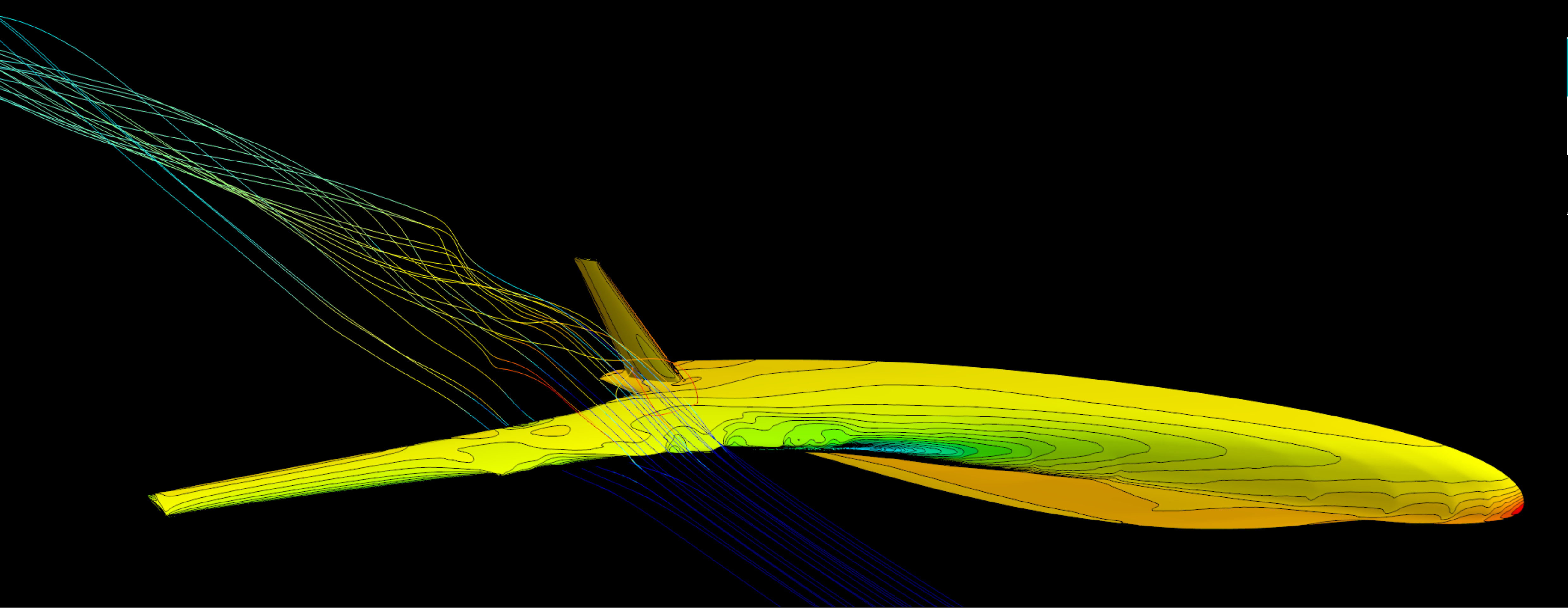


Applied Computational Fluid Dynamics

Project:
MIRA Model and NASA N2A HWB

By: Group 6

Ashwin Sunder, Yash Gandhi
& Lucas Schurbaum

Table of Contents

Original Investigation

- By: Gregory M. Gatlin, Dan D. Vicroy, and Melissa B. Carter
  - NASA Langley Research Center. 2012

- Wind tunnel

- Hybrid Wing Body Configuration
  - Configurable

Computational Investigation

- By: Dan Almosnino
  - Aerion Technologies Corporation / Desktop Aeronautics. 2016

- Inviscid Euler equations solver

- Results close to experimental data

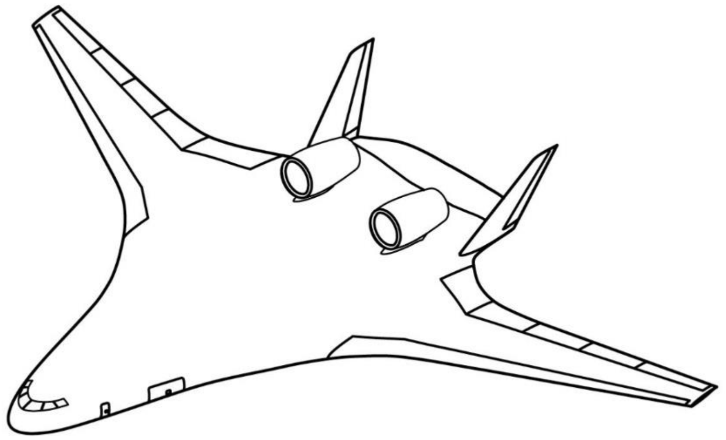
Task

- Reproduce experimental results
  - Angle of attack sweep
  - cP-plots
  - Flow visualization

- Half model was provided
  - Dimensions given

- Group specifications:
  - Mesh: Polyhedral
  - Turbulence model: k-ω SST (Menter)
  - Angle of attacks: 4.19°, 8.36° & 12.53°

- Free hand on simulation settings
  - Problem solving on our own jurisdiction



Dimension	5.8% Model	Full Scale	Units	Misc.
Wing Span, 2b	12.354	213	feet	Reference Length for Lateral Coefficients
Wing Twist	-8.87	-8.87	degrees	At wing tip (linear variation)
Body Length, L	8.583	147.983	feet	
Reference Area, S_{ref}	33.499	9958.8	feet^2	
Reference Length, L_{ref}	5.046	87	feet	
Moment Reference Point	4.6297	79.82	feet	0.5394L
Balance Support Point	5.8364	N/A	feet	0.68L

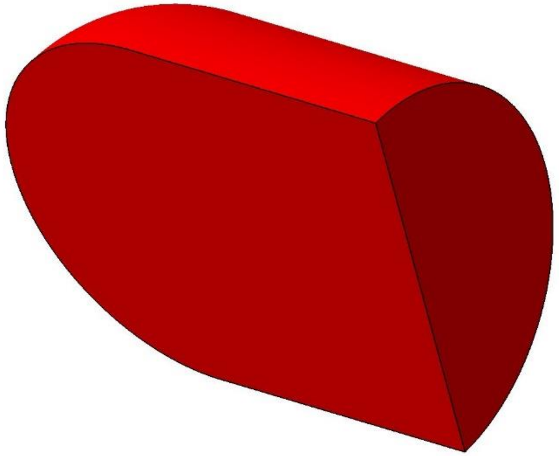
Meshing

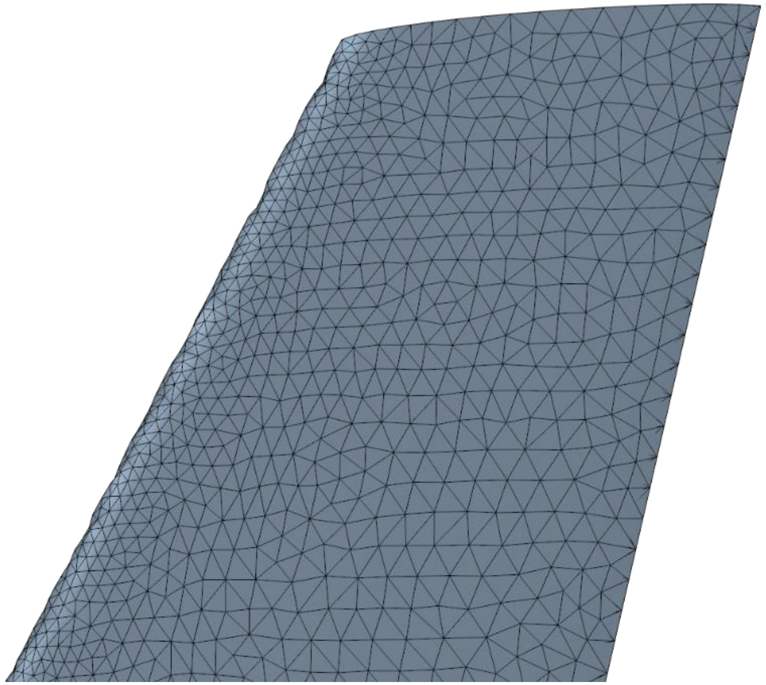
- Bullet shaped flowfield designed in CATIA V5
  - Specifications given

- Base size (B):
  - First: 1.54 m
  - Final: 0.85 m

- Surface mesh (aircraft):
  - Target size: 5 %B
  - Min size: 0.5 %B
  - Curvature: 80 Pts/circle
  - Growth rate: 1.15

- Surface mesh in base settings non-sufficient
  - Refinements needed





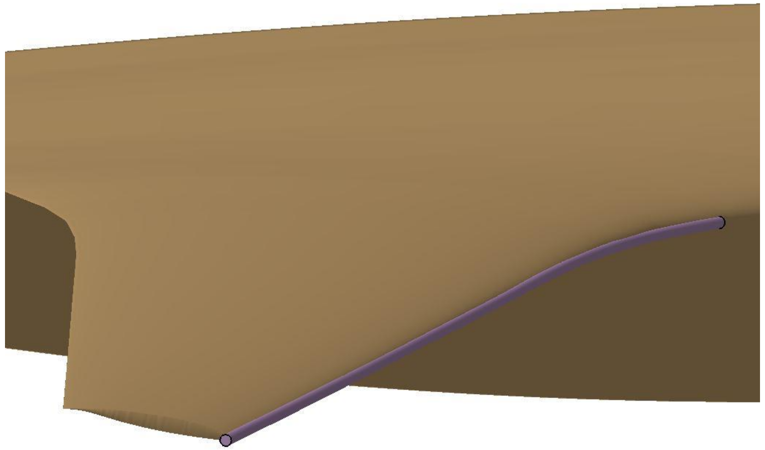
Meshing

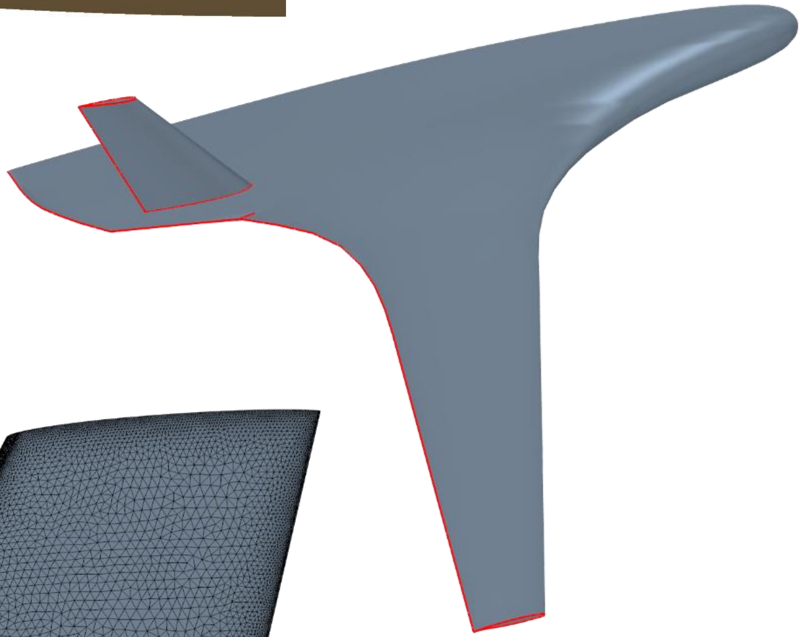
- Surface refinements:

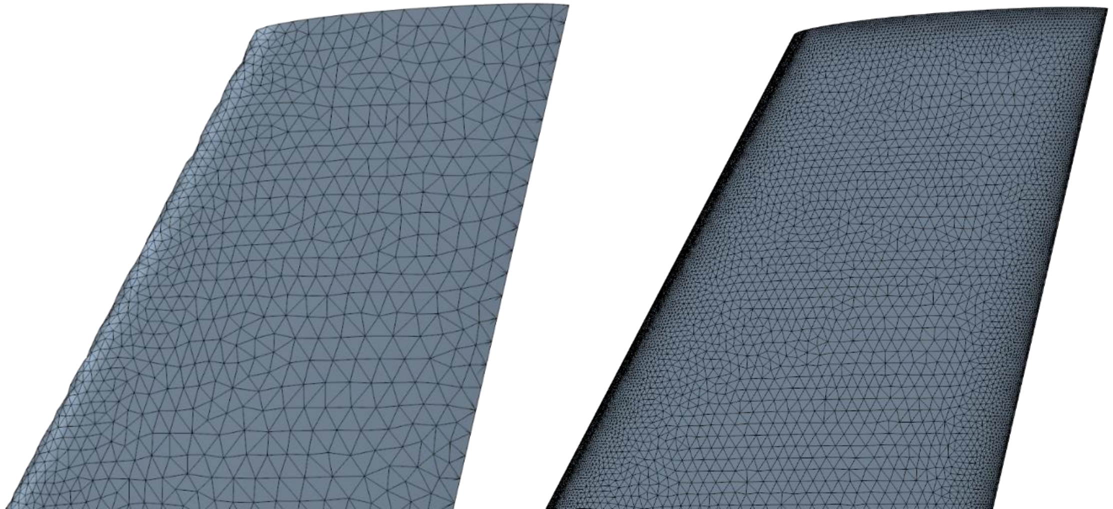
  - Leading-edge dented
    - Custom leading-edge volume

  - Trailing-edge in volume mesh not straight
    - Computed sharp edges
      - Applied curve control

- Improvement of surface mesh

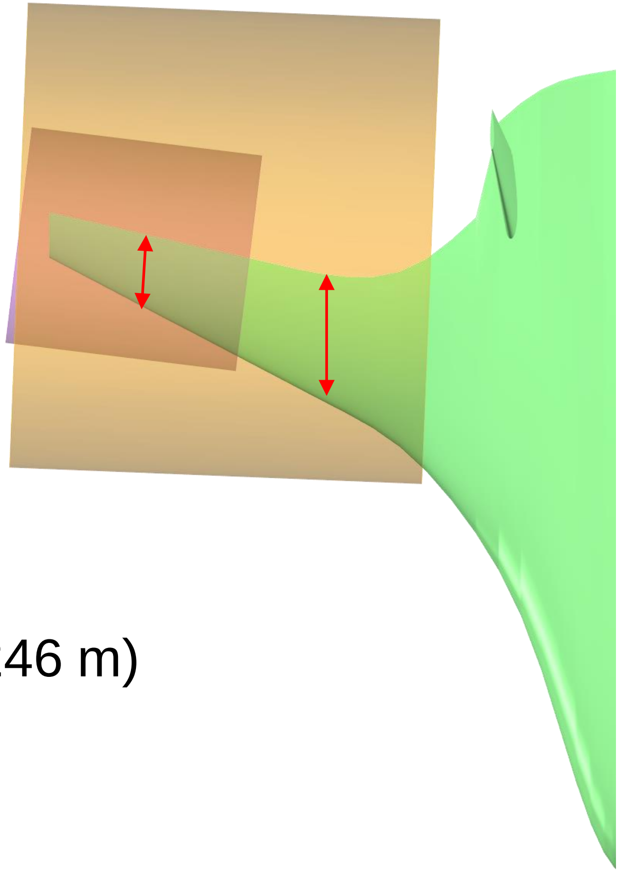






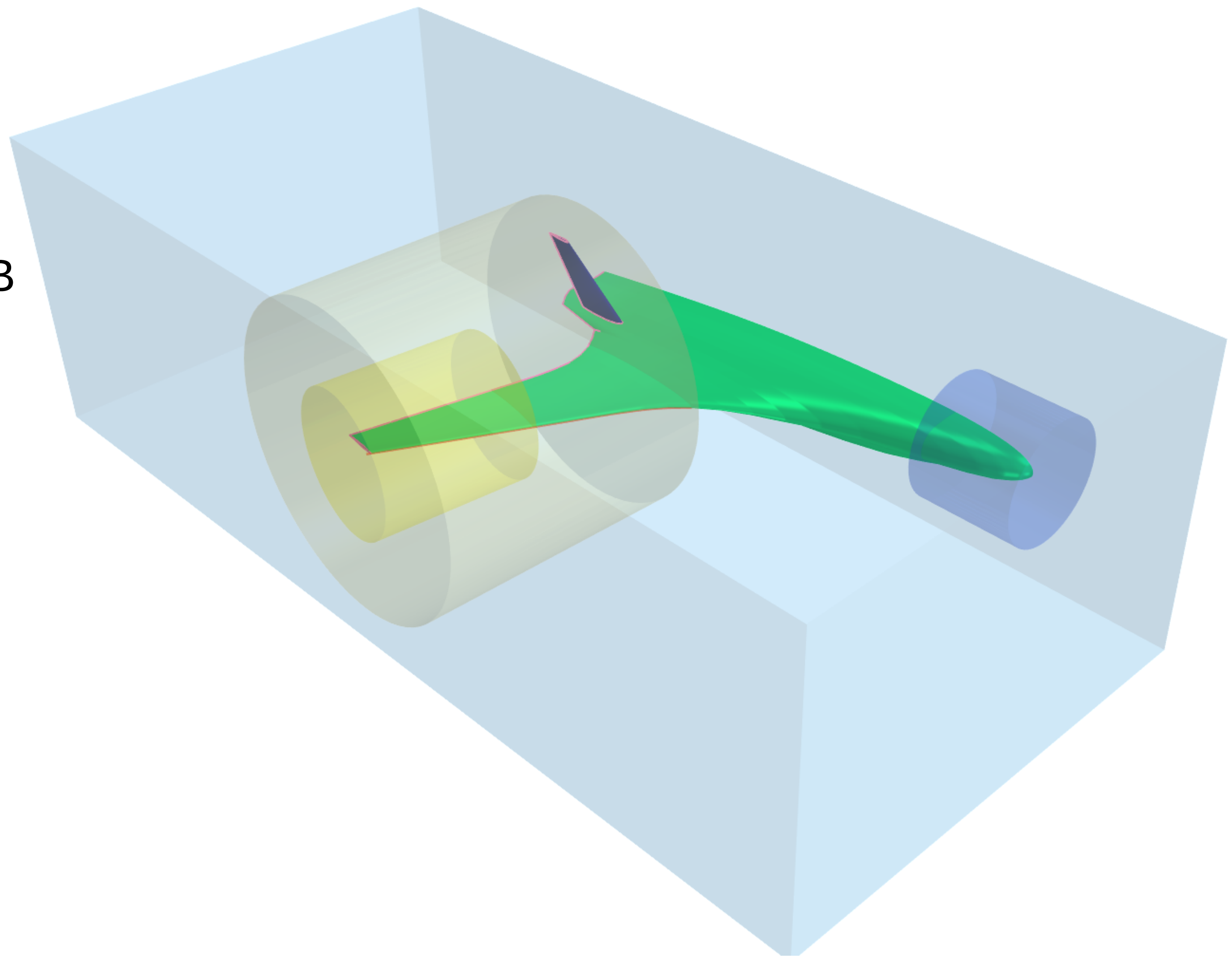
Meshing

- Prism layers (20 layers)
  - Fuselage
    - Based on reference length
    - Near wall thickness adjusted to inner wing value for cell quality
  - Inner and outer wing
    - Based on the average chord length between sections
  - Vertical stabilizer
    - Reference length of 0.15 m
  - Nose
    - Reduced total thickness of 0.021 m (standard: 0.0246 m)
    - Later: Disabled due to near core layer aspect ratio of 2.0



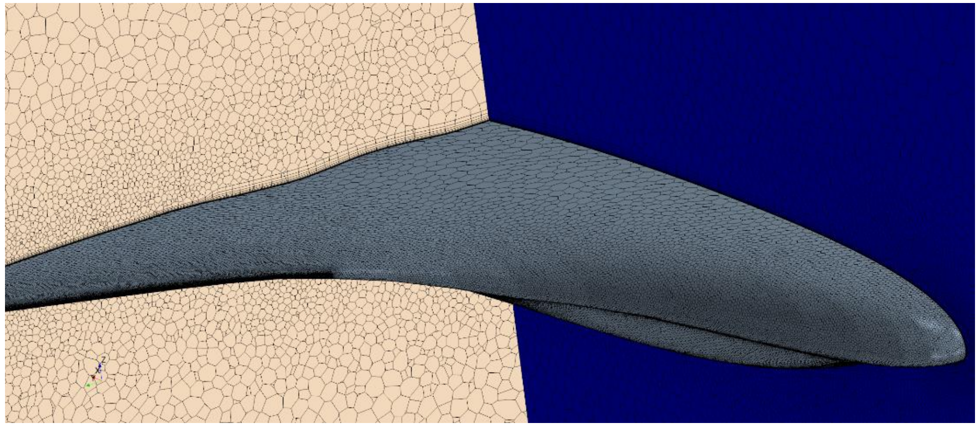
Meshing

- Volume mesh (Polyhedral)
  - Overall
    - Volume growth rate of 1.05
    - Maximum cell size 1000 %B
  - Nearfield
    - Surface and volume mesh
    - Custom size of 10 %B
  - Wake refinements
    - Fuselage / Wing
      - Isotropic size 10 %B
      - Growth rate 1.05
    - Vertical stabilizer
      - Isotropic size 25 %B
      - Growth rate 1.3



Meshing

Flow field (Bullet shape)	
Radius	26 m
Length	39 m
Default Controls	
Base size	0.85m
Target surface size	50 %
Minimum surface size	10 %
Surface Curvature	80 pts/circle
Surface Growth rate	1.15
Number of Prism Layers	20
Prism Layer near Wall Thickness	5.8E-6m
Prism Layer Total Thickness	0.0246m
Volume Growth Rate	1.05

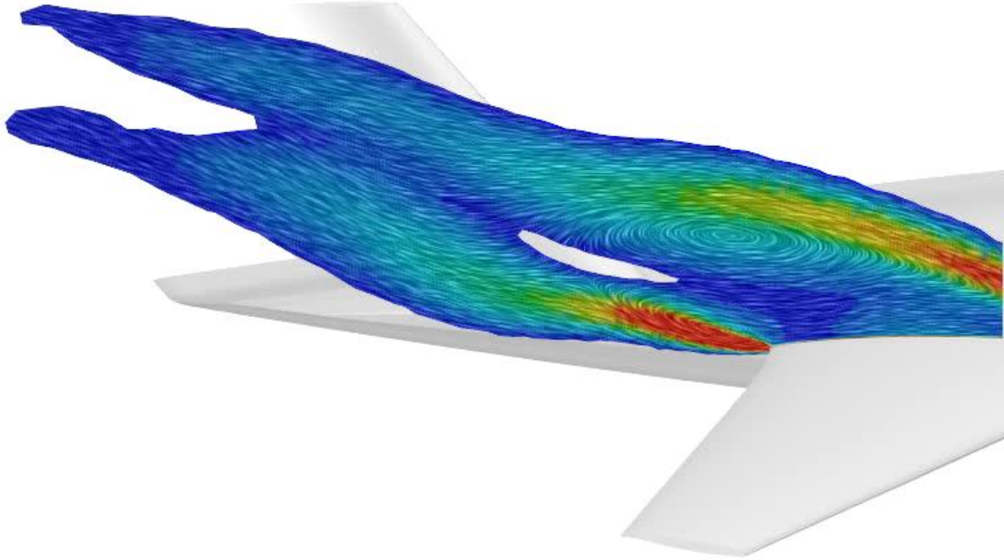


Custom Controls	
Main Body (Surface Control):	
Target Surface size	5%
Minimum Surface Size	0.5%
Wake Refinement	45m / 0°
Isotropic size	10%
Growth Rate	1.05
Sharp Edges (Curve Control):	
Target Surface size	0.1%
Leading Edge (Surface Control):	
Target Surface size	0.05%
Inner Wing Section (Volume Control):	
Prism Layer near Wall Thickness	5.8E-6m
Prism Layer Total Thickness	0.0101m
Outer Wing Section (Volume Control):	
Prism Layer near Wall Thickness	5.5E-6m
Prism Layer Total Thickness	0.00662m
Vertical Stabilizer (Surface Control):	
Target Surface size	0.5%
Minimum Surface Size	0.05%
Wake Refinement	45m / 0°
Isotropic size	25%
Growth Rate	1.3
Prism Layer near Wall Thickness	5.2E-6m
Prism Layer Total Thickness	0.00383m
Nose Section (Volume Control):	
Prism Layer Total Thickness	0.021m
Nearfield (Volume Control):	
Isotropic size (Surface & Volume)	10%

Physics

- RANS simulation with:
  - Steady state
    - Changed to unsteady for 12.53° AoA
      (Timestep: 0.001s; Inner Iterations: 10; 2^{nd} order Temp. Discret.)
  - Segregated solver
    - Low Mach number of 0.2
  - Constant density
  - Constant dynamic viscosity
    after Sutherland's law
  - Assumed turbulent flow
  - k-ω SST turbulence model
    - Constitutive option on quadratic
  - All y+ wall treatment

  - Additional:
    - Solution interpolation
    - Cell quality remediation



Mesh independence

- For 4.19° angle of attack

- Several iterations of mesh
  - From 5.26M to 19.56M cells
  - Variation of the Base Size

Base Size (m)	Number of Cells (Mio.)	C_L	% Deviation	C_D	% Deviation
1.54	5.26	0.19918	0.91%	0.01216	2.80%
1.225	6.85	0.19907	0.85%	0.01206	1.90%
0.85	11.10	0.19882	0.72%	0.01192	0.77%
0.77	13.92	0.19842	0.52%	0.01189	0.50%
0.60	19.56	0.19739	0,00%	0.01183	0.00%

- Mesh with approximately 11 million cells was chosen as base mesh:
  - Good solution accuracy
  - Faster convergence
  - Justifiable hardware load

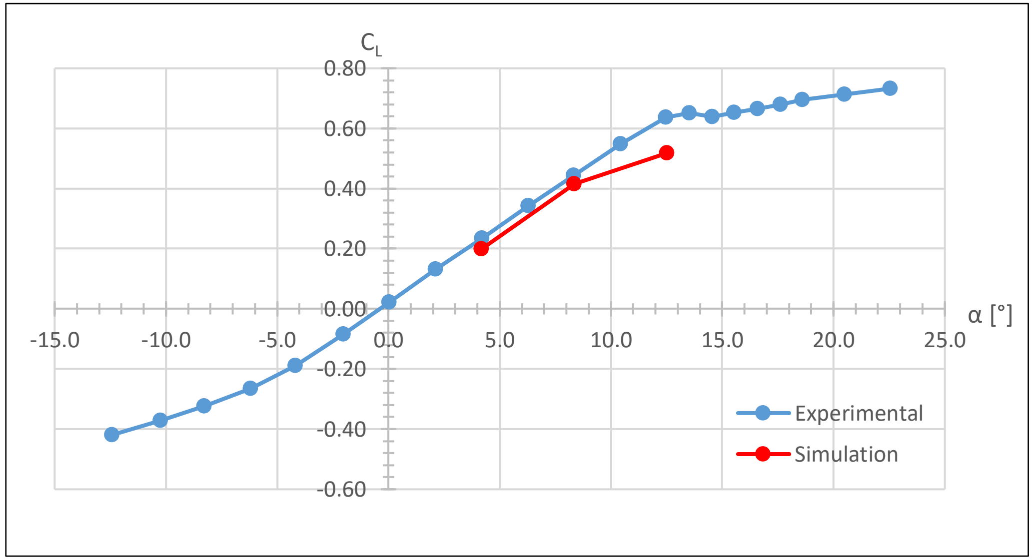
Lift and Drag

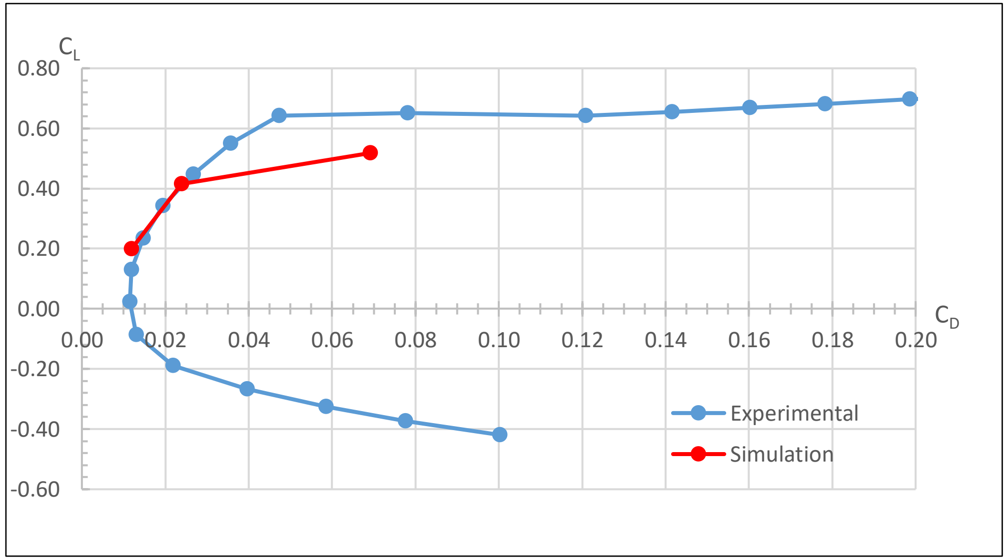
- For lower AoA very good results
  - Constant offset

- At 12.53° AoA big deviation
  - Less Lift
  - More Drag

AoA (°)	C_L simulation	C_L experiment	Abs. error	Rel. error (%)
4.19	0.1988	0.2331	-0.0343	-14.71
8.36	0.4153	0.4443	-0.0290	-6.51
12.53	0.5185	0.6380	-0.1195	-18.73

AoA (°)	C_D simulation	C_D experiment	Abs. error	Rel. error (%)
4.19	0.0119	0.0147	-0.0028	-18.63
8.36	0.0239	0.0264	-0.0025	-9.54
12.53	0.0691	0.0468	+0.0223	+47.71



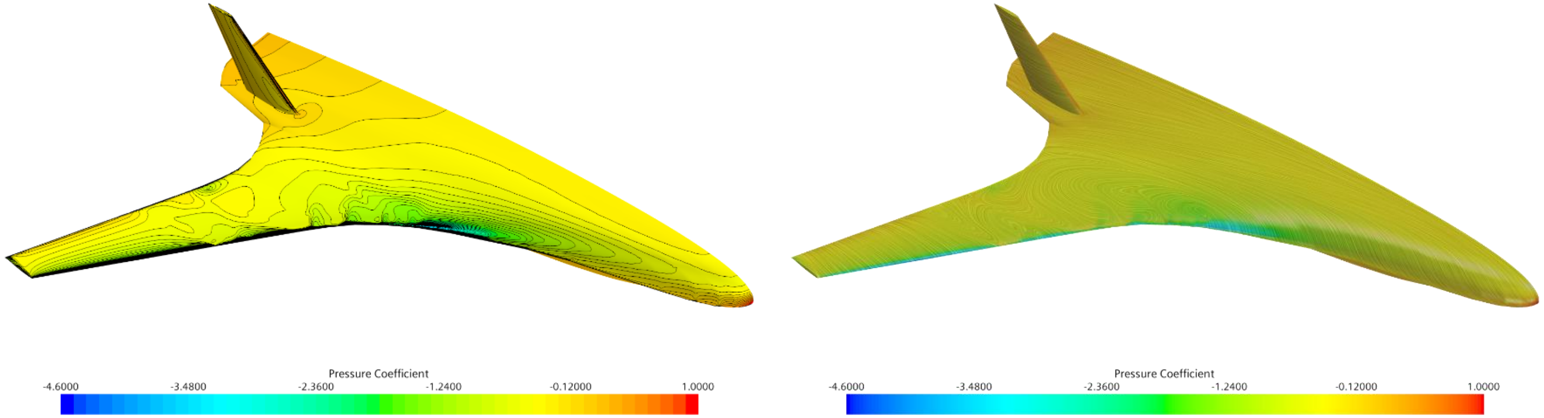


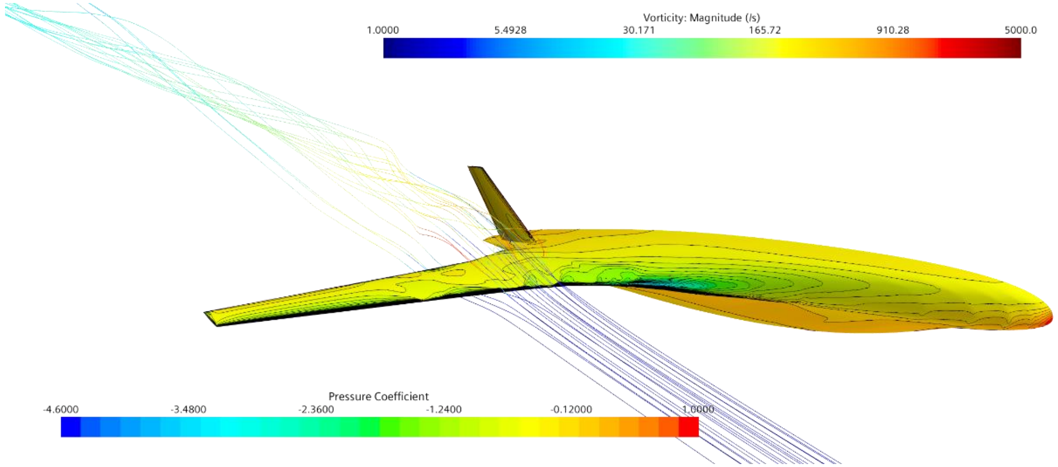
AoA 12.53°

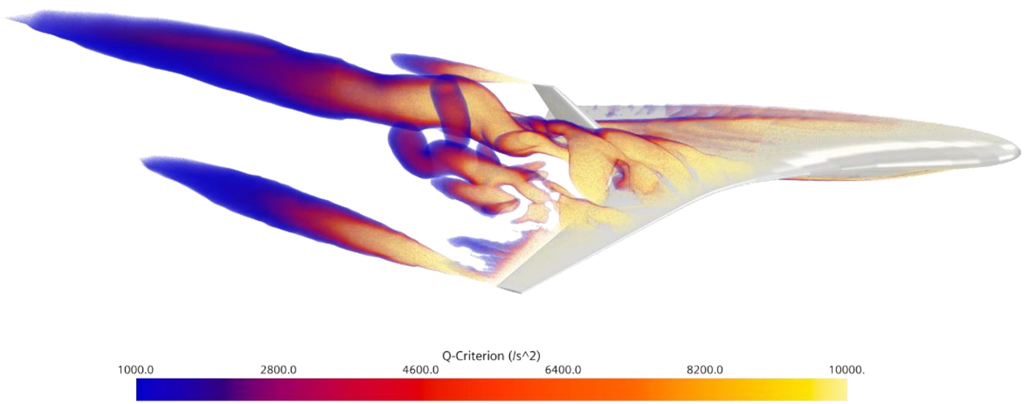
- When looking at:
  - Lift and Drag
  - C_P distribution
  - Streamlines over Wing
  - Q-Criterion
- **Visible flow separation over inner wing**

- **However:**
  Experimental results suggest no separation

- Differences Sim to wind tunnel:
  - Unknown test conditions
  - Sim model quality
  - Leading edge prone for bad surface mesh







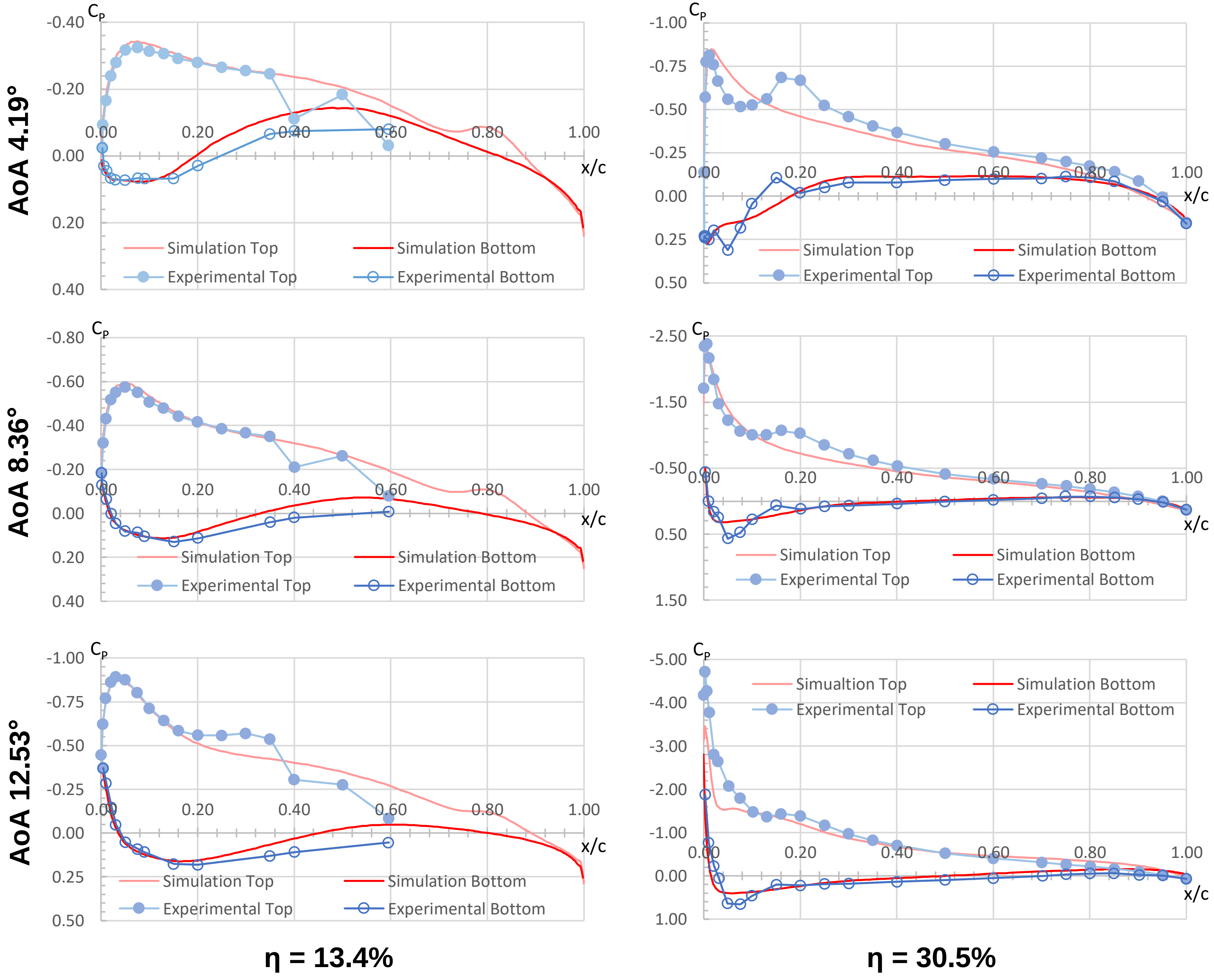
Pressure distributions

- Generally good results

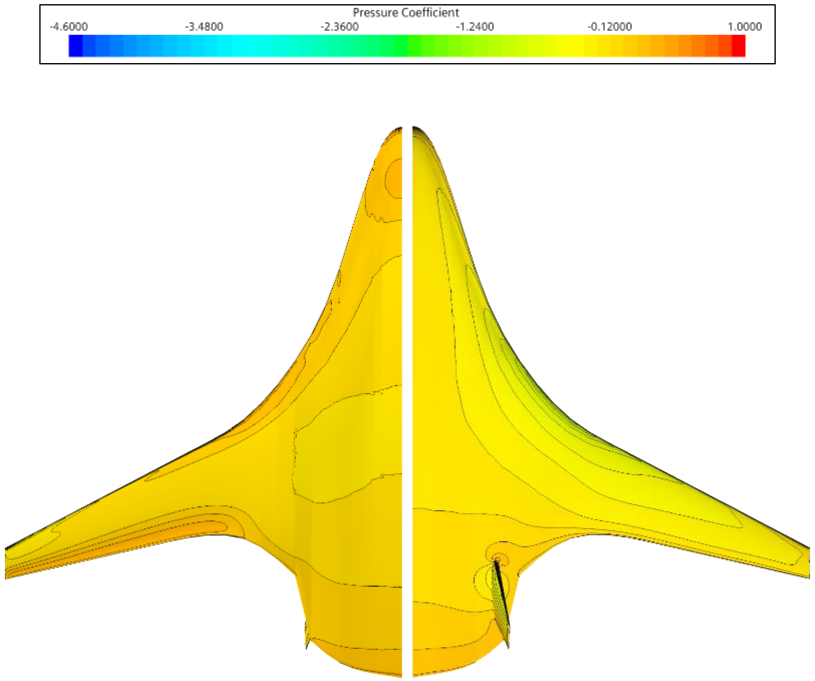
- Some deviation
  - Experimental data has disturbances
  - Simulation suggests clean results

Thesis:

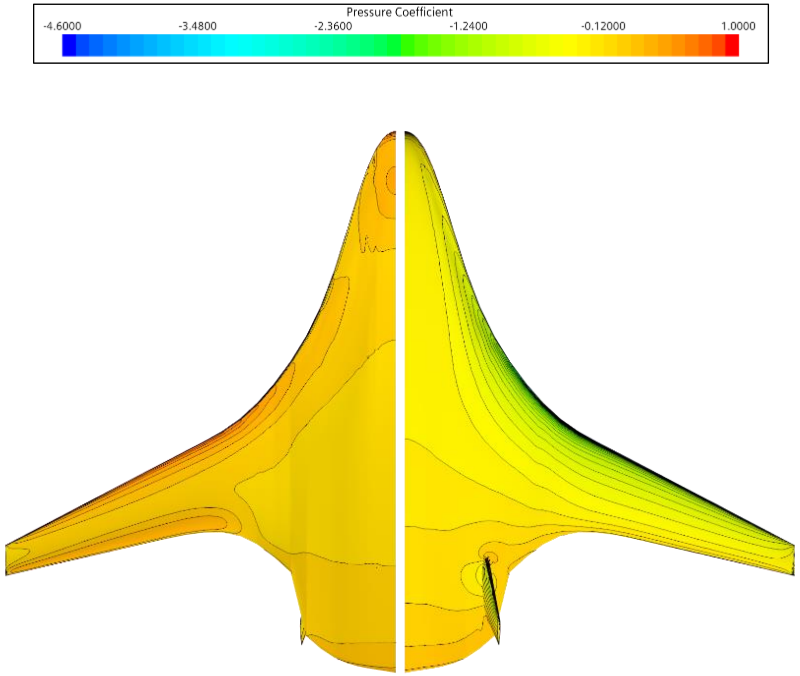
- Wind tunnel model may have had:
  - Panel gaps
  - Unclean pressure measurement bores



Pressure distributions



AoA 4.19°
(left) bottom; (right) top



AoA 8.36°
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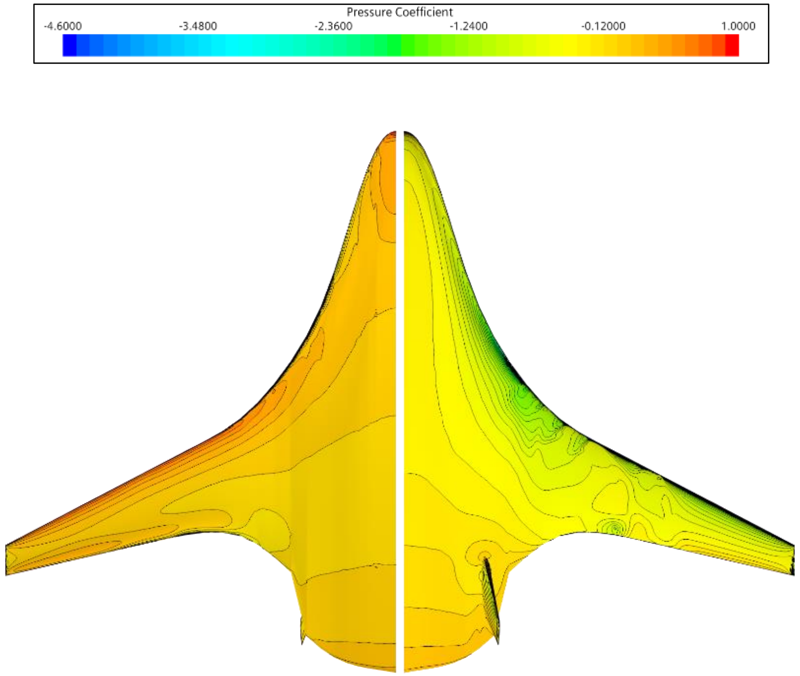
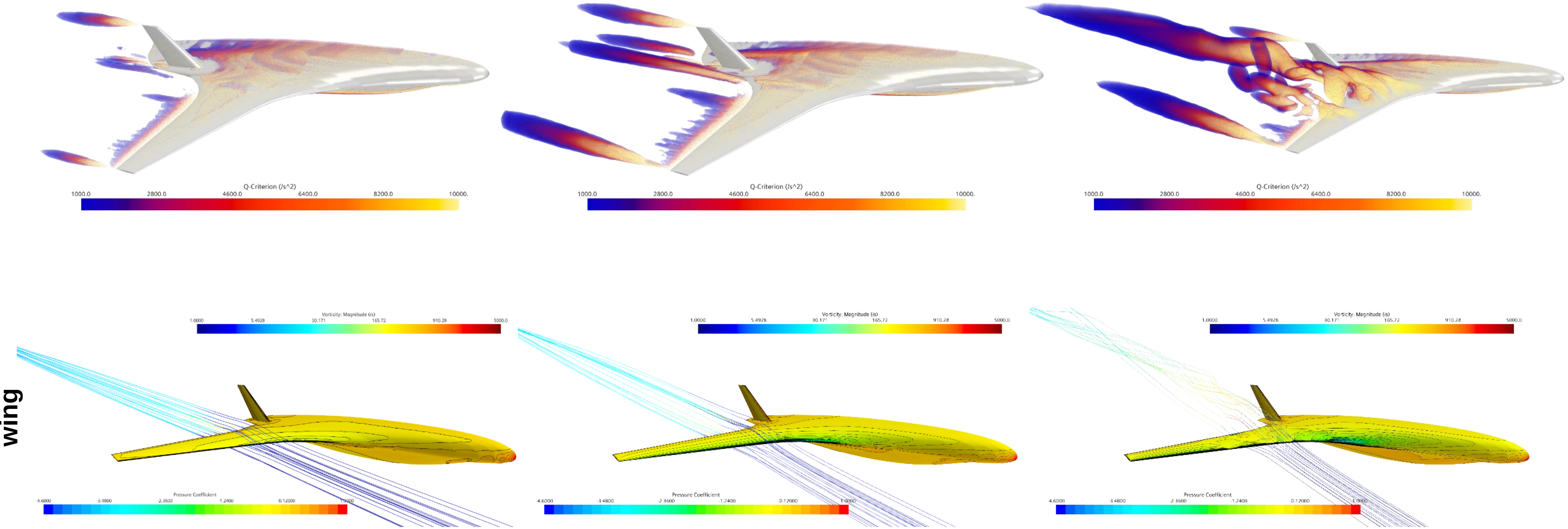


AoA 12.53°
(left) bottom; (right) top

Flow visualization

Q-Criterion

Streamlines and Vorticity over inner wing



AoA 4.19°

AoA 8.36°

AoA 12.53°

Conclusion

- Simulation with mesh and physics was setup

- Extensive mesh independence study

- Simulation successfully conducted

- Sufficiently accurate drag, lift and pressure coefficients for lower AoAs
    - However, some pressure peaks not reproducible in simulation

- At highest AoA experienced flow separation
    - Switch to unsteady solver
    - Separation likely did not occur in reference experiment

- Likely deviation to experiments due to:
    - Unknown test parameters
    - Model geometry

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References

- Gatlin, G. M., Vicroy, D.D., Carter, M.B., "*Experimental Investigation of the Low-Speed Aerodynamic Characteristics of a 5.8-Percent Scale Hybrid Wing Body Configuration*", NASA Langley Research Center, June 2012

- Almosnino, D, "*A Low Subsonic Study of the NASA N2A Hybrid Wing-Body Using an Inviscid Euler-Adjoint Solver* ", Aerion Technologies Corporation / Desktop Aeronautics, Palo Alto, June 2016

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Thank you for your Attention!