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

**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
\( W_w/W_p = 3.0 \)

ASMAT Rainbirds
\( W_w/W_p = 4.5 \)

♦ ASMAT Rainbird design based upon Shuttle design

♦ Flow rates are ratios of water to propellant \( W_w/W_p \)

<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>( 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>
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</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

Relevant ASMAT Cases

<table>
<thead>
<tr>
<th>VERT5:</th>
<th>5 ft + Drift + Launch Mount + Below Deck Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>VERT7:</td>
<td>5 ft + Drift + Launch Mount + Below Deck Water</td>
</tr>
<tr>
<td>VERT11:</td>
<td>5 ft + Drift + Below Deck Water</td>
</tr>
<tr>
<td>VERT8:</td>
<td>5 ft + Drift + Launch Mount + Below Deck Water + Rainbird Water at 2 flow rate</td>
</tr>
<tr>
<td>VERT9:</td>
<td>5 ft + Drift + Launch Mount + Below Deck Water + Rainbird Water at 3.5 flow rate</td>
</tr>
<tr>
<td>VERT10:</td>
<td>5 ft + Drift + Below Deck Water + Rainbird Water at 3.5 flow rate</td>
</tr>
<tr>
<td>VERT12:</td>
<td>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.
Sound Pressure Levels and $\Delta$dB Reduction at Zone 1

![Diagram showing vehicle stations and sound pressure levels at Zone 1.]

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

- **Vehicle Station (Inches):**
  - Zone 12: 187
  - Zone 11: 512
  - Zone 10: 750
  - Zone 9: 523
  - Zone 8: 1000
  - Zone 7: 1085
  - Zone 6: 1285
  - Zone 5: 1458
  - Zone 4: 1630
  - Zone 3: 1780
  - Zone 2: 2004
  - Zone 1: 2122

- **1/3 Octave Band Center Frequency (Hz) (Full Scale):**
  - 10 20 32 40 50 63 80 100 125 160 200 250 315 400 500 630 800 1000 1250 1600 2000

- **Noise Reduction (dB):**
  - **No LM, 5 feet, No Rainbird (Vert#11):**
  - **No LM, 5 feet Rainbird ww/wp = 3.5 (Vert#10):**

- **Graph showing sound pressure level and noise reduction at Zone 1.**
Sound Pressure Levels and ΔdB Reduction at Zone 4

ASAAM Zone 4

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

Noise Reduction (Ww/Wp = 3.5, No LM)
Sound Pressure Levels and $\Delta$dB Reduction at Zone 6

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**Graph 1:**
- **X-axis:** 1/3 Octave Band Center Frequency (Full Scale)
- **Y-axis:** Sound Pressure Level (dB)
- **Legend:**
  - Red dashed line: No LM, 5 feet, Rainbird $w_w/w_p = 3.5$ (Vert#10)
  - Red line: No LM 5 feet no Rainbird (Vert#11)

**Graph 2:**
- **X-axis:** 1/3 Octave Band Center Frequency (Full Scale)
- **Y-axis:** Noise Reduction (dB)
- **Legend:**
  - Black bars: Noise Reduction ($w_w/w_p = 3.5$, No LM)
# Sound Pressure Levels and ΔdB Reduction at Zone 10

## Data Table

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Sound Pressure Level (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>150</td>
</tr>
<tr>
<td>100</td>
<td>140</td>
</tr>
<tr>
<td>1000</td>
<td>130</td>
</tr>
</tbody>
</table>

## Graphs

### ASMAT Zone 10

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

### Noise Reduction (Ww/Wp= 3.5, No LM)

- **Zone 10**

## Diagram

- Vehicle Station (inches)
- Zones and sub-zones labeled

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1/3 Octave Band Center Frequency (Hz) (Full Scale)

Noise Reduction (dB)

1/3 Octave Band Center Frequency (Full Scale)
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

![Graph showing overall sound pressure level comparison between Vert10 with and without rainbirds vs. Vert11 without rainbirds. The graph indicates a decrease in overall sound pressure level (OASPL) by 5 dB with the use of rainbirds.](image-url)
ASMAT Findings and Recommendation

♦ 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