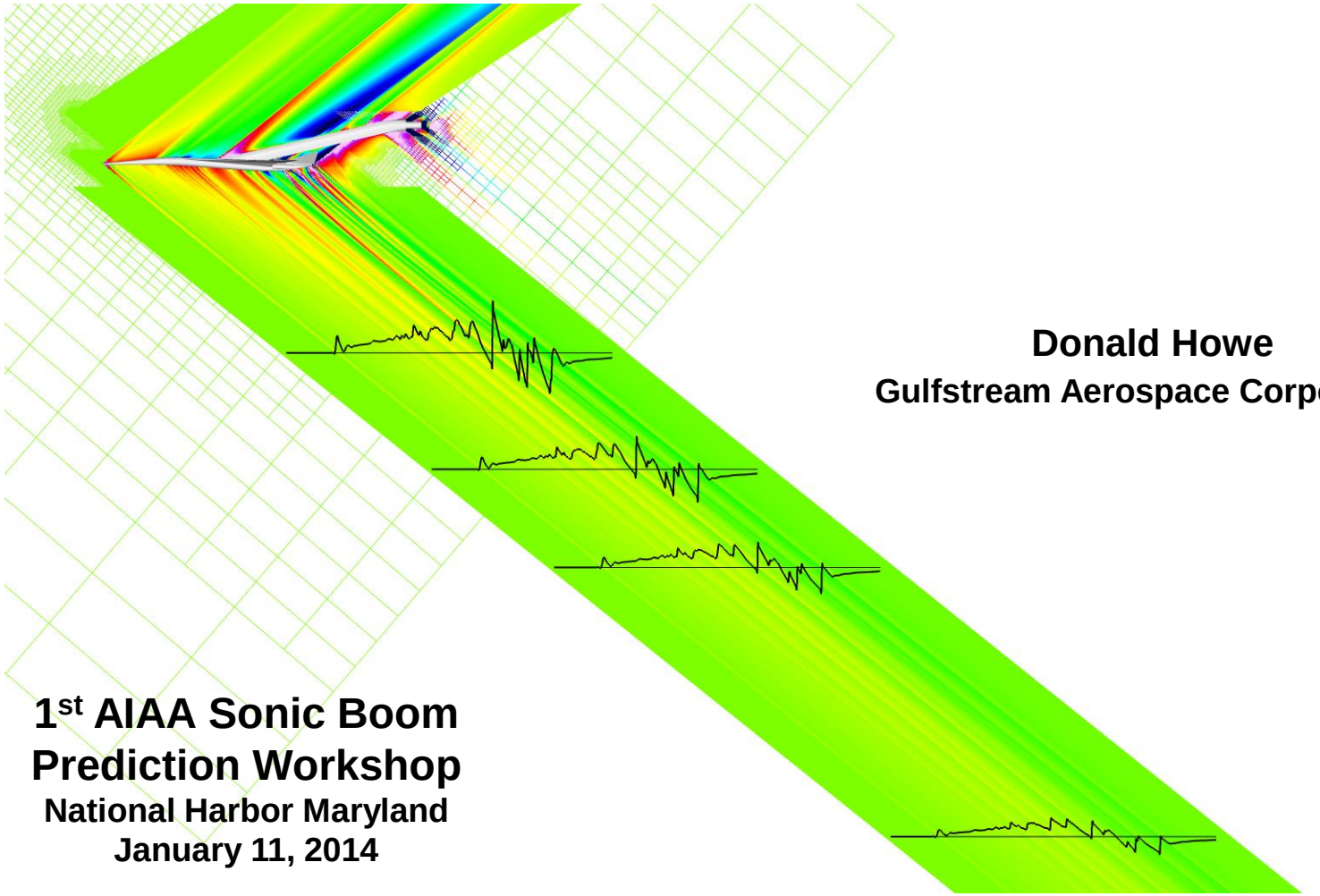
Hybrid CART3D/OVERFLOW Analysis for Sonic Boom Prediction Workshop



Donald Howe
Gulfstream Aerospace Corporation

1st AIAA Sonic Boom Prediction Workshop
National Harbor Maryland
January 11, 2014

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Hybrid Cart3D/Overflow Sonic Boom Analysis

Hybrid Cart3D/Overflow Methodology

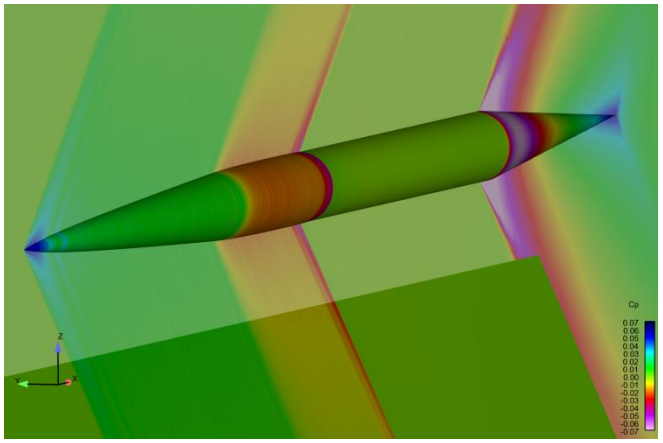
- Motivation
- Cart3D “Near-Field”
- Overflow “Midfield”

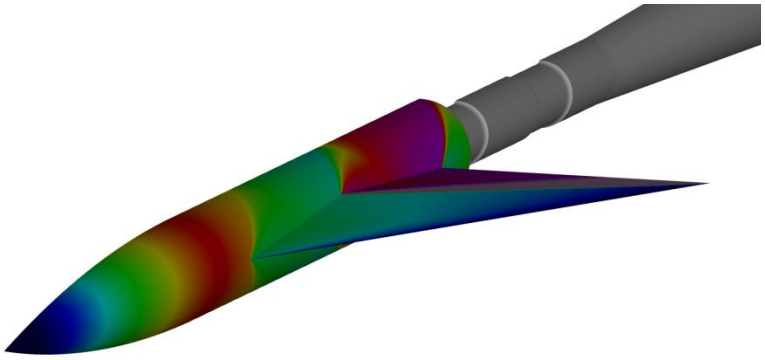
SEEB Body of Revolution Results

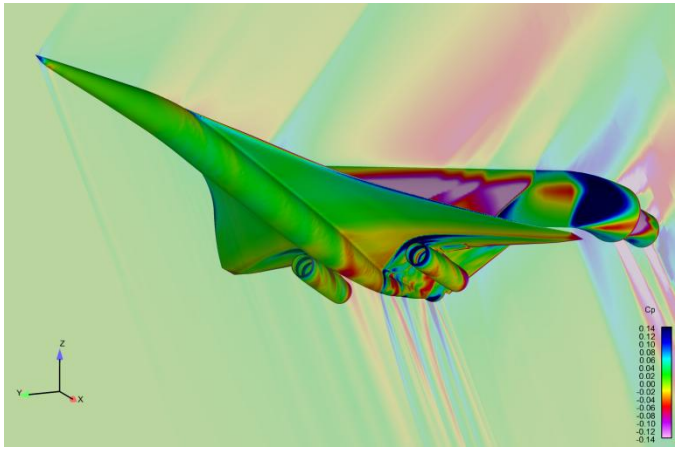
69° Delta Wing/Body Results

Lockheed LM1021 Results

Summary

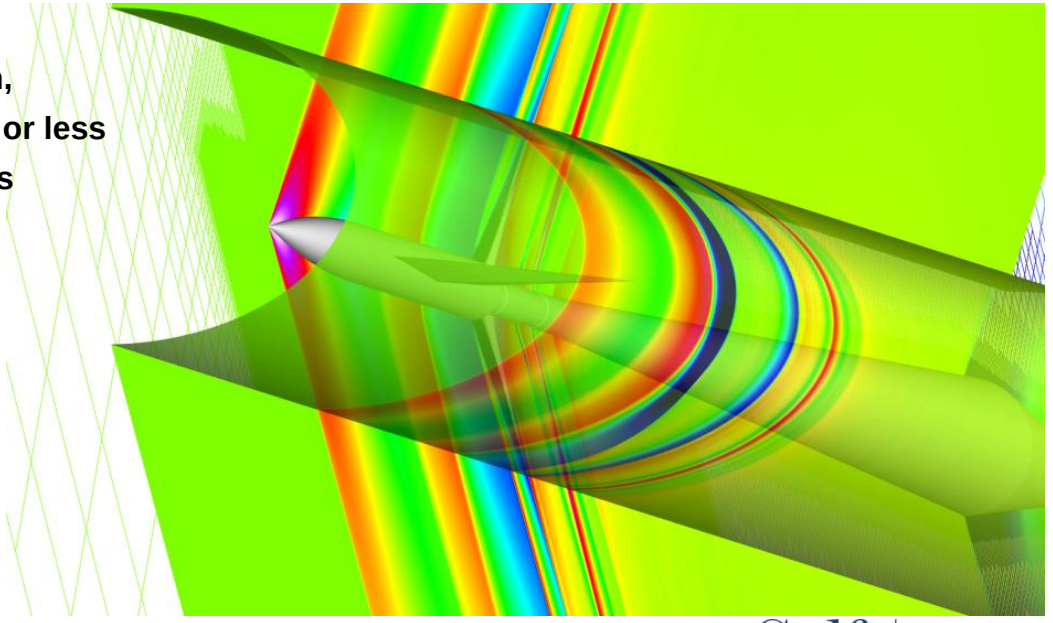






Hybrid Cart3D/Overflow Sonic Boom Analysis

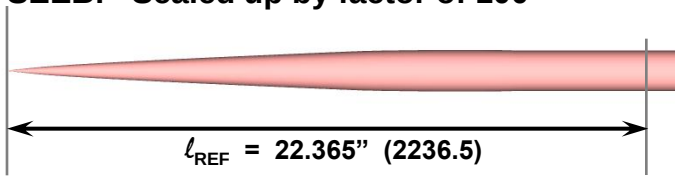
- **Hybrid Near-/Mid-Field method developed in the following context:**
  - **Implement existing analysis codes into a design setting**
  - **Complete complex configurations including propulsion integration**
  - **Applicable to both global and local optimization with automated configuration changes**
  - **Adequate mid-field distance for propagation (at least 5 to 6 body lengths)**
  - **Simultaneous on- and off-track analysis**
  - **Fast enough on available hardware for many solutions during design**
- **Flow field split into separate near-field and mid-field zones using different codes where each topology is best suited**
  - **Near-Field:**
    - **CART3D unstructured Cartesian,**
    - **Focusing the grid within h/l = ½ or less**
    - **Pre-Specified refinement regions**
  - **Mid-Field:**
    - **OVERFLOW structured mesh**
    - **Single annular grid block**
- **AIAA 2011-3336**



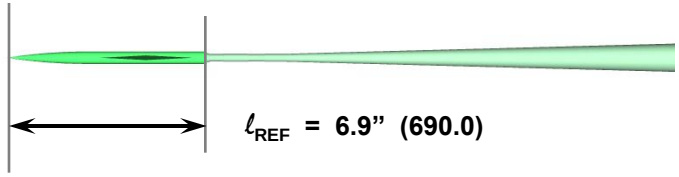
Cart3D Near-Field Analysis

- **Workshop objective was to use this "production" analysis technique as close to "as is" with minimal changes**
- **Scaled the workshop configurations up to approximately the same size as current designs and ran with the same basic gridding**

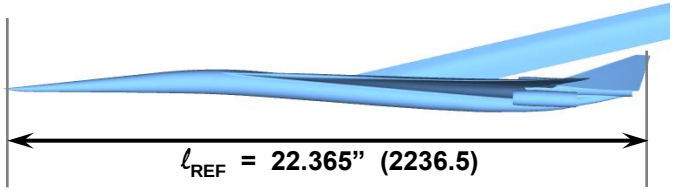
SEEB: Scaled up by factor of 100

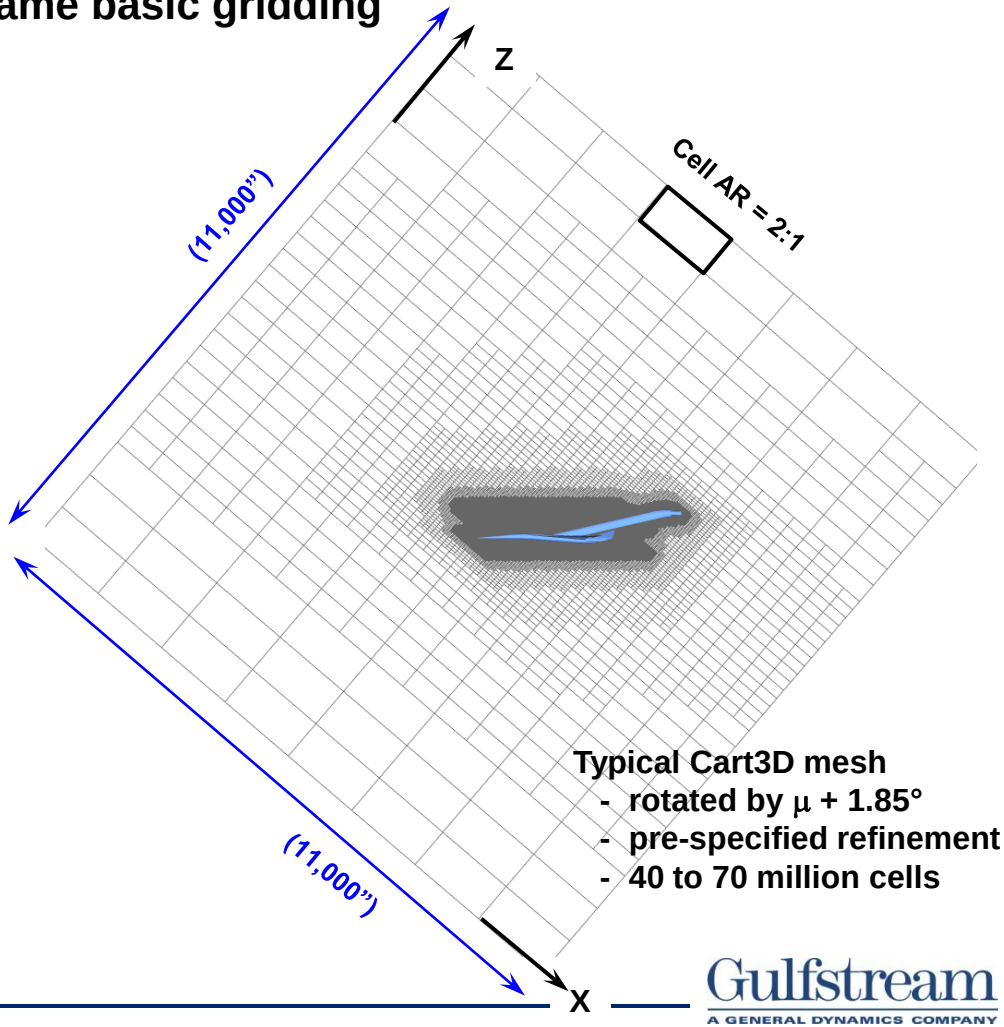


69° Delta W/B: Converted to inches & scaled by 100



LM 1021: Scaled up by factor of 100





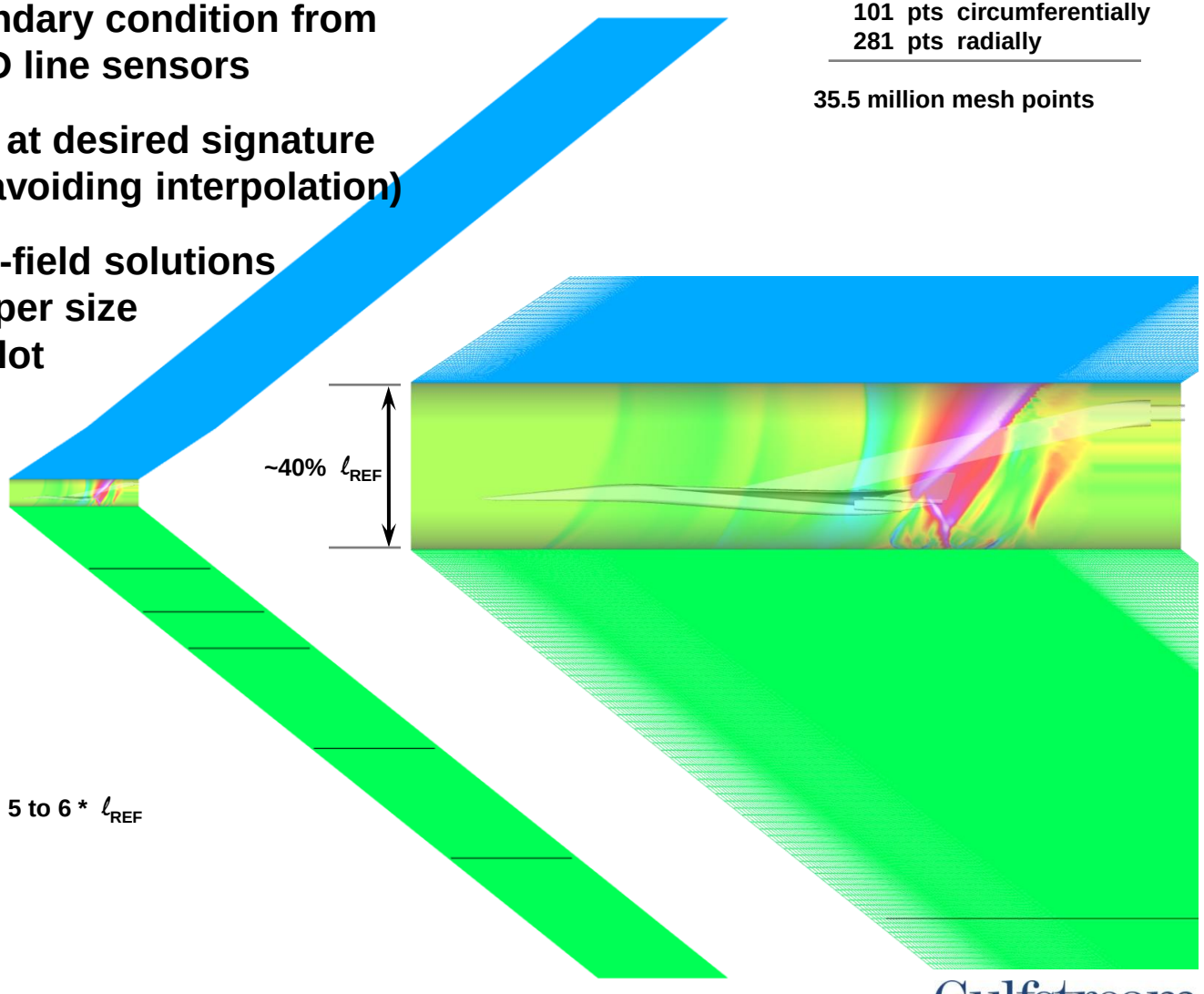
Typical Cart3D mesh
- **rotated by μ + 1.85°**
- **pre-specified refinement**
- **40 to 70 million cells**

Overflow Mid-Field Analysis

- Single structured block mid-field mesh
- Inner cylinder boundary condition from interpolated Cart3D line sensors
- Axial grid lines set at desired signature extract locations (avoiding interpolation)
- For workshop, mid-field solutions scaled back to proper size and provided Tecplot macros run to extract signatures

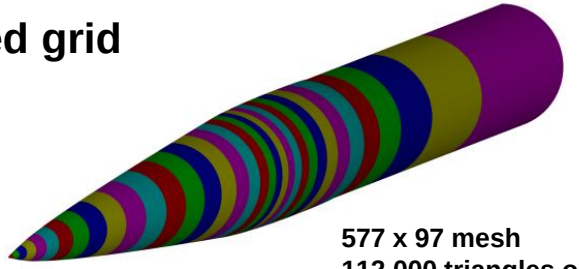
Single structured block
1281 pts axially
101 pts circumferentially
281 pts radially

35.5 million mesh points



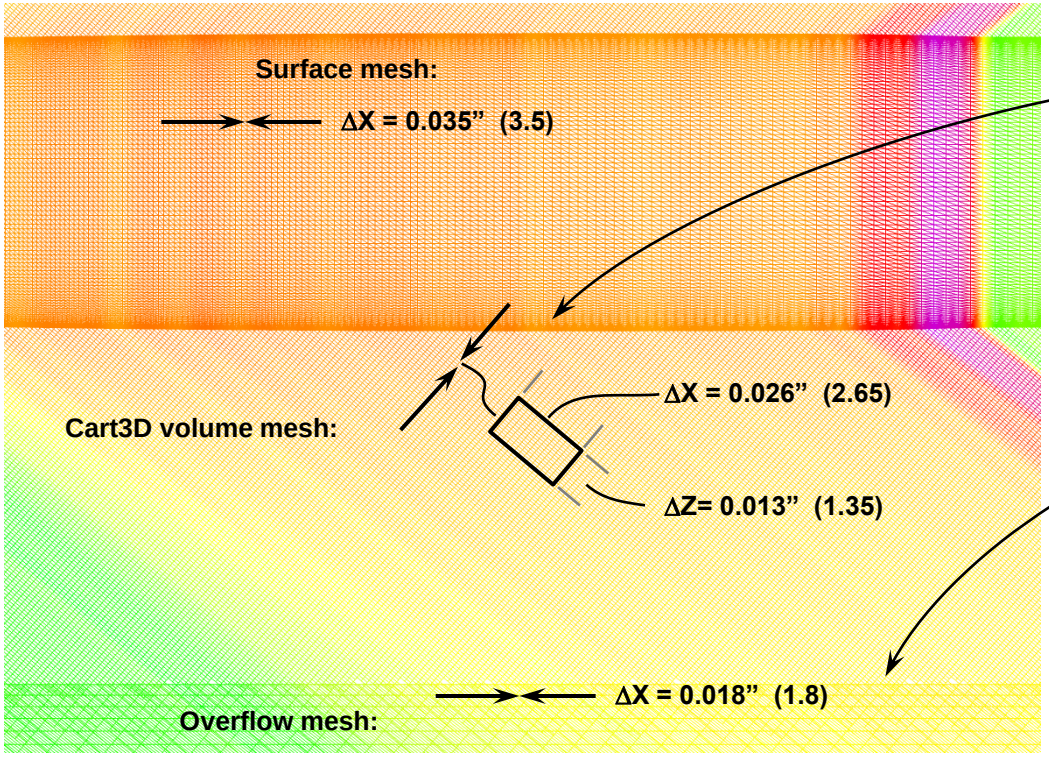
SEEB Body of Revolution Modeling

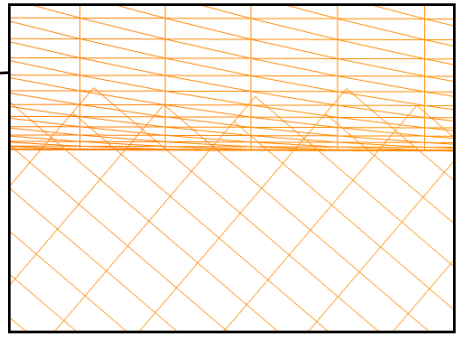
- Started from workshop provided multi-block structured grid
  - Extracted surface mesh
  - Triangulated the structured mesh
  - Added conical close out on the back
  - 38.6 million cells in Cart3D mesh

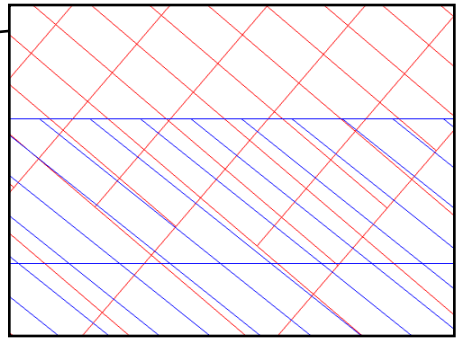


577 x 97 mesh
112,000 triangles on
half body

Typical mesh sizes:







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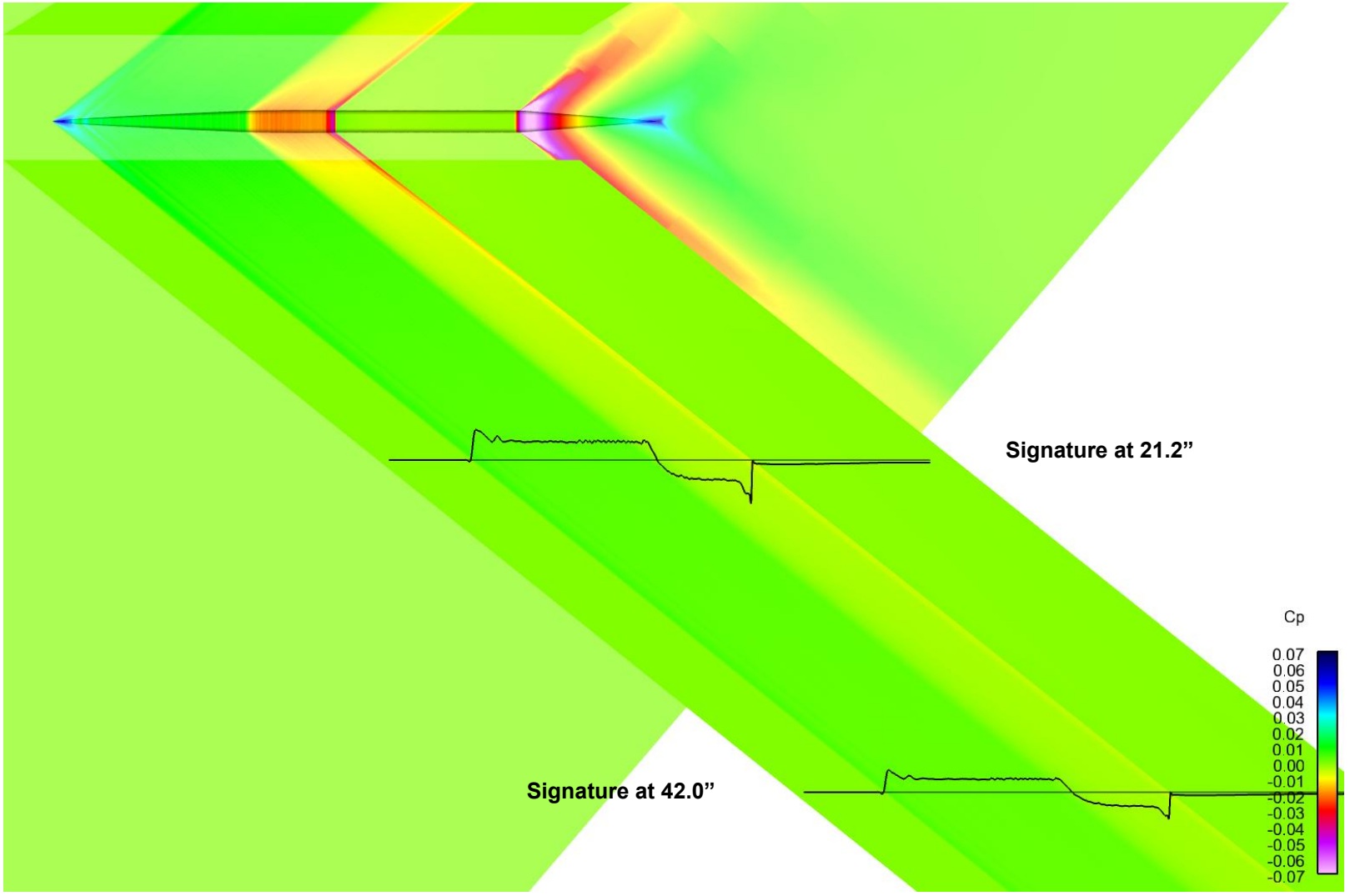
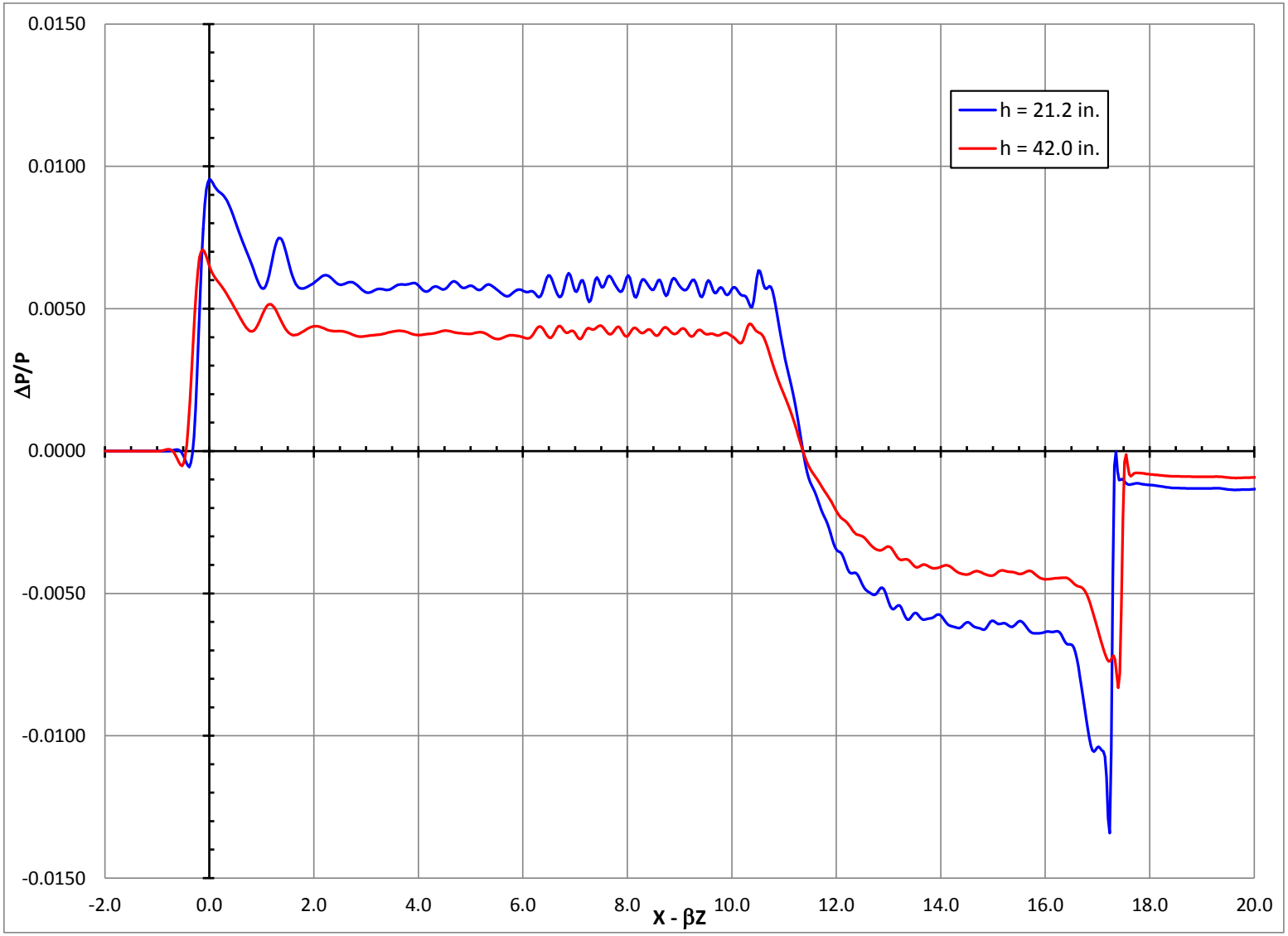
SEEB Body of Revolution Solution

Symmetry plane solution with extracted signatures



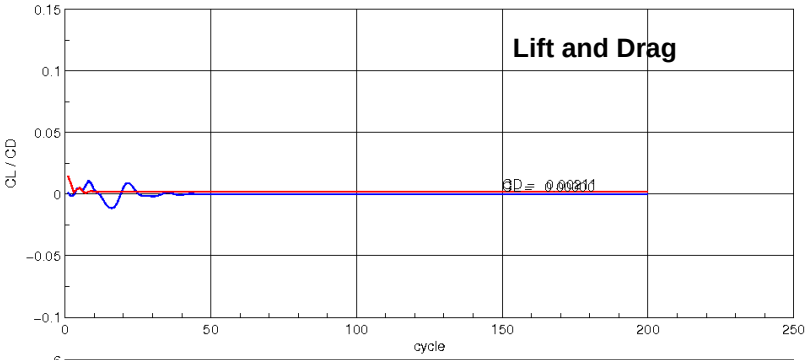
SEEB Body of Revolution Signatures

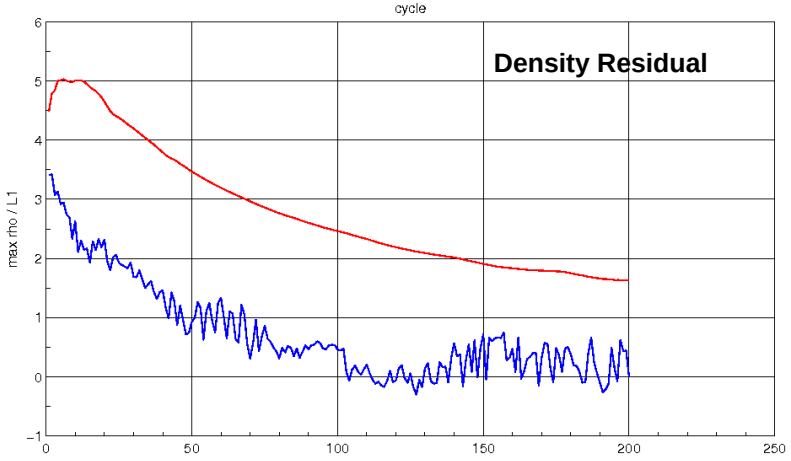


SEEB Body of Revolution Convergence

Cart3D

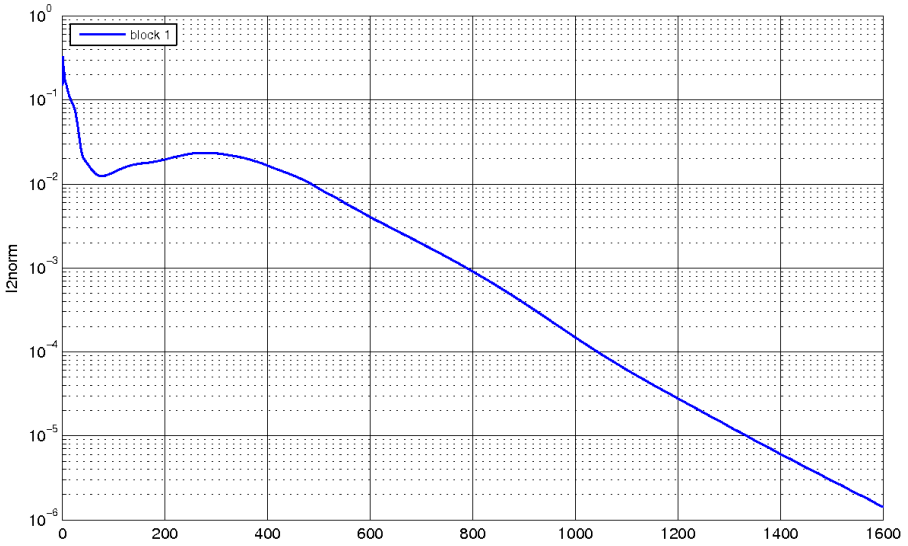
- Second order upwind
- van Leer flux function
- van Leer limiter
- 5 levels of V-cycle multi-grid
- no initial grid sequencing
- 200 iterations
- 1.4 hours on 12 core Sandy Bridge compute node



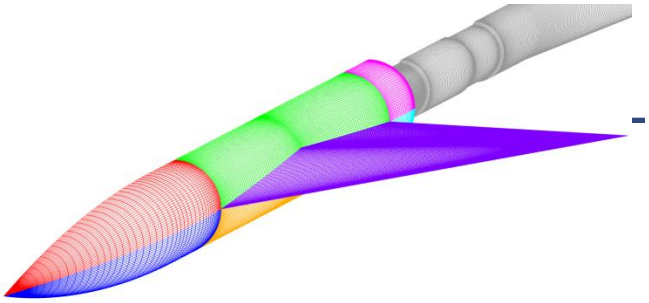


Overflow 2.1ae

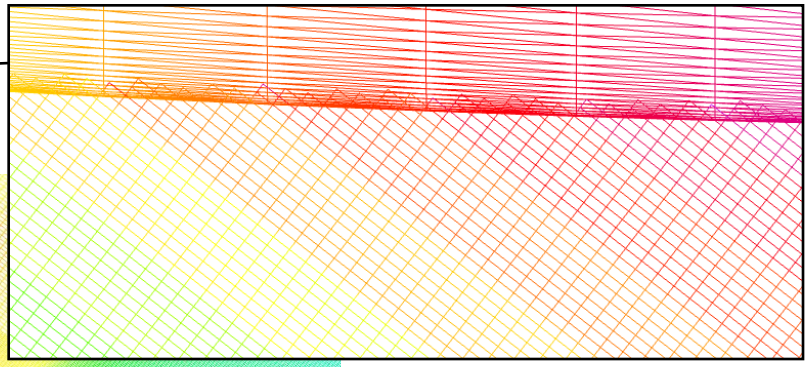
- Central difference
- ARC3D diagonal
- Matrix dissipation
- 3 levels of multi-grid
- no initial grid sequencing
- 1600 iterations
- 1.6 hours on 36 Sandy Bridge cores



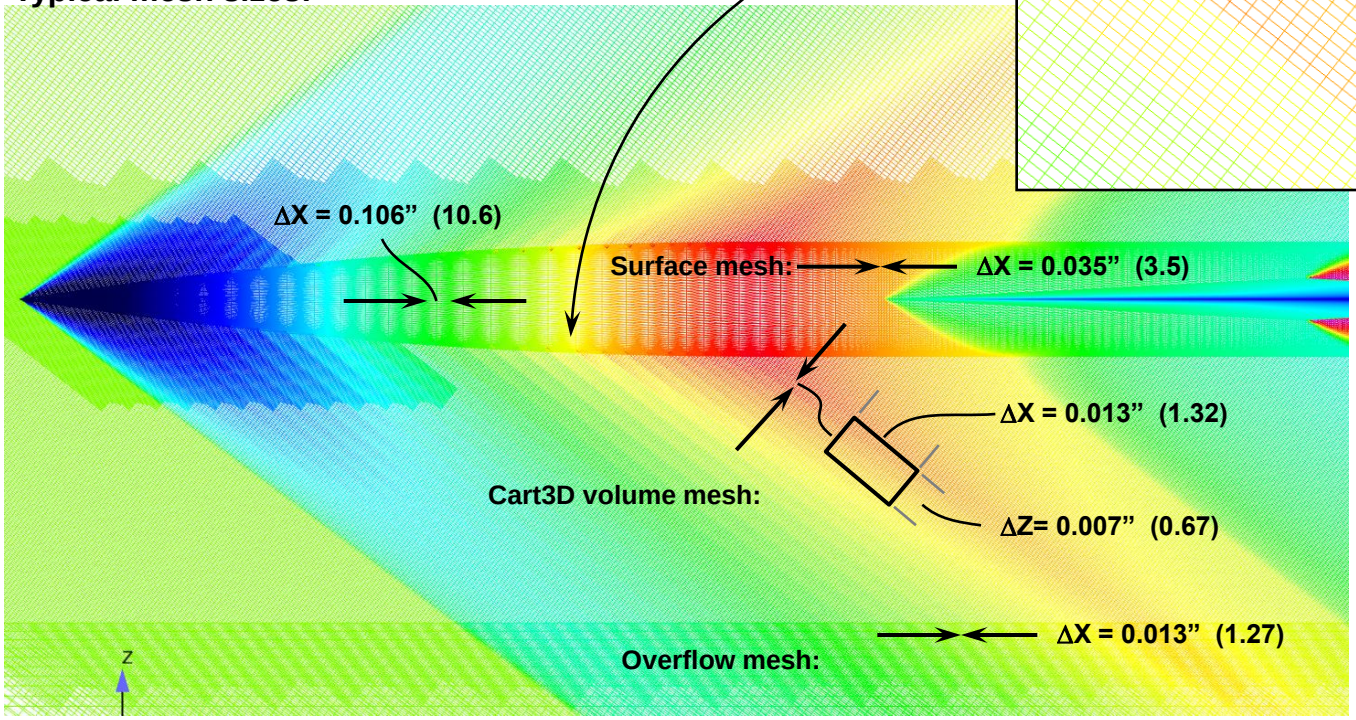
69° Delta Wing/Body Modeling



- Started from workshop provided multi-block structure
  - Extracted surface mesh
  - Triangulated the structured mesh
  - Added conical close out on the back of sting
  - One more level of refinement than other cases
  - 72.2 million cells in Cart3D mesh



Typical mesh sizes:



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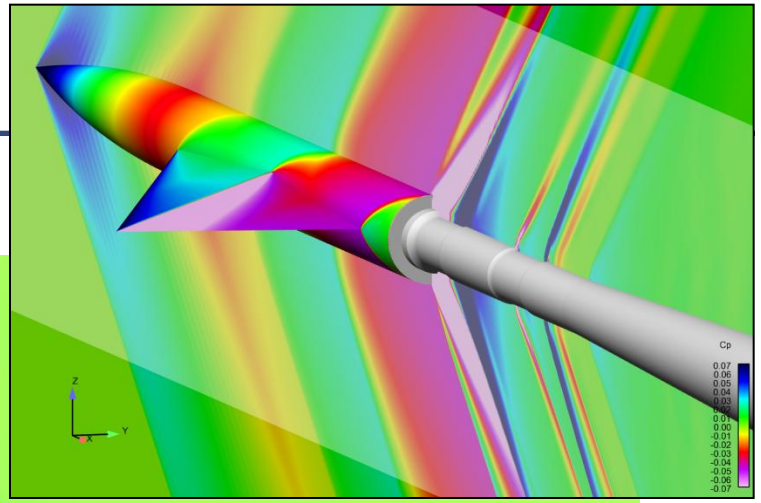
69° Delta Wing/Body Solution

Symmetry plane solution with extracted signatures



Signature at 21.2”

Signature at 24.8”

Signature at 31.8”

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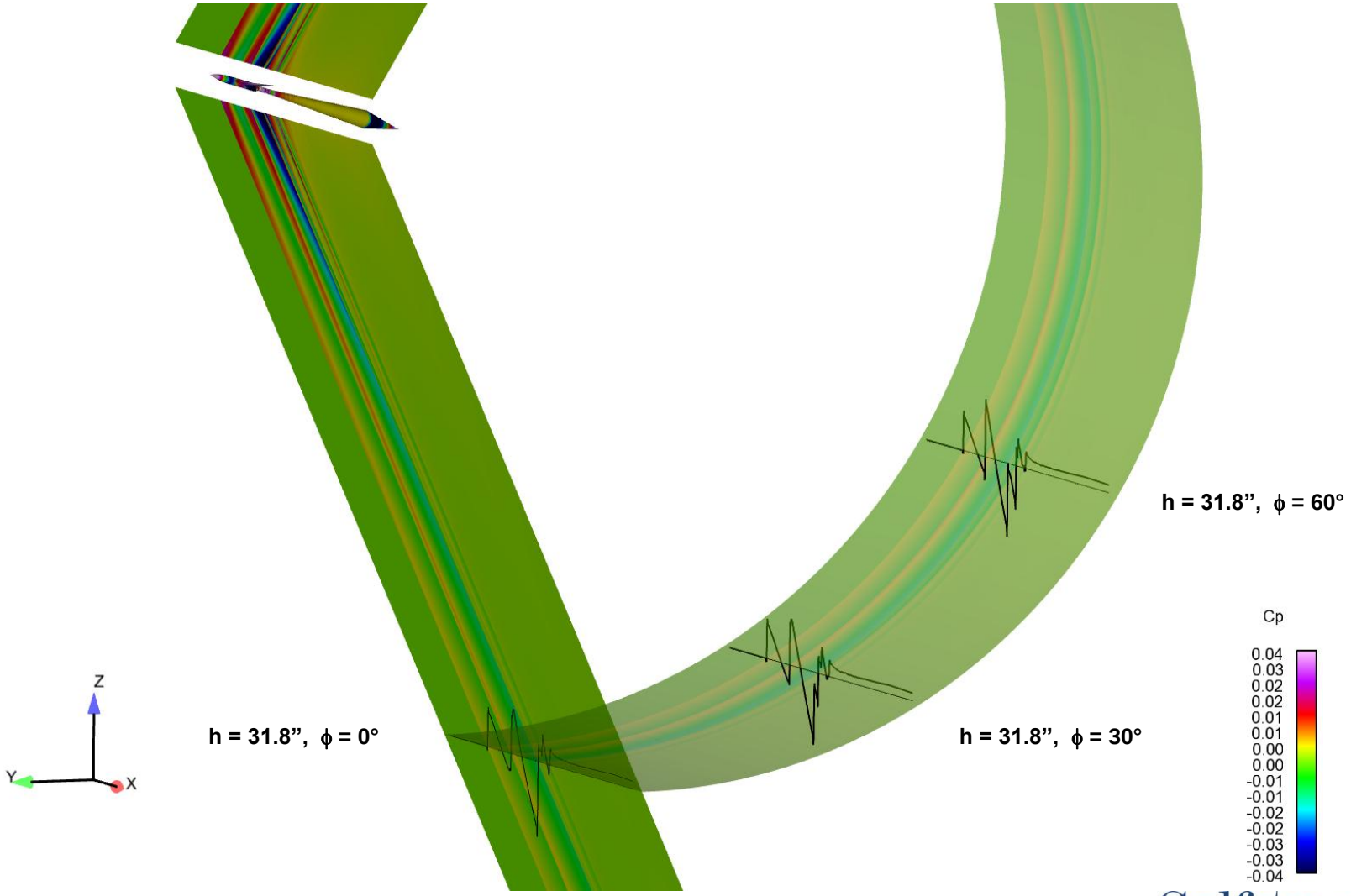
69° Delta Wing/Body Off Track



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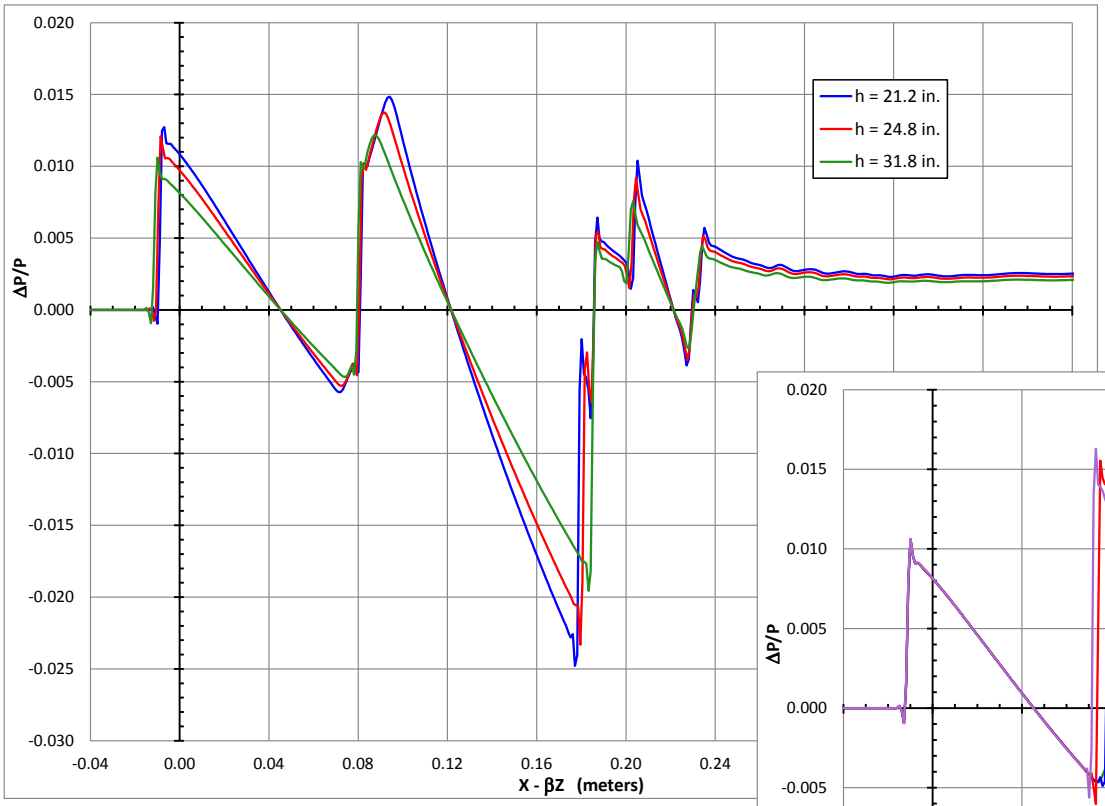
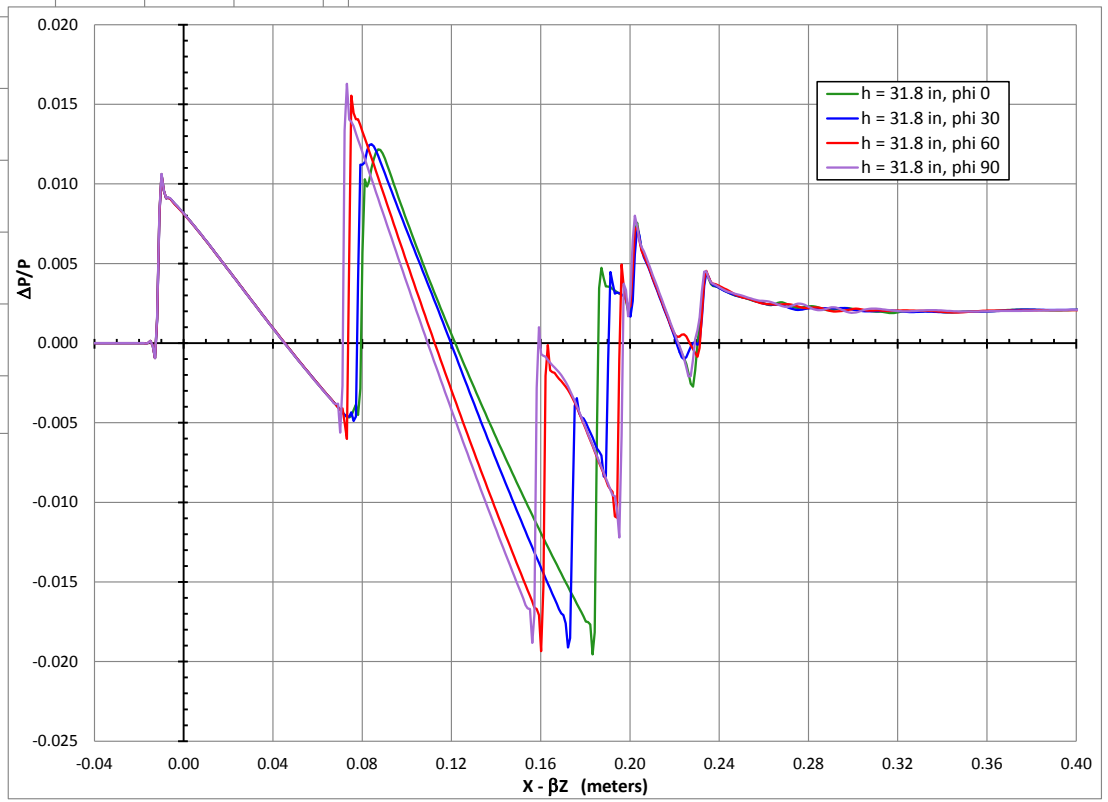
69° Delta Wing/Body Signatures



On Track at h = 21.2, 24.8, 31.8

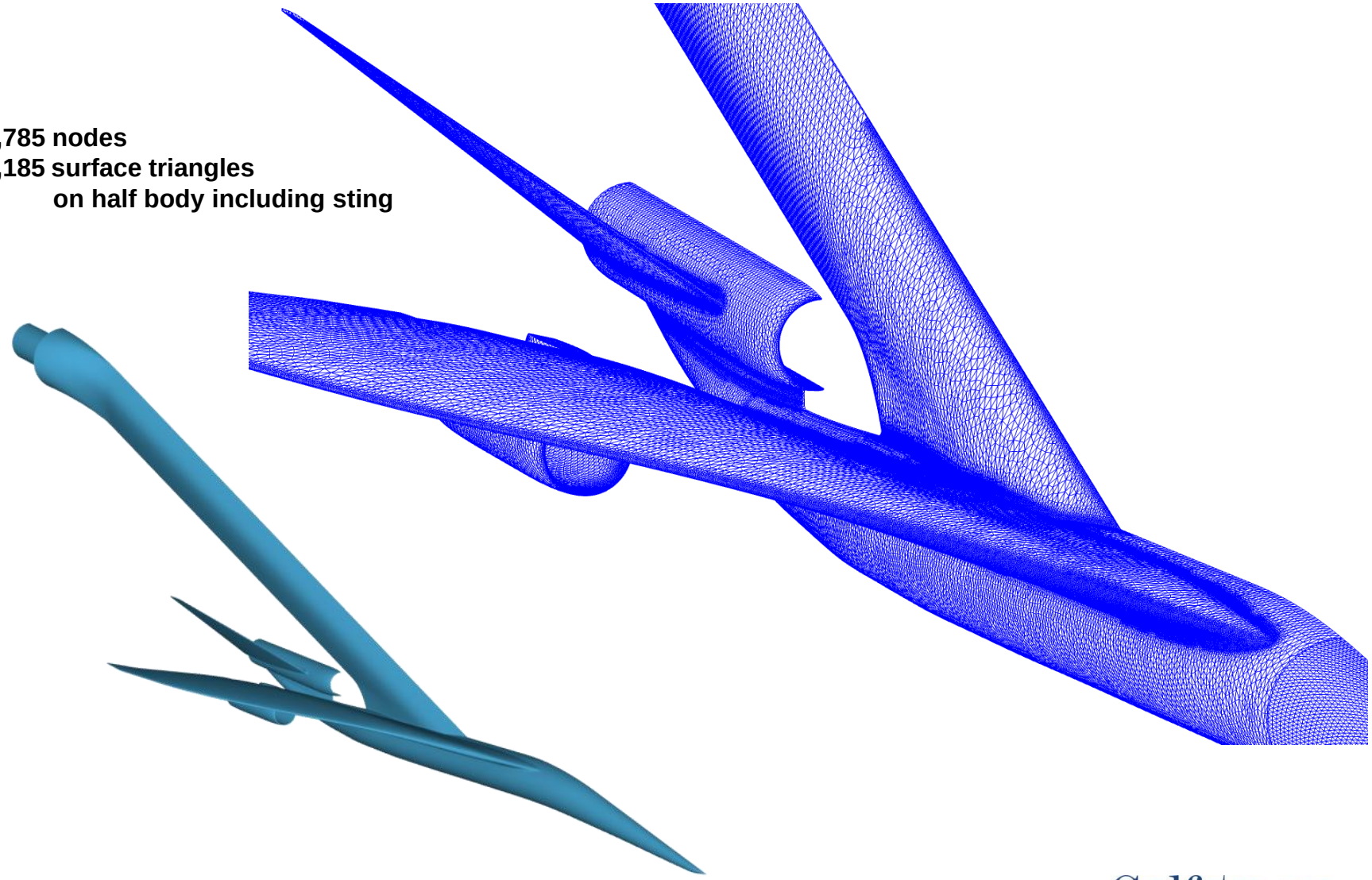
Off Track at h = 31.8 and ϕ = 0, 30, 60, 90°



Lockheed LM1021 Modeling

Used workshop provided surface triangulation (.tri) file

69,785 nodes
137,185 surface triangles
on half body including sting



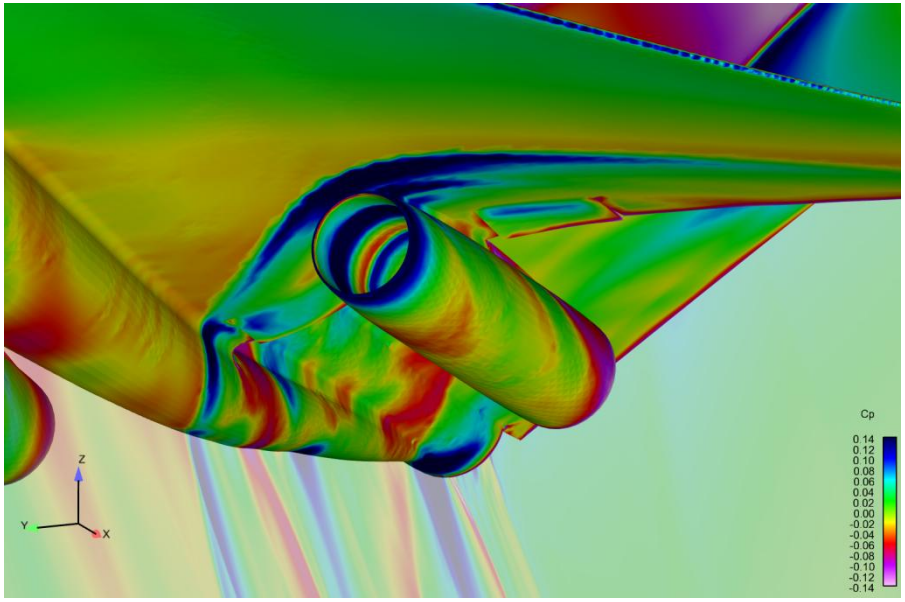
Lockheed LM1021 Modeling

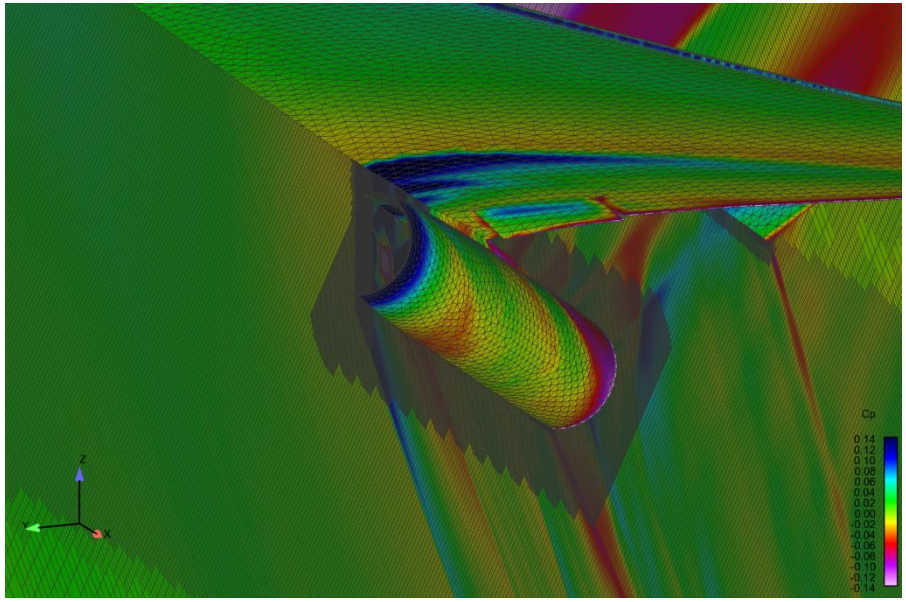
Pre-specified refinement region around entire nacelle with ΔX = 0.013” (1.32)

Pre-specified refinement region around inlet with ΔX = 0.007” (0.66)

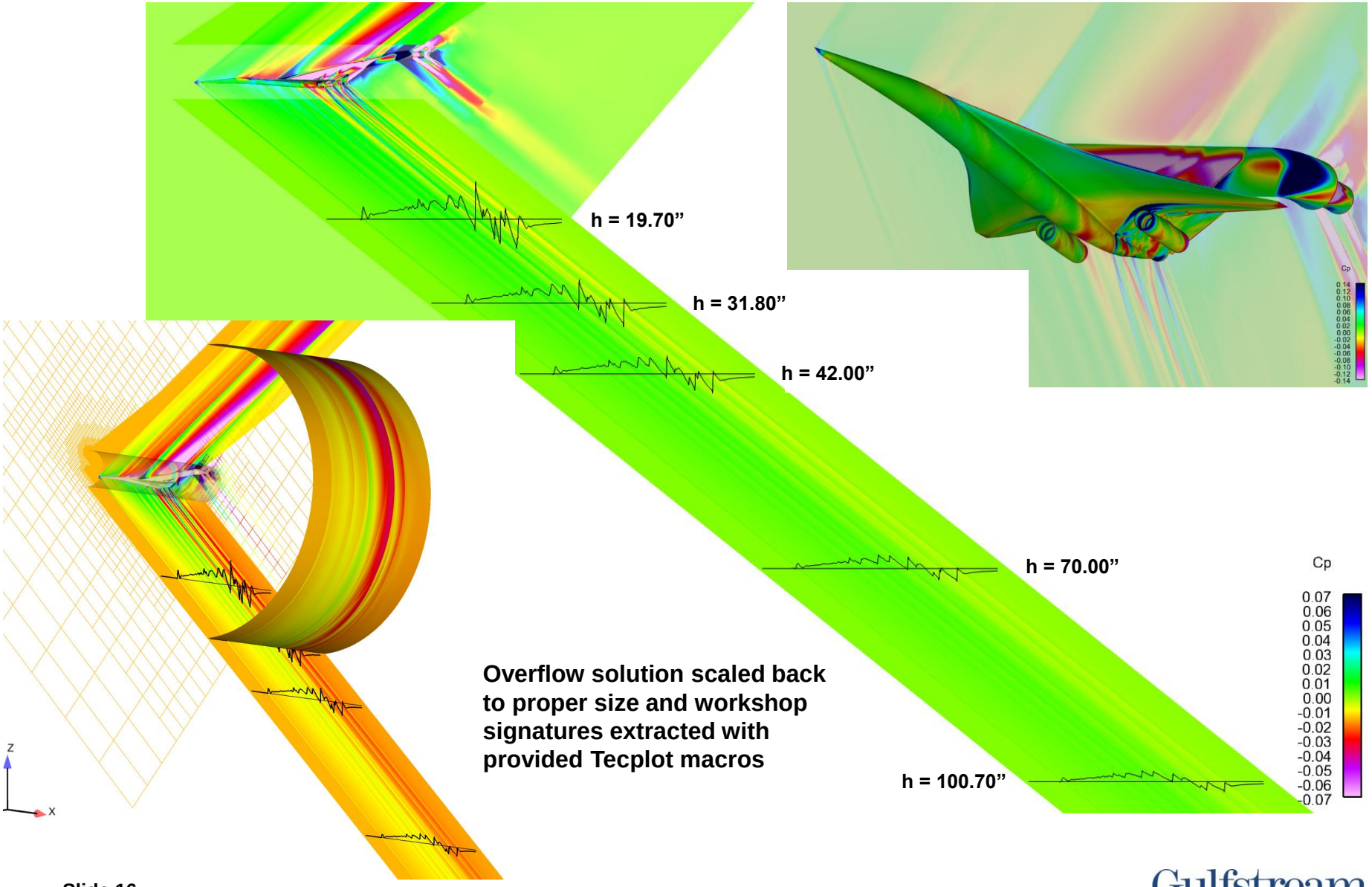
Mesh sizes at Cart3D to Overflow interface the same as for the SEEB model

51 million cells in Cart3D mesh





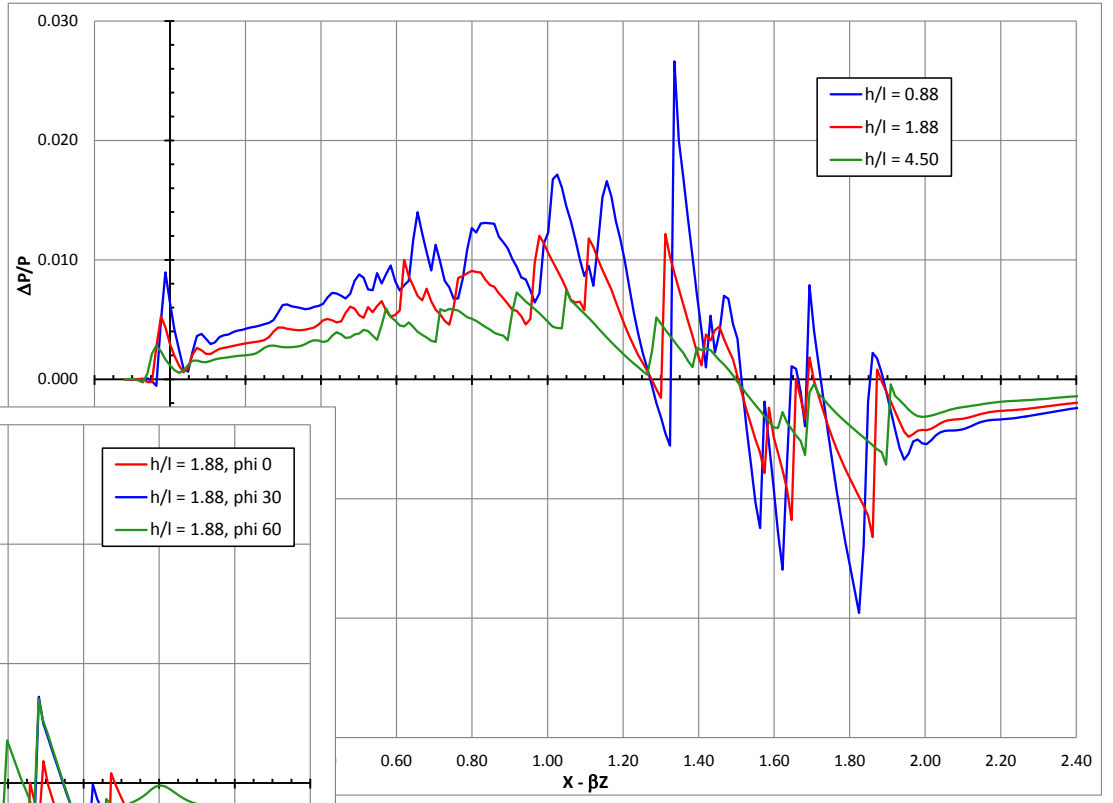
Lockheed LM1021 Solution



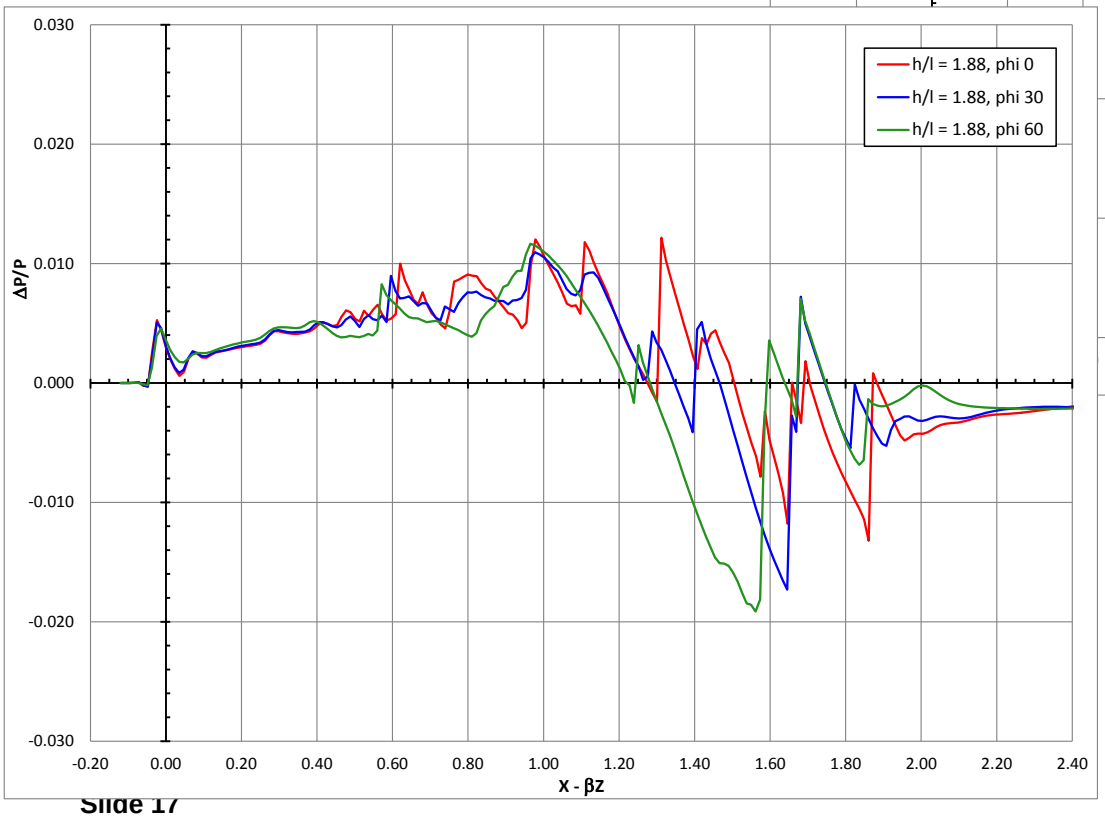
Overflow solution scaled back to proper size and workshop signatures extracted with provided Tecplot macros

Lockheed LM1021 Signatures

On Track at h/l = 0.88, 1.88, 4.50



Off Track at h/l = 1.88 and ϕ = 0, 30, 60°



Summary

- **Hybrid sonic boom prediction method using CART3D (unstructured Cartesian) in the near-field and OVERFLOW in the mid-field**
- **Utilizes each code in the flow regime for which it is best suited**
- **Frequently used “production” analysis method applied to Sonic Boom Prediction Workshop configurations**
- **Comparisons to wind tunnel data . . .**