UTCart Contribution to HiLiftPW-3

The University of Tokyo
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Summary of cases completed:

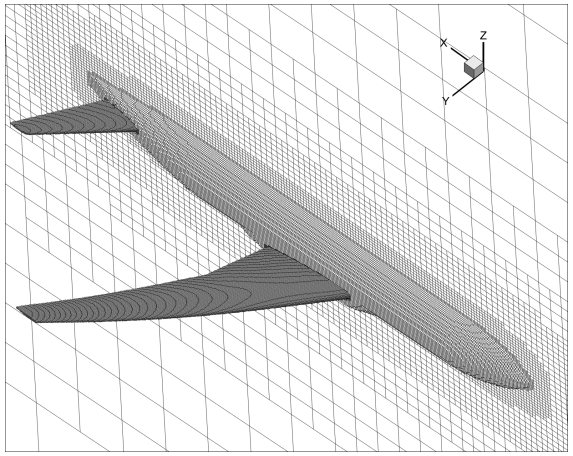
Case	Alpha=8, Fully turb, grid study	Alpha=16, Fully turb, grid study	Other
1	no	no	

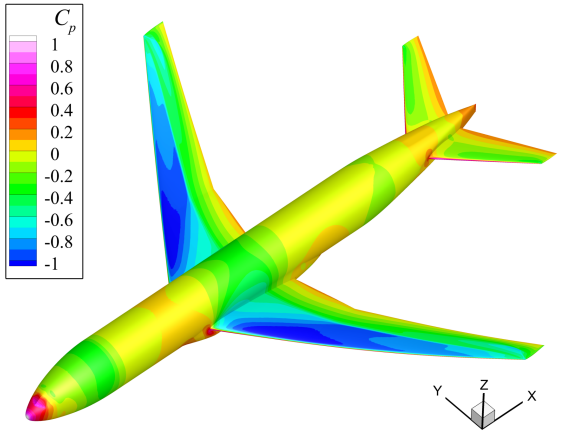
Case	Polar, Fully turb	Polar, specified transition	Polar, w transition prediction	Other
2a (no nacelle)	yes	no	no	
2b (no nacelle w adaption)	no	no	no	
2c (with nacelle)	yes	no	no	
2d (with nacelle w adaption)	no	no	no	
Other				

Case	2D Verification study	Other
3	yes	
Other		

Background/Objective

- UTCart (The University of Tokyo Cartesian grid based automatic flow solver) is developed as a platform for aerodynamic designing
  - The immersed boundary method with a wall function is used for the wall boundary condition
  - UTCart has been validated in simple 2D turbulent problems[1)] and simulation of NASA-CRM[2)]
- Validation in more complex problem is desirable to check the accuracy and robustness of UTCart





1) Tamaki, Y. et al, AIAA J, 2017 (accepted)
2) Tamaki, Y. et al, AVIATION 2017, APA-41 (Thursday, 3:30PM)

Overview of UTCart

➢ Grid generation

- Automatic generation by oct-tree structure

➢ Domain partitioning

- METIS

➢ Flow calculation

- Compressible flow solver parallelized by MPI
- Immersed boundary method for wall boundary

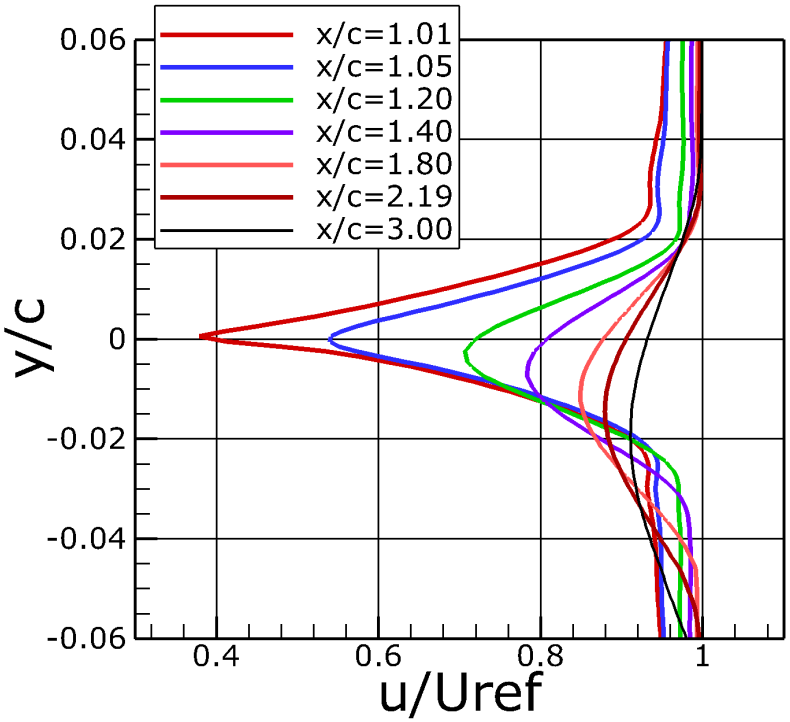
Turbulence Model	SA-noft2-R
Inviscid Flux	SLAU (AUSM-type all speed)
Spatial Scheme (Inviscid Term)	Fourth-order upwind-biased[3)]
Limiter	N/A
Time Integration	Matrix-free Gauss-Seidel

3)Tamaki & Imamura, Comp. &Fluids, 2017.

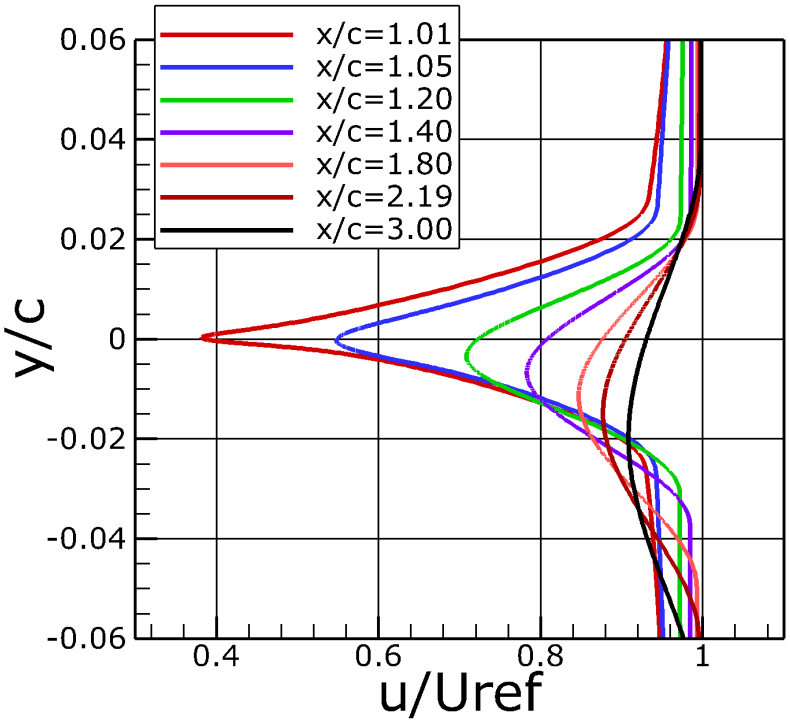
Verification study (case3)

Wake velocity profile

Grid 4 (Finest, 103,790 cells)



CFL3D

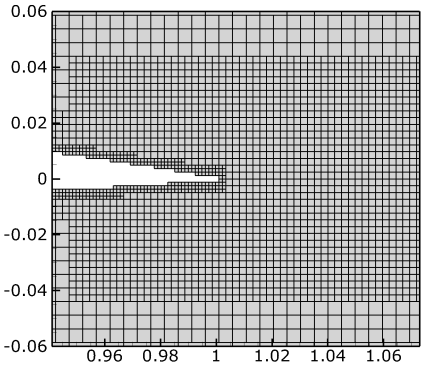


Verification study (case3)

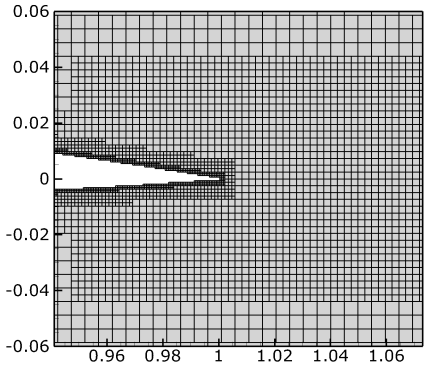
- Near-field profile is difficult to be predicted
  - Resolution of Cartesian grid around sharp edge
- Far-field profile is relatively accurate even on coarse grid

	Grid 1	Grid 2	Grid 3	Grid 4	CFL3D
Min(u/U_∞) at x/c=1.01	0.4784	0.4503	0.4209	0.3791	0.3815
Min(u/U_∞) at x/c=1.8	0.8409	0.8455	0.8458	0.8493	0.8472

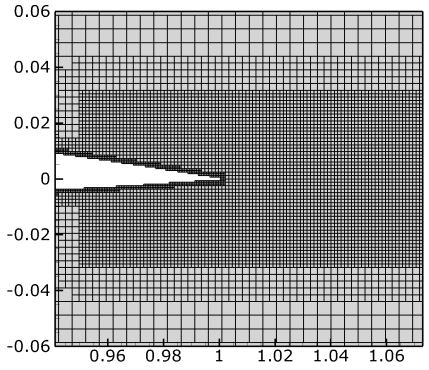
Grid 1



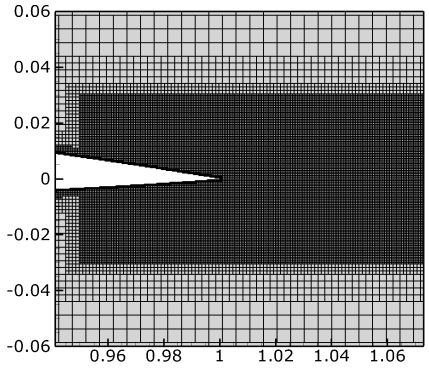
Grid 2



Grid 3

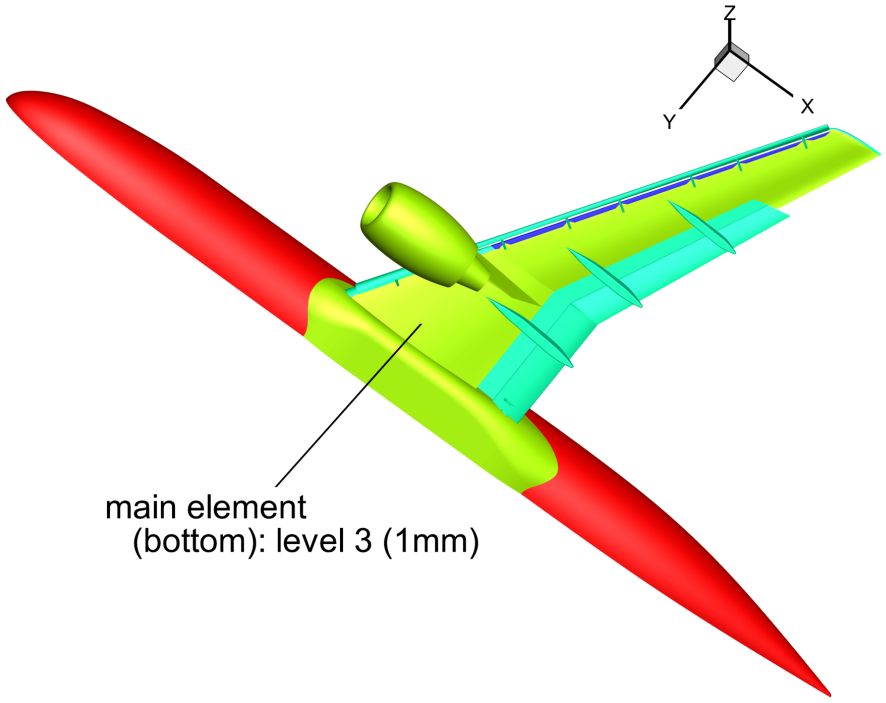


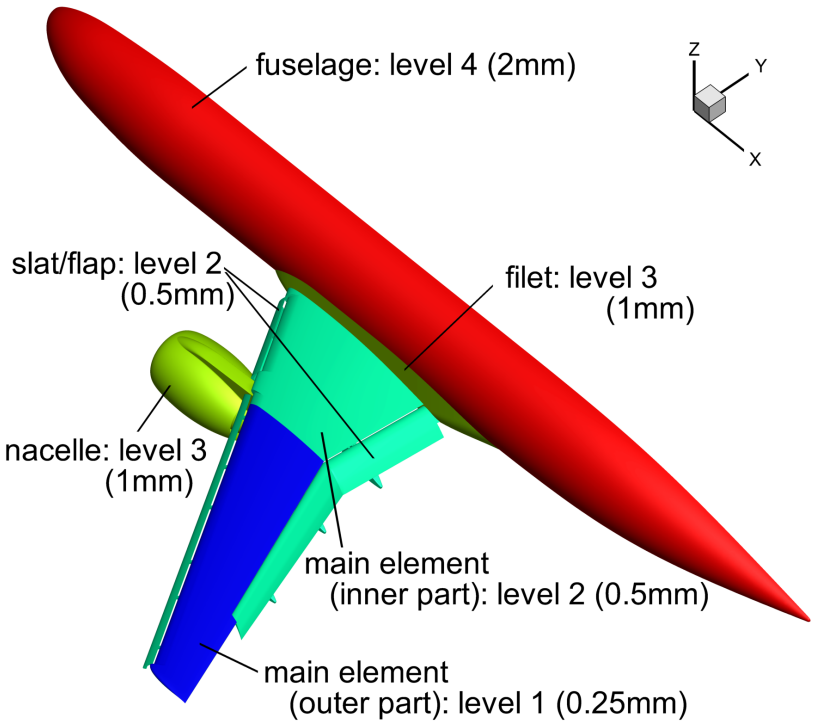
Grid 4



Computational grids around JSM

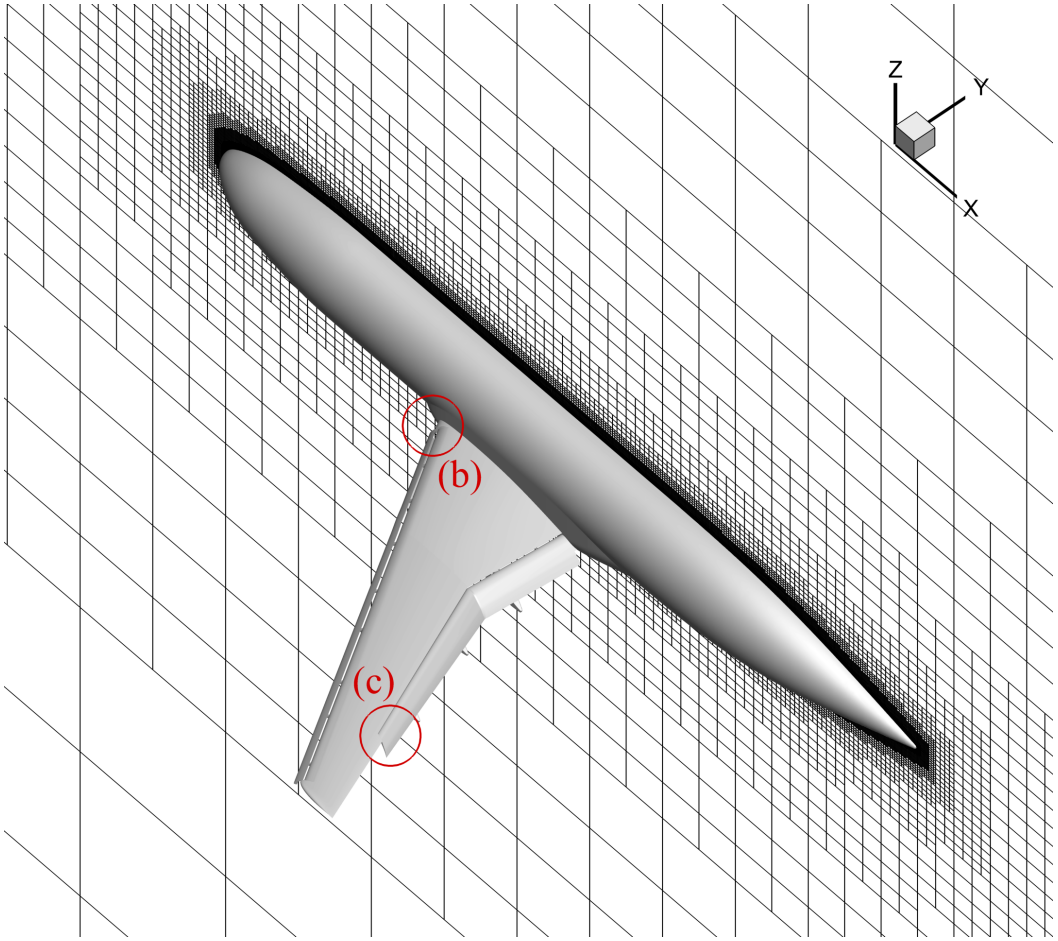
- Grid size on the wall is variable to save the cell number
- More than 1000 cells in local chord (MAC=529.2mm)



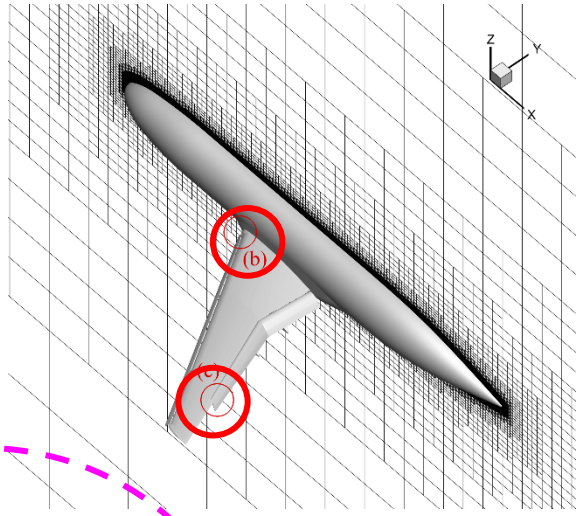


Computational grids around JSM

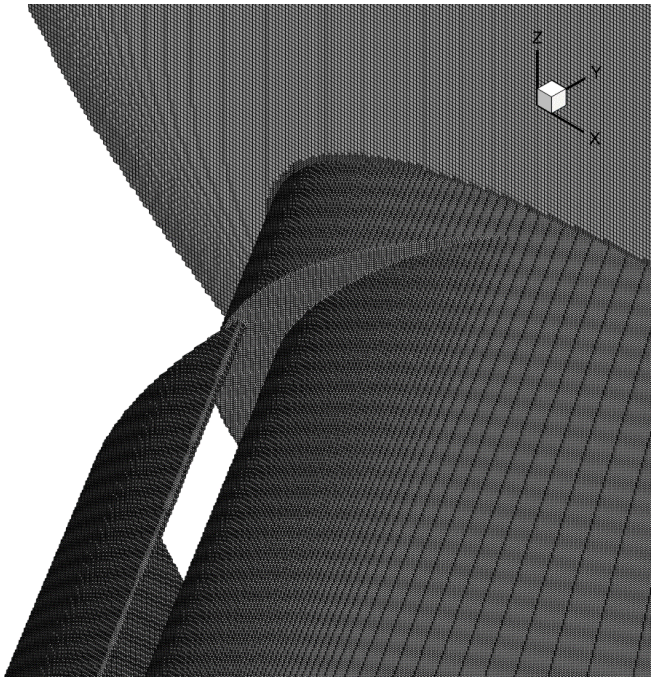
- Nacelle off: 114,466,104 cells
- Nacelle on: 123,077,385 cells

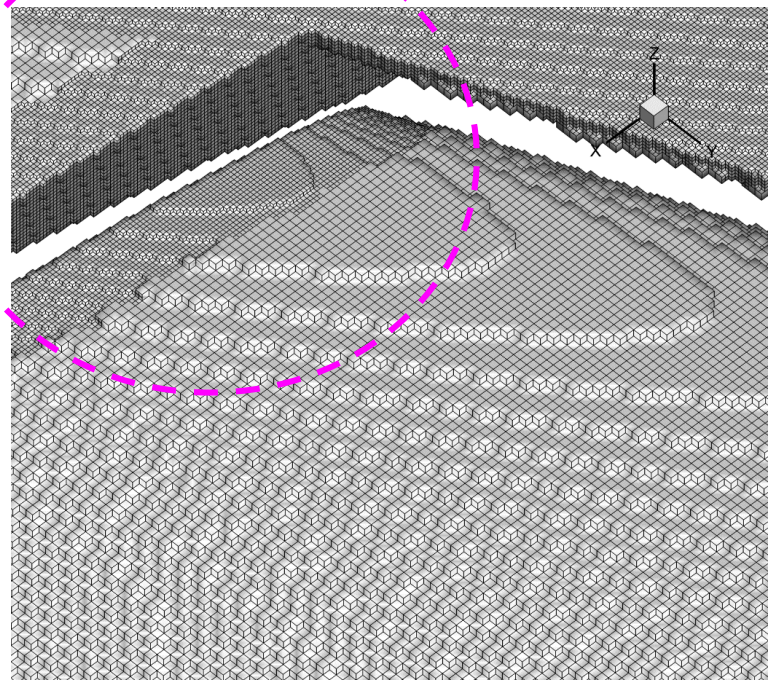


Computational grids around JSM

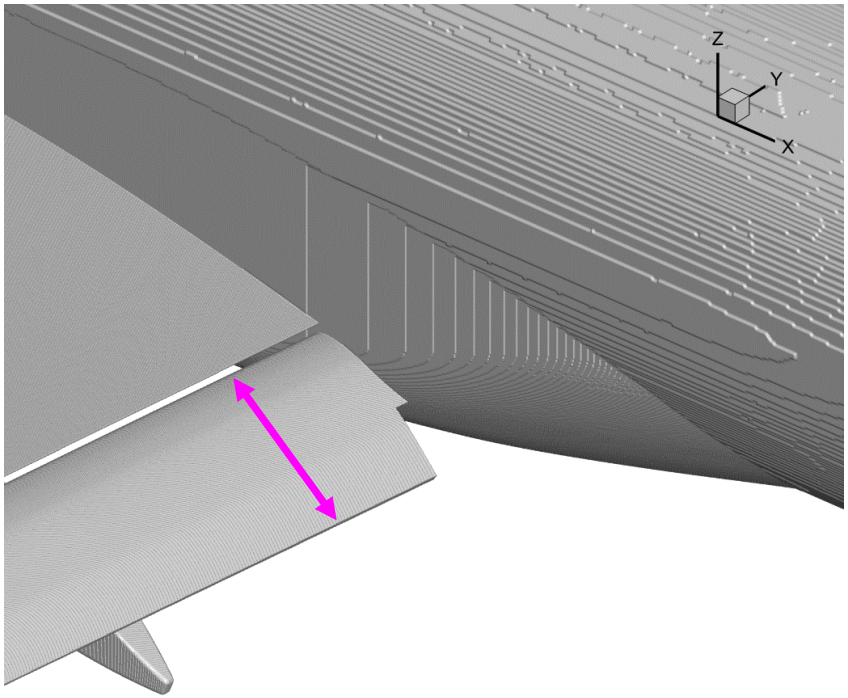


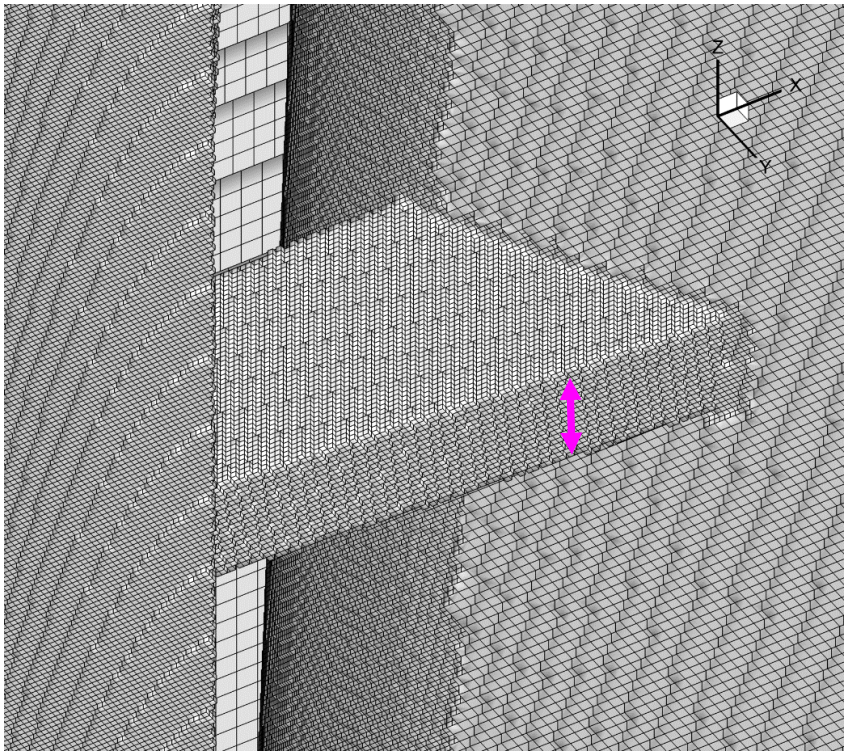
Local refinement (level 1)





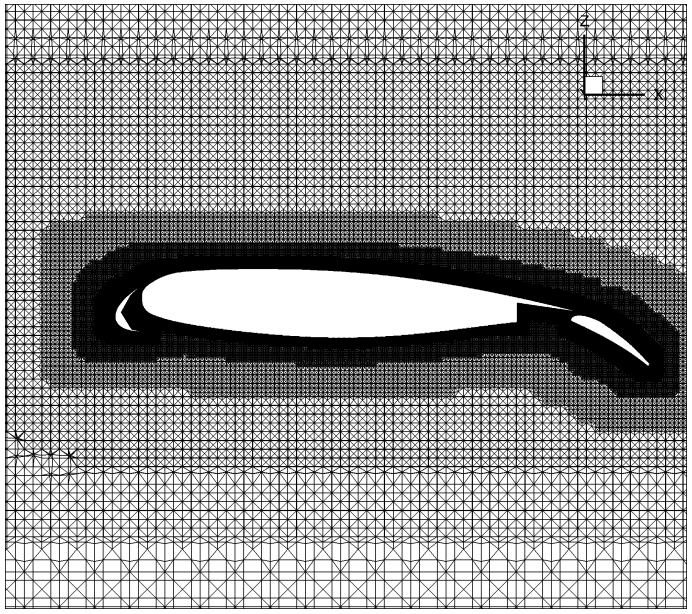
Computational grids around JSM

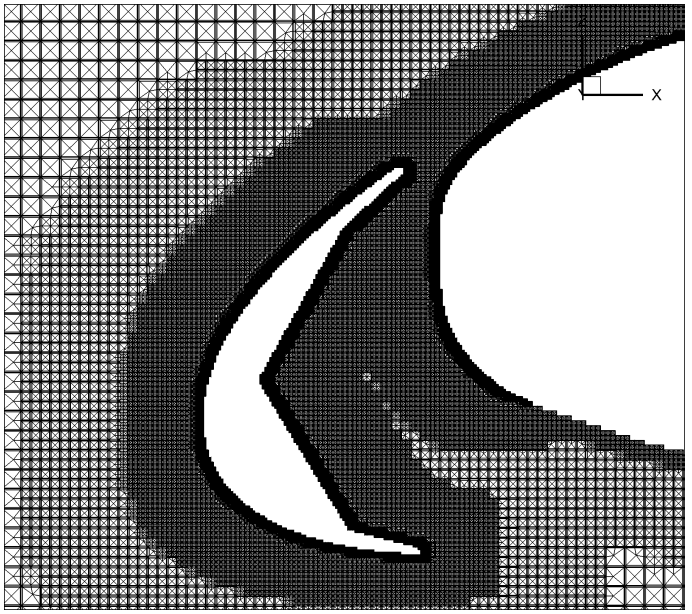


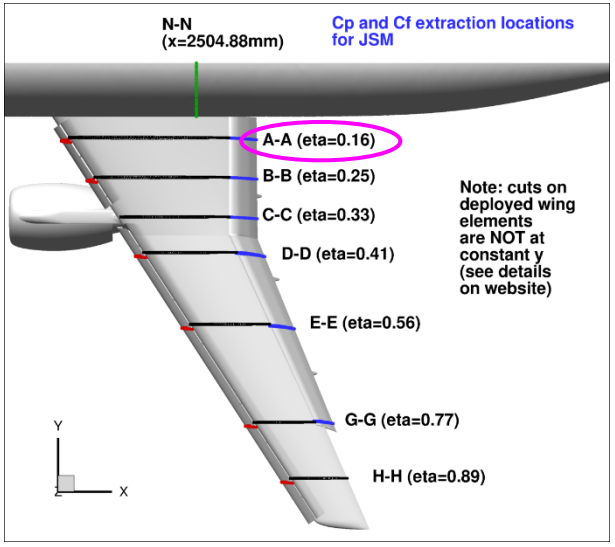


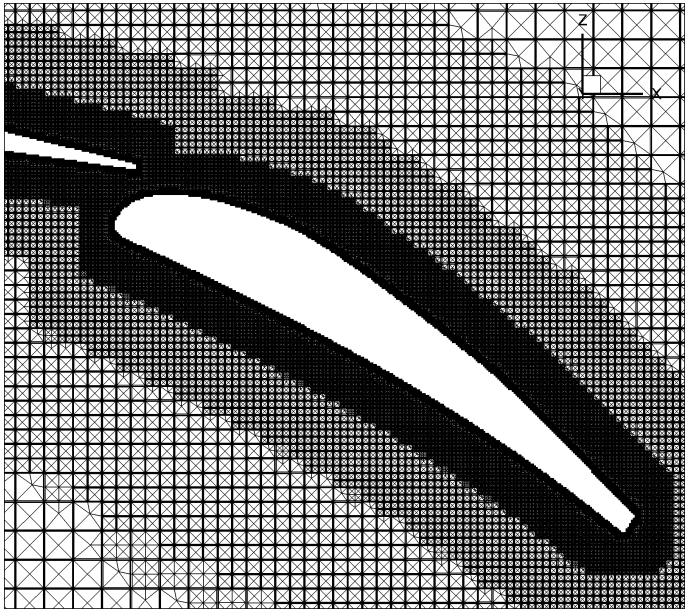
- 400 cells / flap chord
- 20 cells / slat support width

Computational grids around JSM (A-A)







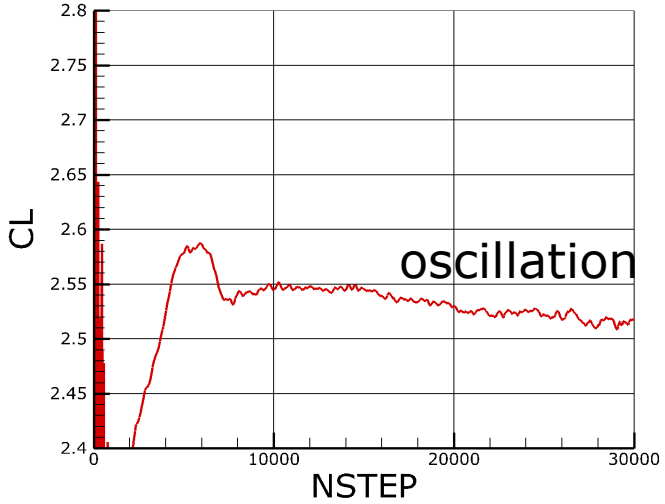


Computational resources

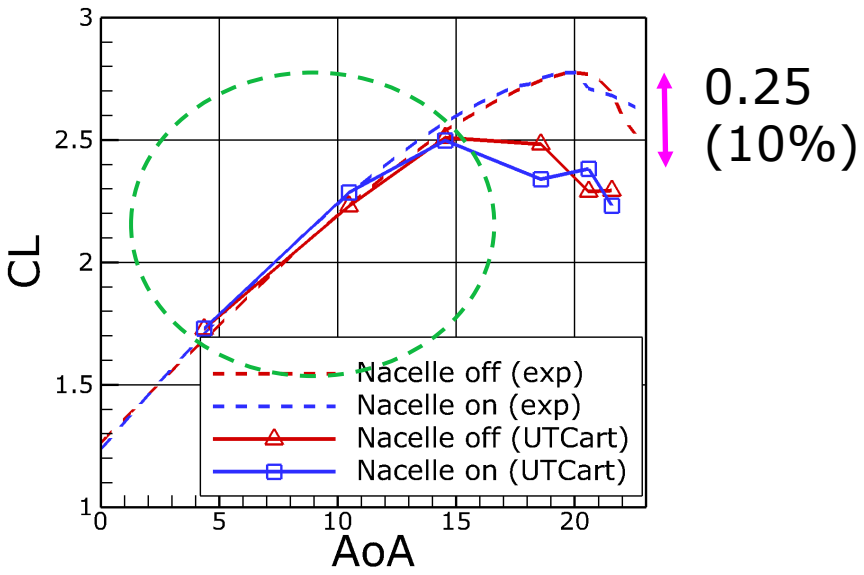
For nacelle-off configuration (117M cells)

- Grid generation
  - Workstation, Xeon E5-2643 v3 @ 3.4GHz, 1 core
  - 1 h 40 min, 120 GB

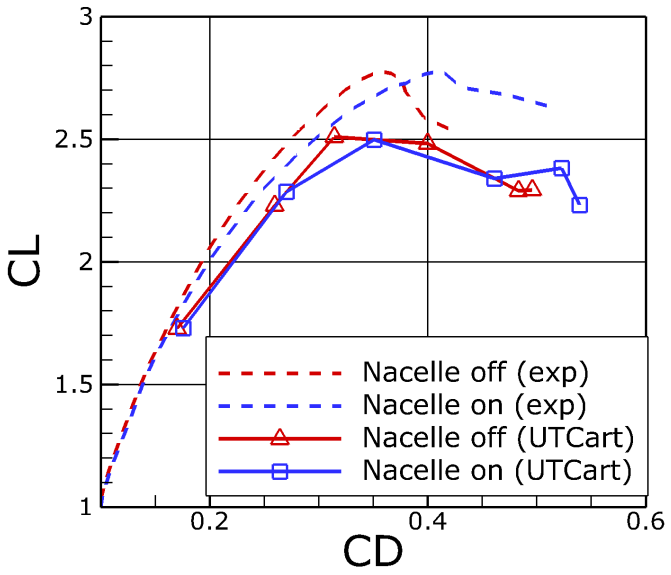
- Flow calculation
  - Reedbush-U supercomputer (UTokyo), Xeon E5-2697 v4 @ 2.1 GHz, 144 cores (pure MPI)
  - 56 h (30,000 steps), 150 GB

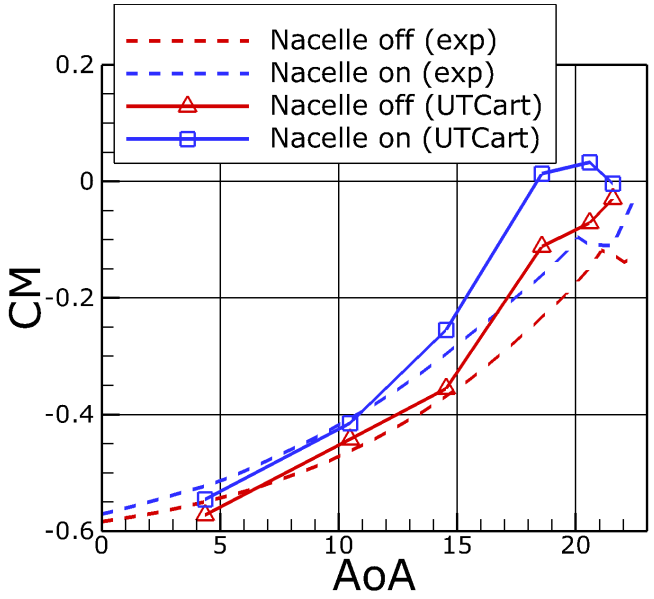


Aerodynamic coefficients

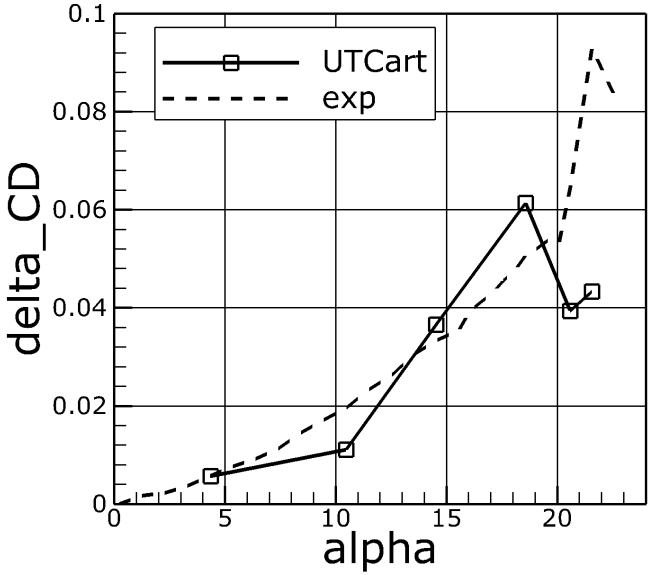


- Fair agreement with experiment at low angles of attack
- 10% low CL_{max}

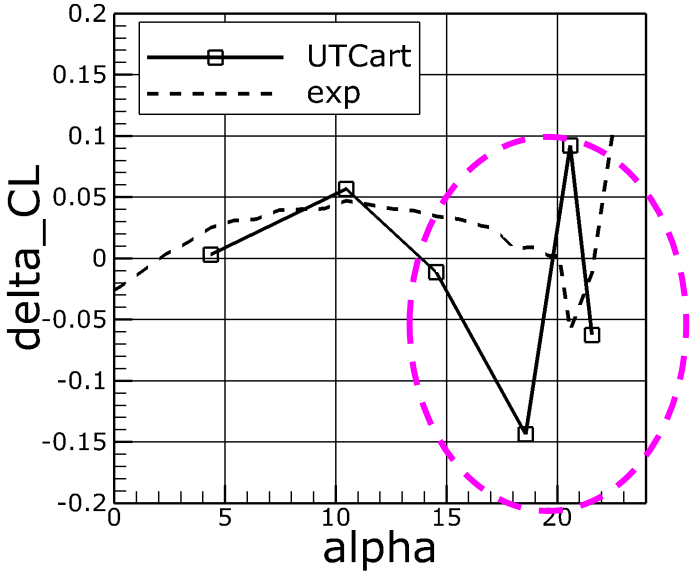


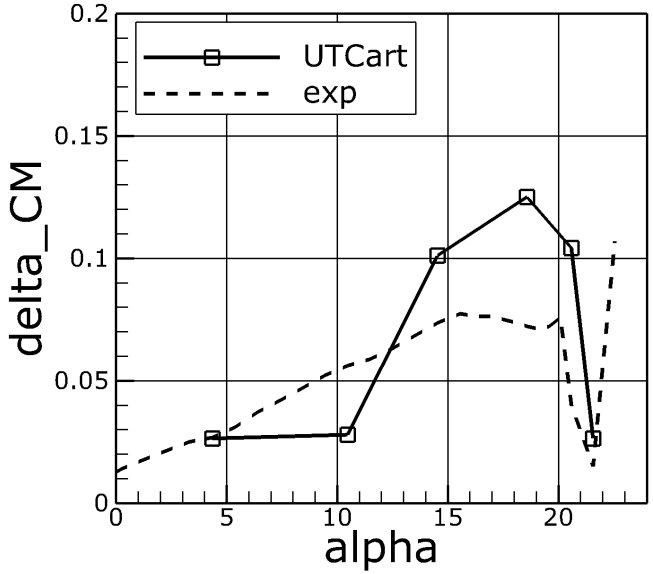


Nacelle increment



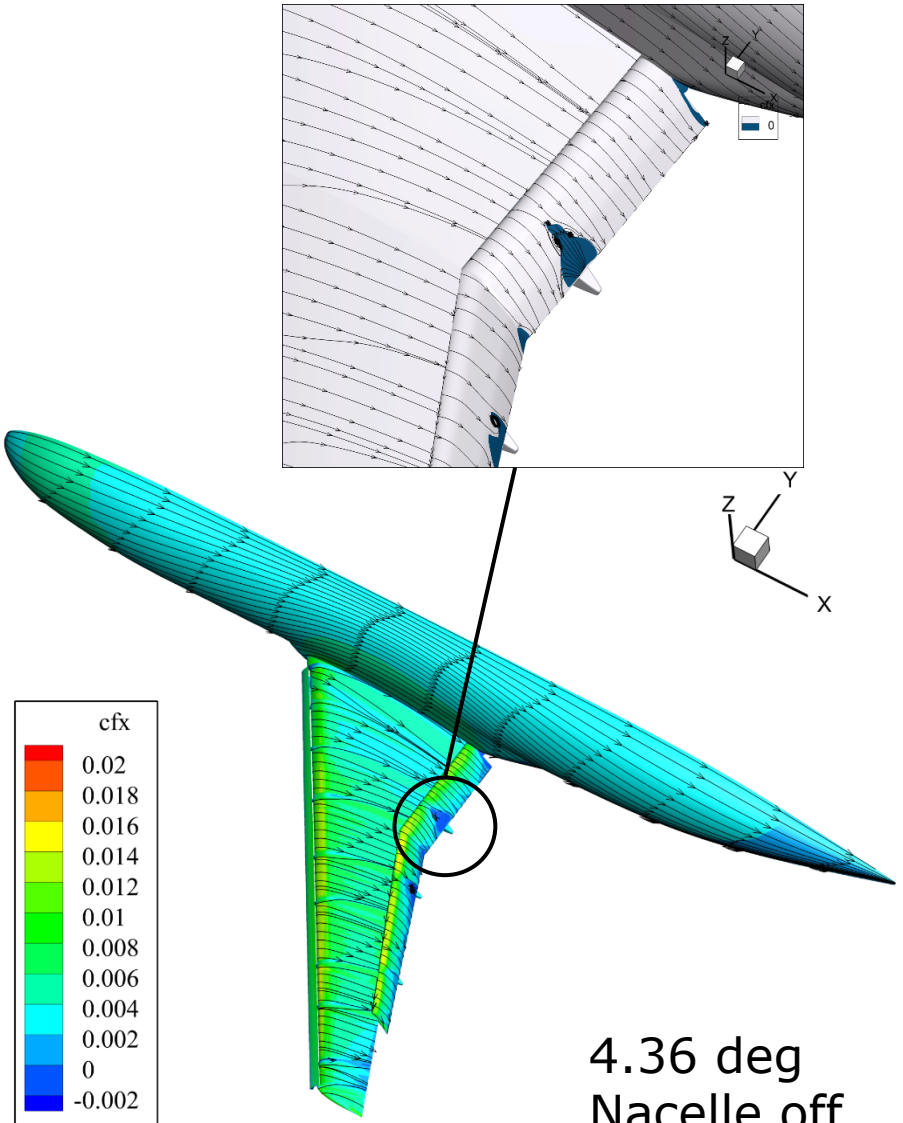
- Delta CD is relatively accurate
- Delta CL at high angles of attack is difficult to be predicted (due to separaton?)



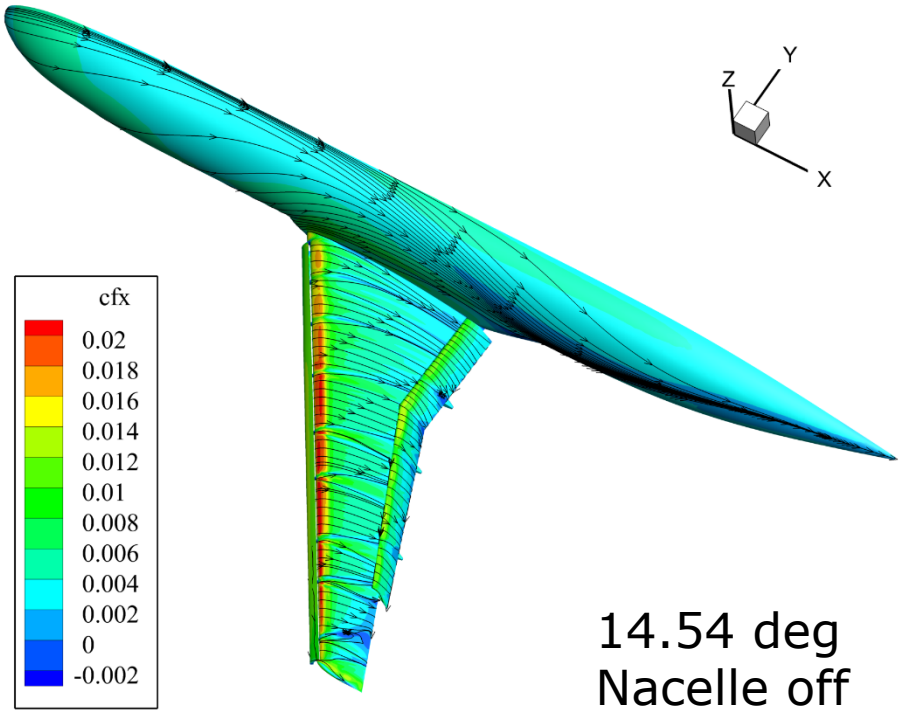


Surface streamline (Nacelle off)

- TE separation on flap



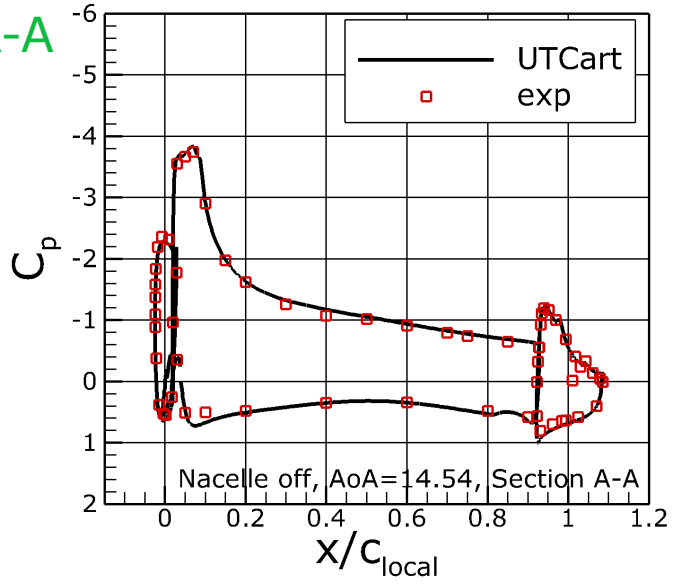
4.36 deg
Nacelle off



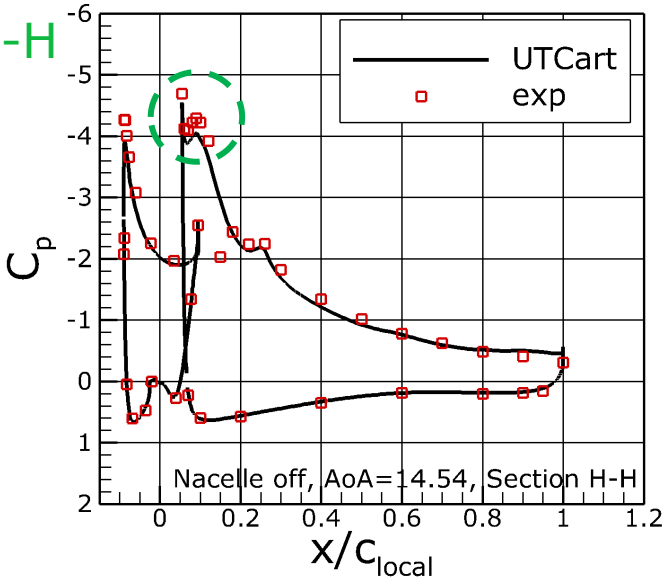
14.54 deg
Nacelle off

Surface pressure (Nacelle off, α=14.54 deg)

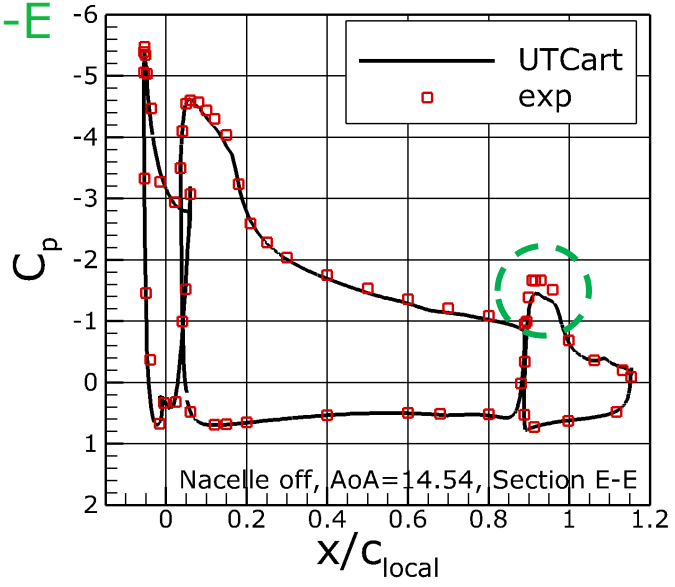
A-A

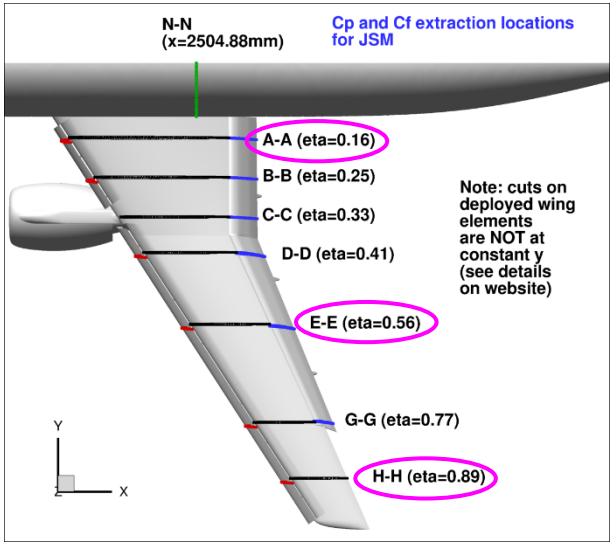


H-H



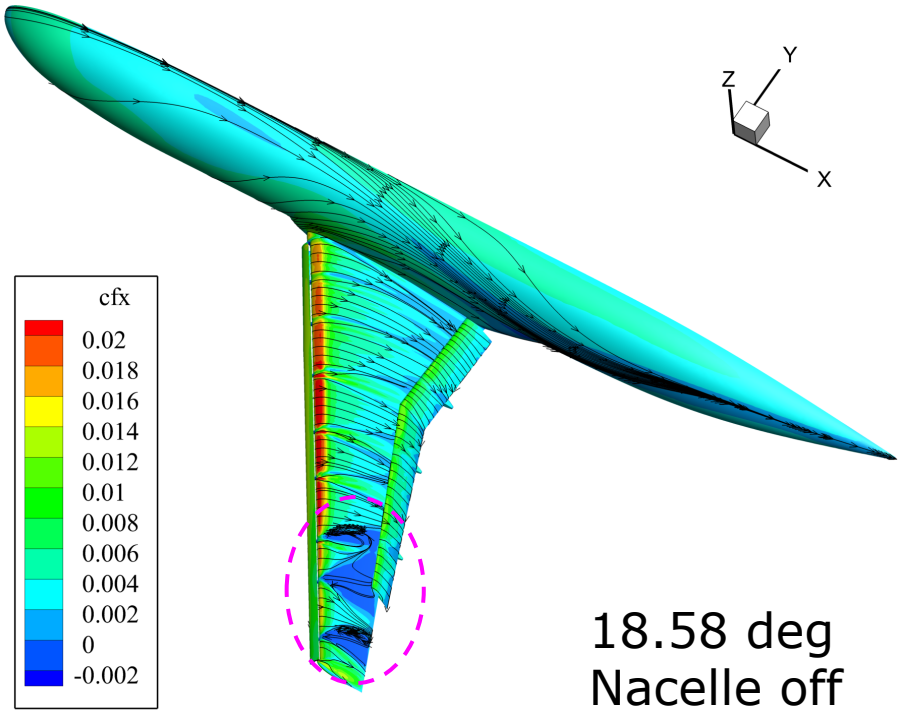
E-E



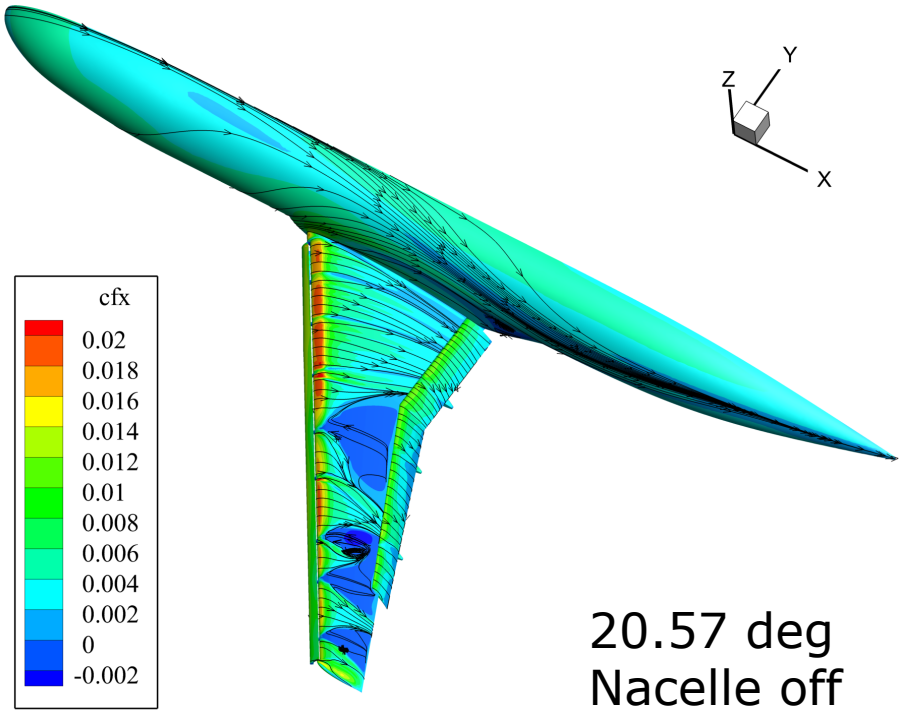


Surface streamline (Nacelle off)

- Separation at wake of slat support



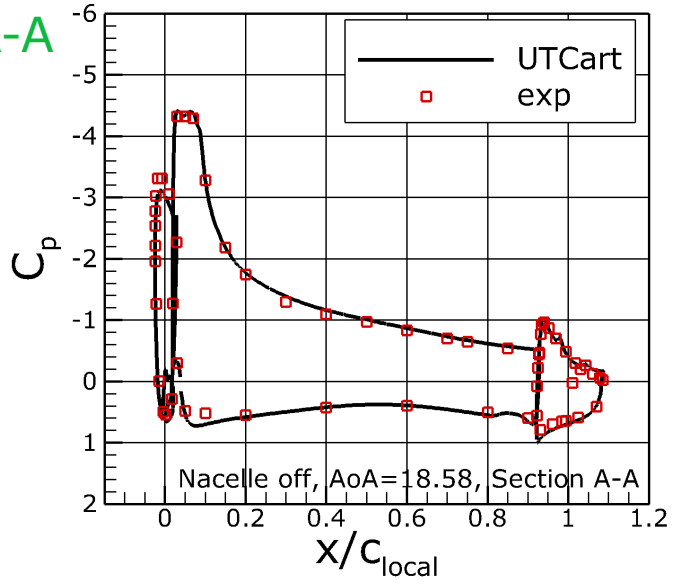
18.58 deg
Nacelle off



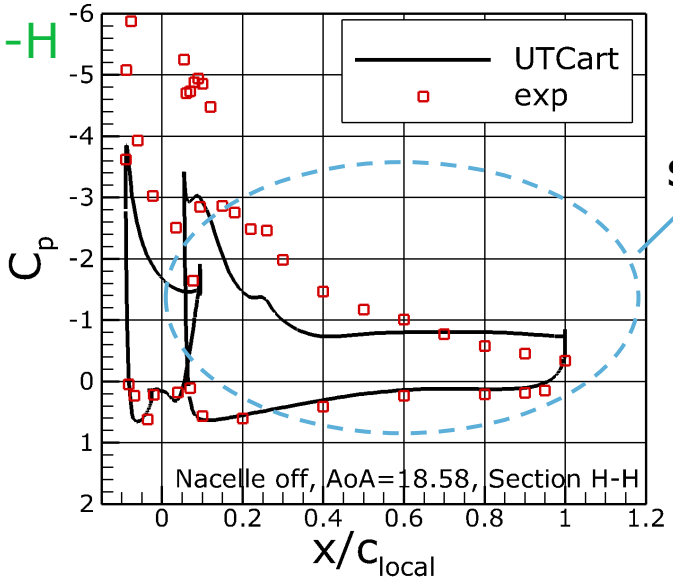
20.57 deg
Nacelle off

Surface pressure (Nacelle off, α=18.58 deg)

A-A

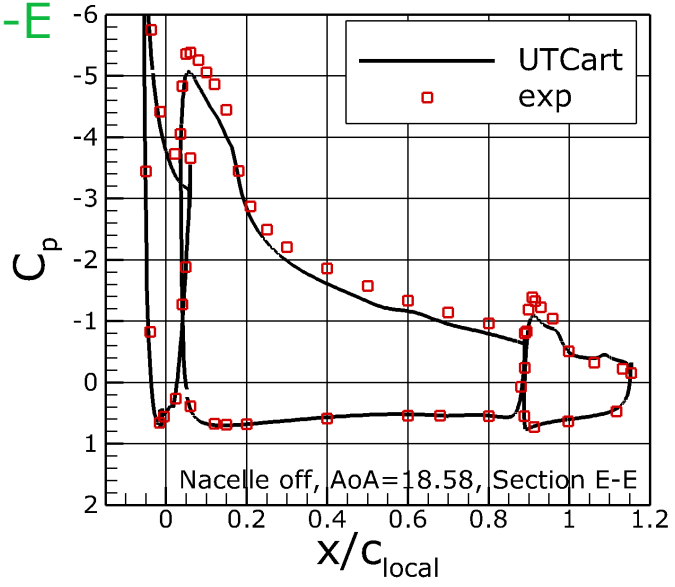


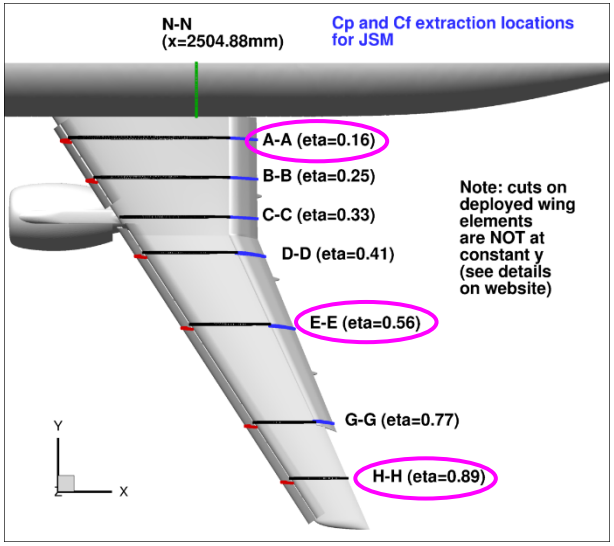
H-H



separation

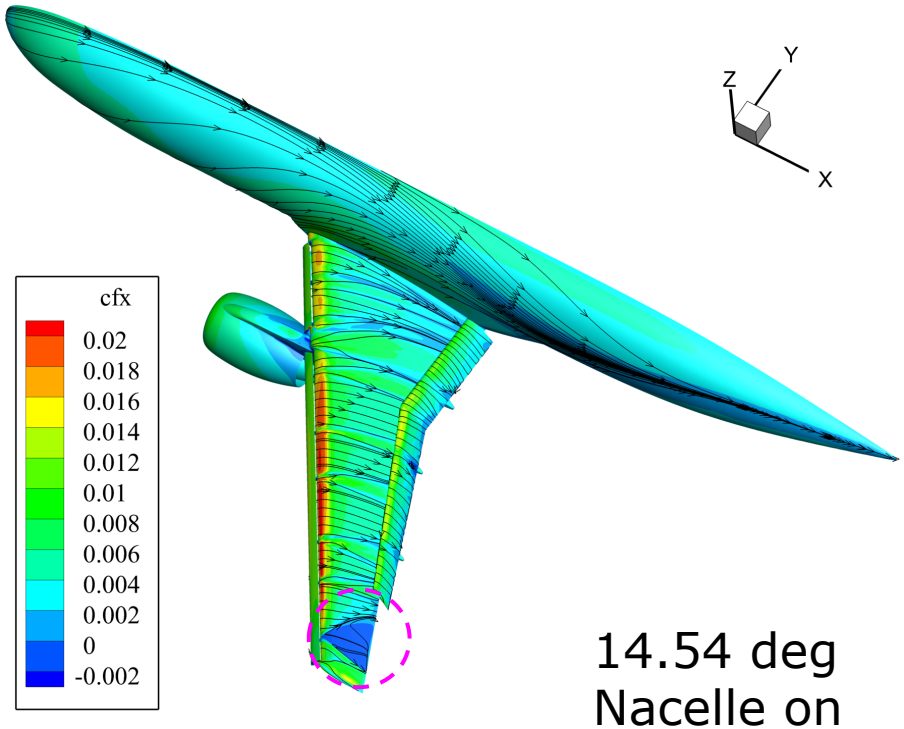
E-E



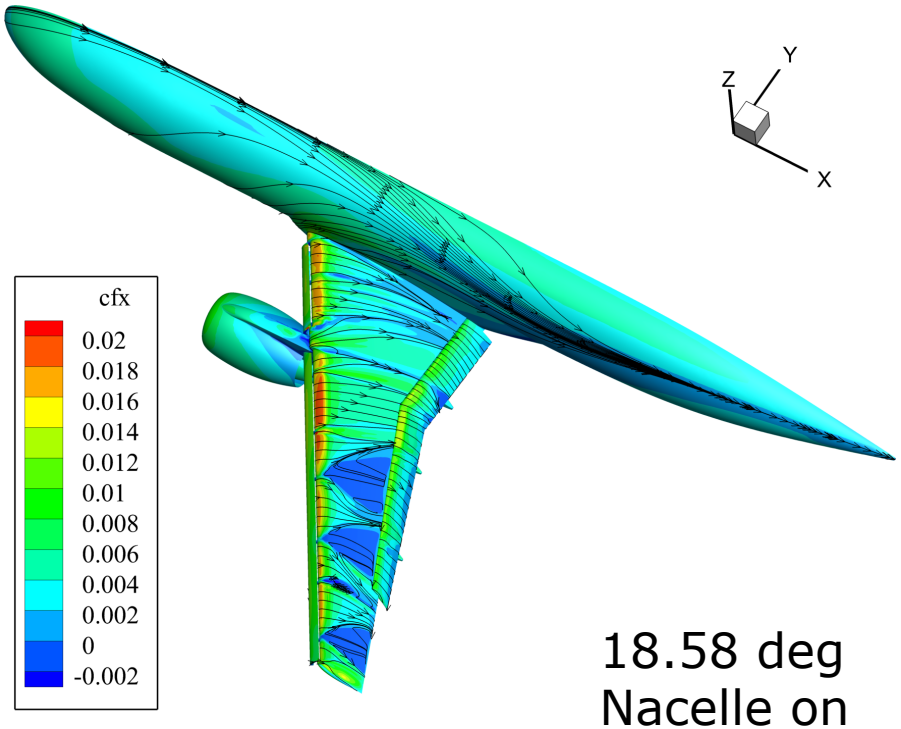


Surface streamline (Nacelle on)

- Separation become large compared with case 2a



14.54 deg
Nacelle on



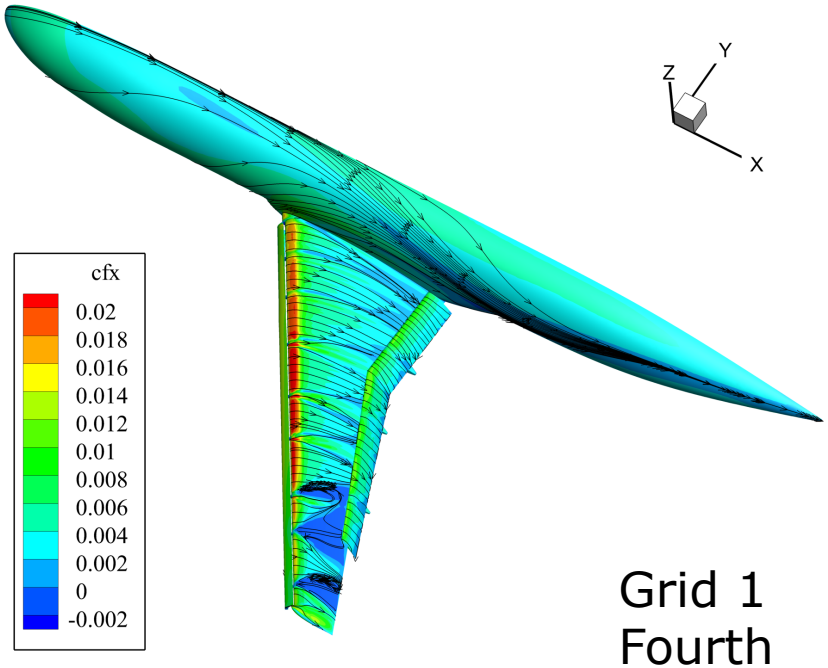
18.58 deg
Nacelle on

Sensitivity study (Nacelle off, α=18.58 deg)

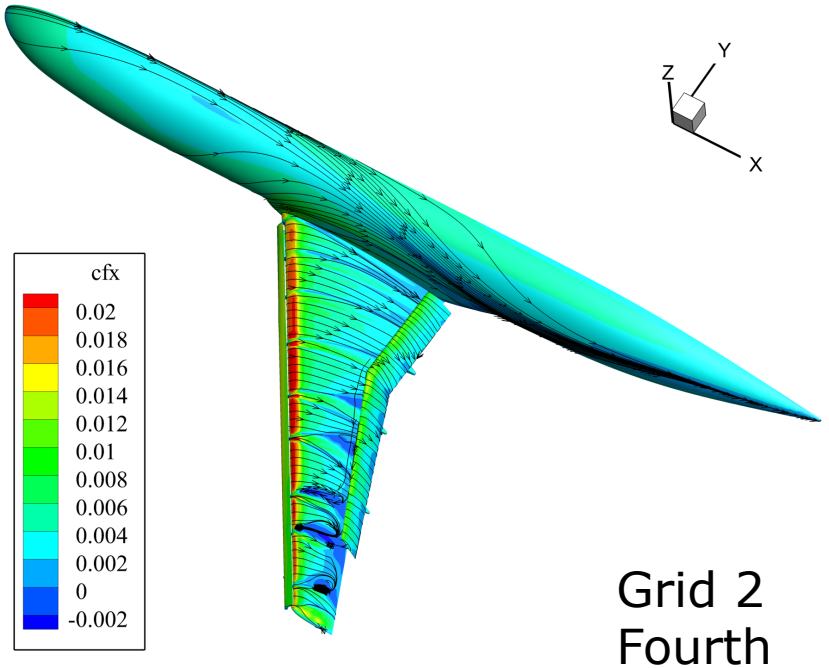
Grid	Grid 1 (117M)	Grid 2 (140M)	Grid 1 (117M)
Inviscid term	Fourth-order	Fourth-order	Second-order
CL	2.494	**2.516**	2.409

Grid 1: Δx_{min}=0.250 mm

Grid 2: Δx_{min}=0.225 mm



Grid 1
Fourth



Grid 2
Fourth

Summary

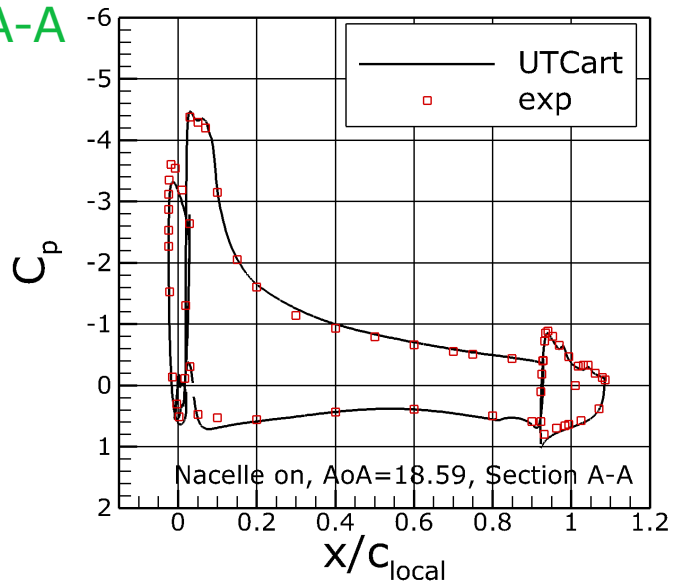
- JAXA Standard Model is simulated using UTCart
  - Oct-tree Cartesian grid and Immersed boundary method with a wall function is used

- Possibility and challenge of the Cartesian grid are confirmed
  - Grid is generated in a robust way, and the small features (e.g. gaps) are reproduced
  - Flow feature (e.g. surface pressure) at low angles of attack ($\alpha <= 14.54$ deg) is accurately predicted

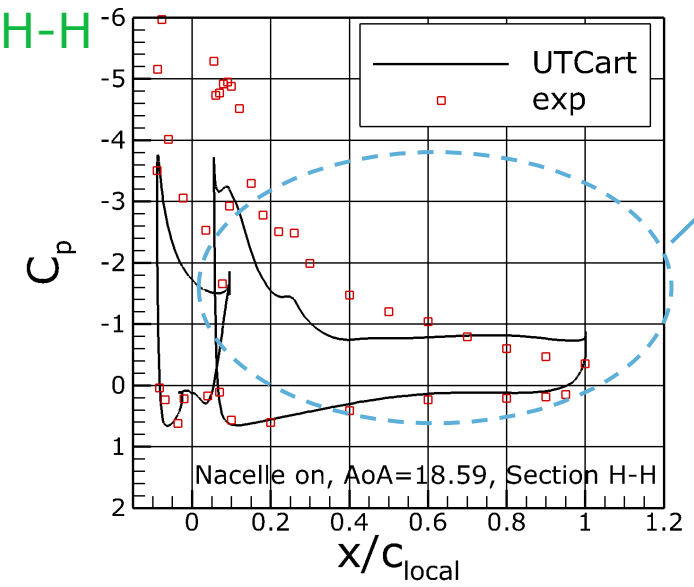
  - Flow unsteadiness remains
  - CL_{max} is 10% lower than experimental data
    - High-order scheme is effective
    - Further grid convergence should be examined

Surface Pressure (Nacelle on, α=18.58 deg)

A-A

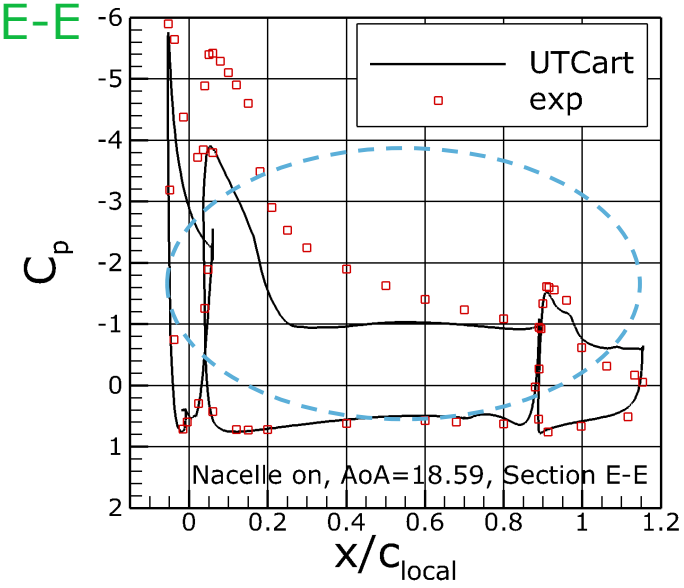


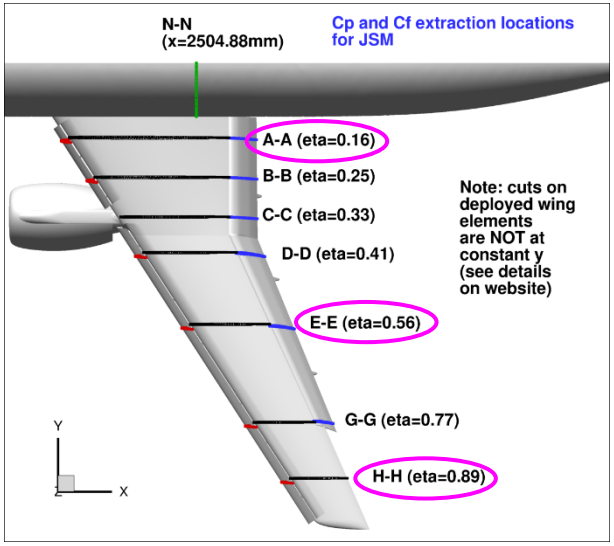
H-H



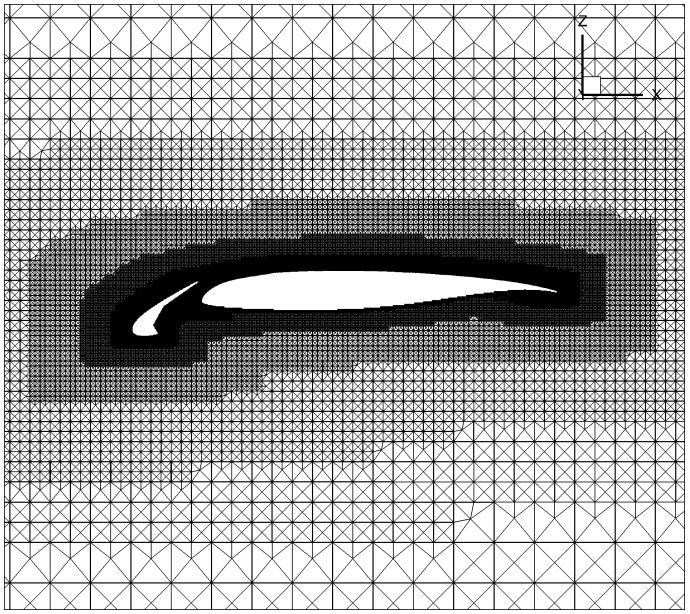
separation

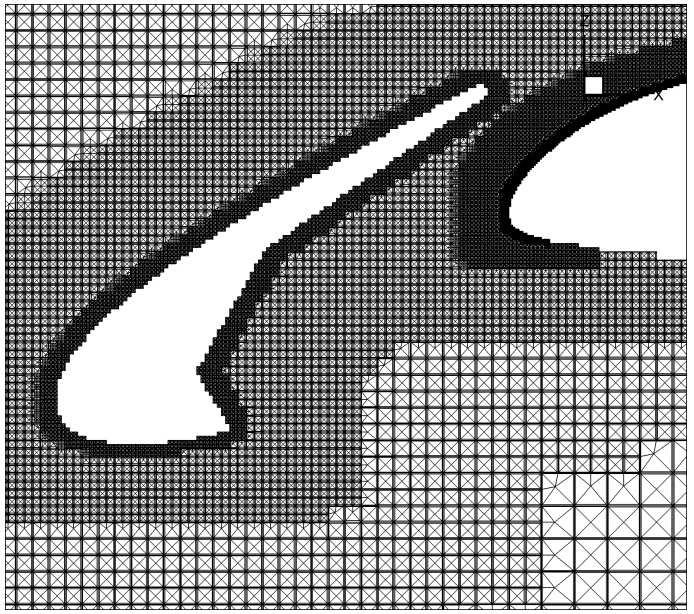
E-E

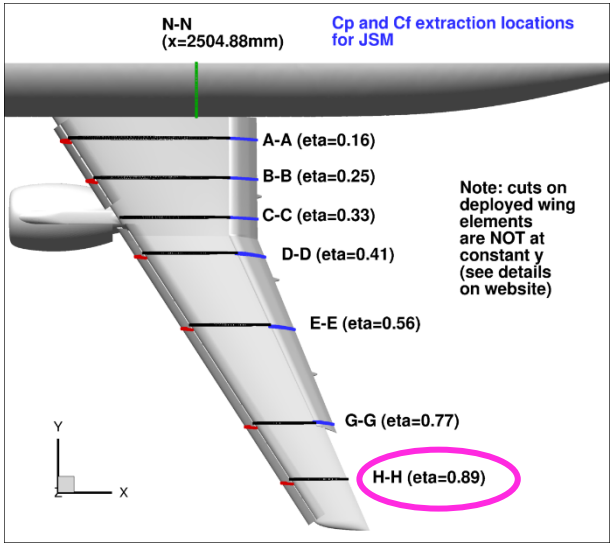




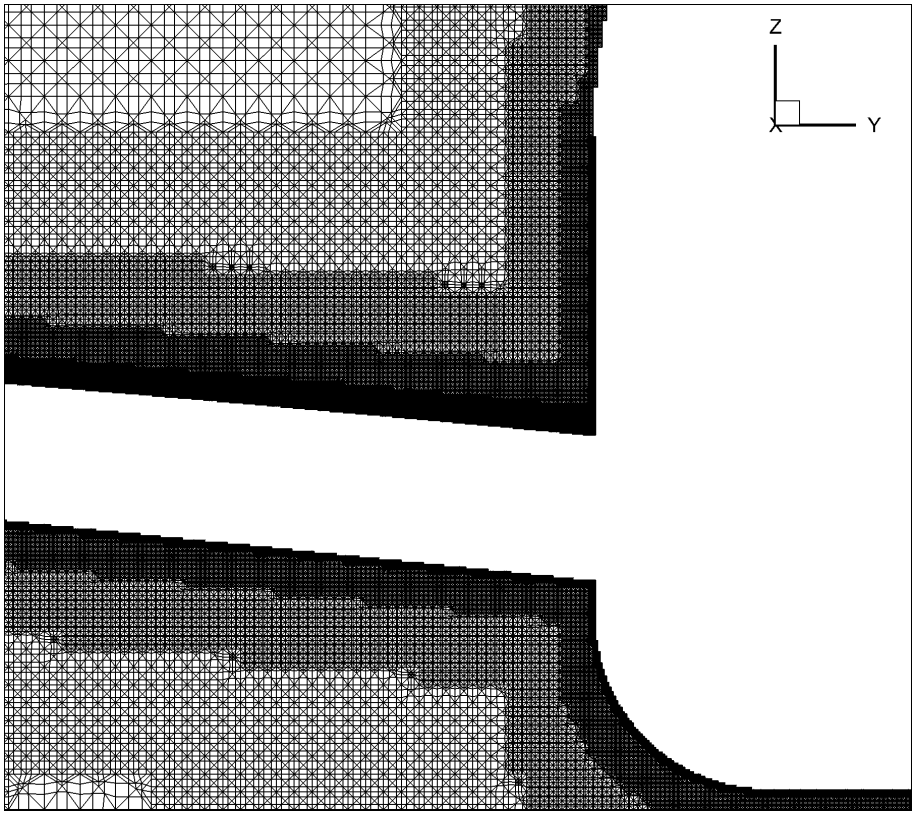
Computational grid (H-H)

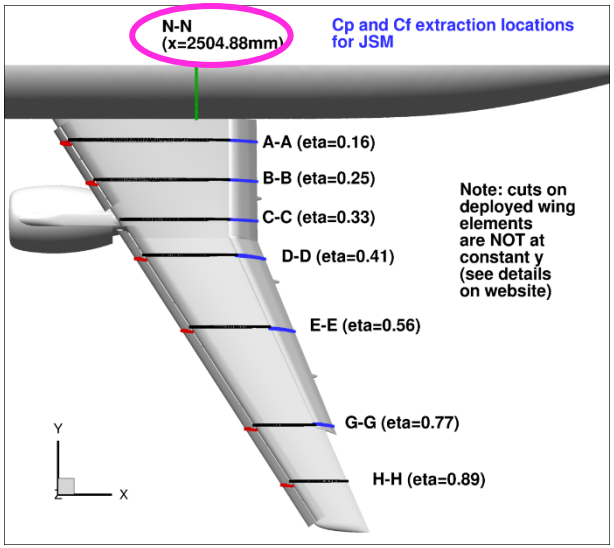




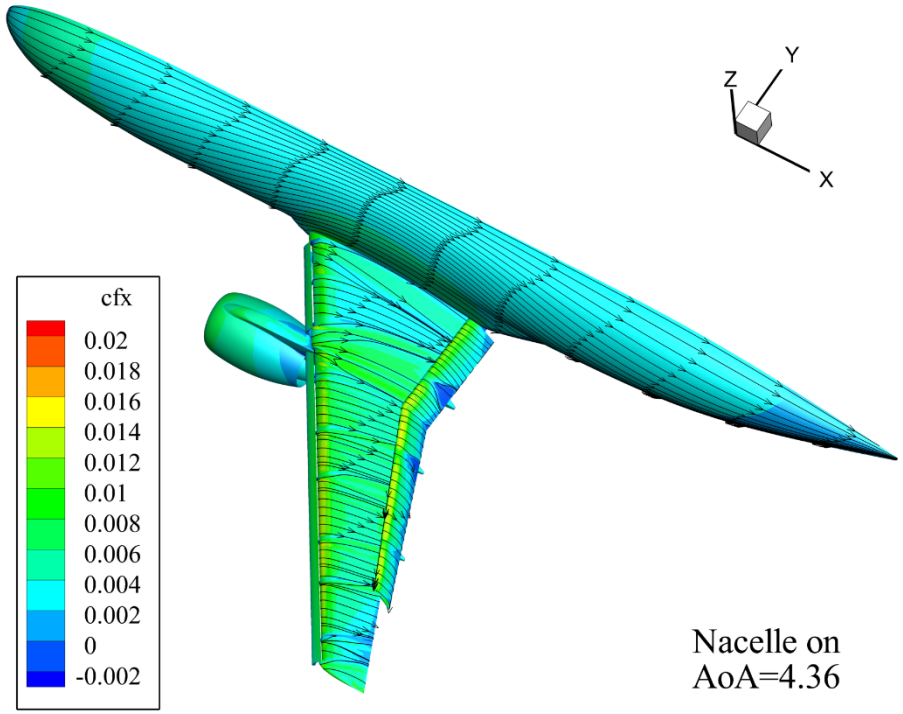


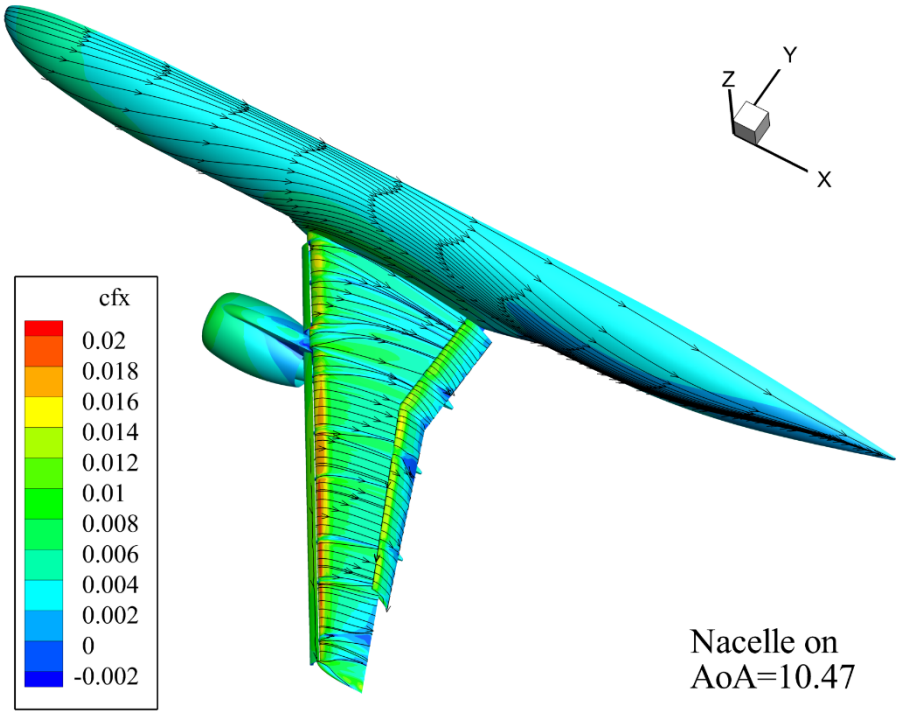
Computational grid (N-N)



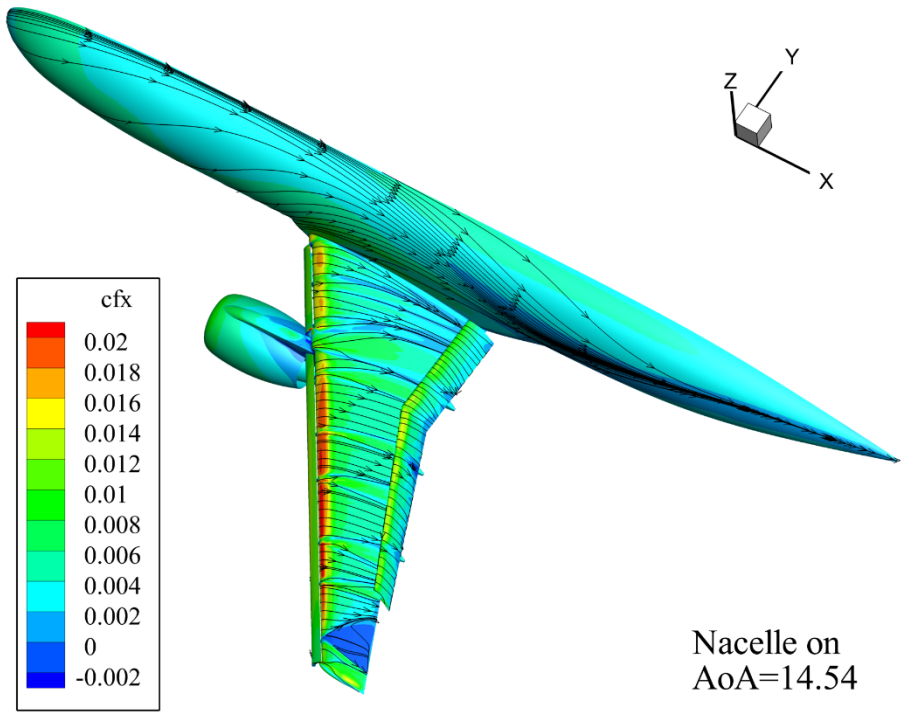


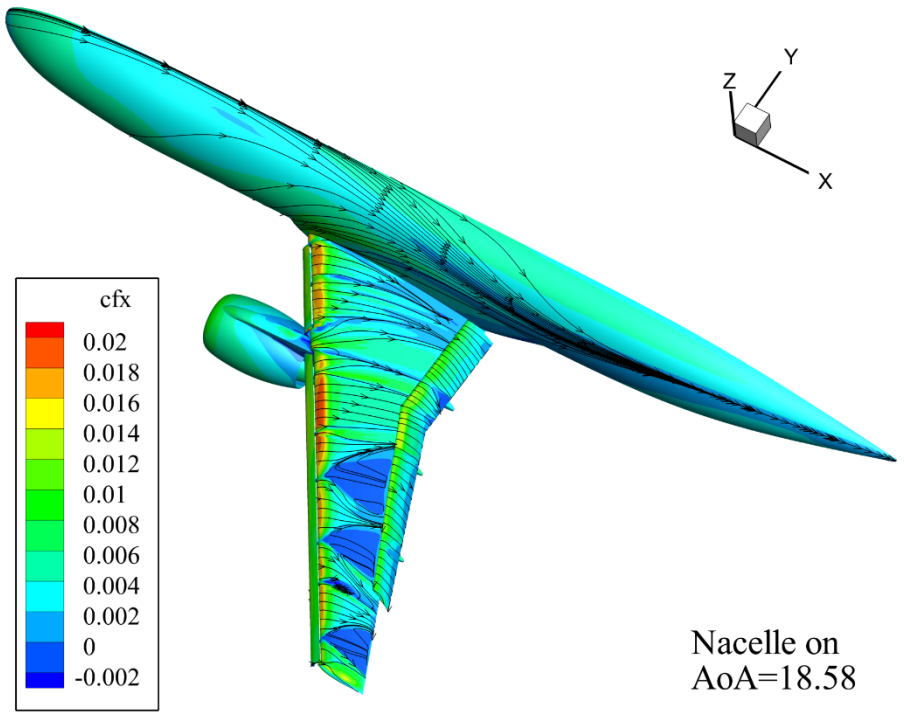
Surface Streamline (Nacelle on)





Surface Streamline (Nacelle on)





Surface Streamline (Nacelle on)