Automated FUN3D Off-Body Pressure Analysis Results

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First AIAA Sonic Boom Prediction Workshop
January 11, 2014

Outline

- Automated boom-suitable mesh generation process
- Summary of cases run
- Results
  - SEEB
  - Delta Wing
  - LM 1021
- Summary/Conclusions

Automation of Tetrahedral Mesh Generation with AFLR2/3

Objective:

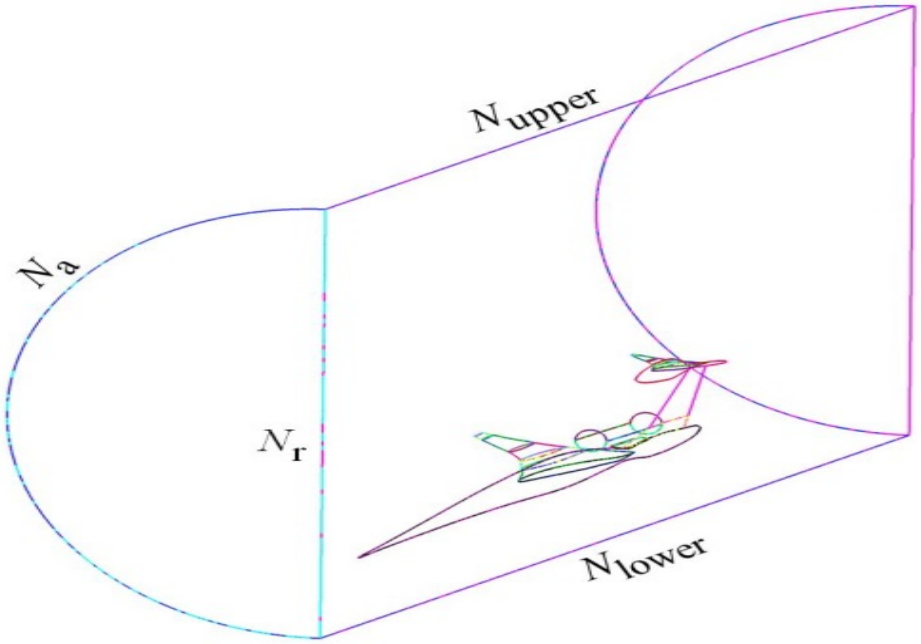
- Enable robust and automated generation of tetrahedral CFD mesh from a surface mesh

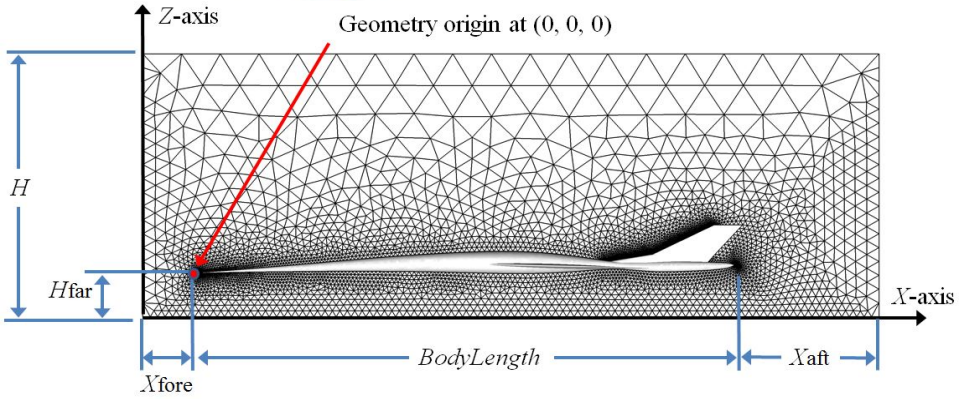
Approach:

- Generate a high-quality boundary mesh with AFLR2 for a surface mesh (triangulation) based on a few simple input parameters
- Generate a high-quality volume mesh for the boundary mesh with AFLR3
- Generate outer mesh for off-body CFD analysis with BG code from Dick Campbell

Significance:

- Addresses an existing analysis process gap by enabling robust mesh generation for CFD solvers (e.g., FUN3D and USM3D) in-house
- Allows integration of adjoint-based design capability with FUN3D into in-house design process
- Allows direct assessment of CFD-based analysis and design with Cart3D, FUN3D, and USM3D for a common surface mesh definition





Process used for each of the cases to generate a volume mesh from a surface triangulation

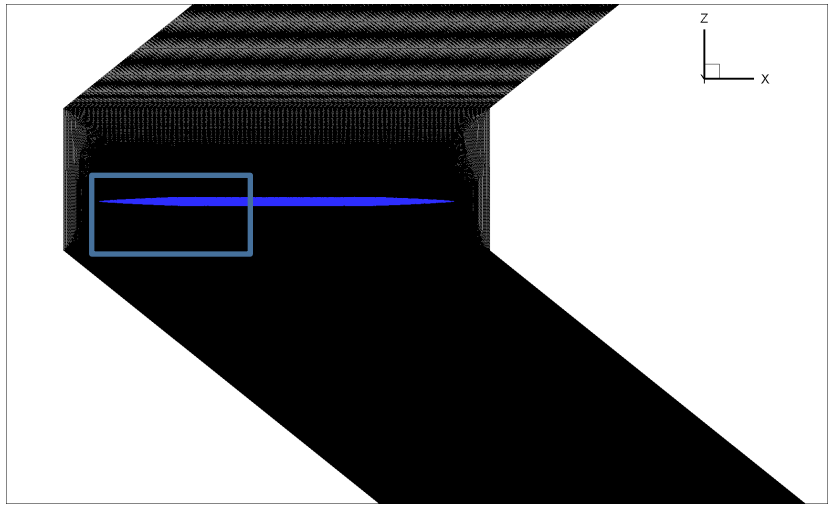
Slide and automated process borrowed from Irian Ordaz, NASA Langley

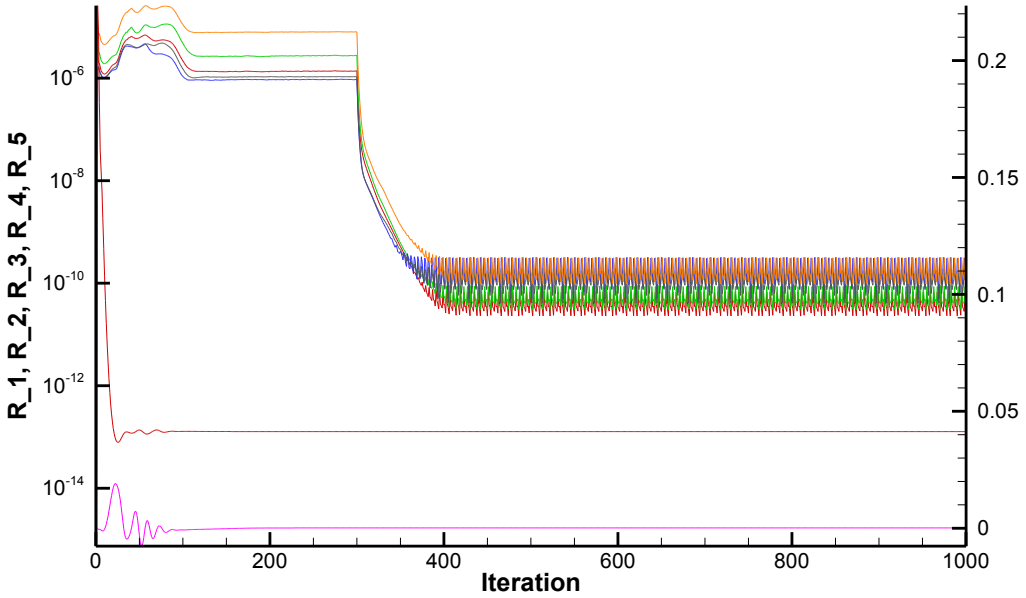
Summary of cases analyzed

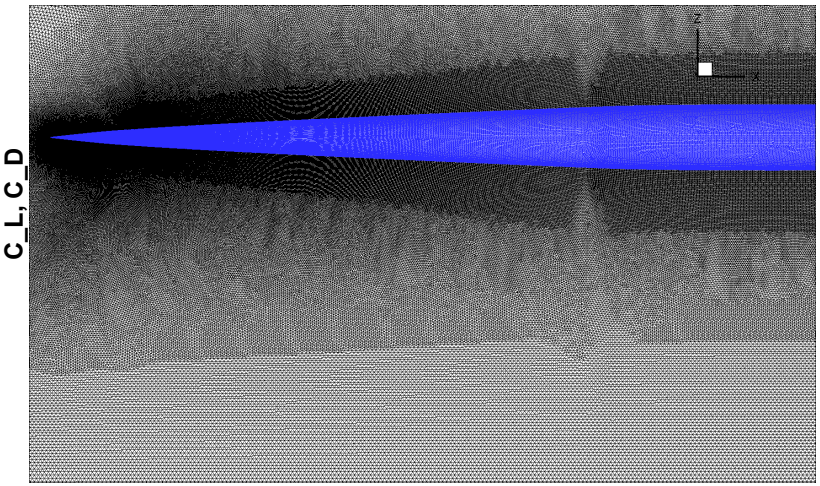
- **All analysis performed using:**
  - FUN3D 12.3-66105M
  - Tetrahedral VGRID meshes
  - Runs made on parallel clusters with one of the following architectures
    - 64 nodes (512 processors) with each node being a Dual socket quad core 2.66 GHz Intel 5355 (2 x 4MB cache) 1333MHz FSB
    - 43 nodes (516 processors) with each node being a Dual socket hex core 3.07 GHz Intel X5675 Westmere (2 x 12MB cache)
    - 32 nodes (512 processors) with each node being a Dual socket 8 core 2.60 GHz Intel E5-2670 Sandybridge (2 x 20MB cache)
- **SEEB Body of Revolution**
  - Euler analysis, M=1.6, AoA = 0.0, Hvanalbada limiter, frozen after 300 iterations
  - Surface grid corresponding to Seeb-080 used, Volume Grid Size: 124M Tets
- **Delta Wing**
  - Euler analysis, Hvanalbada limiter, frozen after 300 iterations
  - Grid Size: 97M Tets
- **LM1021**
  - SA turbulence model
  - 500 first order iterations with eigenvalue smoothing turned on
  - Flow restart, 1000 second order iterations with eigenvalue smoothing turned on
  - Flow restart, 1000 second order iterations with eigenvalue smoothing turned off
  - Hvanalbada limiter, frozen in each step after 500 iterations
  - Grid Size: 164M Tets

FUN3D Analysis of SEEB-080

- Convergence criteria: 1000 iterations
- Residual convergence history
  - Residual drop by 5 orders of magnitude
  - CL and CD converged

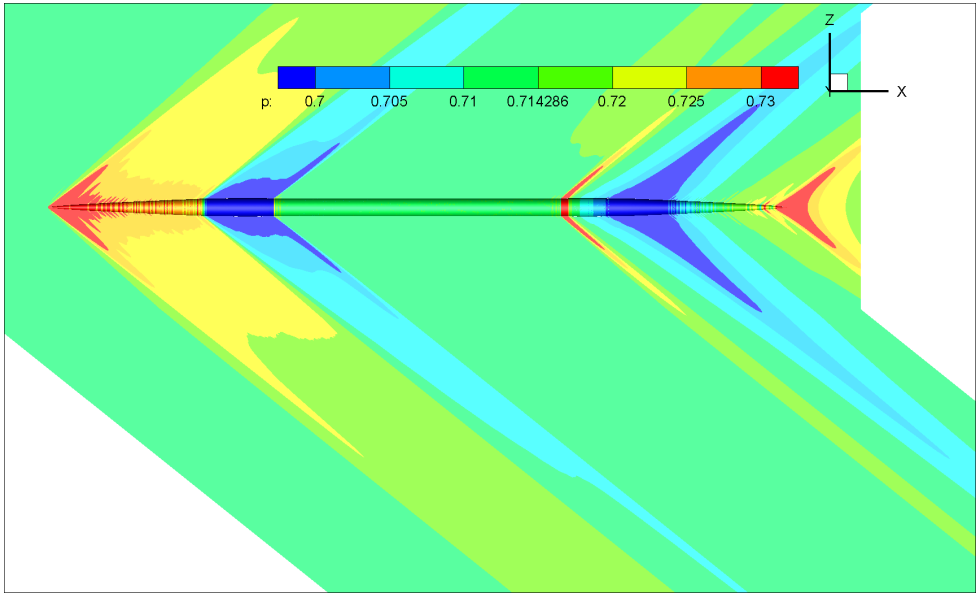


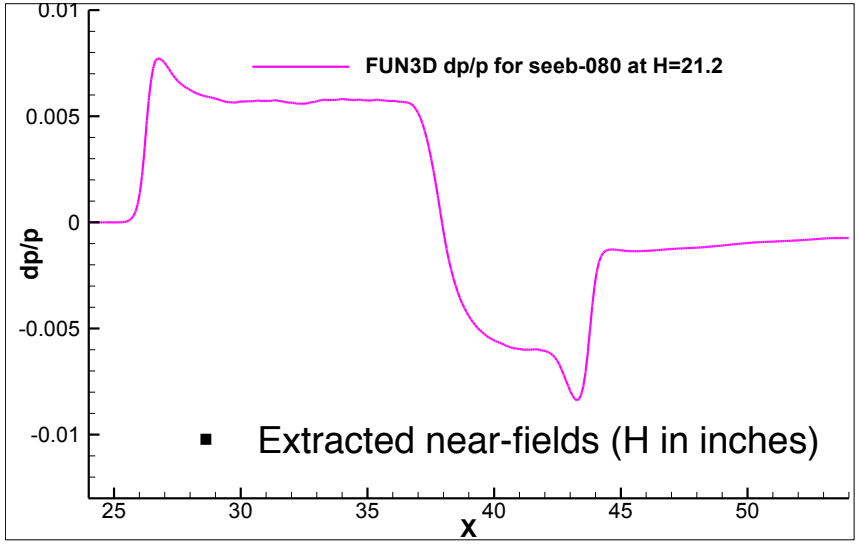


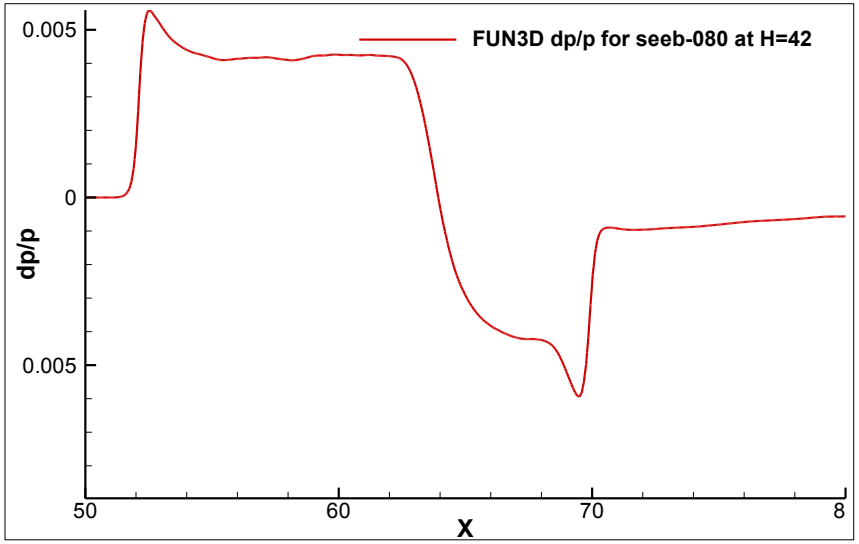


FUN3D Analysis of SEEB-080

- Pressure contours

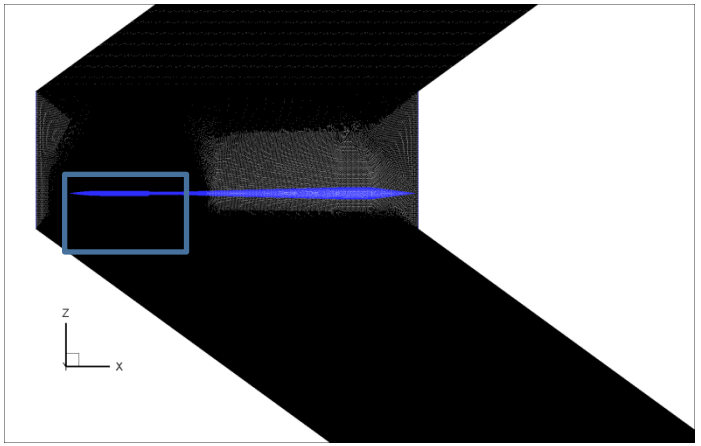


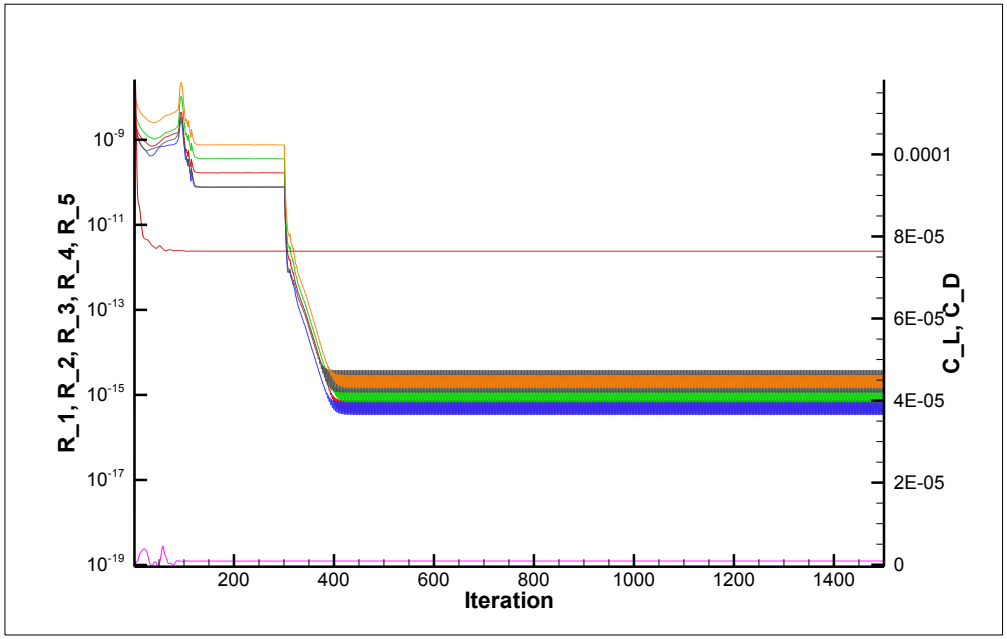


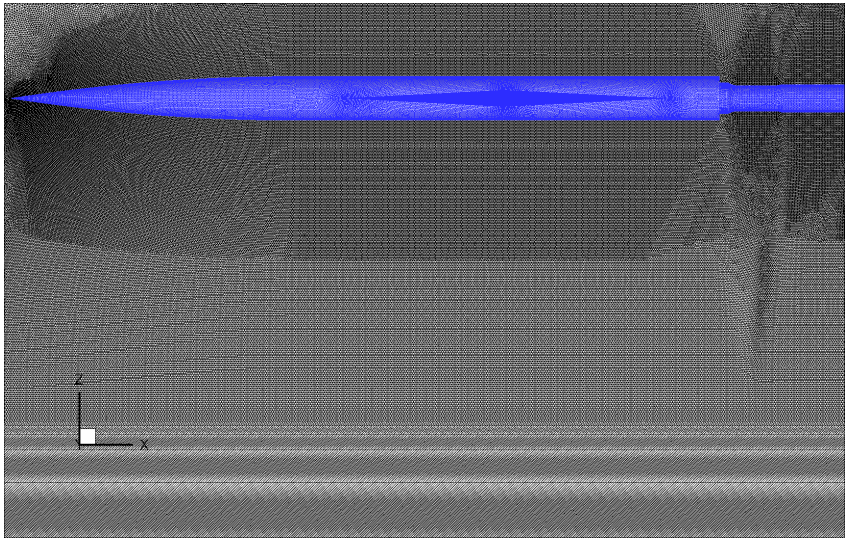


FUN3D Analysis of Delta Wing

- Convergence criteria: 1500 iterations
- Residual convergence history
  - Residual drop by 7 orders of magnitude
  - CL and CD converged







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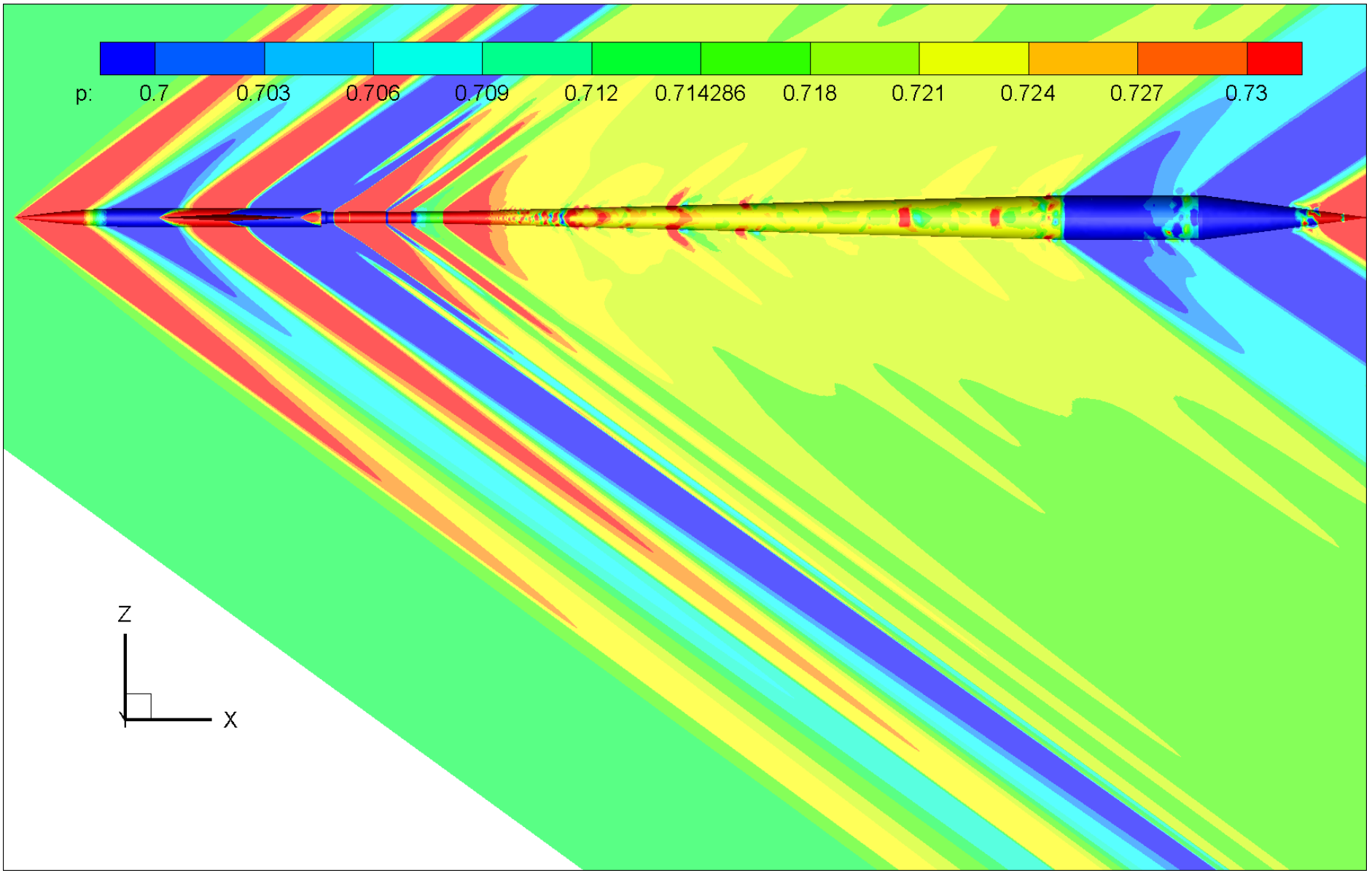
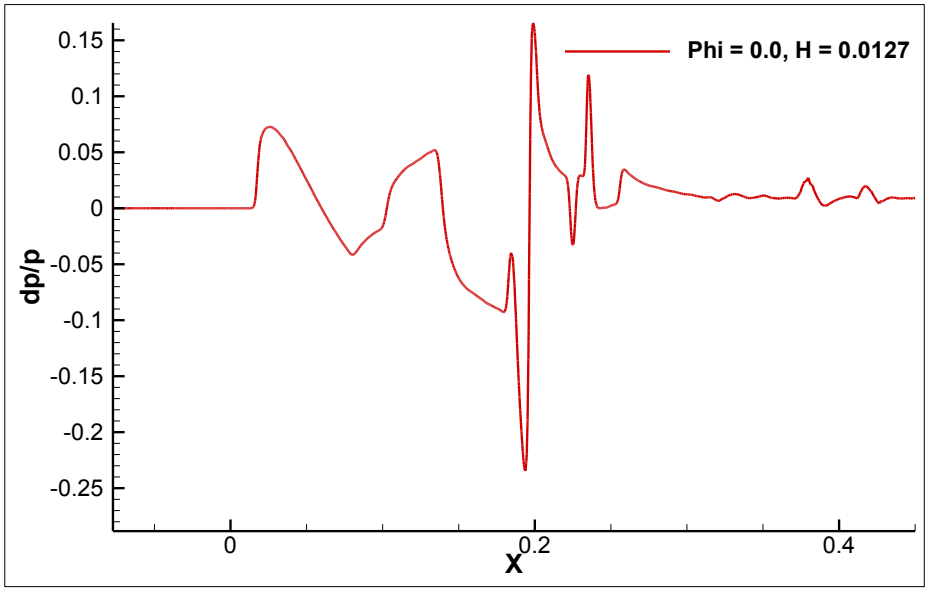
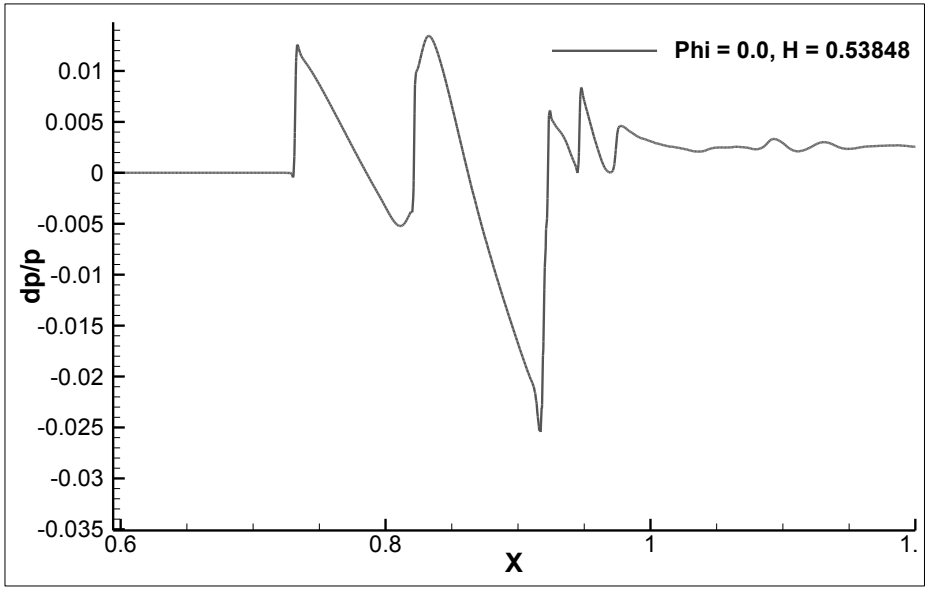
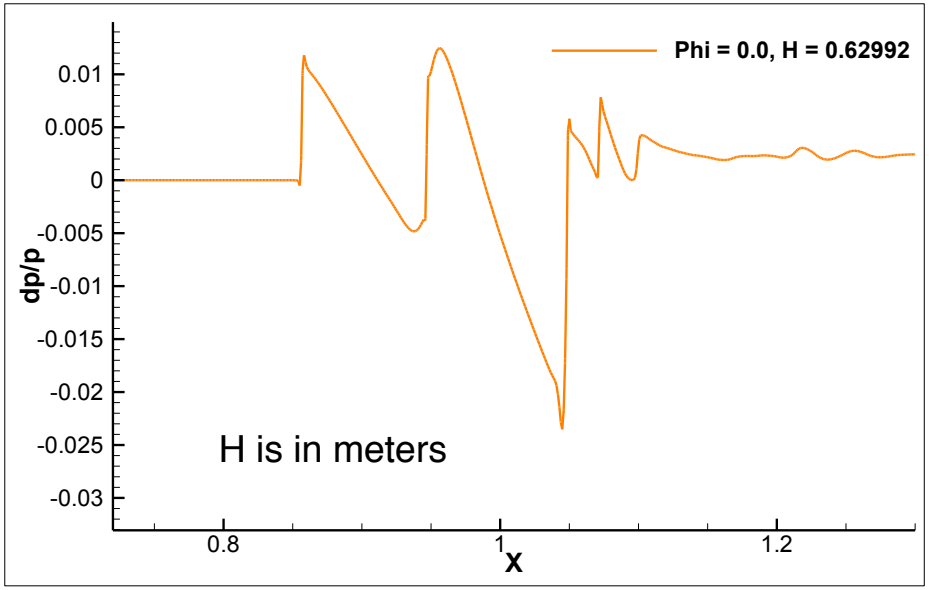
FUN3D Analysis of Delta Wing: Pressure contours under-track

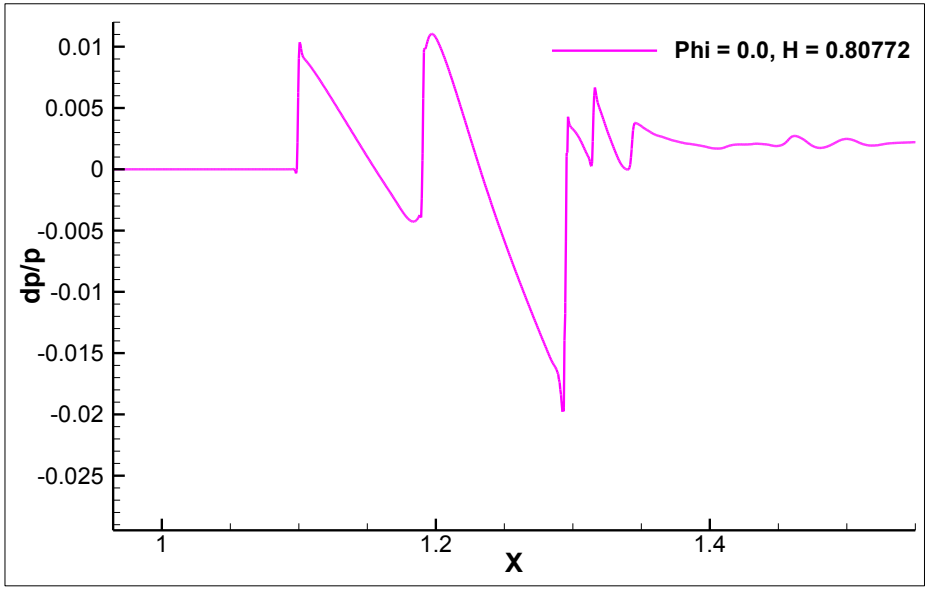


FUN3D Under-Track Analysis Results for Delta Wing

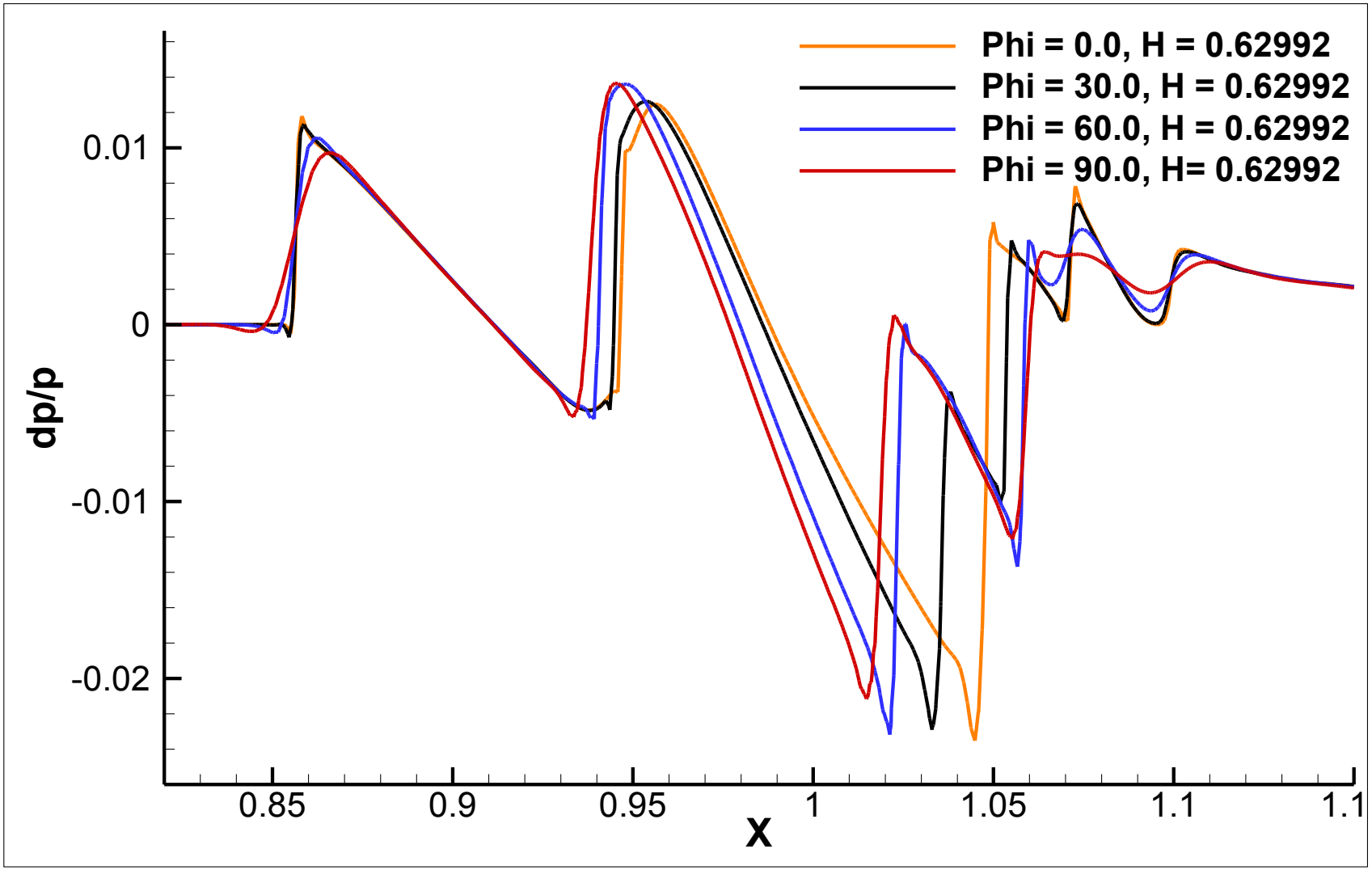




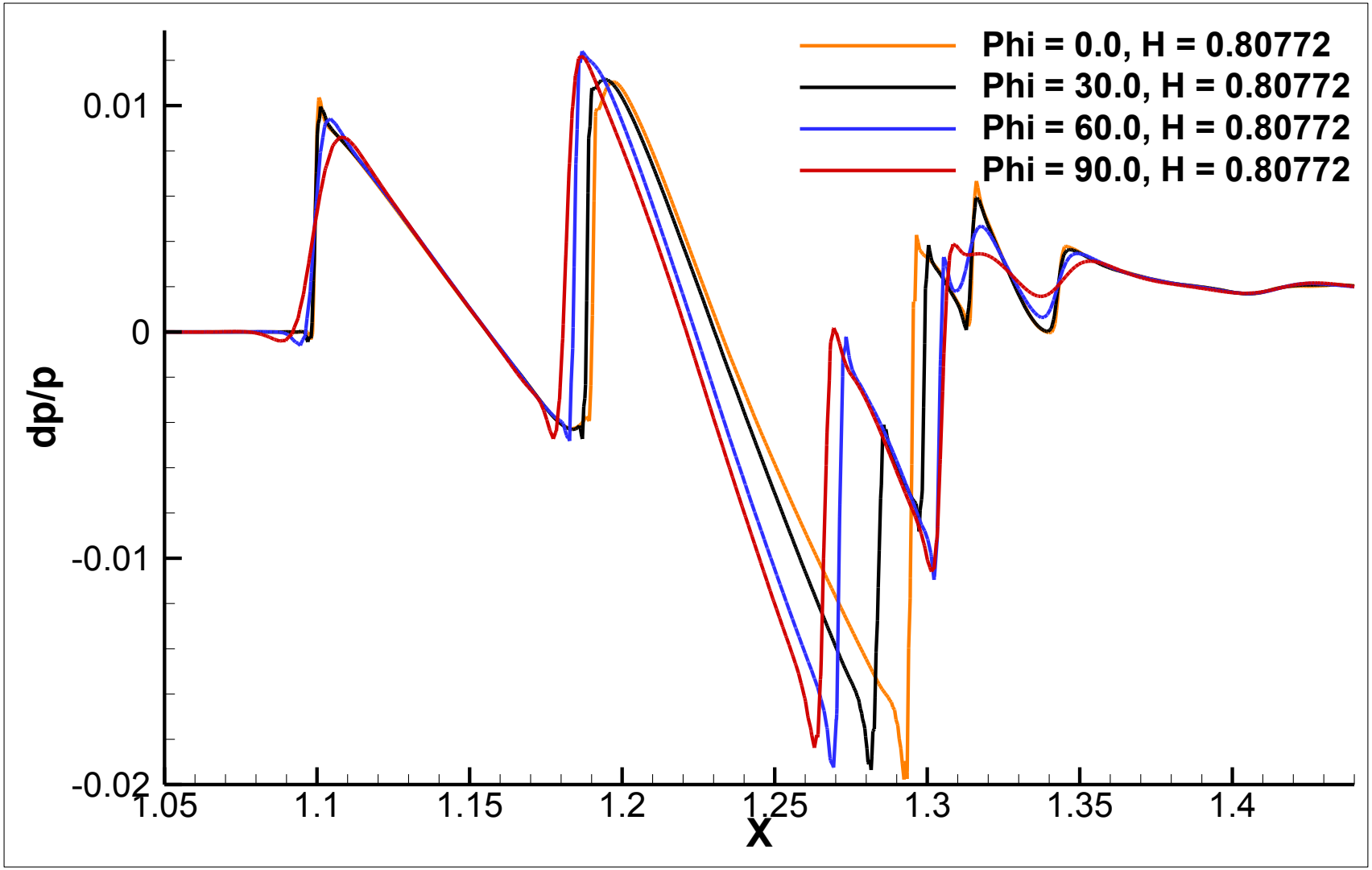




FUN3D Comparison of dp/p at H = 0.62992m for Delta Wing

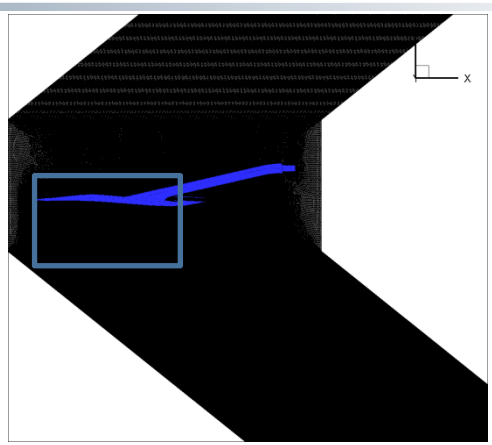


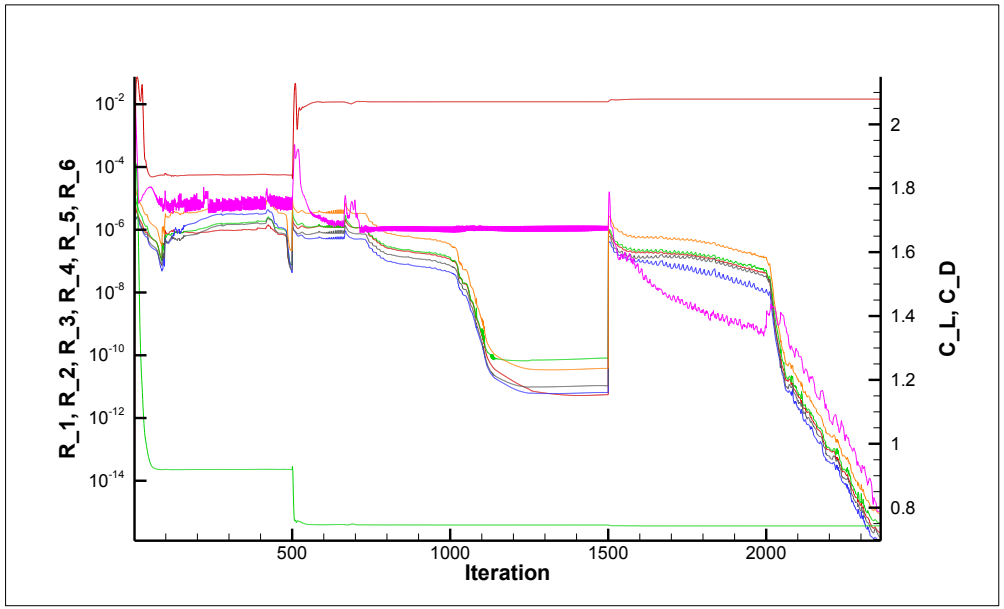
FUN3D Comparison of dp/p at H = 0.80772m for Delta Wing

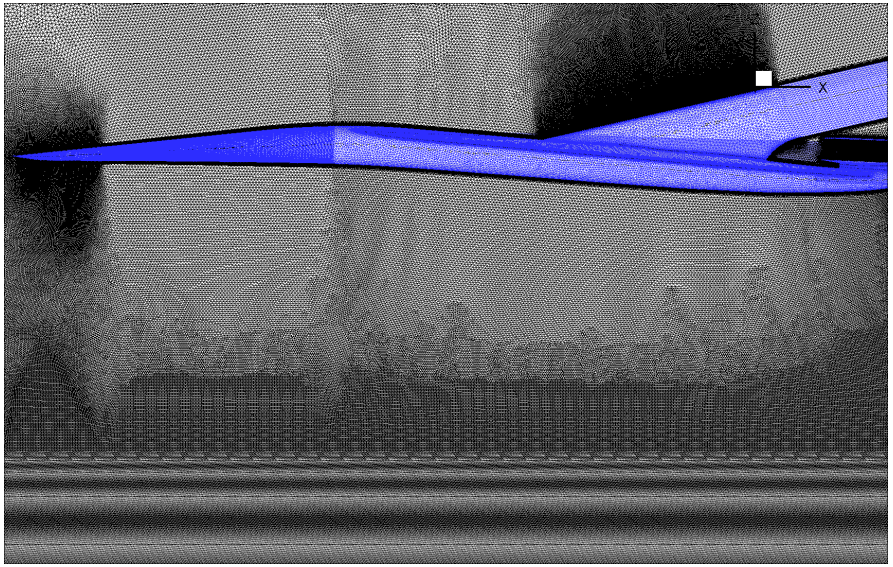


FUN3D Analysis of LM1021

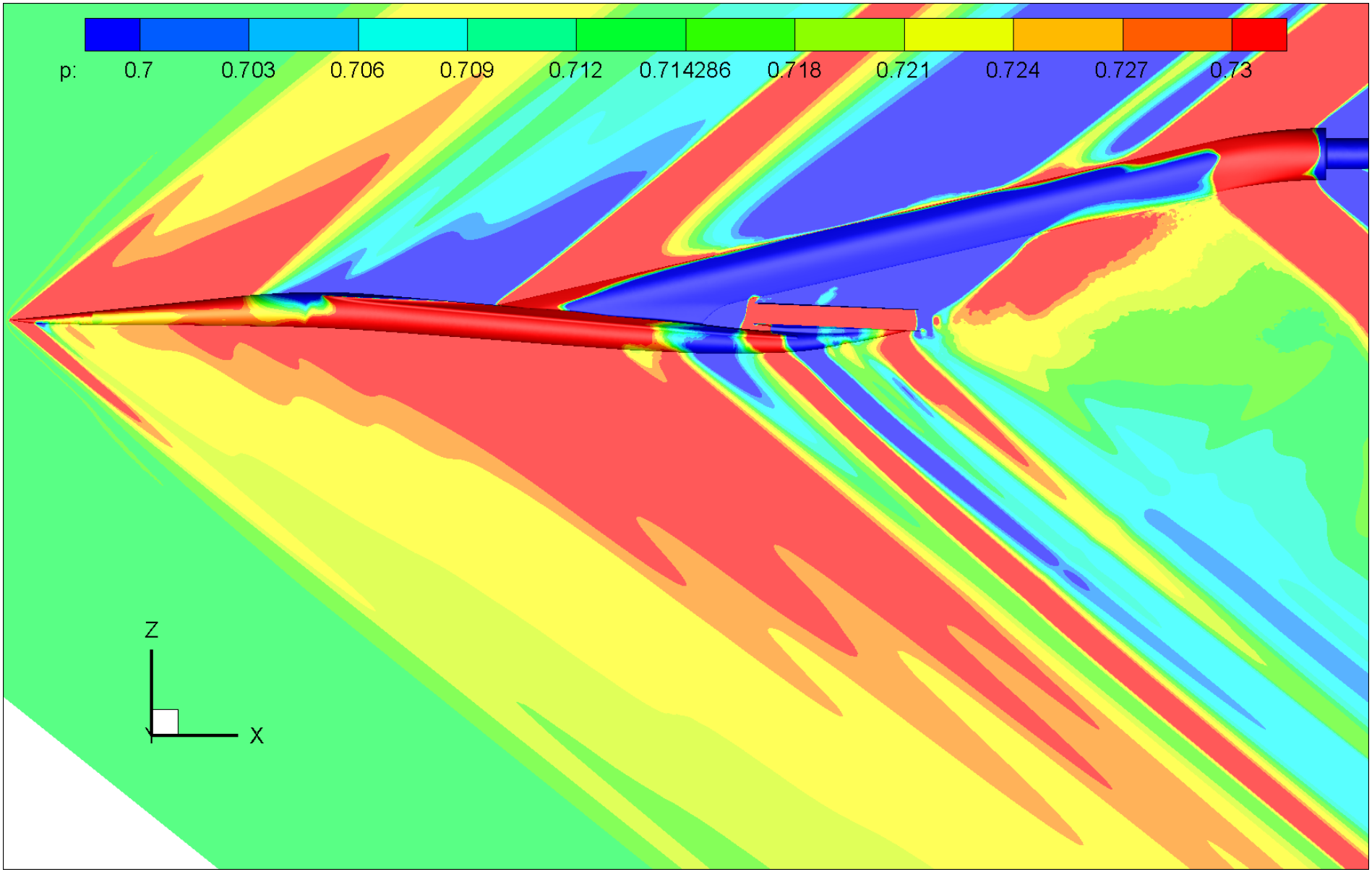
- Viscous mesh generated using AFLR3
- Convergence criteria: 2500 iterations
- Residual convergence history
  - Residual drop over 12 orders of magnitude with 2 restarts
  - CL and CD converged



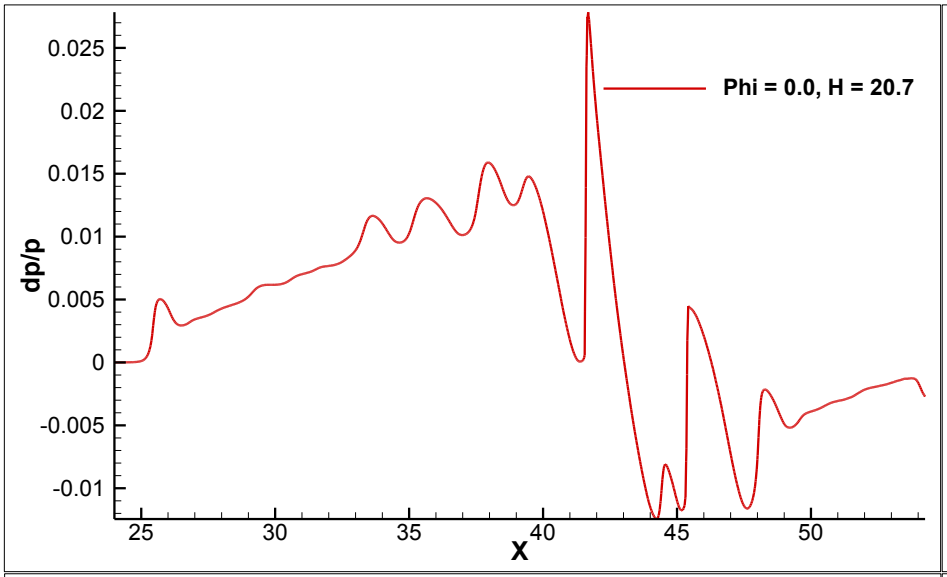


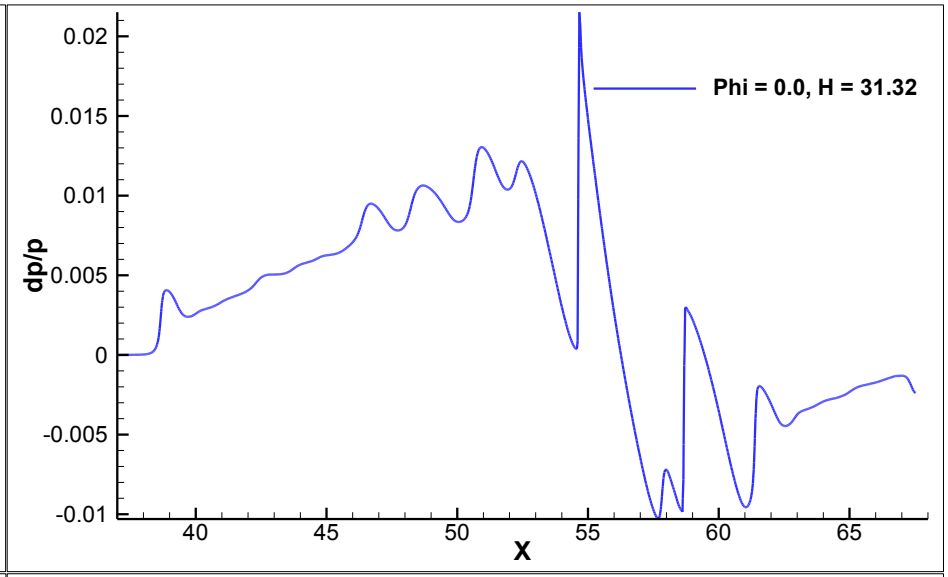


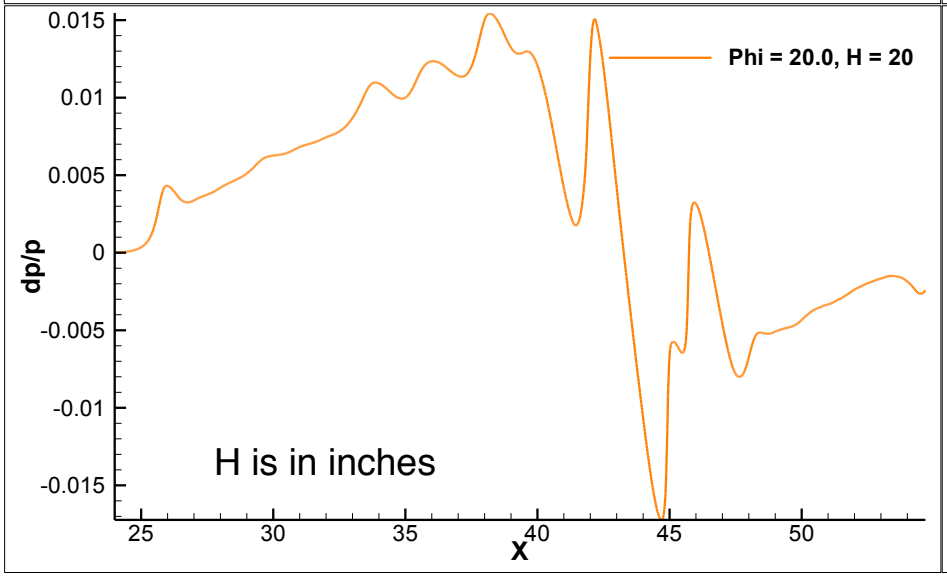
FUN3D Analysis of LM1021 : Pressure Contours under-track

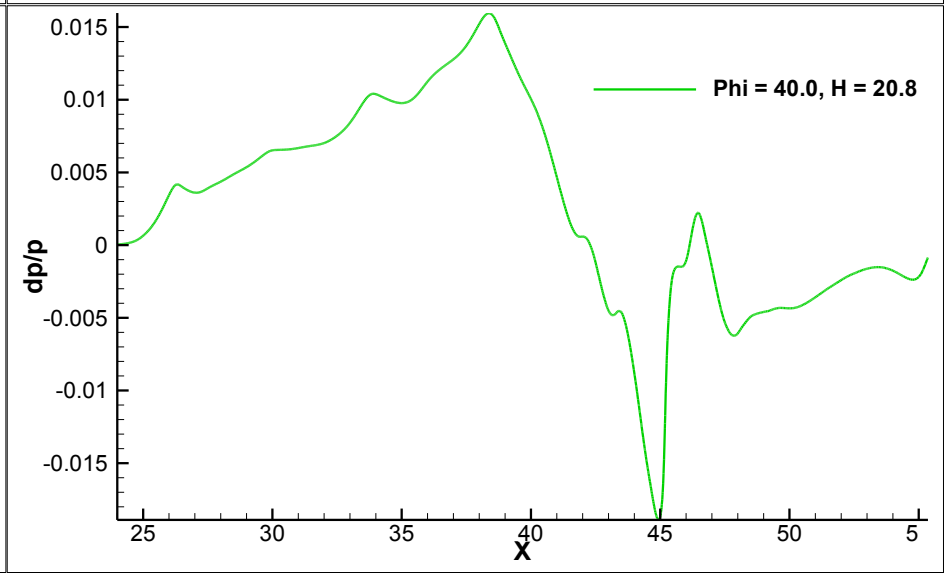


FUN3D Analysis of LM1021 : Extracted near-field signatures

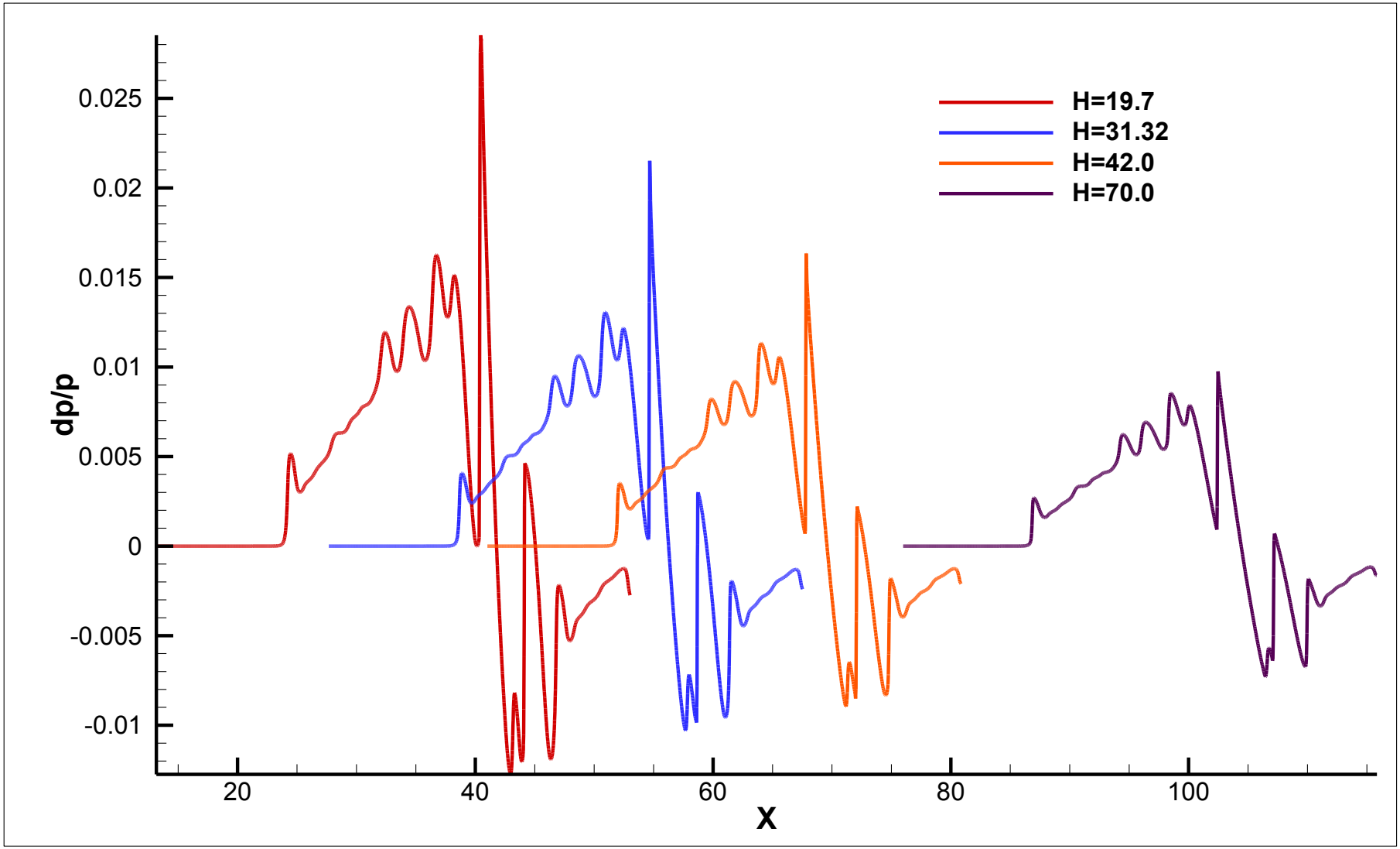




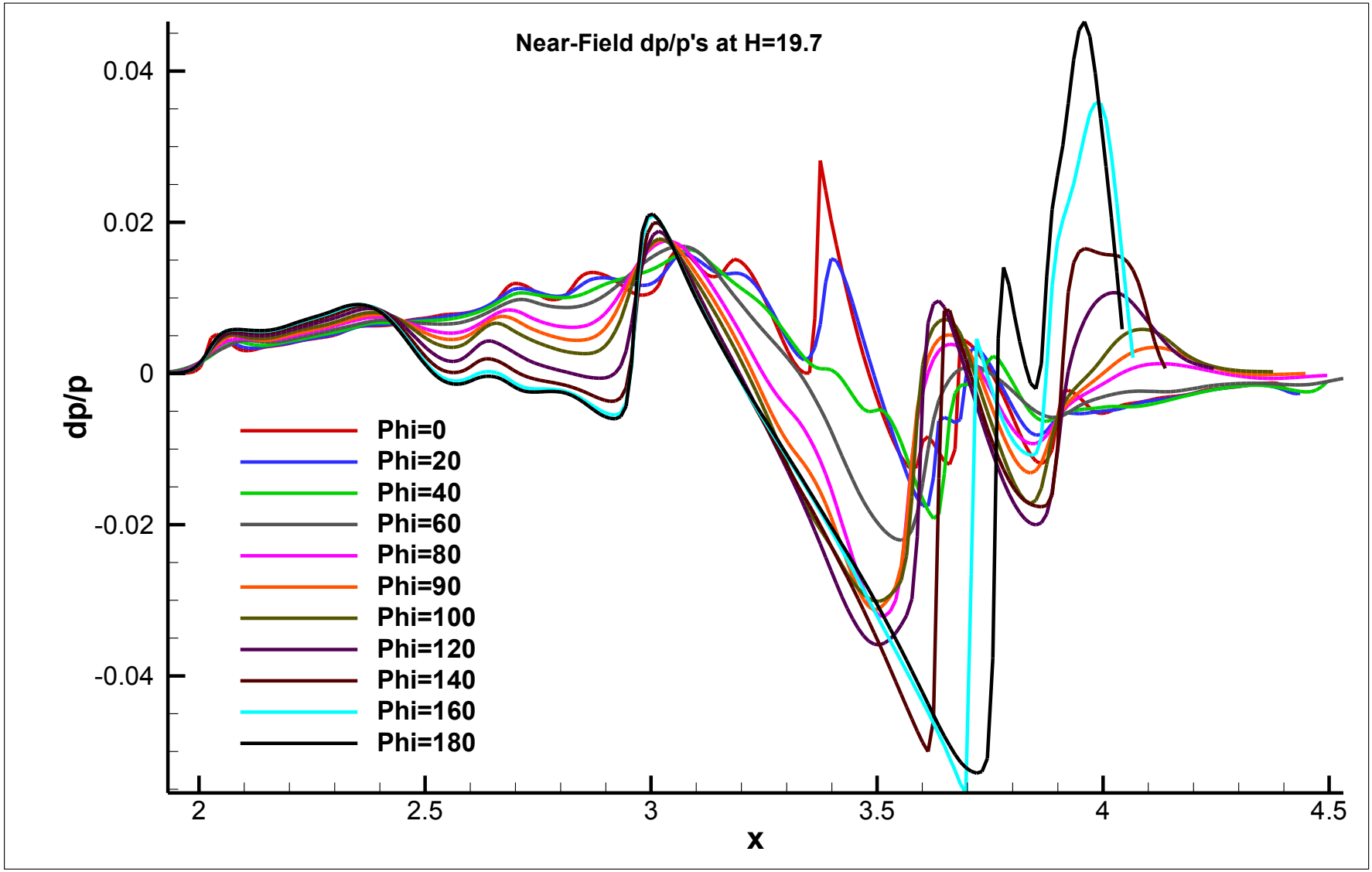




FUN3D Analysis of LM1021 : Under-track at different offsets



FUN3D Analysis of LM1021 : Different azimuths at H=19.7in

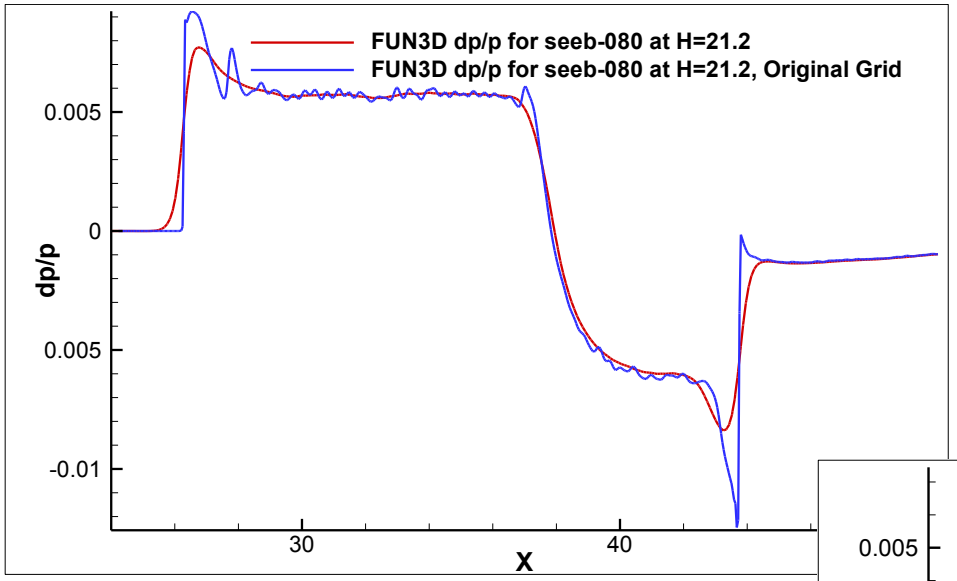


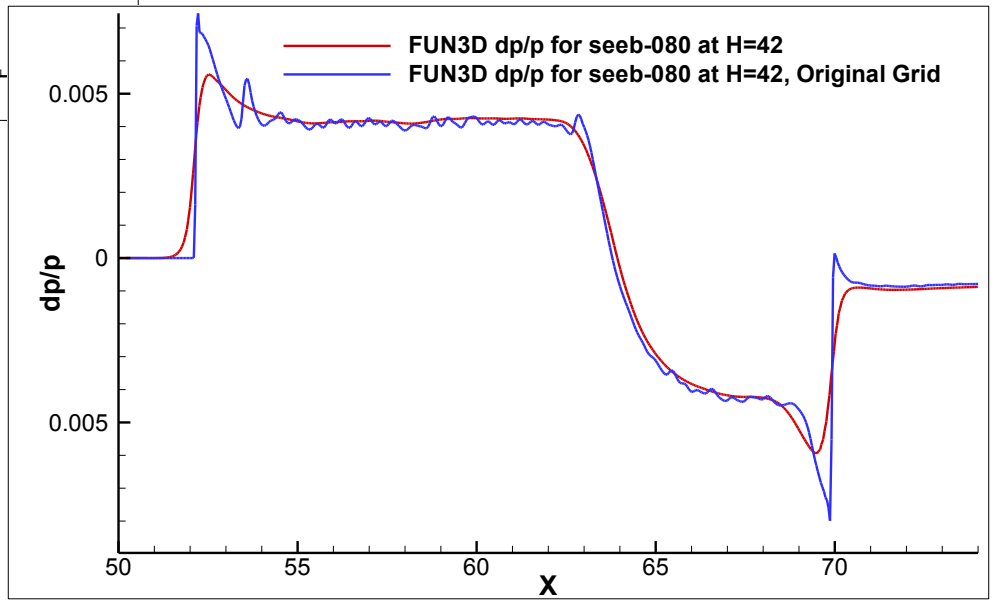
Summary

- Have a unique process to use a surface triangulation to generate volume meshes for boom analysis and design
- Automated FUN3D analysis starting from a surface mesh relied heavily on volumetric mesh generation through AFLR2/3 – some trial and error had to be done to figure out what parameters to choose for appropriate grid generation (Thanks to Irian Ordaz for helping out in this respect)
- Specifically avoided adaptive mesh refinement during boom analysis to test the usefulness of the AFLR2/3 mesh generation process in a production environment
- Mesh generation and preprocessing time
  - ~90% of total computational time for SEEB and Delta
  - ~80% of total computational time for LM1021
- Gained some experience generating viscous meshes using AFLR2/3 and running viscous solutions using FUN3D (Thanks to Mike Park for sharing scripts to resolve convergence issues with LM1021)

QUESTIONS?

SEEB


FUN3D dp/p for seeb-080 at H=21.2
FUN3D dp/p for seeb-080 at H=21.2, Original Grid
0.005
0
dp/p
0.005
-0.01
30
40
X


FUN3D dp/p for seeb-080 at H=42
FUN3D dp/p for seeb-080 at H=42, Original Grid
0.005
0
dp/p
0.005
50
55
60
65
70
X