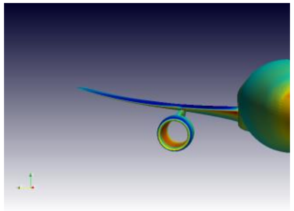
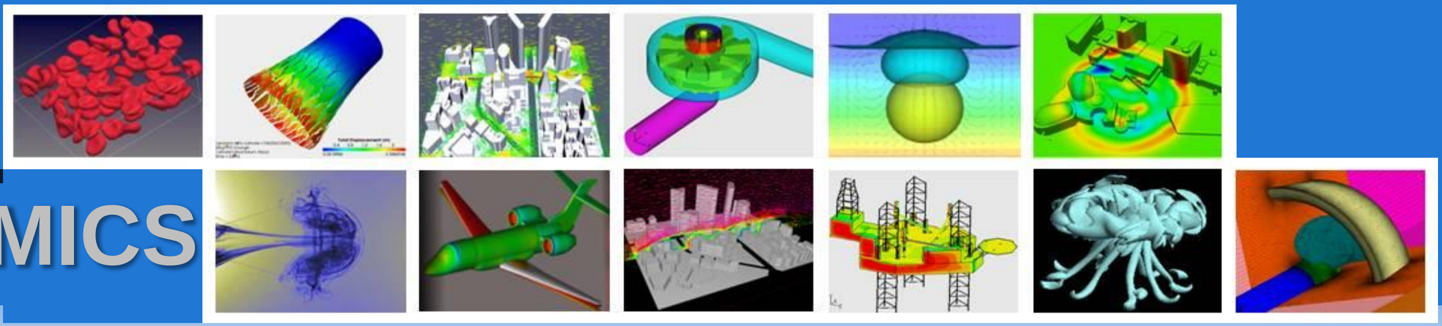
AIAA - 6TH DRAG PREDICTION WORKSHOP



FLUID DYNAMICS



Dominic Chandar

Nguyen Vinh-Tan, Raymond Quek and Sivamoorthy Kanagalingam

INSTITUTE OF HIGH PERFORMANCE COMPUTING(IHPC)

AGENCY FOR SCIENCE TECHNOLOGY AND RESEARCH(A*STAR)

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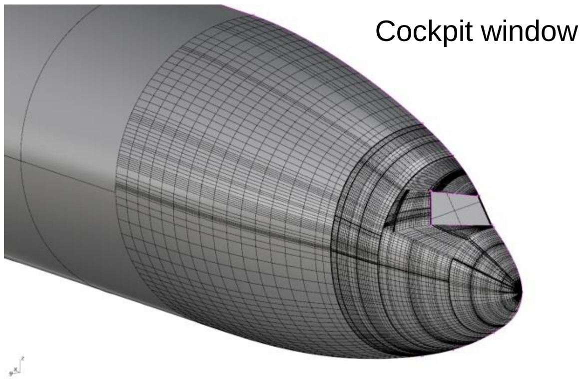
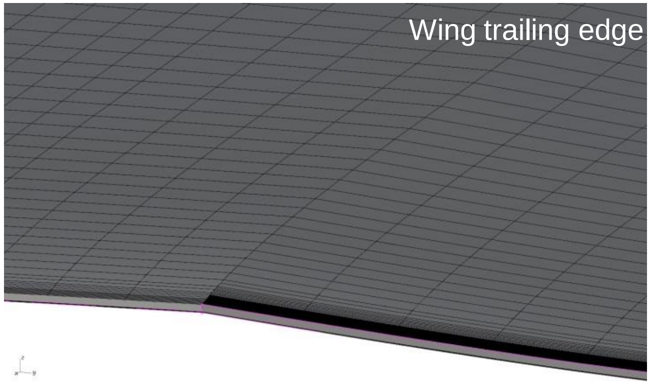
Agenda

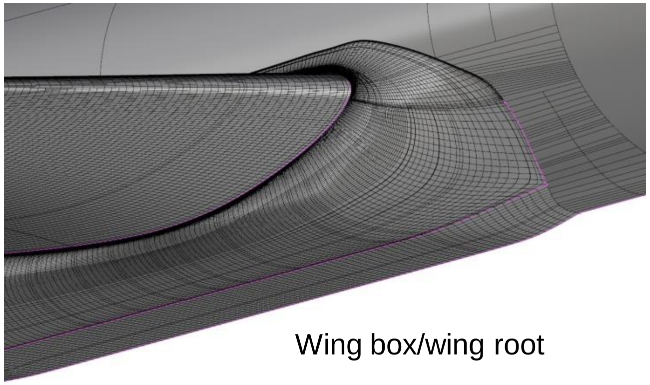
1. CRM Geometry issues
2. $\mu SICS$ flow solver introduction and capabilities
3. Case 2 – WB/WBNP Drag increment
4. Case 3 – Aeroelastic deflections
5. Conclusions

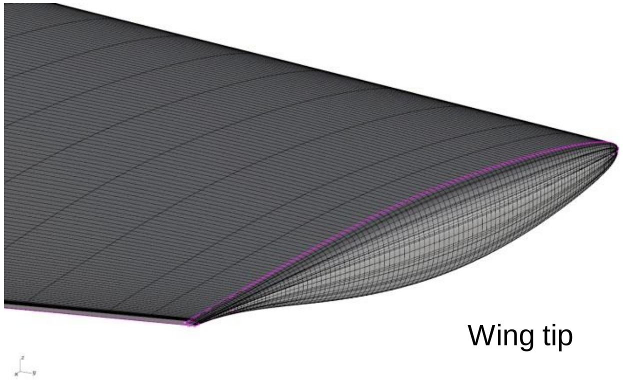
CRM Geometry Issues

Naked edges (magenta) when surfaces are joined at tolerance of 0.001”









DPW6_CRM_wbnp_ih+0_v09-2016-01-28_ae2.75deg_cf.stp

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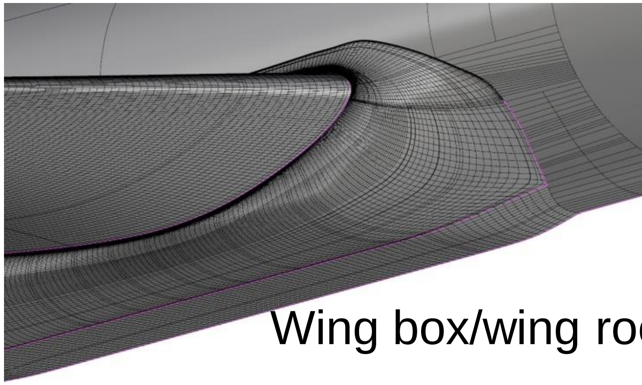
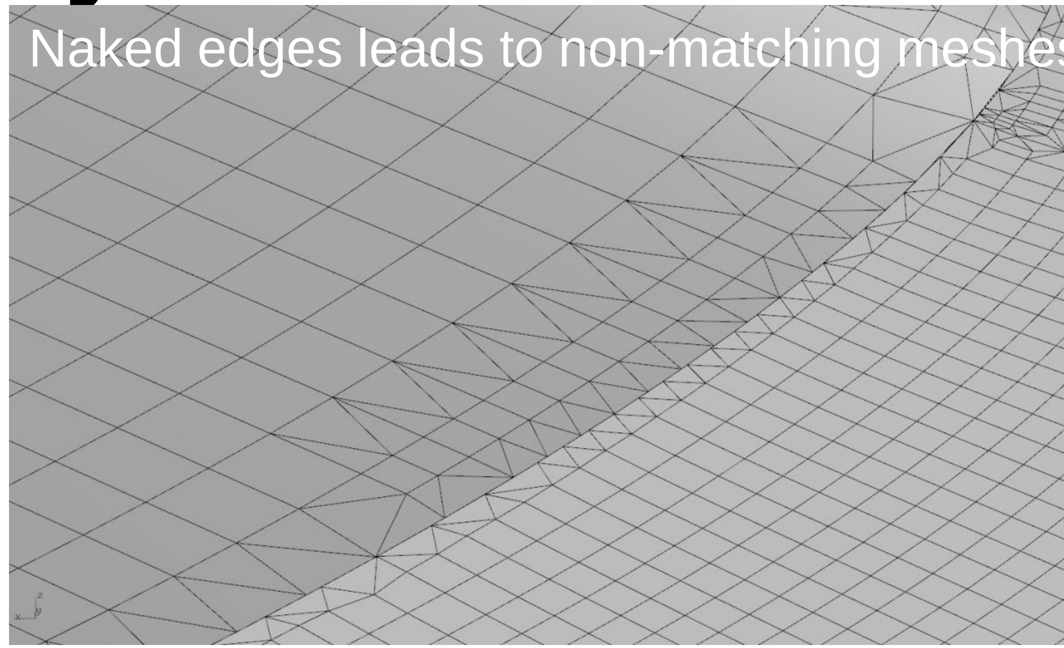
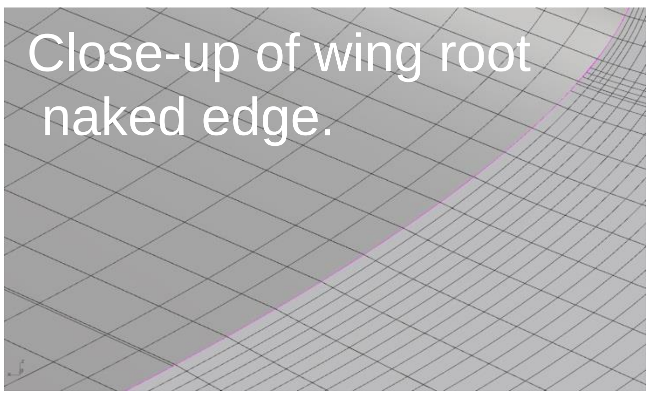
CRM Geometry Issues

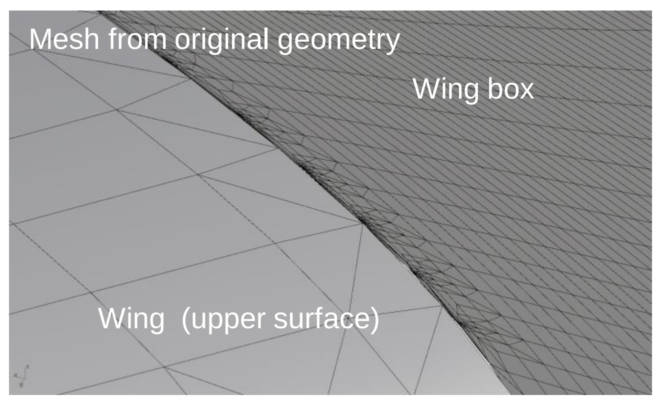


Wing box/wing root

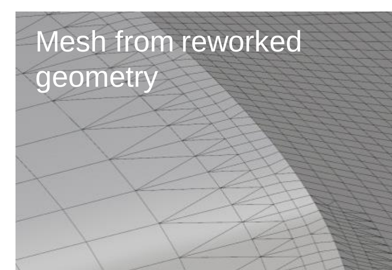


Close-up of wing root naked edge mesh for STL. Non-matching mesh is generated. May cause problems for mesher.





Collapsed mesh near wing root.



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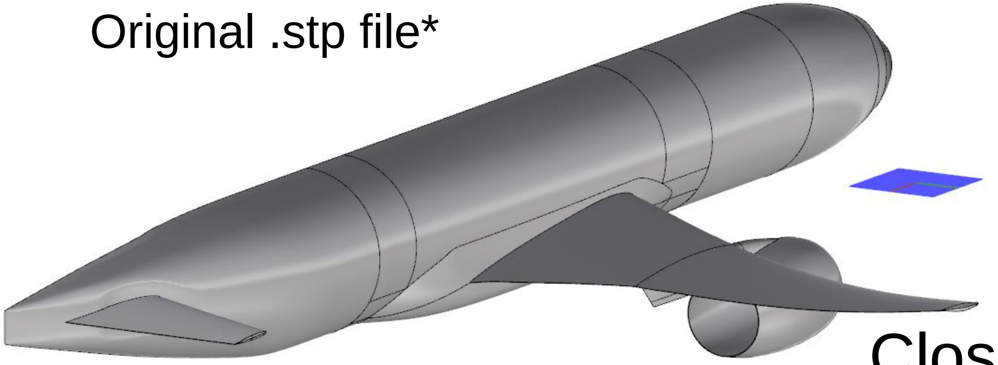
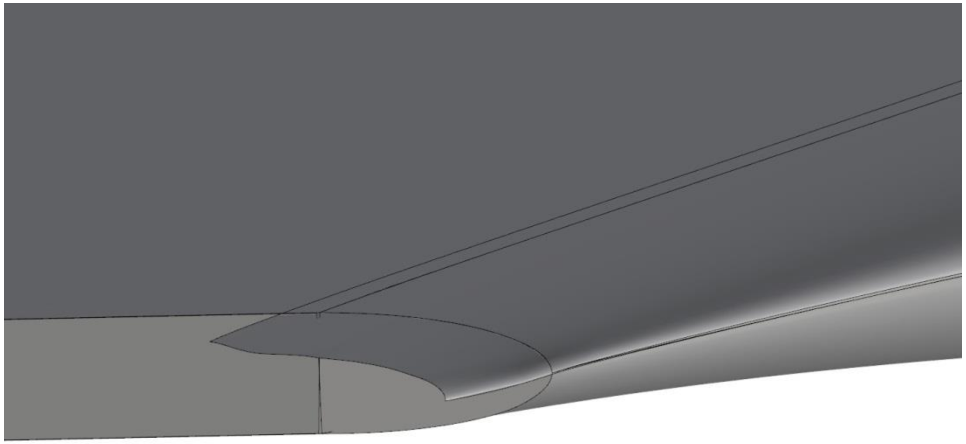
CRM Geometry Issues

Original .stp file*

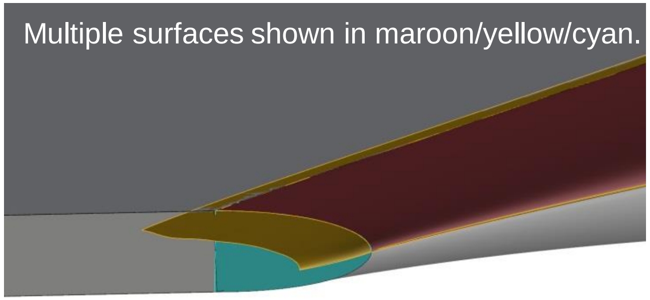


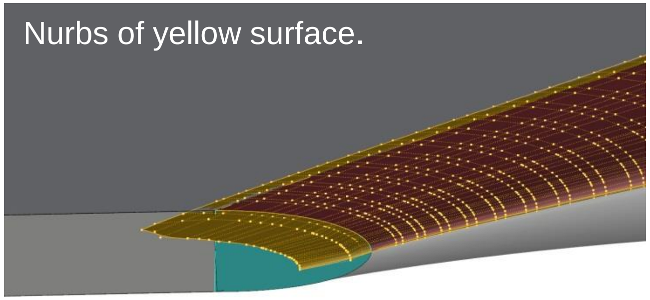
Close-up of trailing-edge wing tip

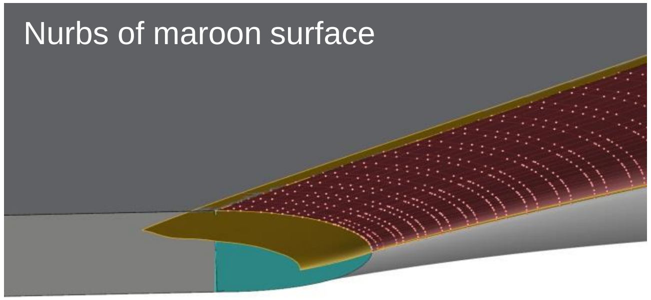


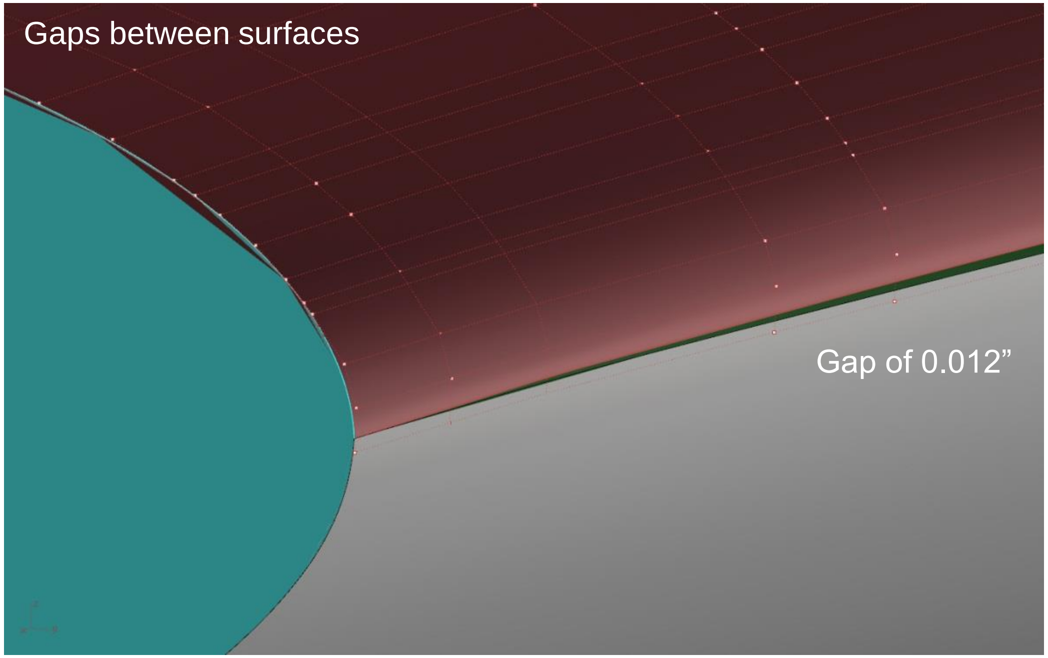
*DPW6_CRM_wbnp_ih+0_v09-2016-01-28_ae2.75deg_cf.stp

CRM Geometry Issues









DPW6_CRM_wbnp_ih+0_v09-2016-01-28_ae2.75deg_cf.stp

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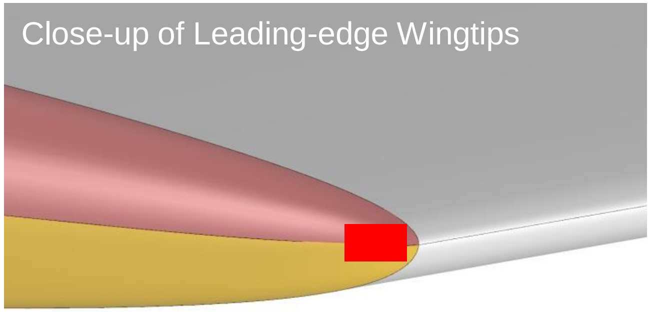
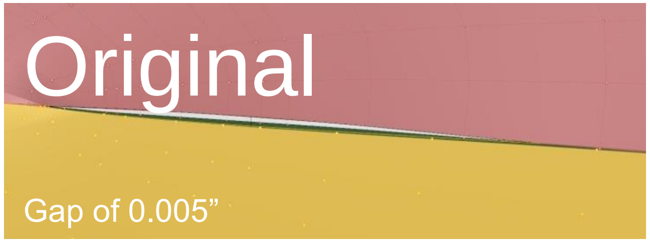
CRM Geometry Issues





CRM Geometry Issues - Summary

- Gaps are small, but enough to flag warnings and errors in muSICS mesher. Mesher attempts to join the gaps, sometimes with undesirable results.

- Some gaps result in naked edges; STL surface mesh does not match

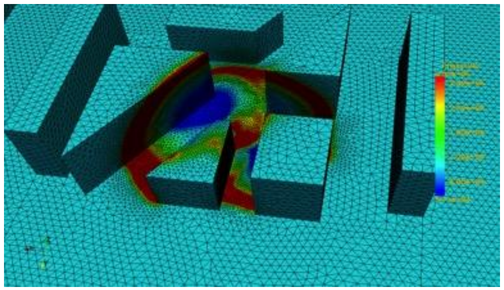
- UV point arrangement result in collapsed mesh.

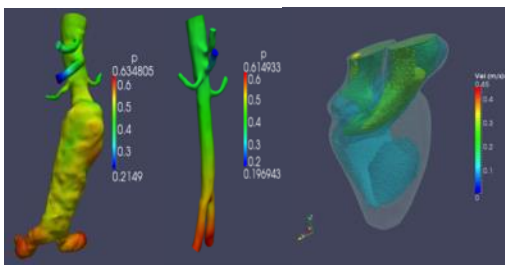
- If a nurb surface is too small, mesher attempts to extend the nurb surface, sometimes with undesirable results.

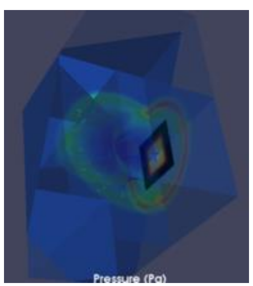
- Therefore most of the surfaces were reworked to make nurbs precisely represent the surface.

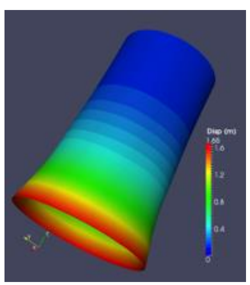
μSICS – Multiphysics Simulation of Interactive and Coupled Systems

μSICS: a FSI computational framework









Robust and efficient flow solvers

- compressible, incompressible flows,
- free surface

Fast and reliable structural solvers

- Non-linear, large deformation
- fractures, fragmentation, multi-body flow structure interactions

Advanced meshing capability

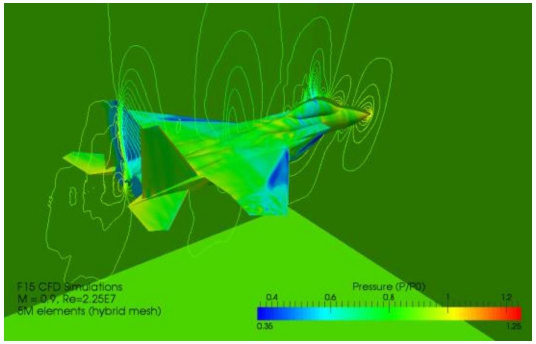
- Unstructured mesh generation for complex domains
- Fast local feature-based mesh adaptation

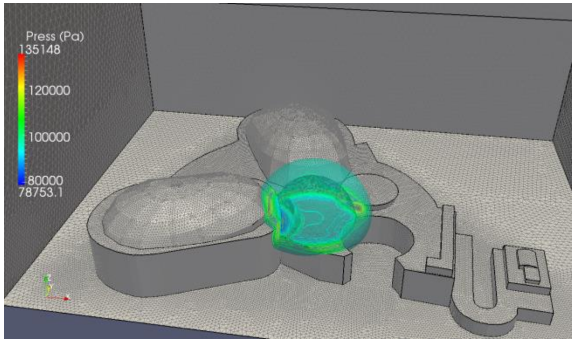
Versatile and accurate coupler

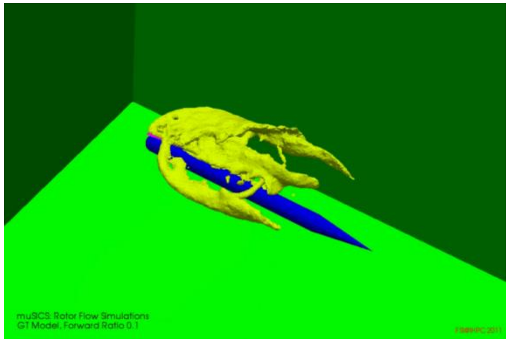
- advanced coupling approaches, accurate coupling algorithms

*μSICS developed from FLITE cores in collaboration with Swansea University

µSICS Capabilities







- Physics
  - Compressible Navier-Stokes flows
    - Subsonic, supersonic flows
  - Incompressible (density-based) flows
  - Turbulence models
    - RAS: SA, ke, kwSST
  - Multiple component gas
    - Ideal gas EOS, Jones-Wilkins-Lee
- Numerics
  - 3D unstructured edge-based vertex centered solver
    - Artificial dissipation (JST)
  - Multigrid solution techniques
    - Automatic agglomeration
  - Advanced shock capturing schemes
    - HLLC 2nd Order shock capturing
    - TVD, LED solution limiters

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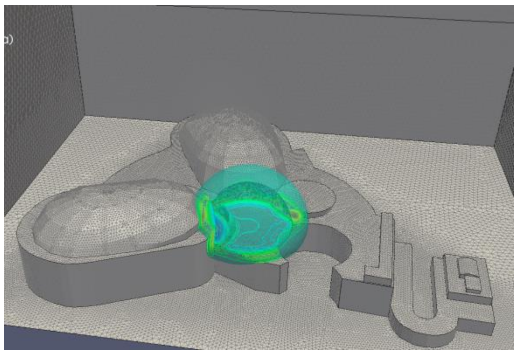
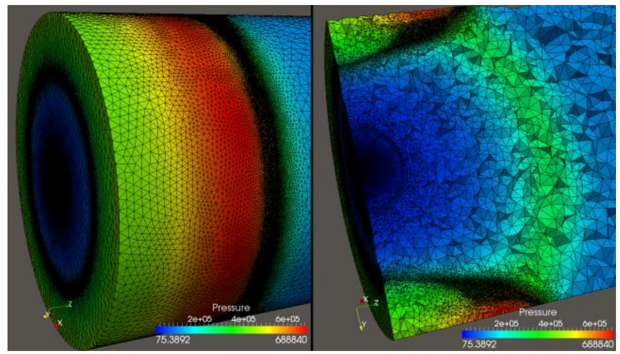
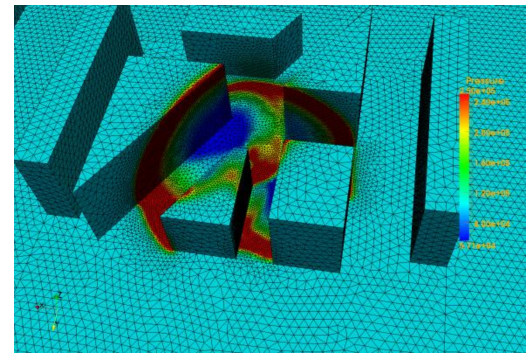
μSICS Capabilities







- Mesh adaptation
  - Feature-based mesh adaptation
  - Refinement: computing optimal nodal spacing, cutting holes, point distribution and refill holes
  - Surface and edge refinement
- Unstructured grid generation
  - Advancing front surface and Delaunay volume mesh generation
  - Hybrid unstructured mesh: advancing layer method

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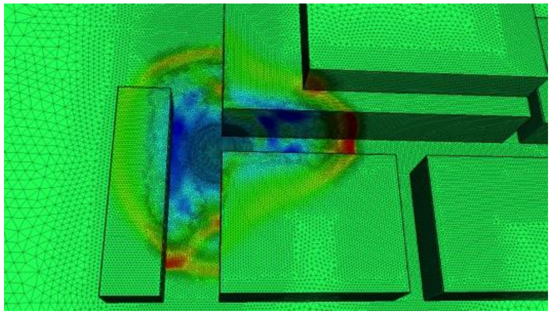
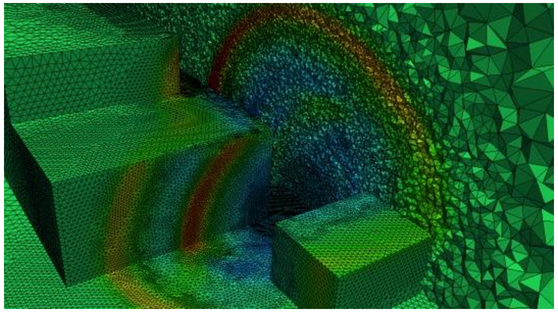
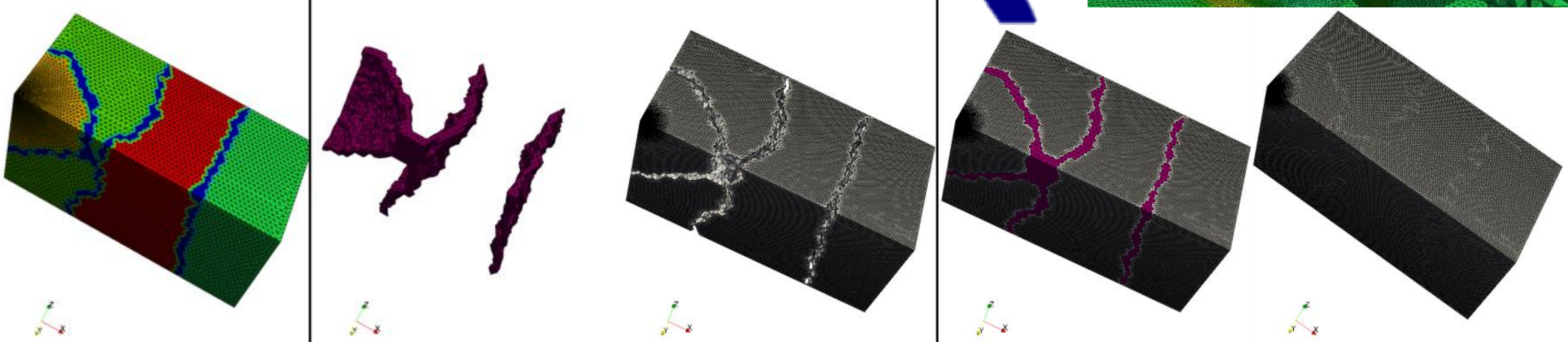
Mesh Generation and Adaptation

- Unstructured mesh generation
  - A desired hybrid unstructured mesh generation process for very large scale applications
  - Feature based adaptation
  - Parallel mesh generation



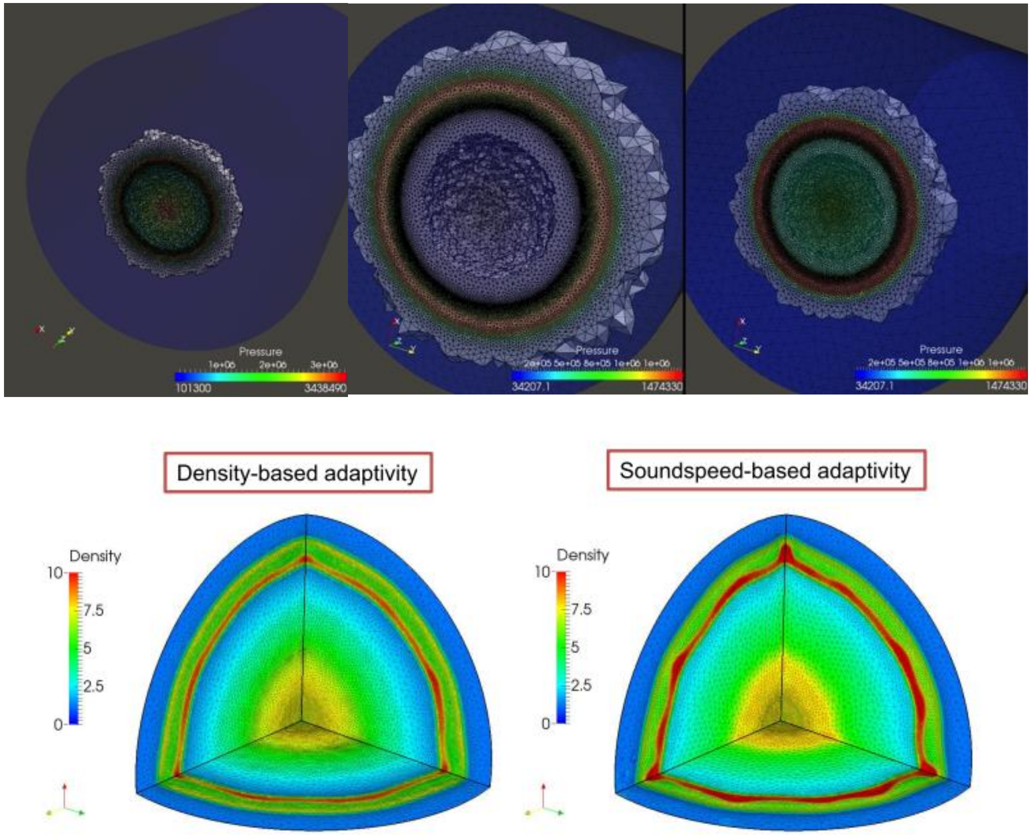


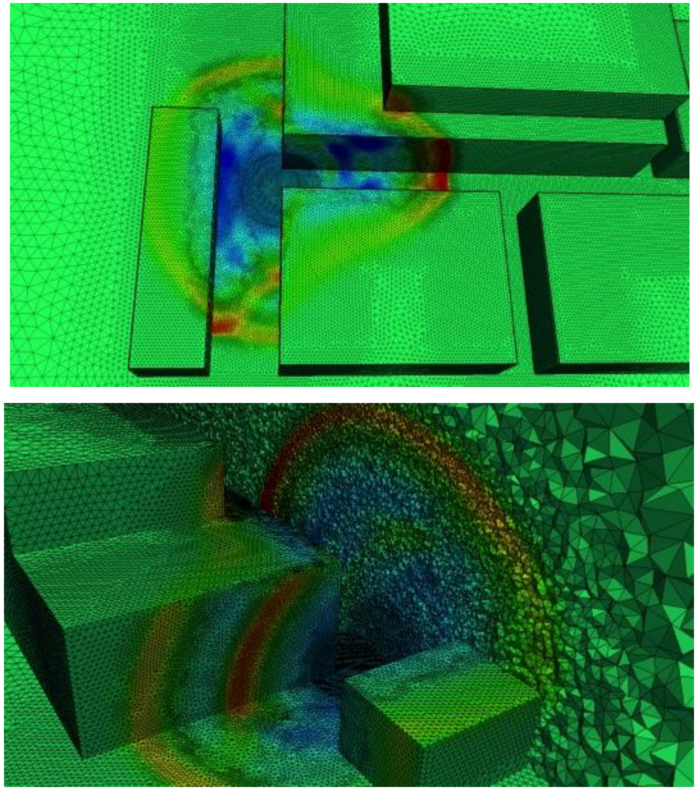


H.H. Nguyen et al, Meshing Roundtable 2013
H. H. Nguyen et al.,, Applied Math. Modelling, 2015

Mesh Generation & Adaptation

- Feature based adaptivity



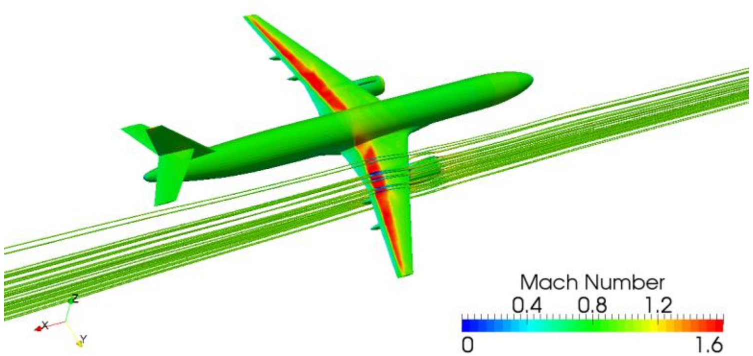


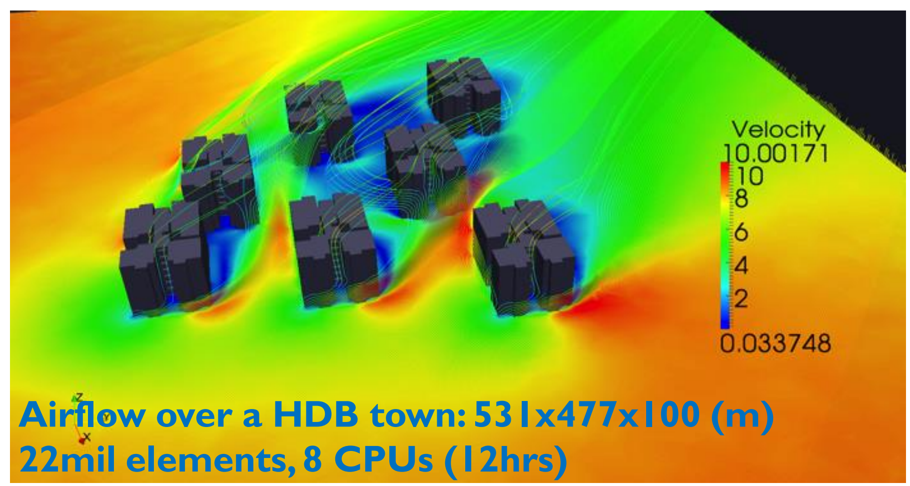
Blast in an Urban Environment

H. H. Nguyen et al., A Local Solution-Based Mesh Adaptation on Unstructured Grids for Computational Fluid Dynamics, Applied Math. Modelling, 2015

Flow Solvers Development

- Incompressible and compressible flow solvers
  - All-speed flow solvers (incompressible, compressible)
  - Parallelized solver with good scalability
  - Designed for large-scale applications with robustness and efficiency





V. T. Nguyen, et al., Shock Capturing Schemes with Local Mesh Adaptation on Unstructured Grids in Three Dimensions, *Computers & Fluids*, 70 (2012) 126-135.

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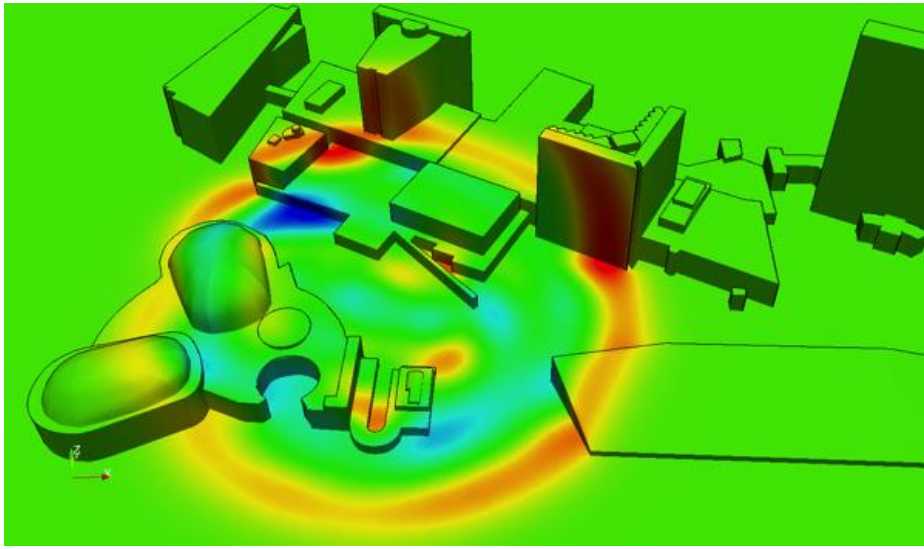
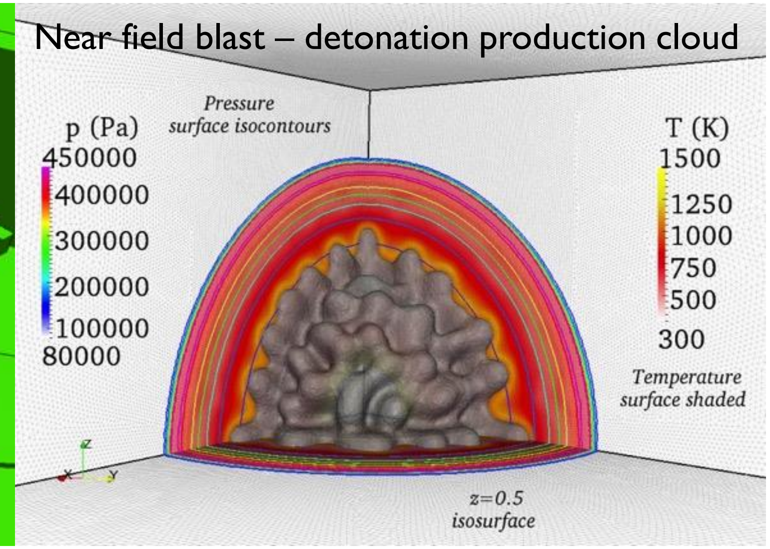
Multimaterial Compressible Solver





- Multimaterial compressible flow solver
  - Inviscid, compressible, multi-fluid flow model
    - Mass conservation for each phase + phase transport equation (5-equation model), isobaric closure (P=const), single mixture velocity
    - Combined with sub-models: detonation model, Langrangian particles (fragmentations, shape-charges, etc).

Price et al.,, *Journal of Computers and Fluids*, 2014.
V. T. Nguyen, et al., *Computers & Fluids*, 70 (2012) 126-135

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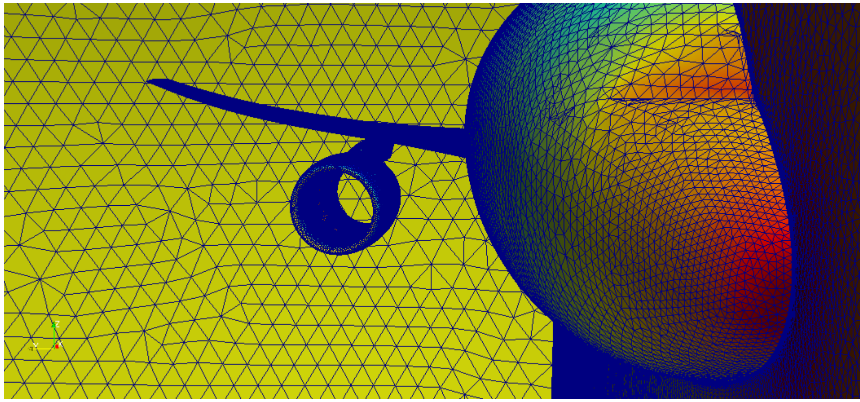
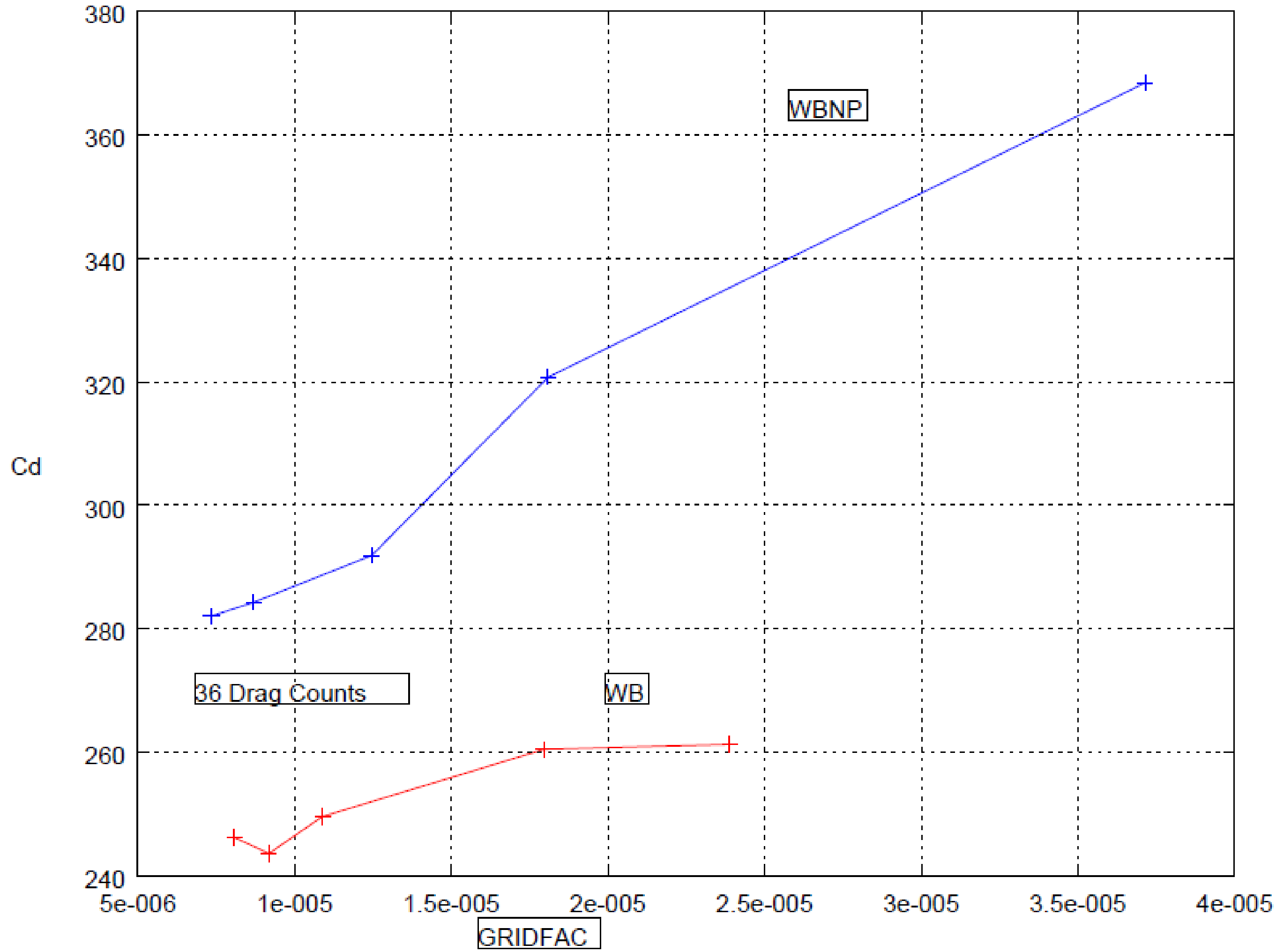
Grid Metrics - Nodes



Grid	WB	WBNP	1^{st} Cell
T	8.57M	4.05M	0.0005
C	13.13M	12.99M	0.0005
M	27.83M	22.73M	0.0004
F	35.94M	38.99M	0.0004
X	43.59M	50.3M	0.0003
U	57.03	-	0.0002

Case 2 – Drag convergence



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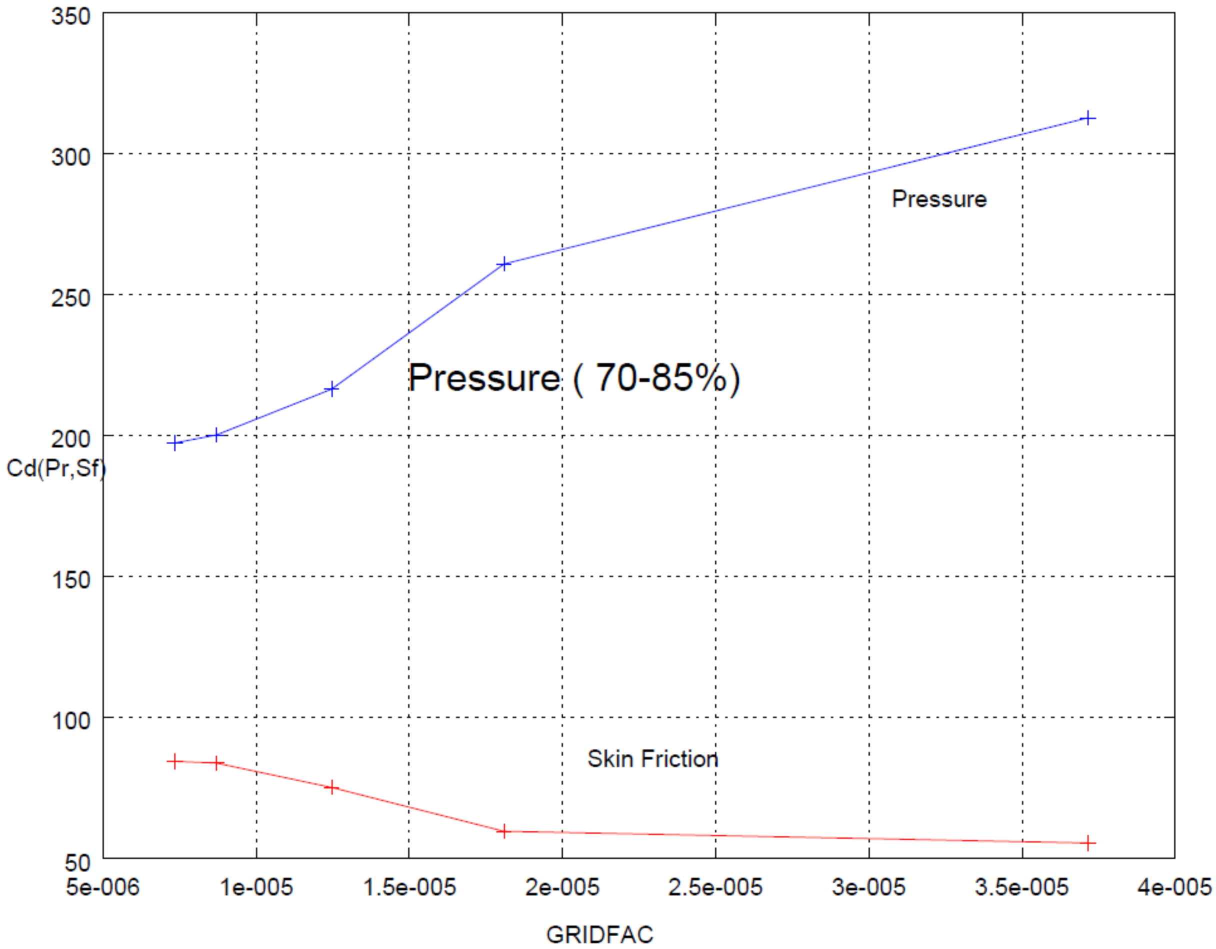
Case 2 – Drag convergence



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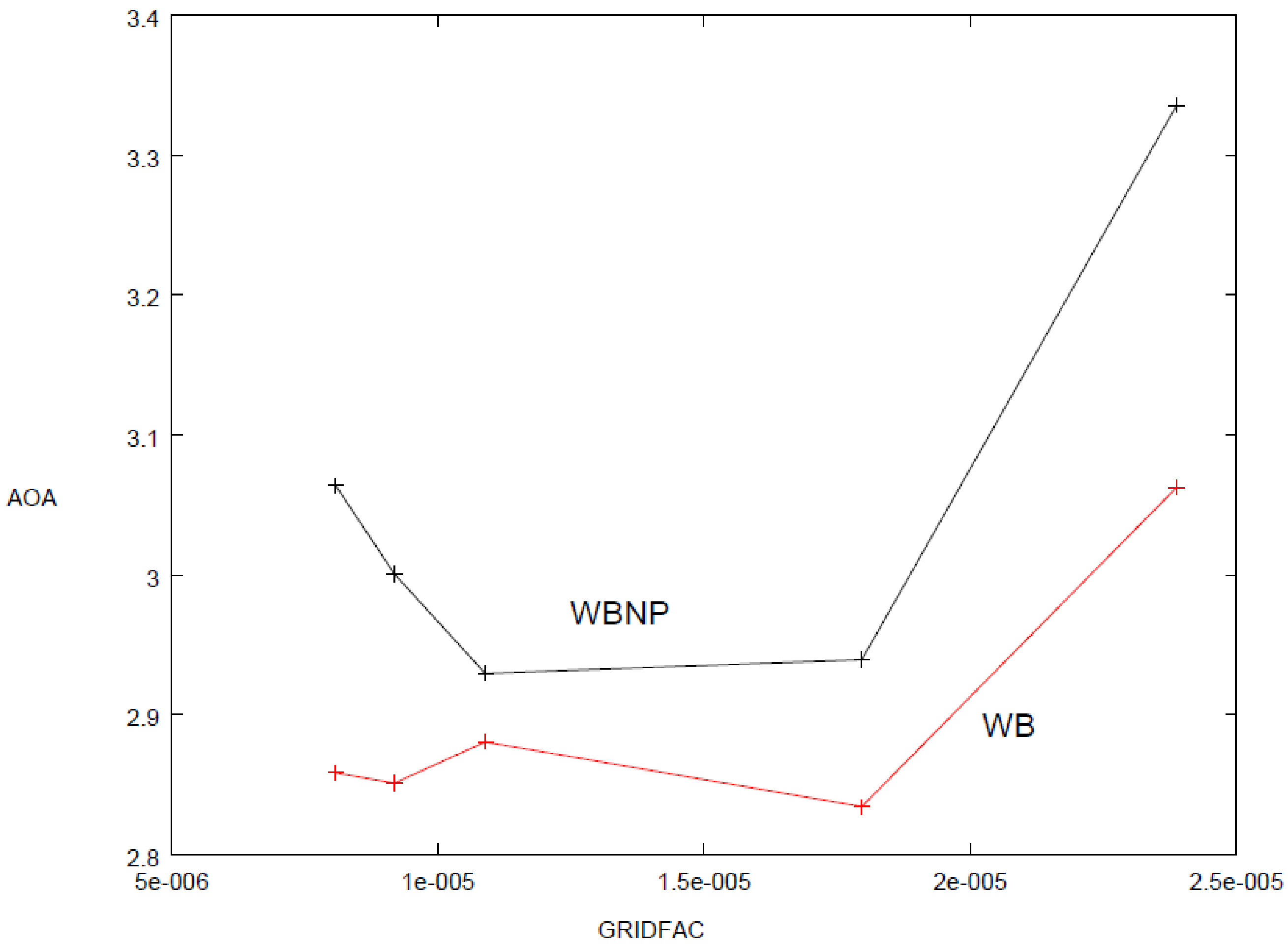
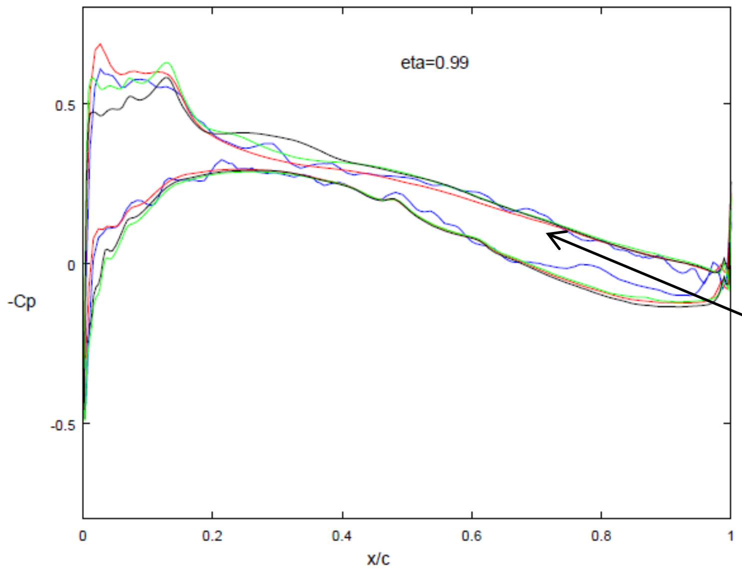
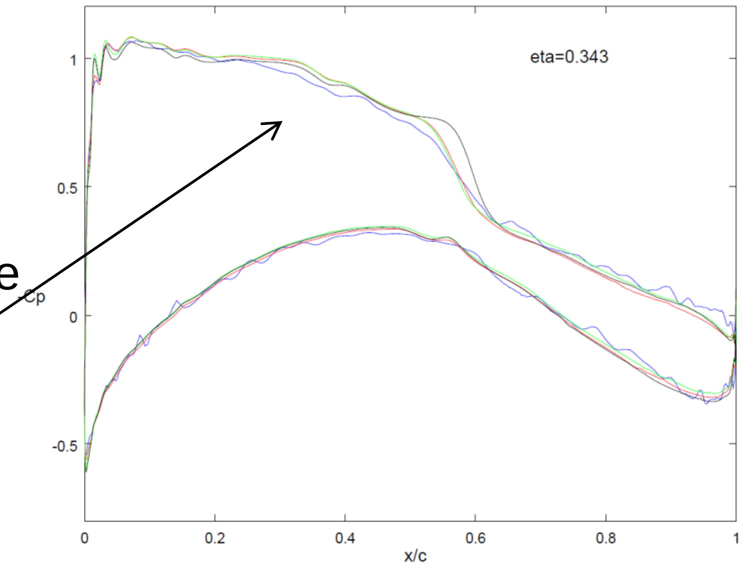
Case 2 – Drag convergence

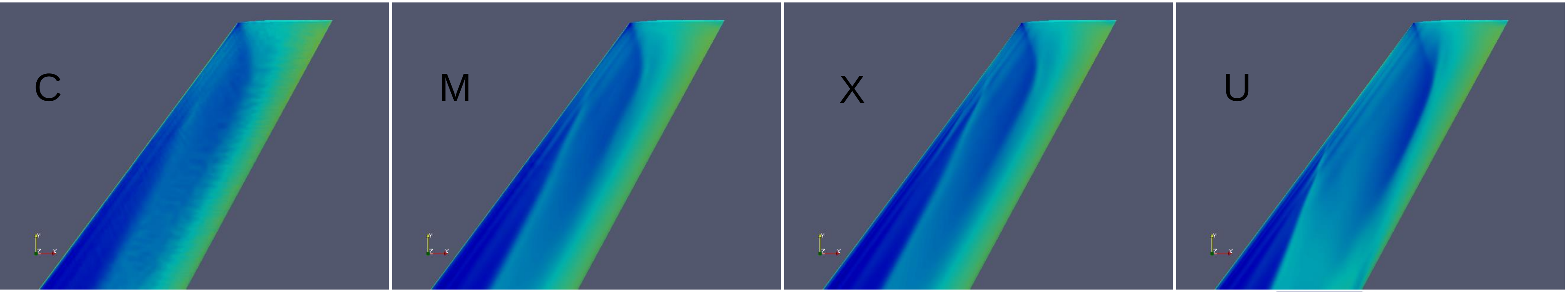


Case 2 – Sectional Cp

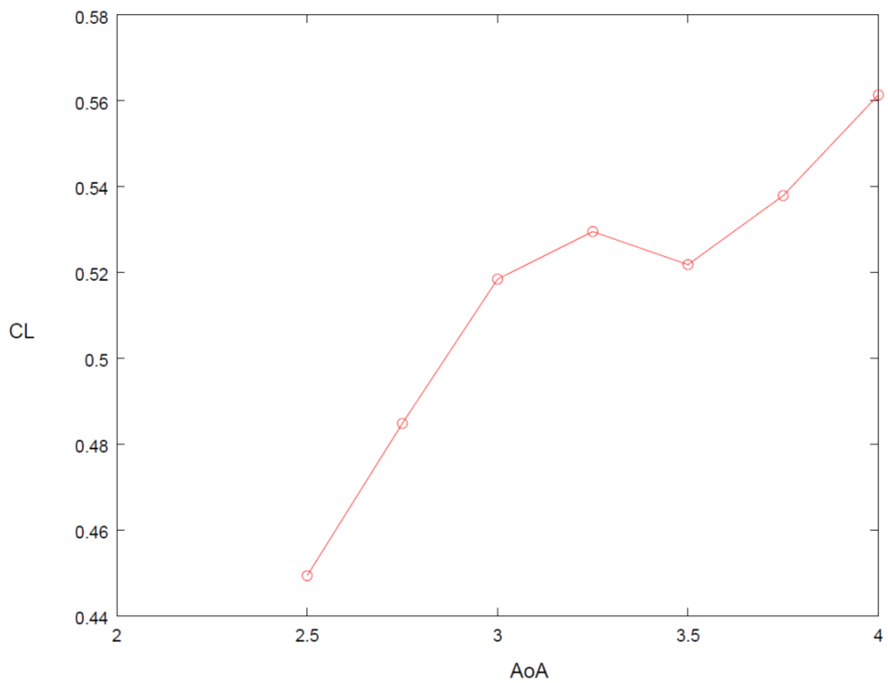


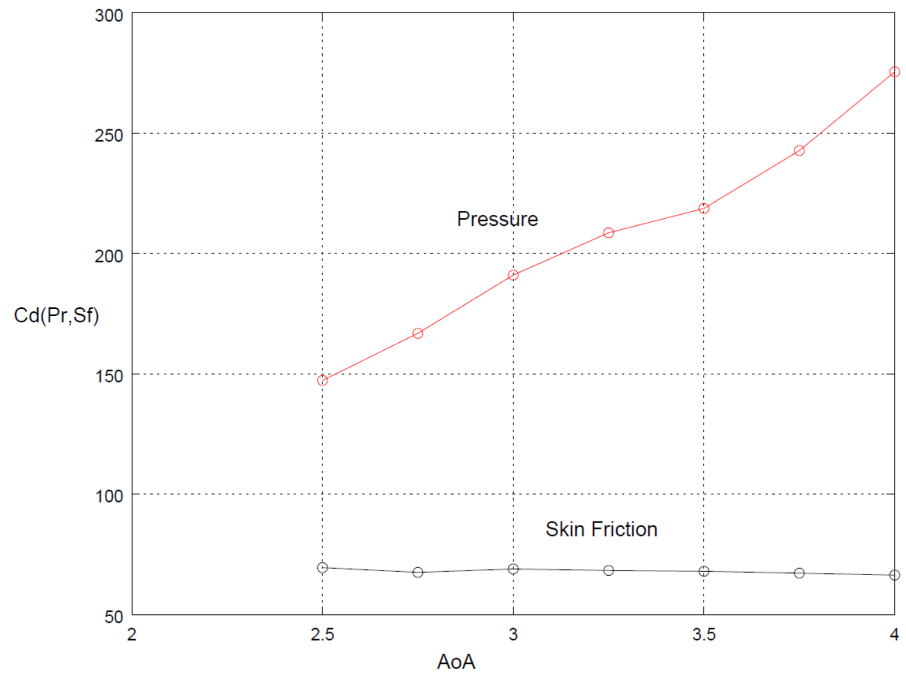
Convergence
With
Grid size





Case 3 – Angle of Attack Sweeps

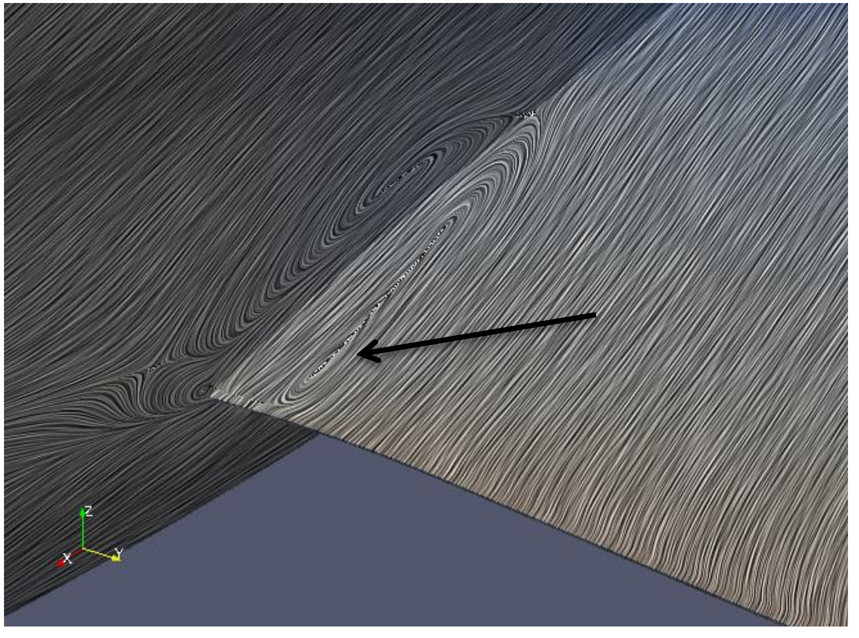




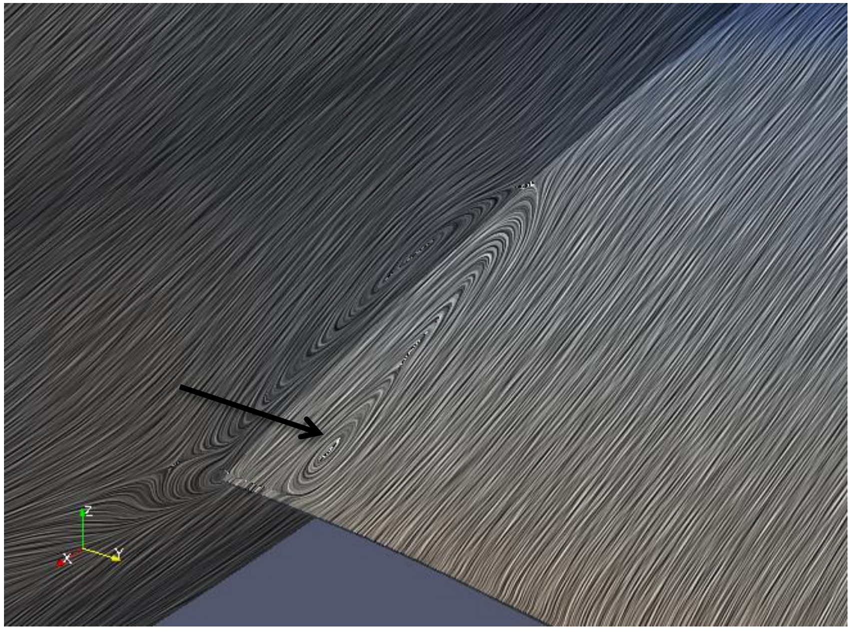
Dip in the lift curve between 3 and 3.5

Skin friction drag varies by ~ 3 drag counts over the range of AoA

Surface LIC – SOB Separation



Coarse



Medium

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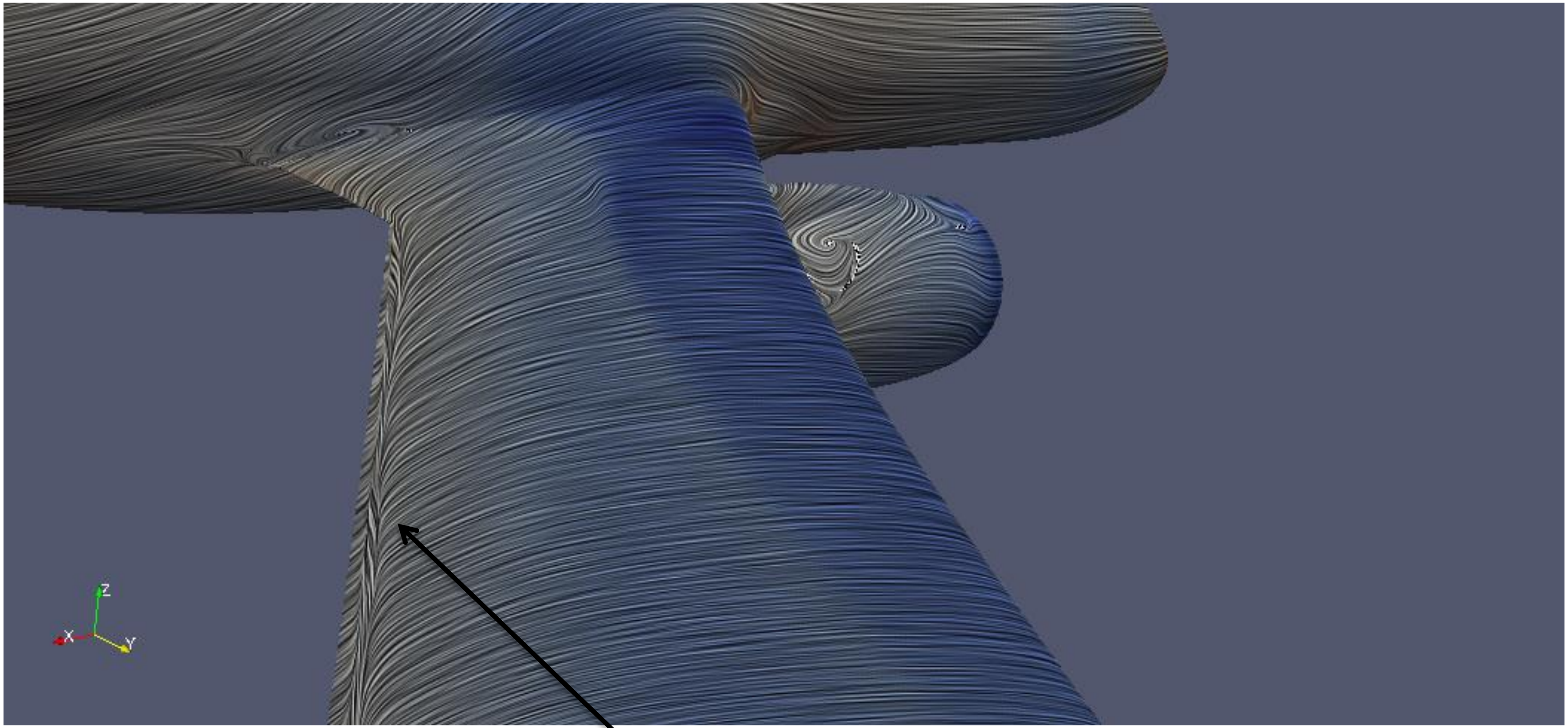
Surface LIC – T.E Separation



T.E Separation well captured

Concluding Remarks

1. CRM Geometry clean-up consumed considerable amount of time
2. 36 drag count delta for NP compared to some of others with 24 drag counts.
3. Drag convergence as per existing data – heading in the right direction for better validation and verification of muSICS.
4. SOB separation is visible from surface LIC contours.