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Drag Prediction for the DLR-F6 configuration using the TetrUSS Unstructured Grid CFD Software

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- Acknowledgements to the *TetrUSS* team at NASA Langley
  - USM3Dns flow solver
    - *Neal Frink, Paresh Parikh, Mohagna Pandya*
  - GridTool / Vgrid grid generator
    - *Shahyar Pirzadeh, Jamshid Samareh*

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- DLR-F6 Configurations

Configuration	*Grid Class*	*Tetrahedra*	*Surface Triangles*	*Boundary layer cells*	*No. of cell layers across wing t.e.*
DLR-F6 Wing Body	Medium	6,483,682	78,540	z0 = 0.03868 mm (y+ = 50) 8 layers	8
DLR-F6 Wing Body + FX2B fairing	Coarse	3,142,285	59,660	z0 = 0.03868 mm (y+ = 50) 8 layers	8
	Medium	6,284,018	80,522	z0 = 0.03868 mm (y+ = 50) 8 layers	8
	Fine	11,521,175	136,710	z0 = 0.03868 mm (y+ = 50) 8 layers	8

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- *Vgrid* grid generator *(Shahyar Pirzadeh et al; NASA Langley)*
  - Unstructured tetrahedra, using advancing front method
  - Element size distribution controlled through field source distributions

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- *USM3Dns* flow solver *(Neal Frink et al; NASA Langley)*
  - Cell centered, unstructured tetrahedra
  - Implict time stepping
  - Spalart Allmaras turbulence model, with wall functions
  - Special boundary conditions on blunt wing trailing edges.

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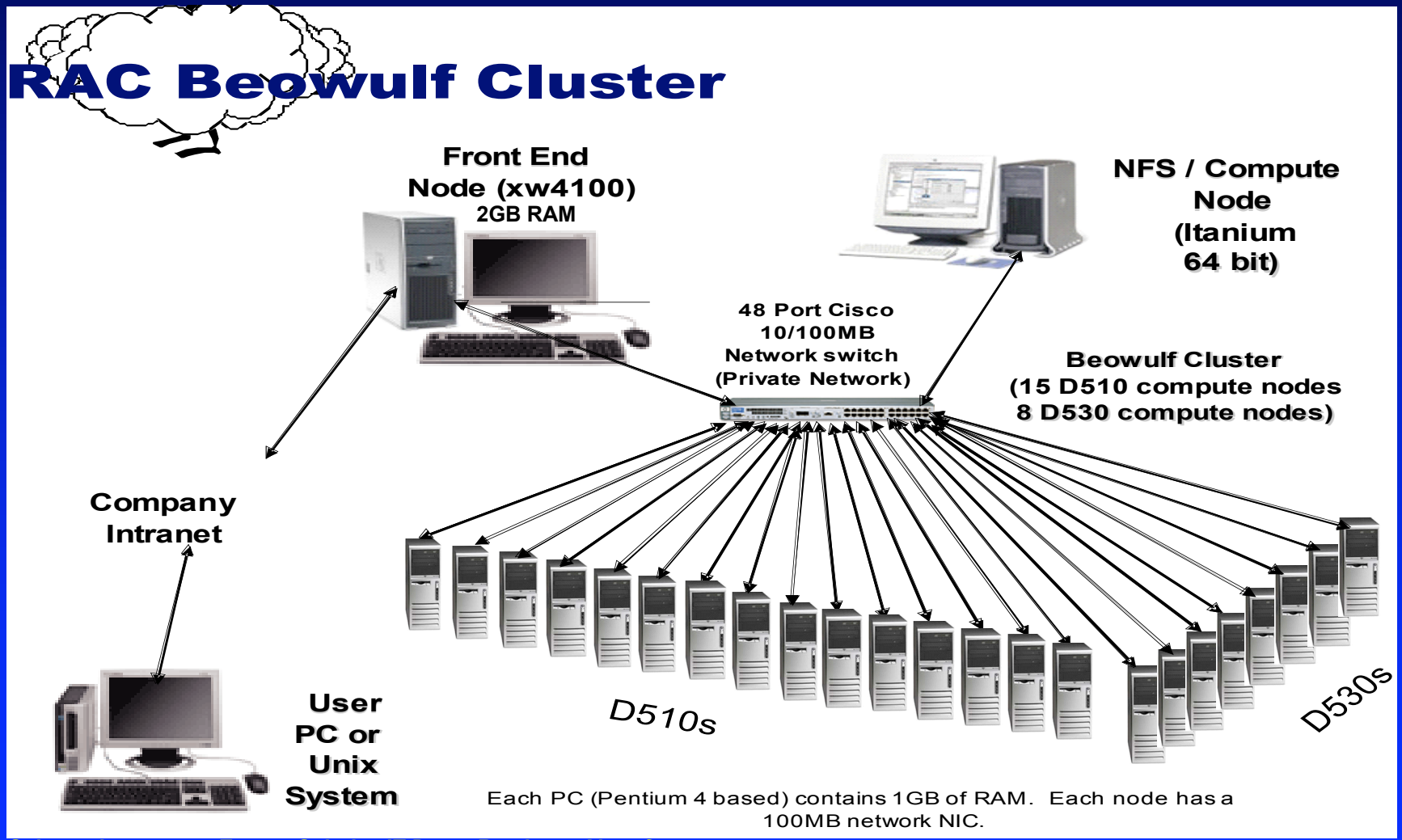
- Computer Hardware



Schematic courtesy Everett Schultz, IT Dept., Raytheon Aircraft

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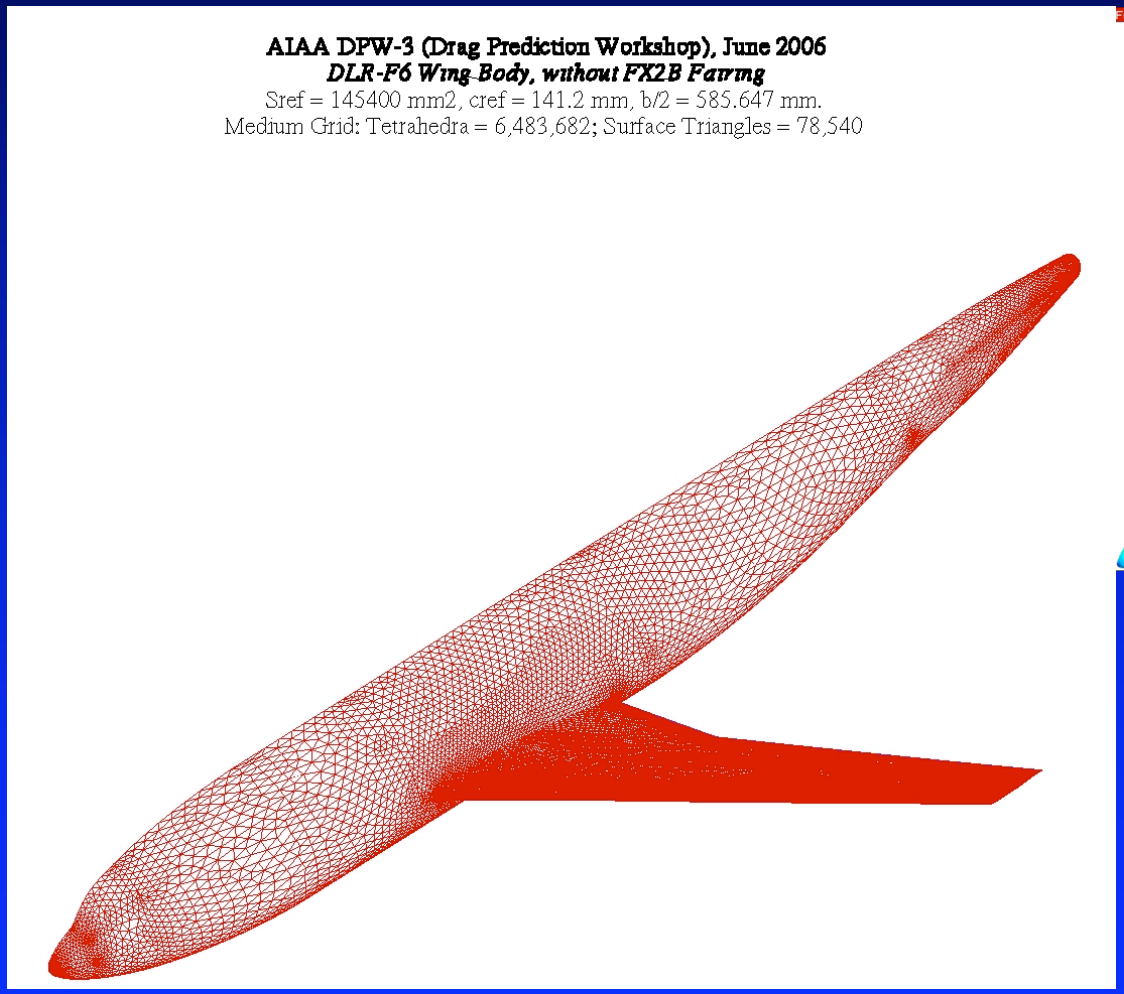
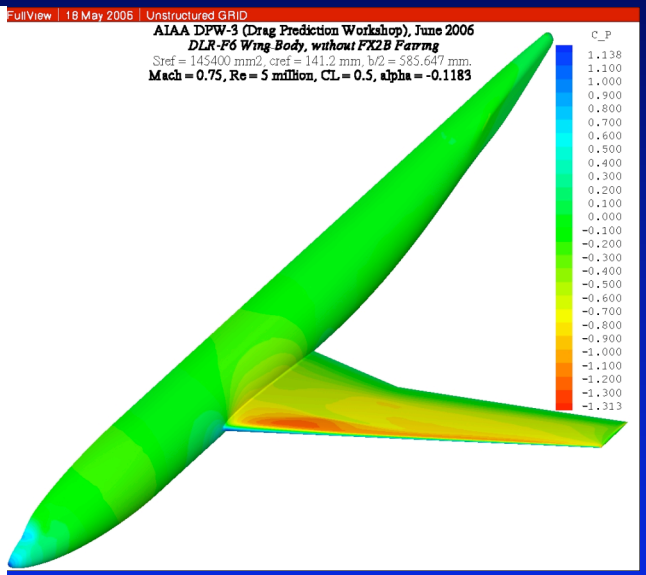
- DLR-F6 + Wing Body





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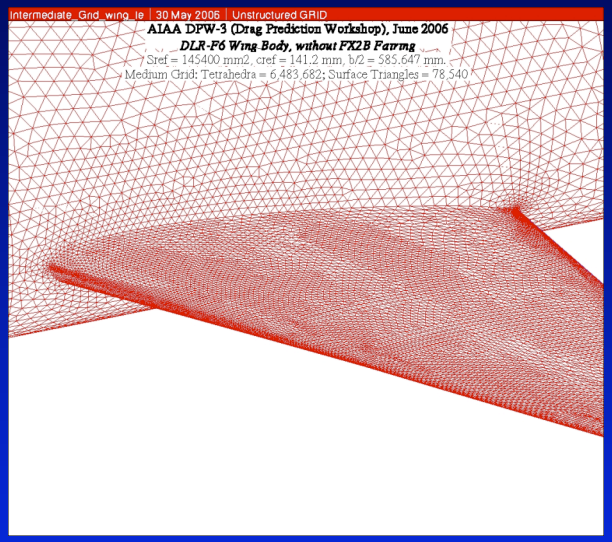
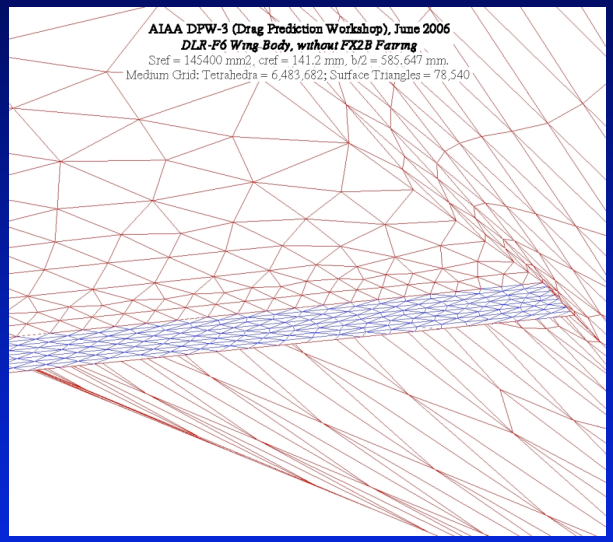
- DLR-F6 + Wing Body

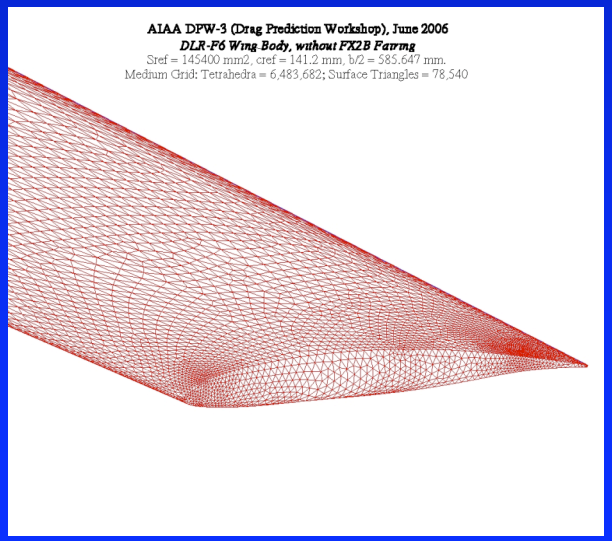


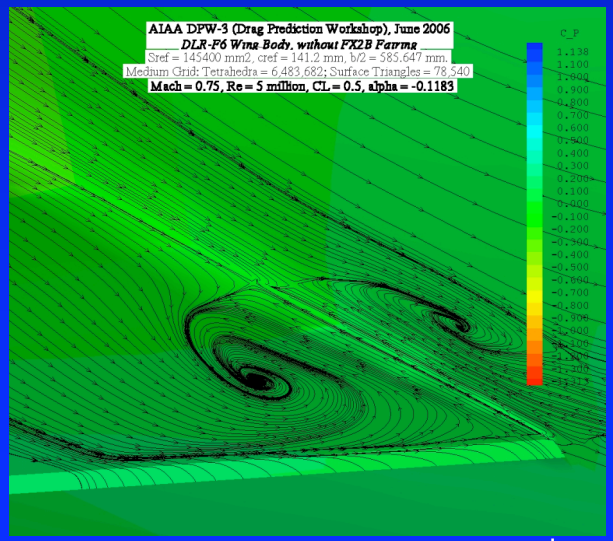
Medium Grid

Tetrahedra = 6,483,682

Triangles = 78,540







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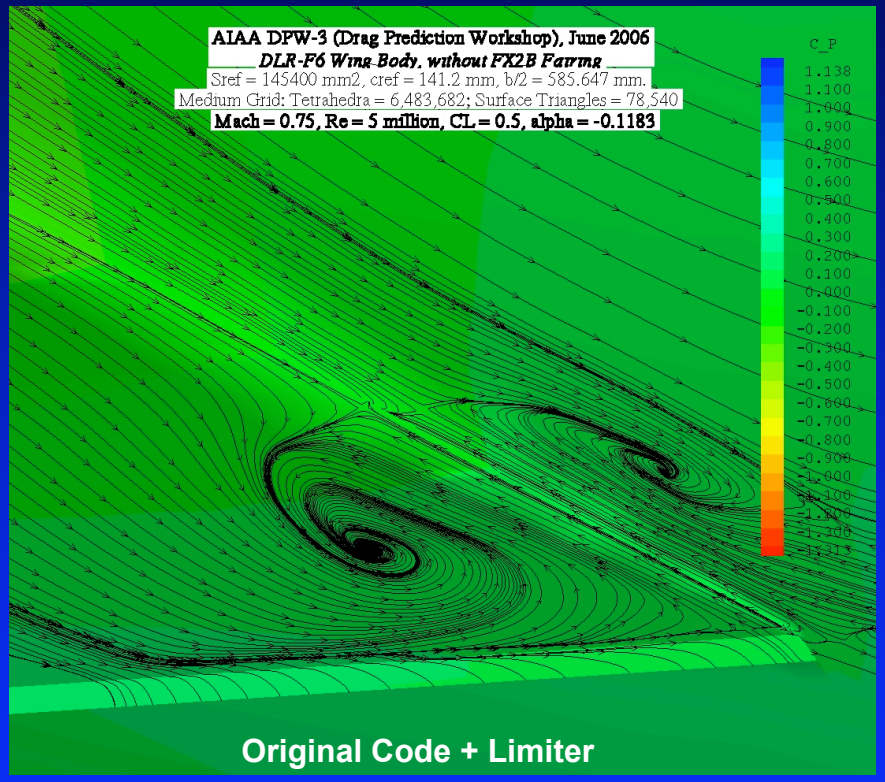
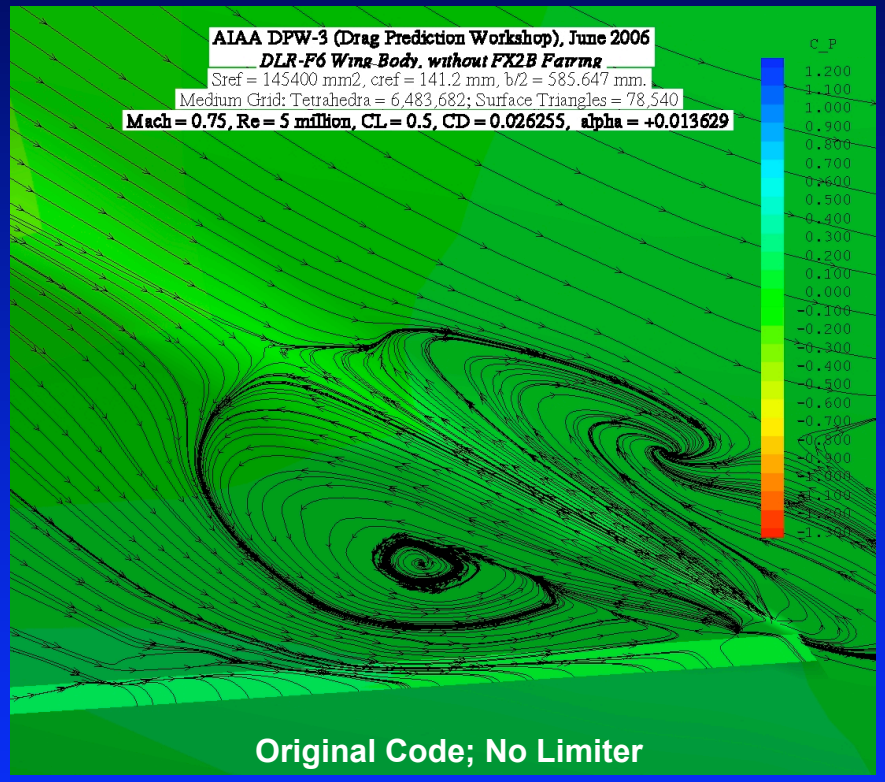
- DLR-F6 + Wing Body (Medium Grid)



Original Code + Limiter



Original Code; No Limiter

	BUB	EYE_B	EYE_W
FS	226.68	238.383	234.11
BL	-87.57	-66.429	-73.259
WL	-5.469	-7.801	-9.16

	BUB	EYE_B	EYE_W
FS	222.528	238.968	235.125
BL	-82.114	-66.705	-72.295
WL	-3.724	-7.326	-9.677

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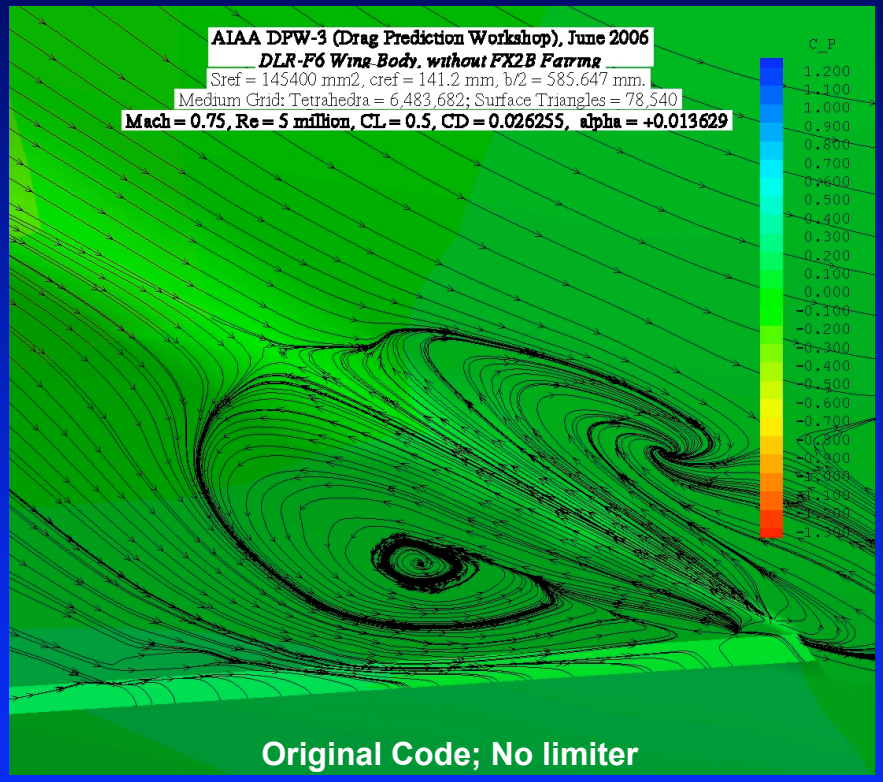
- DLR-F6 + Wing Body (Medium Grid)



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	BUB	EYE_B	EYE_W
FS	222.528	238.968	235.125
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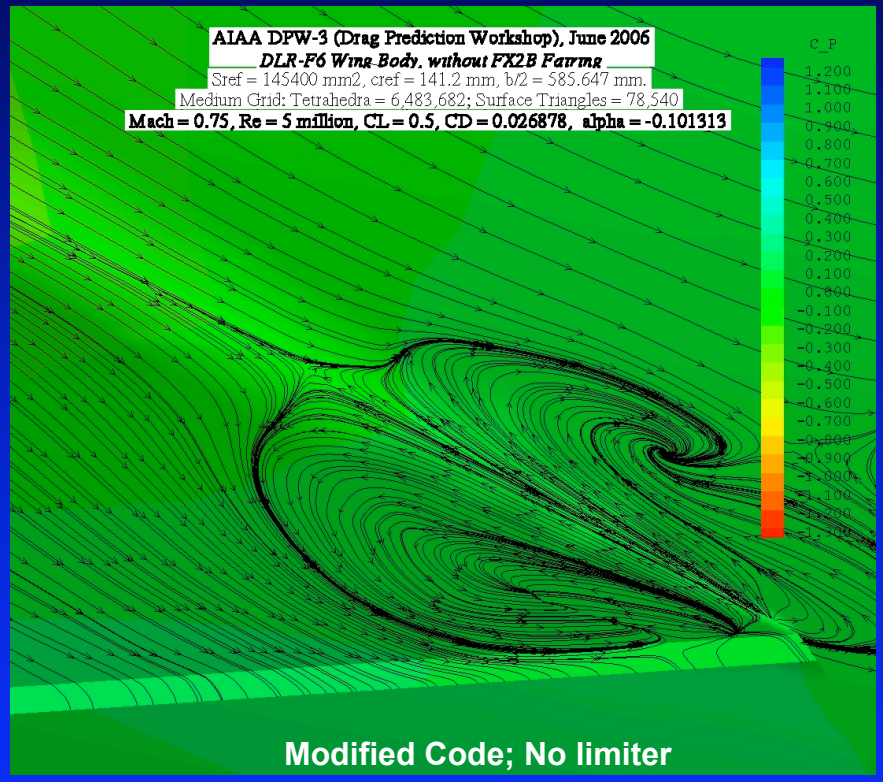

Modified Code; No limiter

	BUB	EYE_B	EYE_W
FS	224.785	238.878	236.891
BL	-76.465	-66.697	-70.147
WL	-4.279	-7.364	-10.665

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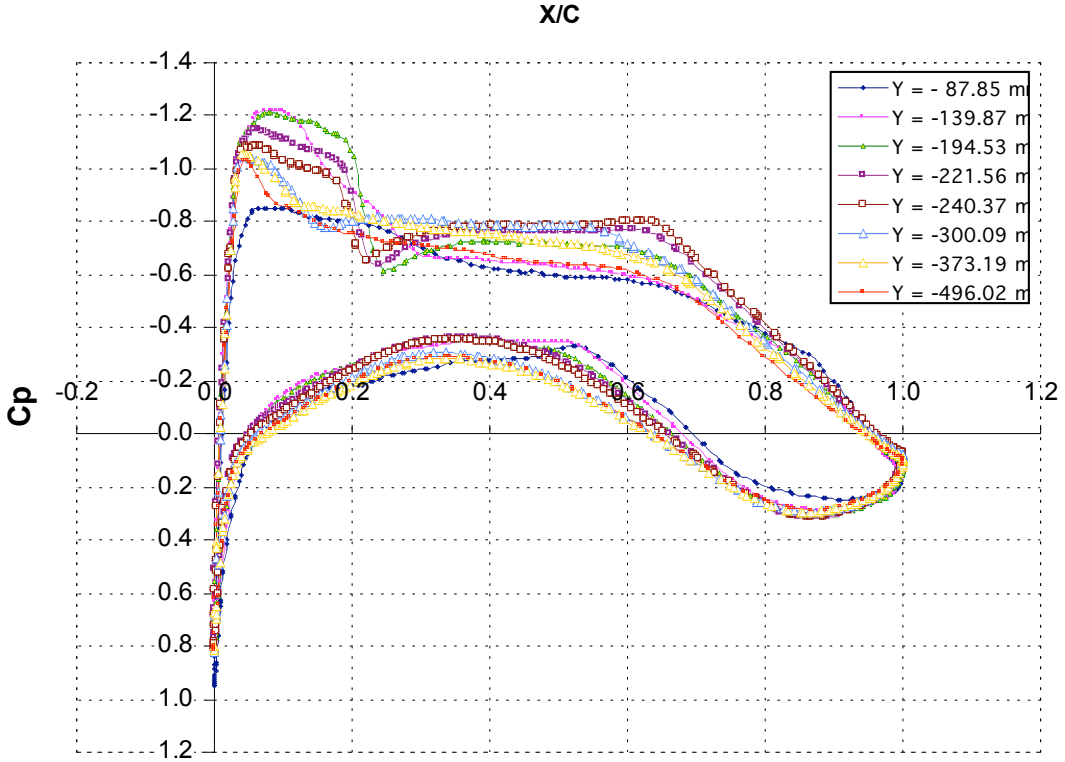
- DLR-F6 + Wing Body (Medium Grid)



Original Code
+
Limiter

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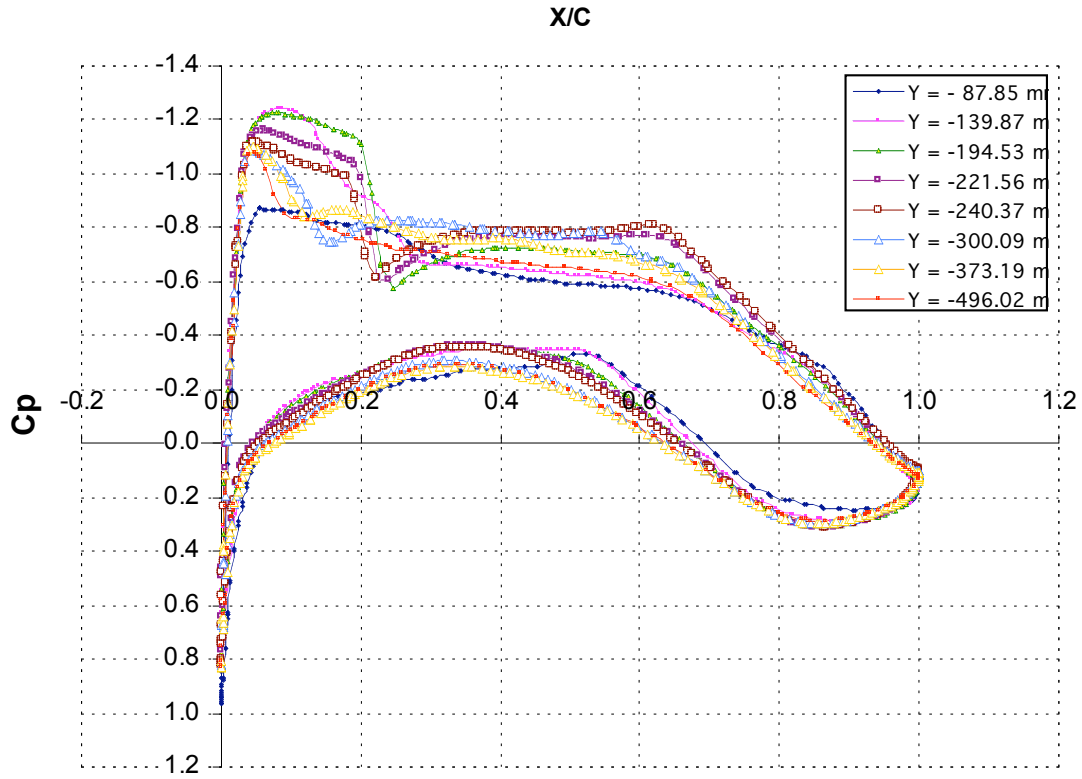
- DLR-F6 + Wing Body (Medium Grid)



Modified Code

No Limiter

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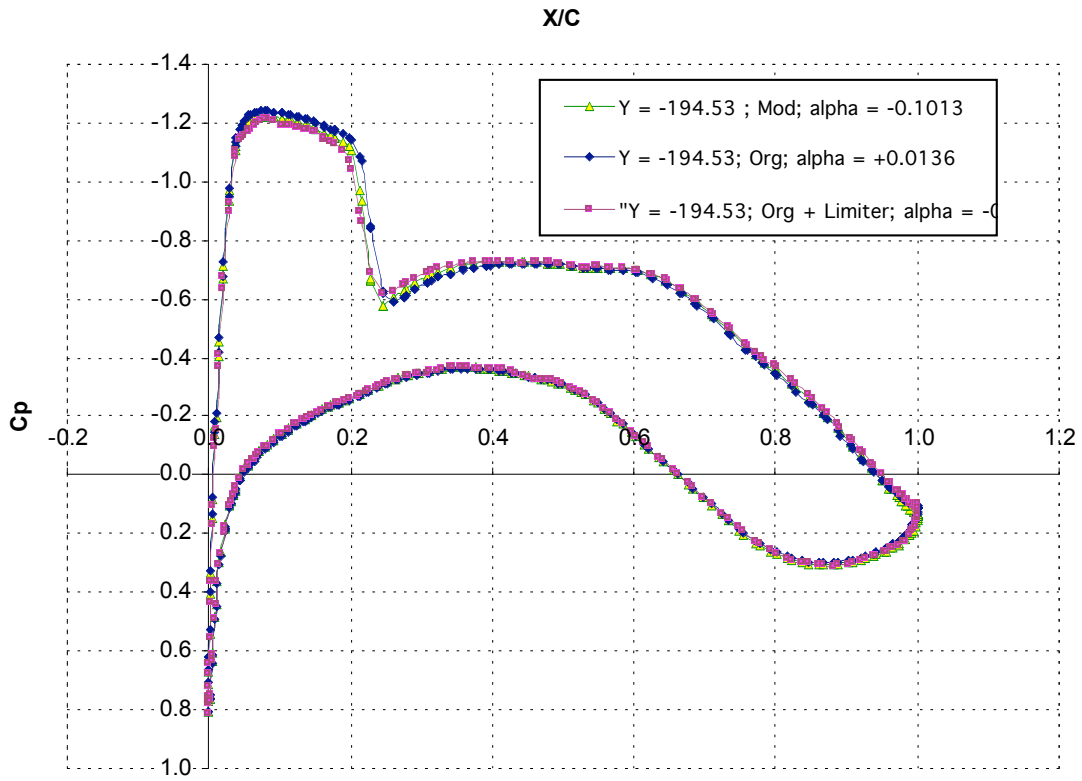
- DLR-F6 + Wing Body (Medium Grid)



Comparisons of Code Variants

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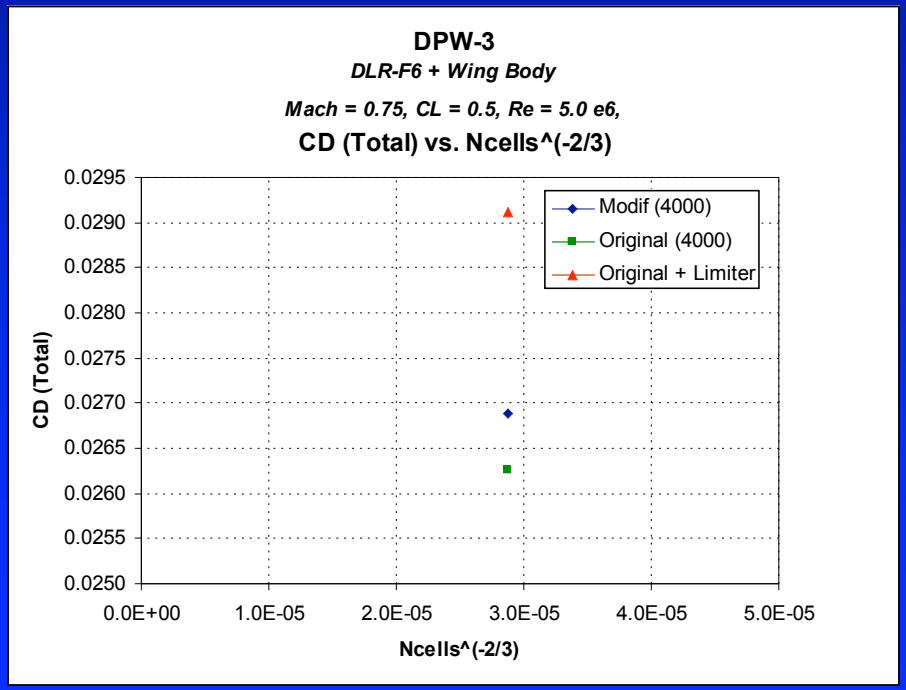
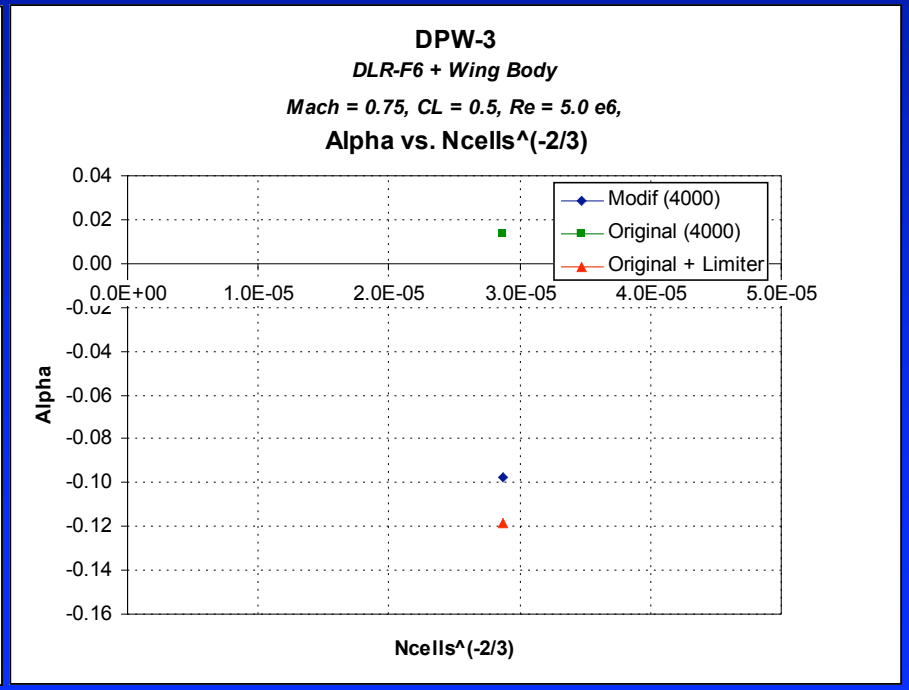
- DLR-F6 + Wing Body (Medium Grid)

Comparisons of Code Variants

- "Modified" Version is preferred to "Original"
  - Limiter is not preferred





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- DLR-F6 + Wing Body (Medium Grid)

Comparisons of Code Variants

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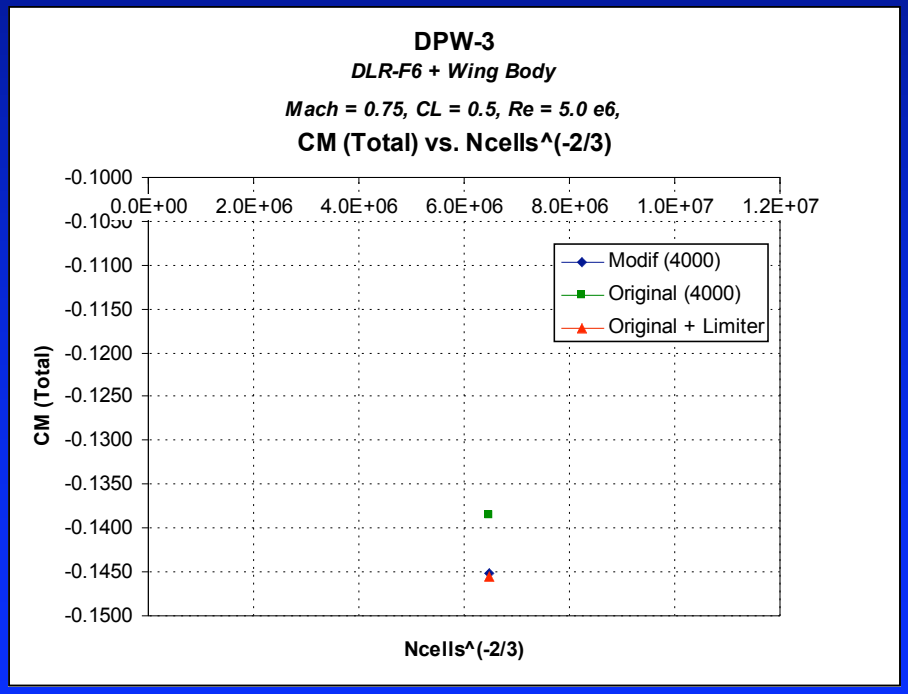

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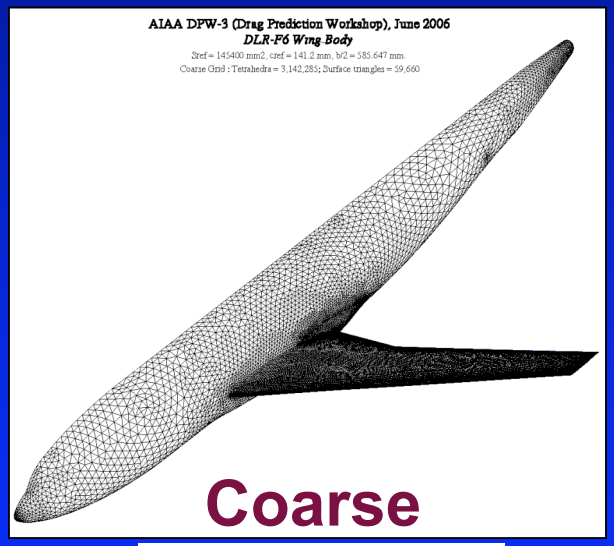
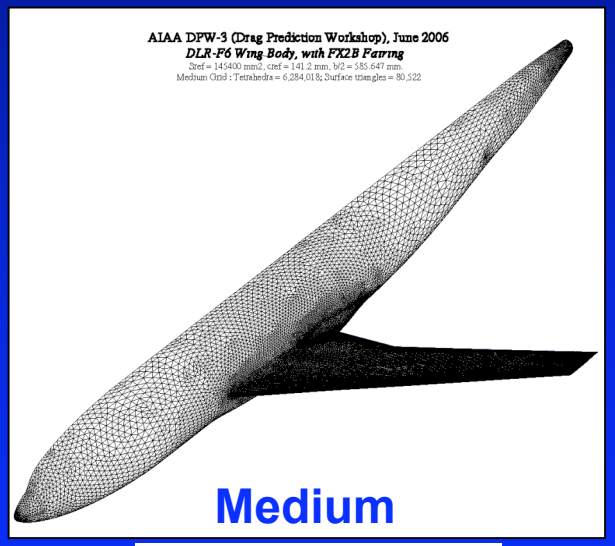
- DLR-F6 + Wing Body + FX2B Fairing



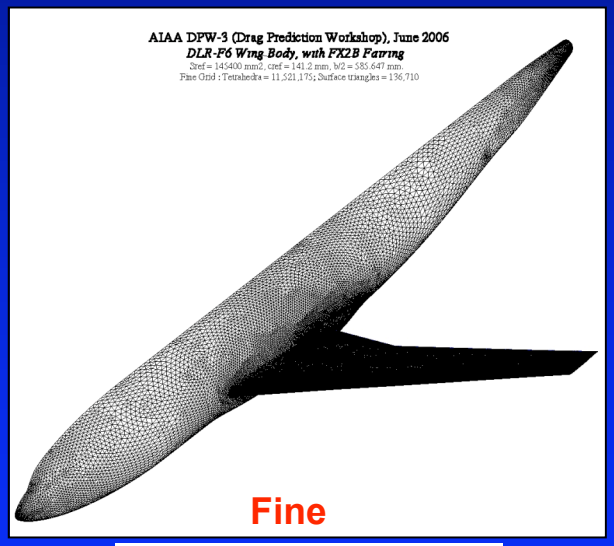
Coarse

Tets = 3,142,285
Triangles = 59,660



Medium

Tets = 6,284,018
Triangles = 80,522



Fine

Tets = 11,521,175
Triangles = 136,710

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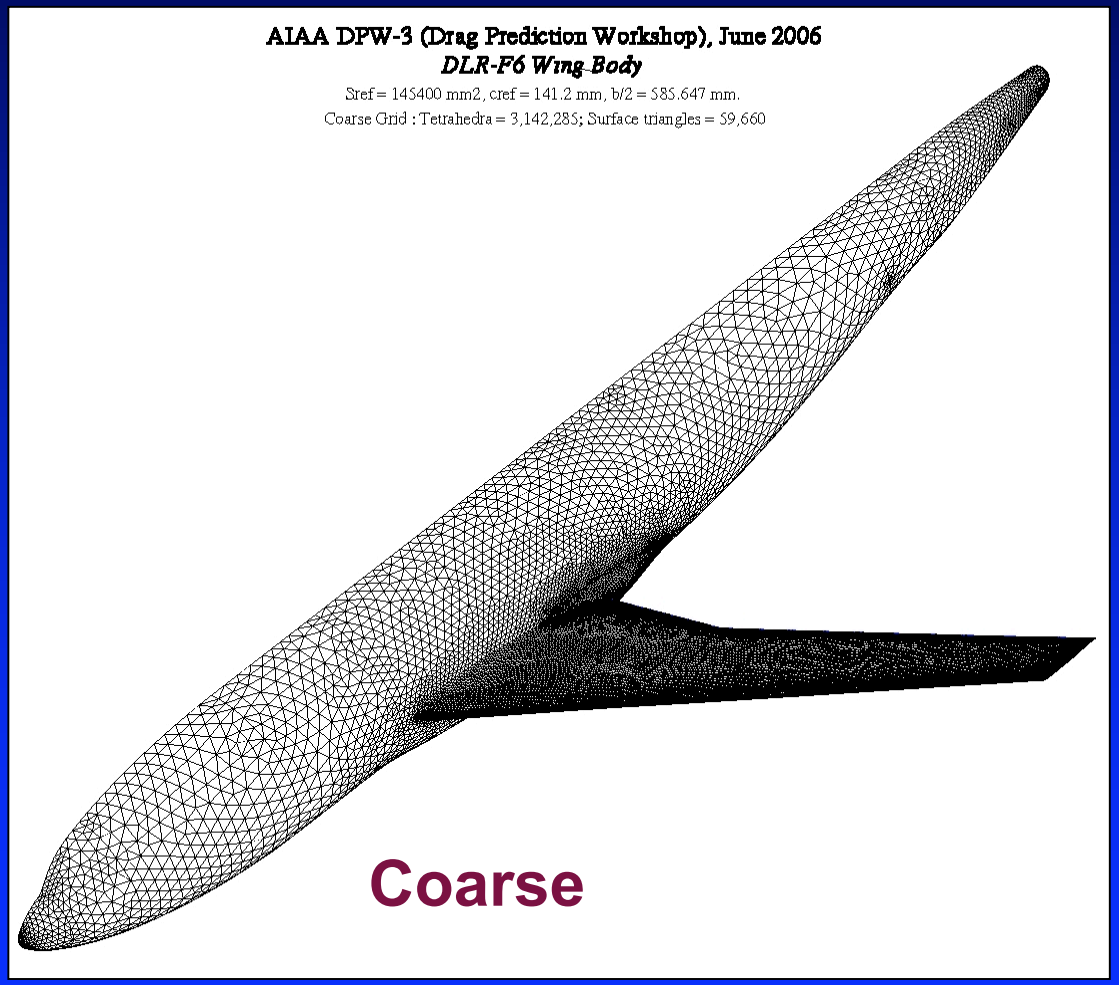
- DLR-F6 + Wing Body + FX2B Fairing



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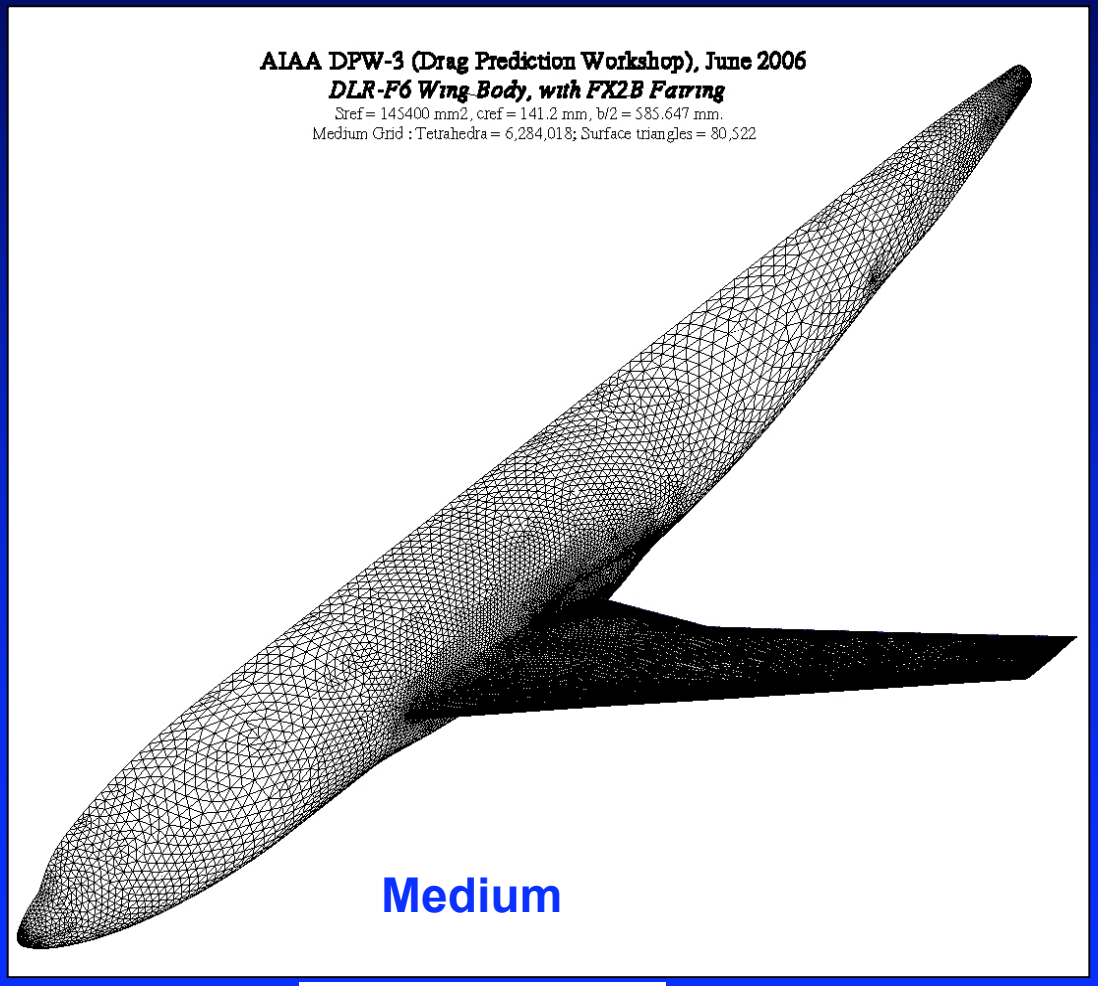

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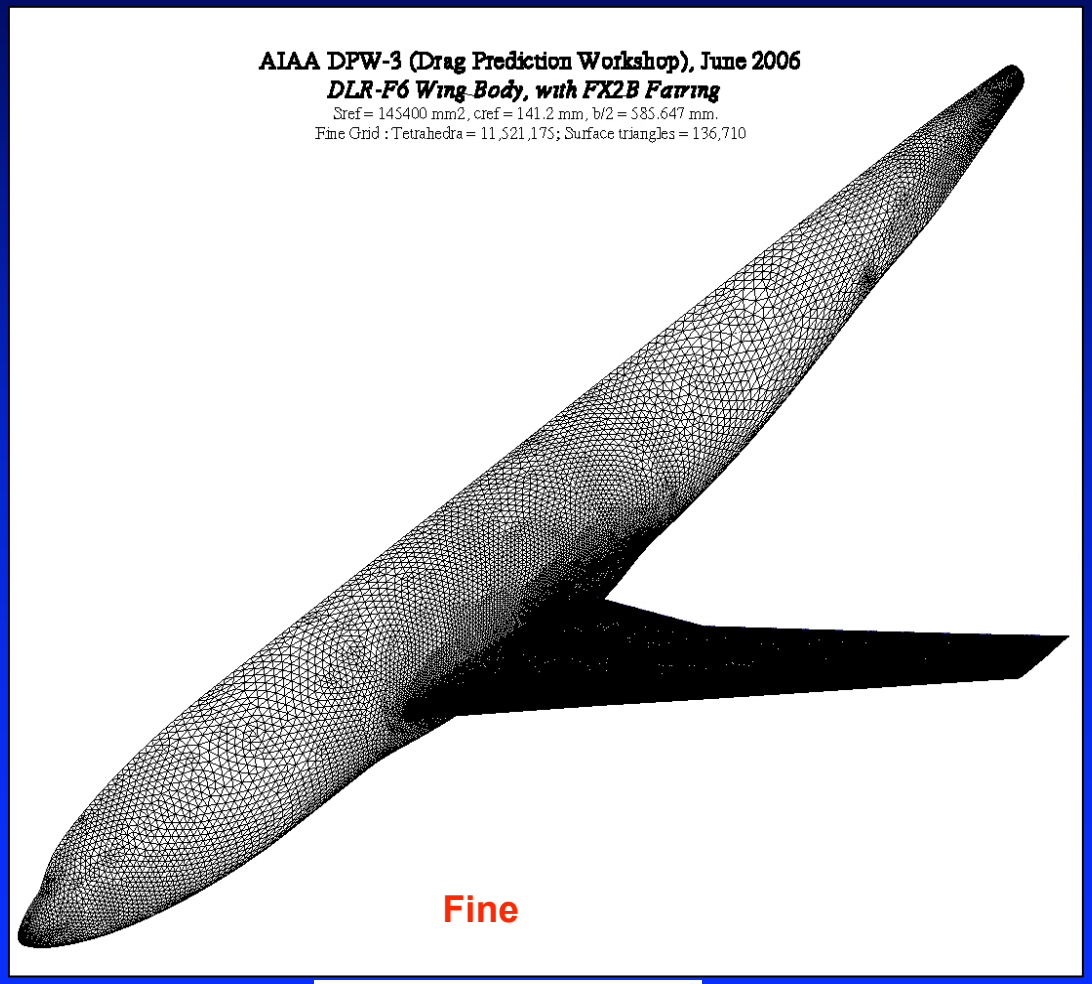

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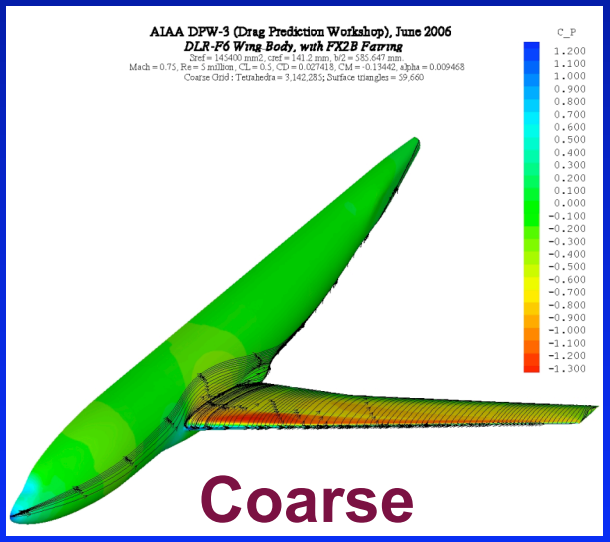

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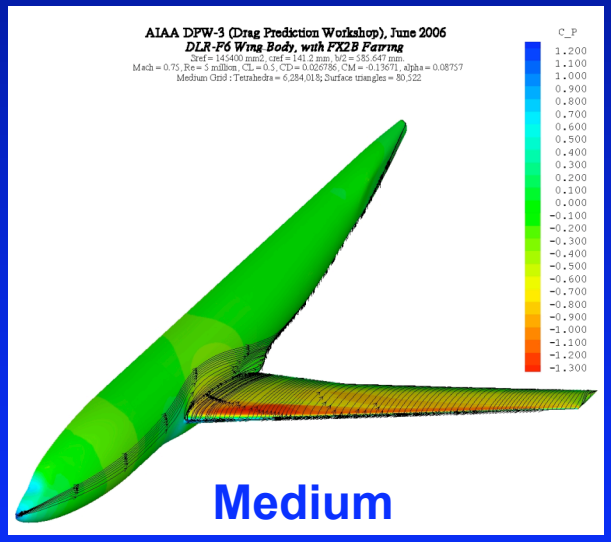

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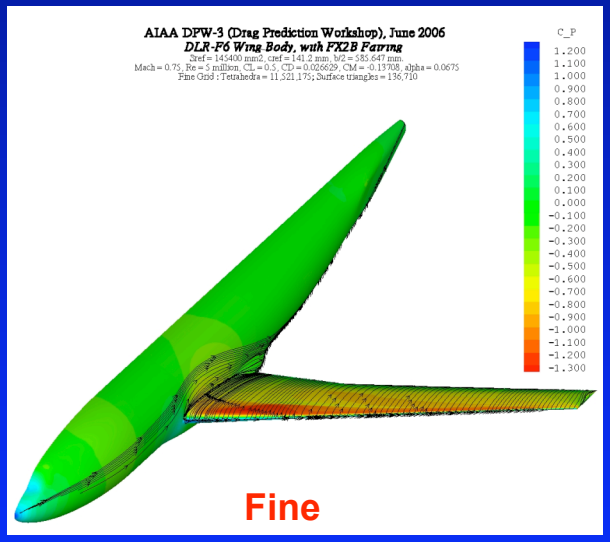

Fine

Tets = 11,521,175
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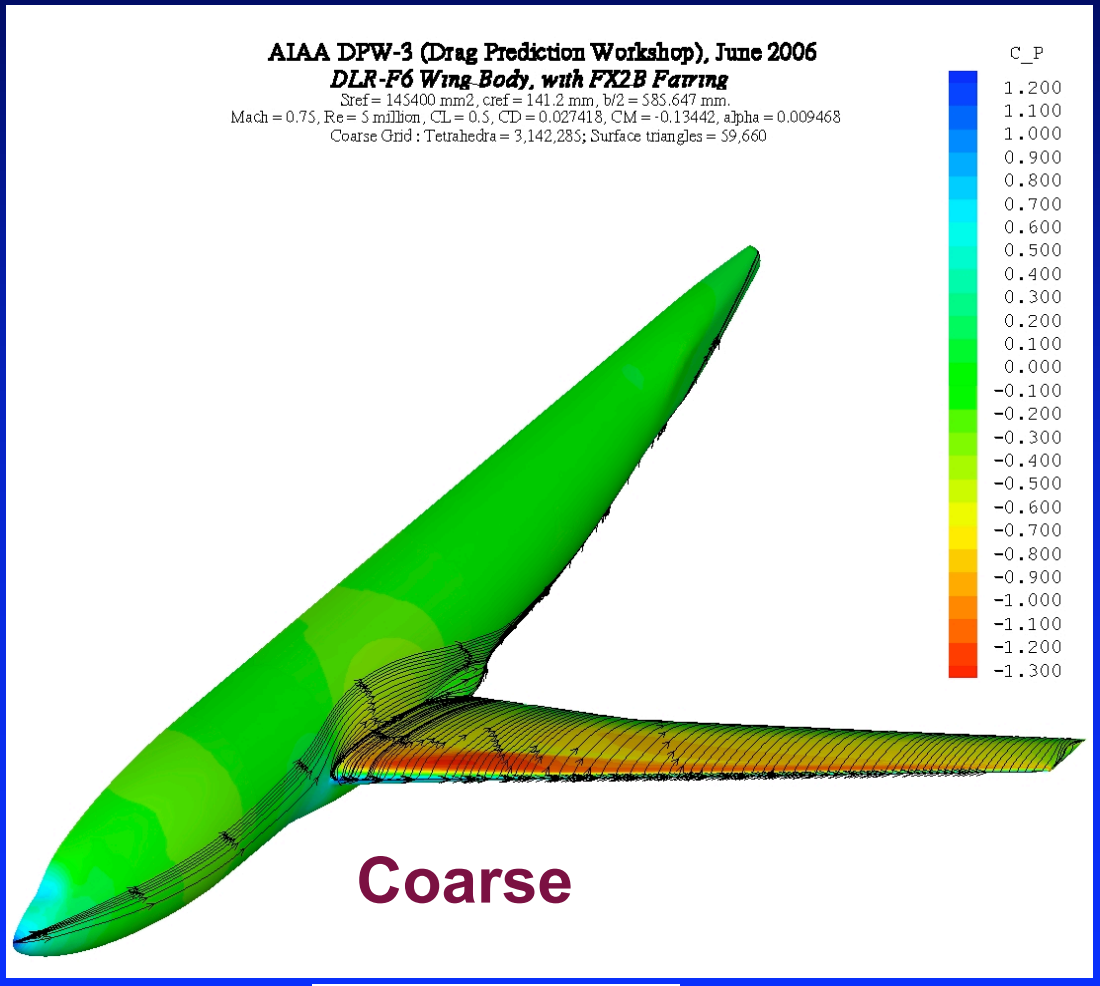
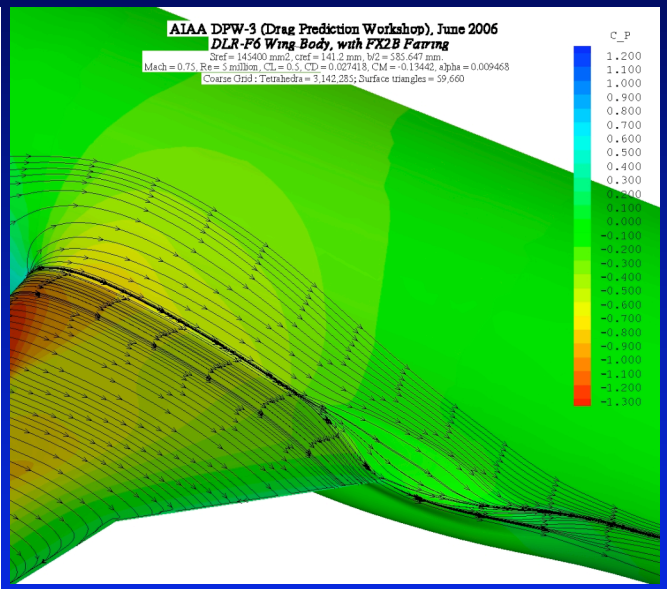
- DLR-F6 + Wing Body + FX2B Fairing



Coarse



Tets = 3,142,285
Triangles = 59,660

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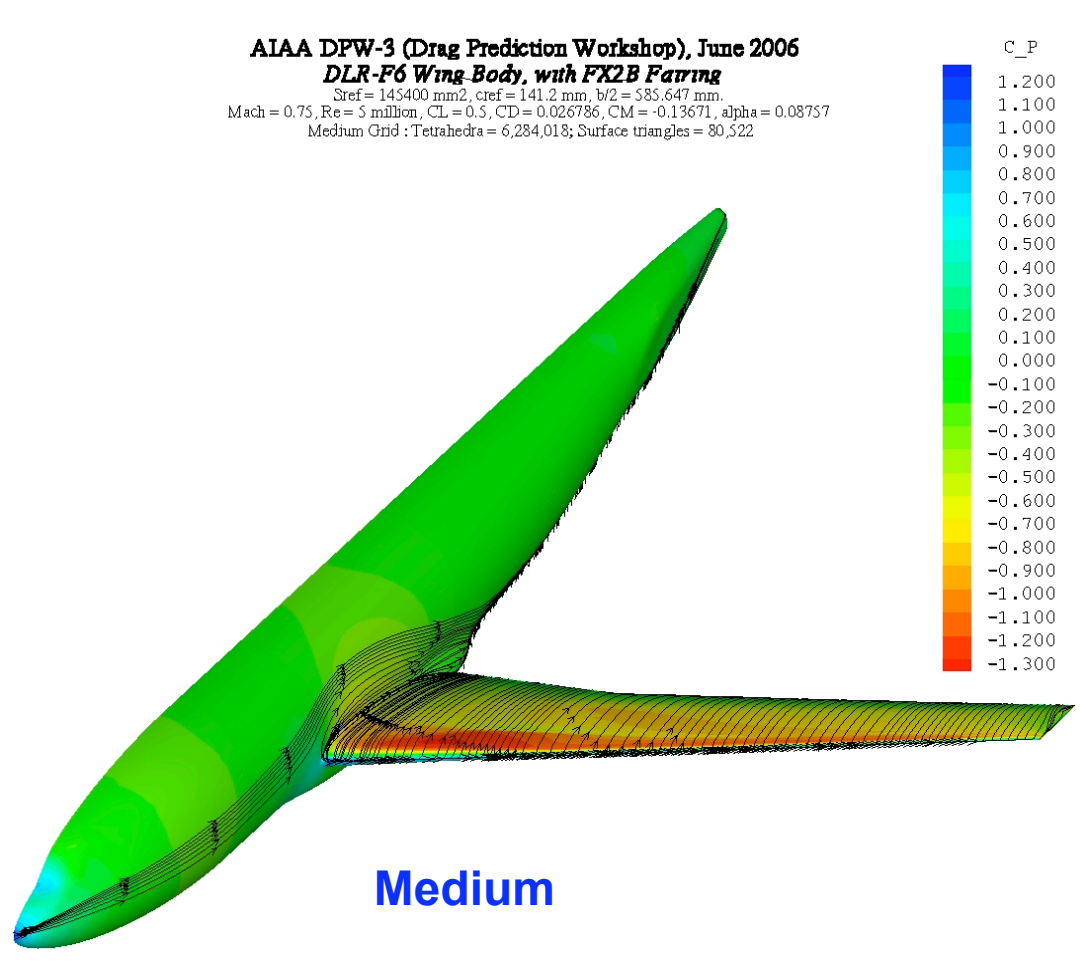
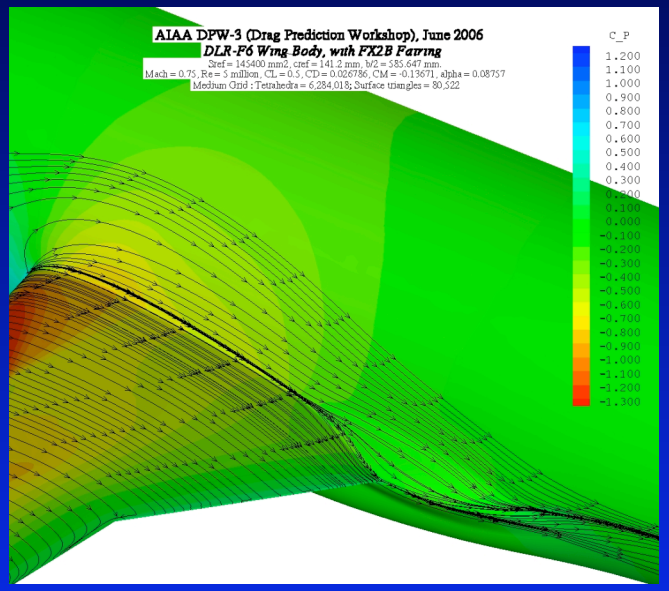
- DLR-F6 + Wing Body + FX2B Fairing





Tets = 6,284,018
Triangles = 80,522

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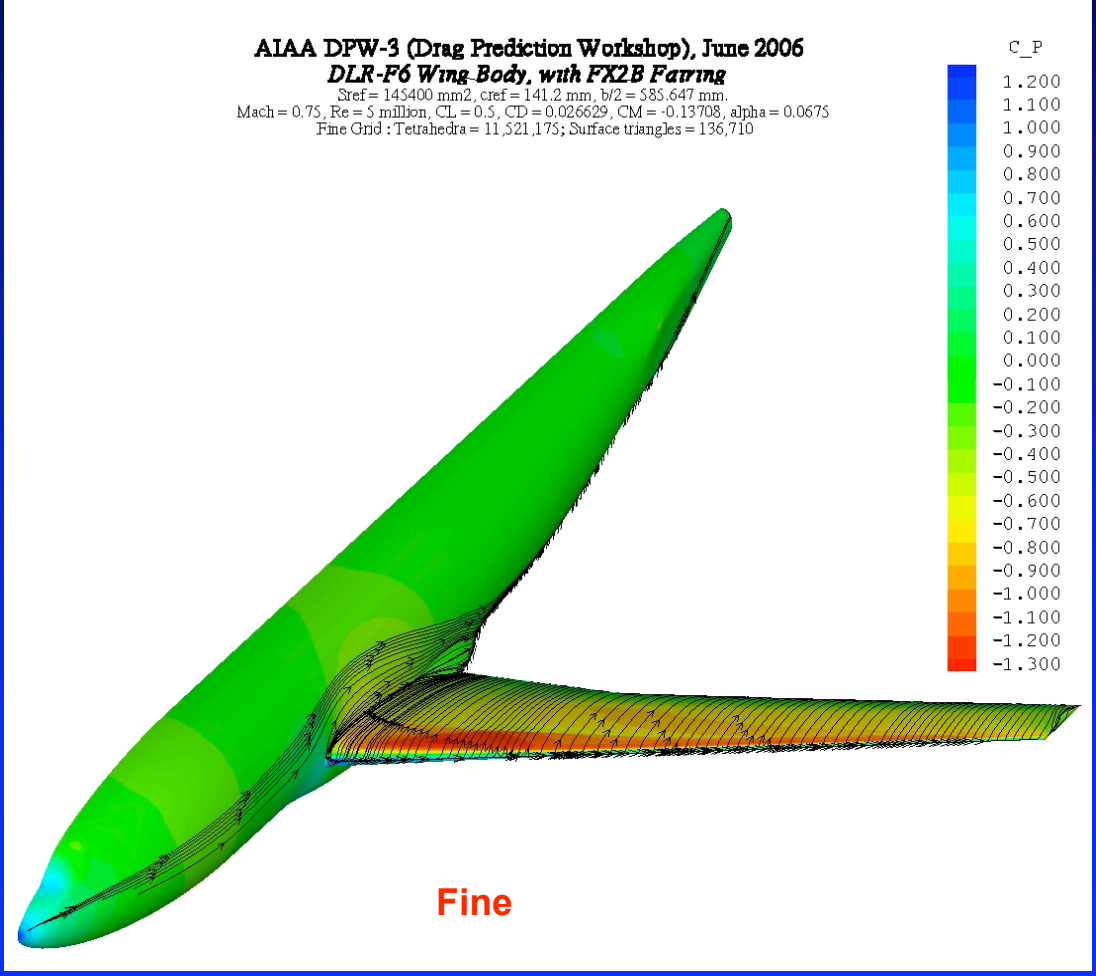
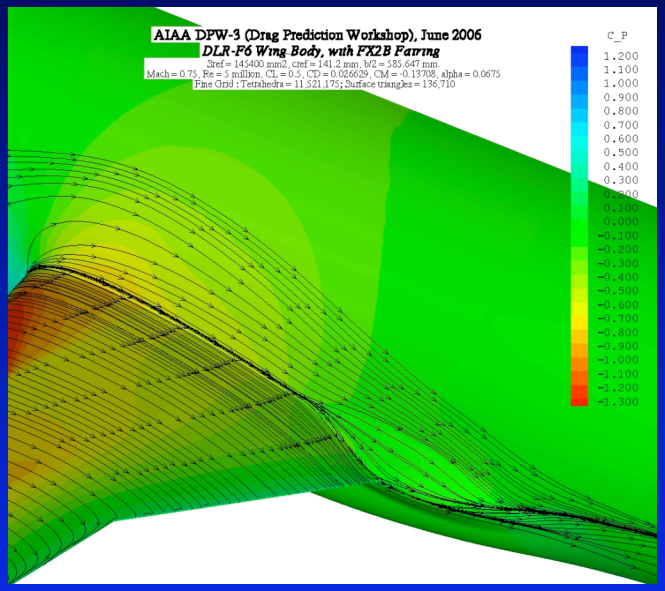
- DLR-F6 + Wing Body + FX2B Fairing



Fine



Tets = 11,521,175
Triangles = 136,710

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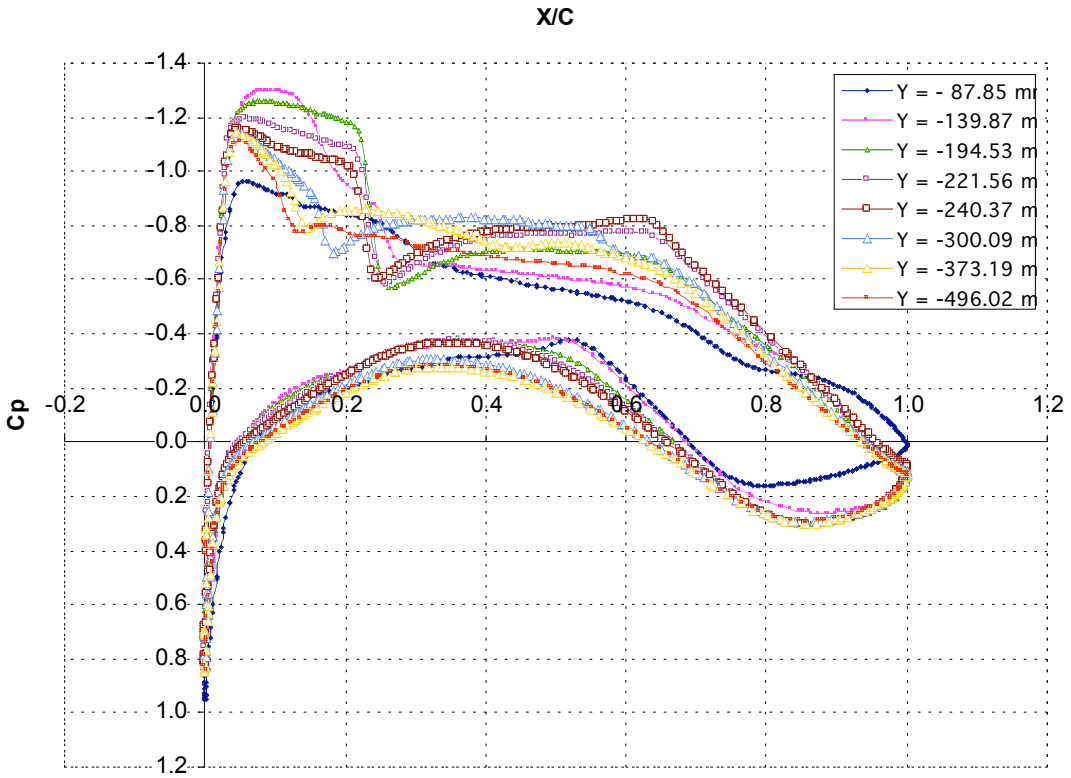
- DLR-F6 + Wing Body + FX2B (Coarse Grid)



Wing Pressures

Coarse = 3,142,285 cells

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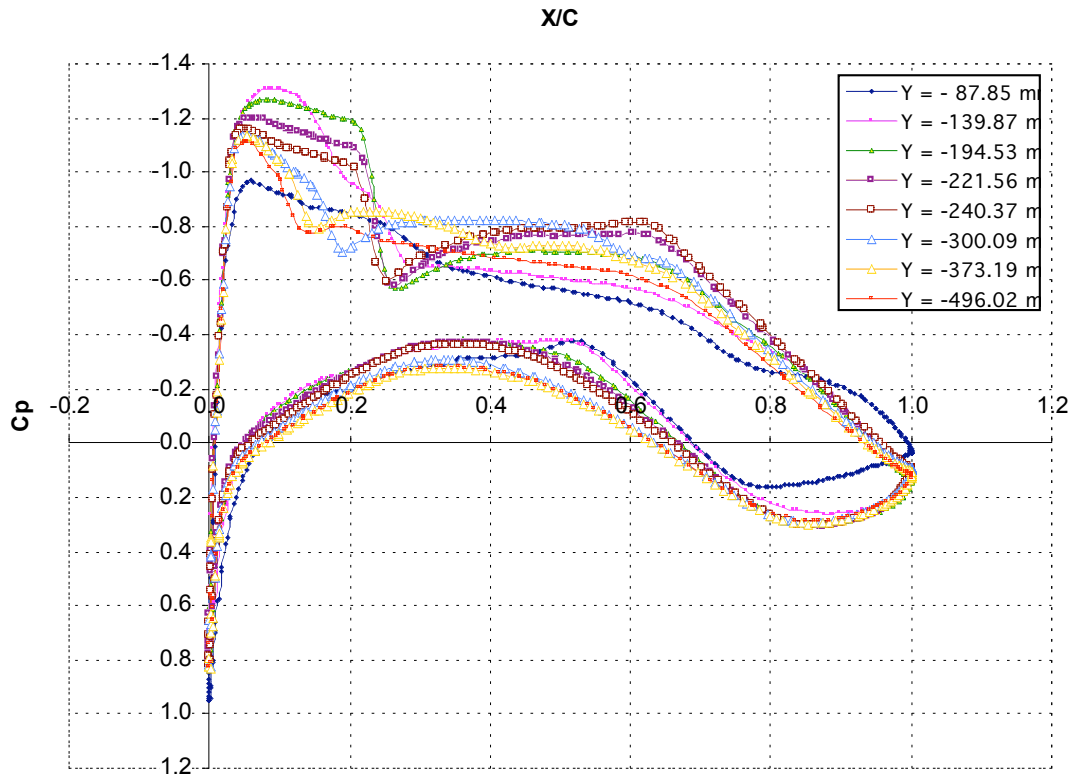
- DLR-F6 + Wing Body + FX2B (Medium Grid)



Wing Pressures

Medium = 6,284,018 cells

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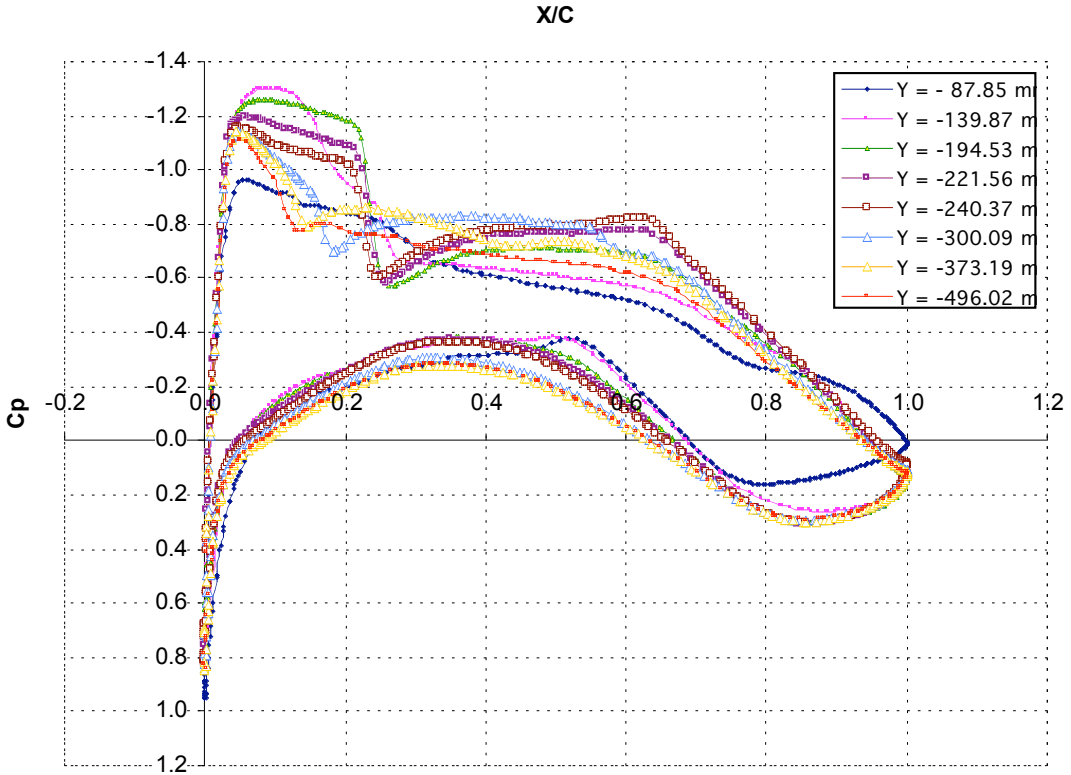
- DLR-F6 + Wing Body + FX2B (Fine Grid)



Wing Pressures

Fine = 11,521,175 cells

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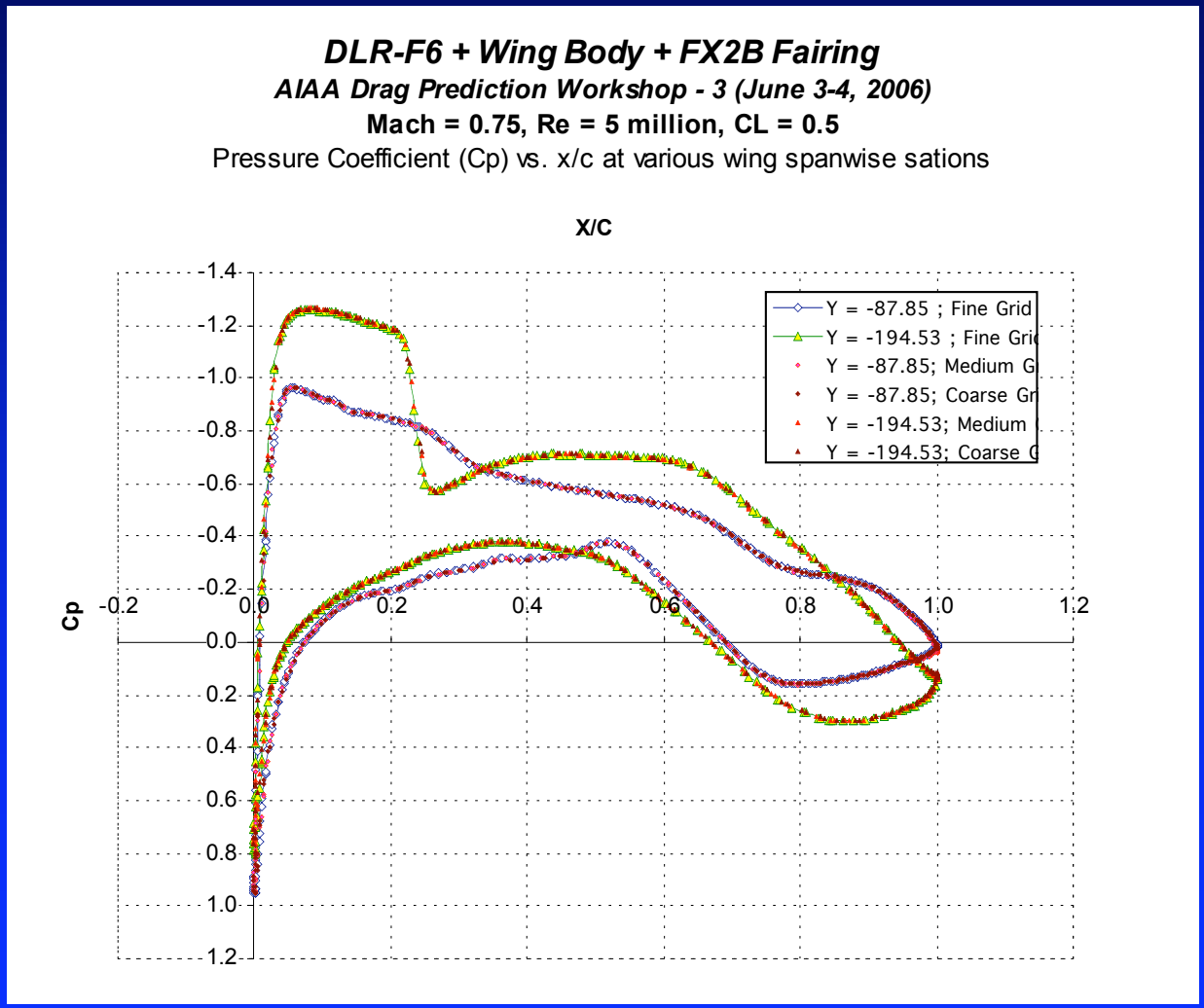
- DLR-F6 + Wing Body + FX2B



Grid Convergence

Coarse = 3,142,285 cells
Medium = 6,284,018 cells
Fine = 11,521,175 cells

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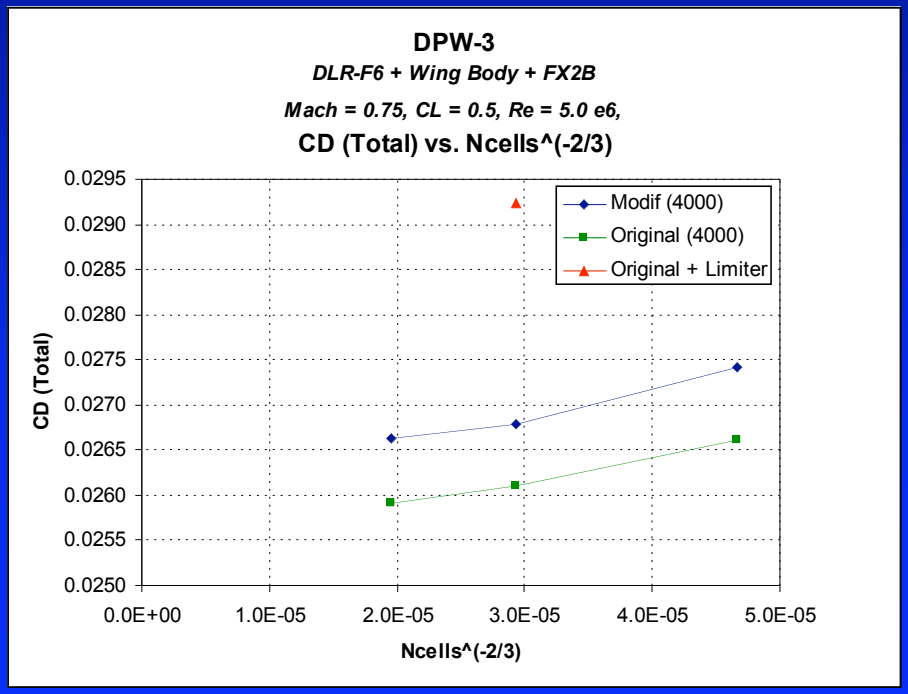
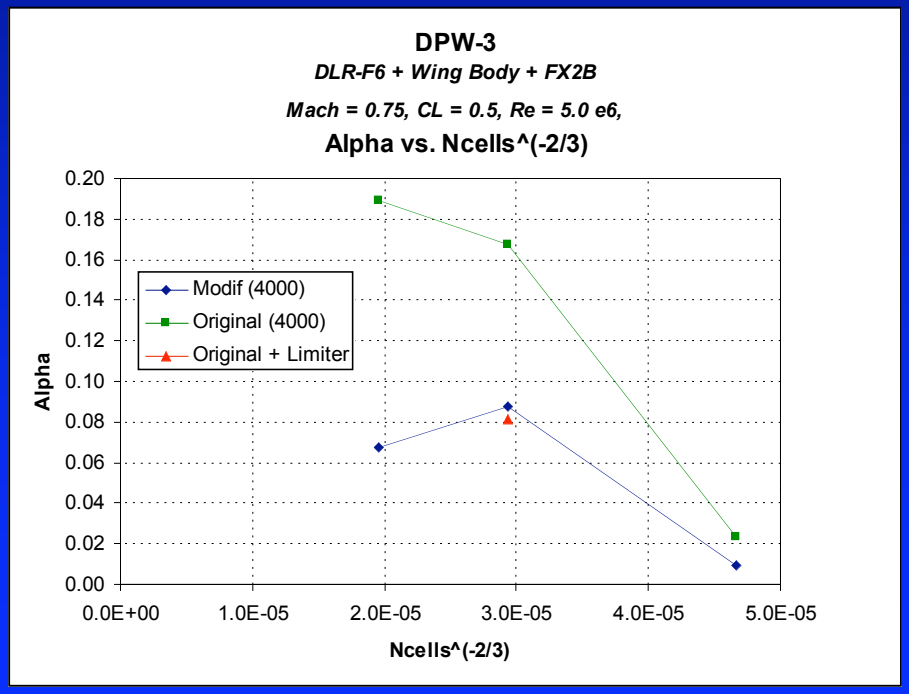
- DLR-F6 + Wing Body + FX2B

Comparisons of Code Variants & Grid Convergence

- "Modified" version is preferred to "Original"
- Limiter is not preferred





ΔCD (No Fairing – FX2B); Medium Grid = 1.06 counts

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- DLR-F6 + Wing Body + FX2B

Comparisons of Code Variants & Grid Convergence

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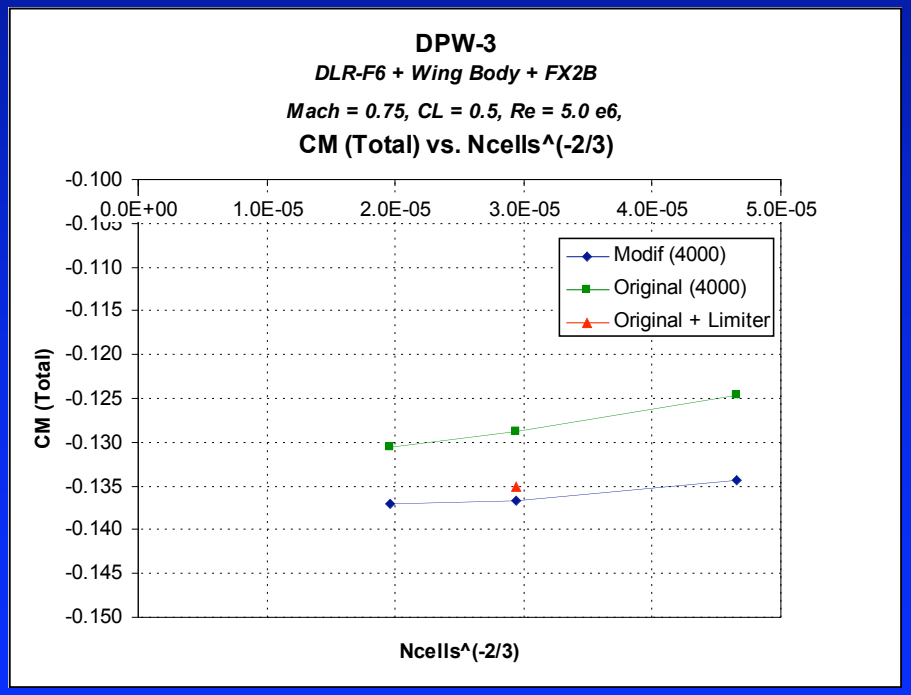

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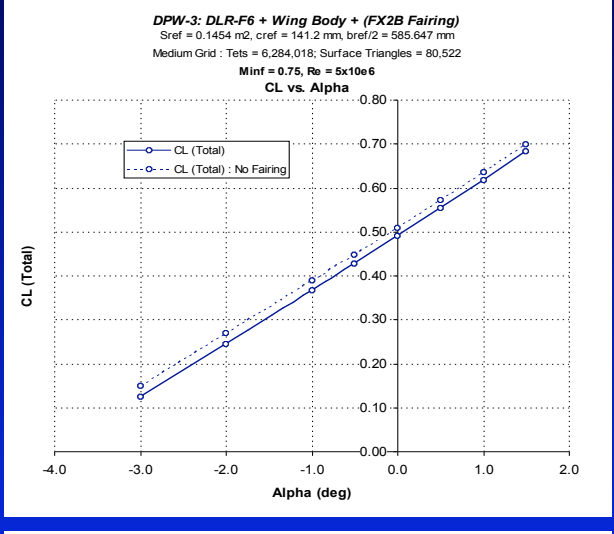
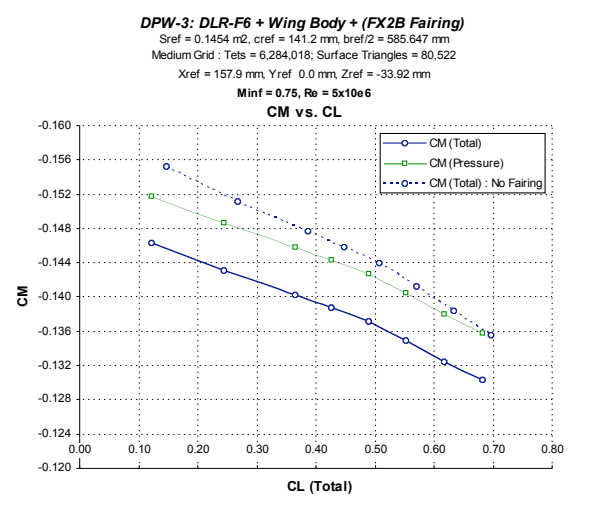
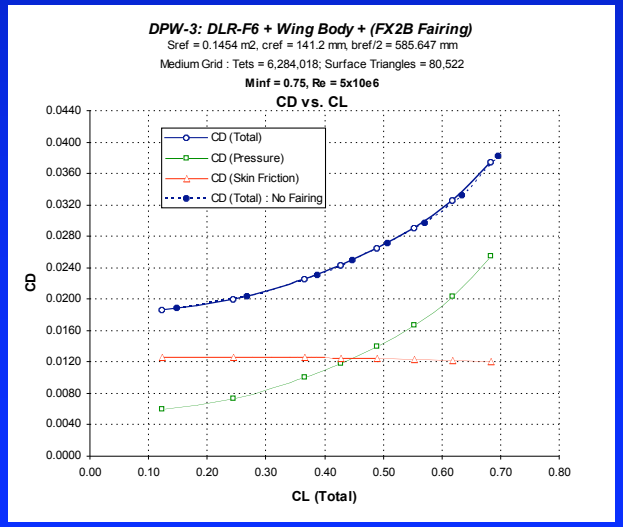
- Lift & Moment curves, Drag Polars (with & without FX2B Fairing)



- Slight +ve Alpha shift with FX2B added
- No noticeable change in Drag Polar
- Noticeable decrease in pitch down moment with FX2B added





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- Conclusions
  - Bubble detected for DLR-F6 + Wing Body
  - No Bubble detected for DLR-F6 + Wing Body + FX2B
  - Wing trailing edge separation detected with or without FX2B
  - Drag reduction: ΔCD (No Fairing – FX2B); Medium Grid = 1.06 counts
  - Results obtained under Industrial Conditions!

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- Further work
  - Solution adaptive grid refinement using *RefineMesh (NASA Langley)*
    - Uses unique hole creation algorithm (*Pirzadeh*)
    - Generates high quality multilevel grid refinement for unstructured tetrahedra
    - Smooth transition between refinement levels
    - Improved estimation of wave drag
    - Useful in production environment, to reduce grid size & computation time
  - Plot Skin Friction Coefficients

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- Thanks for your attention