Space Launch System
Scale Model Acoustic Test
Liftoff Results and Comparisons

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• NASA is developing the Space Launch System (SLS)
• Pre-test liftoff acoustic (LOA) environments predicted with assumptions based on 6.4% Space Shuttle and Ares I Scale Model Acoustic Tests
• Scale Model Acoustic Test (SMAT) implemented to verify predictions
  • Marshall Space Flight Center (MSFC) East Test Area Test Stand 116
  • 16 hot fires April to December 2014
SMAT Objectives & Test Article

- Assess how LOA environment changes with vehicle elevation
- Assess water suppression systems for hold-down and elevated cases
- Assess above-deck water sound suppression system effectiveness at different flow rates
- Compare SMAT above-deck water sound suppression results with ASMAT and 6.4% Space Shuttle Test
Water Sound Suppression Systems
Below & Above Deck

Rainbirds
Design / Test
Trade Space
• 4 Rainbirds
• Taller Rainbirds

Trench

Duct & 5 Nominal Rainbirds
Three instrumentation suites:

- **Liftoff Acoustics**
  - B&K 4944-B microphones
- **Ignition Overpressure**
  - Kulite XTL-123B-190-30SG & -65 SG
- **Spatial Correlation**
  - Kulite XCEL-12-100-2D

**Data Acquisition:**
- 4000 sps
- 256,000 sps

**Data Analysis Window:**
- 1 second
Simulating Liftoff

- SMAT model elevated at liftoff positions:
  (a) 2.5’, (b) 5.0’, (c) 7.5’, and (d) 9.0’
Systems Operations

- Operation of the propulsion systems:
  (a) Rainbirds operational at full flow rate
  (b) Liquid engines ignited and ramped to full power
  (c) RATOs ignite and run simultaneously with liquid engines
Data Analysis Windows

The graph illustrates the pressure dynamics over time for different events and phases:

- **RATO Ignition**
- **RATO steady state**
- **RATO/Thruster Shutdown**
- **Thruster Startup & Ignition**
- **Thruster steady state**

The x-axis represents time aligned to the booster ignition command (in seconds), while the y-axis shows pressure levels in psi (pounds per square inch). The graph uses various colored lines to differentiate between different engine states and pressures.
Measuring the Event

- Movies
Repeatability

2 wet tests to determine repeatability
-Less than 1 dB difference
Hold Down Noise Levels

Important for ground equipment such as umbilicals

Addition of water in the exhaust hole and trench reduces overall sound pressure level (OASPL) by ~10 dB everywhere on vehicle
Liftoff Noise Levels

The highest OASPL was measured at the 7.5' elevation.

As the vehicle continues to liftoff, the OASPL drops.
Inclusion of rainbirds provides a ~2dB decrease in OASPL over entire vehicle.
Removing a rainbird and increasing the flow to the nozzles on the same line does not decrease the OASPL.
Noise Reduction Results
Taller vs Nominal Rainbirds

Making the rainbirds taller does decrease the OASPL by ~ 0.5 dB

Reduction not enough to warrant recommendation for design change
Available water tower and design allows for nominal $W_w/W_p = 1.9$

Increasing flowrate to $W_w/W_p = 3.5$ provides ~1dB decrease in OASPL at locations above 20” on vehicle
• More water does not necessarily mean more sound suppression
• Rainbird water has highest effectiveness at $\frac{W_w}{W_p} = 3.5$
Conclusions & Recommendations

• Scale Model Acoustic Test allowed for:
  • Simulation of liftoff conditions allowing for determination of elevation at which maximum SPL occurs: 7.5’
  • Simulation of water sound suppression systems
    • Determined the best solution within the trade space
    • 5 nominal rainbirds
    • Showed that available flow rate reduces the noise
      • But not optimal compared with other scale model test results

• Recommendations
  • Ratio of 3.5 for rainbirds provides best noise reduction
  • Scale model testing is useful for design of launch vehicles and water sound suppression systems