CFL3D and FUN3D Contributions to the First AIAA Sonic Boom Prediction Workshop

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Cases

- All provided grids
 - SEEB-ALR structured grid coarsened 3 times (CFL3D)
 - Delta Wing Body structured grid coarsened 3 times (CFL3D)
 - 5 SEEB-ALR mixed-element and tetrahedral grids (FUN3D)
 - 4 Delta Wing Body mixed-element and tetrahedral grids (FUN3D)
 - LM 1021 (FUN3D)

CFL3D

- Cell-centered structured multiblock grids
- Blended (one third) upwind (Roe) and central difference
- Default "smooth" limiter
- Euler
- Full multigrid with grid sequencing
- Delta Wing Body required Mach ramping to start

FUN3D

- Node-based mixed-element solver
- Blended upwind and central difference with van Albada limiter

- van Leer (Euler) and Roe (turbulent) flux

- Euler and SA-neg turbulence model, see Allmaras, Johnson, and Spalart (ICCFD7)
- Utilizes convergence improvements, see Nishikawa et al. (AIAA-2013-863)

Resources

- NASA Langley mid-range computing facility

 SGI ICE Altix Cluster
- CFL3D
 - 24-144 core jobs limited by block sizes
 - Few hours
- FUN3D
 - 128-512 core jobs limited by number of free cores and queue sizes
 - Few minutes to an hour

SEEB-ALR CFL3D Iterative Convergence



Delta Wing Body CFL3D Iterative Convergence



SEEB-ALR FUN3D Mixed-Element Iterative Convergence



SEEB-ALR Body FUN3D Tetrahedral Iterative Convergence



Delta Wing Body FUN3D Mixed-Element Iterative Convergence



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Delta Wing Body FUN3D Tetrahedral Iterative Convergence



LM 1021 FUN3D Tetrahedral Iterative Convergence



Data Extraction

- Exported volume Plot3D files from CFL3D and CGNS files from FUN3D
- Loaded volume files into tecplot
- Executed the workshop supplied macros
 - Modified the centerline extraction location by 0.0001 for small symmetry plane waviness



SEEB-ALR CFL3D Signature H=21.2in



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SEEB-ALR CFL3D Fine Grid



SEEB-ALR Body FUN3D Mixed-Element Signatures H=21.2in



SEEB-ALR Body FUN3D Fine Grid Signatures H=21.2in



Delta Wing Body Pressure Disturbance





Ζ

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Delta Wing Body CFL3D Signature H=0.5in



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Delta Wing Body FUN3D Mixed-Element Signature H=0.5in



LM 1021 Pressure Disturbance



LM 1021 First Cell y⁺



Conclusions (Cases)

- Utilized all provided structured grids with CFL3D (and recursively coarsened)
- Utilized all provided mixed-element and purely-tetrahedral unstructured grids with FUN3D

Conclusions (Convergence)

- CFL3D iterative convergence stalled on coarse SEEB-ALR grids and fine Delta Wing Body Grids
- FUN3D residuals converged to machine precision (frozen limiter) for most cases
 - Except finest SEEB-ALR mixed-element grids (five order reduction)

Conclusions (CFL3D)

- CFL3D on the coarsest SEEB-ALR (S4) and two coarsest Delta Wing Grid (S3,S4) structured grids miss details of bow shock
- Finest (S1) CFL3D SEEB-ALR solution resolves waviness of the geometry

Conclusions (FUN3D)

- Small variation in the unstructured signatures with grid refinement
 - Largest variation in Delta Wing Body base region and under resolved sting surface
- LM 1021 grid has a larger first cell height than standard practice for the SA turbulence model