X-47 A/B

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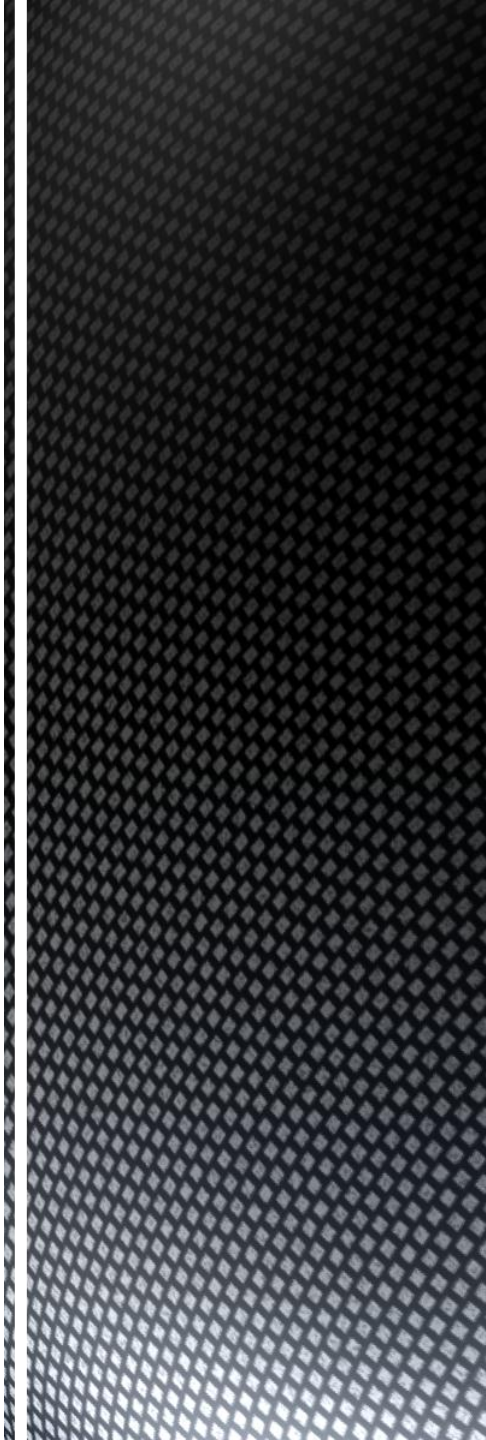


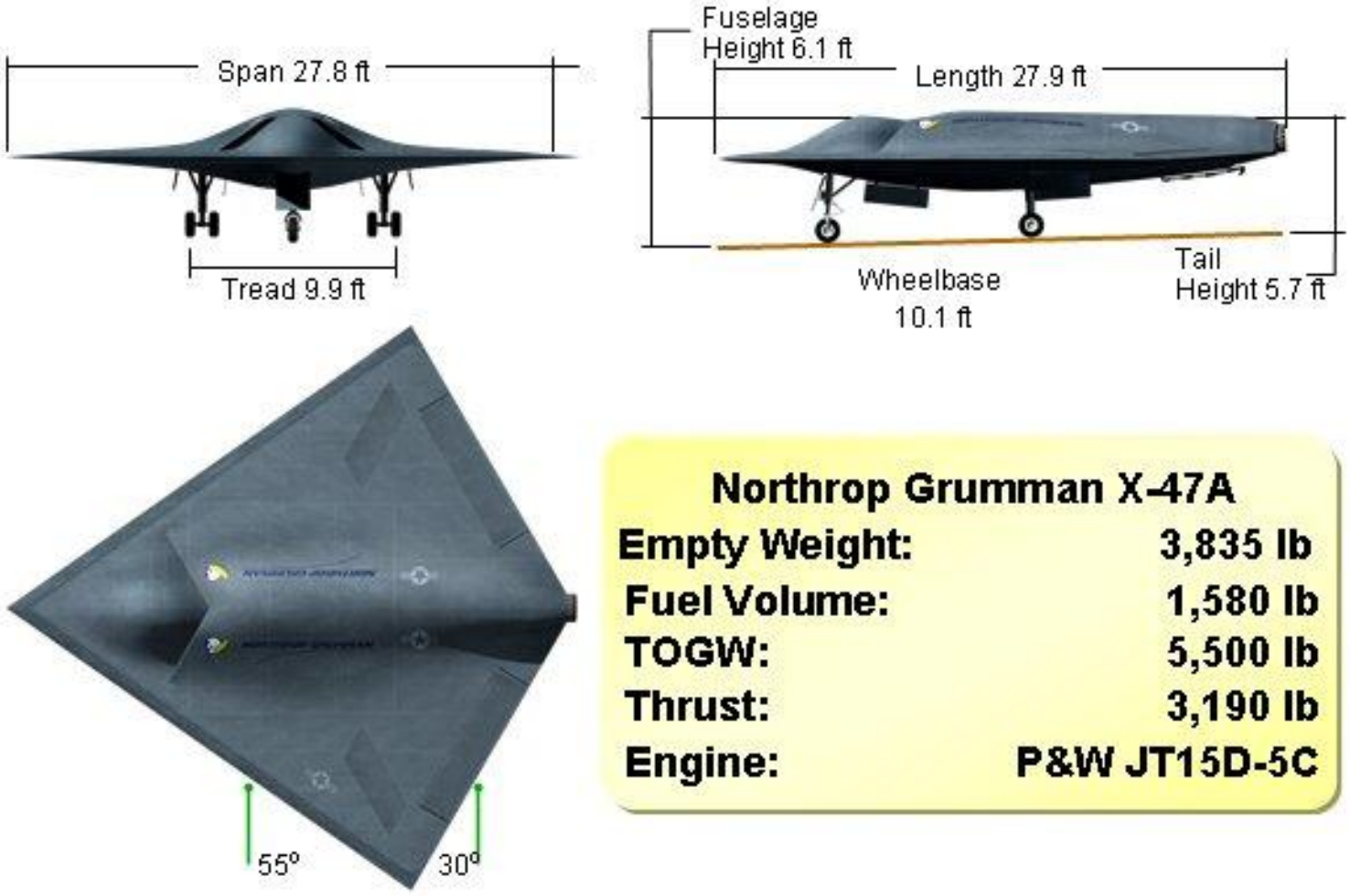
Mission Profile

- Subsonic Unmanned Combat Aerial Vehicle (UCAV)
- Launched from Aircraft Carrier/ Airfield
- Used as Advanced Recon / Bomber in the field
- X-47A was a proof of concept Vehicle

http://en.wikipedia.org/wiki/Northrop_Grumman_X-47A_Pegasus

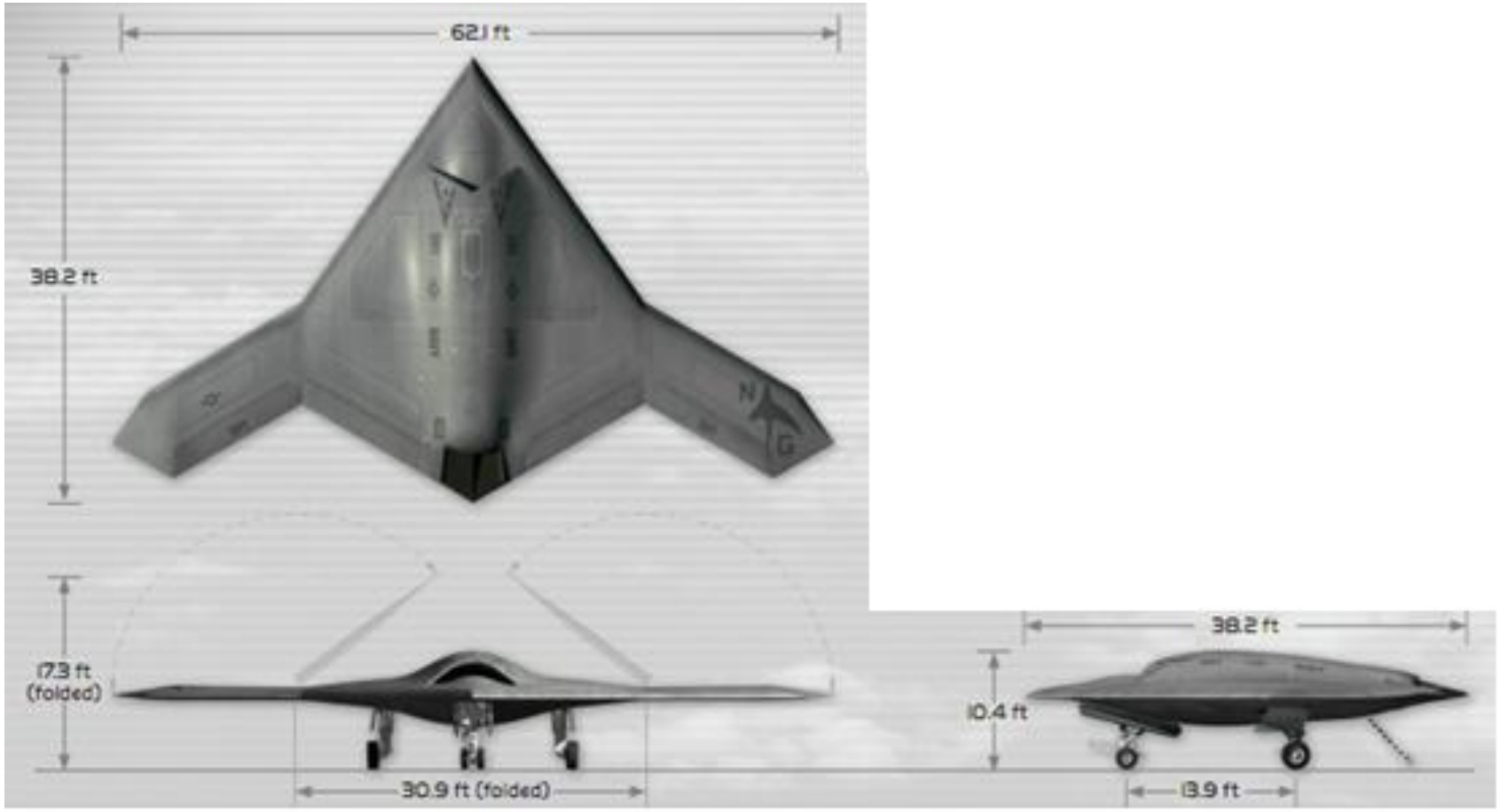
www.popsci.com

X-47A Configuration



Scaled Composites X-47A Three View with Facts and Figures
http://air-attack.com/page/28/X-47-Pegasus-UCAV-N.html.

X- 47B Configuration



Northrop Grumman X-47 UCAV Three View. http://www.as.northropgrumman.com/products/nucasx47b/assets/X-47B-UCAS-Fact-Sheet.pdf. 4/19/2011.

Specifications

X-47 A

- Length: 27.9 ft
- Height: 6.1ft
- Wingspan: 27.8ft
- Empty Weight: 3,835 lbs
- TOGW: 5500 lbs
- Payload: 500 lbs
- Powerplant: P&W JT15D-5C Turbofan Engine

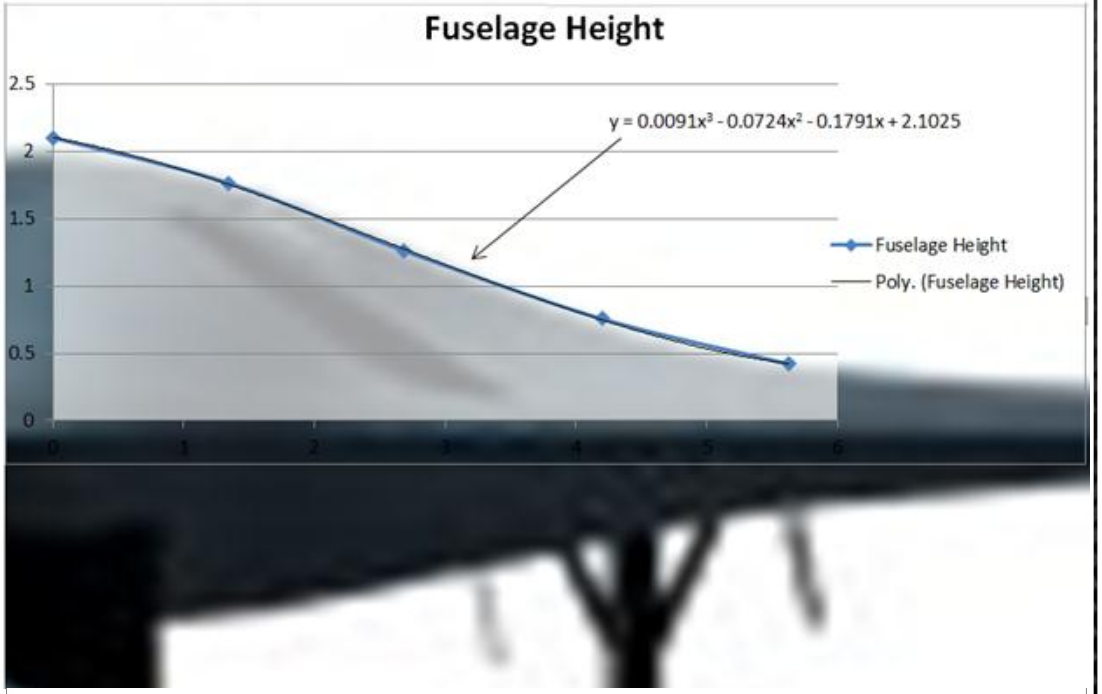
X-47B

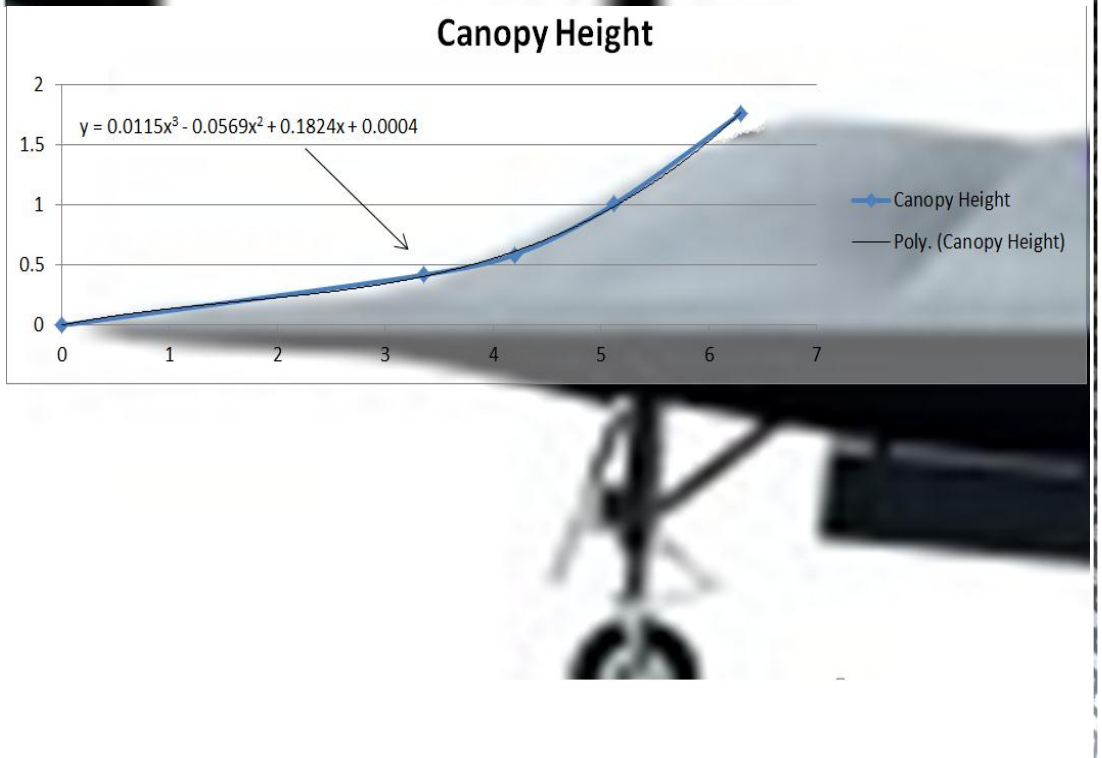
- Length: 38.2 ft
- Height: 10.4 ft
- Wingspan: 62.1 ft
- Empty Weight: 14,000 lbs
- TOGW: 44,567 lbs
- Payload: 4500 lbs
- Powerplant: P&W F100-220U Turbofan Engine

Specifications

X47A	Value	Units
C_root	27.9	ft
C_tip	0	ft
Sref	387.81	ft^2
Control Surface		
Area	26.93	ft^2
Moment Arm	10.28	ft
Aspect Ratio	1.99	
Leading Edge Sweep	55.00	degrees
Trailing Edge Sweep	30.00	degrees
MAC	18.60	ft
yMAC	4.63	ft
t/c max	0.12	

Tailscrape: 20 degrees





Aerodynamic Specifications

X-47 A

- L/D_{cruise} = 5.58
- Cruise Speed: Mach 0.45
- Range: 953 Miles
- Max Endurance: 6.0 hours
- W/S = 14.52
- T/W = 0.58
- Service Ceiling: 54 kft
- Airfoil: NACA 64_1-212
- Elevator Required to Trim: (-6.8^o)

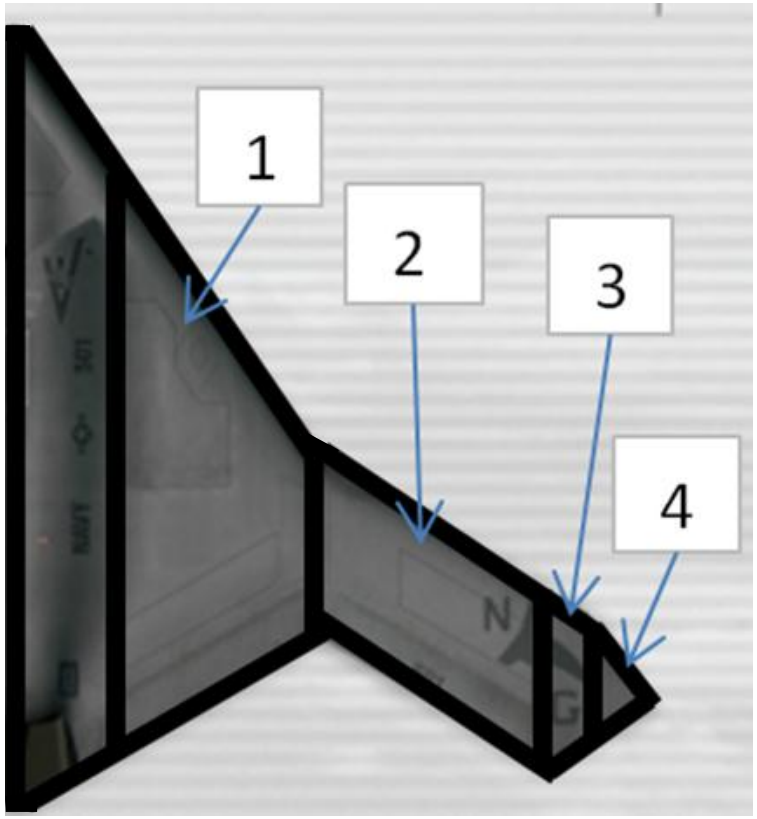
X-47B

- L/D_{cruise} = 12.62
- Cruise Speed: Mach 0.45
- Range: 2461 Miles
- Max Endurance: 6.6 hours
- W/S = 46.2
- T/W = 0.38
- $T/W_{augmented}$ = 0.56
- Service Ceiling: 40 kft
- Airfoil: NACA 64_1-212
- Elevator Required to Trim: (-23.4^o)

Specifications

X47B	**Value**	**Units**
Sref1	335.08	ft^2
Sref2	91.49	ft^2
Sref3	18.26	ft^2
Sref4	9.73	ft^2
Total: Sref	909.11	ft^2
Control Surface Area	98.70	ft^2
Inner moment arm	14.51	ft
Outer moment arm	23.556	ft

Tailscrape: 41 degrees

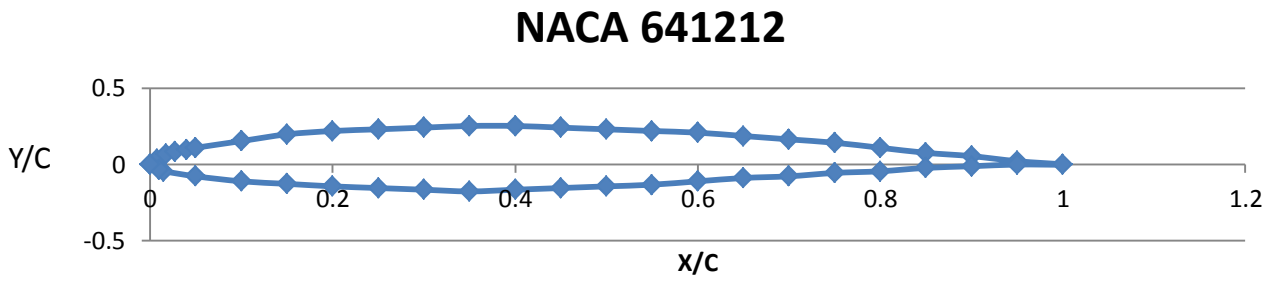


Aerodynamic Specifications

6-Series Airfoil

Attributes:

- maintain a lower radar cross section
- uniform pressure distribution
- NACA 641212, low drag at low angles of attack



Design Features

- Flying wing
- Carrier Launched
  - Corrosive Salt-Water Environment
- Unmanned
- Stealth
- Multi-role
  - Reconnaissance
  - Combat

X-47 Final Concept Art

www.unmannedwarfare.webs.com

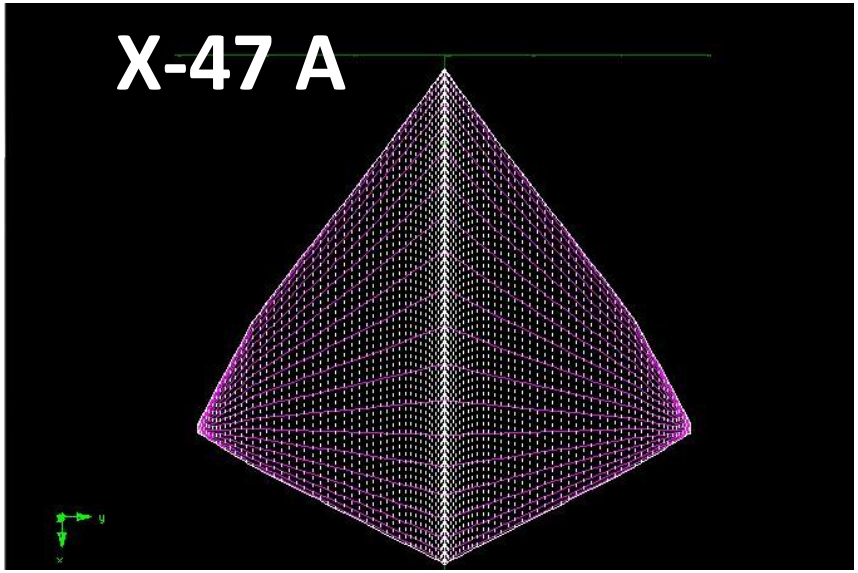
Design Features

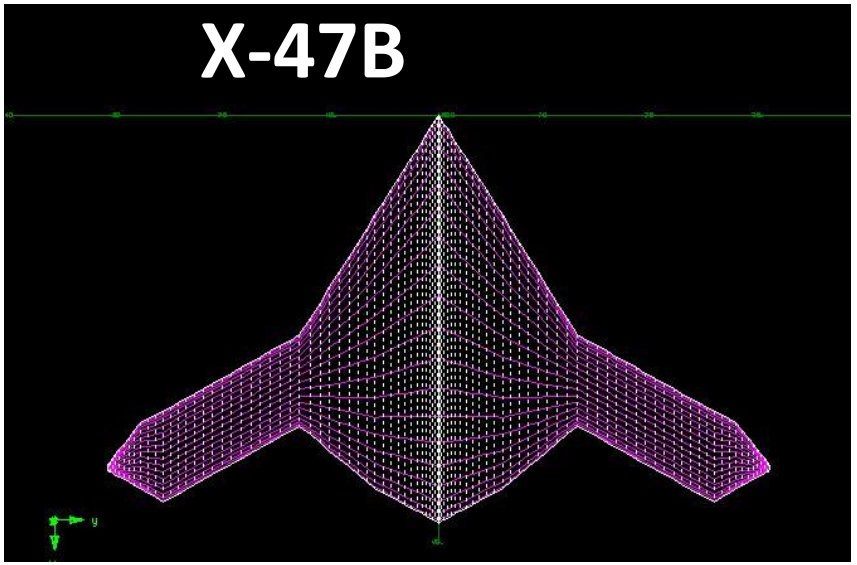
X-47B in Landing Configuration
www.technewsdaily.com

Additional Control Surfaces

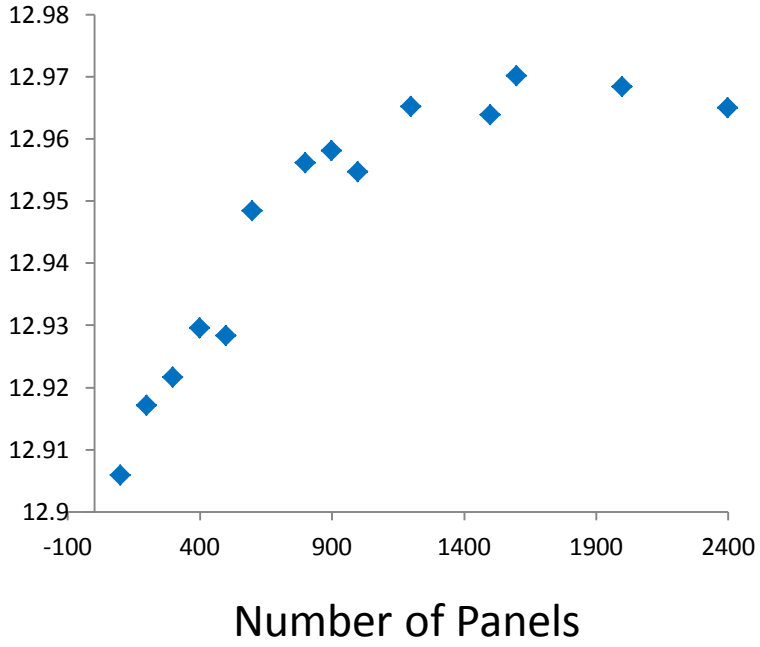
- **Spoilers**
  - **Rapid deceleration**
  - **Rapid descent**
  - **Generate roll**

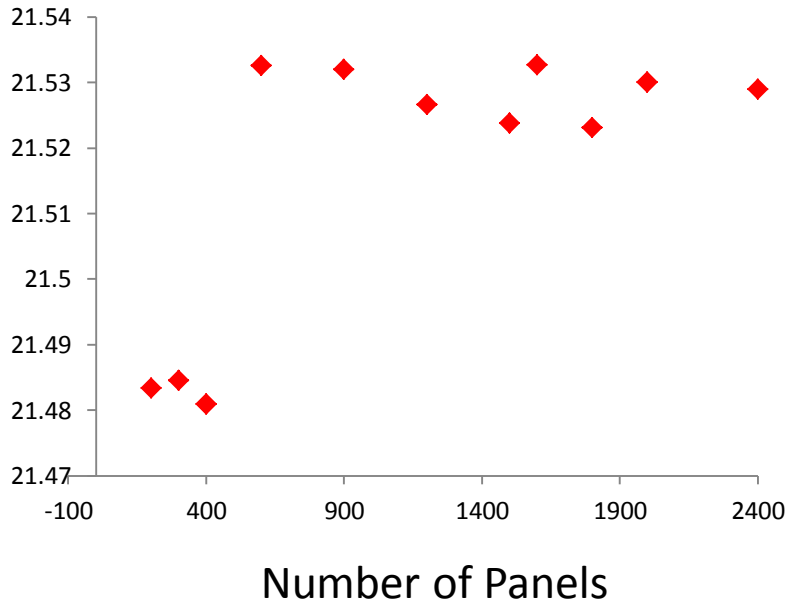
AVL Modeling & Drag Buildup



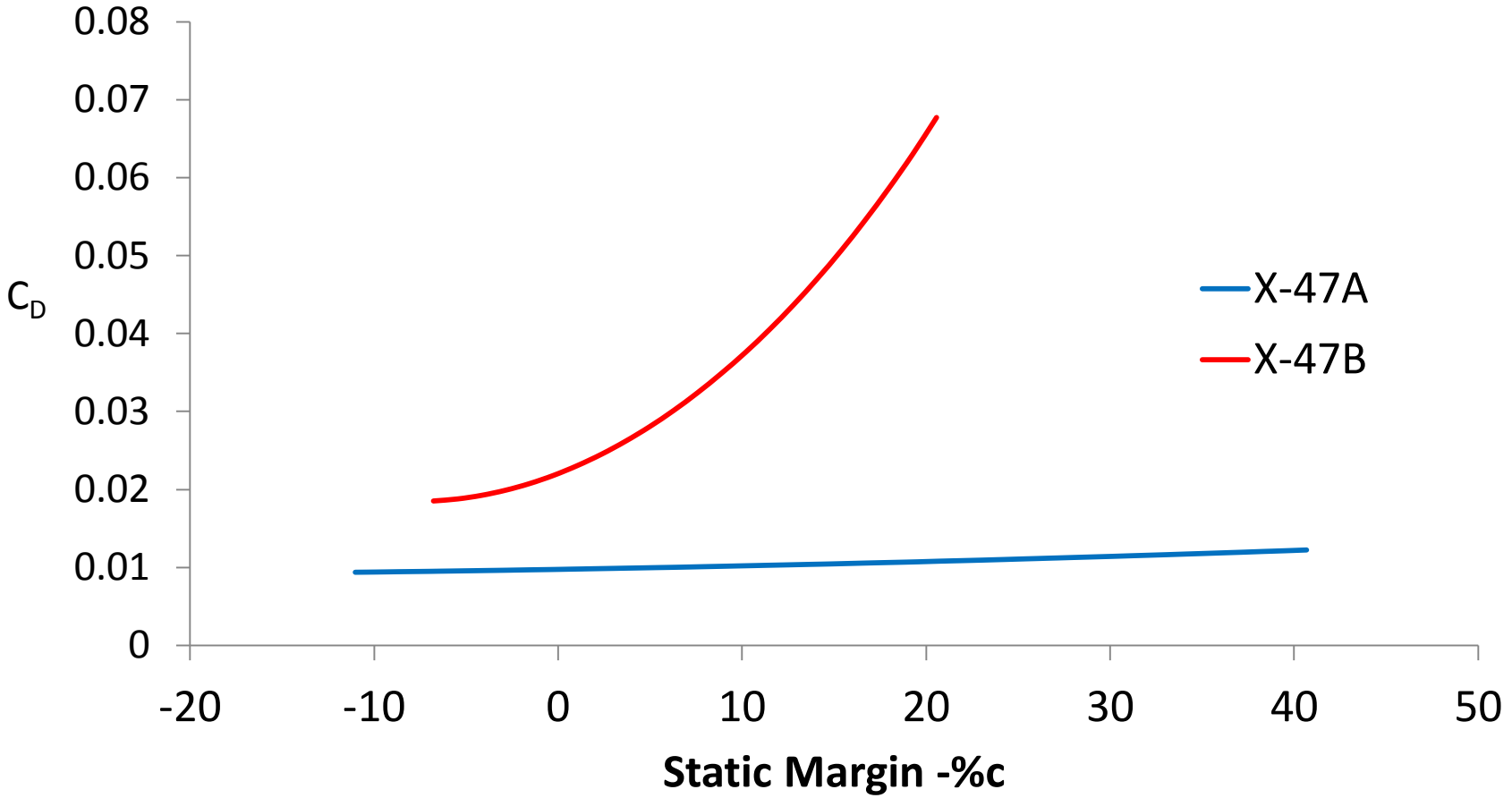


Neutral Point Location





Trim Drag



Modeled via AVL

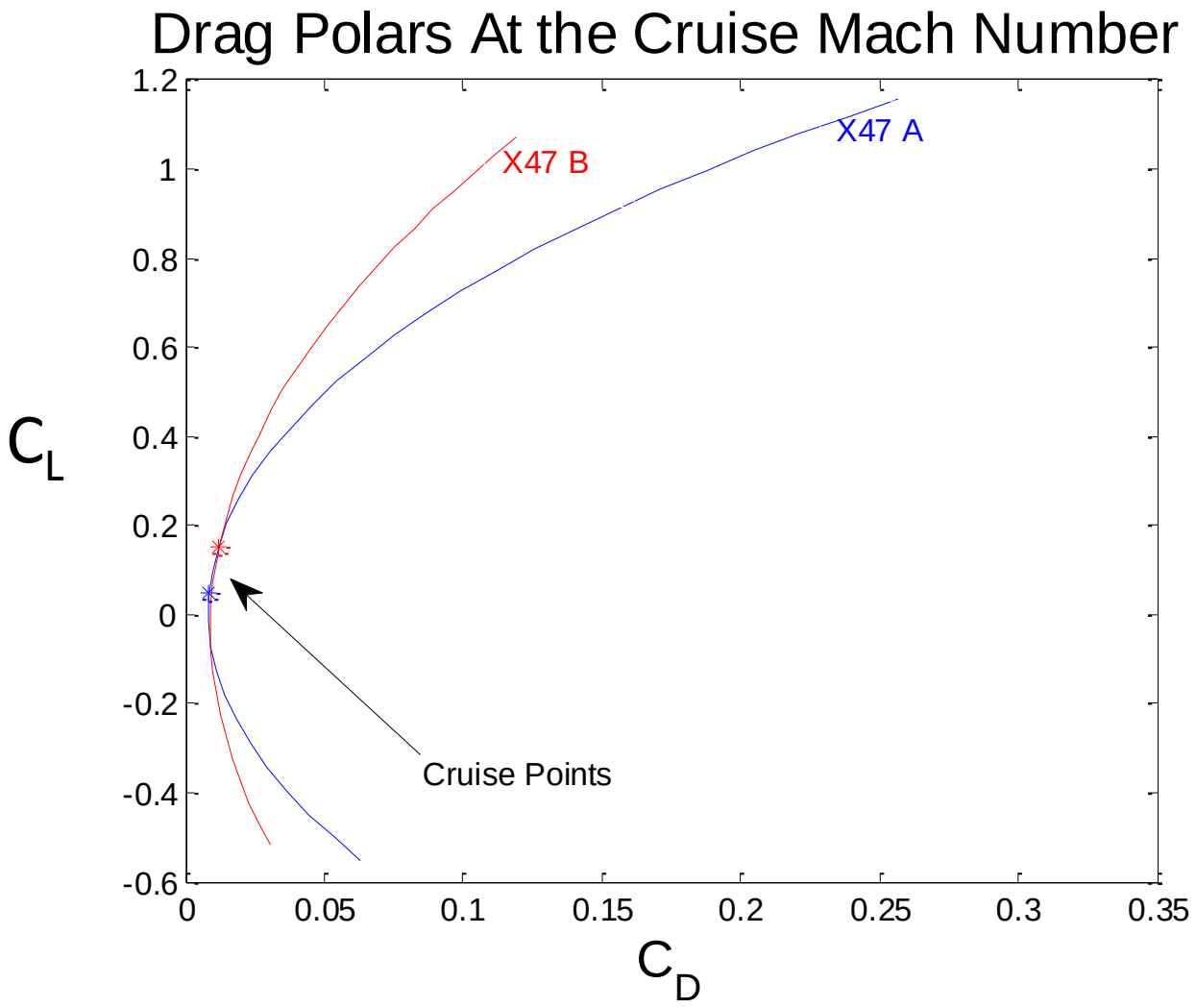
Performance

X-47A

- W/S = 14.52
- T/W = 0.58

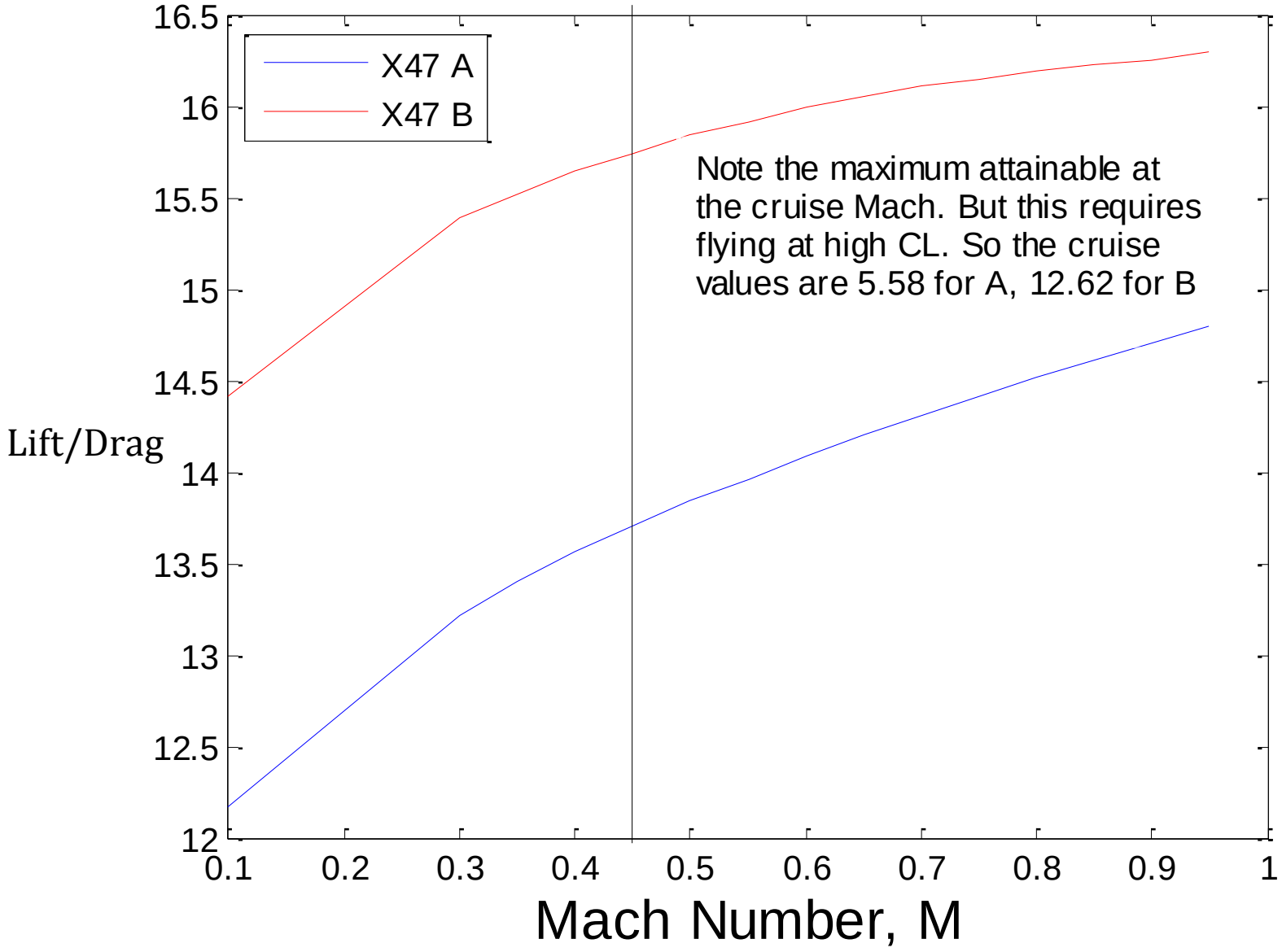
X-47B

- W/S = 46.2
- T/W = 0.38

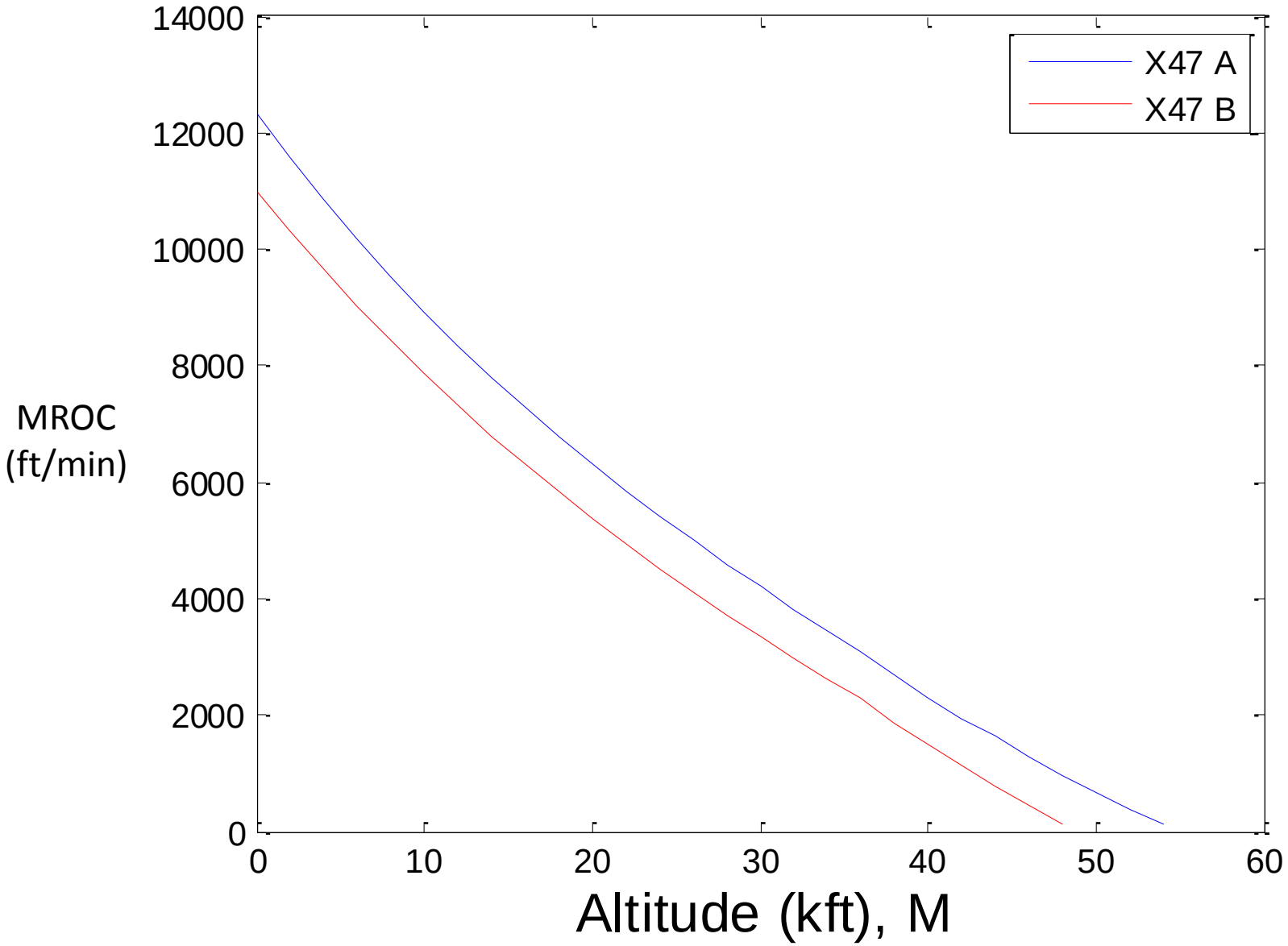


Modeled via AVL

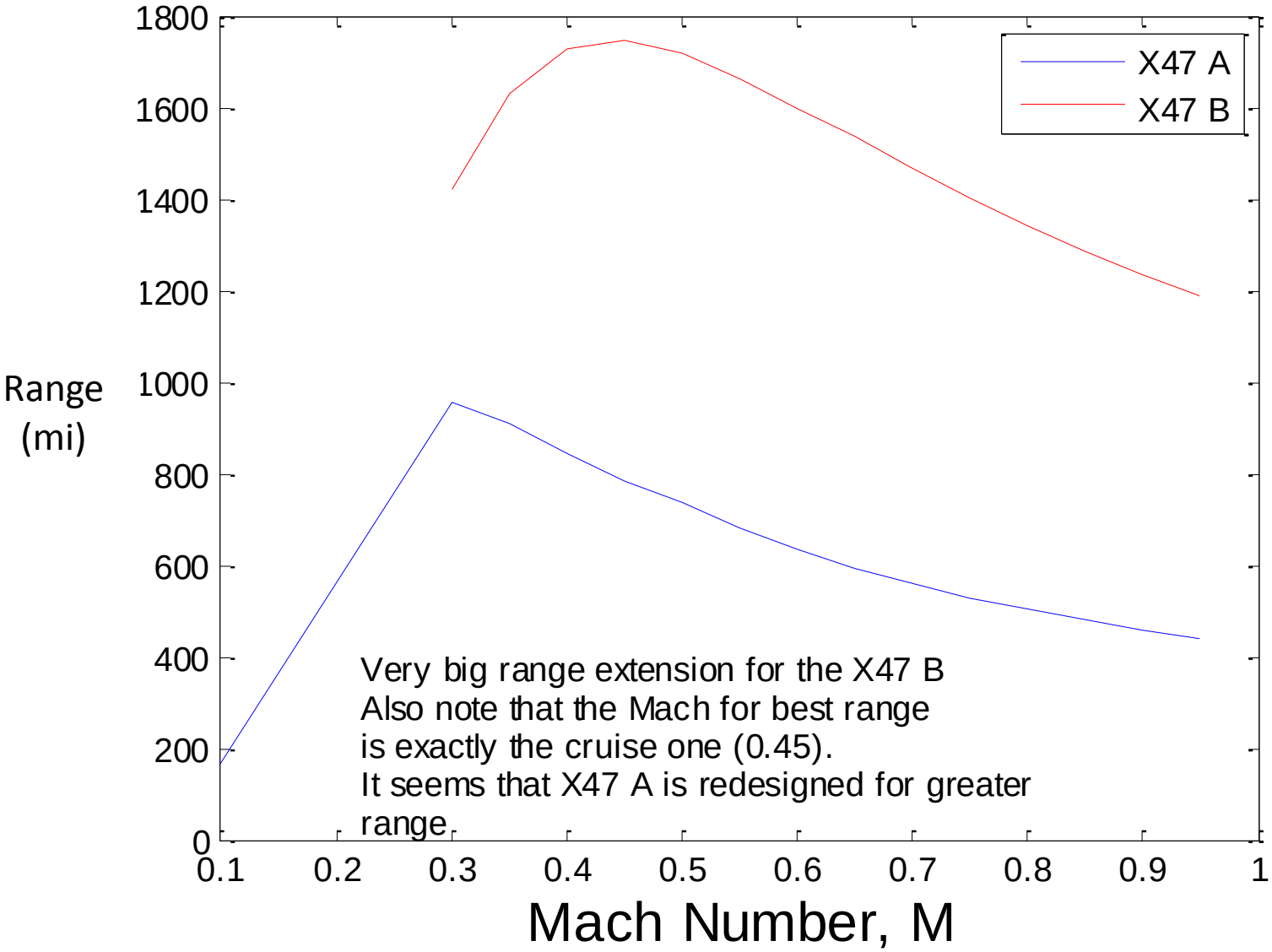
L/D as a function of Mach Number



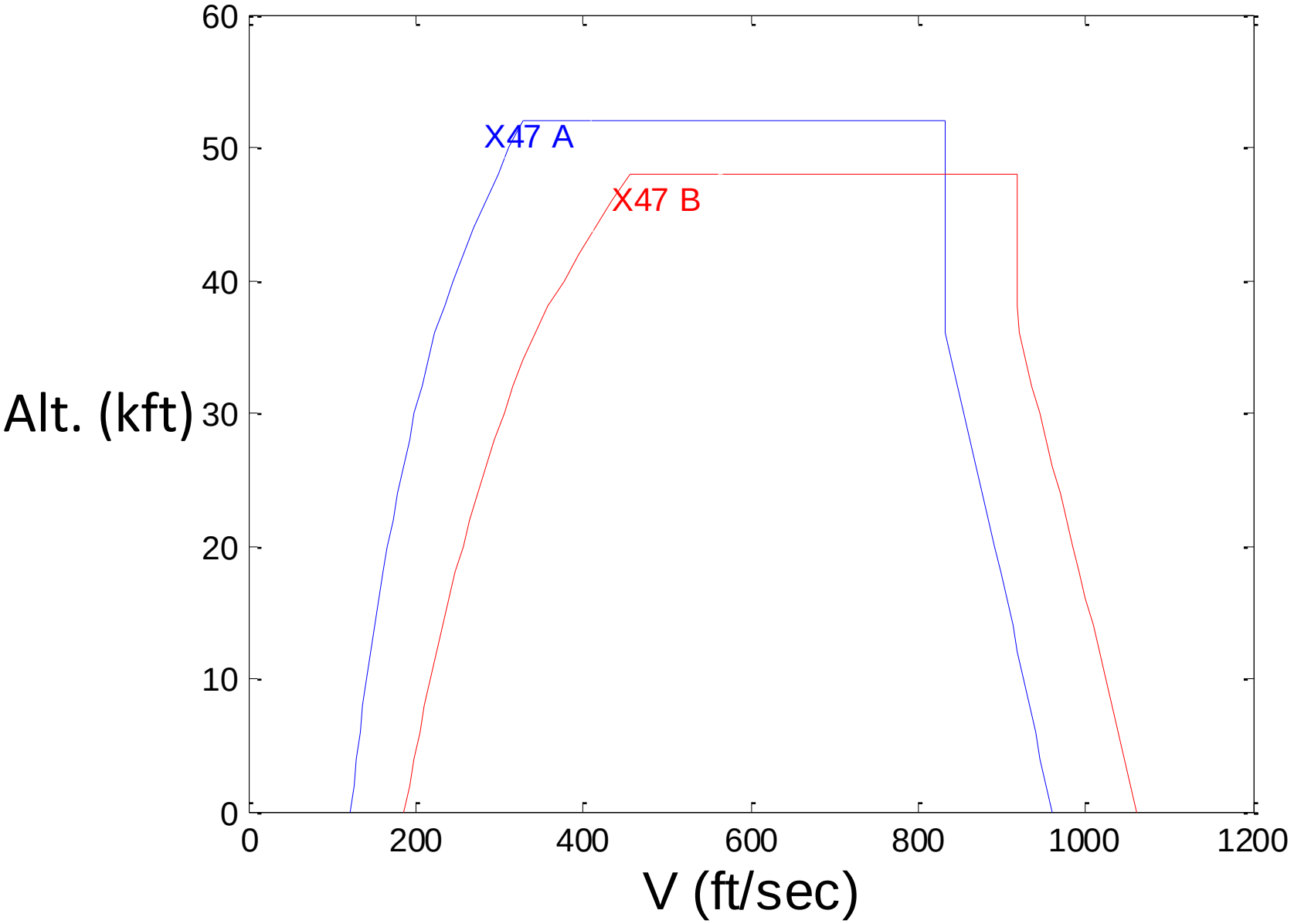
Max Rate of Climb “MROC” vs. Altitude



Range as a Function of Mach Number

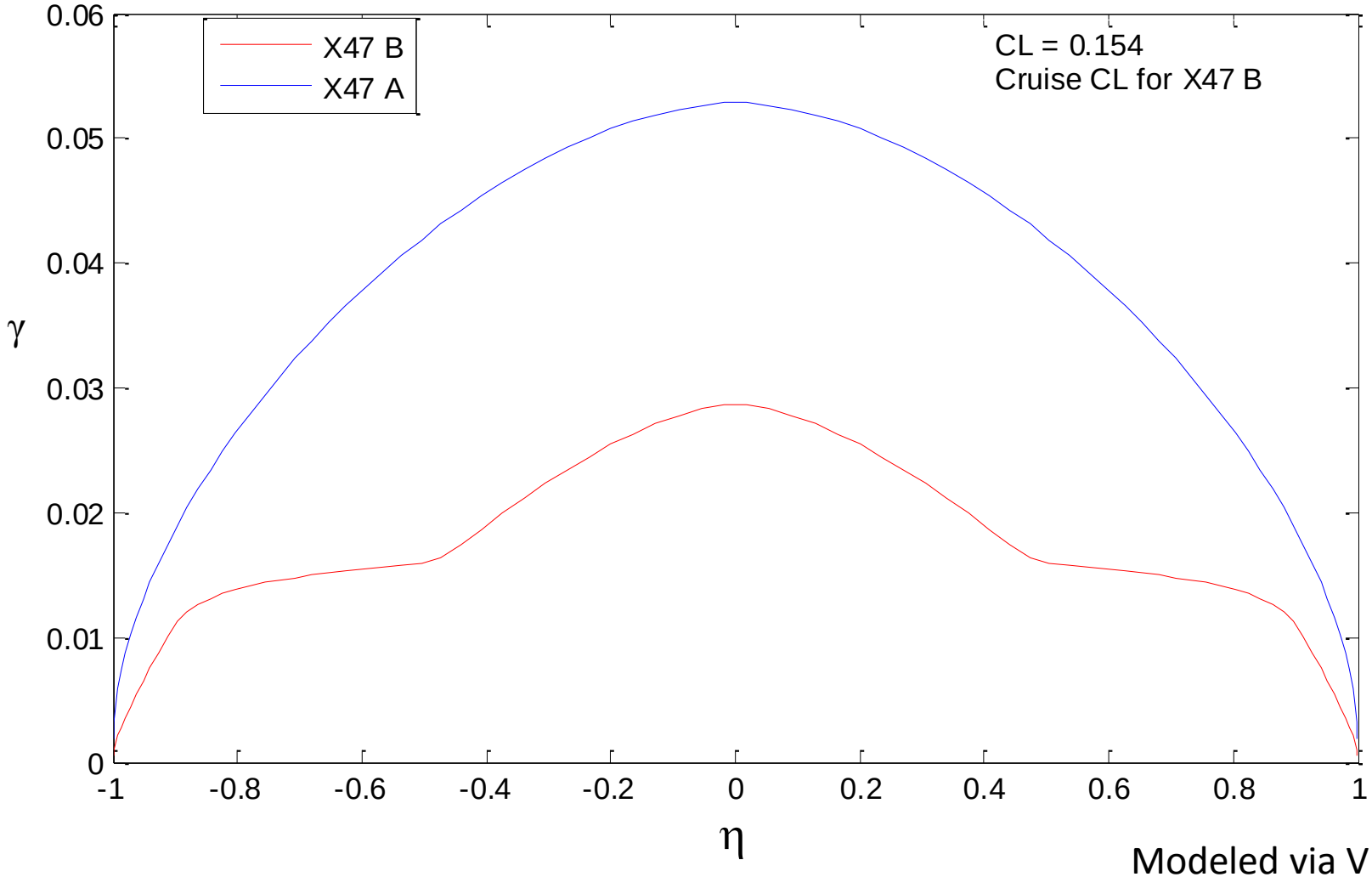


The Flight Envelope



Span Loads

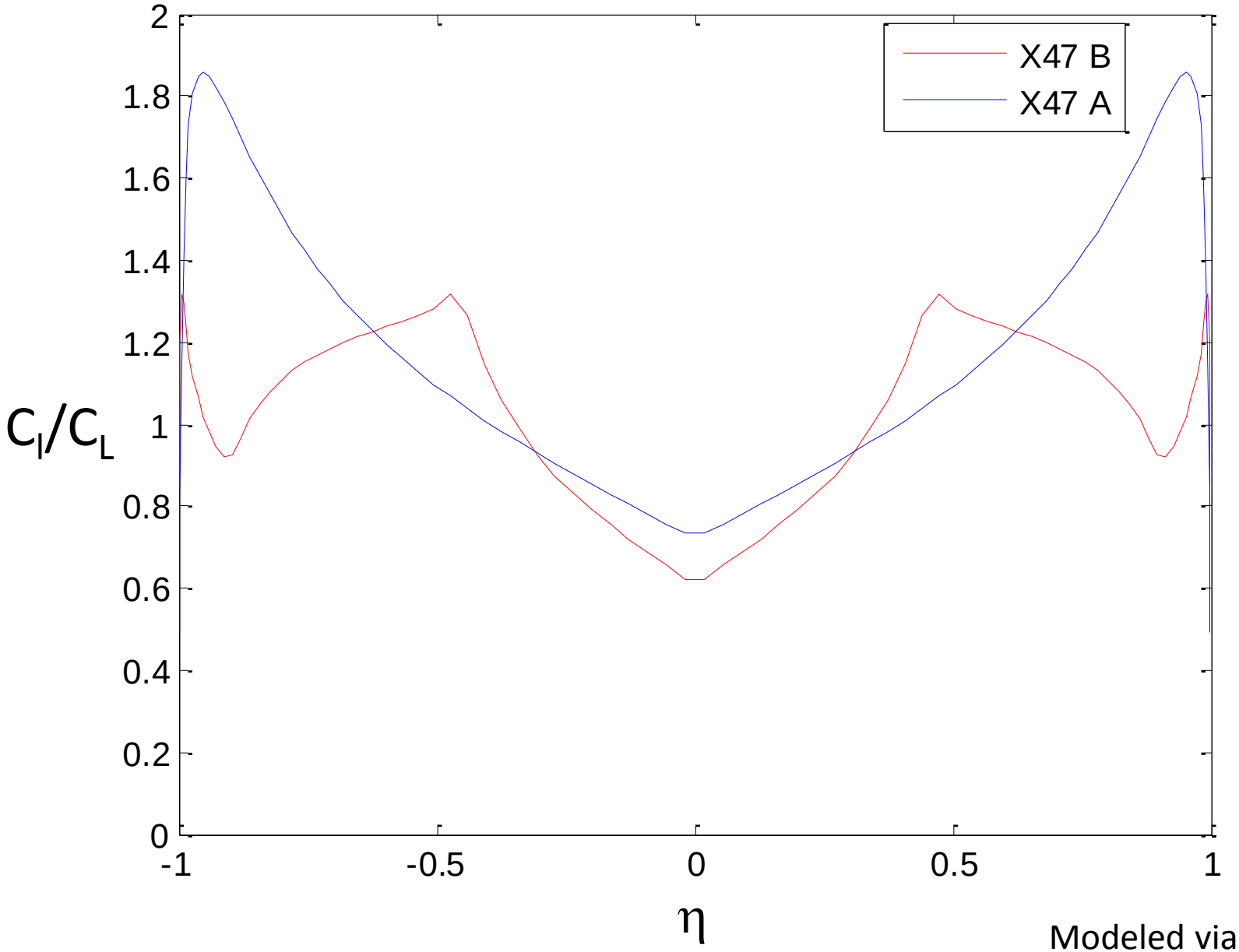
Load Distributions



Modeled via VLM

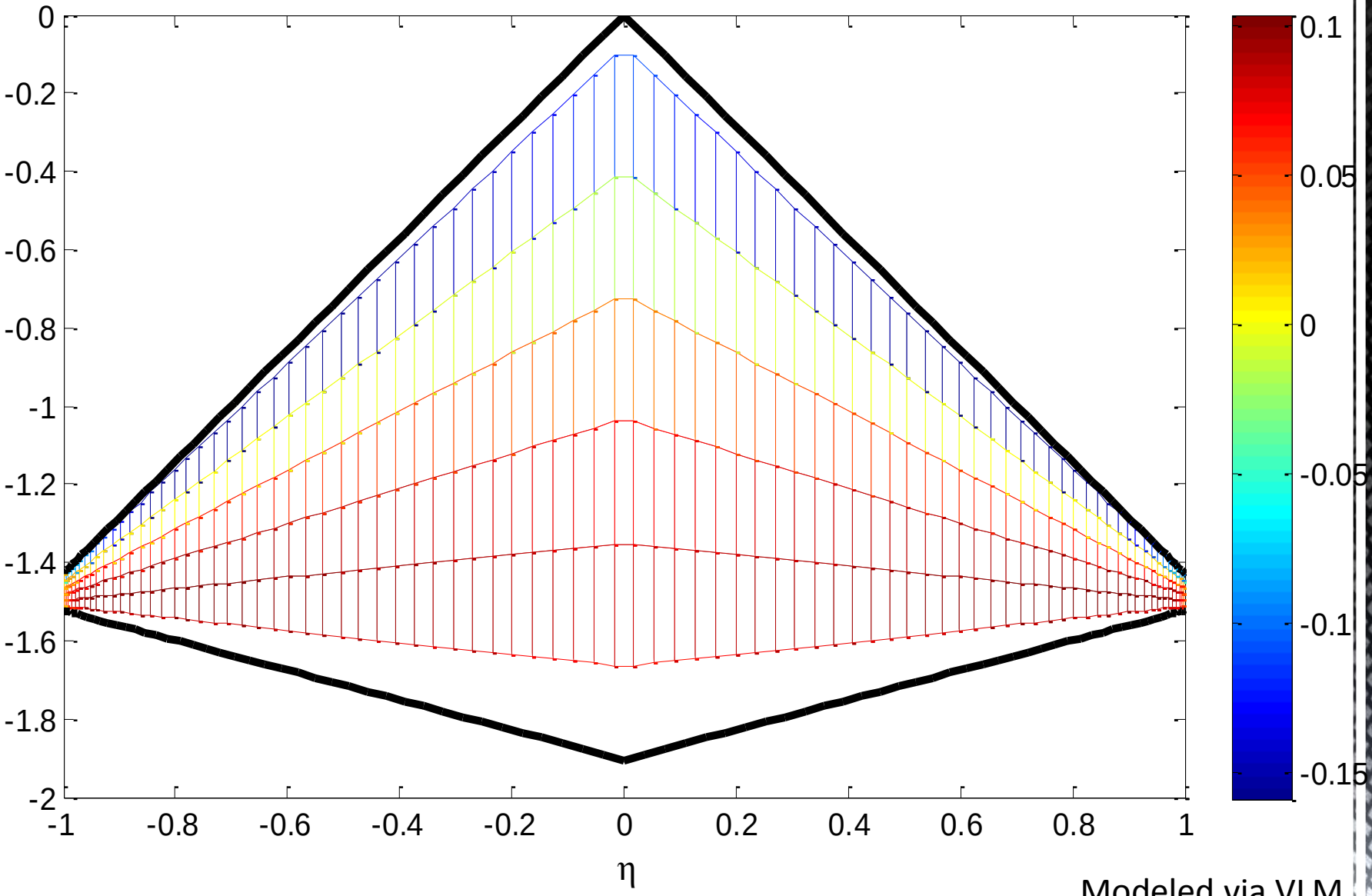
- These are determined using 0.05 taper ratio to avoid infinite sectional lift coefficient at tips.

Section Lift Coefficient Ratio



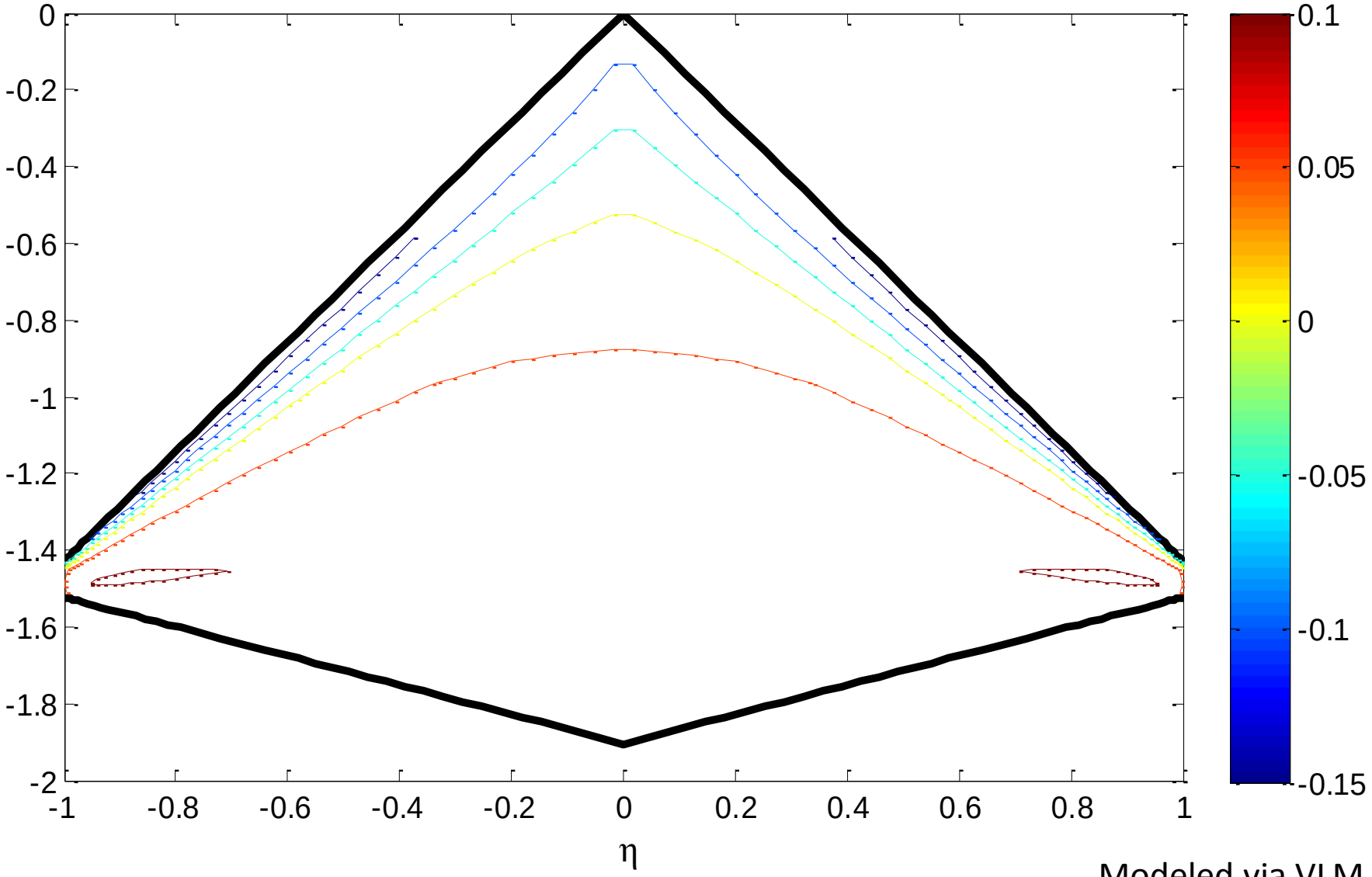
Modeled via VLM

C_p Distribution for X47 A at the cruise C_L



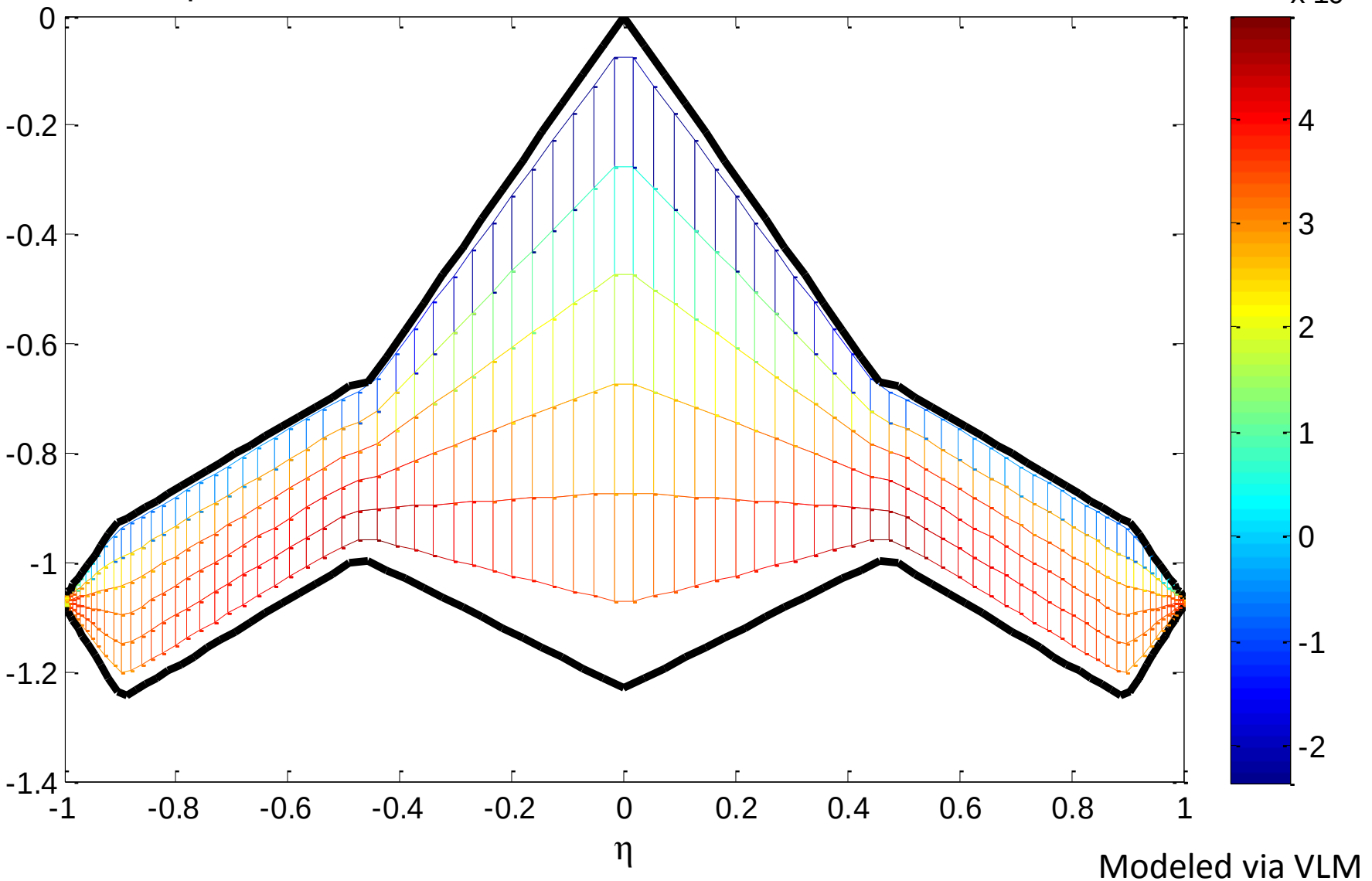
Modeled via VLM

C_p Contours for X47 A at the cruise C_L



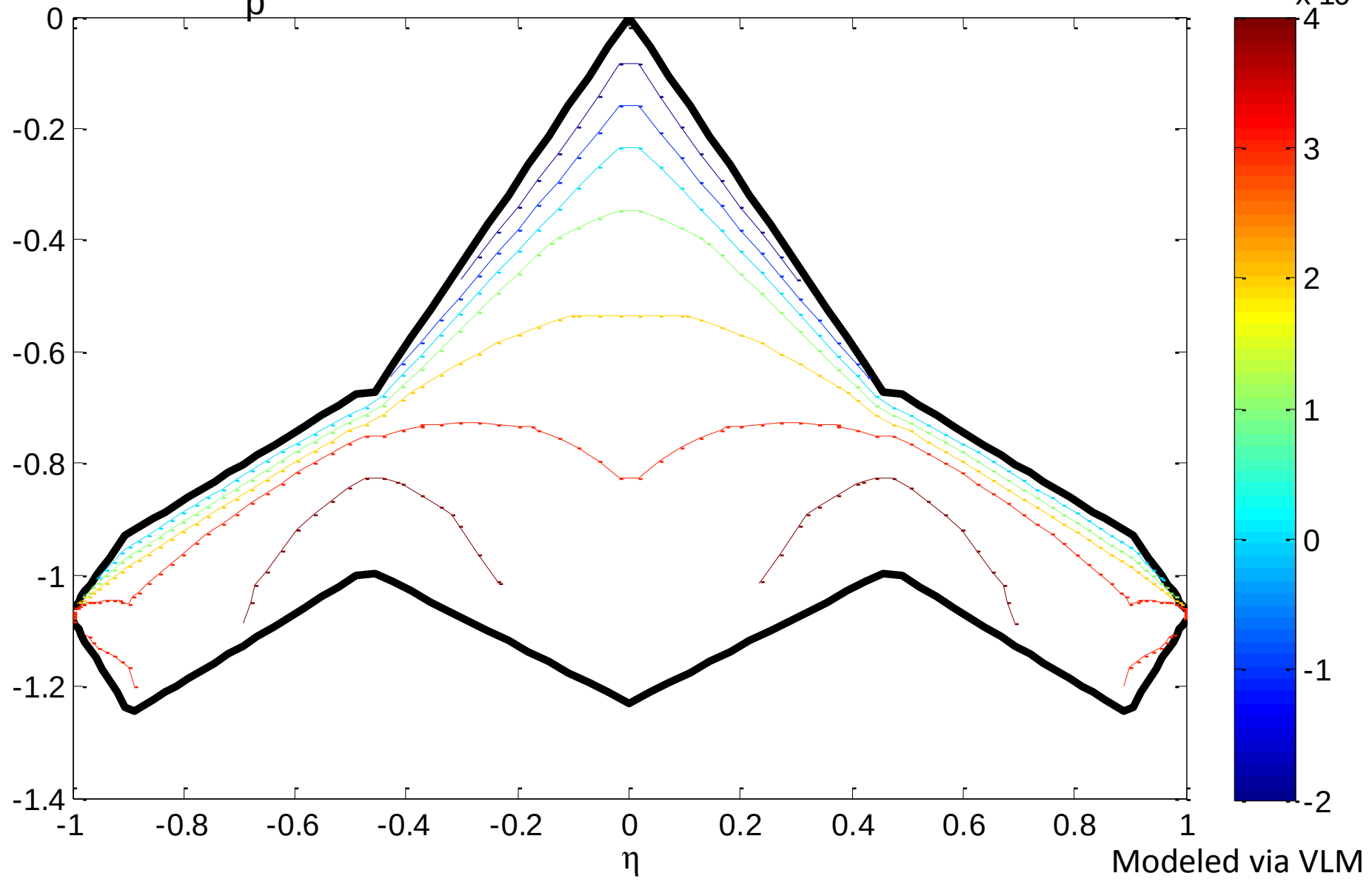
Modeled via VLM

C_p Distribution for the X47 B at the cruise C_L



Modeled via VLM

C_p Contours for the X47 B at the cruise CL



Modeled via VLM

Stability

X-47 A

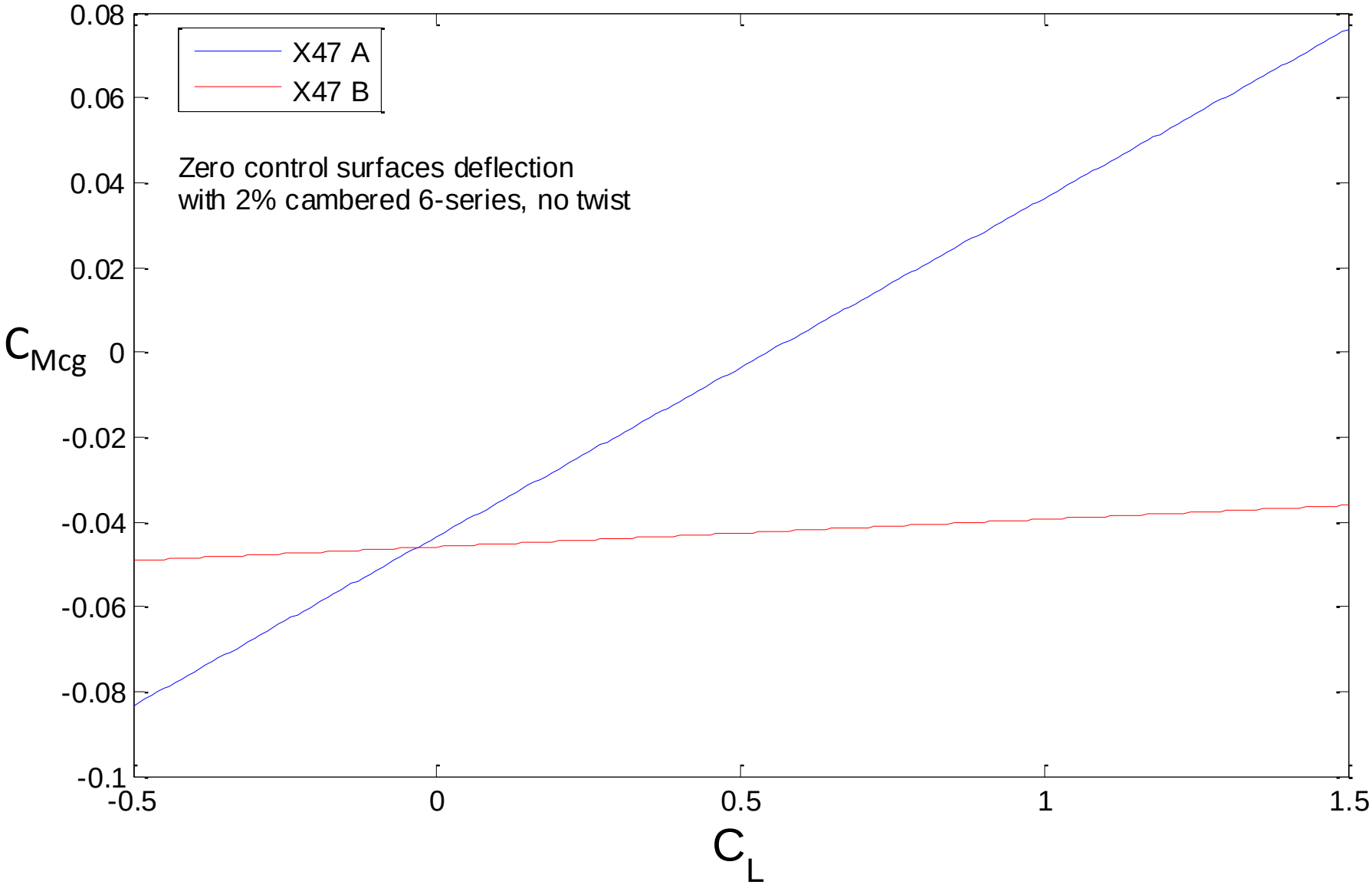
- CG: $\frac{X_{cg}}{\bar{C}}$ =0.46 MAC
- Static Margin: -8%
- Neutral Point: $\frac{X_{np}}{\bar{C}}$ =0.54 MAC

X-47B

- CG: $\frac{X_{cg}}{\bar{C}}$ =0.23 MAC
- Static Margin: -.65%
- Neutral Point: $\frac{X_{np}}{\bar{C}}$ = 0.24 MAC

$\bar{c}$ is the mean aerodynamic chord.

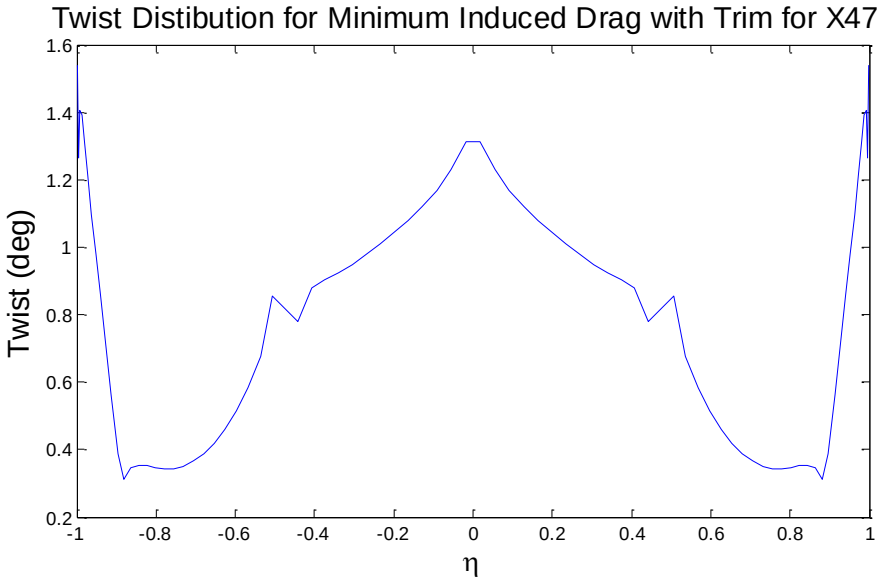
Cm Vs CL

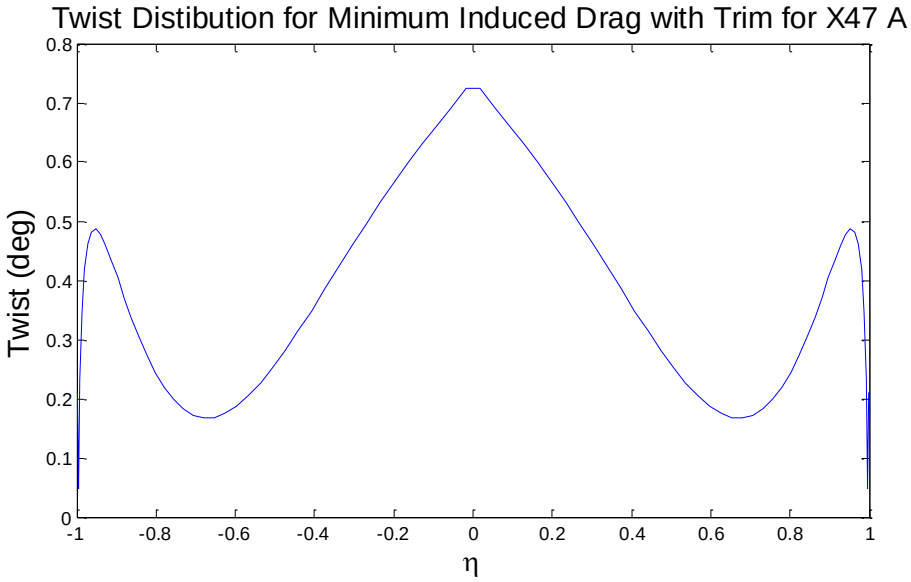


Modeled via VLM

Camber & Twist

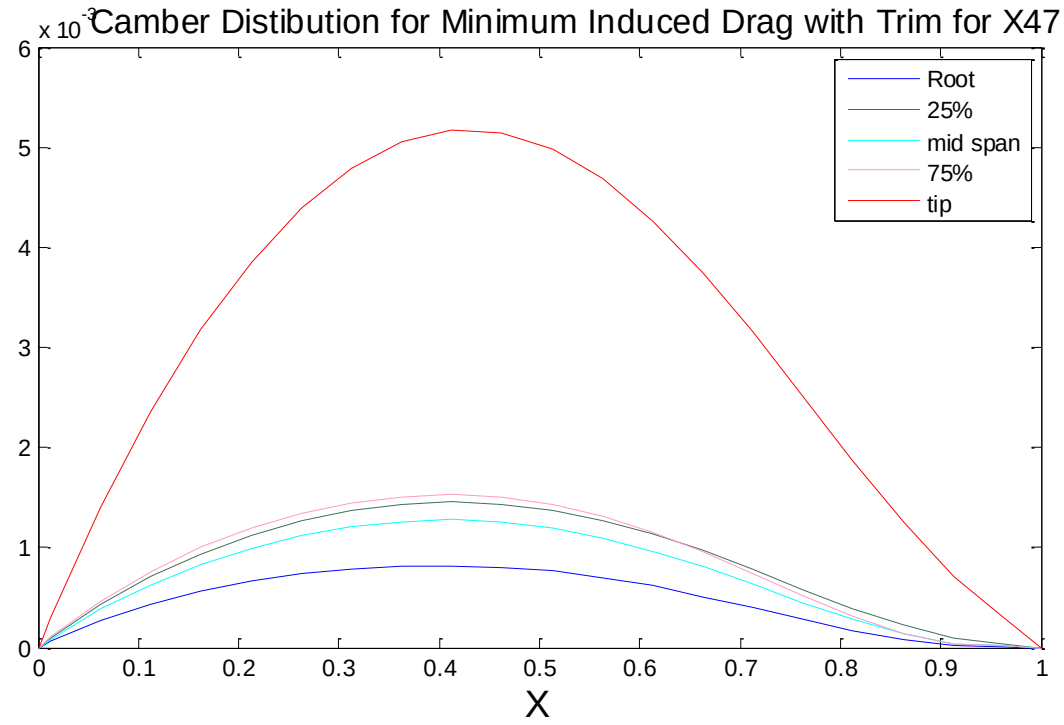
- X-47A: Camber and Twist distribution led to a reduction in induced drag from 43 counts to 1.1 counts.
- X-47B: Reduction from 87 counts to 5.6 counts.



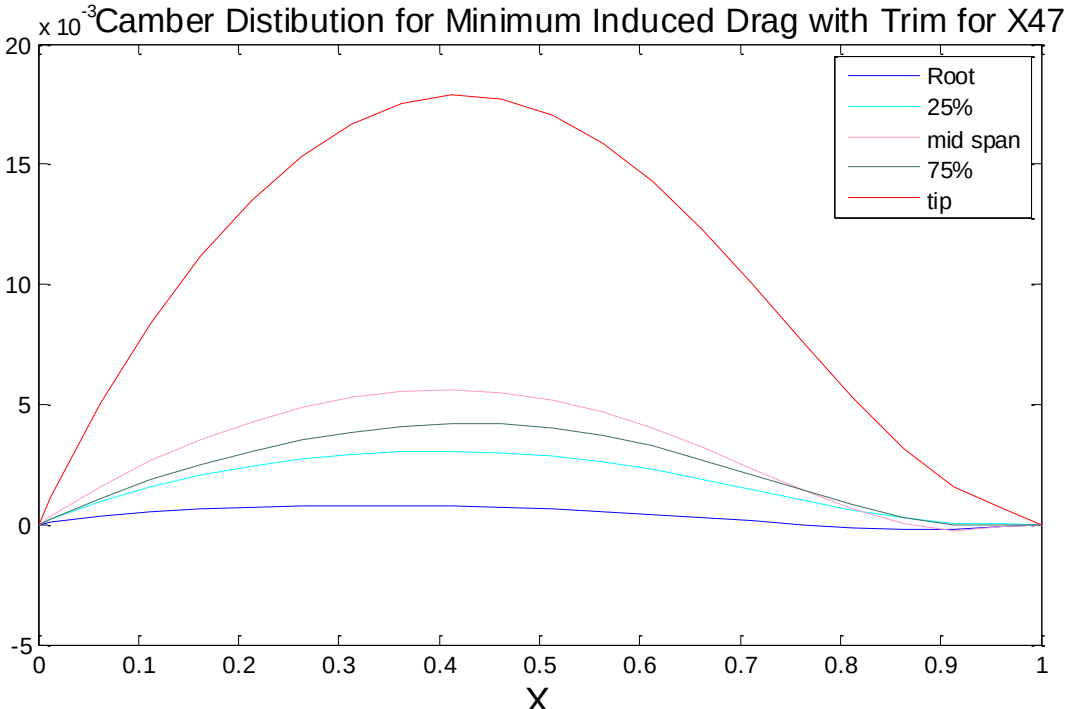


Modeled via VLM

Z_{camber}



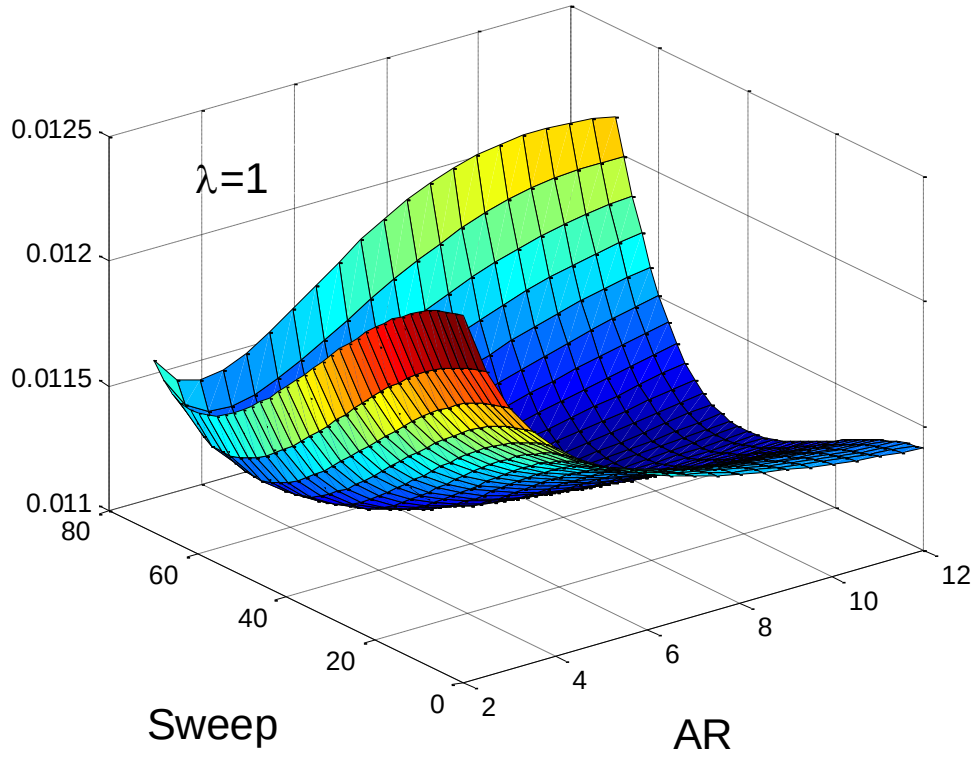
Z_{camber}



Modeled via VLM

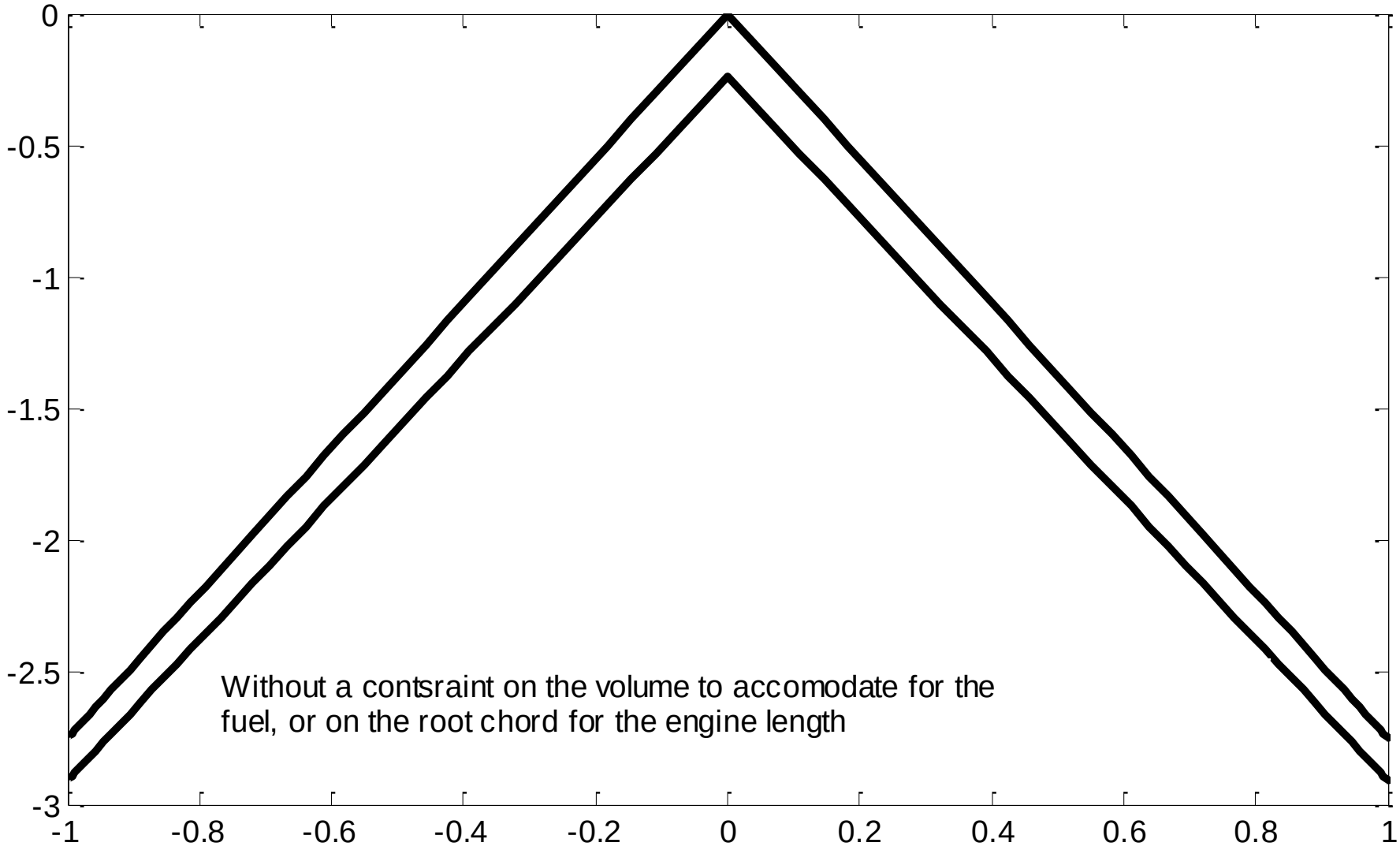
Optimization for the existing wing loading

- DV's: AR, λ, Sweep Angle to:
- Minimize the total Drag
- Maximize the Flutter Speed
- While trimming the airplane at the cruise CL
- Stable balance (negative $C_{M\alpha}$)



Modeled via VLM

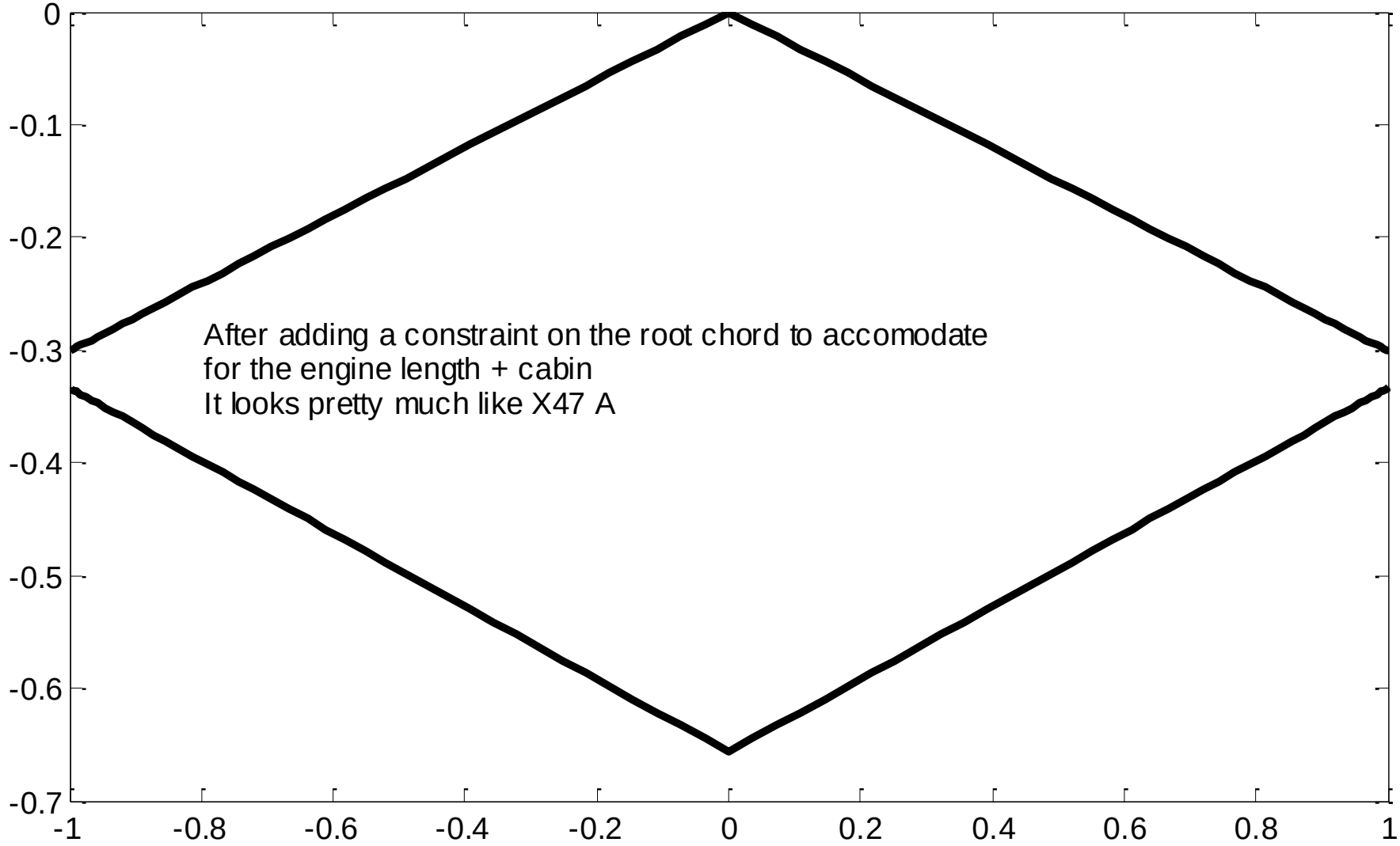
Shape for the X47 B wing planform for minimum Induced Drag at the cruise CL + Trim



For: AR = 10, $\lambda = 0.67, \text{Sweep} = 70^0, C_{di} = 0.23$ counts

Modeled via VLM , Matlab Optimization Toolbox

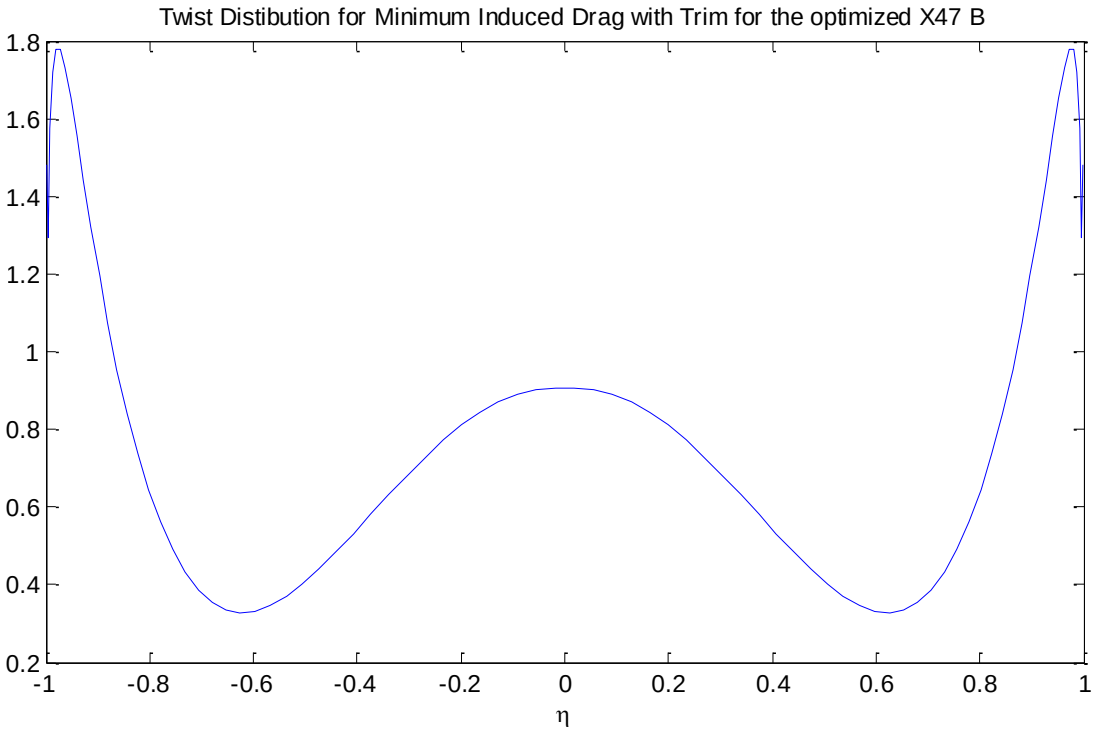
Shape for the X47 B wing planform for minimum Induced Drag at the cruise CL + Trim



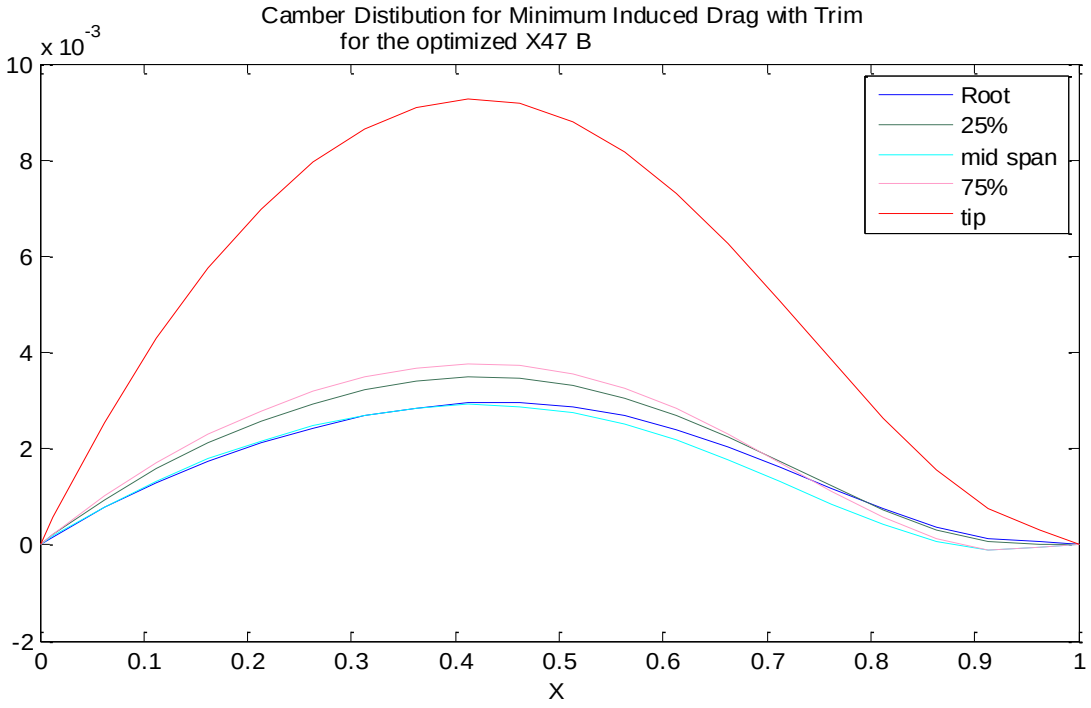
AR = 5.8, $\lambda = 0, \text{Sweep} = 16.7^{o}, C_{Di} = 4.8$ counts.

Modeled via VLM , Matlab Optimization Toolbox

Twist (deg)



Z_{camber}



Modeled via VLM

Conclusion

- X-47A is redesigned for optimum range operation
- X-47B has 10 times the payload capacity of the X-47A
- X-47B has better drag characteristics than the A
- X-47B is neutrally stable, improving on the unstable A concept.

Artist Concept of the X-47B landing on an Aircraft Carrier.
www.strategypage.com

References

Technical Data and Published facts taken from.

1. Scaled Composites X-47A Facts and Figures, http://air-attack.com/page/28/X-47-Pegasus-UCAV-N.html.
2. X47B Facts and Figures. http://www.as.northropgrumman.com/products/nucasx47b/assets/X-47B-UCAS-Fact-Sheet.pdf. 4/19/2011.
3. A Vortex Lattice Method for the Mean Camber Shapes of Trimmed Non-Coplanar Planforms with Minimum Vortex Drag. By: *John E. Lamar.* NASA Report TN D-8090.

Artist Drawings and Photographs taken from:

1. X-47A. www.wikipedia.org.
2. X-47B www.northropgrumman.com.
3. Artist Concept of the X-47B landing on an Aircraft Carrier. www.strategypage.com.
4. X-47B in Landing Configuration www.technewsdaily.com.
5. X-47 Final Concept Art www.unmannedwarfare.webs.com.