CFD Drag Prediction Workshop

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Sponsored by the
Applied Aerodynamics TC

9–10 June 2001
Anaheim, CA

AIAA CFD Drag Prediction Workshop
OUTLINE

Approach

Supplied-Grid Results - Case 2

Targeted Grid-Refinement Procedure

Refined-Grid Results - Case 2

Conclusions

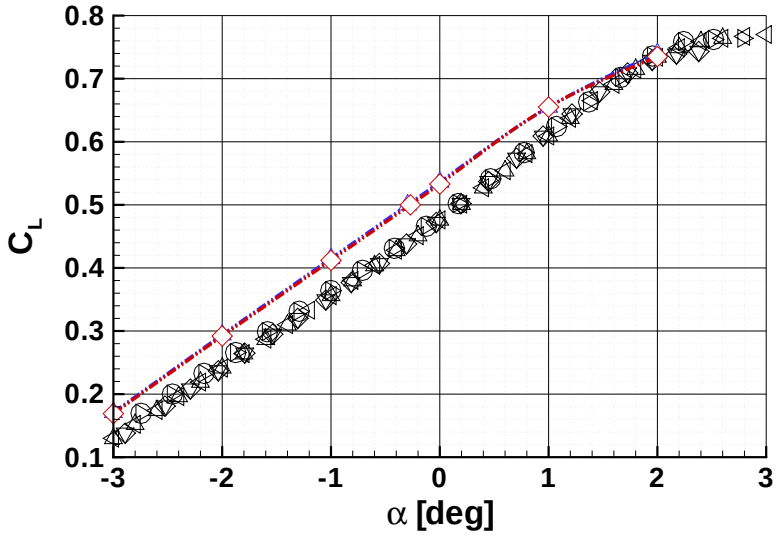
DLR-F4 Wing-Body Structured Multiblock Grid
APPROACH

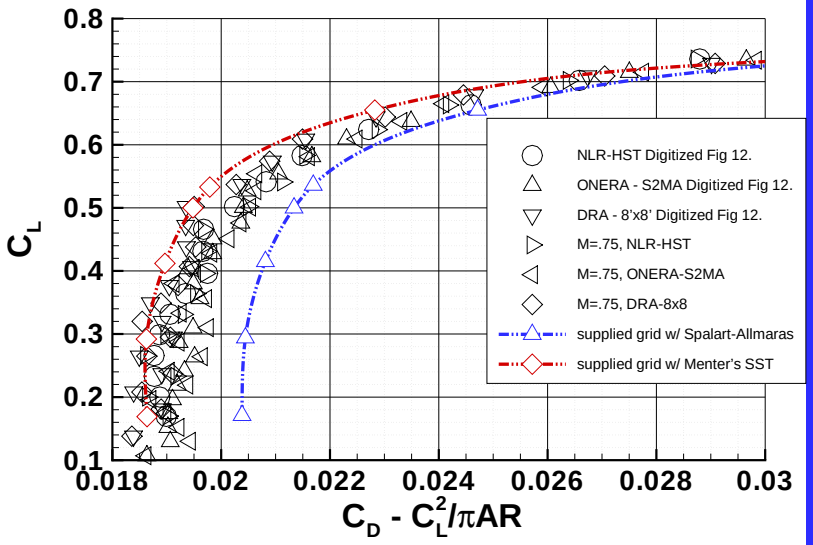
Code:	**CFL3D (Renolds-Averaged thin-layer NS solver)**
Developer:	**NASA Langley Research Center, Hampton, VA**

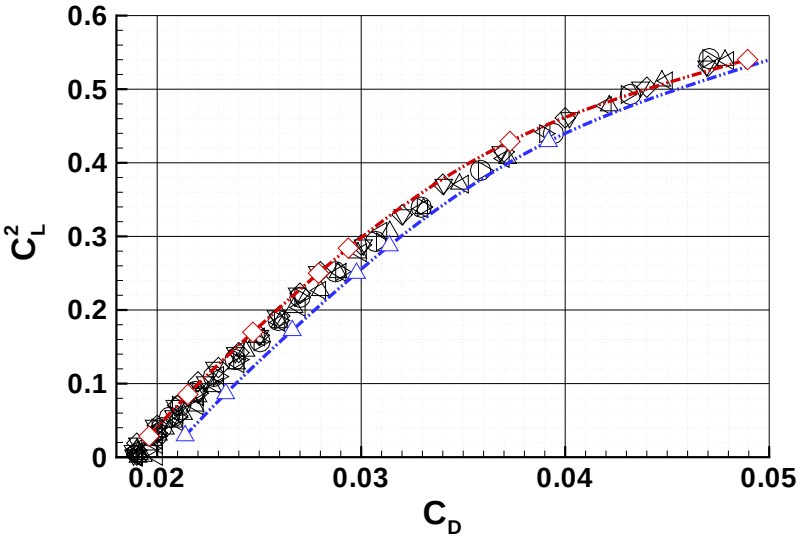
http://fmad-www.larc.nasa.gov:80/~biedron/Cfl3dv6/cfl3dv6.html

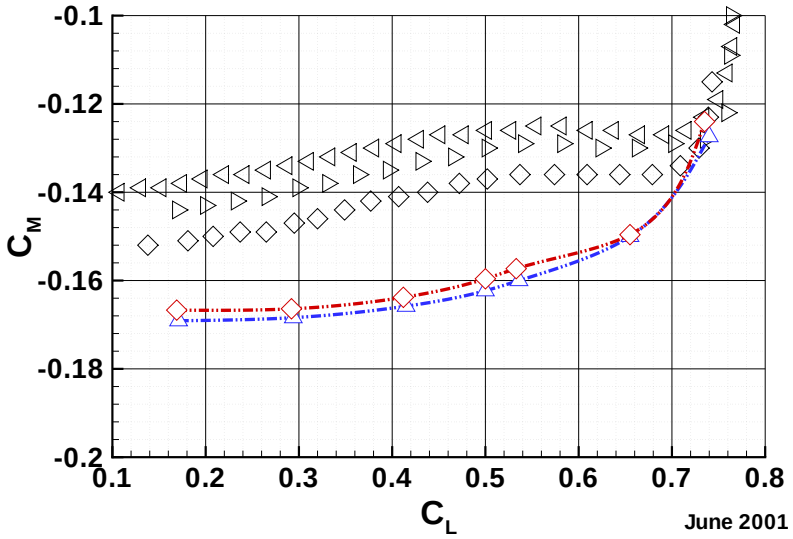
Turbulence Models:	**1) Spalart-Allmaras**
	2) Menter's k-ω SST
Grids:	**Multiblocked with 1-1 Grid-Node Connectivity**
Grid-Generator:	**ICEM**
Size:	**1) 49 blocks / 3.26 million nodes (supplied)**
	2) 49 blocks / 7.17 million nodes (refined)
Computer Platform:	**Microway Beowulf w/ VP2000 Motherboards**
# Processors:	**4+1 (supplied), 8+1 (refined)**
Operating System:	**Red Hat LINUX 6.2**
Compiler:	**Compaq Fortran V1.0-920**
Wall-Clock Run Time:	**~ 20 hours**
Results:	**Case2 - Drag Polar at M = 0.75**

DLR-F4 Wing-Body Structured Multiblock Grid
CFL3D, Case 2 Results, M = 0.75, Re = $3x10^6$









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Solution Reconstruction Analysis

Difference bewteen computed cell-average value & the reconstructed cell-averaged value.

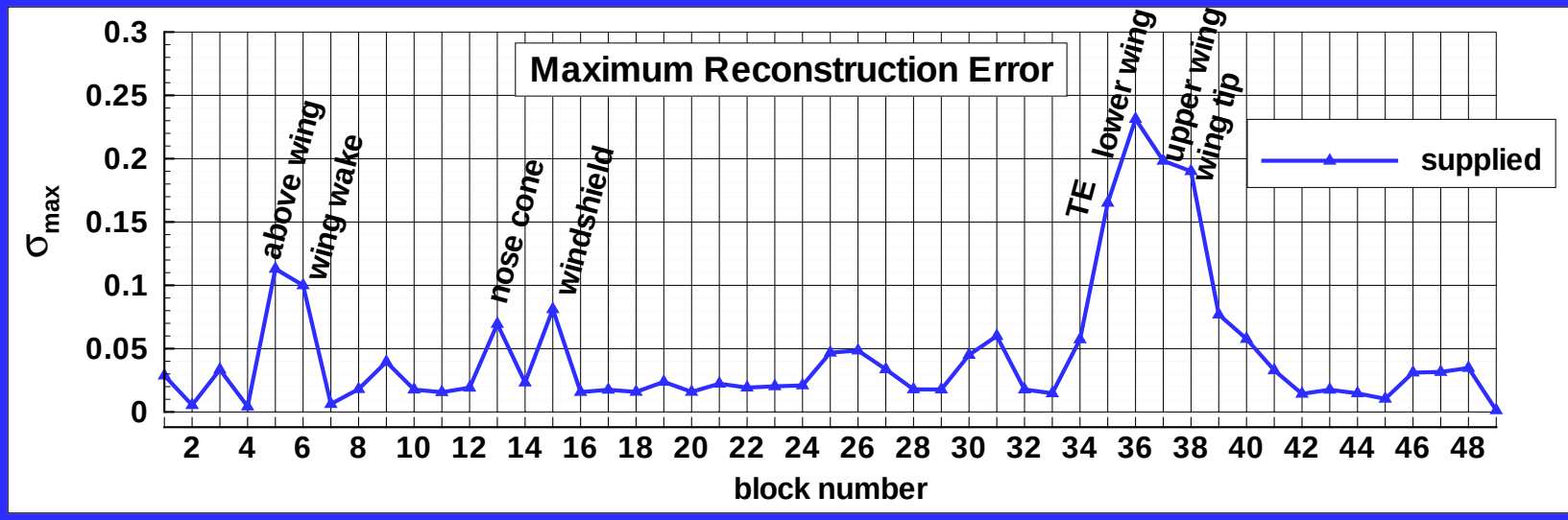
$$\sigma_i = \left\| \vec{U}_i - \frac{1}{V_i} \int_{\Omega_i} U(\vec{r})\, dV \right\|$$

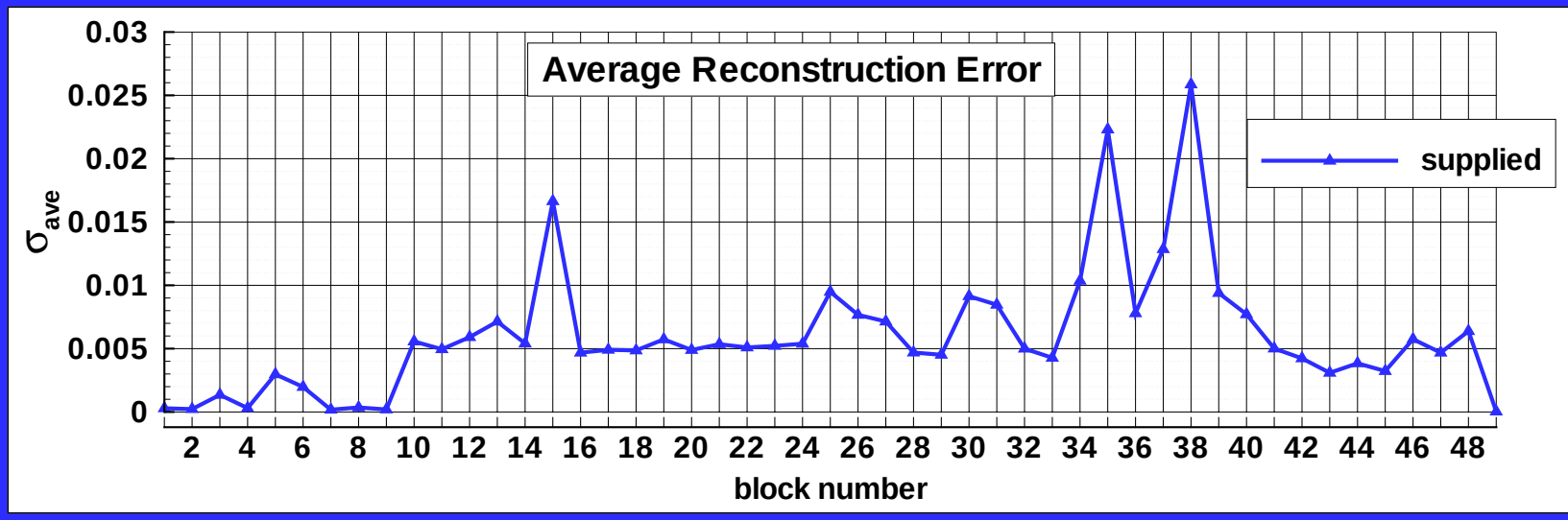
Efficiently approximated using a weighted Laplacian.

$$\sigma_i \approx \left\| \sum_k (\vec{U}_i - w_k \vec{U}_k) \right\| \approx \left\| \nabla^2 \vec{U} \right\|$$

$$\vec{U} = (\rho, u, v, w, p)^T$$

DLR-F4 Wing-Body Structured Multiblock Grid
CFL3D - Spalart-Allmaras, Case 2 Results, M = 0.75, Re = 3×10^6, $\alpha = 2^o$

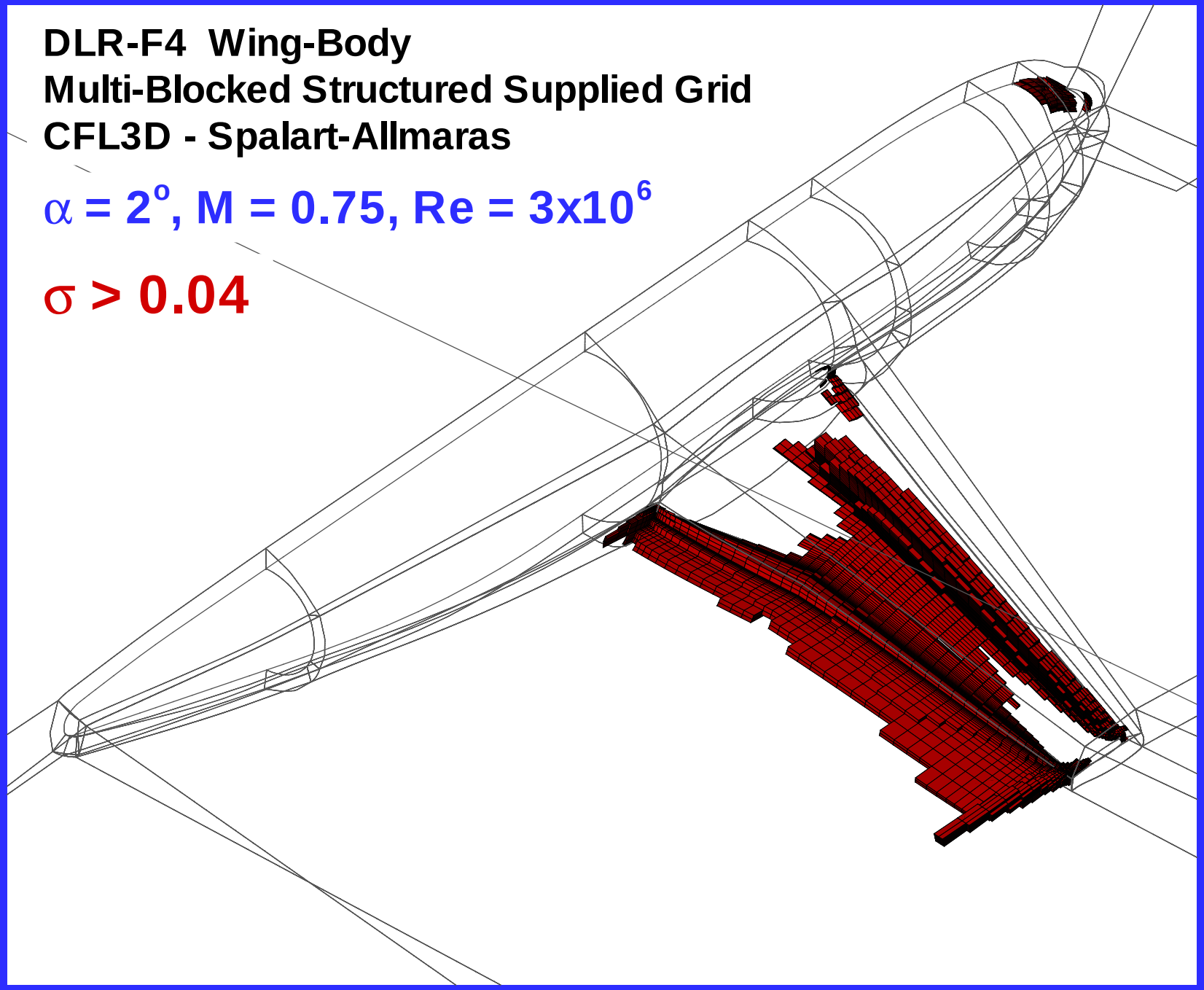




DLR-F4 Wing-Body
Multi-Blocked Structured Supplied Grid
CFL3D - Spalart-Allmaras

$\alpha = 2^{o}$, M = 0.75, Re = 3×10^{6}

$\sigma > 0.04$



DLR-F4 Wing-Body Structured Multiblock Grid Parameters Supplied vs. Refined

Supplied

Cells:	3,180,800
wing chord:	69 nodes
chordwise spacing - root:	~ 0.002c
tip:	~ 0.0007c
wing span:	57 nodes
spanwise spacing - root:	~ 0.007c
tip:	~ 0.006c
fuselage length:	191 nodes
fuselage circum.:	69 nodes
wing TE:	9 nodes
O-grid:	21 nodes

$y+_{max} = 3.0,\ y+_{ave} = 0.93$

Refined

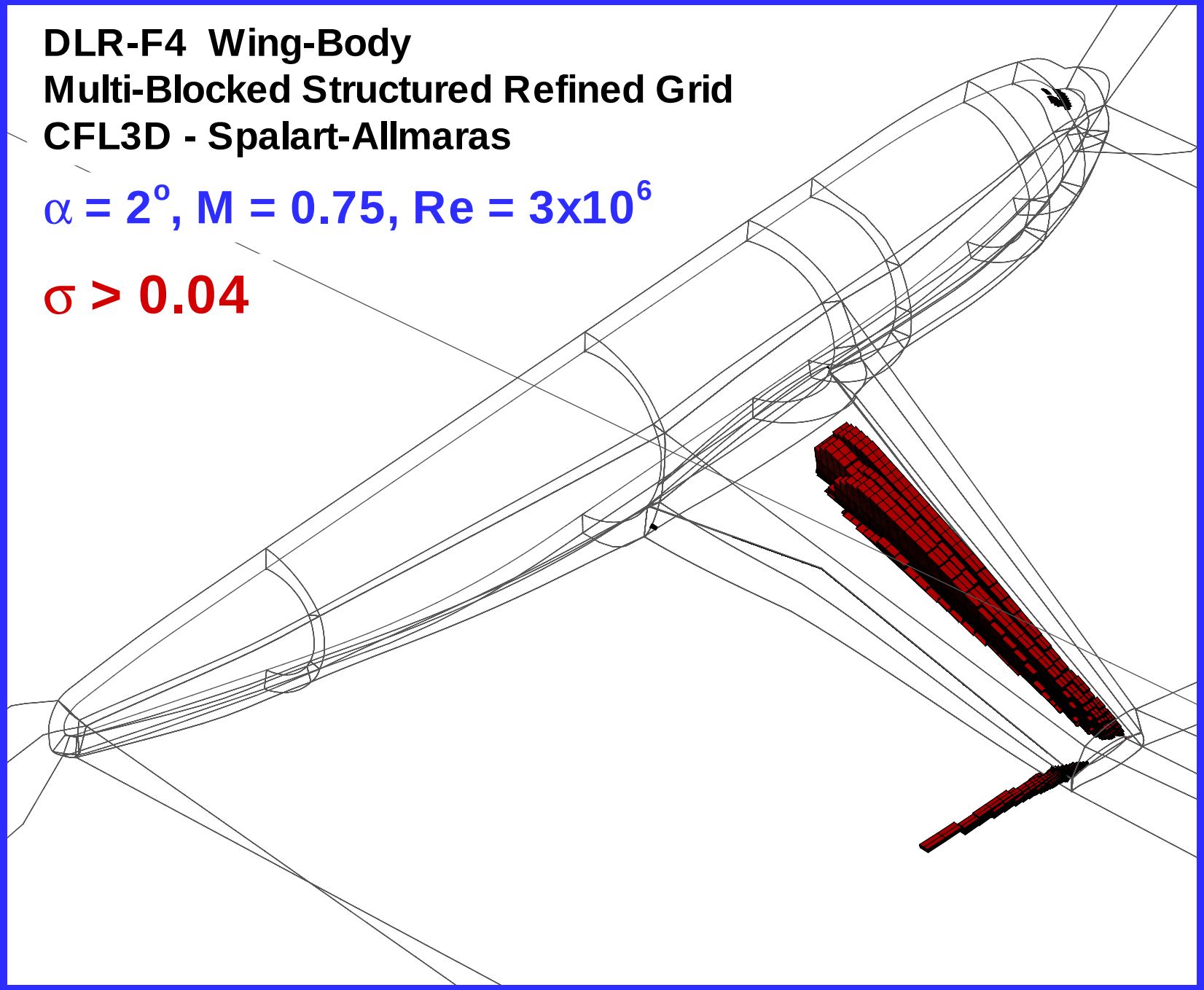
Cells:	7,042,048
wing chord:	73 nodes
chordwise spacing - root:	~ 0.0004c
tip:	~ 0.0002c
wing span:	93 nodes
spanwise spacing - root:	~ 0.0007c
tip:	~ 0.0007c
fuselage length:	229 nodes
fuselage circum.:	129 nodes
wing TE:	33 nodes
O-grid:	33 nodes

$y+_{max} = 5.0,\ y+_{ave} = 0.65$

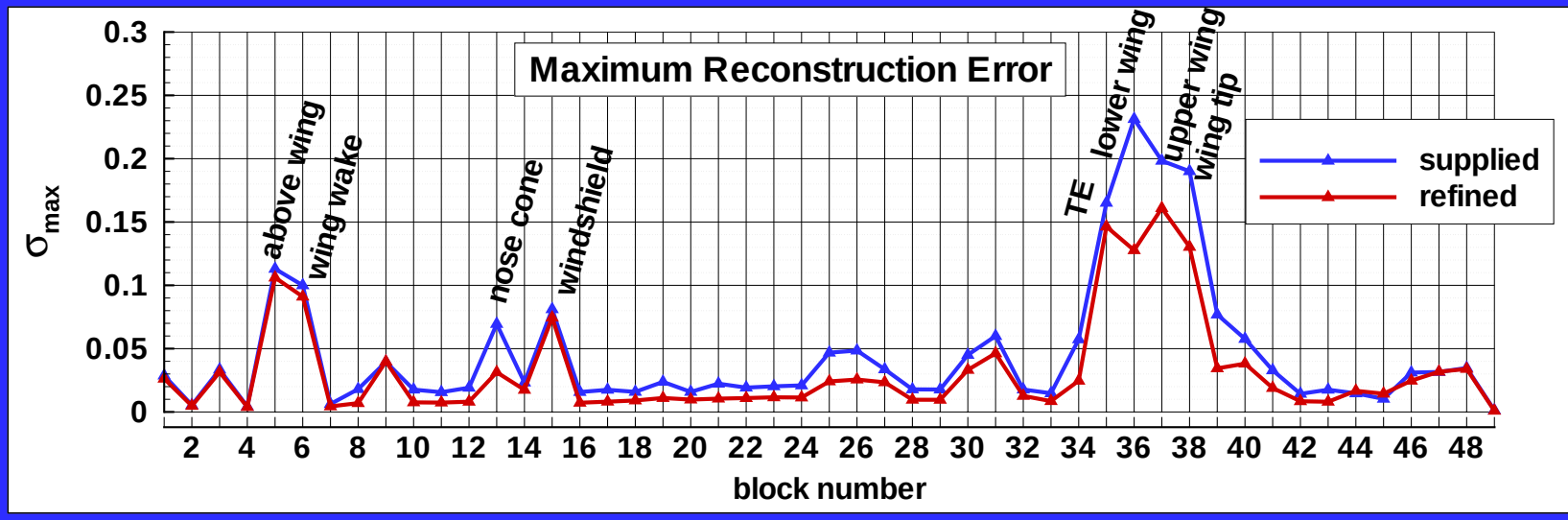
DLR-F4 Wing-Body
Multi-Blocked Structured Refined Grid
CFL3D - Spalart-Allmaras

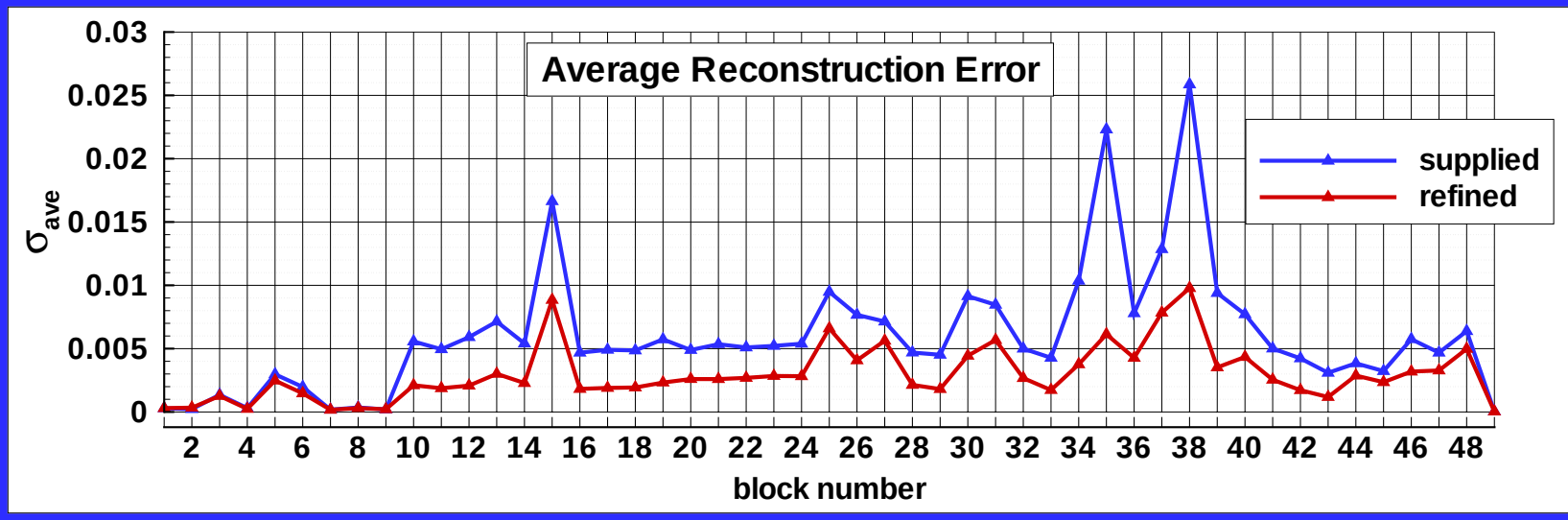
$\alpha = 2^{o}$, M = 0.75, Re = 3×10^{6}

$\sigma > 0.04$



DLR-F4 Wing-Body Structured Multiblock Grid
CFL3D - Spalart-Allmaras, Case 2 Results, M = 0.75, Re = 3×10^6, $\alpha = 2^o$





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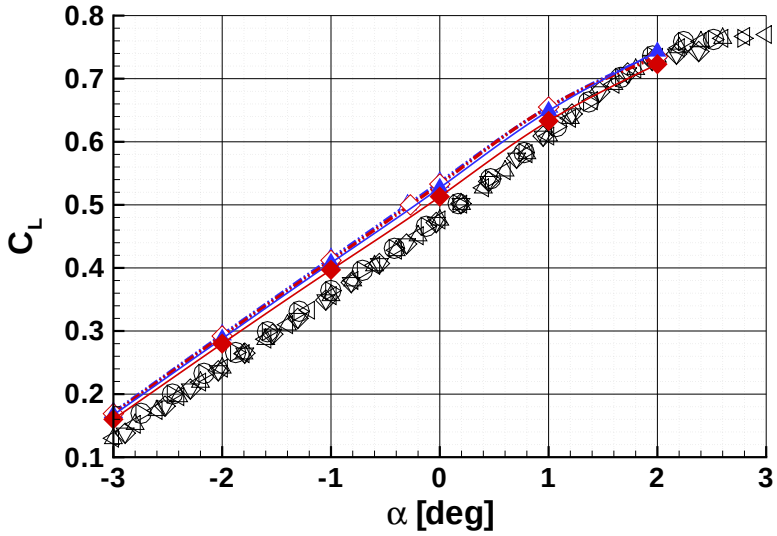

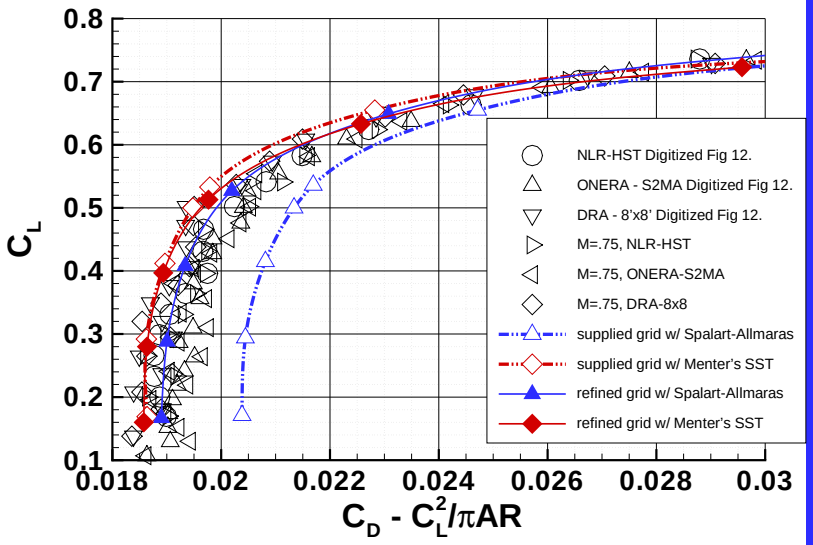

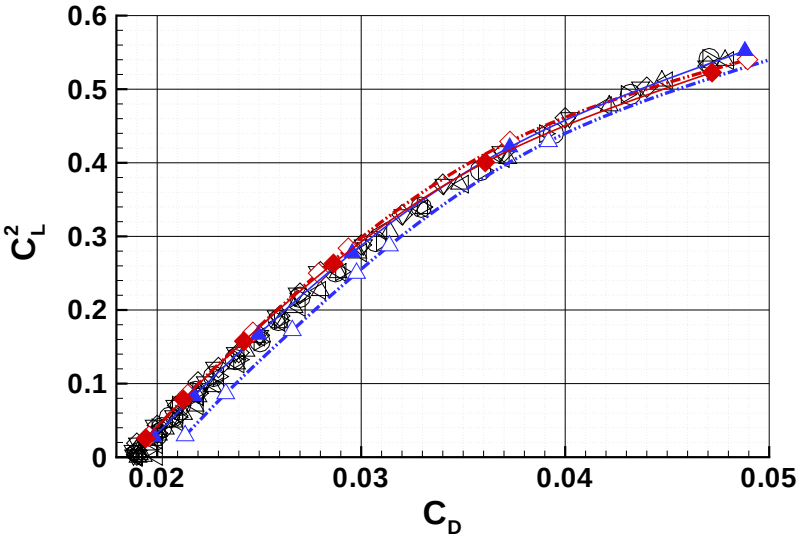

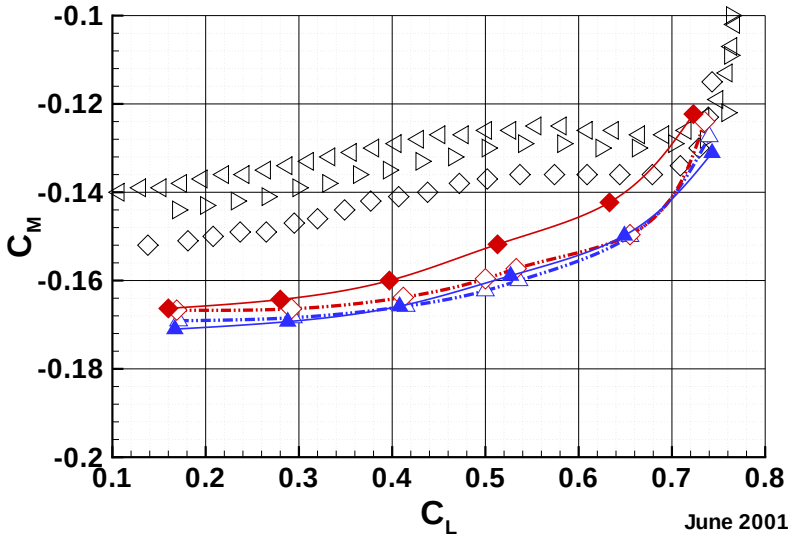

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CONCLUSIONS

CFL3D is robust and gives reasonable results, even if grids of "questionable" quality are used.

Spalart-Allmaras turbulence model was more sensitive to grid refinement than was Menter's k-ω SST model.

Drag decreases with grid refinement using Spalart-Allmaras model.
Drag increases with grid refinement using Menter's k-ω SST model.
(Analysis shows that the difference in drag between the two models is primarily attributed to differences in skin friction drag.)

Solution Reconstruction Analysis led to targeted grid refinement, resulting in "improved" drag prediction for both turbulence models.

Using the targeted grid refinement procedure, the scatter in drag between CFL3D results using the Spalart-Allmaras model and Menter's k-ω SST model was reduced from about 18 drag counts on the supplied grid to about 3 drag counts on the refined grid, at CL=0.5.