Canard Based Attitude Stability Unit

By

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Introduction

- Super ARLISS
  - Very slow subsonic
  - Expense to 30K ft
    - Super ARLISS 3x
    - Single Stage 6x
  - Wind instability

- Solution: Canard based Altitude Stability Unit (ASU) tested on a 4 inch diameter rocket

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Objective

- Model the Canard based ASU to predict the aerodynamic forces, and benchmark them against actual flight data.

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Impact Statement

- It will greatly reduce the cost of sending a student or amateur designed payload to greater altitudes than previous launches were capable.

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Approach

- Hand Calculations
  - Assume: Incompressible, Inviscid, Steady-State
  - Lift Generated (Canards)
    - 51.1 Newton
    - Predicted Roll of .38Hz

Flight Conditions October 2010		
Airspeed	542 ft/sec	165m/sec
Mach	0.49	
Altitude	2745ft	837m
Air Density	1.0614kg/m^3	
S	32in^2	.02065m^2
Cl(2)	.0797	

$$\cos(\alpha)\sin^2(\alpha)$$

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Approach

- Model
  - Assumptions
    - Incompressible
    - Inviscid
    - Steady-State
- Testing Range from 0 degrees to 8 degrees in increments of 2 degrees

Flight Conditions October 2010		
Airspeed	542 ft/sec	165m/sec
Mach	0.49	
Altitude	2745ft	837m
Air Density	1.0614kg/m^3	
S	32in^2	.02065m^2

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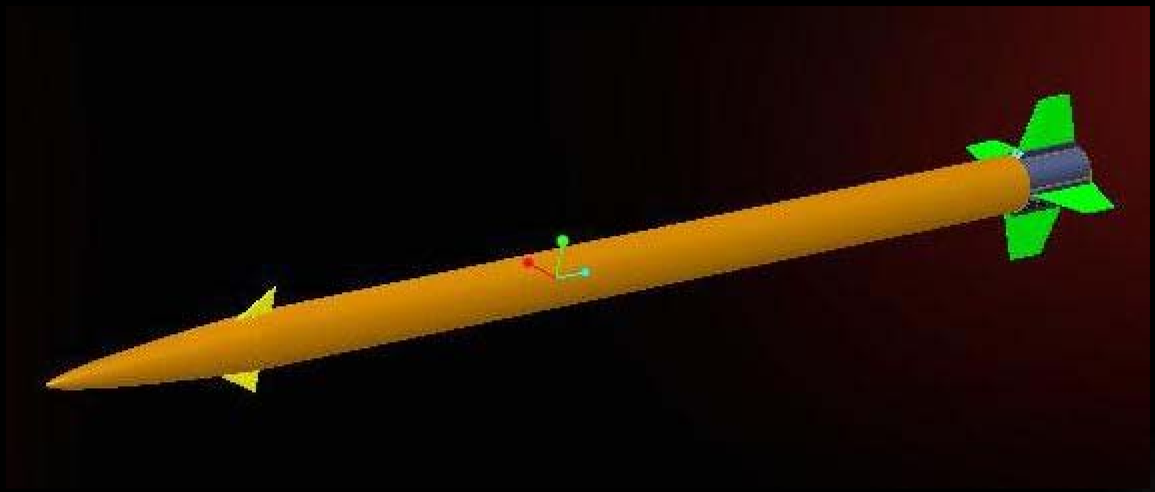
Geometry

- Exact Specifications Obtained from Design Drawings created by Bob Feretich
- Geometry was created using Pro/E
  - Final Assembly exported as an STL file



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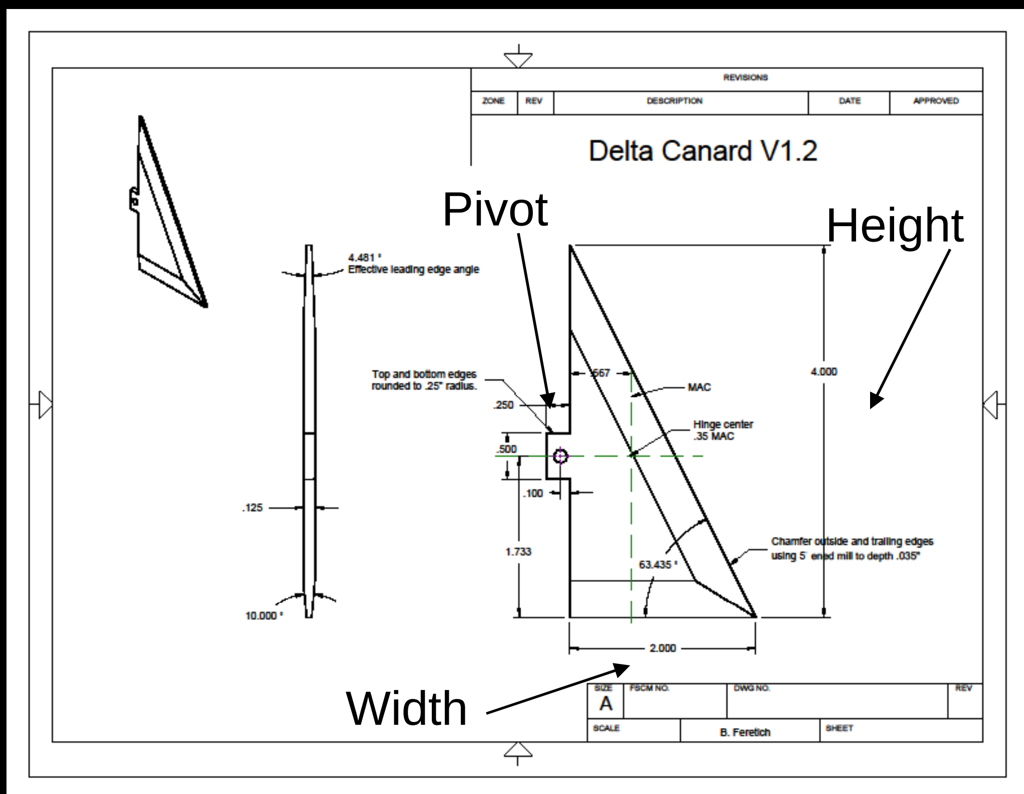
Geometry

- Parameters of Interest
  - Height and Width of Canard
  - Pivot point of Canard



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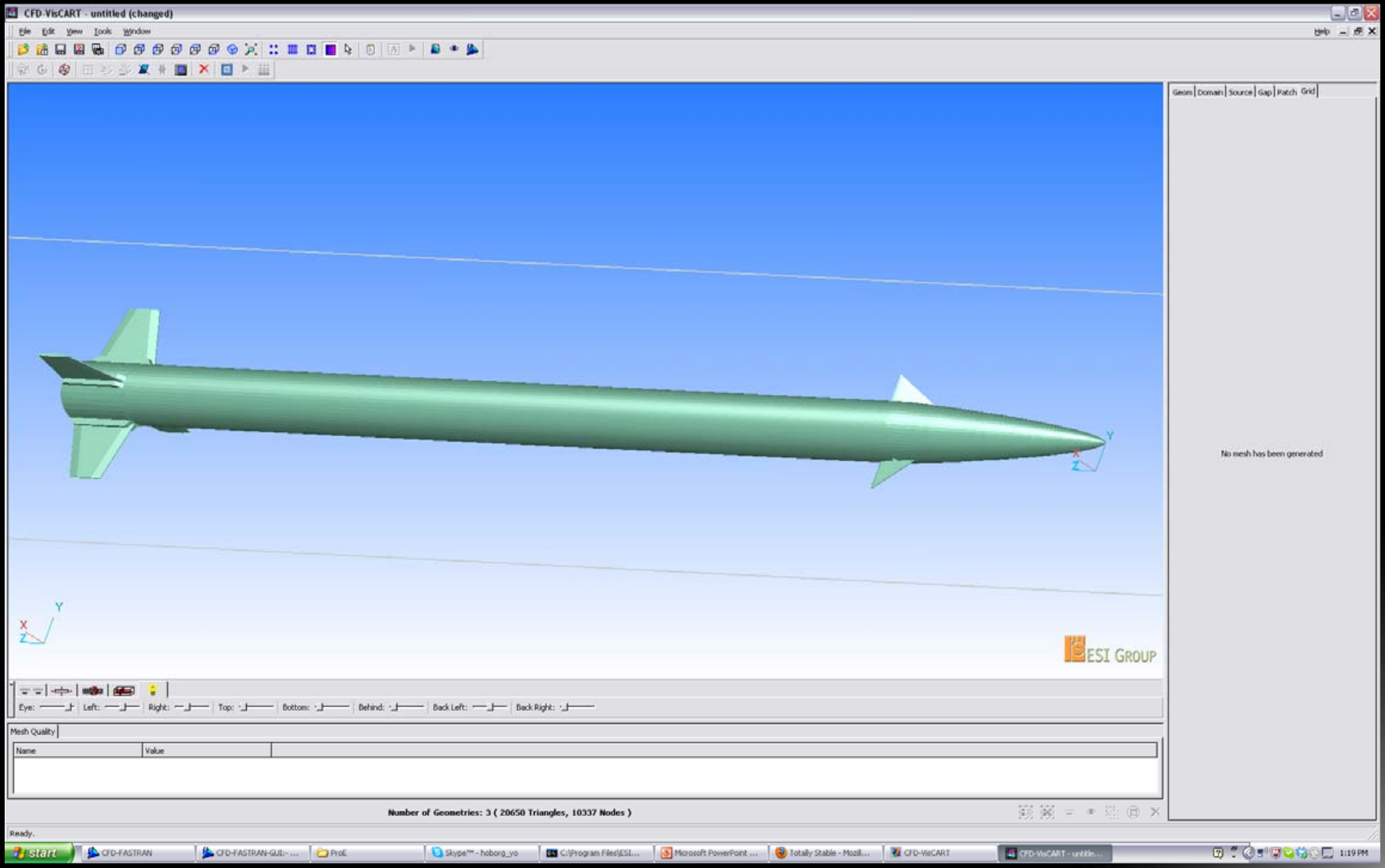
Mesh Generation

- Vis-CART – Import Geometry (.STL)



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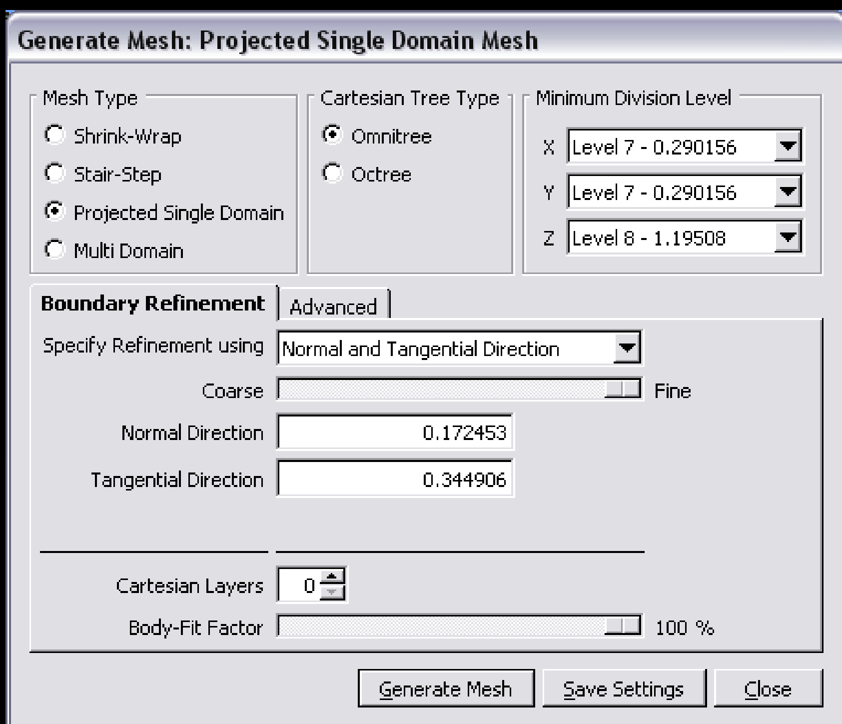
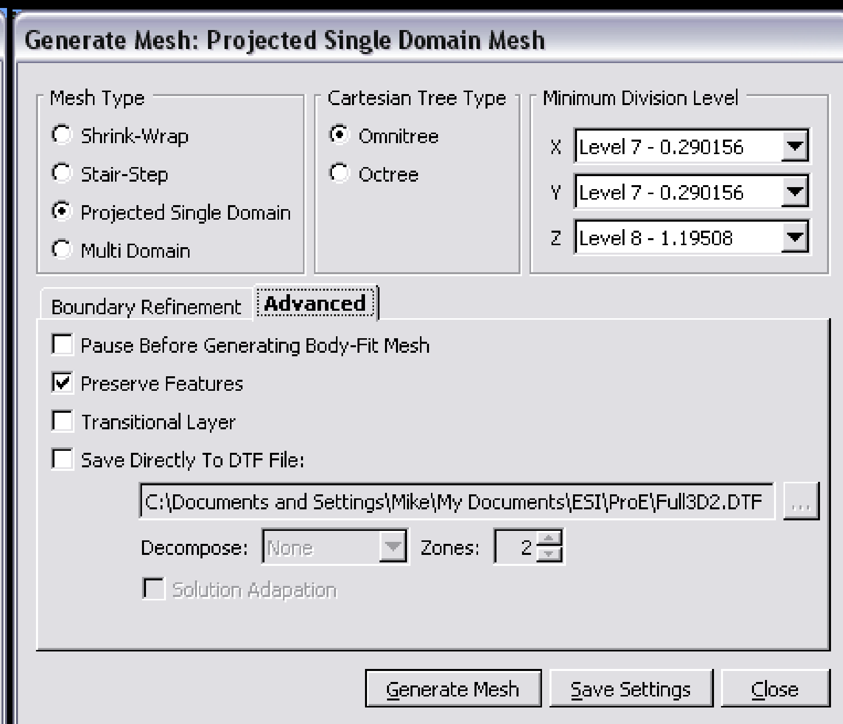
Mesh Generation

- Vis-CART - Automatic Cartesian mesh generator





Mesh Generation

- Vis-CART - Use the built in Mesh Quality tools to determine the quality of the Mesh

Mesh Quality | Face Angle Distribution

Name	Value
Number of Cells	4255710
Negative Volumes	0
Small Volumes	0
Non-convex Cells (skewed angle...	0
Degenerate Faces	0
Skewed Interior Faces (< 5)	0
Minimum Interior Face Angle	29.0507
Skewed Boundary Faces (< 5)	0
Minimum Boundary Face Angle	5.08234
Minimum Interior Interface Face ...	90

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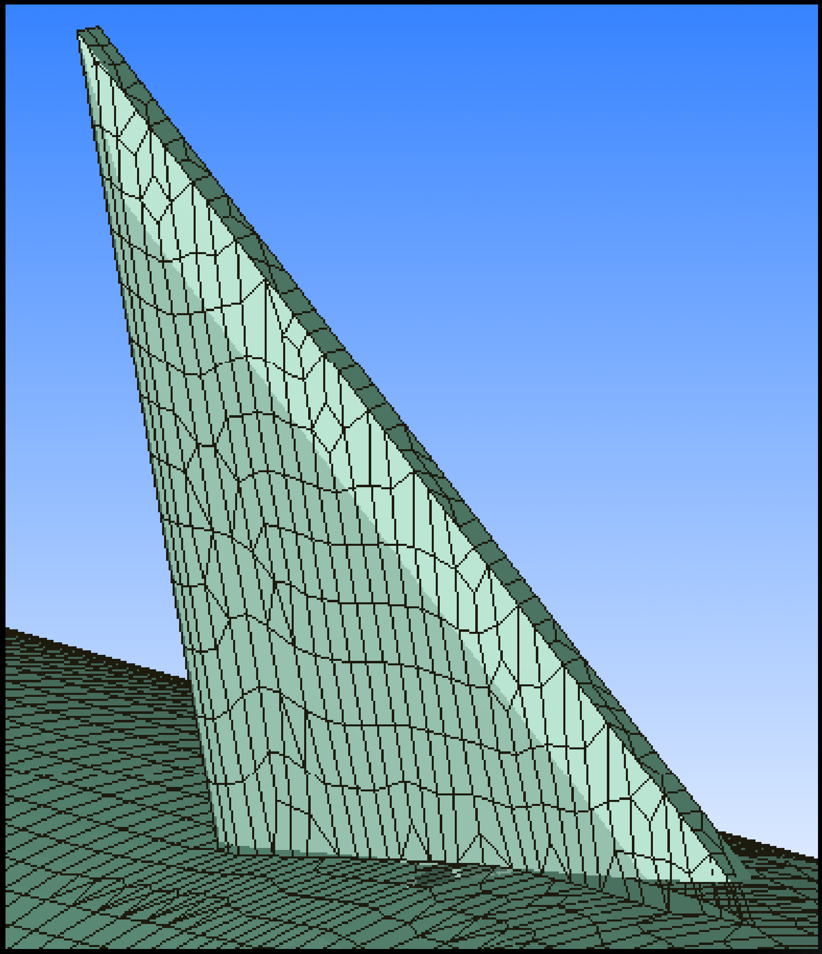
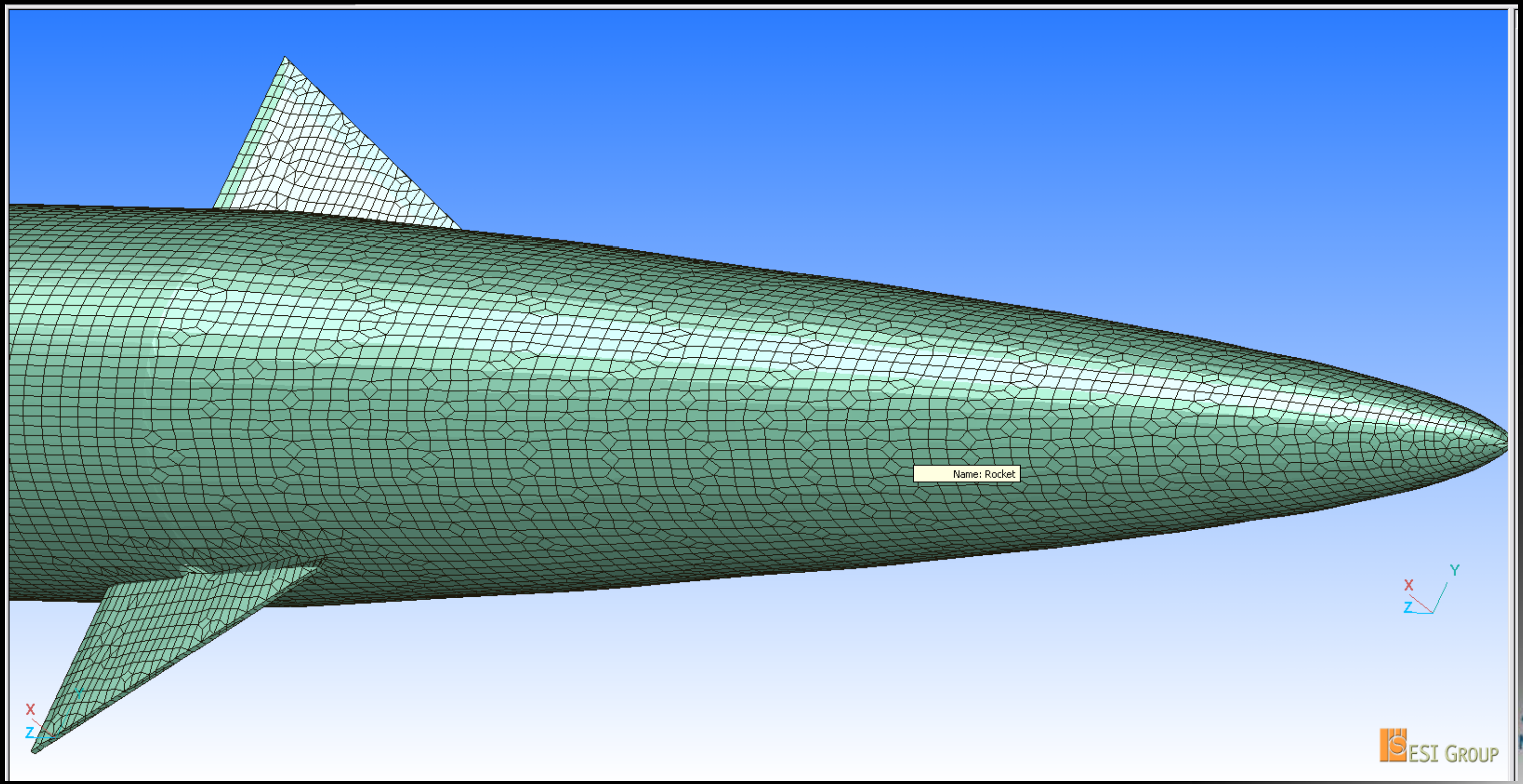
Mesh Generation

- Vis-CART - Visual Inspection of Grid Quality



Mesh Generation

- Vis-CART - Visual Inspection of Grid Quality



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Mesh Generation

- Vis-CART
  - Used Projected Single Domain
    - Allows for mesh adaptation after solver runs to improve the mesh for flow features

Solution

- Boundary Conditions/Initial Conditions
  - From Table
  - All walls except for Z-axis set as inlet and outlet
- Solver Controls for ACE
  - Residual of 10^5
  - 200 interations
  - Elapsed CPU Time
    - 2.006781E+03

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S	32in^2	.02065m^ 2

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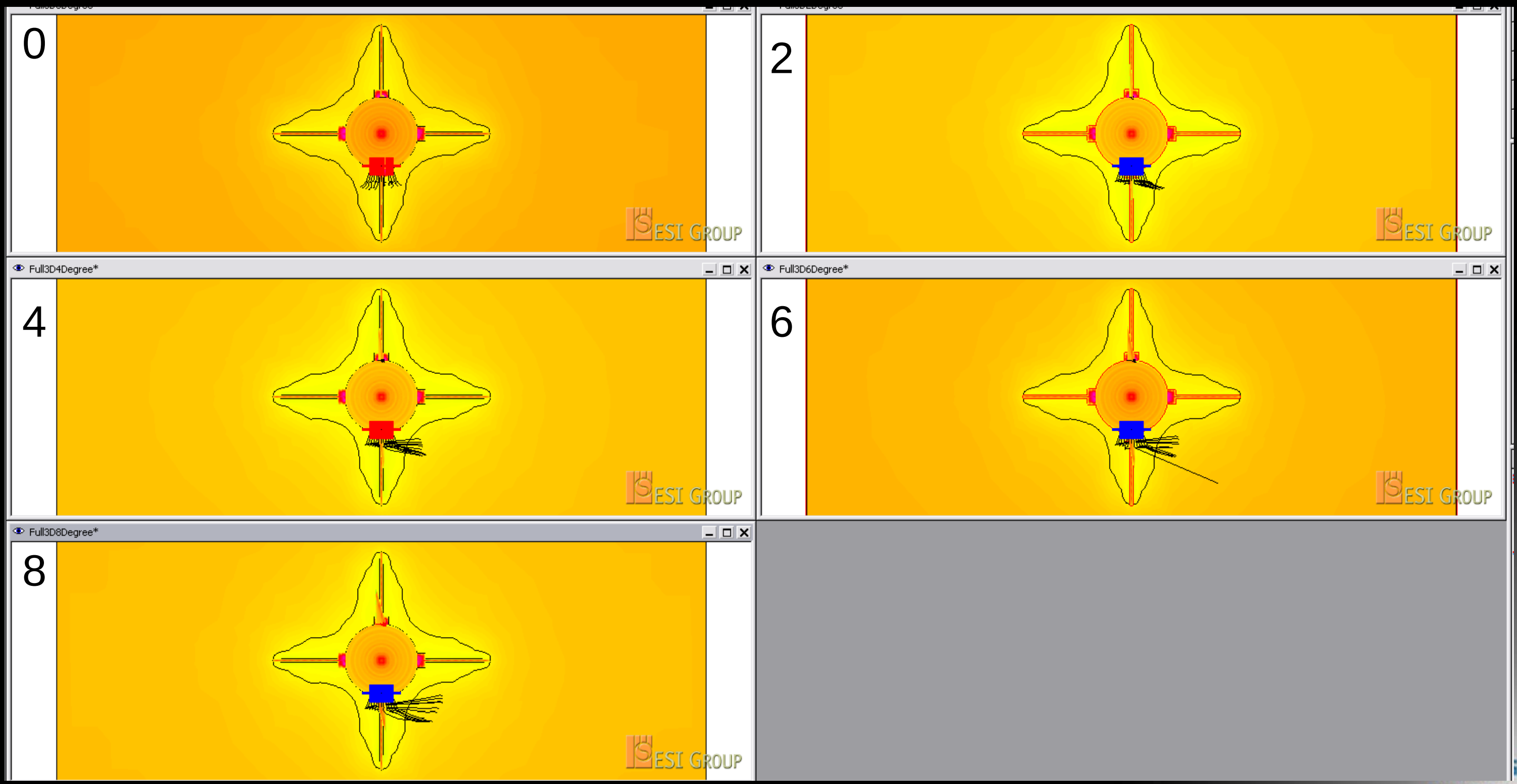
Post-Processing

- Flow Field Analysis 0 degree to 8 degree



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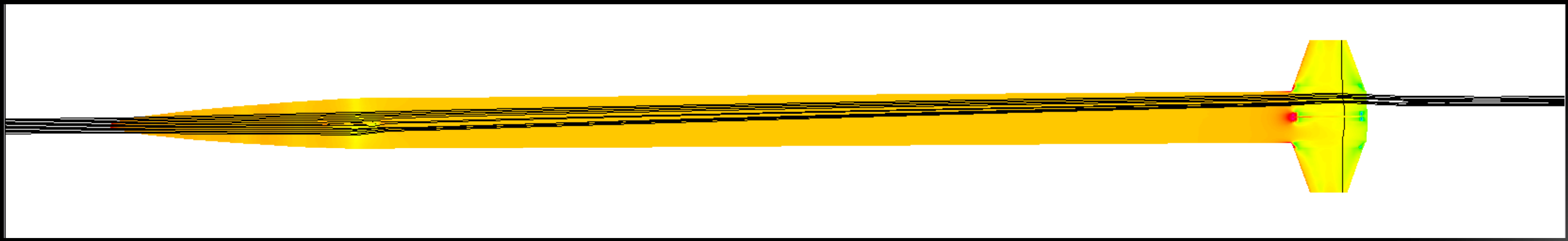
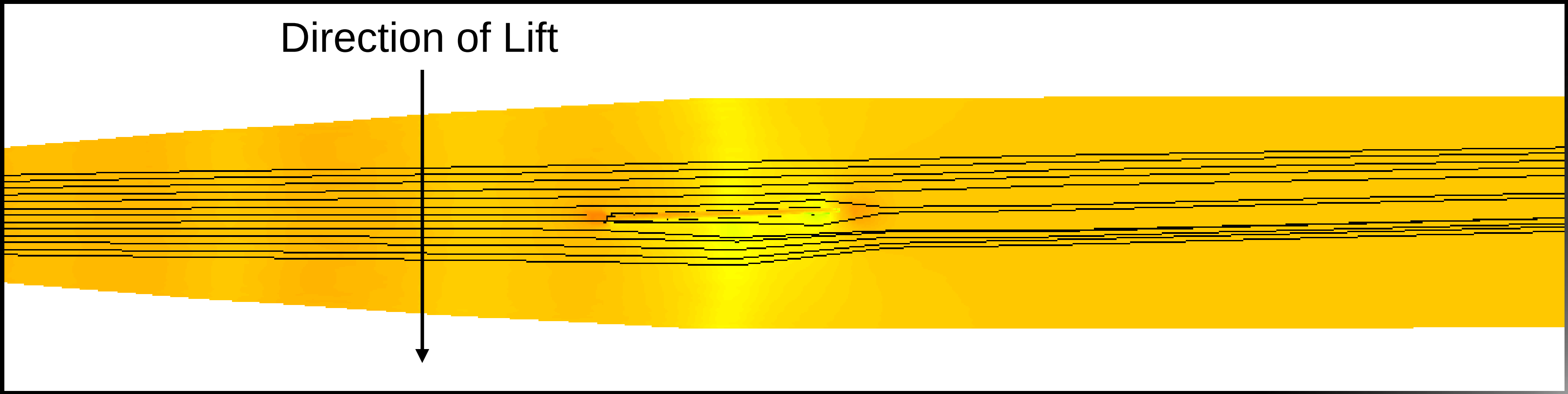
Post-Processing

- 2 Degrees - Streamlines over the rocket



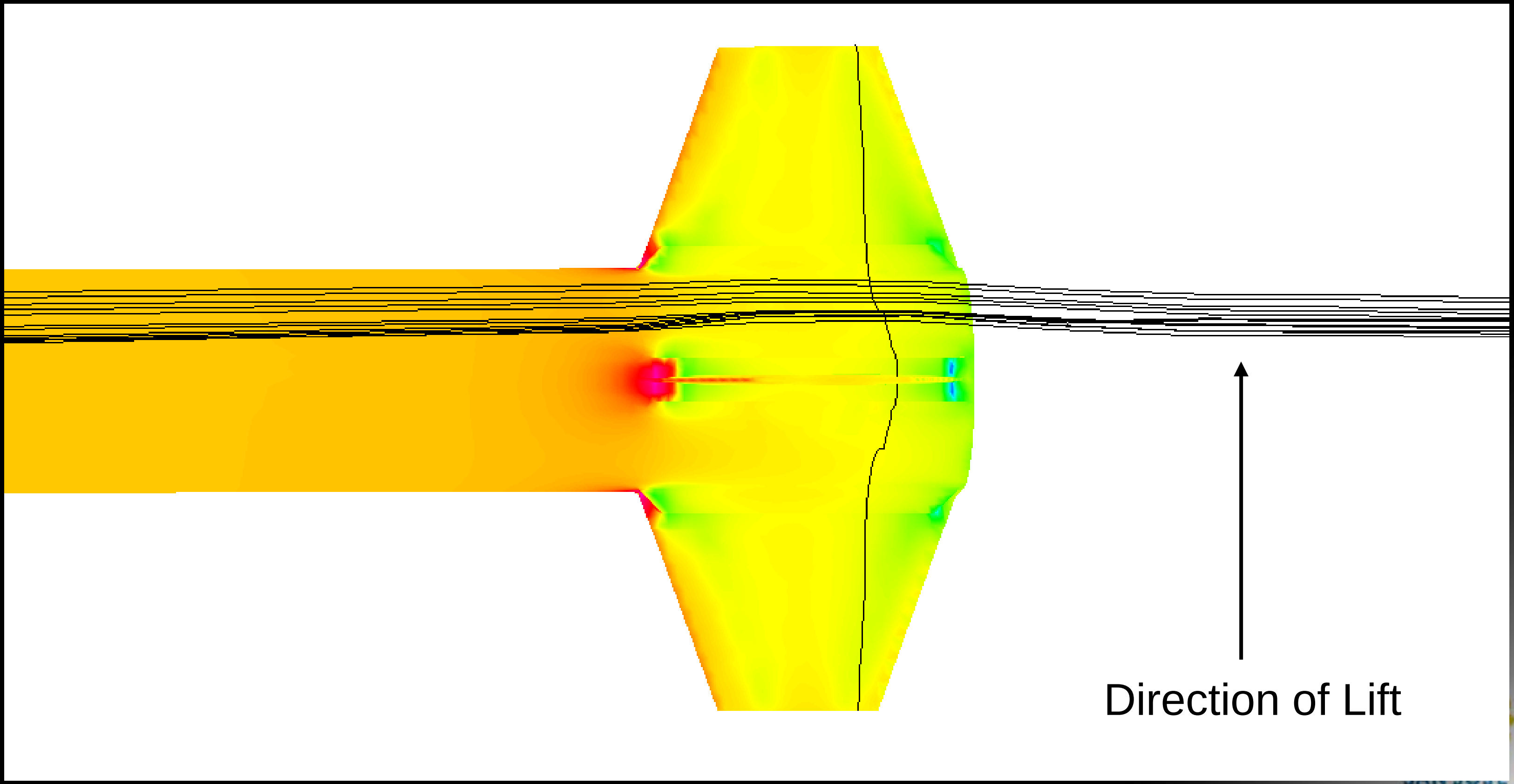
Post-Processing

- 2 Degrees - Streamlines over the canard



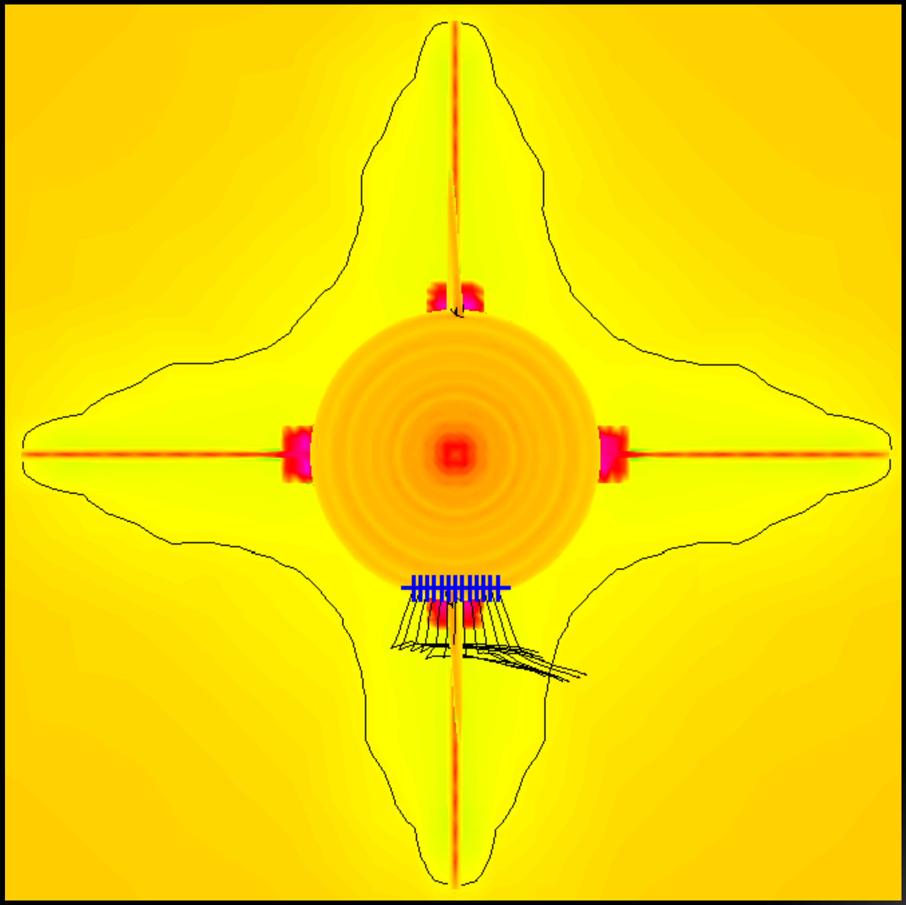
Post-Processing

- 2 Degrees - Streamlines over the Rear Fin



Post-Processing

- 2 Degrees – Pressure Distribution around the tail



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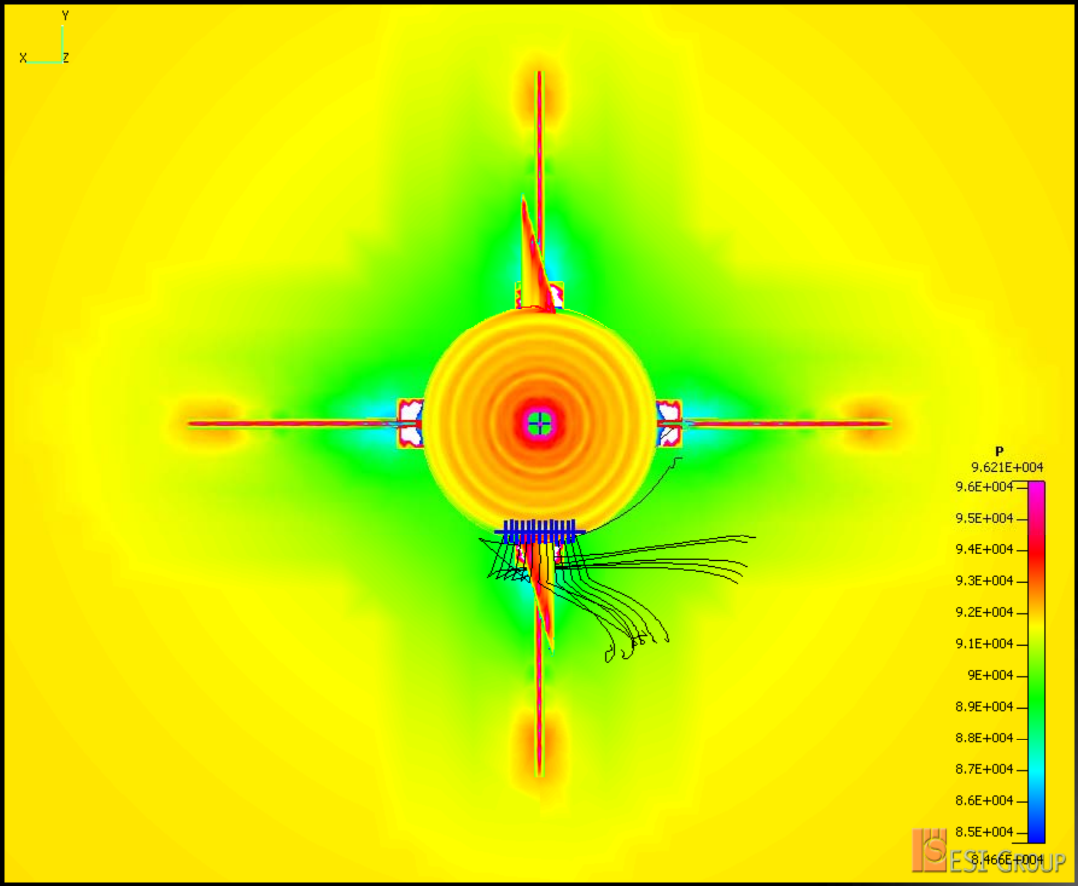
Post-Processing

- 8 Degrees – Pressure Distribution around the tail



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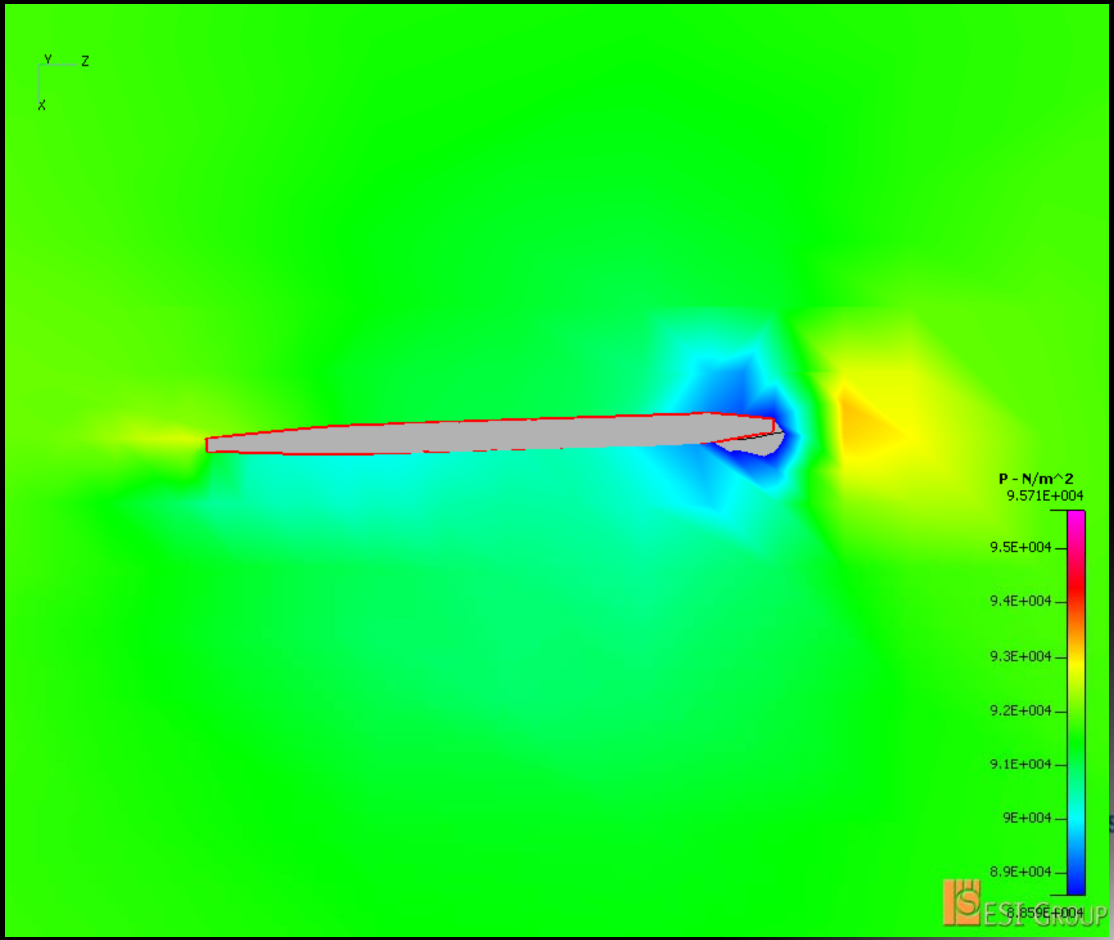
Post-Processing

- 2 Degrees – Pressure Profile around the Canard



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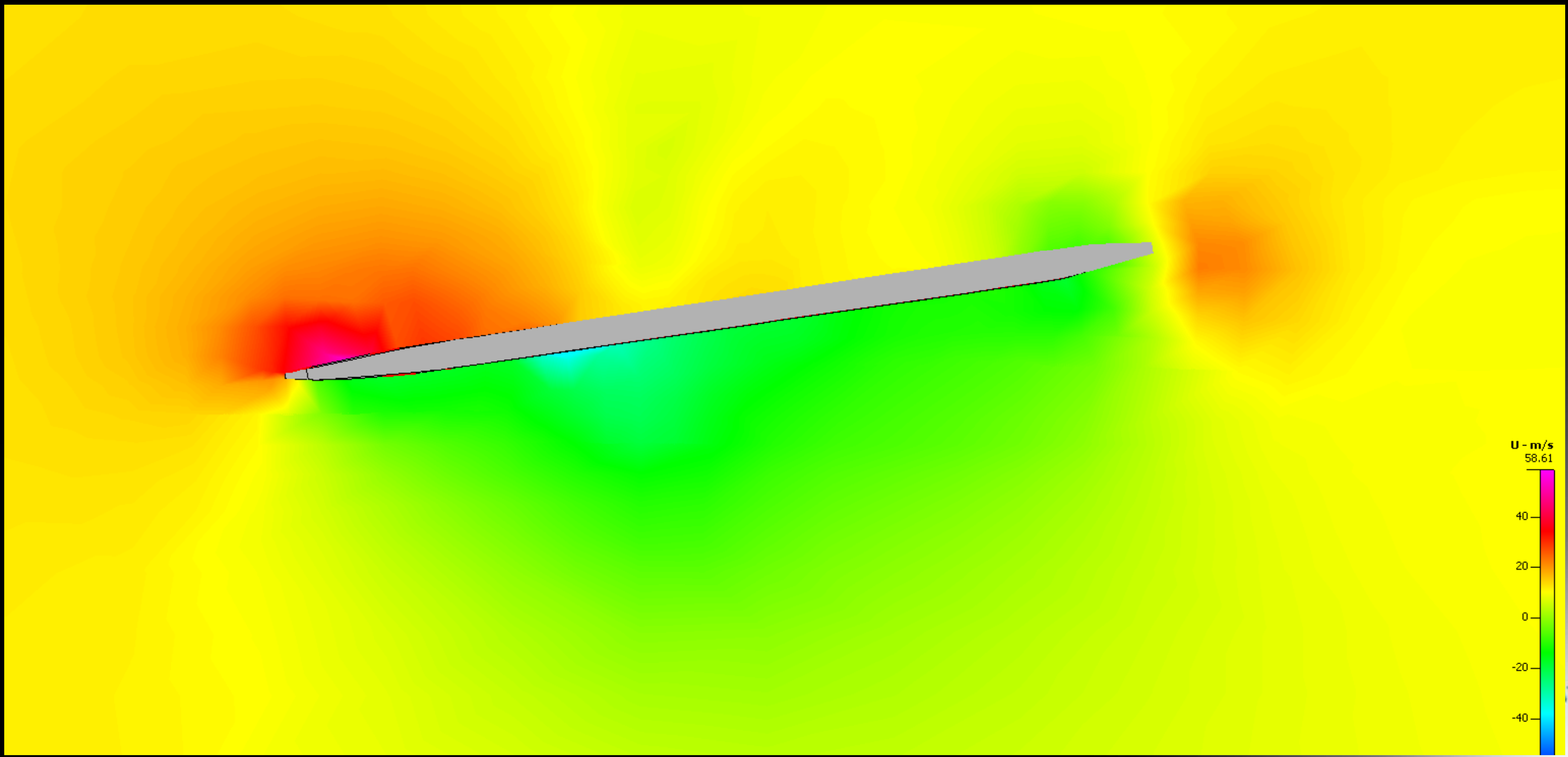
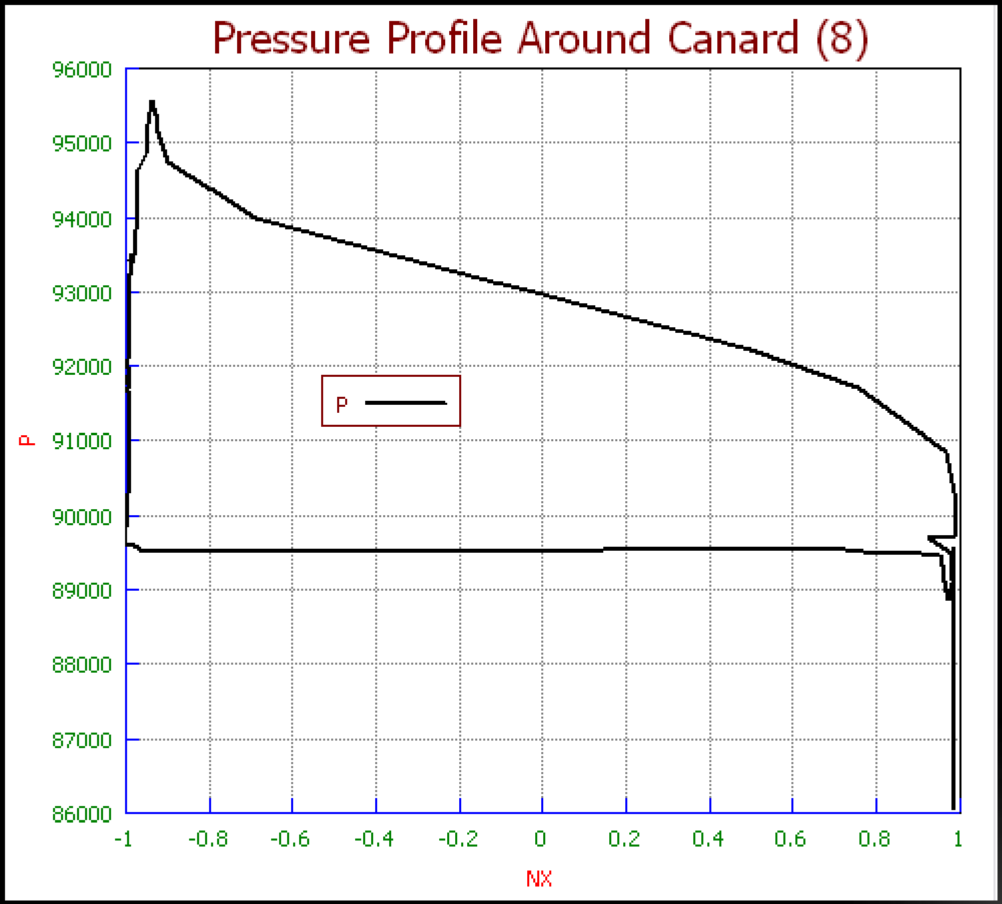
Post-Processing

- 8 Degrees – Pressure Profile around the Canard



Post-Processing

- Pressure Profile around the Canard



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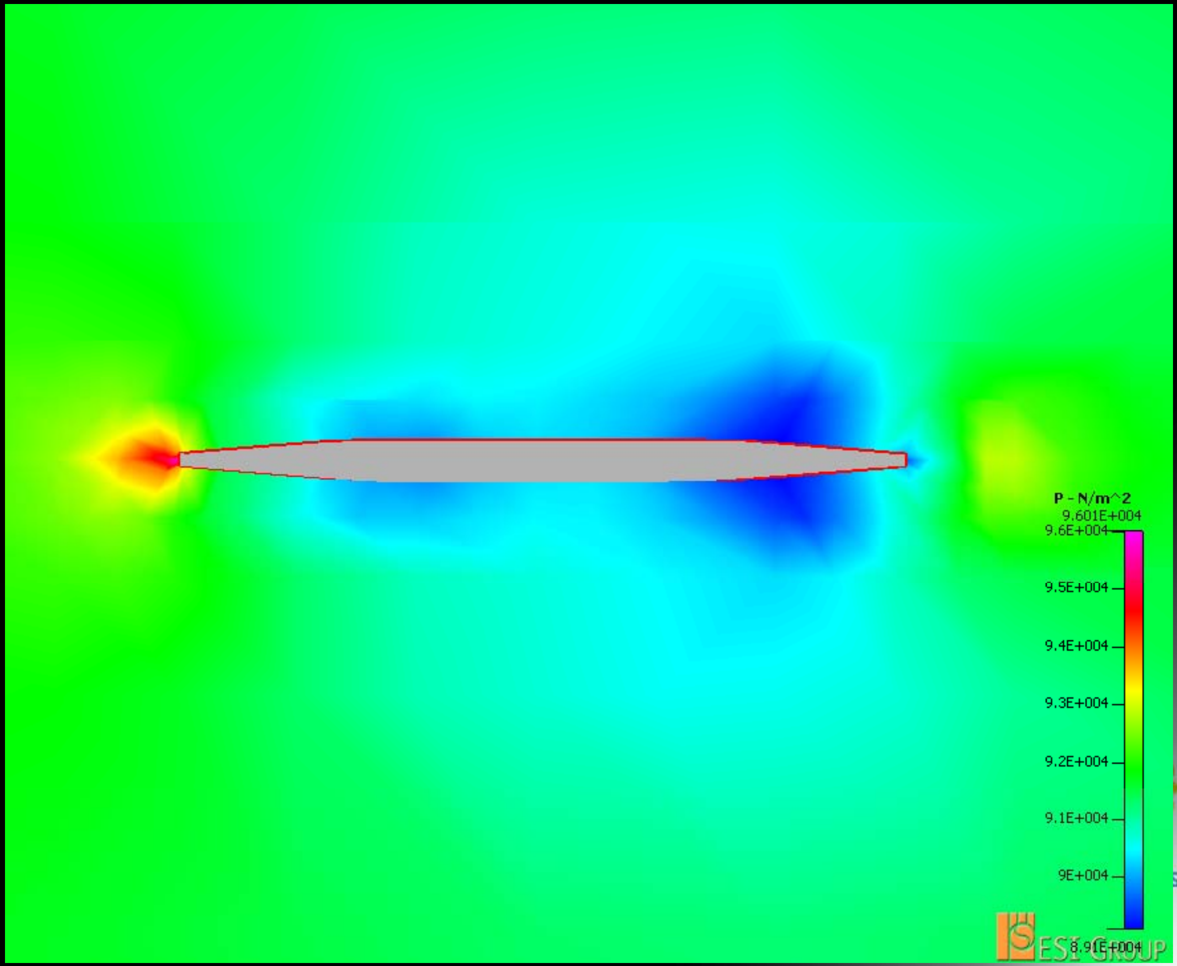
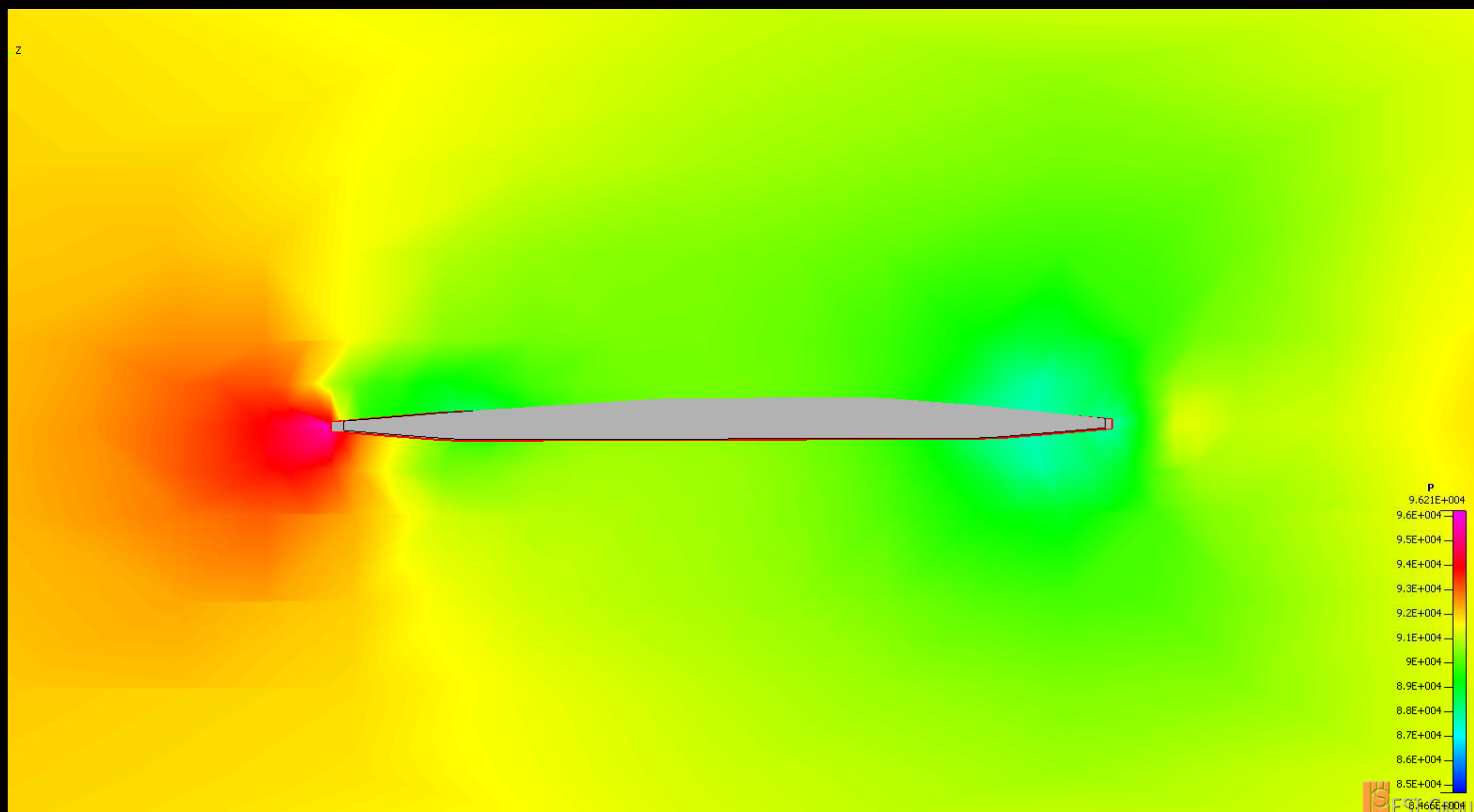
Post-Processing

- 2 Degrees – Pressure Profile around the Rear Fin



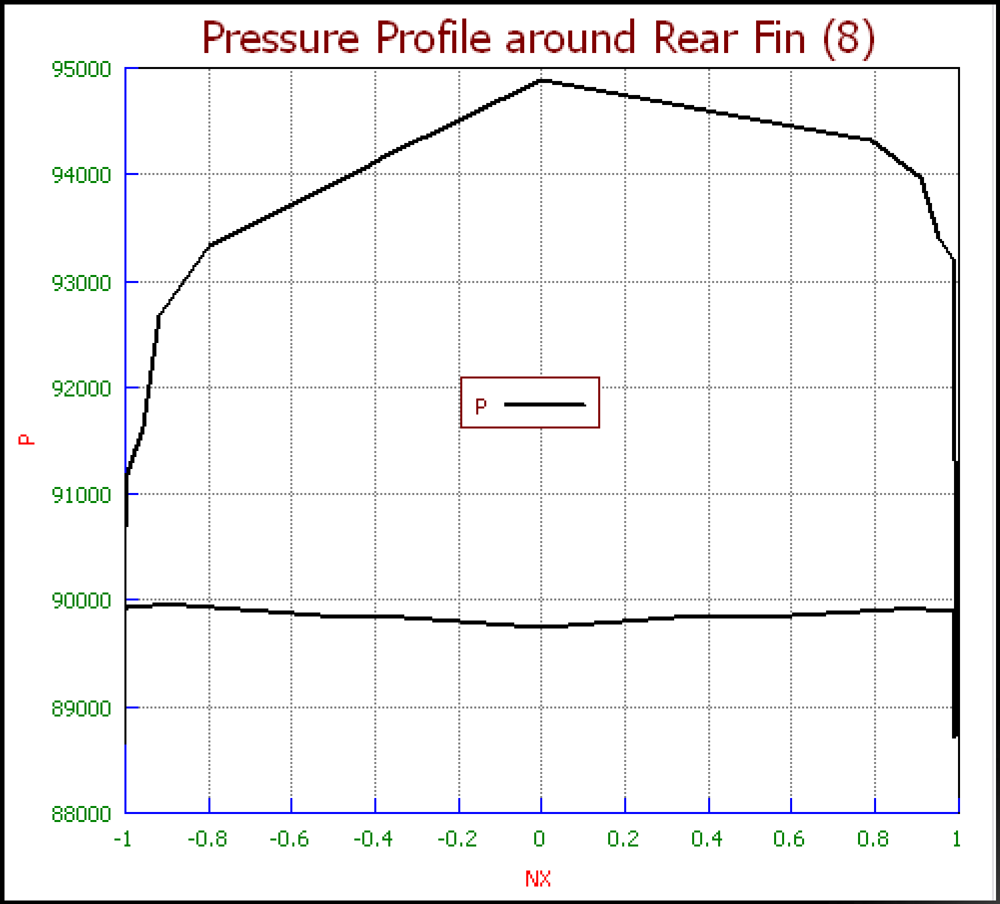
Post-Processing

- 8 Degrees – Pressure Profile around the Rear Fin



Post-Processing

- Pressure Profile around the Rear Fin



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Post-Processing

- Summary of Pressure Forces

Pressure Forces Summary (N)			
Location	X-Dir	Y-Dir	Z-Dir
7 REAR FIN 1	7.11E+03	-9.35E+04	3.12E+03
8 REAR FIN 2	-9.36E+04	-3.68E+03	3.11E+03
9 REAR FIN 3	9.32E+04	3.57E+03	2.27E+03
10 REAR FIN 4	-5.63E+03	9.29E+04	4.57E+03
11 CANARD 2	9.63E+03	4.37E+04	2.80E+03
12 CANARD 1	-1.44E+04	-4.40E+04	3.29E+03
75 N	Sum X -Dir	Sum Y-Dir	Sum Z-Dir
	-3729.61	-891.58	19154.00

ion of Lift

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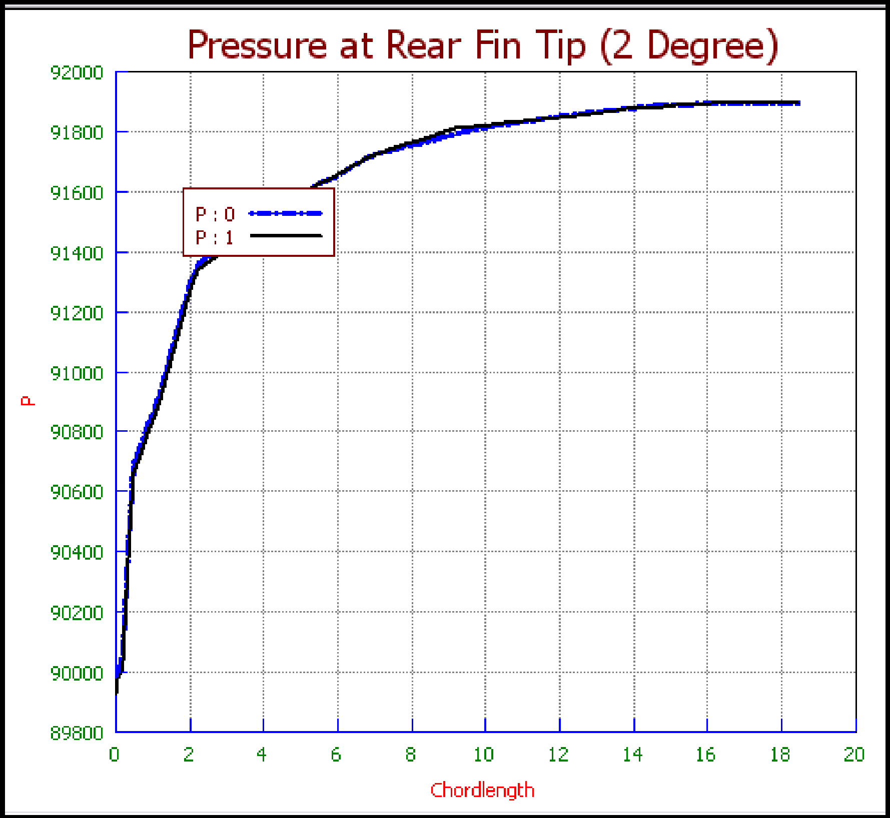
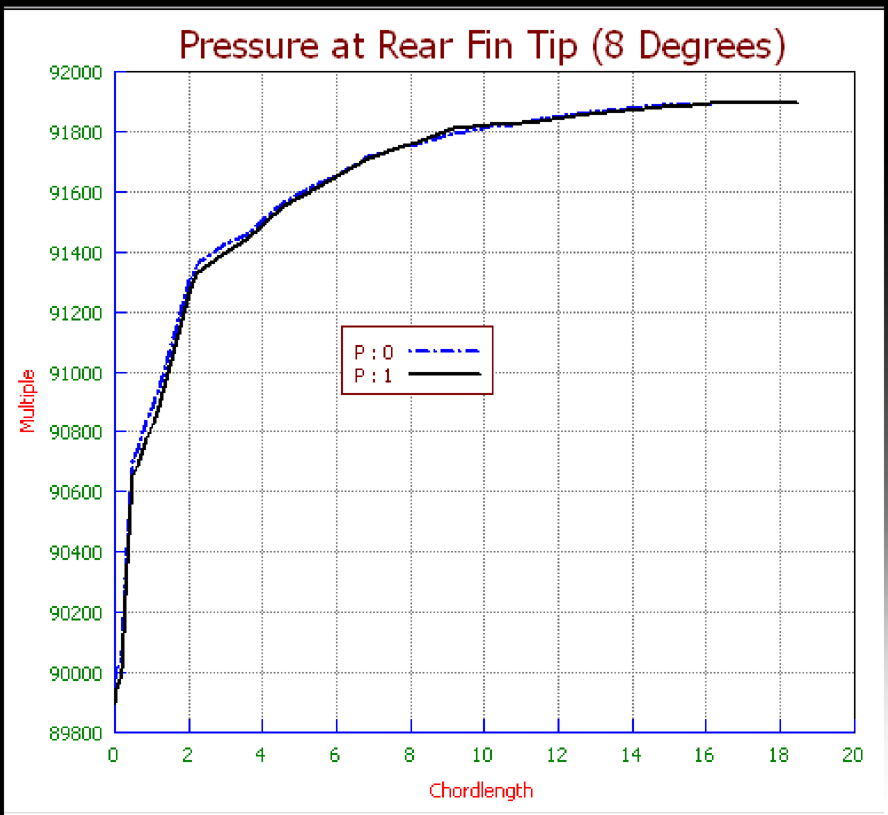
Post-Processing

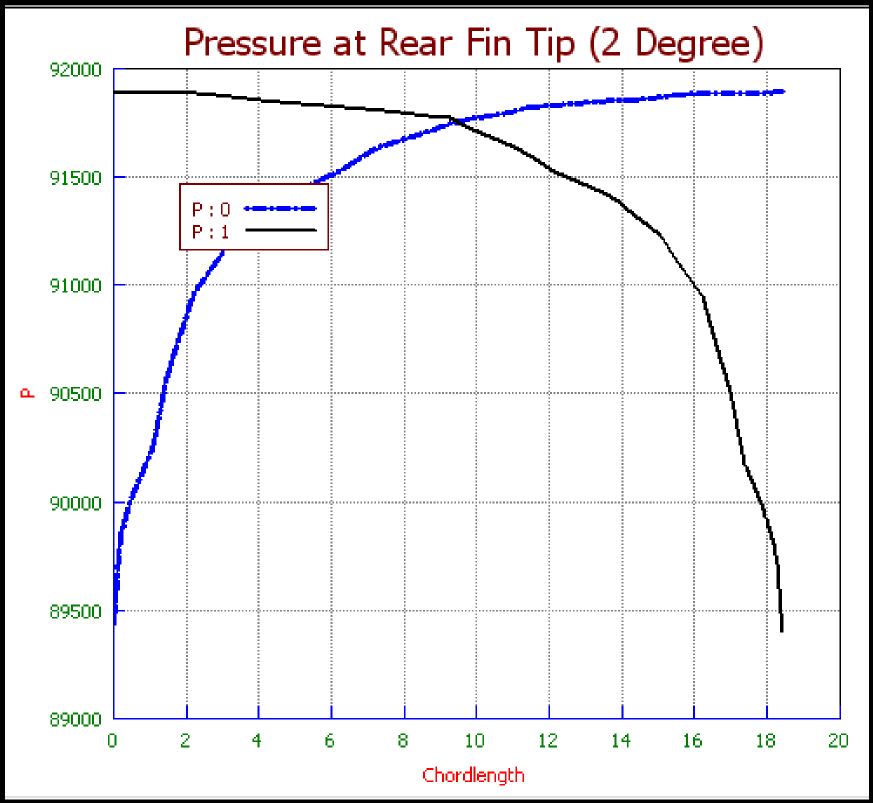
- Pressure Distribution around the tail

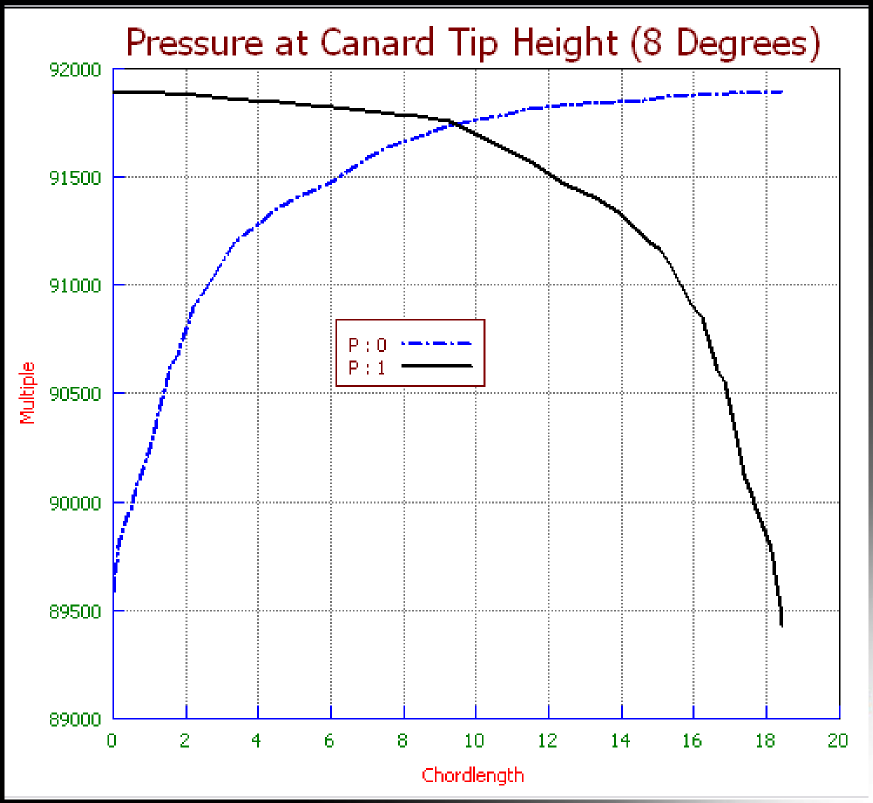




Post-Processing

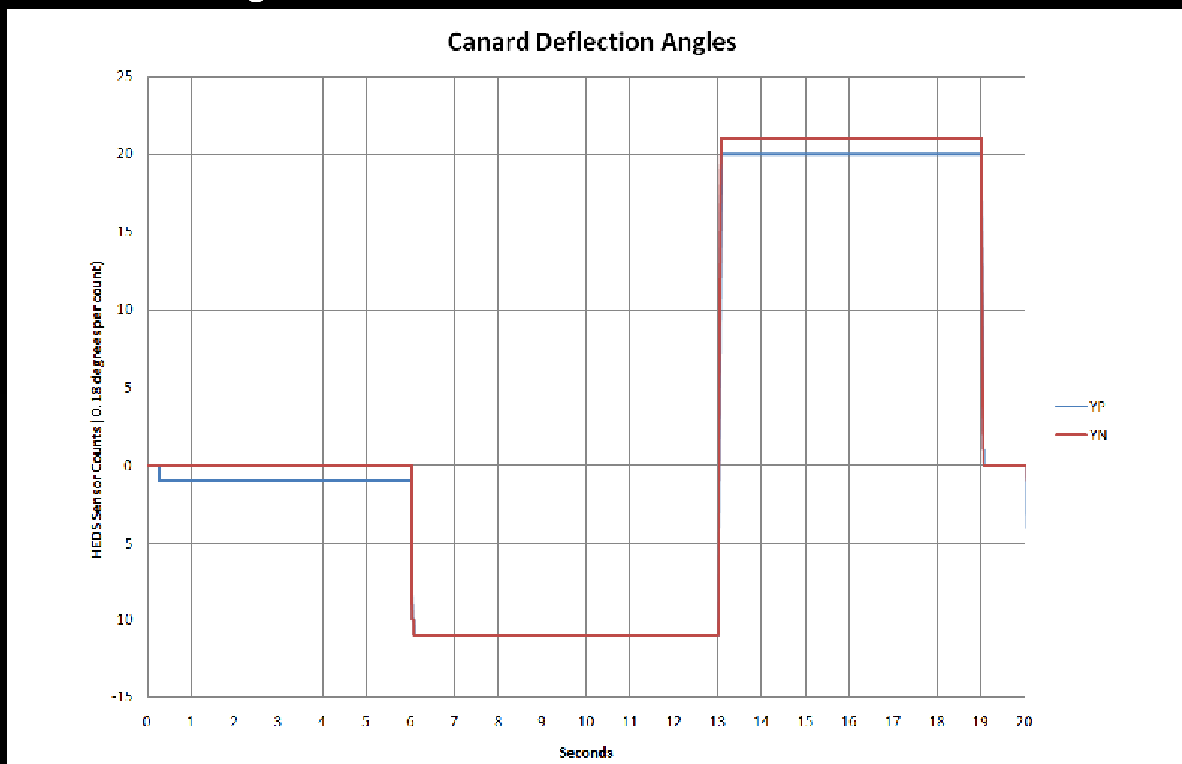
- Pressure Distribution around the tail





Benchmark

- Flight Data Canard Position
  - Canard Deflections
    - -2 degree 6sec – 13sec
    - +4 degree 13sec – 19sec



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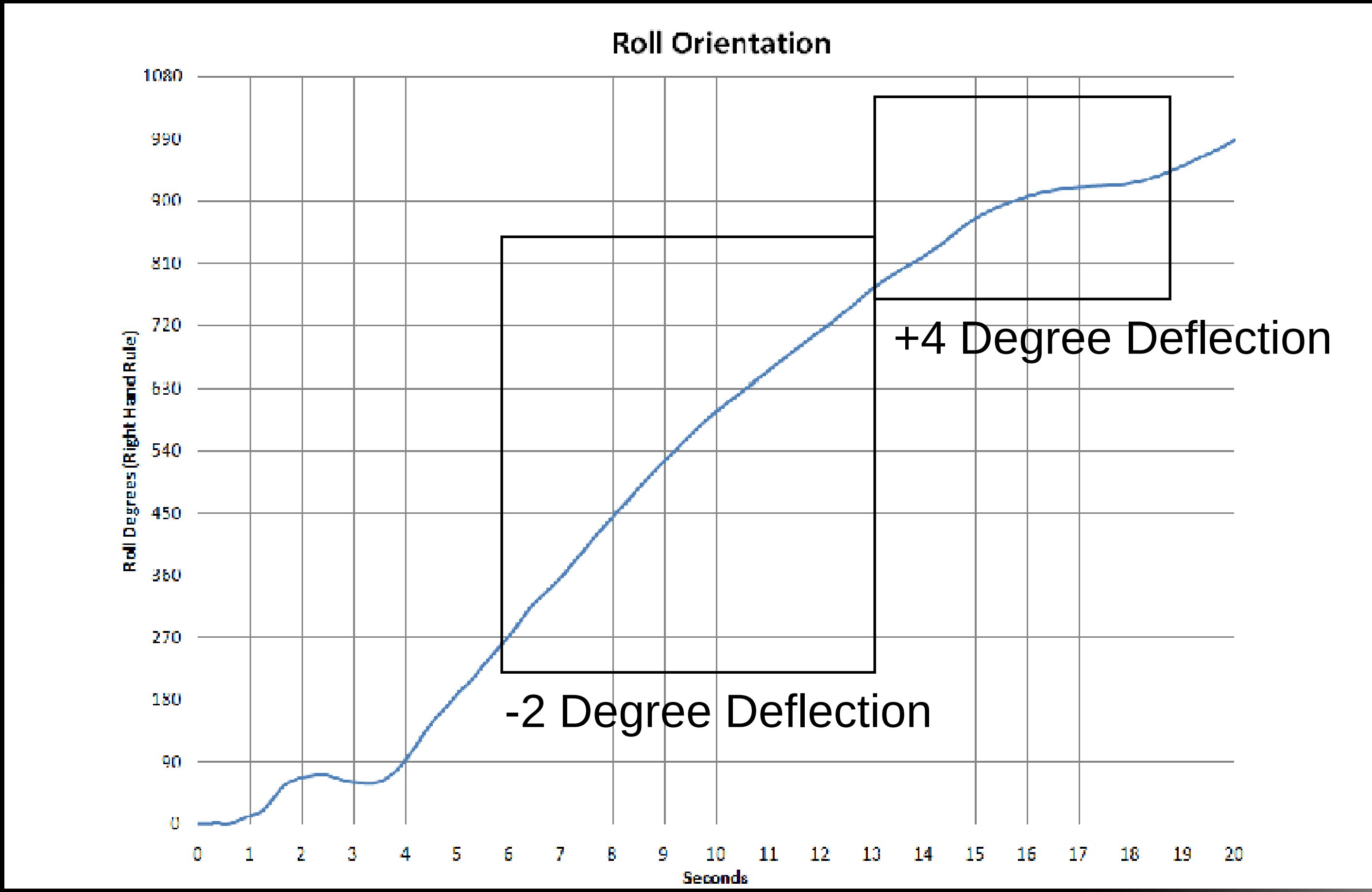
Benchmark

- Flight Data Roll Rate



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Design Conditions

Discussion

- 2 Degree Deflection
  - Very little noticeable affect on the role rate
- 8 Degree Deflection
  - No significant affect on the role rate
- Canard Deflection actually changes Angle of Attack for the rear fins causing lift in the opposite direction

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Conclusion

- Active Automatic Stability Units have potential to lower high altitude payload delivery costs
- Are Canards practical?
  - Unable to determine absolutely without a further parametric study
  - Do not deliver the required roll rates
  - 2 degrees to 8 degrees produced no significant roll effects

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References

- Anderson, John D Jr. (2007). *Fundamentals of Aerodynamics*. New York NY. McGraw Hill
- Polhamus, Edward C. (1968). *Application of the Leading-Edge-Suction Analogy of Vortex Lift to the Drag Due to Lift of Sharp-Edge Delta Wings*. Hampton VA. Langley Research Center
- Totally Stable. (2010). htttp://www.feretich.com/Rocketry/TotallyStable/index.html

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Questions?

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