階層型直交格子流体ソルバUTCartによる風洞壁を含むCRM-HL周り流れの定常RANS解析・

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第55回流体力学講演会/第41回航空宇宙数値シミュレーション技術シンポジウム
2023/7/12-14 国立オリンピック記念青少年総合センター

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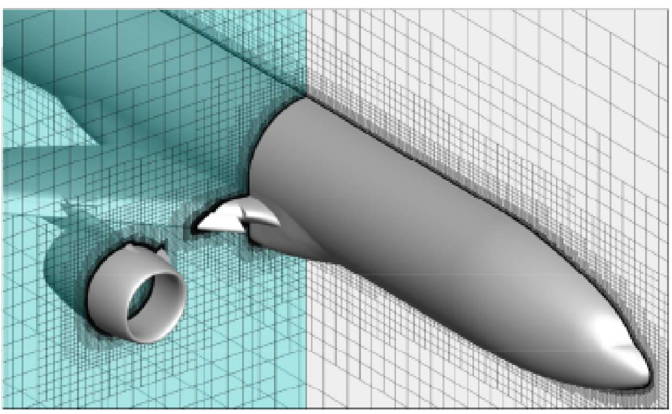
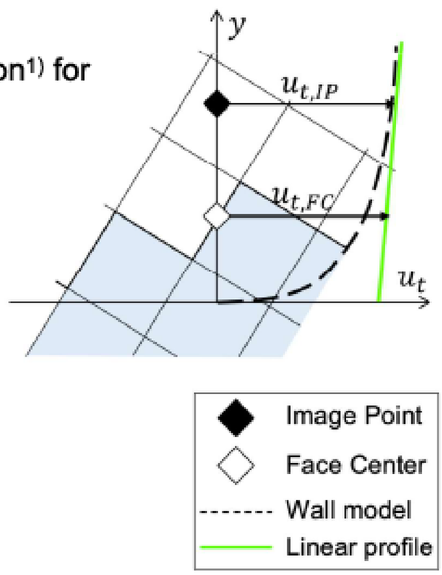
UTCart

(The University of Tokyo Cartesian-grid-based automatic flow solver)

- Hierarchical Cartesian grid (cell-based refinement)
  - Automatic and robust grid generation
  - Orthogonality of the grid
  - Immersed boundary method with a wall function[1)] for high-Re flows



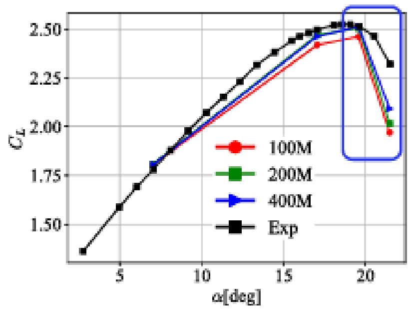


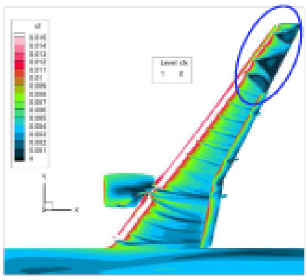
1) Tamaki, Harada, and Imamura, AIAA J., Vol 55, 2017.

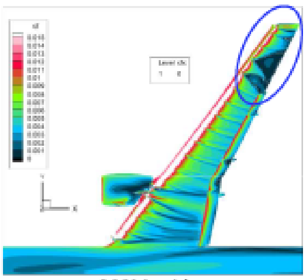
UTCart in APC-8

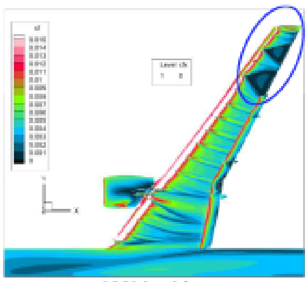
(Funada, Imamura, & Sugaya)

- Free-air cases were simulated with three different grid resolutions
- Grid convergence of C_L is obtained with >200M grid points (using a second-order scheme)




100M-grid


200M-grid


400M-grid

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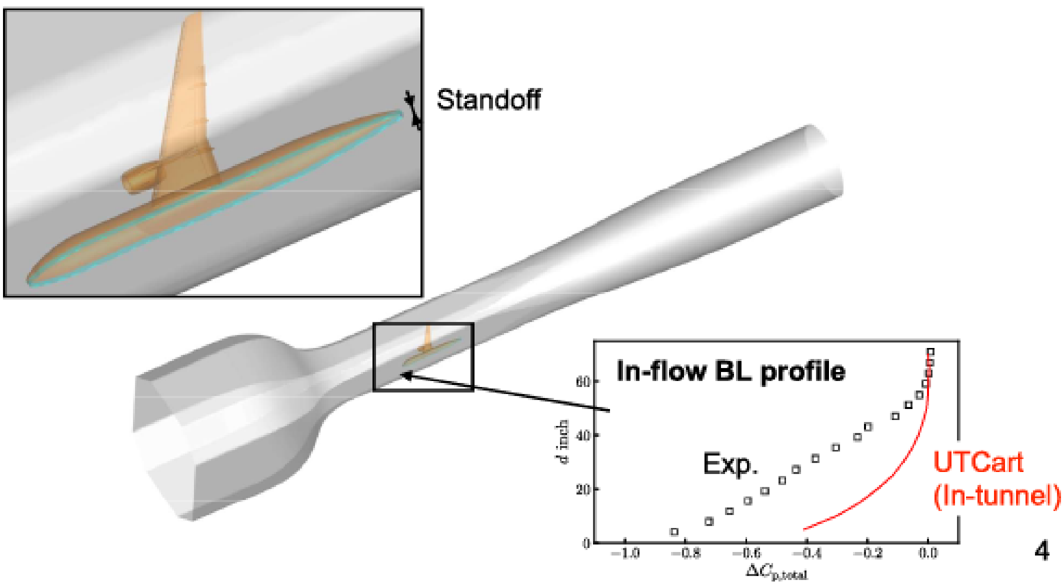
Objective

- Demonstrate capability of UTCart for complex in-tunnel flow geometries
- Evaluate effects of tunnel wall / floor boundary layer / standoff



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Numerical methods/ grids

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Governing Equation	RANS
Turbulence Model	SA-noft2
Inviscid Flux	4rd-order upwind biased[3] + SLAU
Viscous Flux	2nd-order central difference
Time Integration	MFGS (Local Time Stepping)
Wall Boundary Condition	IB+SA wall model
Distance between IP and wall	3Δx

- Minimum cell size: 0.26 inch ($C_{\mathrm{ref}}/1024$)
- # of cells: 114~119 M

3) Tamaki and Imamura, Computers & Fluids, Vol 144, 2017.

Results at low-AoA

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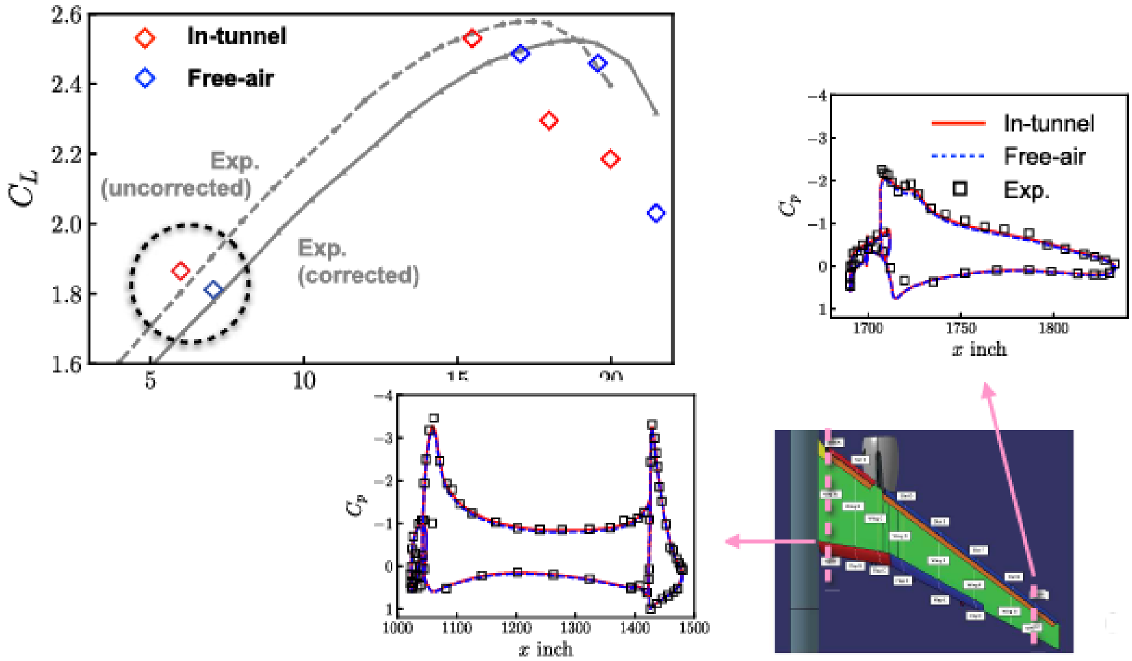
- Lift at low angle of attack is predicted accurately



Tunnel effects at low AoA

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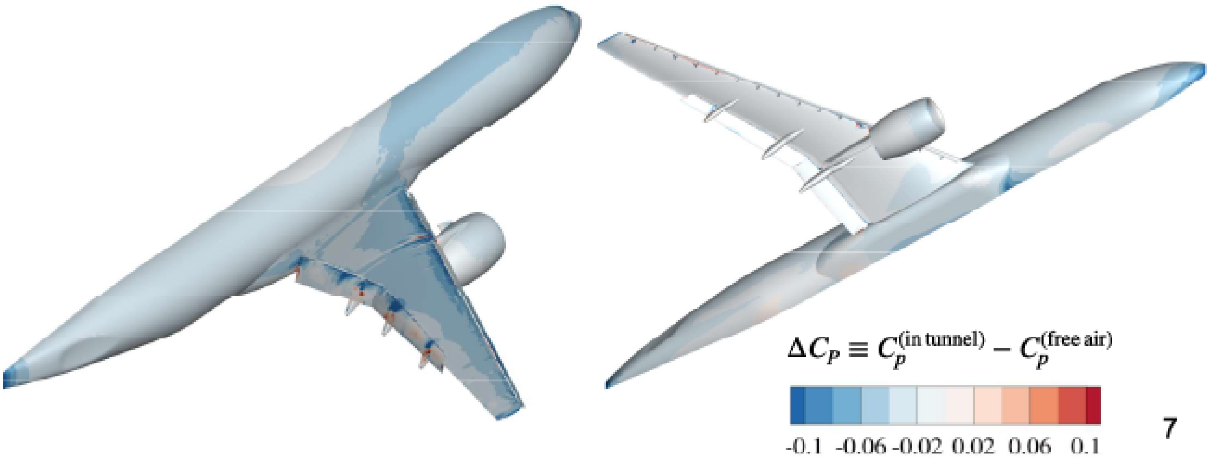
- UTCart predicted tunnel effects at low AoA with reasonable accuracy

$\alpha_{\text{uncorrected}} = 5.98^{\circ}$
$\alpha_{\text{corrected}} = 7.05^{\circ}$

	ΔC_D	ΔC_L	ΔC_M
CFD	-0.032	0.045	-0.001
Exp.	-0.033	0.025	-0.005



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Stall prediction

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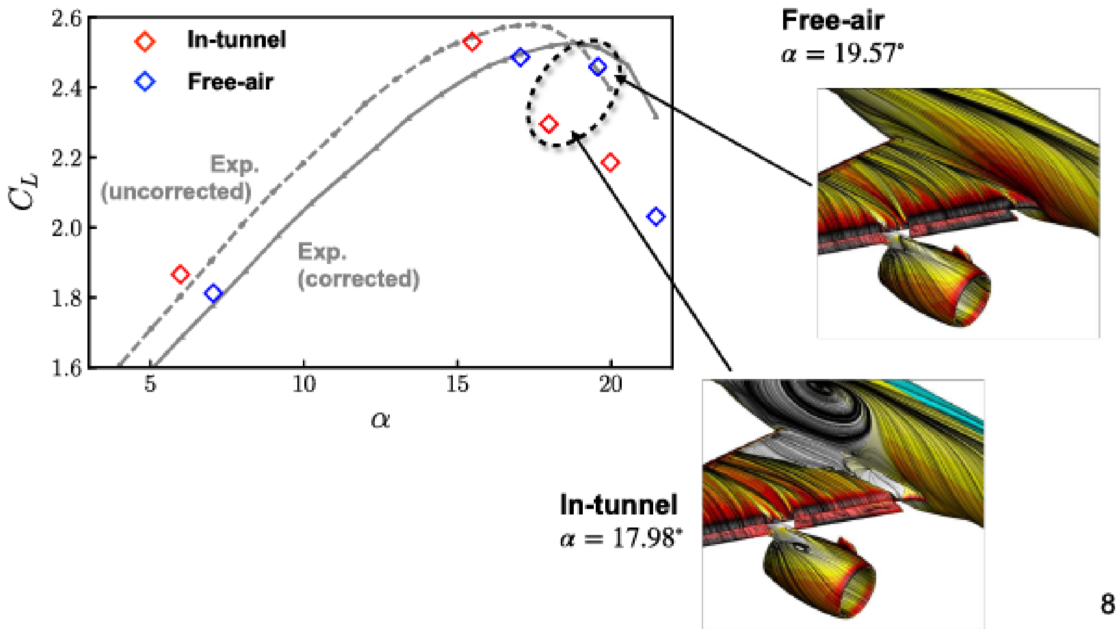
- Stall AoA differs between the free-air/in-tunnel simulations



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Floor BL / standoff height

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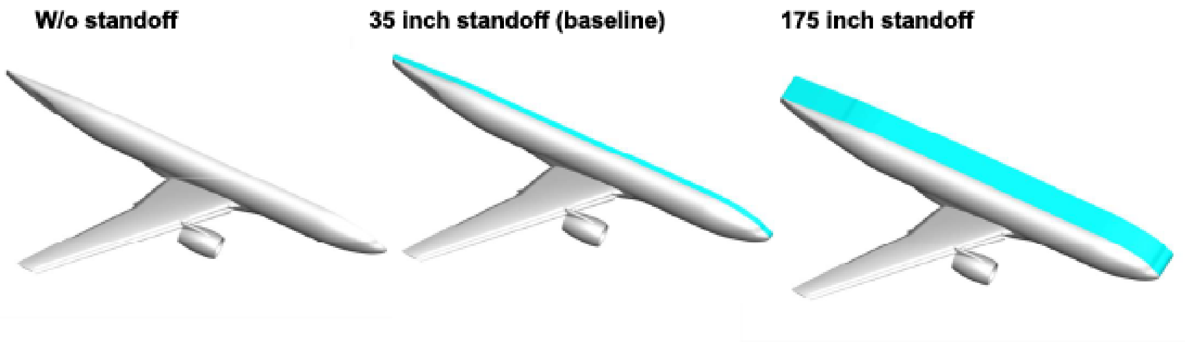
- Several additional cases are conducted at $\alpha_{\mathrm{uncorrected}} = 17.98^{\circ}$ to clarify the causes of the different stall behaviors
- Simulations are conducted with/without the floor BL



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Effects of floor BL

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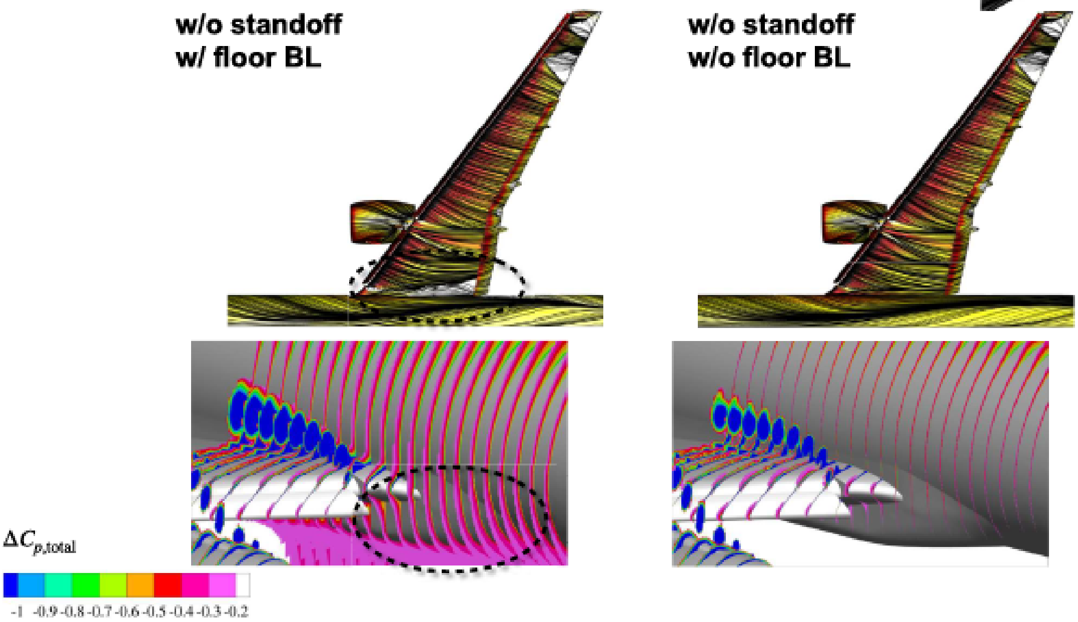
- SB separation is promoted due to the floor BL
- BL over the fuselage is thickened (as in Ito *et al.* (2022))



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Effects of floor BL

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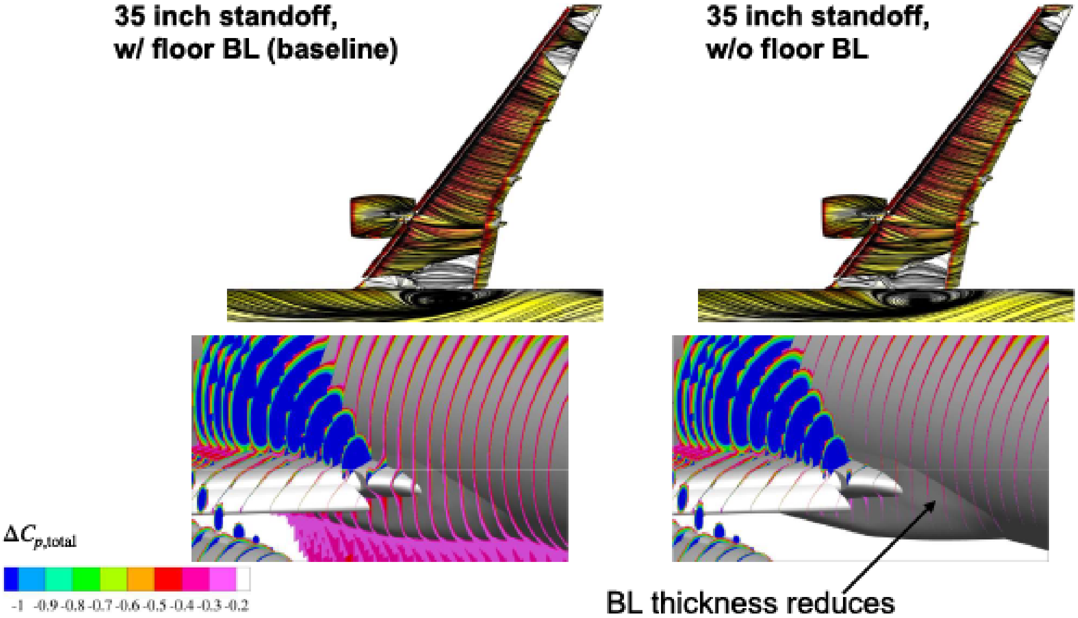
- Contrary to expectations, the floor BL does not make almost any difference when using the 35 inch standoff



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Effects of standoff height

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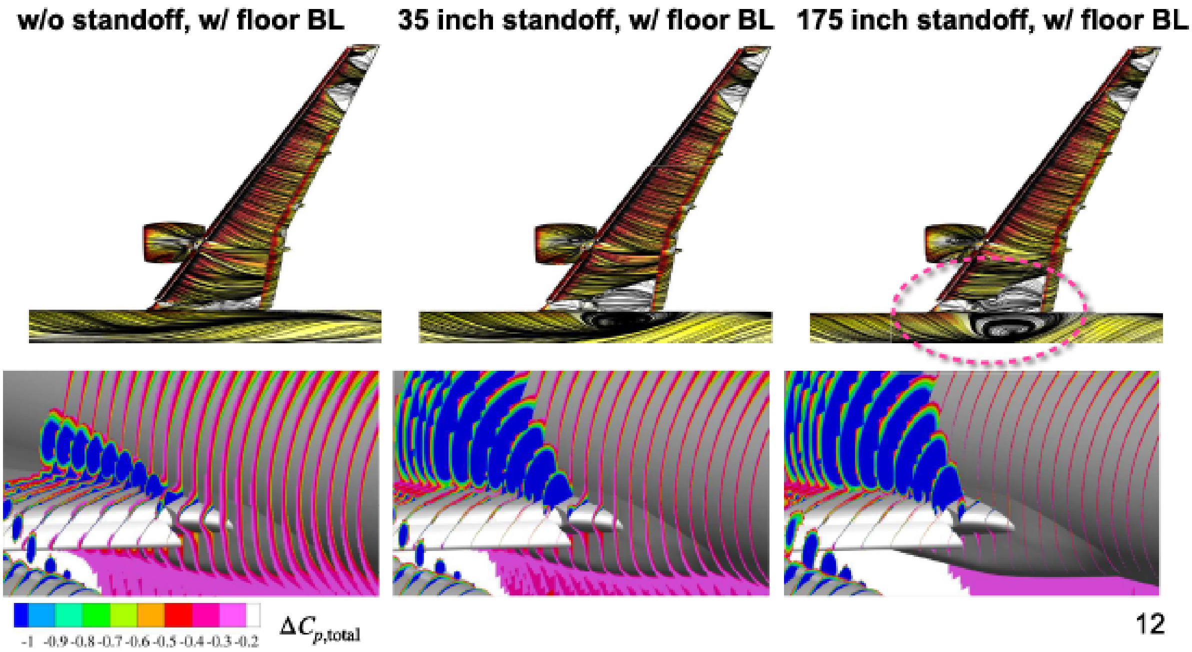
- Separation enlarges with a higher standoff height



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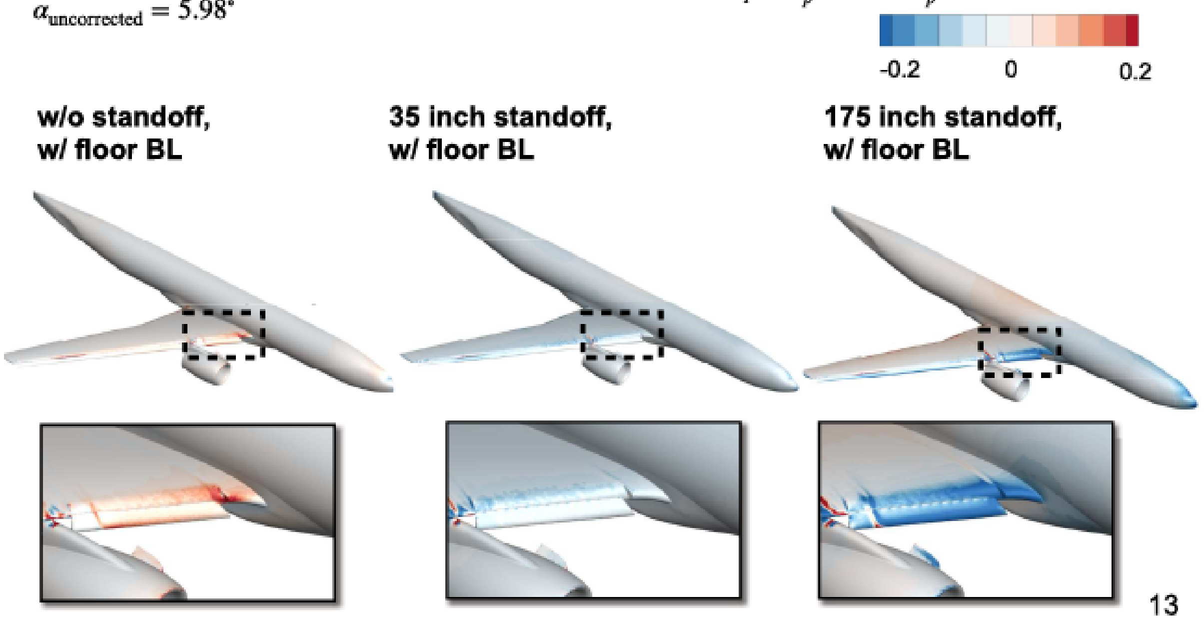
Effects of standoff height

- Inboard suction peak strengthens as standoff height increases

$\alpha_{\text{uncorrected}} = 5.98^{\circ}$

$\Delta C_P \equiv C_p^{(\text{in tunnel})} - C_p^{(\text{free air})}$



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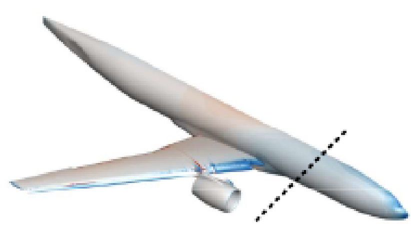
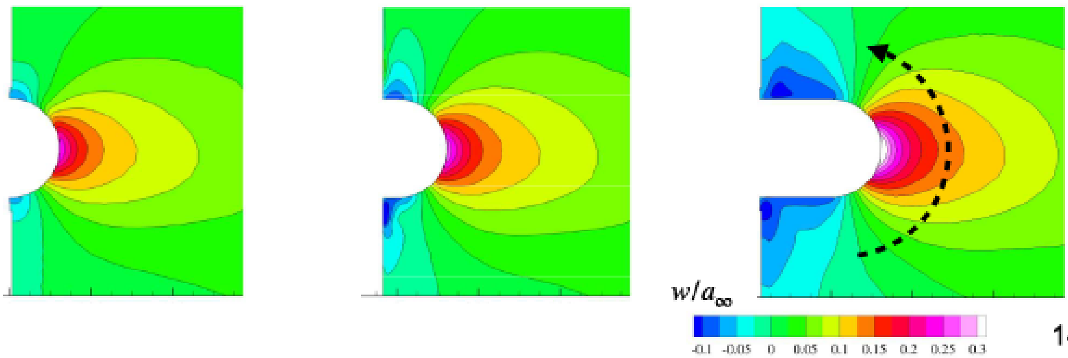
Effects of standoff height

- Effective AoA increases due to the fuselage
→ Separation in the inboard region is promoted



$\alpha_{\text{uncorrected}} = 5.98^{\circ}$



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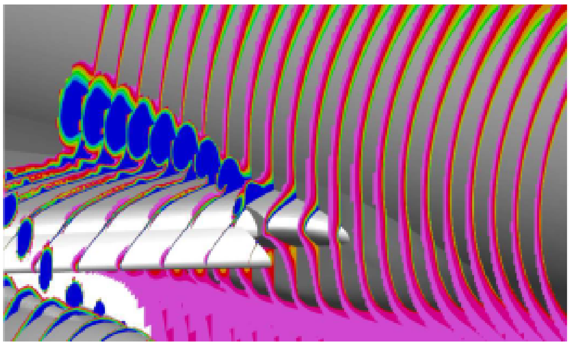
Effects of standoff height

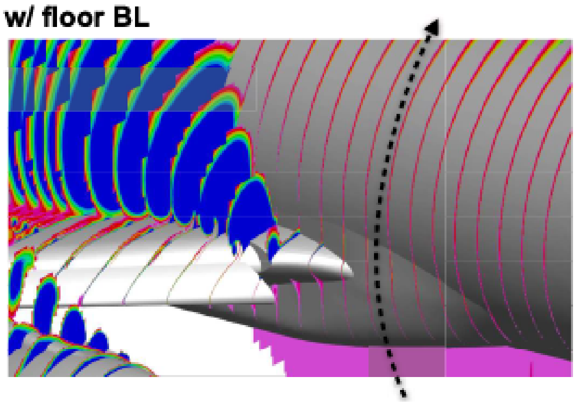
- Effective AoA increases due to the fuselage
→ Separation in the inboard region is promoted

$\alpha_{\text{uncorrected}} = 17.98^{\circ}$

w/o standoff,
w/ floor BL



175 inch standoff,
w/ floor BL



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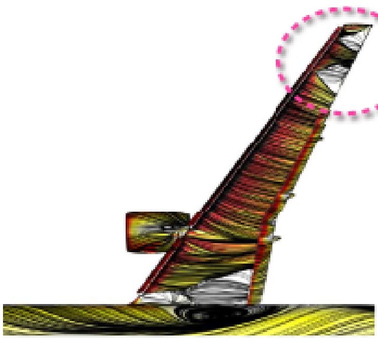
Sensitivity to turbulence model

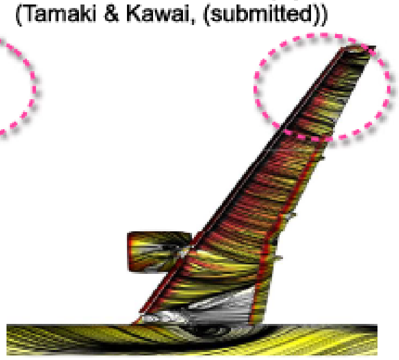
- Turbulence model has certain influences on the separation pattern

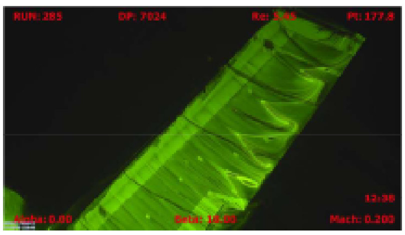
SA-noft2



SA-noft2-QCR2000

SA-noft2-QCR2023(b)
(Tamaki & Kawai, (submitted))





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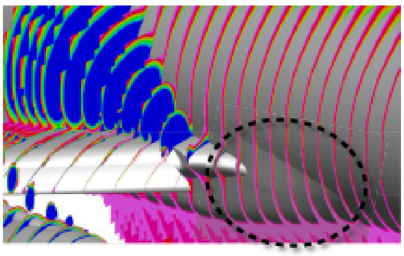
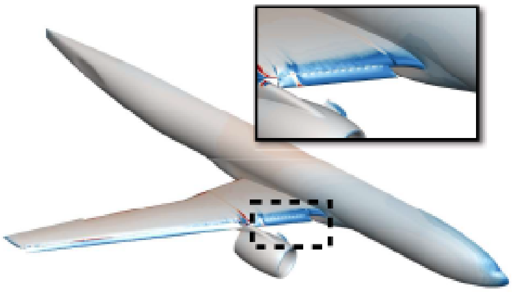
Conclusions

- UTCart has been successfully applied to the in-tunnel flow simulations
- Except for the stall conditions, the CFD simulations well predict the aerodynamics including tunnel effects
- Half-span model experiment introduces twofold effects on the stall
  - Floor BL thickens the BL over the fuselage
  - Standoff increases the effective AoA in the inboard region
- Turbulence model should be improved further for accurate stall prediction





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