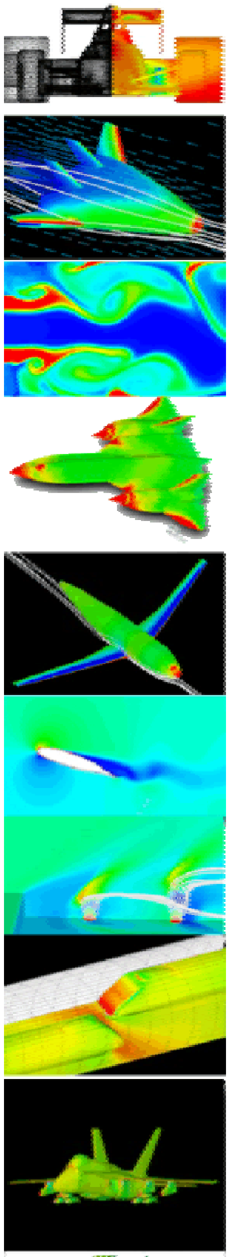

AIAA CFD Drag Prediction Workshop

Presenter: **Dr. Uriel Goldberg**

Metacomp Technologies, Inc.

Anaheim, CA June 9-10, 2001

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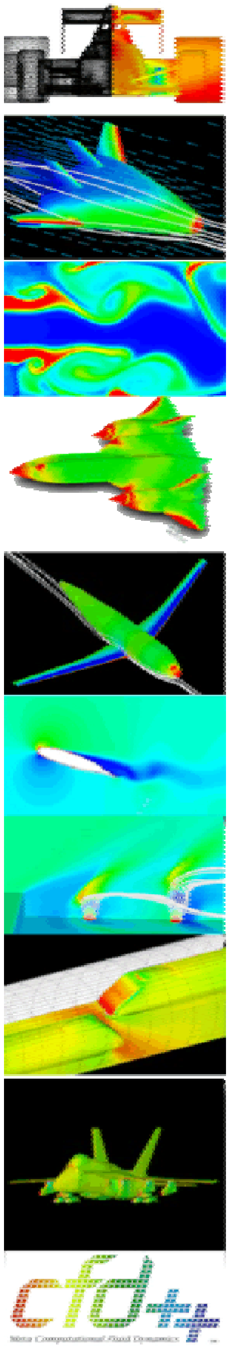


Attributes of CFD++

Seamlessly handles most flow regimes

- Hypersonic
- Supersonic
- Transonic
- Low Speed
- Incompressible

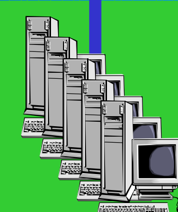
Flow Regime

- **Ability to handle all Cell types; e.g.:**
  - Hexahedral
  - Tetrahedral
  - Prism
  - Pyramid
  - Quadrilateral
  - Triangle
  - Line
- **Ability to handle all grids**
  - Structured
  - Unstructured
  - Hybrid
  - Patched non-aligned
  - Overset
  - Meshes with gaps

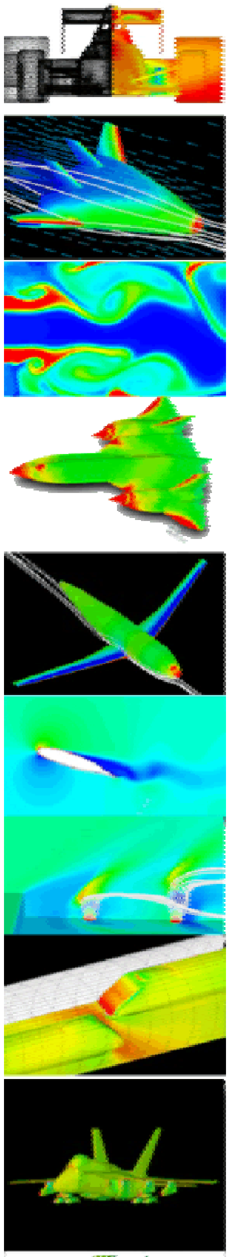
Linux | Windows NT Server | Unix

CFD++'s Unified Computing Environment

Massively Parallel

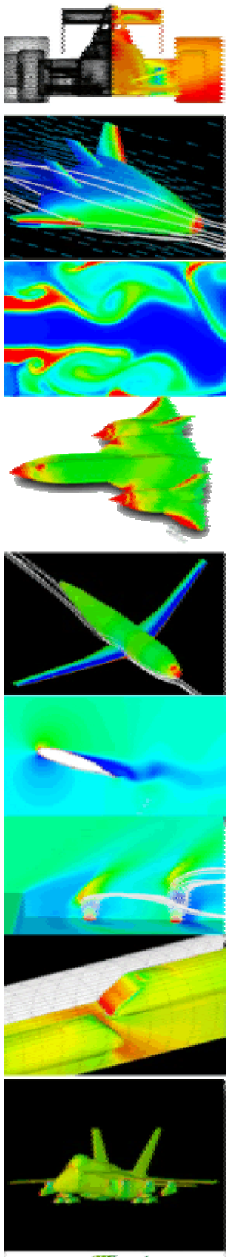


Workstation Clusters



Numerical Framework in CFD++

- Finite Volume Framework
- Spatial discretization
  - Multi-dimensional TVD scheme for inviscid terms
  - Non-decoupling non-limited face polynomials for viscous terms.
- Time Integration
  - Explicit Runge-Kutta schemes
  - Point Implicit with Multigrid relaxation
- Riemann Solvers



Physical Models

- Turbulence Models
  - 1,2, & 3 Eq. closures
  - Linear, Cubic
  - Advanced Wall Function
- LES and hybrid RANS/LES models
- Reacting flows
- Multi-phase

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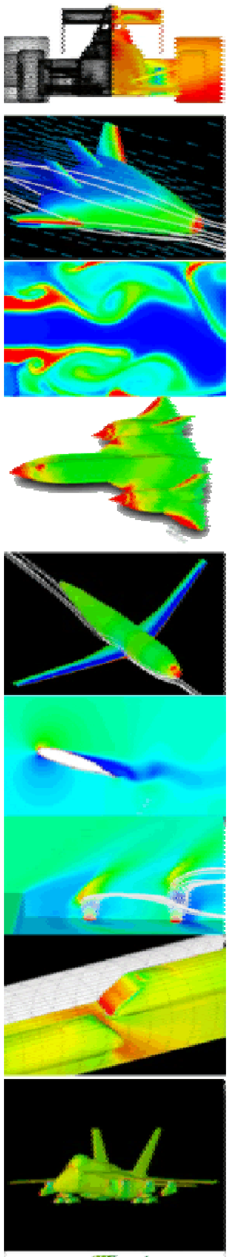
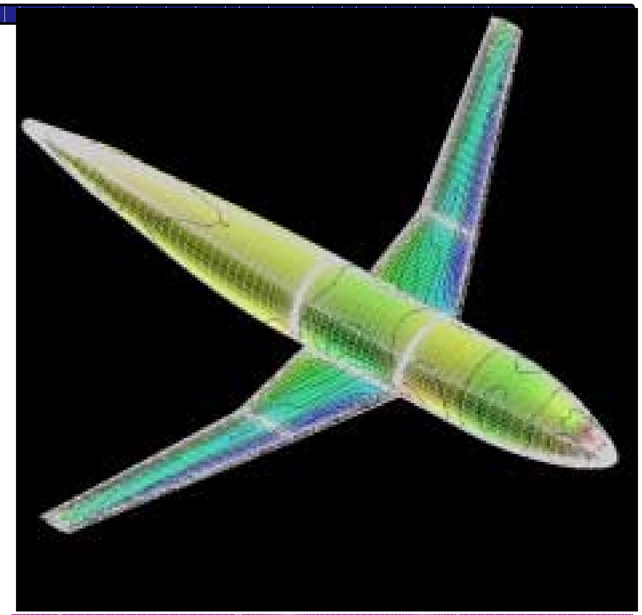
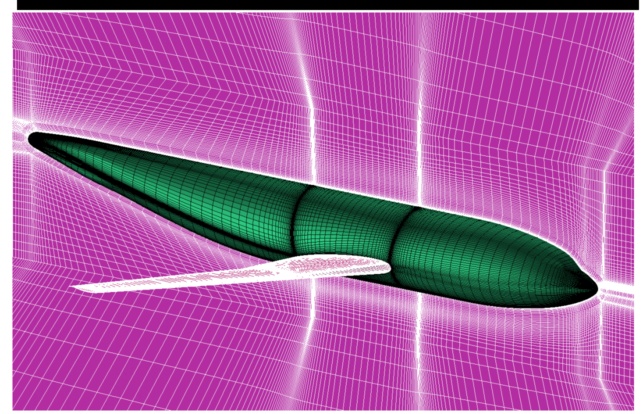


Computational Grid

- Utilized ICEM CFD Hexa
- 3.5 Million hexahedras
- cell height off the wall: 0.007mm
- cell growth rate: 1.21-1.30
- B.L. cells:20
- 8 hours to produce from IGES





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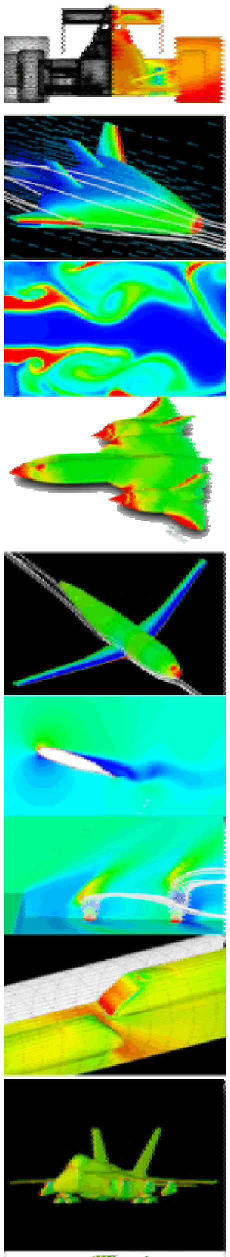

DLR-F4 WING/BODY Flow Conditions

- Re = 3x10^6 (based on Cref = 141.2 mm)
- M = 0.75
- T’ = 0.2%
- turb. length scale <u>not specified</u>
- A.O.A -3 to 2 deg.
- Fully turbulent free air flow

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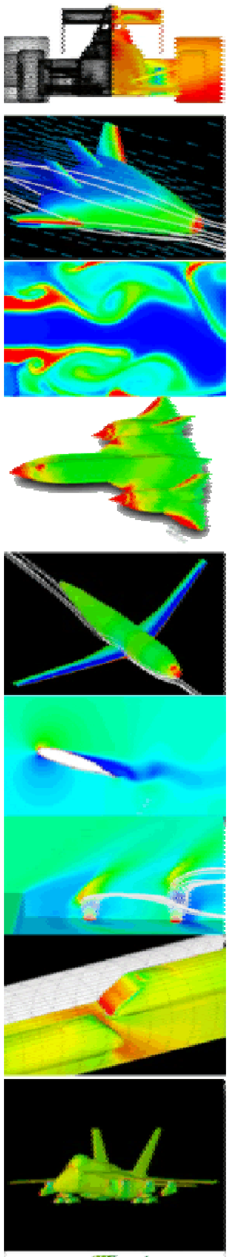
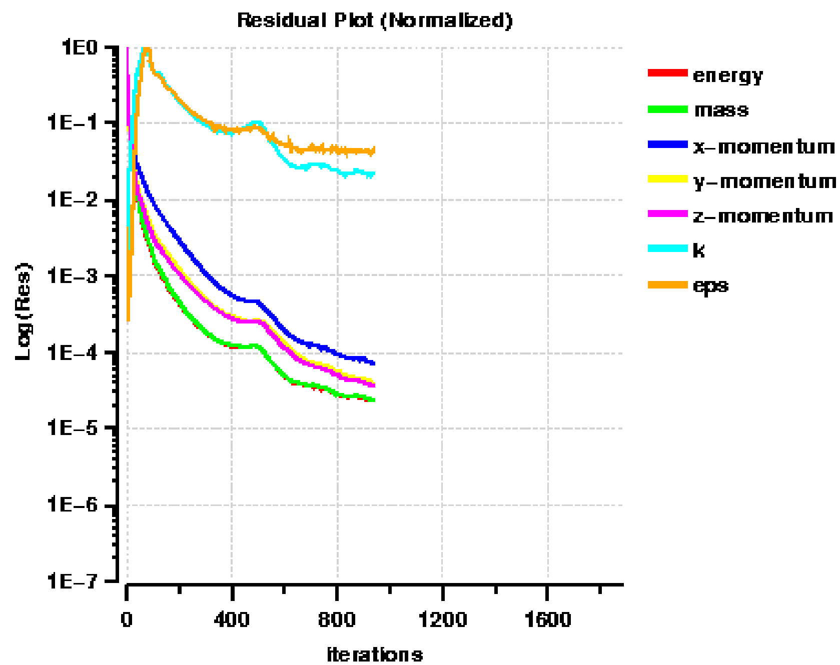


DLR - F4 WING/BODY Solution

- Wall-distance-free realizable k-ε model
  - obeying the Schwartz inequality
- Case 1: solve-to-wall (STW), $y^+<2$ (3.5M Hex)
- Case 2: wall function, $y^+=50$ (3.2M Hex)
- Computer: SGI Origin 2000
- Processors: 16 R12000 300 MHz
- Run time: 20 hours wall clock
- Memory: 8.1GB
- No grid refinements done



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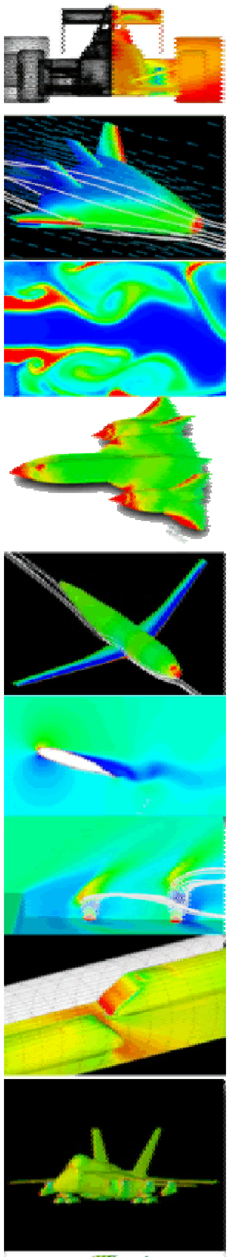
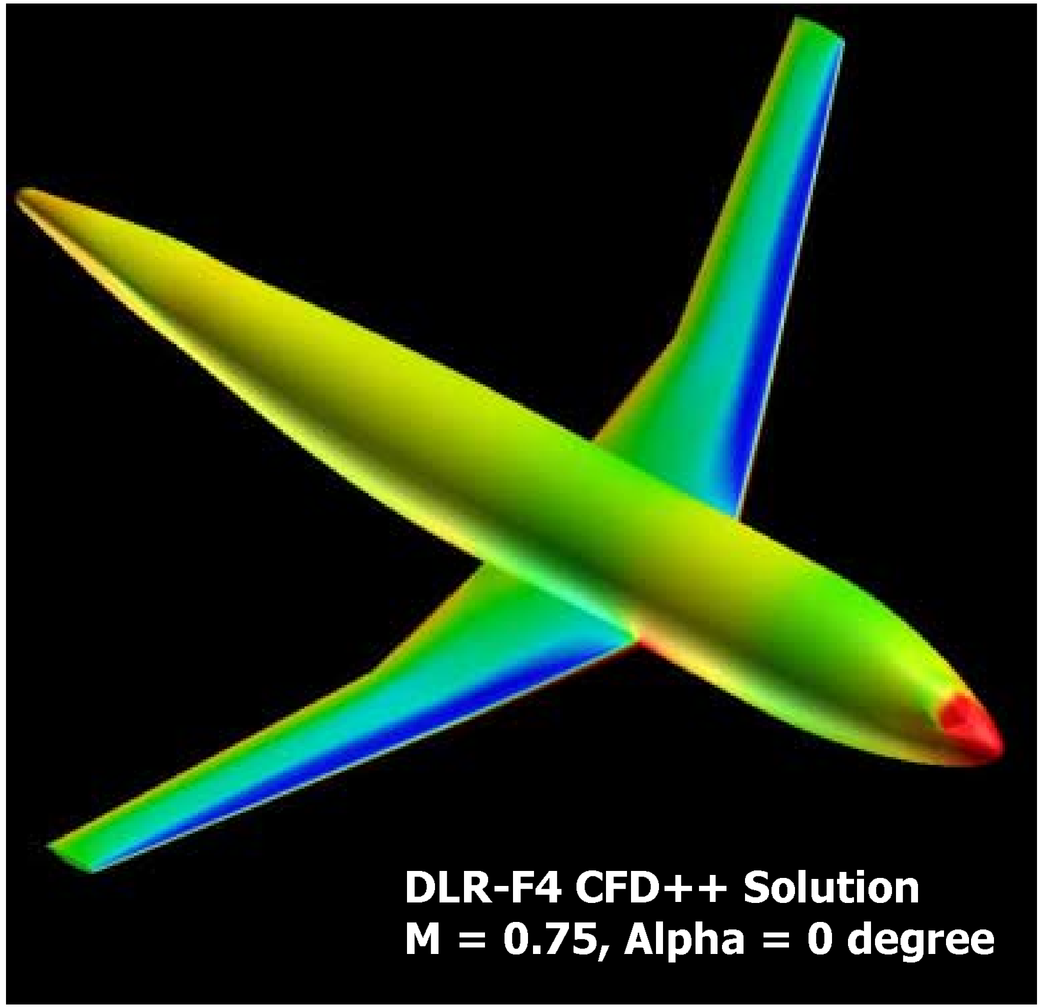
DLR F4 - CFD++ Solution Results





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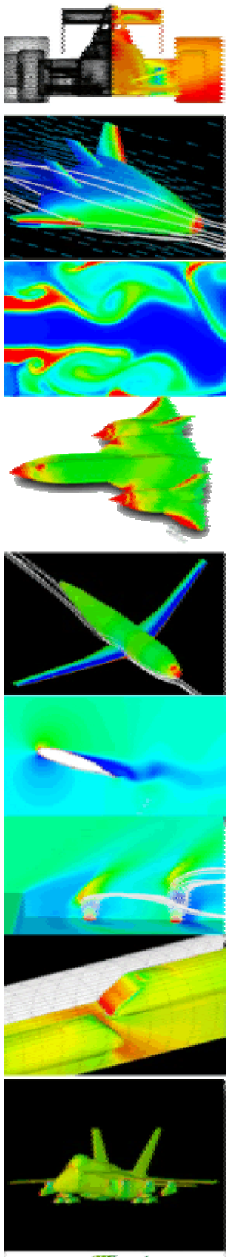
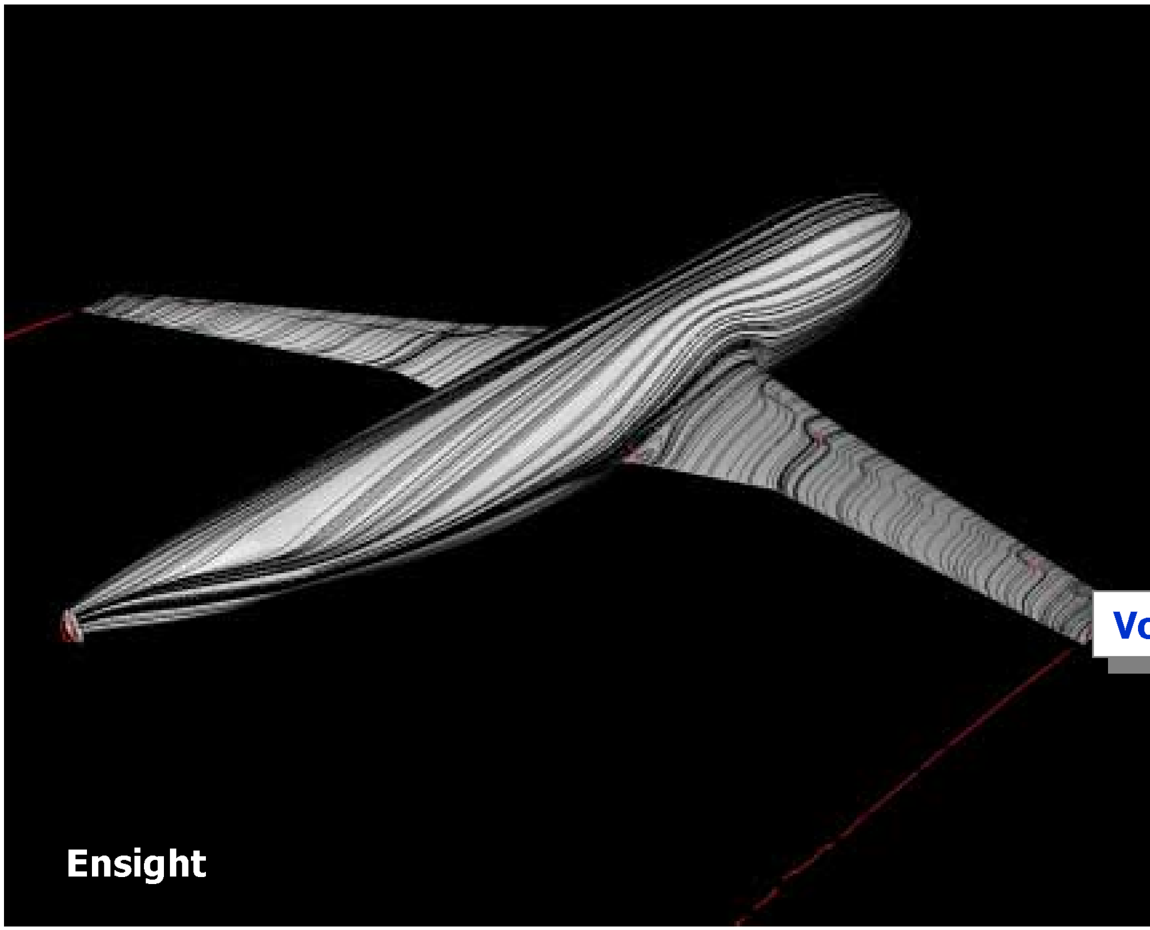
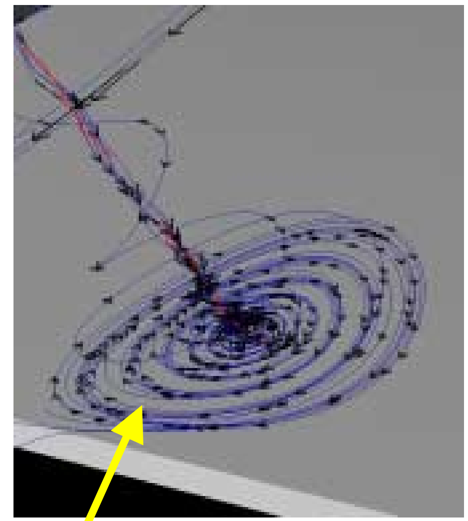
DLR Wind Tunnel Test Geometry







Vortex cores at wing root

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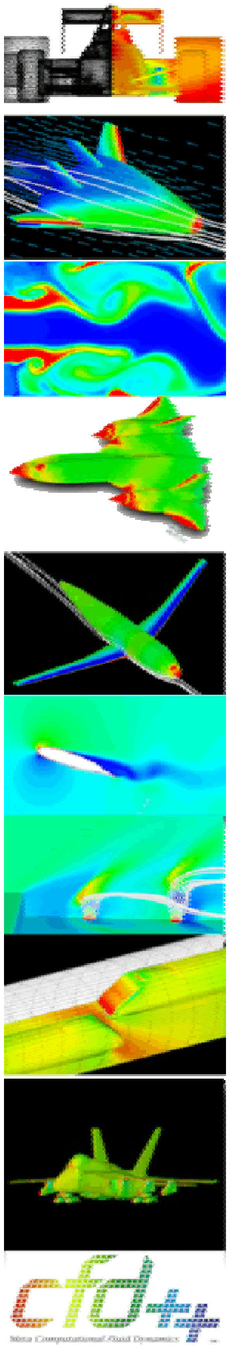
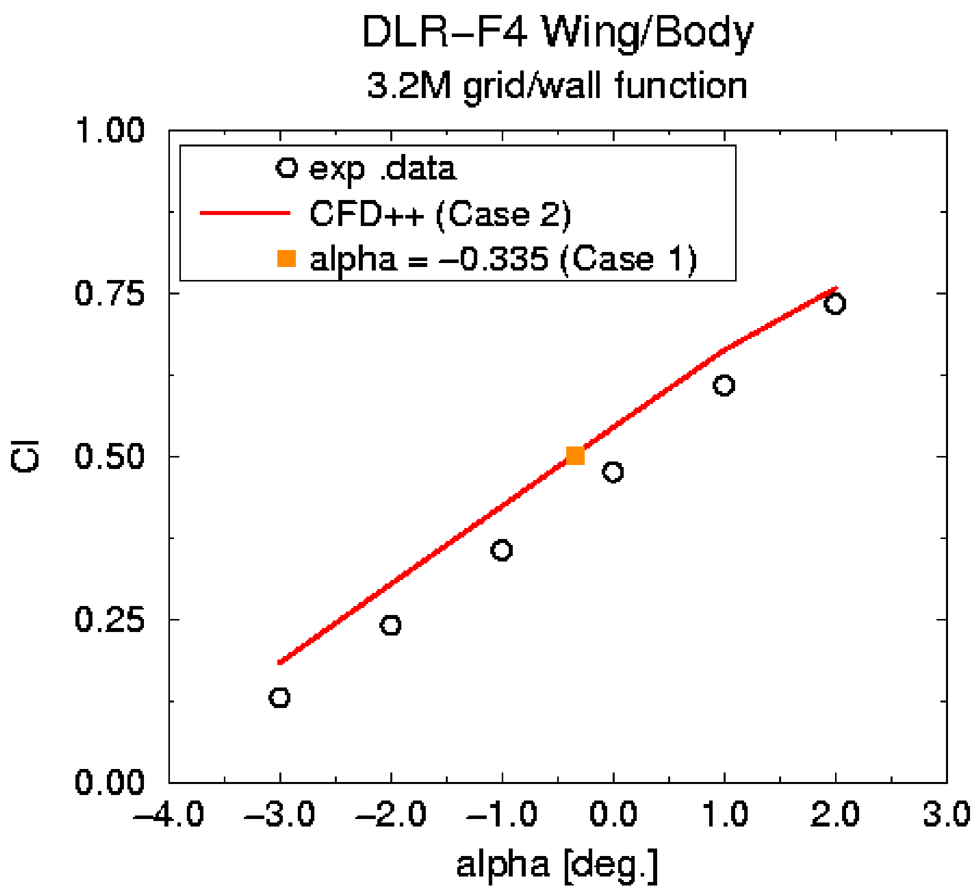
DLR F4 - CFD++ Solution Results





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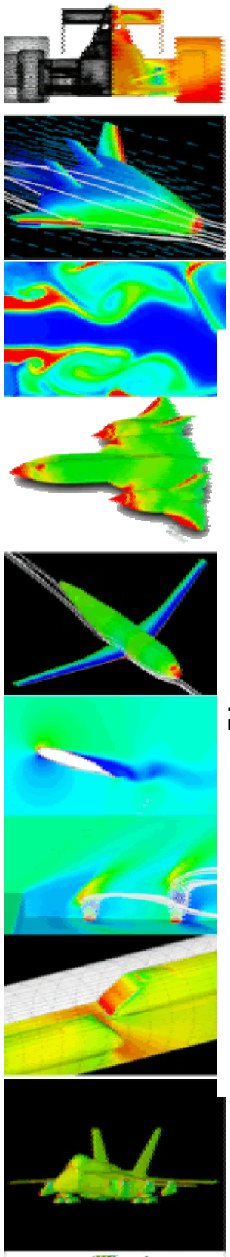
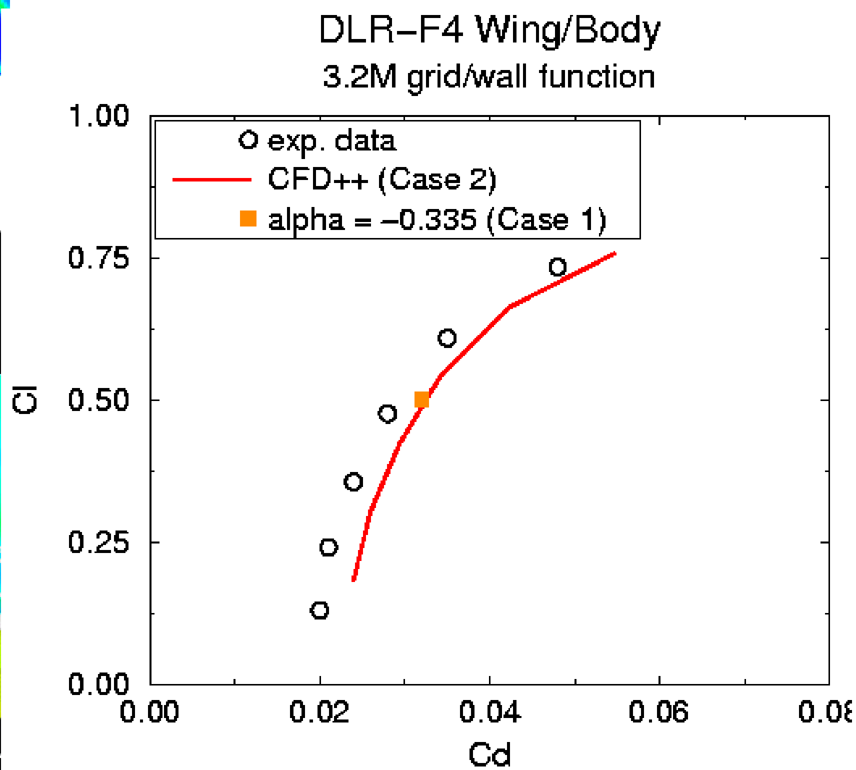
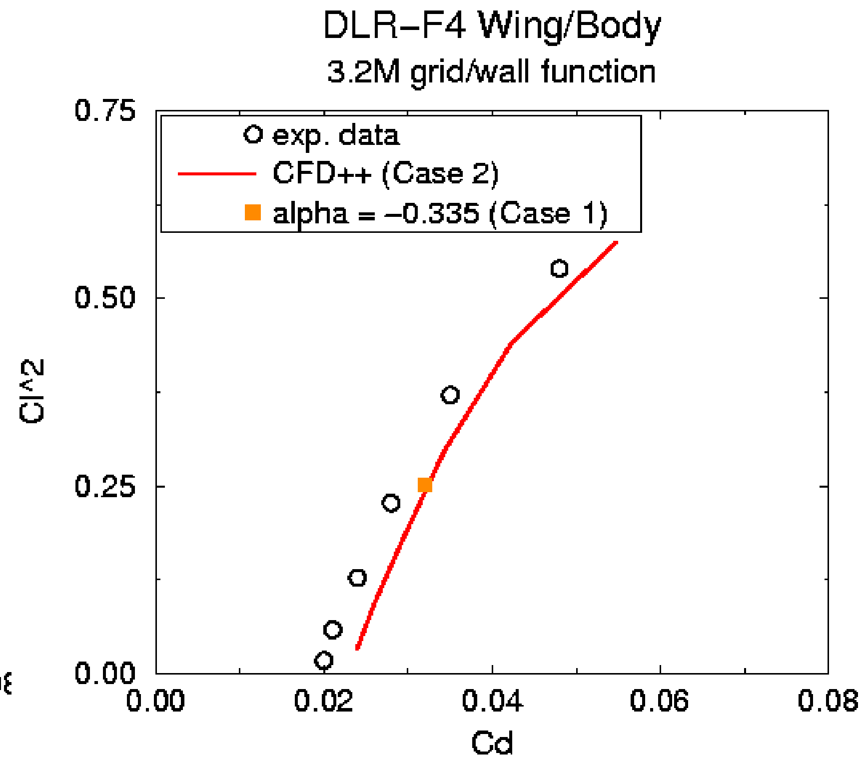


DLR F4 - CFD++ Solution Results





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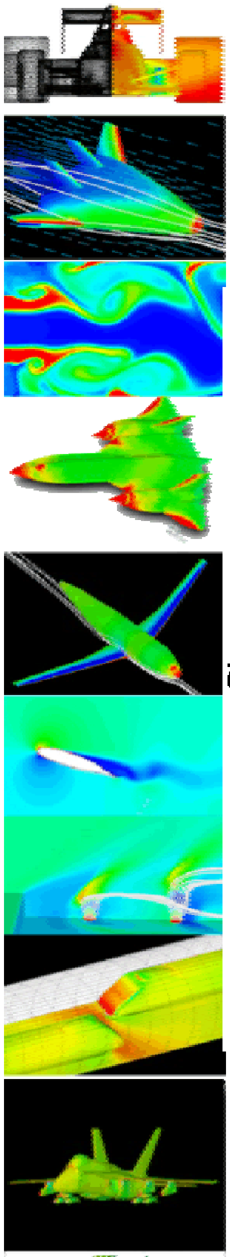
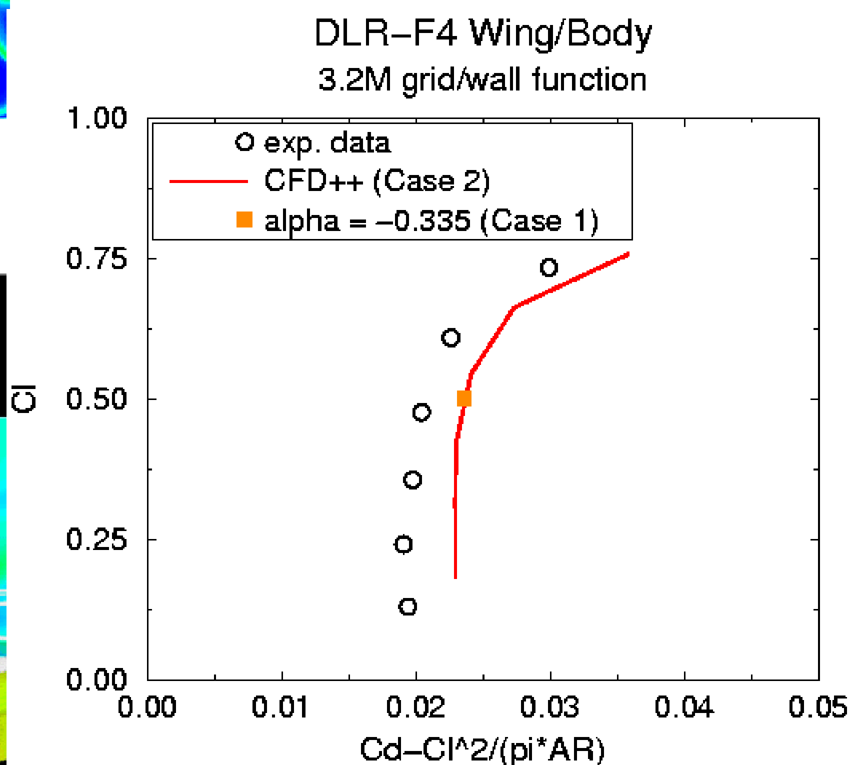
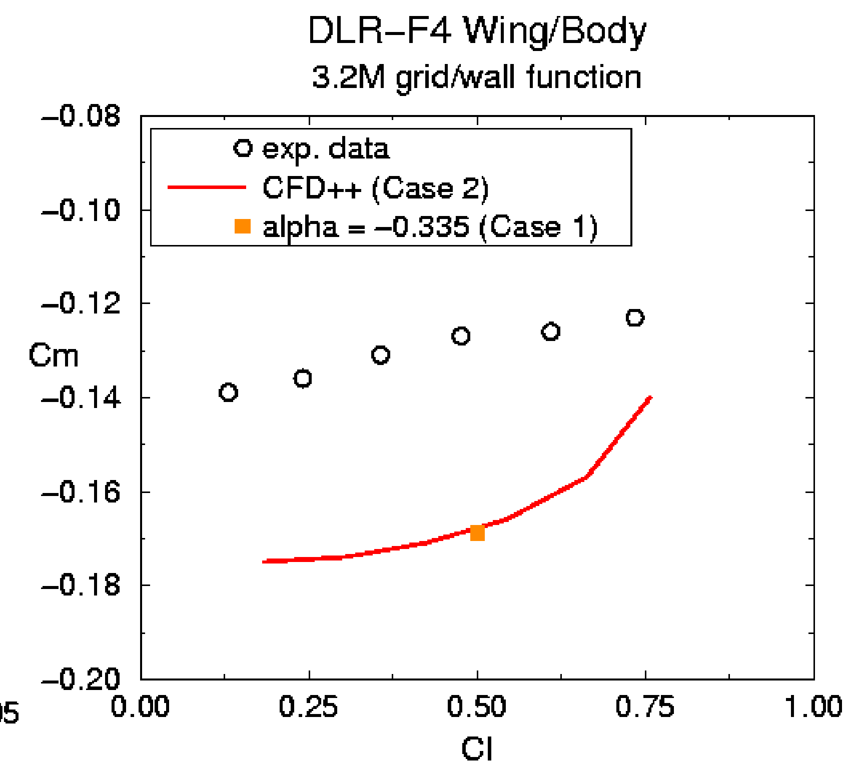
DLR F4 - CFD++ Solution Results







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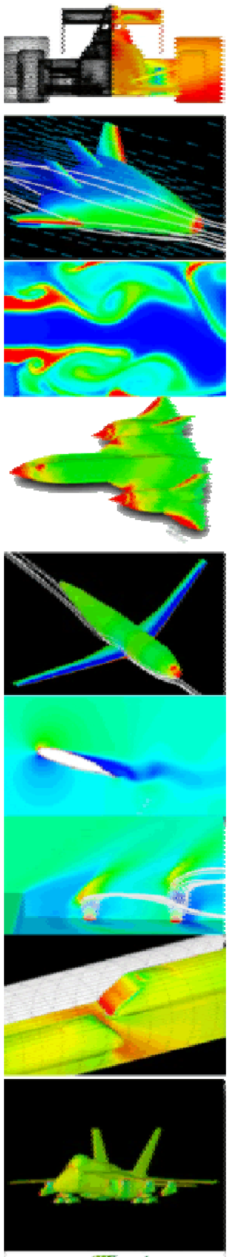


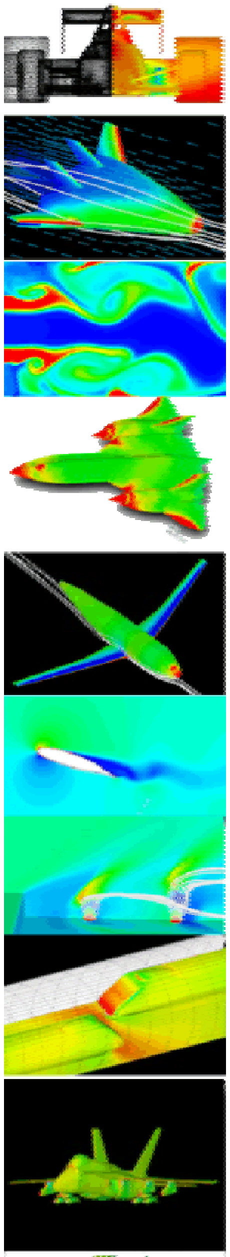
DLR-F4 WING/BODY

Solution input affecting the results:

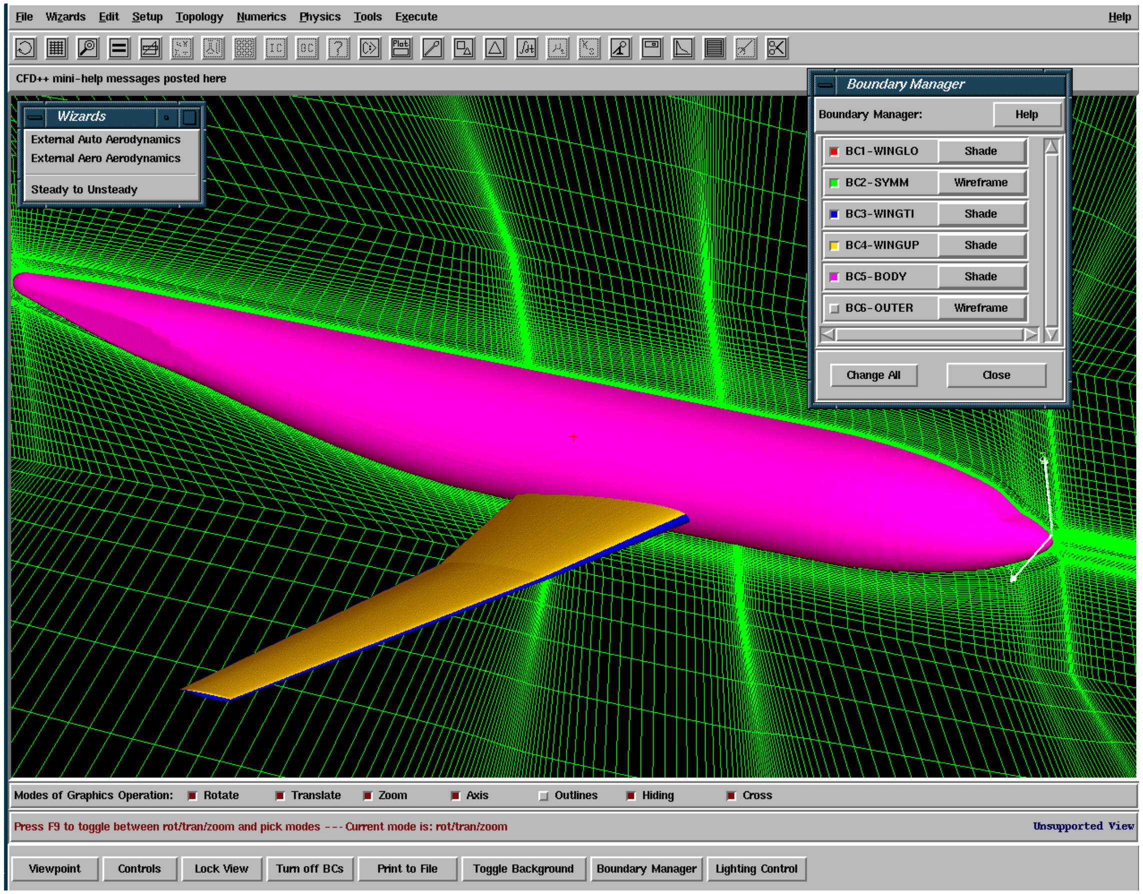
Inflow turbulence length-scale, l , **not specified**

Used $$\varepsilon = \frac{C_\mu^{3/4}}{\kappa}\frac{k^{3/2}}{l}$$

With $$l = 1mm$$



CFD++'s ease of use aspects



- User-friendly, self-guiding GUI
- Aero Wizard sets up case based on Re & M
- Only B.C.s need to be specified

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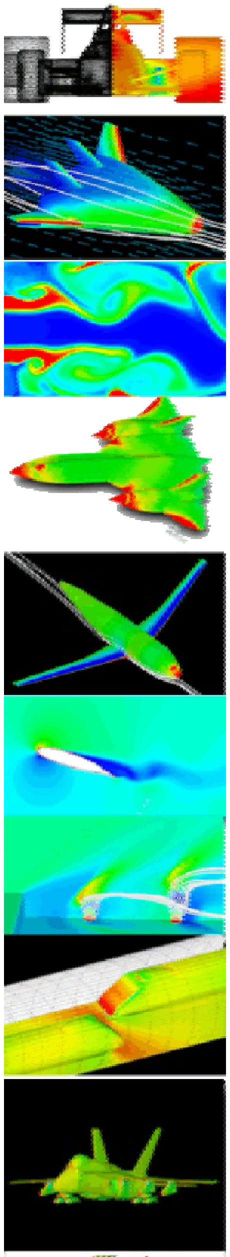

Conclusions

- CFD++ unstructured grid solver used to predict cases 1 (STW) and 2 (Wall function)
- STW and Wall function predictions are in excellent agreement at $\alpha = -0.335°$
- All results, except C_m vs. C_l, follow the data trend
- Given turbulence inflow conditions were incomplete
- 3.2M grid used; no mesh refinements done

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