

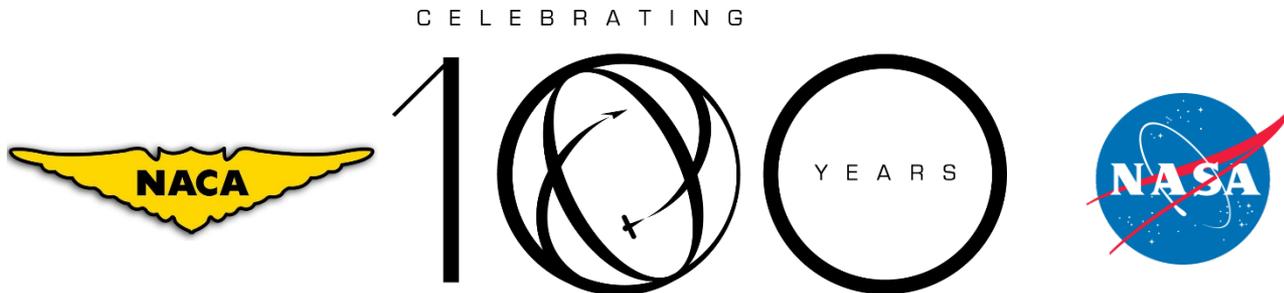
Contribution to HiLiftPW-3

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NASA Langley Research Center 1917-2017

3rd High Lift Prediction Workshop
Denver, CO June 3-4, 2017

Overview

- This presentation is exclusively focused on a partially sealed gap case on the Common Research Model (CRM) at 8 degrees angle of attack.
- Cases were run with PowerFLOW[®], a Lattice Boltzmann Method (LBM) solver.
- Workshop provided grids could not be used.

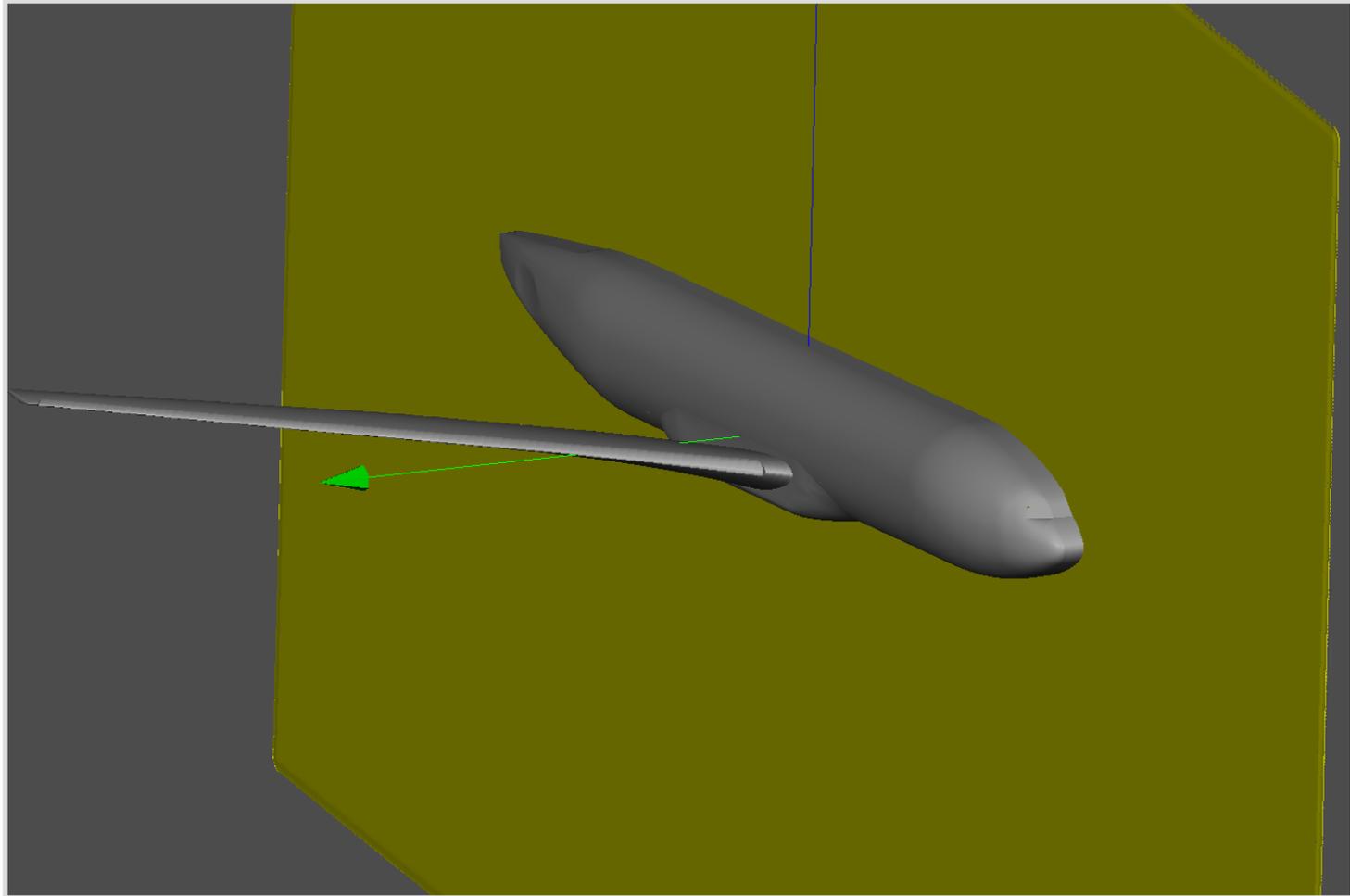
Governing Equations/Numerical Approach

- Flowfield simulated with 3D Lattice Boltzmann model
- Solver: PowerFLOW[®] 5.3c - 5.4b
 - Derived from velocity/space discretization of Boltzmann equation
 - Recovers second order unsteady Navier-Stokes equations
 - High subsonic formulation: valid to Mach 0.9
 - Hybrid turbulence model: Lattice Boltzmann Very Large Eddy Simulation (LB-VLES)
 - Fully resolve energy carrying large scales
 - Model small scales in near wall regions using wall functions
 - Solution advanced in time using explicit time-marching scheme
 - All cases were run until time averaged Cl, Cd were not changing.

Differences from workshop cases

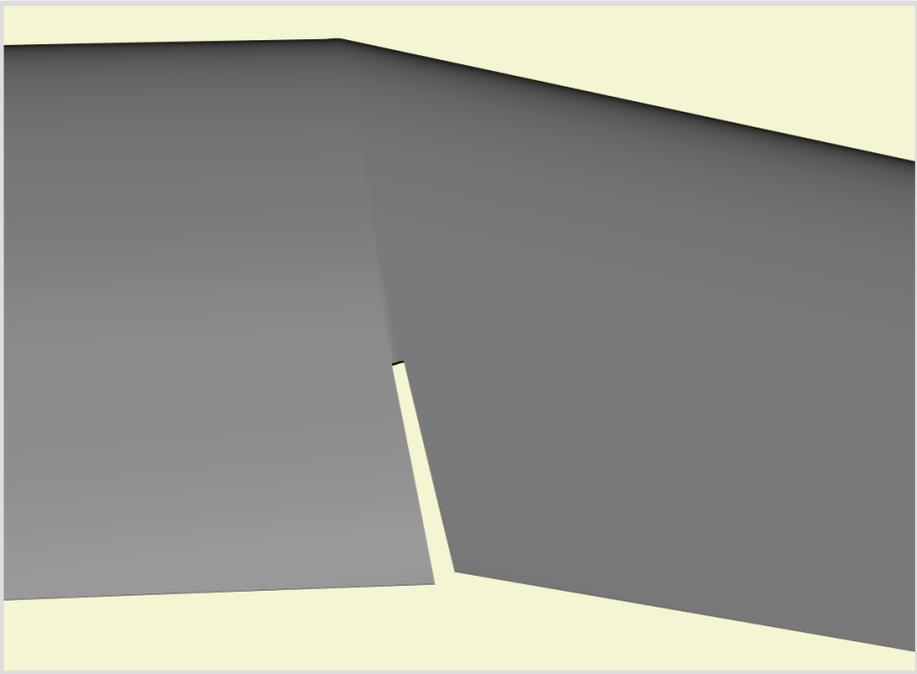
- Cases were run on a 10% scale model but still with the $Re_{MAC} = 3.27$ million
- The geometry has a 3.5 inch standoff height from the tunnel floor including a 0.25 inch beveled plate.
- The flap gap geometry is different from the workshop cases.
- The floor is inviscid; not symmetry.
- Cases were run free-air, no tunnel walls were used.

Geometry Overview

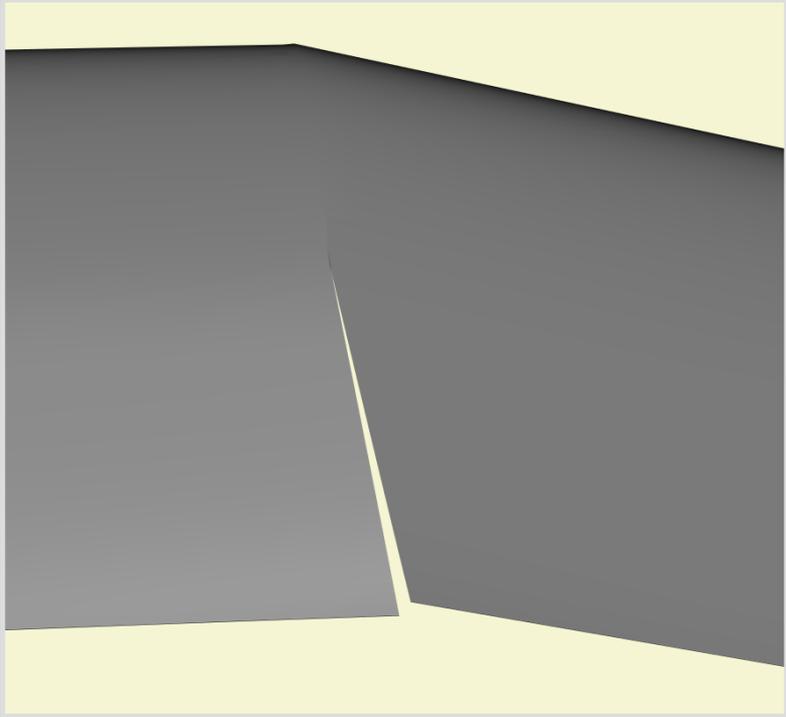


Flap Gap Differences

Workshop Geometry



Simulated Geometry



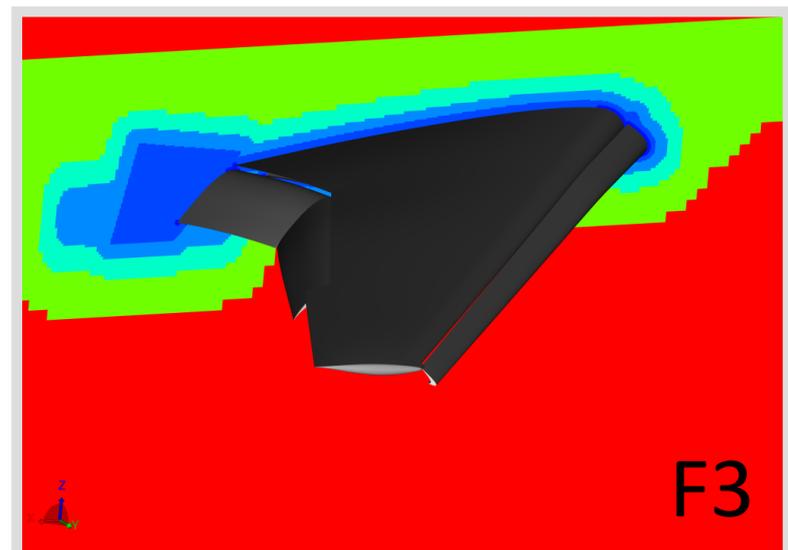
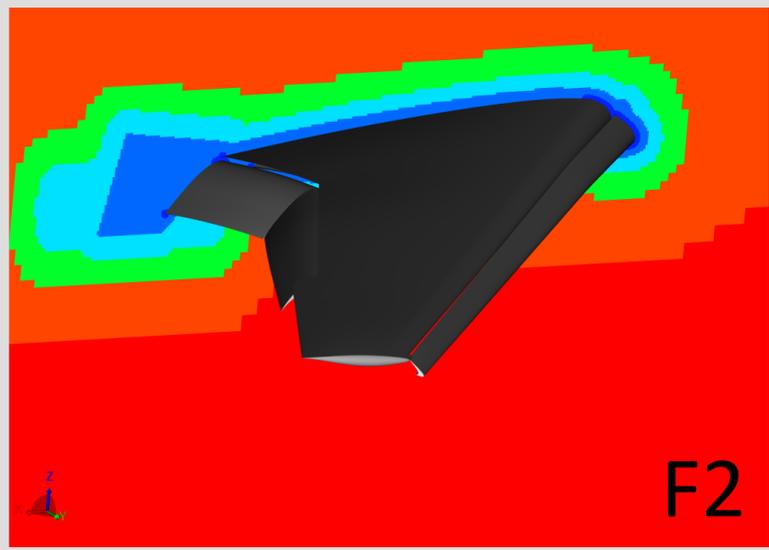
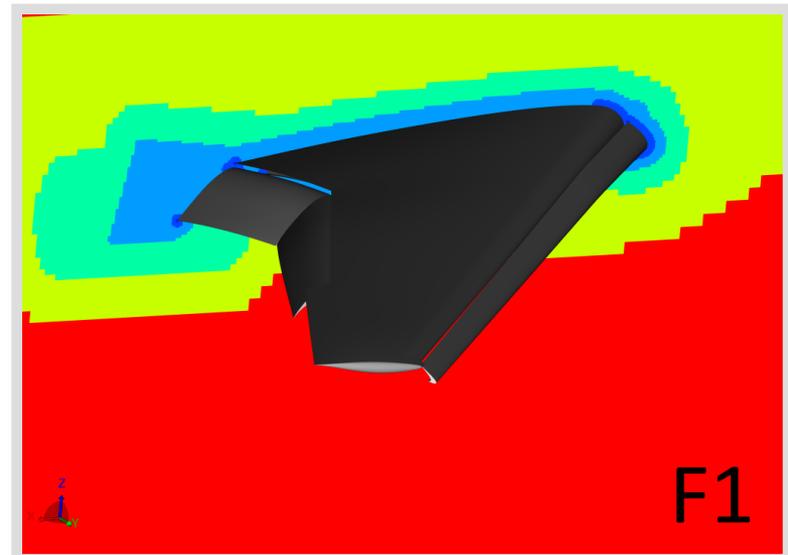
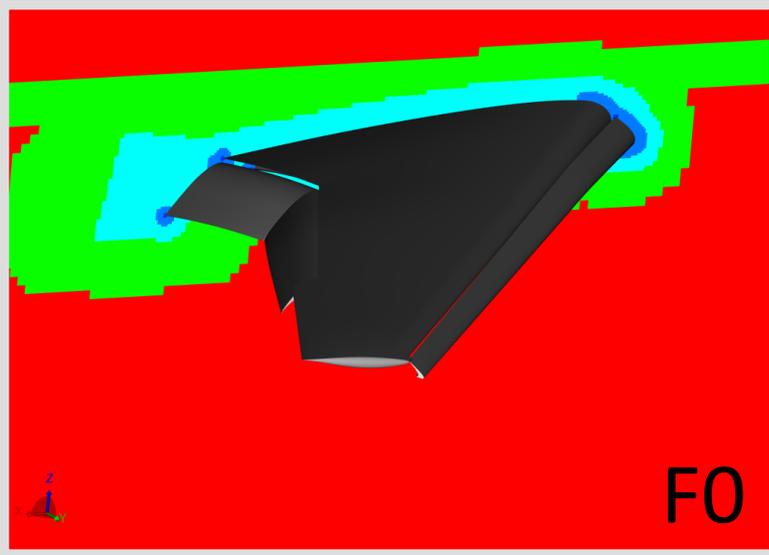
Initial Grid Family

	F0	F1	F2	F3
Total Voxel Count	80.5 M	141 M	432 M	1.10 B
Fine Equivalent Voxel Count	19.4 M	51.4 M	88.3 M	210 M
Minimum Voxel Spacing (% of MAC)	0.649 mm (0.099 %)	0.432 mm (0.062 %)	0.288 mm (0.041 %)	0.192 mm (0.027 %)

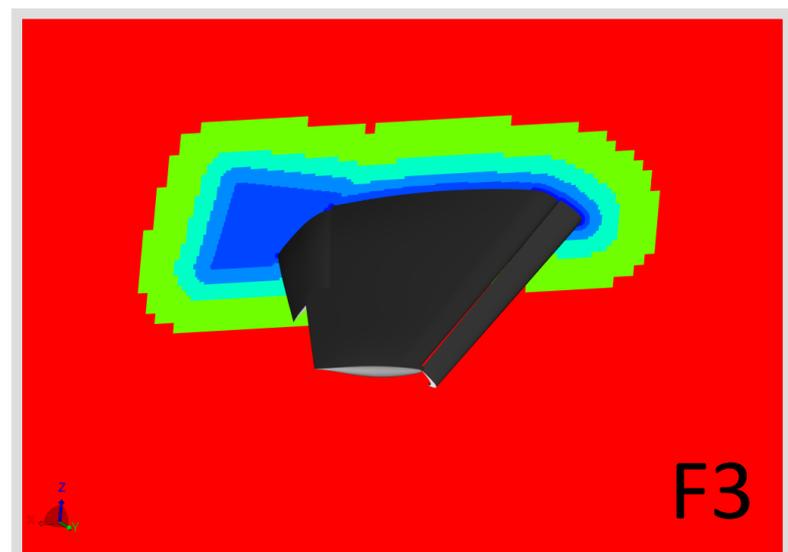
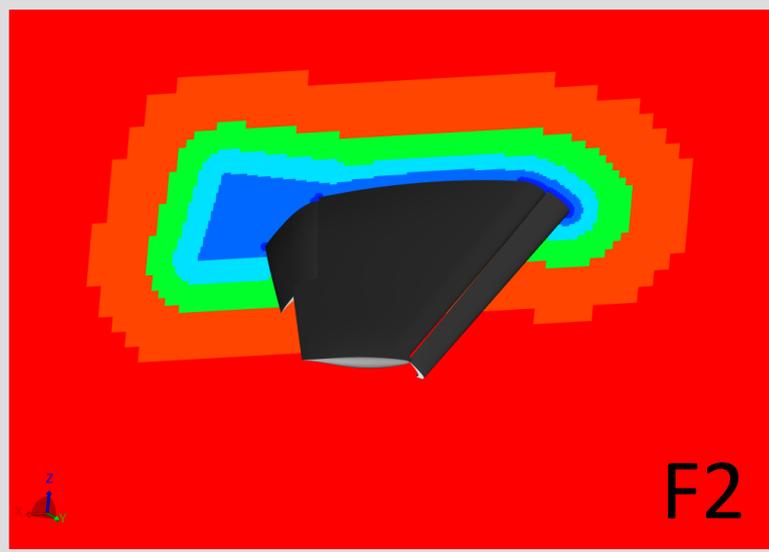
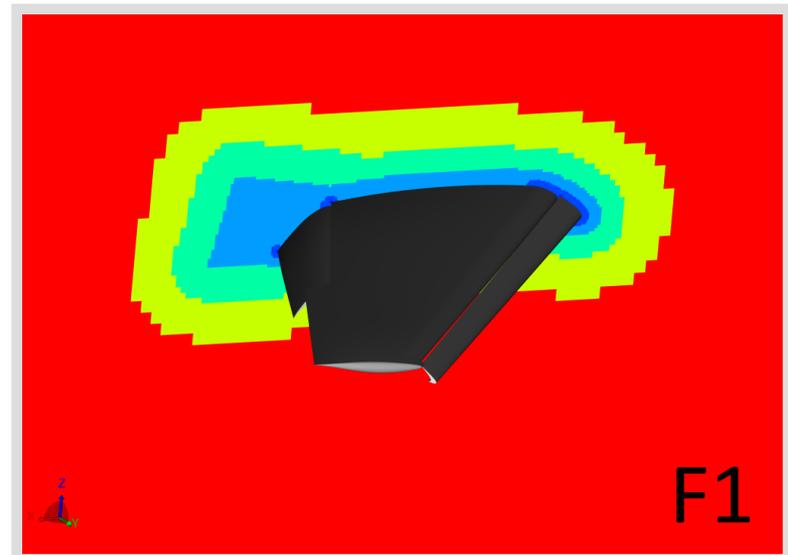
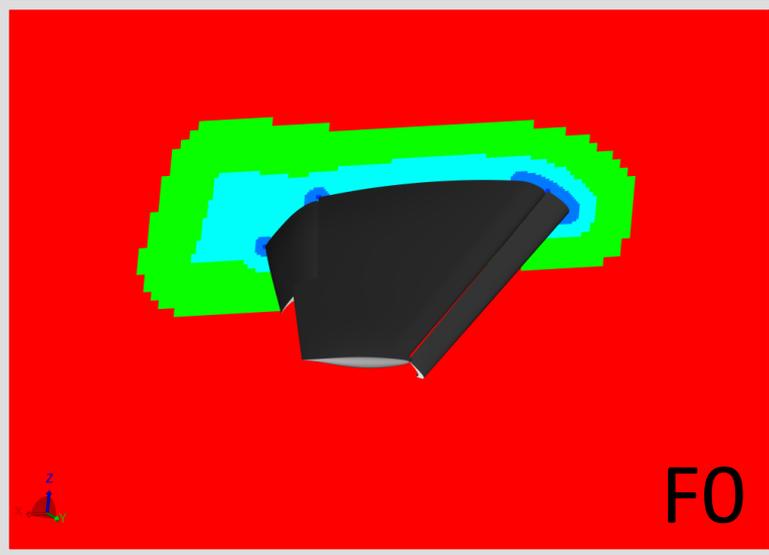
Voxel = grid cell

Fine Equivalent Voxels = average number of voxels updated each time step

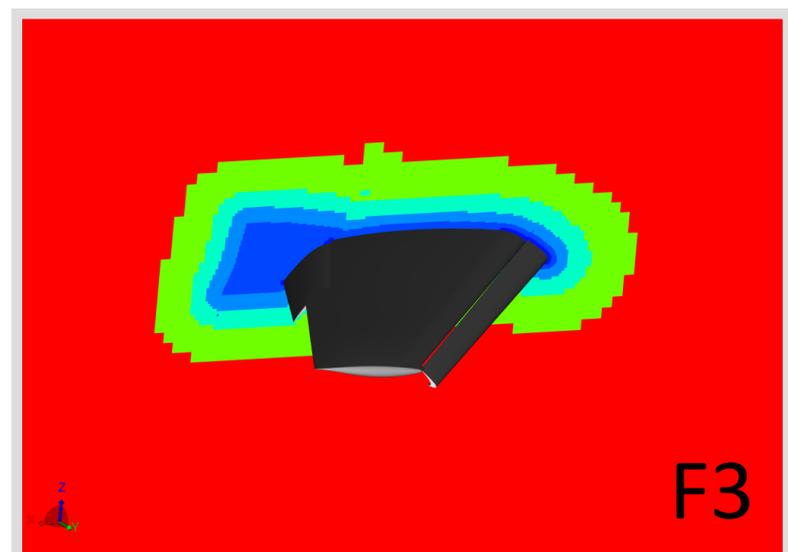
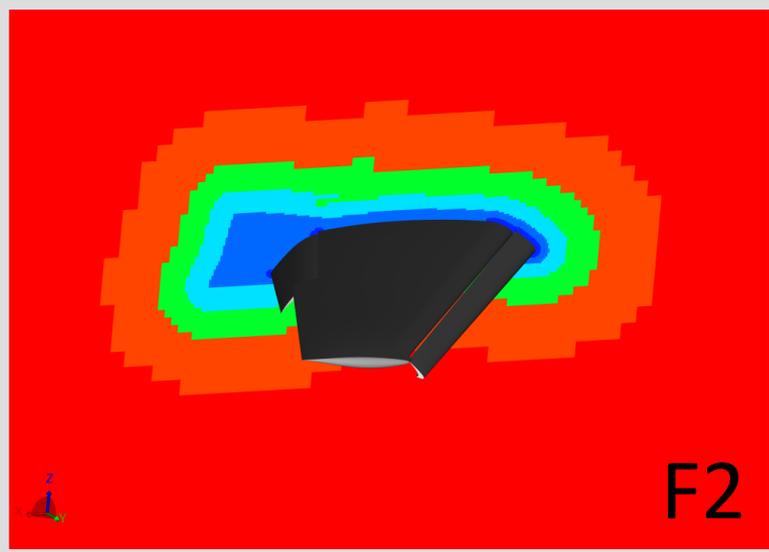
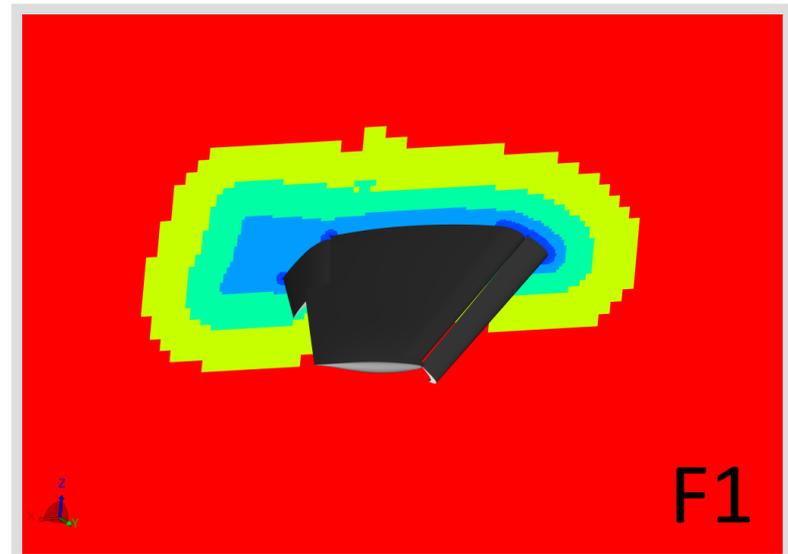
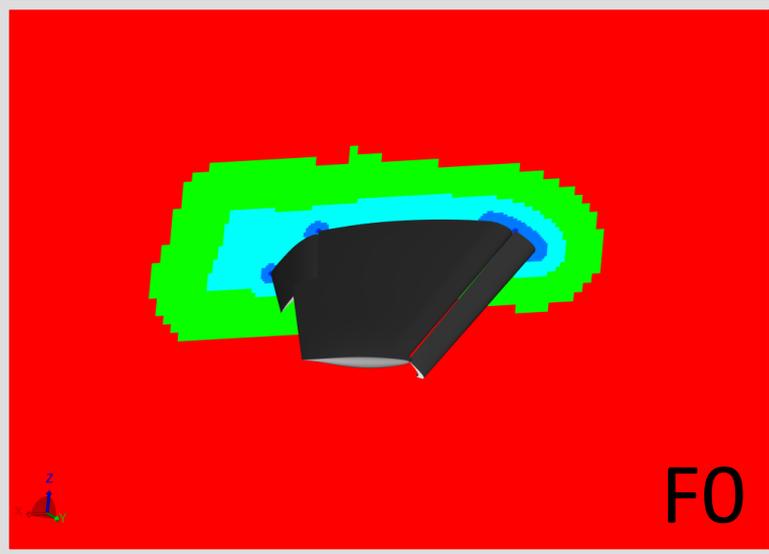
Grid Family F, eta 0.151



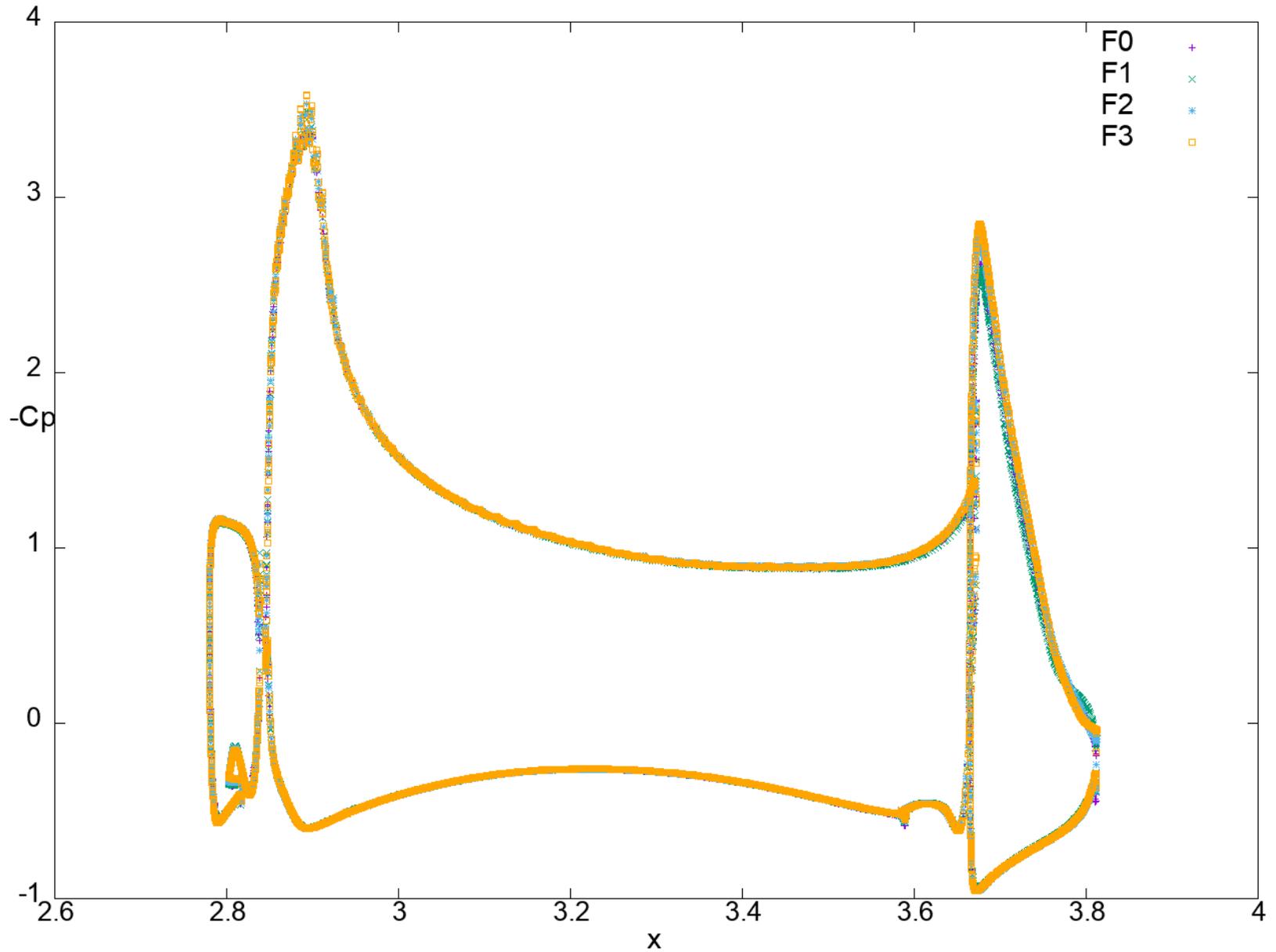
Grid Family F, eta 0.418



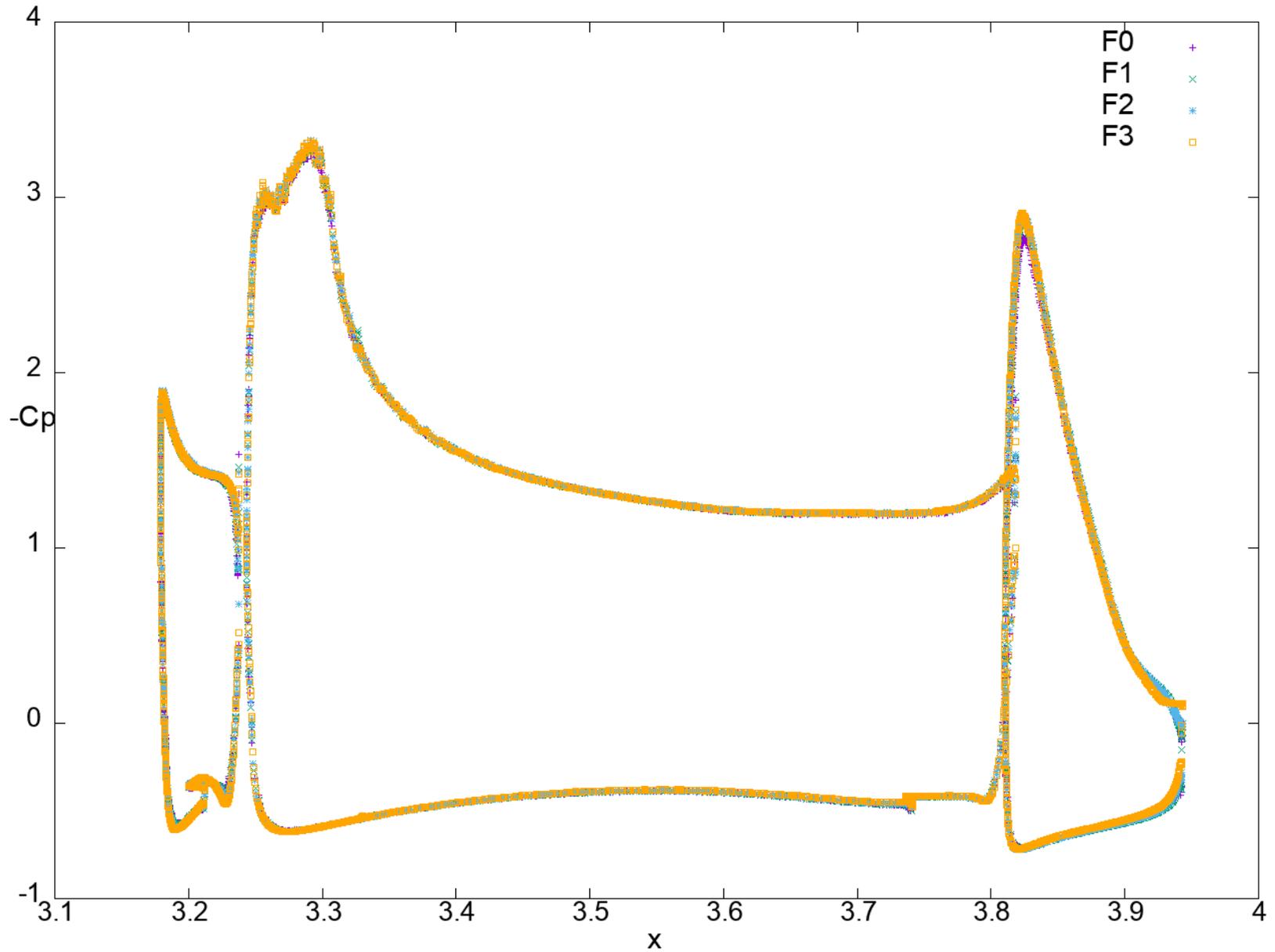
Grid Family F, eta 0.552



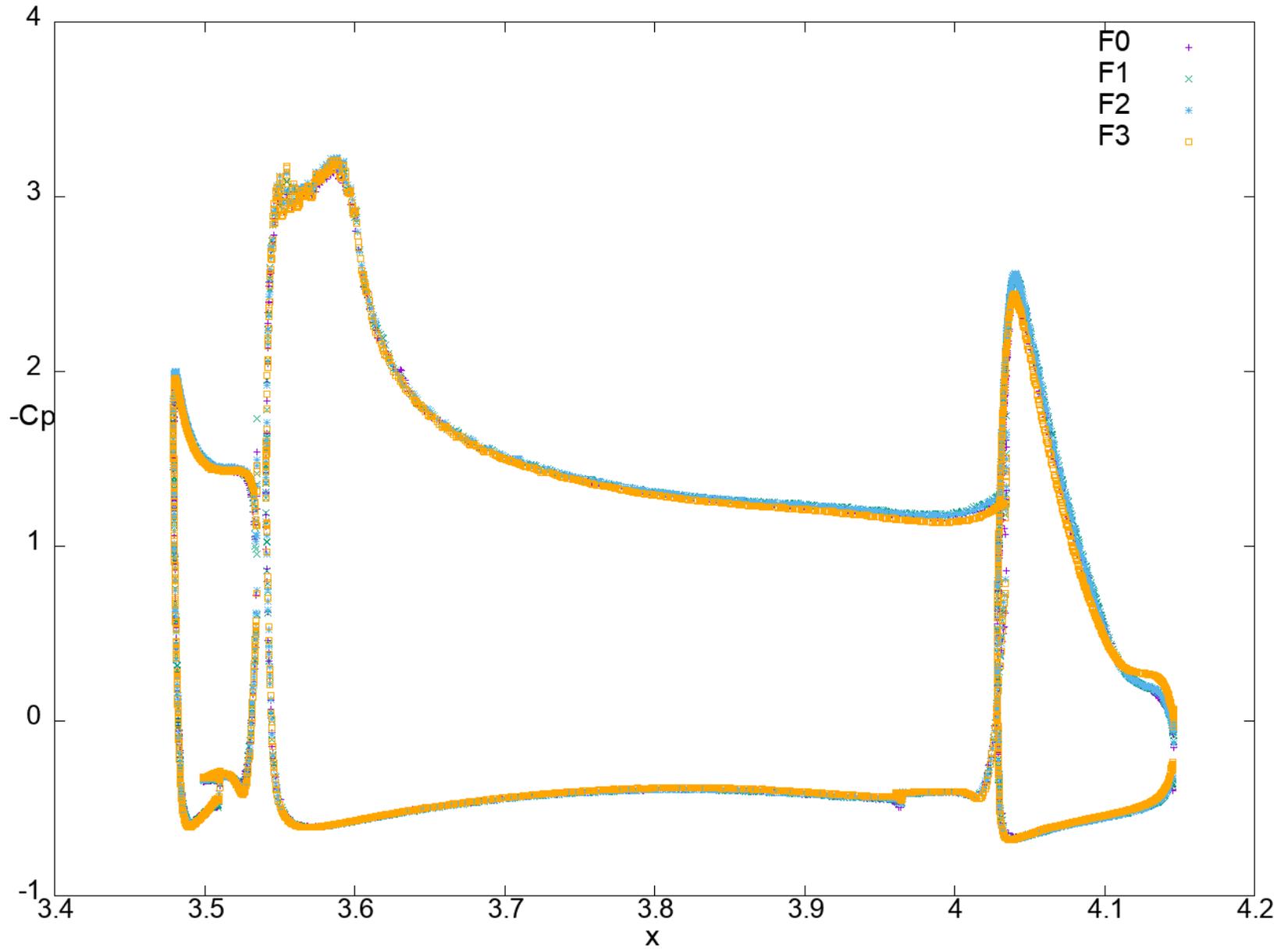
Cp eta = 0.240



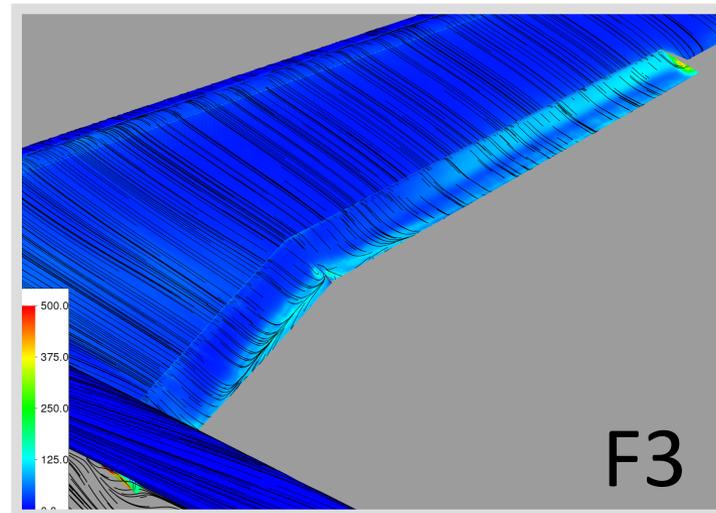
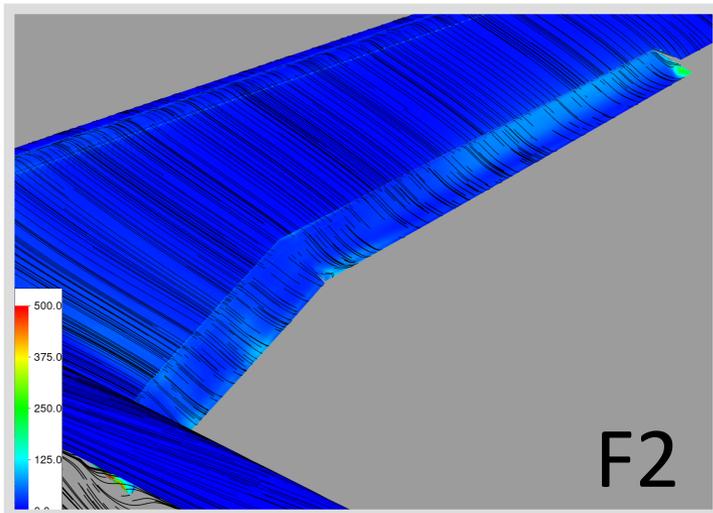
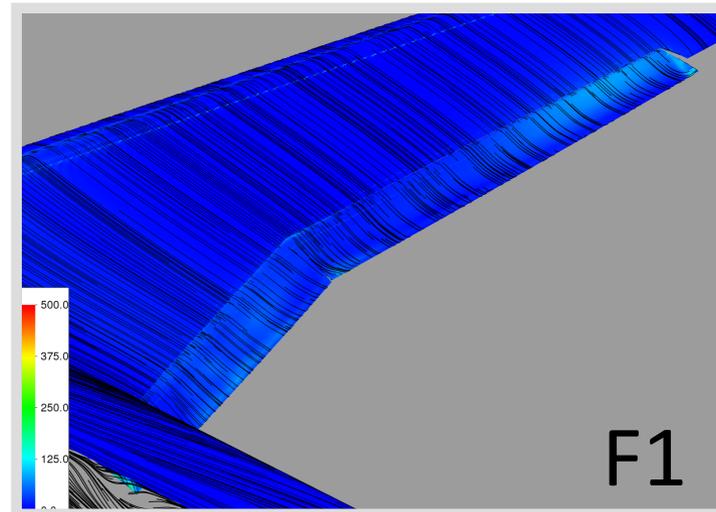
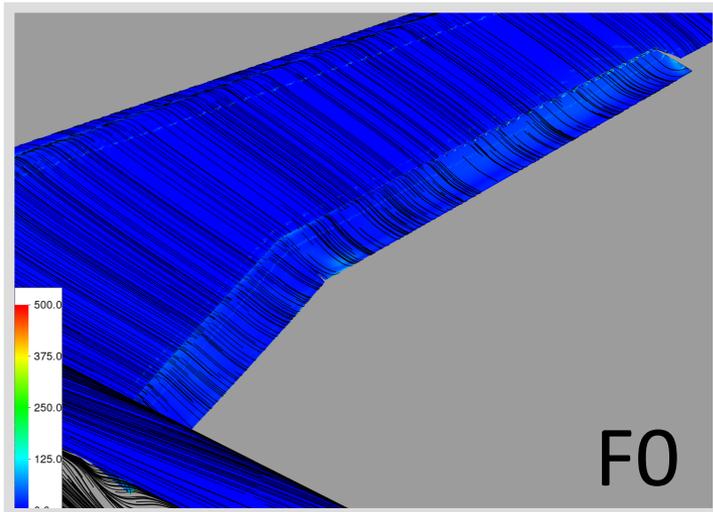
Cp eta = 0.418



Cp eta = 0.552

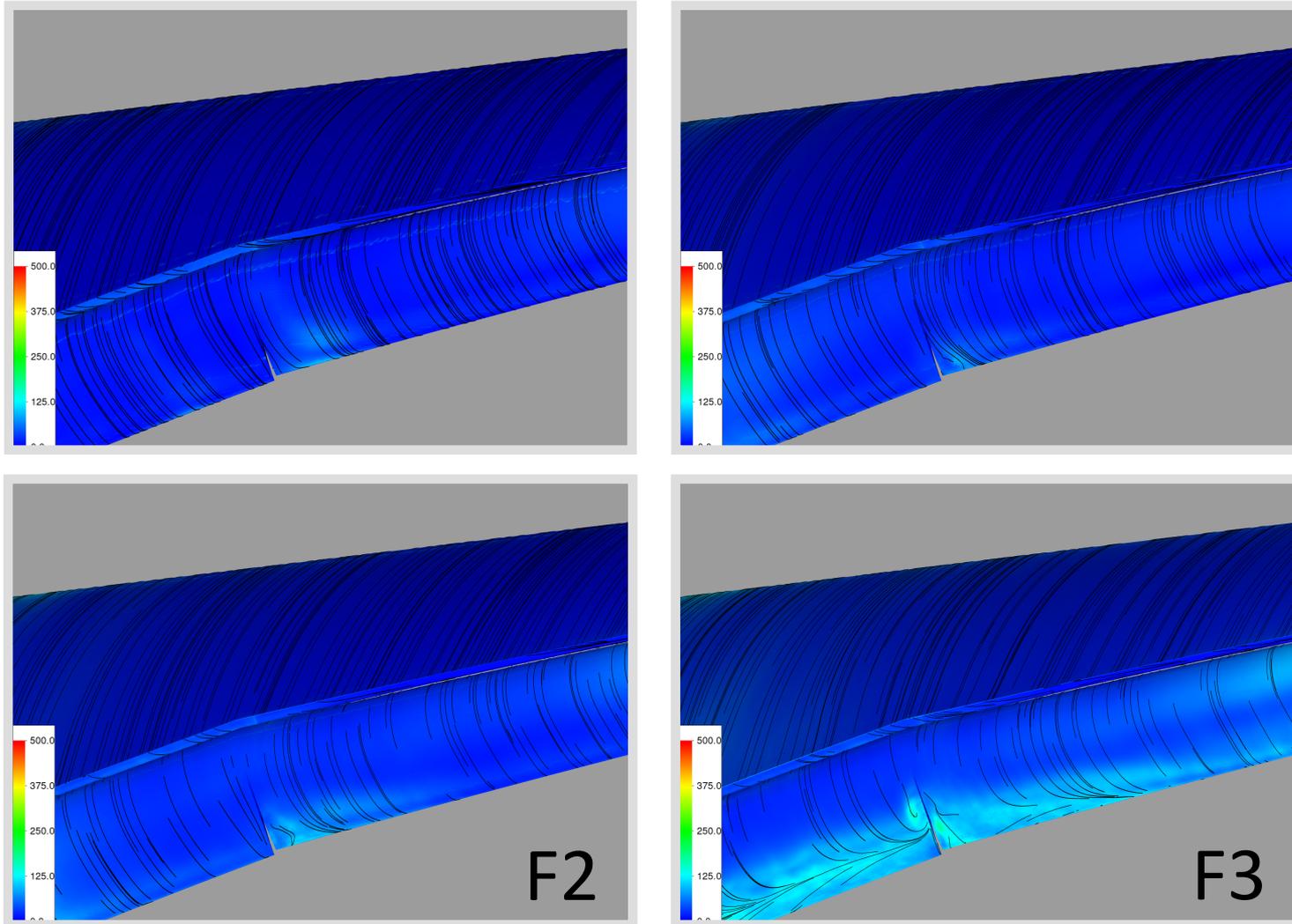


Flap Separation



Surface streamlines, contours of p'_{rms}

Flap Separation Around Break



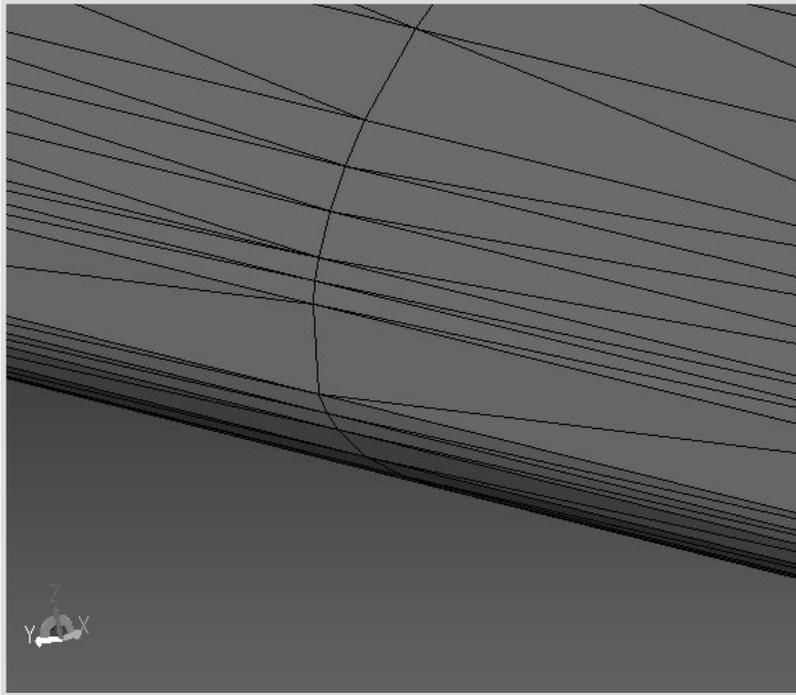
Surface streamlines, contours of p'_{rms}

Augmented Grids

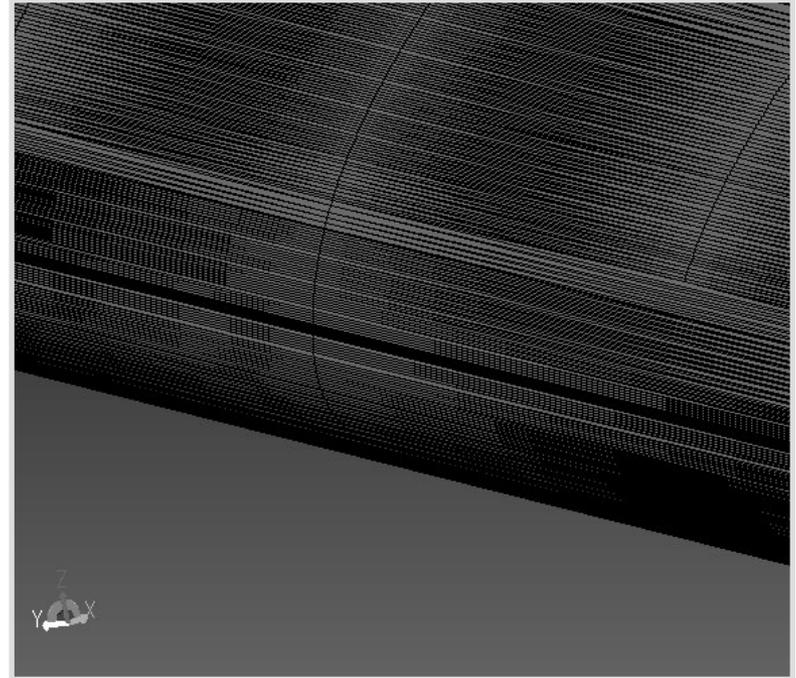
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Minimum Voxel Spacing (% of MAC)	0.649 mm (0.099 %)	0.432 mm (0.062 %)	0.288 mm (0.041 %)	0.192 mm (0.027 %)
Flap Surface Spacing (% of MAC)	2.59 mm (0.37 %)	1.73mm (0.25 %)	1.15 mm (0.16 %)	0.768mm (0.11 %)

	R4	R5
Total Voxel Count	480 M	1.29 B
Fine Equivalent Voxel Count	151 M	618 M
Minimum Voxel Spacing (% of MAC)	0.144 mm (0.021 %)	0.144 mm (0.021 %)
Flap Surface Spacing (% of MAC)	0.288 mm (0.42 %)	0.144 mm (0.42 %)

Refined Surface Grid

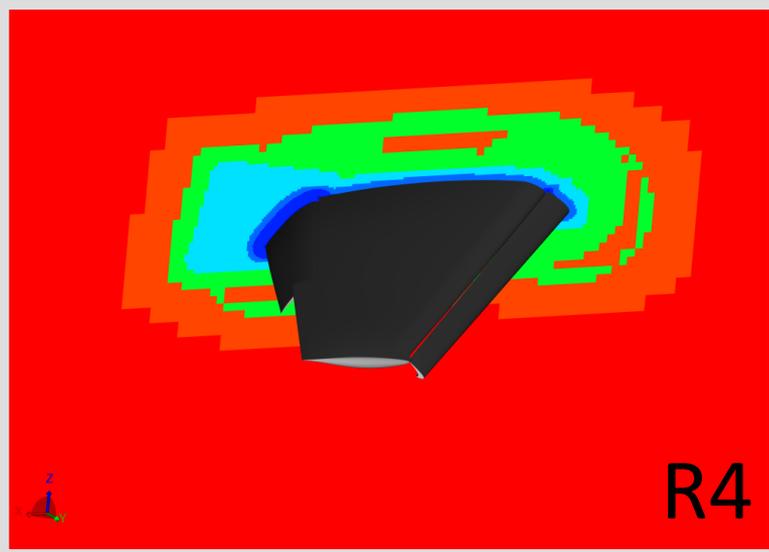
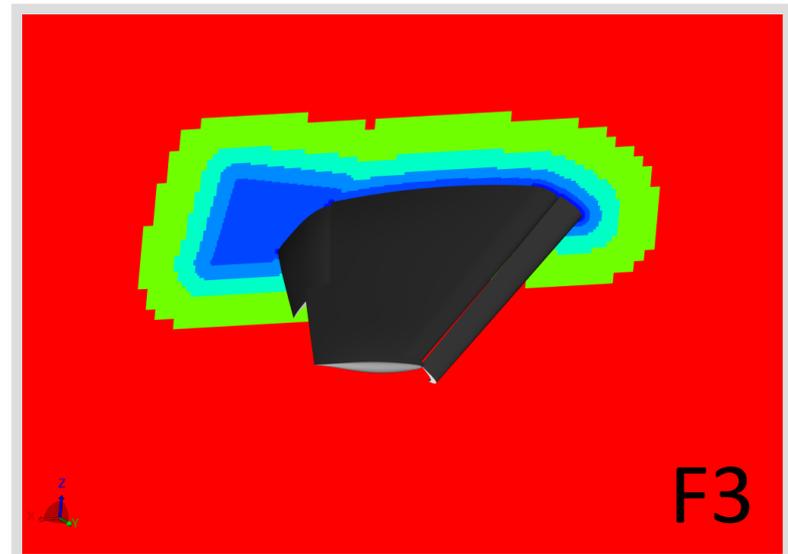
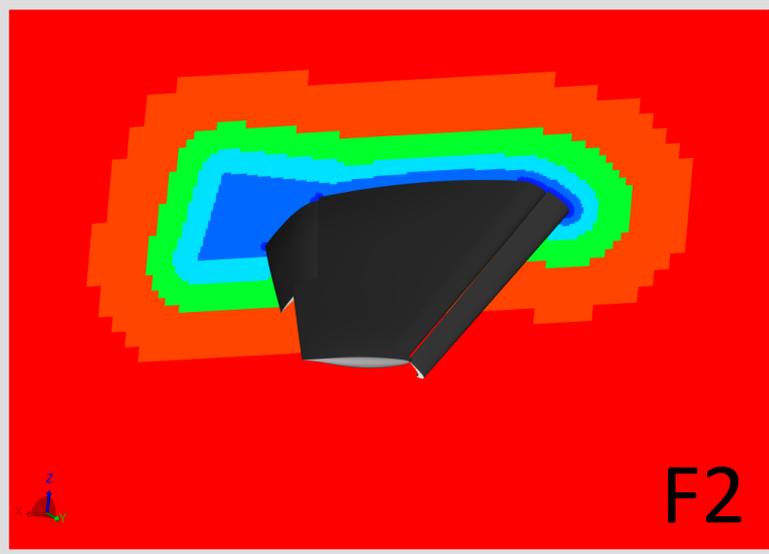


F grid family surface grid on
wing leading edge

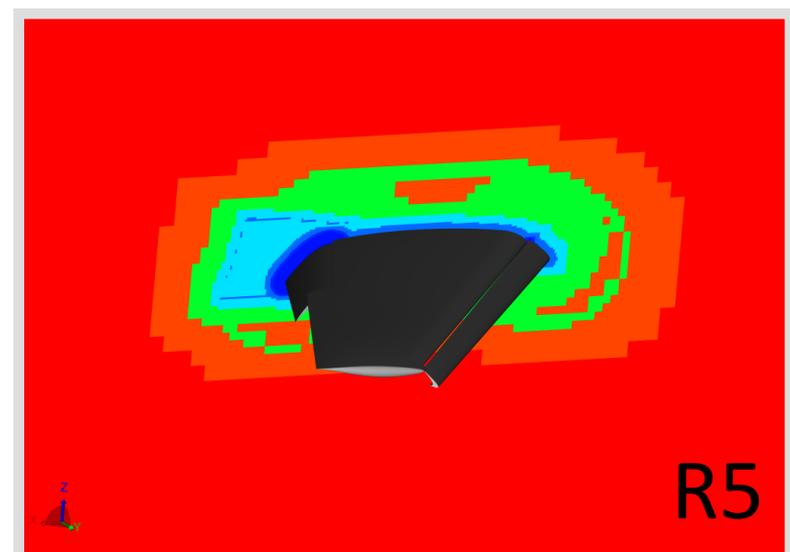
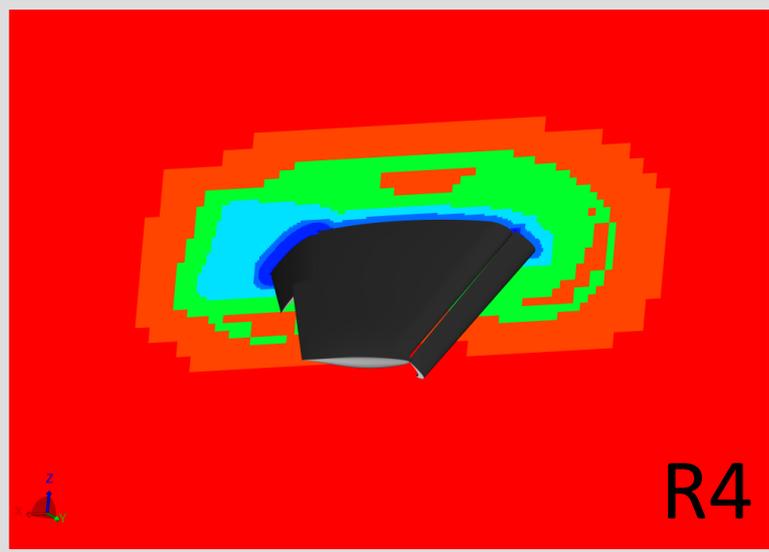
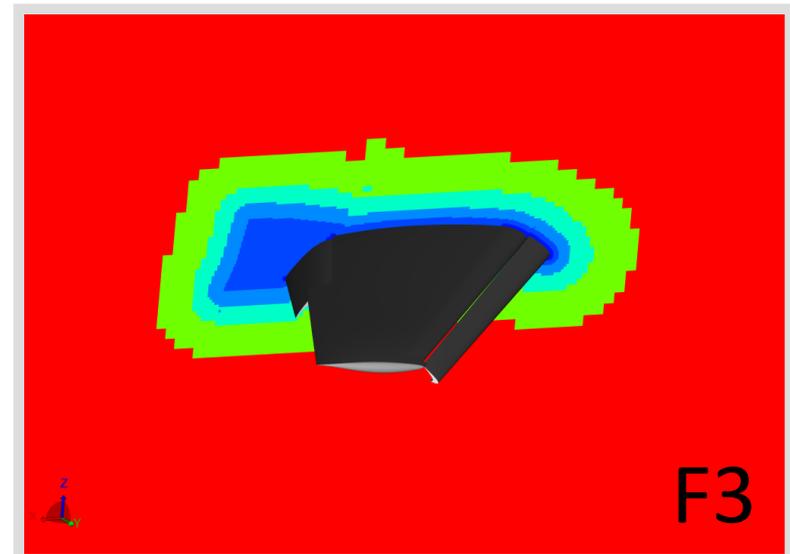
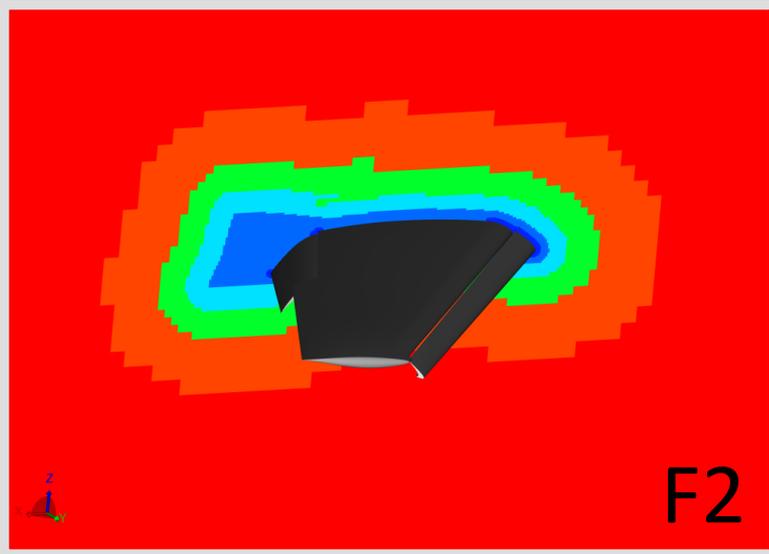


R grid family surface grid on
wing leading edge

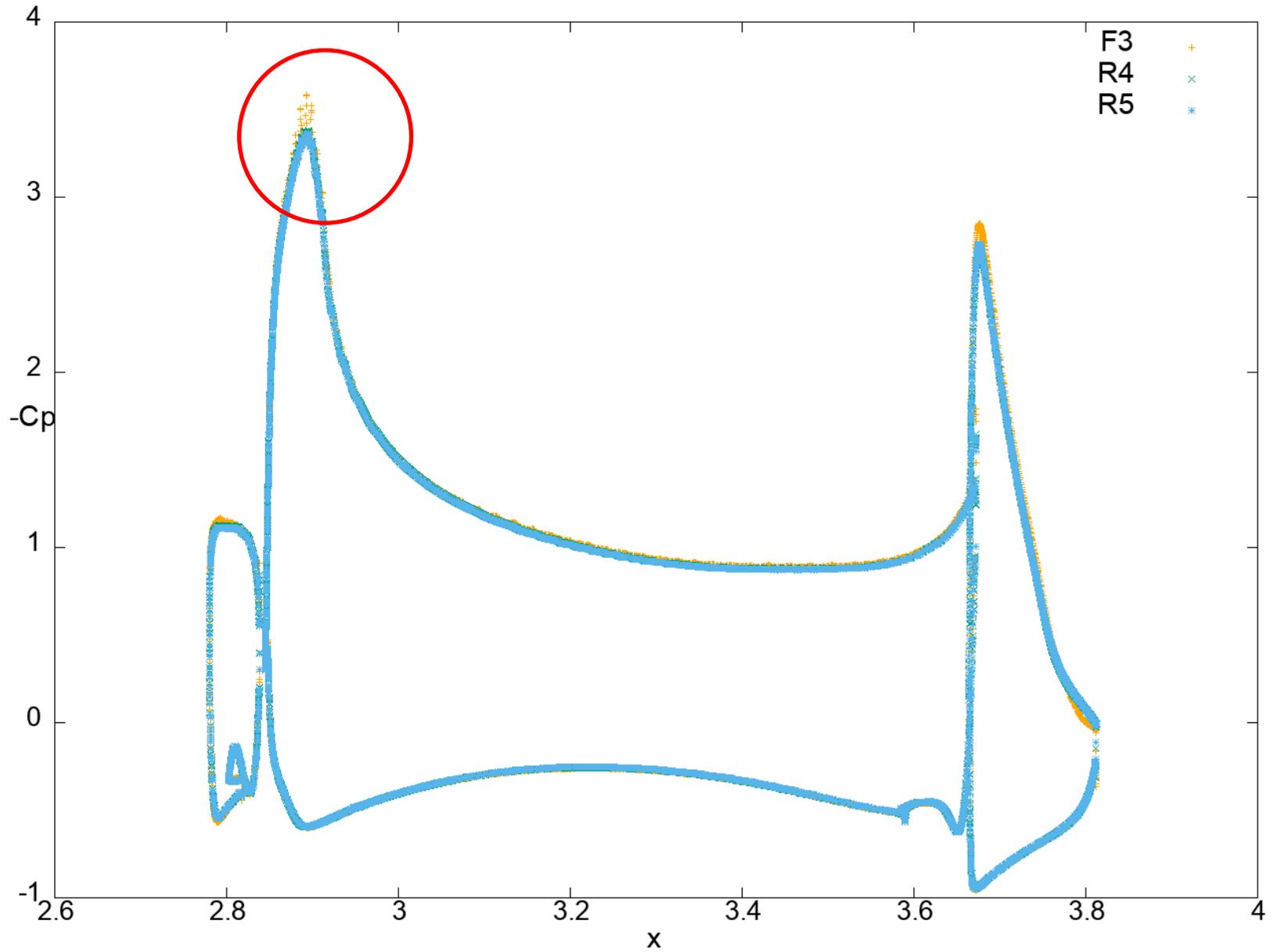
Grid Families, eta 0.418



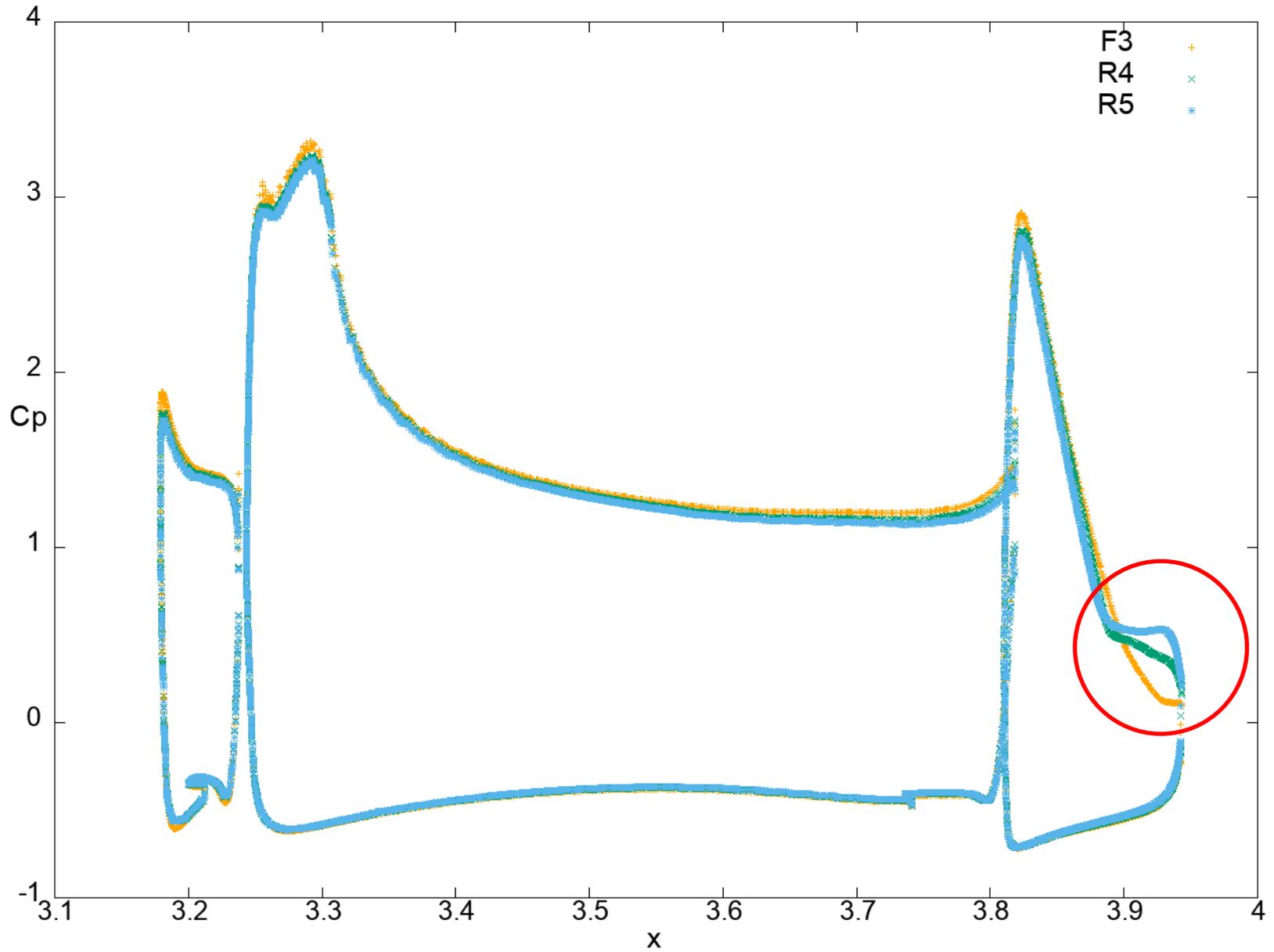
Grid Families, eta 0.552



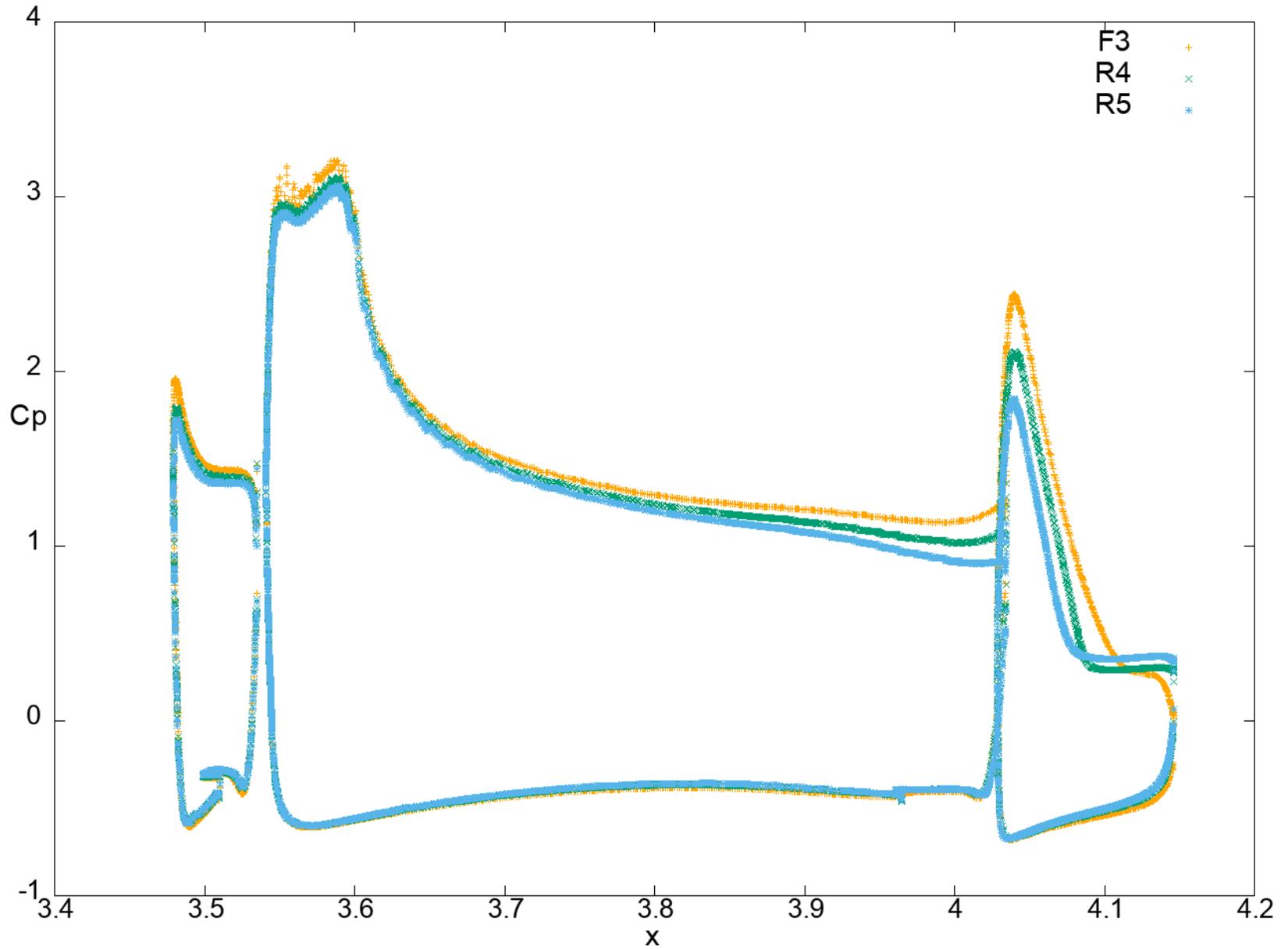
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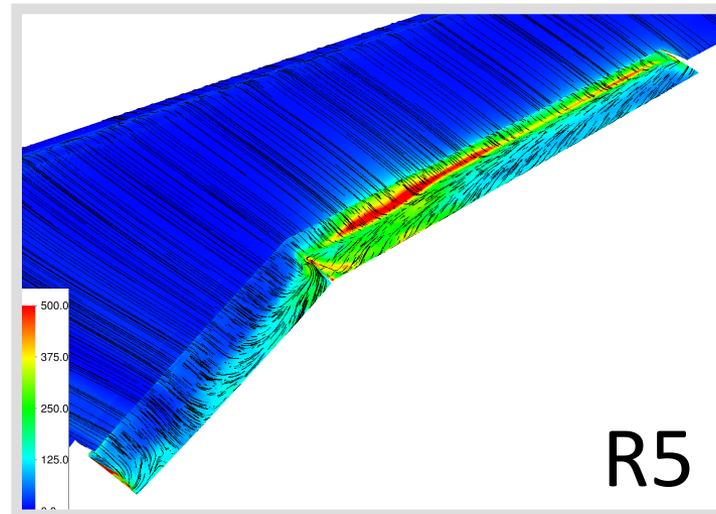
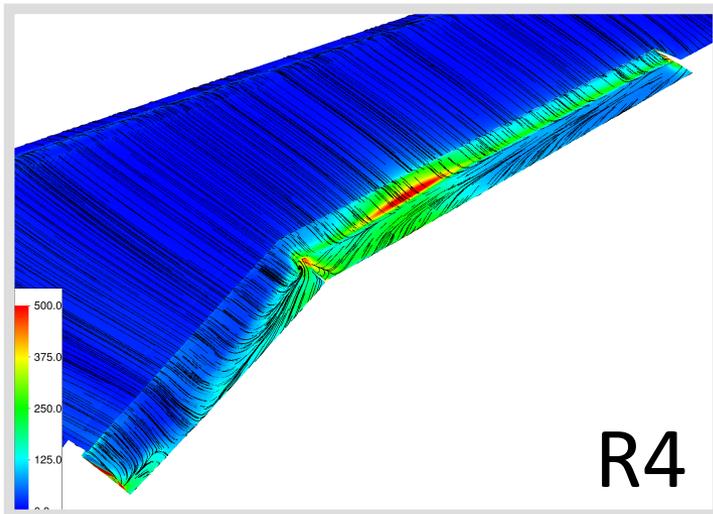
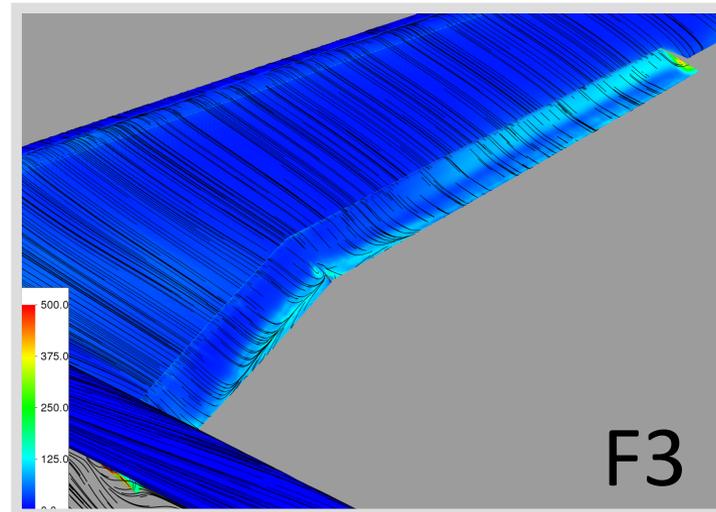
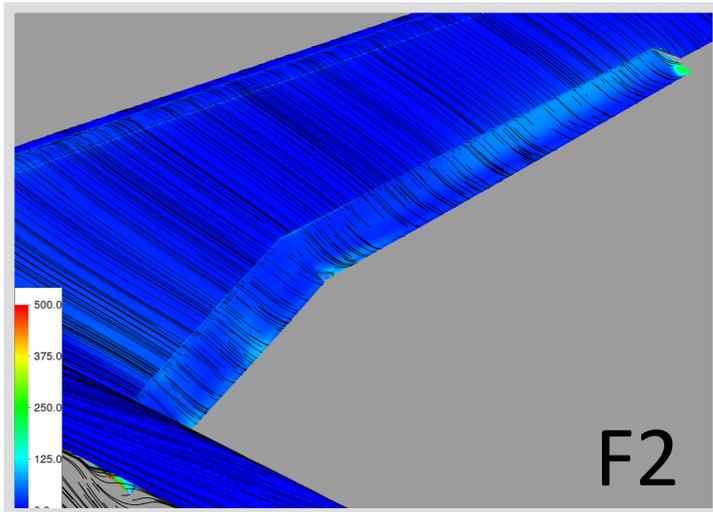
Cp eta = 0.418



Cp eta = 0.552

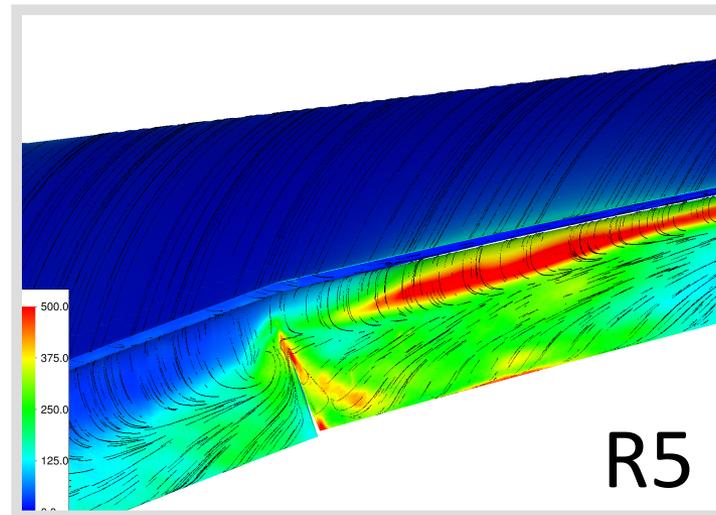
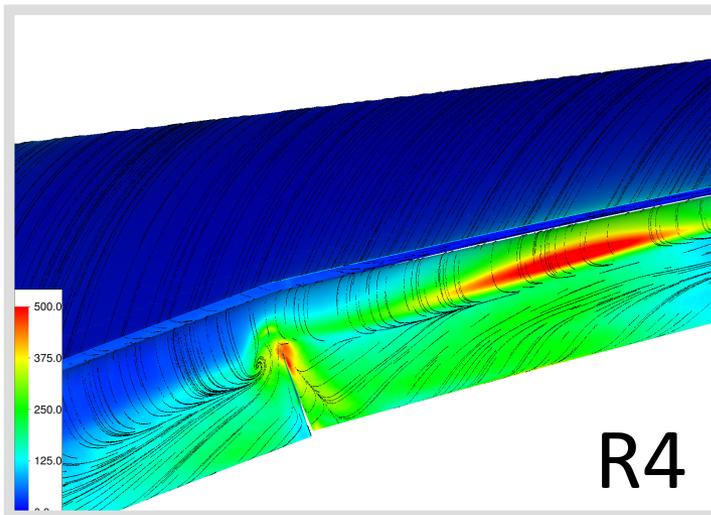
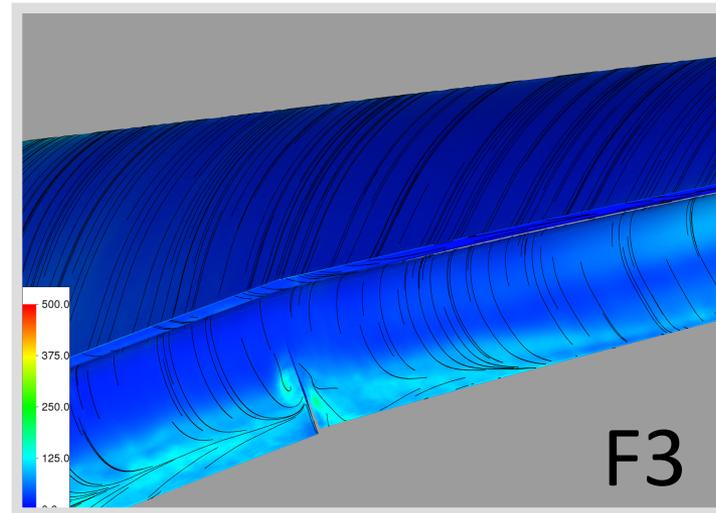
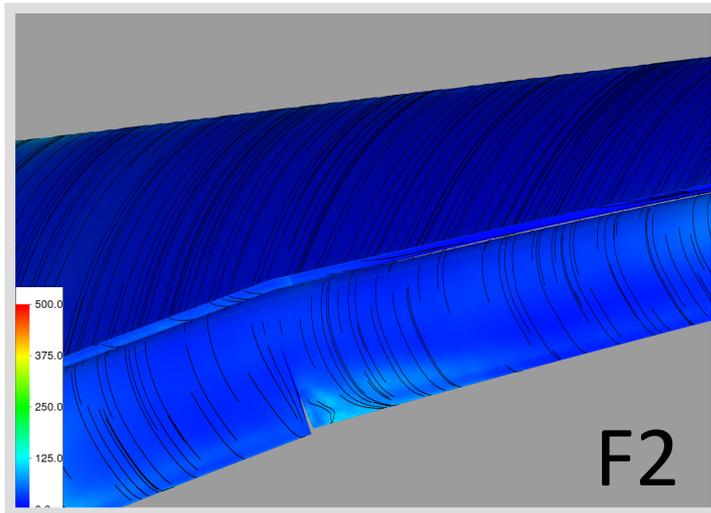


Flap Separation



Surface streamlines, contours of p'_{rms}

Flap Separation Around Break



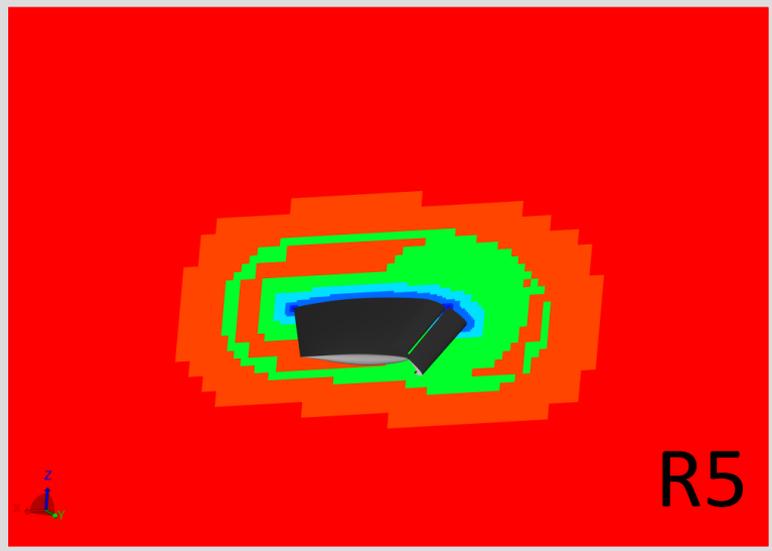
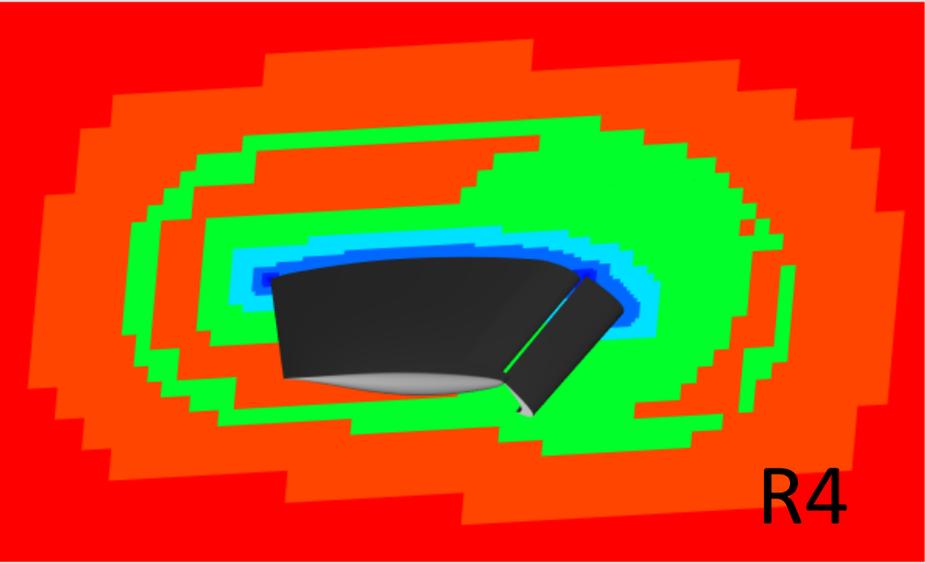
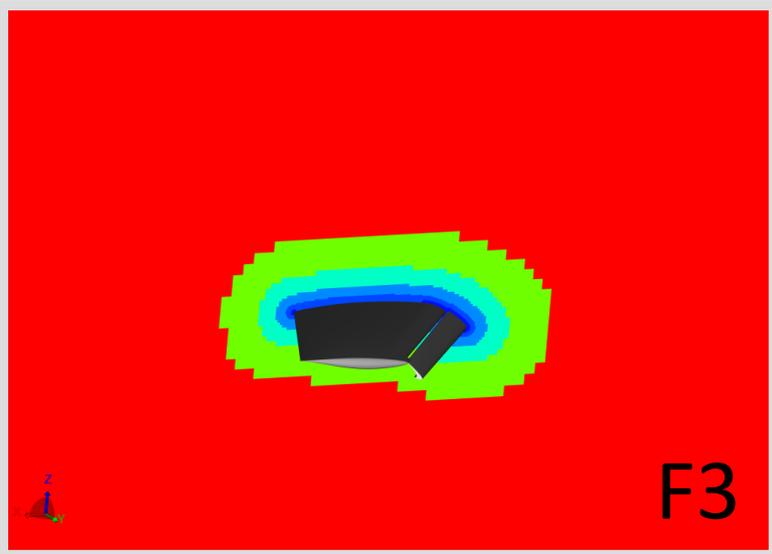
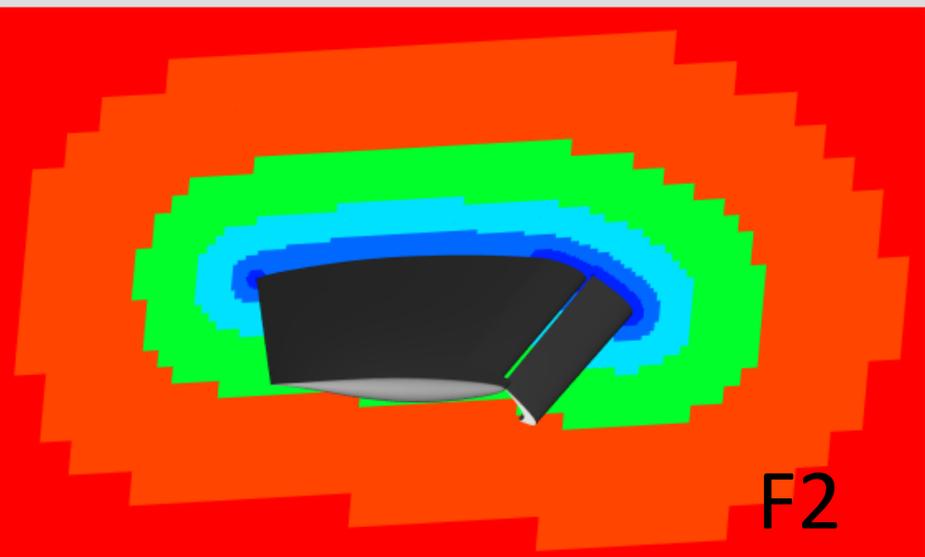
Surface streamlines, contours of p'_{rms}

Summary

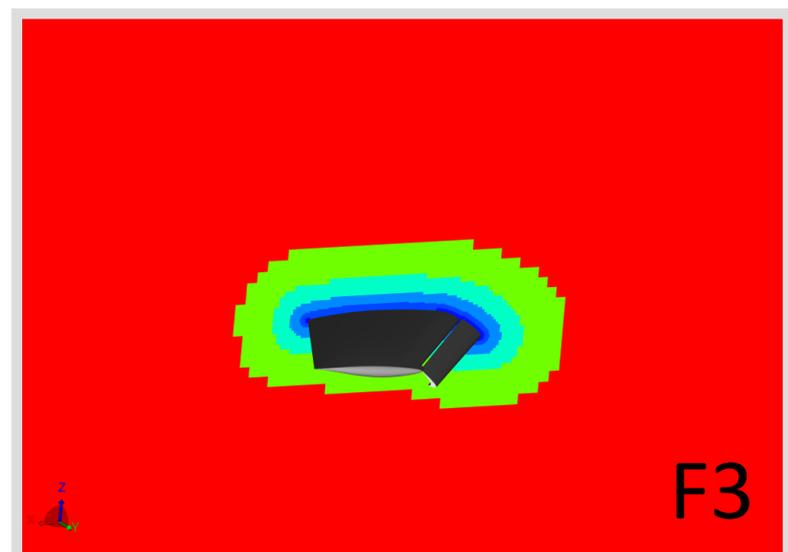
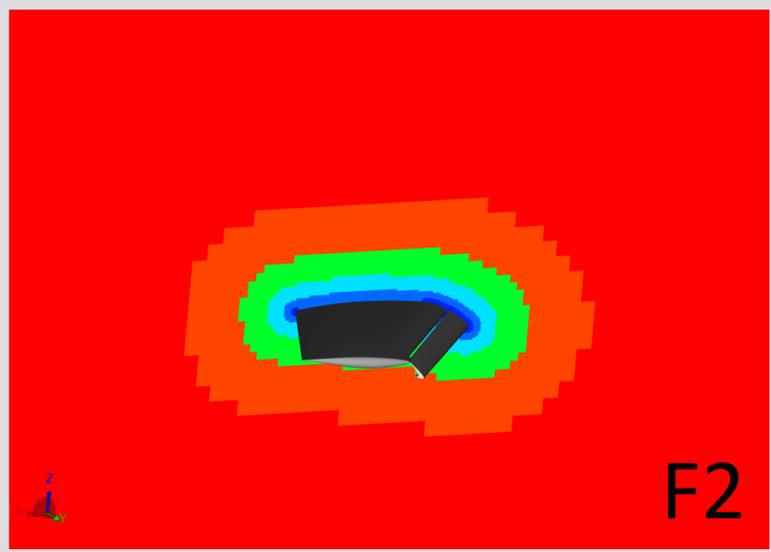
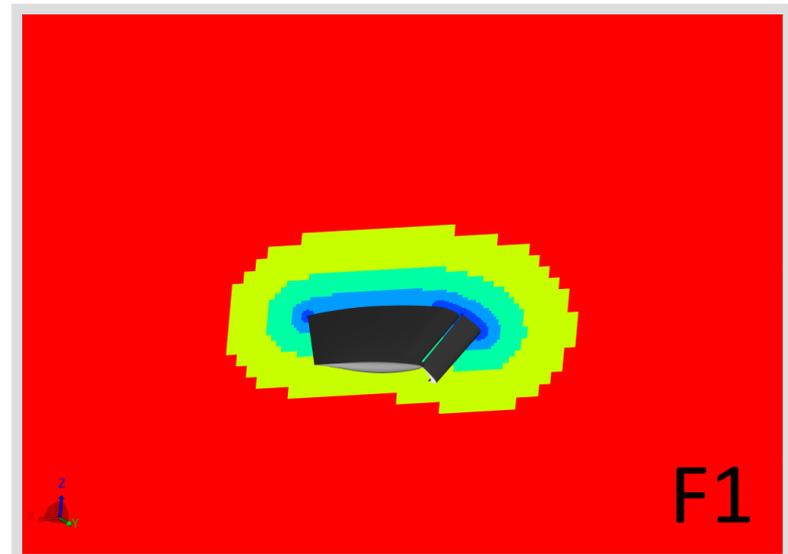
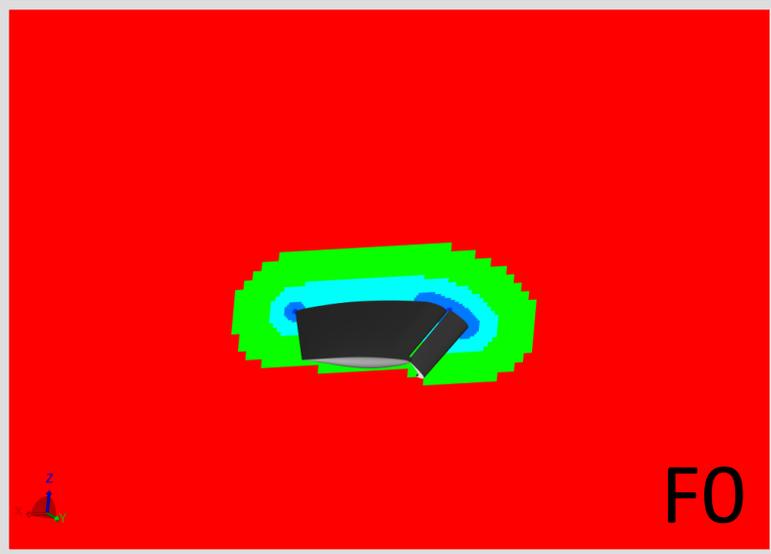
- What was learned?
 - As was shown in HiLift-PW1 & 2; resolution, both surface resolution and volume resolution have a major impact on high lift flow features.
 - Targeted mesh resolution is critical to achieving efficient solutions.
 - Finding where to add resolution is challenging. We need additional tools to help.
 - Lots of uncertainty remains, we have yet to achieve a grid converged solution.

Backup

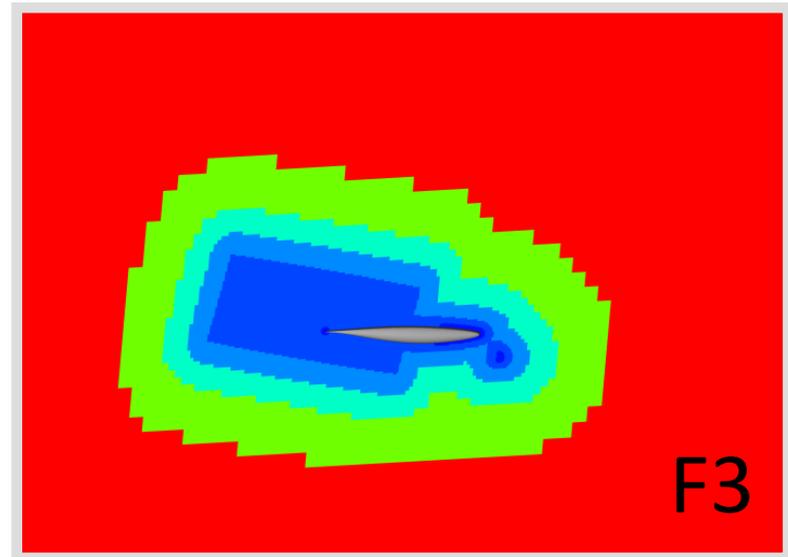
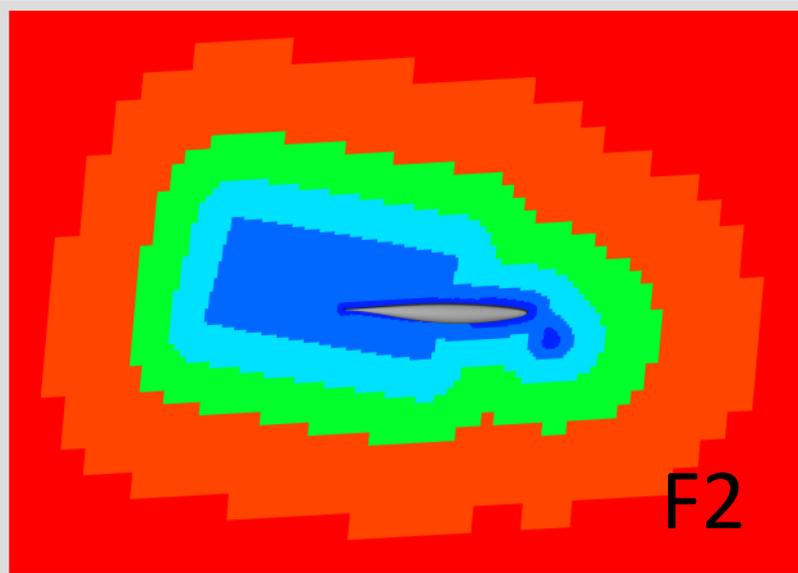
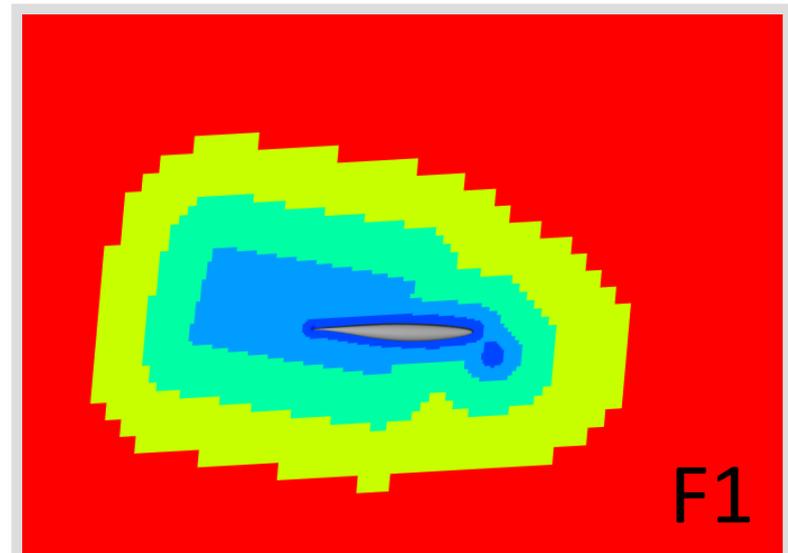
Grid Families, eta 0.819



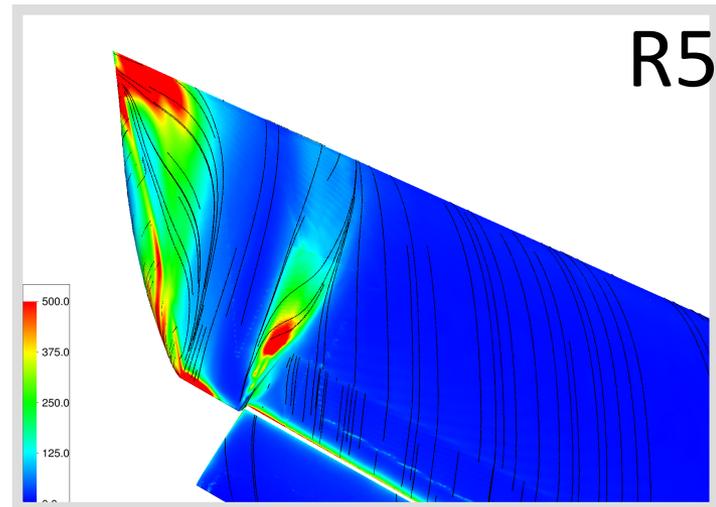
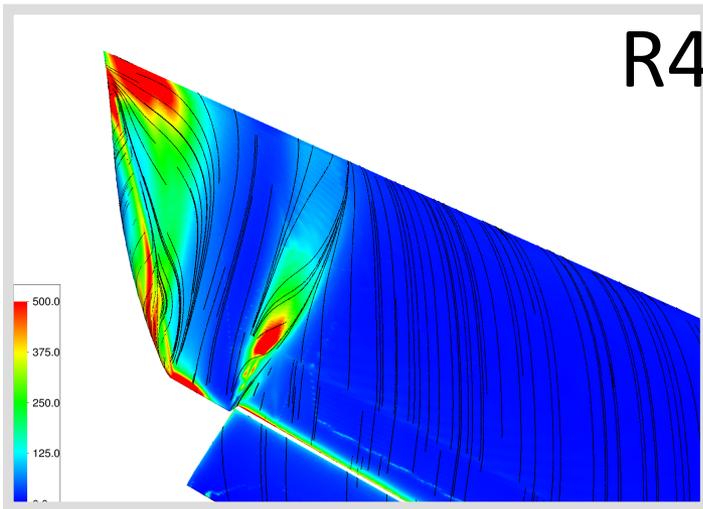
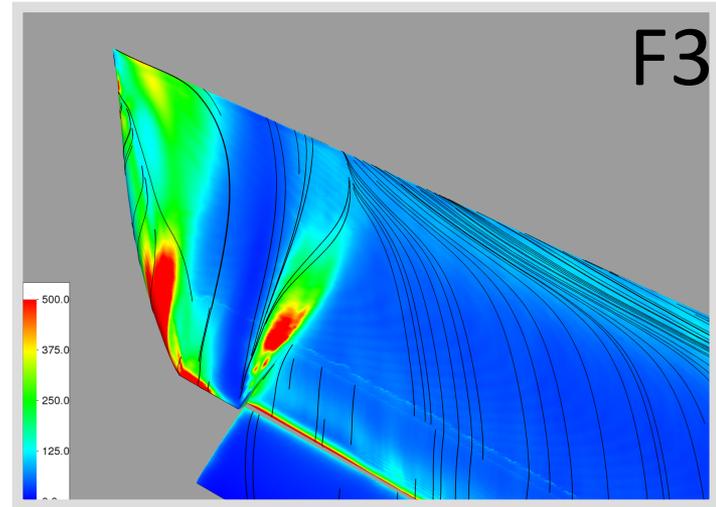
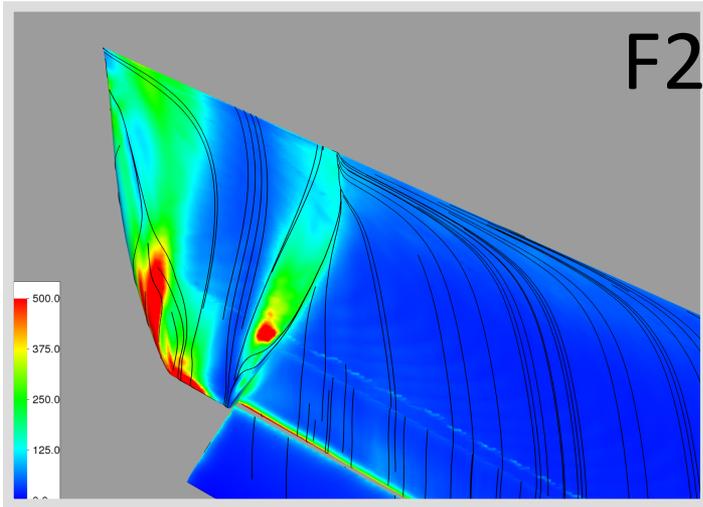
Grid Family F, eta 0.819



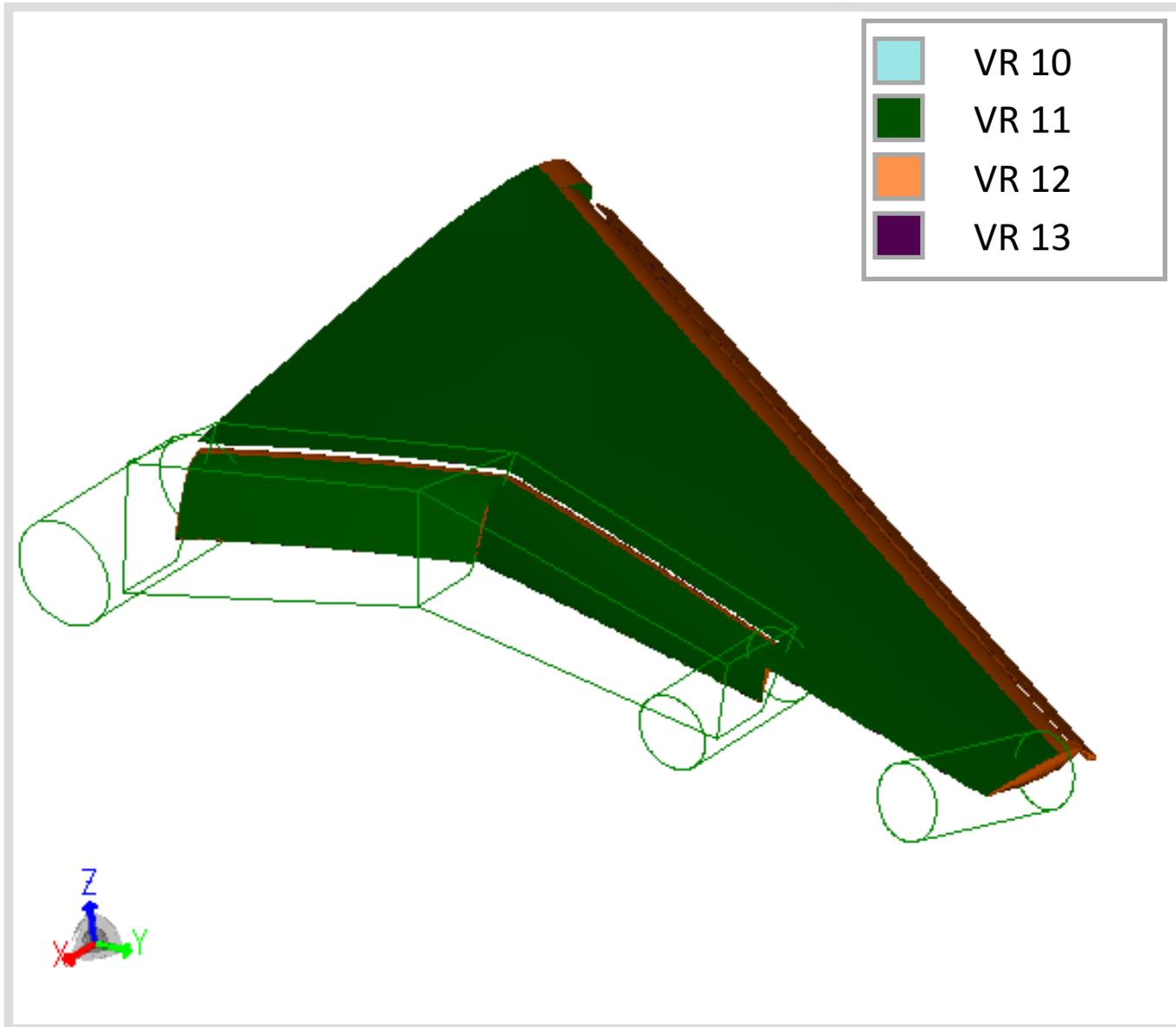
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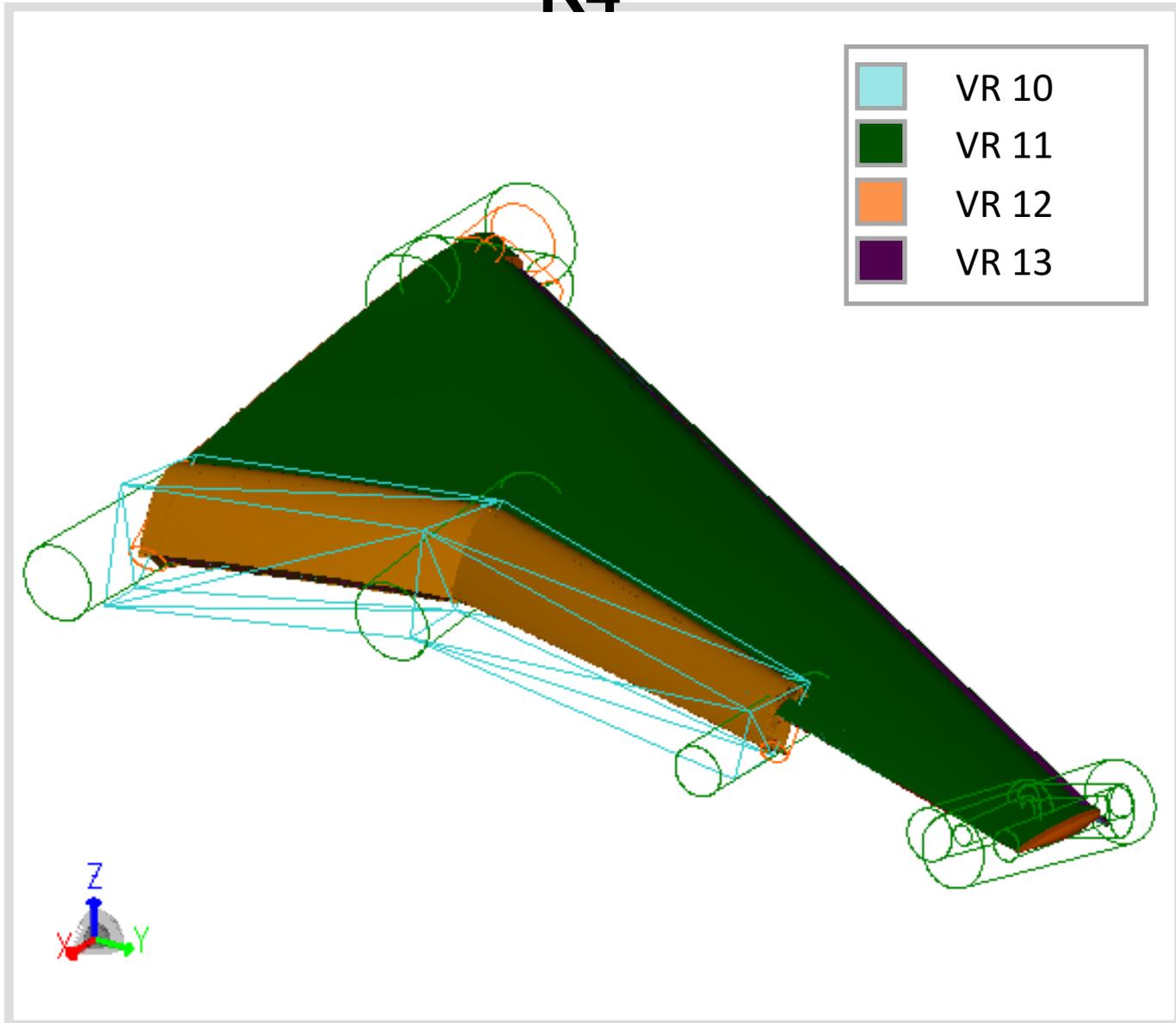
Tip System



Initial Grid Family



R4



R5

