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Current Practice Unstructured Grid CFD Results for 3rd AIAA High Lift Prediction Workshop

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Overview

- **Completed series of simulations based on High Lift Prediction Workshop 3 cases to assess flow solvers, committee-provided grids, and turbulence models**
  - Specific focus on JAXA Standard Model without pylon (Case 2a)
  - Emphasis is on comparing CFD results, not comparison to experiment
  - CFD Solvers: BCFD, CFD++, GGNS
  - Grids: JAXA (D), ANSA (E), VGRID (C)
  - Turbulence Models: Spalart-Allmaras (SA), SA-QCR, SA-RC-QCR
- **Principal results:**
  - Different CFD codes on same/similar meshes with same turbulence model generate similar results
  - Mesh and turbulence model differences lead to different results
  - Once significant flow separation occurs, families of pseudo-solution attractors appear that are associated with flow separation from different slat brackets

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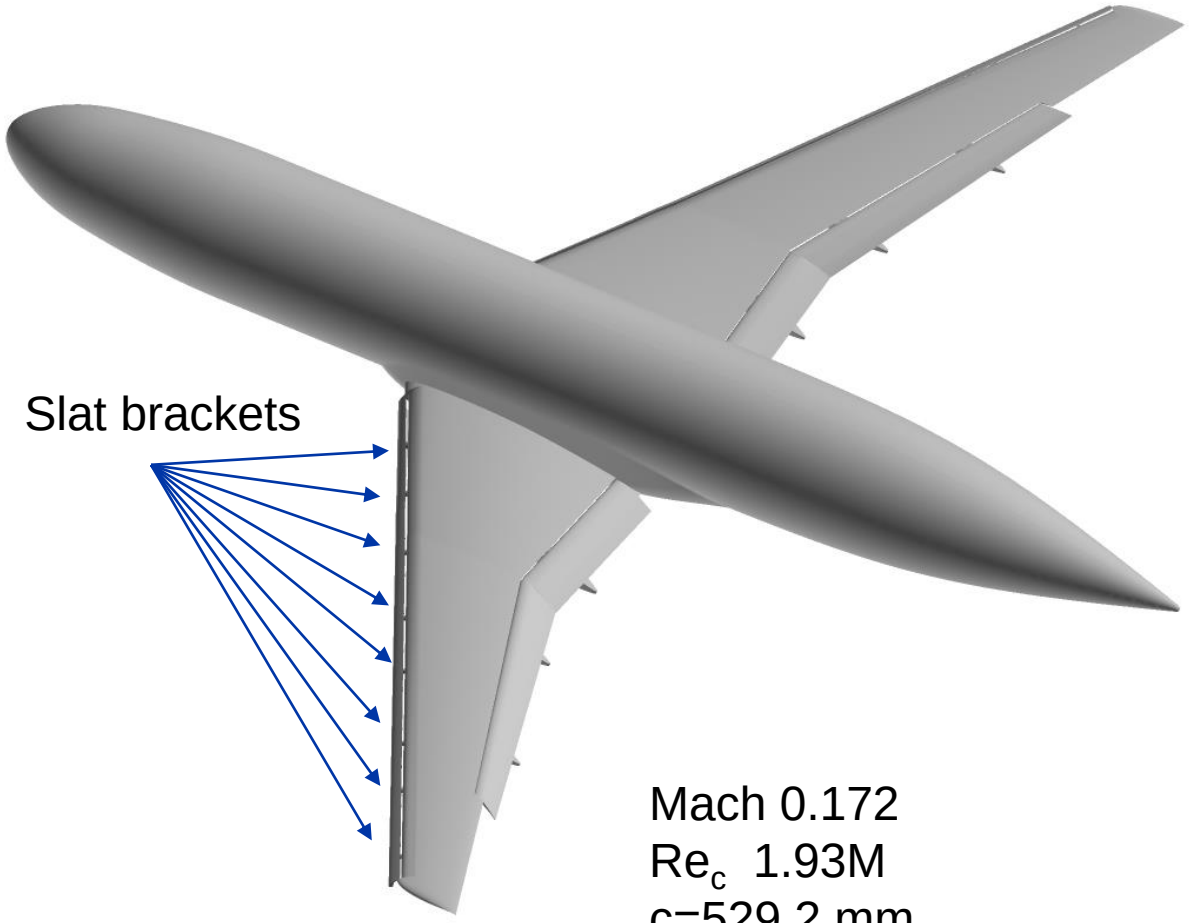
JSM Case overview (case 2a)



Mach 0.172
Re_c 1.93M
c=529.2 mm

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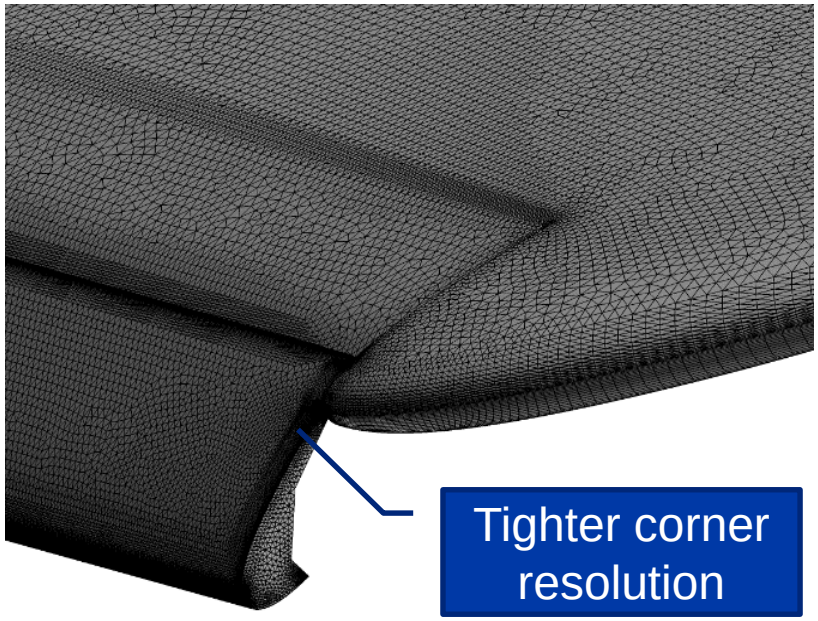
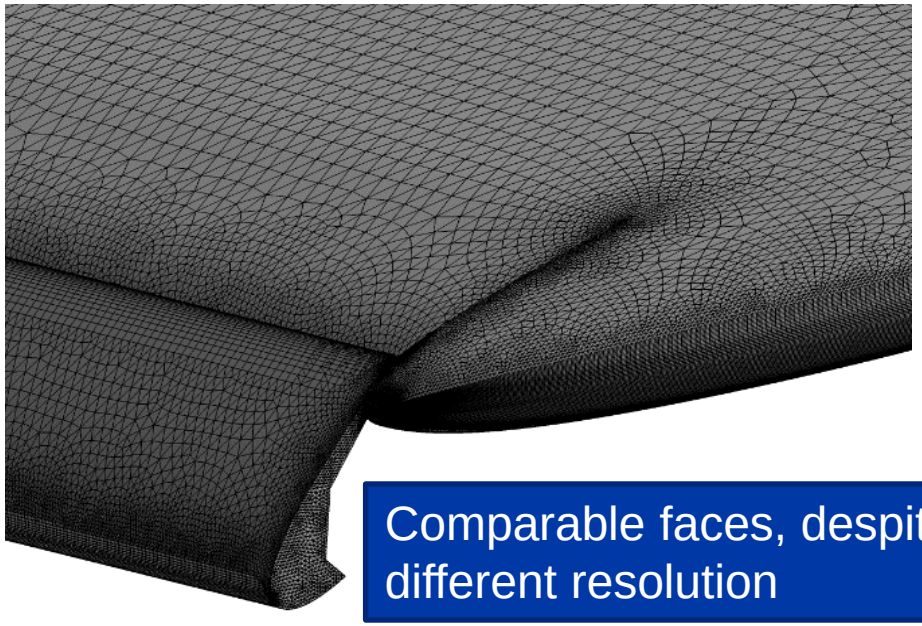
Mesh Comparison - Surface





JAXA Grid (D)

ANSA Grid (E)

Grid Series	Grid Type	Number of Volume Cells	Number of Volume Nodes	Wall Faces	Number of Hex/Prism cells
C1 - VGRID	Tetrahedra	96.6M	16.4M	0.93M	N/A
D – JAXA	Mixed Element	120M	50.4M	1.49M	81.3M
E – ANSA	Mixed Element	107M	51.9M	1.64M	79.5M
E2 - ANSA (fine)	Mixed Element	165M	82.8M	1.81M	129M

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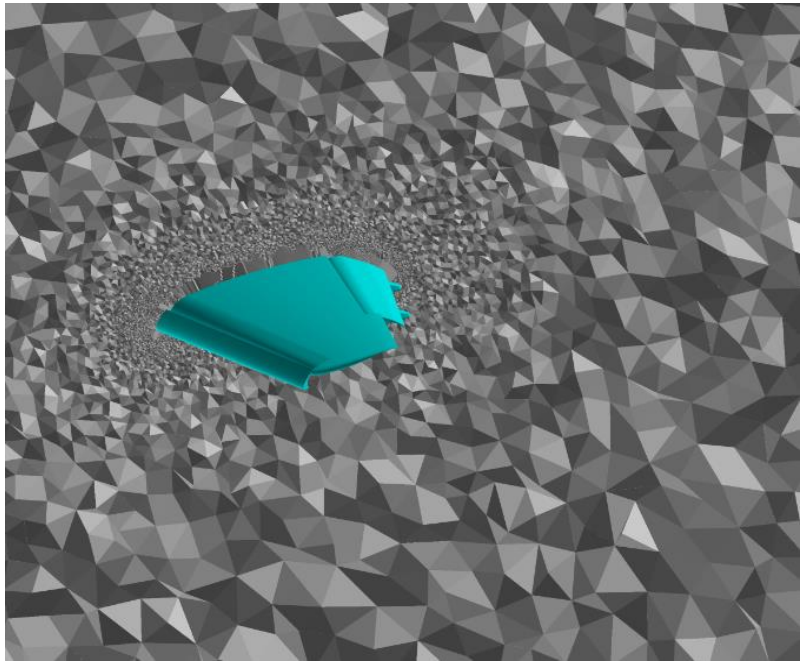
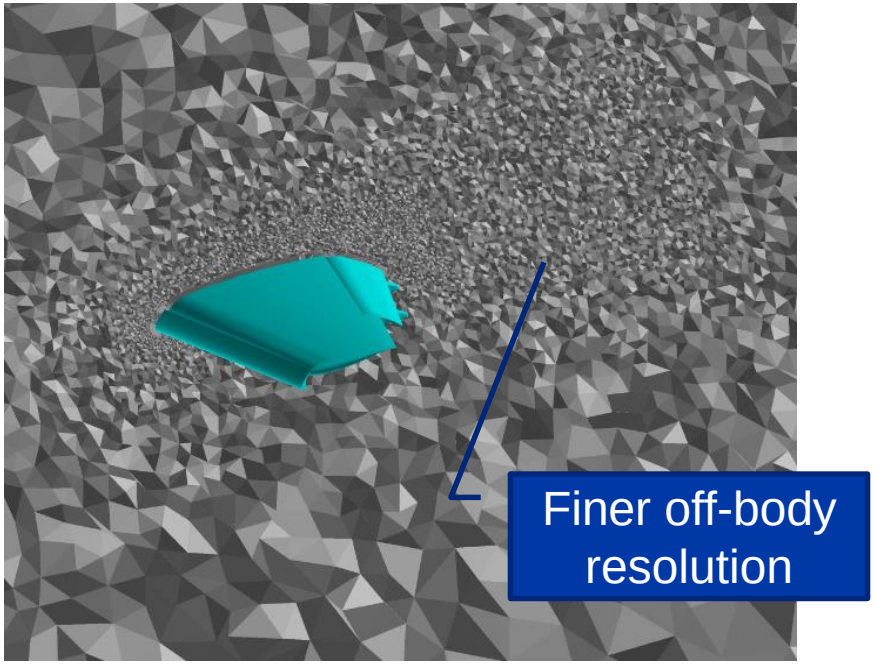
Mesh Comparison - Volume



JAXA Grid (D)



ANSA Grid (E)

Grid Series	Grid Type	Number of Volume Cells	Number of Volume Nodes	Wall Faces	Number of Hex/Prism cells
C1 - VGRID	Tetrahedra	96.6M	16.4M	0.93M	N/A
D – JAXA	Mixed Element	120M	50.4M	1.49M	81.3M
E – ANSA	Mixed Element	107M	51.9M	1.64M	79.5M
E2 - ANSA (fine)	Mixed Element	165M	82.8M	1.81M	129M

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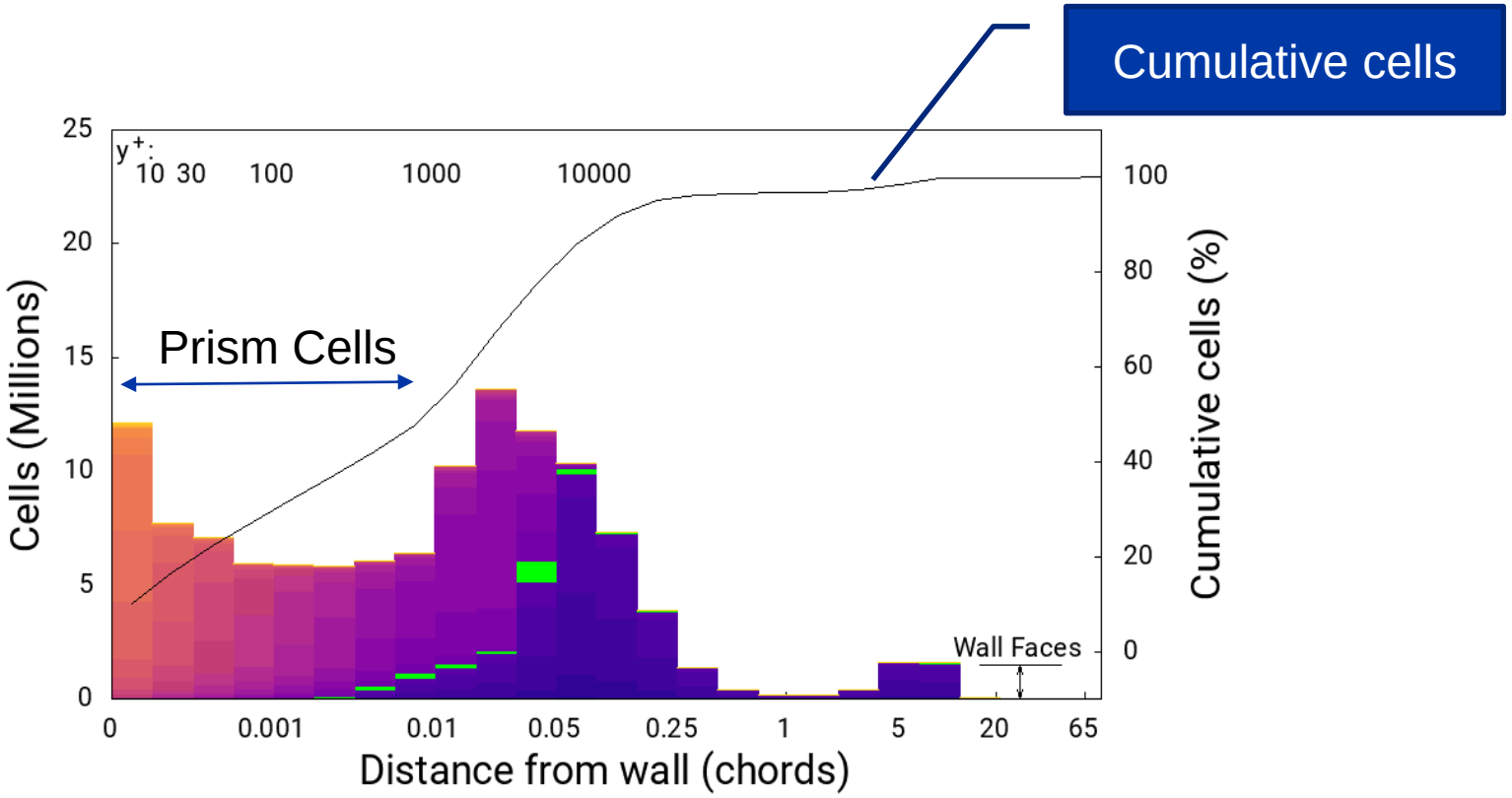
Volume Mesh Statistics



- Bins of wall distance (geometric growth)
- Cells colored by aspect ratio (green division is AR=2)
- 35% cells are within y^+ approx. 50
- 80% cells are within 5% MAC of body

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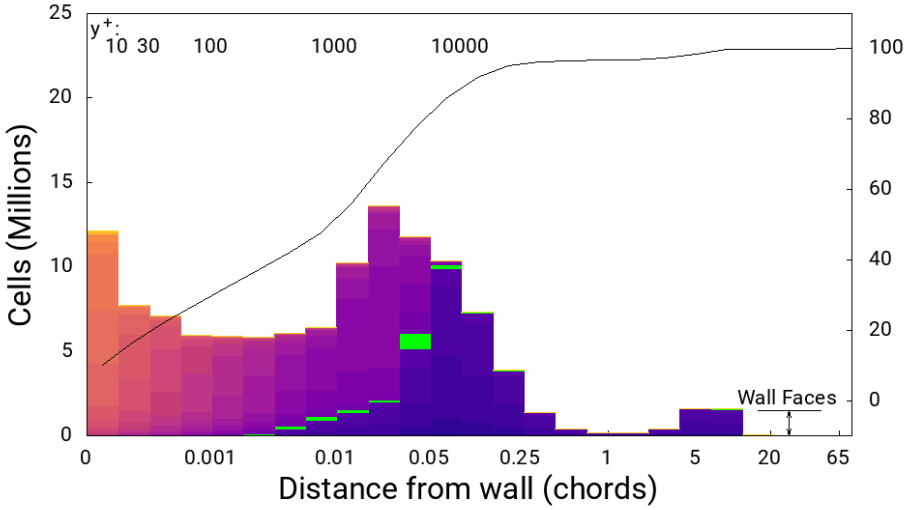
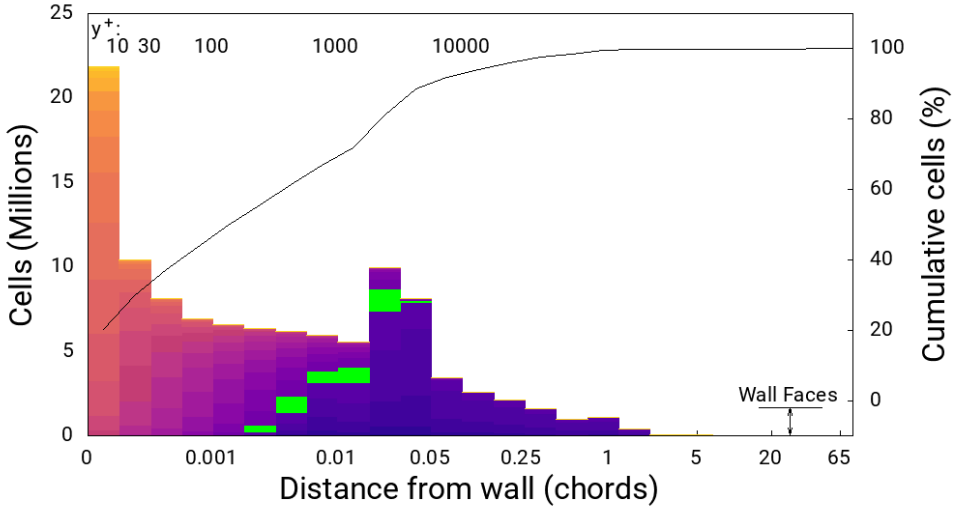
Mesh Comparison – Volume Metrics



JAXA Grid (D)



ANSA Grid (E)

- **ANSA grid packs more cells in lower part of boundary layer**
- **ANSA grid has less overall resolution between 5% and 25% chord, but more resolution at about 1 chord**

- **Image does not reflect spacing/distribution on surface**

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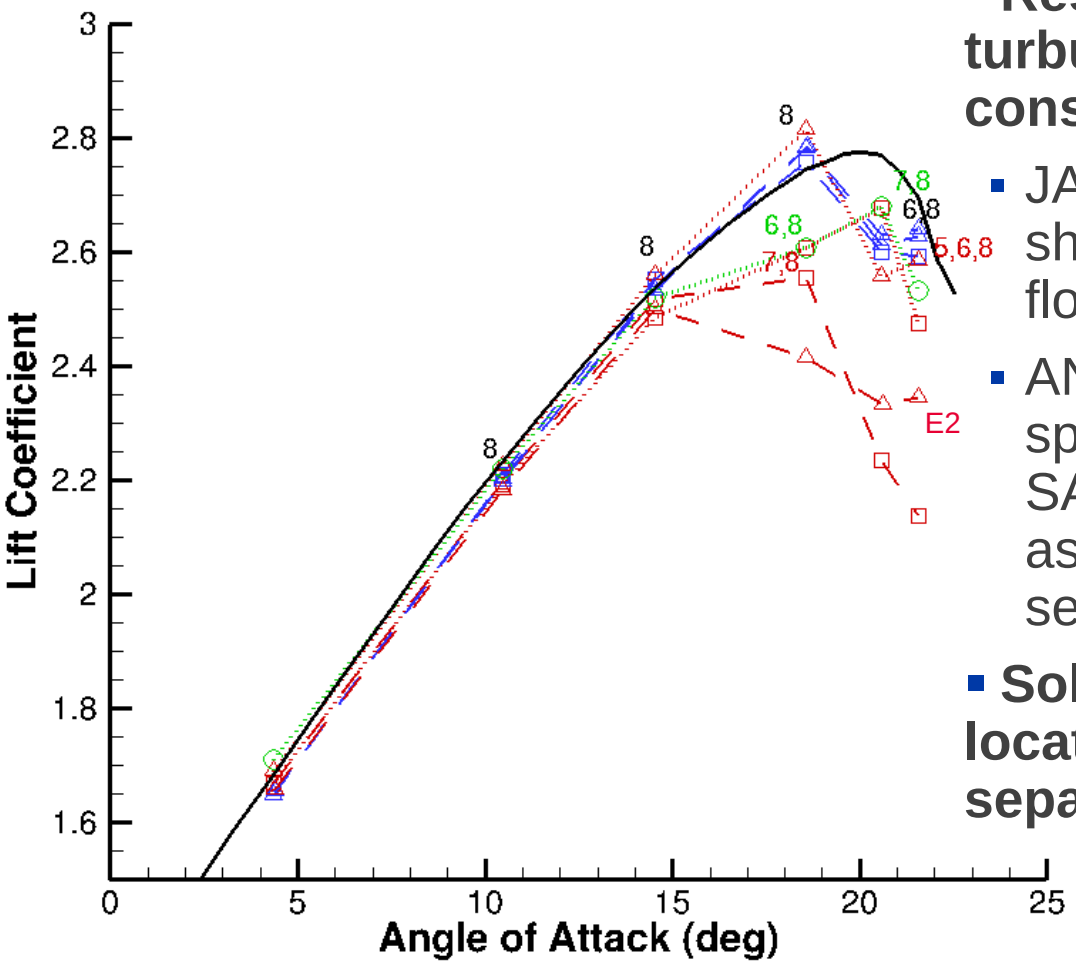
Lift Coefficient: Result Consistency



- **Results with same grid and turbulence model generally consistent**
  - JAXA (SA-RC-QCR) results show strong consistency across flow solvers, users
  - ANSA results show larger spread for both SA-QCR and SA-RC-QCR; primarily associated with slat bracket separation
- **Solutions cluster based on location of slat bracket separations (annotation)**

Mesh: JAXA, ANSA, VGRID, EPIC
Solver: □ BCFD, △ CFD++, O GGNS
Turbulence Model: — SA, ----- SA-QCR, --- SA-RC-QCR

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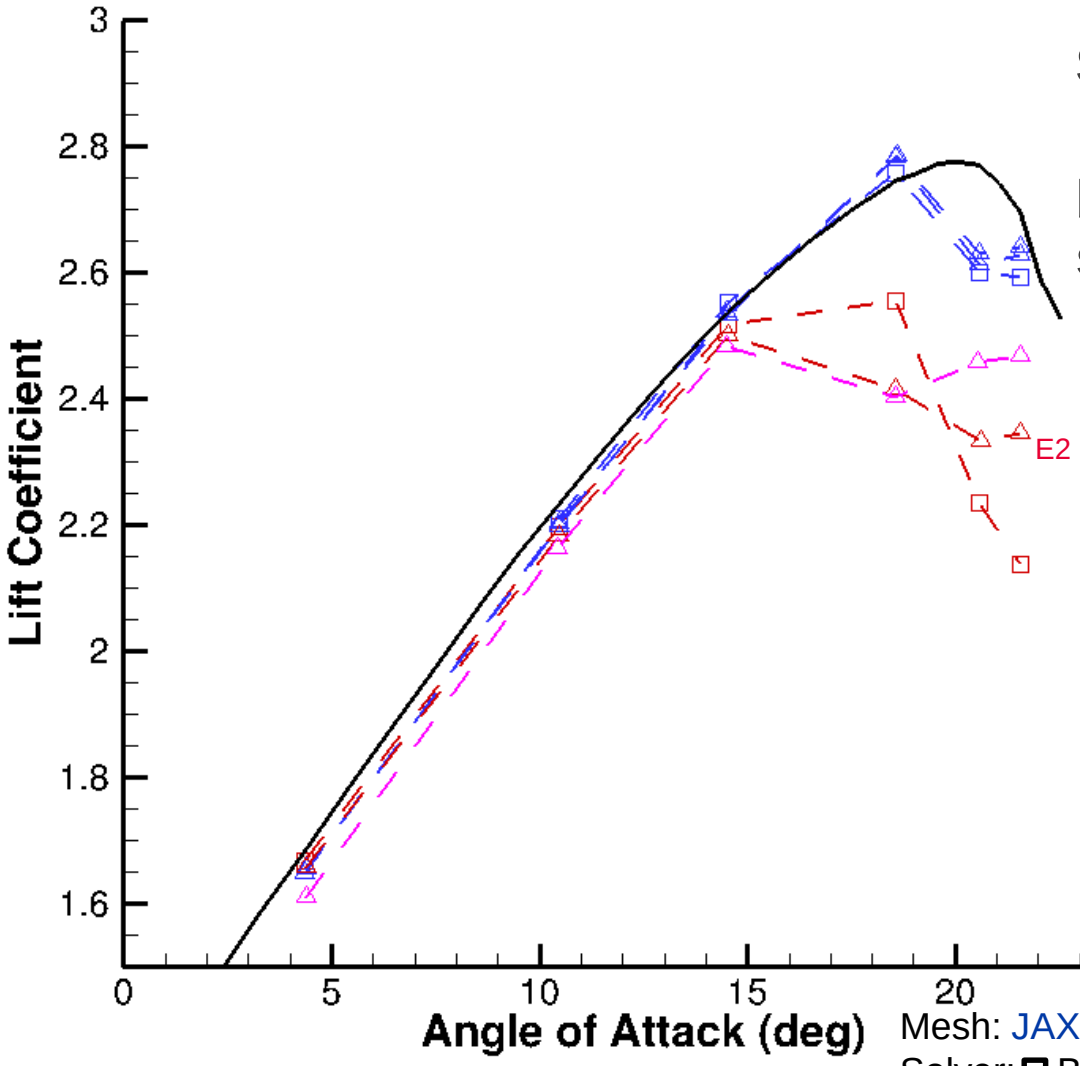
Lift Coefficient: SA-RC-QCR



- **Recommended variation of SA turbulence model**
- **Results sensitive to mesh but reflect different pseudo-solution attractors**

Mesh: JAXA, ANSA, VGRID, EPIC
Solver: □ BCFD, Δ CFD++, O GGNS
Turbulence Model: — SA, ----- SA-QCR, - - - SA-RC-QCR

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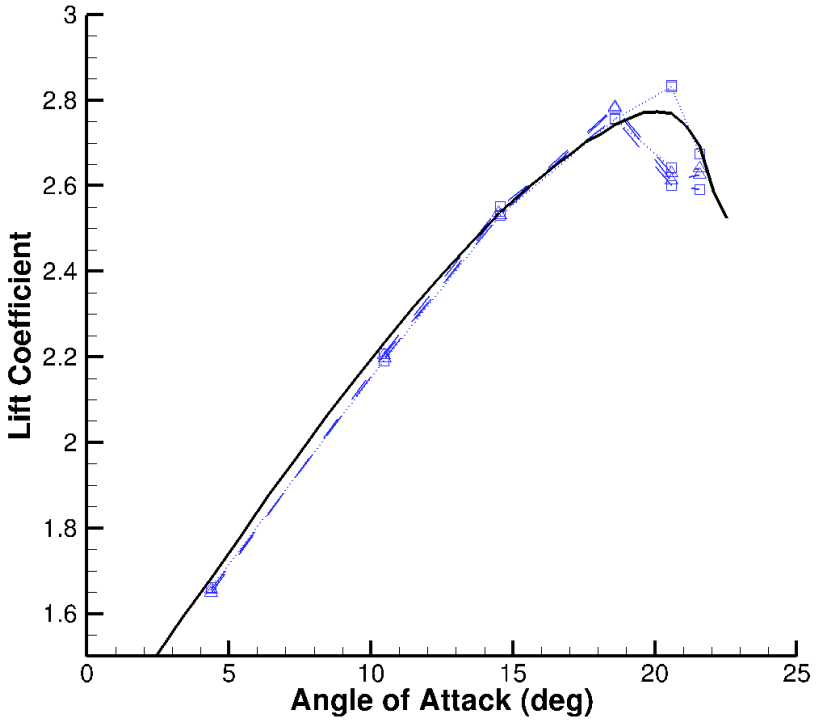
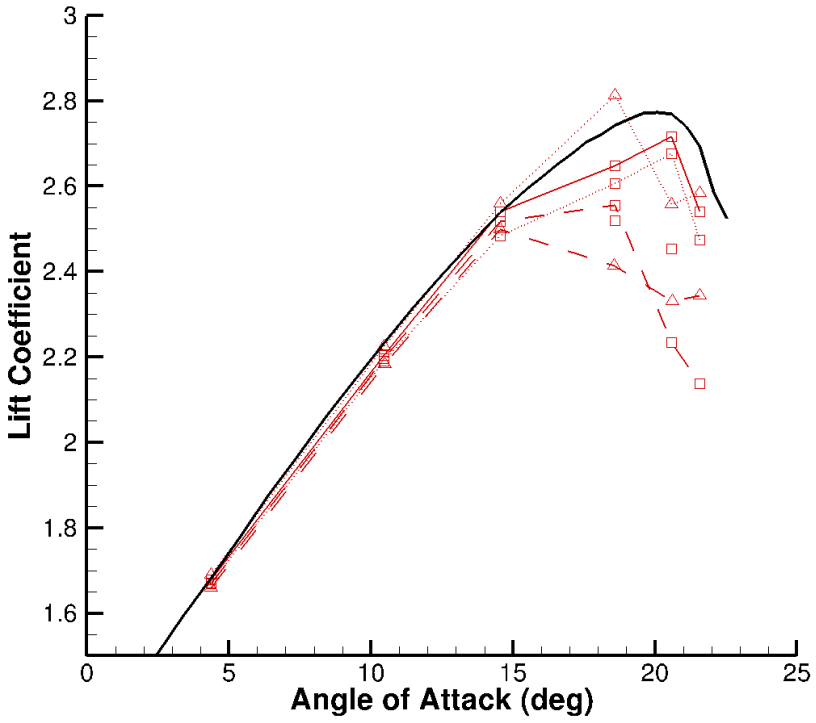
Lift Coefficient: Grid Sensitivity





- **ANSA mesh appears more sensitive to turbulence model than JAXA mesh**
- **Solution variation with iteration less than symbol size; typically 3-5 orders of magnitude residual convergence**

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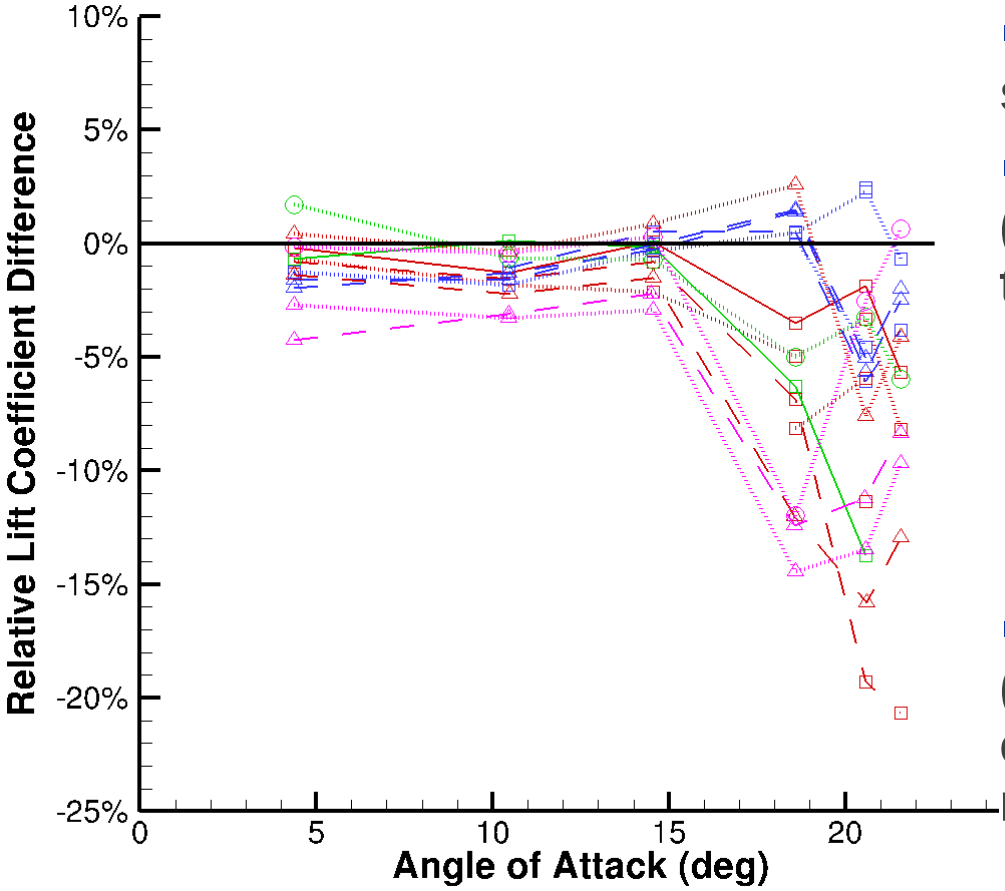
Lift Coefficient – Overall Comparison



- **General agreement until significant flow separation**
- **Consistent trends for given mesh (multiple flow solvers and turbulence models)**
  - JAXA grid particularly tightly clustered
  - Adapted mesh results similar until final angle of attack
- **Large spread near key areas (CLmax, AoAmax) limits engineering usefulness in these regions**

Relative difference from experimental data to facilitate comparison

Mesh: JAXA, ANSA, VGRID, EPIC
Solver: □ BCFD, △ CFD++, O GGNS
Turbulence Model: — SA, ----- SA-QCR, - - - SA-RC-QCR

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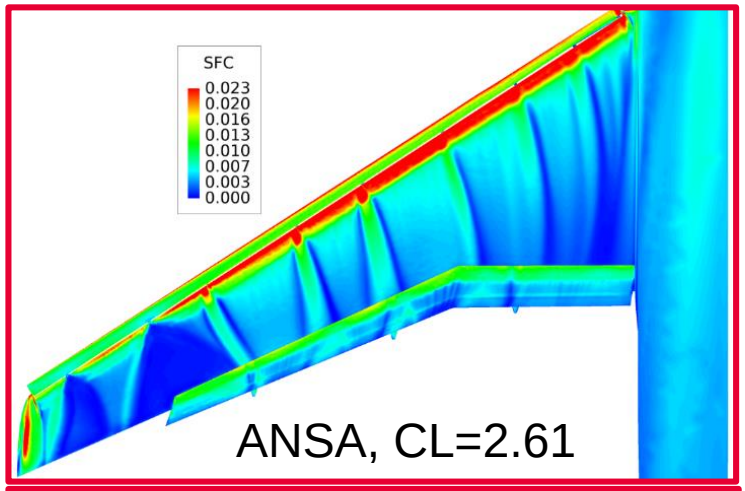
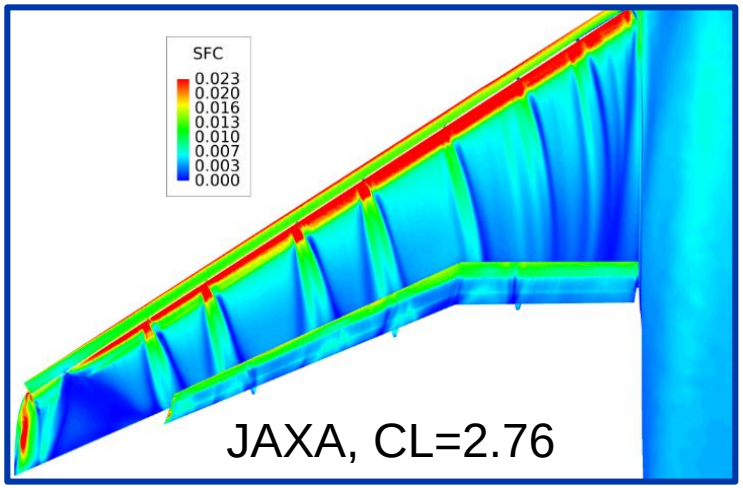
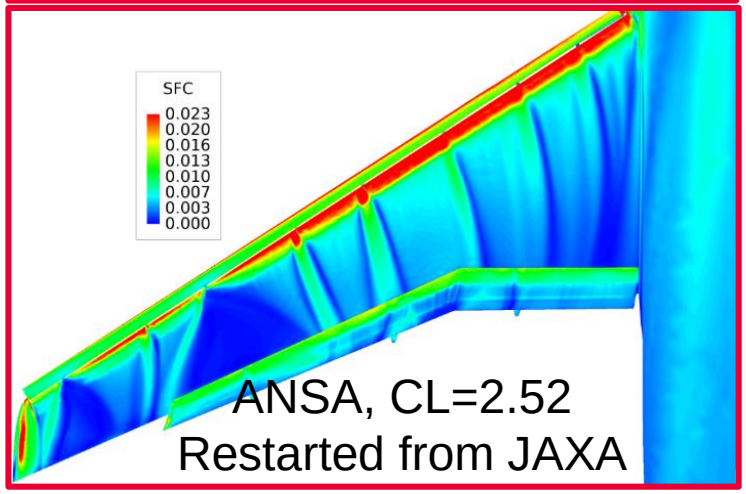
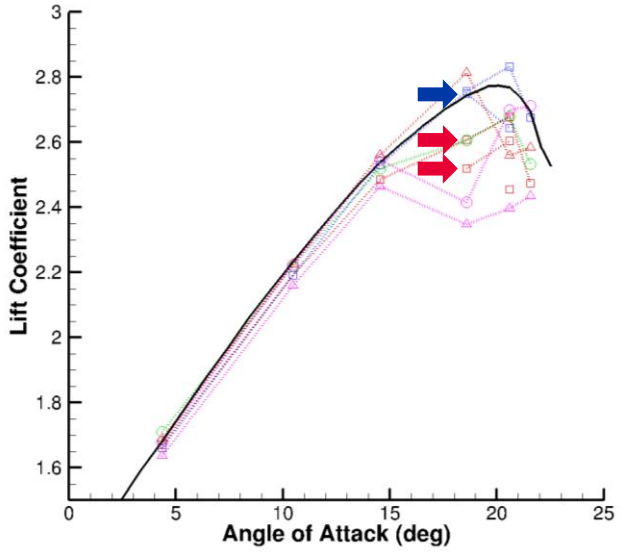
Pseudo-Solution Robustness (soln interp)









- **BCFD SA-QCR, 18.58°**
- **Interpolate JAXA solution onto ANSA grid and reconverge**

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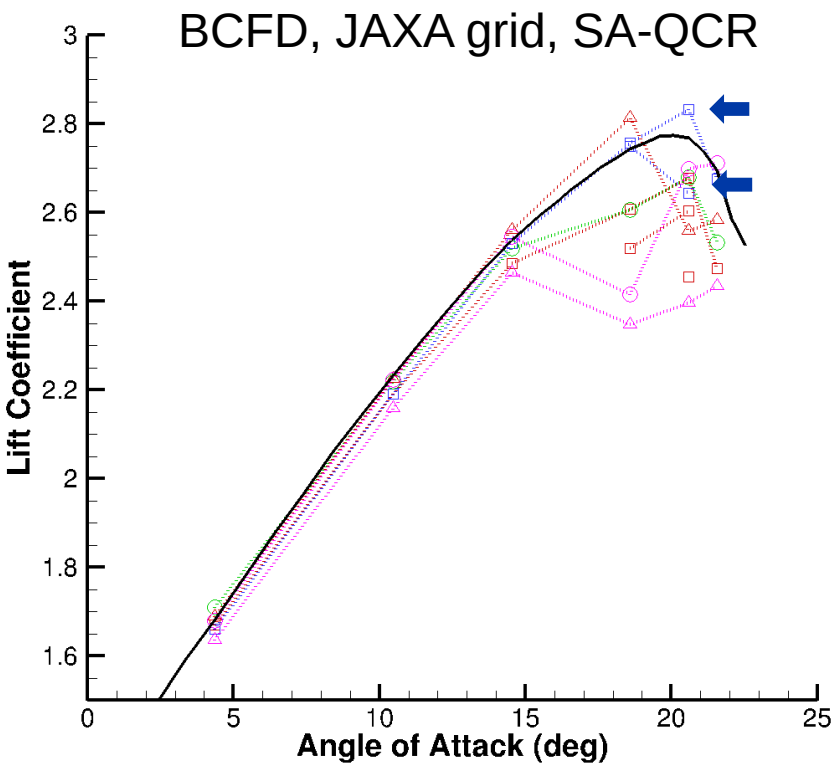
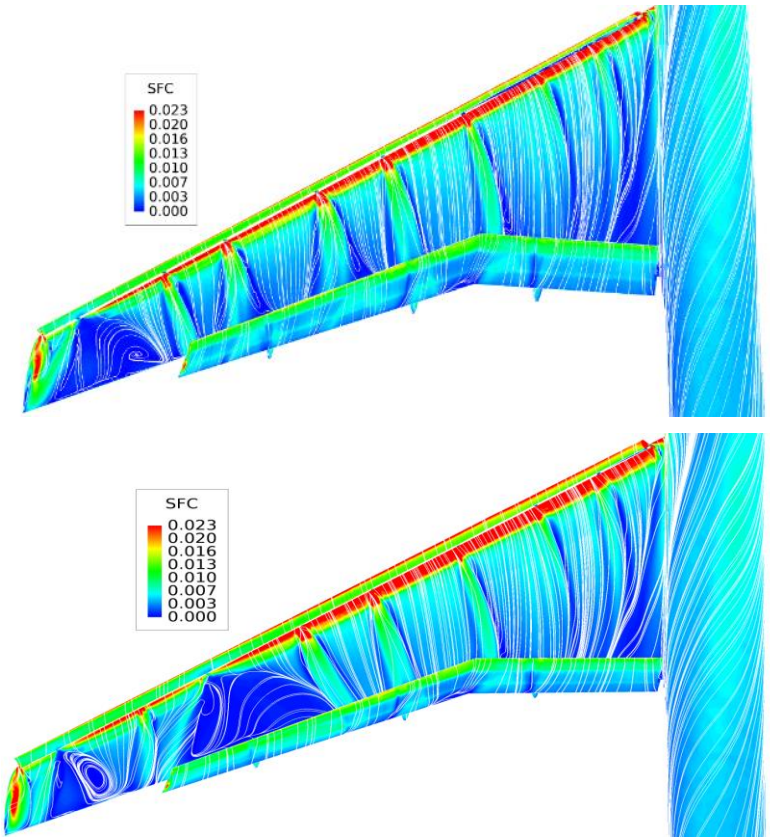
Pseudo-Solution Robustness (change CFL)





- **Changing CFL number switches pseudo-solution sometimes (indication of strength of attractor)**
- **Need flow solver convergence to assess grid, turbulence model, but what if multiple solutions?**

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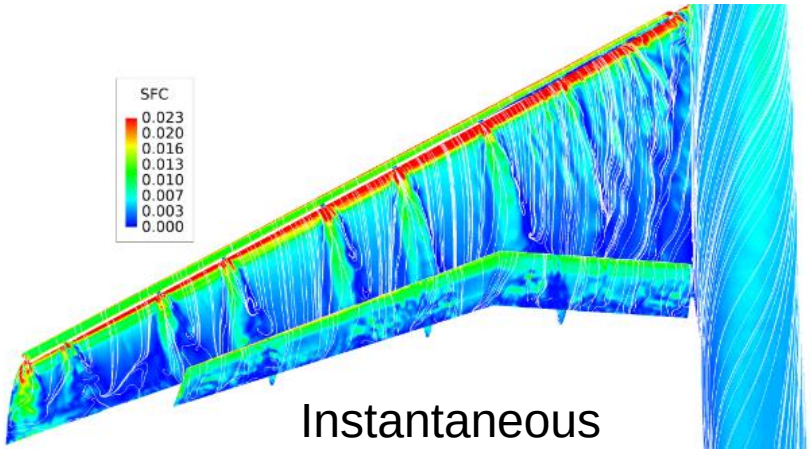
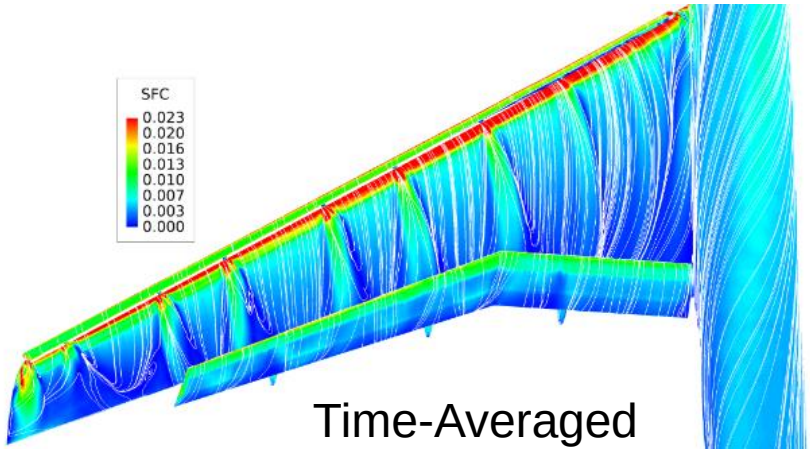
Time-Accurate Simulation Impact

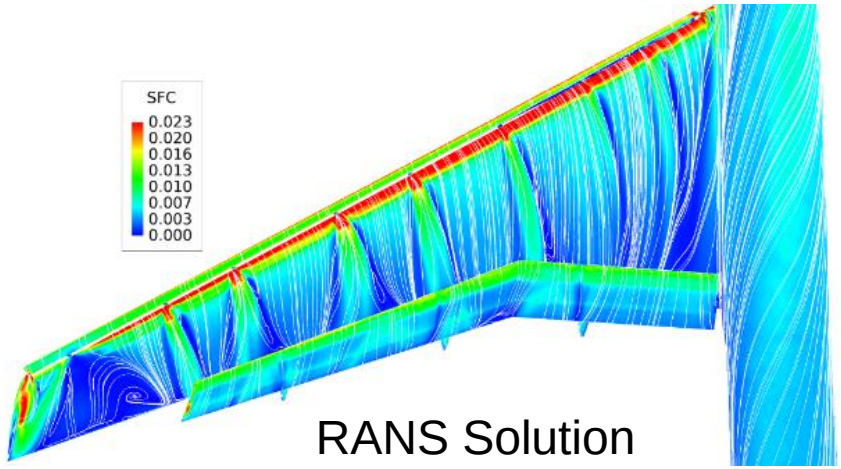


Instantaneous Solution



Time-Averaged Solution

- **Start time-accurate DDES solution on JAXA grid, SA-QCR, 20.59°**
- **Time-averaged solution shows no separation**
- **Lift comparable to RANS**



RANS Solution

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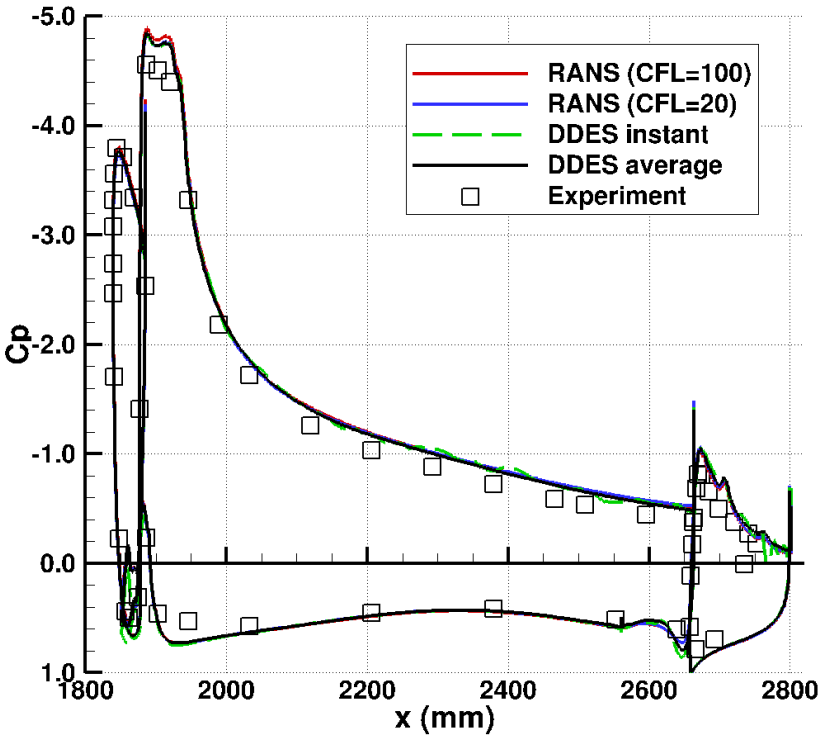
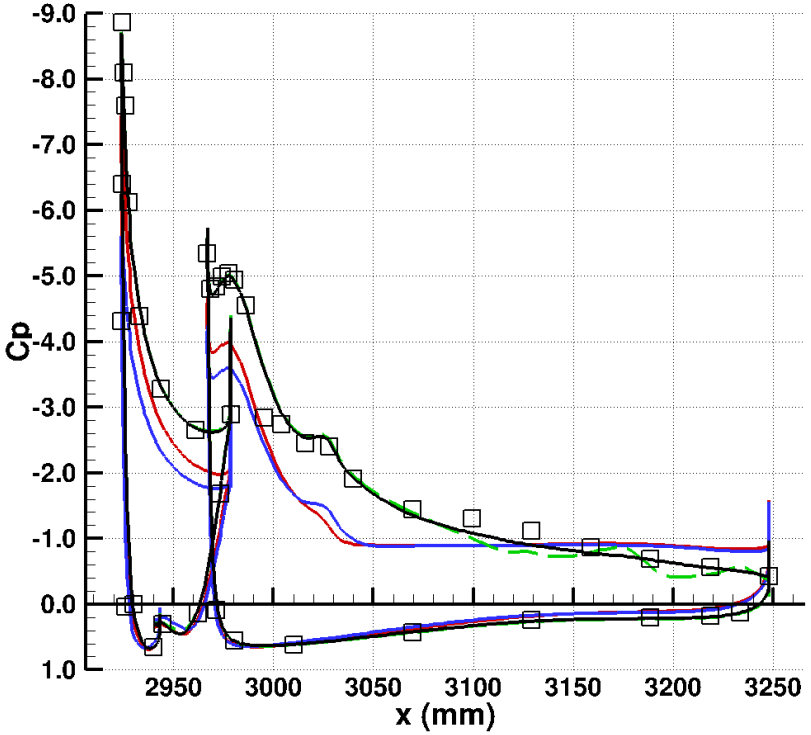
Time-Accurate Simulation Pressure Distribution



Inboard



Outboard

- **Inboard pressure cut (A-A) compare well to RANS; show little variation**
- **Outboard pressure cut (H-H) shows average flow is attached; improved comparison to experimental measurement**

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Summary

- **Effort focused on current technology flow solvers with committee-provided meshes and standard turbulence models**
- **Generally good agreement among solvers for same grid and turbulence model**
- **Grid convergence has not been assessed**
  - Significant amount of grid very close to aircraft
  - JAXA committee-provided grid shows less variation in results than ANSA grid, but had less off-body resolution
- **Solver identifies multiple pseudo-solutions that can sometimes be perturbed to different attractors**
  - Interpolation of new solutions
  - Change CFL number
- **Running time accurate may lead to improved comparison to experiment**

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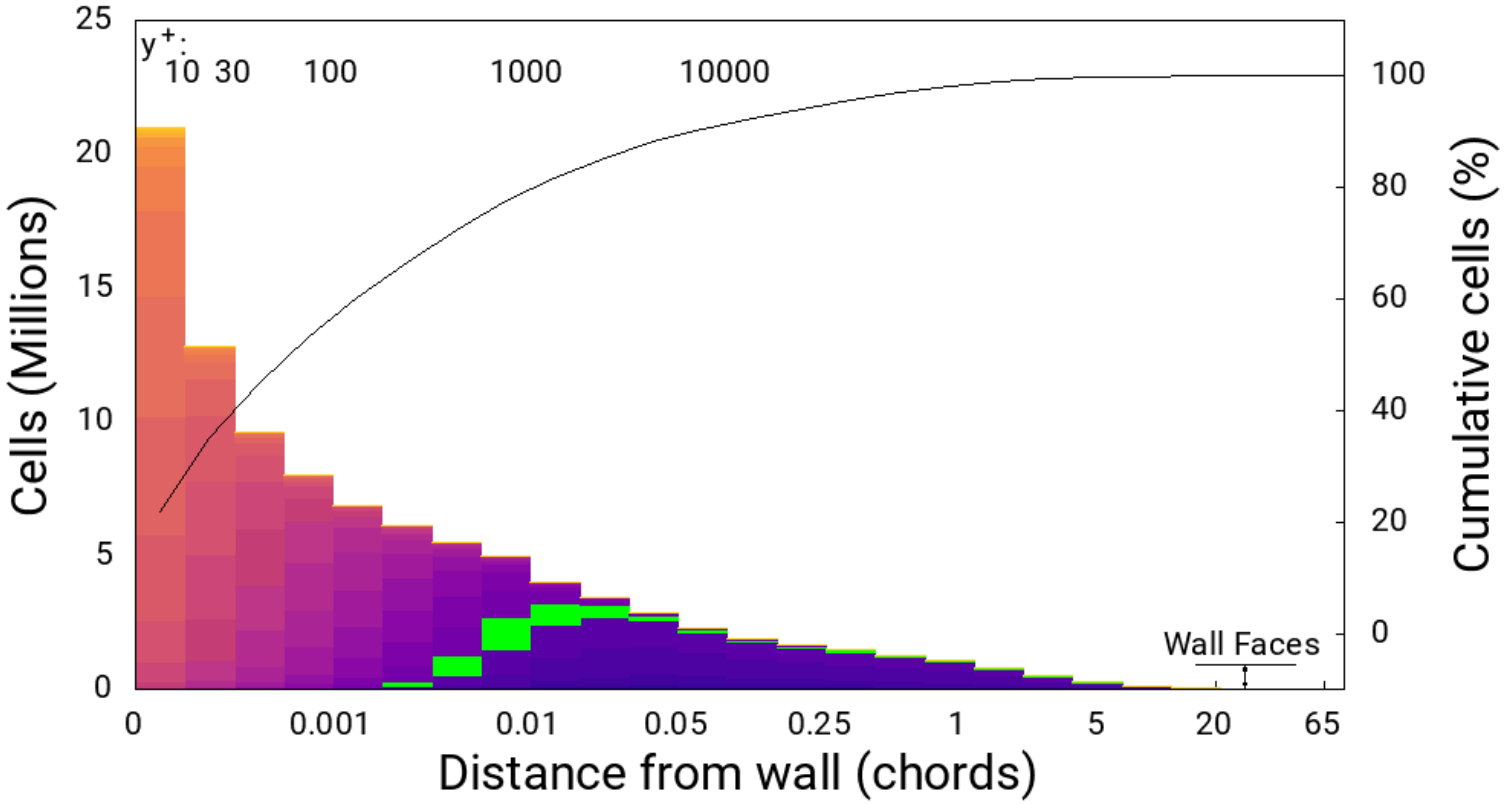
C-VGRID mesh



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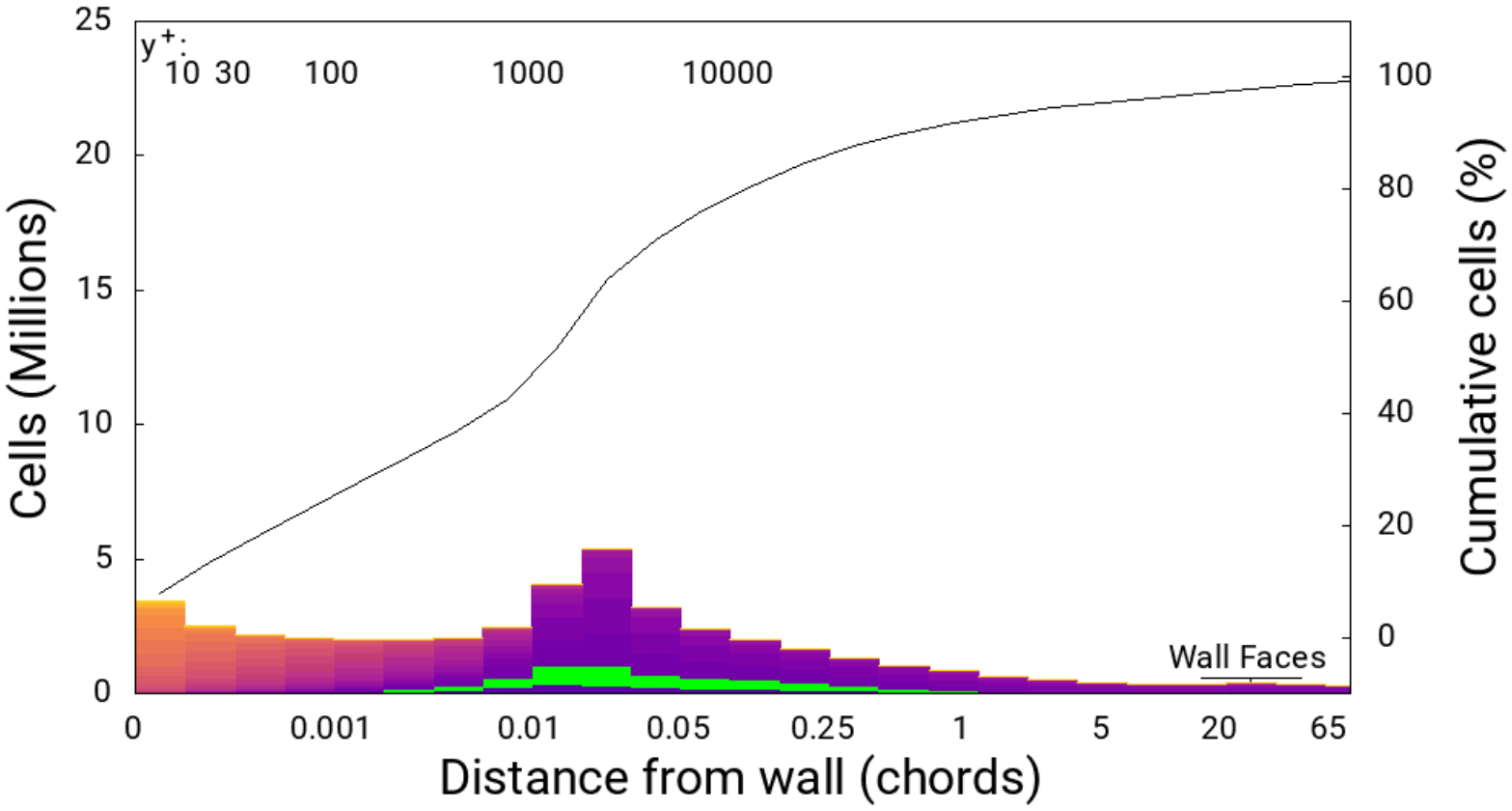
EPIC mesh



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