Embraer Contribution to DPW-8/AePW-4: Wind Tunnel Environment

Eduardo Molina and Joao Luiz Perez

Embraer

Drag Prediction Workshop 8, 6-7 June 2026

Volcano ScaLES

- **Spatial discretization**: Finite Difference 4th order (inviscid) + 2nd order (viscous)
- **Time integration**: Explicit (3rd order Runge-Kutta)
- **Initialization method**: Freestream / impulsive start for free air and grid-sequencing
- **Grid topology**: Octree Cartesian grids with immersed boundary
- **Typical mesh points**: up to 2 Billions (8 x Nvidia L40s)
- **Wall modeling**: Equilibrium Wall Modeling (Algebraic)
- **SGS closure**: Smagorinsky with Dynamic Procedure
- **Transition treatment**: None (numerical discretization controls it)
- **Typical time step normalized by CTU**: 2.2E-4
- **Aspect ratio range (tangential spacing/wall-normal):** 1
- **Wall model exchange location**: 1.5 x (Dx)
- **Relevant publication**:
  - Ghate et. al. "Large Eddy Simulations of High-Lift Common Research Model in the NTF Wind Tunnel at Flight Scale Reynolds Number." AIAA SciTech 2026-0020

2.7% Scale Simulation Setup

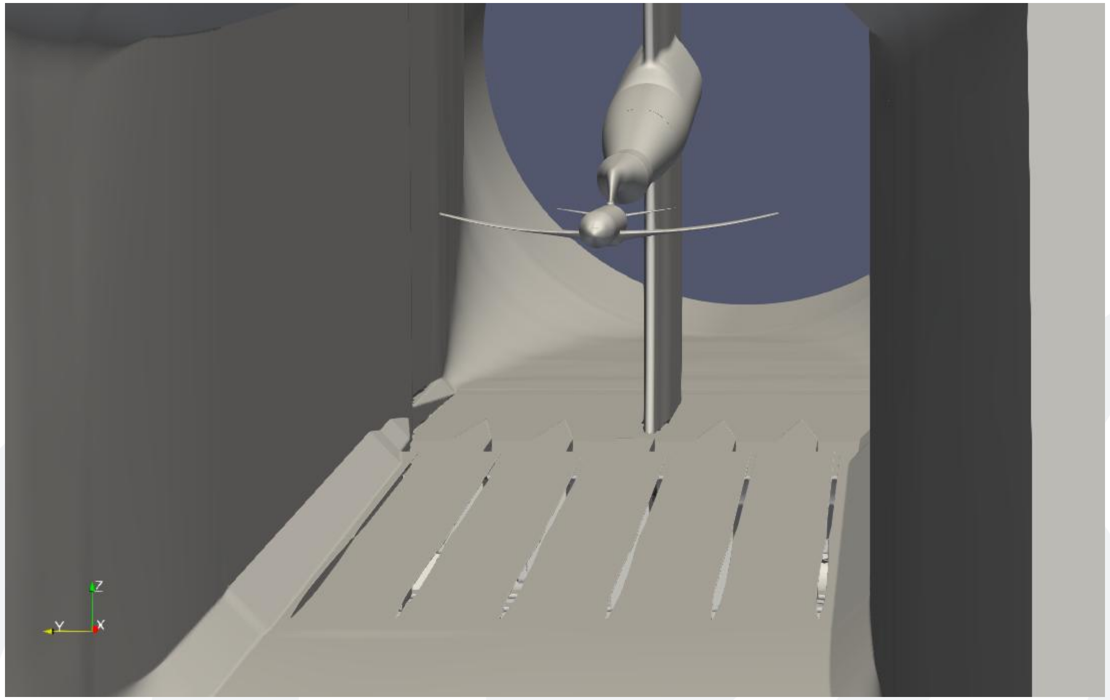
In-Tunnel Grid Sequencing and PID Controller

- Automate PID Controller to adjust the back-pressure based on a probe at the beginning of the test section.
- Grid Sequencing: 5 grid levels
  - 3 precursor grids followed by a coarse grid.
  - Loads averaged on "baseline grid" from time 18.06250s to 18.125s (100 CTUs)
- Each case completed in 92 hours using 8xL40s

WBH and WBHS

- Same near-body grid resolution as the NTF grids.
- Simulations were run both with and without transition trip on the full airplane (without symmetry plane).

Grid Level	WBH	WBHS
	Total Cells	Total Cells
Level 1 ($dx_{min} = 0.1944mm$)	283,013,676	348,843,408
Level 2($dx_{min} = 0.0972mm$)	755,114,010	1,006,661,483

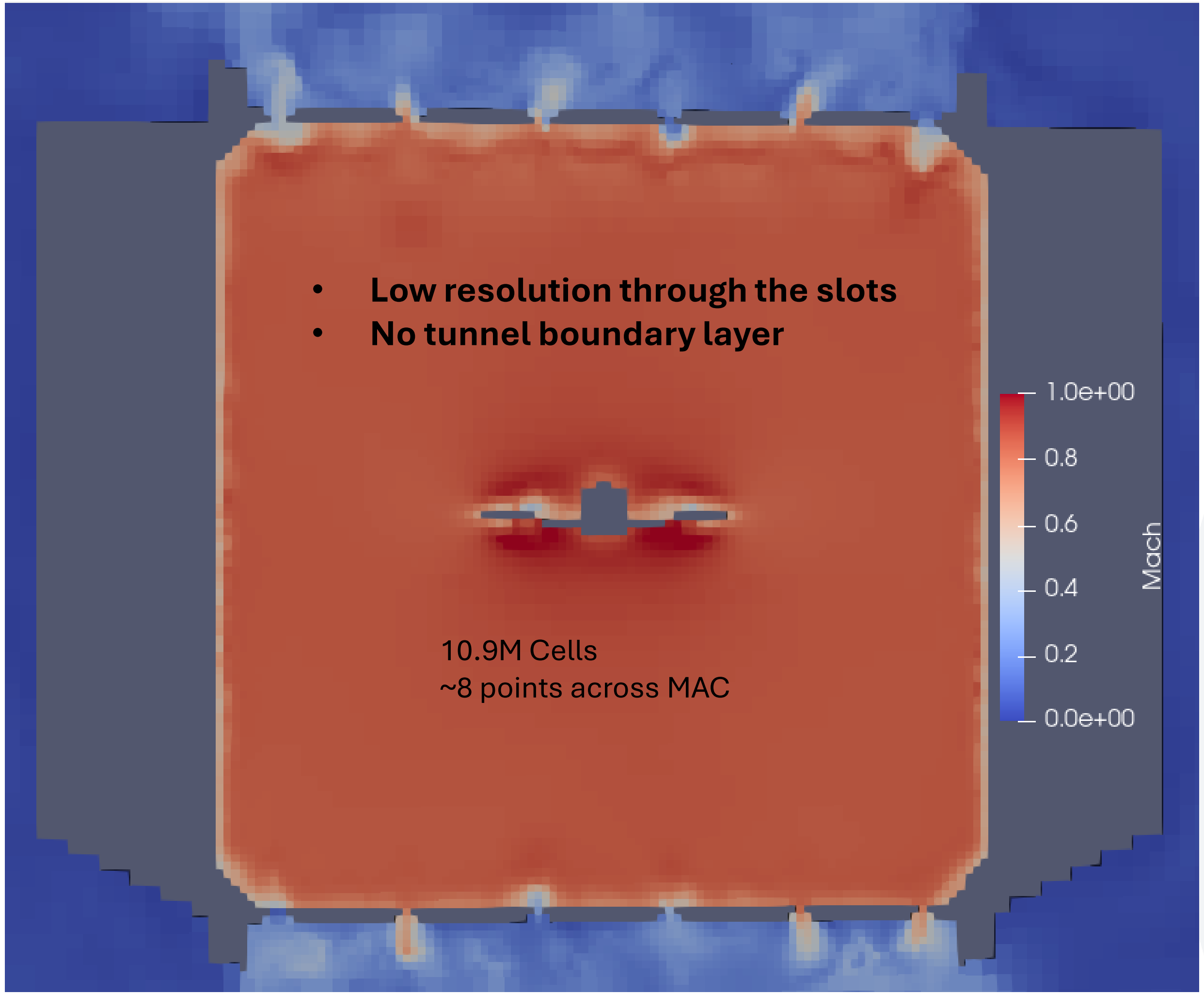


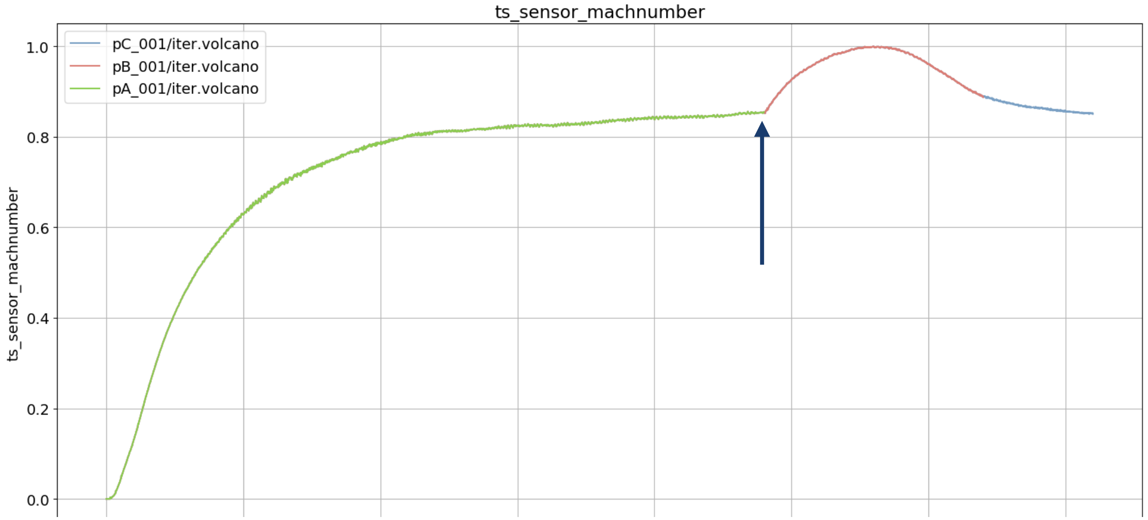
Grid Level	NTF In-Tunnel Simulation		
	Total Cells	Physical Time [s]	Wall Time [h]*
pA	10,986,788	12.0	0.86
pB	243,289,368	16.0	23.61
pC	511,617,165	18.0	76.67
gA	**584,325,111**	**18.03125**	**80.67**
gB (Level 1)	**815,959,874**	**18.06250**	**91.81**

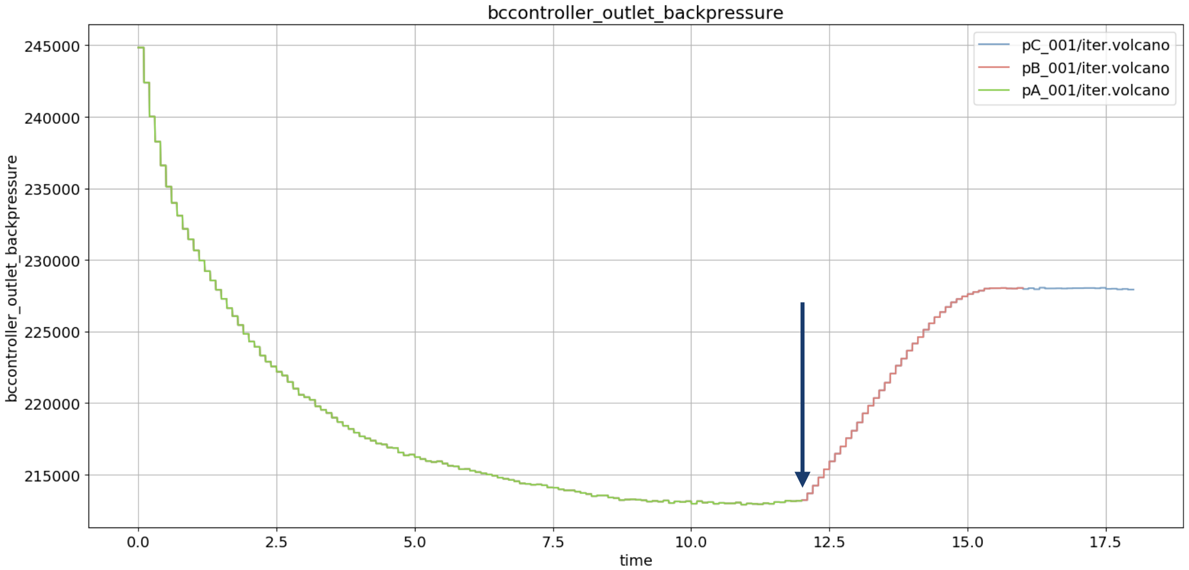
*Precursor stages could be further optimized

NTF In-Tunnel Simulation

Precursor A: Model "barely" represented

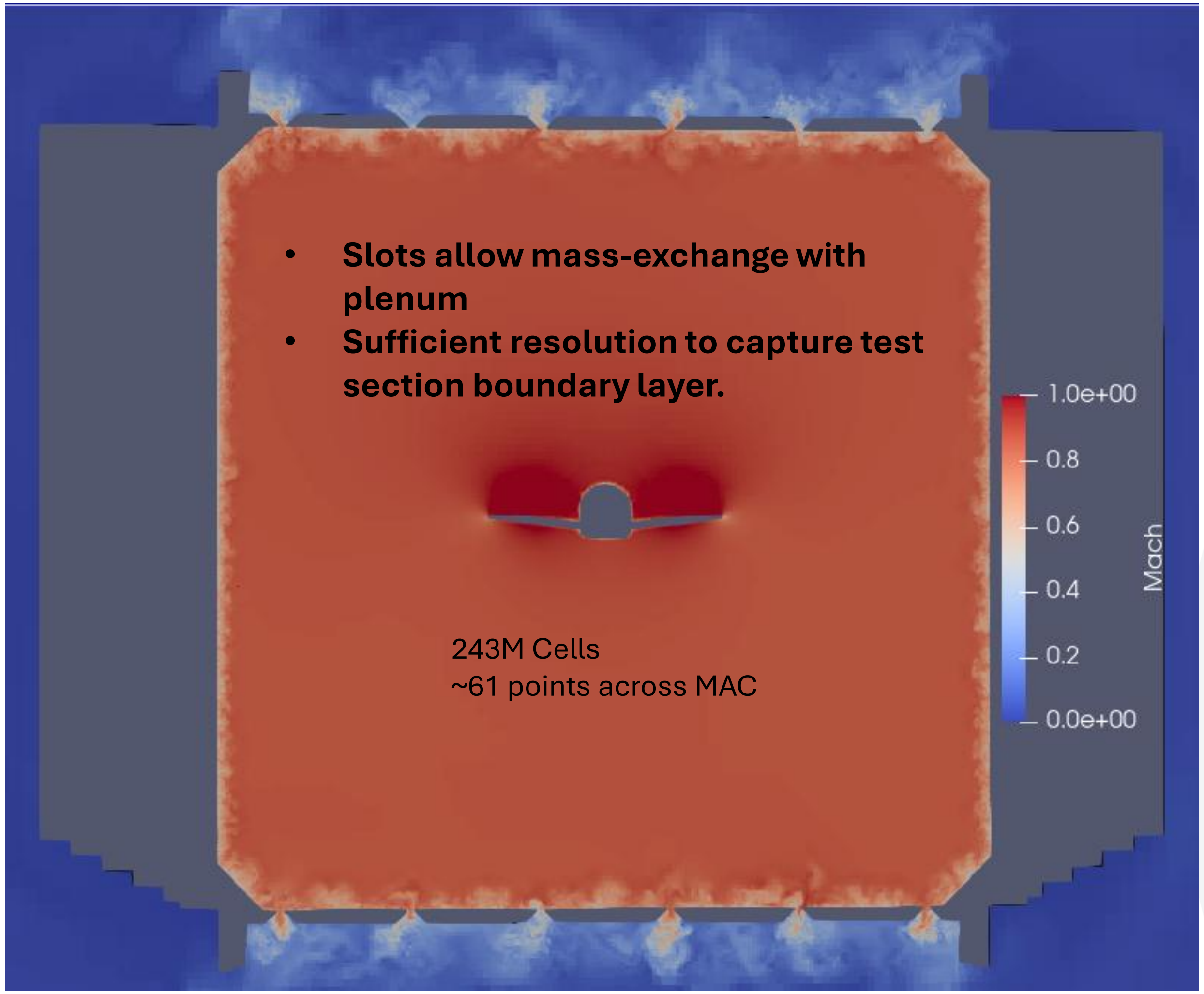


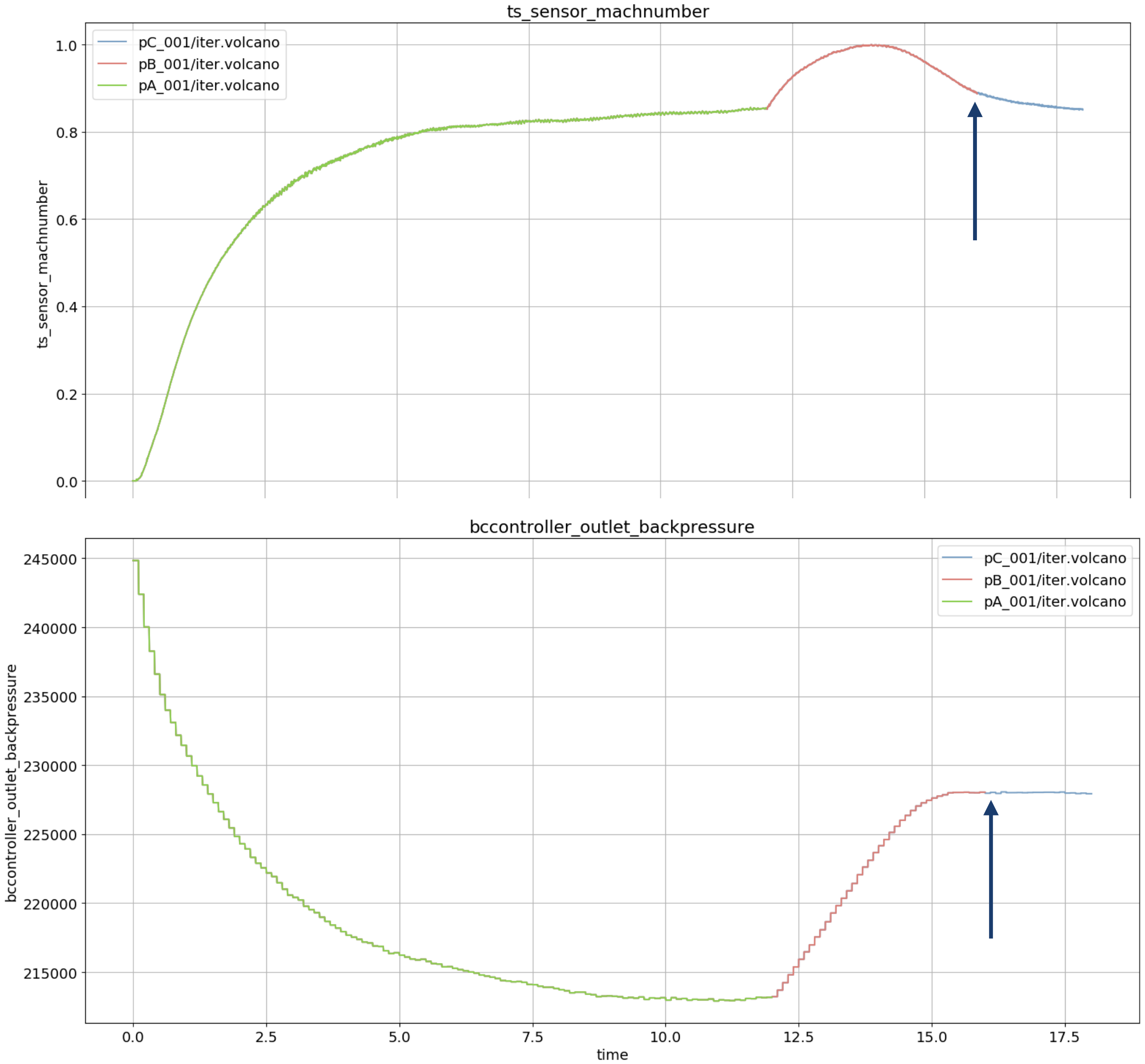




NTF In-Tunnel Simulation

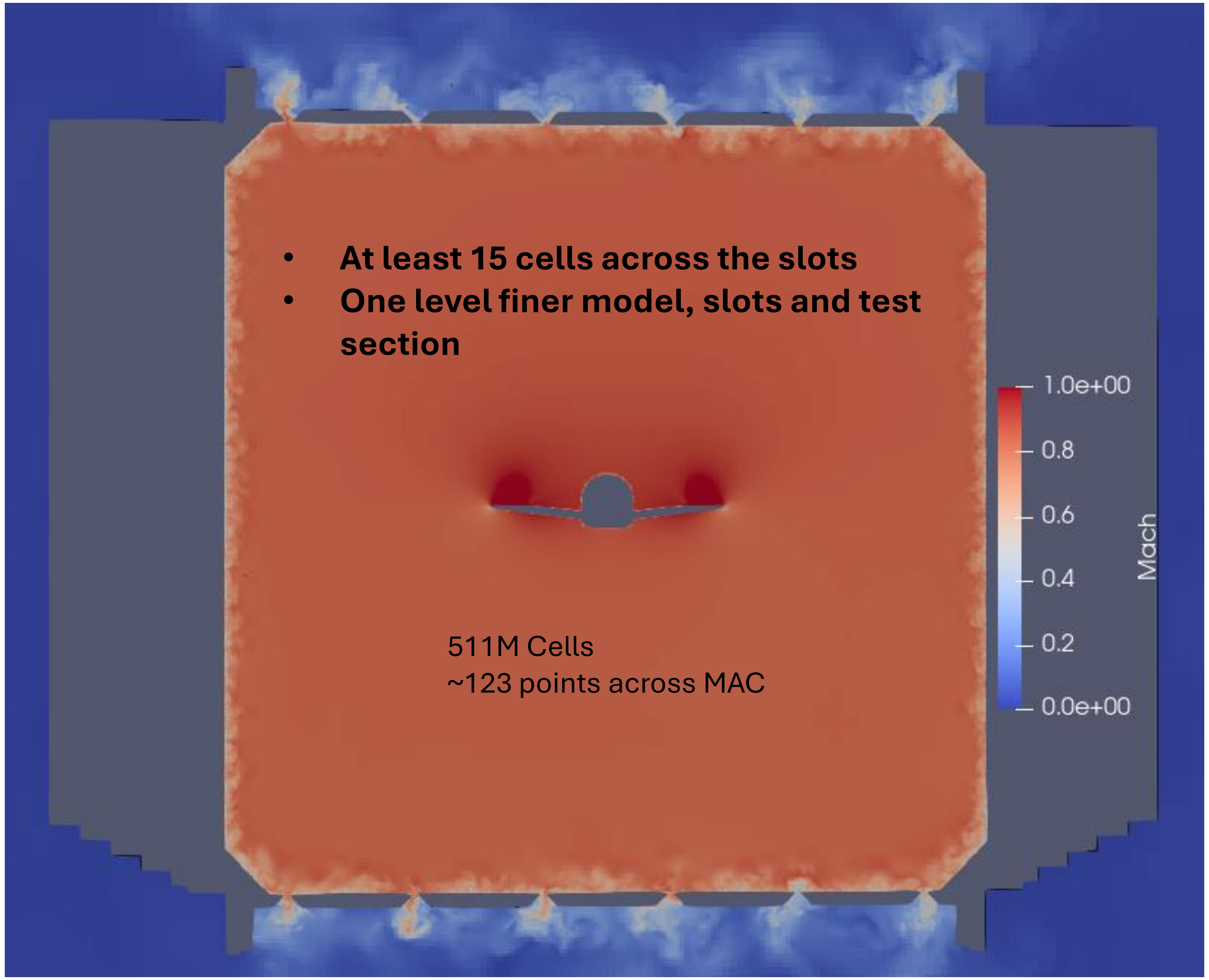
Precursor B: Wind Tunnel representation

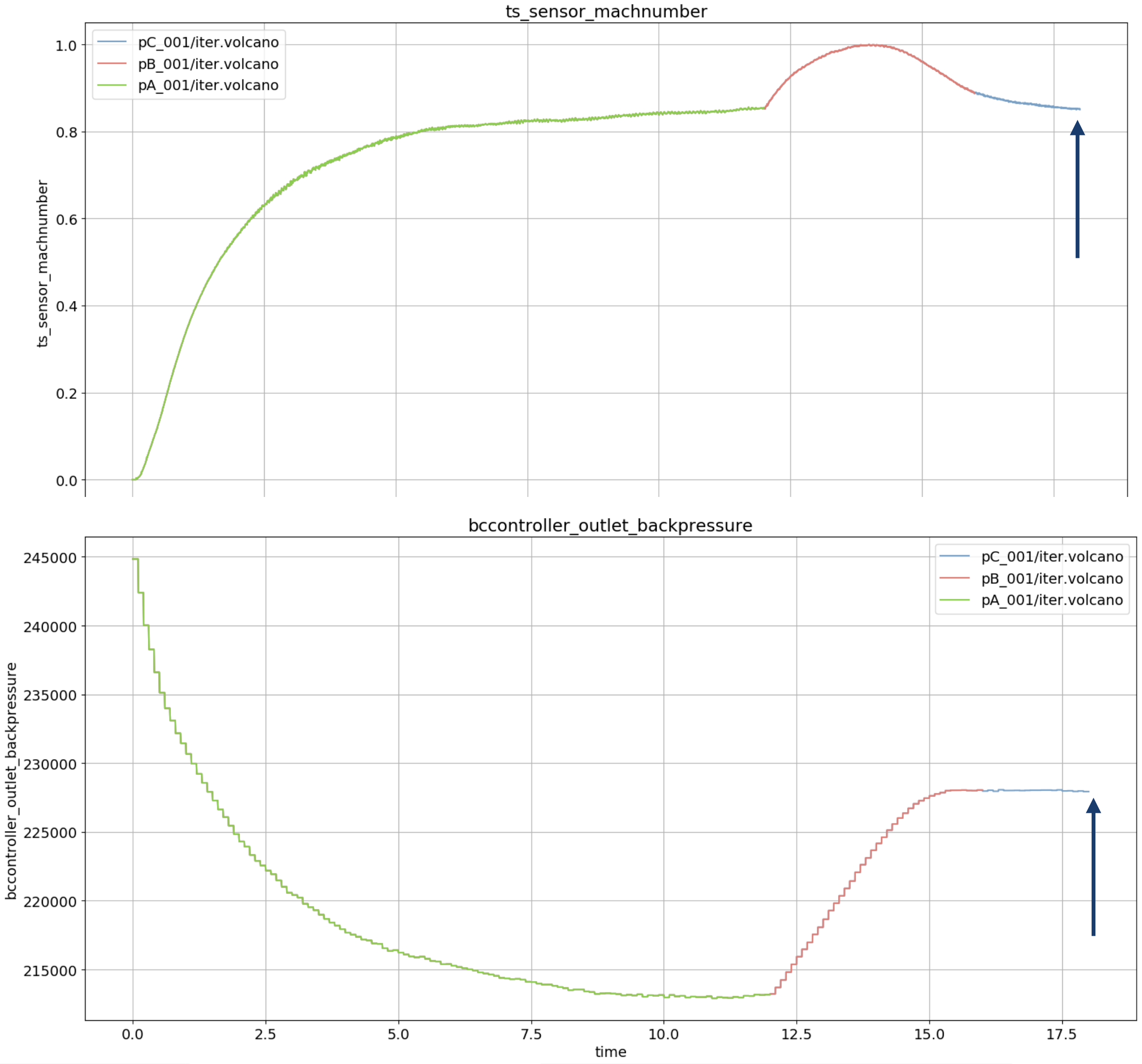




NTF In-Tunnel Simulation

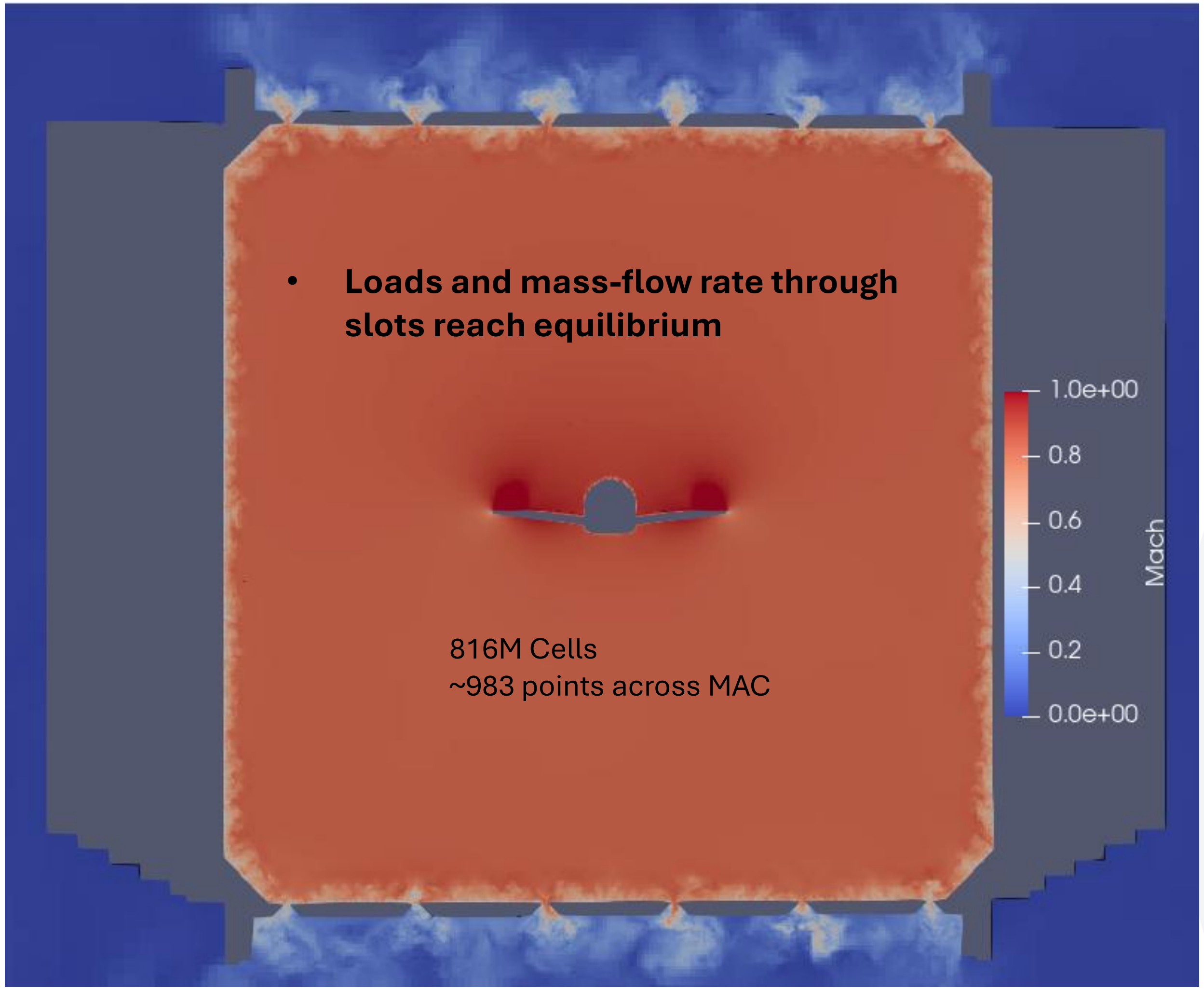
Precursor C: Model is reasonably resolved





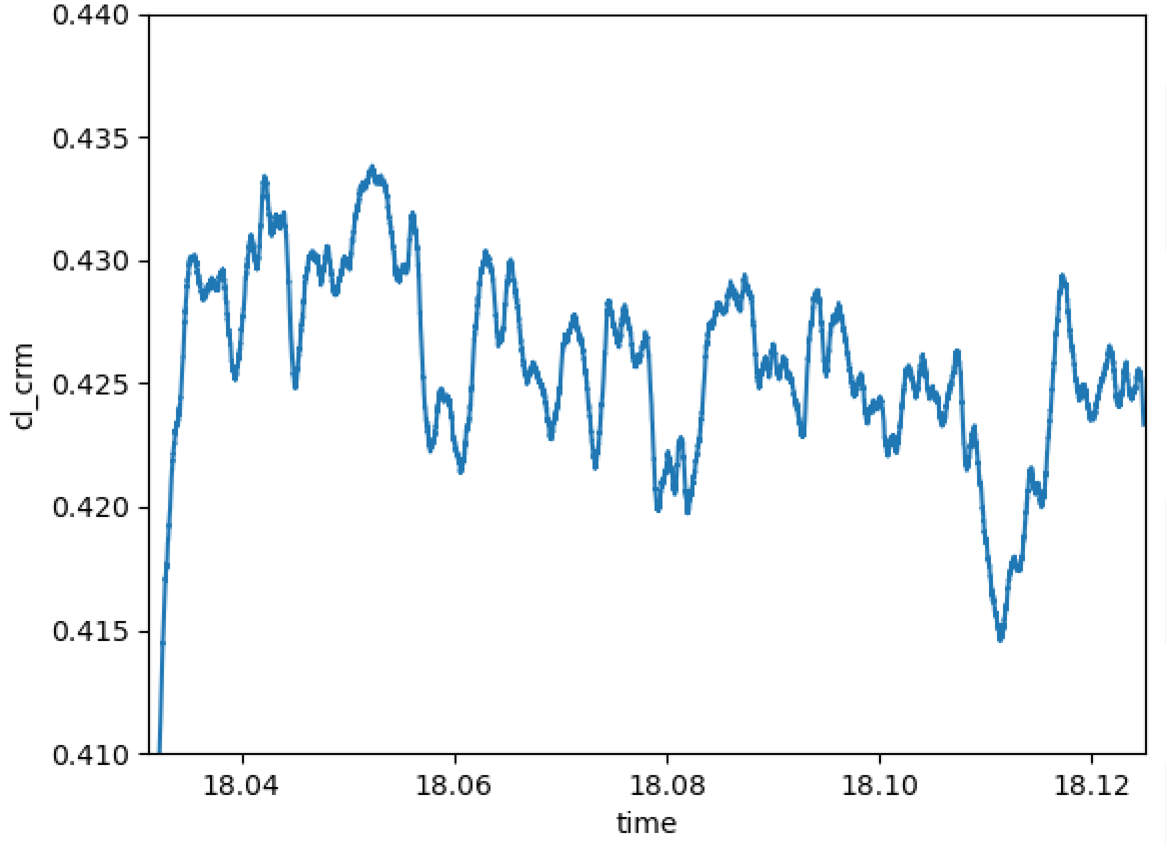
NTF In-Tunnel Simulation

Baseline grid: Free-air Model target resolution



- **Loads and mass-flow rate through slots reach equilibrium**

816M Cells
~983 points across MAC

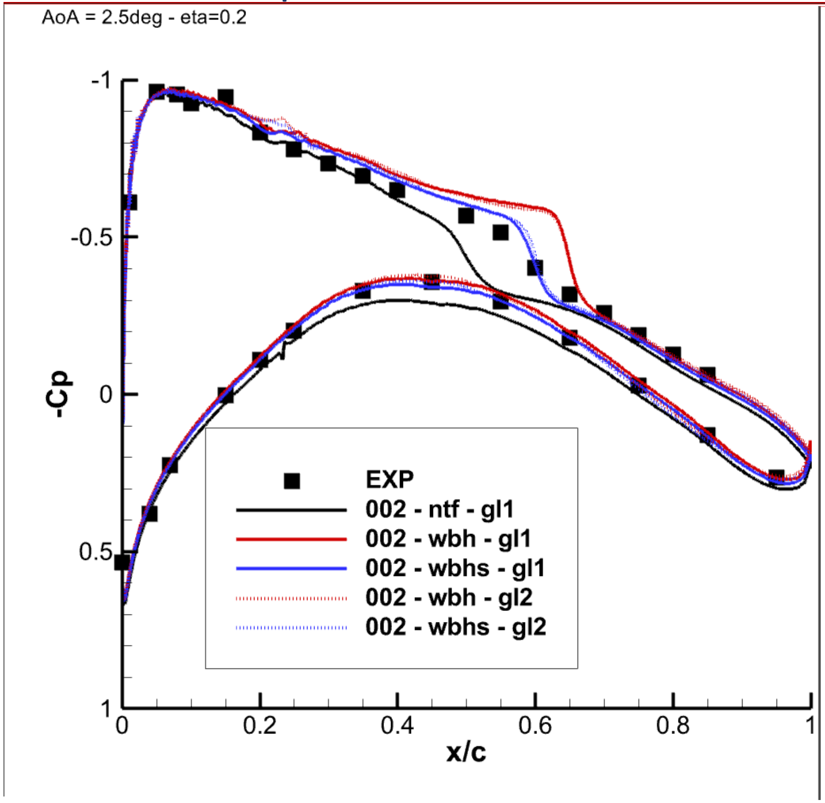


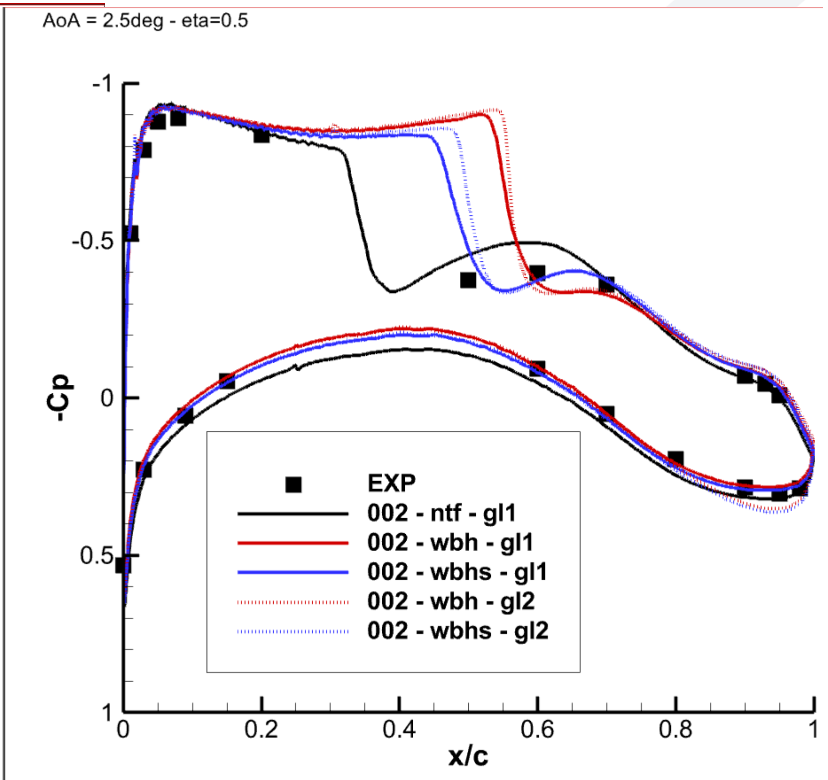
100 CTUs

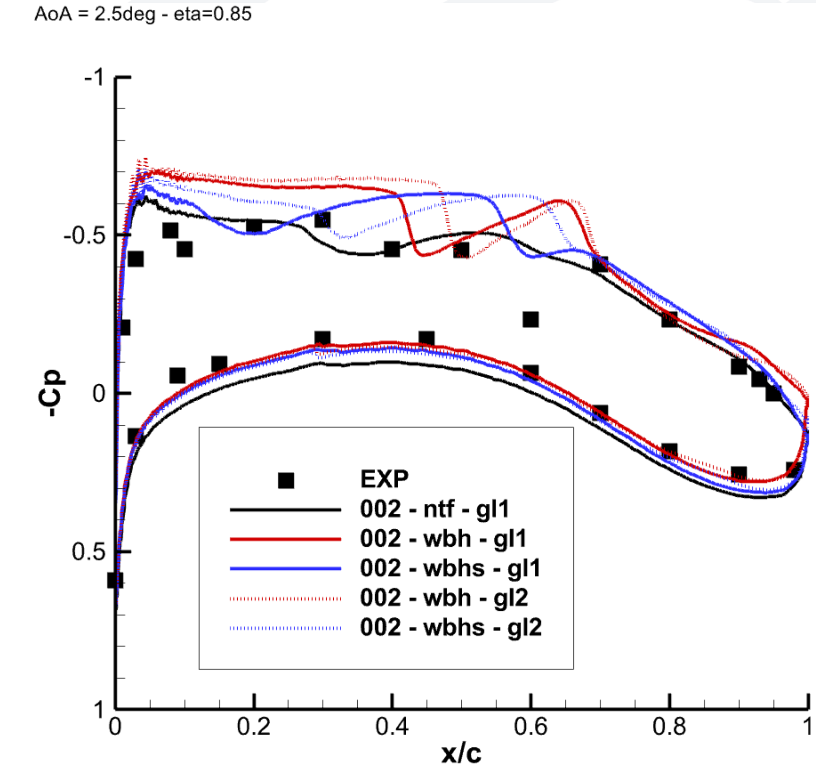
Results

Pressure Coefficient at 2.5 deg

- In-Tunnel simulations showed a higher pressure on the lower surface of the wing. Uncertainty on the rotation center position (moment center was used to rotate).
- Adding the sting and the tunnel significantly moved the wing shock position forward closer to the experimental results.







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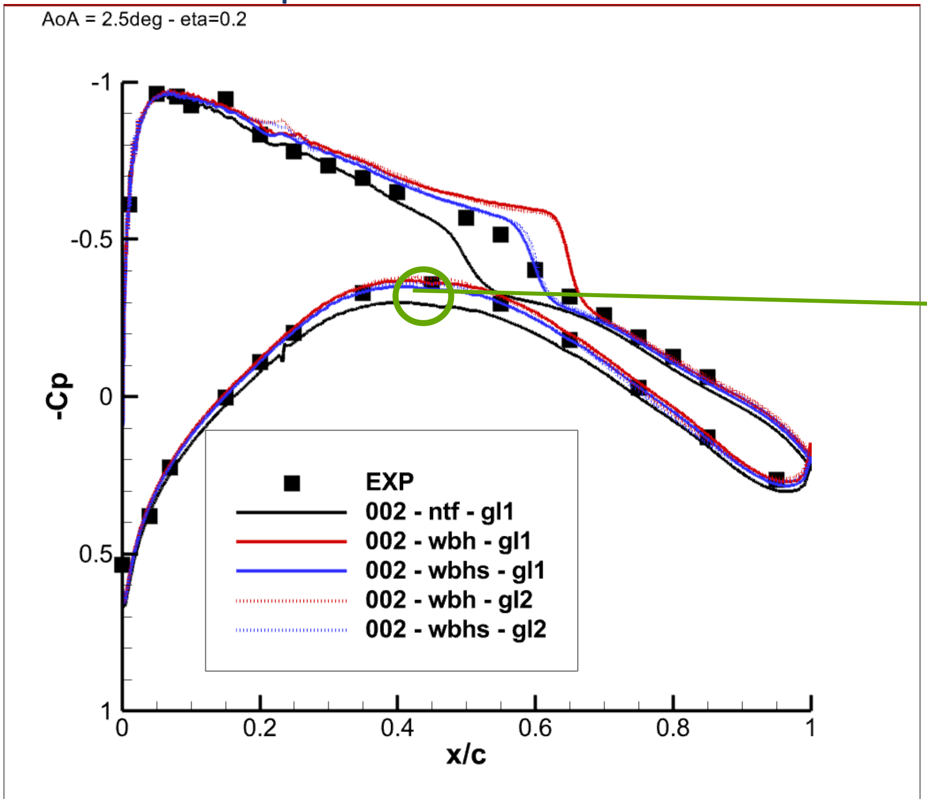
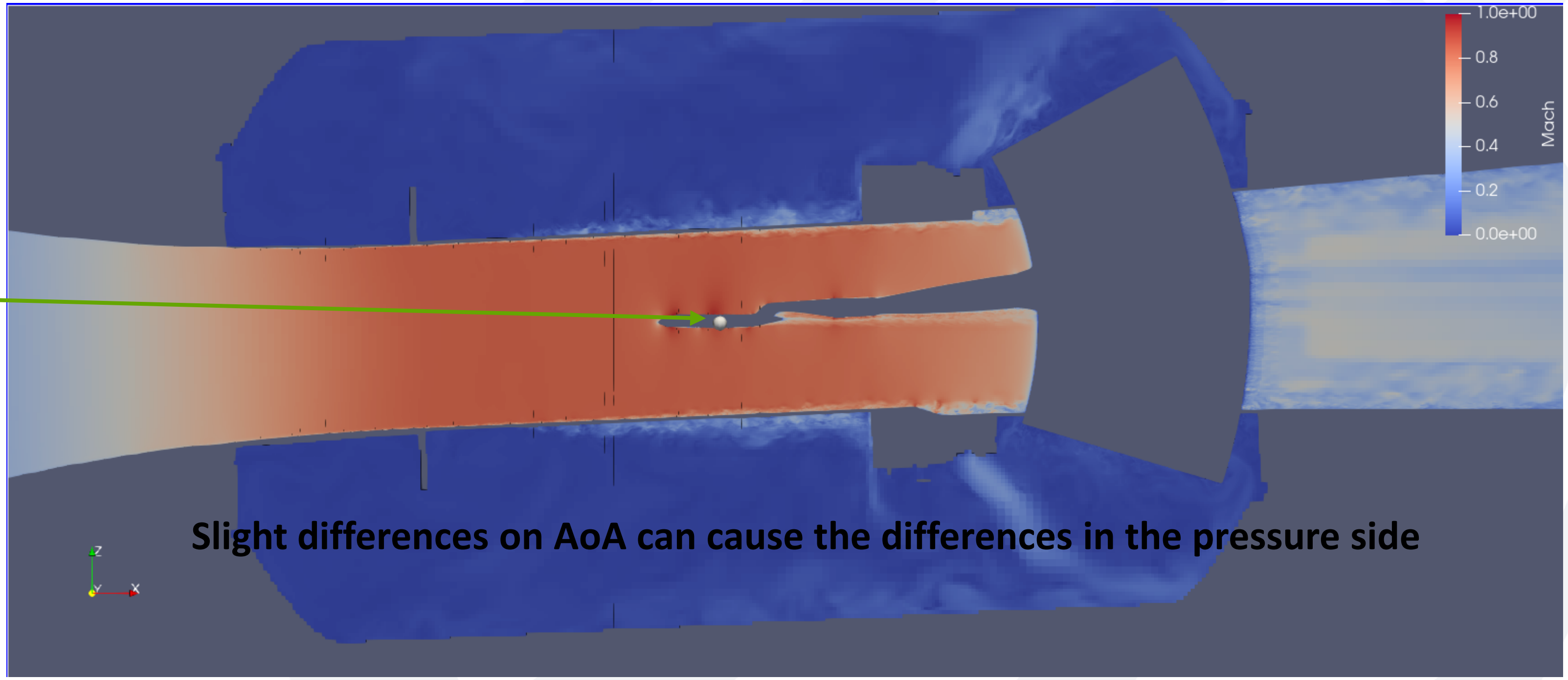
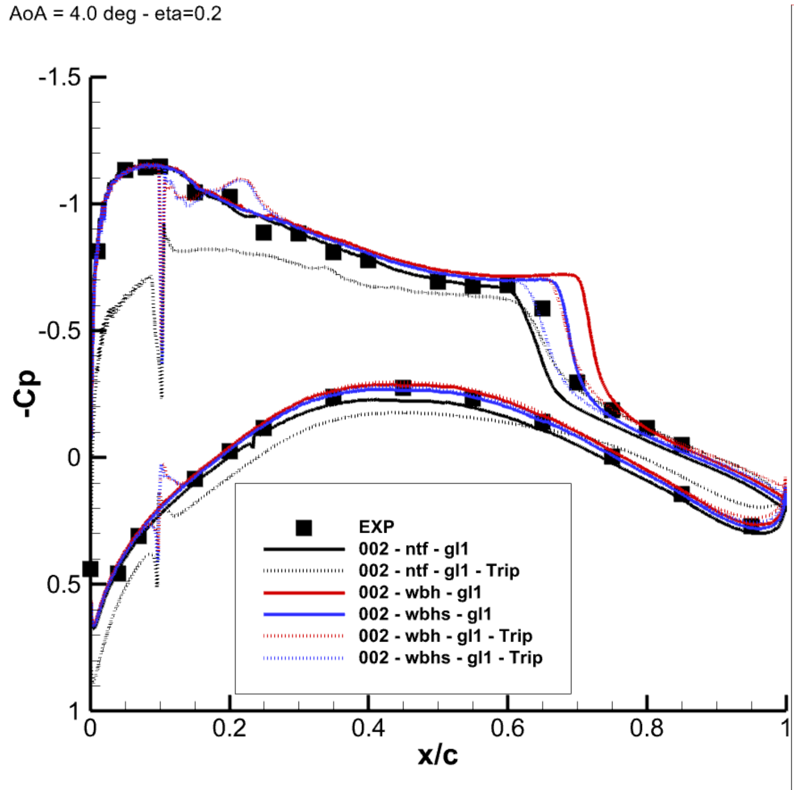


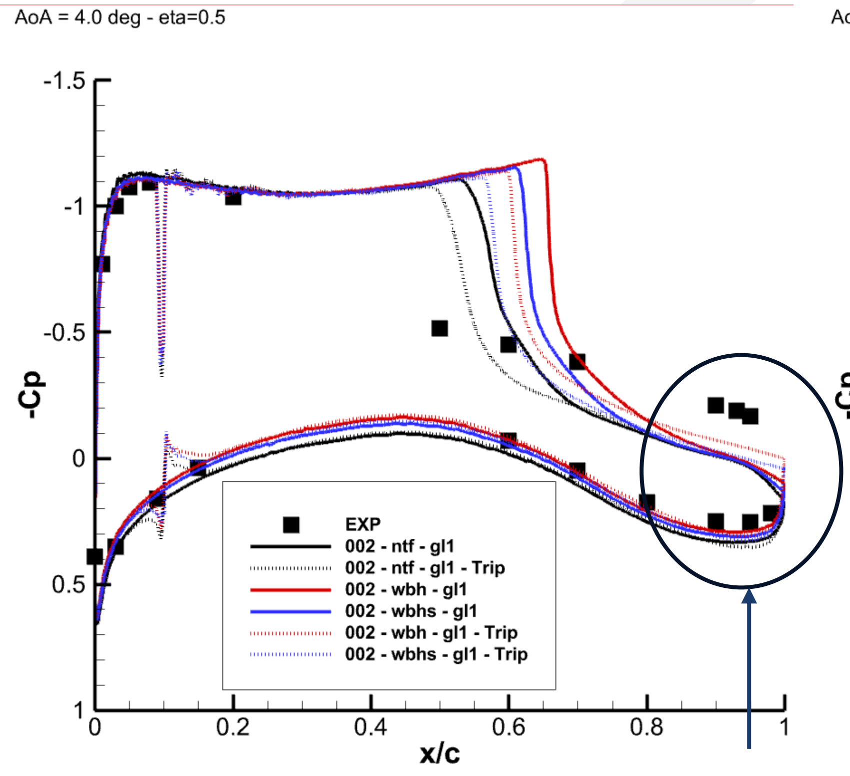


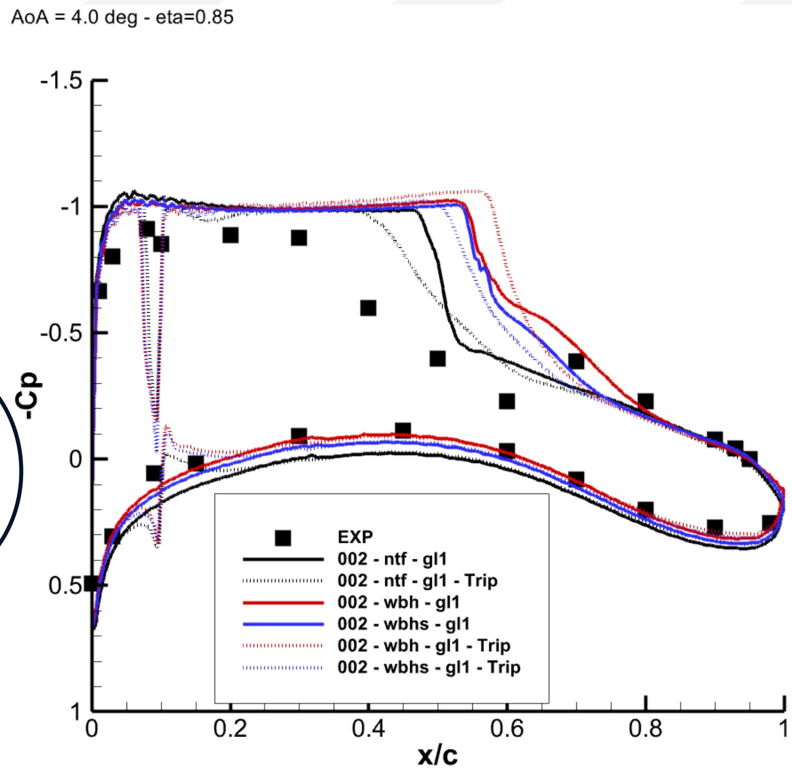
Results

Pressure Coefficient at 4.0 deg

- A transition trip of 2dx height at 10% x/c moved the shock even more forward but it was intrusive.
- A higher resolution might be needed to accurately simulate after the pitch-break (transonic shock buffet).





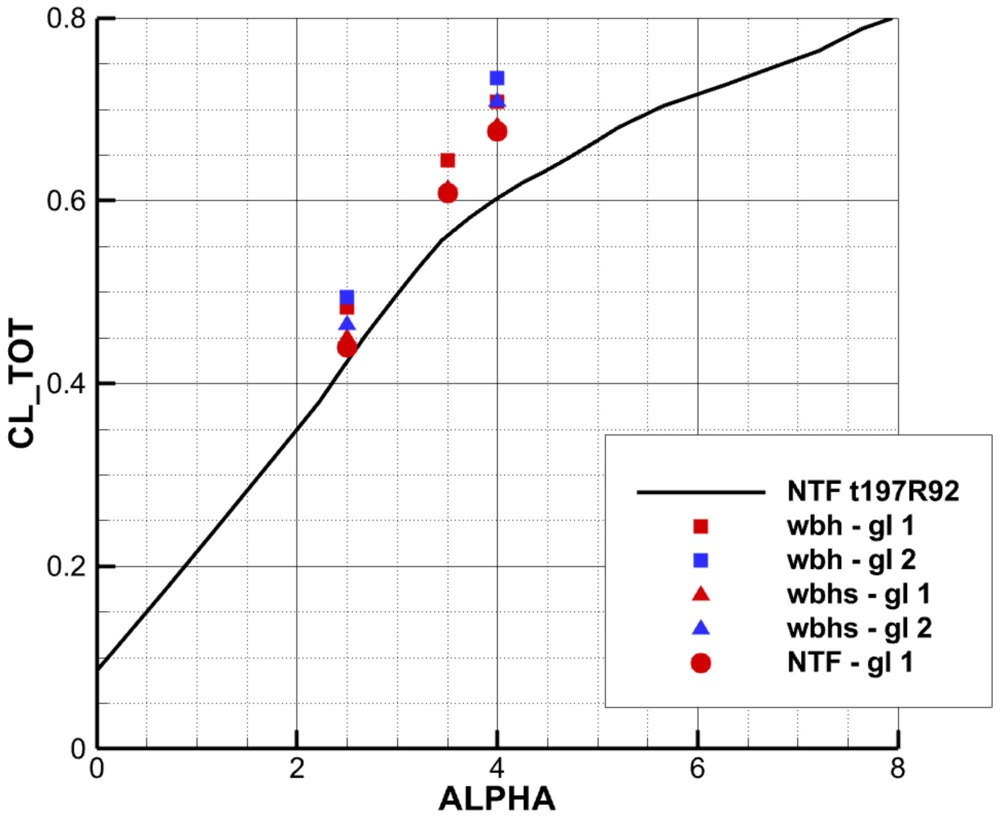


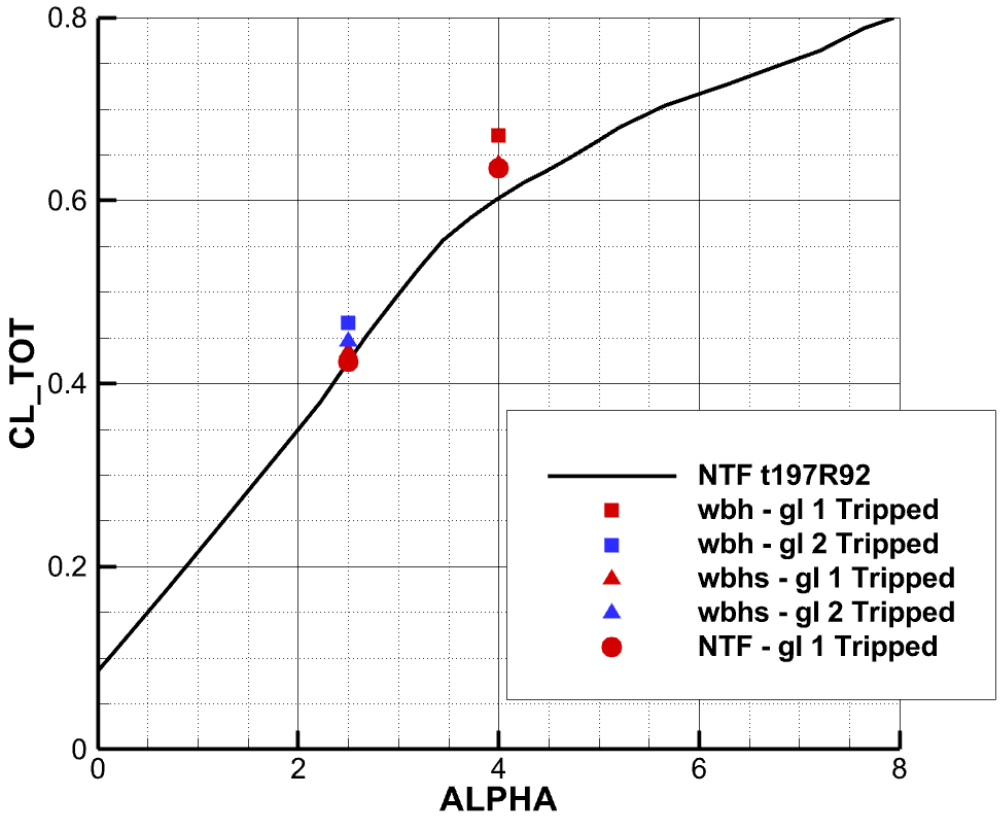
Turbulent boundary layer might be needed to capture trailing edge separation.

Results

Lift Coefficient

- Inclusion of the sting and test section reduced the lift and drag when compared with baseline configuration (wing/body/tail).
- Inclusion of the transition trip is more representative, but a higher resolution is needed to accurately model its effects. Although, a small sensitivity to grid resolution is observed at 2.5 deg.





Conclusion and Next Steps

- A Wall Model LES methodology was developed to simulate the full NTF test section:
    - Grid sequencing until the loads reach equilibrium.
    - Automate PID controller to adjust the back-pressure.
- Initial results showed a strong effect on the force and pressure coefficients by the presence of the sting and the full NTF, specially at 2.5deg.
- In-tunnel vs free-air simulations show differences across the entire wing.
- For a more representative In-Tunnel simulation, we might need:
    - Test section probe location: We used a point at beginning of the test section.
    - Center of rotation: It was assumed the airplane moment center.
- Additional resolution study is needed to accurately capture the pitch break at higher Angles of Attack.
- Transition Trip is important to capture trailing edge separation at high Angles of Attack.

Acknowledgement

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AIAA

Thank You