



**DPW-V**

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**June 23, 2012**

# Outline

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- **Solver**
- **Grids**
- **Typical Convergence**
- **Test Case 1: Grid Study**
  - Section cuts
  - Drag
  - Wing trailing edge (TE) separation
  - Side of Body (SOB) separation
- **Test Case 2: Buffet Study**
  - Wing trailing edge (TE) separation
  - Side of Body (SOB) separation
  - Drag
  - Lift
- **Alternate Solver and Grid Study**
  - Drag
  - Flow Features

# Solver: FUN3D v 12.1

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- **Full Navier-Stokes, unstructured, node-centered**
- **Spalart-Allmaras (SA) turbulence model**
- **Roe's flux difference splitting**
- **All solutions executed from scratch**

**USM3D was also used, but to a limited extent. This will be addressed in a later slide.**

# Grids: DPW supplied unstructured-hybrid

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- Utilized Common L1 – L5 hybrid grids

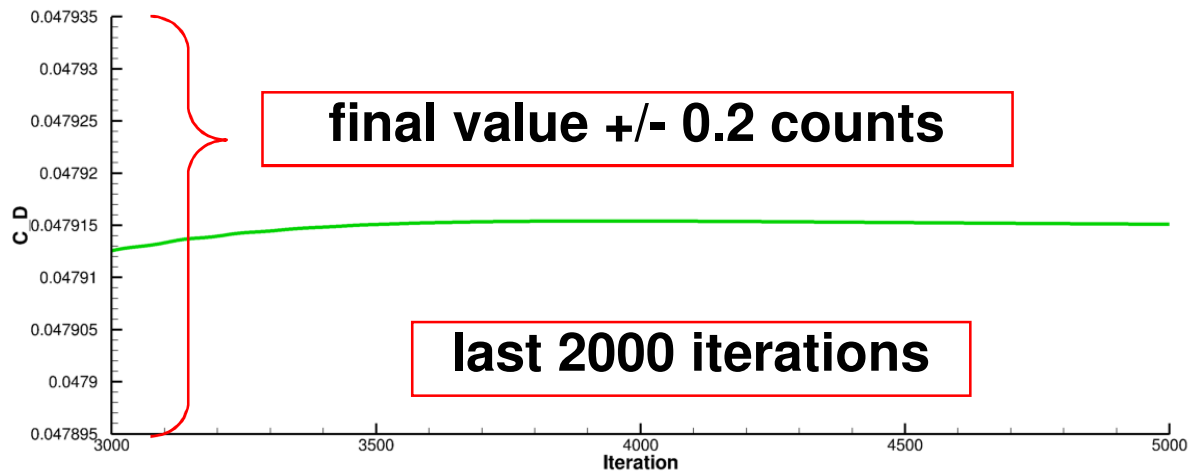
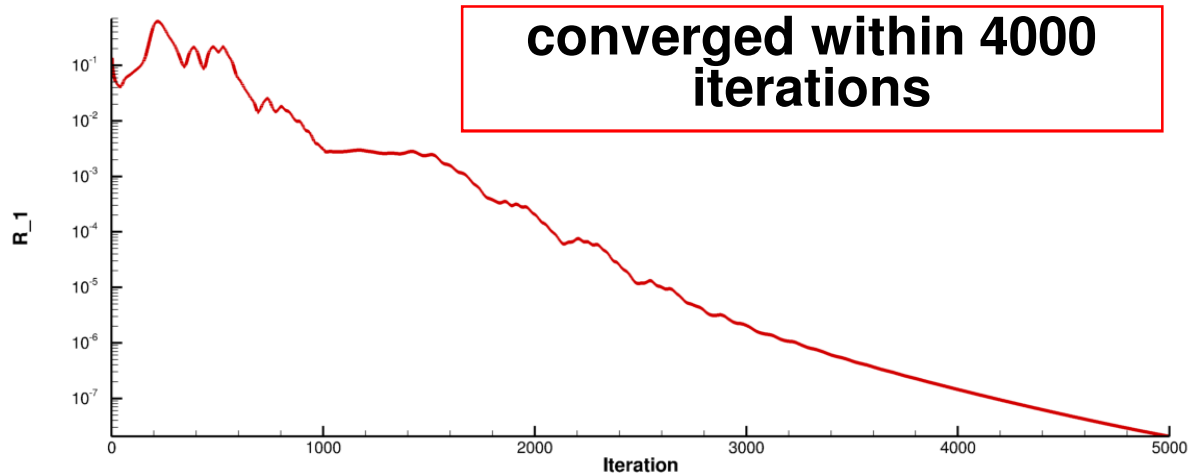
Level	Refinement	Y+	# of Nodes	# of Tets	# of Prisms
1	Tiny	2.00	2,204,089	2,555,904	425,984
2	Coarse	1.33	660,177	8,626,176	1,437,696
3	Medium	1.00	5,196,193	20,766,720	3,301,376
4	Fine	0.67	17,441,905	69,728,256	11,261,952
5	Extra Fine	0.50	41,231,169	166,133,760	26,411,008

- Converted files to stream format (.b8).

**Additional grids were generated using VGRID, but have limited commonality. This will be addressed in a later slide.**

# Typical FUN3D Convergence

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# Test Case 1: Grid Study

Level 1 - Level 5 grids

Mach = 0.85, CL = 0.5

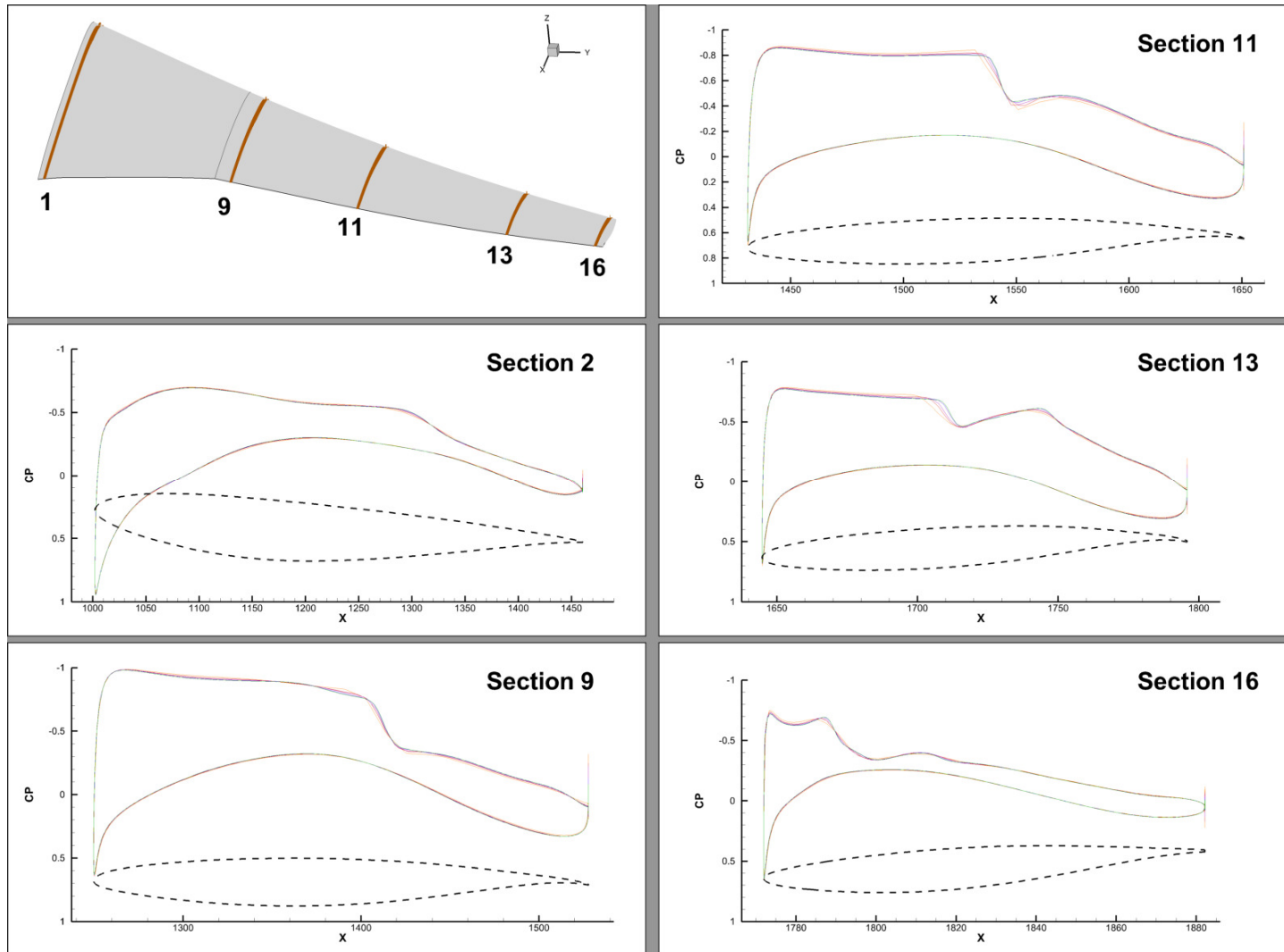
$S_{\text{ref}} = 297,360 \text{ in}^2$  (half model)

$R_N = 5 \times 10^6$ ,  $C_{\text{ref}} = 275.8 \text{ in.}$

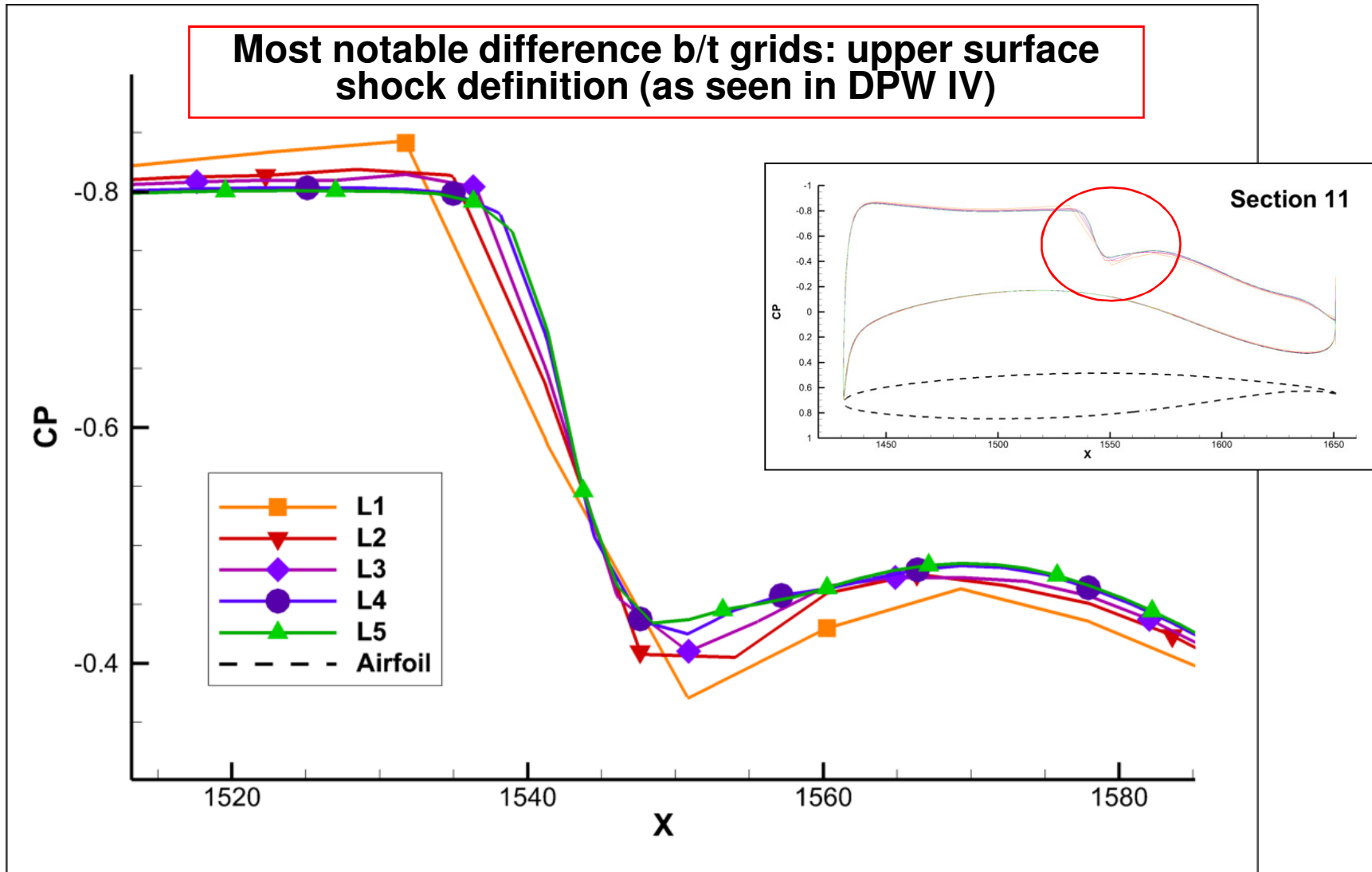
$T_{\text{ref}} = 559.67^\circ\text{R}$  ( $100^\circ\text{F}$ )

$X_{\text{ref}} = 1325.90 \text{ in.}$ ,  $Z_{\text{ref}} = 177.95 \text{ in.}$

# Grid Study: Section Cuts

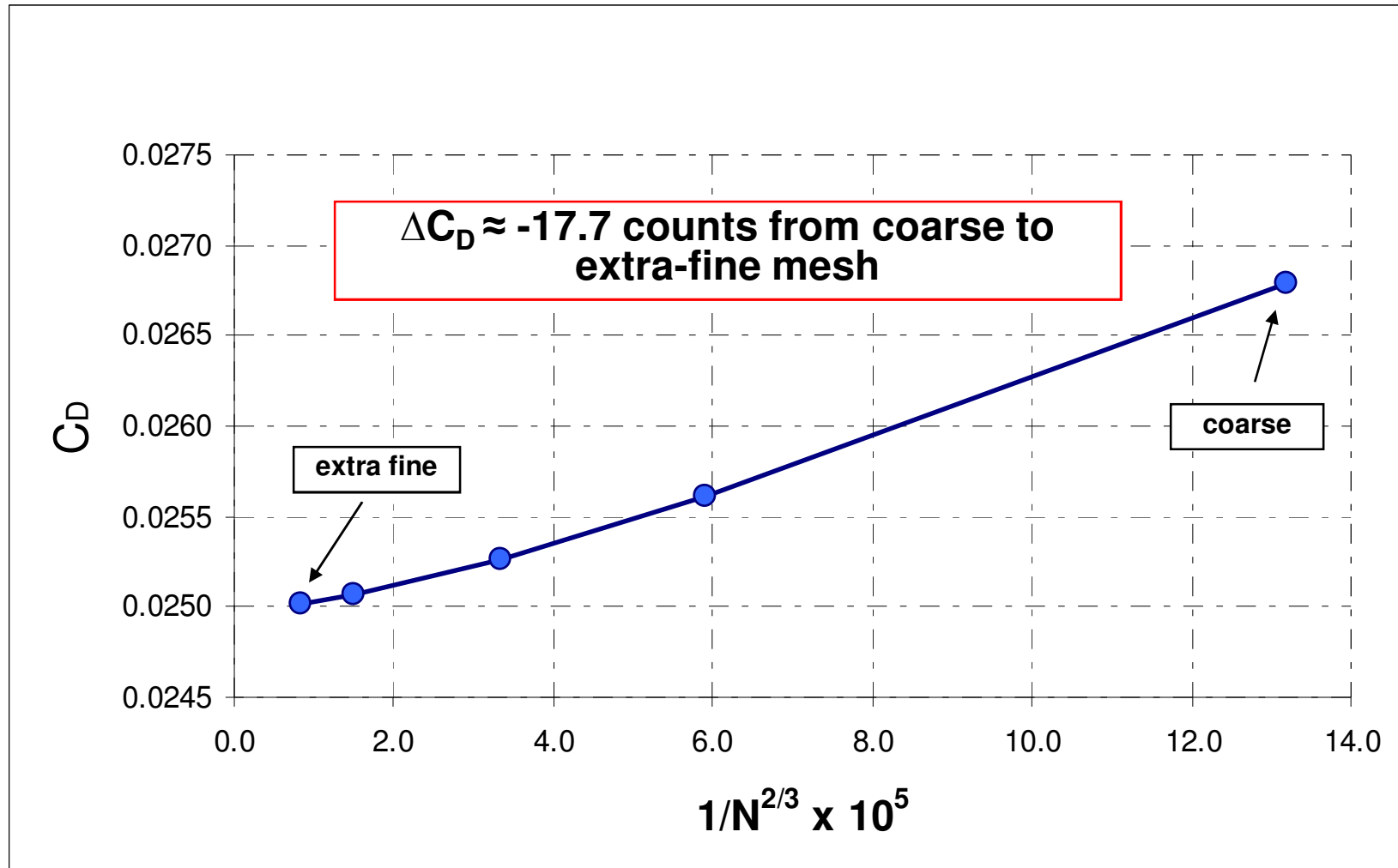


# Grid Study: Section Cuts

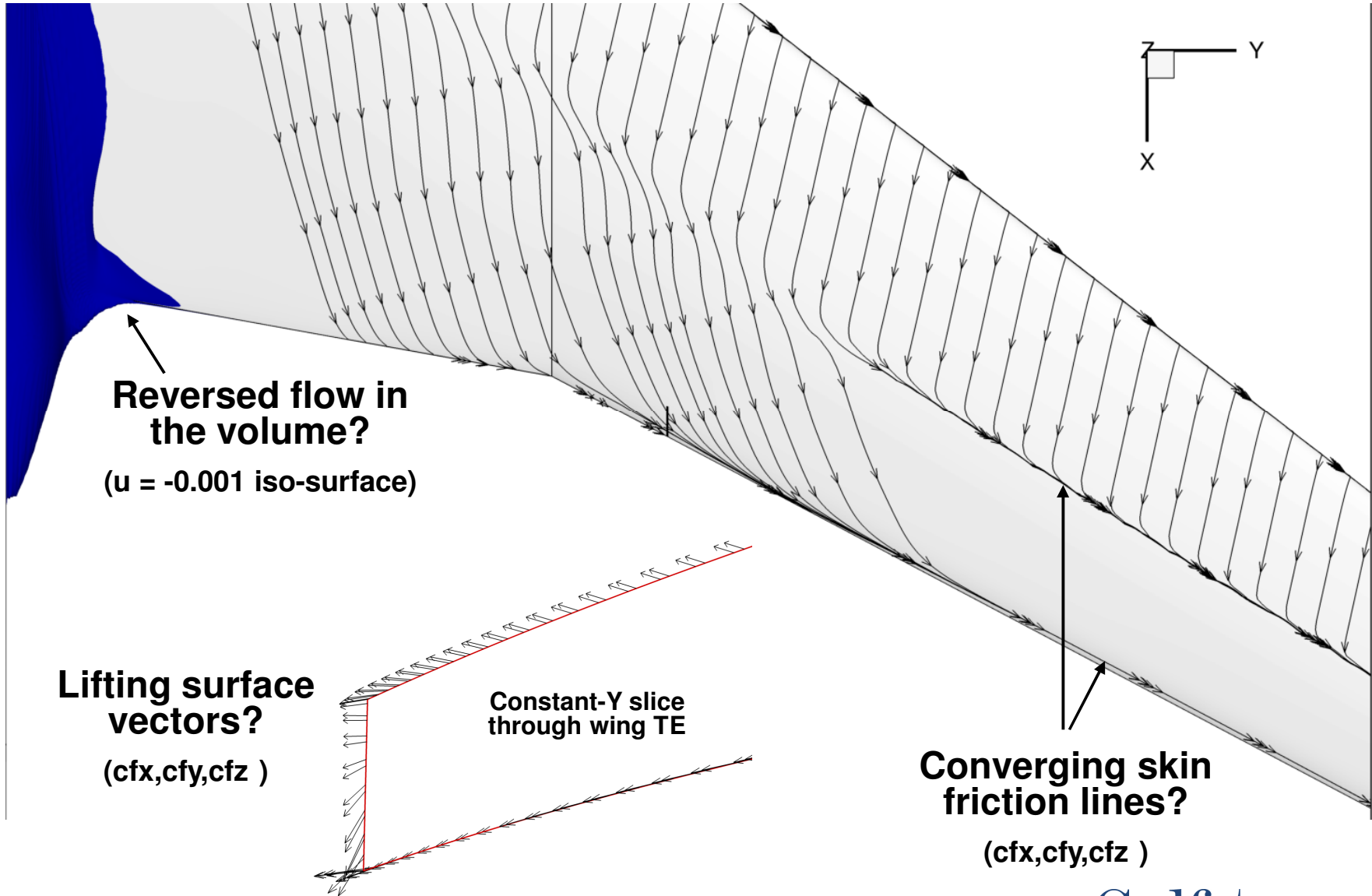




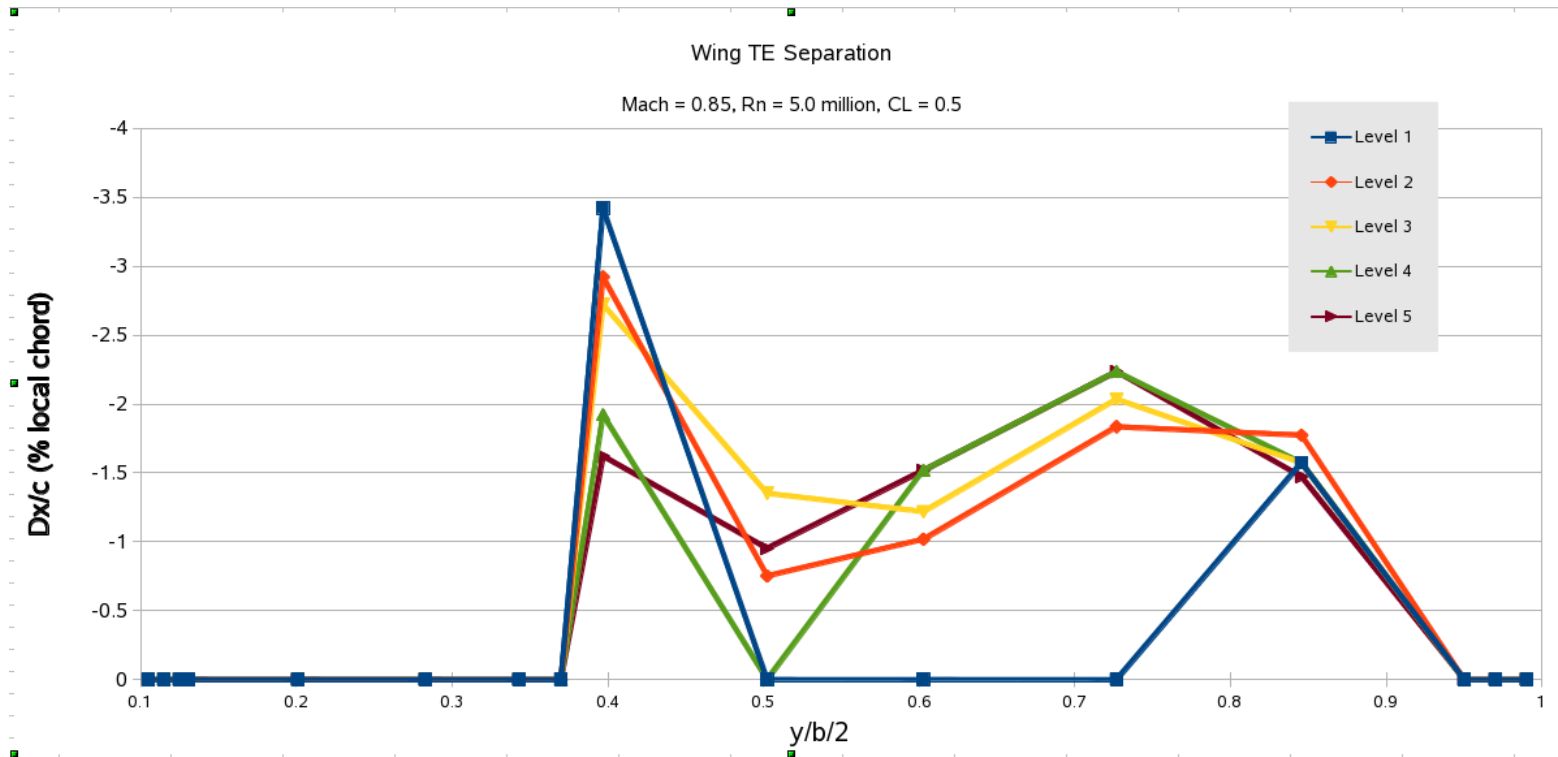
# Grid Study: Drag



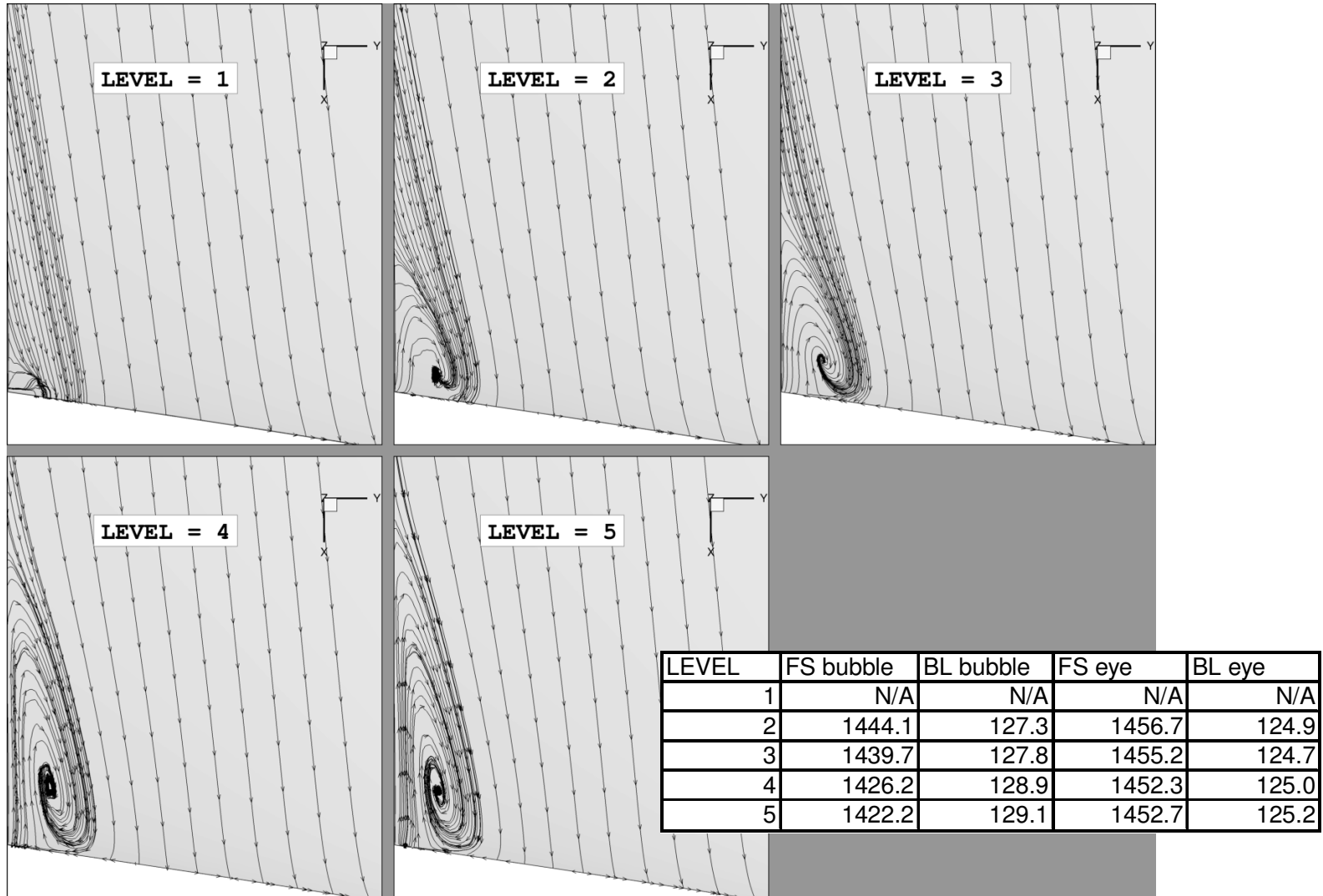
# What Determines TE Separation?



# Grid Study: Wing TE Separation



# Grid Study: SOB Separation



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# Test Case 2: Buffet Study

Level 3 grid

Mach = 0.85

$\alpha = [2.5, 2.75, 3.0, 3.25, 3.5, 3.75, 4.0]$

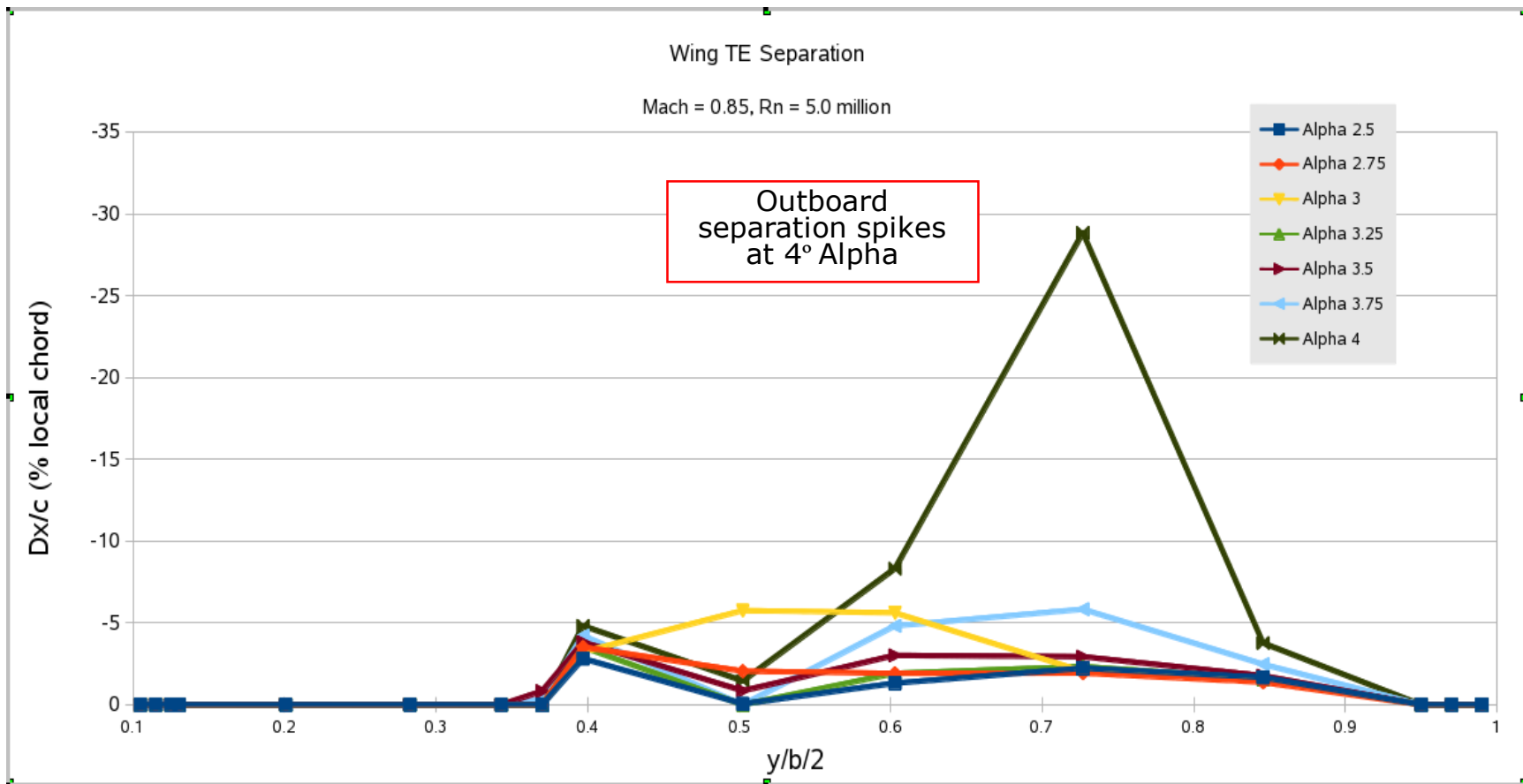
$S_{\text{ref}} = 297,360 \text{ in}^2$  (half model)

$R_N = 5 \times 10^6$ ,  $C_{\text{ref}} = 275.8 \text{ in.}$

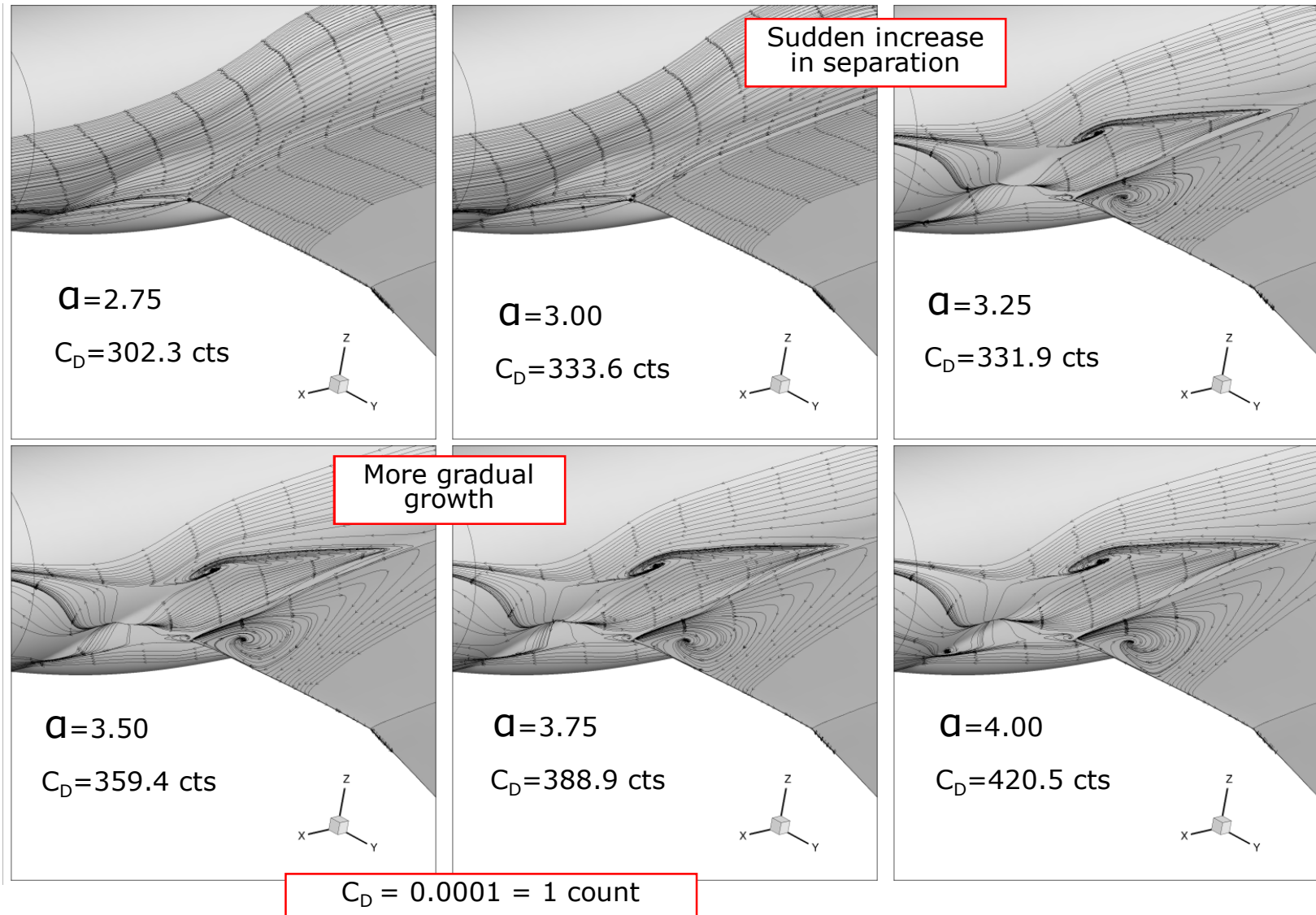
$T_{\text{ref}} = 559.67^\circ\text{R}$  (100°F)

$X_{\text{ref}} = 1325.90 \text{ in.}$ ,  $Z_{\text{ref}} = 177.95 \text{ in.}$

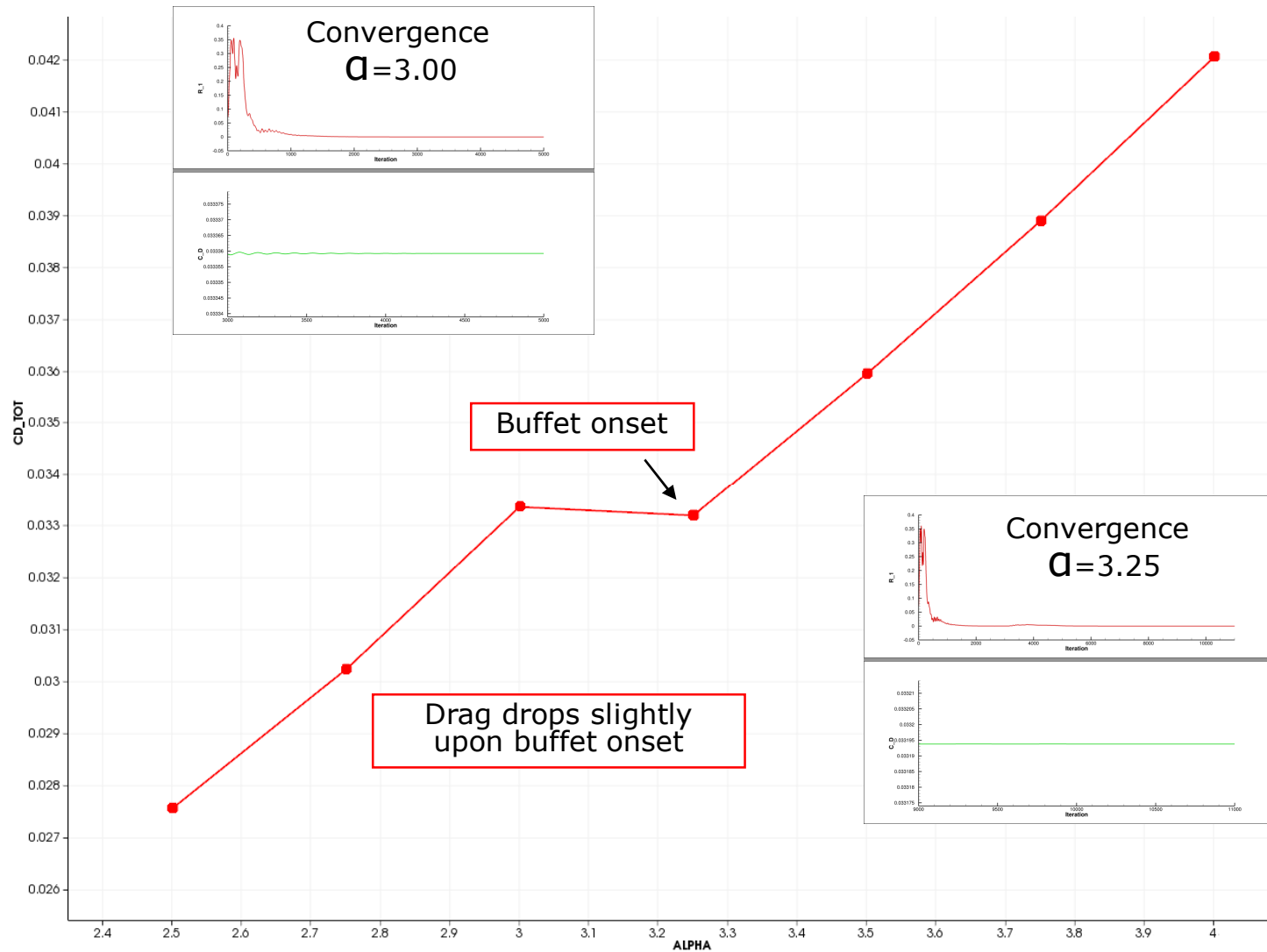
# Buffet Study: TE Separation



# Buffet Study: SOB Separation



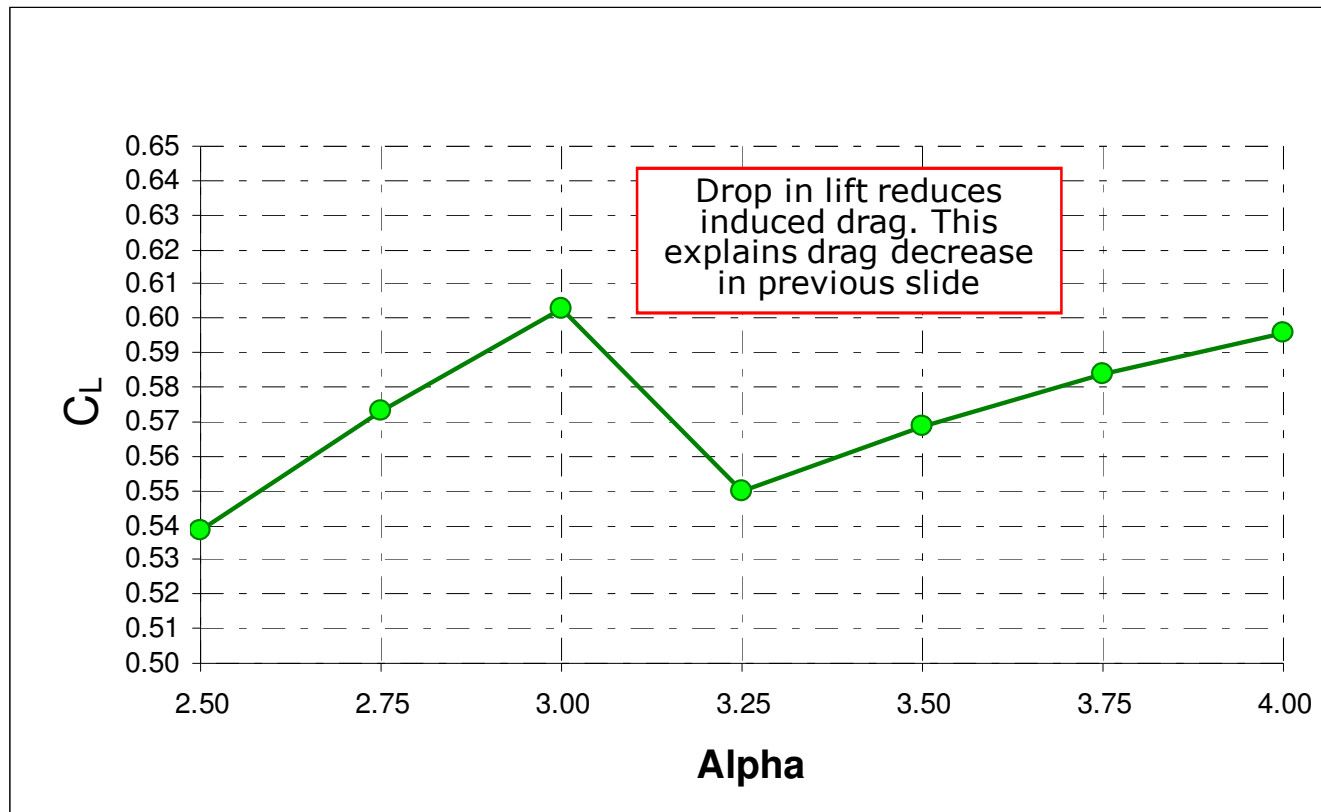
# Buffet Study: Drag





# Buffet Study: Lift

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# Alternate Solver and Grid Study

Level 3 + 2 custom grids

USM3D and FUN3D

Mach 0.85

Complete alpha sweep for USM3D

$S_{\text{ref}} = 297,360 \text{ in}^2$  (half model)

$R_N = 5 \times 10^6$ ,  $C_{\text{ref}} = 275.8 \text{ in.}$

$T_{\text{ref}} = 559.67^\circ\text{R}$  ( $100^\circ\text{F}$ )

$X_{\text{ref}} = 1325.90 \text{ in.}$ ,  $Z_{\text{ref}} = 177.95 \text{ in.}$

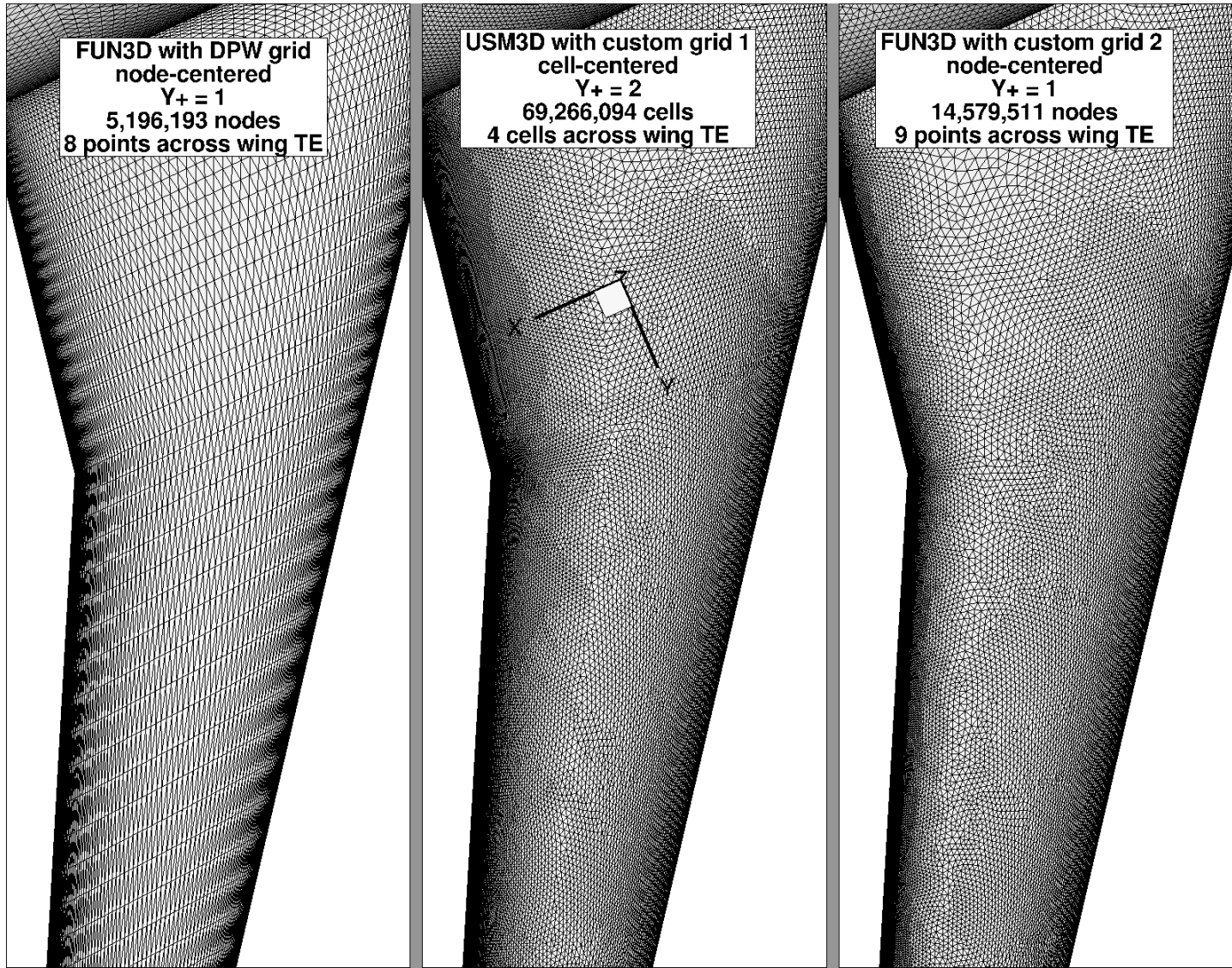
# Alternate Solver and Grids

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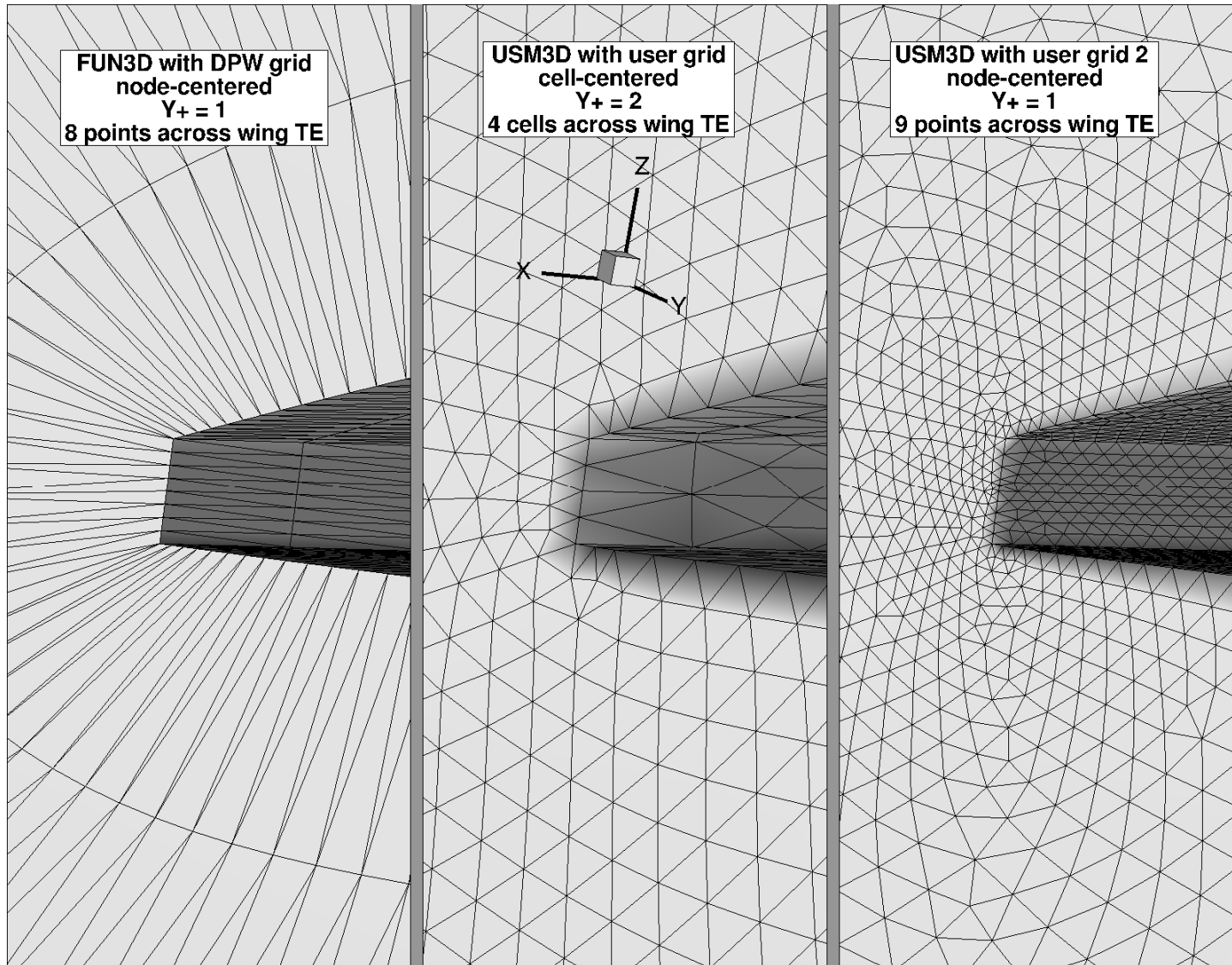
- **Solver: USM3D**
  - Full Navier-Stokes, tetrahedral, cell-centered
  - SA turbulence model

Designation	Code	Y+	# of Nodes	# of Tets	# of Prisms
Common L3	FUN3D	1.00	5,196,193	20,766,720	3,301,376
Custom Grid 1	USM3D	2.00		69,266,094	0
Custom Grid 2	FUN3D	1.00	14,579,511		0

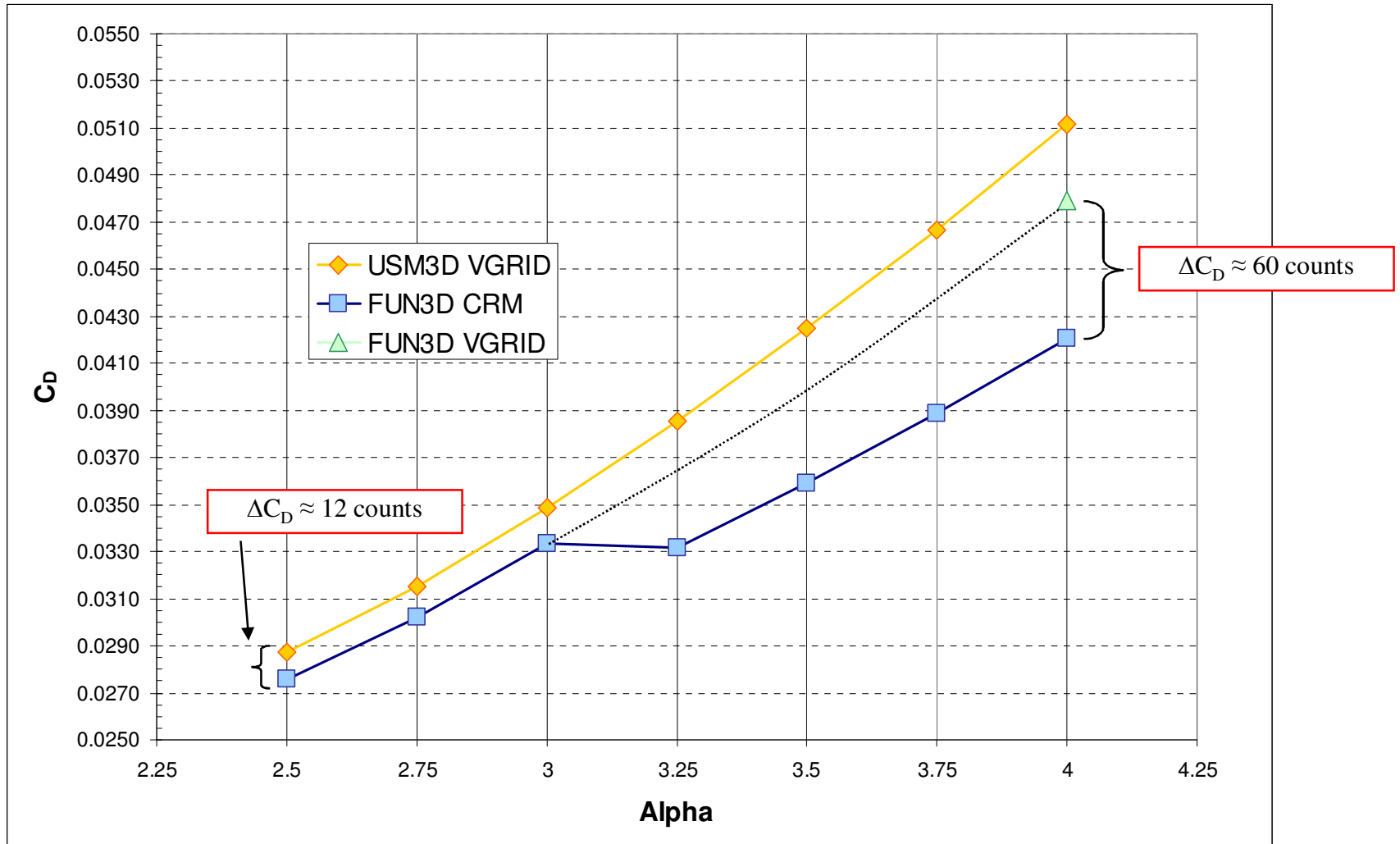
# Alternate Grids



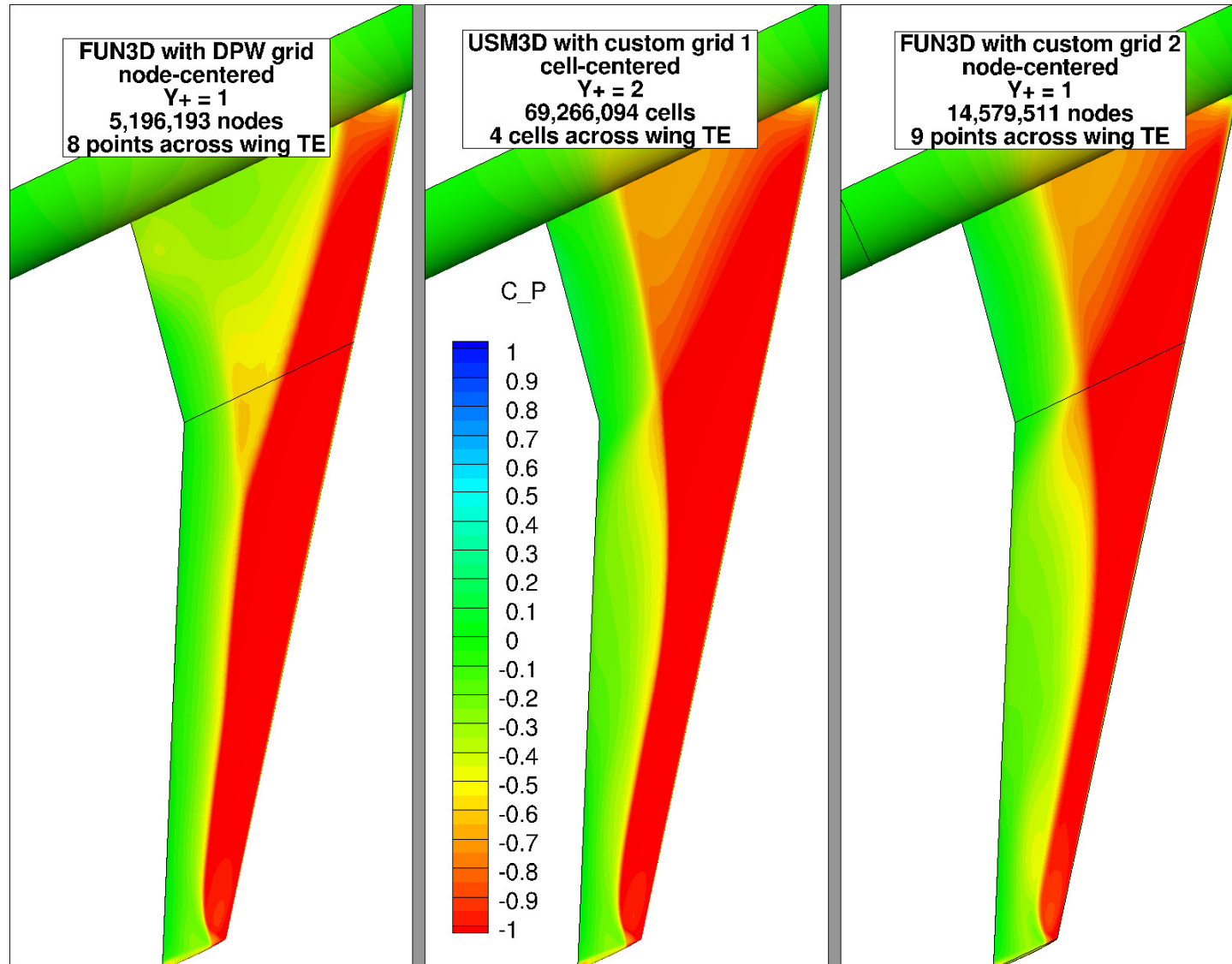
# Alternate Study: Grids



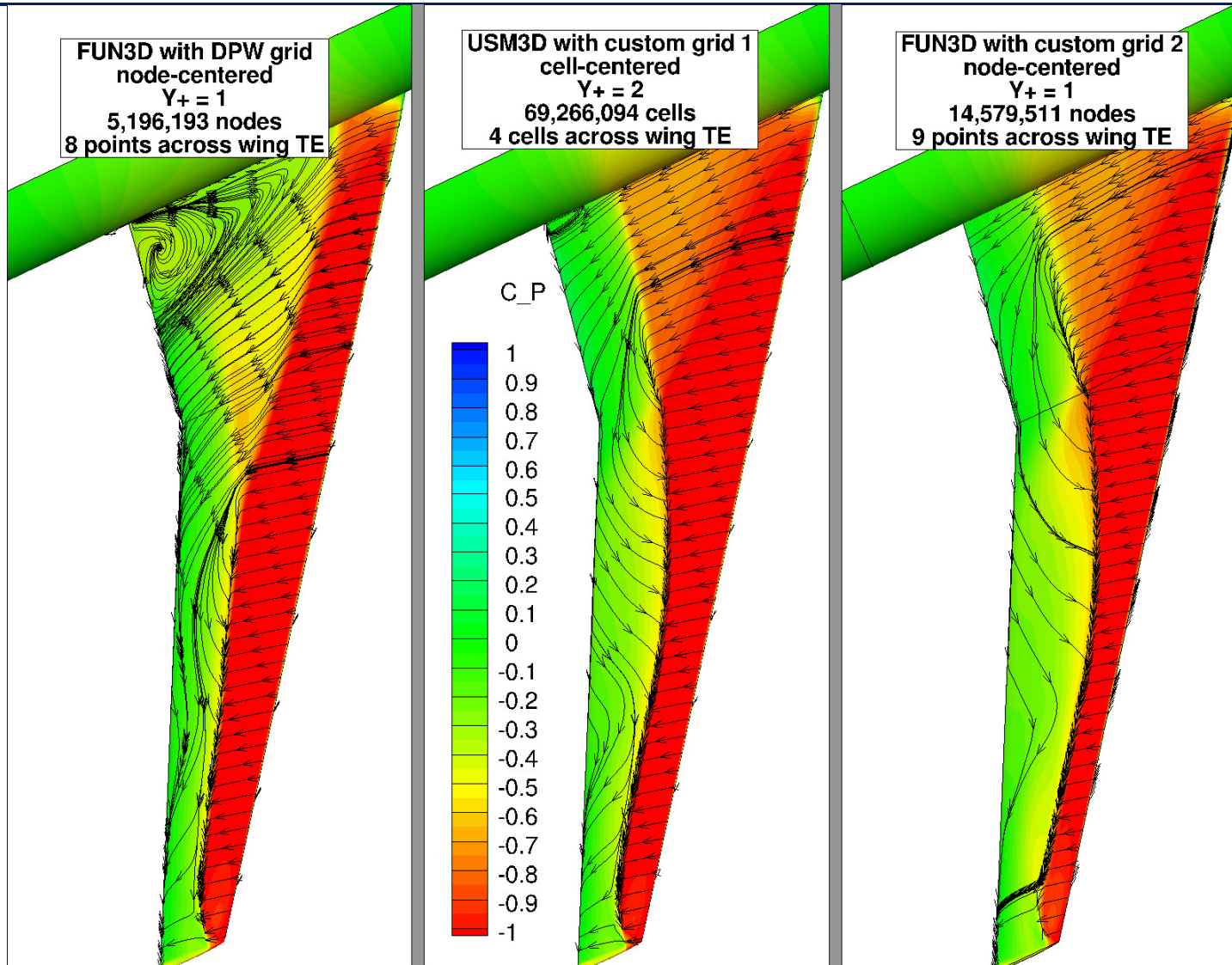
# Alternate Study: Drag



# Alternate Study: Cp



# Alternate Study: Surface Stream Lines





# Conclusions

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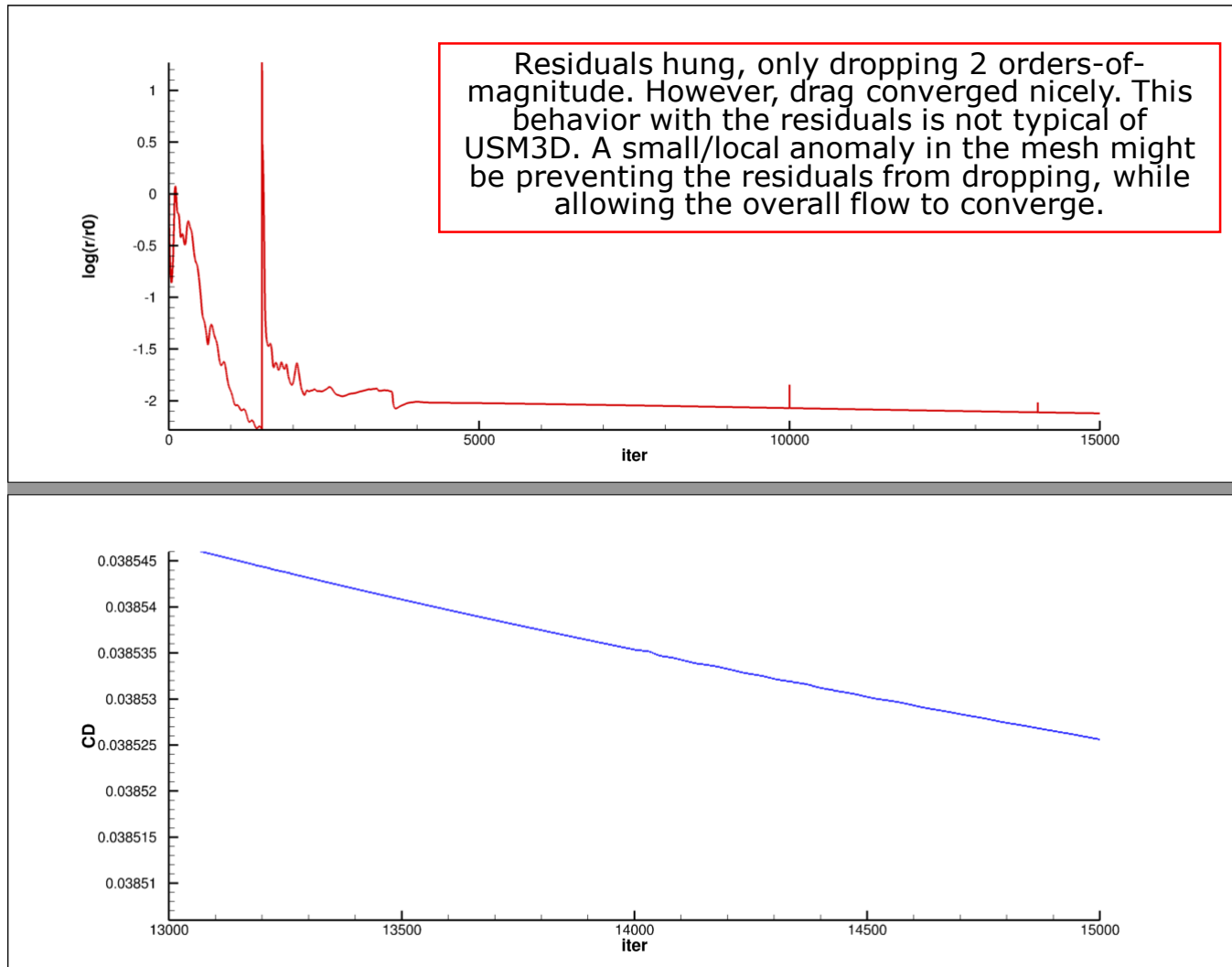
- **Massive SOB Separation seen in the Buffet Study seems to be due to an interaction between FUN3D and the L3 common-hybrid grid.**
  - **Possible issue with tangential mesh density at the upper wing/fuselage intersection.**
  - **Possible issue with SOB separation bubble interacting with the shock on the upper surface of the wing.**
  - **Further investigation is, of course, required to understand this interaction**
- **Further investigation is also needed into the wake resolution for all three meshes in the Alternate Study.**

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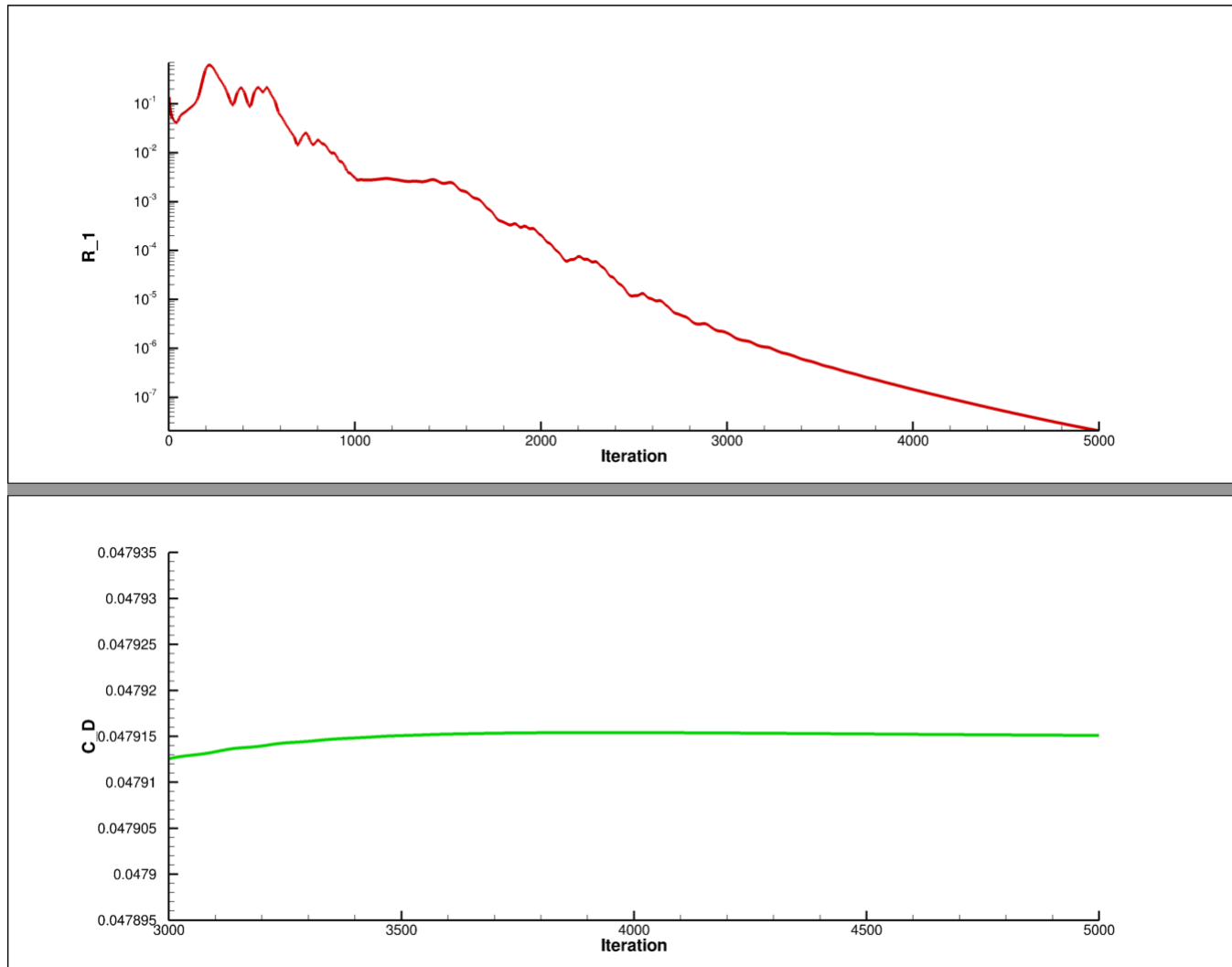
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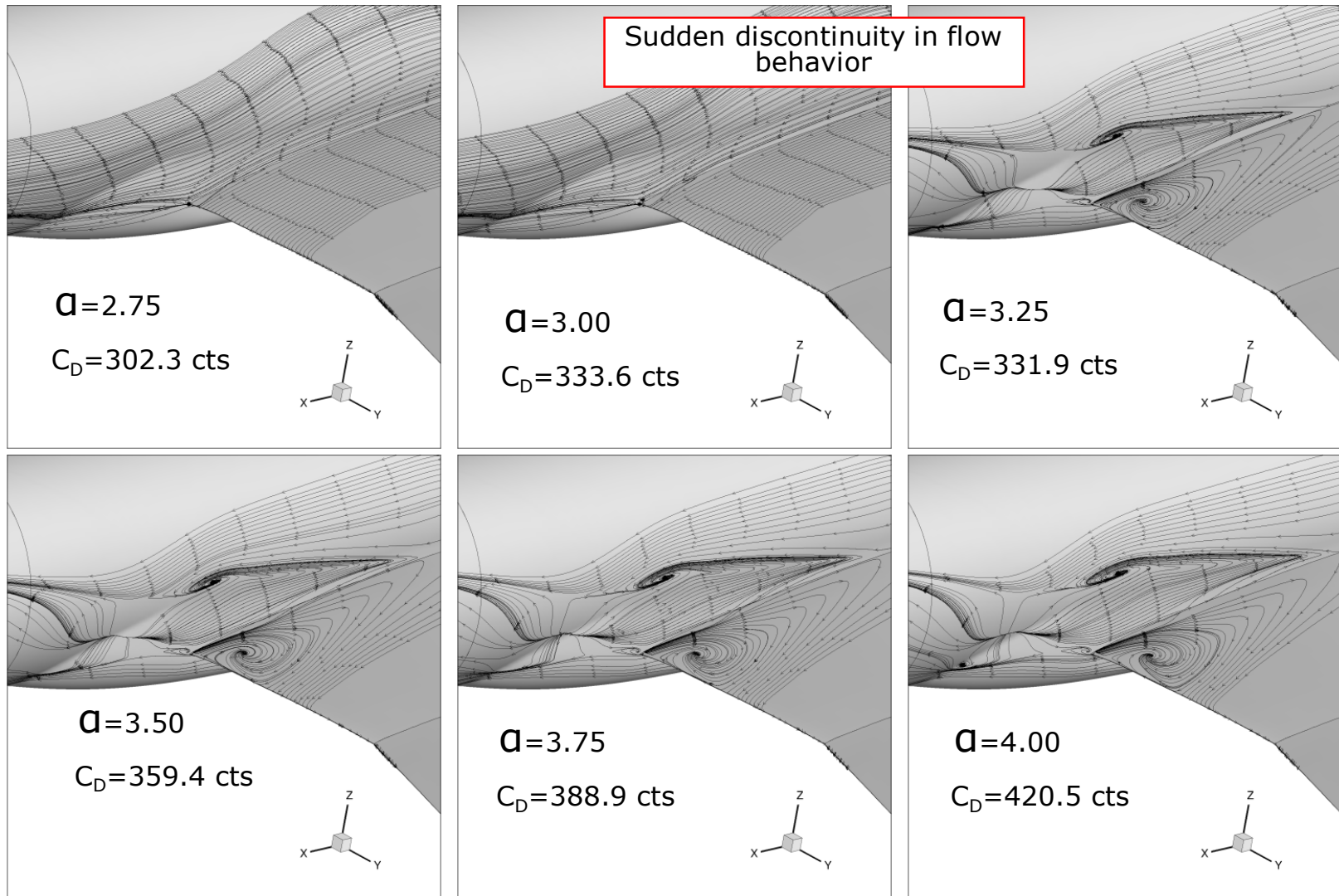
# USM3D Convergence: Custom Grid 1



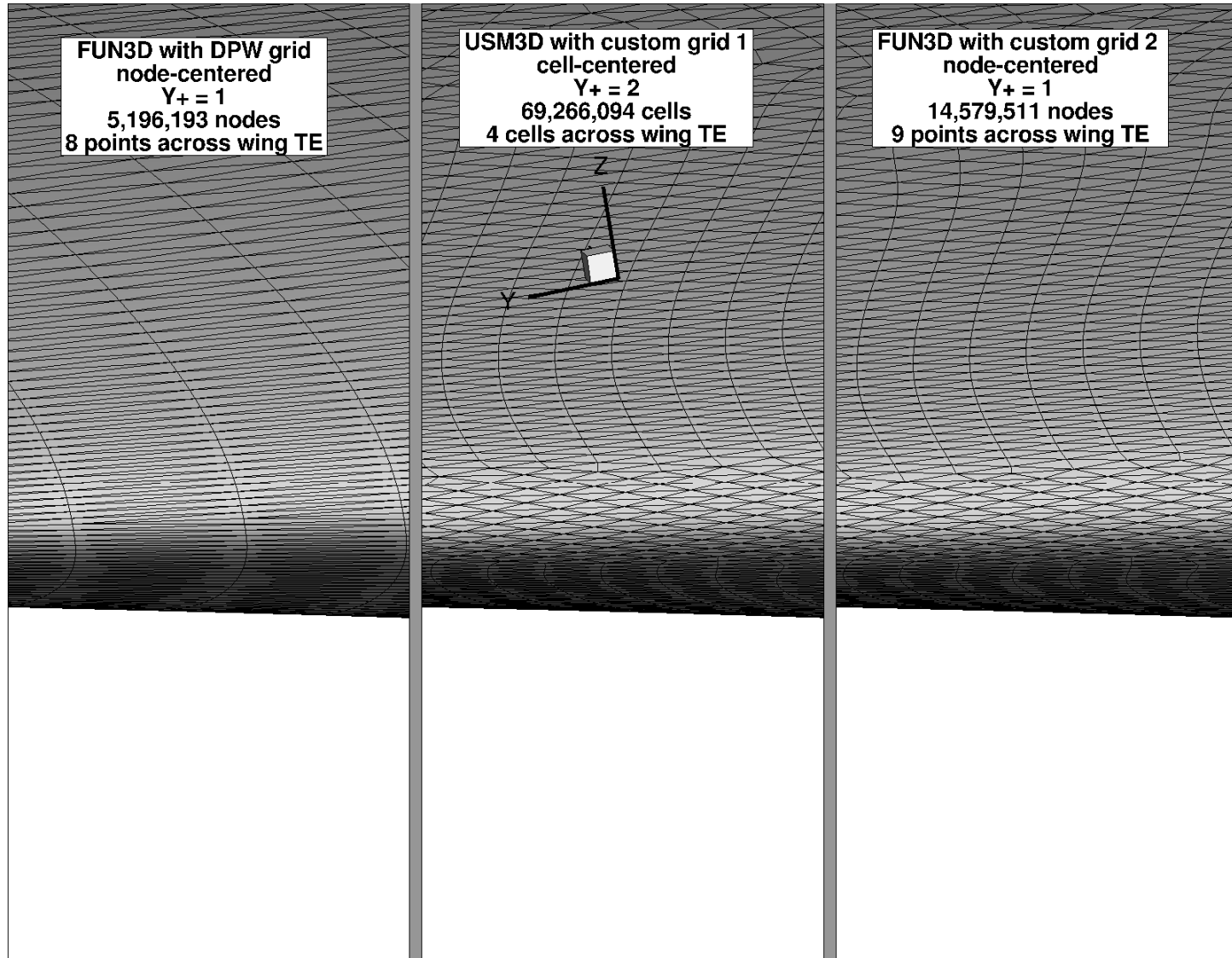
# FUN3D Convergence: Custom Grid 2



# Steady CFD



# Alternate Study: Grids



# Grid Study: TE Separation

