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# Evaluation of Novel Wing design for UAV

(MASTERS THESIS)

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# Outline

- Introduction
- Non Planar Wing design
- Aerodynamic Evaluation
- Structural Evaluation
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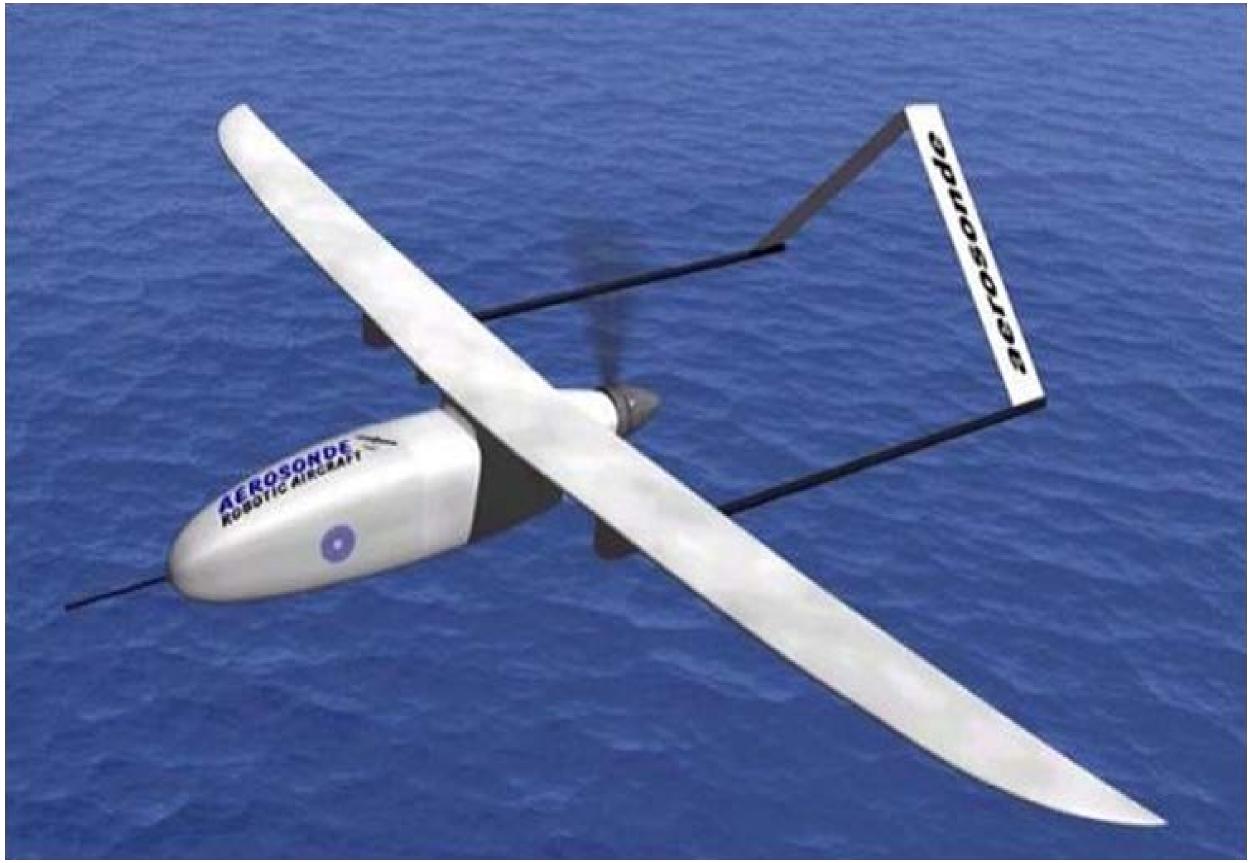
# Introduction

- Great demand in small scale UAVs produced by both government and private companies like
    - Boeing
    - Lockheed Martin
    - AeroVironment
    - AAI Coorperation

# AAI Aerosonde

- Reconnaissance
- Inverted V Tail
- Catapult Launched
- Long Range
- All Sensors in Fuselage

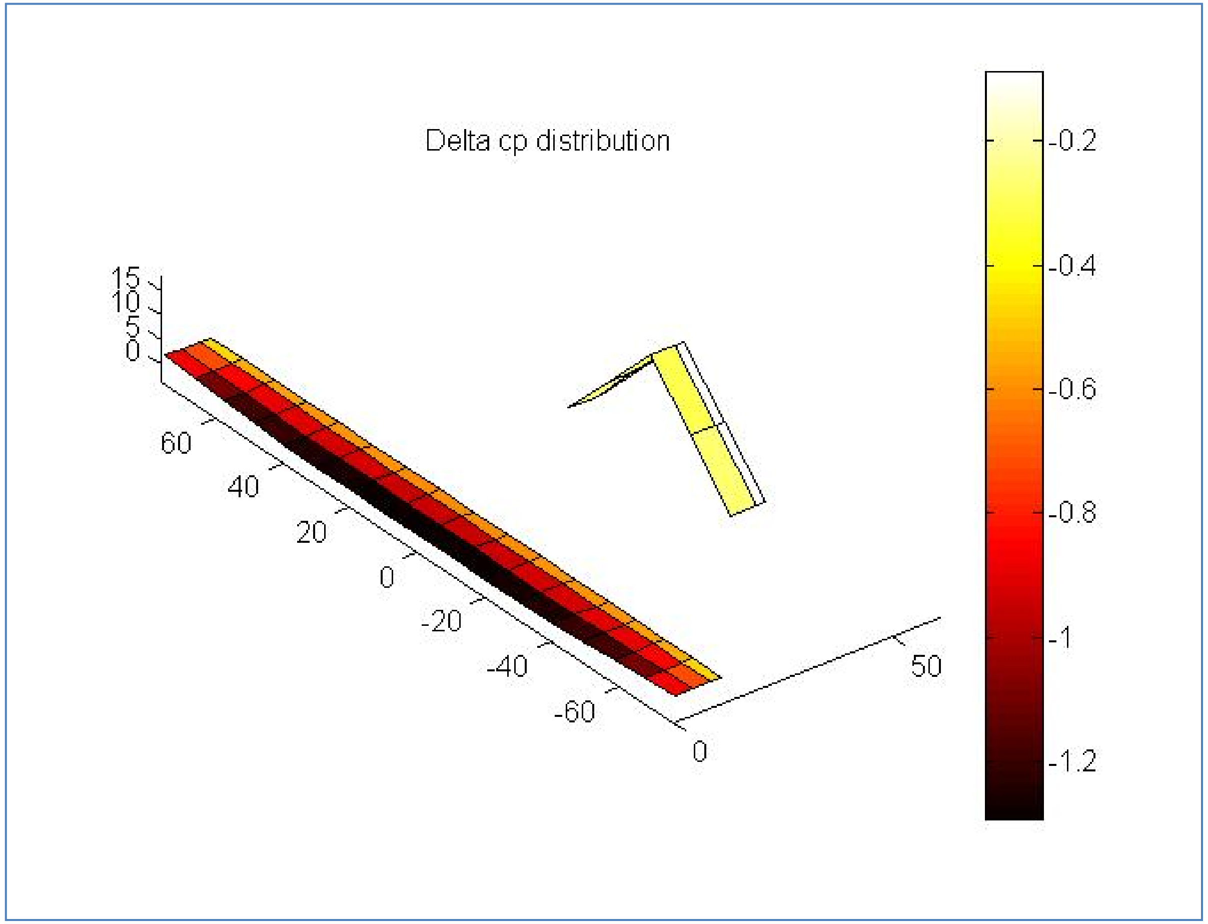


# Aerosonde Specifications

| Geometry & Weight | |
|---|---|
| Length | 5.58 ft (1.7 m) |
| Height | 1.97 ft (0.60 m) |
| Wingspan (b) | 9.67 ft (2.95 m) |
| Mean Chord ($\bar{c}$) | 0.631 ft (0.192 m) |
| Wing Area (S) | 6.1 $ft^2$ (0.567 $m^2$) |
| Aspect Ratio ($AR=b^2/S$) | 15.33 |
| Max GTOW | 55 lbs (24.94 kg) |
| Wing Loading (W/S) | 9.02 $lbs/ft^2$ (432 $N/m^2$) |

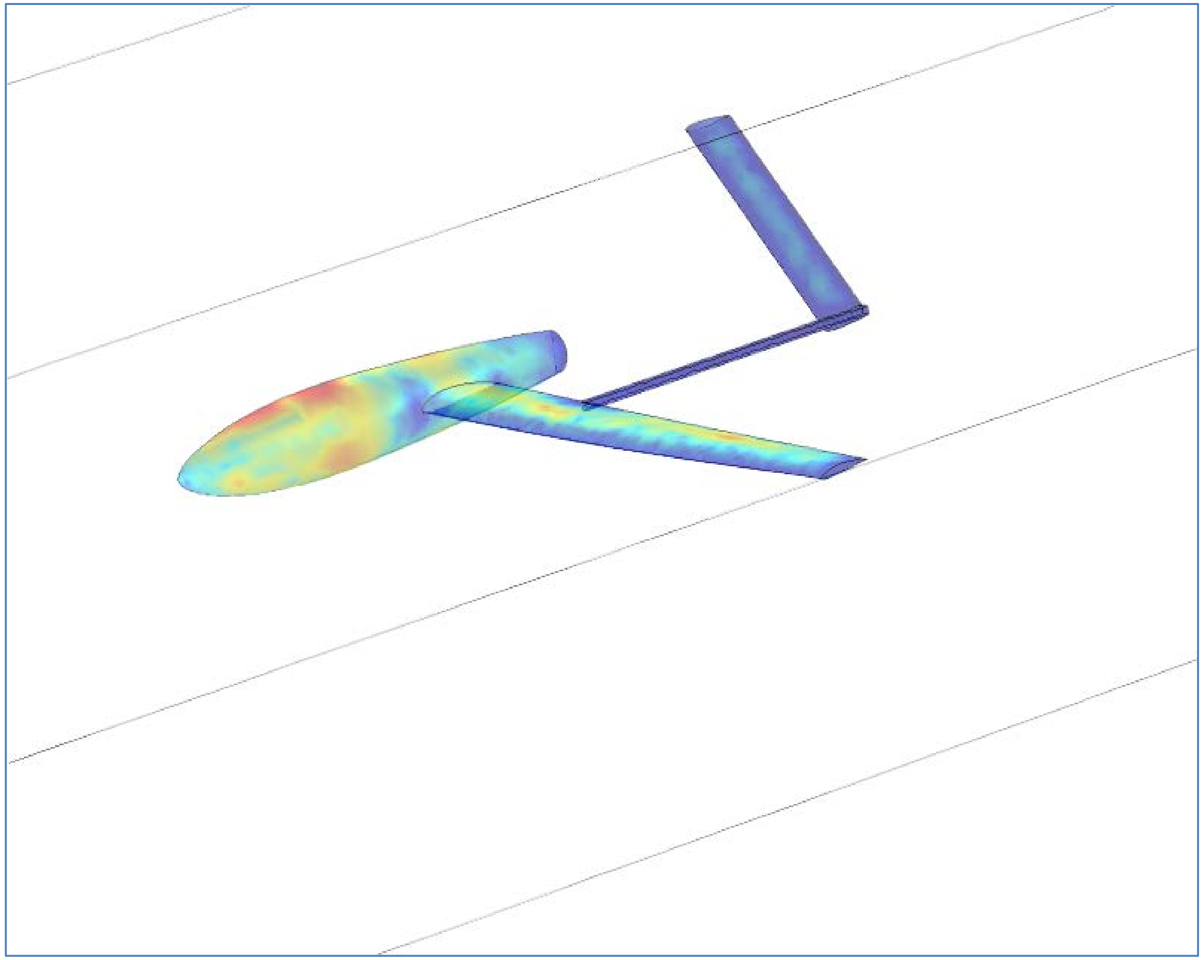
# Tornado Analysis of Aerosonde

- NACA 4415 for Wing
- NACA 0012 for Tail
- Lift, Drag, CL, CD have been Obtained for Various angles of attack



# COMSOL Analysis of Aerosonde

- Model imported from Solid Edge
- Applying a block around it for simulating a wind tunnel
- Meshing using ahmed body method in COMSOL
- Mesh Evaluation study has been carried out
- Results of COMSOL has been verified by comparing the Lift with Tornado



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# Non Planar Wing Configurations

- Non Planar configurations have been considered as an alternative
  - Various Configurations of Box wing have been considered
    - Varying the Gap and Stagger
  - Various Configurations of Joined wing have been considered
    - Varying the wing span and Apex of the tail

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# Aerodynamic Evaluation

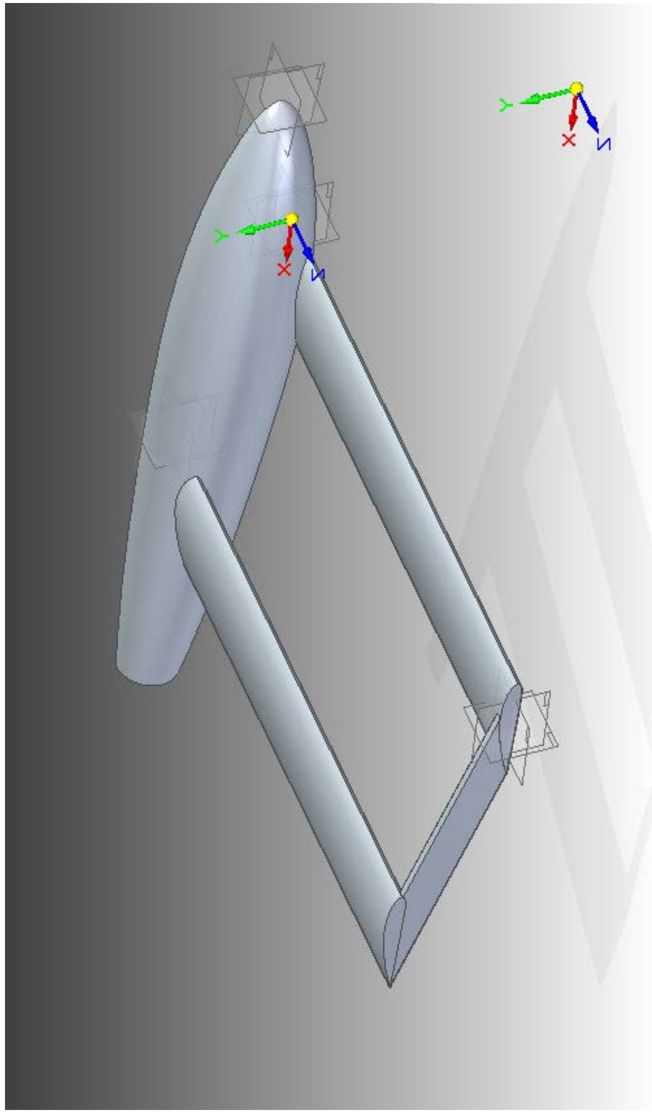
- Aerodynamic evaluation of the Non Planar configurations have been done by the following method
  - Evaluate various box wing configurations in Tornado
  - Evaluate various Joined wing configurations in Tornado
  - Compare the best configurations of Box wing and Joined wing in COMSOL using the method of comparison.

# Method of Comparison

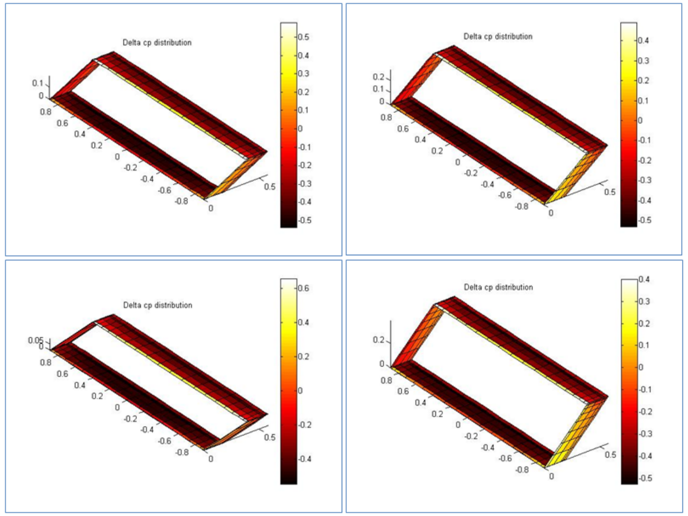
- In each comparison, the following have been kept constant/ Consistent
  - Center Body (Fuselage)
  - Wing Plan form Area
  - Total Load
  - Structural Material
  - Thickness
  - Airfoils
  - Load distribution
  - Flying Conditions

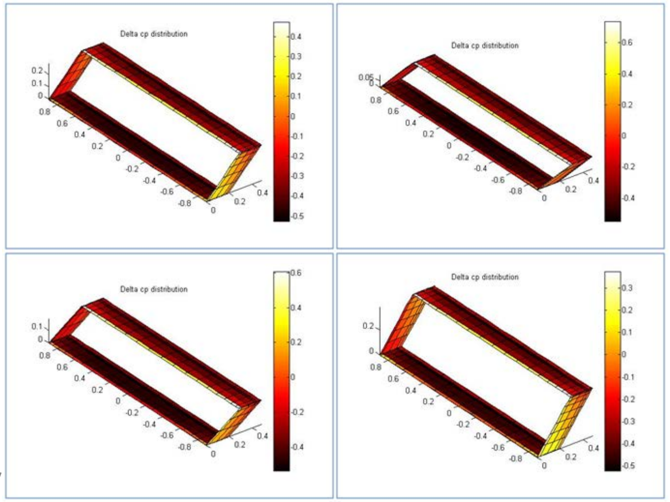
# Box Wing

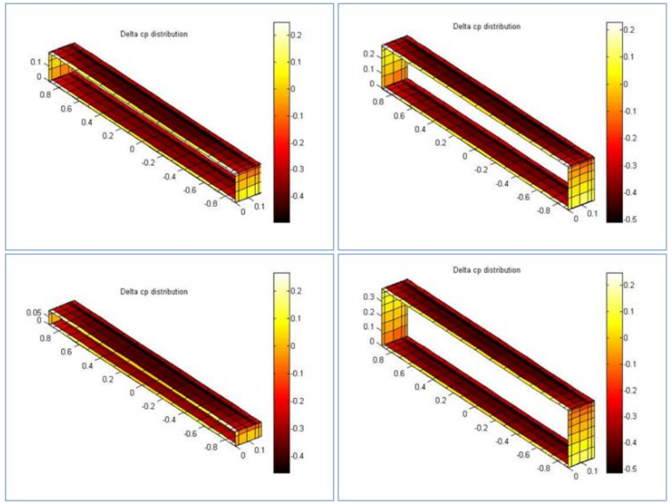
- Different configurations with varying gap and stagger have been tested
- Aerodynamically Best configuration has been selected using Tornado
- The best Configuration that is selected is with 0.75c Stagger and 2c Gap
- The entire aircraft has been tested in COMSOL for accurate comparison to Aerosonde

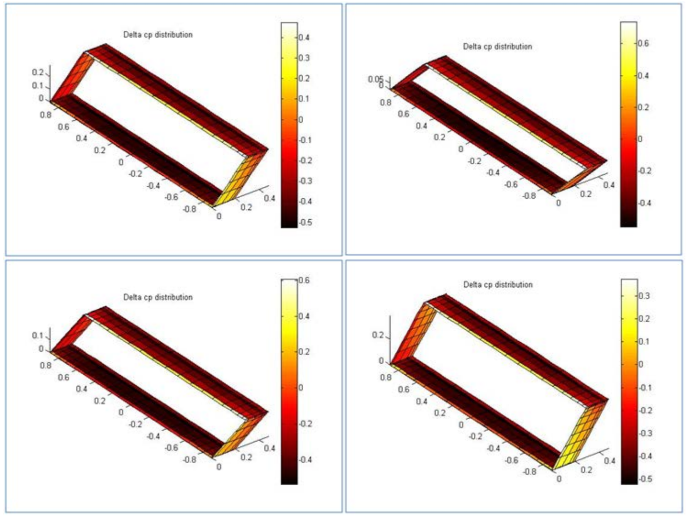


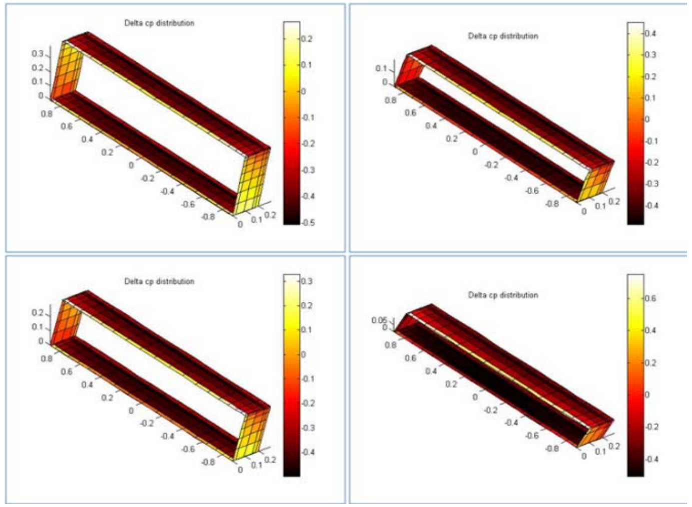
# Different Box wing Configurations tested



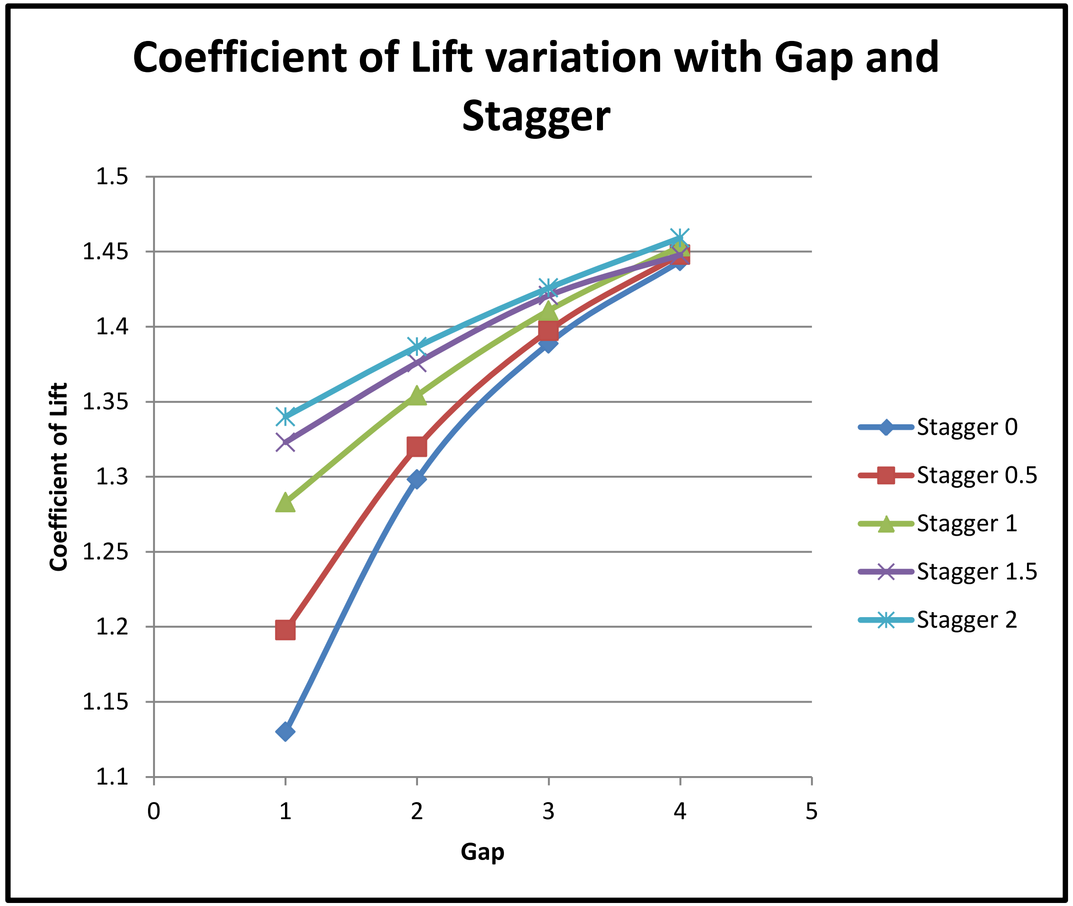



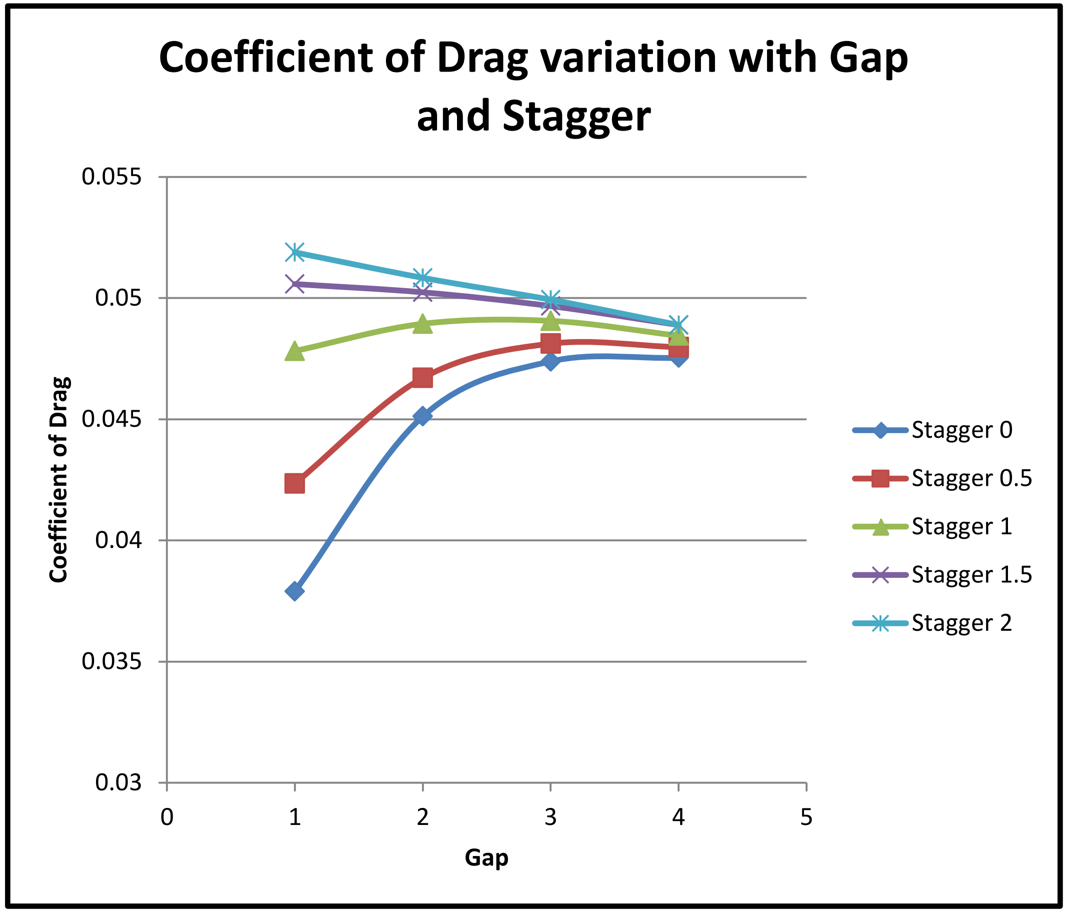



# Results from Tornado



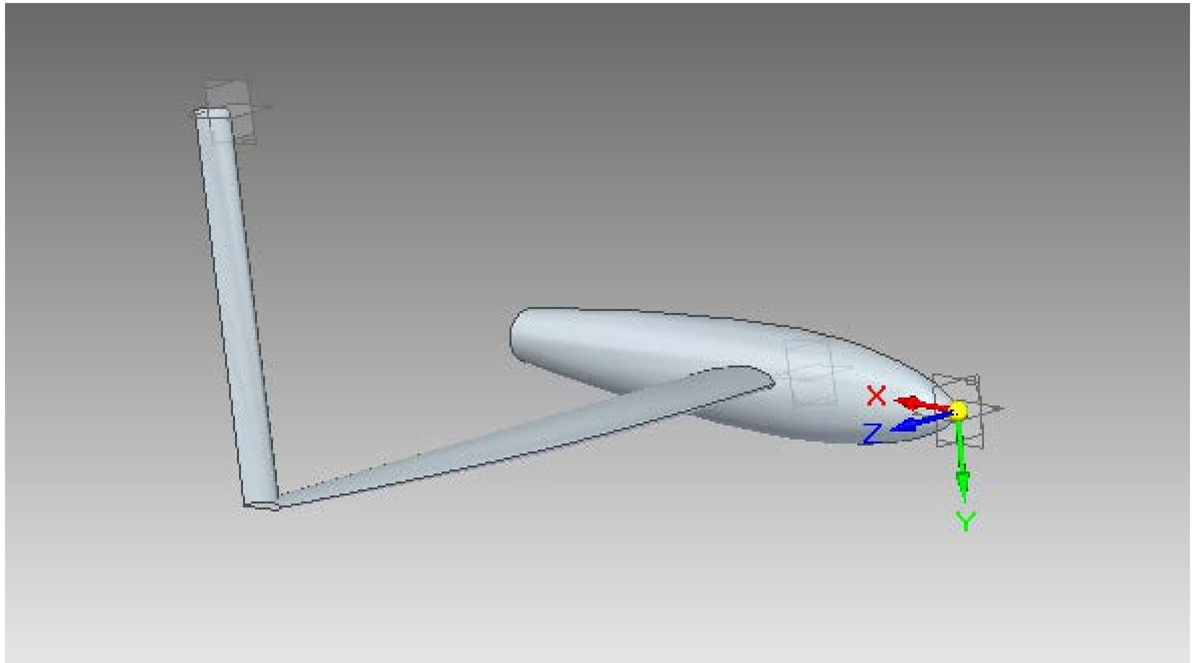



# Results from COMSOL

| Slno | Property | Aerosonde | Box wing |
|---|---|---|---|
| 1 | Lift | 252.2674 N | 227.268 N |
| 2 | Drag | 10.8782 N | 11.023 N |
| 3 | CL/CD | 23.1901 | 20.6176 |

# Joined wing Configuration

- The Same wing and tail plan form area combined has been kept constant
- 2.5% increase in Lift has been Obtained with an increase of 0.77% drag
- A reduction of 9.2% span can be accomplished keeping the same Lift Coefficient.



COMSOL

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# Joined wing aircraft

| Sl no | Parameter | Aerosonde | Joined wing | % difference |
|---|---|---|---|---|
| 1 | Ref. Area | 1868.78 | 1708.2 | 8.59% |
| 2 | Ref. Span | 152 | 138 | 9.21% |
| 3 | Coefficient of Drag | 0.02427 | 0.02525 | -4.04% |

# Evaluation of results

- Mesh control analysis has been done and proven that a mesh finer than what we used in the analysis would not change the results
- The same model has been analyzed in both COMSOL and Tornado to compare the results and it has been proven that COMSOL is very accurate in its results using not only the Tornado values but also by generic Data (Analysis of NACA 0012)

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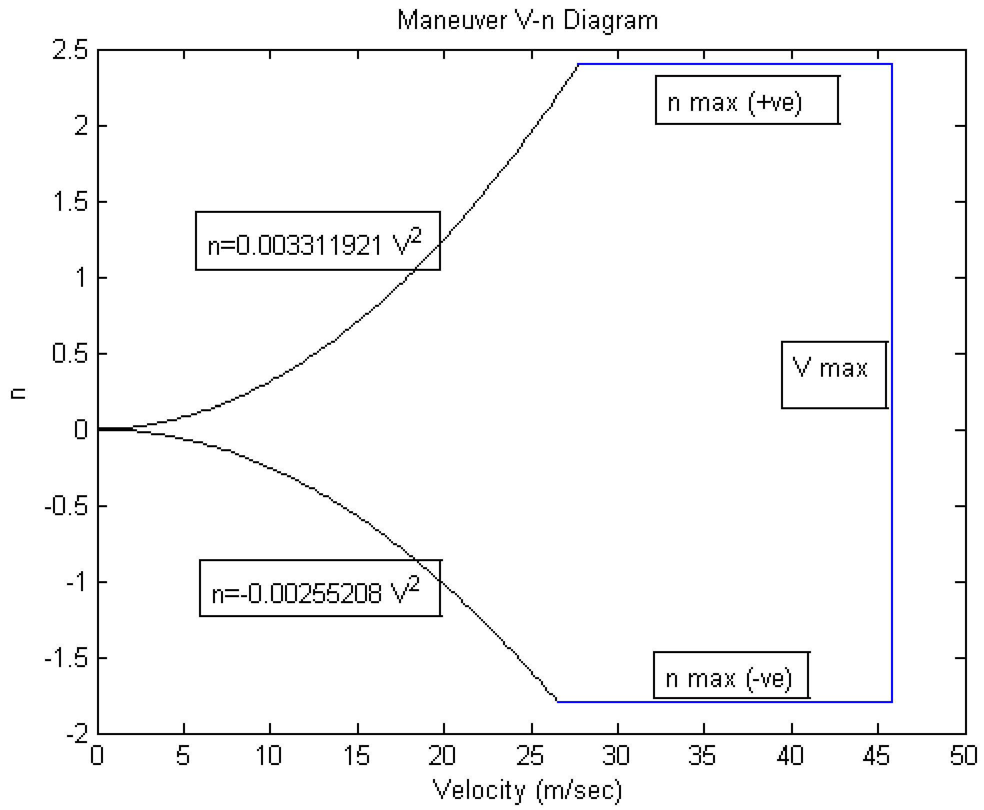
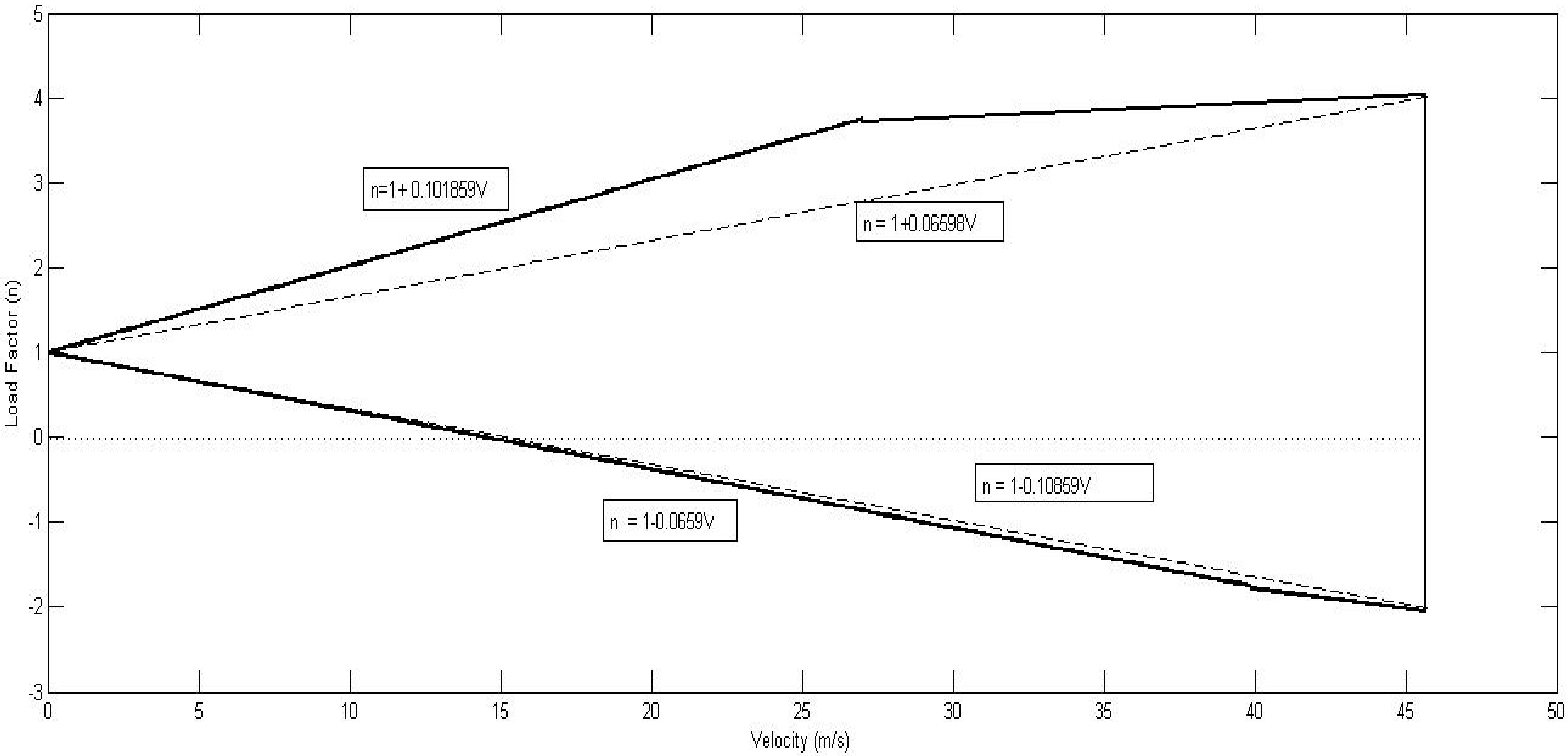
# Structural analysis

- For performing the structural analysis, we need to calculate the loads affecting the aircraft.
- The V-n diagram for Gust loads has been calculated
- The V-n diagram for maneuver loads has been calculated
- The maximum loads that the aircraft will experience has been taken
- The max load is then applied to all three aircraft configurations

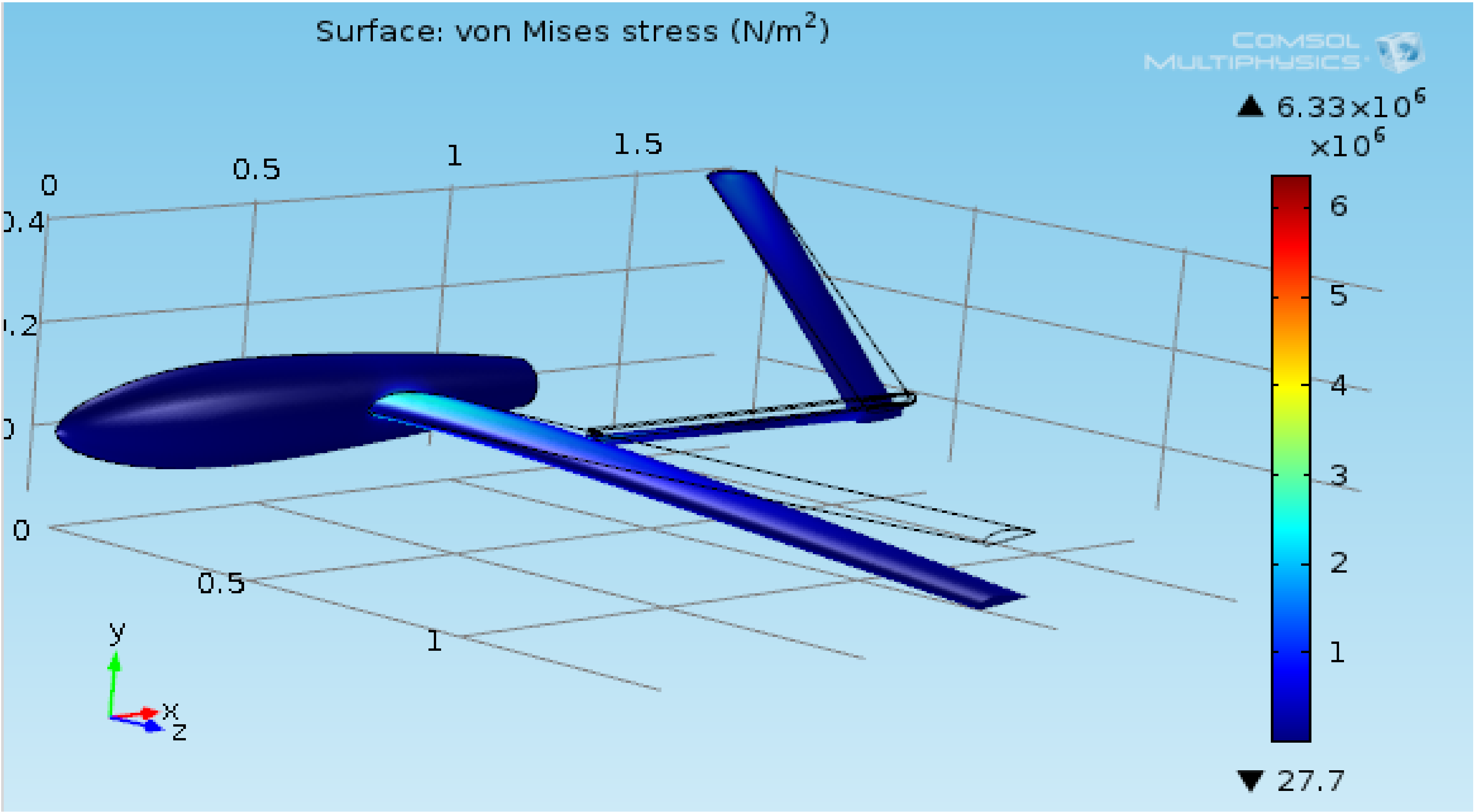
# Maneuver V-n Diagram



# Gust V-n Diagram



# Analyzing in COMSOL



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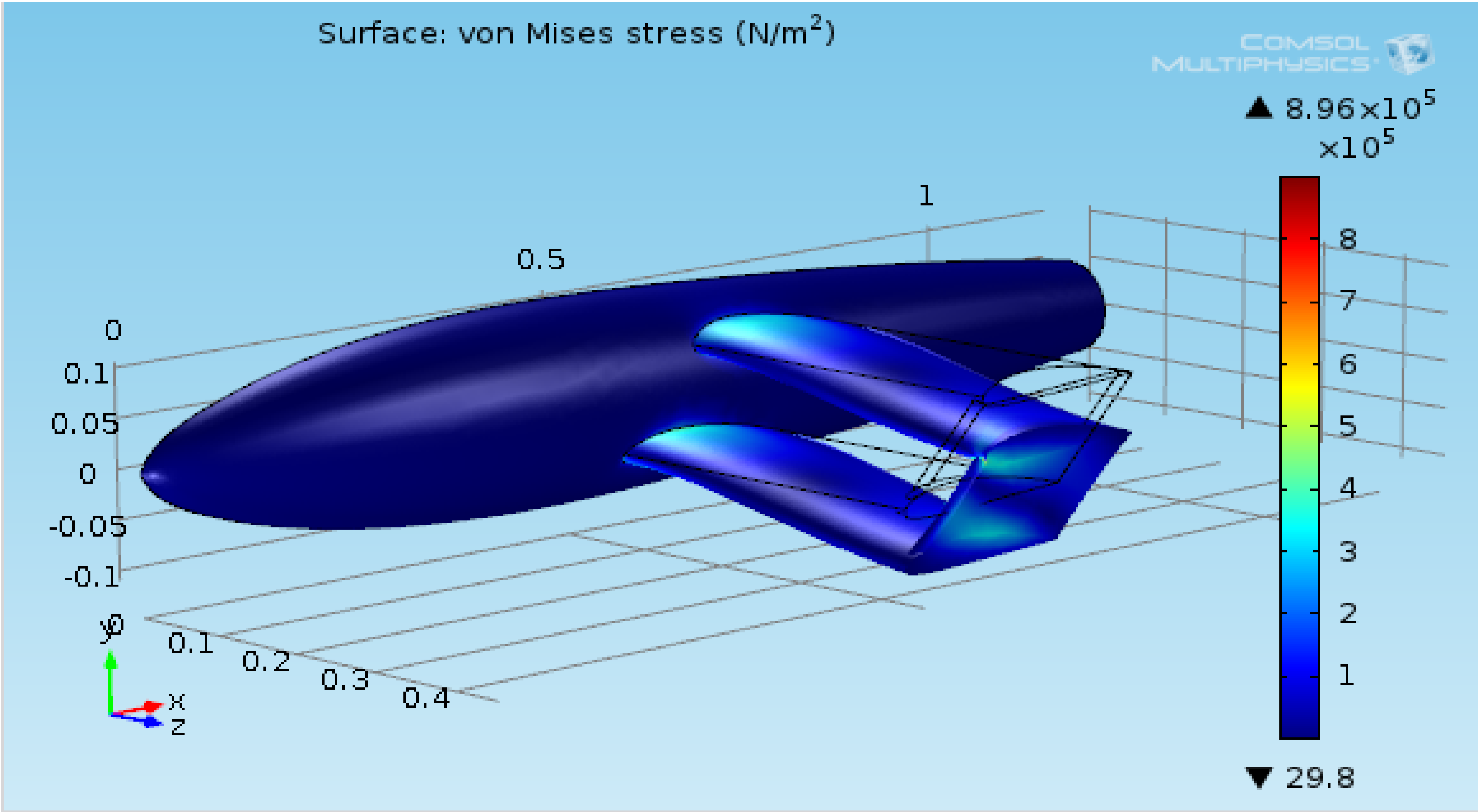

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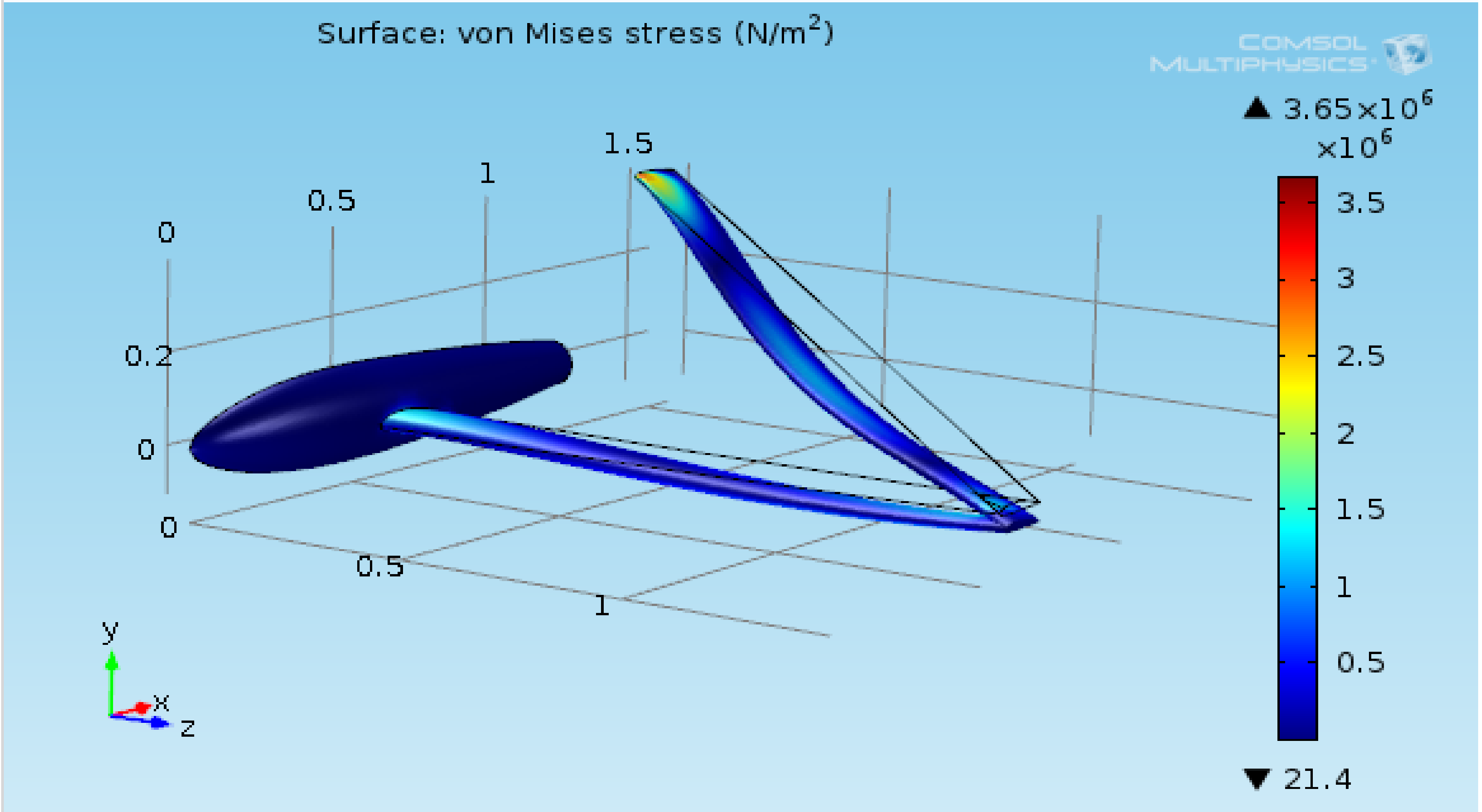
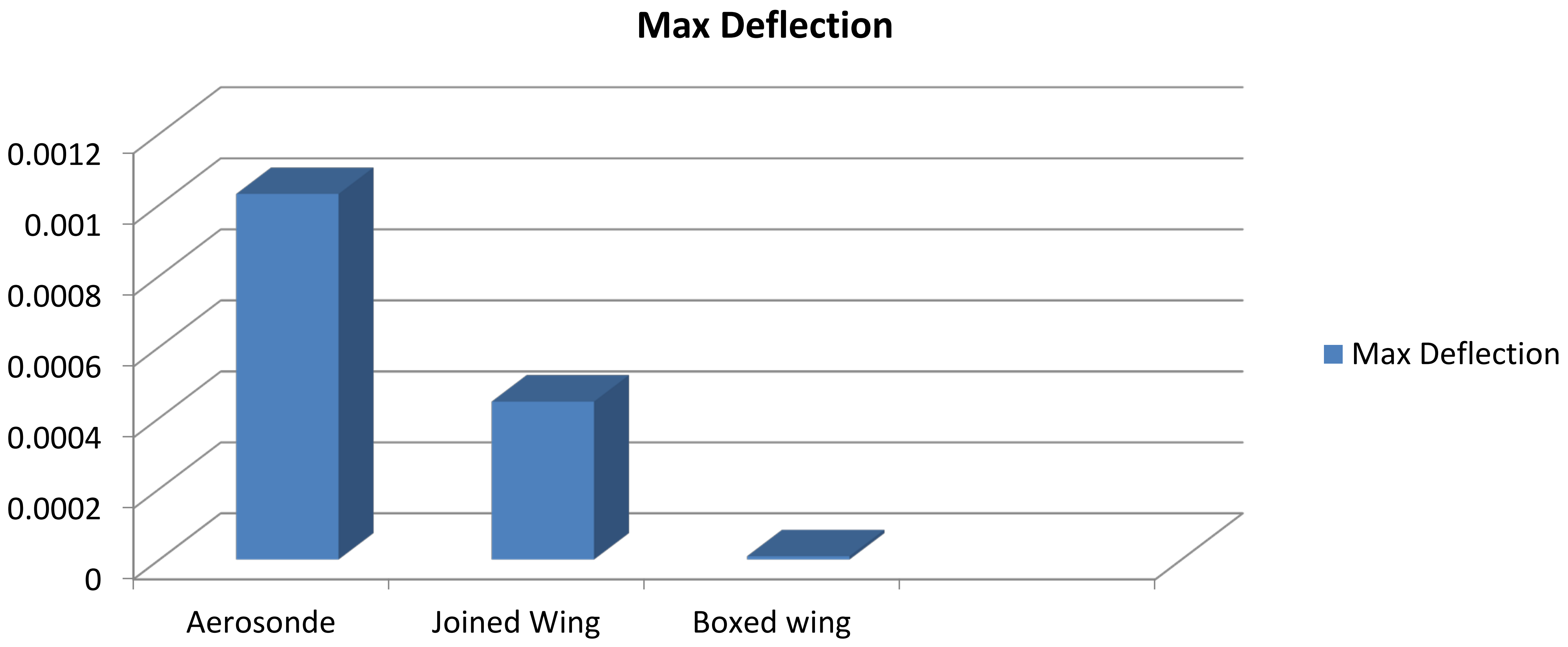


# Comparison of Results

| Result Set | Aerosonde | Joined Wing | Box wing |
|---|---|---|---|
| Max Stress | 3.38821 MPa | 3.28974 MPa | 0.50346 MPa |
| Max Displacement | 1.03 $e^{-3}$ m | 4.4558$e^{-4}$ m | 9.425$e^{-6}$ m |

# Maximum Deflection



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# Choosing the best configuration

- Aerodynamically, Joined wing is the best configuration
- Structurally, Box wing is the best configuration
- Trade off should be made whether to use monoplane wing, Joined wing or Box wing.
- Box wing is a great alternative as it reduces the size of the aircraft giving decent aerodynamic performance and a very good structural performance for long range usage.
- Joined wing has higher aerodynamic performance when compared to the box wing and Aerosonde and can be chosen when aerodynamics is the main concern.

# Conclusion

- Box wing aircraft is the best configuration that can be used on small scale UAV and the best alternative for AAI Aerosonde configuration as it can provide
  - High Maneuverability
  - Stronger aircraft
  - Easily transportable and Storable.

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# Thank you