HUNS3D Simulation for the 2nd Sonic Boom Prediction Workshop

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Outline

- Summary of cases analyzed
- Numerical Method
- Test Cases and Computational results
- Summary

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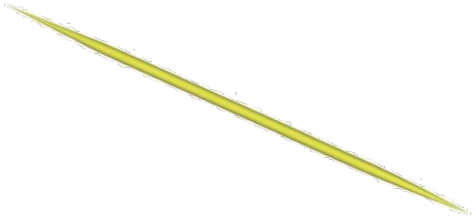
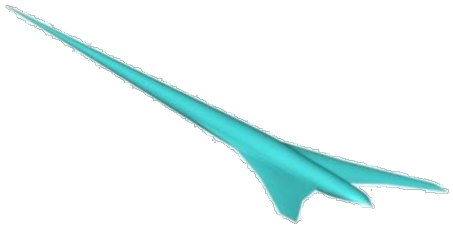
Summary of cases analyzed

- **All submitted computations using:**
  - **HUNS3D solver**
  - **Hybrid viscous mesh/ Euler mixed mesh**
  - **Central /Entropy-consistent (EC) schemes**
  - **Spalart-Allmaras (SA) turbulence model**



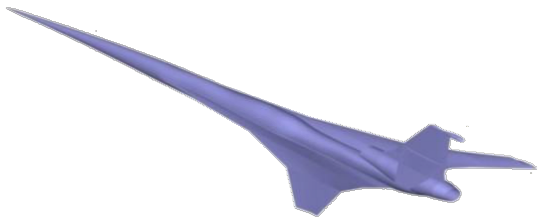
AXIE



JWB

- **Test cases**

Geometry	Inviscid	Viscous	Provided mesh	Self-generated
AXIE	√	√	√	√
JWB		√		√
C25D flowthru		√		√



C25D flowthru

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Numerical Method

• Computational Fluid Dynamic (CFD) Solver

- **Hybrid Unstructured Navier-Stokes 3D (HUNS3D) is used, which is a FORTRAN Code parallized by OpenMP.**

Flow Pattern	Inviscid/ Viscous
Supported Mesh Type	Structured/ unstructured/Hybrid
Discretization method	Cell-centered finite volume
Turbulence model	Euler/SA/MSST/Correlation-based γ-Reθt /DES
Shock capture schemes	Central/ROE/AUSM series/ Entropy-Consistent/Ecusp
Spatial accuracy	2nd order
Time integration	Runge-Kutta /LU-SGS implicit method

- Mian, H. H., Wang, G. and Raza, M. A., "Application and Validation of HUNS3D Flow Solver for Aerodynamic Drag Prediction Cases," Applied Sciences and Technology (IBCAST), 2013 10th International Bhurban Conference on IEEE, 2013.
- Wang Gang, Ye Zhengyin. "Mixed Element Type Unstructured Grid Generation and its Application to Viscous Flow Simulation", 24th International congress of aeronautical sciences, Yokohama, Japan, 2004.
- Li CN, Ye Z, Wang G, "Simulation of flow separation at the wing-body junction with different fairings," Journal of Aircraft 2008; 45(1): 258-266

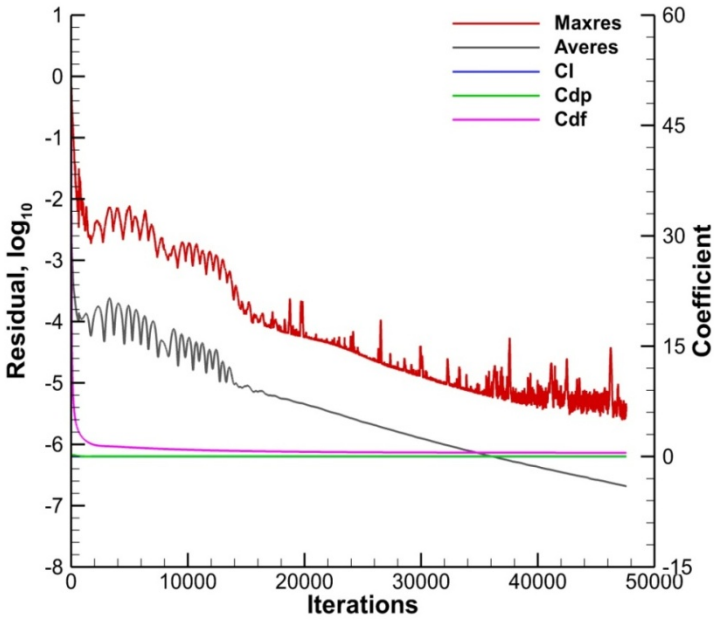
Numerical Method

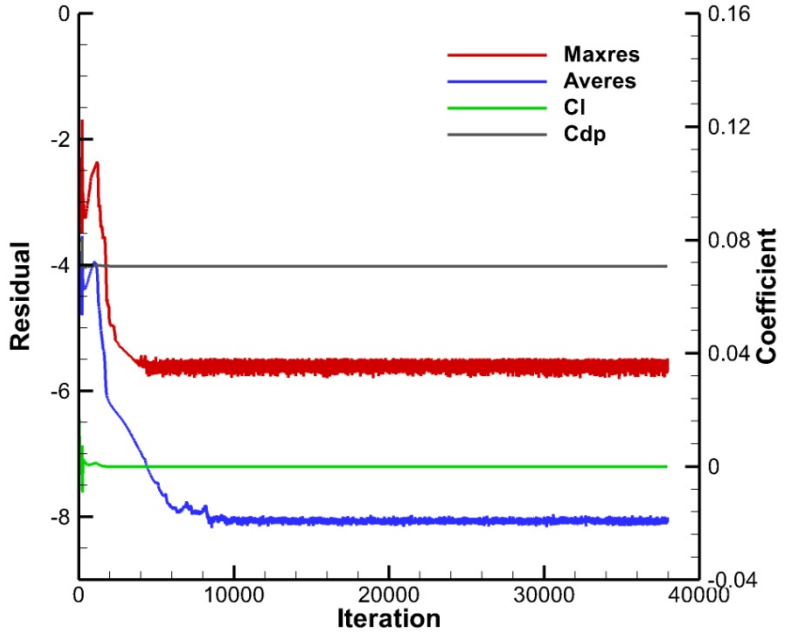
- **Convergence features (**on AXIE configuration**)**

➢ **Solver convergence Criteria:** 40000 iterations

➢ **Residual convergence history:**

- Residual drop by 6 orders of magnitude
- Cl and Cd converged





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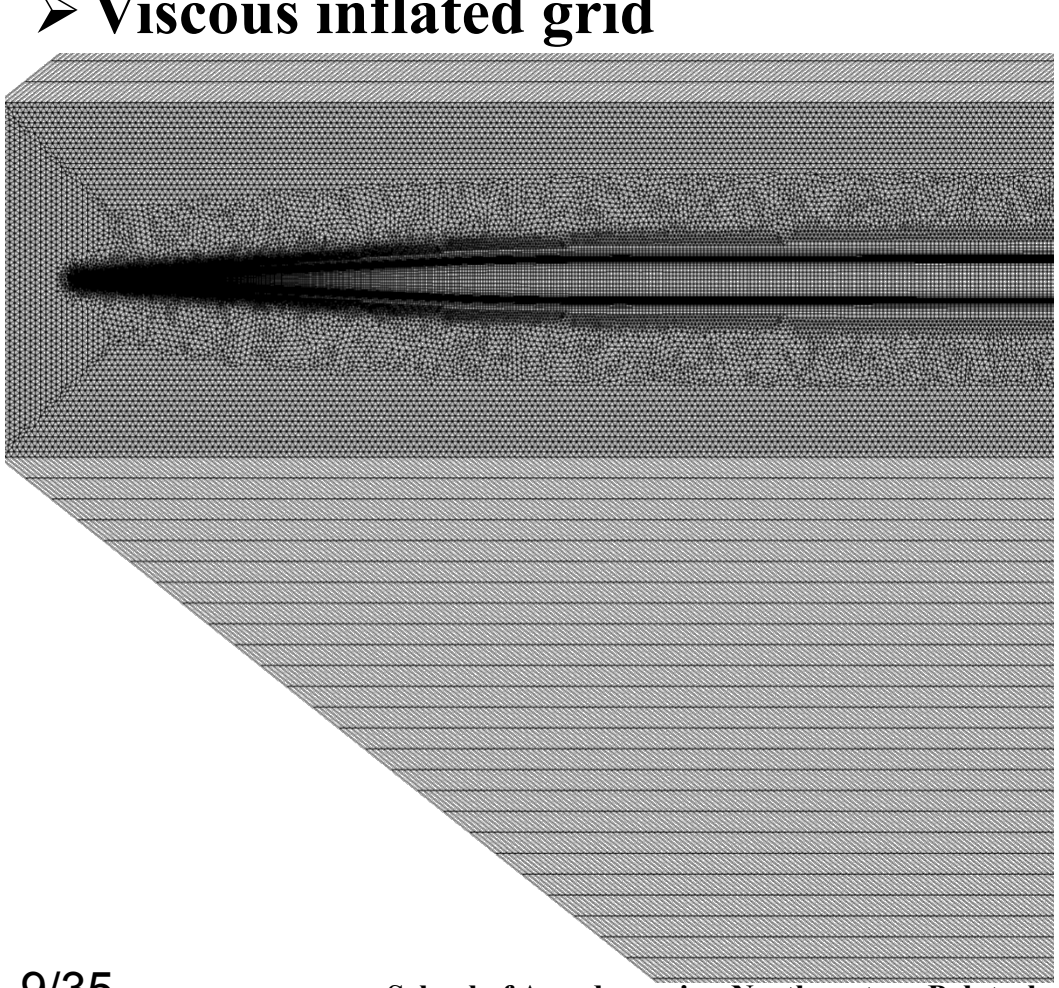
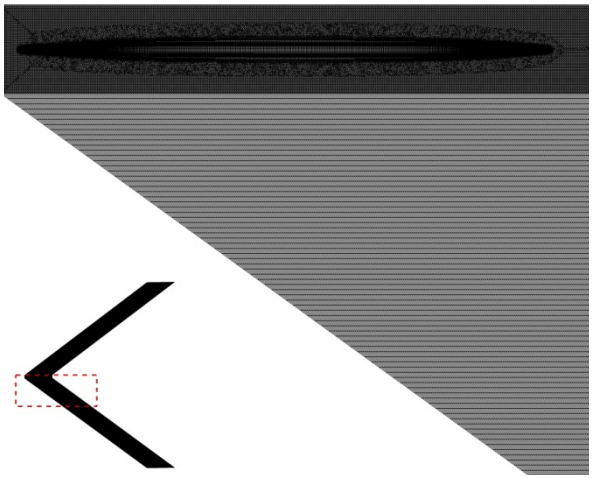
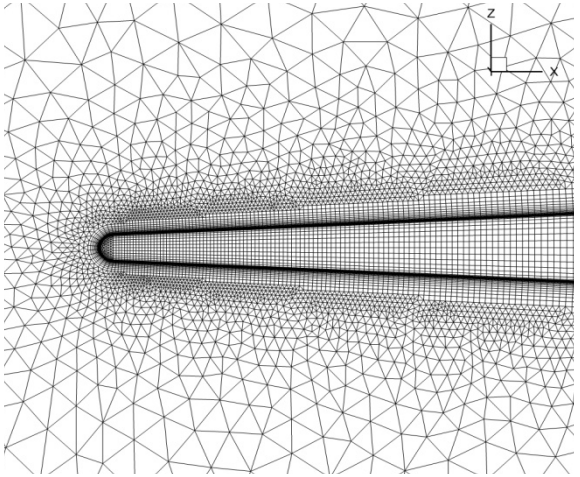
Test Cases and Computational results

- **AXIE Configuration**

➢ **Viscous inflated grid**







Test Cases and Computational results

- **Axie Configuration**

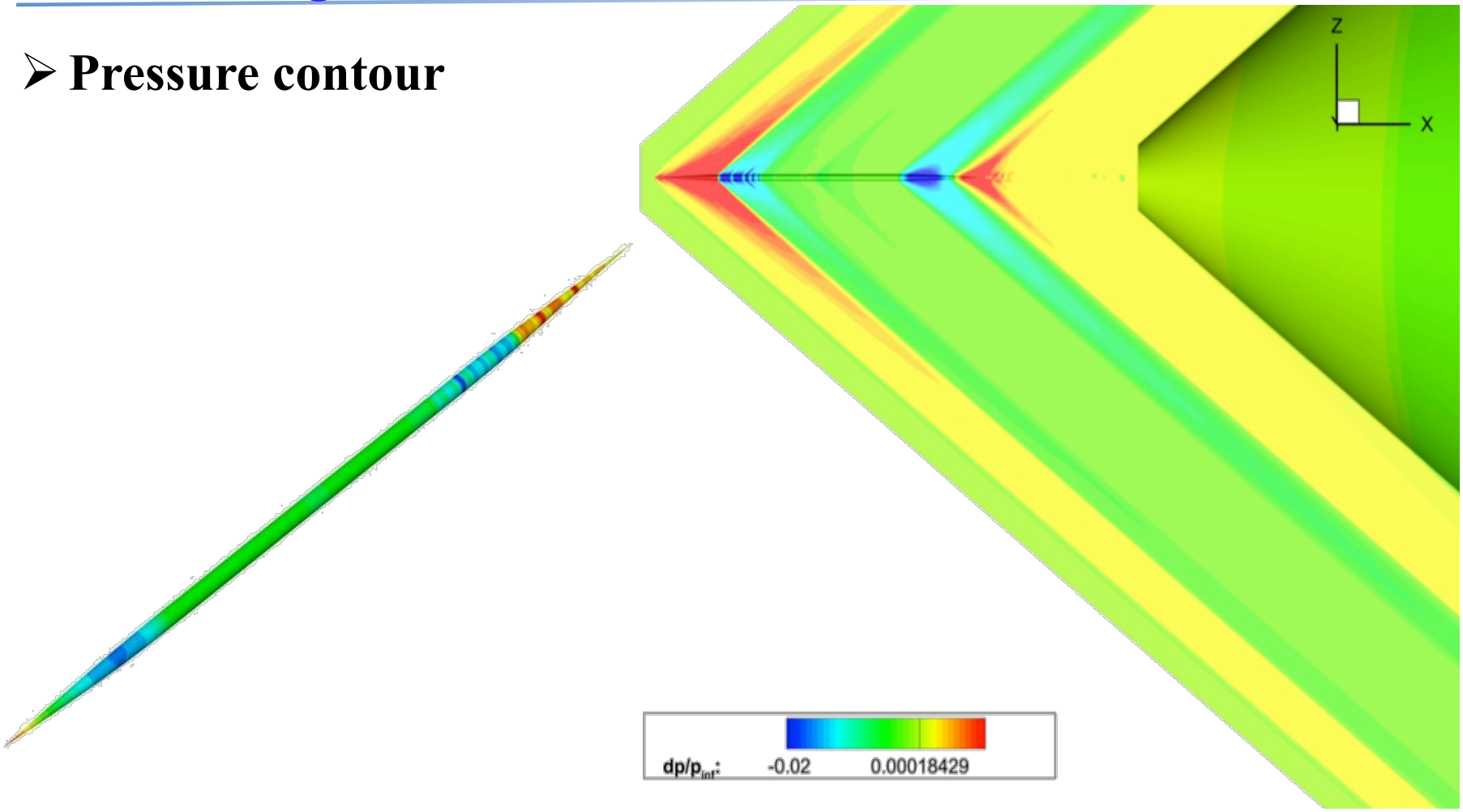
➢ Grid information (viscous)

Grid name	Case name	Nodes	Cells
axie_viscous_base.zip	axie-near-Wang-Case_1	4,186,065	6,281,796
axie_viscous_refined1.zip	axie-near-Wang-Case_2	8,152,956	11,668,864
axie_viscous_refined2.zip	axie-near-Wang-Case_3	20,228,695	24,181,761

Test Cases and Computational results

- **Axie Configuration**

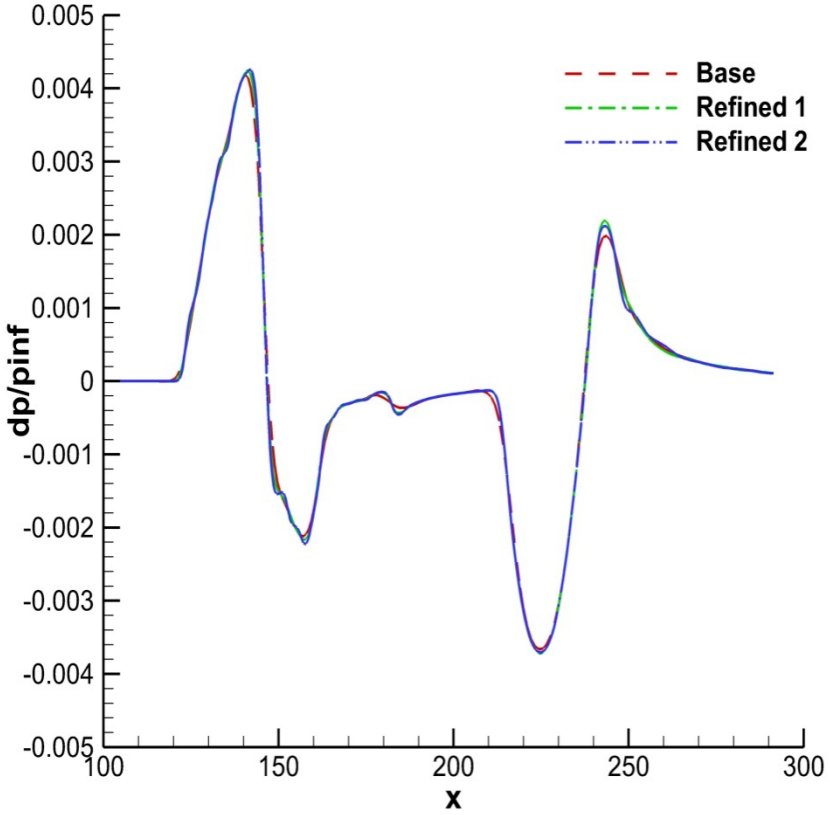
➢ **Pressure contour**



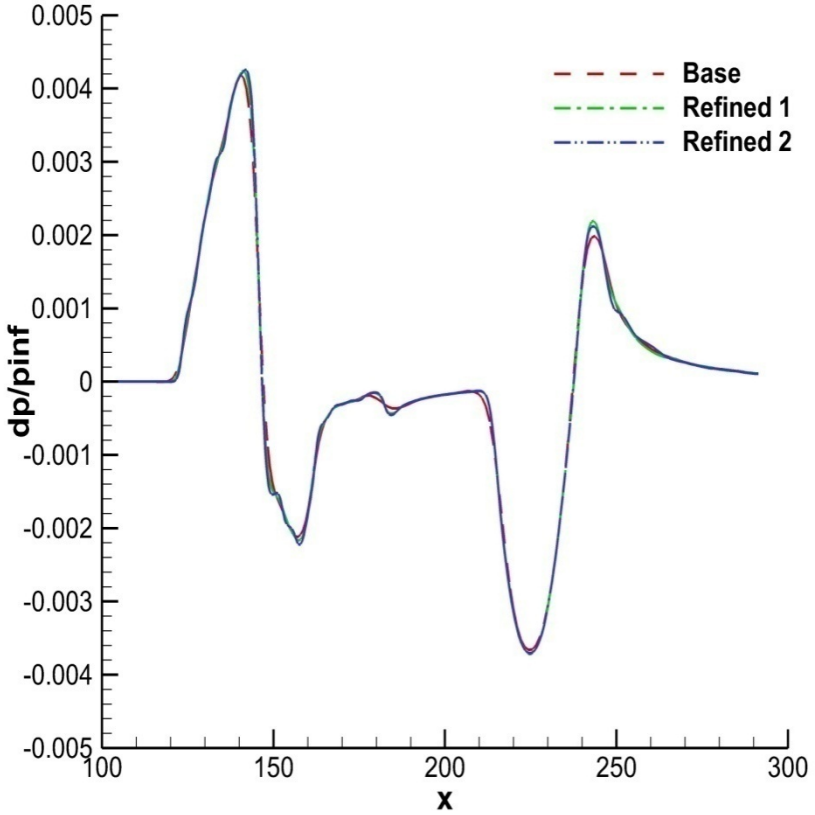
Test Cases and Computational results

- **Axie Configuration**

➢ Extracted near-field signature (viscous)



(a) h/L=1.0



(b) h/L=3.0

Test Cases and Computational results

- **Axie Configuration**

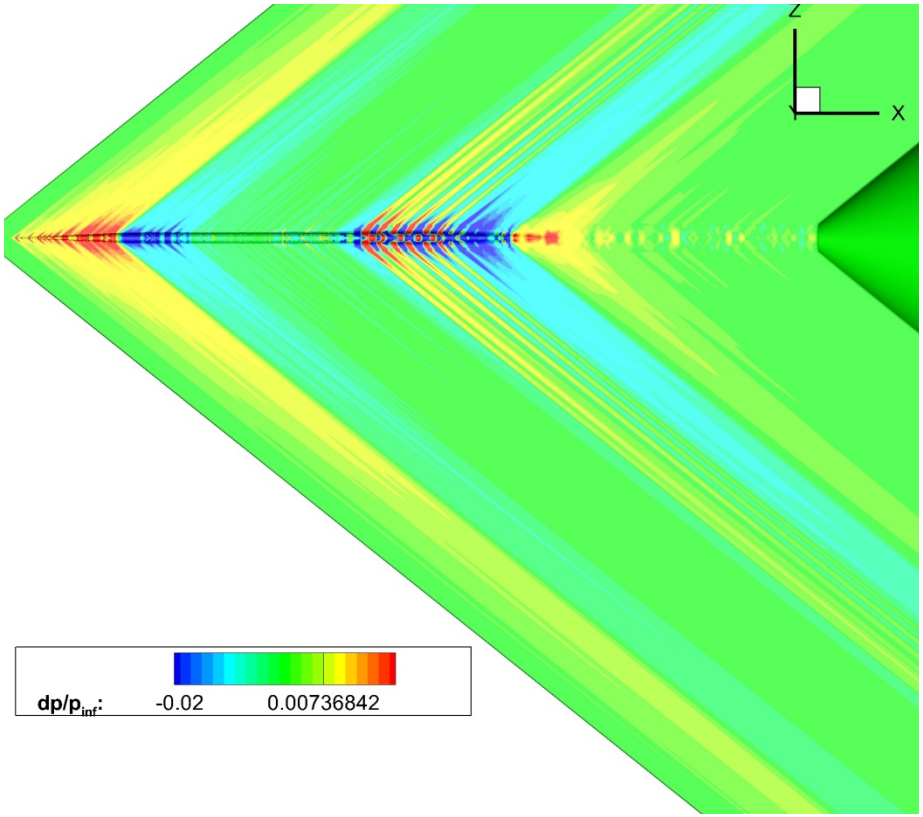
➢ Grid information (inviscid)

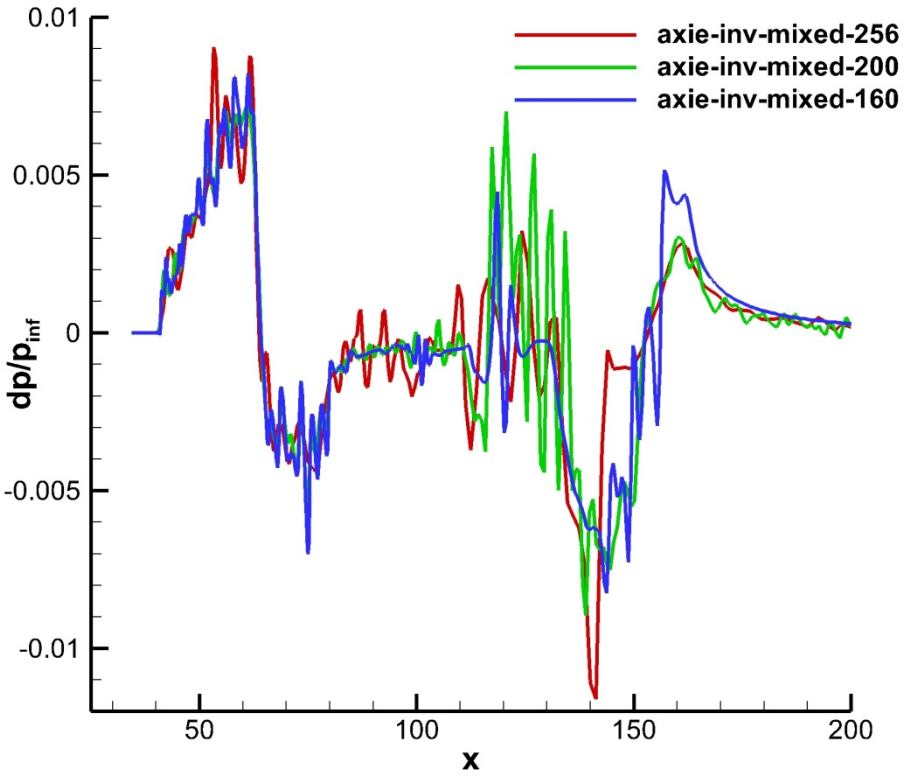
	Grid name	Case name	Nodes	Cells
workshop provided	axie-inv-mixed-256.cgns	axie-near-Wang-Case_4	646,467	1,381,894
	axie-inv-mixed-200.cgns	axie-near-Wang-Case_5	1,601,681	3,702,826
	axie-inv-mixed-160.cgns	axie-near-Wang-Case_6	5,077,104	12,310,640
Self-generated	axie-inv-mixed-test	-	2,888,525	5,492,686

Test Cases and Computational results

- **Axie Configuration**

➢ **Extracted near-field signature** (on workshop provided grid)

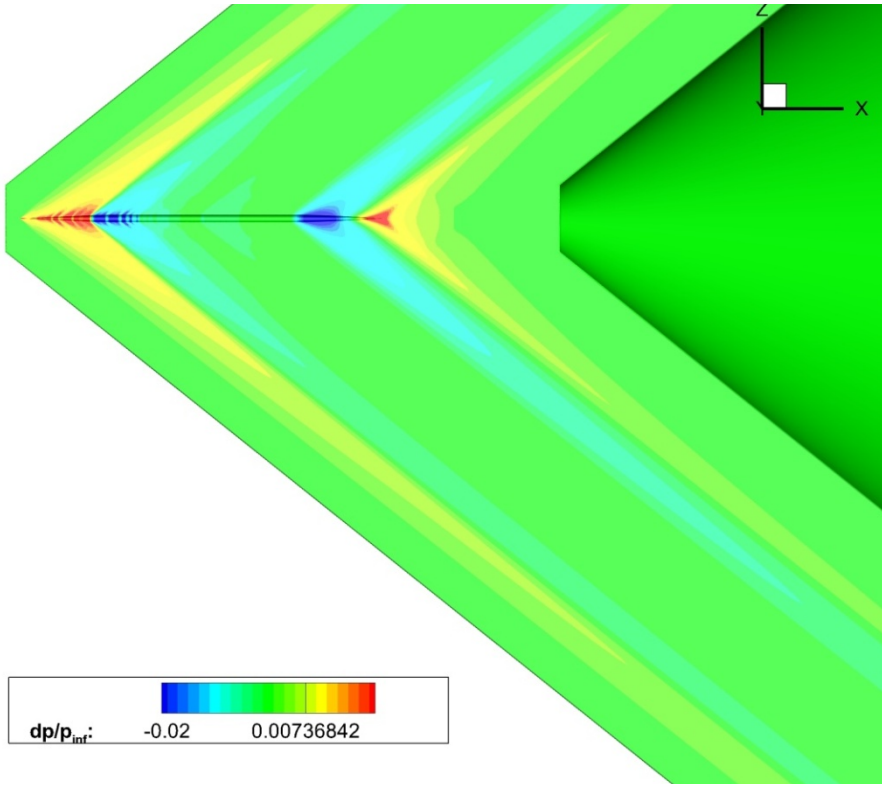


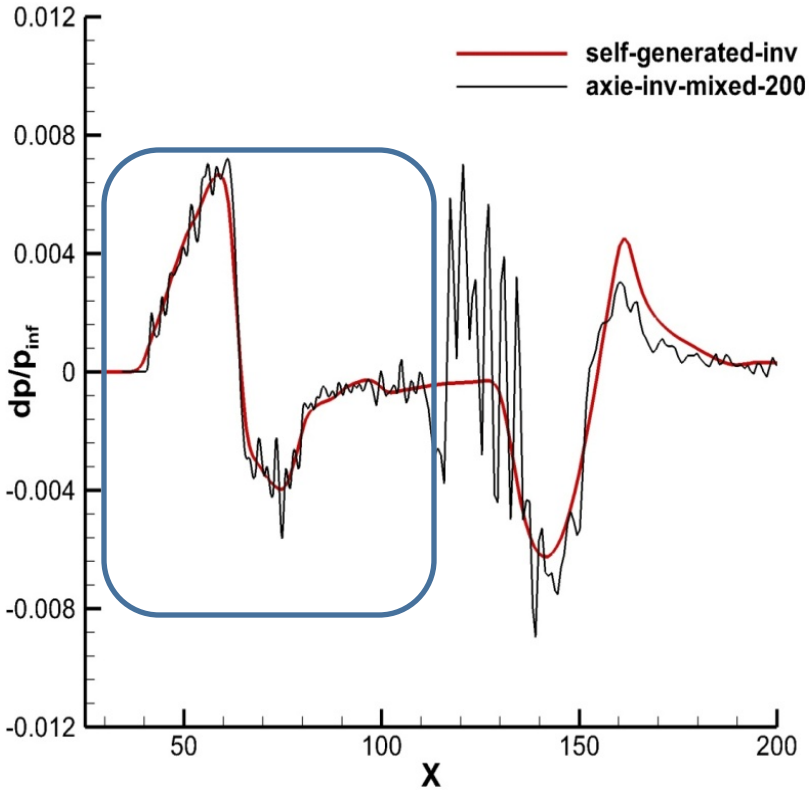


Test Cases and Computational results

- **Axie Configuration**

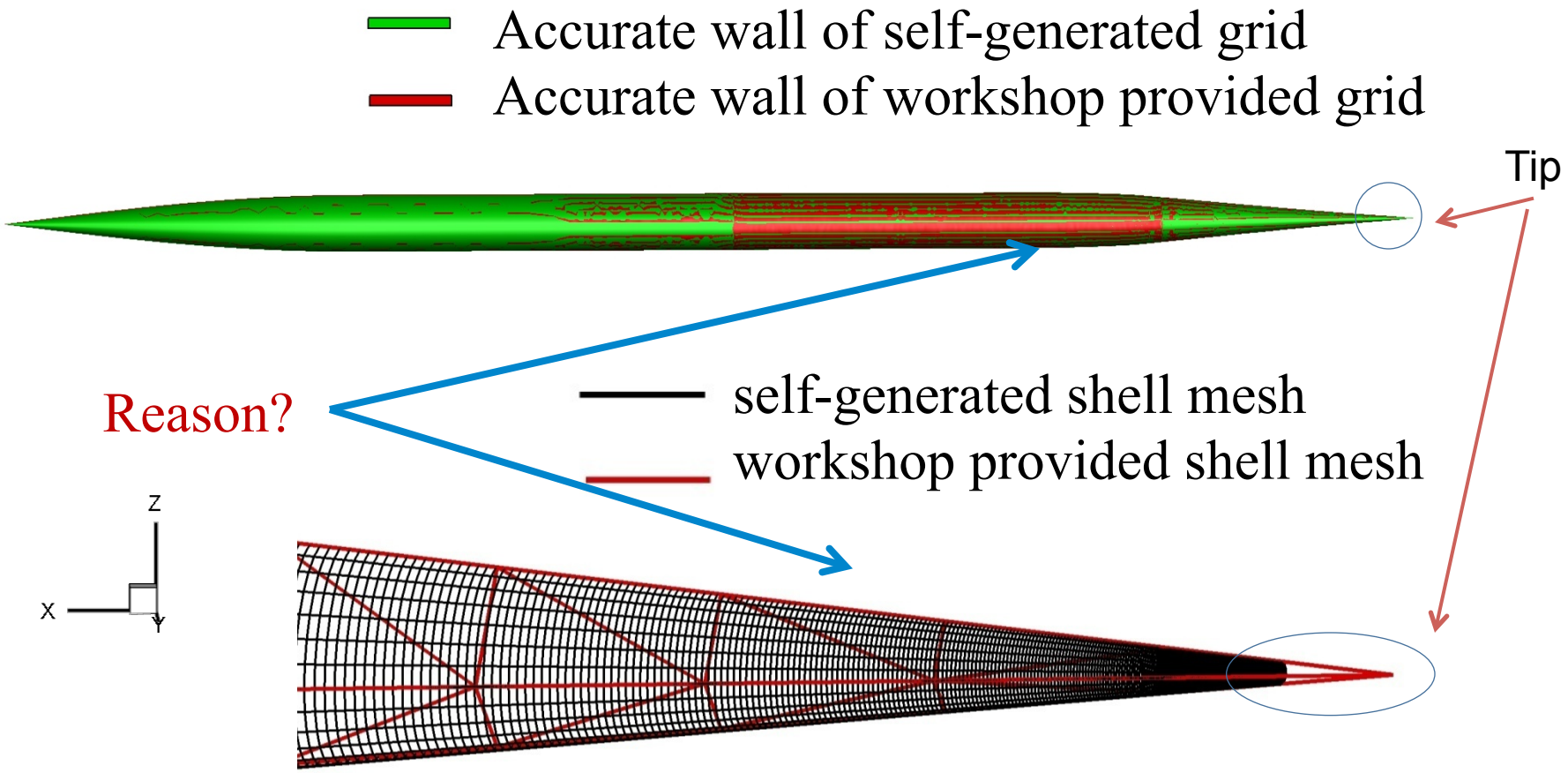
➢ **Extracted near-field signature** (on self-generated grid)





Test Cases and Computational results

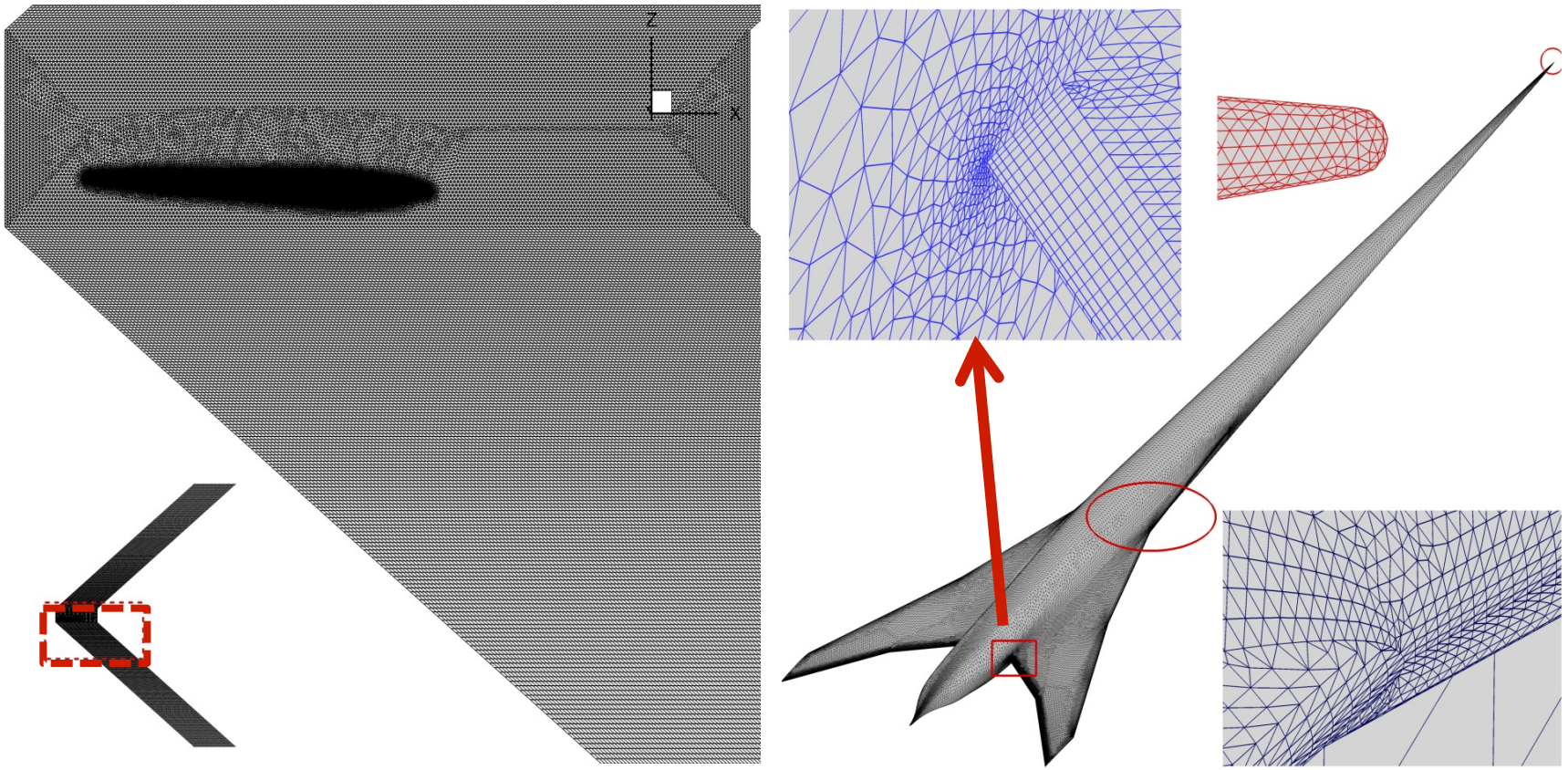
- **Axie geometry and mesh comparasion**



Test Cases and Computational results

- **JWB Configuration**

➢ **Viscous grid**



Test Cases and Computational results

- **JWB Configuration**

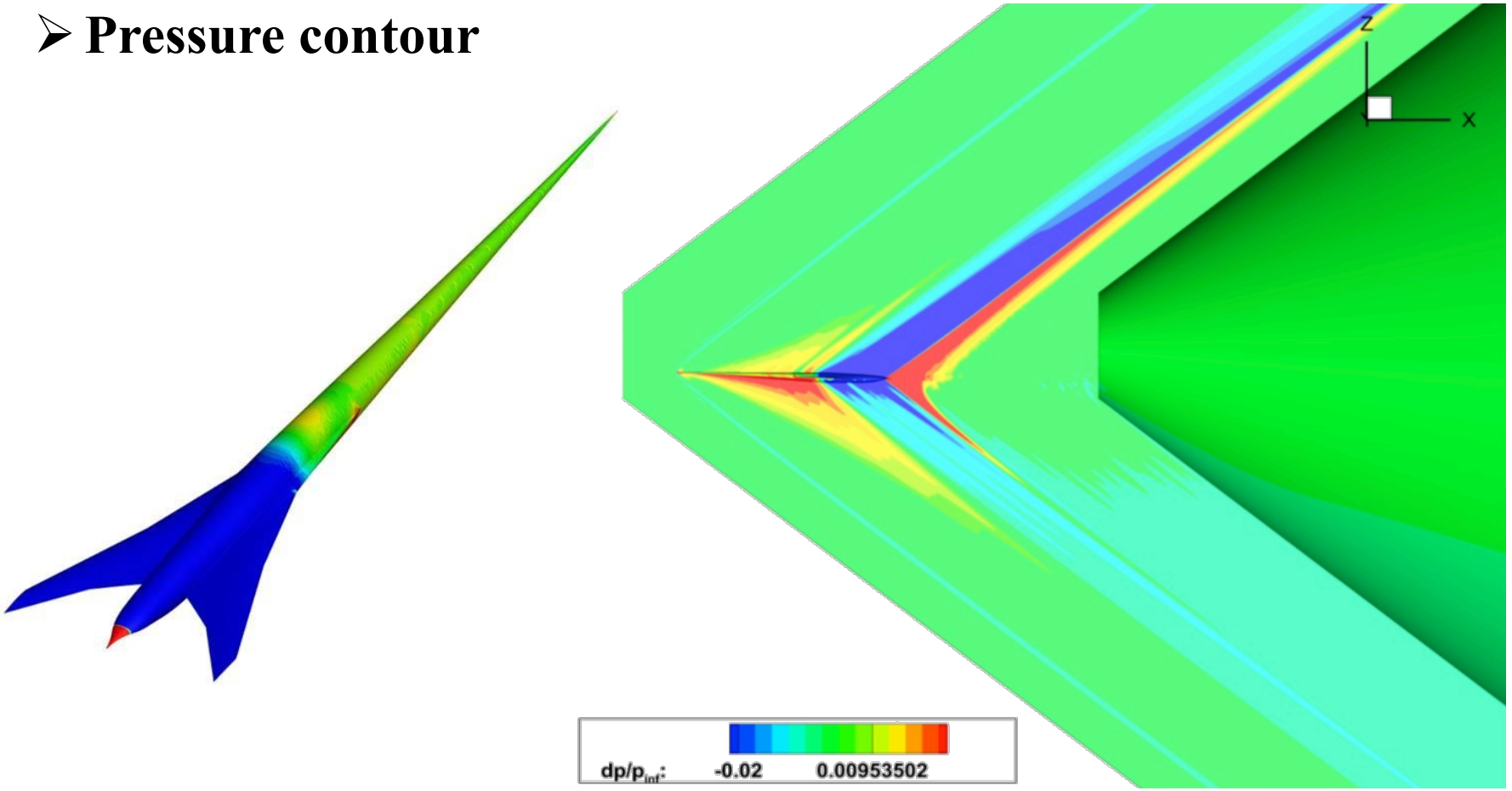
➢ Grid information

Grid name	Case name	Nodes	Cells
jwb_viscous_hybrid_**base**.zip	jwb-near-Wang-Case_1	6,608,885	12,425,695
jwb_viscous_hybrid_**refined1**.zip	jwb-near-Wang-Case_2	12,839,826	21,529,795
jwb_viscous_hybrid_**refined2**.zip	jwb-near-Wang-Case_3	26,417,451	44,437,660

Test Cases and Computational results

- **JWB Configuration**

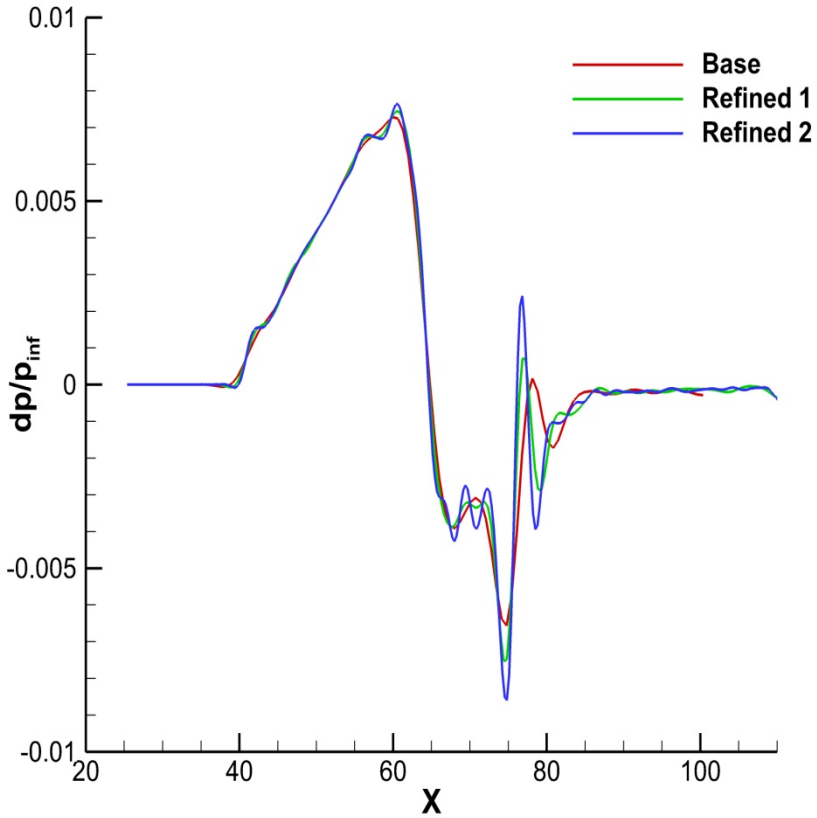
➢ **Pressure contour**



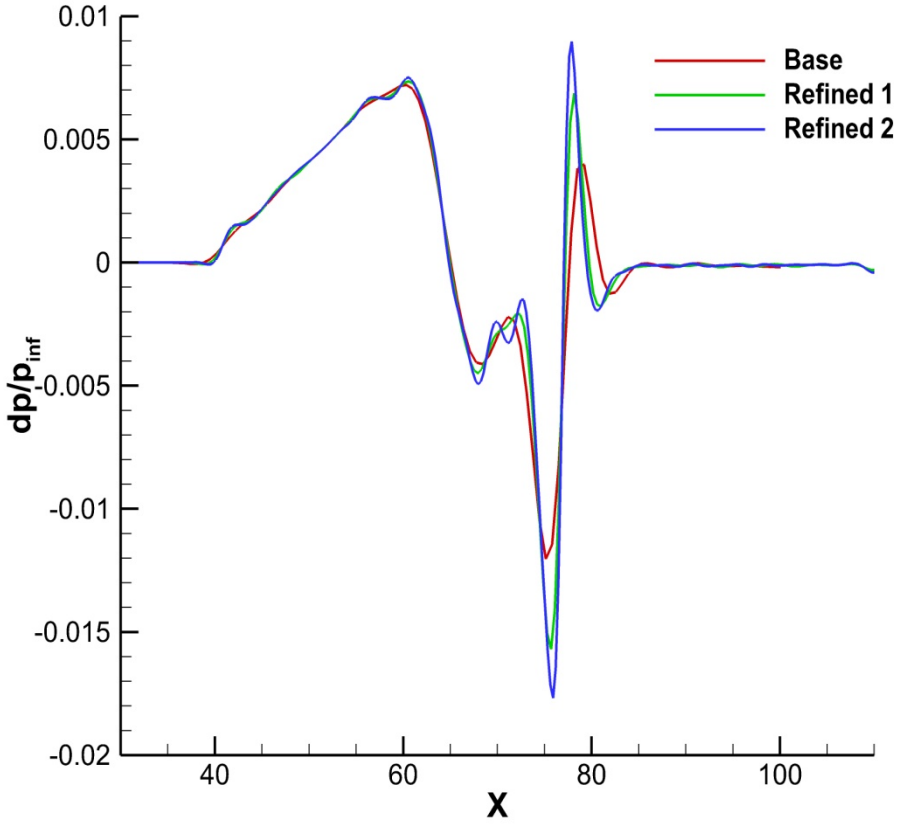
Test Cases and Computational results

- **JWB Configuration**

➢ **Extracted near-field signature** (h/L=0.85)



(a) phi=0

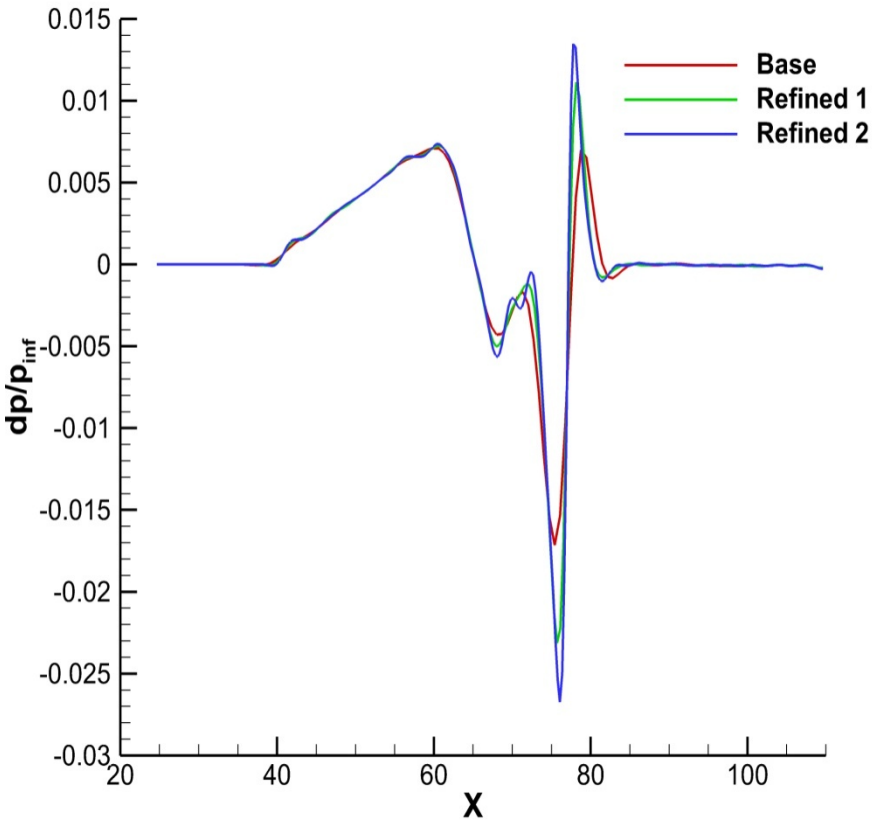


(b) phi=20

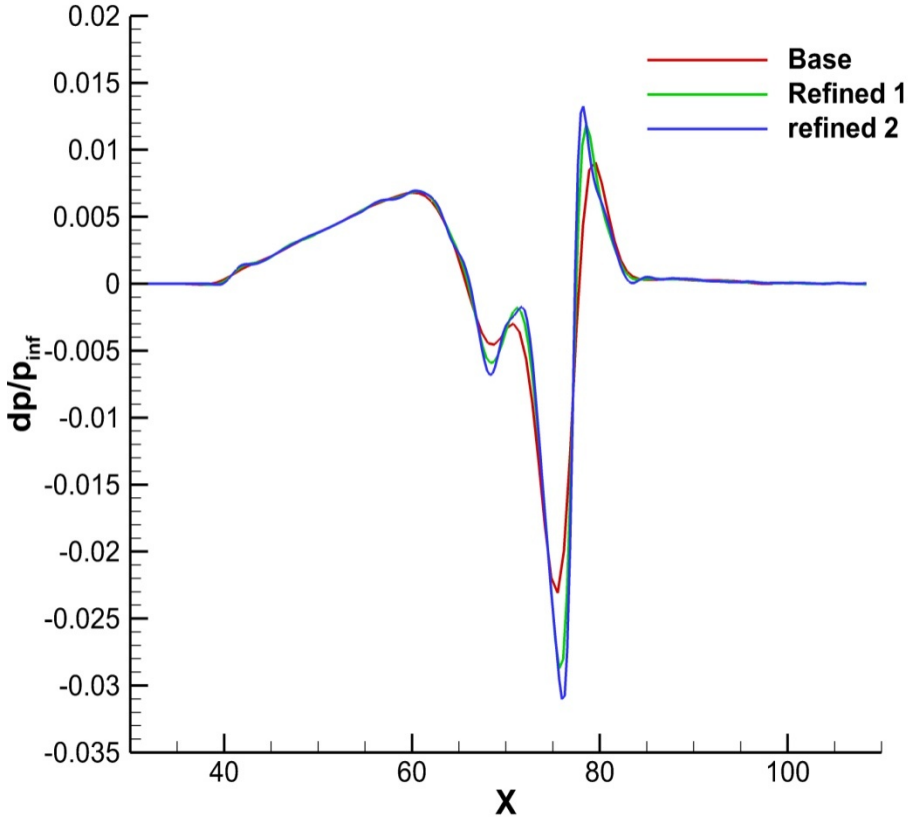
Test Cases and Computational results

- **JWB Configuration**

➢ **Extracted near-field signature** (h/L=0.85)



(c) phi=30

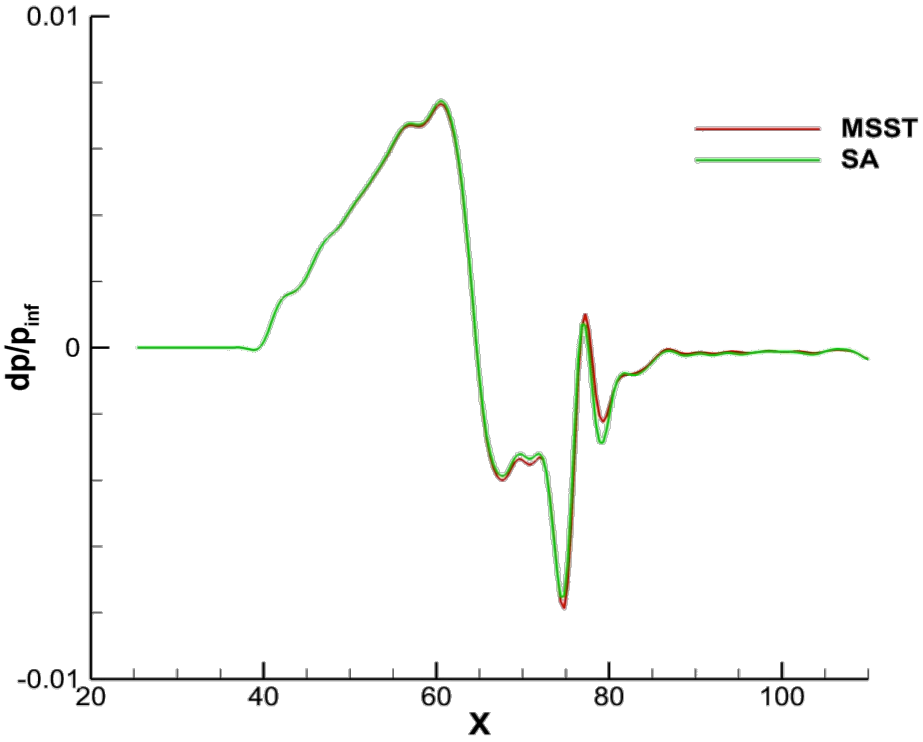


(d) phi=50

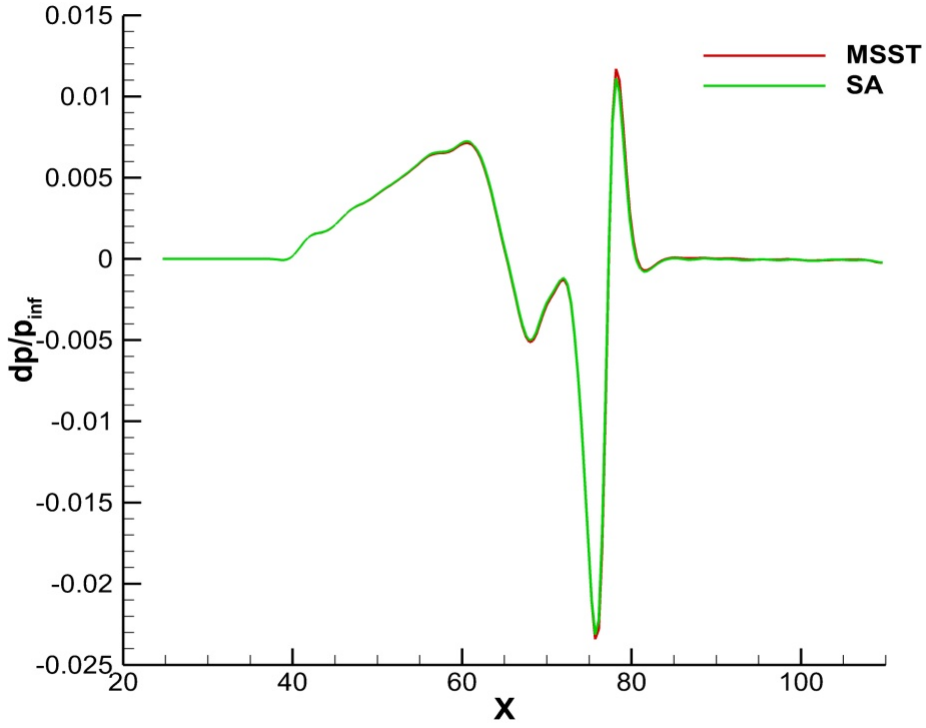
Test Cases and Computational results

- **JWB Configuration**

➢ **Effects of *Turbulence model*** (h/L=0.85, on refined 1 mesh)



(a) phi=0

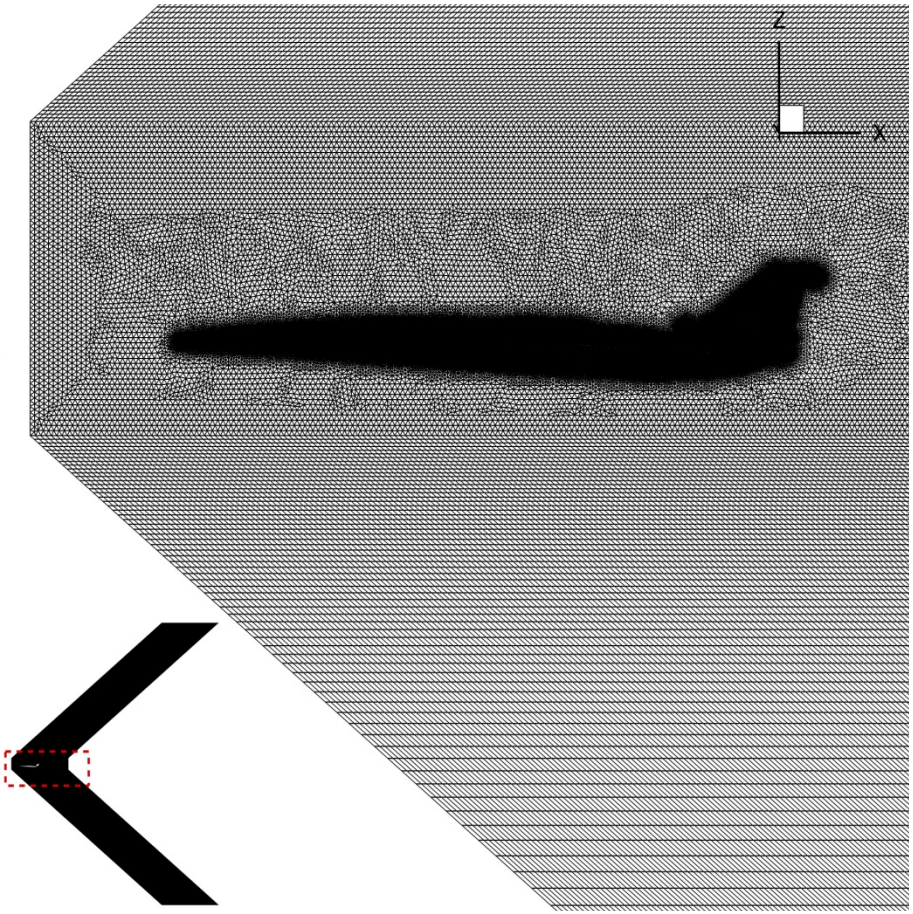


(b) phi=20

Test Cases and Computational results

- **C25d-flowthru Configuration**

➢ **Viscous grid**



Test Cases and Computational results

- **C25d-flowthru Configuration**

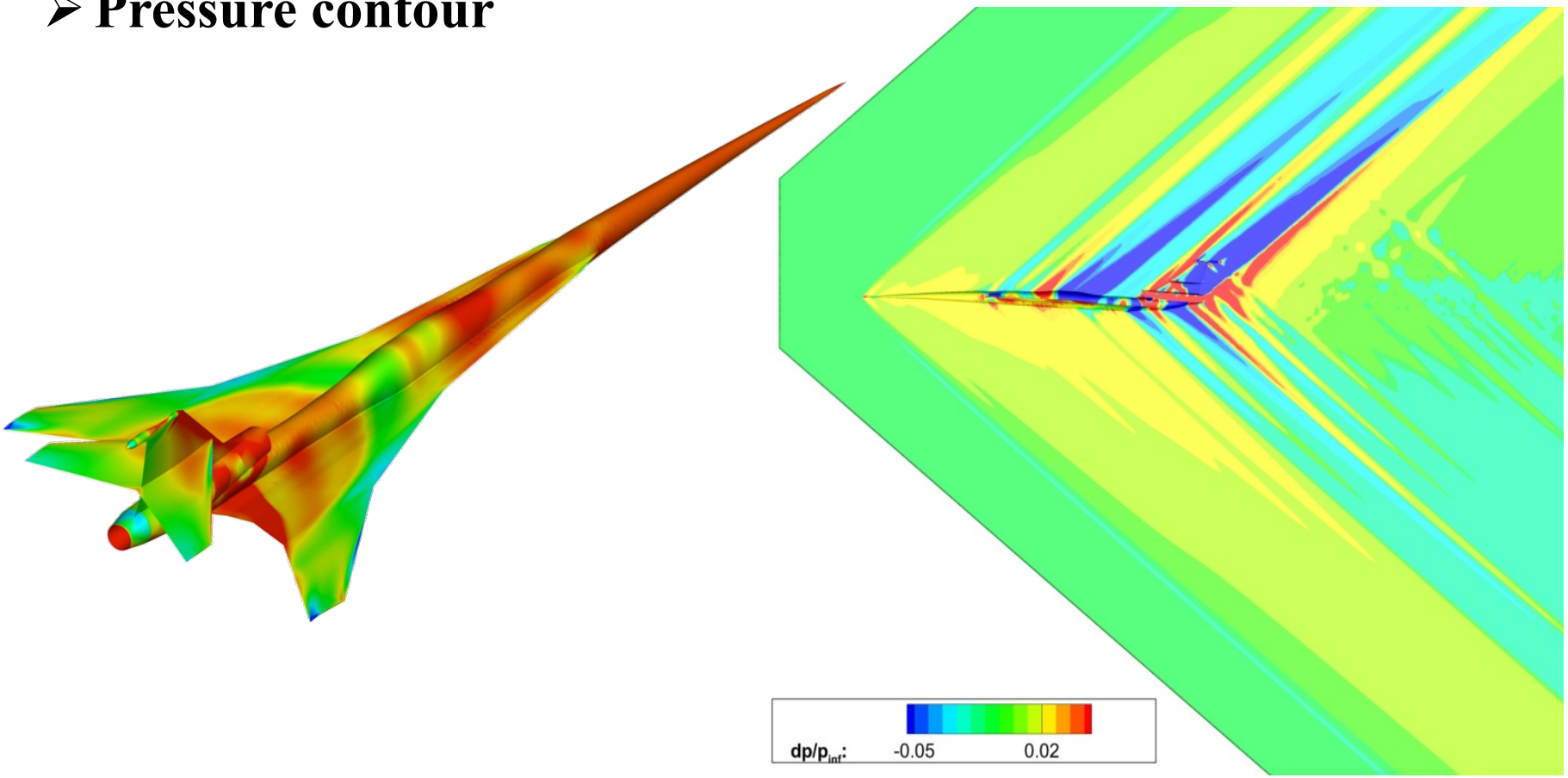
➢ Grid information

Grid name	Case name	Nodes	Cells
c25d_viscous_base.tar.gz	c25d-flowthru-near-Wang-Case_1	11,340,201	22,348,632
c25d_viscous_refined1.tar.gz	c25d-flowthru-near-Wang-Case_2	15,767,383	30,375,923
c25d_viscous_refined2.tar.gz	c25d-flowthru-near-Wang-Case_3	28,530,775	52,022,490

Test Cases and Computational results

- **C25d-flowthru Configuration**

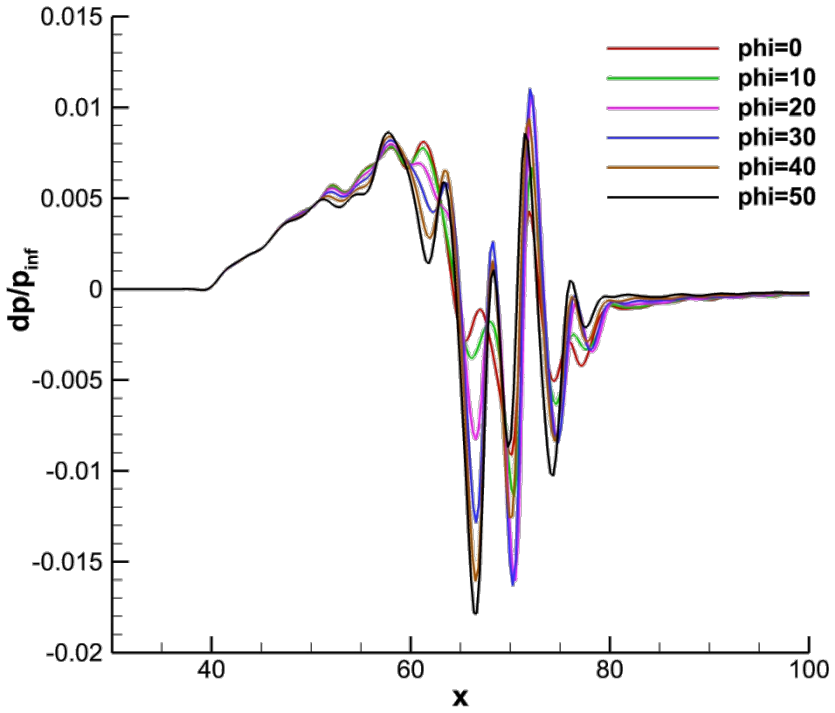
➢ **Pressure contour**



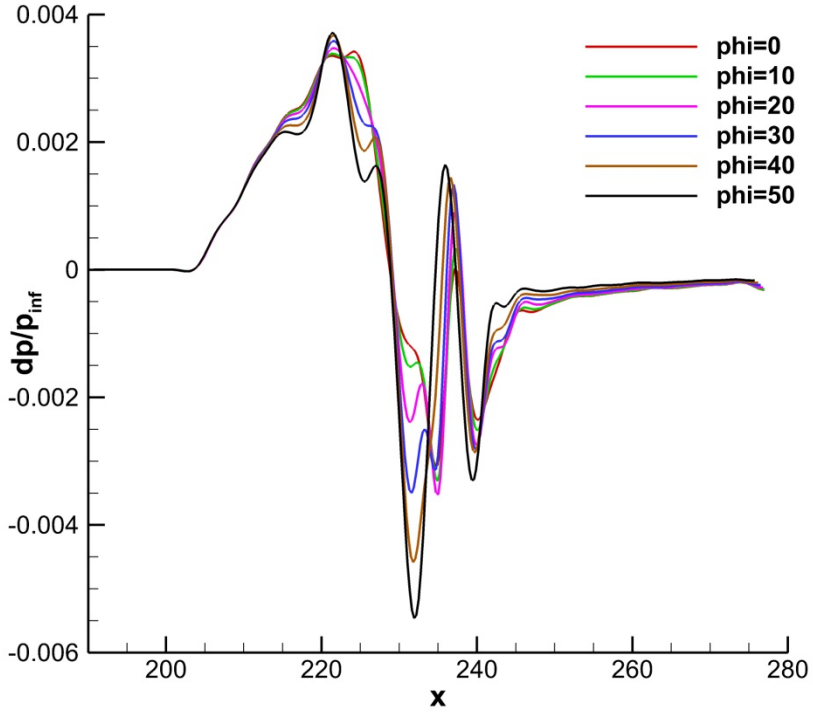
Test Cases and Computational results

- **C25d-flowthru Configuration**

➢ **Extracted near-field signature** (on refined 1 mesh)



(a)h/L=1

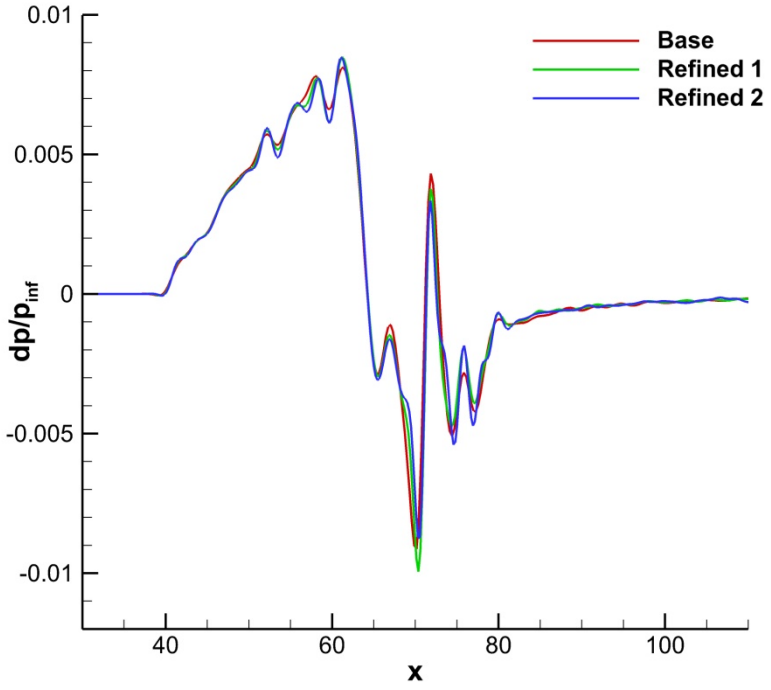


(b) h/L=5

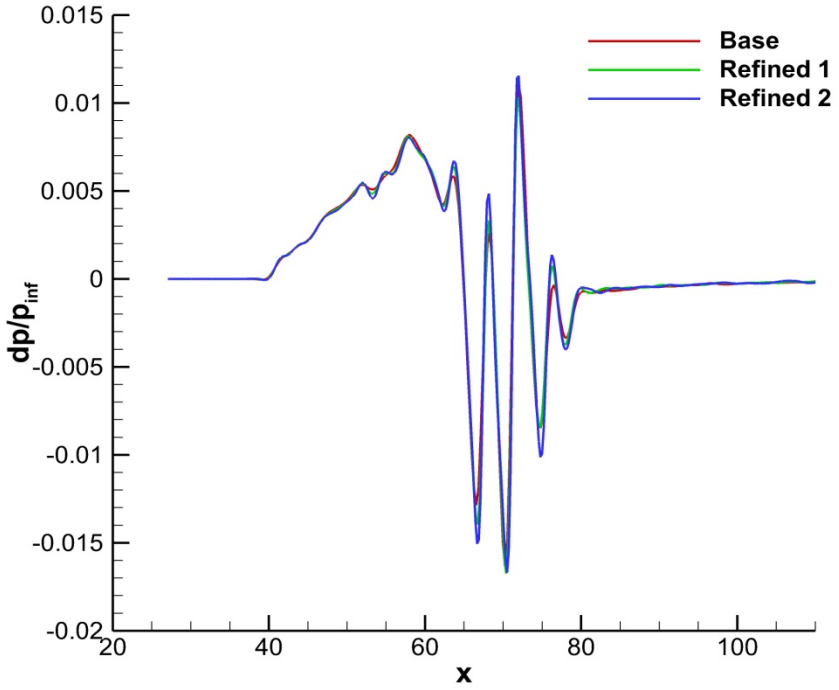
Test Cases and Computational results

- **C25d-flowthru Configuration**

➢ **Extracted near-field signature** (h/L=1)



(a) phi=0

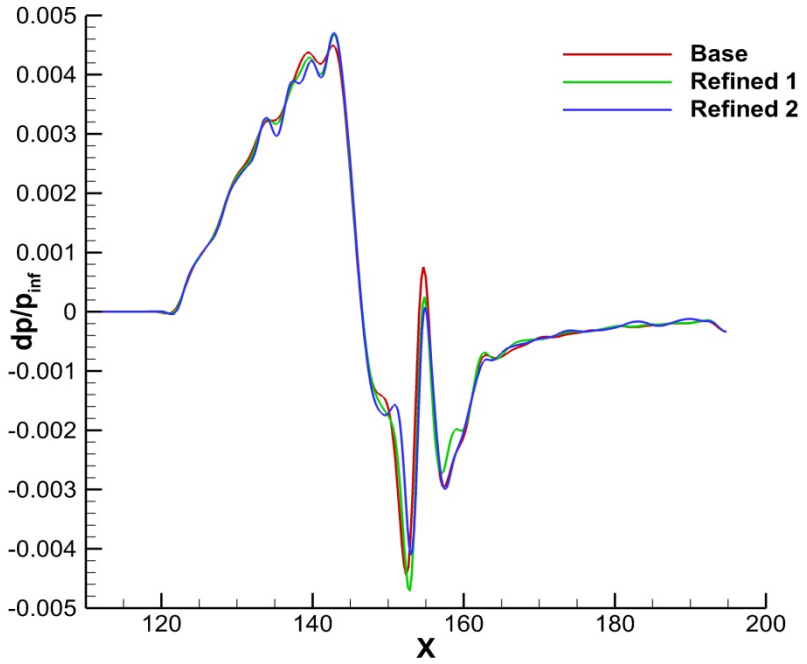


(b) phi=30

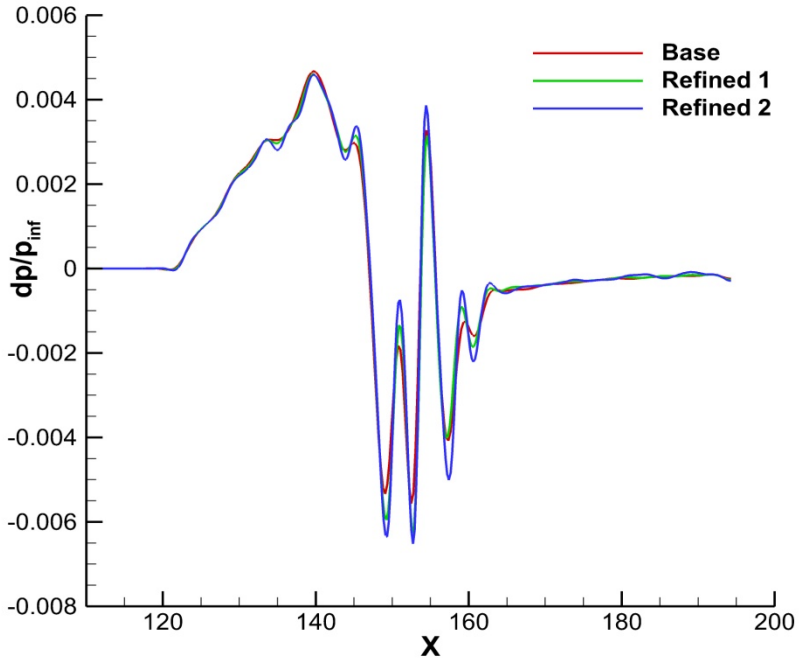
Test Cases and Computational results

- **C25d-flowthru Configuration**

➢ **Extracted near-field signature** (h/L=3)



(a) phi=0

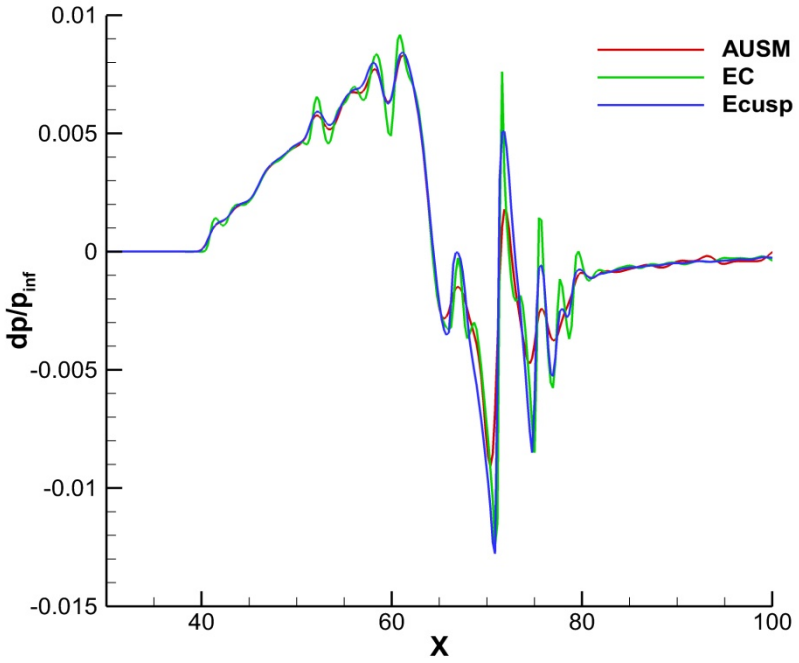


(b) phi=30

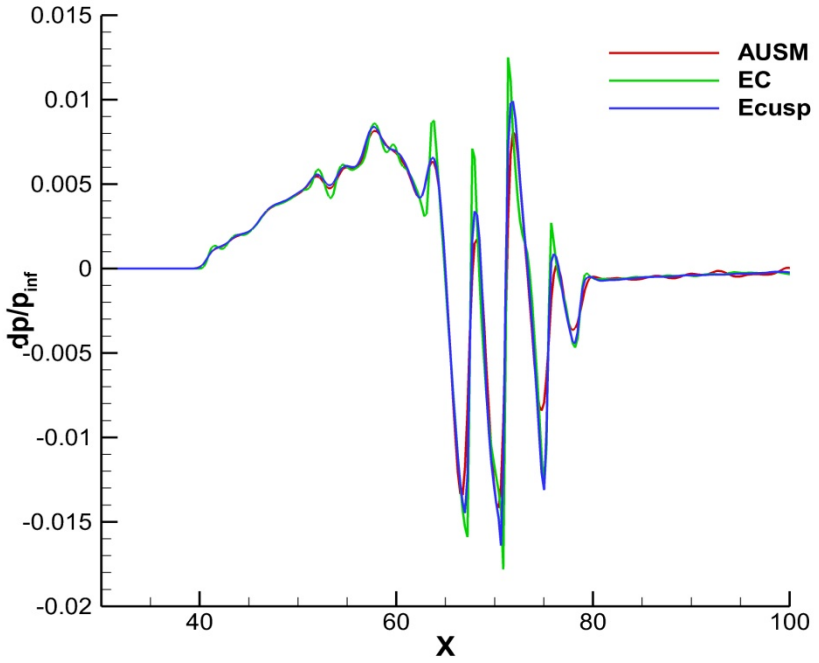
Test Cases and Computational results

- **C25d-flowthru Configuration**

➢ **Effect of *Shock capture scheme*** (h/L=1, on refined 1 mesh)



(a) phi=0



(b) phi=30

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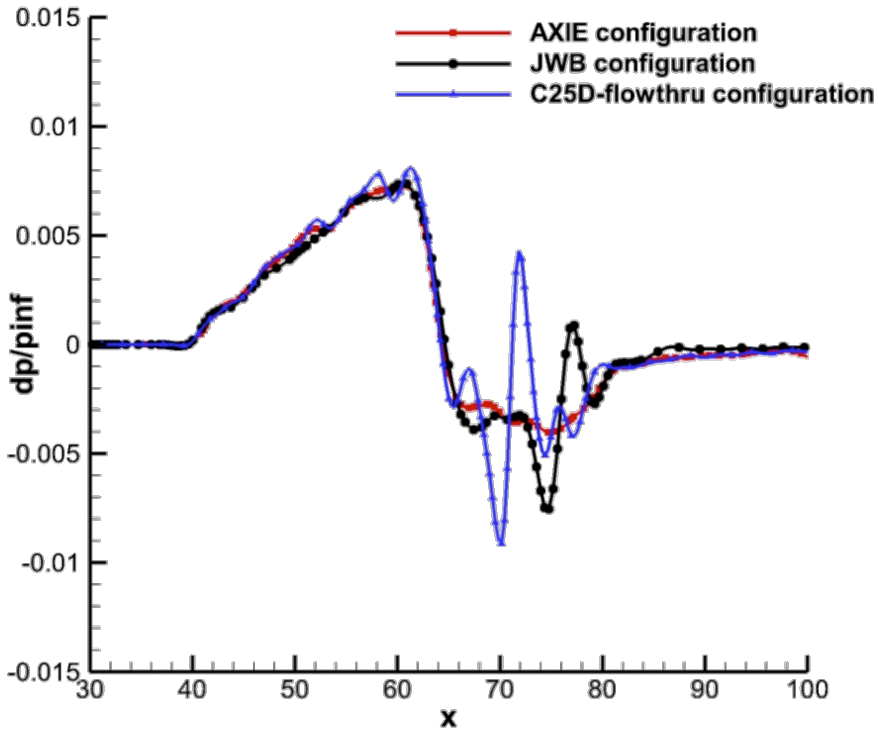
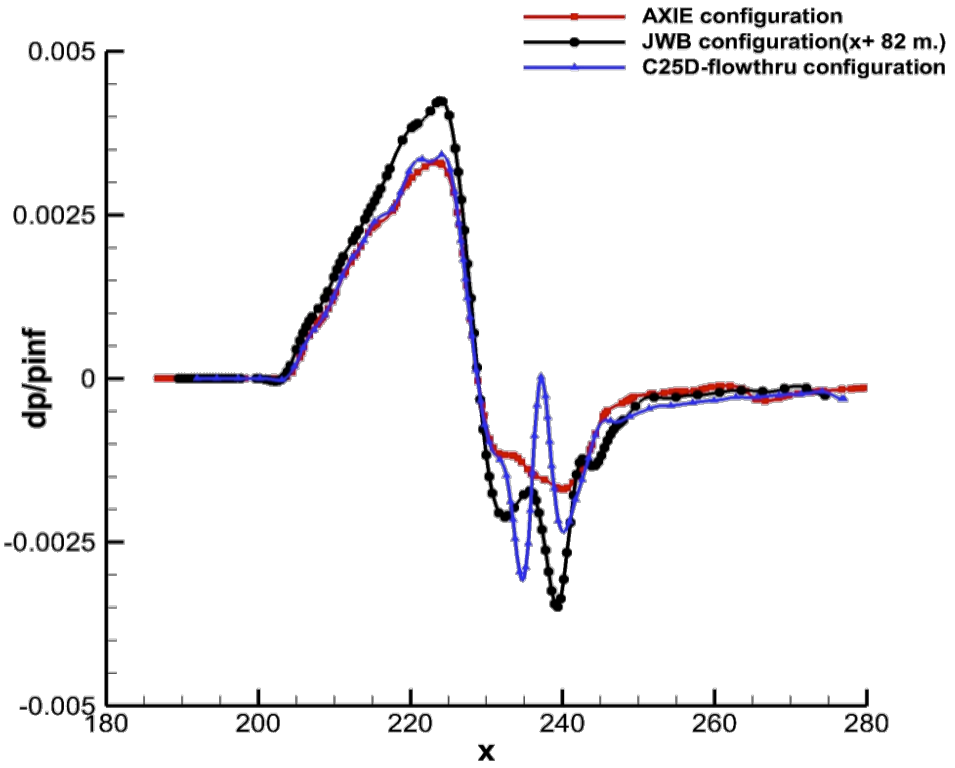
Test Cases and Computational results

- **All Configuration comparasion**

➢ **On-track** (on grid with cell number approximately 20M)



(a) h/L=1, phi=0

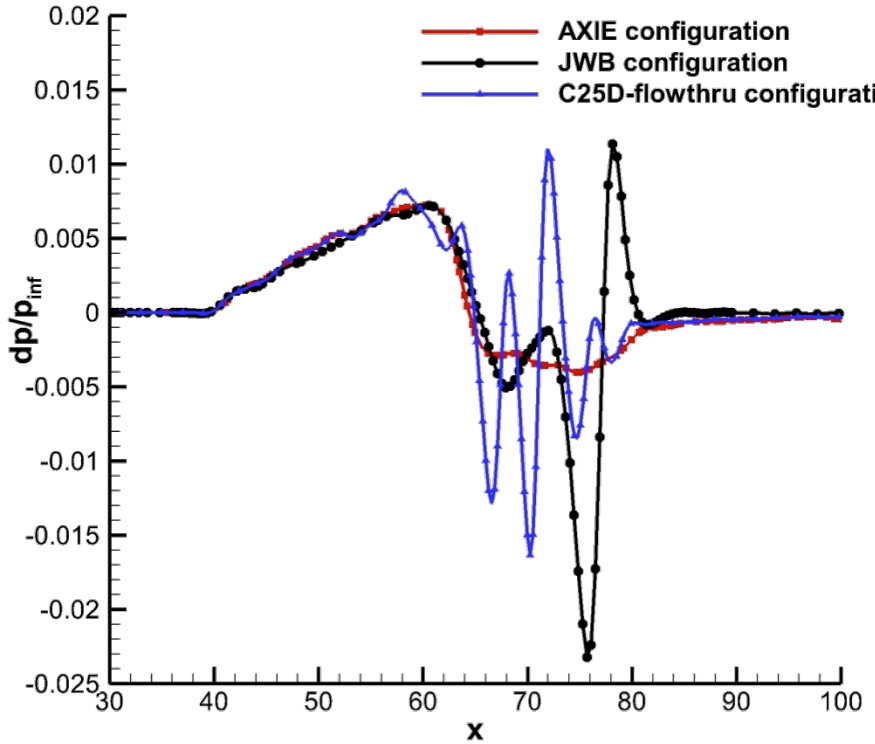


(b) h/L=5, phi=0

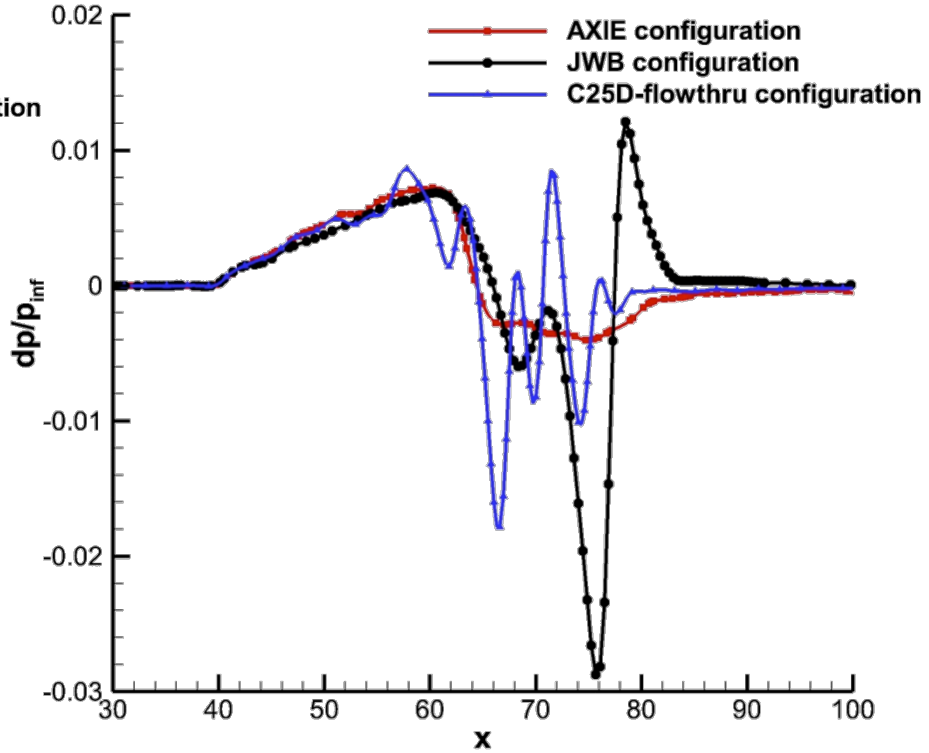
Test Cases and Computational results

- **All Configuration comparasion**

➢ Off-track



(a) h/L=1, phi=30



(b) h/L=1, phi=50

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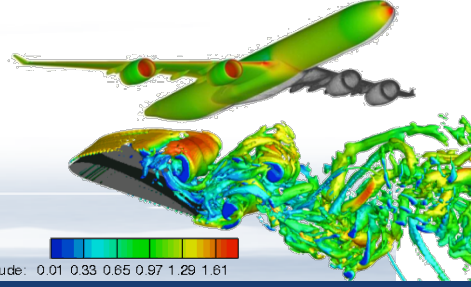
Summary

- All required test cases have been computed
- Mesh affects strongly in near field sonic boom prediction
- Advancing-Front method and inflated grid strategy well suited
- Geometry and mesh distribution will cause oscillations
- Turbulence models and shock capture schemes have moderate effects
- Equivalent area method proved simple and effective

Acknowledgement

- Thanks to Mike Park for pointing out our problems and responding our questions.
- Thanks to Prof. Gecheng ZHA for his advice
- Thanks to Zhijin LEI for kindly providing beneficial advices and modifying this presentation material.



Thanks for Your Attention !

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7th Jan. 2017