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Near Field Sonic Boom Predictions Using STAR-CCM+

3rd AIAA Sonic Boom Prediction Workshop

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Siemens Digital Industries Software

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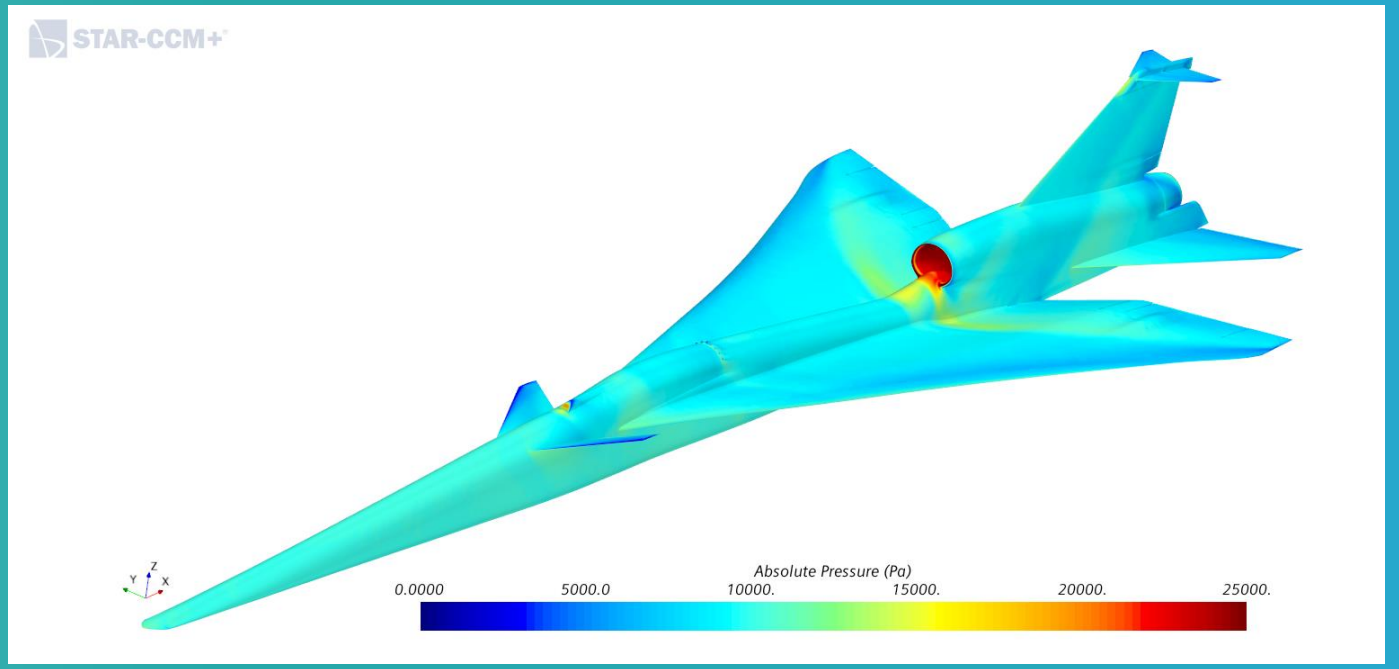
Agenda:

Summary of cases
Flow solver/computing platform
Computational meshes
Biconvex case results
C608 case results
Summary/conclusions



Summary of Cases

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- Biconvex 9x7
  - Three workshop-provided grids
    - biconvex-visc-mixed-157
    - biconvex-visc-mixed-128
    - biconvex-visc-mixed-100
- C608
  - Three workshop-provided grids
    - c608-visc-mixed-128.cgns
    - c608-visc-mixed-100.cgns
    - c608-visc-mixed-080.cgns

Flow Solver and Computing Platform

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Flow Solver

- STAR-CCM+ v2020.1 (pre-release)
  - Flux scheme-
    - 2nd order in space (cell-centered)
    - Venkat limiter
    - Pre-conditioned Roe (Biconvex case)
    - AUSM+up (C608)
  - Mentor SST turbulence model
  - Ideal gas (Sutherland's Law)
  - "Expert Driver CFL" used for most cases
  - New "AutoCFL" tested as well (C608)

Computing Platform

- Various Siemens Linux clusters
- MPI for parallelization

Computational Meshes

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- All cases run (so far) used workshop-provided meshes
  - Native STAR-CCM+ poly meshes under development
  - Application of new AMR algorithm also being investigated
  - Results to be included in paper for AVIATION 2020

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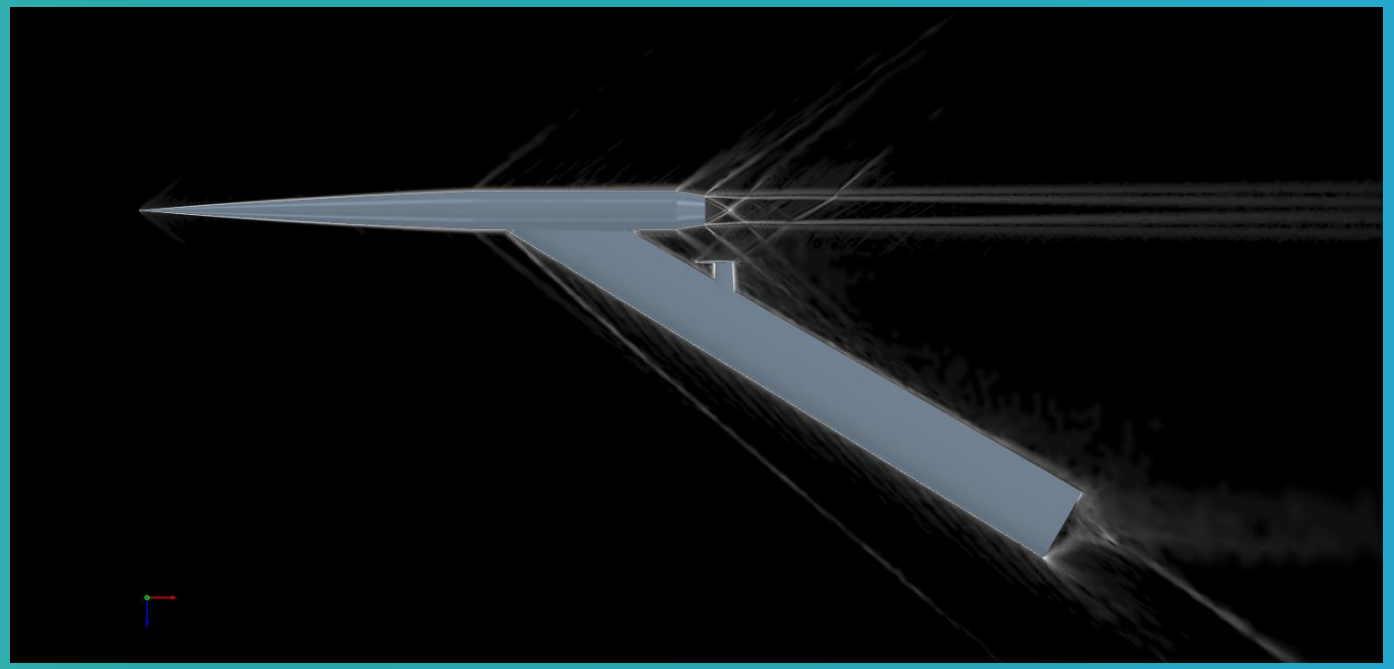
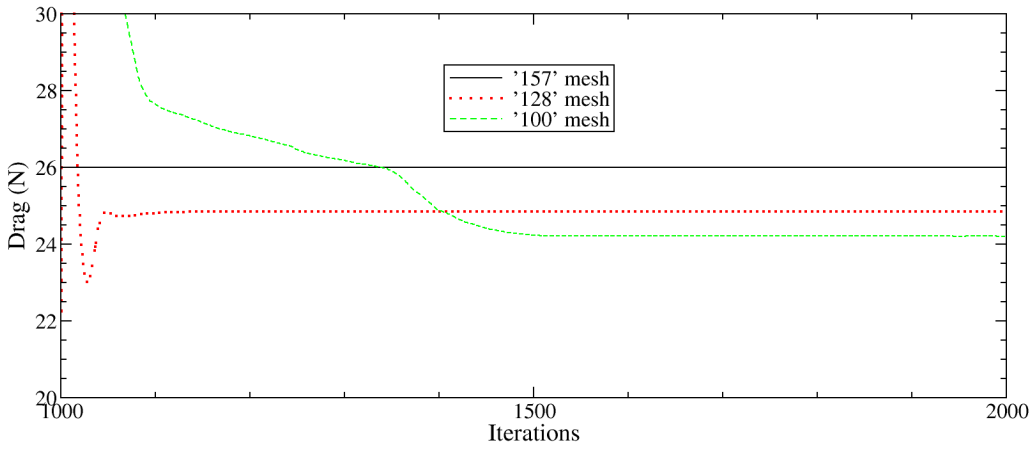
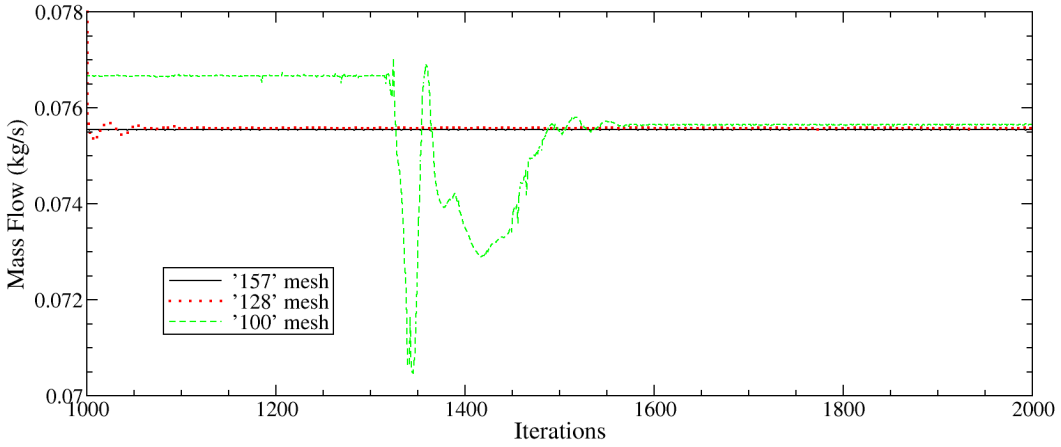


Convergence Criteria

- Residuals not a good indicator of convergence for this case
  - Limit cycle reached early on
  - Possibly due to non-native mesh topology (tets)
- Looked at convergence of drag and mass flow through the nozzle instead
  - Convergence obtained for all meshes
    - Drag appears to be converging with increased resolution
    - Mass flow very similar for all cases

- Note- initial runs with ‘128’ and ‘100’ resolution meshes used incorrect units. Meshes were rescaled and solutions continued

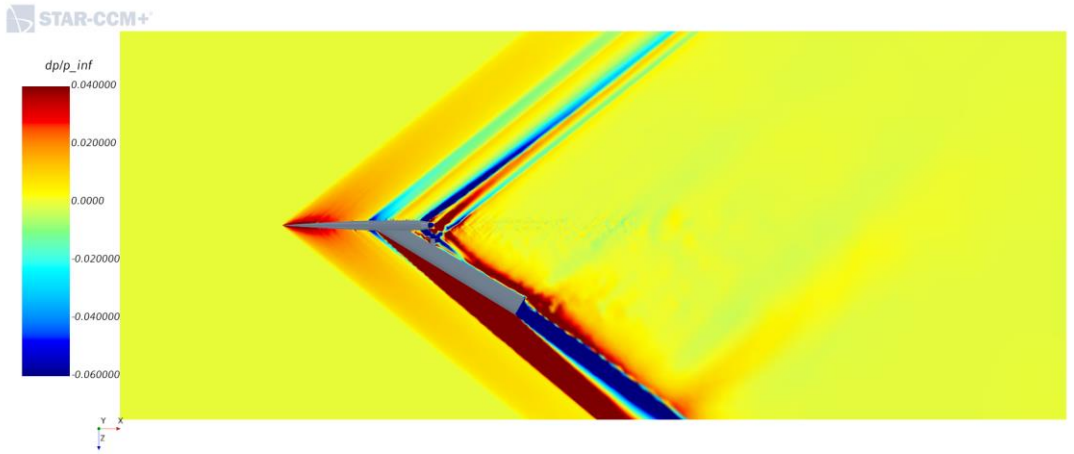




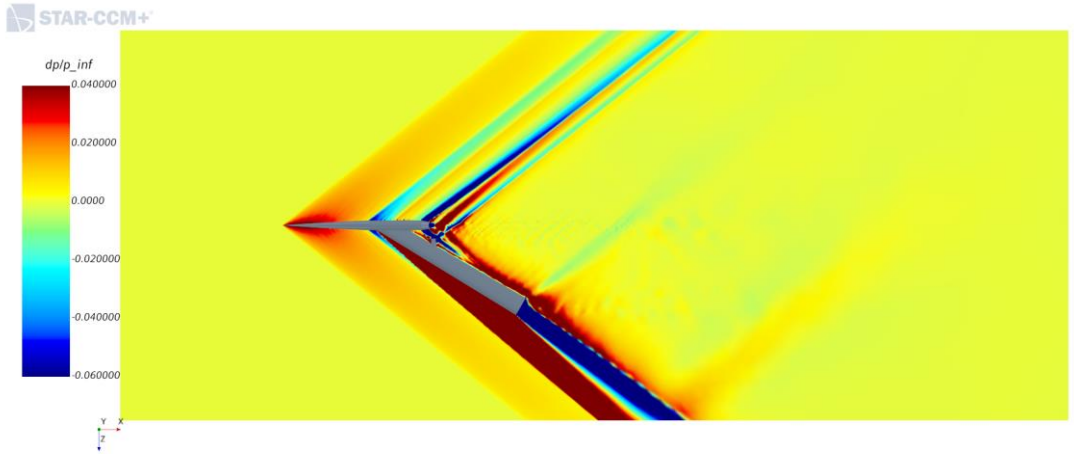
Pressure Contours

- Major flowfield features very similar for all mesh resolutions

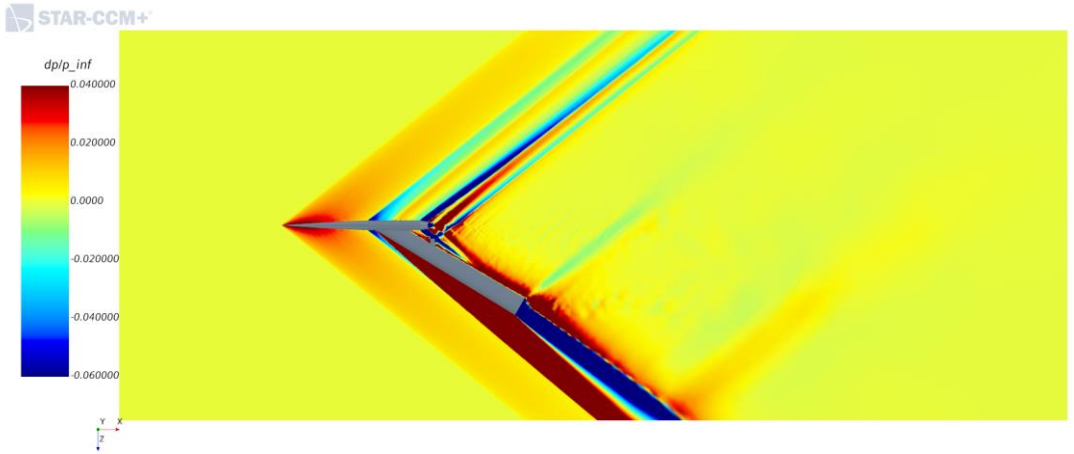
‘157’ mesh



‘128’ mesh



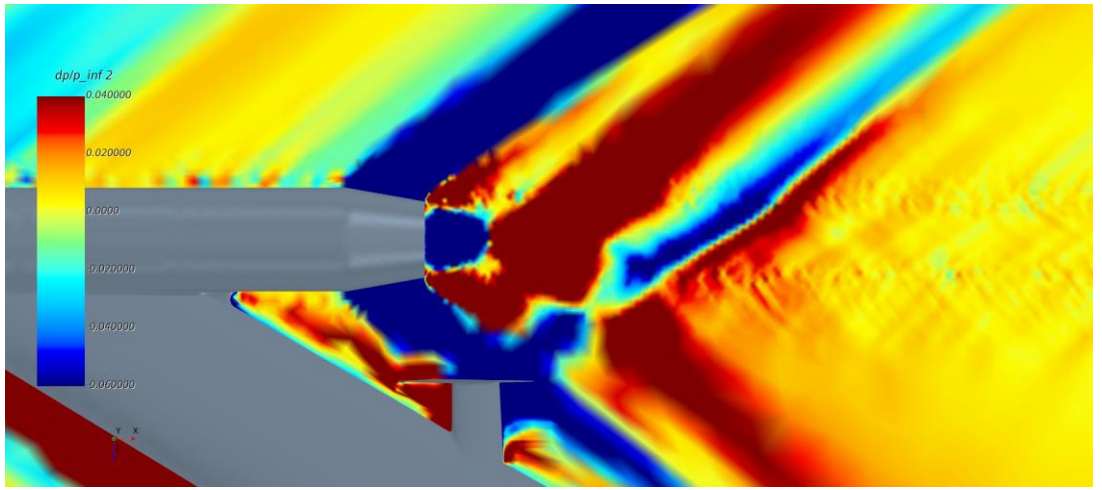
‘100’ mesh



Pressure Contours- Nozzle Exit Region

- Differences in pressure contours most apparent in vicinity of nozzle exit
- Increasing resolution improves smoothness of results

‘157’ mesh



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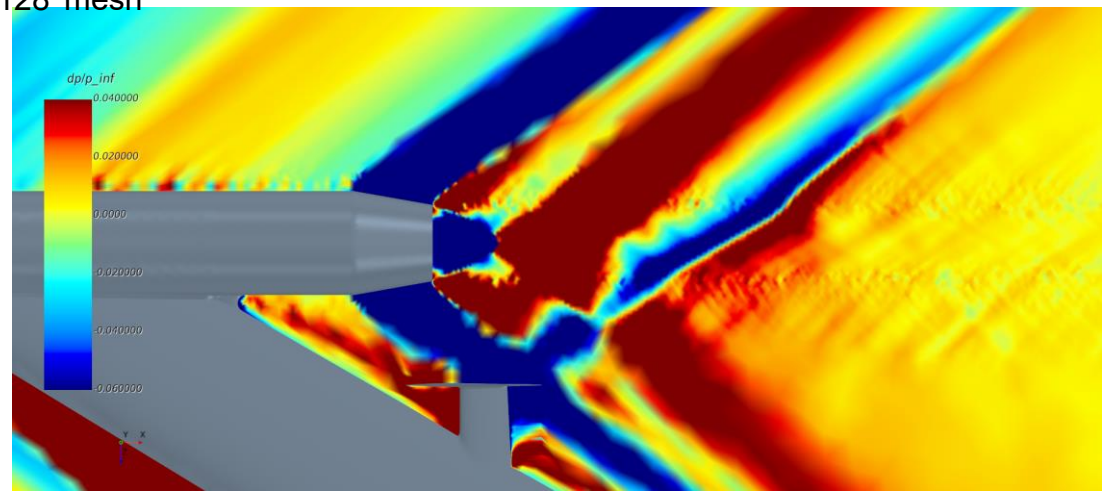

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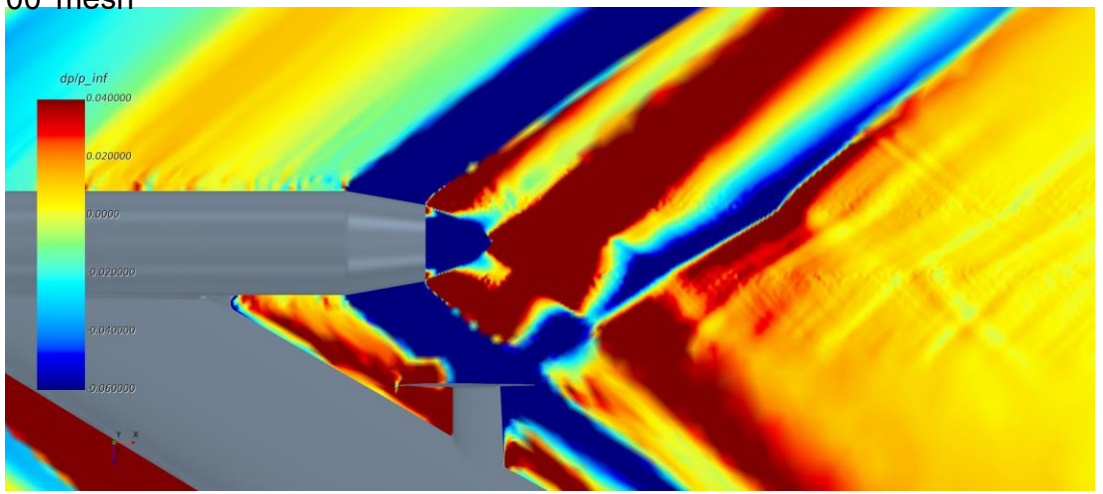

Near Field Pressure Signatures

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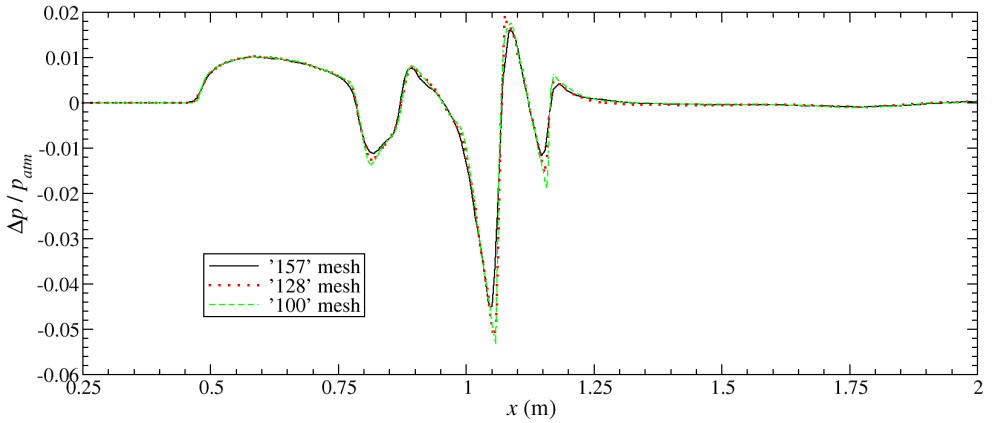
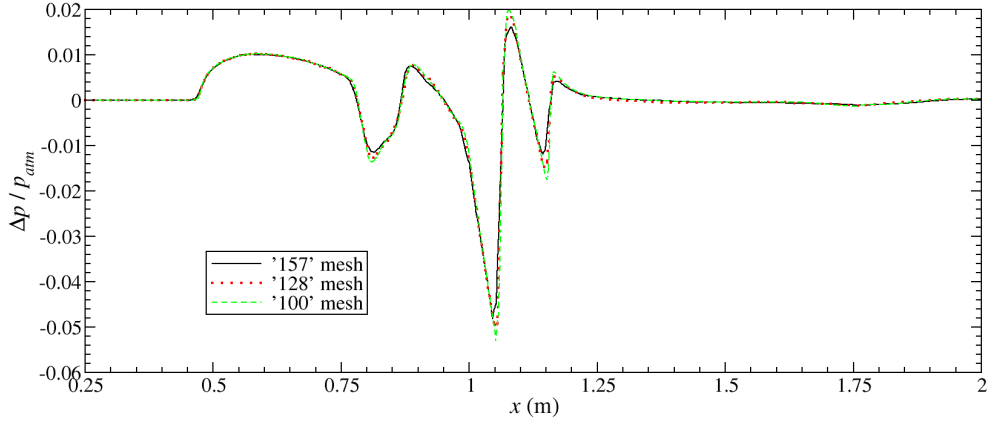
- All three meshes produce similar results
- Finer resolution sharpens peaks
- Waves emanating from jet plume not seen at measurement locations (likely due to mesh resolution)

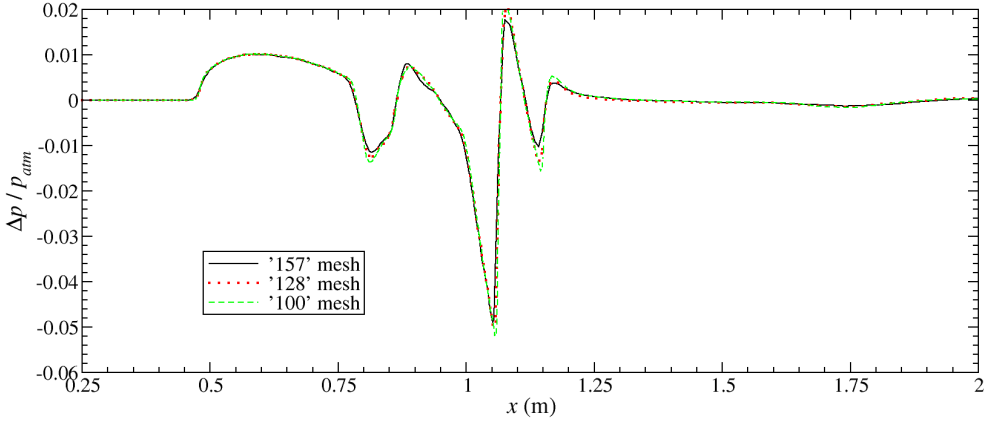
0 deg



15 deg



30 deg



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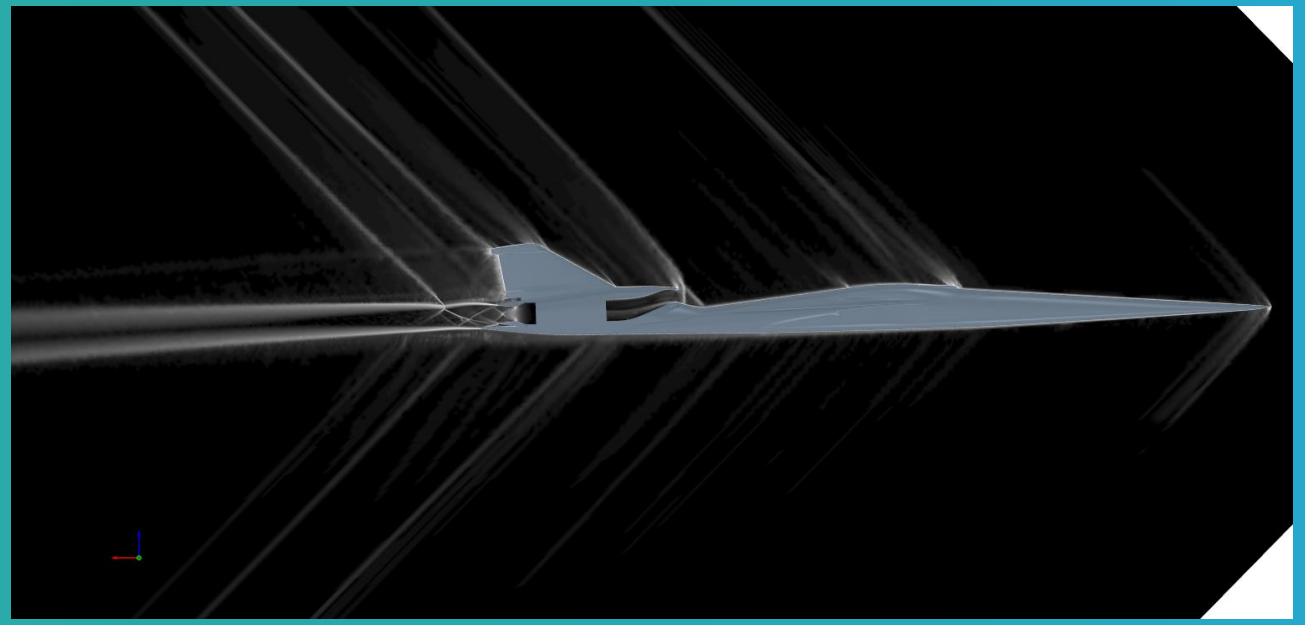
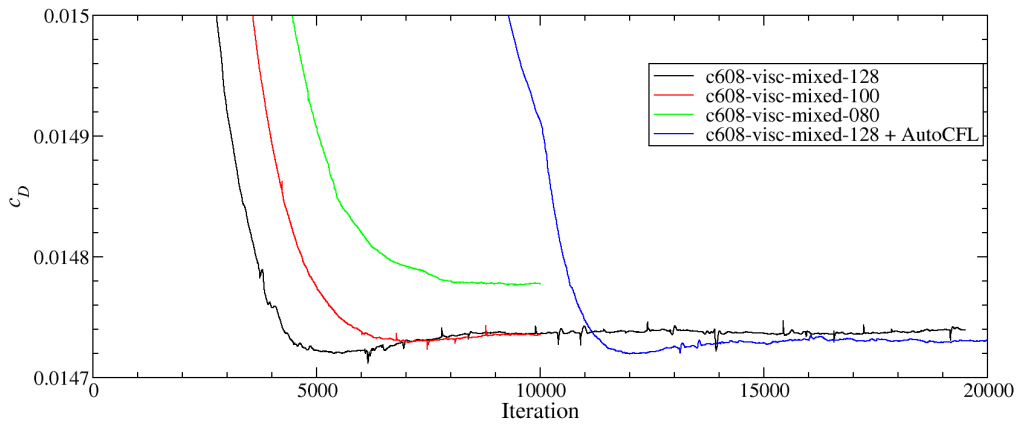


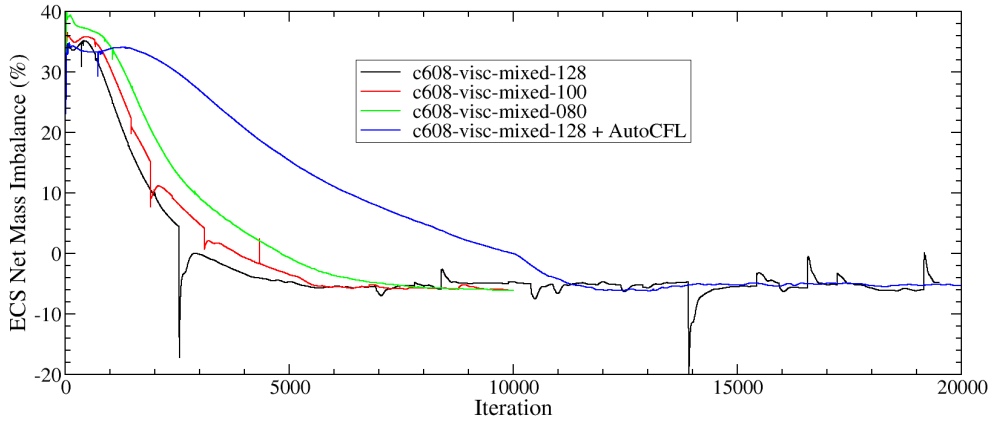
Convergence Criteria

- As with Biconvex case, C608 residuals reach limit cycle early
- Convergence assessed using other means:
  - Drag coefficient
  - Engine intake/exit mass flow imbalance
  - ECS intake/exit mass flow imbalance

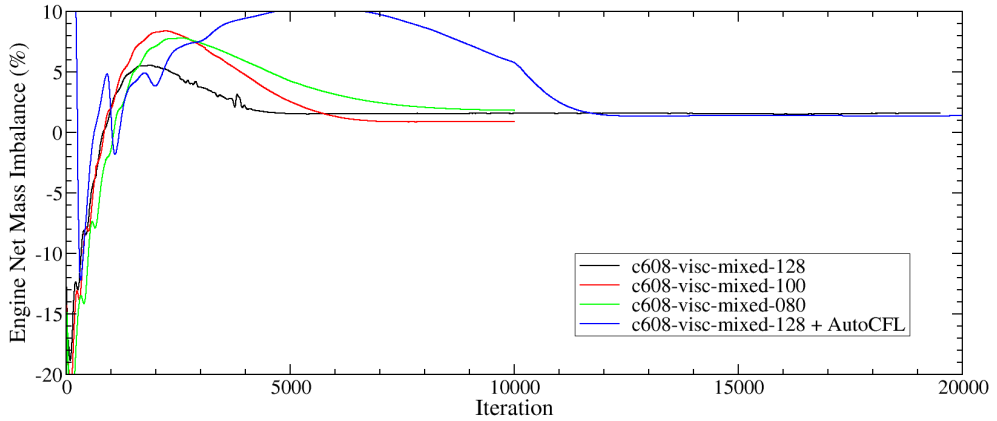
Drag Coefficient



Mass Imbalance- ECS System



Mass Imbalance- Engine



Pressure Contours

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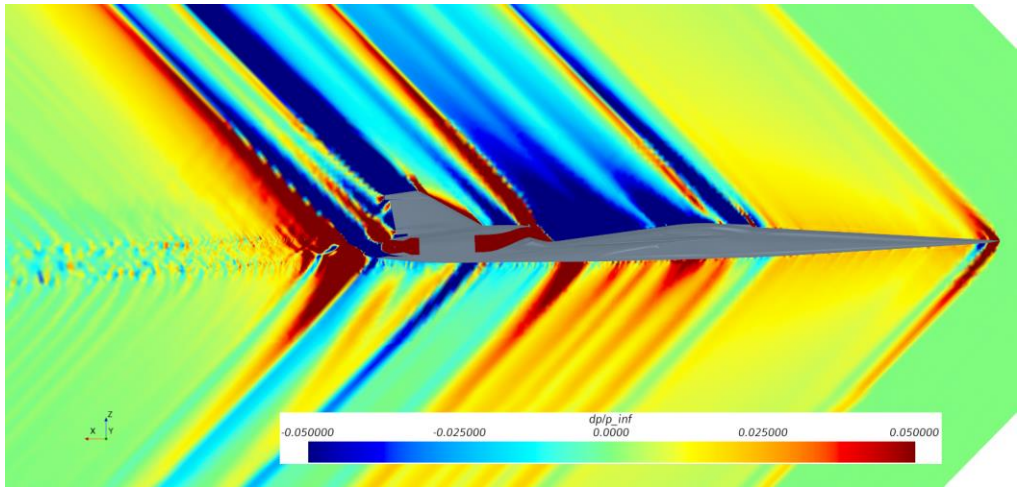
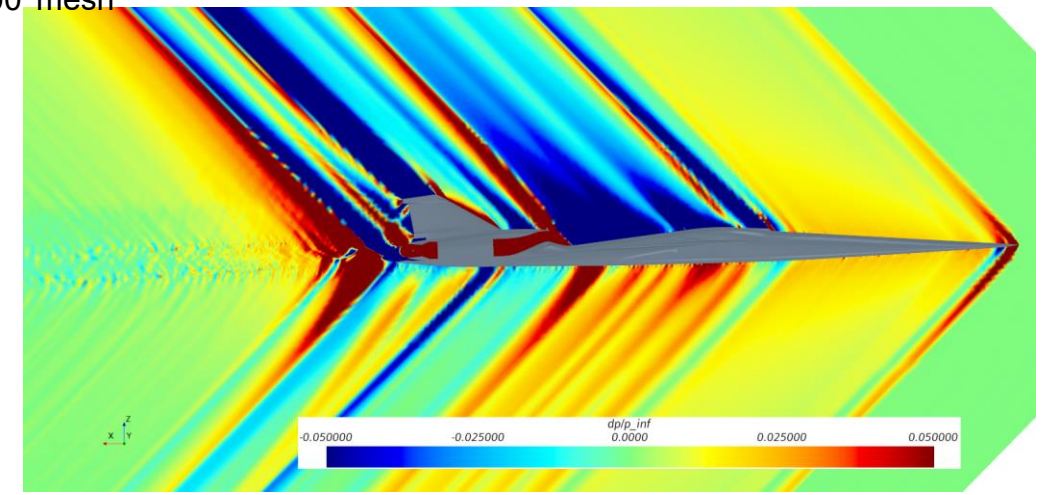
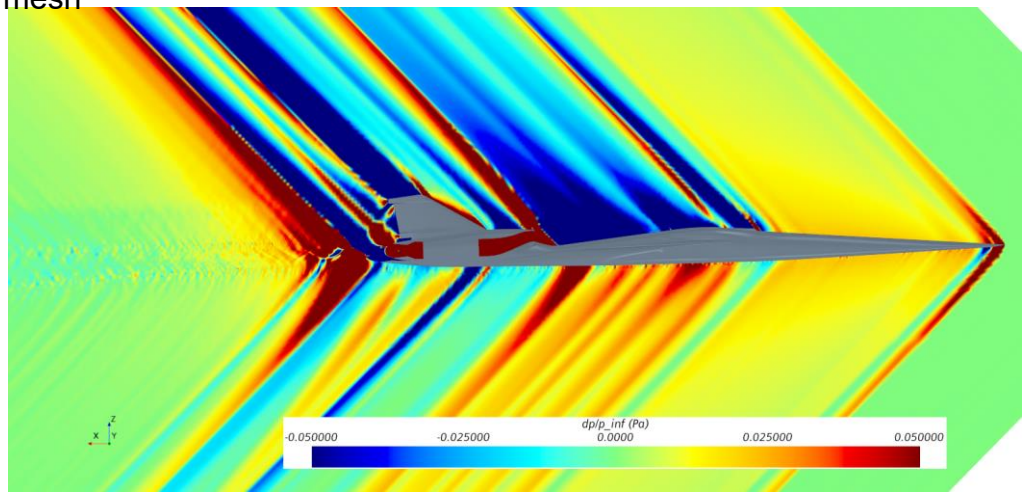
‘128’ mesh



‘100’ mesh



‘80’ mesh



Numerical Shadowgraph

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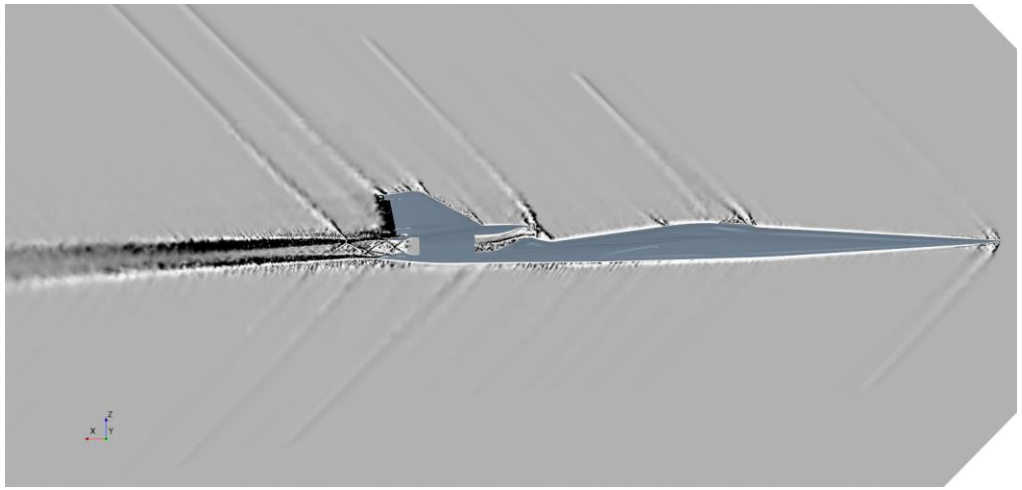
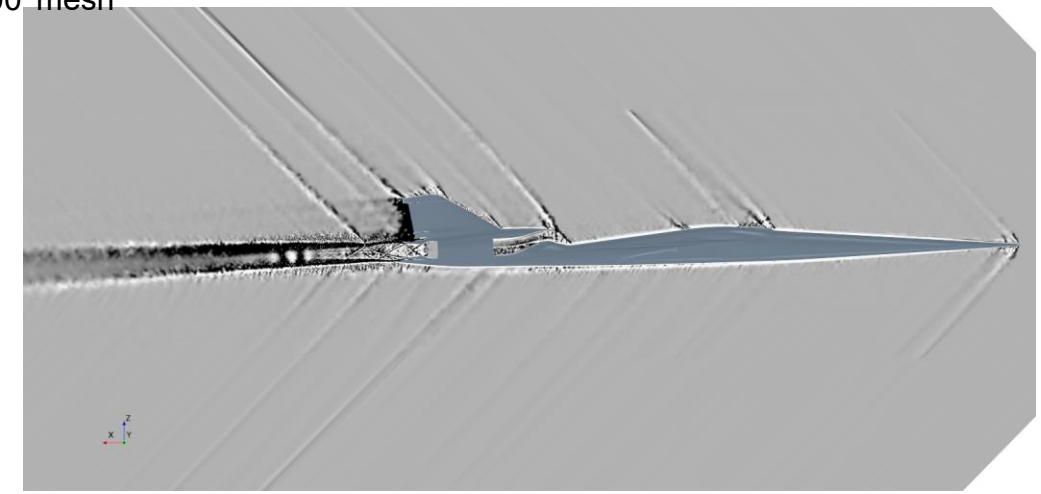
- Effects of mesh resolution more apparent
- Possible impact of cell topology changes

‘128’ mesh



‘100’ mesh



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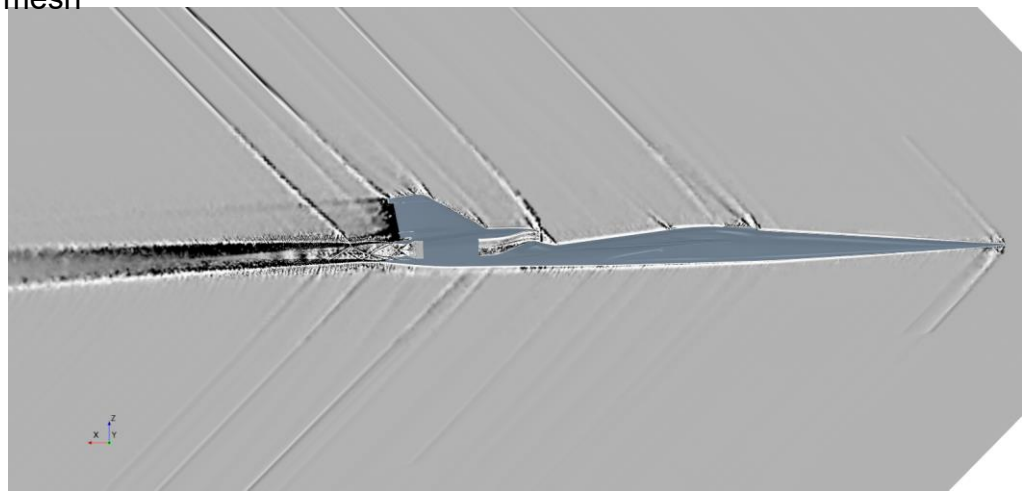

AutoCFL vs. Expert Driver

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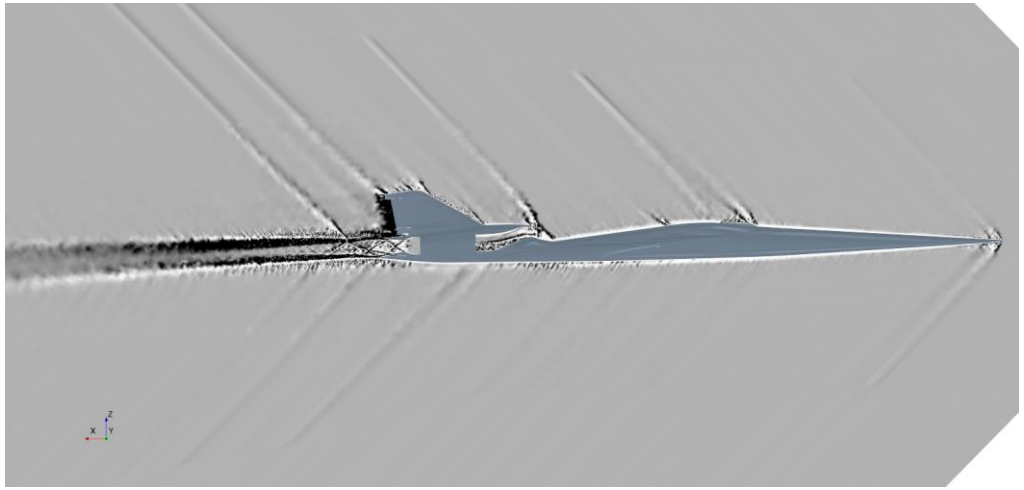
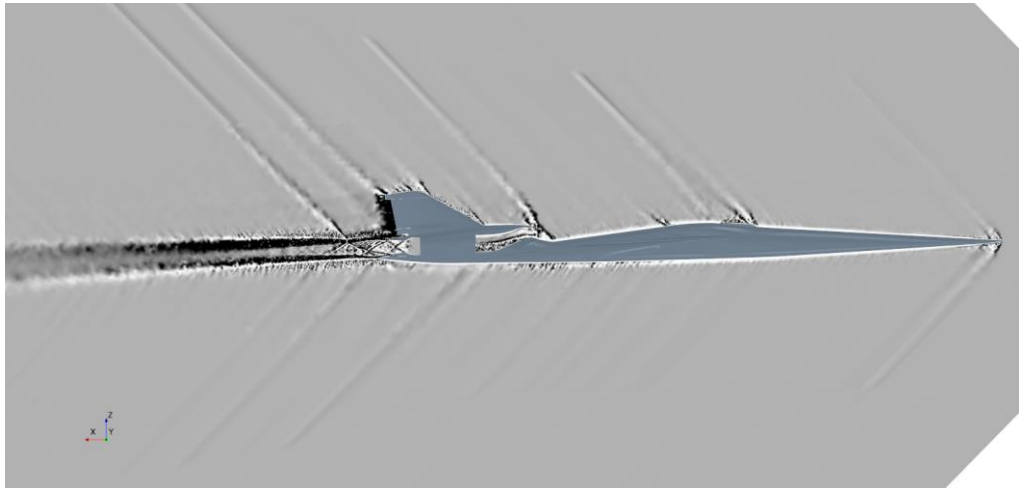
- Both are algorithms for controlling solution advancement (e.g. CFL number, desired number of AMG cycles, solution under-relaxation factor)
- Final solutions very similar
- AutoCFL intended to replace Expert Driver
  - More stable
  - Less (or no) tweaking required to reach converged solution
  - With minimal adjustment, can usually obtain good solutions faster than with Expert Driver
- Current runs used deliberately conservative settings for AutoCFL
  - Increased target AMG cycles
  - No attempt made (yet) to optimize settings

Expert Driver



AutoCFL



Near Field Pressure Signatures

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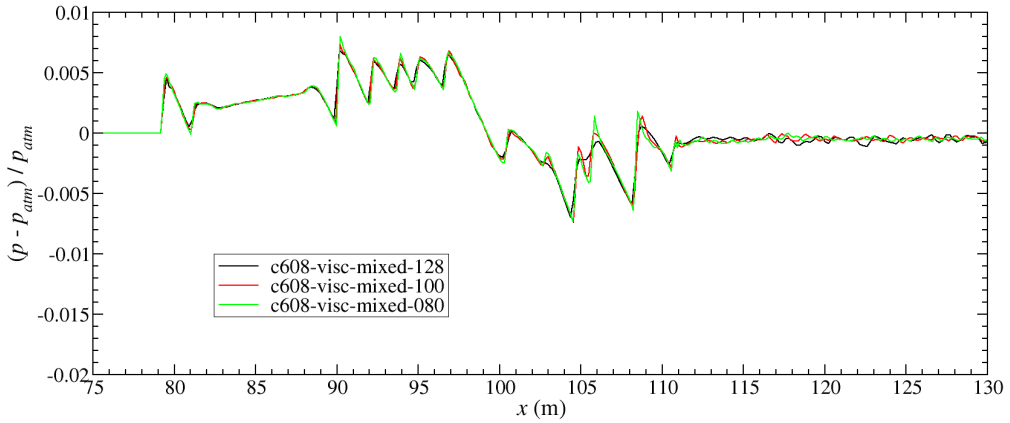
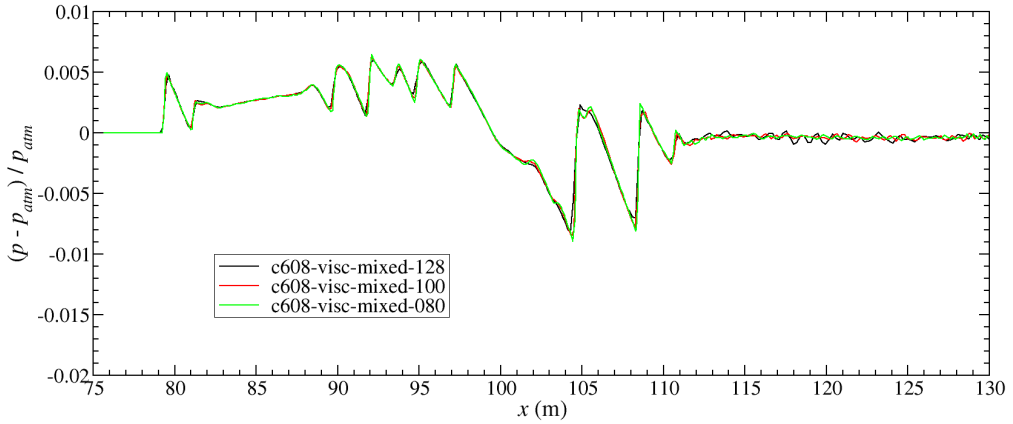
- Solutions similar for all meshes
- As expected, higher resolution yields sharper signal
- Waves much stronger above vehicle (as designed)
- Unlike Biconvex case, waves emanating from plume reach data collection region, but are low amplitude by comparison

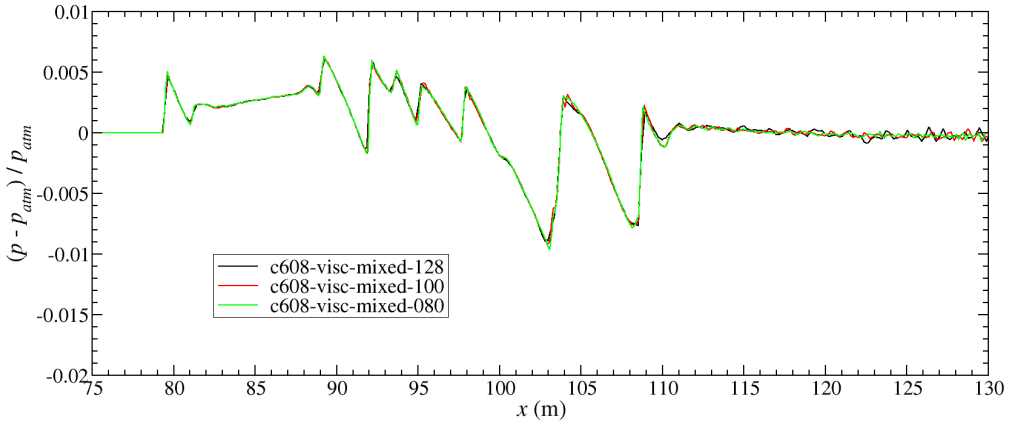
0 deg



30 deg



60 deg



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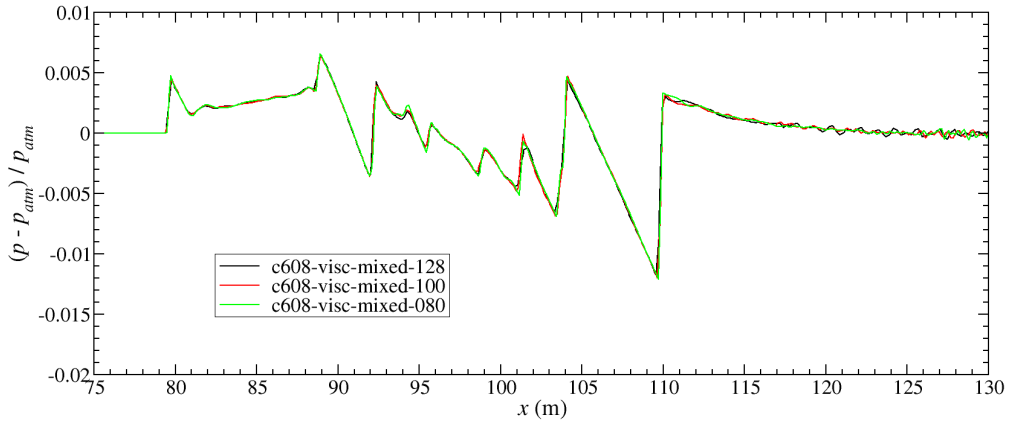
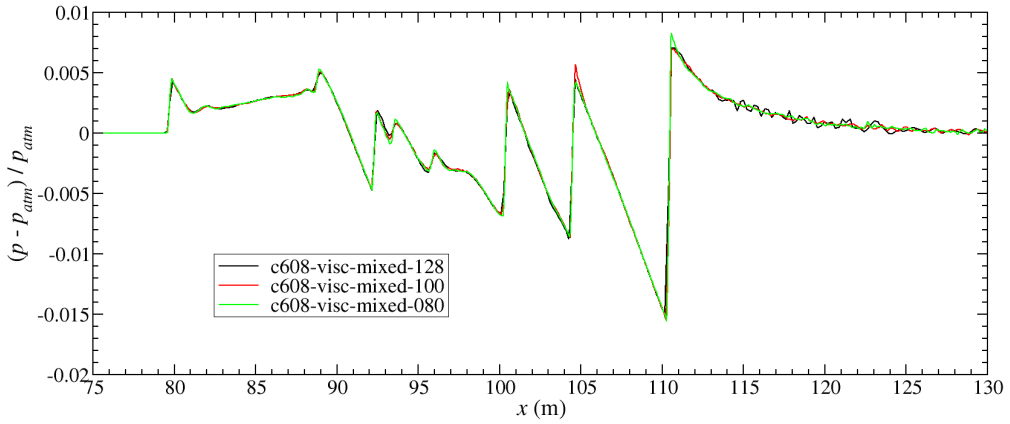
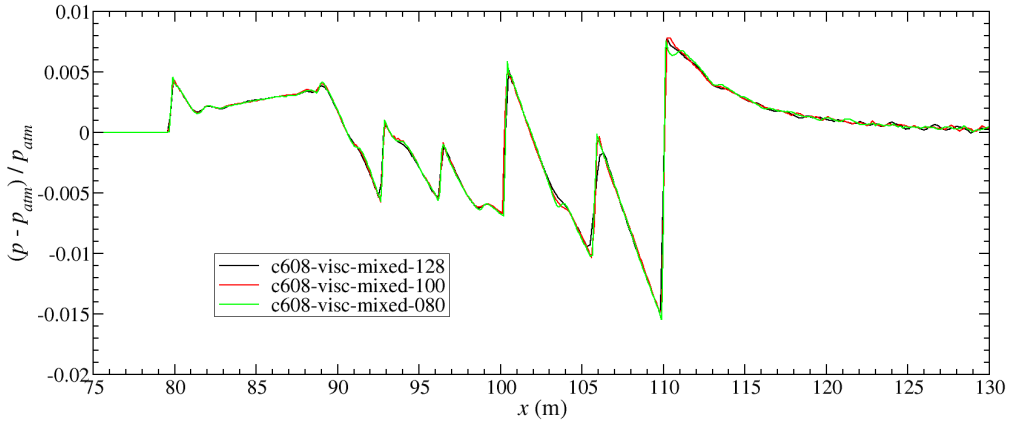
90 deg



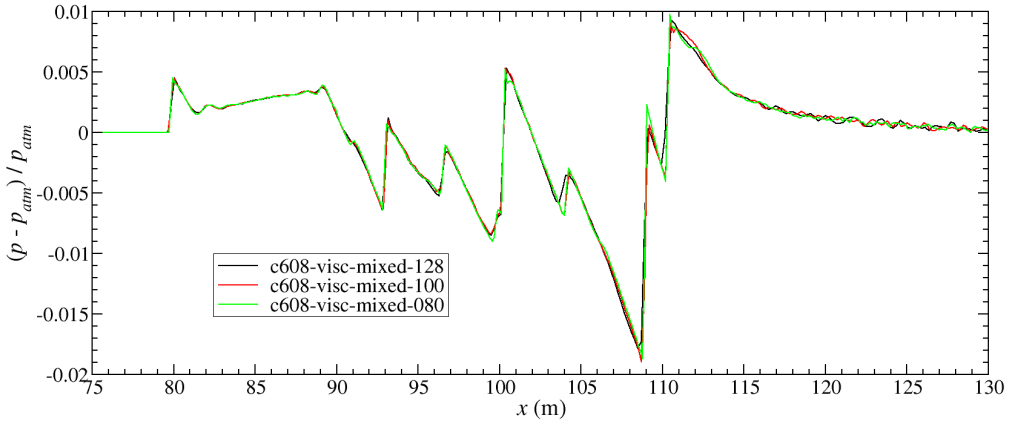
120 deg



150 deg



180 deg



Summary

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Caveat: Drawing conclusions before seeing comparison data for a blind test is always risky

- Current solutions suggest that even the coarsest workshop meshes give reasonable results
- As expected, increasing mesh resolution sharpens waves and provides more detail in plume region
- Specific to STAR-CCM+: New AutoCFL algorithm (with conservative settings) takes longer to converge, but seems to provide improved stability of results compared to previous Expert Driver algorithm

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Thank you.

Chris Nelson

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