Senior Aero Design 2004

Tradeoff Study

Last Modified 2004.02.03 by David Altherr

Note that this file may take a while to run, even on fast machines, due to the effective length of the model and the resource hog nature of MathCAD. In the event that a referenced file is modified, the most efficient way to recalculate everything may be to save and close this model, then reopen it.

Calculations

Iterator Variables

$ii := 0, 1 .. 180$ $\quad vv_{ii} := ii \cdot \frac{1}{2} fps$ $\quad iv_{ii} := ii$ $\quad vr := 0fps, 0.5fps .. 90fps$

$ct := -1$

Independet Variables

Design Weight

$$W_{dsgn.to} := \begin{pmatrix} 39.66 \\ 42 \\ 44 \\ 46 \\ 48 \\ 50 \\ 51 \\ 52 \\ 54 \end{pmatrix} \cdot lbf$$

Wing Span

$$b_{w.to} := \begin{pmatrix} 10 \\ 11.41 \\ 12.83 \\ 14.53 \\ 16.63 \\ 19.37 \\ 21.17 \\ 23.35 \\ 31.35 \end{pmatrix} ft$$

Wing Area

$$S_{w.to} := \begin{pmatrix} 21.0 \\ 23.66 \\ 26.08 \\ 28.6 \\ 31.27 \\ 34.1 \\ 35.57 \\ 37.05 \\ 40.25 \end{pmatrix} \cdot ft^2$$

Iterations I love MathCAD...

Reference:C:\Academics\SeniorDesign\MathCAD Model 2004\Tradeoff.Block.mcd(R)

ct = –1

Reference:C:\Academics\SeniorDesign\MathCAD Model 2004\Tradeoff.Block.mcd(R)

ct = 0

Reference:C:\Academics\SeniorDesign\MathCAD Model 2004\Tradeoff.Block.mcd(R)

ct = 1

Reference:C:\Academics\SeniorDesign\MathCAD Model 2004\Tradeoff.Block.mcd(R)

ct = 2

Reference:C:\Academics\SeniorDesign\MathCAD Model 2004\Tradeoff.Block.mcd(R)

ct = 3

Reference:C:\Academics\SeniorDesign\MathCAD Model 2004\Tradeoff.Block.mcd(R)

ct = 4

Reference:C:\Academics\SeniorDesign\MathCAD Model 2004\Tradeoff.Block.mcd(R)

ct = 5

Reference:C:\Academics\SeniorDesign\MathCAD Model 2004\Tradeoff.Block.mcd(R)

ct = 6

Reference:C:\Academics\SeniorDesign\MathCAD Model 2004\Tradeoff.Block.mcd(R)

ct = 7

ct = 8 cts := 0.. ct

Conditional Monitors

$$RoC_{to} \cdot \frac{min}{ft} - 200 = \begin{pmatrix} 0.11 \\ -0.058 \\ -0.132 \\ 0.042 \\ 0.069 \\ -0.023 \\ 0.055 \\ -0.056 \\ -0.088 \end{pmatrix}$$

$$180 - Groundroll_{to} \cdot \frac{1}{ft} = \begin{pmatrix} -0.198 \\ -0.075 \\ 0.055 \\ -0.051 \\ -0.057 \\ 0.036 \\ 0.077 \\ -0.072 \\ -0.018 \end{pmatrix}$$

These vector elements should be close to zero, meaning:

1. Liftoff Climb Rate target of 200 ft/min.
2. Groundroll target of 180 ft.

Excess Climb Rate for first term is due to 10 ft minimum span constraint.

Results

Performance Parameters

Payload Weight

$$Wt_{pyld.to} = \begin{pmatrix} 25.348 \\ 26.625 \\ 27.589 \\ 28.399 \\ 28.986 \\ 29.223 \\ 29.112 \\ 28.801 \\ 26.23 \end{pmatrix} \text{lbf}$$

Liftoff Velocity

$$V_{LO.to} = \begin{pmatrix} 39.213 \\ 38.018 \\ 37.063 \\ 36.188 \\ 35.353 \\ 34.552 \\ 34.167 \\ 33.805 \\ 33.051 \end{pmatrix} \frac{\text{ft}}{\text{sec}}$$

Liftoff Climb Rate

$$RoC_{to} = \begin{pmatrix} 200.11 \\ 199.942 \\ 199.868 \\ 200.042 \\ 200.069 \\ 199.977 \\ 200.055 \\ 199.944 \\ 199.912 \end{pmatrix} \frac{\text{ft}}{\text{min}}$$

Groundroll Distance

$$Groundroll_{to} = \begin{pmatrix} 180.198 \\ 180.075 \\ 179.945 \\ 180.051 \\ 180.057 \\ 179.964 \\ 179.923 \\ 180.072 \\ 180.018 \end{pmatrix} \text{ft}$$

Wing Parameters

Area

$$S_{w.to} = \begin{pmatrix} 21 \\ 23.66 \\ 26.08 \\ 28.6 \\ 31.27 \\ 34.1 \\ 35.57 \\ 37.05 \\ 40.25 \end{pmatrix} \text{ft}^2$$

Wing Loading

$$Load_{A.w.to} = \begin{pmatrix} 1.889 \\ 1.775 \\ 1.687 \\ 1.608 \\ 1.535 \\ 1.466 \\ 1.434 \\ 1.404 \\ 1.342 \end{pmatrix} \text{psf}$$

M.A. Chord

$$mac_{w.to} = \begin{pmatrix} 25.193 \\ 24.877 \\ 24.386 \\ 23.614 \\ 22.558 \\ 21.12 \\ 20.157 \\ 19.035 \\ 15.403 \end{pmatrix} \text{in}$$

Aspect Ratio

$$AR_{w.to} = \begin{pmatrix} 4.762 \\ 5.502 \\ 6.312 \\ 7.382 \\ 8.844 \\ 11.003 \\ 12.6 \\ 14.716 \\ 24.418 \end{pmatrix}$$

Root Chord Length

$$C_{r.w.to} = \begin{pmatrix} 27.692 \\ 27.344 \\ 26.805 \\ 25.956 \\ 24.796 \\ 23.215 \\ 22.157 \\ 20.924 \\ 16.93 \end{pmatrix} \text{in}$$

Root Chord Thickness

$$Thick_{r.w.to} = \begin{pmatrix} 3.553 \\ 3.508 \\ 3.439 \\ 3.33 \\ 3.181 \\ 2.978 \\ 2.843 \\ 2.685 \\ 2.172 \end{pmatrix} \text{in}$$

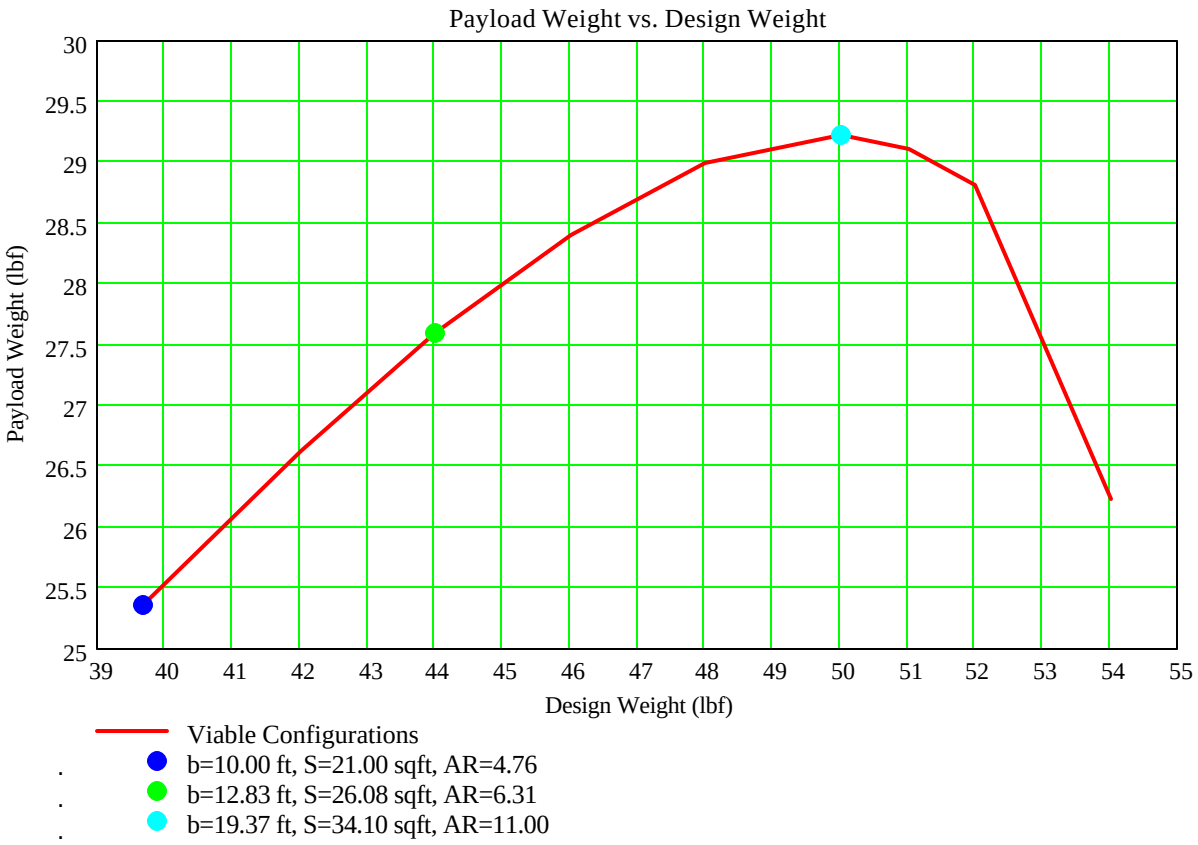
Tip Chord Length

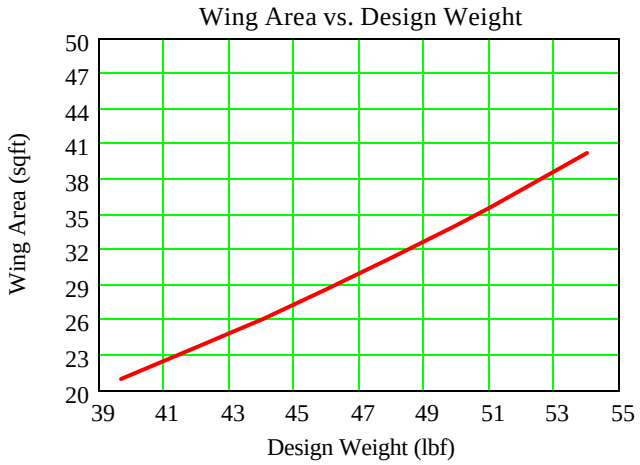
$$C_{t.w.to} = \begin{pmatrix} 16.615 \\ 16.407 \\ 16.083 \\ 15.574 \\ 14.877 \\ 13.929 \\ 13.294 \\ 12.554 \\ 10.158 \end{pmatrix} \text{in}$$

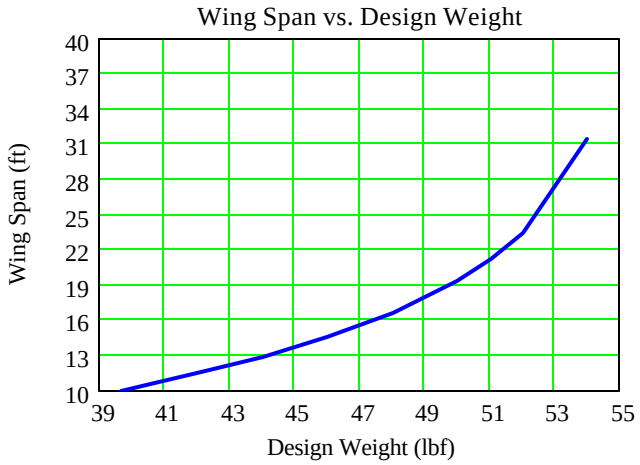
Tip Chord Thickness

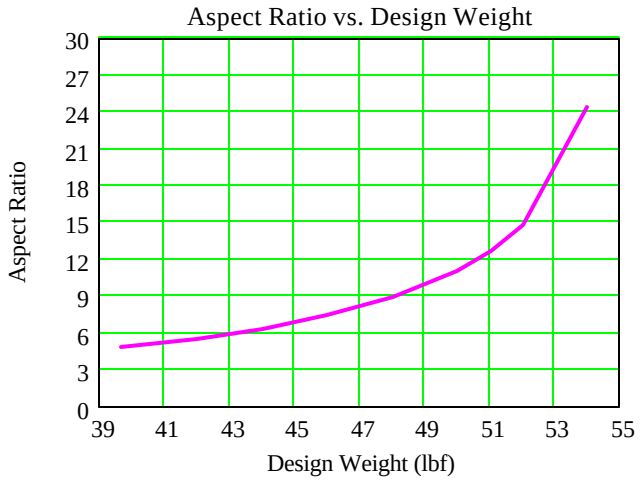
$$Thick_{t.w.to} = \begin{pmatrix} 2.132 \\ 2.105 \\ 2.063 \\ 1.998 \\ 1.909 \\ 1.787 \\ 1.706 \\ 1.611 \\ 1.303 \end{pmatrix} \text{in}$$

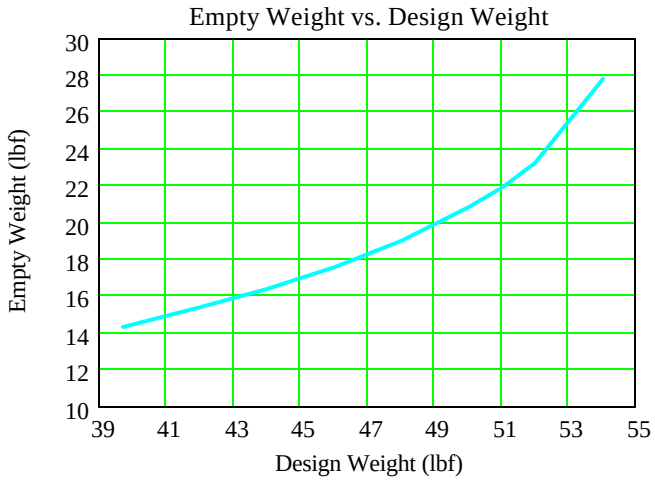
Graphs

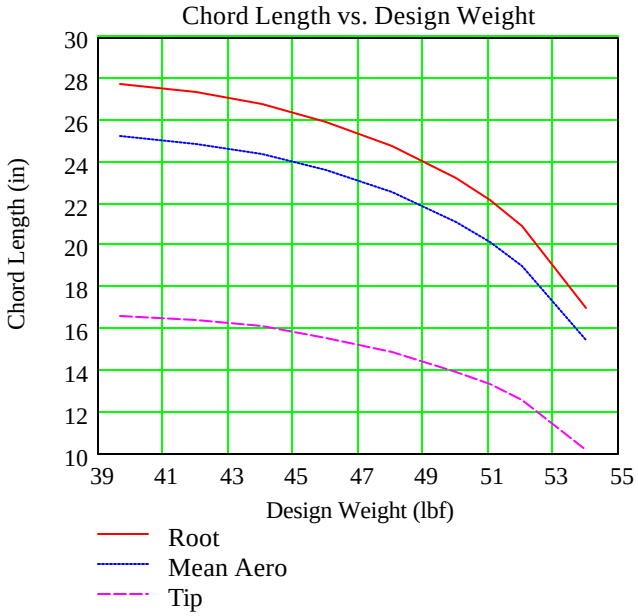

Payload Weight vs. Design Weight
Payload Weight (lbf)
30
29.5
29
28.5
28
27.5
27
26.5
26
25.5
25
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
Design Weight (lbf)
Viable Configurations
b=10.00 ft, S=21.00 sqft, AR=4.76
b=12.83 ft, S=26.08 sqft, AR=6.31
b=19.37 ft, S=34.10 sqft, AR=11.00

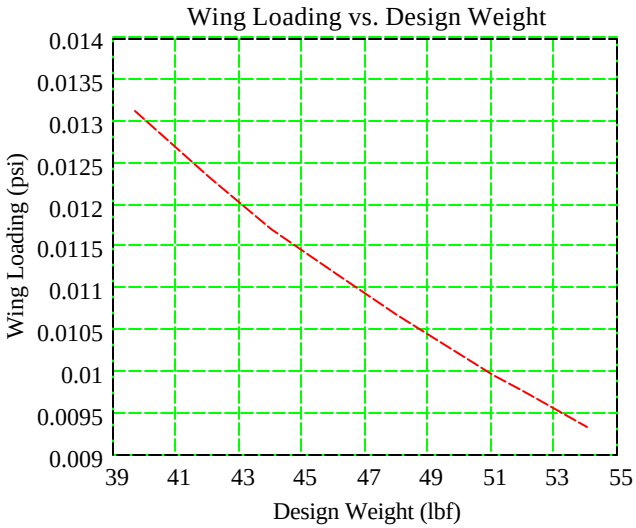

Wing Area vs. Design Weight
Wing Area (sqft)
50
47
44
41
38
35
32
29
26
23
20
39
41
43
45
47
49
51
53
55
Design Weight (lbf)

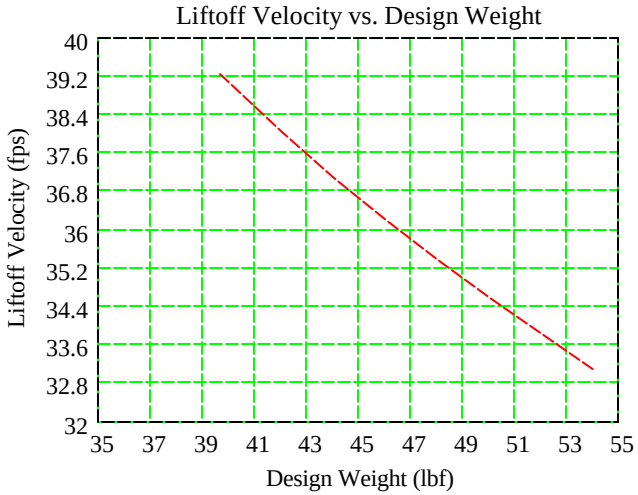

Wing Span vs. Design Weight
Wing Span (ft)
40
37
34
31
28
25
22
19
16
13
10
39
41
43
45
47
49
51
53
55
Design Weight (lbf)

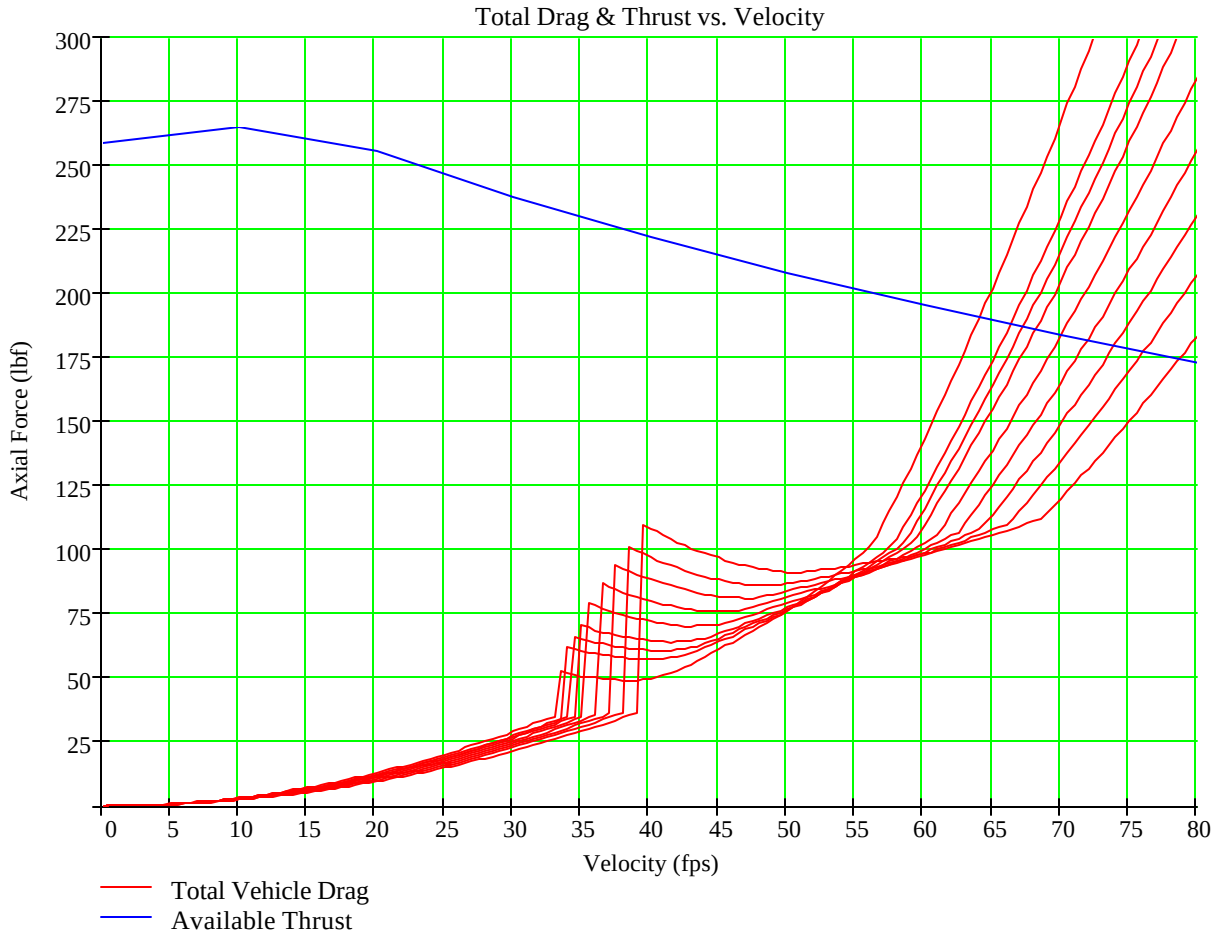

Aspect Ratio vs. Design Weight
Aspect Ratio
30
27
24
21
18
15
12
9
6
3
0
39
41
43
45
47
49
51
53
55
Design Weight (lbf)


Empty Weight vs. Design Weight
Empty Weight (lbf)
30
28
26
24
22
20
18
16
14
12
10
39
41
43
45
47
49
51
53
55
Design Weight (lbf)


Chord Length vs. Design Weight
Chord Length (in)
30
28
26
24
22
20
18
16
14
12
10
39
41
43
45
47
49
51
53
55
Design Weight (lbf)
Root
Mean Aero
Tip

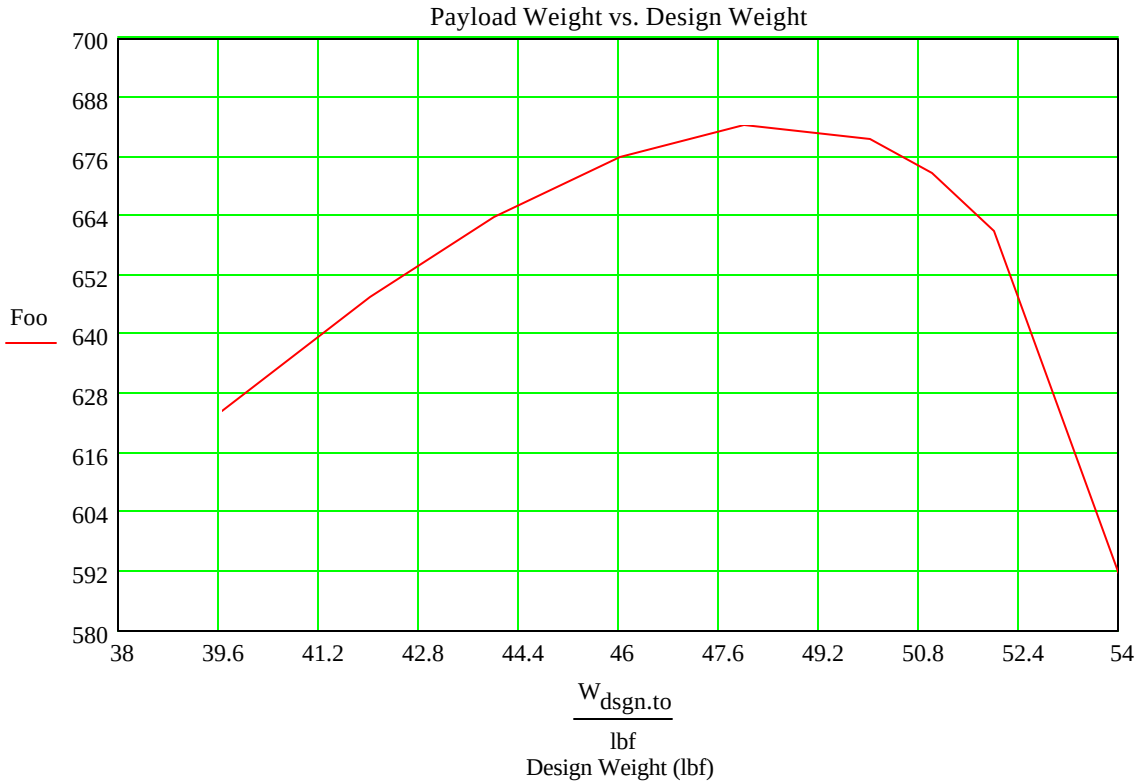

Wing Loading vs. Design Weight
Wing Loading (psi)
0.014
0.0135
0.013
0.0125
0.012
0.0115
0.011
0.0105
0.01
0.0095
0.009
39
41
43
45
47
49
51
53
55
Design Weight (lbf)

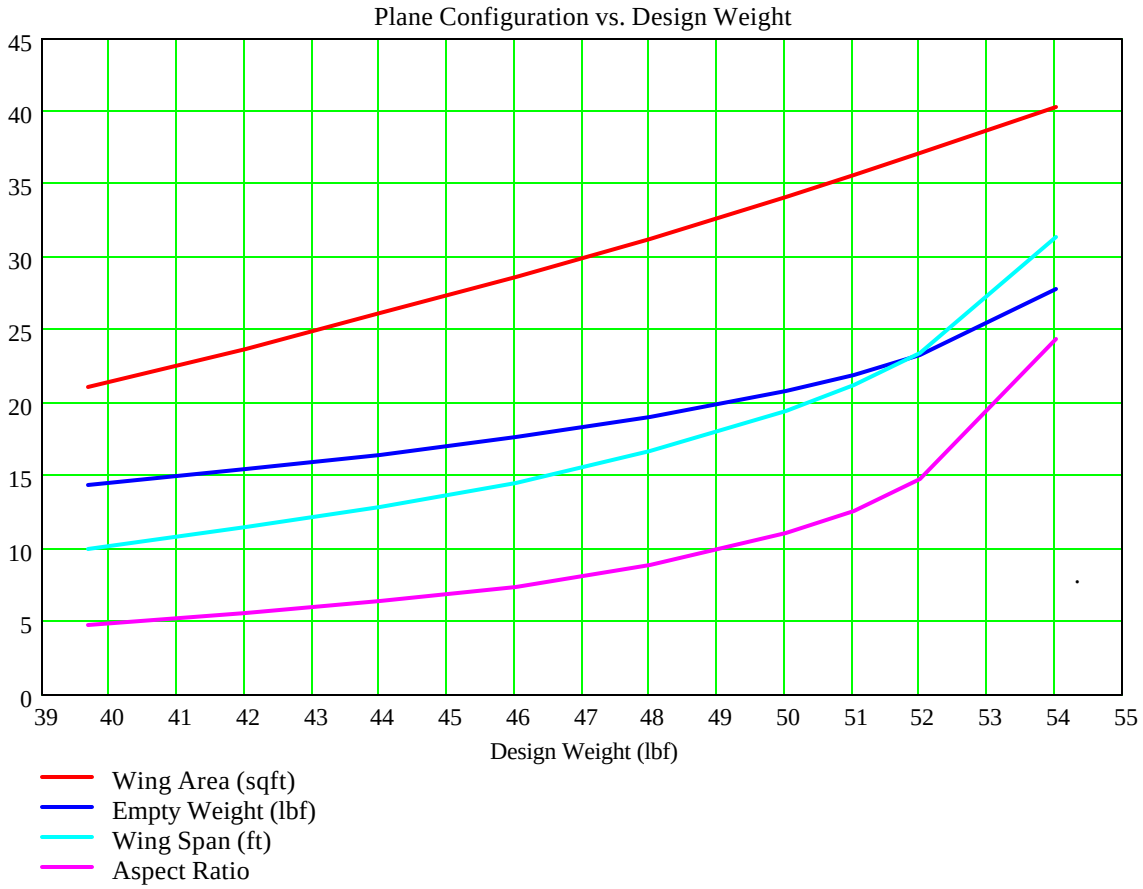

Liftoff Velocity vs. Design Weight
Liftoff Velocity (fps)
40
39.2
38.4
37.6
36.8
36
35.2
34.4
33.6
32.8
32
35
37
39
41
43
45
47
49
51
53
55
Design Weight (lbf)



Note that in the above figure, the plot with the lowest takeoff veloctity is associated with the highest design weight of 50 lbs. Likewise, the highest takeoff velocity is associated with the lowest design weight.

$$Foo_{cts} := Wt_{pyld.to_{cts}} \cdot \left(S_{w.to_{cts}} \right)^{-0.05} \cdot \left(b_{w.to_{cts}} \right)^{-0.05}$$




Plane Configuration vs. Design Weight
45
40
35
30
25
20
15
10
5
0
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
Design Weight (lbf)
Wing Area (sqft)
Empty Weight (lbf)
Wing Span (ft)
Aspect Ratio