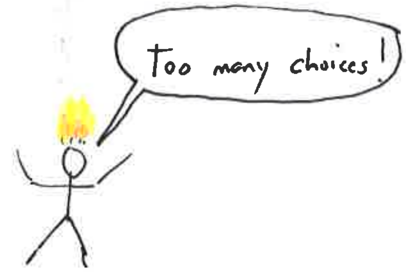
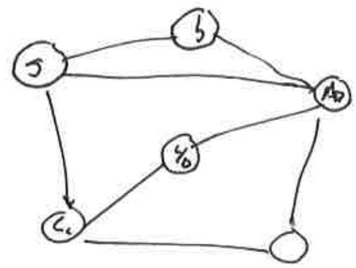
Primary Design Variables?

- 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 } = ?



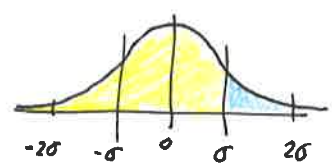


Pareto's Law

80% of results determined by 20% of actions

$(.80^2 = 0.64 \quad \text{by} \quad .20^2 = 0.04)$

Think of standard deviations



Simplify

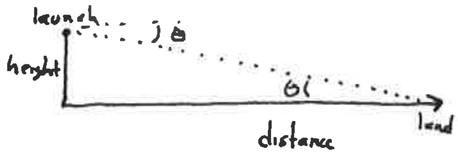
$AR \equiv \frac{b^2}{S}$, so track { b, S / b, AR / S, AR } pick one

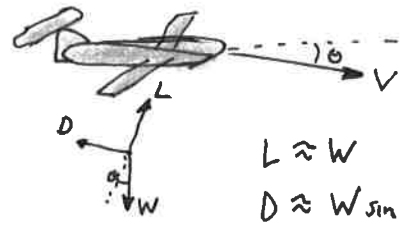
~~b, S, AR~~

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

$$Re \approx 6350 \cdot V \cdot \bar{c} \quad \text{unless } \lambda \neq 1$$

Objective: Maximize distance





$L \approx W$

$D \approx W \sin\theta$

$$\frac{L}{D} \approx \frac{W}{W\sin\theta} \approx \frac{1}{\sin\theta} \approx \frac{1}{\theta}$$

Maximizing distance

$$\tan\theta = \frac{h}{d} \approx \frac{\sin\theta}{\cos\theta} \approx \frac{\theta}{1} \Rightarrow \frac{1}{\theta} = \frac{d}{h}$$

Thus,

$$\frac{L}{D} \approx \frac{1}{\theta} \approx \frac{d}{h}$$

To maximize, d/h, maximize L/D

Aerodynamics

$$\frac{L}{D} = \frac{C_L}{C_D} \approx \frac{C_L}{C_{D_0} + \frac{C_L^2}{\pi AR e}}$$

$$C_{D_0} = \underbrace{C_{D_{0,wing}} + C_{D_{0,tail}} + C_{D_{0,fuselage}}}_{\text{function of Re\#}}$$

Since C_L is a prominent factor in L/D, select C_L as a design variable

AR is a prominent factor in L/D, select AR

C_L:

$$L = W = \tfrac{1}{2}\rho V^2 C_L S = \tfrac{1}{2}\rho V^2 C_L\left(\frac{b^2}{AR}\right) \Rightarrow V = \sqrt{\frac{2W\,AR}{\rho C_L b^2}}$$

Tail:

$$S_h = 0.8\,\frac{S\cdot\bar{c}}{l_t}$$

the tail is relatively small for $l_t > \bar{c}$, so drag really determined only by wing.

Re:

$$Re = 6350 \cdot V \cdot L \quad \text{if } \lambda = 1 \quad L = \bar{c} = \frac{S}{b}$$

Suggests avoiding λ near 0, since C_d is large for lower Re ?!

Excel speadsheet

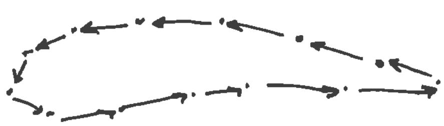
Primary design variables

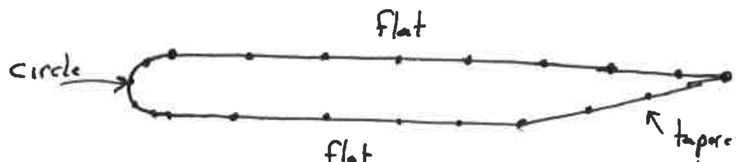
C_L , b , AR , airfoil

everything else is calculated from these.

C_L	b	AR	S	$\bar{c}$ ($\lambda=1$)	C_{D_i}	V	Re	$C_{D_{o_{wing}}}$	C_D	L/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	$C_{D_o}+C_{D_i}$	$\frac{C_L}{C_D}$

Airfoils?





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

Camber

Transform via camber line

$\sin(\pi x)\cdot Camber = Z^+ \Rightarrow Z_{new} = Z_{flat} + Z^+$

you can pick the camber function ....