LAVA Results for SBPW3

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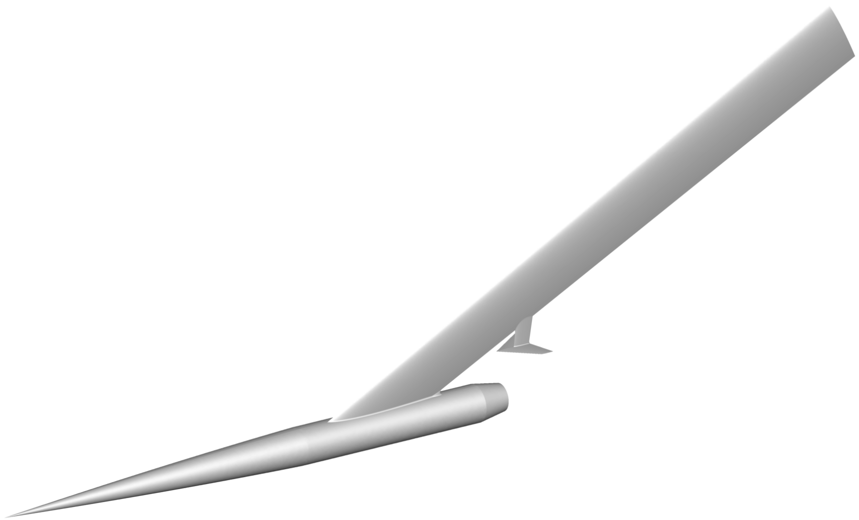
Outline

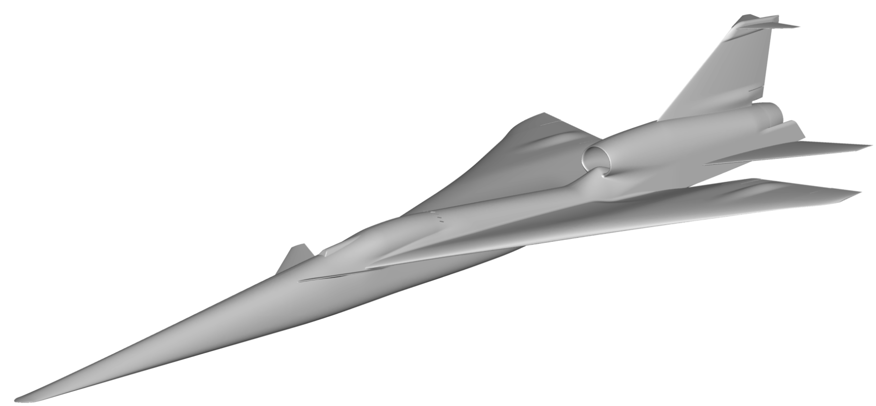
- Summary of Cases Analyzed
- Computational Methodology
  - LAVA Framework
  - Computational Meshes
- Computing Resources
- Typical Flow Solver Convergence
- Solution Visualizations
- Challenge
  - Sensitivity to Solution Initialization in C608 Simulations
- Summary

Summary of Cases

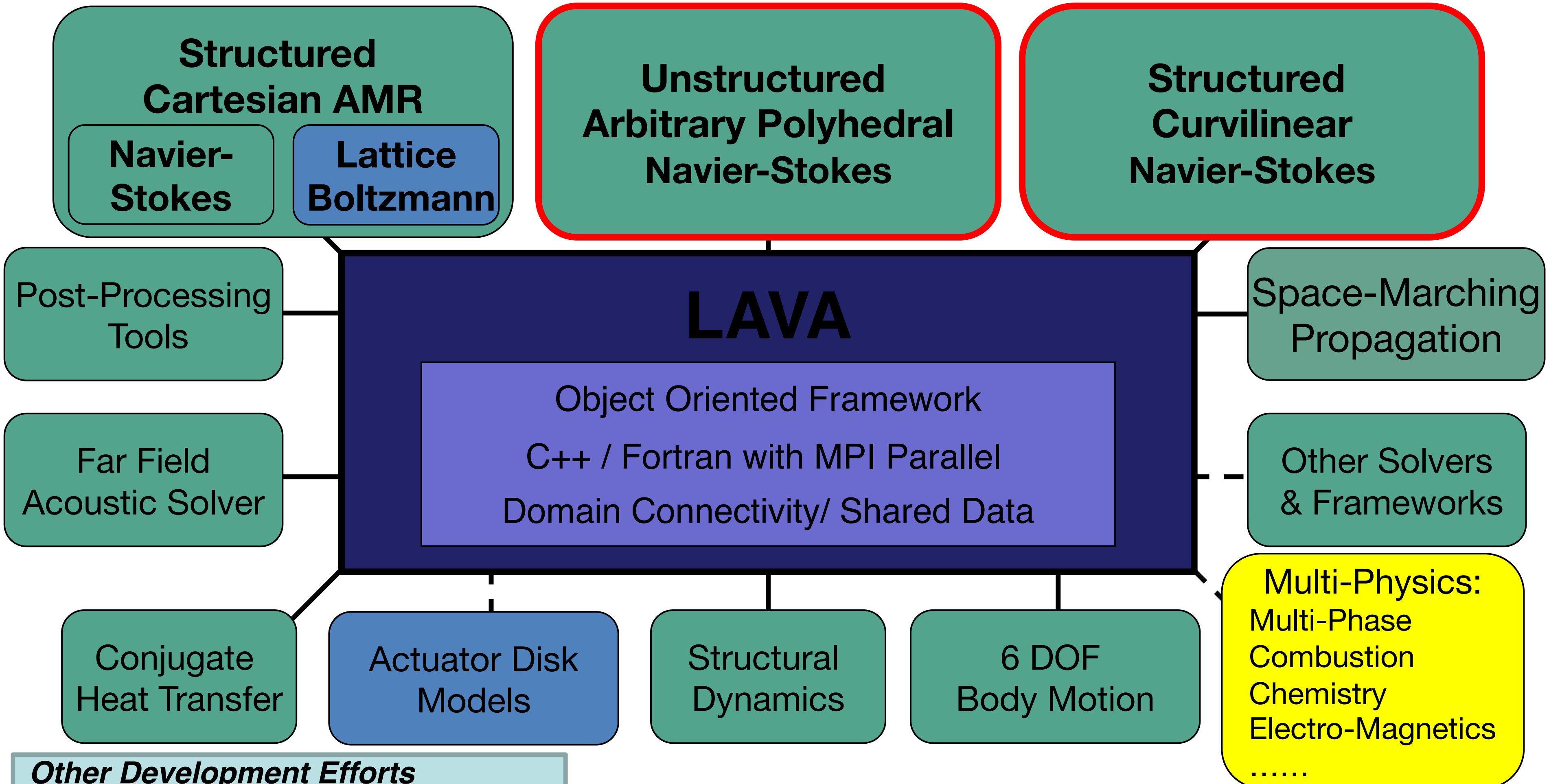
- Biconvex
  - Grid Refinement Study
  - Comparison between different numerical schemes



- C608 LBFD
  - Grid Refinement Study
  - Comparison between two flight conditions

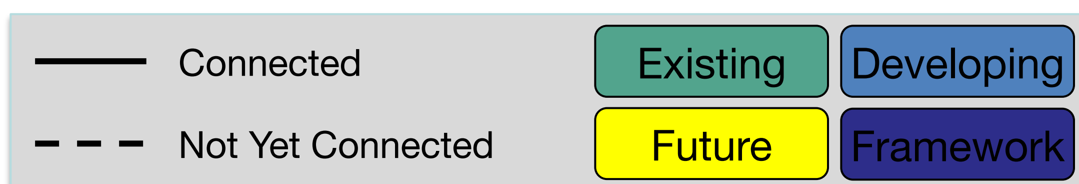


Launch, Ascent, and Vehicle Aerodynamics (LAVA) Framework



Other Development Efforts

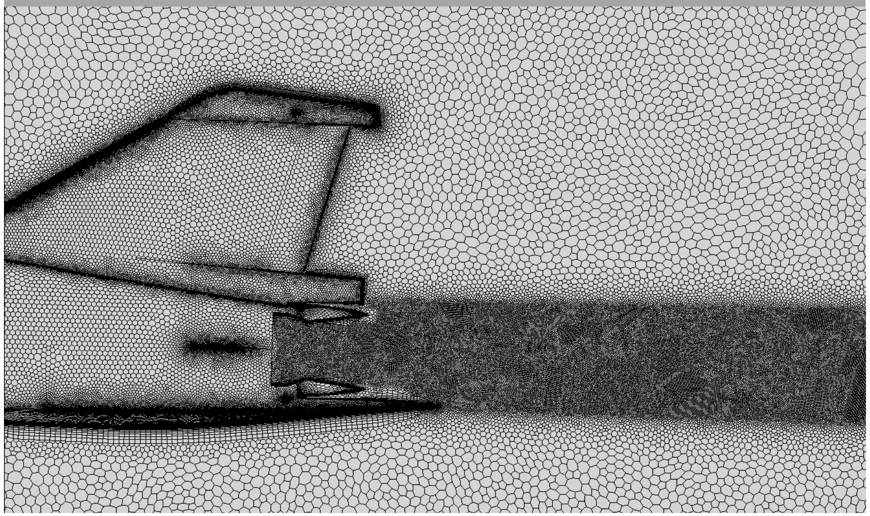
- Higher order and low dissipation
- Curvilinear grid generation
- Wall modeling
- LES/DES/ILES Turbulence
- HEC (optimizations, accelerators, etc)

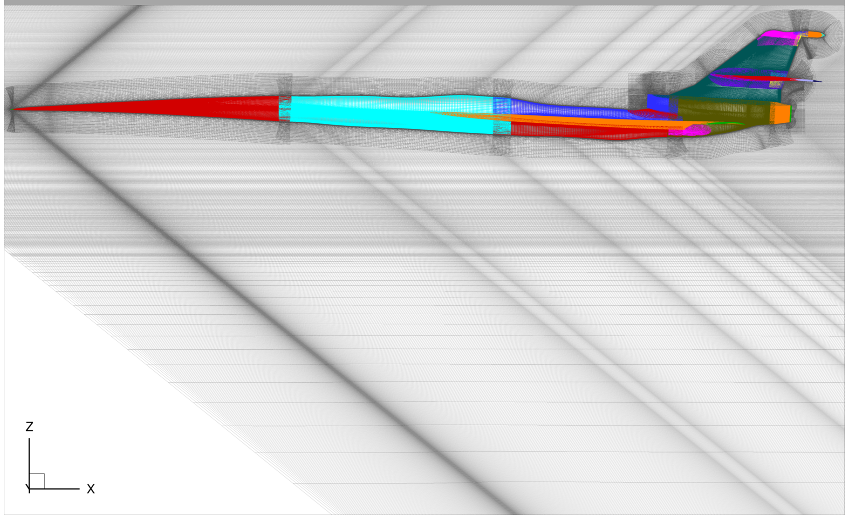


Kiris at al. AIAA-2014-0070 & AST-2016

LAVA Solver Details

Unstructured Arbitrary Polyhedral	*Structured Curvilinear*





Unstructured Arbitrary Polyhedral

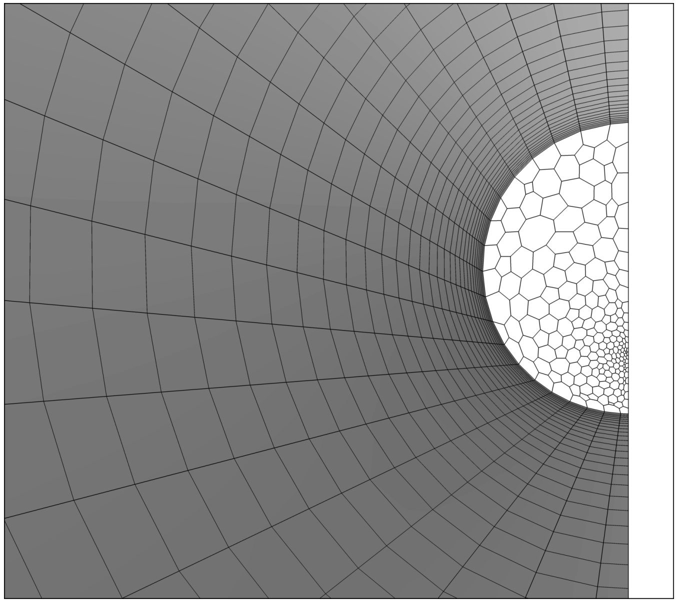
- Cell Centered
- Steady-state RANS
- Spallart-Allmaras Turbulence Model
- 2nd Order AUSMPW+ flux function
- Minmod limiter

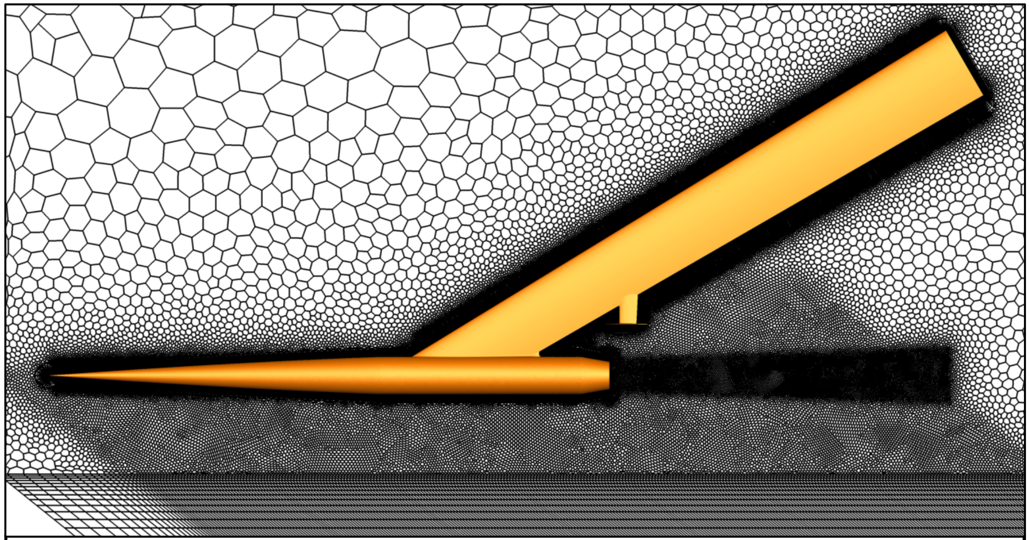
Structured Curvilinear

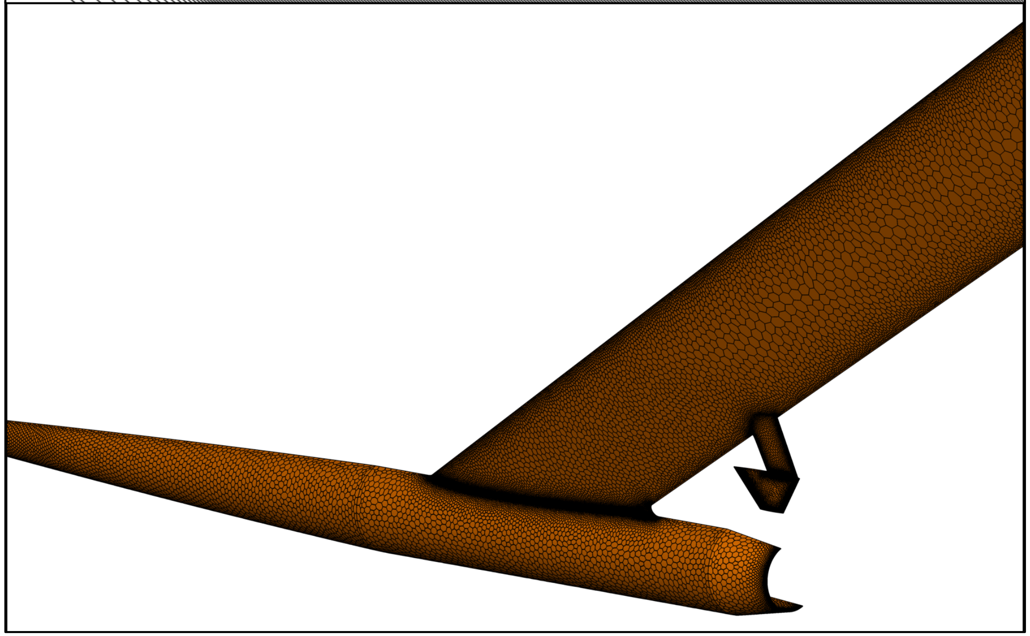
- Vertex Centered
- Steady-state RANS
- Spallart-Allmaras Turbulence Model with RC and QCR2000
- 4th Order Hybrid Weighted Compact Nonlinear Scheme (HWCNS) and 3rd Order Upwind scheme with central blending (UPW)

Grid Information (Unstructured Arbitrary Polyhedral)

- Biconvex
  - Very Coarse: 7.4 M
  - Coarse: 12.4 M
  - Medium: 27 M
  - Fine: 55.1 M
- C608
  - Coarse: 27.7 M
  - Medium: 94.4 M
  - Fine: 140 M

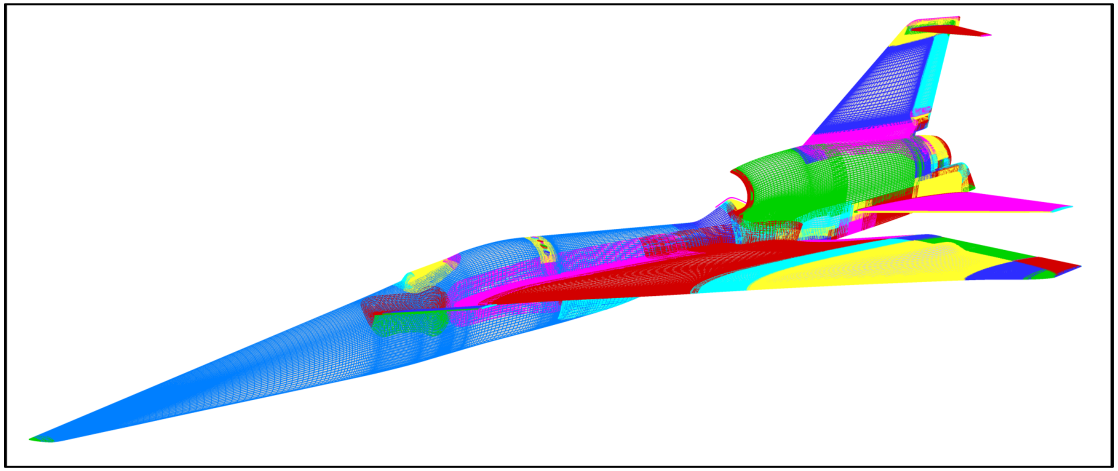


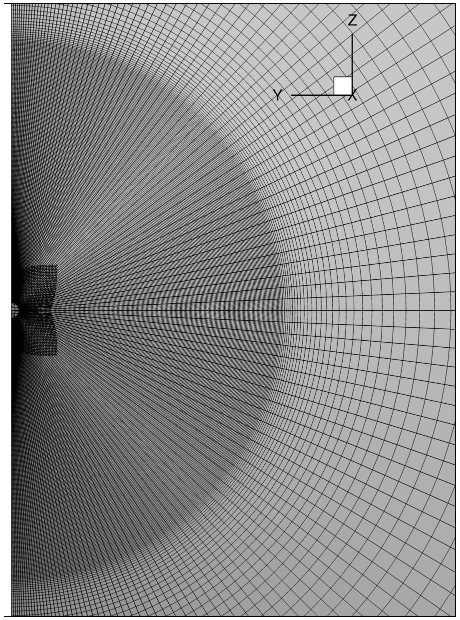


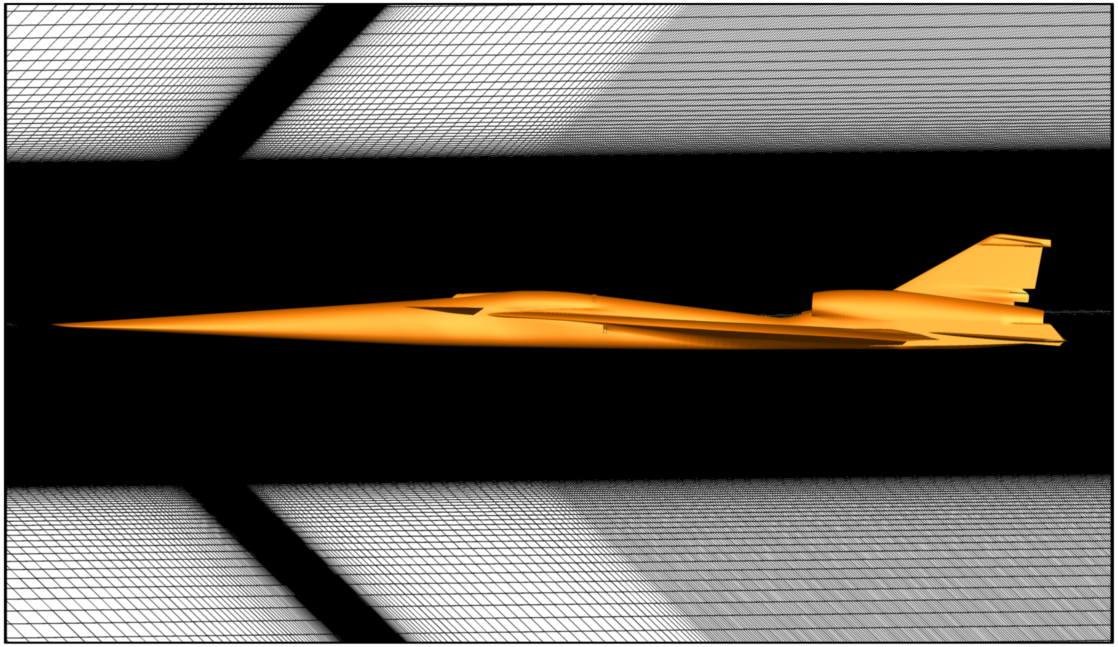


Grid Information (Structured Curvilinear)

- Biconvex
  - Coarse: 29.1 M
  - Medium: 60 M
  - Fine: 136.2 M
- C608
  - Coarse: 40.3 M
  - Medium: 127.4 M
  - Fine: 450.9 M







Computing Requirements

Pleiades Supercomputer (NAS)

- Manufacturer: SGI/HPE
- 158 racks (11,207 nodes)
- 7.09 Pflop/s peak cluster
- 5.95 Pflop/s LINPACK (#32 Nov. 2019)
- Total Cores: 241,324

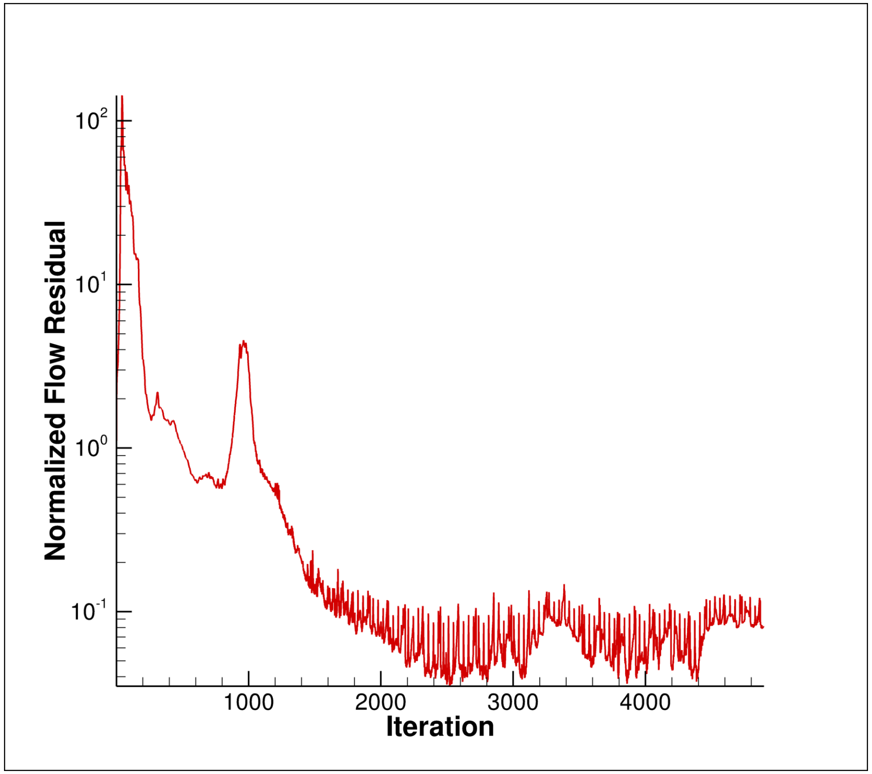
Resources (Time per 1000 steps)

- Case: C608

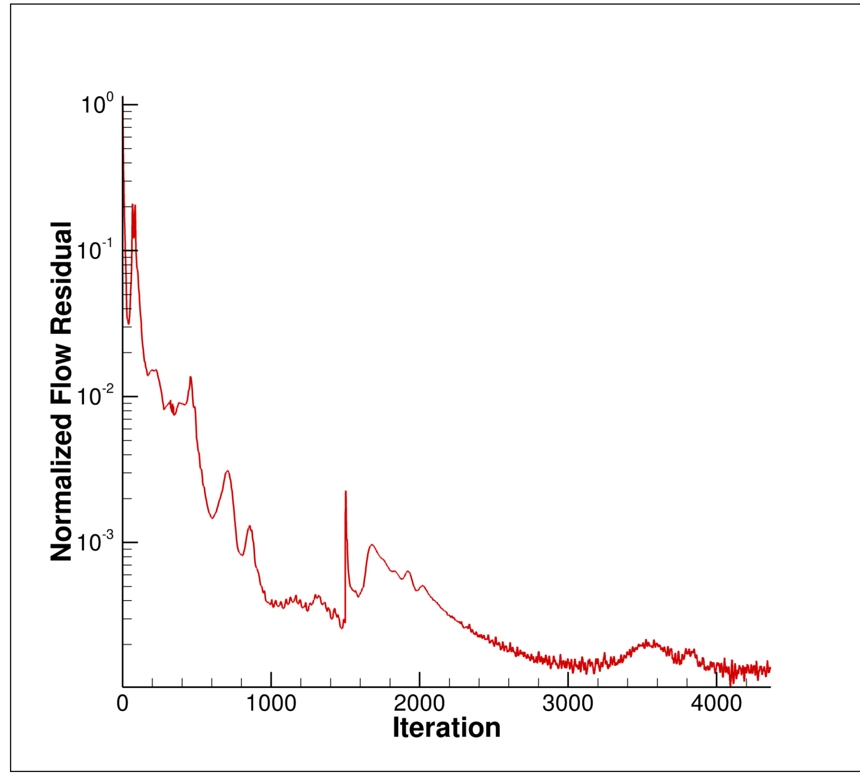
Grid ($x10^6$)	Flux	Model	Proc	Nodes (cores)	Time
U-Coarse (27.7)	AUSMPW+	RANS-SA	Broadwell	28 (560)	43 min.
U-Medium (94.4)	AUSMPW+	RANS-SA	Broadwell	38 (1064)	1 hr. 38 min.
U-Fine (140)	AUSMPW+	RANS-SA	Broadwell	60 (1680)	2 hr.
S-Coarse (40.3)	Roe	RANS-SA-RC-QCR2000	Ivy Bridge	30 (600)	55 min.
S-Medium (127.4)	Roe	RANS-SA-RC-QCR2000	Ivy Bridge	64 (1280)	1 hr. 22 min.
S-Fine (450.9)	Roe	RANS-SA-RC-QCR2000	Ivy Bridge	292 (5840)	1 hr. 25 min.

Flow Solver Convergence (C608 Medium Grids)

Unstructured

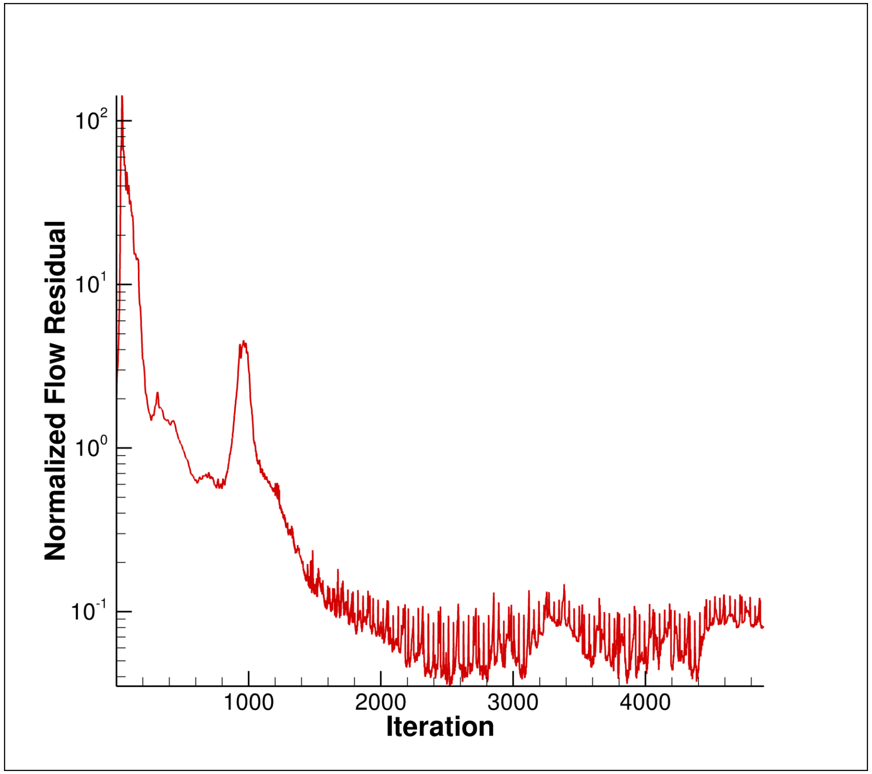


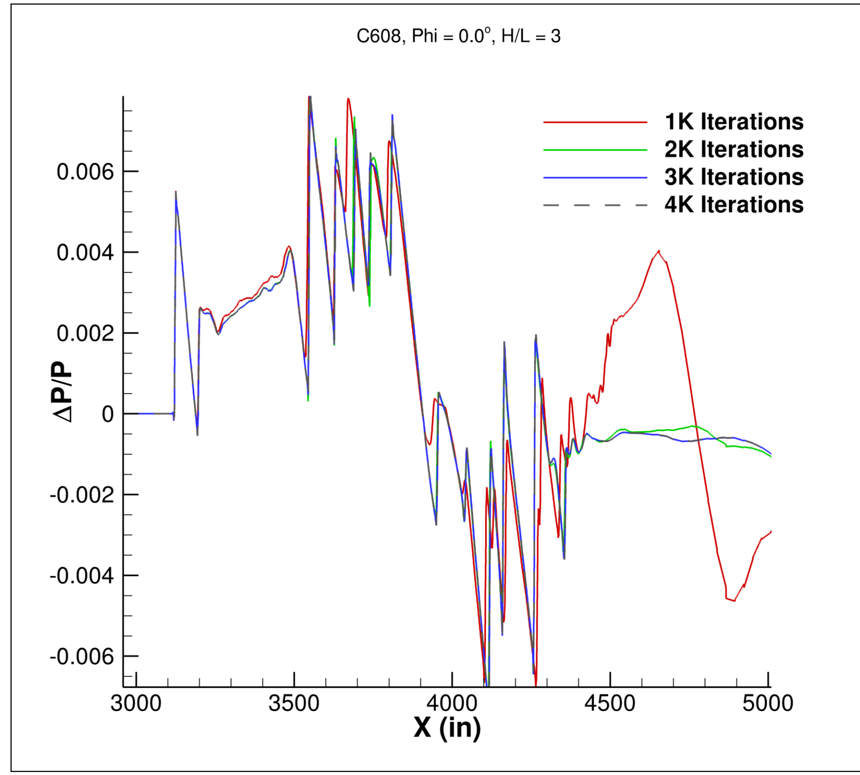
Structured



- Observed approximately three orders of magnitude reduction in the flow equation residual using both mesh topologies
- Both plots are representative of the convergence across both geometries

Flow Solver Convergence (Unstructured Example)

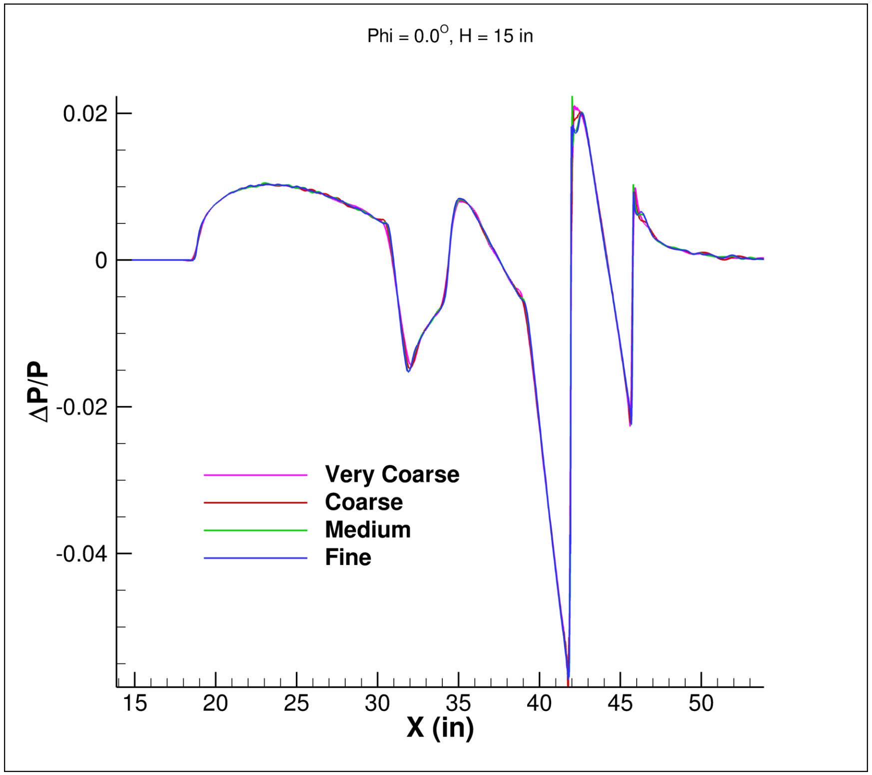




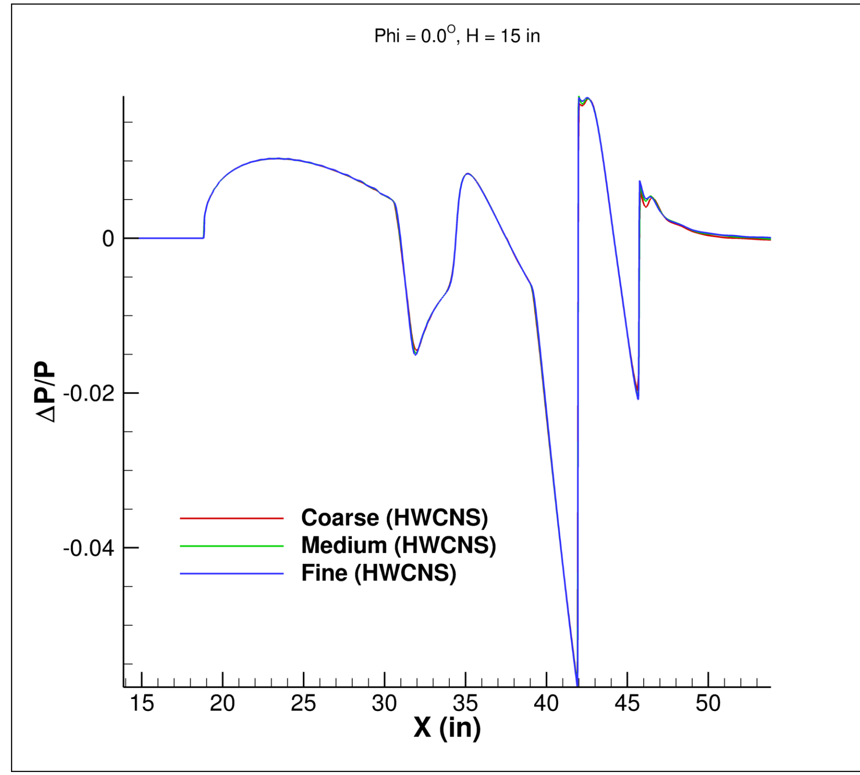
- ➢ Can see that by 3000 iterations our line signature has converged to its final predicted value

Biconvex Near Field Signals

Unstructured



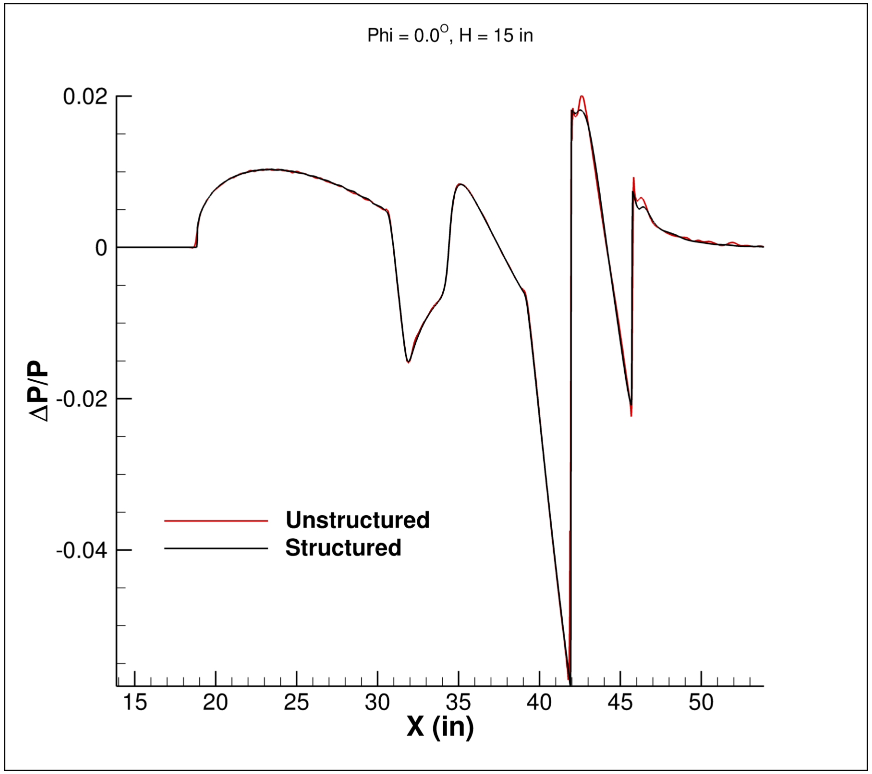
Structured



- For both mesh topologies, as the grids are refined the largest areas of difference are at the expansion after the nose of the nozzle (x = 32 in), the shock coming from the nozzle lip (x = 42 in), and the shock coming from the biconvex test article (x = 46)

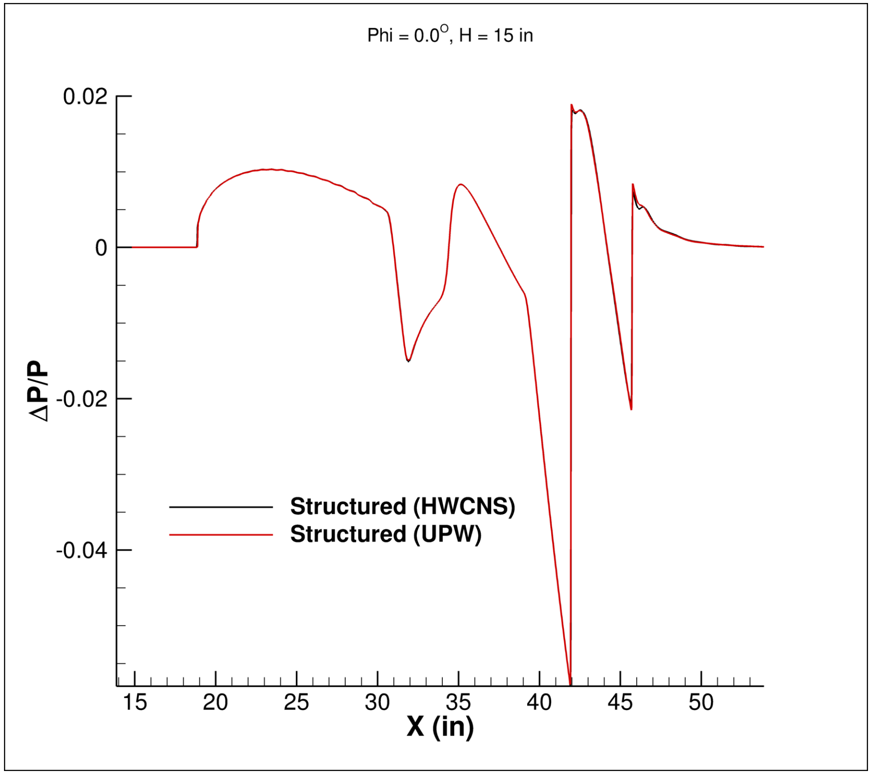
Biconvex Near Field Signals (Continued)

Grid Type Comparison (Fine)



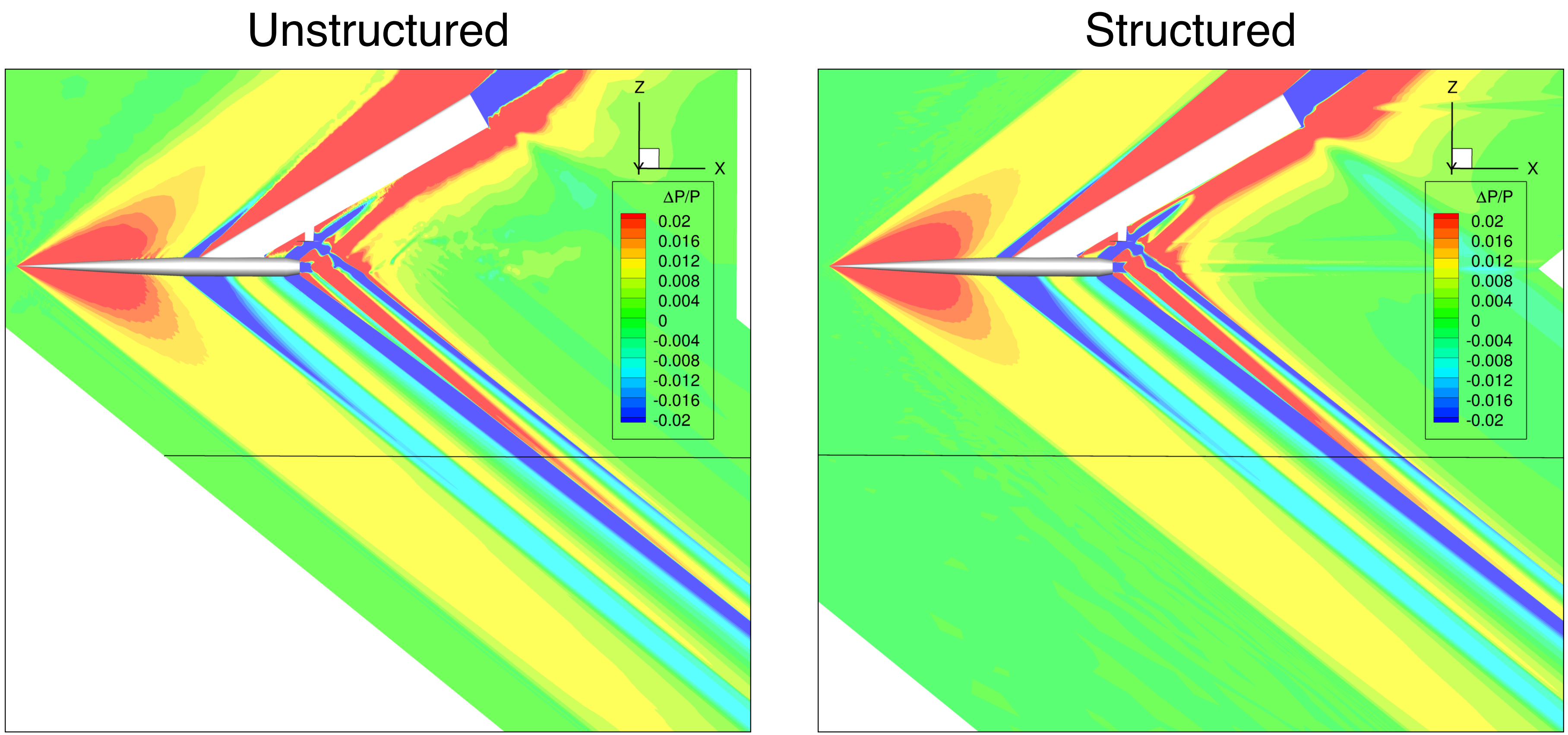
- Both mesh types agree well with each other with only slight variation in the nozzle and biconvex shocks

Scheme Differences (Structured)



- Only minor differences between the two schemes were observed

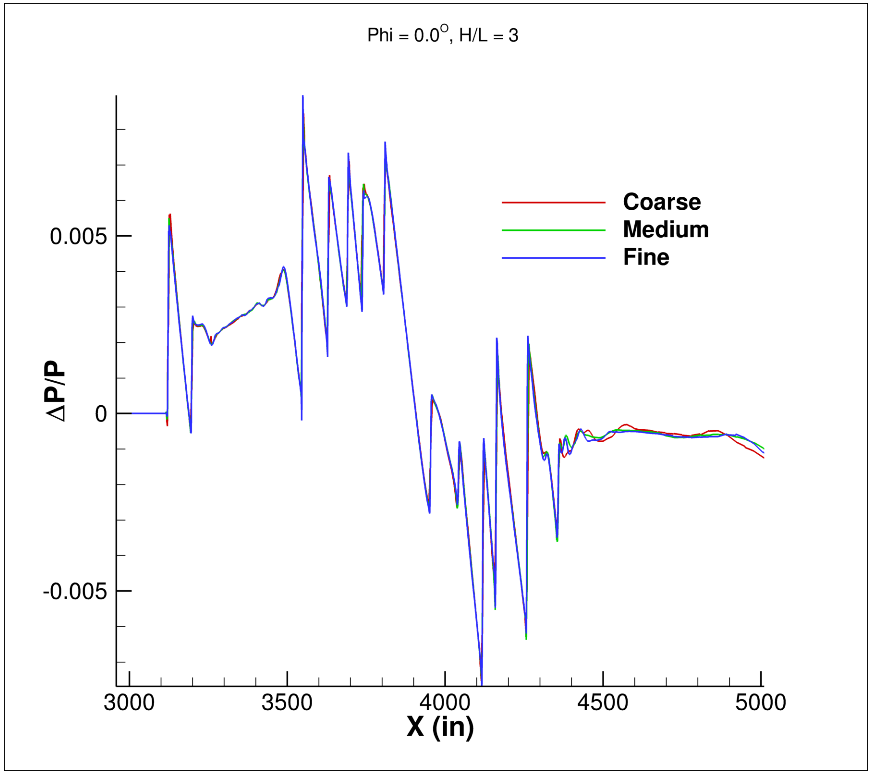
Biconvex Pressure Fields



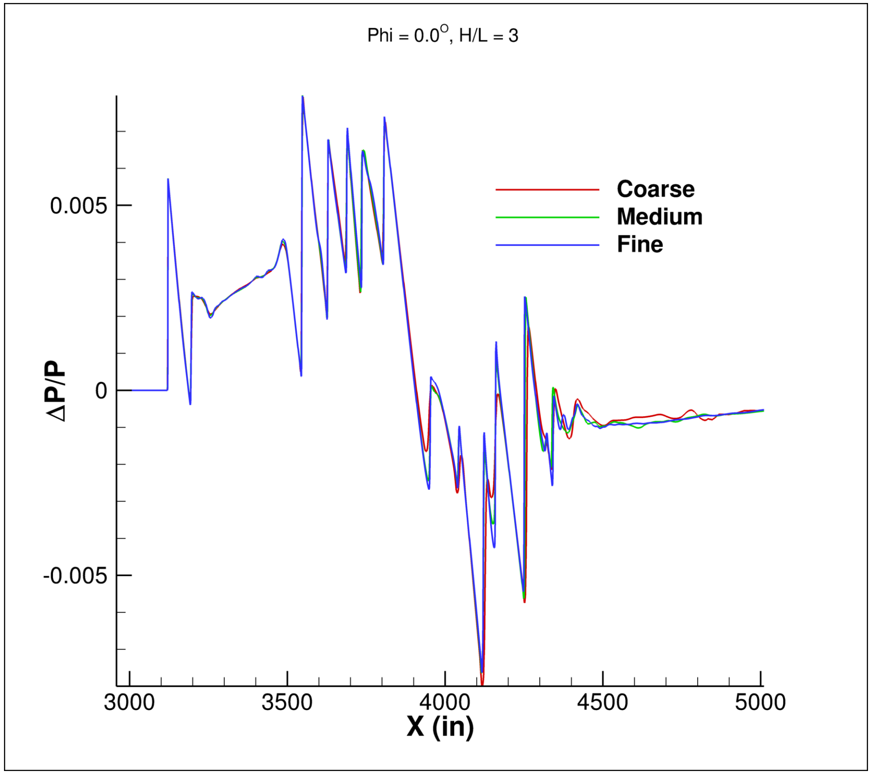
- Pressure fields reflect what was observed in the line probes
- Only minor differences near the aft end of the signature

C608 Near Field Signals

Unstructured



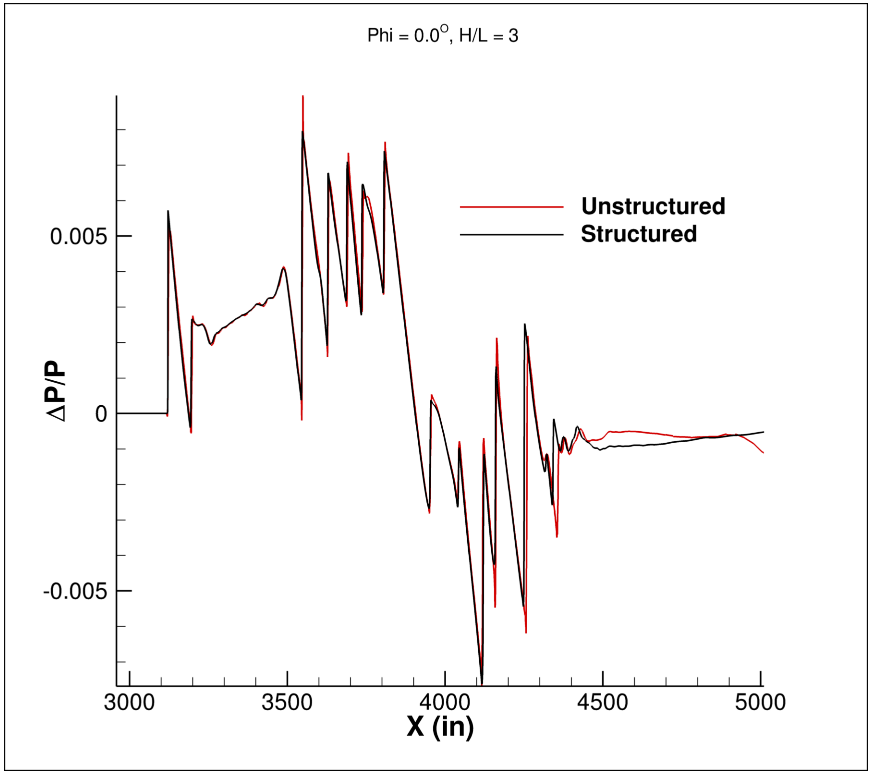
Structured



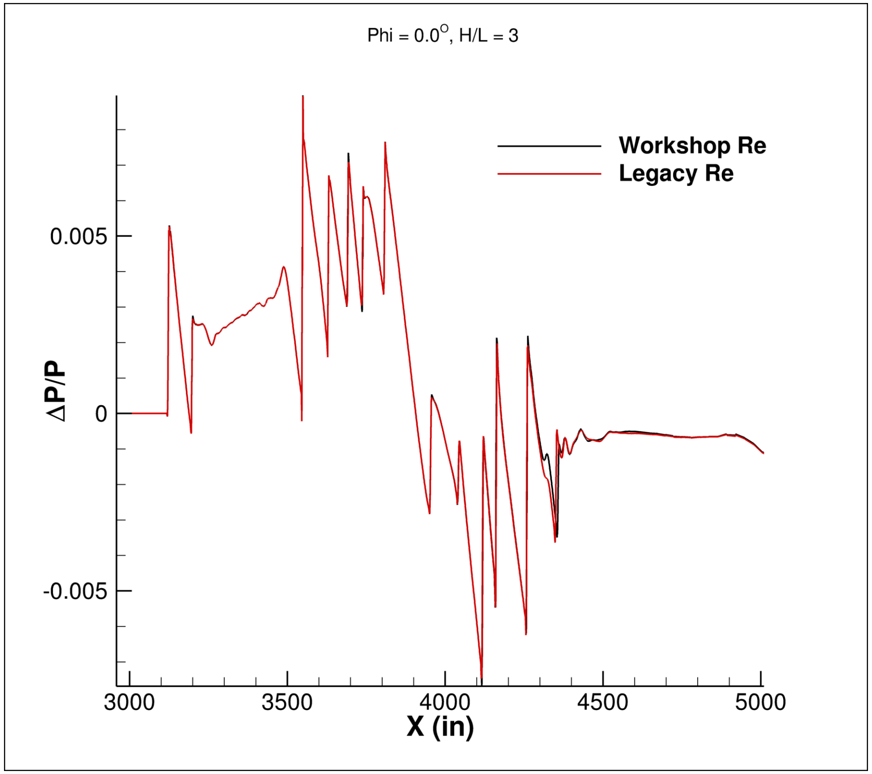
➢ For both mesh topologies, the aft end of the signature shows the most sensitivity to discretization

C608 Near Field Signals (Continued)

Grid Type Comparisons (Fine)

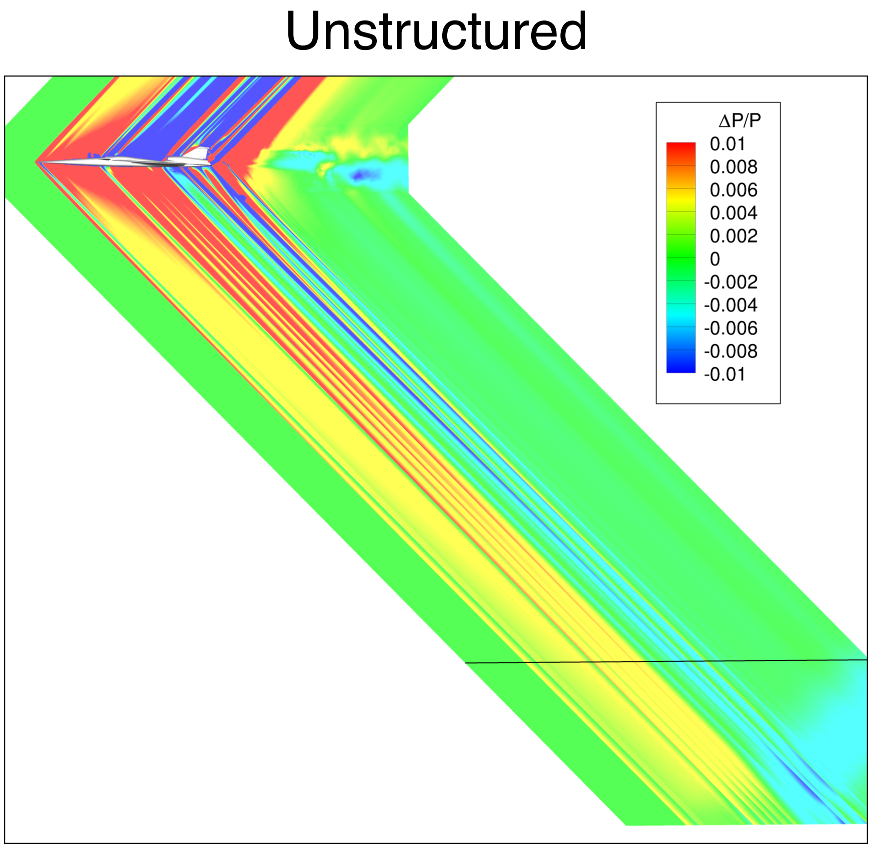


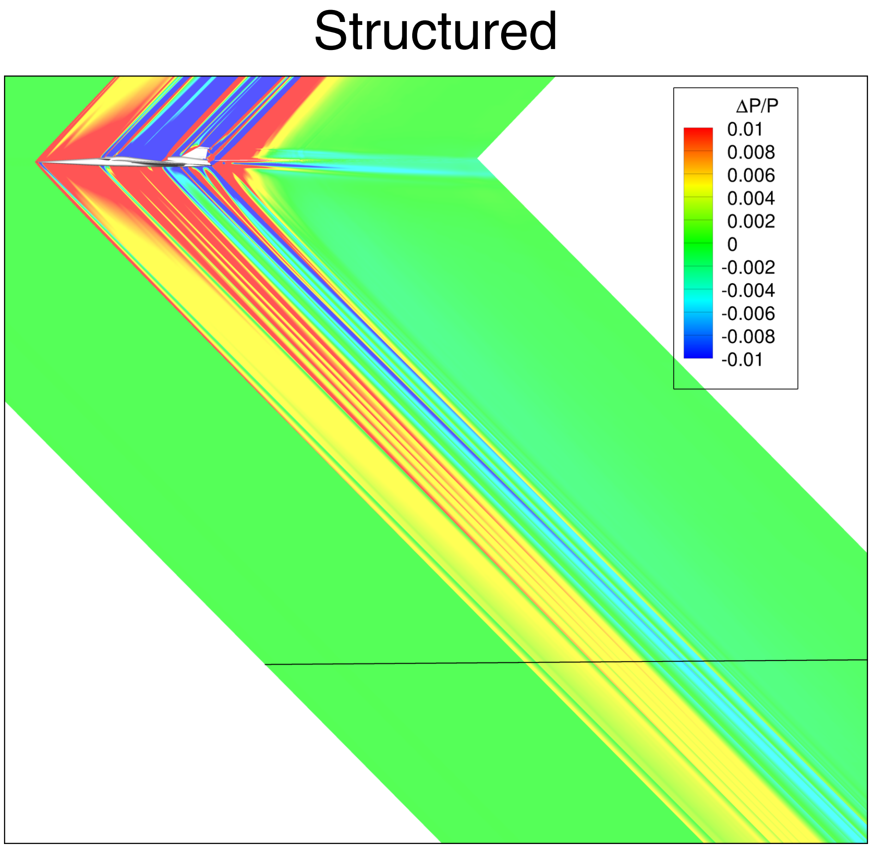
Reynolds Number Comparison (Unst)



- Both mesh topologies agree well with each other with the aft end of the signature being the area of larges disagreement between the two
- Running with the two different Reynolds numbers showed only a minor difference between the two signatures

C608 Pressure Fields

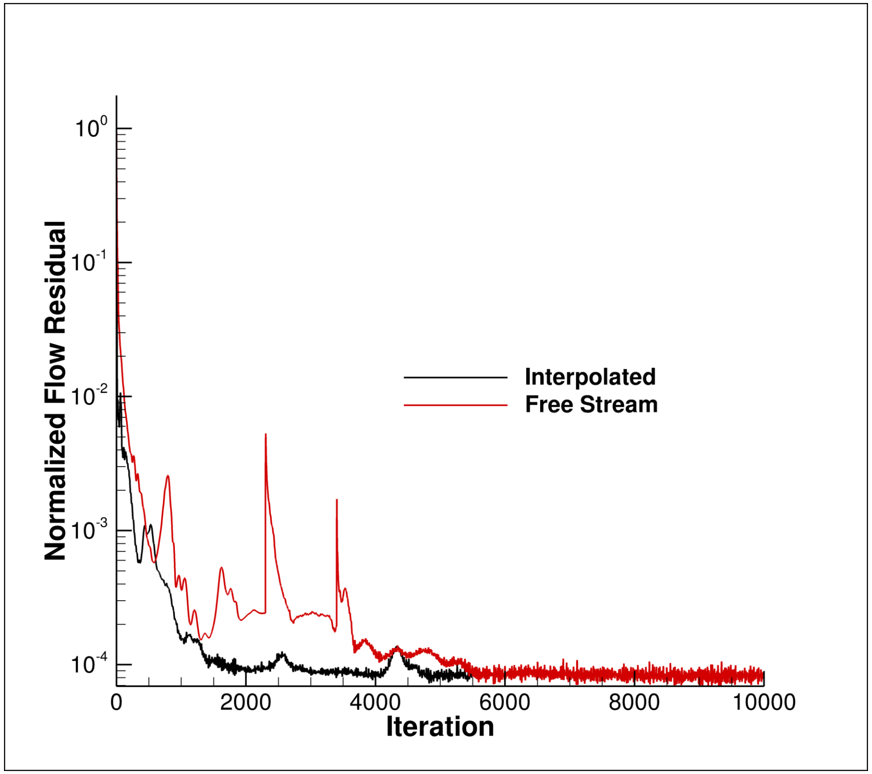




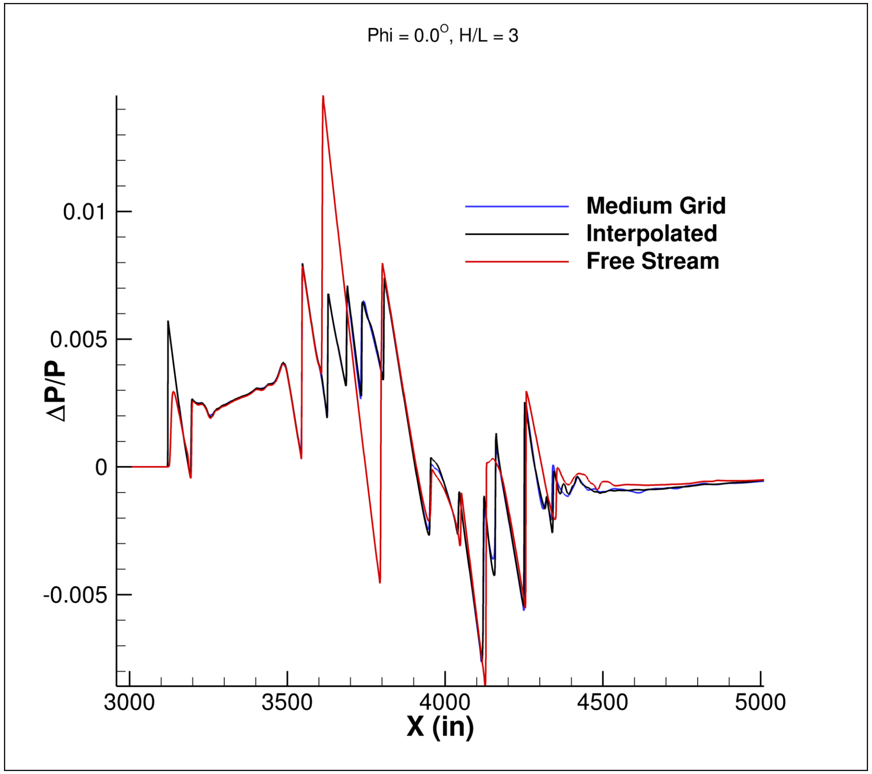
- Pressure fields agree well with one another
- Can see the reflection of the shocks off the boundary in the unstructured solution

C608 Flow Field Initialization (Structured Overset - Fine Grid)

Residual Convergence



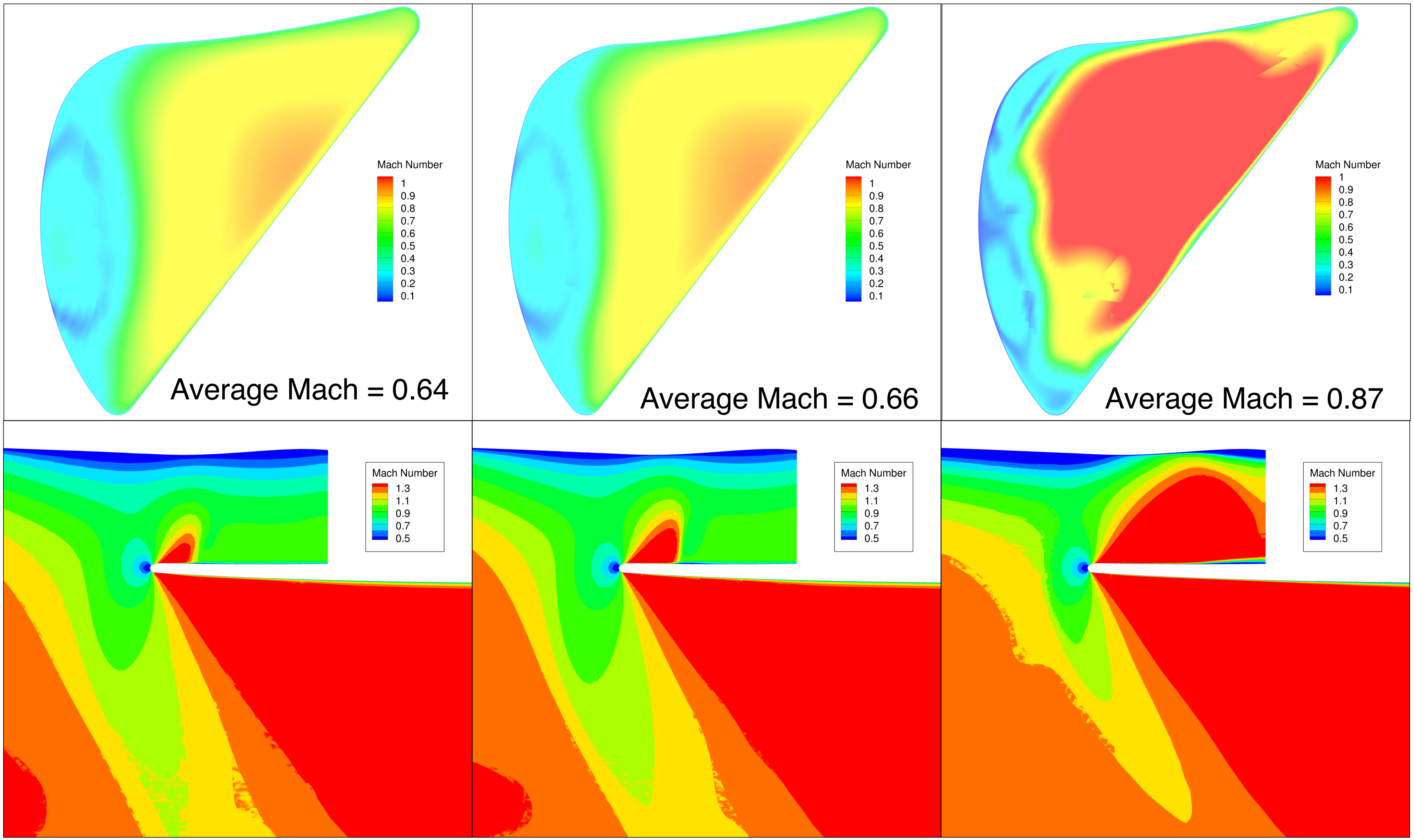
Nearfield Pressure



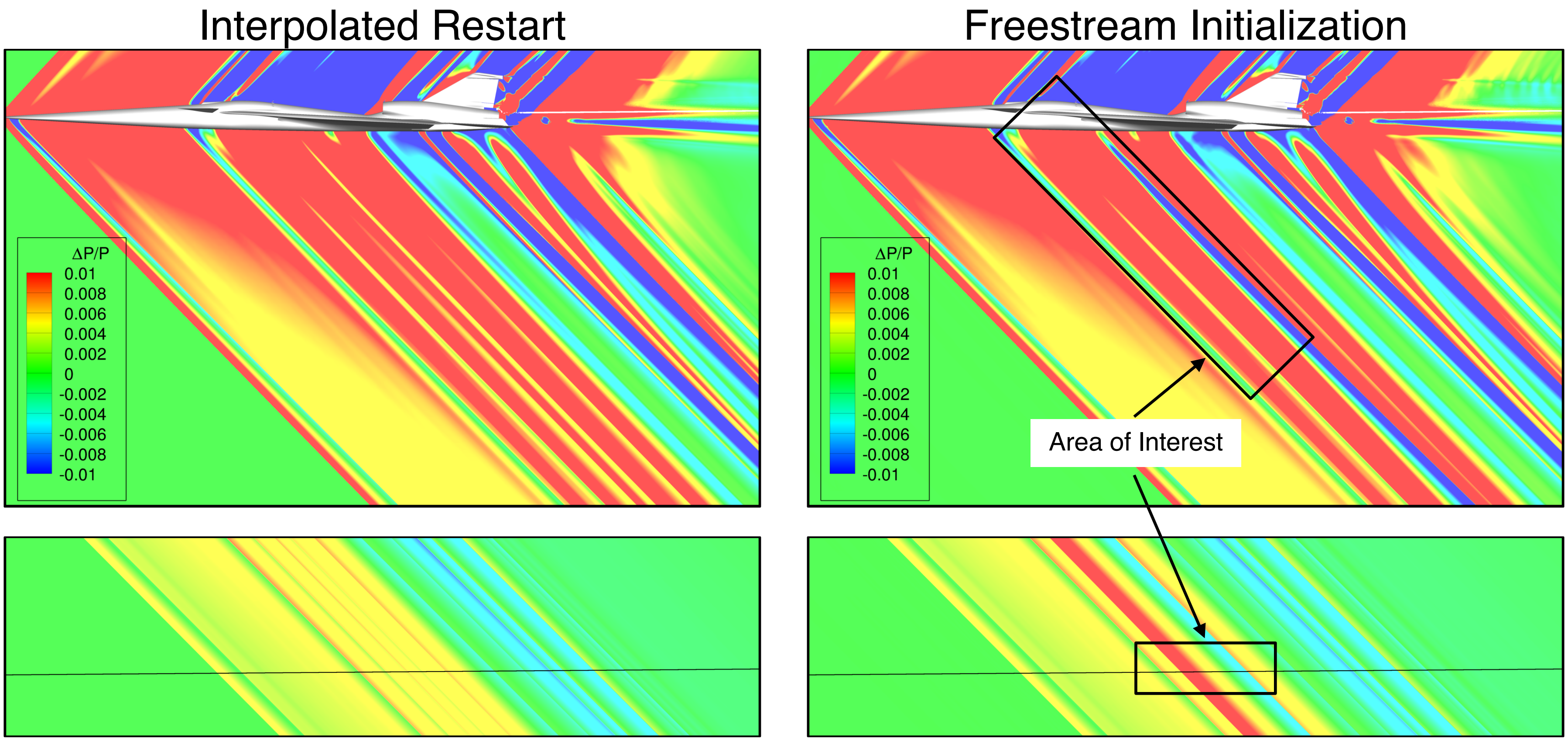
1. Initialized whole field to free stream
2. Manually specified subsonic conditions in Environmental Control System inlet duct
3. Started case with lower order scheme and then increased the order with restarts (Freestream)
4. Initialized flow field by interpolating the medium grid solution onto the fine grid (Interpolated)

Flow Field Initialization – ECS BC Face Comparison

Medium Grid | Interpolated Restart | Freestream Initialization



Flow Field Initialization – Pressure Fields



- ➢ The pressure fields near the body show that the area between the leading edge of the wing root and the ECS inlet show the largest difference between both solutions
- ➢ The increased shock strength at the ECS inlet is causing the waves to coalesce differently

Summary

- Successfully ran the Biconvex and C608 workshop cases using both the unstructured arbitrary polyhedral and structured curvilinear solvers within LAVA and saw good agreement between the two

- Observed that the fine grid case of the C608 in the structured solver had a large sensitivity to the method of flow field initialization
  - Root cause appears to be the ECS inlet boundary condition getting stuck at a much higher Mach number than desired

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