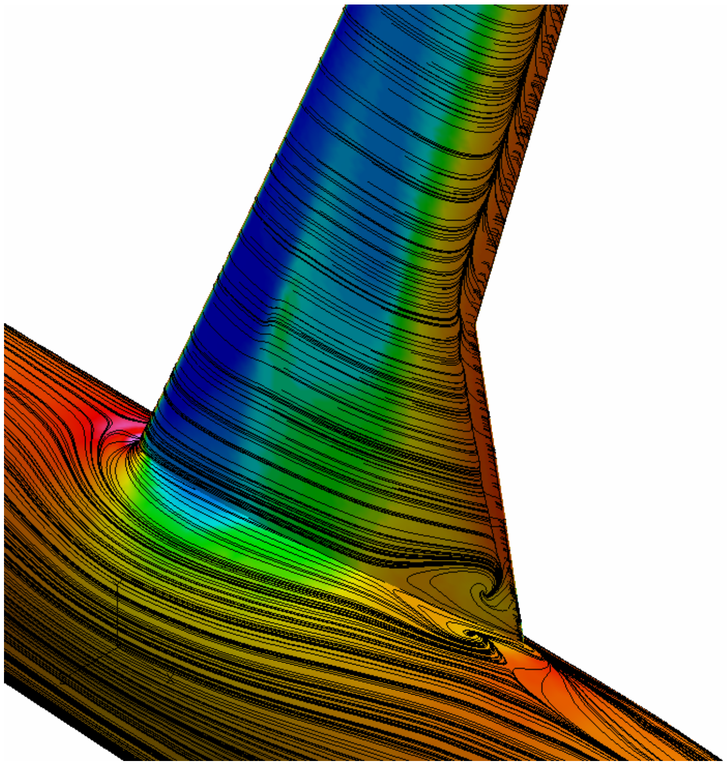
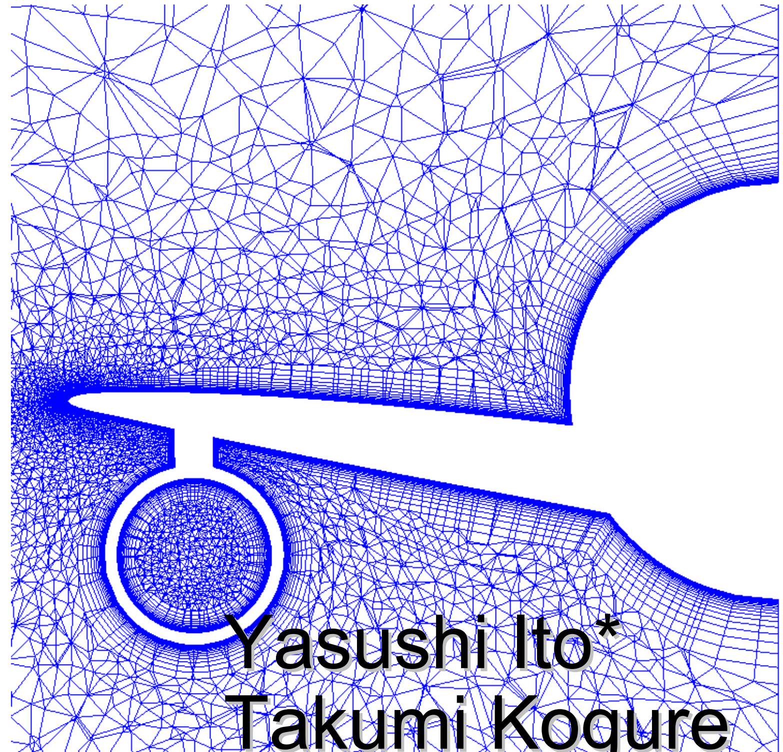
Unstructured Hybrid Mesh Generation for DLR-F6 Configuration

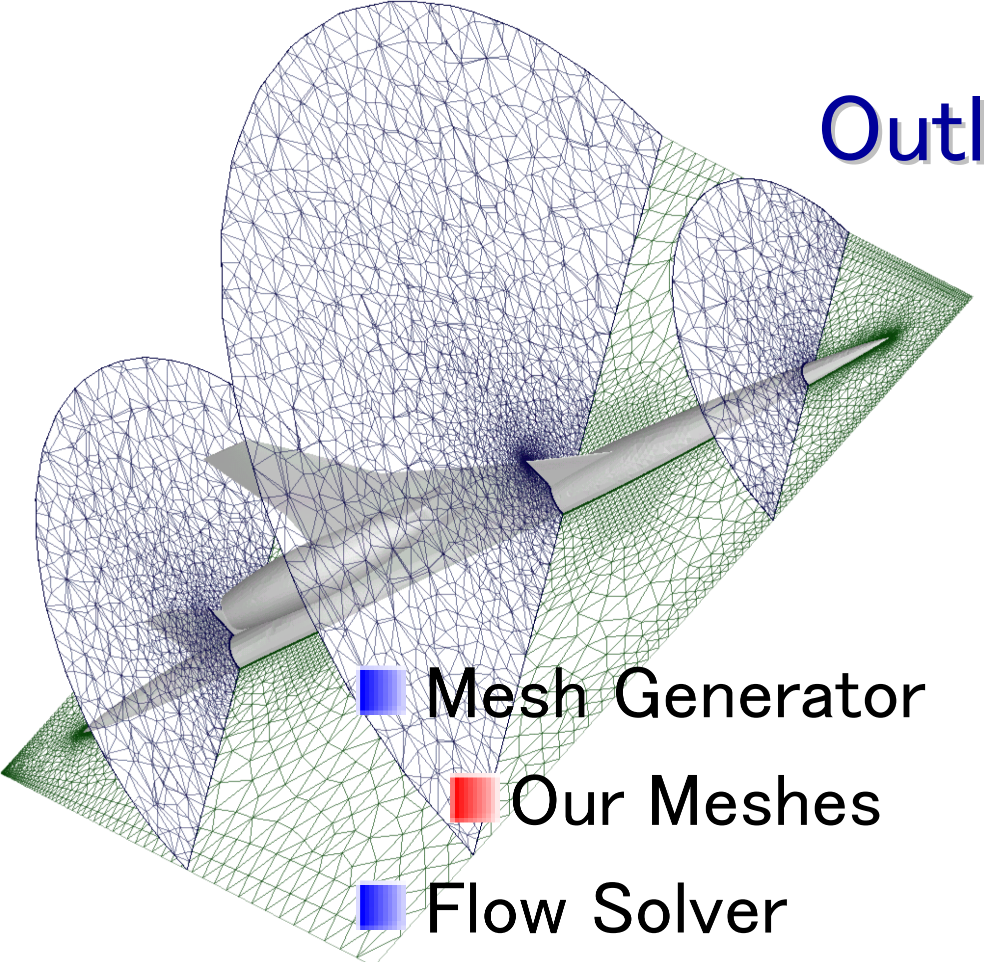


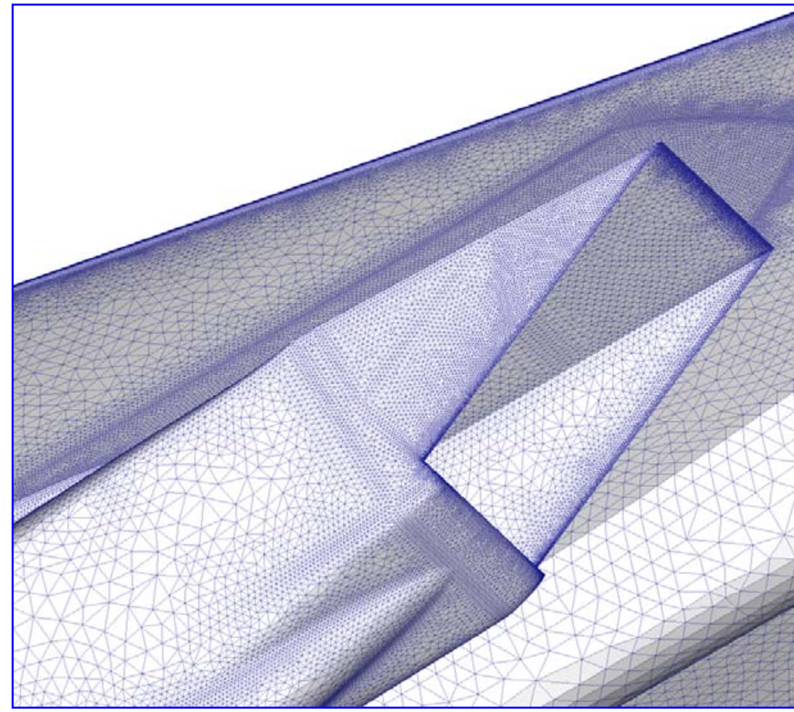


Yasushi Ito*
Takumi Kogure
Kazuhiro Nakahashi

Dept. of Aeronautics and Space Eng., Tohoku Univ., JAPAN
**Currently, Dept. of Mechanical Eng., Univ. of Alabama at Birmingham*

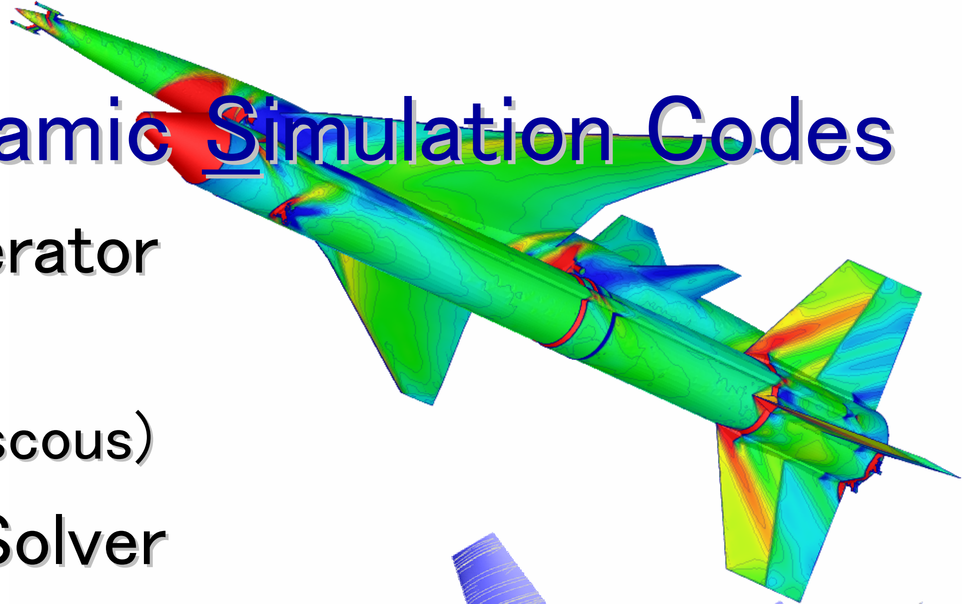
Outline



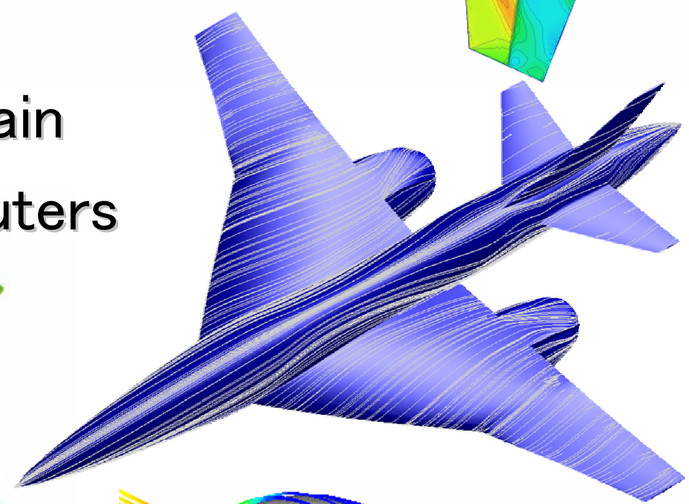


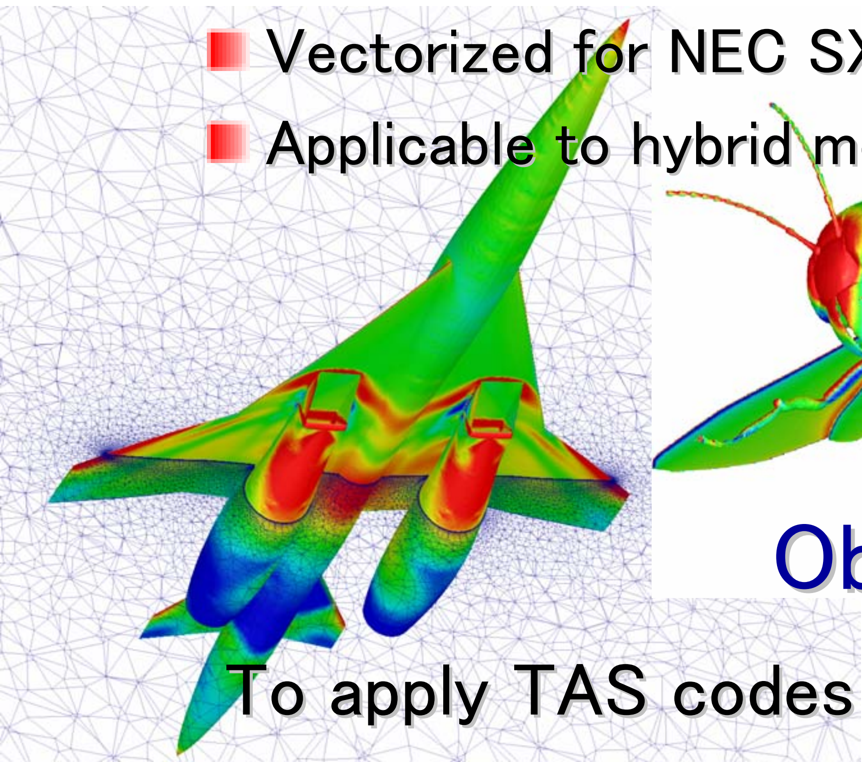
- Mesh Generator
  - Our Meshes
- Flow Solver
- Result
  - Mesh Density Effect (WB)
  - Turbulence Model Effect (WBNP)
- Conclusions

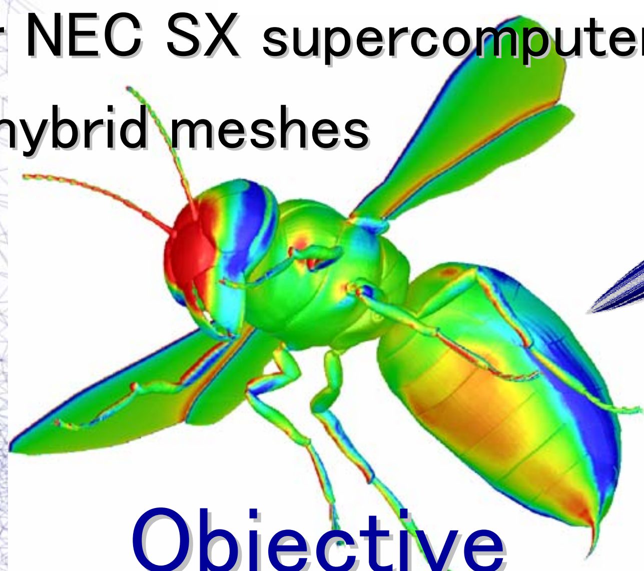
Tohoku Univ. Aerodynamic Simulation Codes

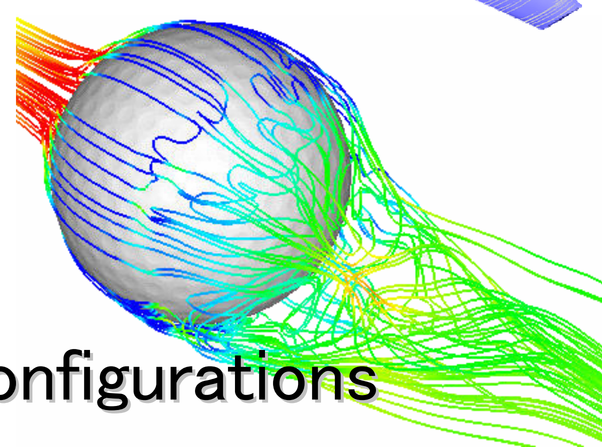


- Unstructured Mesh Generator
  - Surface mesh
  - Volume mesh (inviscid/viscous)
- Unstructured Euler/NS Solver
  - Parallelized by partitioning the domain
  - Vectorized for NEC SX supercomputers
  - Applicable to hybrid meshes









Objective

To apply TAS codes to DLR F-6 configurations

Mesh Generation: TAS-Mesh

(Tohoku Univ. Aerodynamic Simulation)

CAD STL File

↓

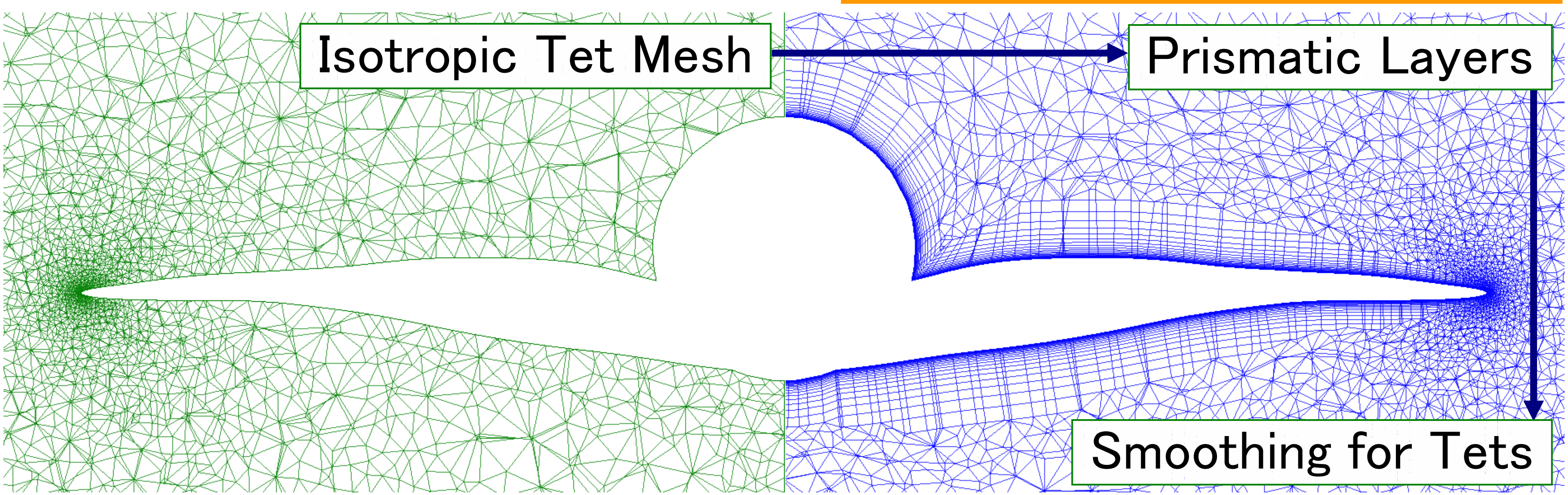
Surface Mesh

- Automation
- Controllability – GUI

→

Volume Mesh

- Fully-automated
- User-specified parameters
  - Min. spacing
  - Stretching factor
  - Max. number of layers



Surface Mesh Generation

Use of repaired STL data for background grids

↓

Extraction of geometrical features

- To represent models more accurately
- To control local grid density
- To simplify initial front setup

↓

Construction of an initial front

- Mouse picking to specify parameters

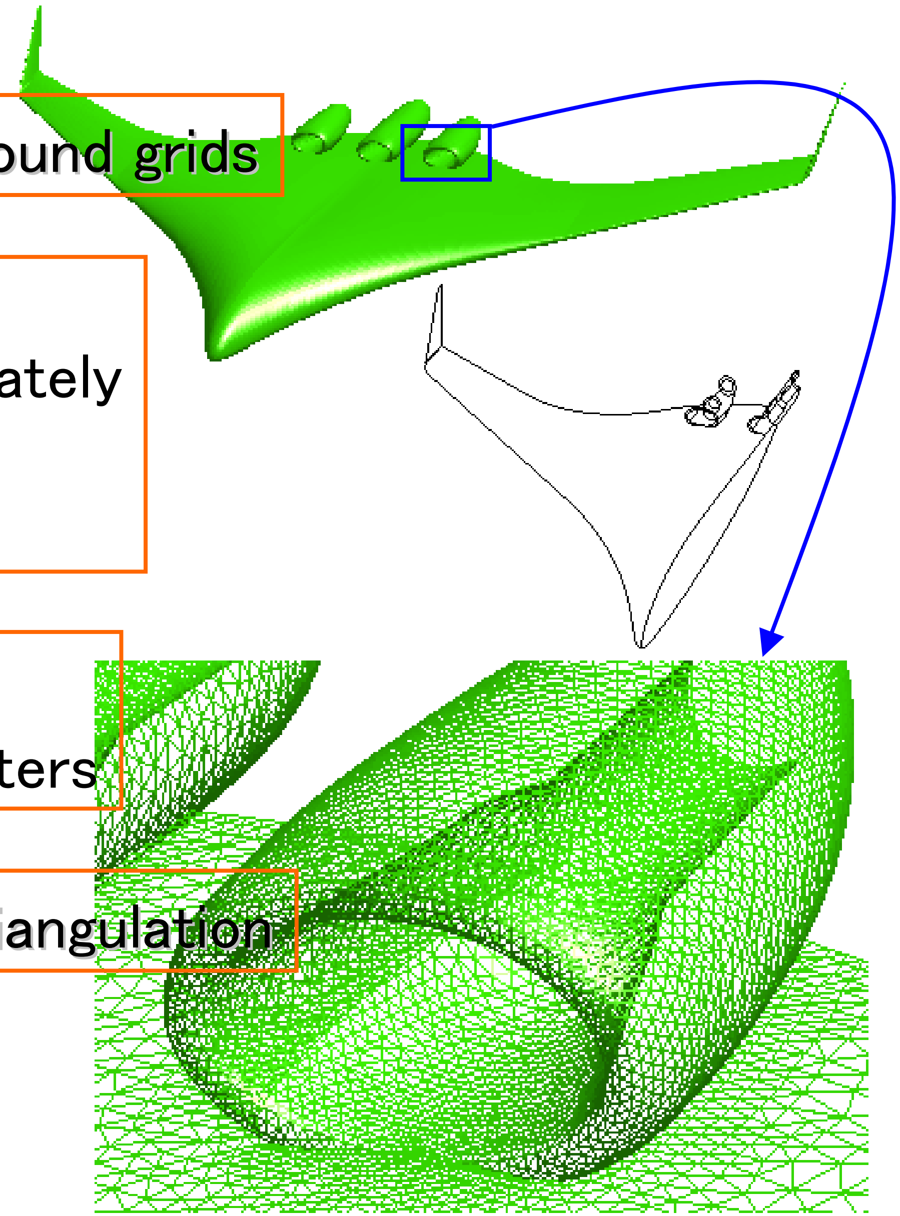
↓

Direct advancing front method for triangulation

↓

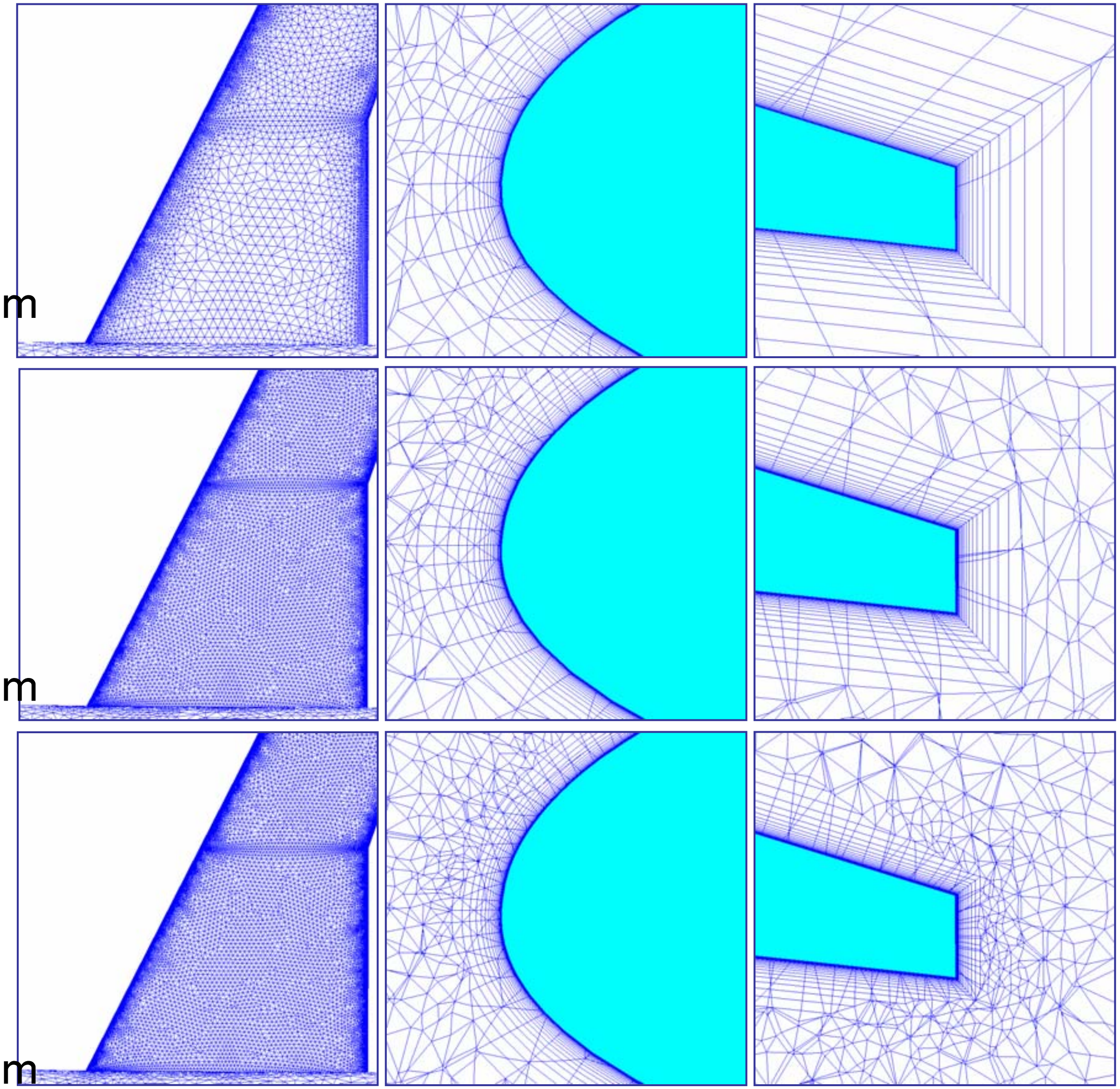
Surface recovery

- To enhance mesh quality



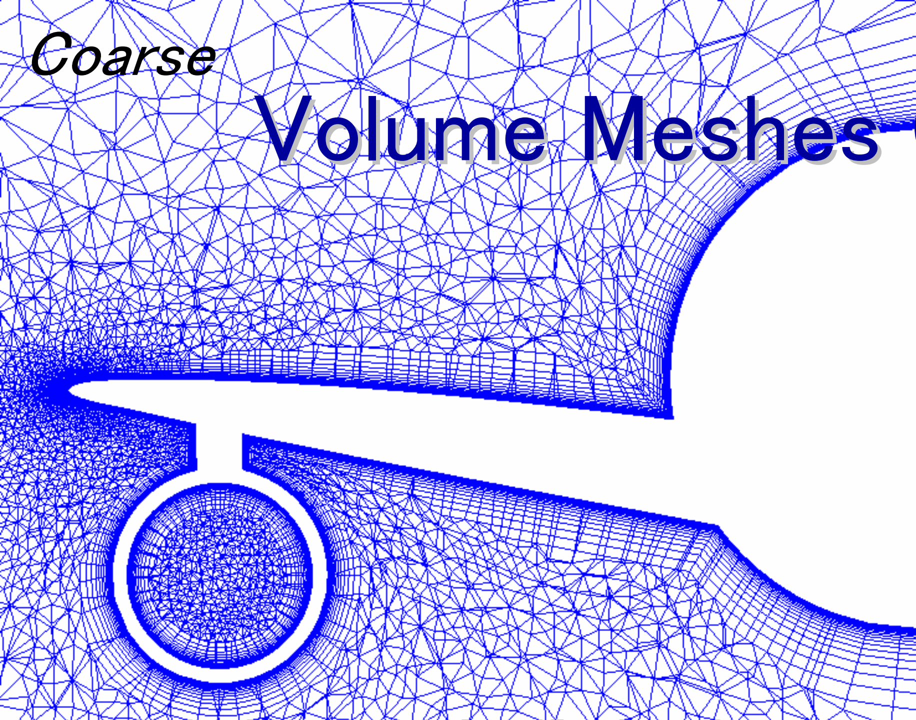
Three Meshes

- Coarse
  - 1.3M nodes (WB)
  - 2.0M nodes (WBNP)
  - TE base: 1 cell
  - Min. spacing: 2.4×10^{-3} mm
- Intermediate
  - 3.9M nodes (WB)
  - 5.6M nodes (WBNP)
  - TE base: 3 cells
  - Min. spacing: 6.0×10^{-4} mm
- Fine
  - 11.3 M nodes (WB)
  - 17.0 M nodes (WBNP)
  - TE base: 9 cells
  - Min. spacing: 1.5×10^{-4} mm

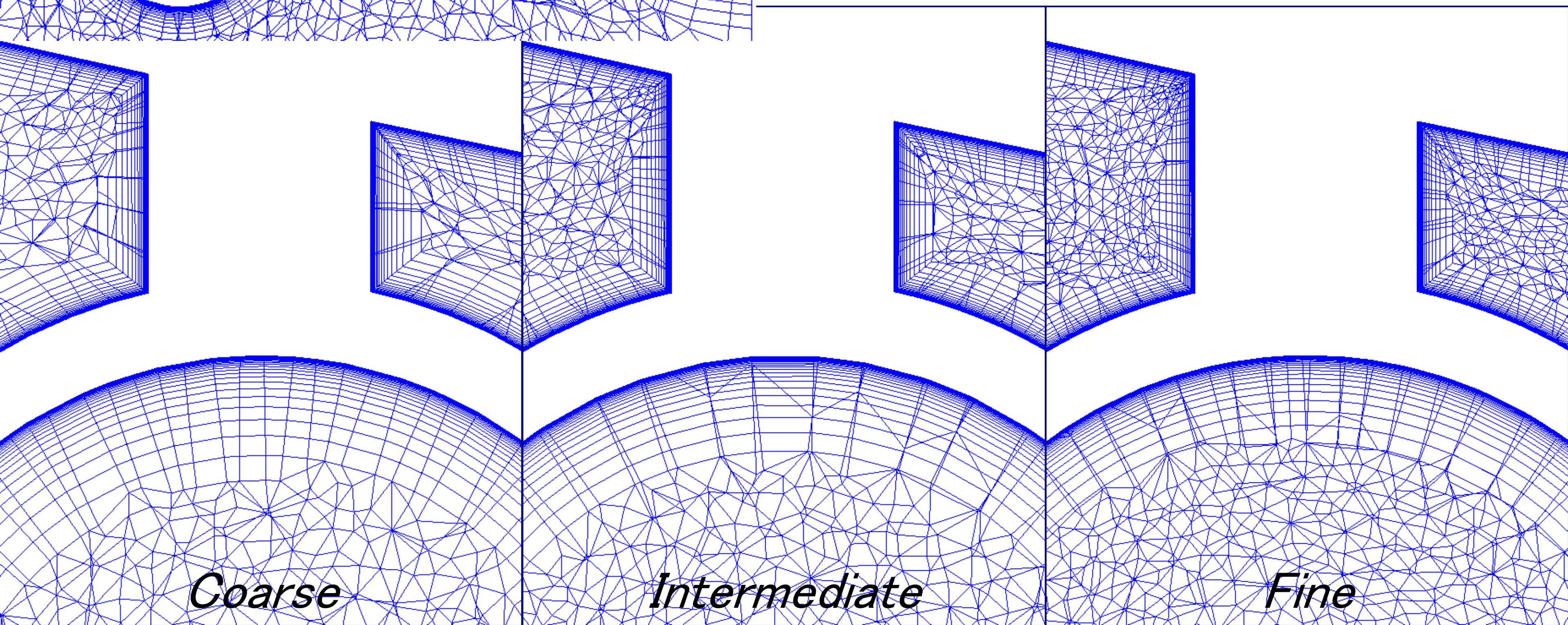


Wing upper surf. LE TE

Volume Meshes (WBNP, $x/L = 40\%$)



- Smooth transition from prismatic layers to tets

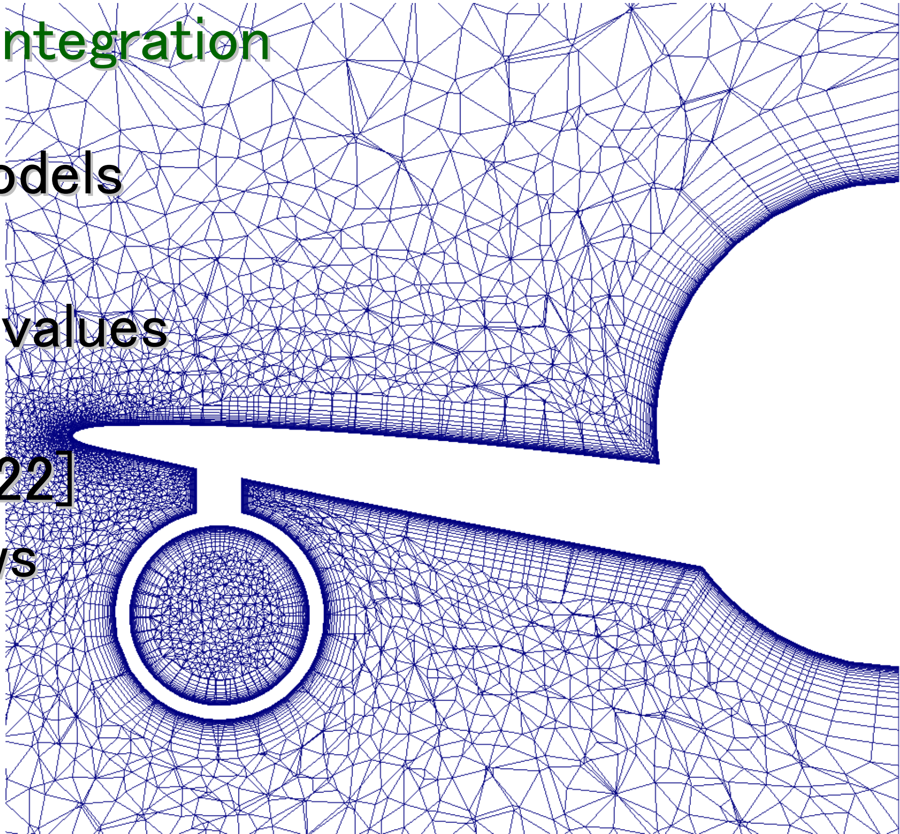


Flow Solver: TAS-FLOW

(Tohoku Univ. Aerodynamic Simulation)

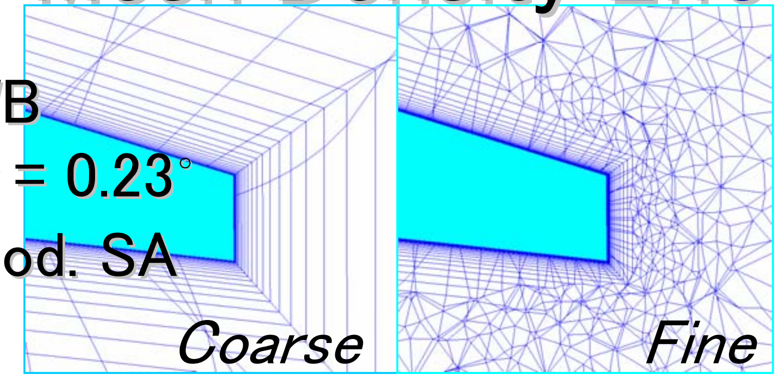
- RANS equations
- Cell-vertex finite volume method
- HLLEW Riemann solver for flux computation
- Venkatakrishnan's limiter to reconstruct 2nd order accuracy
- LU-SGS implicit method for time integration

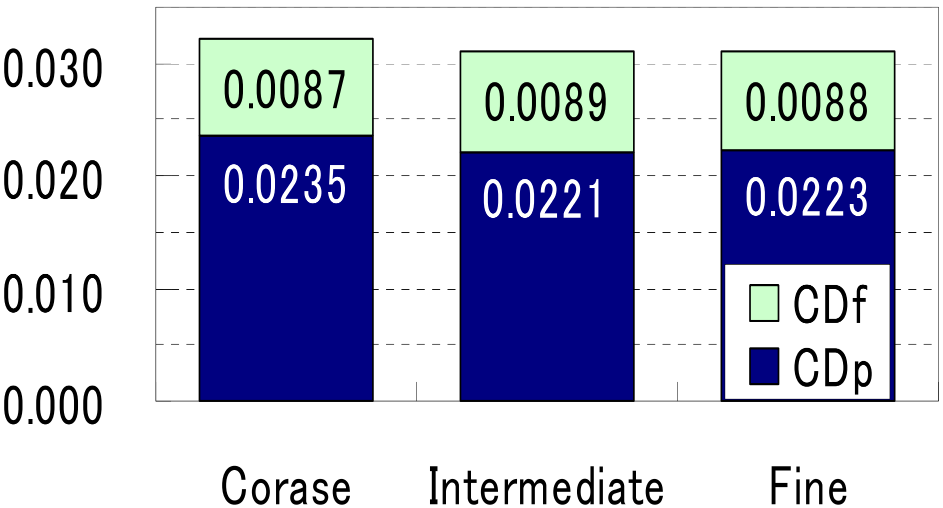
- Three one-equation turbulence models
  - Goldberg-Ramakrishnan (GR)
    - ✓ Not requiring wall distance values
  - Spalart-Allmaras (SA)
  - Mod. SA [AIAA Paper 2000-2222]
    - ✓ Modified for free shear flows
- Fully turbulent

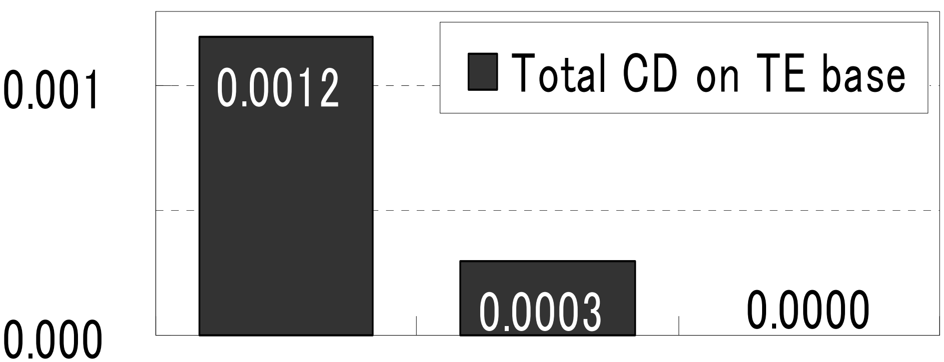


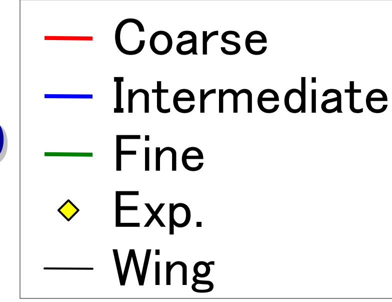
Mesh Density Effect on CD & Cp

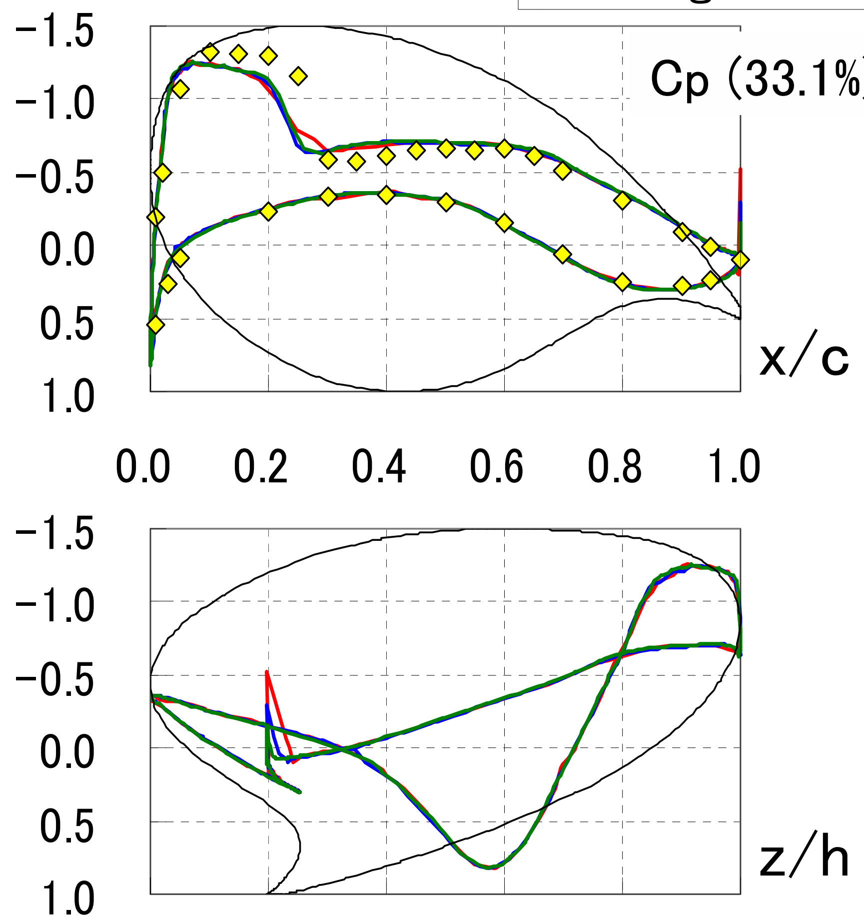
- WB
- $\alpha = 0.23°$
- Mod. SA







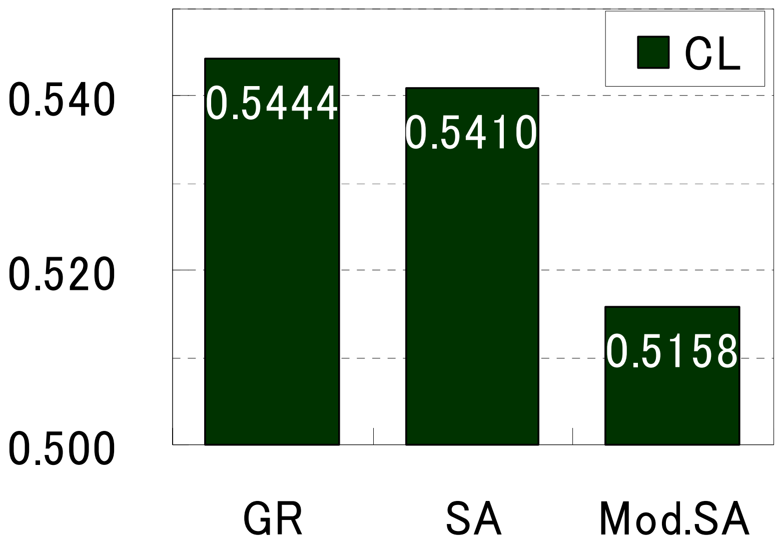


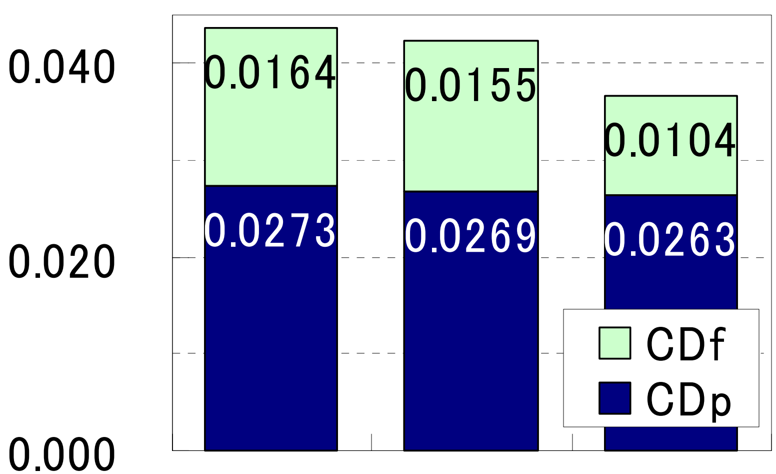


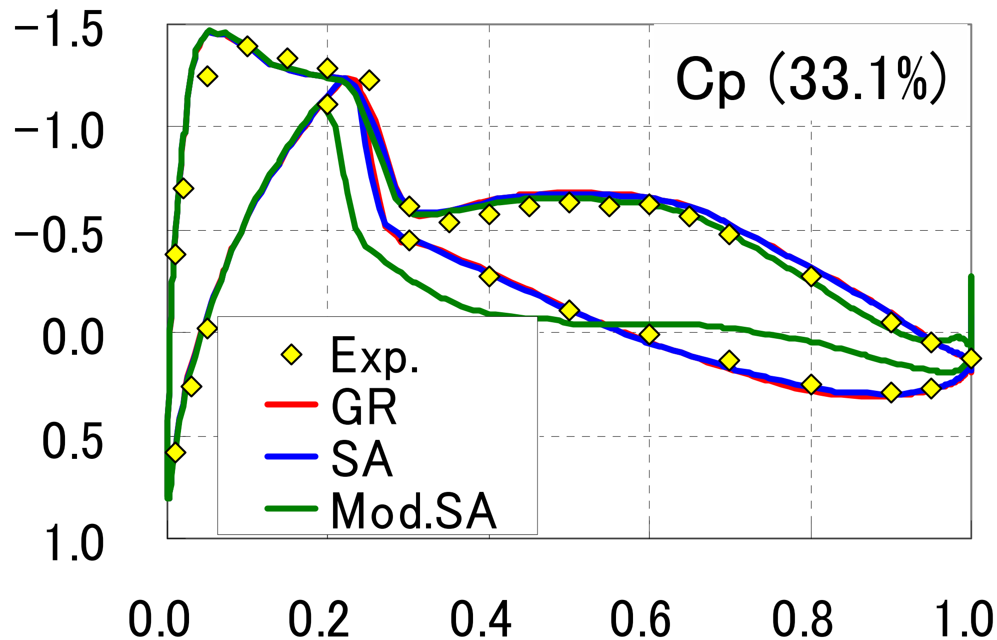
- Almost the same total CD
- Big difference at TE base

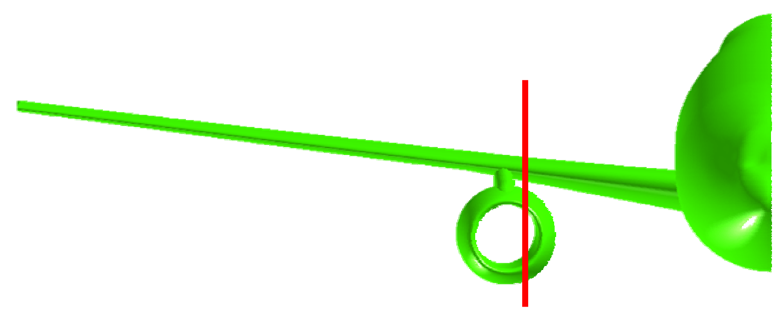
Turbulence Model Effect on CL, CD & Cp

- WBNP (Intermediate)
- $\alpha = 1.0^\circ$ (CL = 0.5)



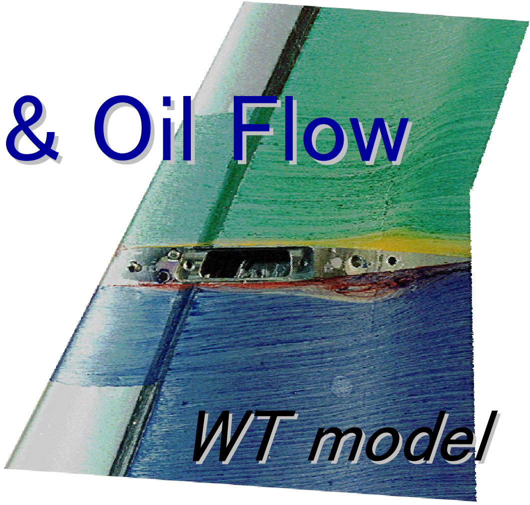




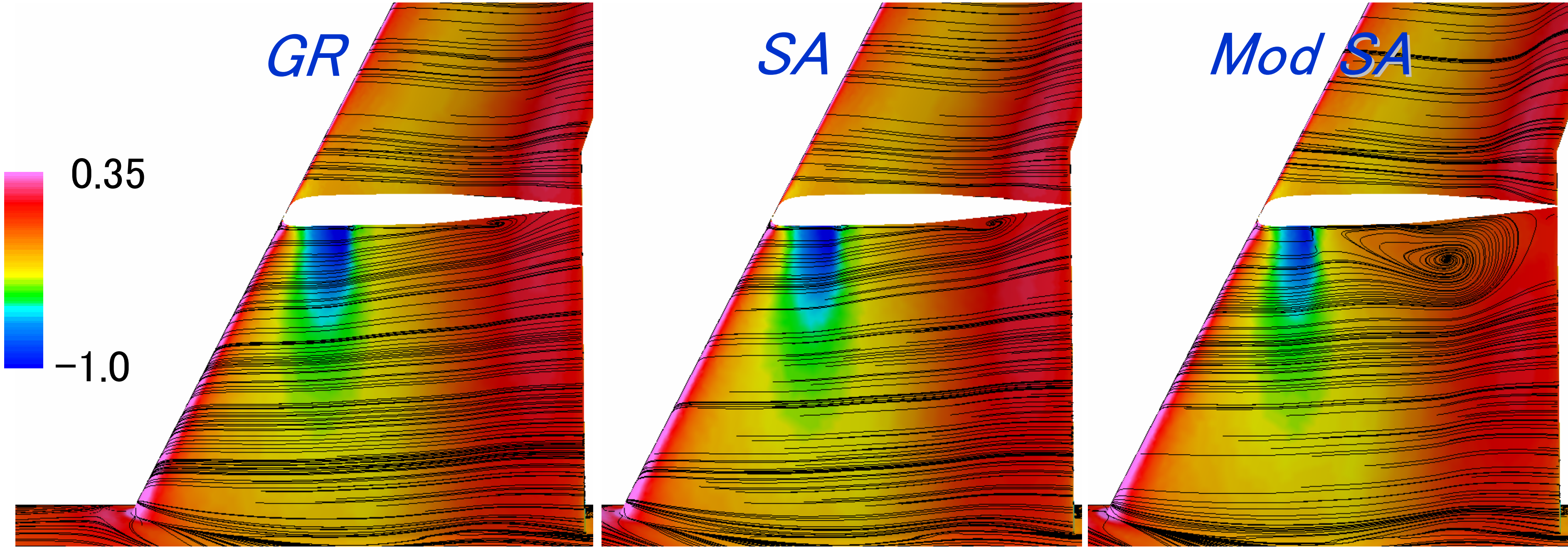


- CL & CDf: Mod. SA estimating smaller
- Cp: Big difference at 33.1% station

Turbulence Model Effect on Cp & Oil Flow



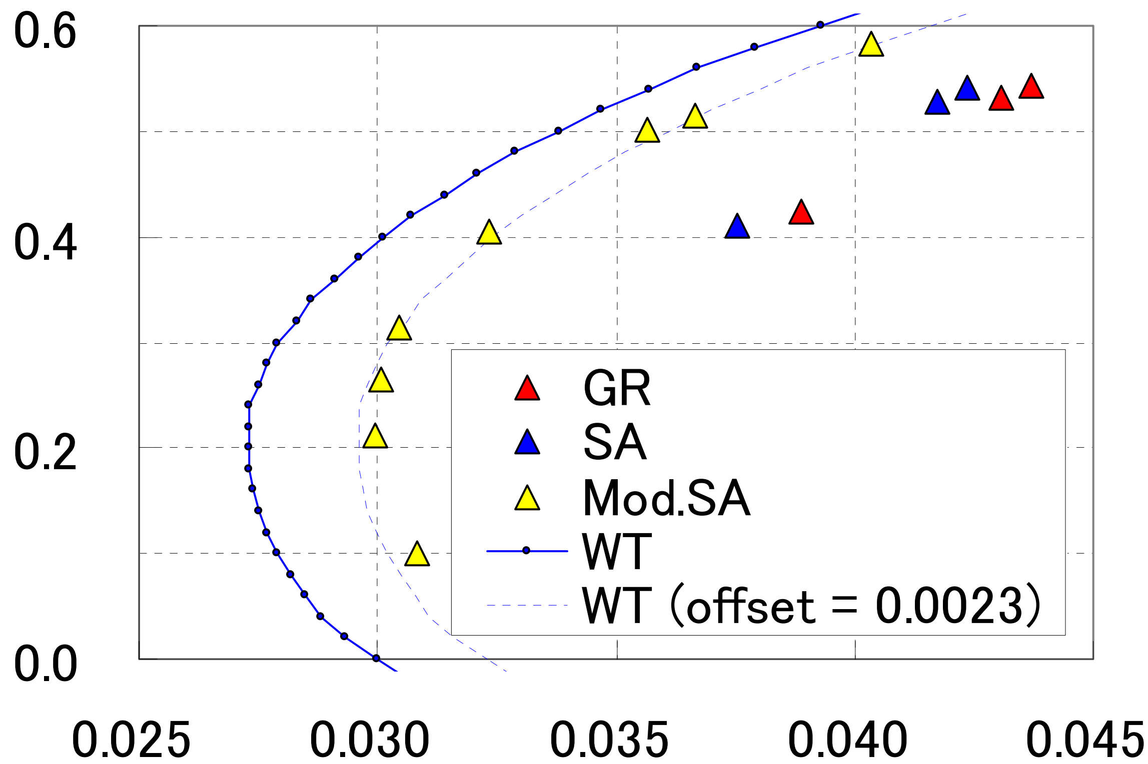
- WBNP (Intermediate)
- $\alpha = 1.0^\circ$ (CL = 0.5)

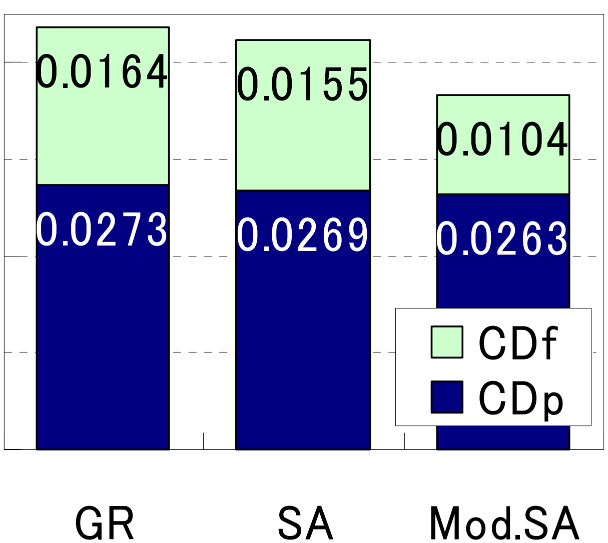


- Mod. SA estimating
  - Too big separation
  - Different shock wave location

Turbulence Model Effect on Drag Polar

- WBNP (Intermediate)





- *Fully turbulent*
- *Mod. SA estimating smaller CDf*
- Still higher CD comparing with exp.
  - Higher CDp?
  - Spatial mesh resolution?

Conclusions

Tohoku Univ. Aerodynamic Simulation codes were applied to the numerical simulation of the DLR F-6 configurations

- TAS-Mesh: Unstructured mesh generator
- TAS-FLOW: Unstructured, parallelized flow solver

- Attached flow regions were not affected by
  - Mesh resolutions
  - Type of turbulence models
- GR and SA produced basically similar results
- Mod. SA estimated
  - Smaller CL and CDf
  - Bigger separations
- The effect of the spatial mesh resolution to the solution accuracy should be evaluated