SAE Aero Design

Group 10

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Competition Assessment

$$Final\ Flight\ Score = i\ x\ (Best\ Flight\ Score)$$

$$i = 1 + (Ao - 40\%)\ x\ .25$$

Target A_o for Regular Class 2012 will be 40%

$$A_o = \frac{[\text{Successful Flight Round}]}{[\text{Successful Flight Round}] + [\text{Missed Flight Round}]}$$

$$FS = RAW + PPB + EWB - TP$$

RAW = Raw Weight Score
PPB = Prediction Point Bonus
EWB = Empty Weight Bonus
TP = Total Penalty Points

$$RAW = W \times 4$$

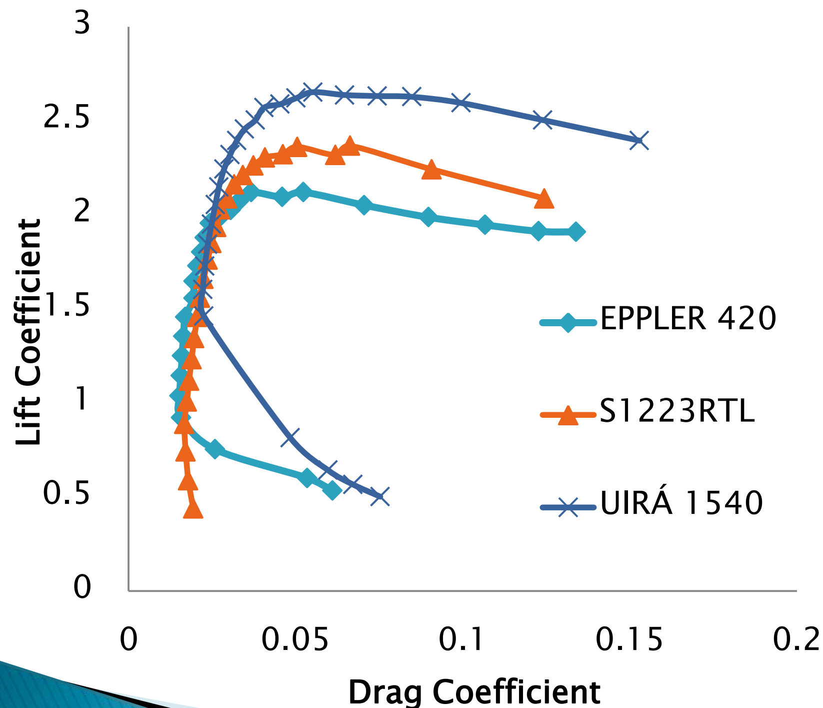
W = Weight Lifted in Pounds

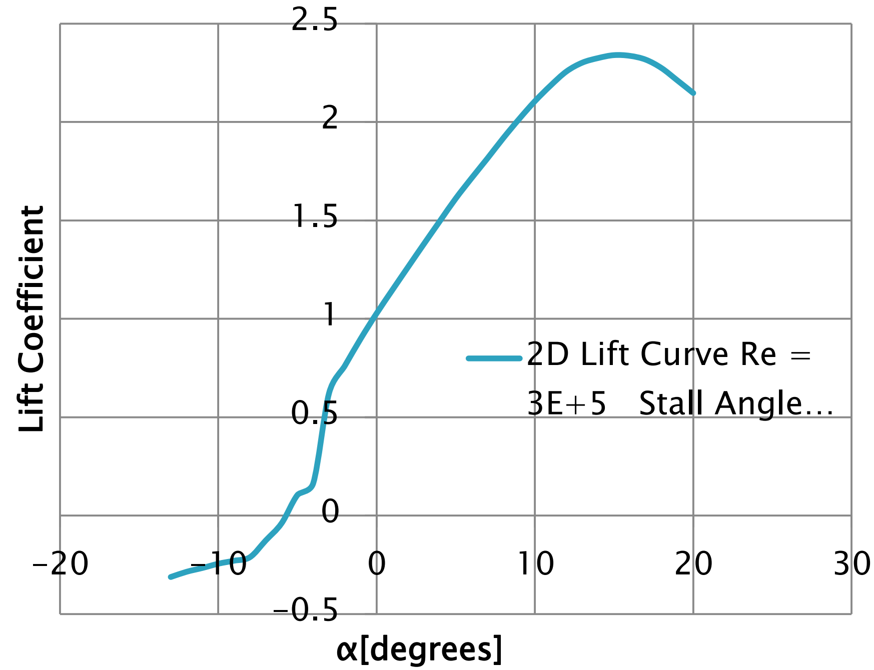
$$PPB = 20 - (P_{Predicted} - P_{Actual})^2$$

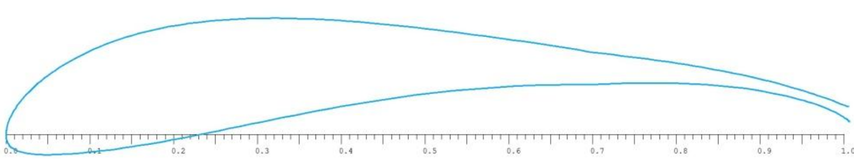
$P_{Predicted}$ = Predicted Payload
P_{Actual} = Actual Payload

Wing Profile

- Knowing the MTOW, we find $C_{L_{Design}} = 1.94$
- According to the literature(Abbot), the vortex effects decrease 20% of the aircraft`s lift coefficient.







Airfoil data calculate for Cl_max

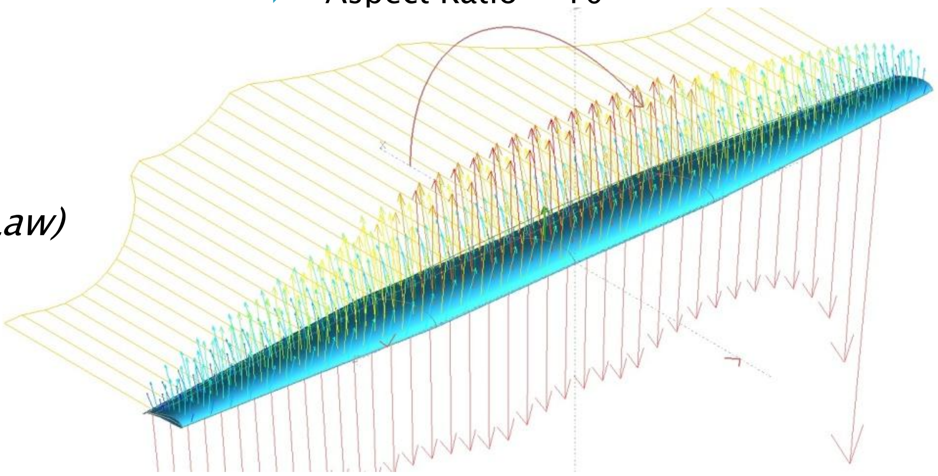
Lift Coefficient = 2.34
Drag Coefficient = 0.048
L/D = 48.8
Moment Coefficient = -0.202

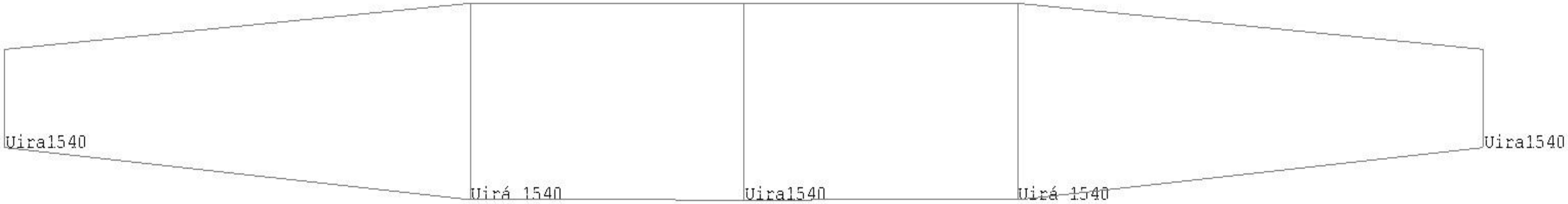
Wing Design

•The software utilized was the Cea-*VLM (vortex lattice method)*

- Several iterations were made varying:
  - *Wingspan*
  - *Wing root and chord*
  - *Taper ratio and its position*
- considering it's consequences to:
  - *Wing weight (estimated via the Cubic Law)*
  - *Wing lift and drag*
- this process was monitored by the:
  - *Oswald 's factor*

- Wing span = 2.7 m
- Root Chord = 0.32m
- Tip Chord = 0.16 m
- M.A.C = 0.28 m
- Tip Twist = - 2 degrees
- Wing Area = 0.728 m^2
- Aspect Ratio = 10

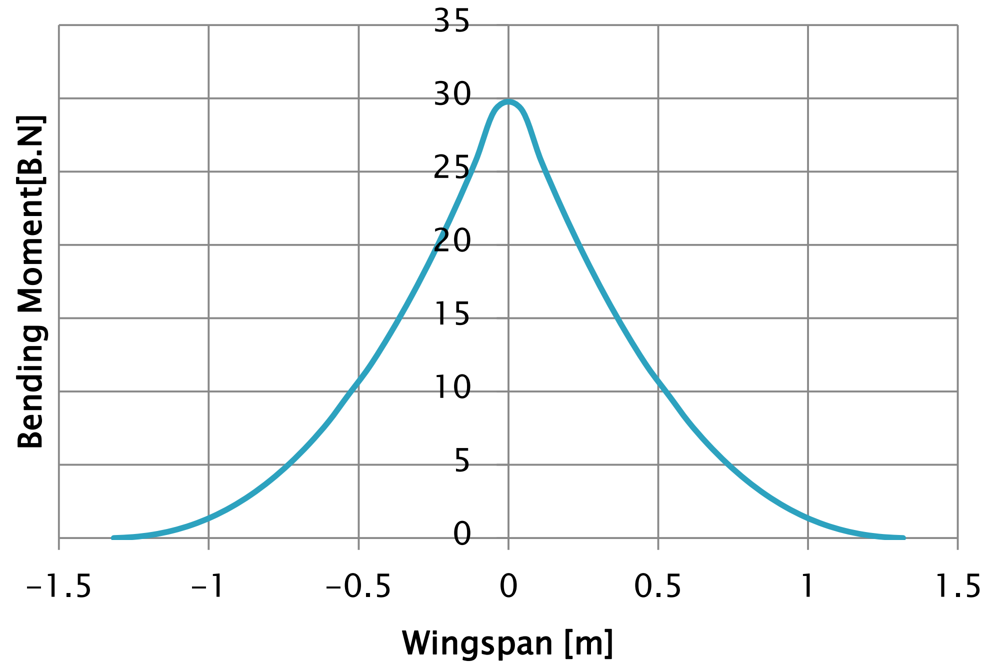


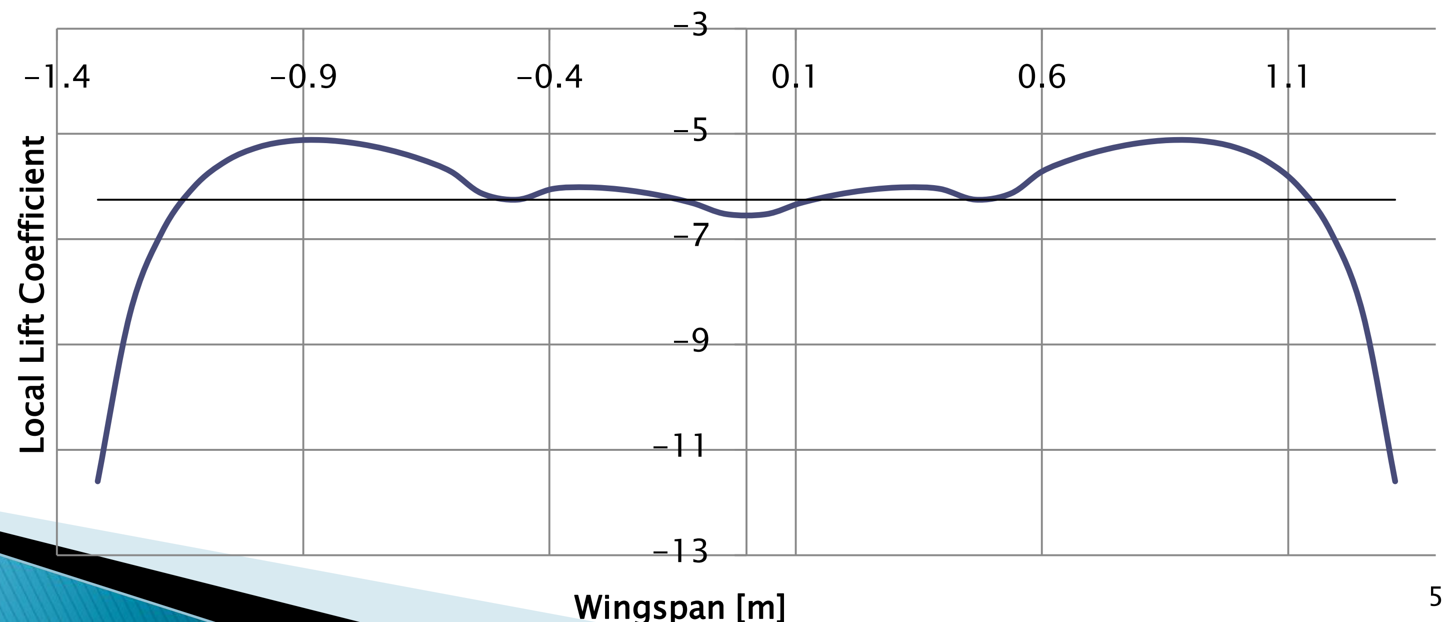


Wing Loads

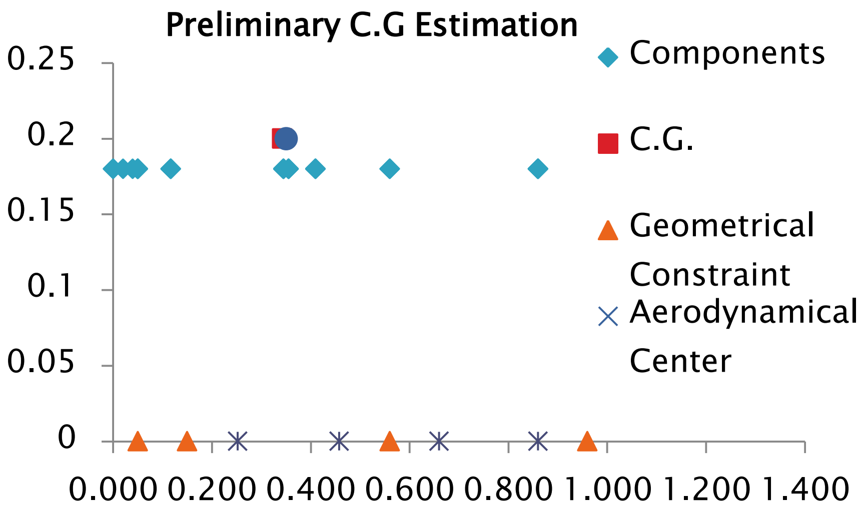
•The wing loads were estimated utilizing the methodology proposed by Schrenk

•In a later analysis this data will be used to size the wing spar by using finite element methods





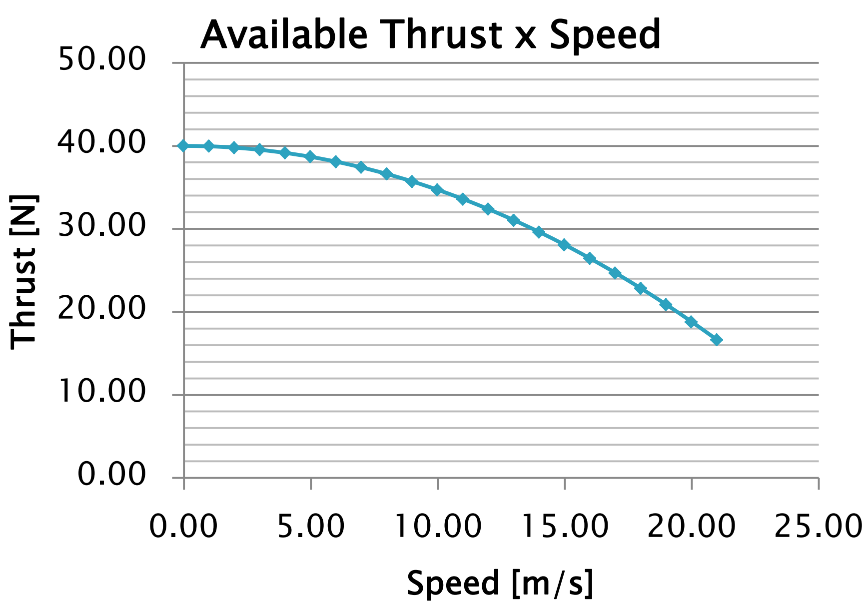
Performance Calculations

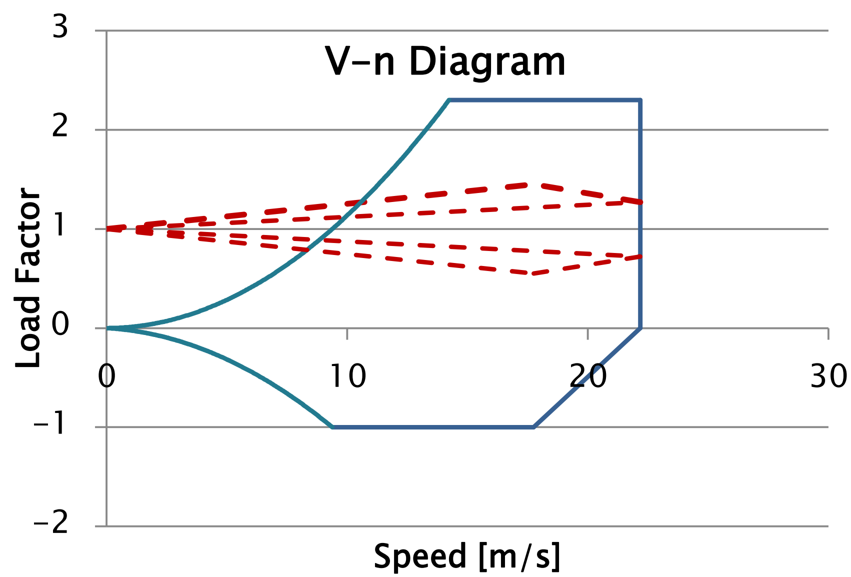


- The components will be positioned according to the overall effect that they have on C.G.
- The V-n Diagram gives an overview of the flight envelope by relating its velocities to the load factor that the aircraft will undergo under that speed.

Performance Parameters

Climb Angle	5.1670	degrees
Rate of Climb	0.1920	m/s
Vstall	10.6832	m/s





Takeoff Gross Weight

- $W_o = W_{payload} + W_{fuel} + W_{empty}$
  - $W_{payload}$ can assume a value of about 35.3 lbs which was the max payload of last year's 1st place aircraft
  - W_{fuel} can be determined using the following givens and relations:
    - Given:
      - $\rho_{fuel} = 1.1371\ g/cm^3$; $V_{tank} \approx 350\ cm^3$; $g = 9.81\ m/s^2$
      - $W_{fuel} = \rho_{fuel}\ x\ V_{tank}\ x\ g \approx 3.904\ N \approx 0.8777$ lbs
  - W_{empty} can be estimated using a minimum ratio of 0.2 (W_e / W_o)
    - $W_o = \dfrac{W_{payload}}{1 - \frac{W_{fuel}}{W_o} - \frac{W_e}{W_o}} = \dfrac{35.3}{0.8 - \frac{0.8777}{W_o}} \cong 45.22$ lbs
    - $W_e = W_o - W_{payload} - W_{fuel} = 9.0423$ lbs
  - $W_o \leq 55$ lbs

Fuselage – Sizing

- Using the W_o as 45.22 lbs, we can now size the fuselage (theoretically) using the following equation,
  - $Length = aW_o{}^C$

    where "a" and "C" are constants based on a powered sailplane and respectively assume values of 0.71 and 0.48

  - $Length =$ 4.424 ft
- Average diameter can be calculated using a fineness ratio (FR) of 8 and the length of the fuselage
  - $FR = \frac{L}{D_{avg}}$ $D_{avg} = \frac{4.424}{8} =$ 6.396 in (circular)
- If the cross section is noncircular, the height and width can be attained using the relation,
  - $D_{avg} = \frac{H+W}{2}$ If we set H = 2W for clearance purposes
  - W = 4.264 in H = 8.528 in (rectangular)

Fuselage – Drag Calculations

- Wetted Area Estimation (blunt body)
  - $A_w = Perimeter \times Length$
    - *Circular Cross Section*: $A_w = \pi(0.553\ ft) \times 4.424\ ft$
      - $A_w \approx$ 7.686 ft^2
    - *Rectangular Cross Section*: $A_w = 2(4.264 + 8.528) ft \times 4.424\ ft$
      - $A_w \approx$ 113.18 ft^2
- Drag Estimation

$$F_d = qA_wC_f$$

Assume: q = 1.0665 lb/ft^2 Re = 300,000 (laminar)

- ***Circular Cross Section***

$$F_d = \left(1.0665 \frac{lb}{ft^2}\right)(7.686 ft^2)\left(\frac{1.328}{\sqrt{300{,}000}}\right) = 0.0199\ lbs$$

- ***Rectangular Cross Section***

$$F_d = \left(1.0665 \frac{lb}{ft^2}\right)(113.18 ft^2)\left(\frac{1.328}{\sqrt{300{,}000}}\right) = 0.293\ lbs$$

Payloads

- With an approximated payload $W_{payload} = 35\ lbm \approx 16\ kg$ we can approximate the volume of the payload based on densities of various common metals and their corresponding cost, and decide on a material for the payload.

Material	Density (gm/cm^3)	Cost (USD/kg)	Volume (in^3)	Cost (USD)
Steel Alloy	7.85	0.5	123.414	7.94
Stainless Alloy	8	2.15	121.1	34.13
Gray Cast Iron	7.3	1.2	132.712	19.05
Copper Alloy	8.5	3.2	113.976	50.8

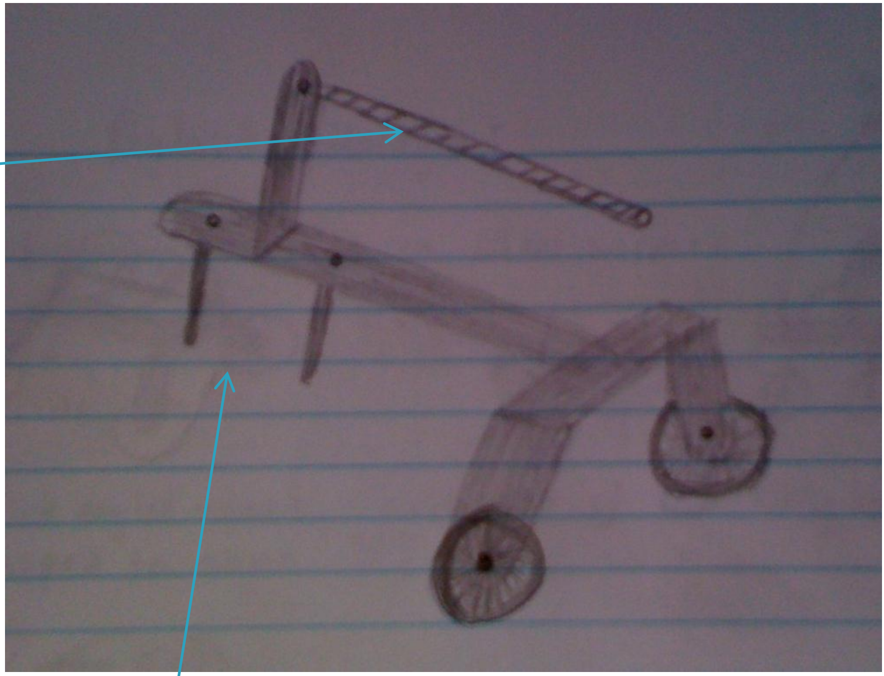
- From this analysis our payload will likely be Steel

*Data selected from Callister 7th edition

Payload Structure

Initial Concept:

- Threaded shaft running horizontally down fuselage
- Allows for:
  - Weights to be spun and still with help of wing-nuts
  - Adjusting of Center of Gravity



Potential front wheel locations (must be steerable)

Landing gear support made of a resilient composite material, Kevlar matrix and epoxy.

Engine Mount

- Engine will be a Magnum xls 61
- No "standard" mount on the market
- Adjustable mount is suggested
- Inexpensive~$4-$6
- Very effective

http://www.hooked-on-rc-airplanes.com/model-airplane-engine.html

- There exist many variations
- Essentially the same
- Attaches directly to the fuselage
- Decision will be made upon final shape of fuselage

http://www.activepowersports.com/great-planes-adjustable-engine-mount-60120-gpmg1091/

Tail Booms

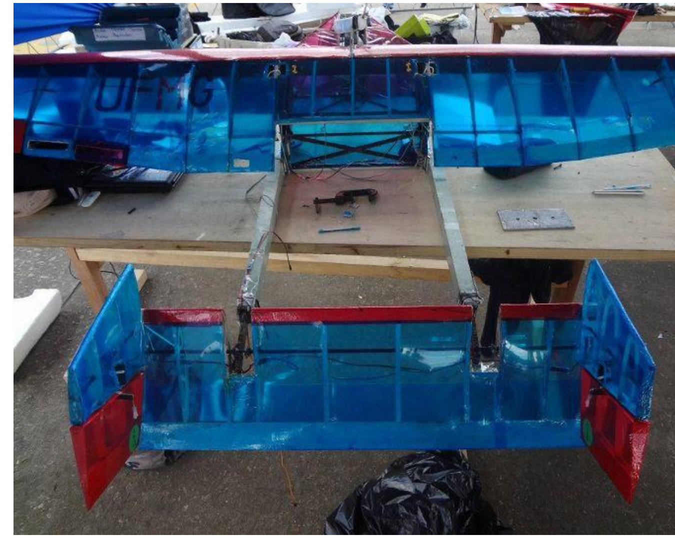
http://www.me.mtu.edu/saeaero/images/IMG_1215.JPG

Conventional:

- Commonly used in commercial passenger aircraft as cargo area
- Design
  - Flush with fuselage
- Strength:
  - Good torsion resistance
- Weight:
  - Heavier weight in comparison to other options of tail booms.

Pipe:

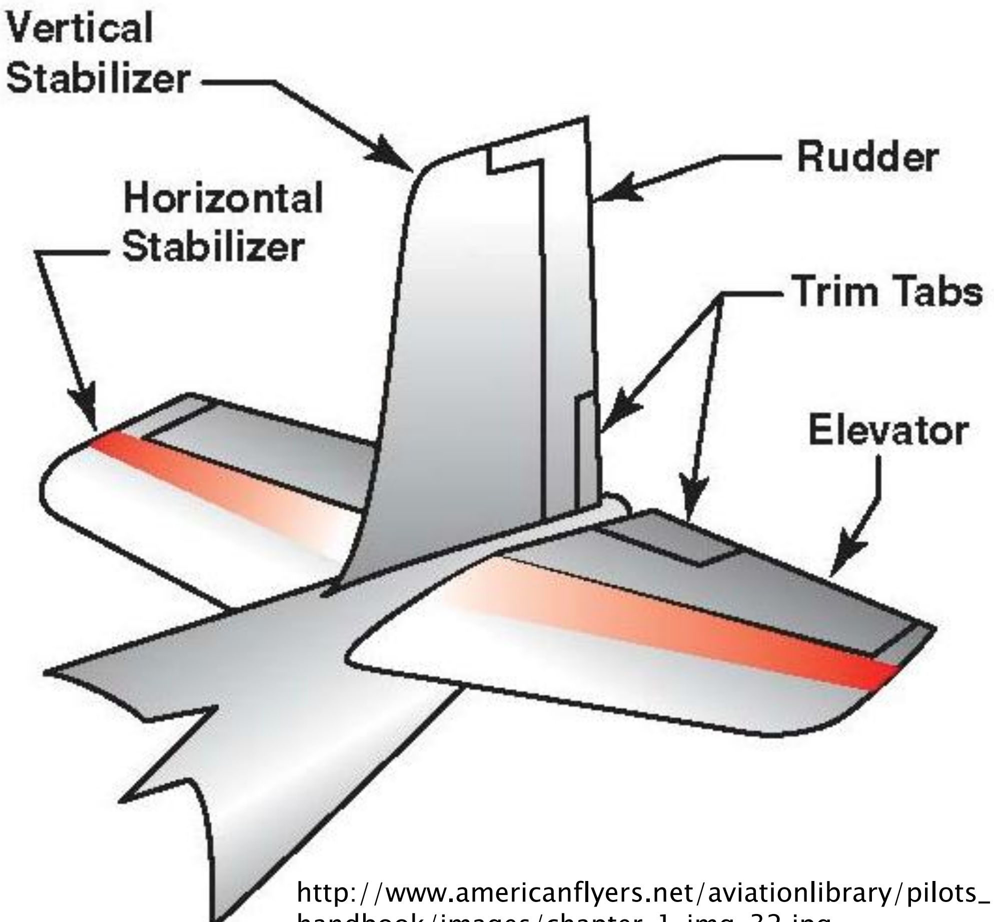
- Used in model aircraft and small helicopters
- Design:
  - Best done with carbon fiber (not permitted)
- Strength:
  - Low torsion resistance
- Weight:
  - Lightest weight design



Twin Boom:

- Design:
  - Greatly affects fuselage design
- Strength:
  - Great torsion resistance
  - High stability
- Weight:
  - Highest weight compared to other booms

Tail Design

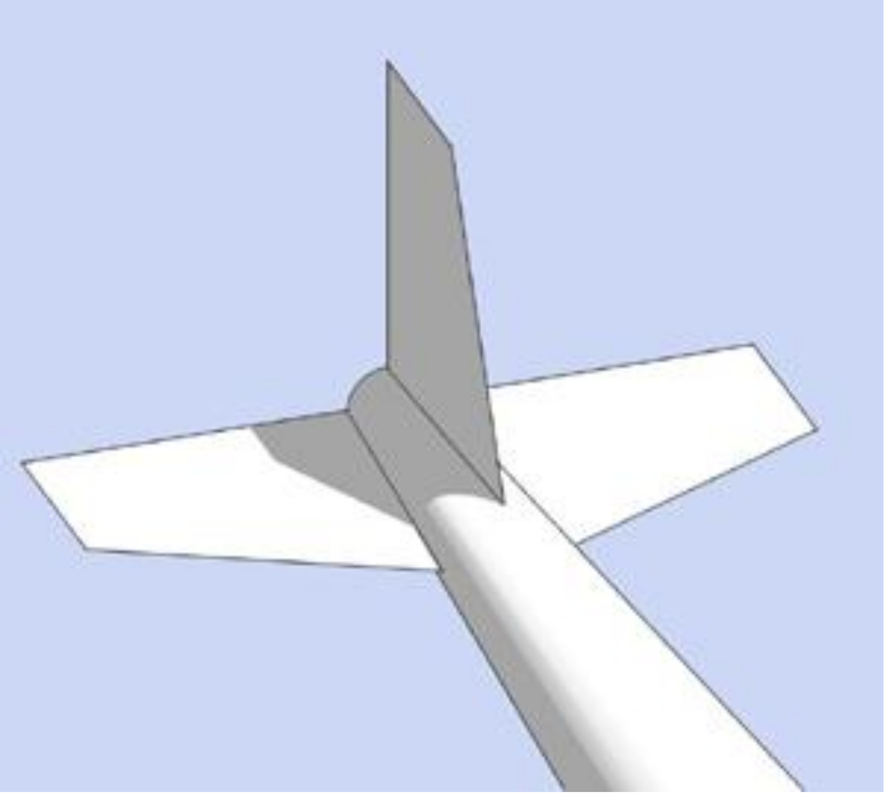


http://www.americanflyers.net/aviationlibrary/pilots_handbook/images/chapter_1_img_32.jpg

- Tail design deals mostly with stability, control, and trim
- Sized small to reduce wetted area and weight
- Symmetric non-lift inducing airfoil
- Design affected by:
  - Boom length
  - CG location
  - Aircraft stall velocity

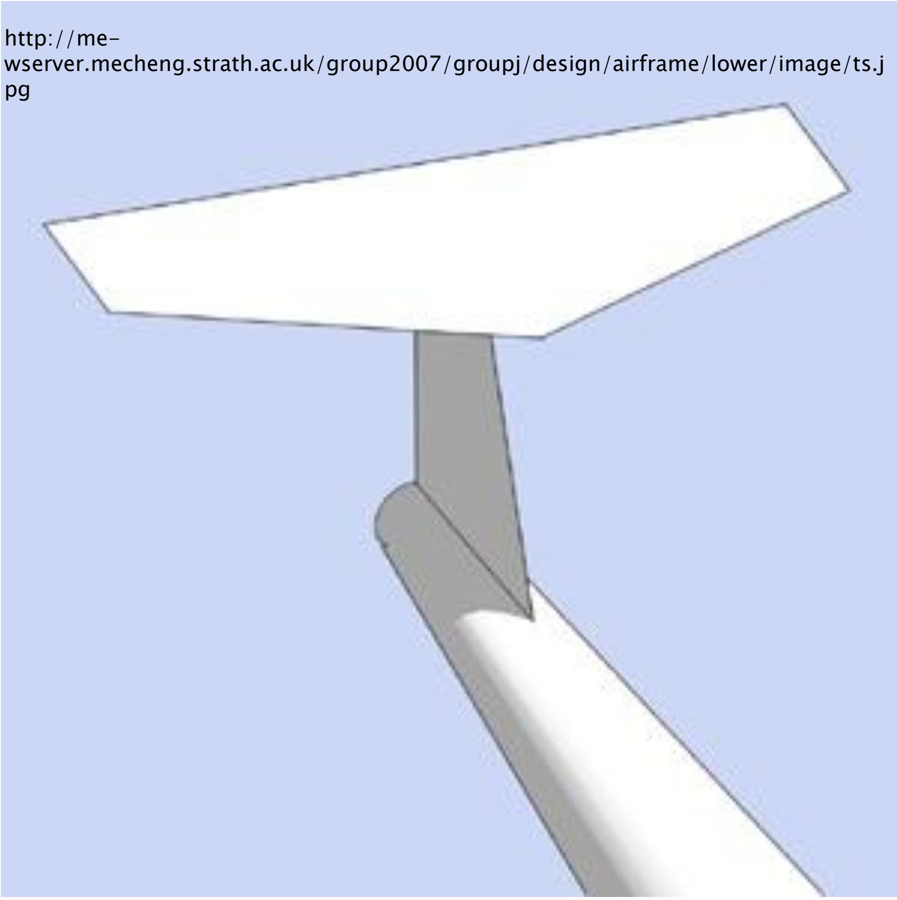
Tail Design – Conventional

http://me-wserver.mecheng.strath.ac.uk/group2007/groupj/design/airframe/lower/image/conventionals.jpg



- Roots of both stabilizer attached to fuselage
- Effectiveness of vertical tail is large
- Vertical tail height removes possible length from wing

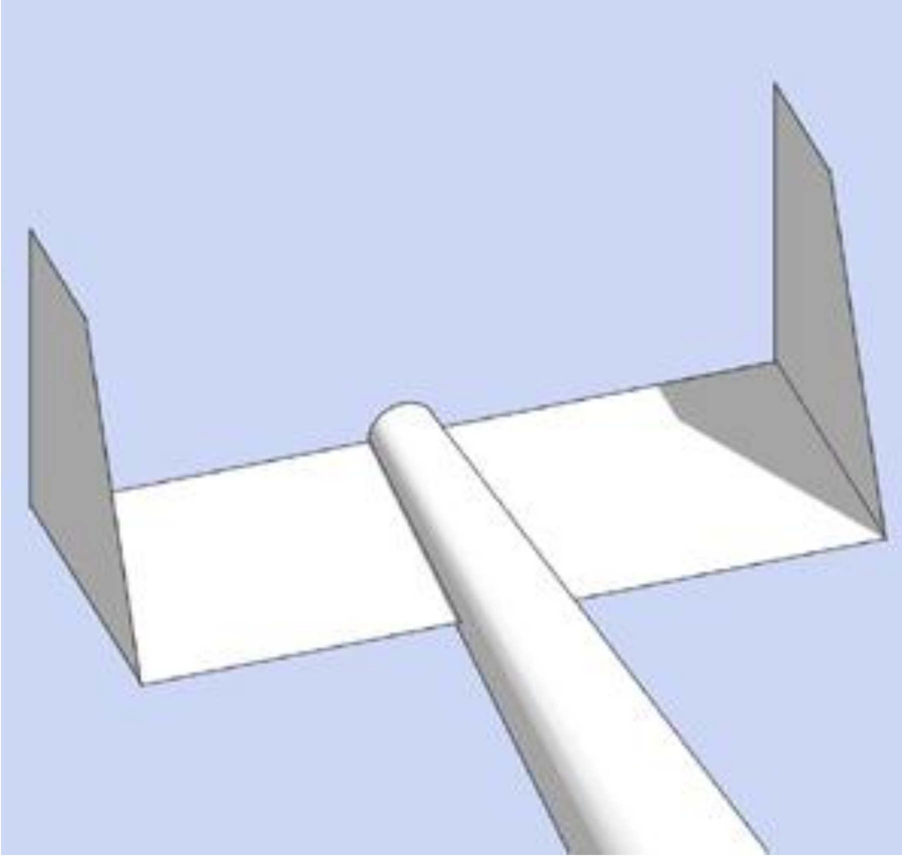
Tail Design – T-tail



- Reduced aerodynamic interference
- Vertical tail very effective due to fuselage and horizontal tail endplates
- Horizontal tail can be lengthened for short boom designs

Tail Design – H-tail

http://me-wserver.mecheng.strath.ac.uk/group2007/groupj/design/airframe/lower/image/us.jpg



- Uses the vertical surfaces as endplates for the horizontal tail
- Vertical surfaces can be made less tall, adding to allowable wing length
- Reduced yawing moment associated with propeller aircraft
- More complex control linkages required

Tail Design – Decision Matrix

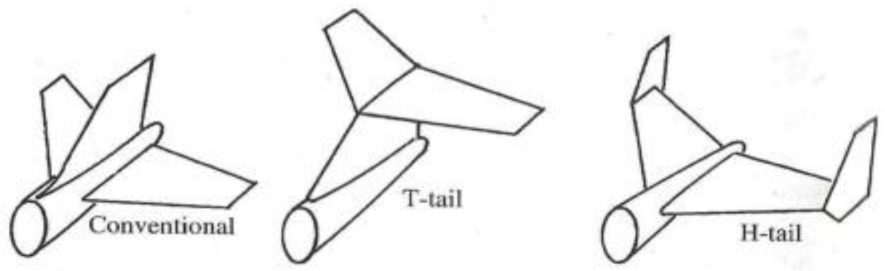


Figure of Merit	Weighting factor	Conventional	T-tail	H-tail
Drag	0.20	3	2	1
Ease of Build	0.10	5	3	2
Maneuverability	0.15	3	4	5
Stability	0.35	4	4	5
Weight	0.20	4	4	3
Total	1.00	3.75	3.5	3.5

Cost Analysis

Item	Description	Quantity	Cost
Engine	Magnum xls 61	1	$240
Balsa Wood	Structure of aircraft, various lengths and shapes	~50 ft.	$100
Monokote	Skin around structure	~50 sq. ft.	$60
Servos	Controls flaps (elevator, aileron, rudder, etc.)	5	$125
Fuel Tank	Holds fuel within fuselage	1	$5
Battery	Powers servos and receiver	1	$15
Radio and receiver	Radio controller for the plane and the receiver to send control functions to servos	1	$0
Miscellaneous Items	Wheels, pushrods, hardware, engine mounts, propeller	TBD	$75-$150
Total		*estimate	*$620-$695

Future Plans

- Newly Acquired Sponsor:
  - highflyhobbies.com
- Further, in-depth analysis
- Control selection
  - Servo sizing
- Decide on a final layout before the end of the semester

References

- SAE Aero Design Rule Book
  - http://students.sae.org/competitions/aerodesign/rules/rules.pdf
- Aircraft Design: Synthesis and Analysis
  - http://adg.stanford.edu/aa241/AircraftDesign.html
- O.Schrenk, A Simple Approximation Method for Obtainign the Spanwise Lift Distribuition, TM 948, 1940.
- NACA TN-1269, *"Method for calculating wing characteristics by lifting-line theory using nonlinear section lift data".*
- http://media.hobbypeople.net/manual/210802.pdf

Questions

Perguntas???