Boeing Technology
Phantom Works

# BCFD Predictions for the 3rd AIAA Drag Prediction Workshop (DPW3)

Chad Winkler, Andy Dorgan, Mark Fisher, Mori Mani
The Boeing Company
St. Louis, MO

S. P. Vanka
University of Illinois at Urbana-Champaign
Urbana, IL

# BCFD Code Details



- Cell-centered, finite-volume approach
- HLLE flux calculation with second-order spatial reconstruction
  - Linear preserving gradient calculation
- Fully implicit time integration
- Turbulence models
  - Spallart-Allmaras
  - SST
- Additional capabilities: Time accurate LES, real gas effects, hybrid structured/unstructured solver, additional flux formulations available

# Grid Details

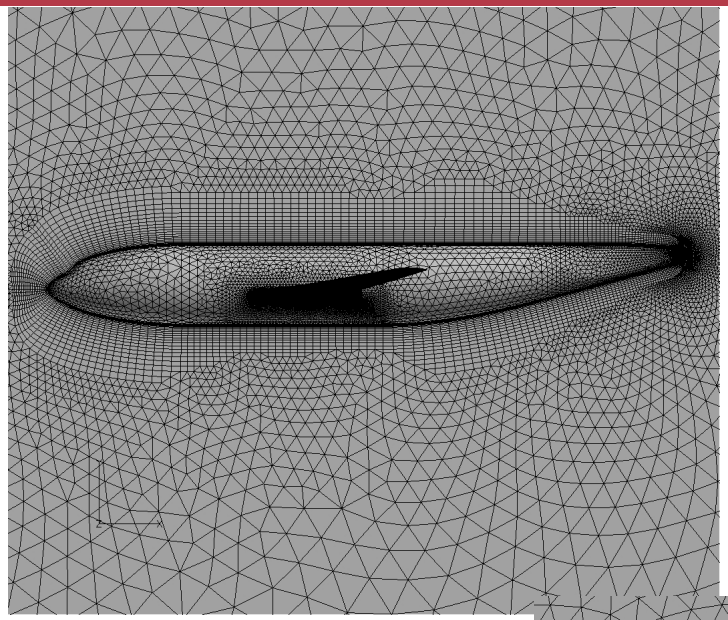


- Unstructured grids
  - Mixed tetrahedra and prisms (boundary layer)
  - Surface grids generated with MADCAP
  - Volume grids generated with AFLR3
  - Available on NASA FTP site

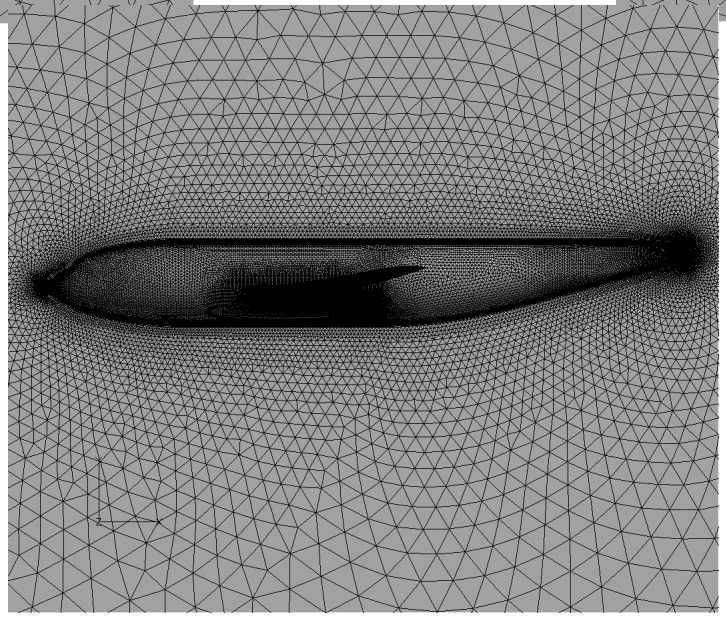
- Running on 64 bit Linux clusters
  - Typical execution time : 24 hours on fine grid (33M cells) running on 33 processors

# F6 Wing/Body Grids

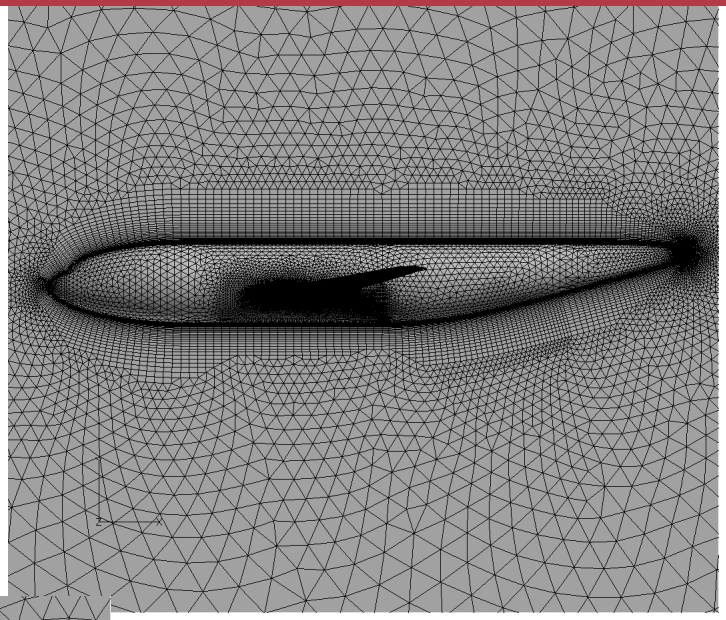




Coarse (~4M cells)



Fine (~33M cells)



Medium (~8M cells)

# F6 Wing Root Region Grid

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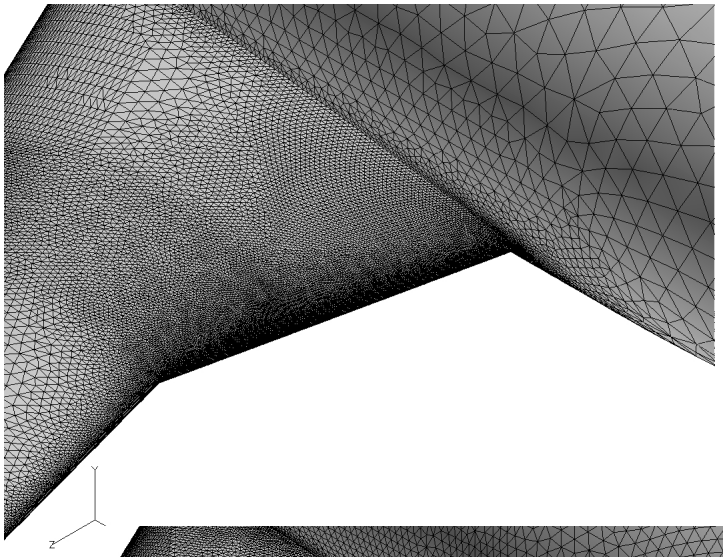
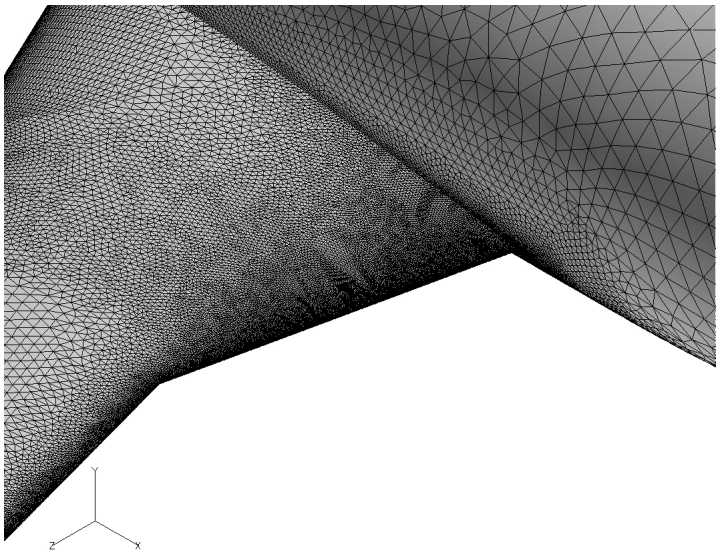
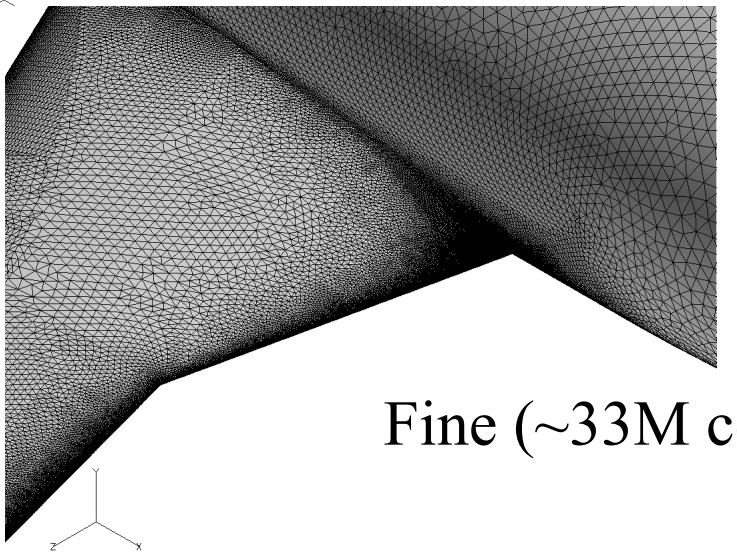


Coarse (~4M cells)

Medium (~8M cells)

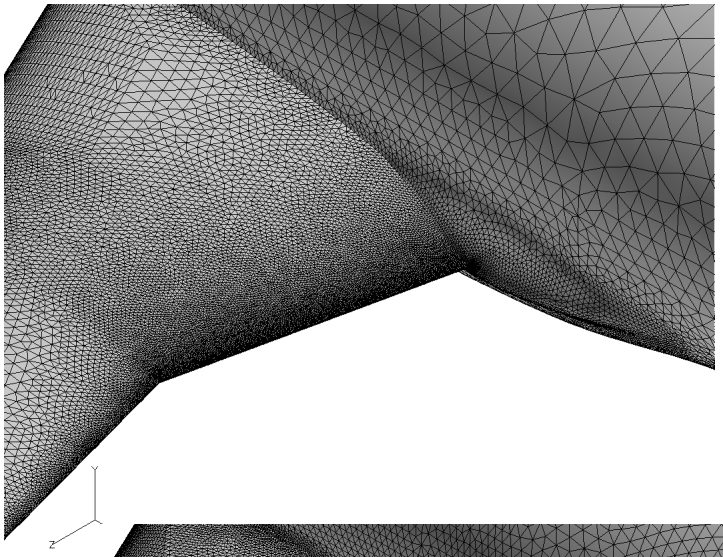




Fine (~33M cells)

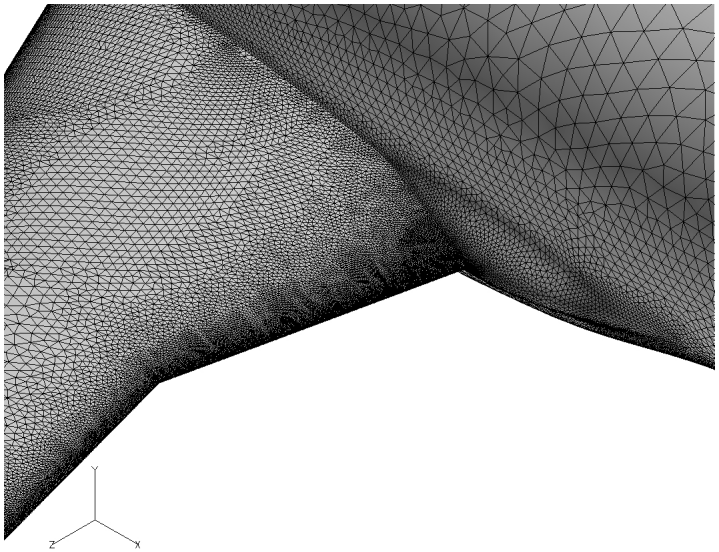
# F6 + FX2B Wing Root Region Grid

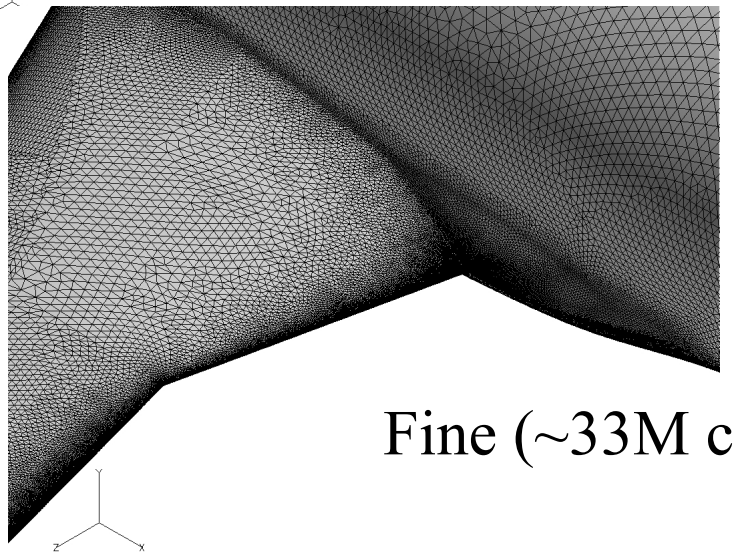




Coarse (~4M cells)

Medium (~8M cells)

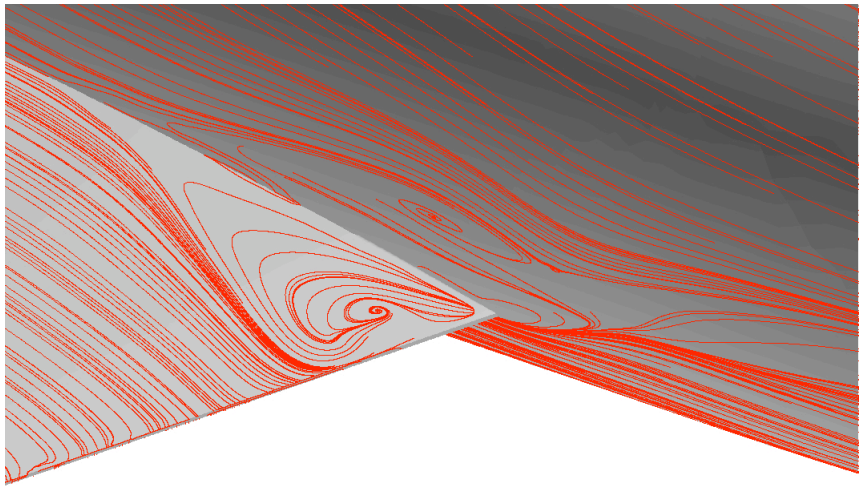


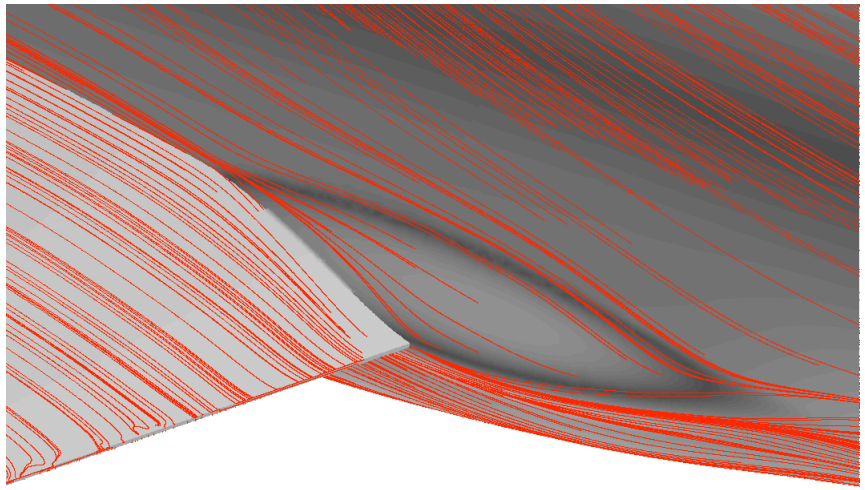


Fine (~33M cells)

# Wing Root Region
# Surface flow – Fine grid $C_L$=0.5





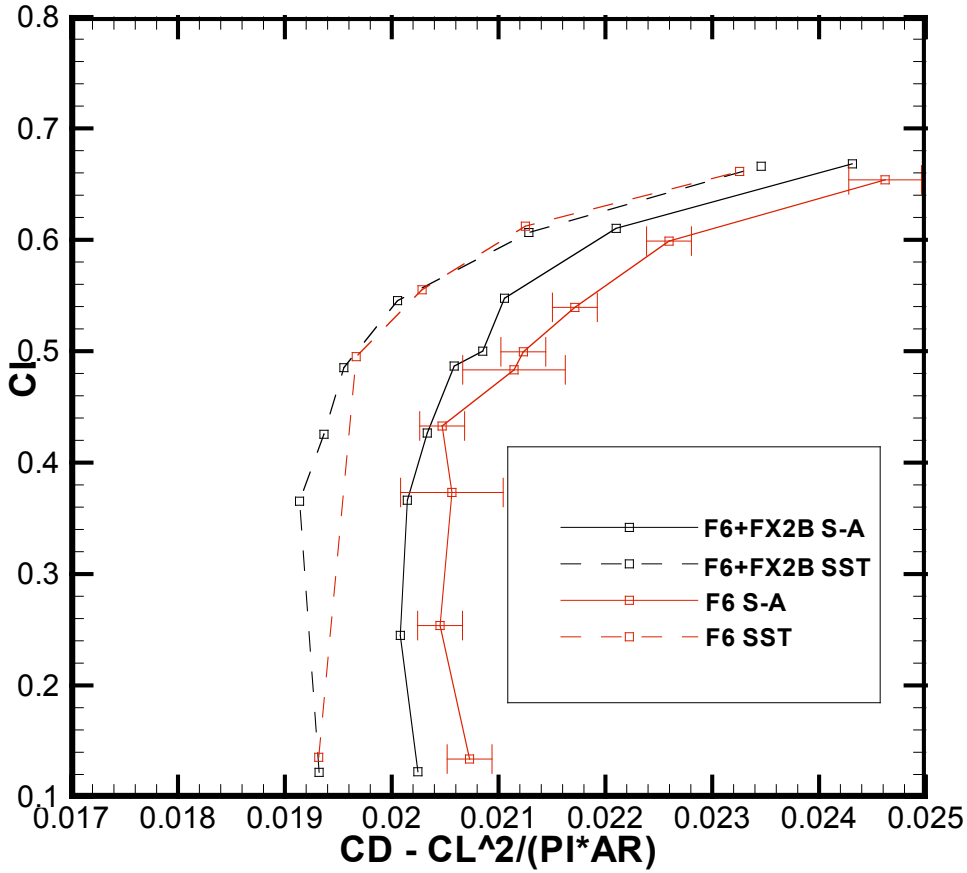


•Separation seen on the F6 geometry wing root

•No separation seen on the F6+FX2B geometry wing root

# Drag Polars

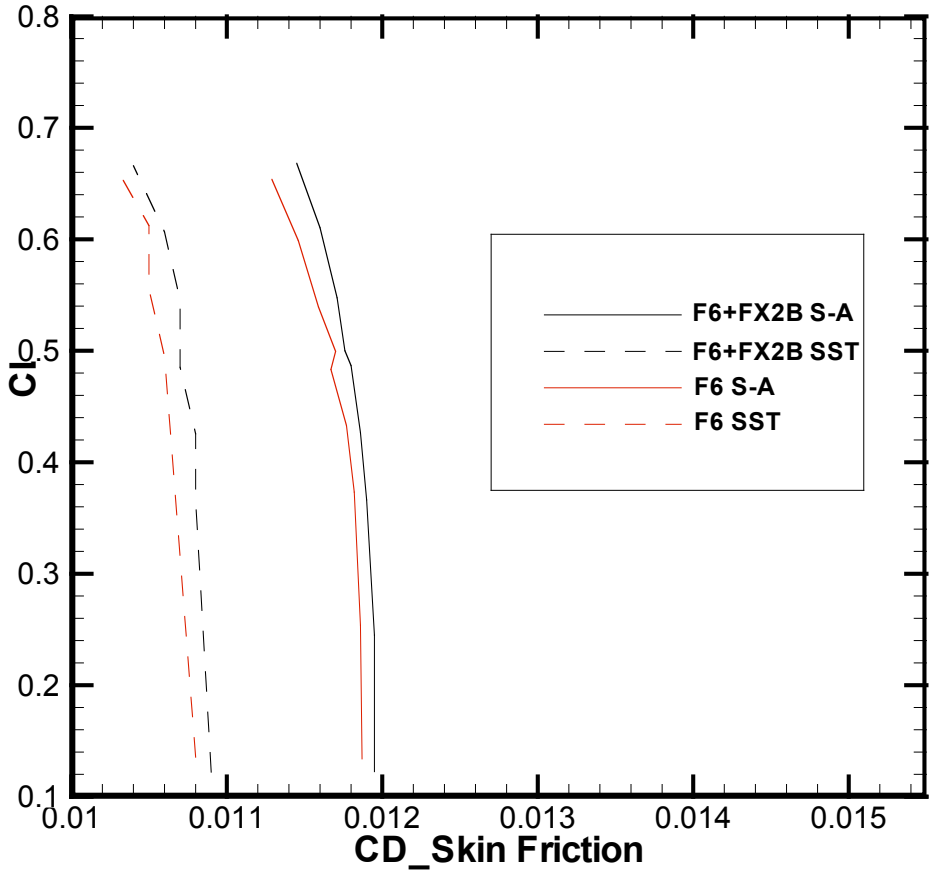





- Error bars represent magnitude of oscillations of CL in the F6 solution
- F6+FX2B solutions saw little oscillation
- SST model seen to predict ~10 counts less drag than the S-A model
- FX2B fairing seen to reduce drag regardless of turbulence model

# Skin friction behavior

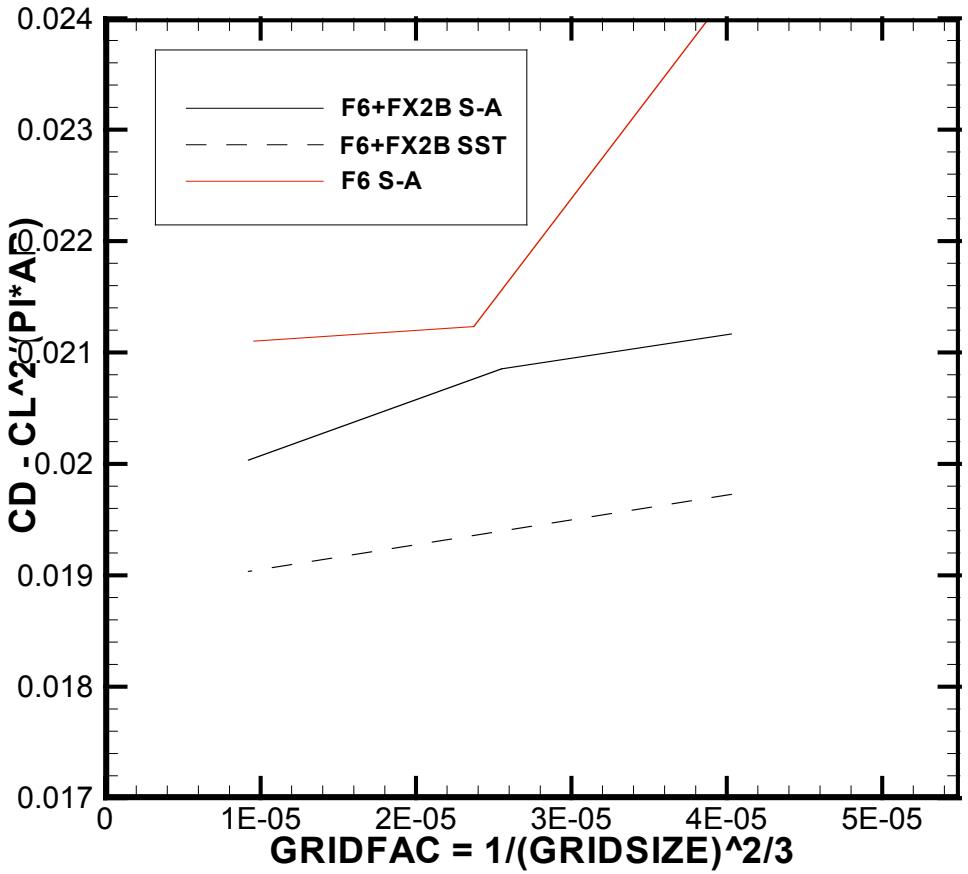





•Lower SST drag comes from reduced viscous drag contribution

# Grid convergence study

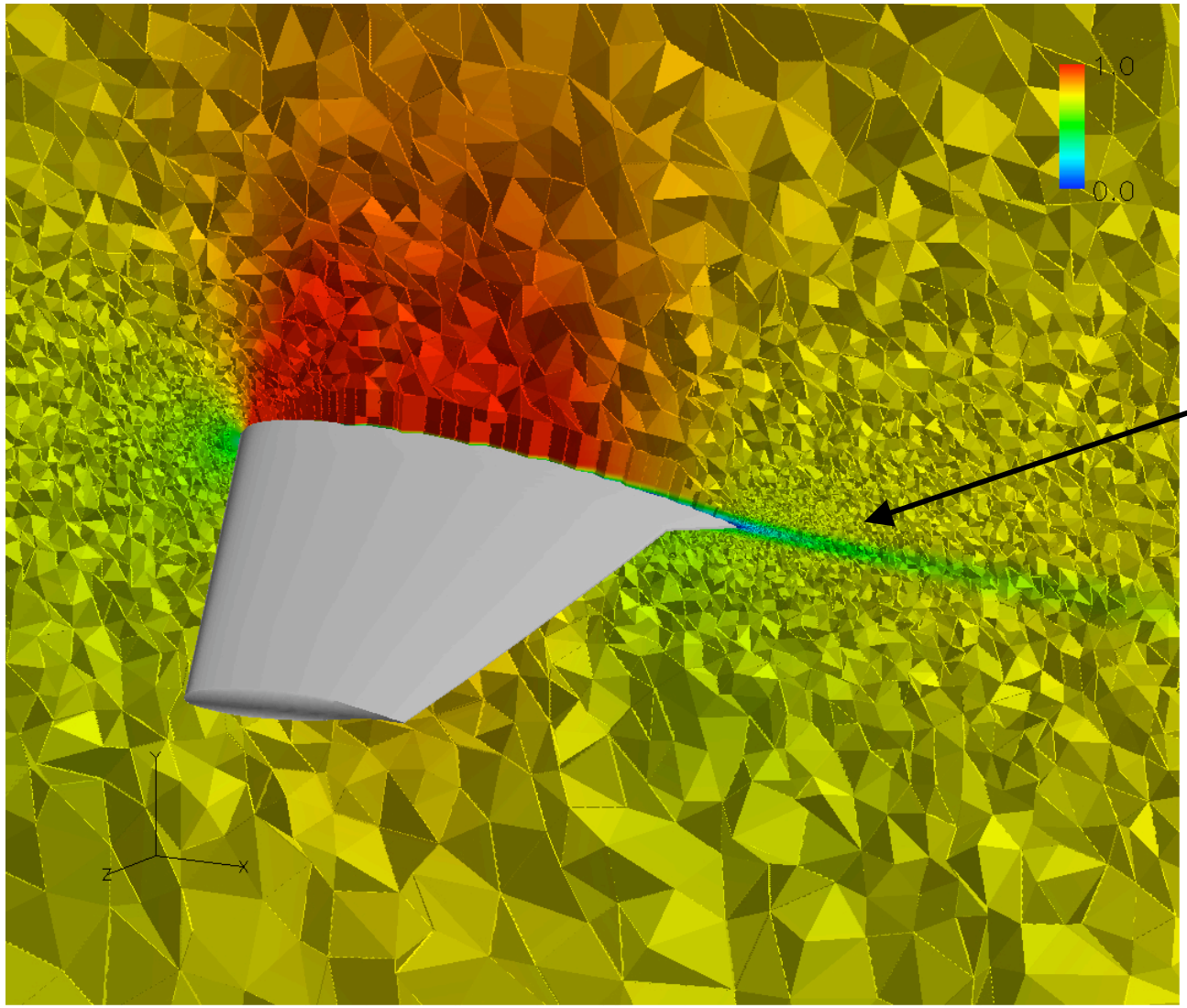





•SST results seen to extrapolate to a lower drag value when compared to S-A for the FX2B configuration

# Crinkle cut, F6+FX2B , S-A , Mach contours at BL=200mm



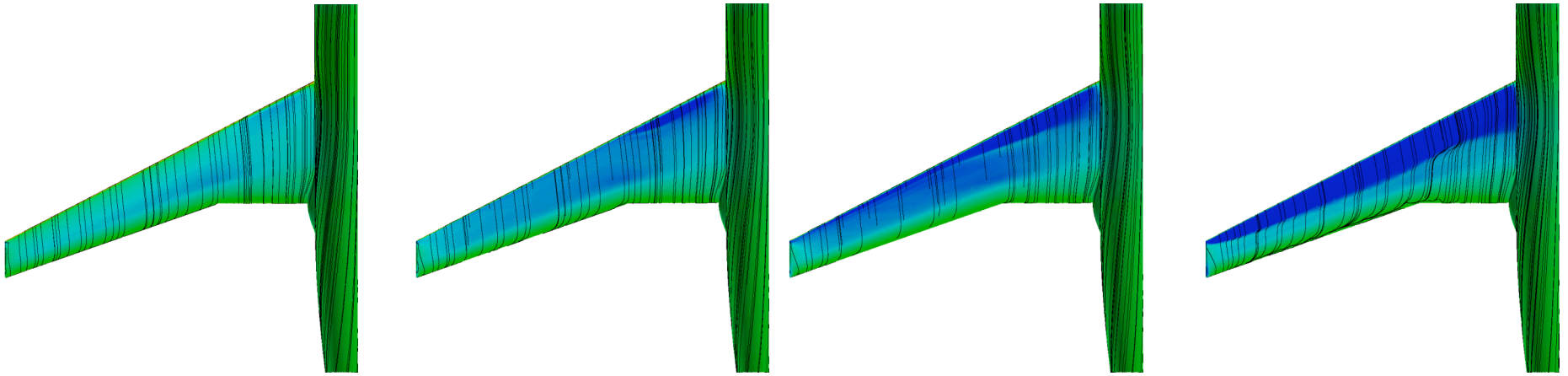



Isotropic tetrahedra quickly dissipate wake

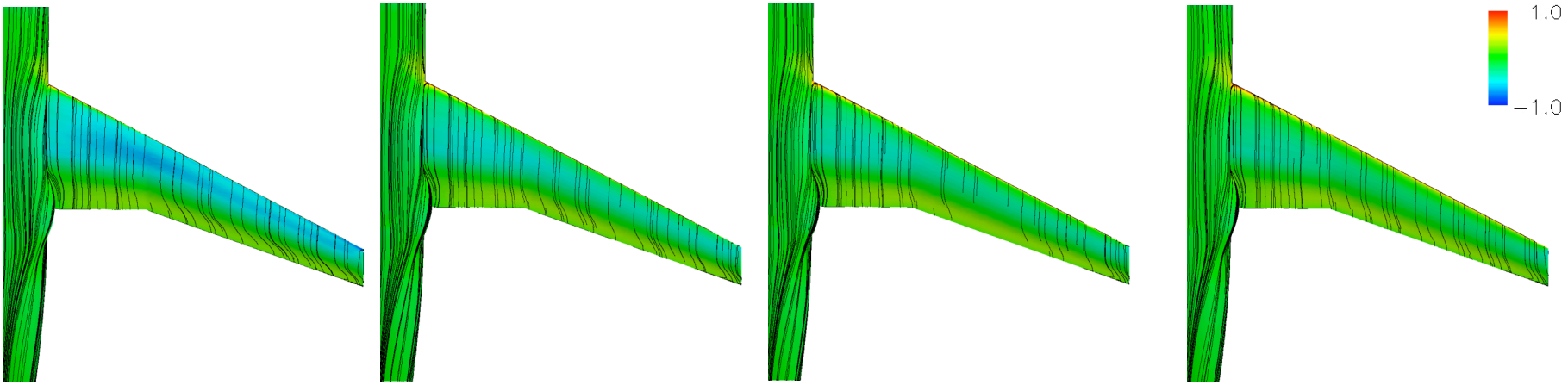
# Wing Cp contours, F6+FX2B, S-A model



Top View



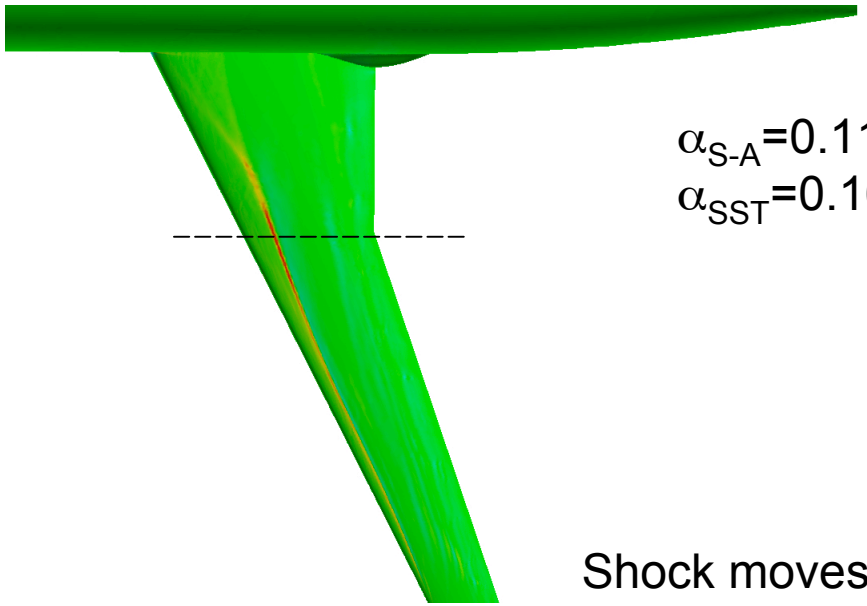
Bottom View




AoA = -3 -1 0 1.5

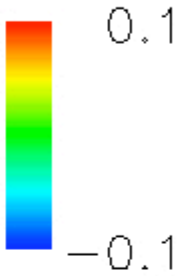
# Comparison of Cp between turbulence models
# CL=0.5, fine grid



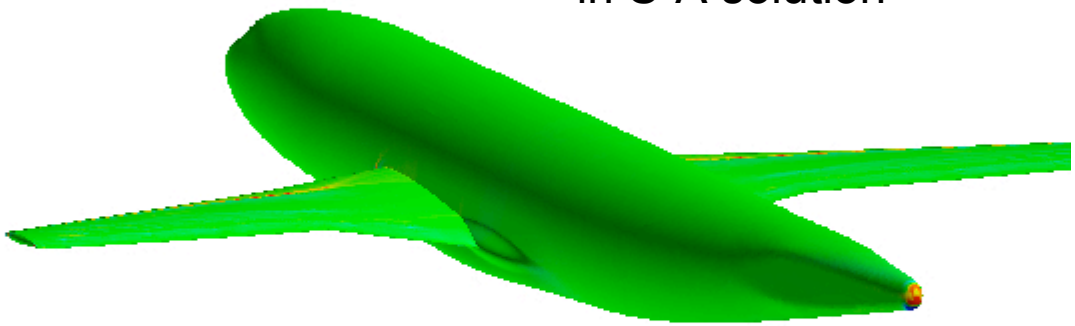


$\alpha_{S\text{-}A}$=0.119°
$\alpha_{SST}$=0.166°

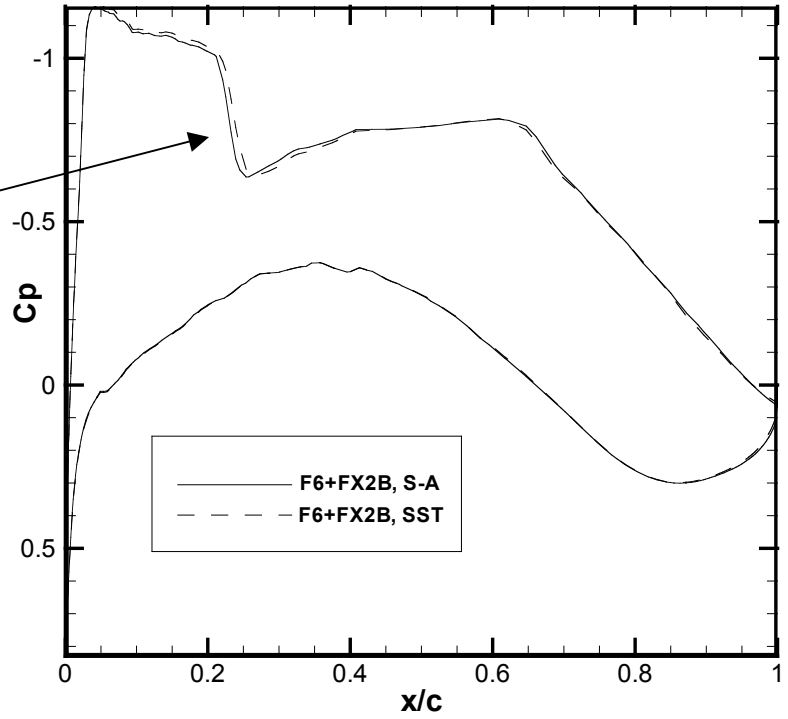
(Cp_Spalart – Cp_SST)




Shock moves forward
in S-A solution

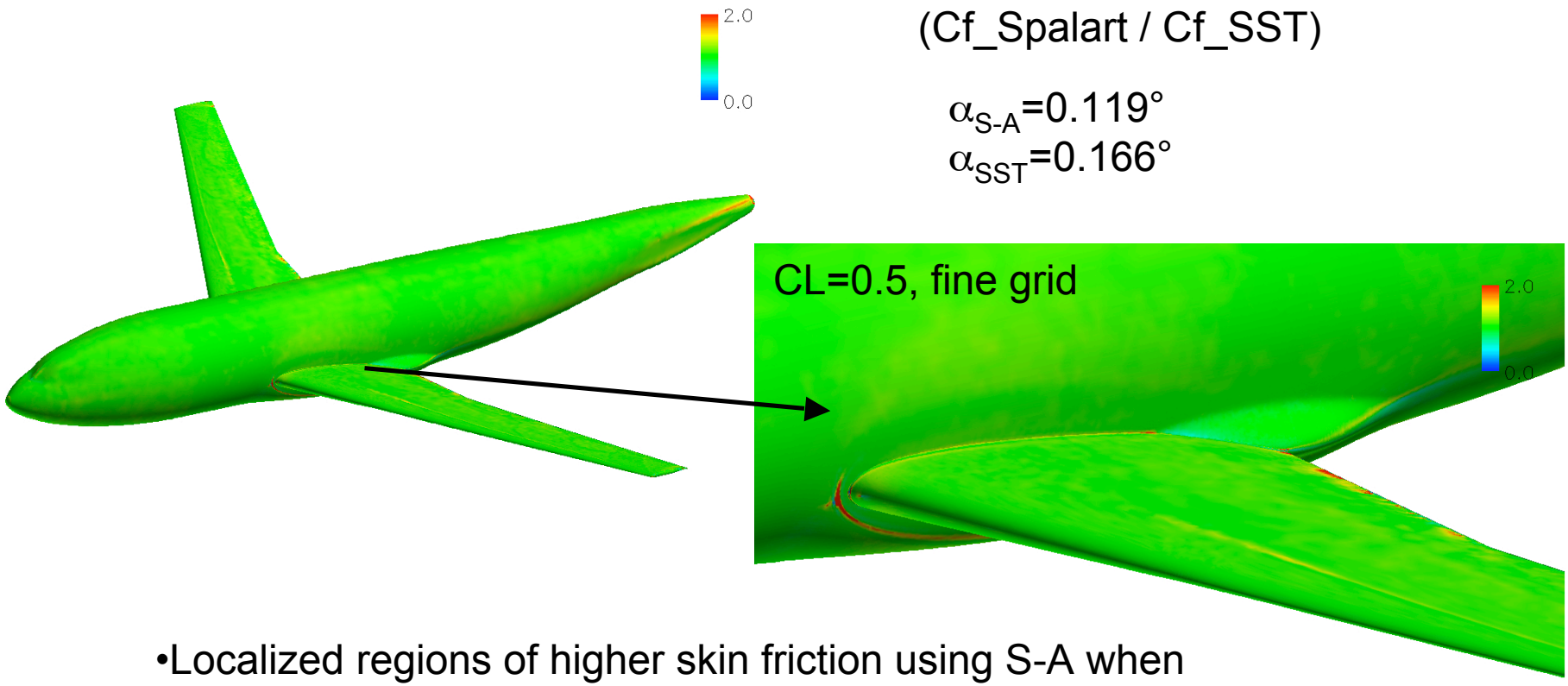


Cp cut at BL=240.37mm



# Comparison of skin friction between turbulence models






•Localized regions of higher skin friction using S-A when compared to SST

# Summary



- Strong need for best-practices in unstructured grid generation – both surface and volume gridding
- Refine wake region using localized source nodes in volume grid generation
- Difficulty converging F6 cases (without fairing) for both turbulence models
- Turbulence model + grid dependencies
  - ~10 counts drag difference predicted between S-A and SST models
  - Refine grid further to remove any grid dependency on turbulence model
- Future plans
  - Alternate grids – highly resolved and selectively resolved grids, other DPW3 grids
  - Unsteady simulations
  - Cross-code solution comparisons