Dedicated to innovation in aerospace

Drag Prediction Workshop VII

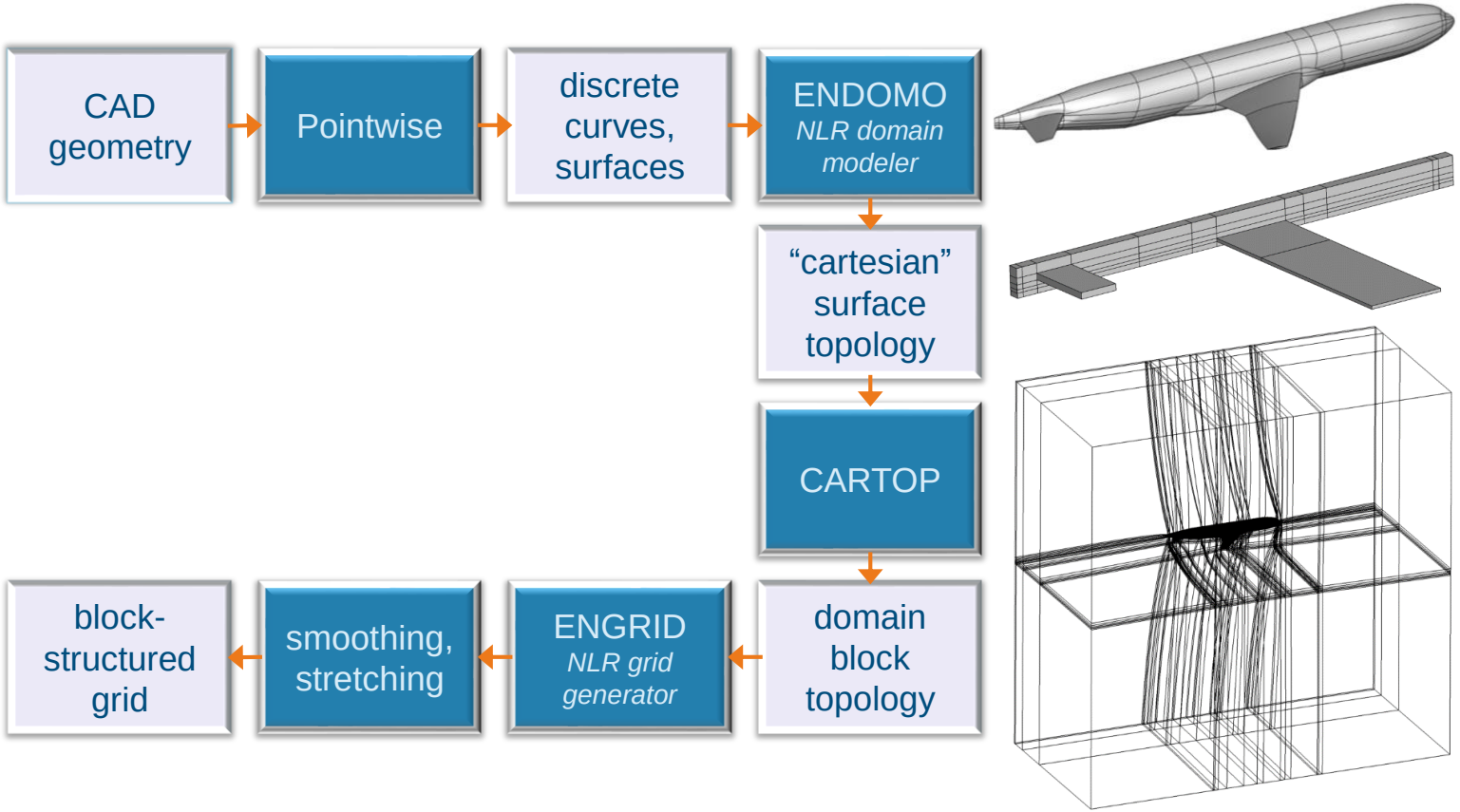
NLR Grids & Results | Michel van Rooij and Peter Blom

Structure

- Grid generation at NLR
- Solver Description
- Results
- Conclusion

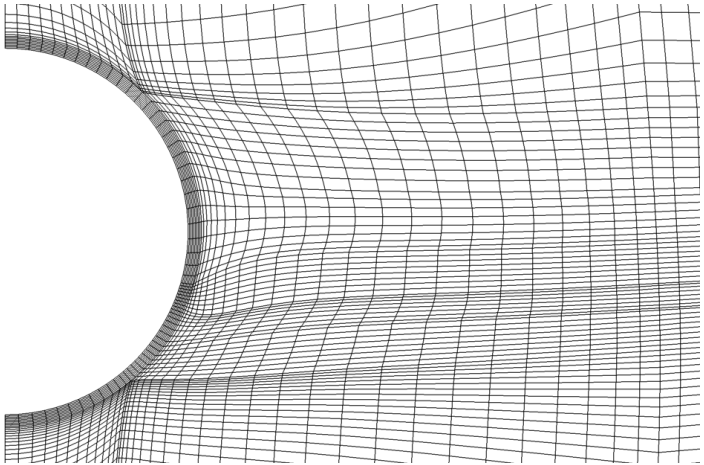
Grid Generation at NLR

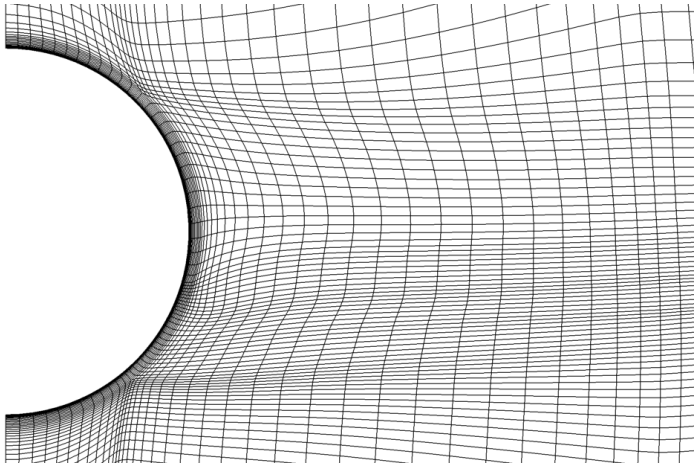
Grid generation process



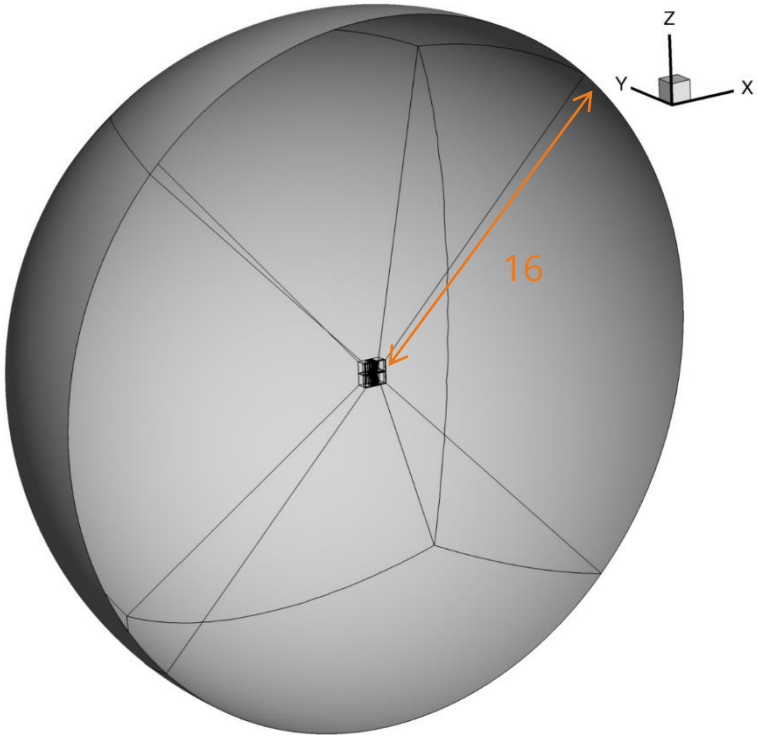
Grid generation process

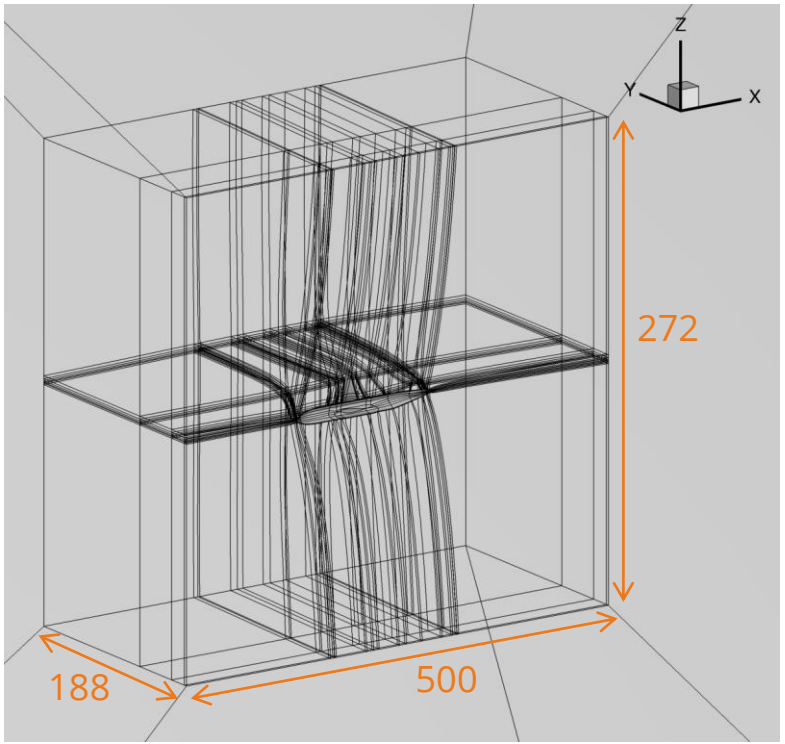
- **Grid smoothing**
  - surface and/or volume smoothing
  - option to freeze specified faces / edges
- **Grid stretching**
  - near-wall cell size and #cells in NS-blocks specified
  - cell size can be adjusted locally



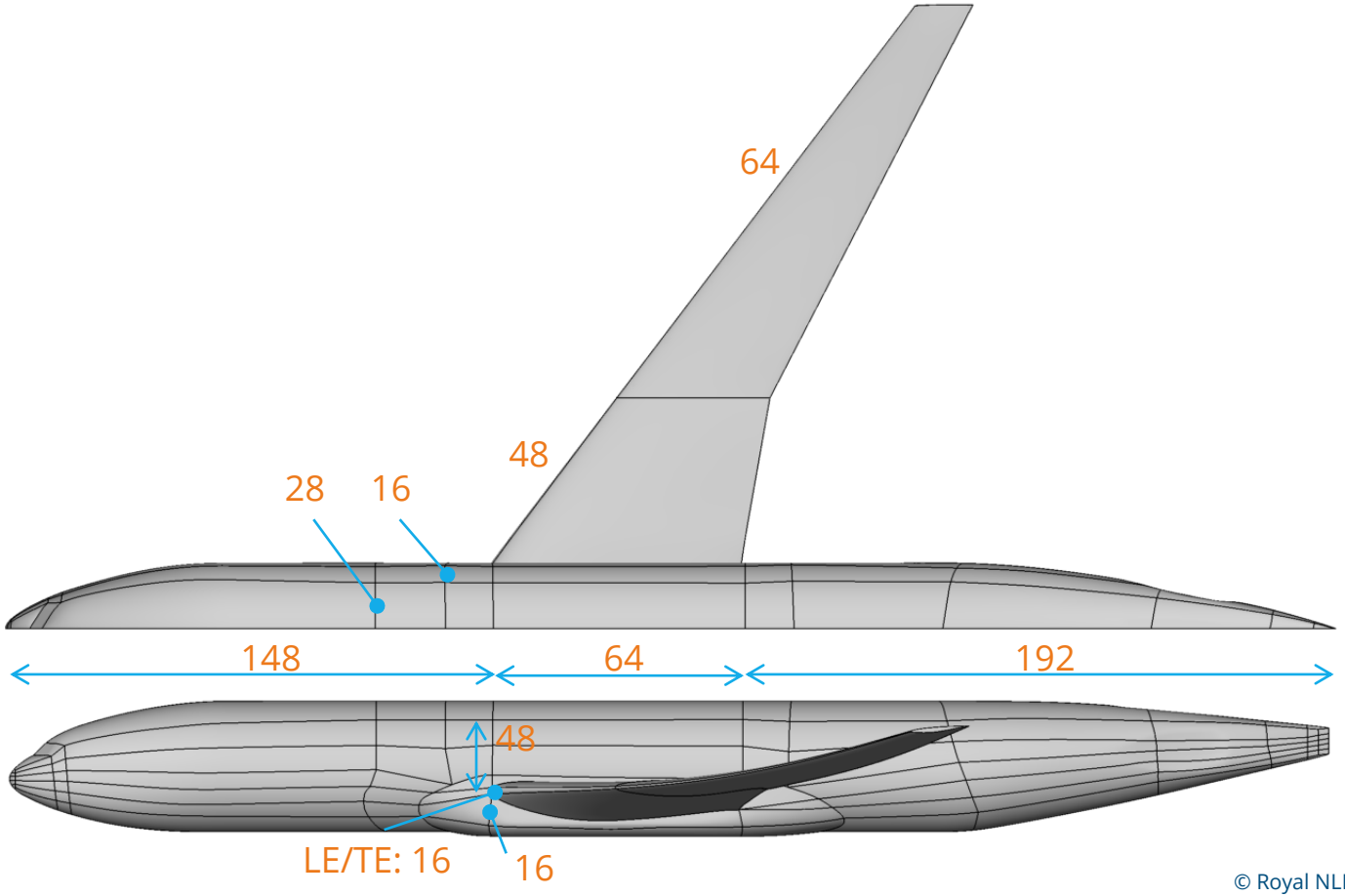


Grid topology and cell count (L3M)





Grid topology and cell count (L3M)



Grid topology and cell count (L3M)

grid	#blocks*	#cells	#points
L1T	592	4,344,832	5,102,256
L2C	760	15,100,992	16,923,108
L3M	1,408	36,318,720	40,199,392
L4F	2,445	71,552,320	78,780,353

*after splitting for MPI

Solver Description

ENSOLV

- In-house, compressible flow solver
- Both steady and unsteady (Euler, (u)RANS, LES, hybrid RANS-LES)
- Many capabilities, including:
  - Aeroelasticity
  - Aeroacoustics
  - Adjoint optimization
  - Overset & discontinuous grids

ENSOLV – Simulation Details

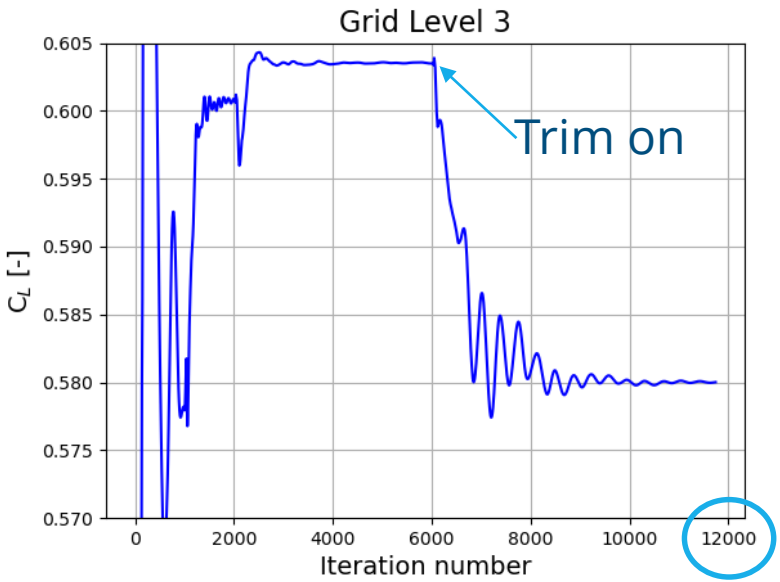
- 2nd order spatial discretization
- 5-stage Runge-Kutta time integration with residual averaging
- Multigrid friendly for 3 grid levels
- Turbulence Models:
  - Standard SST
  - Custom EARSM
    - Based on TNT k-ω EARSM used at NLR*
    - Modified production term in ω-equation†
    - More generalized formulation
    - Aims to provide similar results to SST with adverse pressure gradients

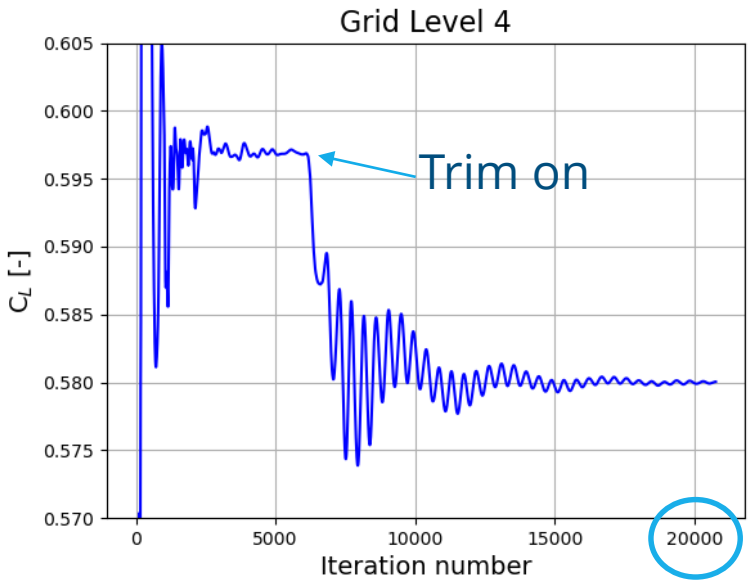
*see H.S. Dol, J.C. Kok and B. Oskam. Turbulence modelling for leading-edge vortex. *AIAA 2002-0843* for more details
† production term based on: C.G. Speziale and T.B. Gatski. Analysis and modelling of anisotropies in the dissipation rate of turbulence, *Journal of Fluid Mechanics*, 344:155–180, 1997.

Results

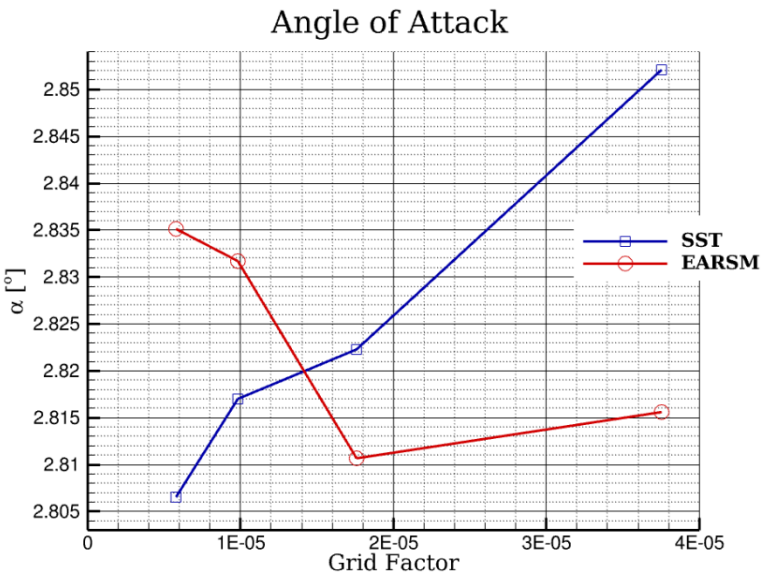
Grid Convergence Study

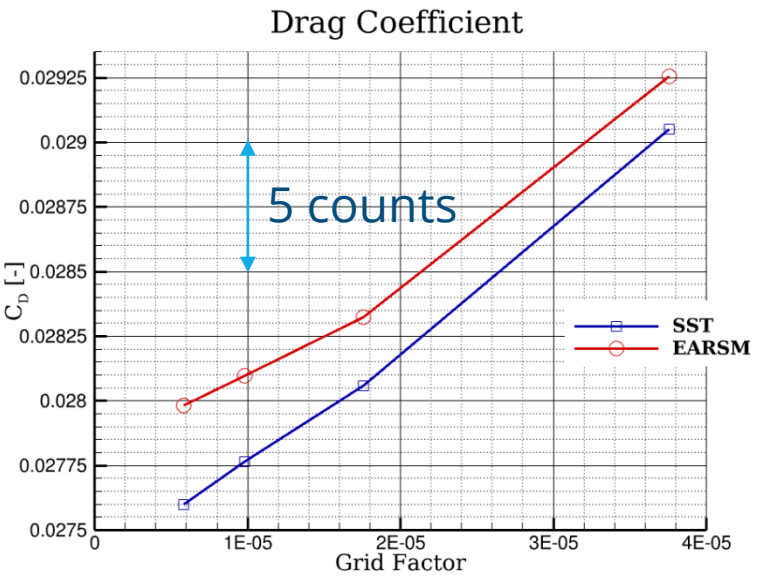
Convergence (EARSM)



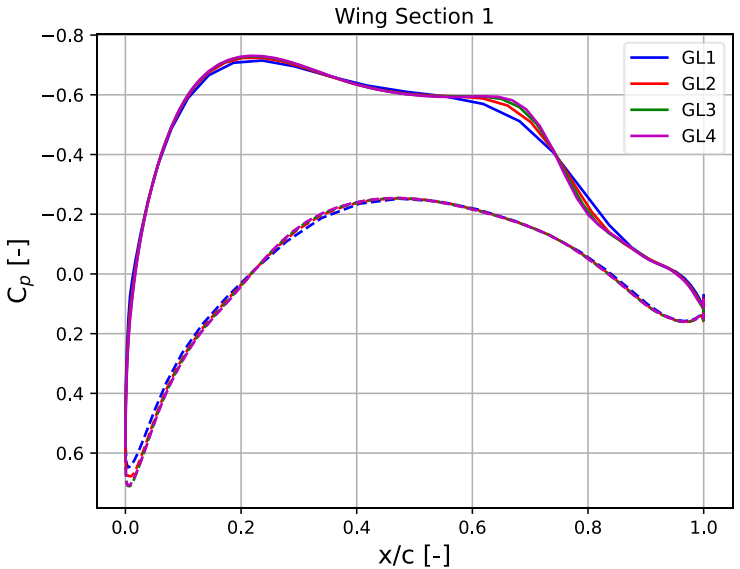


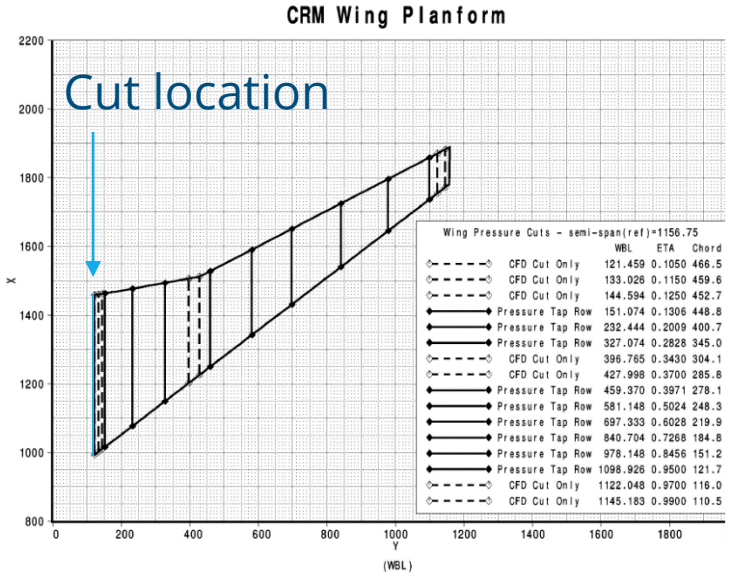
Convergence Study





Pressure Coefficients (EARSM)





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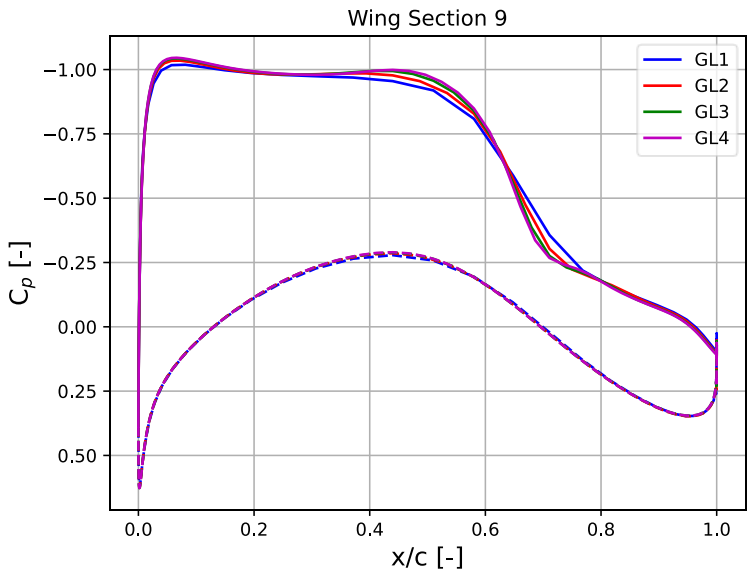

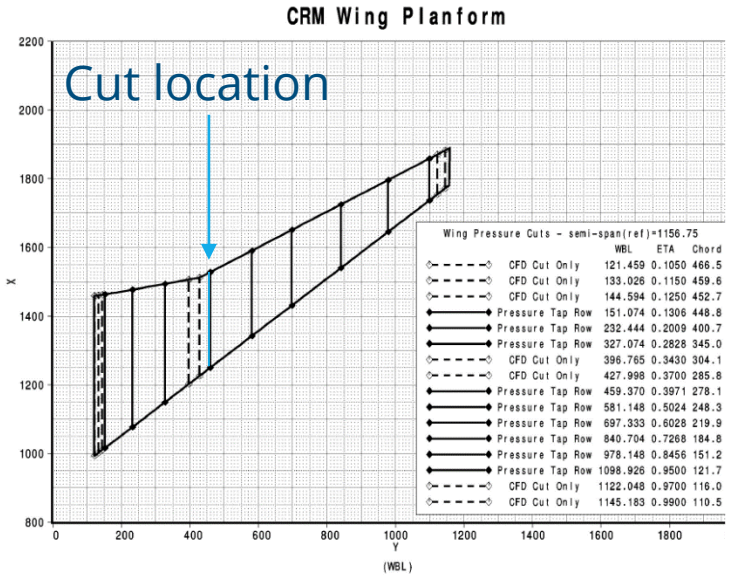

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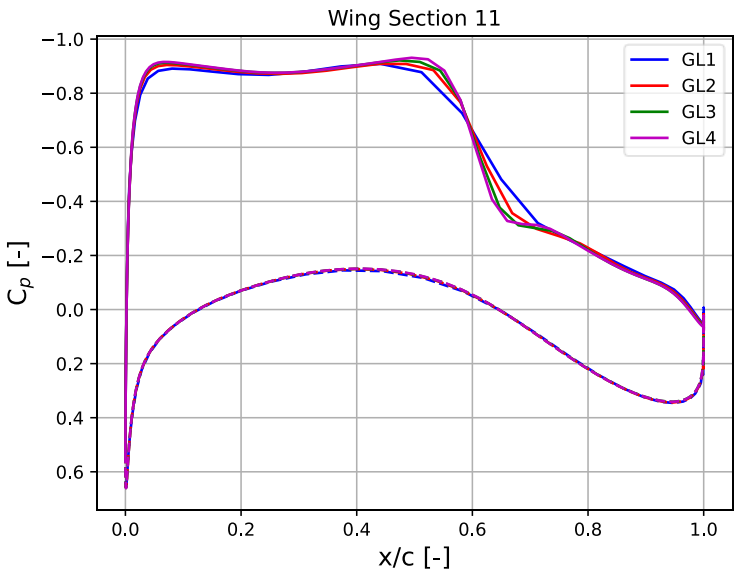

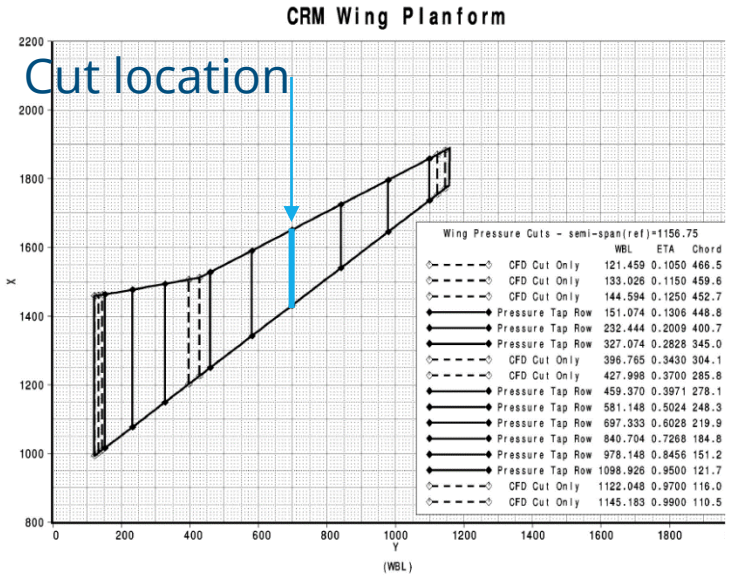

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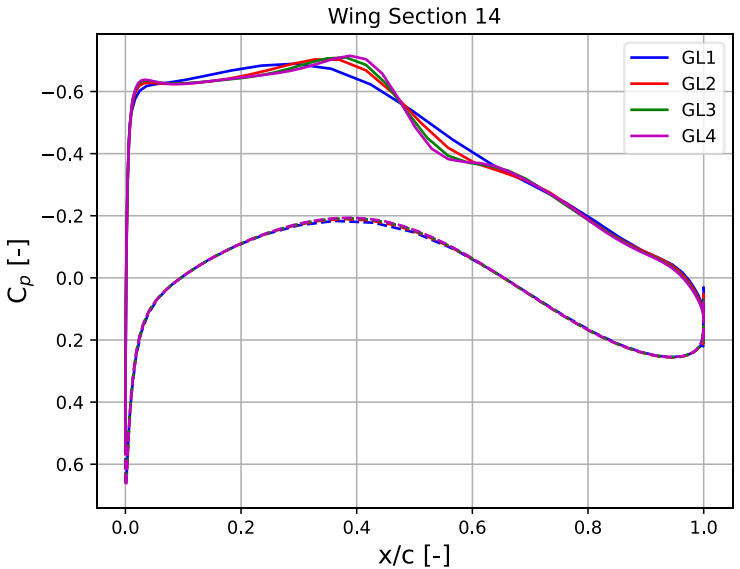
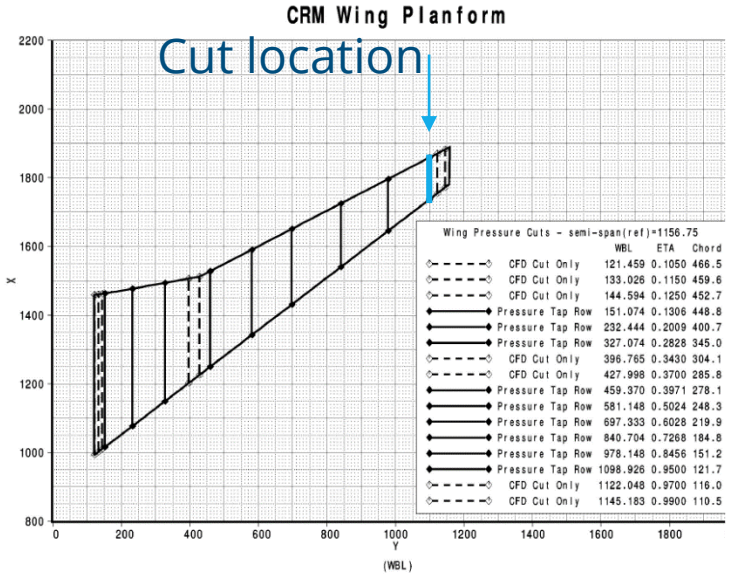




SST Convergence C_D

Grid Level	C_D (counts)	$\lvert C_{Di}-C_{Di-1} \rvert$ (counts)	$\lvert C_{Di}-C_{D4} \rvert$ (counts)	$\lvert C_{Di}-C_{D0} \rvert$* (counts)
1	290.527	N/A	14.52	16.9
2	280.597	9.93	4.59	7.01
3	277.666	2.93	1.66	4.08
4	276.003	1.66	0	2.4

*Where C_{D0} is based on Richardson extrapolation

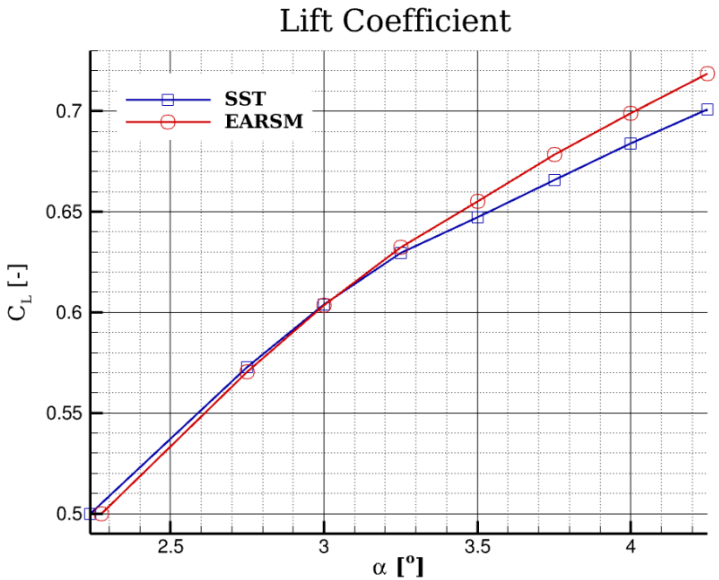
EARSM Convergence C_D

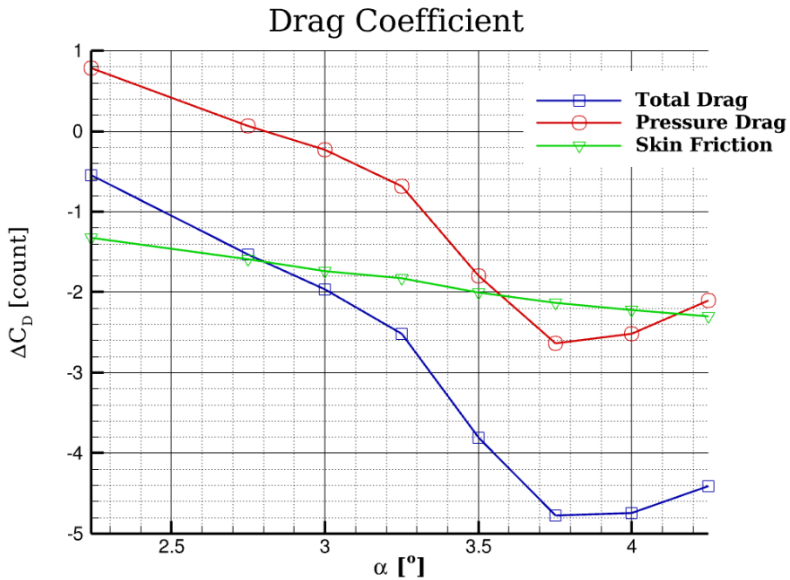
Grid Level	C_D (counts)	$\lvert C_{Di}-C_{Di-1} \rvert$ (counts)	$\lvert C_{Di}-C_{D4} \rvert$ (counts)	$\lvert C_{Di}-C_{D0} \rvert$* (counts)
1	292.551	N/A	12.73	14.39
2	283.224	9.33	3.40	5.07
3	280.974	2.25	1.15	2.82
4	279.825	1.15	0	1.67

*Where C_{D0} is based on Richardson extrapolation

Angle of Attack Sweep

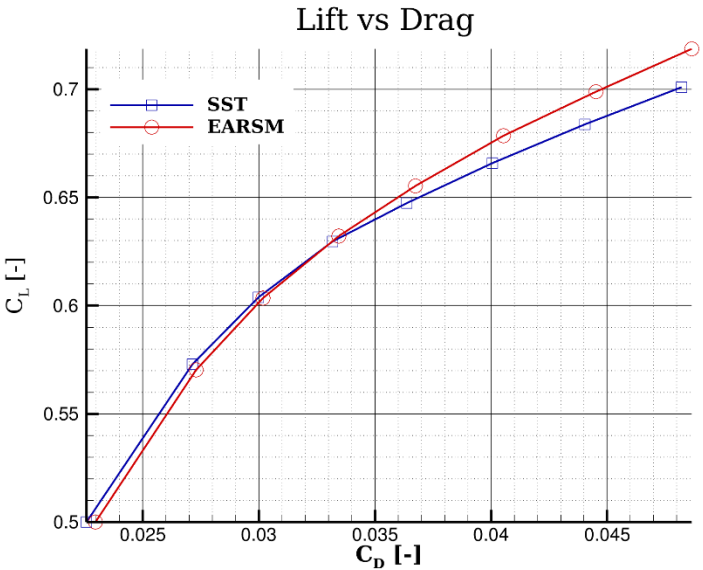
Force Coefficients

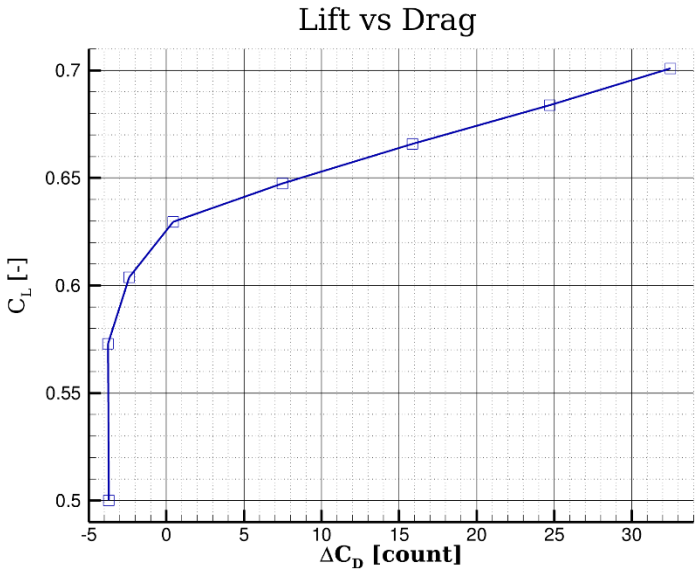




$$\Delta C_D = C_{D,SST} - C_{D,EARSM}$$

Force Coefficients





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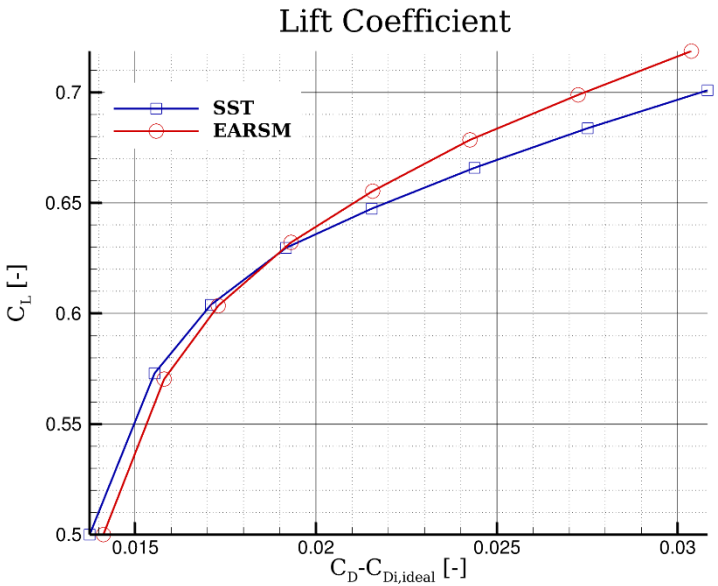
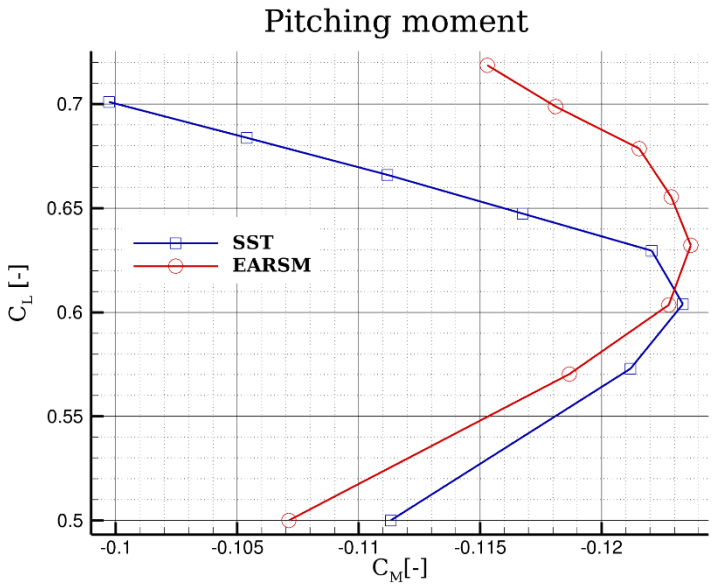
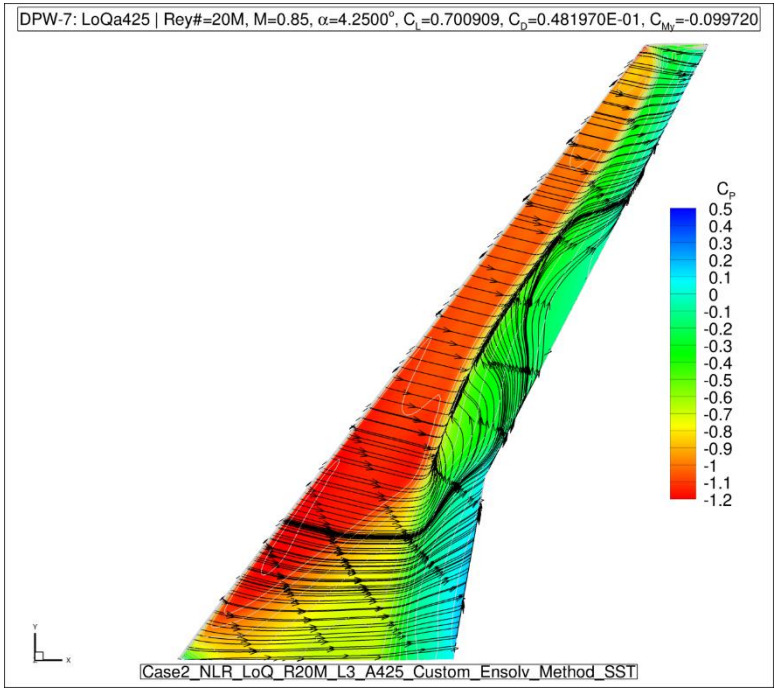
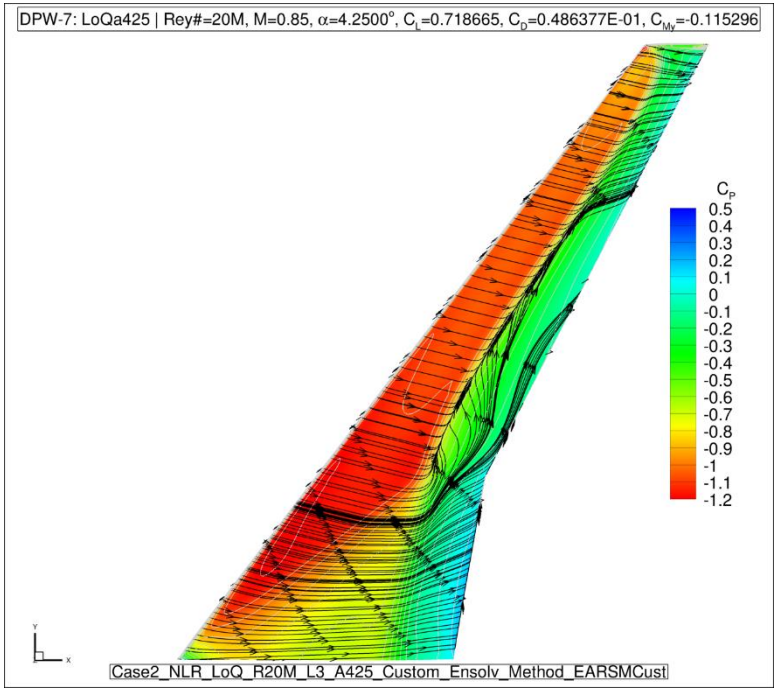




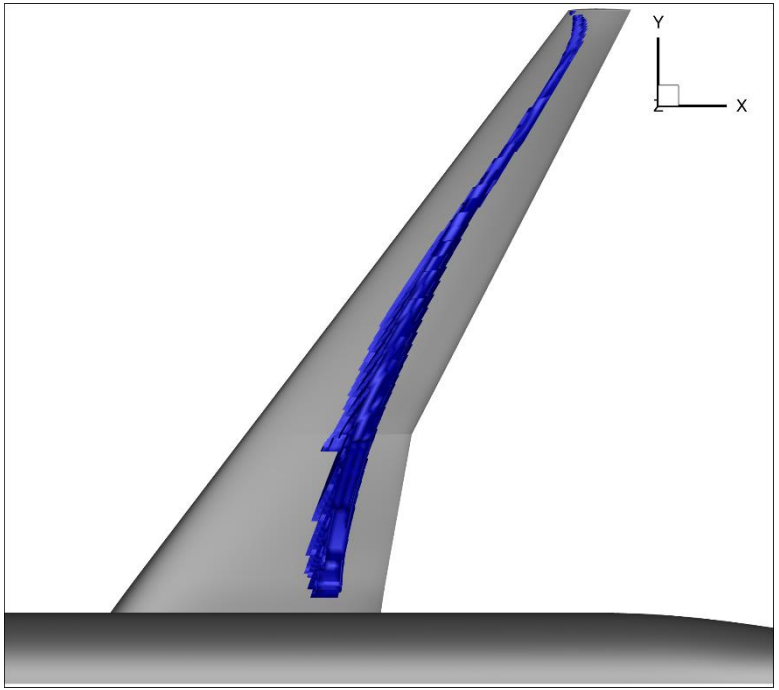
Contour plot SST @ α = 4.25°



Contour plot EARSM @ α = 4.25°



Shock SST @ α = 4.25°



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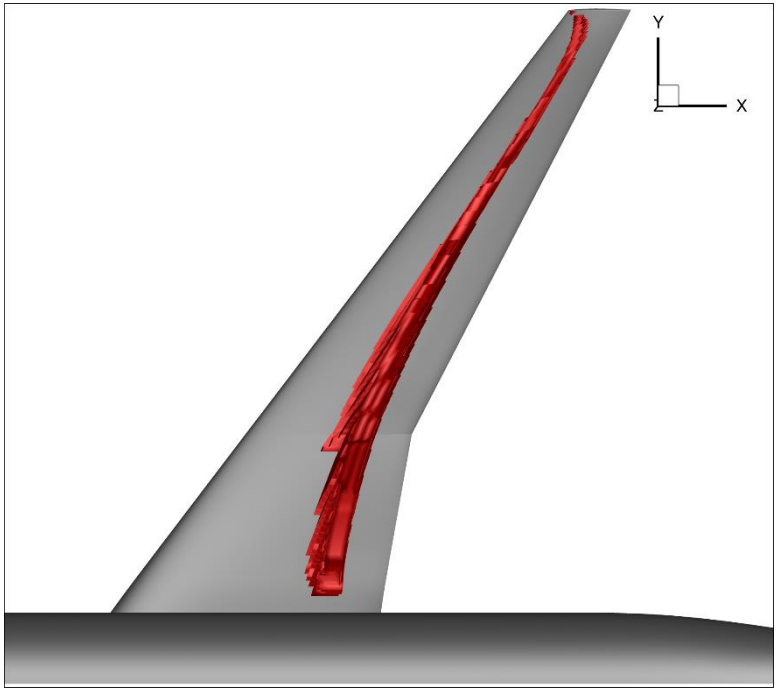
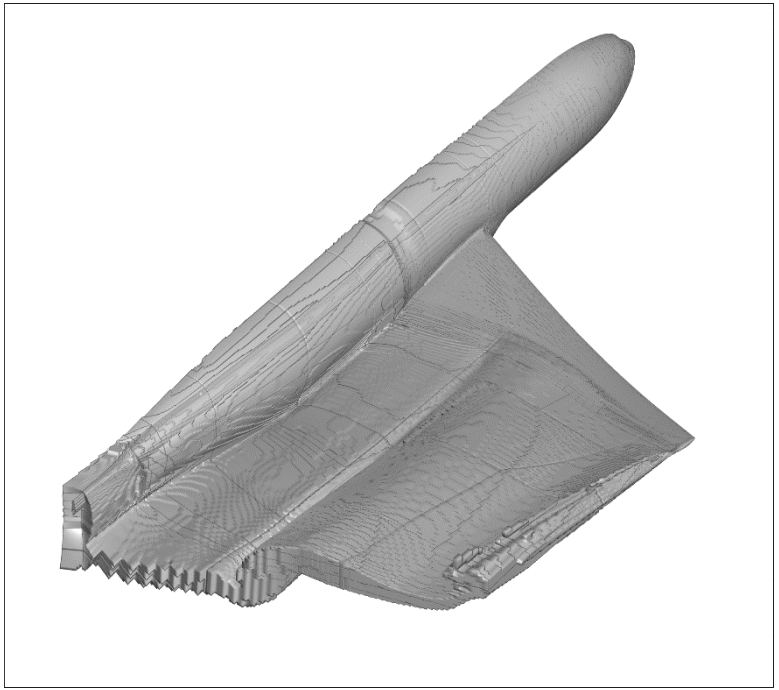
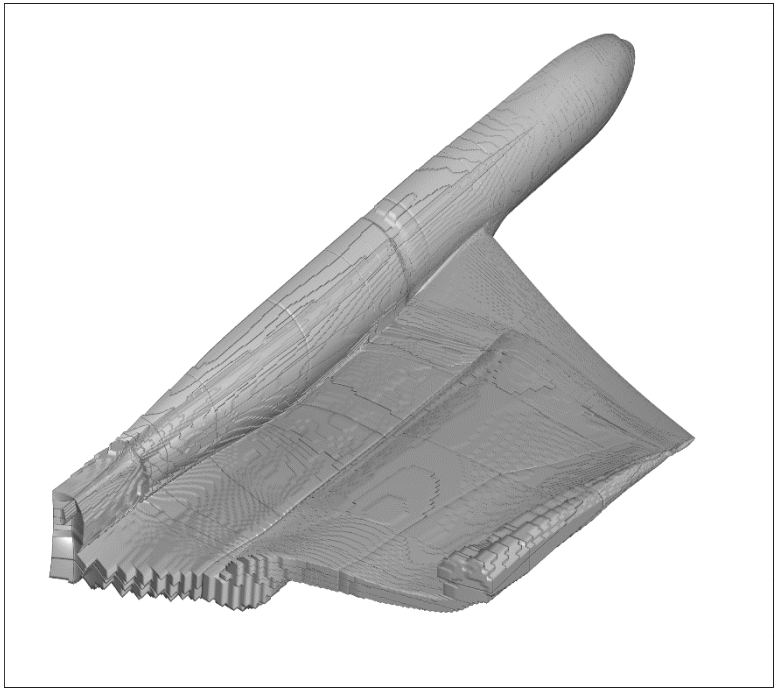


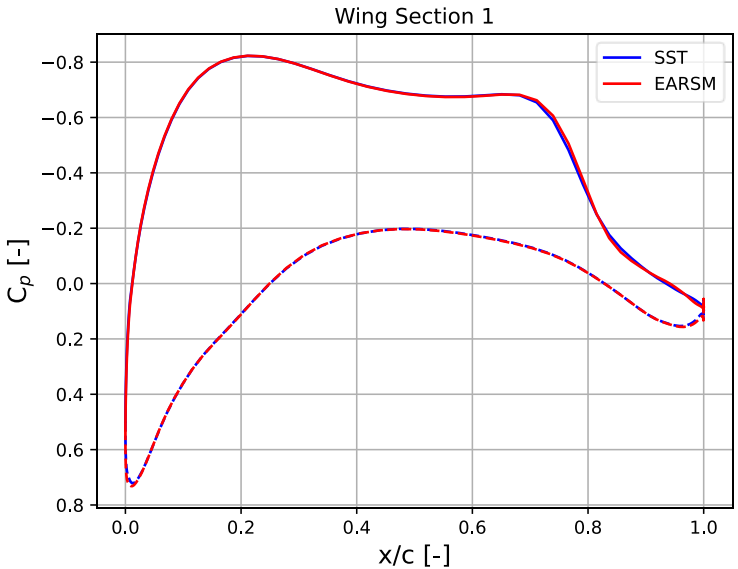
Viscous Region SST @ α = 4.25°

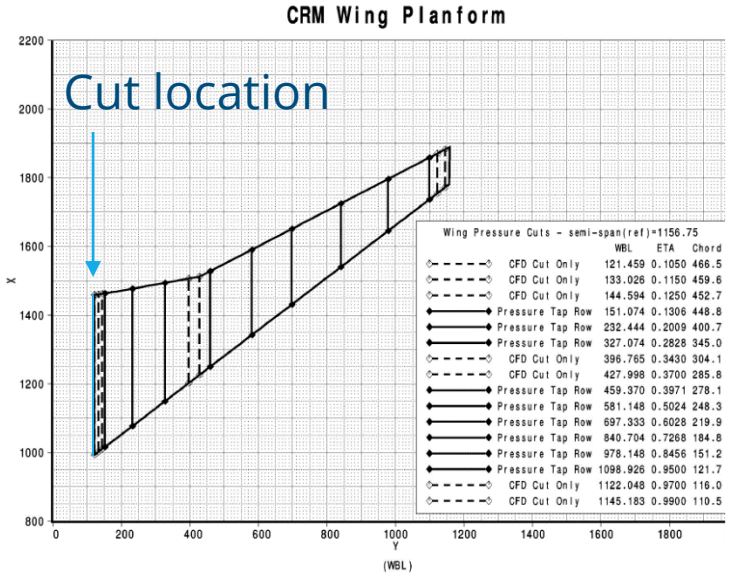


Viscous Region EARSM @ α = 4.25°



Pressure Coefficient @ α = 4.25°





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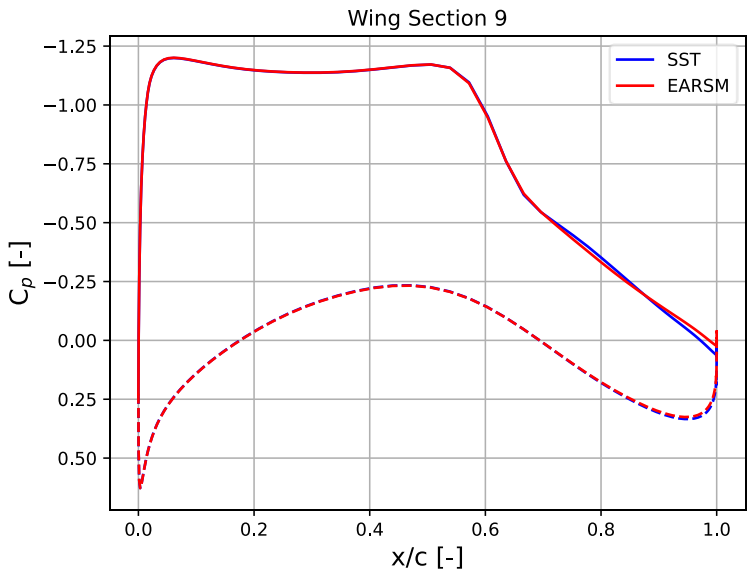

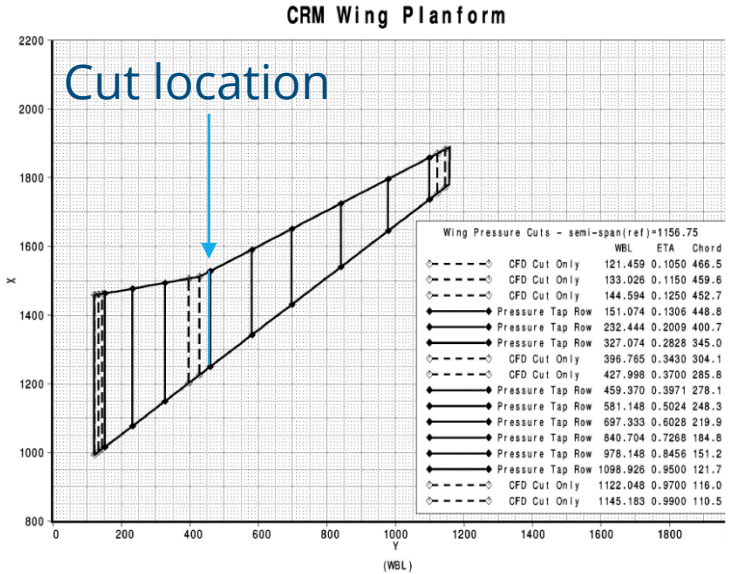

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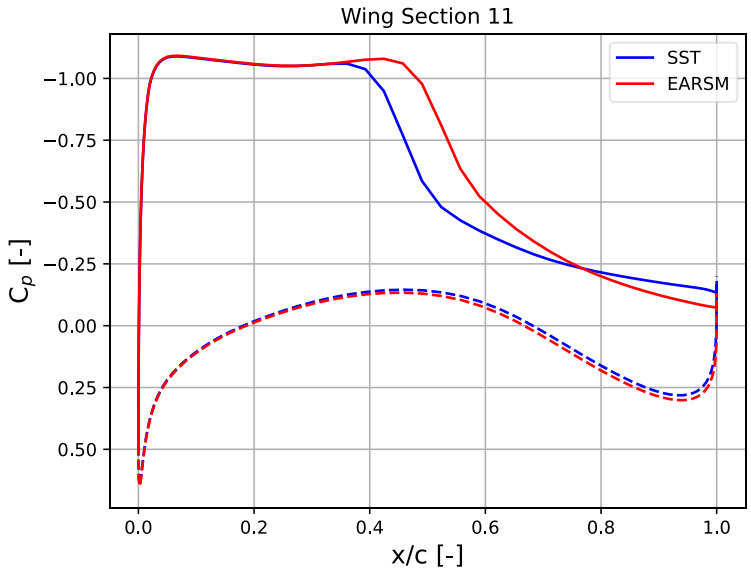

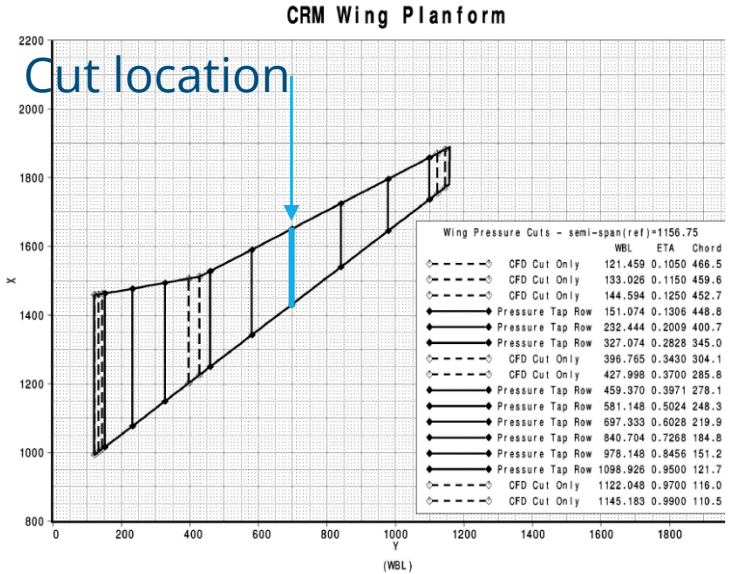

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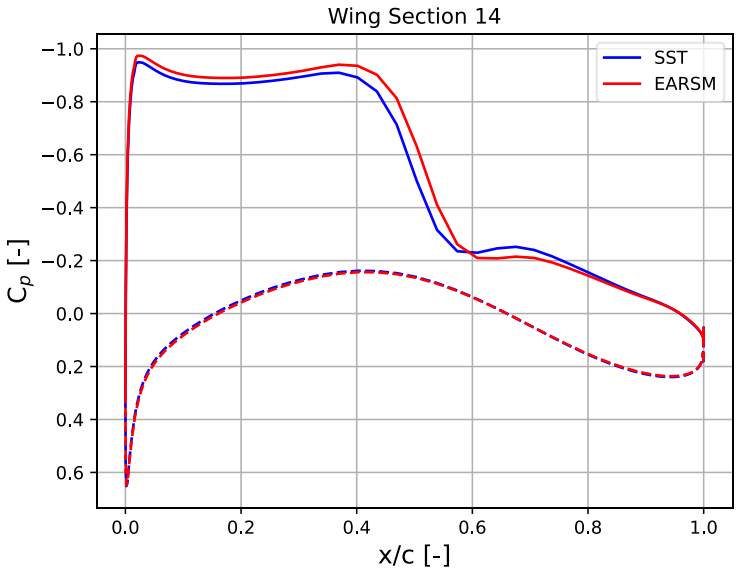
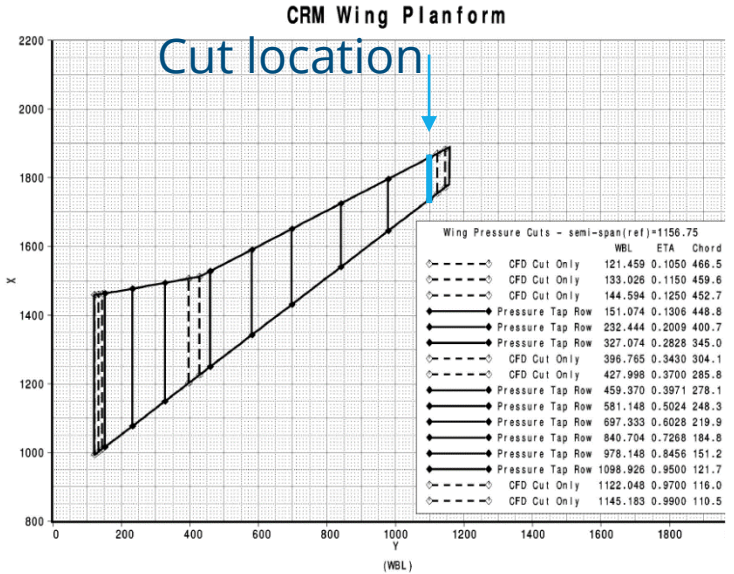
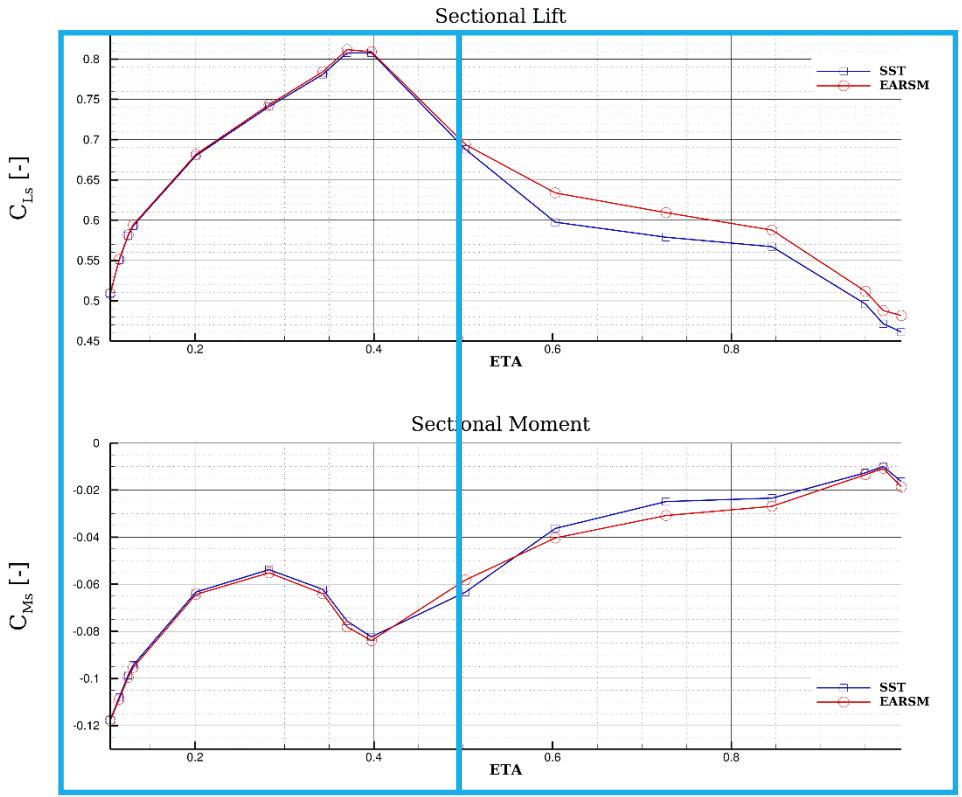


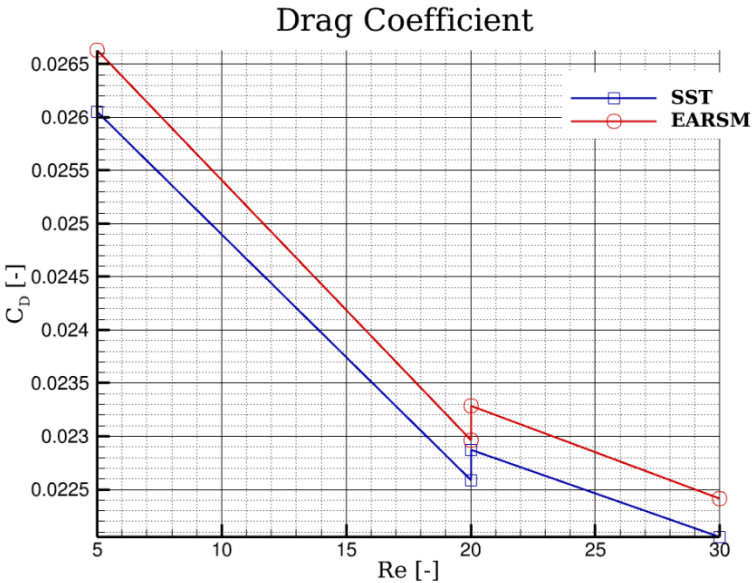


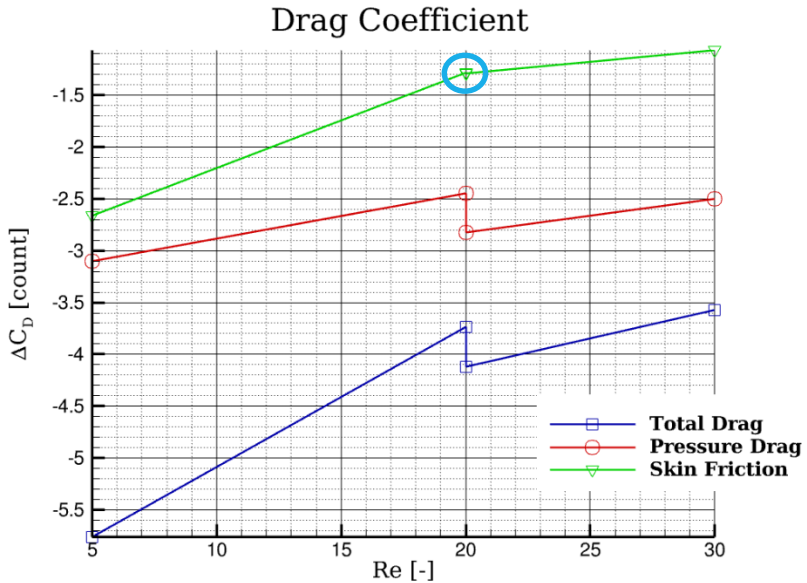
Sectional Lift & Moment @ α = 4.25°



Reynolds Number Sweep

Drag Coefficients





Conclusion

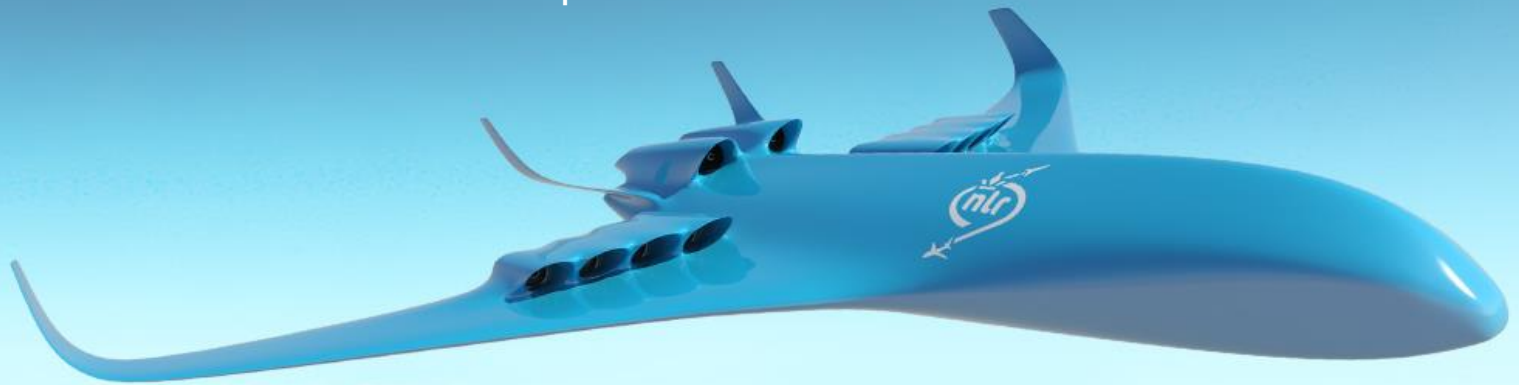
Conclusions

- **Many iterations required on higher grid levels**
  - Possibly due to solution close to unsteady
  - Convergence similar for both turbulence models
  - Finest grid level within 3 drag counts according to Richardson extrapolation
- **AoA sweep**
  - Main difference at higher AoA due to shock location
  - EARSM predicts shock location further downstream

Dedicated to innovation in aerospace

Fully engaged

NLR - Netherlands Aerospace Centre



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