Drag Prediction Workshop Study Using Falcon

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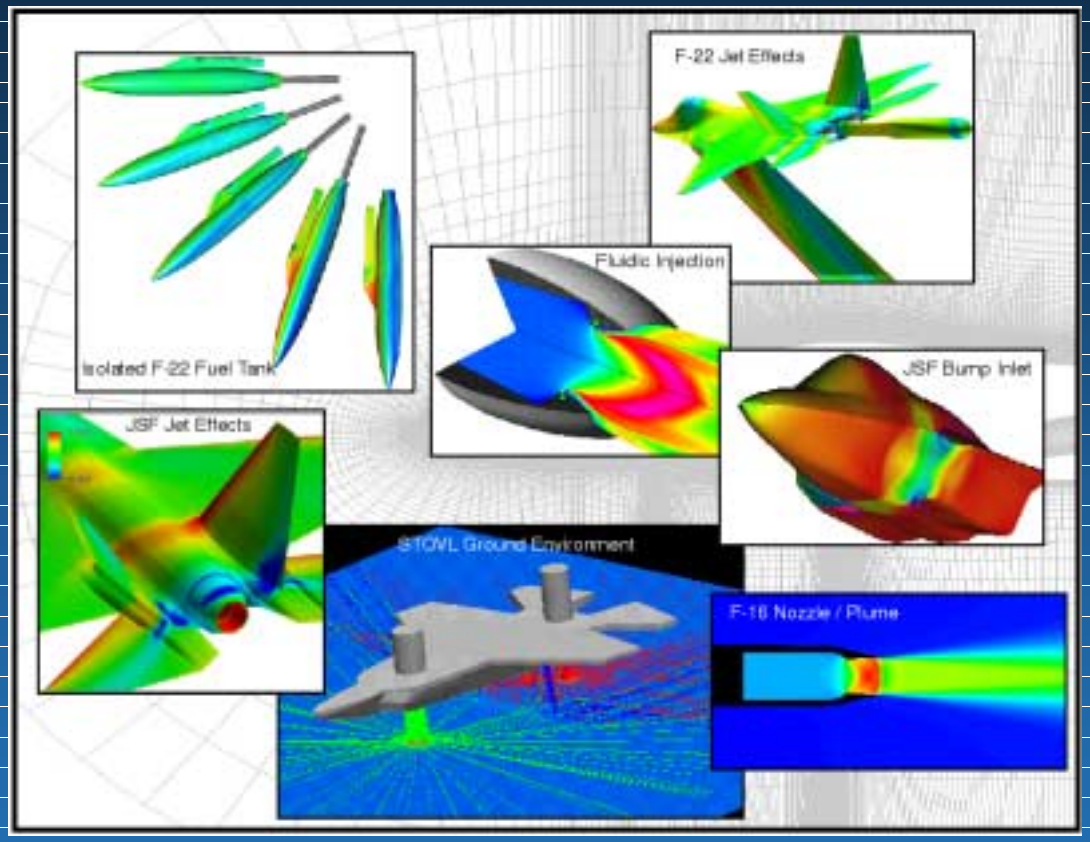
Outline

- Falcon code description
- Lift, Drag and Moment coefficient comparisons
- Grid generation issues
- Convergence issues
- Conclusions

Falcon Flow Solver

Capabilities

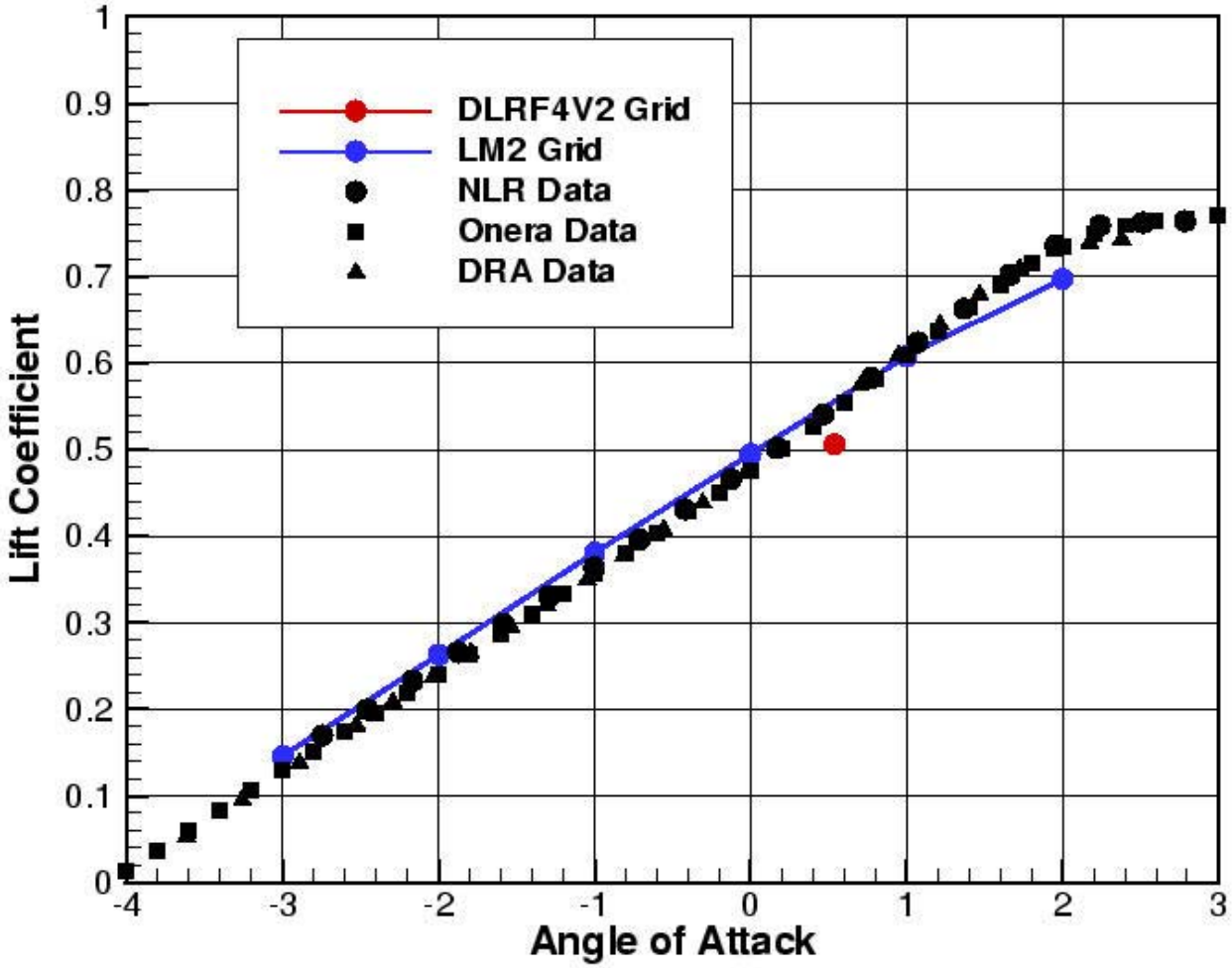
- **Multiple block structured grids for accurate viscous flow analysis. Point-to-point or overset.**
- **Euler/Navier-Stokes with turbulence modeling, wall functions and LES.**
- **Very low subsonic to high supersonic Mach numbers.**
- **Highly implicit solvers for fast solution convergence.**
- **Unsteady capability using dual time-stepping, with time varying boundary conditions.**



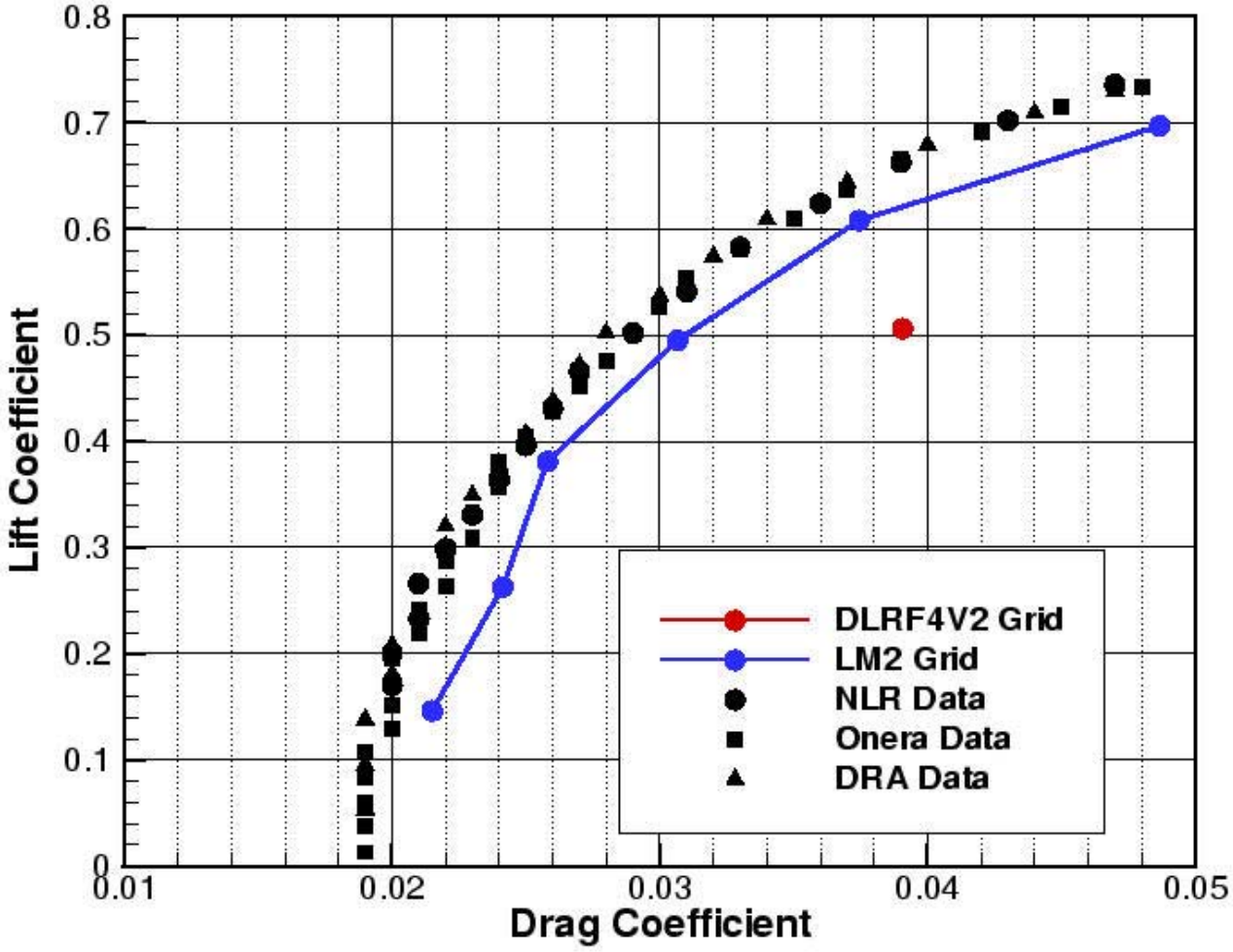
Falcon Flow Solver cont'd

- **Cell-centered, finite-volume**
- **Roe's Flux Difference Split scheme for inviscid fluxes, central differenced viscous fluxes**
- **Second order or third order MUSCL extrapolation with limiters**
- **Limiter varies between MINMOD and Superbee**
- **Two equation k-kl turbulence model with wall functions**
- **Large Eddy Simulation capability**
- **Optional local time-stepping for convergence acceleration, otherwise use a block global time-step**
- **MPI communications between processors**
- **Several implicit solver options:**
  - ***LU-SSOR***
  - ***SIP***
  - ***Modified SIP (Jacobian storage)***

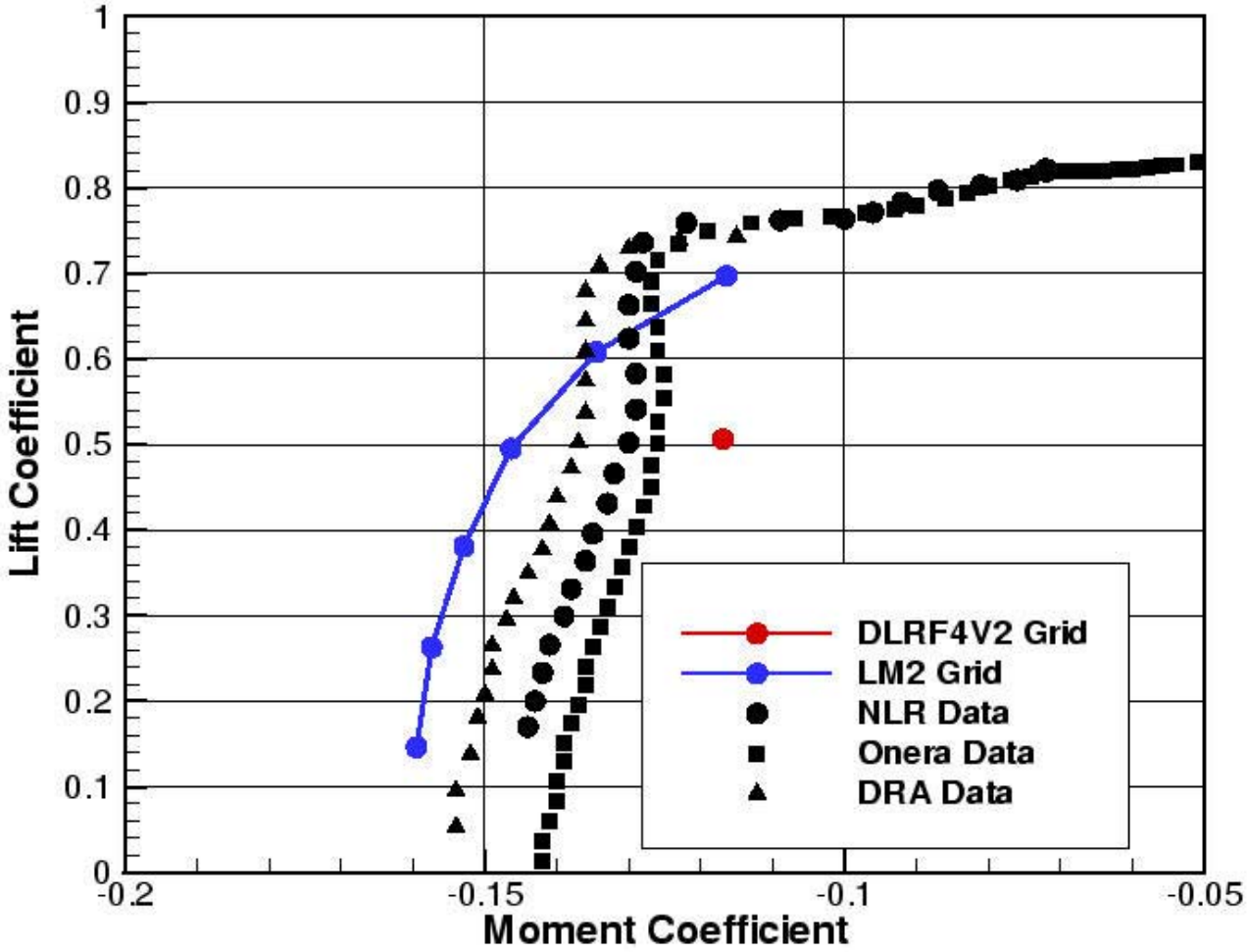
Comparison of Falcon Lift Curve With Experiment



Comparison of Falcon Drag Polar With Experiment



Comparison of Falcon Moment Curve With Experiment



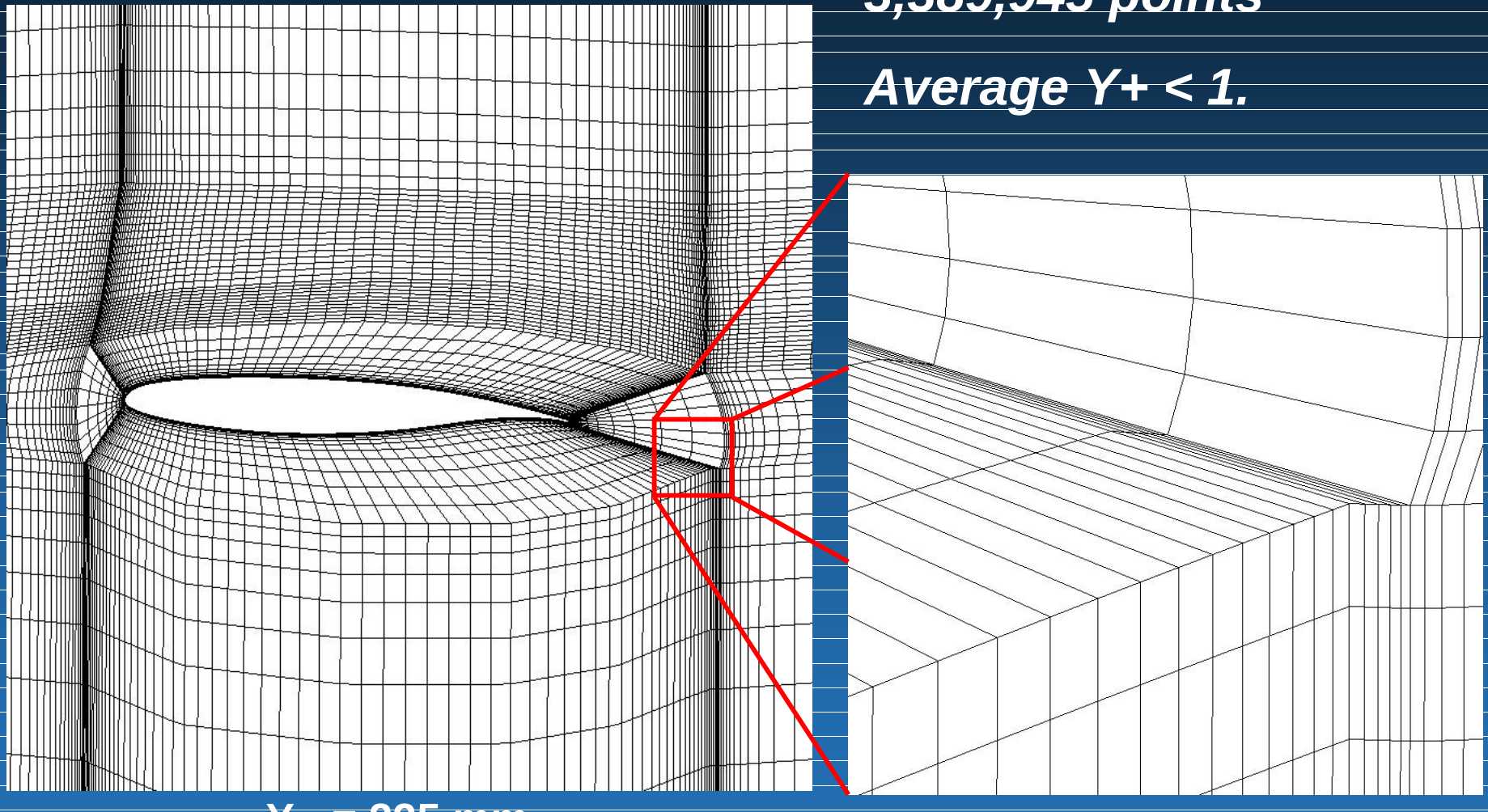
Grid Generation Issues

- **Supplied grid used for Case 1.**
- **Gridgen, a commercial package marketed by Pointwise Inc., was used to make two additional grids (LM1 & LM2).**
  - ***LM1 contained 1,393,485 points (same number of surface points as supplied grid)***
  - ***LM2 contained 1,913,373 points (increased number of points on wing)***
  - ***LM2 has better surface resolution and was selected for Case 2 solutions.***
- **Grid spacing in the supplied grid (DLRF4V2) may have affected solution accuracy.**

Disparate Grid Spacings at Block Boundaries in DLRF4V2 Grid

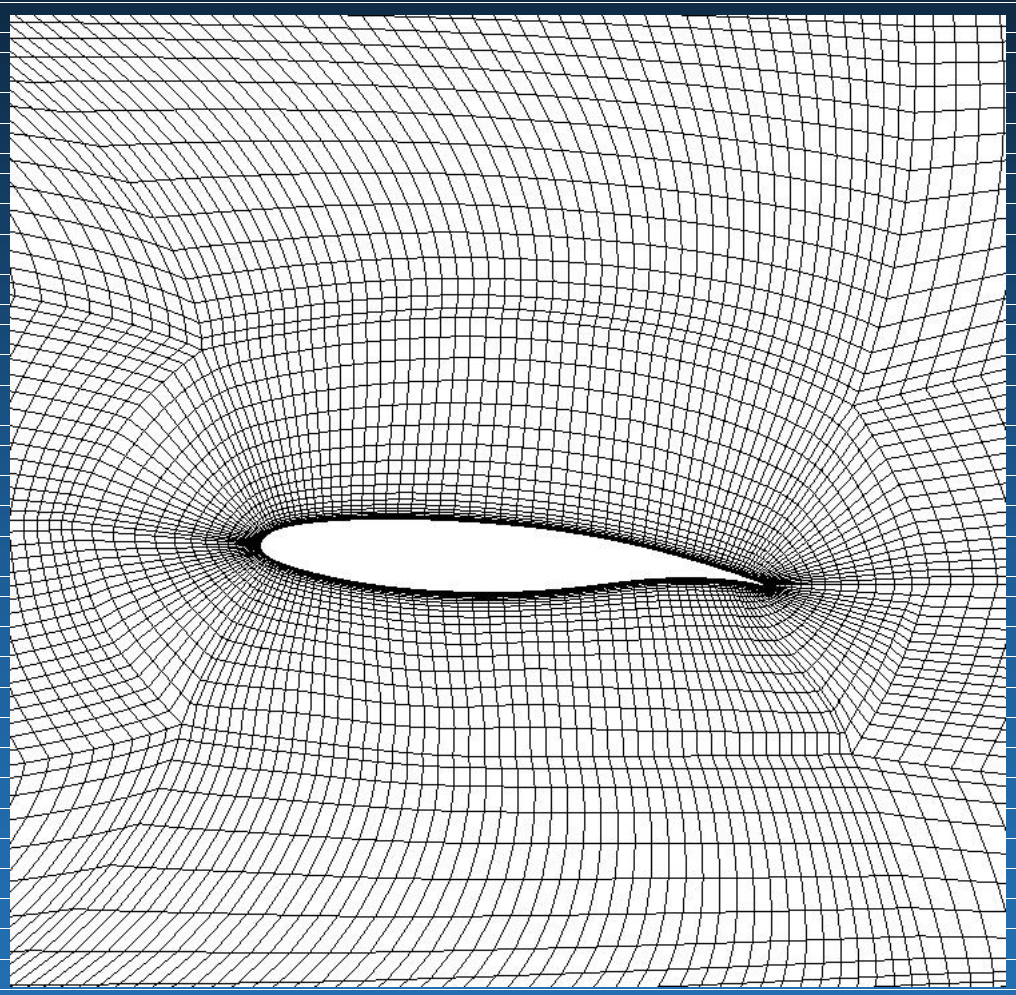
3,389,945 points

Average Y+ < 1.



Y ~= 225 mm

Smoother Grid Spacings at Block Boundaries in LM2 Grid



Y ~= 225 mm

1,913,373 points

1,798,464 cells

24 Blocks

31,392 boundary nodes

29,402 boundary faces

BL 1st-cell = 0.1mm

BL Max-Growth = 1.25

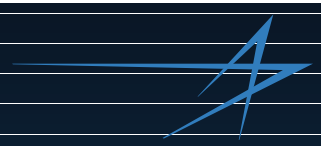
BL cells = ~15

Average Y+ ~61.

Convergence Issues

- **The usual solution strategy is to incorporate local time-stepping to accelerate convergence.**
- **Disparate grid spacing results in disparate time-steps, especially at block boundaries.**
- **Disparate time-steps for Case 1 affected solution accuracy and solution convergence. Case 2 solutions using LM2 grid unaffected.**
- **Residual and force history plots for supplied grid seemed to show solution convergence.**
- **When solution computed using global time step, a more accurate result was obtained.**

Solution Information



Case 2 - LM2 Grid Stats

- 4 HP-V2500 400 MHz processors
- HPUX 11.0
- HP Fortran 90
- Average CPU Time = 216 Hrs.
- Average Wall Time = 62 Hrs.
- Memory = 727 Mb

Conclusions

- **Solution accuracy is highly dependent on grid quality. No surprises here!**
- **Solution convergence is dependent on grid spacing and the use of local time-stepping.**
- **The use of wall functions greatly enhances robustness and efficiency.**
- **Bottom Line -- Falcon can produce good results using our established procedures.**
- **This workshop is not so much a comparison of flow solver accuracy as it is a comparison of grid generation expertise and analysis process. (A Validated User!)**