Summary and Comparison of NASA’s Supersonic Boom Prediction Methods

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Presentation Outline

• Comparison of Computational Results with Experimental Data
• Comparison of Computational Results from Delta Wing Body Distance Study
• Time to Obtain CFD Results Comparison
Configurations Studied

• Bodies of Revolution
  – Cone-Cylinder
  – Parabolic
  – Quartic
• 69-degree Swept Delta-Wing-Body
• Ames Low Boom Wing Tail (LBWT) with 4 Nacelles
Cone-Cylinder - 10 Body Lengths Below
Parabolic Body of Revolution - 10 BL

The graph shows the comparison of different computational fluid dynamics (CFD) simulations against experimental data for a parabolic body of revolution. The simulations include CART3D with Adjoint, FUN3D with Adjoint, AIRPLANE with ANET, CART3D with ANET, and USM3D with SSGRID. The x-axis represents the location along the body, while the y-axis shows the pressure coefficient (Δp/p) variation.
Quartic Body of Revolution - 10 BL
69-degree Swept Delta-Wing-Body - 3.6 BL

Experimental Error is the same size as the symbol
Ames Low Boom Wing Tail (LBWT) with 4 Nacelles - 1.167 BL

Experimental Error is the same size as the symbol
Ames Low Boom Wing Tail (LBWT) with 4 Nacelles - 1.167 BL

Experimental Error is the same size as the symbol
Near Field Study

- Study conducted using Delta Wing Body
- Study included cuts at 0.2, 0.4, 0.8, 1.2, 2.0 and 2.8 body lengths below the model
- No experimental data available for comparison
- No extrapolation (AIRPLANE & CART3D)
69-degree Swept Delta-Wing-Body - 0.2 BL
69-degree Swept Delta-Wing-Body - 0.8 BL
69-degree Swept Delta-Wing-Body - 1.2 BL
69-degree Swept Delta-Wing-Body - 2.8 BL
69-degree Swept Delta-Wing-Body - 3.6 BL

Experimental Error is the same size as the symbol.
**Time to Obtain Data**

- Data Includes Only Computer Time
  - Time to Create Grid
  - Time to Get Computational Solution
- All of the methods used different computers!!!
Cone-Cylinder Timings

- 3,290,000* for CART3D w/Adjoint
- 3,636,000* for FUN3D w/Adjoint
- 313,500 for AIRPLANE
- 10,240,000 for CART3D
- 9,700,000 for USM3d w/SSGRID

* Final Grid Size

# of Control Volumes

Flow Solver (& Adjoint Method if applicable)

Mesh Generation

Time (minutes)
Cone-Cylinder Timings

- **CART3D w/ Adjoint**: 3,290,000*
  - 8 core Intel Xeon (3.2 Ghz, 16gb RAM)

- **FUN3D w/ Adjoint**: 3,636,000*
  - 24 Pentium 4 (3.6 Ghz, 2gb Ram each)

- **AIRPLANE**: 313,500
  - 64 Columbia Processors

- **CART3D**: 10,240,000
  - 64 Columbia Processors

- **USM3d w/ SSGRID**: 9,700,000
  - 48 Columbia Processors

* Final Grid Size
# Parabolic Body of Revolution

<table>
<thead>
<tr>
<th>Tool</th>
<th># of Control Volumes</th>
<th>Final Grid Size</th>
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</thead>
<tbody>
<tr>
<td>CART3D w/Adjoint</td>
<td>3,580,000*</td>
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</tr>
<tr>
<td>8 core Intel Xeon</td>
<td>3.2 Ghz, 16gb RAM</td>
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<td>FUN3D w/Adjoint</td>
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<tr>
<td>24 Pentium 4</td>
<td>3.6 Ghz, 2gb Ram each</td>
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<tr>
<td>AIRPLANE</td>
<td>522,400</td>
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<td>64 Columbia Processors</td>
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<tr>
<td>CART3D</td>
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<td>USM3d w/SSGRID</td>
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<td>48 Columbia Processors</td>
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</table>

* Final Grid Size

Flow Solver (Adjoint Method if applicable)
Quartic Body of Revolution

# of Control Volumes
* Final Grid Size

Flow Solver (& Adjoint Method if applicable)

Time (min) x # of Cores

<table>
<thead>
<tr>
<th>System</th>
<th>Control Volumes</th>
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<tbody>
<tr>
<td>CART3D w/Adjoint</td>
<td>3,980,000*</td>
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<tr>
<td>FUN3D w/Adjoint</td>
<td>1,120,000*</td>
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<td>AIRPLANE 64 Columbia</td>
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<tr>
<td>CART3D 64 Columbia</td>
<td>2,910,000</td>
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<tr>
<td>USM3d w/SSGRID</td>
<td>9,500,000</td>
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</tbody>
</table>
69-degree Swept Delta-Wing-Body

Flow Solver (& Adjoint Method if applicable)

# of Control Volumes
* Final Grid Size

Time (min) x # of Cores

- **2,260,000***
  - CART3D w/Adjoint
    - 8 core Intel Xeon
    - (3.2 Ghz, 16gb RAM)

- **6,690,000***
  - FUN3D w/Adjoint
    - 24 Pentium 4
    - (3.6 Ghz, 2gb Ram each)

- **677,900***
  - AIRPLANE
    - 64 Columbia Processors

- **4,390,000***
  - CART3D
    - 64 Columbia Processors

- **10,500,000***
  - USM3d w/SSGRID
    - 48 Columbia Processors

www.nasa.gov
Ames Low Boom Wing Tail (LBWT) with 4 Nacelles

<table>
<thead>
<tr>
<th>Time (min) x # of Cores</th>
<th>CART3D w/Adjoint</th>
<th>FUN3D w/Adjoint</th>
<th>AIRPLANE</th>
<th>CART3D</th>
<th>USM3d w/SSGRID</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>8 core Intel Xeon (3.2 Ghz, 16gb RAM)</td>
<td>24 Pentium 4 (3.6 Ghz, 2gb Ram each)</td>
<td>64 Columbia Processors</td>
<td>64 Columbia Processors</td>
<td>48 Columbia Processors</td>
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<tr>
<td></td>
<td>7,200,000*</td>
<td>6,940,000*</td>
<td>1,060,000</td>
<td>3,850,000</td>
<td>15,900,000</td>
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</table>

# of Control Volumes
* Final Grid Size

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Summary

• Have signatures with a single shock, multiple shocks, wide variety of shapes and signatures
• Any one of the codes can produce reasonable results in hours
• Accuracy of the codes have improved
• Automation has improved

Future Work:
• LBWT is being retested to obtain better fidelity data
• Low boom aft-end models
• How far do we need to go to use propagation to ground?