SAE AERODESIGN EAST
CSULB – TEAM 218
A TAILLESS TALE

CONFIGURATION SELECTION

FOM	Weight	Conventional	Bi-Plane	Flying wing	Canard	Theoretical Ideal
Ease of Construction	0.80	3	2.5	3.5	2.5	5
Cost	0.40	3	2.5	3	3	5
Empty Weight	0.90	2.5	2	4	2	5
Handling Qualities	0.90	4	3.5	3.5	3	5
Historical Data	0.60	4	3.5	3	3	5
Total		**11.85**	**10.05**	**12.55**	**9.5**	**18**

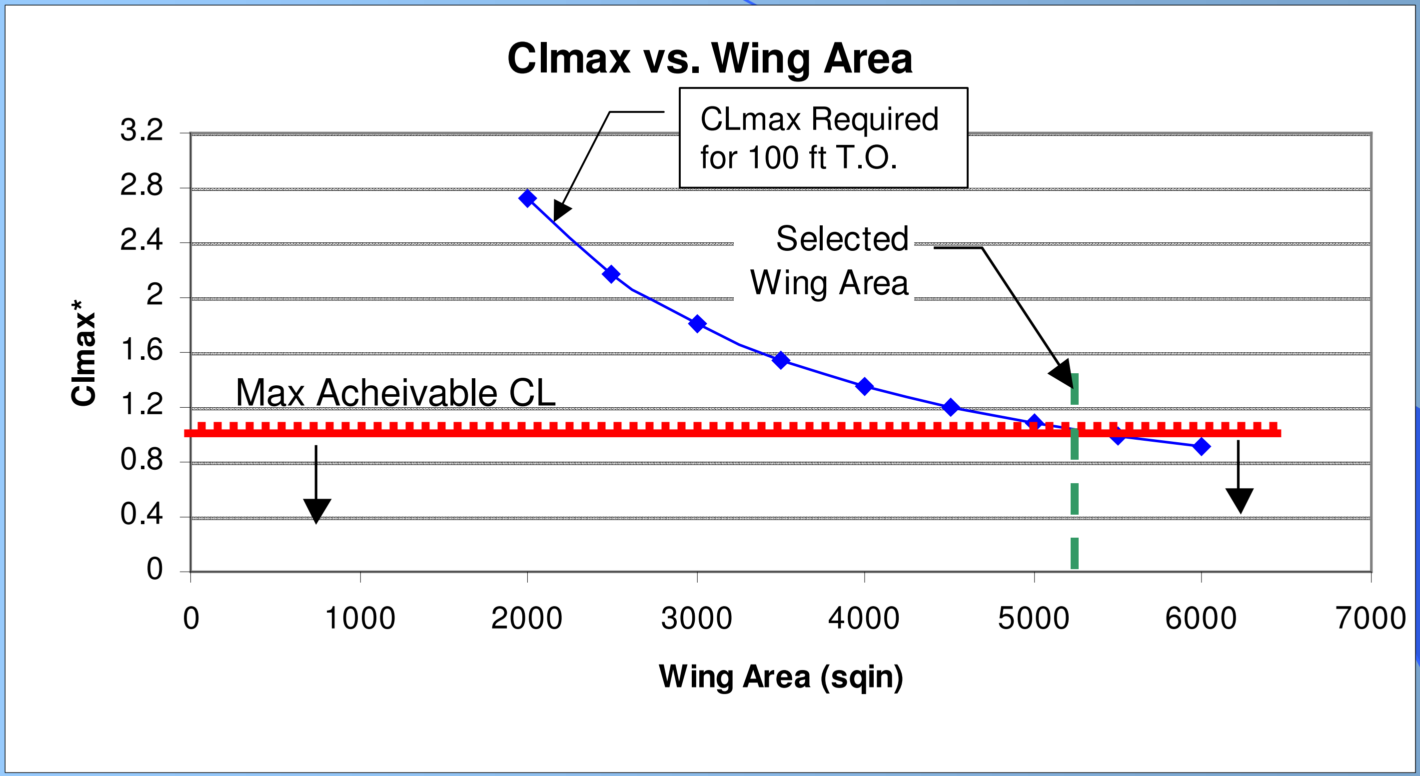
Figure 1 – Configuration Scoring Matrix

- Flying wing scores 6% higher than other types
- Primary risks:
  - Stability and Control
  - Lack of historical design data

PLANFORM SELECTION

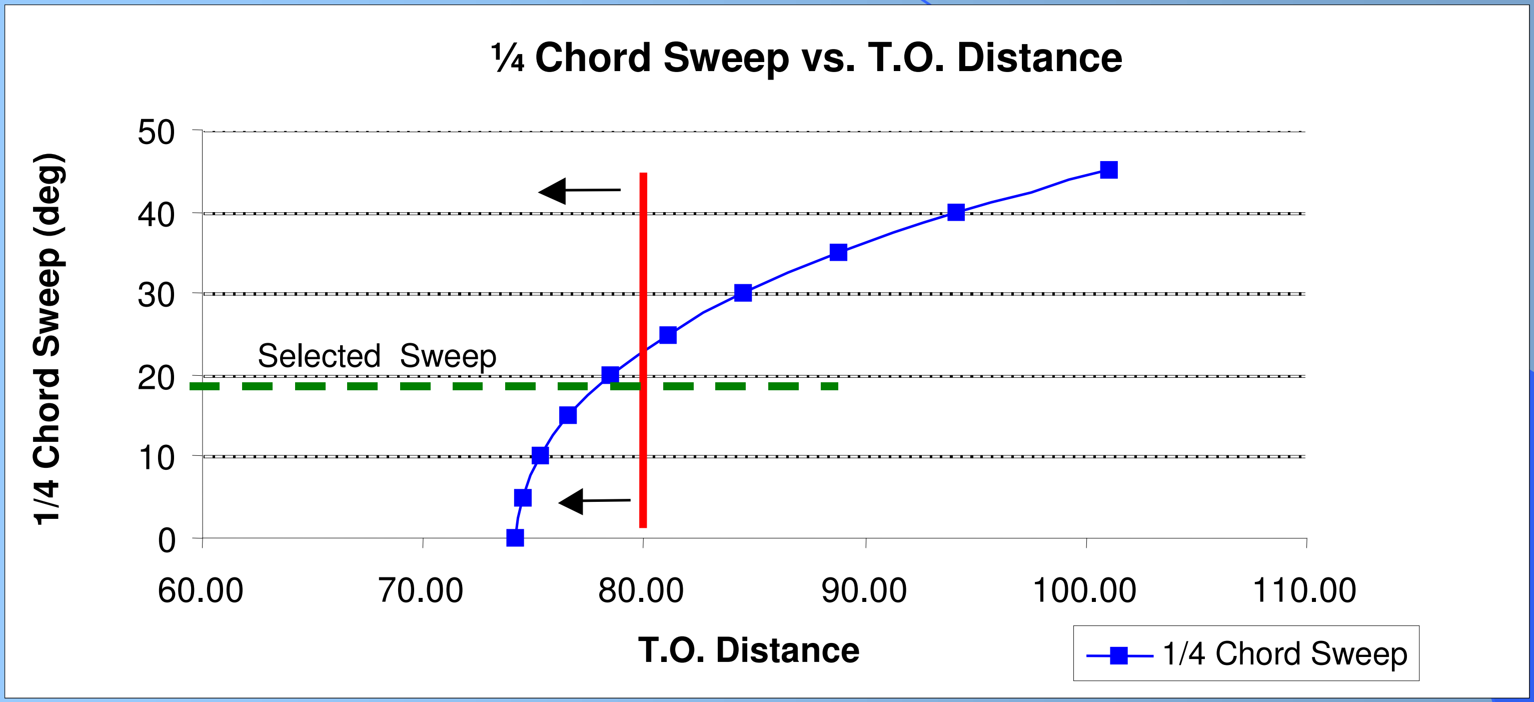
- 12’ Span chosen based on historical Open Class designs
- Center-body extension, ‘beaver tail’ designed to give increased control power for rotation
- LE Sweep = 25 deg

PLANFORM SELECTION



- Wing Area = 5300 sqin based on C_{Lmax} </= 1.0

PLANFORM SELECTION

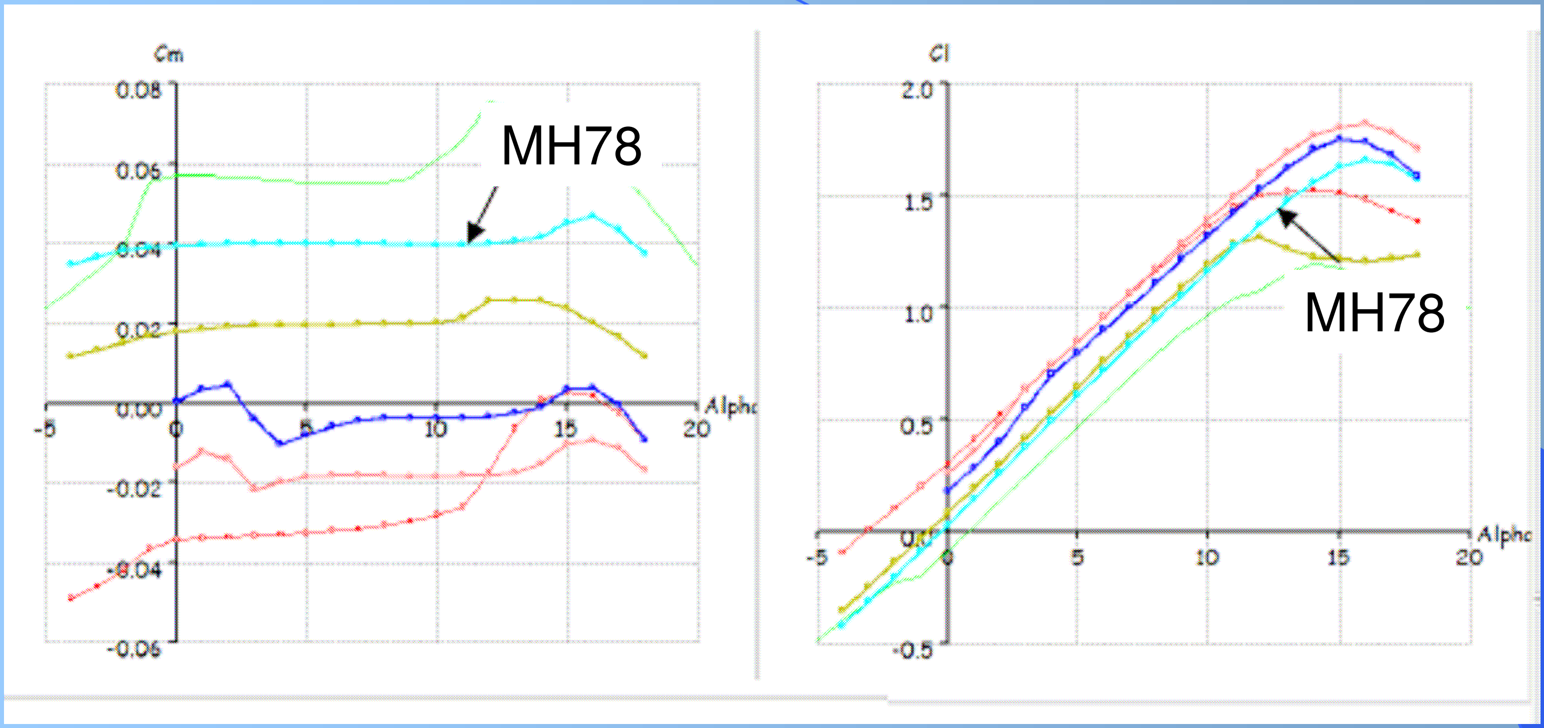


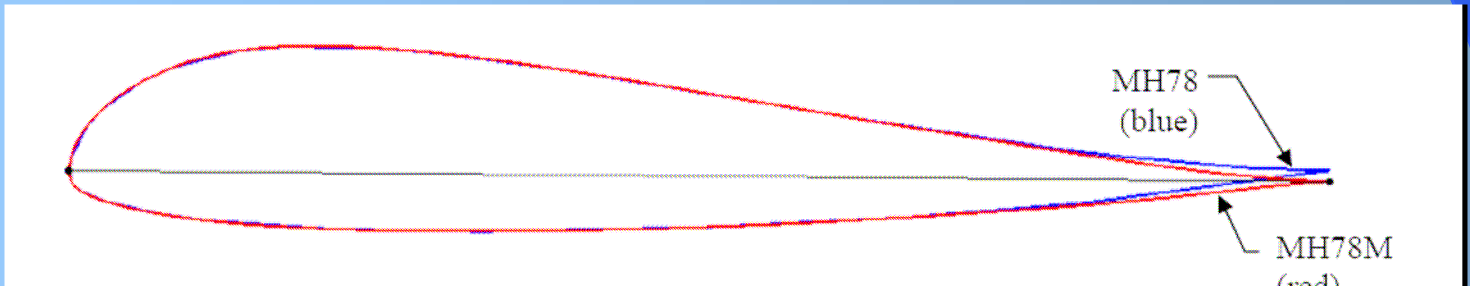
- ¼ chord sweep = 25 deg based on 20% takeoff distance margin

AERODYNAMICS

- Chose airfoil ‘reflex’ instead of wing washout to attain longitudinal stability
  - Does not reduce effective span
  - Easier to jig wing on constant waterline
- MH 78 Airfoil Chosen
  - Smooth Stall Characteristics
  - Positive pitching moment
  - Relatively high Clmax
  - Airfoil modified: Clmax = 1.75 (6% increase)

AERODYNAMICS





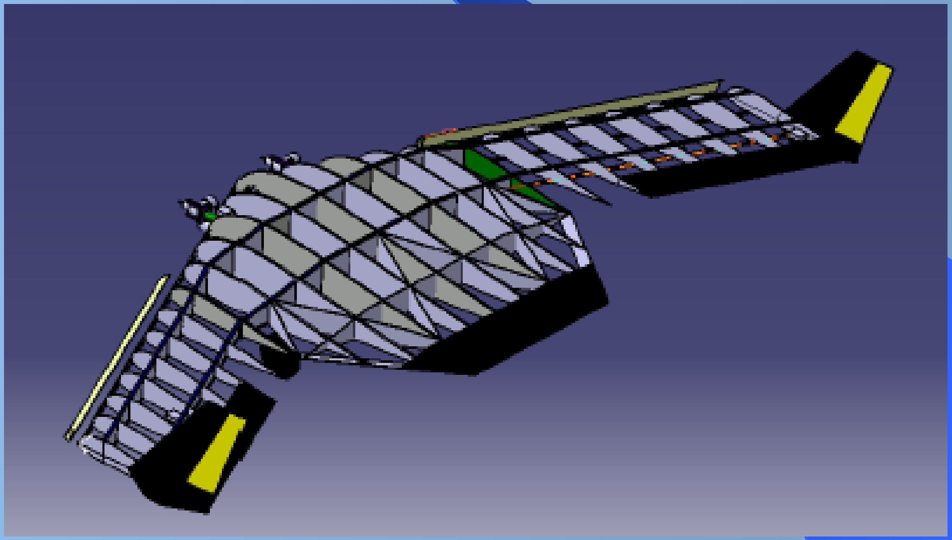
MH78 vs. MH78M

AERODYNAMICS

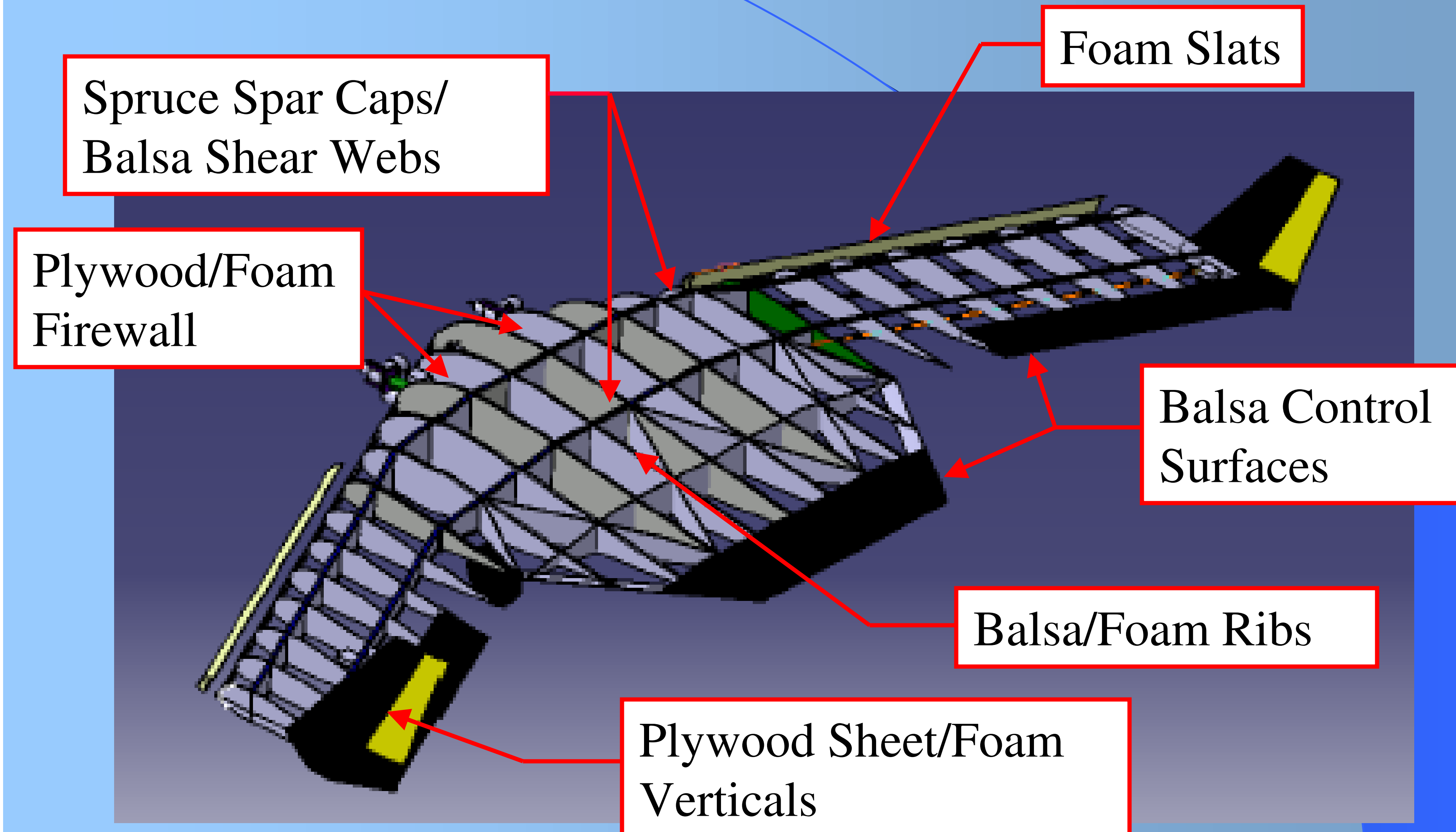
- $C_{Lmax} = 0.9\, C_{lmax}\, (\cos\Lambda_{.25c}) = 1.36$
  - 20% knockdown factor for gusts, maneuvering:
  - $C_{Lmax} = 1.08$
- Slats chosen for tip stall protection
  - Aileron effectiveness through stall
  - Increases CLmax by 0.15
- Winglets chosen for increased directional stability
  - T.O. performance
  - dCl/dalpha increased by 7.5%

WEIGHTS AND BALANCE

- 3D CAD used to estimate Mass Properties
- 15 Lb empty weight, 5% Static Margin CG goal
- As Built at 4% CG location, 25.5 Lb Empty Weight
- Payload bay located on CG
- Discrepancy mainly due to glue weight, leading edge sheeting, and structural reinforcements.

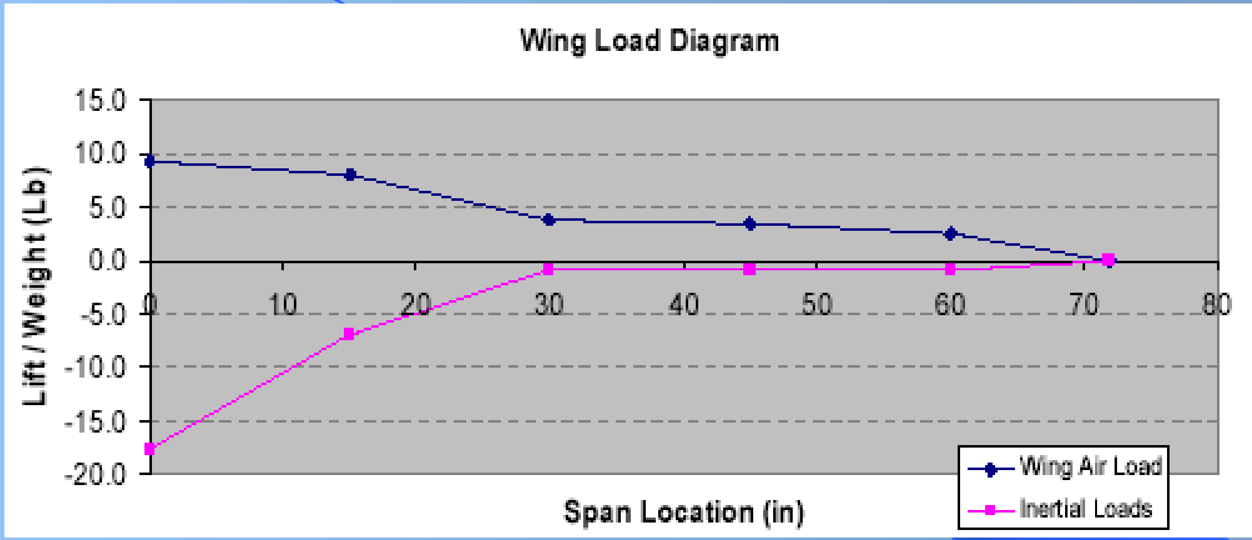


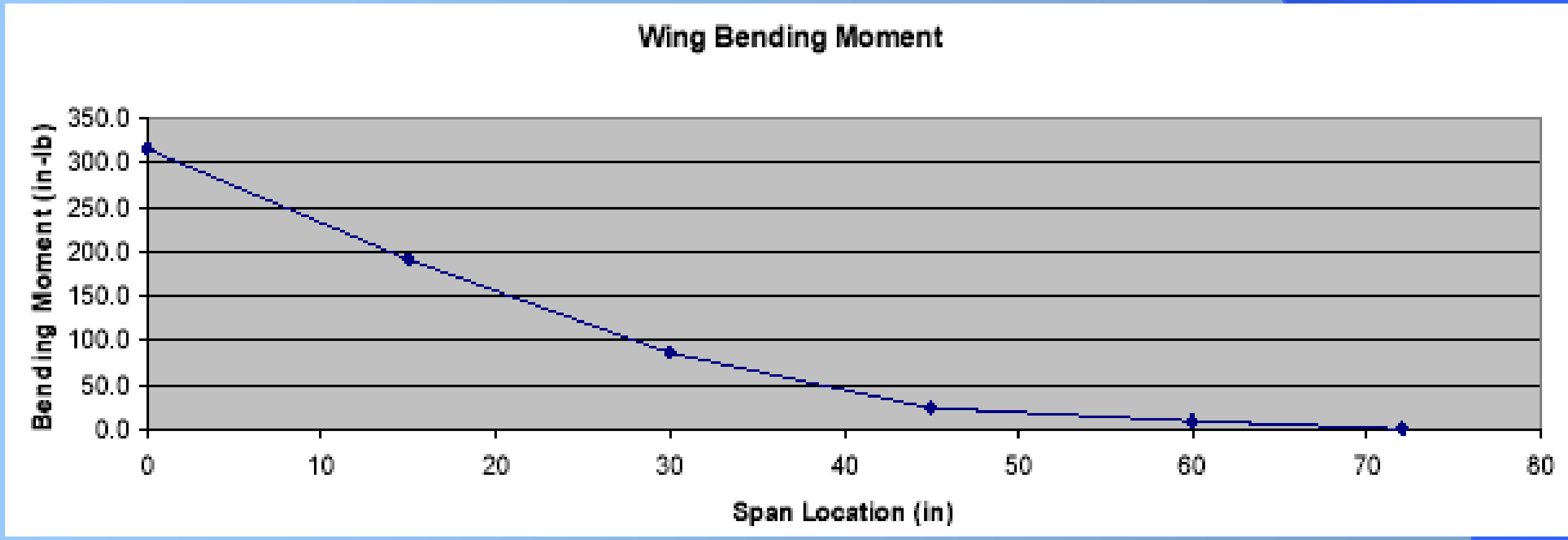
STRUCTURES - Layout



STRUCTURES – Spar Sizing

- 2G Spar Ultimate Load
- Two Spar Layout
- Spruce Spar Caps, Balsa Web.





STABILITY AND CONTROL

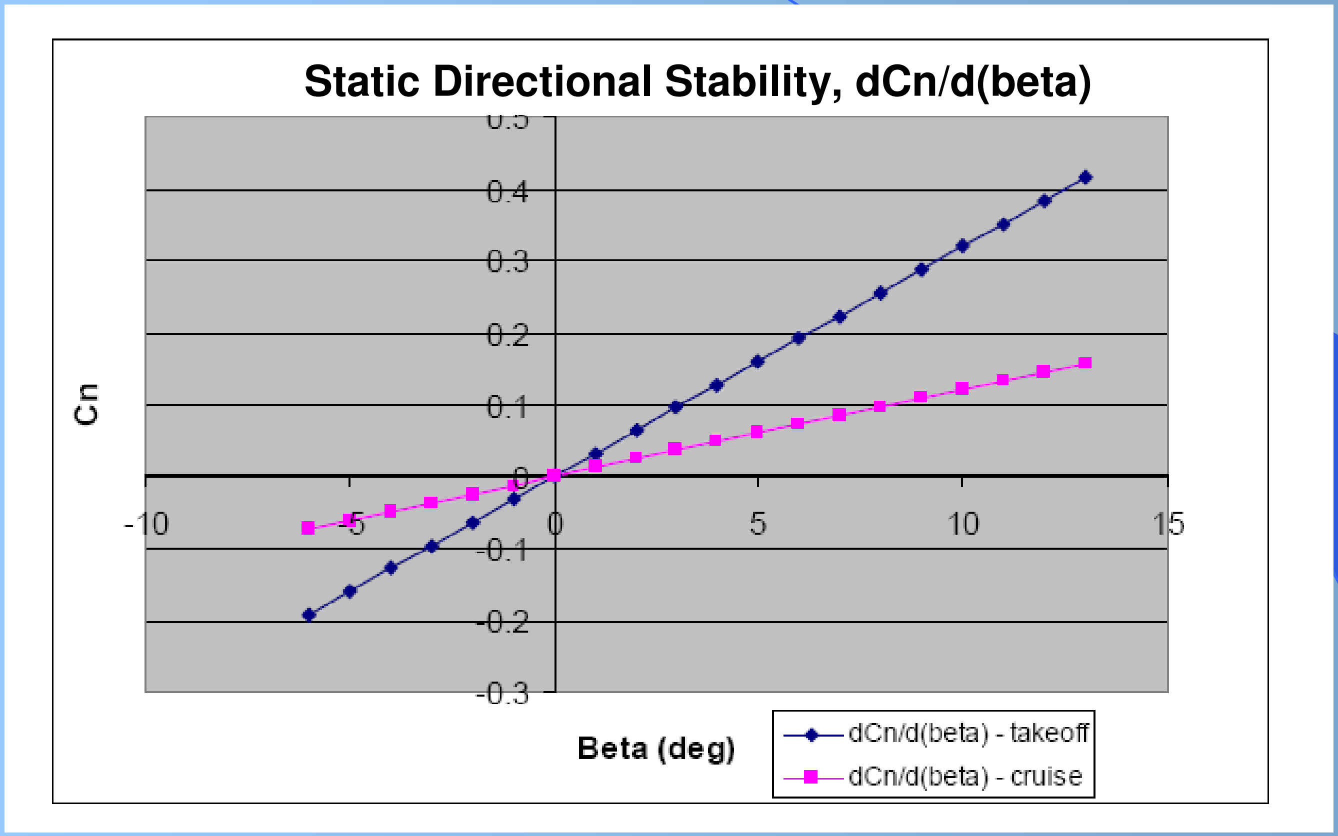
- Static longitudinal stability, dCm/dCl, given by Static Margin:

$$dCm/dCl = -\ SM = (X_{AC} - X_{CG}) / MAC$$

  - Design goal dCm/dCl < -.05
  - Compromise between flight characteristics and performance
  - Wing Aerodynamic Center calculated by Vortex Lattice
  - CG calculated by CATIA model

- Static directional stability, dCn/dbeta, calculated per DATCOM
  - Design goal dCn/dbeta > .001
  - Based on LE sweep and vertical tail volume
  - Calculated in XCEL, dCn/dbeta = .012 at cruise and .032 at takeoff

STABILITY AND CONTROL



STABILITY AND CONTROL

- Control power was assessed for takeoff rotation
  - TE deflections in linear range (less than 20 deg)

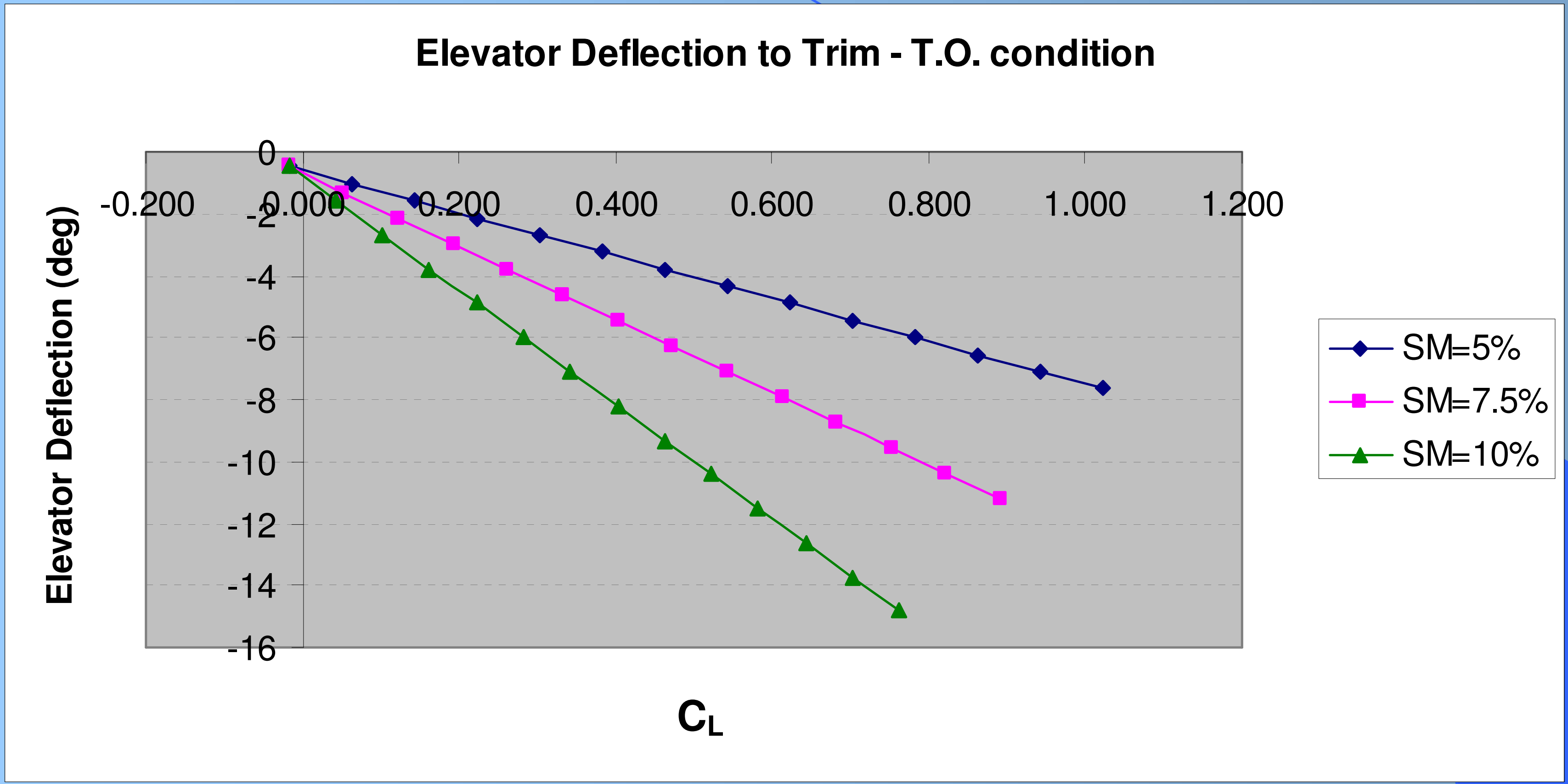
$$\eta_{rotation} = (C_{Mow} + C_{Mcg})/(dC_m/d\eta) = (0+0.138)/(-.012) = -11.5 \text{ deg}$$

- TE deflections to trim and trimmed AOA calculated for various static margins

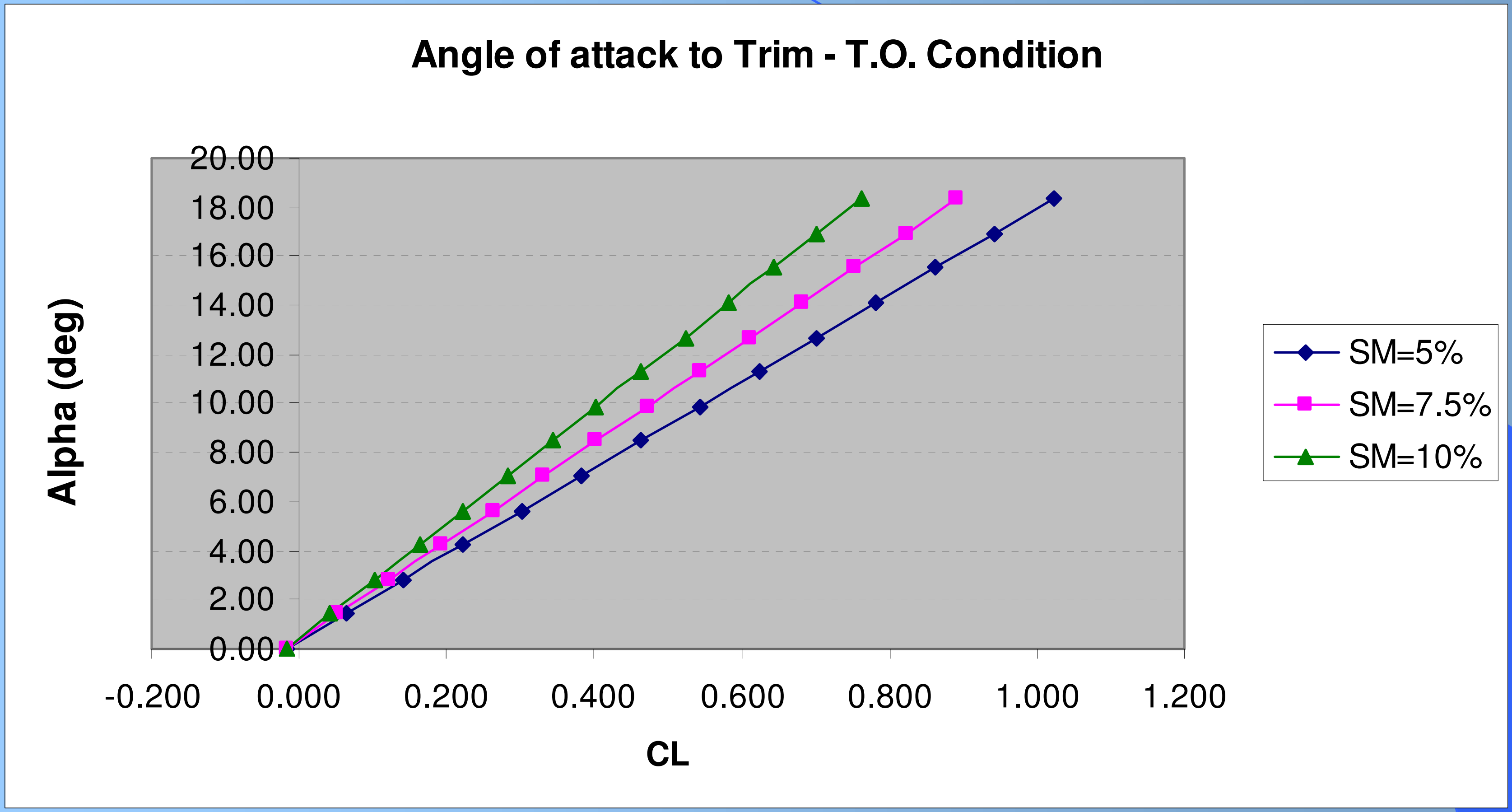
$$d\eta_{trim} = [-1/(dC_L/d\eta)]\,[(C_L(X_{AC} - X_{CG})/0.25) + C_{L0}]$$

- 20% scale glider built and flown, confirming longitudinal and directional stability

STABILITY AND CONTROL



STABILITY AND CONTROL



PROPULSION

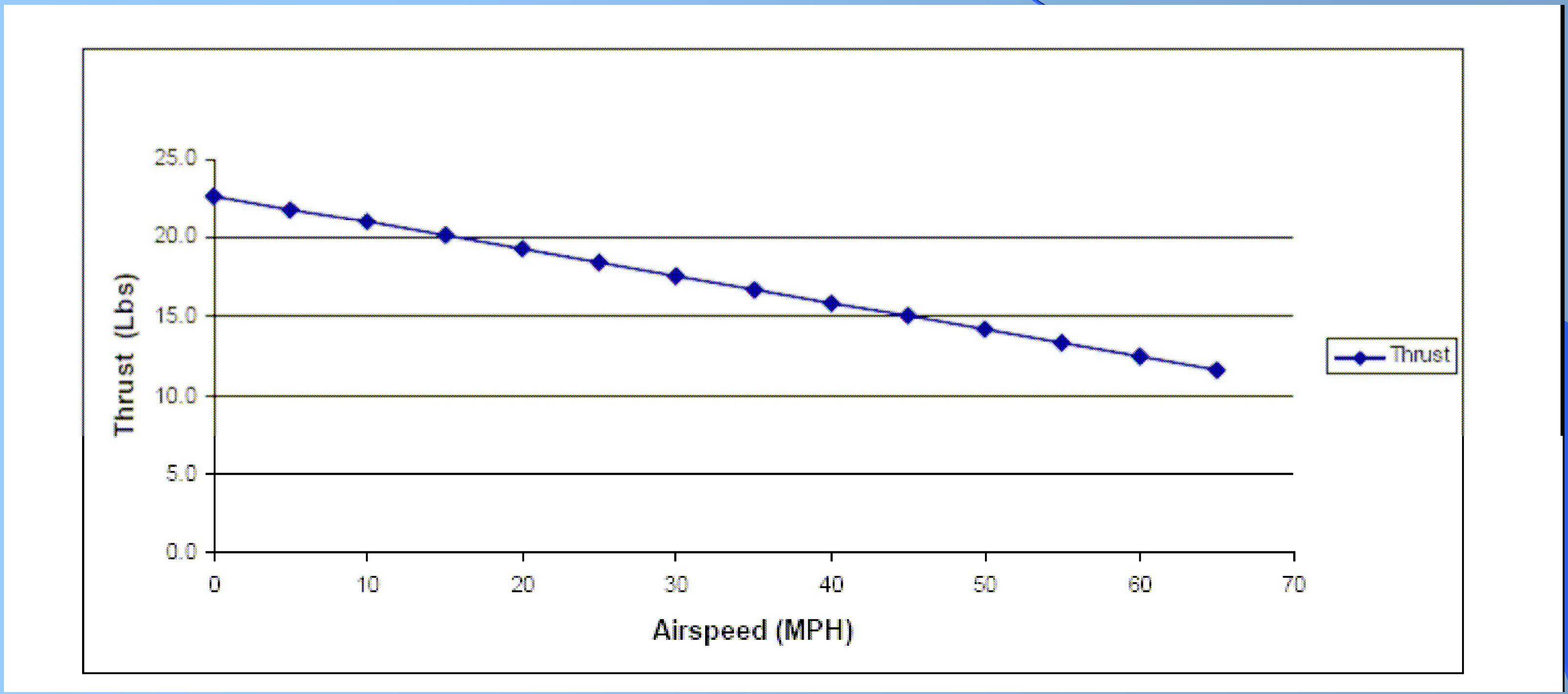
- Static thrust calculated by:

$$T_{static} = Ct/Cp[550bhp/(nD)]$$

- Engine test stand data used for HP and RPM of various propellers on Tower Hobbies 0.61 engine

Prop Dia	Prop Pitch	RPM	Torque (lb-ft)	Static Thrust (lb)
11	6	14450	0.54	10.7
11	7	14150	0.57	11.3
11	8	12850	0.53	10.2
11	11	10950	0.56	7.2
12	6	12150	0.53	9.7
12	7	11250	0.54	9.3
13	7	10450	0.58	9.6
12.5	9	9750	0.55	9.8

PROPULSION



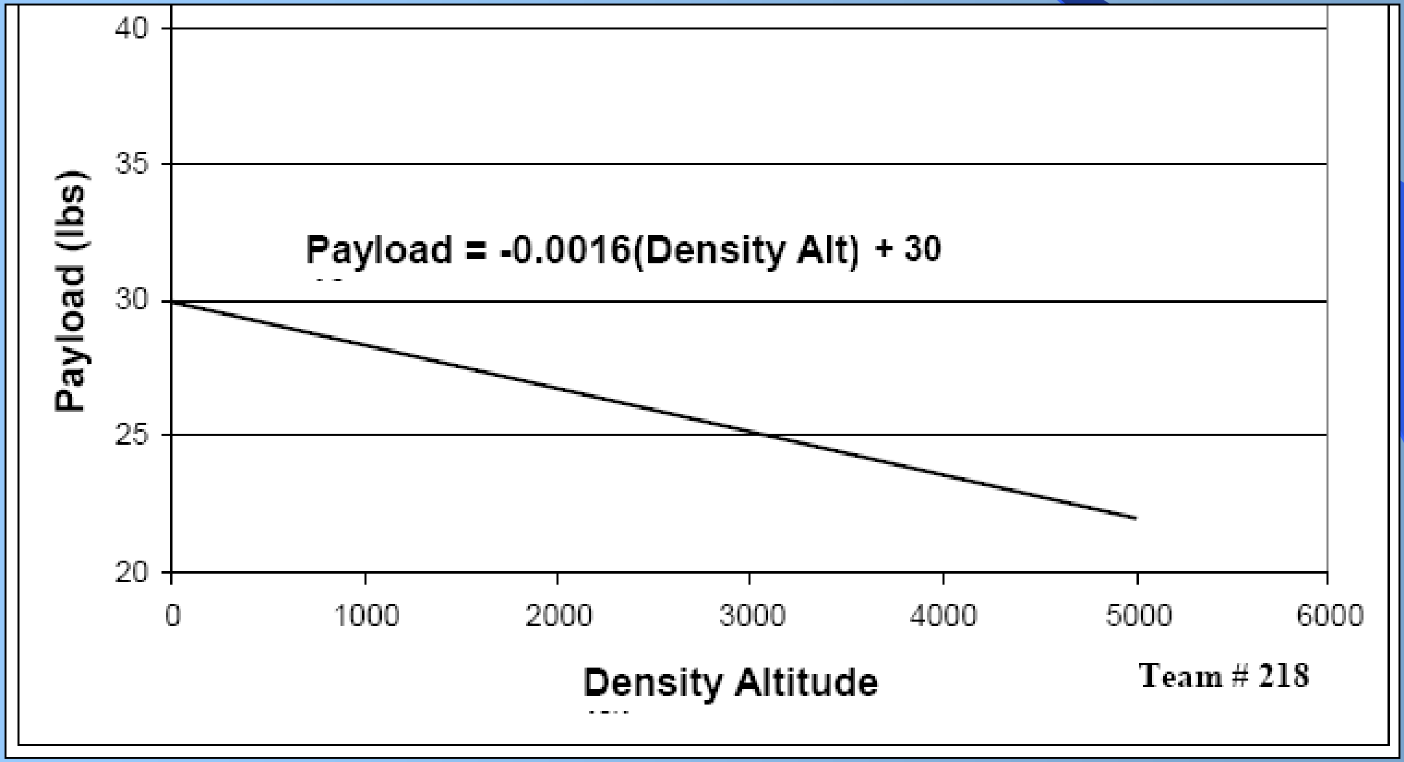
Airspeed vs. Dynamic Thrust

PERFORMANCE

- Skin friction drag and induced drag were calculated by:
  - Cdmin : $C_{D0} = \Sigma(C_{fc}FF_cQ_cS_{wetc})/Sref + C_{Dmisc}$
  - Cdinduced : $C_{di} = C_L^2 / \pi ARe$
- Low speed L/D vs. CL calculated in Excel
- T.O. distance was mostly a function of wing loading, density altitude, and CLmax

PERFORMANCE

Max Payload for 100ft T.O.



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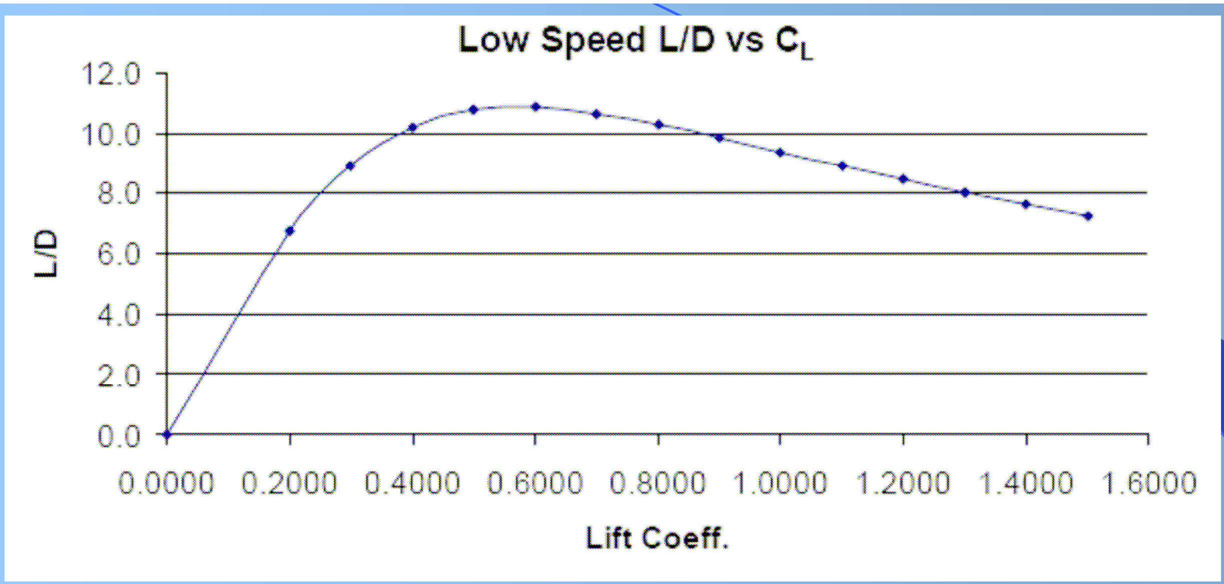

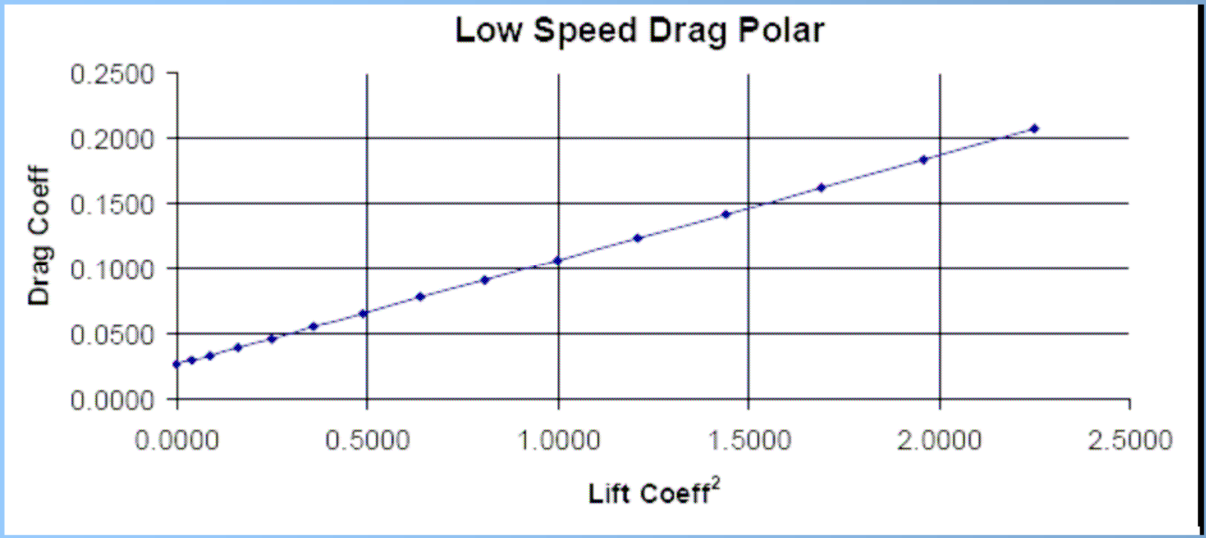

FLIGHT TEST / FLYING QUALITIES

- Takeoff Characteristics
  - Rotation Control Power
  - Thrust margin at climb
- Low speed handling qualities
  - Pitch
  - Yaw
  - Roll
- Cruise handling qualities
  - Pitch
  - Yaw
  - Roll
- Landing Characteristics
  - Ability for stable, low speed approach
  - Float or flare characteristics

CONCLUSION

- Flying Wing configuration closed on SAE Open Class performance requirements
- Designing and building a flying wing provided unique challenges which enhance the team's understanding of aircraft design
- Look forward to demonstrating our 'unusual' configuration to our competitors