Ares I Scale Model Acoustic Test Above Deck Water Sound Suppression Results

The Ares I Scale Model Acoustic Test (ASMAT) program test matrix was designed to determine the acoustic reduction for the LOA environment with an above deck water sound suppression system. The scale model test can be used to quantify the effectiveness of the water suppression system as well as optimize the systems necessary for LOA noise reduction. Several water flow rates were tested to determine which rate provides the greatest acoustic reductions. Preliminary results are presented.
Ares I Scale Model Acoustic Test
Above Deck Water Sound Suppression Results

Noise and Physical Acoustics: Launch Vehicle Noise II
Session 4pNS
November 3, 2011
Introduction: Reducing Liftoff Acoustics

- **Liftoff acoustics (LOA)** noise is caused by the supersonic jet flow interaction with surrounding atmosphere and occurs at ignition and persists for 0-20 seconds as the vehicle lifts off.

- **Vehicle Design**
  - LOA - input for vibro-acoustics

- **If responses are high...**
  - Mitigate at component or vehicle

- **Vehicle mitigation is accomplished with a water sound suppression system provided by the Kennedy Space Center Launch Complex**
  - Mobile Launcher baseline configuration includes Below Deck Water
  - Above Deck Water not baselined
    - Technical, cost and schedule risks

- **Mitigation Pathfinder - scale model test**
  - 5% Ares I Scale Model Acoustic Test (ASMAT)
Above Deck Water: Rainbirds

KSC Rainbirds for Shuttle
\( \frac{W_w}{W_p} = 3.0 \)

ASMAT Rainbirds
\( \frac{W_w}{W_p} = 4.5 \)

- ASMAT Rainbird design based upon Shuttle design
- Flow rates are ratios of water to propellant \( \frac{W_w}{W_p} \)

<table>
<thead>
<tr>
<th>Rainbird Flow Rate Ratio</th>
<th>Ares I Flow Rate (GPM)</th>
<th>ASMAT Flow Rate (GPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \frac{W_w}{W_p} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td>243,000</td>
<td>566</td>
</tr>
<tr>
<td>3.5</td>
<td>340,000</td>
<td>991</td>
</tr>
<tr>
<td>4.5</td>
<td>438,000</td>
<td>1275</td>
</tr>
</tbody>
</table>
**ASMAT Matrix**

- Test matrix designed to determine liftoff acoustics
  - Quantify acoustic reduction with Above Deck Water/Rainbirds
  - Optimize Above Deck Water/Rainbirds flow rate ratio

<table>
<thead>
<tr>
<th>Relevant ASMAT Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VERT5:</strong>  5 ft + Drift + Launch Mount + Below Deck Water</td>
</tr>
<tr>
<td><strong>VERT7:</strong>  5 ft + Drift + Launch Mount + Below Deck Water</td>
</tr>
<tr>
<td><strong>VERT11:</strong>  5 ft + Drift + Below Deck Water</td>
</tr>
<tr>
<td><strong>VERT8:</strong>  5 ft + Drift + Launch Mount + Below Deck Water + Rainbird Water at 2 flow rate</td>
</tr>
<tr>
<td><strong>VERT9:</strong>  5 ft + Drift + Launch Mount + Below Deck Water + Rainbird Water at 3.5 flow rate</td>
</tr>
<tr>
<td><strong>VERT10:</strong>  5 ft + Drift + Below Deck Water + Rainbird Water at 3.5 flow rate</td>
</tr>
<tr>
<td><strong>VERT12:</strong>  5 ft + Drift + Below Deck Water + Rainbird Water at 4.5 flow rate</td>
</tr>
</tbody>
</table>
Test Article Configuration Change

- Removed Launch Mount after VERT9

VERT9 flow pattern with Launch Mount

VERT10 flow pattern without Launch Mount
DATA RESULTS
Overall Sound Pressure Level Comparisons of ASMAT Flow Rate Ratios

- The greatest noise reduction was achieved at a 3.5 flow rate ratio.
- No improvement in noise reduction when flow rate ratio was increased to 4.5.

![Graph showing overall sound pressure level comparisons for different ASMAT flow rate ratios and conditions.](image)
Sound Pressure Levels and ΔdB Reduction at Zone 1

Vehicle Station (inches)

Zone 12
Zone 11
Zone 10
Zone 9
Sub zone 8-4
Sub zone 8-3
Sub zone 8-2
Sub zone 8-1
Zone 8
Zone 7
Zone 6
Zone 5
Zone 4
Sub zone 3-2
Sub zone 3-1
Sub zone 3-3
Sub zone 2-2
Sub zone 2-1
Zone 2
Zone 1

Sound Pressure Level (dB)

1/3 Octave Band Center Frequency (Hz)

ASMAT Zone 1
No LM, 5 feet, No Rainbird (Vert#11)
No LM 5 feet Rainbird ww/wp =3.5 (Vert#10)

Noise Reduction (dB)

1/3 Octave Band Center Frequency (Full Scale)

Zone 1
Noise Reduction (Ww/Wp= 3.5, No LM)
Sound Pressure Levels and $\Delta$dB Reduction at Zone 4

**Graphs:****

1. **Graph 1:**
   - Title: ASMAT Zone 4
   - X-axis: 1/3 Octave Band Center Frequency (Hz) (Full Scale)
   - Y-axis: Sound Pressure Level (dB)
   - Data points for different conditions:
     - Red line: No LM 5 feet No Rainbird (Vert#11)
     - Dotted red line: No LM 5 feet Rainbird $ww/wp=3.5$ (Vert#10)

2. **Graph 2:**
   - Title: Zone 4
   - X-axis: 1/3 Octave Band Center Frequency (Full Scale)
   - Y-axis: Noise Reduction (dB)
   - Data points for different conditions:
     - Black bars: Noise Reduction ($ww/wp=3.5$, No LM)
Sound Pressure Levels and ΔdB Reduction at Zone 6

Vehicle Station (inches)

Zone 12
Zone 11
Zone 10
Zone 9
Zone 8
Zone 7
Zone 6
Zone 5
Zone 4
Zone 3
Zone 2
Zone 1

187
512
700
523
1000
1085
1285
1456
1630
1780
2004
2122
2291
2611
2931
3251
3571
3617
4088

ASMAT Zone 6

--- No LM, 5 feet, Rainbird w/w/wp =3.5 (Vert#10)
--- No LM 5 feet no Rainbird (Vert#11)

Noise Reduction (dB)

1/3 Octave Band Center Frequency (Full Scale)

Zone 6

Noise Reduction (W/w/wp = 3.5, No LM)
Sound Pressure Levels and $\Delta$dB Reduction at Zone 10

- **ASMAT Zone 10**
  - No LM, 5 feet Rainbird $\text{ww/wp} = 3.5$ (Vert#10)
  - No LM 5 feet no Rainbird (Vert#11)

- **Zone 10**
  - Noise Reduction ($\text{Ww/Wp} = 3.5$, No LM)
Overall Sound Pressure Level Comparisons:
No Rainbirds to Rainbirds at 3.5 Flow Rate Ratio

Comparing Vert10 and Vert11, both without the Launch Mount, the rainbirds effectively reduce the OASPL by 5 dB.
Removing Launch Mount resulted in an increased noise reduction

Rainbird noise reduction quantification
- Reduced OASPL by 5 dB at $W_w/W_p = 3.5$
  - 5-6 dB reduction in the 20 to 200 Hz range
  - 3 dB reduction in the 250 to 2000 Hz range
- Noise reduction appears to be consistent along the vehicle

Rainbird flow rate optimization
- Significant improvement in noise reduction from $W_w/W_p = 2$ to 3.5
- No improvement in noise reduction from $W_w/W_p = 3.5$ to 4.5

Recommend Above Deck Water (Rainbird) on future launch systems
- Recommend water to propellant flow rate ratio of 3.5