NASA FUN3D Contributions to HLPW6

(Preliminary Results)

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Solver Details

- FUN3D V14.2, RANS, Steady-state

- Finite Volume Solver

  2nd order node-based discretization
  Roe upwind flux, multicolor point Gauss-Seidel preconditioner
  LHS Jacobian matrix used in preconditioner: 1st order inviscid fluxes, 2nd order viscous fluxes
  SA-neg with 1st order convection
  Hierarchical Adaptive Nonlinear Iteration Method (HANIM): GCR + Frechet derivatives, adaptive CFL, GCR max. search directions = 4

- Stabilized Finite Element Solver

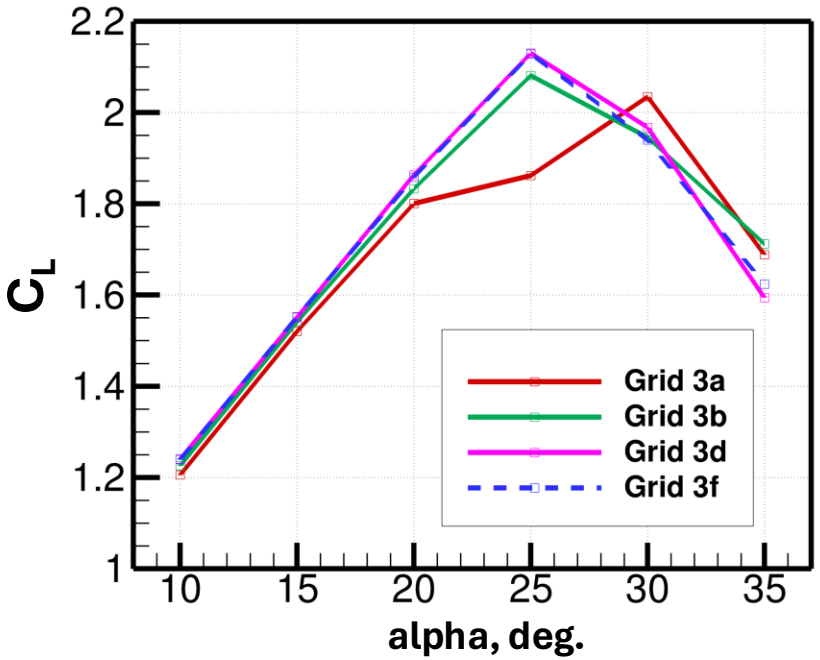
  2nd order low-dissipation SUPG with residual smoothing (currently P1 but extendable to higher order)
  Tightly-coupled SA-neg with 2nd order convection
  Strong linear solver via ILU-preconditioned GMRES
  Globally convergent Newton-type solver with exact linearizations
  Adaptive CFL controller and line search for robust solution advancement

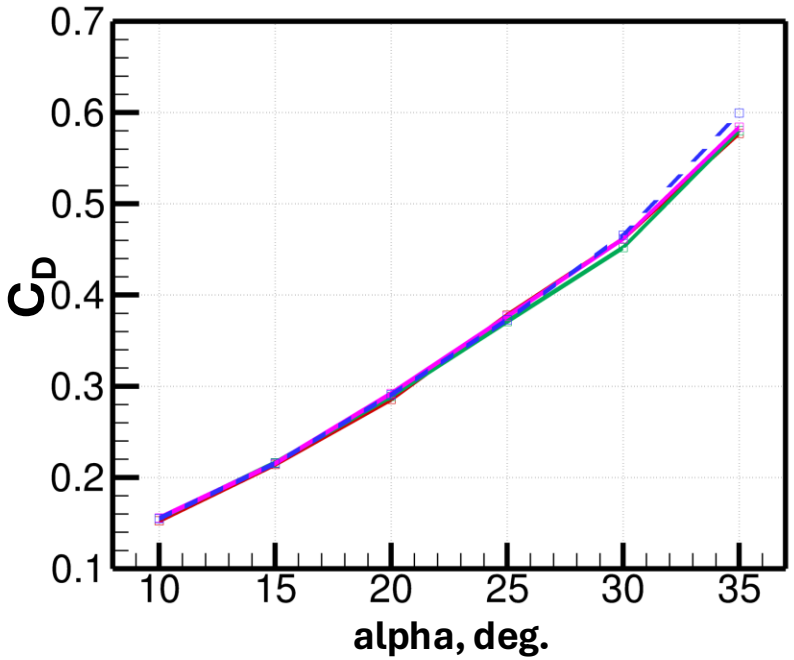
Outline of Talk

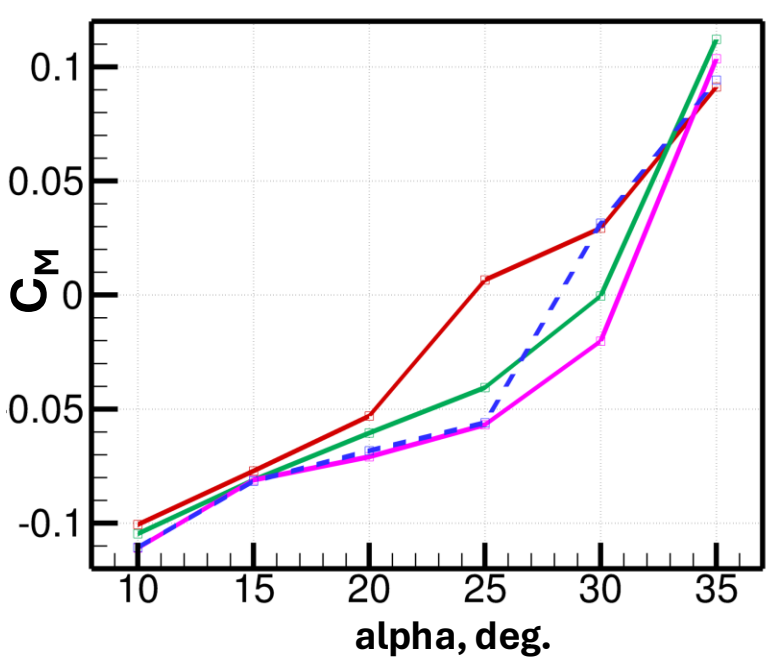
- Preliminary fixed grid results for FV solver

- Multiple solutions study at 20 deg. using SFE and FV solvers: based on Boeing and DLR results shown in TFG

Overview of FV Results



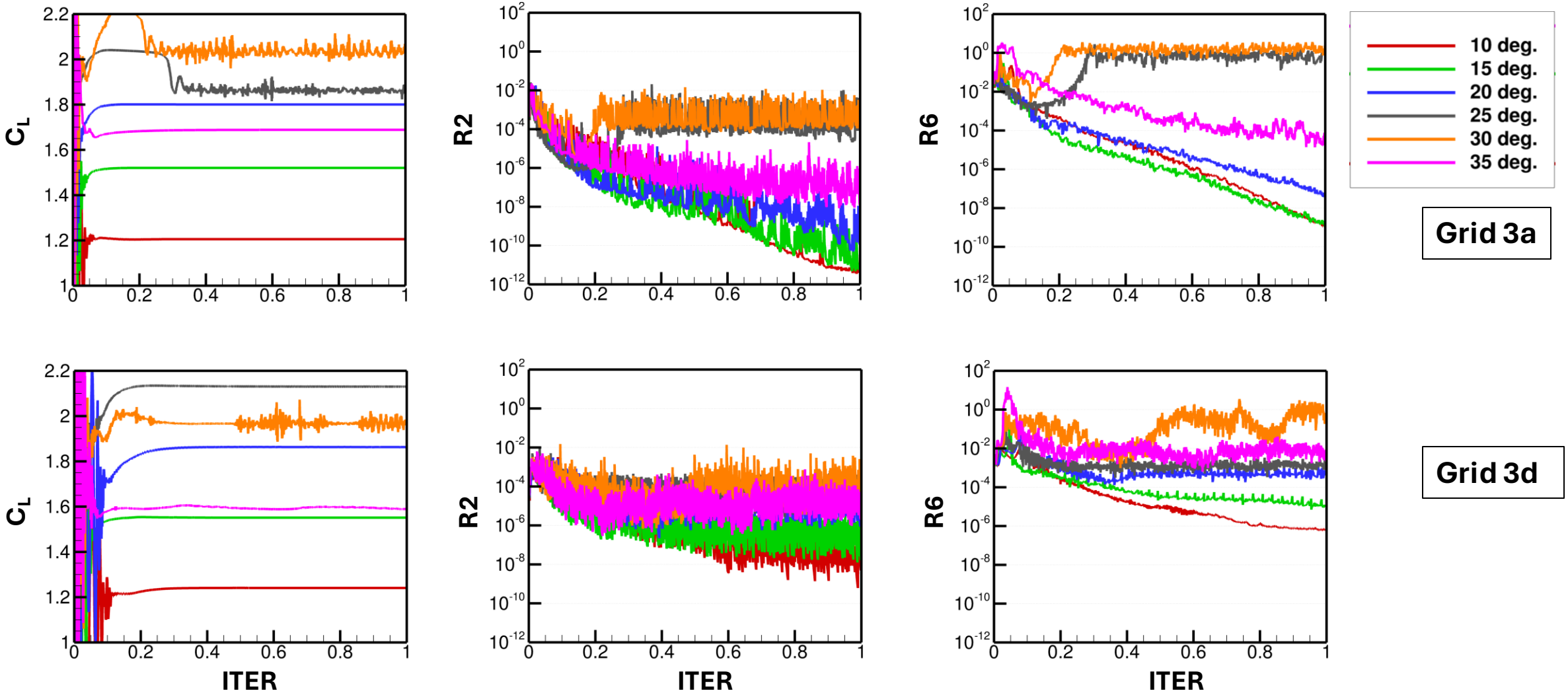




- Results using FUN3D-FV on Helden 3 grid family using cold start.
- Simulations run until lift variation was statistically converged.
- Solutions are essentially grid converged on Grid 3d with ~18M d.o.f. except for C_M at 30 deg.

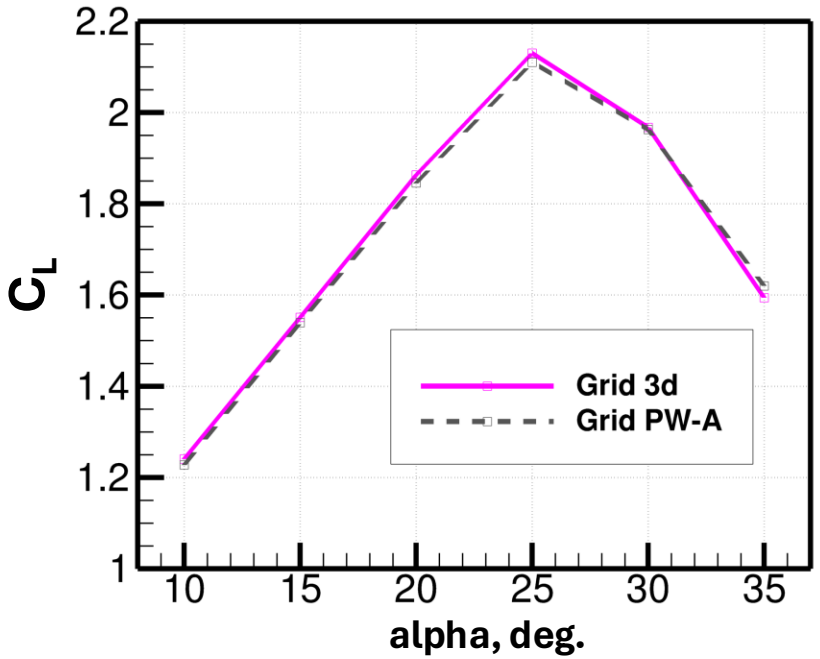
Id Name	#Cells	#Nodes	Avg Y+	#Pts in BL	S_UPPER	S_MIN	Growth Rate
h6c1_rans_3a_1	2,661,338	1,156,796	2	15	0.5	0.01	0.6
h6c1_rans_3b_1	5,730,017	2,563,947	1.5	20	0.375	0.0075	0.45
h6c1_rans_3c_1	17,156,244	7,925,531	1	30	0.25	0.005	0.3
h6c1_rans_3d_1	38,396,606	18,023,391	0.75	40	0.1875	0.00375	0.225
h6c1_rans_3e_1	121,556,755	57,968,323	0.5	60	0.125	0.0025	0.15
h6c1_rans_3f_1	279,592,041	134,413,941	0.375	80	0.09375	0.001875	0.1125
h6c1_rans_3g_1	933,874,390	451,567,875	0.25	120	0.0625	0.00125	0.075

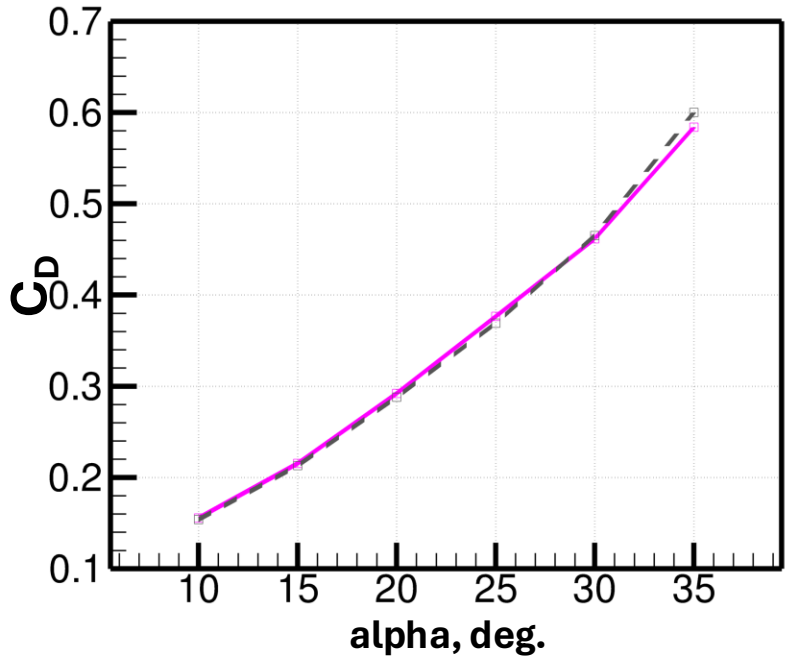
Iterative Convergence for FV

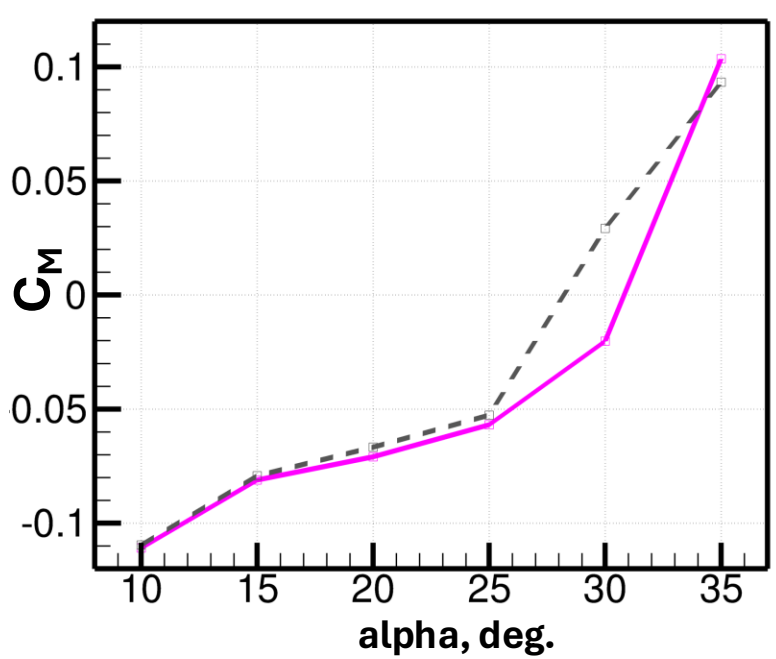


- Residual convergence degrades for higher angles of attack and finer grids

Comparing Grid Families for FV



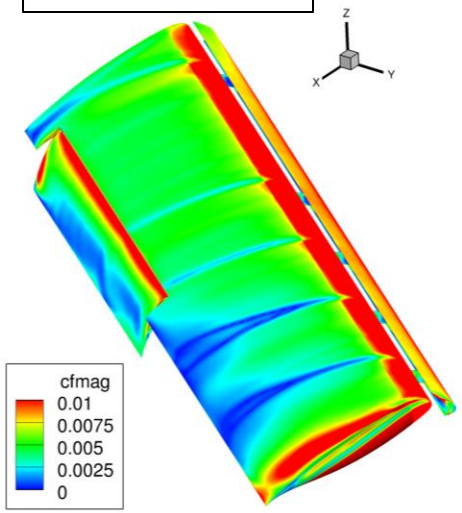




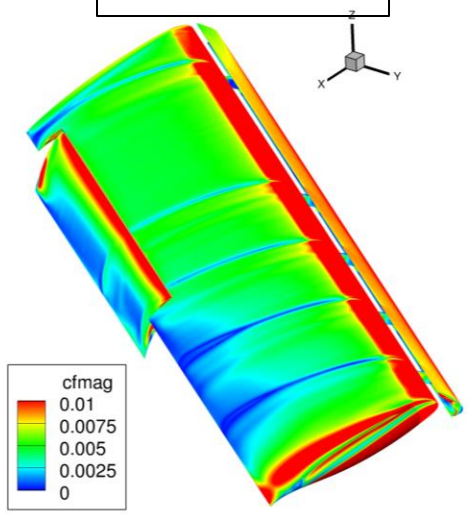
- Comparable results between:
  -> Helden Grid 3d with Tris (surface), Prisms/Tets (volume), $y^+ \sim 1$ with ~18M d.o.f.
  -> Pointwise F1 Grid A with Quad-dominant (surface), Hex/Hex-core (volume), $y^+ \sim 4/3$ with ~15M d.o.f.

Comparing two branches for SFE solutions

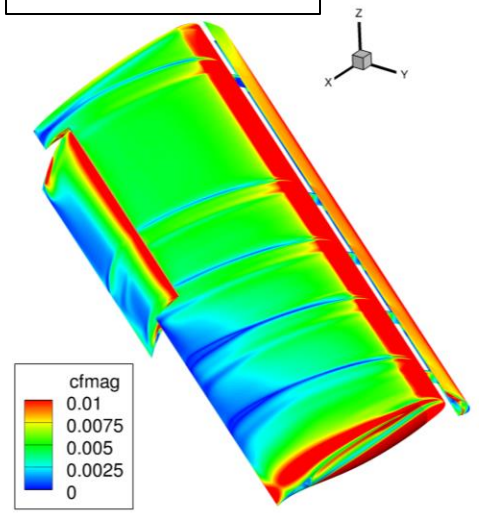
Grid 3a (1.1M nodes) FUN3D-SFE



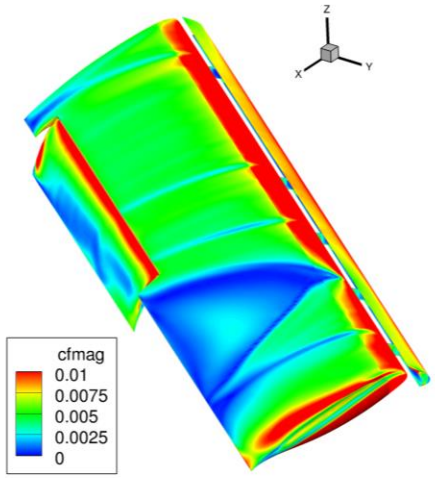
Grid 3d (18M nodes) FUN3D-SFE

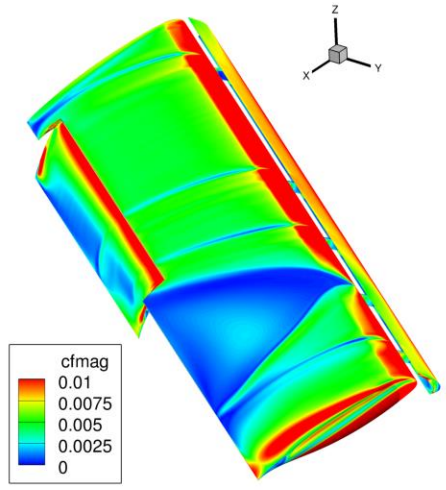


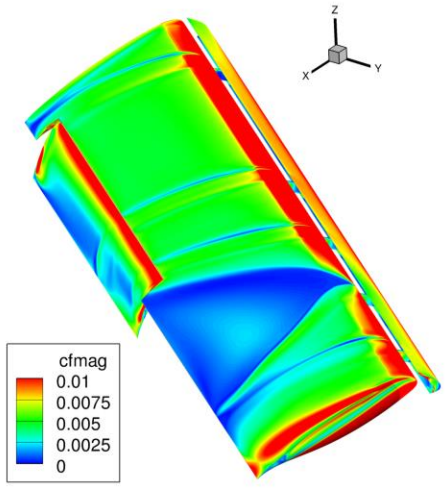
Grid 3f (134M nodes) FUN3D-SFE



Cold Start



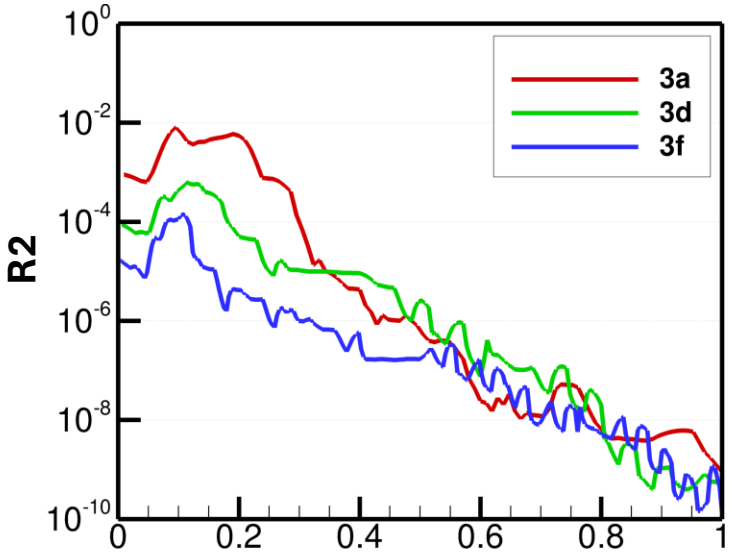


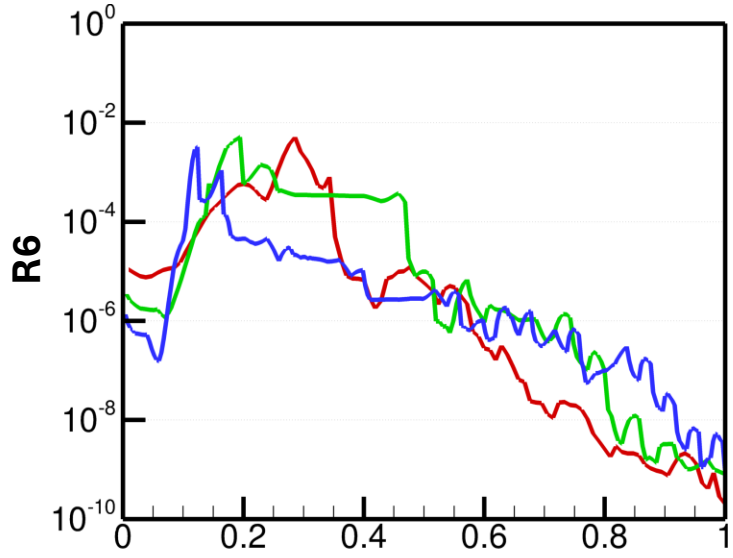


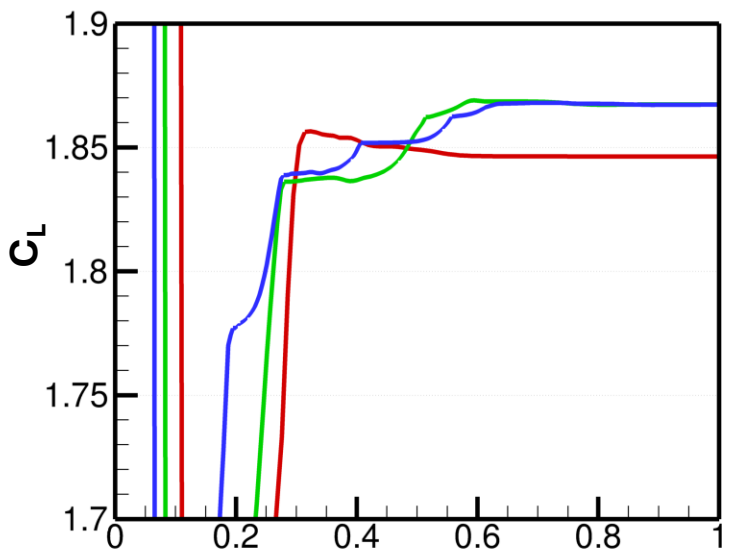
Warm Start

- Warm started from FV solutions.
- Overall, the upper and lower lift branches at 20 deg. look qualitatively very similar between SFE solutions on different grid levels.

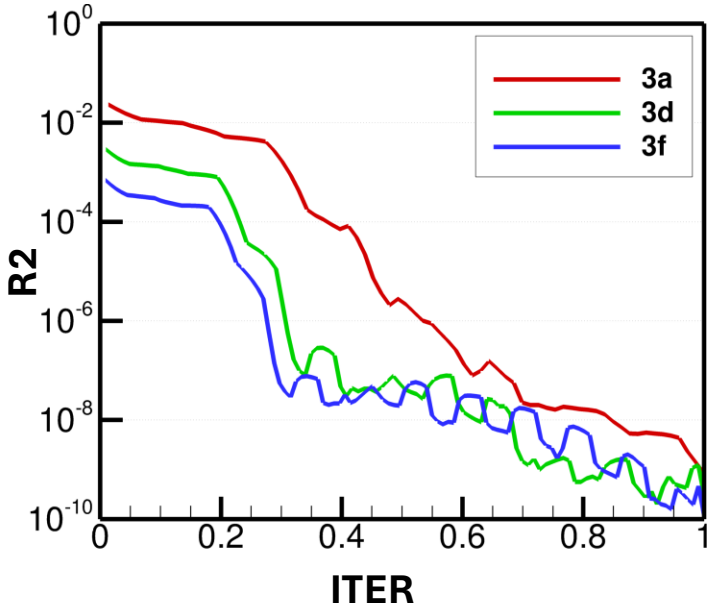
Iterative Convergence for SFE Multiple Solutions at 20 deg.

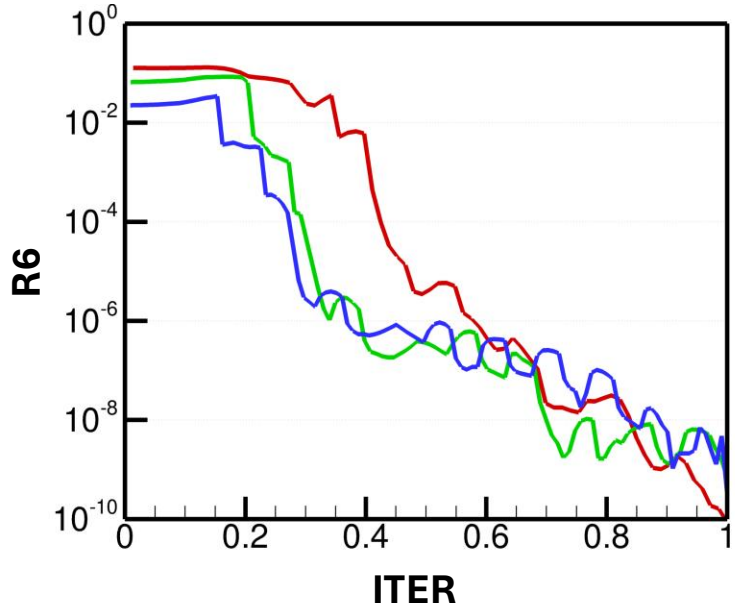


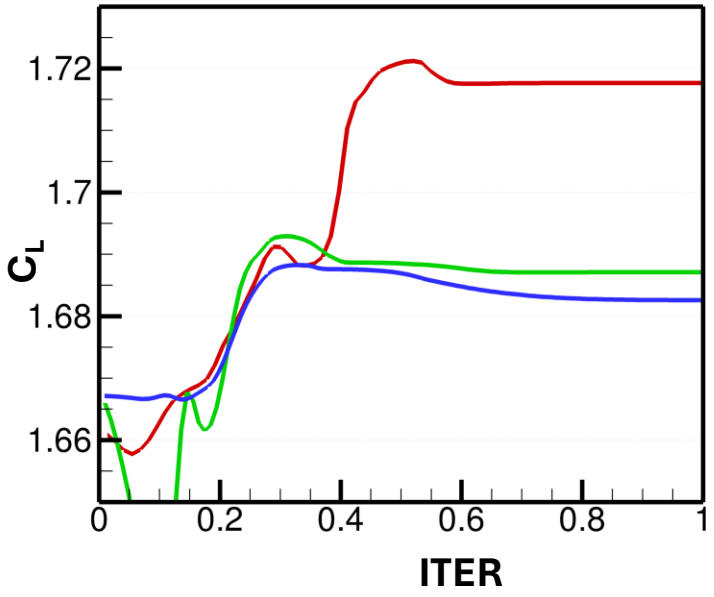




Cold Start







Warm Start

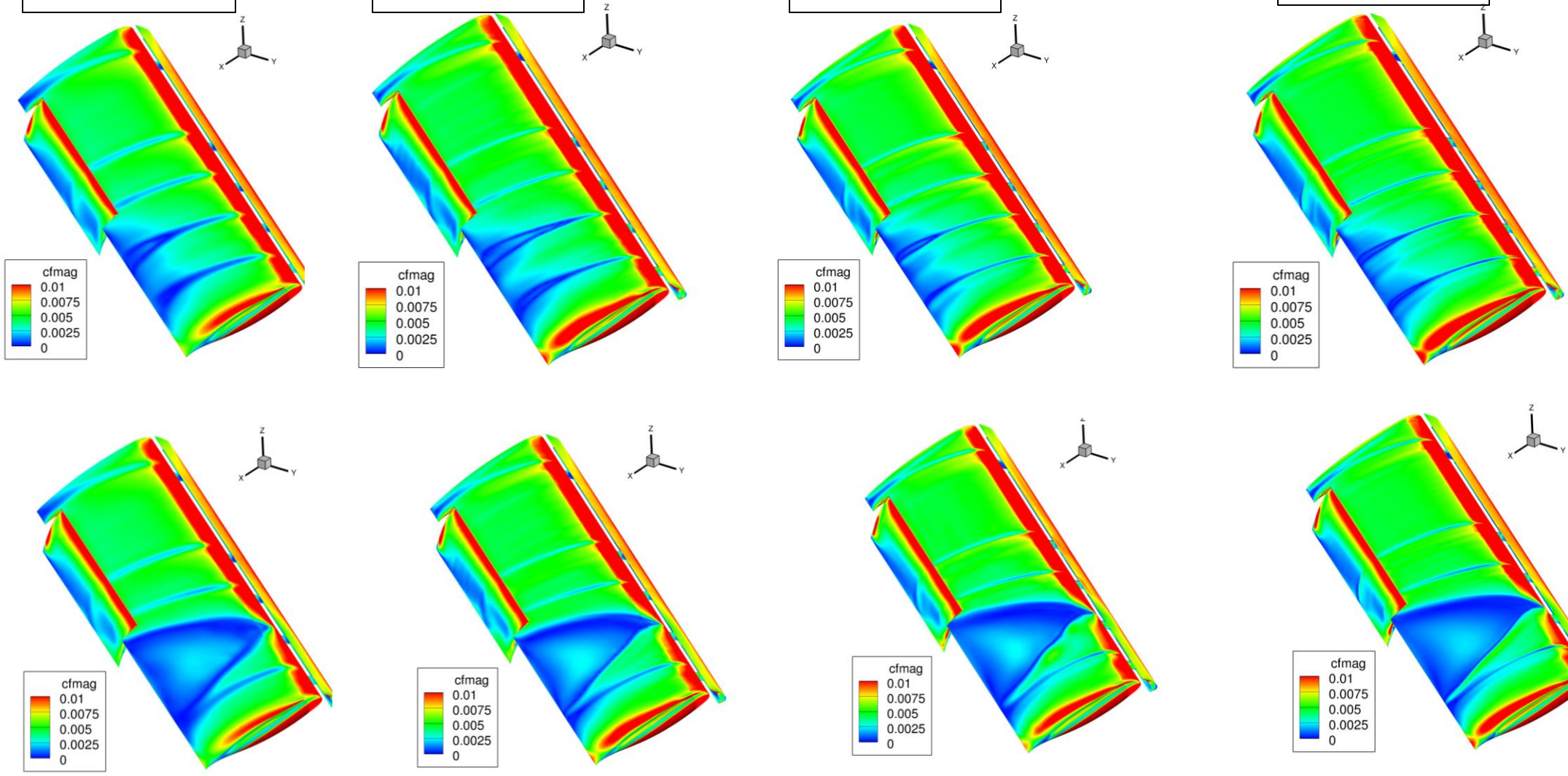
Comparing two branches from 3a and 3d FV and SFE solutions

Grid 3a (1.1M nodes) FUN3D-FV HANIM

Grid 3a (1.1M nodes) FUN3D-SFE

Grid 3d (18M nodes) FUN3D-FV HANIM

Grid 3d (18M nodes) FUN3D-SFE

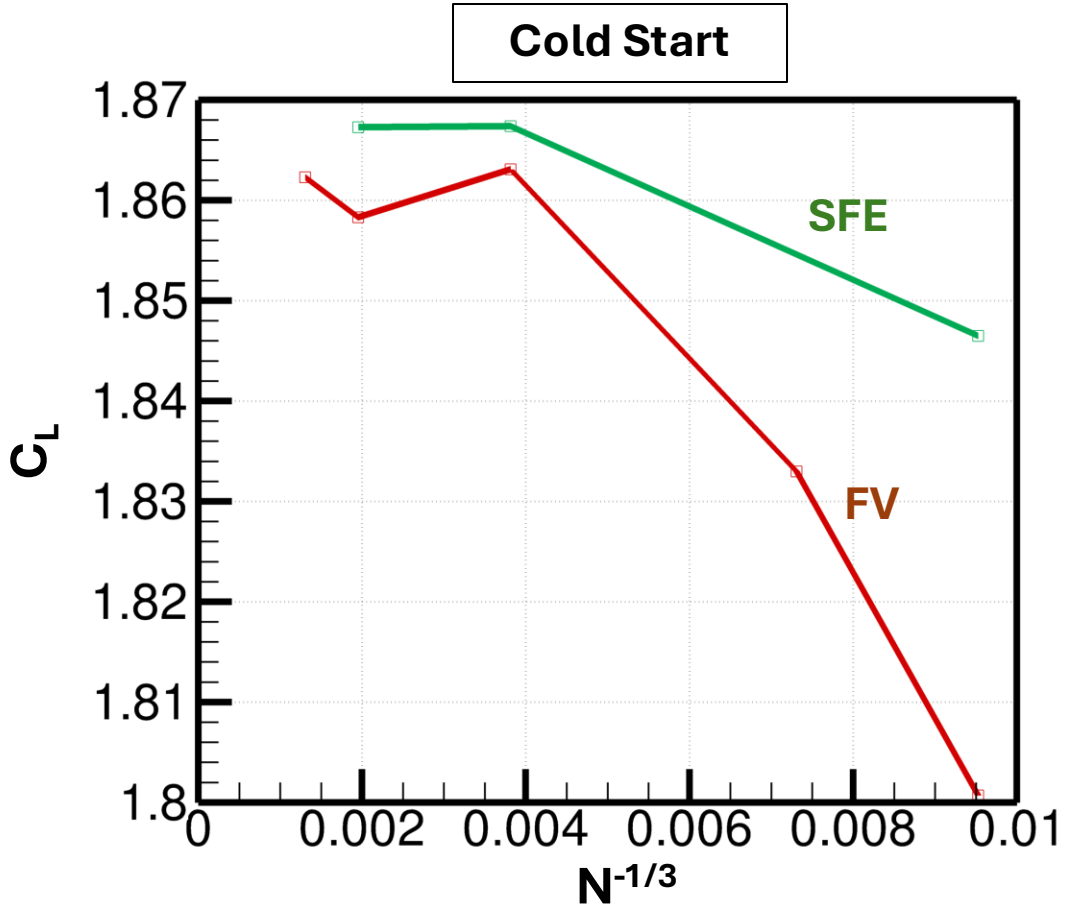


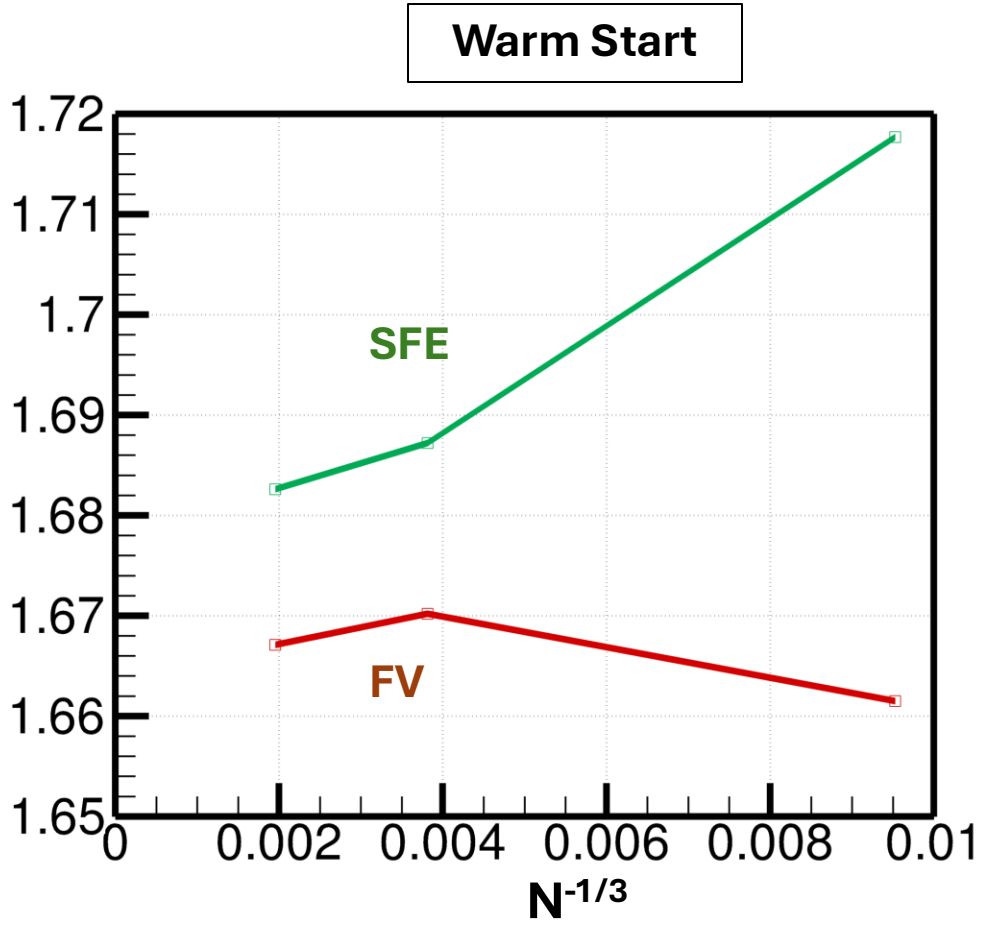
Cold Start

Warm Start

- Overall, the upper and lower lift branches at 20 deg. look qualitatively very similar between FV and SFE solutions (though FV solutions show poor residual convegence), and between different grid levels. Results for 3f look similar.

Grid Convergence of Lift at 20 deg.

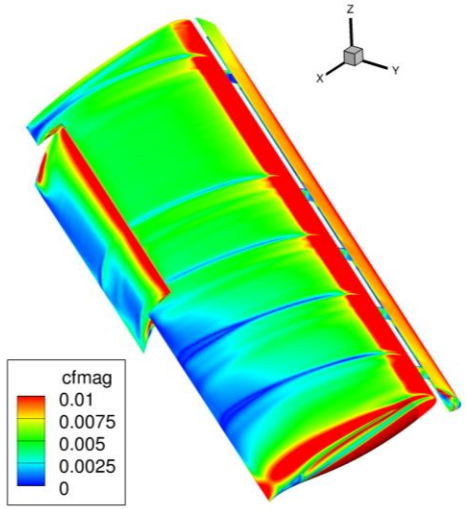




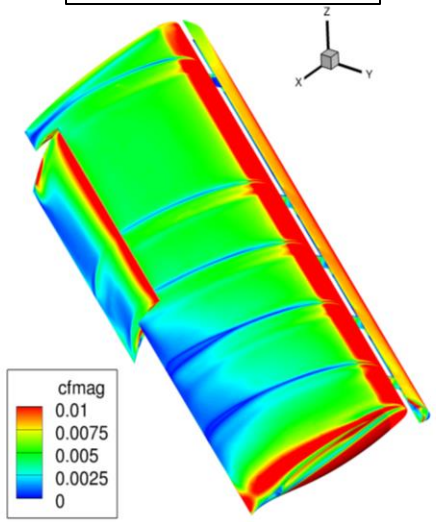
- SFE converges faster on coarser grid for upper branch/ cold-start solution.
- FV variation smaller for lower branch, but it has poor residual convergence!

Comparing two branches for SFE solutions on Different Grid Families

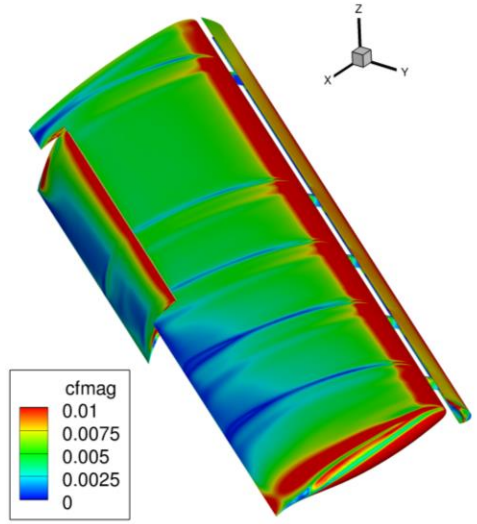
Grid 3d (18M nodes)



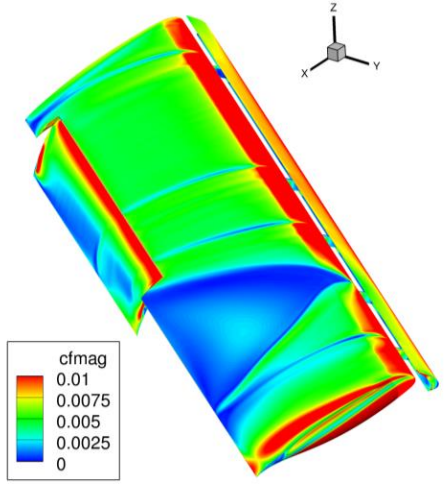
Grid 4d (10M nodes)

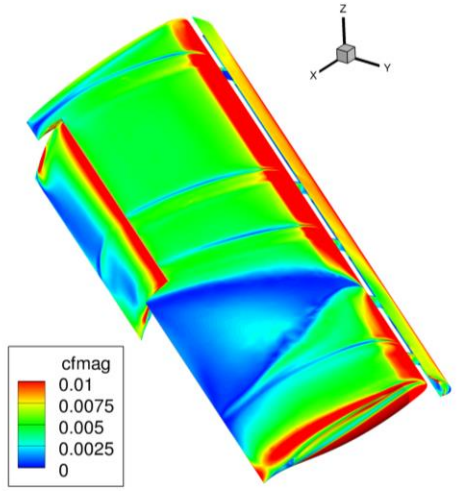


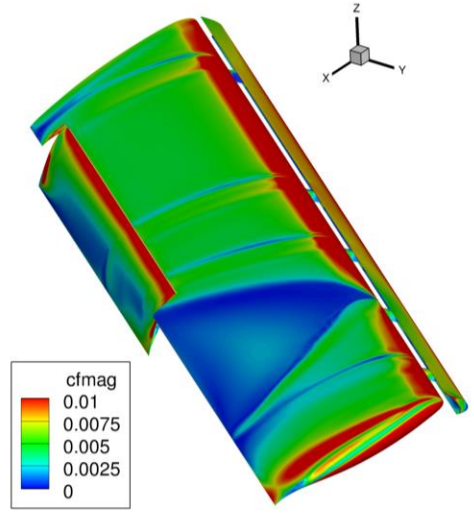
Grid F1-A (15M nodes)



Cold Start







Warm Start

- Qualitatively similar results obtained with Helden 4d grid and Pointwise F1-A grids for 20 deg.
- Future Work: Analyze/understand these results further, and look for multiple solutions at other angles!