drag}} \right)$$

Simplify for a glider ($T = 0$, ~~$\theta \approx 0$~~ $\cos^2\theta \approx 1$)

$$\dot{h} = V_\infty \left(-\frac{1}{2}\rho V_\infty^2 \left(\frac{W}{S}\right)^{-1} C_{D_0} - \frac{W}{S}\frac{2k}{\rho V_\infty^2} \right)$$

Optimize $\dot{h}$ wrt V_∞ (calculus ... set derivative to zero)

$$\frac{d\dot{h}}{dV_\infty} = -\frac{1}{2} 3\rho V_\infty^2 \left(\frac{W}{S}\right)^{-1} C_{D_0} + \left(\frac{W}{S}\right)\frac{2k}{\rho V_\infty^2} = 0$$

$$\boxed{V_{\infty\,\dot{h}_{min}} = \sqrt{\frac{2}{\rho}\sqrt{\frac{k}{3C_{D_0}}}\frac{W}{S}}}$$

$$V_v = \sqrt{\frac{2}{\rho}\frac{1}{C_L^3/C_D^2}\frac{W}{S}} = \boxed{\frac{C_D}{C_L^{3/2}} \cdot \sqrt{\frac{2}{\rho}\frac{W}{S}} = V_v}$$

$\left(C_L^{3/2}/C_D\right)_{max}$ occurs at

$$V_\infty = \sqrt{\frac{2}{\rho}\frac{W}{S}\sqrt{\frac{k}{3C_{D_0}}}}$$

with value

$$\left(\frac{C_L^{3/2}}{C_D}\right)_{max} = \frac{1}{4}\left(\frac{3}{k\,C_{D_0}^{1/3}}\right)^{3/4}$$

For maximum endurance, you want:

- Large $C_L^{3/2}/C_D$
- Low W/S

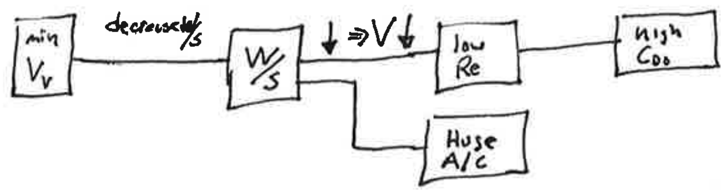
$$V_{v_{min}} = 4\left(\frac{k\,C_{D_0}^{3/2}}{3}\right)^{3/4}\sqrt{\frac{2}{\rho}\,\frac{W}{S}} \qquad \text{at } V_\infty = \sqrt{\frac{2}{\rho}\,\frac{W}{S}\sqrt{\frac{k}{3C_{D_0}}}}$$

with this model of the aerodynamics, you want

- Low drag C_{D_0}
- Low wing loading W/S

Problems / Trade-Offs

Wing area:



Drag

Notice that $\left(C_{D_0}^{3/2}\right)^{3/4} = C_{D_0}^{9/8} \approx C_{D_0}$

structure

- paper and foam are low-performance materials (low E, low $\sigma_{ultimate}$)

  A large wing area will give a big floppy twisting aircraft. (i.e high C_{D_0}, untrimmed)

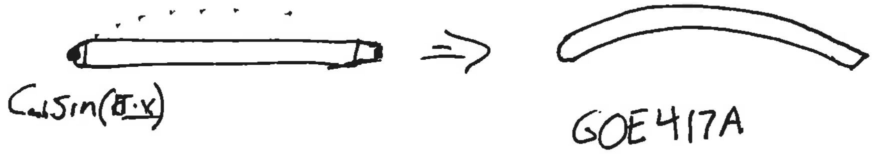
- Difficult to form smooth airfoils. (or even cambered airfoils)

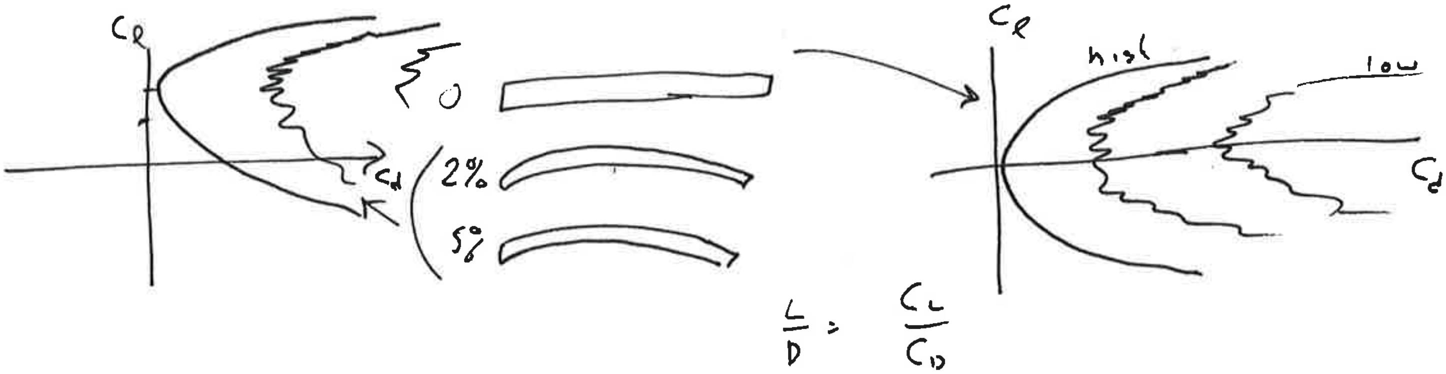
- Highest density objects are the 25¢ quarters. These can provide an advantage for weight + balance.

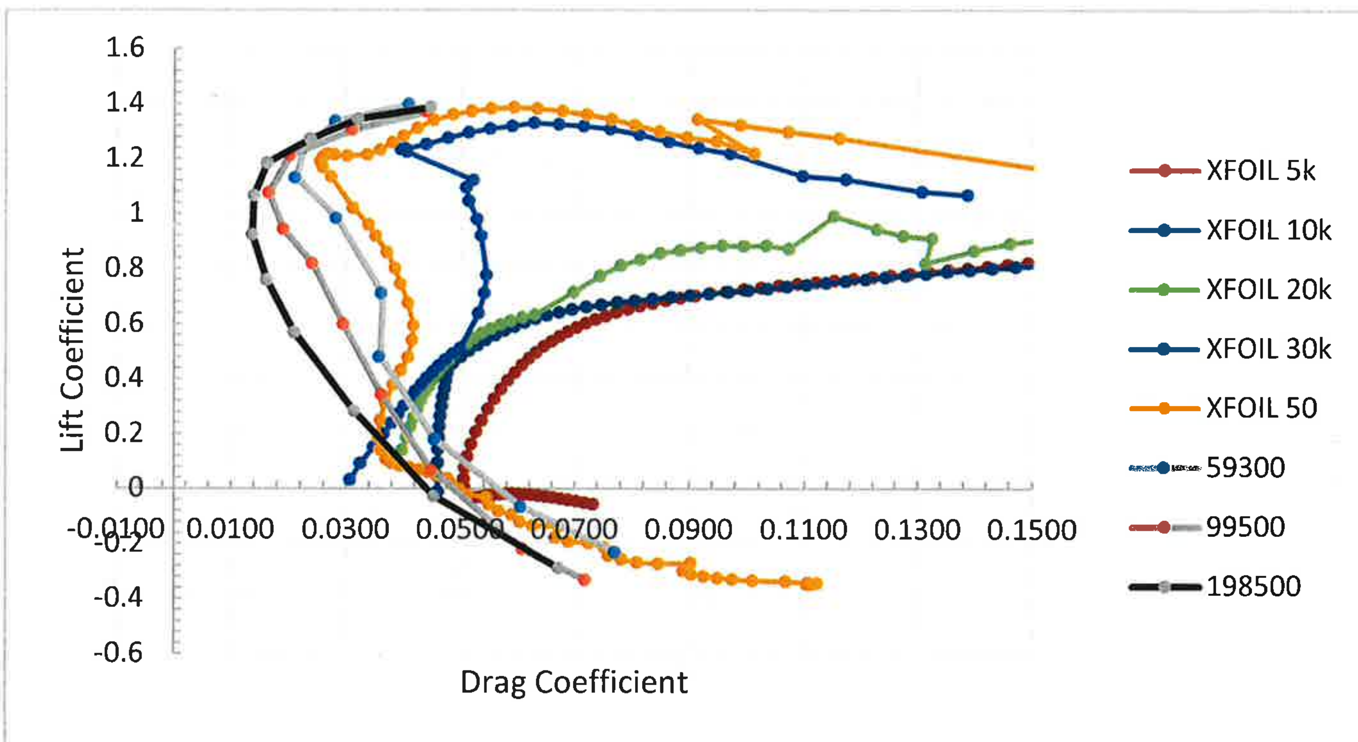
  Remember, you <u>must</u> have the Center of Gravity <u>ahead</u> of the aircraft's Neutral Point / Aerodynamic Center. Make the horizontal tail large enough!

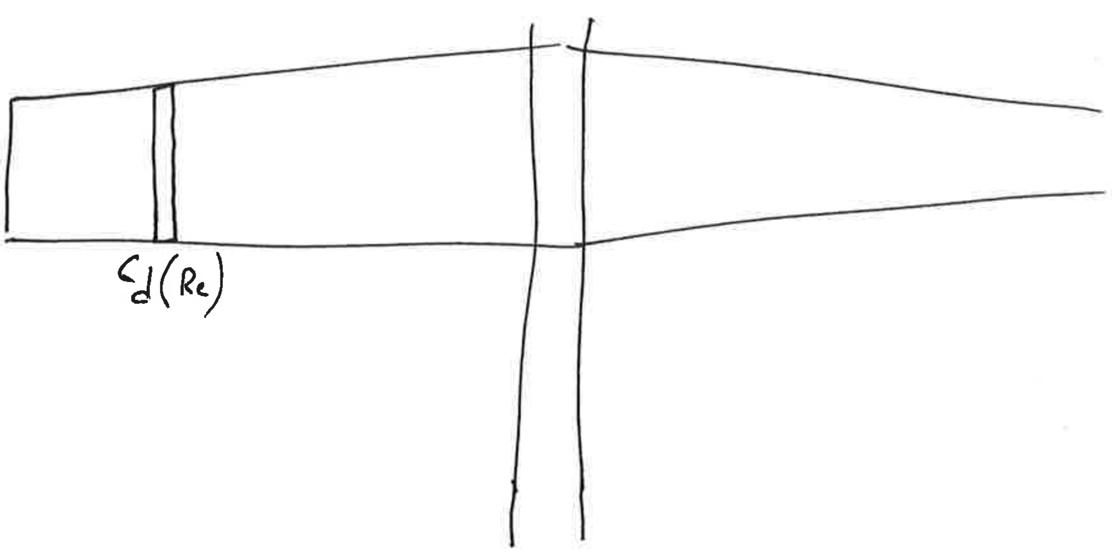
The most common failures will be <u>unstable aircraft</u> and <u>wings folding</u>

unstable aircraft	wings folding
needs C.G and tail area fixed	Keep smaller S and test prior to competition


C sin(π·x)
GOE417A


Cl
Cd
0
2%
5%
Cl
high
low
Cd
L/D = CL/CD


Lift Coefficient
Drag Coefficient
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.0100
0.0100
0.0300
0.0500
0.0700
0.0900
0.1100
0.1300
0.1500
XFOIL 5k
XFOIL 10k
XFOIL 20k
XFOIL 30k
XFOIL 50
59300
99500
198500


Cd(Re)

Excel speadsheet

Primary design variables

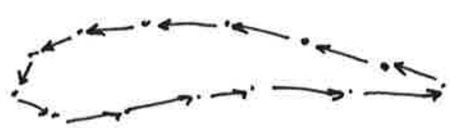
C_L, b, AR, airfoil

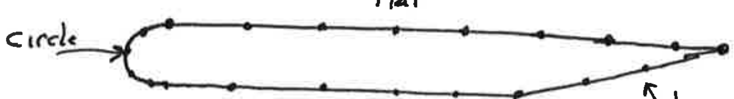
everything else is calculated from these.

C_L	b	AR	S	$\bar{c}$ ($\lambda=1$)	C_{D_i}	V	Re	$C_{D_{0\,wing}}$	C_D	L/D	$\frac{L^{3/2}}{D}$
			$=\frac{b^2}{AR}$	$=\frac{S}{b}$	$=\frac{C_L^2}{\pi AR e}$	$\sqrt{\frac{2W\,AR}{\rho\, C_L b^2}}$	$6350\,V\bar{c}$	lookup from XFOIL at Re and C_L	$C_{D_0}+C_{D_i}$	$\frac{C_L}{C_D}$	$\frac{C_L^{3/2}}{C_D}$

$$\frac{L^{3/2}}{D}\sqrt{\frac{W}{S}}$$

Airfoils?





why on bottom? BL sensitivity is less to $\frac{dp}{dx}$ when θ is smaller! θ is smaller why? less acceleration....

Camber

Transform via camber line

$\sin(\pi x)\cdot \text{Camber} = z^+ \Rightarrow z_{new} = z_{flat} + z^+$

you can Pick the camber function....