NORTHERN ARIZONA UNIVERSITY

The Wright Stuff

Engineering Analysis

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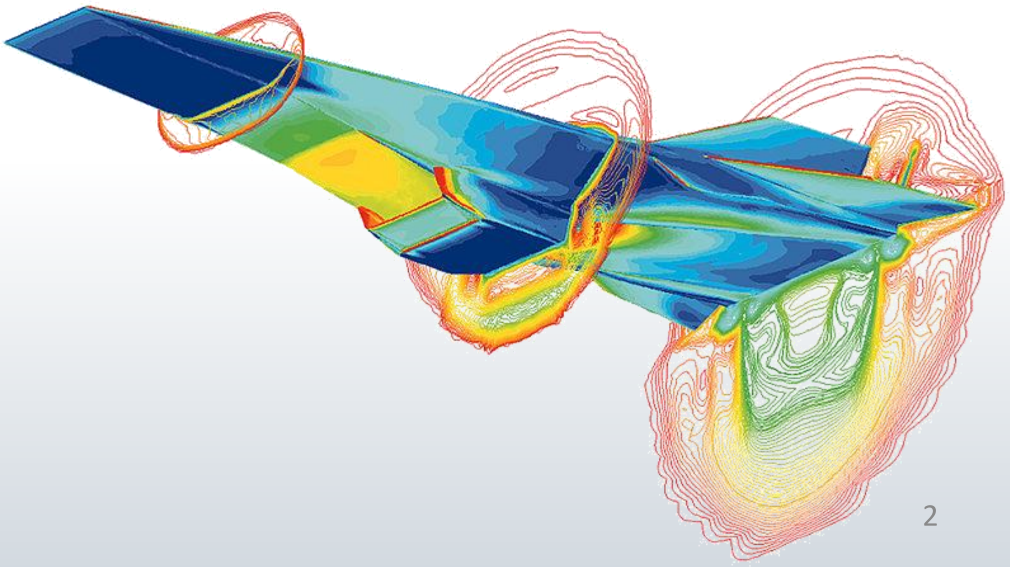
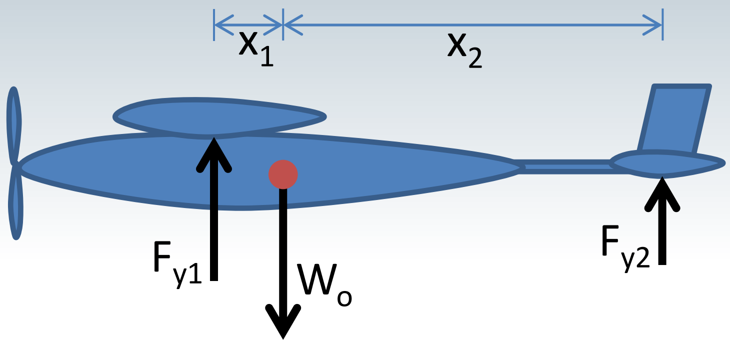
Agenda

- Static Analysis
- Aerodynamic Systems
- Propulsion Systems
- Structural & Material Considerations



Static Analysis



$$\sum M_{CG} = 0$$

$$F_{y1} \times x_1 - F_{y2} \times x_2 = 0$$
$$F_{y1} \times x_1 = F_{y2} \times x_2$$
$$x_2 = \frac{F_{y1}}{F_{y2}} x_1$$

$$\sum F_y = 0$$

$$F_{y1} + F_{y2} = W_o$$

$$\text{Lift Ratio} \equiv \frac{L_{wings}}{L_{tail}} = \frac{F_{y1}}{F_{y2}} = \frac{5}{1}$$

$$x_2 = 5x_1$$

$$F_{y1} = \frac{5}{6} W_o$$
$$F_{y2} = \frac{1}{6} W_o$$

Aerodynamic Systems

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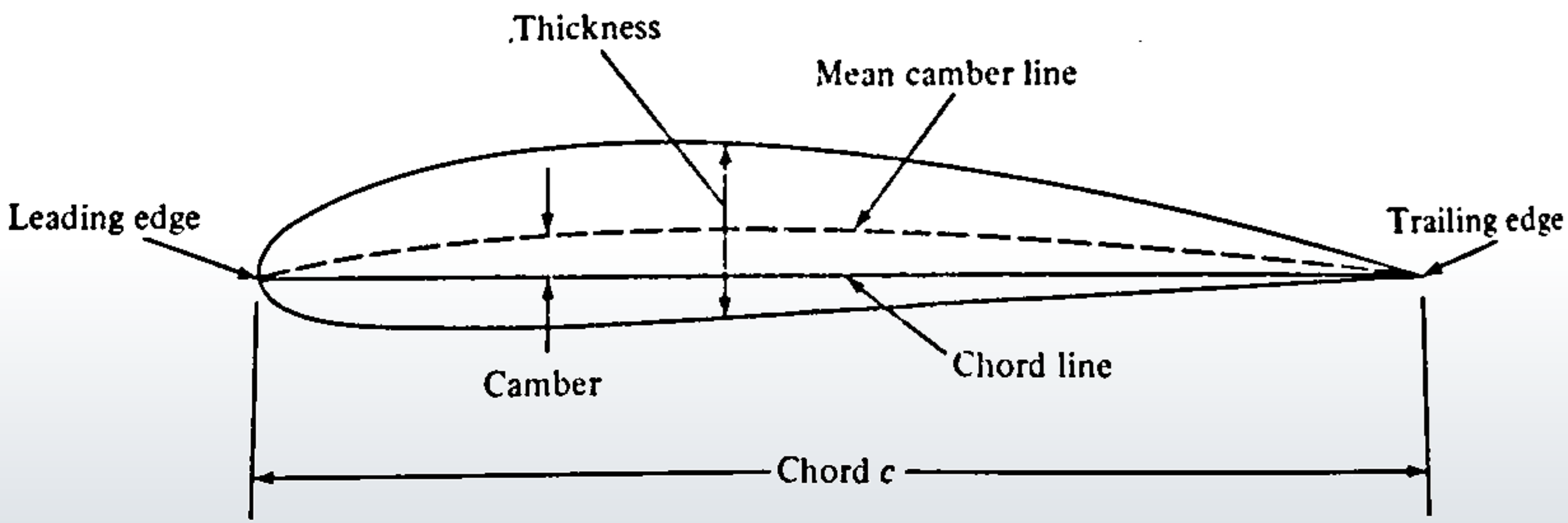
- 220k > Reynolds Number > 110k
  - Laminar Flow
- Pressure drag more significant than skin friction
  - Airfoil Selection
- Induced drag
  - Aspect ratio and planform taper

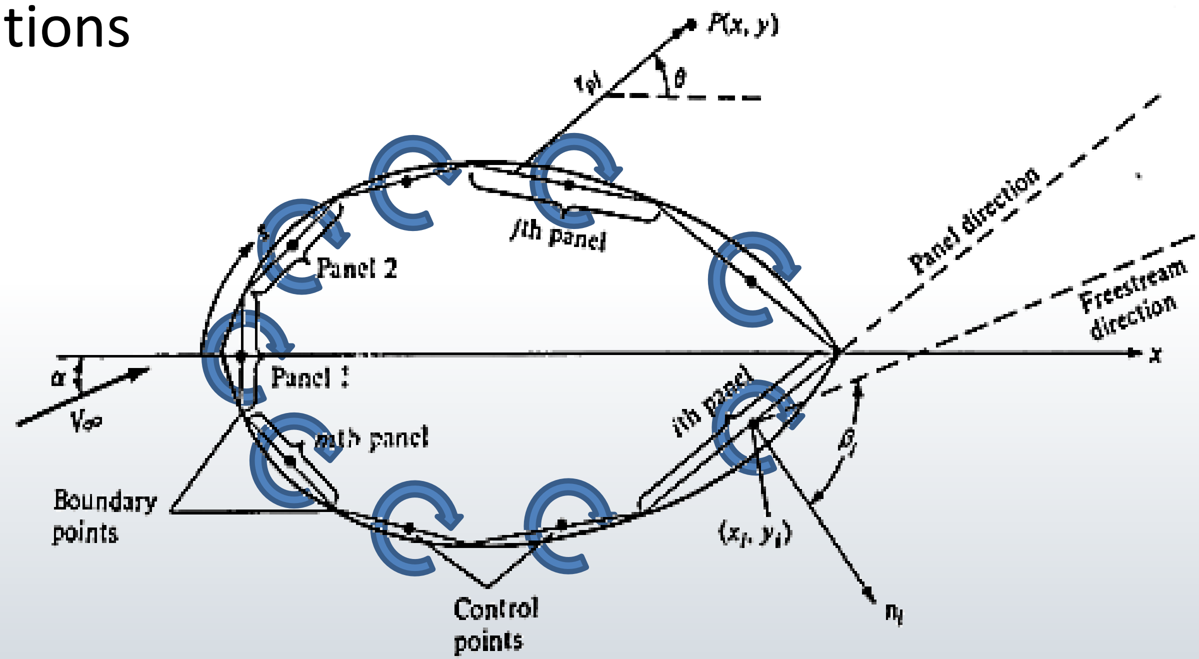
Airfoil Selection

- As thin as possible with minimal camber
  - Reduce flow separation and pressure drag
- Airfoils under consideration
  - NACA 2408, E174, NACA 2412



Vortex Panel Method

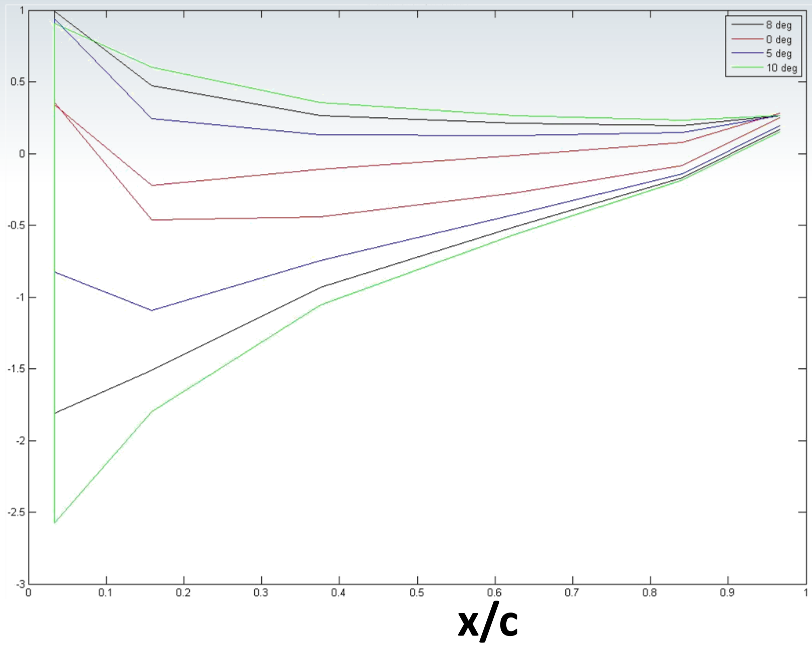
- Method: Discretize an arbitrary body into panels & model each panel as a vortex contribution
- Inputs:
  - Airfoil shape, chord length, angle of attack, environmental conditions



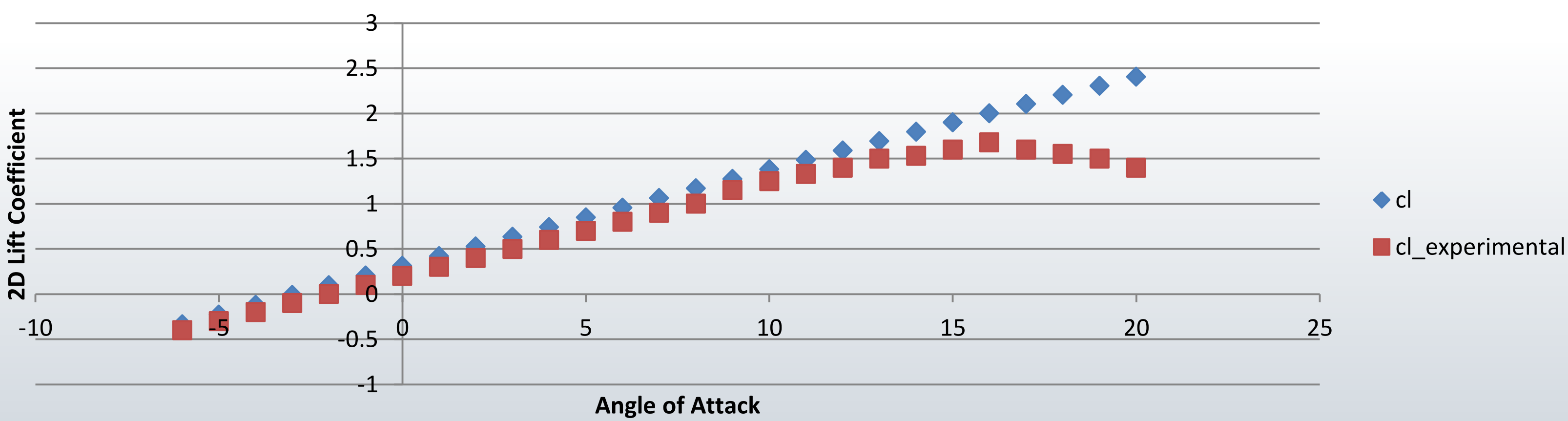
Vortex Panel Method

- Outputs:
  - Lift coefficients per unit span
  - Pressure coefficients per unit span

2D Pressure Coefficients

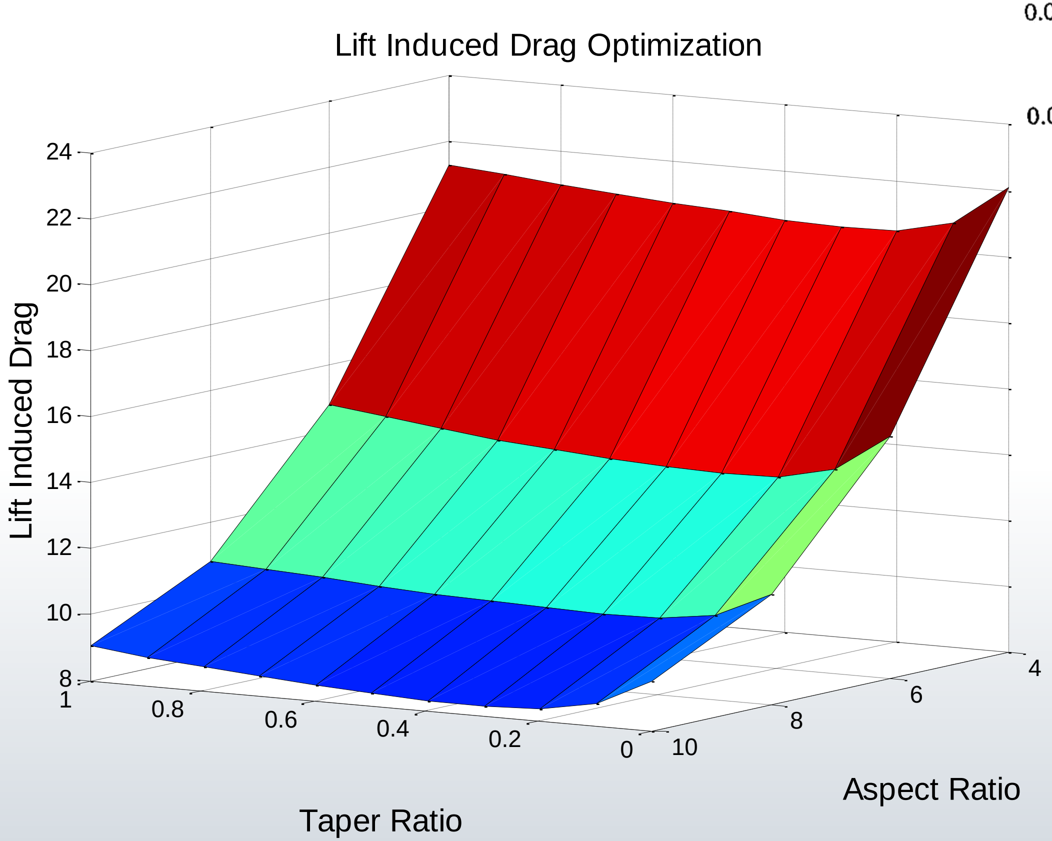


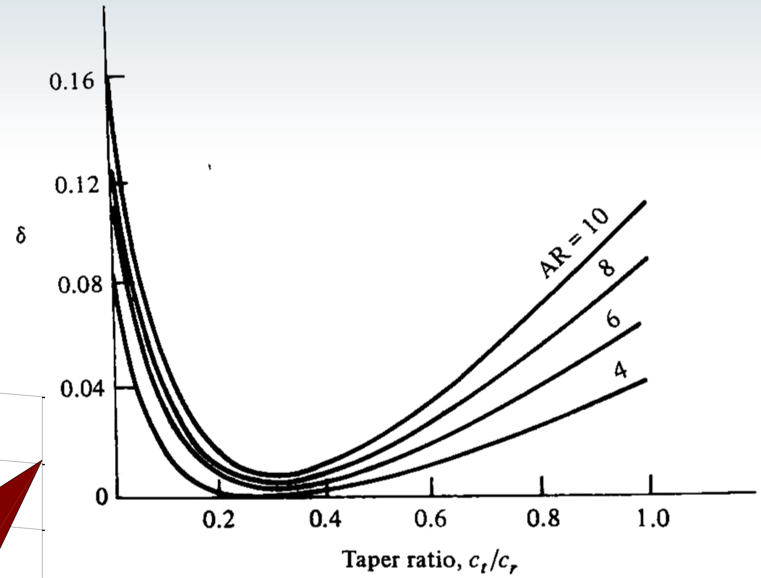
2D Lift Coefficient for Various Angles of Attack



Lift Induced Drag

- Aspect Ratio Vs. Taper Ratio

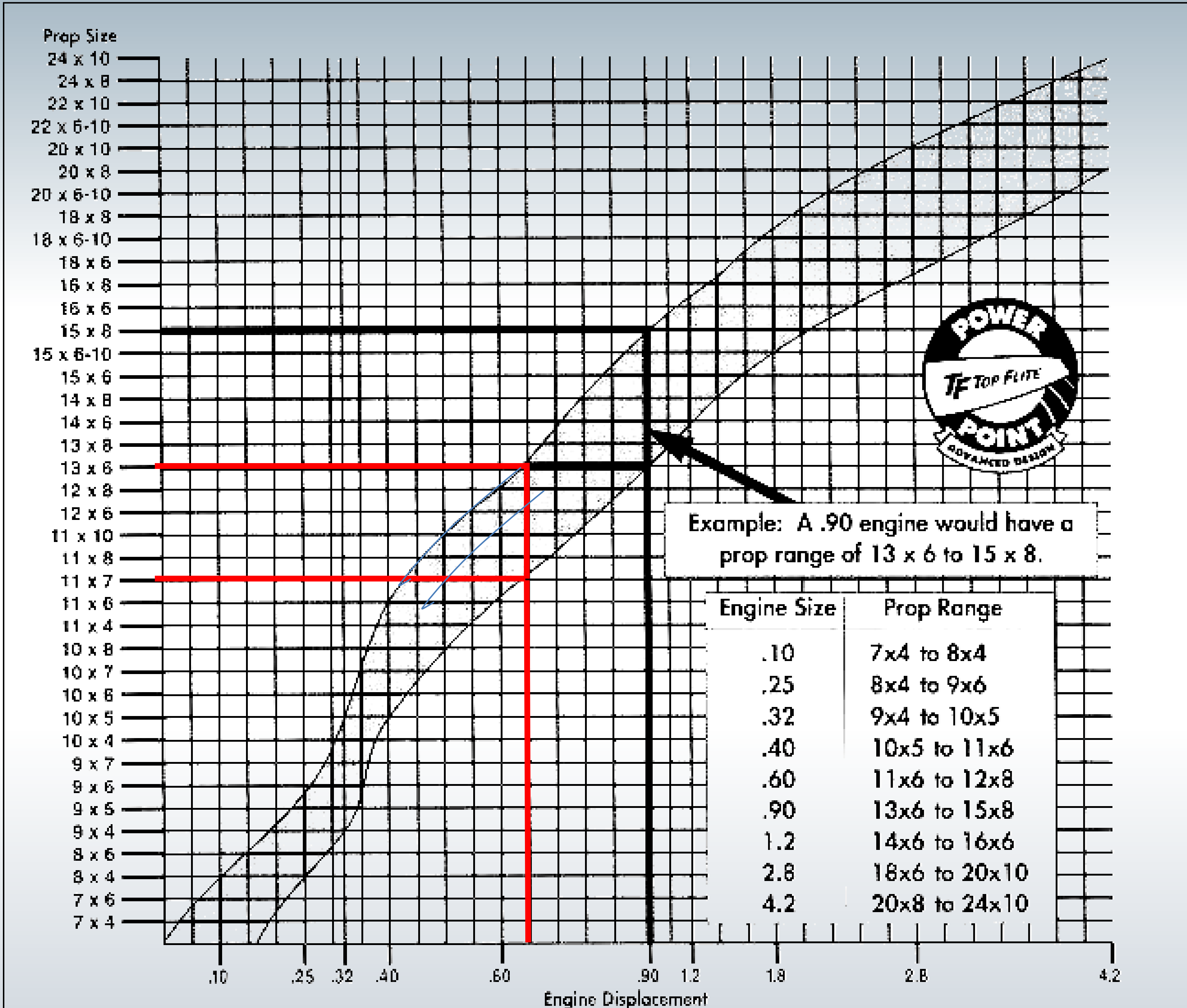




$$C_{D,i} = \frac{C_L^{\ 2}}{\pi\ AR}(1 + \delta)$$

Propulsion Systems

Magnum XLS-61A	
Displacement	9.94cc (0.607ci)
Bore	24mm
Stroke	22mm
Practical RPM	10,000 - 14,000 rpm



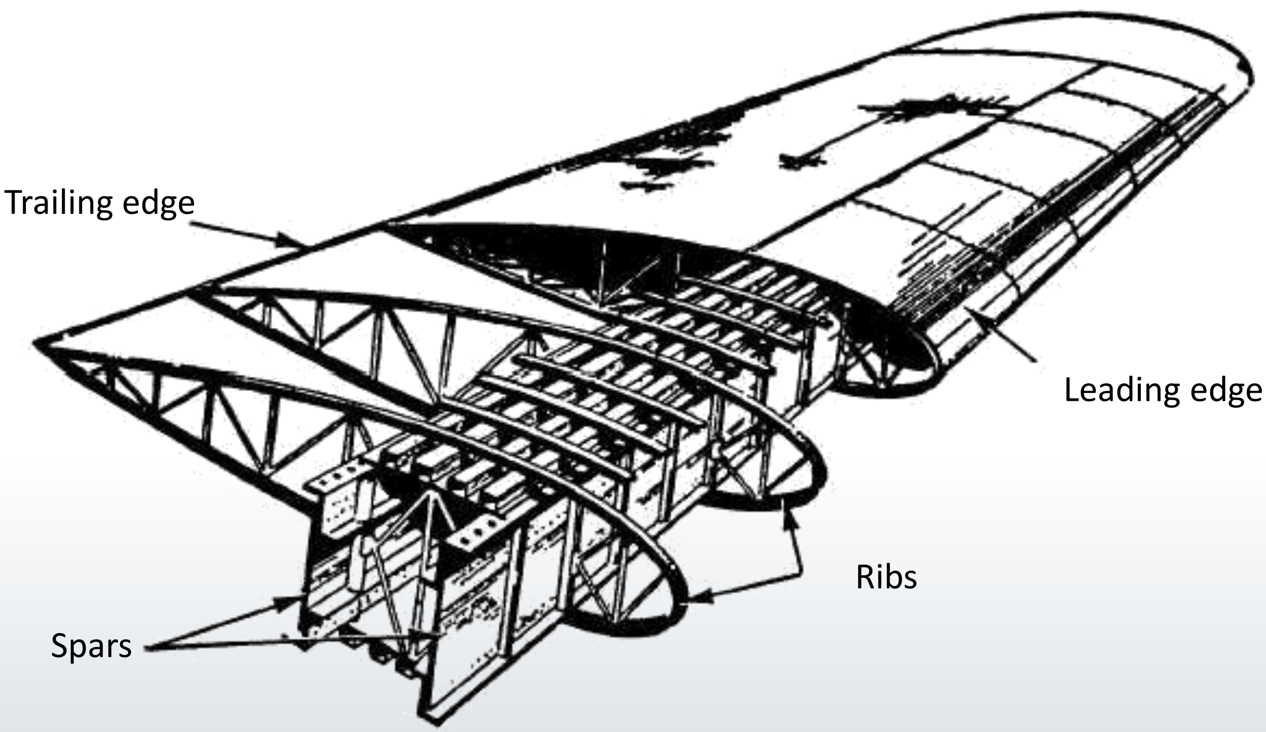
Engine Size	Prop Range
.10	7x4 to 8x4
.25	8x4 to 9x6
.32	9x4 to 10x5
.40	10x5 to 11x6
.60	11x6 to 12x8
.90	13x6 to 15x8
1.2	14x6 to 16x6
2.8	18x6 to 20x10
4.2	20x8 to 24x10

Propeller Selection

- Propeller range of 11 X 7 ➔13 X 6
- 11 X 7 is the best for breaking in the motor
- Physical testing needs to be performed to determine best match

Wing Layout

- Airfoil geometry defines rib layout



Material Selection

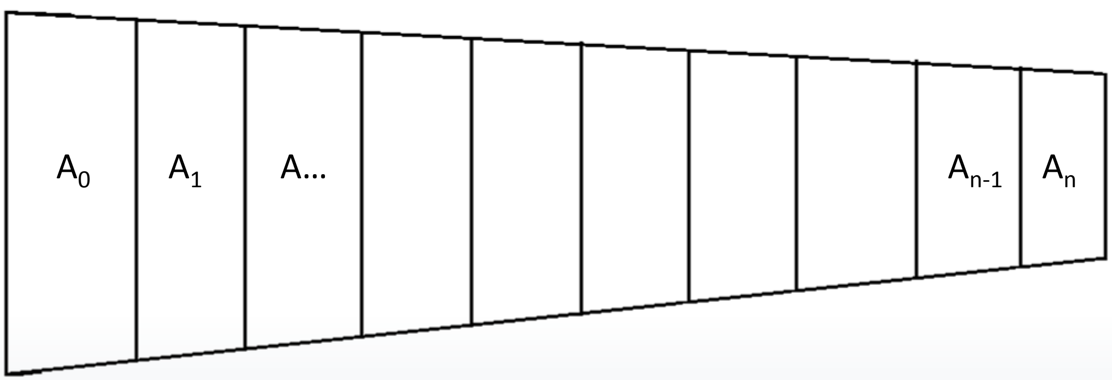
- Utilize rapid prototyping for ribs
- Acrylonitrile Butadiene Styrene (ABS)

  - Polymerization of Acrylonitrile, Butadiene, Styrene monomers.
  - High impact and mechanical strength

	Specific Gravity	Tensile Strength (Mpa)	Tensile Modulus (Mpa)	Flexural Strength (Mpa)	Flexural Modulus (Mpa)
ABS P400	1.04	22	1,627	41	1,834

Discretized Wing Element

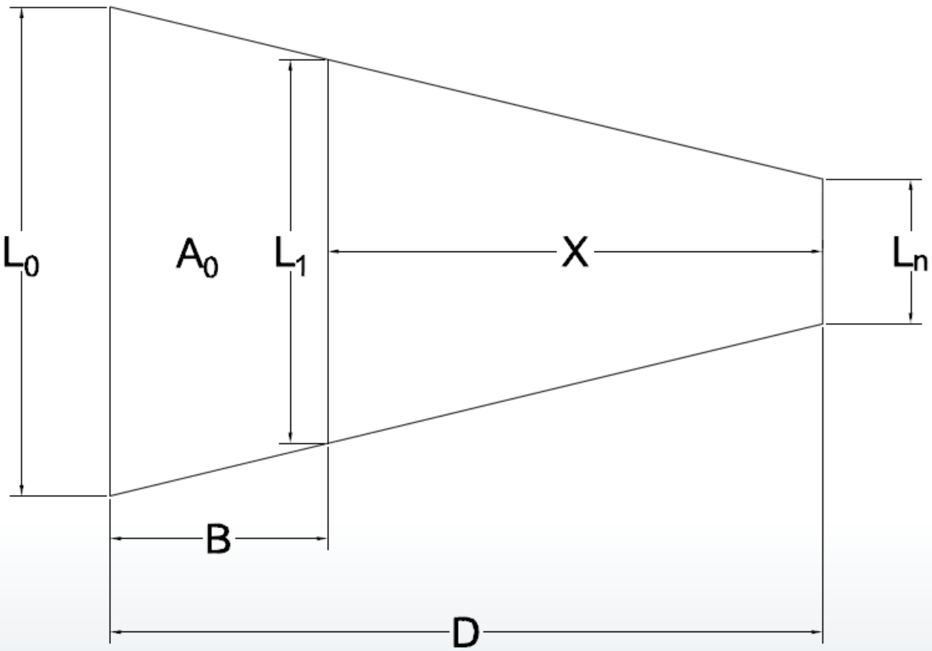
- Determine shear forces and torques across the wing
- Divide wing into sub elements
  - Sections represent distance between individual ribs



- Determine distance to fuselage and CG of each area

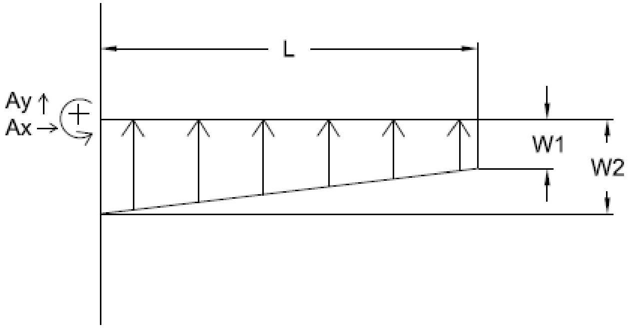
Mechanics of Materials Analysis

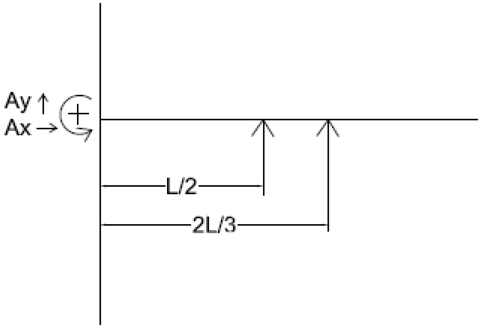
- Chord Length, L_1
  - $L_1 = L_n + \frac{x*(L_0 - L_n)}{D}$
- Section Area, A_0
  - $A_0 = \frac{B}{2}(L_1 + L_0)$
- Trapezoidal CG
  - $CG(x) = \frac{B}{3} * \frac{L_0 + 2L_1}{L_0 + L_1}$
  - $CG(y) = \frac{L_0}{2}$



Mechanics of Materials Analysis

- Shear Force = Pressure * Area
- Bending Moment = Shear Force * Moment Arm

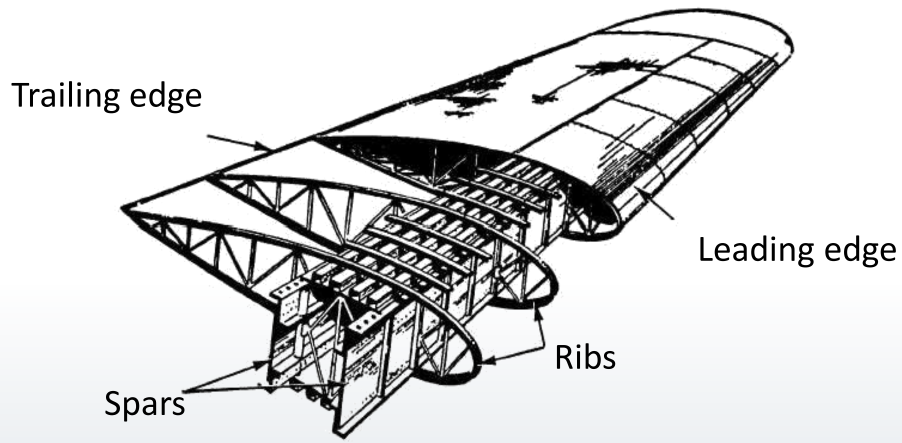


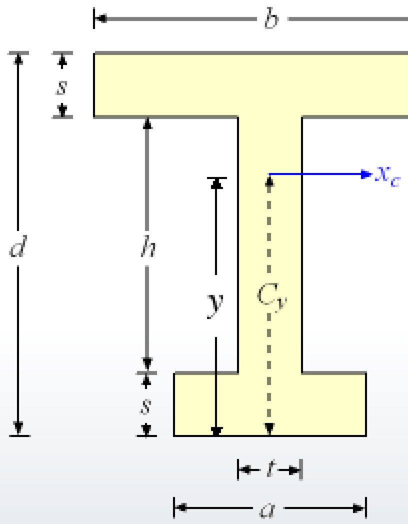


$$\Sigma M_A = \frac{L}{2}(W_1 L) + \frac{2L}{3}\left[\frac{(W_2 - W_1)L}{2}\right]$$

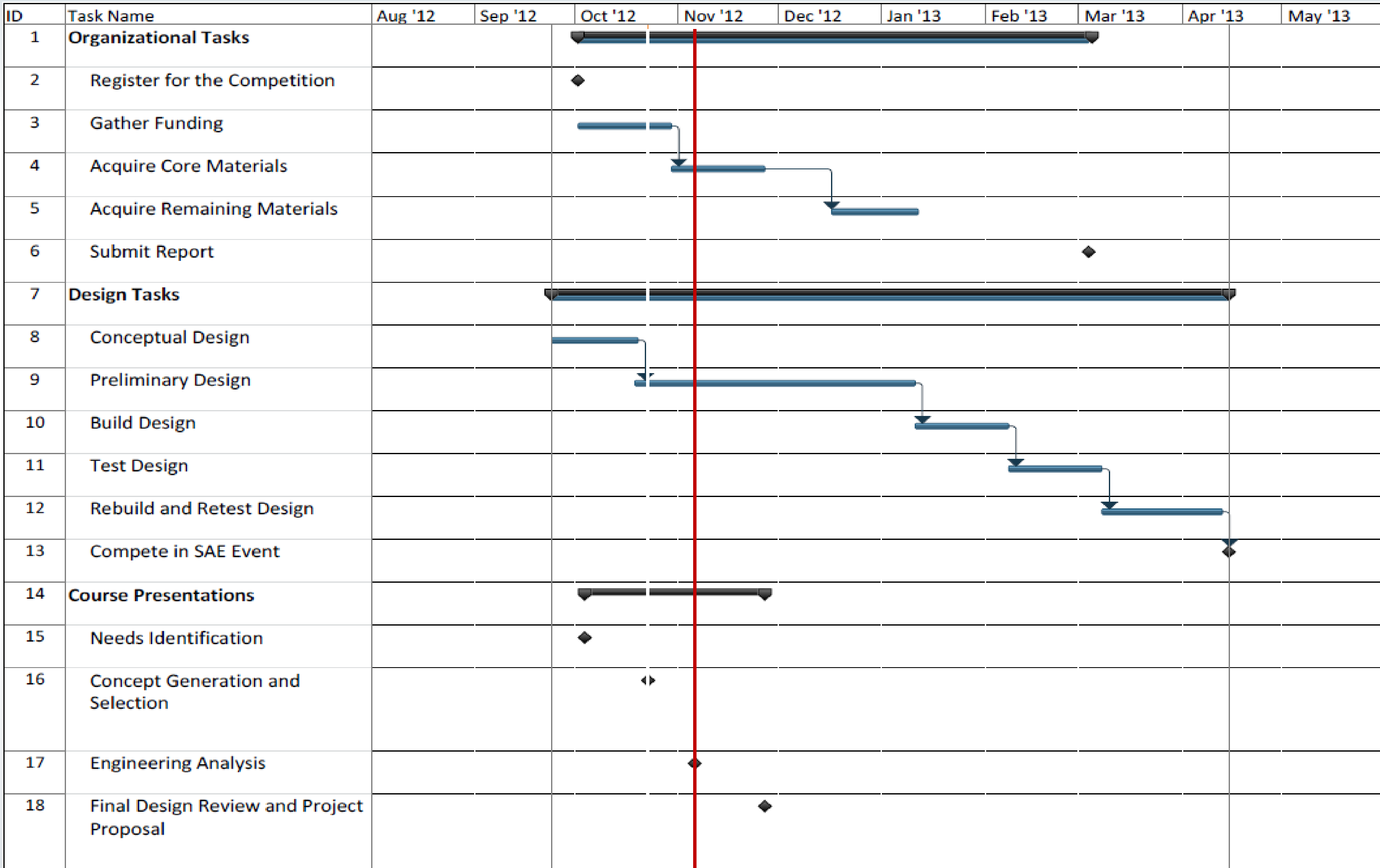
Stress Analysis

- Forces and moments at each rib location related to necessary supporting beam geometry





Project Timeline



Summary

- Static Analysis
- Aerodynamic Systems
- Propulsion Systems
- Structural & Material Considerations

References

[1] Raymer, Aircraft Design: A Conceptual Approach

[2] Johnson, Airfield Models, http://airfieldmodels.com/

[3] Anderson, Fundamentals of Aerodynamics

[4] https://store.amtekcompany.com/products.php?
product=Dimension-Standard-ABS-Model-Material-%25252d-P400

[4] http://www.rc-airplane-world.com/propeller-size.html

[5] Magnum XLS .61a Operating Instructions,
http://media.globalhobby.com/manual/210770.PDF

Questions?

Backup Slides: MATLAB Codes

```
%%%%%%%%%%%Calculate Reynolds Number%%%%%%%%%%%%
%% Input Environmental Variables
speed_ftps=15:.1:30;
%Predicted speeds from previous team's report
speed_mps=speed_ftps.*.3048;
chord=.35;
%[m] Assumes roughly 1/3 of a meter at root with
a taper
T=283.15;
%[K] from wunderground avg on 4/14
p=98532.6;
%[Pa] from wunderground avg on 4/14
R=287.04;
%[J/kg*K] Air
rho=p/(R*T);
mu=1.71E-5*(T/273)^0.7;
%[N*s/m^2] From Power Law eqn., Table A.2, pg.
826, Fluid Mechanics by White

%% Compute Secondary Variables
Re=(rho.*speed_mps.*chord)./mu;
%Theoretical Range
```

```
%%%%%%%%%Input Plane Dimensions%%%%%%%%%%%%%%%%
max_total_dim=(225/12)*.3048;            %[m]
w=6*.3048;                               %[m]
l=5*.3048;                               %[m]
h=2.75*.3048;                            %[m]
total_dim=w+l+h;                         %[m]

%%%%%%%%%Calculate Payload Potential%%%%%%%%%%
Wo=65*4.45;                              %[N]
Wpayload=25*4.45;                        %[N]
Wfuel=.25*4.45;                          %[N]
Based on 120g for 4oz fuel
Wengine=22.5*;                           %[oz]
Wengine=Wengine*.28;                     %[N]
Wempty=Wo-Wpayload-Wfuel-Wengine;

%%%%%%%%%%Calculate PayloadPotential%%%%%%%%%%
W=65*4.45;
Fy1=(5/6)*W;
x1=.5*.3048;
Fy2=W/6;
x2=x1*Fy1/Fy2;
```

Backup Slides: MATLAB Codes

```
%% Assumptions
Vinf=4.5:9;                     %m/s
L=289.13;                        %N
Wingspan=1.83;                  %m
Chordr=.35;                      %chord at root (m)
Chordt=.1;                       %chord at tip (m)
S=0.5*Wingspan*(Chordr-Chordt)+Chordt*Wingspan;
%Planform area triangle 6 ft wingspan and 1 ft chord

%% drag and lift Coefficients
TaperRatio=Chordt/Chordr;
AR=Wingspan^2/S;

de=.16;
%Assuming AR is about 10 (maxed) with
taper ratio of 0 from figure 5.20
e=(1+de)^(-1);

qinf=0.5*rho*Vinf.^2

CL=L./(qinf*S)
Cd=CL.^2/(pi*e*AR)

%% Prandtl scale
CL1=L./(max(qinf)*S);
AR1=Wingspan^2/S;
AR2=4:10;

Cd1=CL.^2/(pi*e*AR1);
Cd2=CL1^2./(pi*e*AR2);

CD=Cd2+CL1.^2./(pi*e)*((1/AR1)-(1./AR2));
```

```
%% Optimization
ARop=4:2:10;
Tratio=0:.1:1;
de4=1.9436*Tratio.^6-7.3838*Tratio.^5+11.402*Tratio.^4-
9.1872*Tratio.^3+4.1177*Tratio.^2-0.9323*Tratio+0.08;
de6=2.402*Tratio.^6-9.802*Tratio.^5+15.844*Tratio.^4-
12.989*Tratio.^3+5.8218*Tratio.^2-1.3172*Tratio+0.125;
de8=4.2892*Tratio.^6-15.352*Tratio.^5+21.865*Tratio.^4-
15.87*Tratio.^3+6.2977*Tratio.^2-1.2806*Tratio+0.1098;
de10=3.0392*Tratio.^6-10.945*Tratio.^5+16.38*Tratio.^4-
13.177*Tratio.^3+6.1703*Tratio.^2-1.5226*Tratio+0.1601;

Cdiop=zeros(length(ARop),length(Tratio));
for i=1:length(ARop)
    for j=1:length(Tratio)
        if i==1
            Cdiop(i,j)=(CL1^2/(pi*ARop(i)))*(1+de4(j));
        end
        if i==2
            Cdiop(i,j)=(CL1^2/(pi*ARop(i)))*(1+de6(j));
        end
        if i==3
            Cdiop(i,j)=(CL1^2/(pi*ARop(i)))*(1+de8(j));
        end
        if i==4
            Cdiop(i,j)=(CL1^2/(pi*ARop(i)))*(1+de10(j));
        end
    end
end

surf(Tratio,ARop,Cdiop)

title('Lift Induced Drag Optimization', 'FontSize',18)
ylabel('Aspect Ratio','FontSize',18)
xlabel('Taper Ratio','FontSize',18)
zlabel('Lift Induced Drag','FontSize',18)
rotate3d
```

Backup Slides: MATLAB Codes

```
% Request dimension and loading input
L=input('What is the length of the Wing?');
W1=input('What is the value of W1?');
W2=input('What is the value of W2?');


% Use statics to determine the overall forces
from the distributed load.

F1=W1*L;
F2=(W2-W1)*L/2;

% Sum moments about point A, or the point where
the spar is connected to
% the fuselage.

MA=L/2*(F1)+2*L/3*(F2);
```