Overview of the Space Launch System Ascent Aeroacoustic Environment Test Program

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Overview

- Objectives
- Test Models
- Instrumentation
- Test Details
- Data Analysis
- Results
- Conclusions

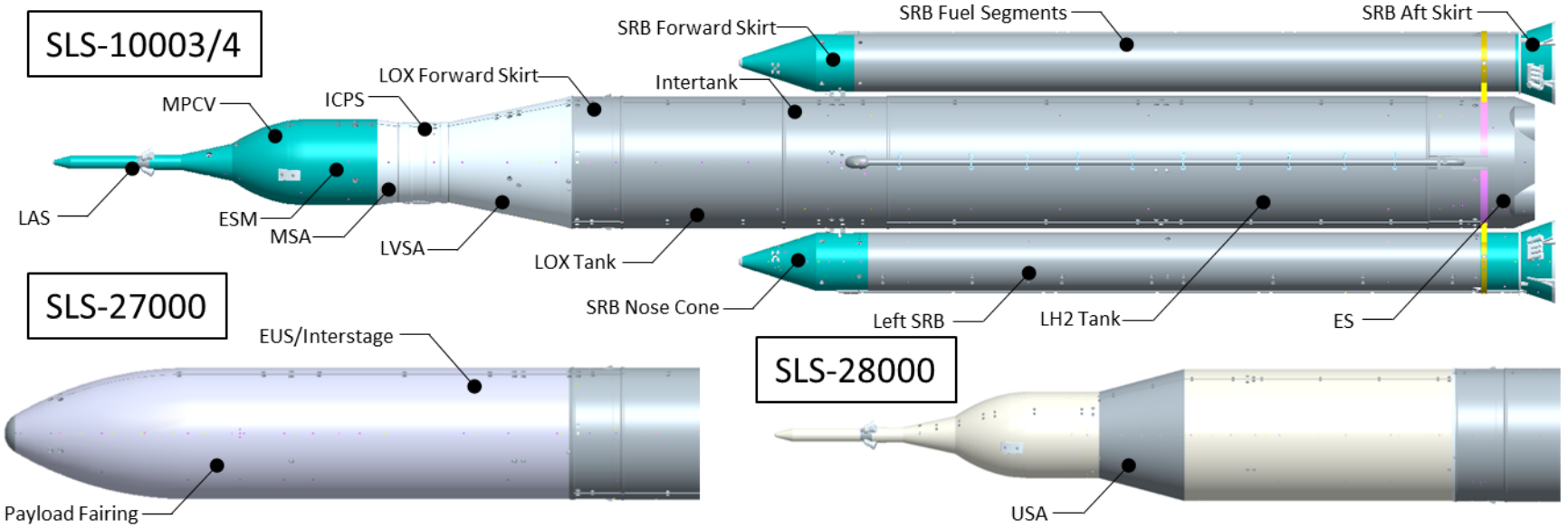
Objectives

- **Primary Objective**
  - Collect sufficient high frequency fluctuating pressure time histories for baseline SLS Block 1 and 1B models to determine ascent aeroacoustic external environments

- **Secondary Objectives**
  - Collect surface static pressure measurements
    - Compartment venting
    - Protuberance airloads
    - CFD substantiation
    - MPCV flush air data system calibration
  - Study alternate booster nose caps (NASA Engineering and Safety Center)
  - Determine buffet and acoustic mitigation option (BMO and AMO) effectiveness

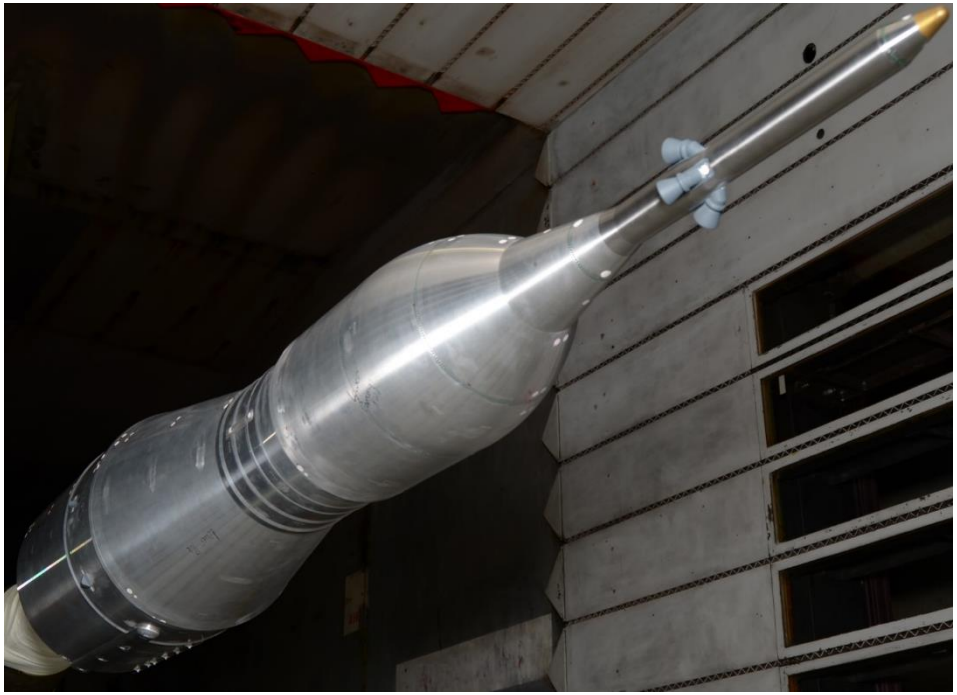
Test Models

- **2.5% Full Stack**
  - Block 1 SLS-10003 OML with updates for -10004 OML
  - Block 1B SLS-27000 (cargo) OML
  - Five NESC nose caps, 21 BMO and AMO
- **4% Forebody (truncated at SRB tip)**
  - Block 1 SLS-10003 OML with updates for -10004 OML
  - Block 1B SLS-28000 (crew) OML

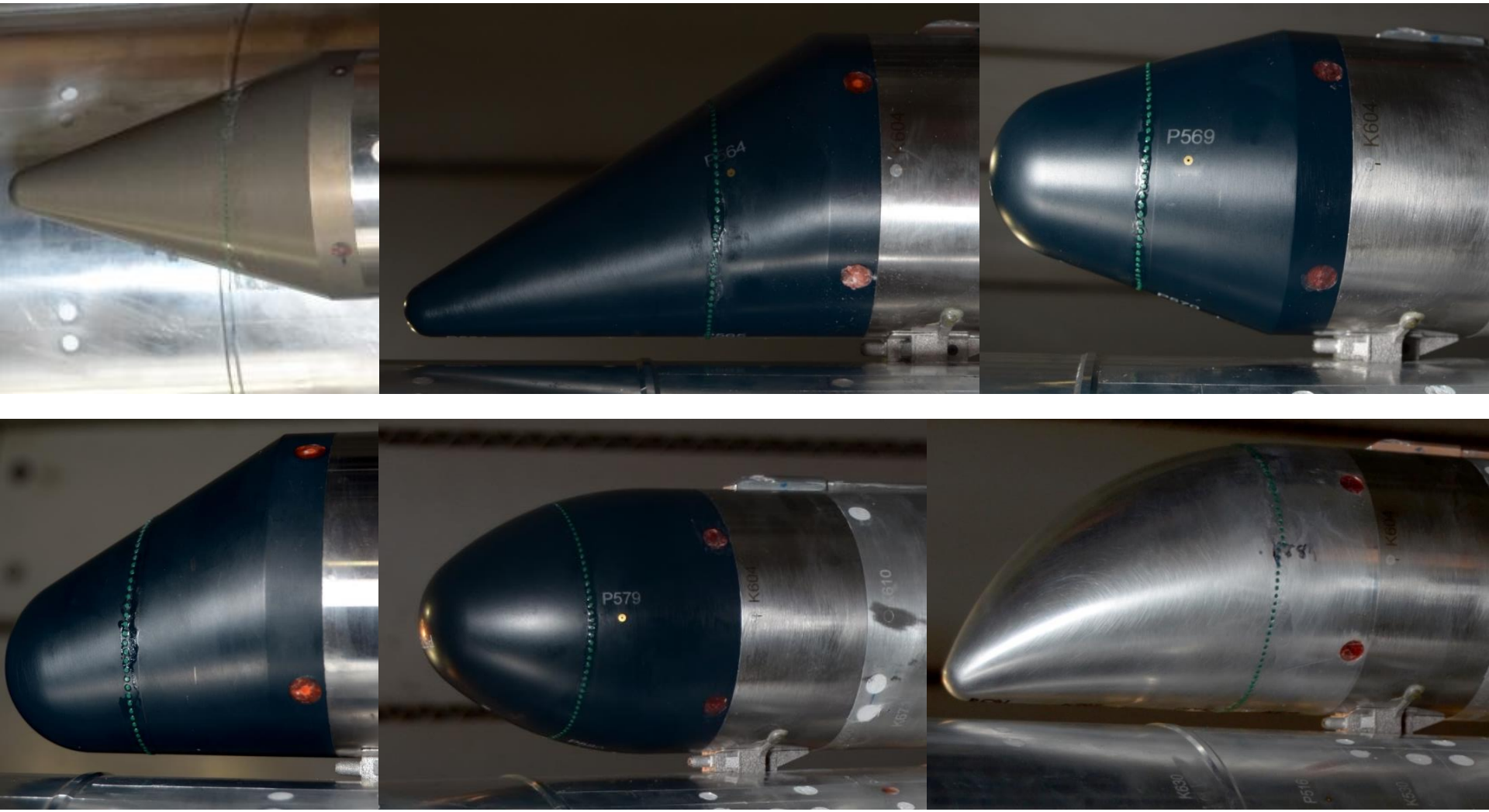


2.5% Models

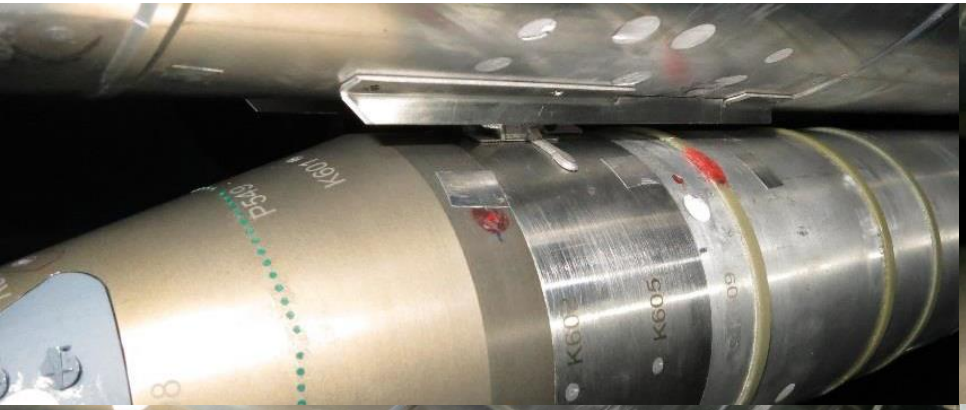
4% Models



NESC Booster Nose Caps



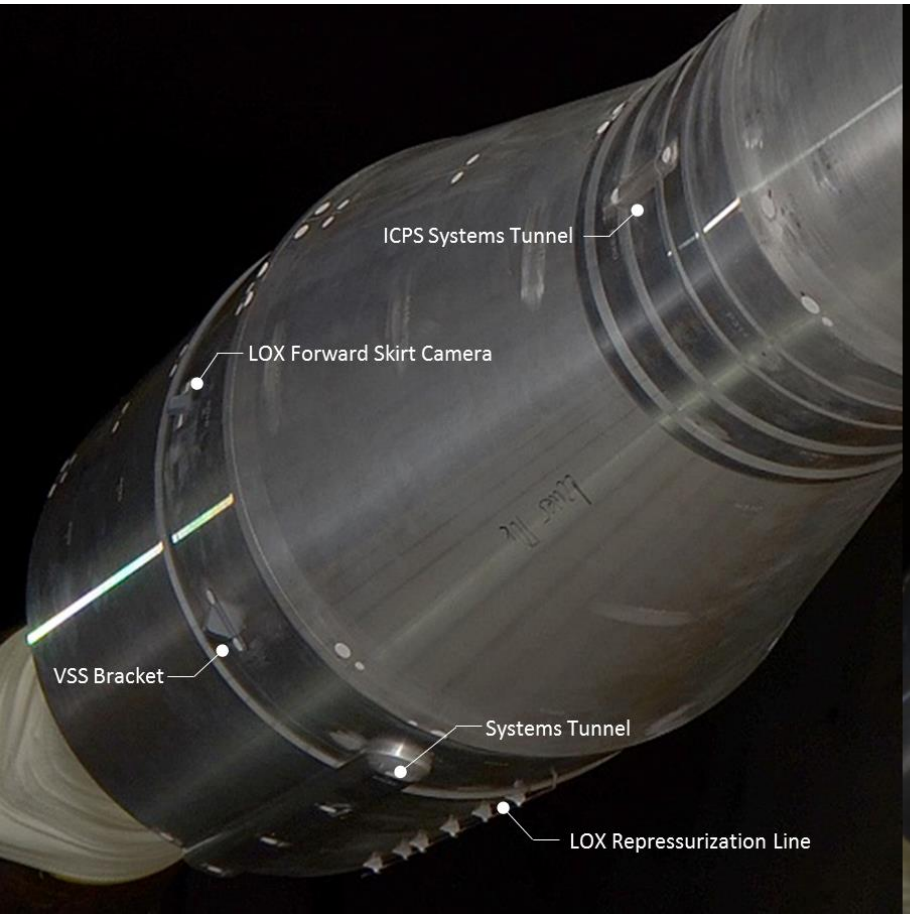
AMO and BMOs



Full Stack Protuberances

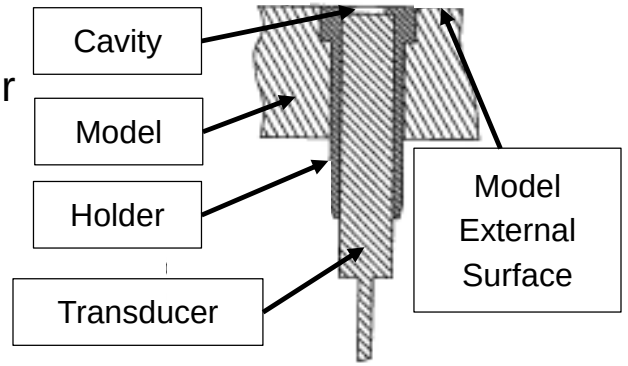
Full Stack Protuberances

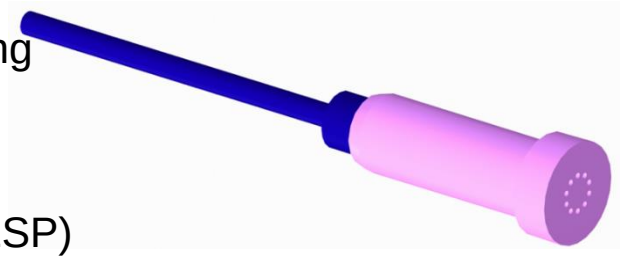
Forebody Protuberances

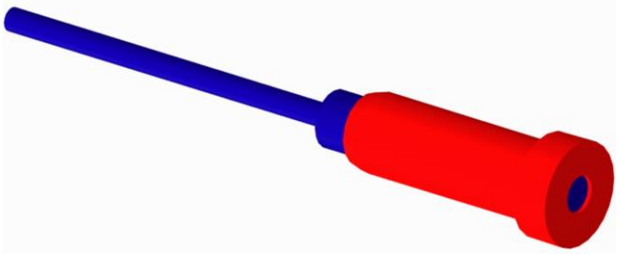


Instrumentation

- **Dynamic Transducers**
  - Kulite Semiconductor Inc. XCL-072-5D and -15D ultra-miniature high frequency pressure transducer
  - Included individual temperature compensation modules and Omnetics connectors
  - Mounted via individually contoured holders
  - Five cross-correlation patches
  - Primarily newly purchased with additional needs met using salvaged transducers
  - ARC provided custom-built amplifiers located in sting
- **Static Measurements**
  - Mounted via individual contoured holders
  - Two 64-channel electronically scanned pressure (ESP) transducer modules with temperature compensation





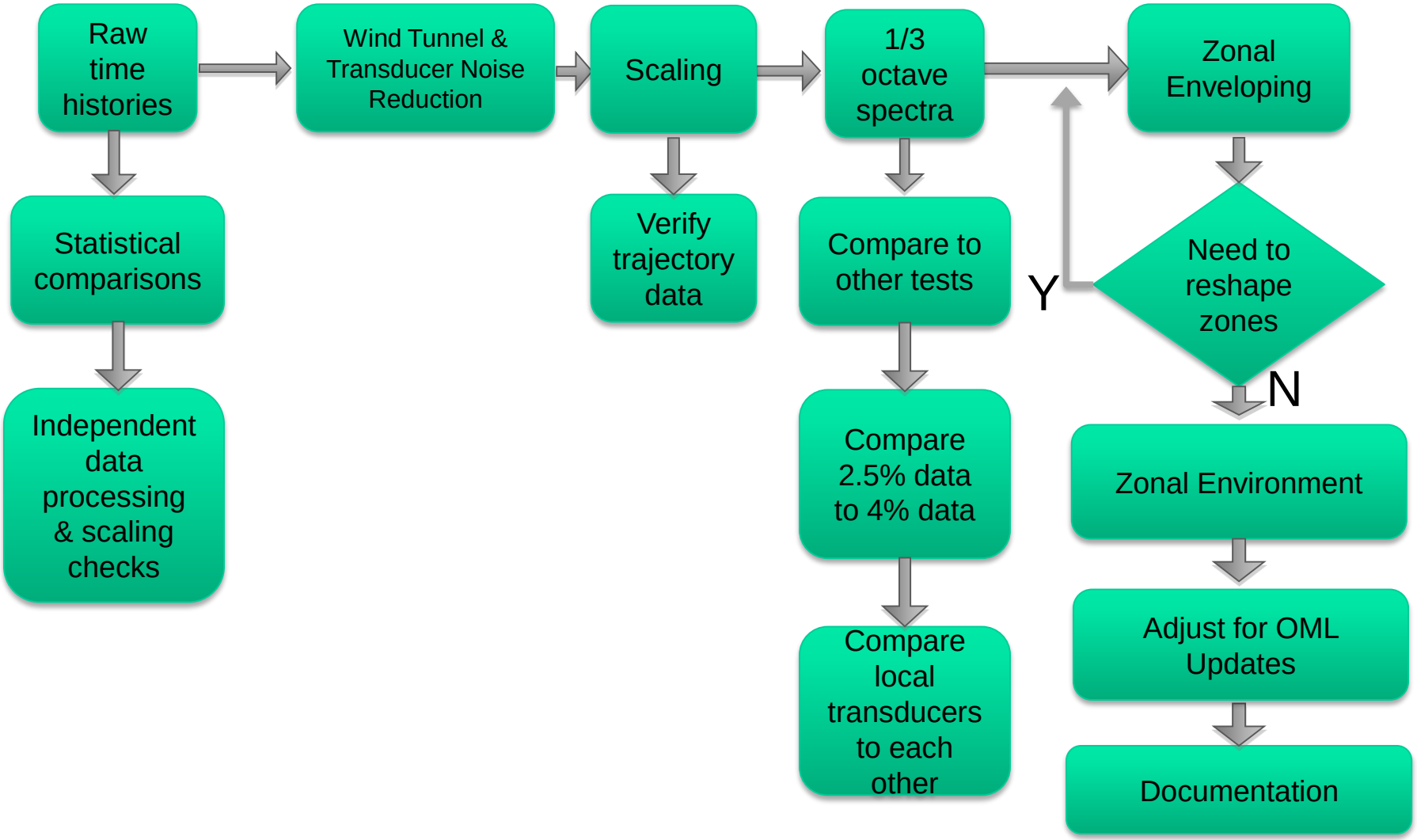


Model	Dynamic Transducers	Static Measurements
SLS-10003, 2.5%	161	39
SRB, 2.5%	60	23
SLS-27000, 2.5%	177	60
SLS-10003, 4%	65	62 + 9 FADS
SLS-28000, 4%	80	58 + 9 FADS

Test Overview

- **Test Facility: NASA Ames Research Center (ARC) Unitary Plan Wind Tunnels (UPWT)**
  - 11' Transonic Wind Tunnel (TWT) : Mach = 0.70 – 1.40
  - 9'x7' Supersonic Wind Tunnel (SWT): Mach = 1.55 – 2.50
- **Facility Test Number: T11-0265, T97-0266, T11-0273, T97-0274**
- **Test Dates**
  - First Campaign: August 19th – September 5th, 2013
  - Second Campaign: December 16th, 2013 – January 8th, 2014
- **Angle of Attack/Side Slip Angle: α/β = 0°, ±1°, ±2°, ±2.83°, ±4°, ±6°**
- **Mach Sweep: At α/β = 0° with full stack Block 1 model**
- **Reynolds Number:**
  - Primary: 3-million/foot
  - Sensitivity study: 5-million/foot
- **Sample Rates/Dwell Times Per Condition:**
  - 2.5% – High Frequency: 153.6 kHz/2.7 seconds, Low Frequency 9.6 kHz/22 seconds
  - 4.0% – High Frequency: 102.4 kHz/4 seconds, Low Frequency 6.4 kHz/11.5 seconds
- **High Speed Data Acquisition: National Instruments PXI based hardware**
  - 24-bit A/D cards
  - 204 ksps
  - DC coupled
  - Manufacturer provided transducer calibration data used
- **Visualization**
  - Shadowgraph photographs and video
  - Retro-reflective background oriented schlieren (RBOS)

Data Analysis



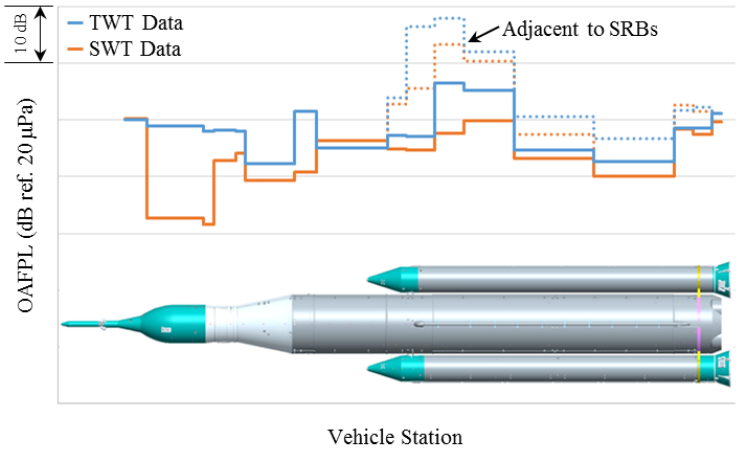
Data Scaling

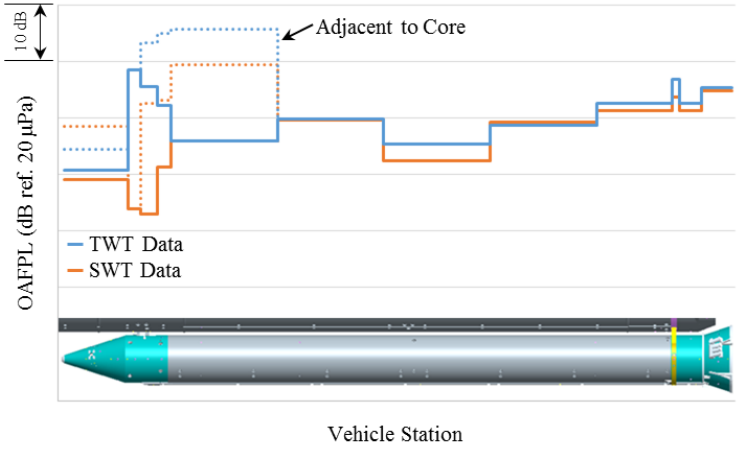
- **Amplitude**
  - Assume: $\left|\Delta C'_p\right|_{flight} = \left|\Delta C'_p\right|_{tunnel}$ where $\Delta C'_p = {p'_{rms}}/{q_\infty}$
  - Therefore: $\mathrm{FPL}_{flight} = \mathrm{FPL}_{tunnel} + 20\log_{10}\left(\frac{q_{\infty,flight}}{q_{\infty,tunnel}}\right)$
- **Frequency**
  - Assume: $|St|_{flight} = |St|_{tunnel}$ where $St = {fl}/{U}$
  - Therefore: $f_{flight} = f_{tunnel}\left(\frac{l_{tunnel}}{l_{flight}}\right)\sqrt{\frac{T_{flight}}{T_{tunnel}}}$

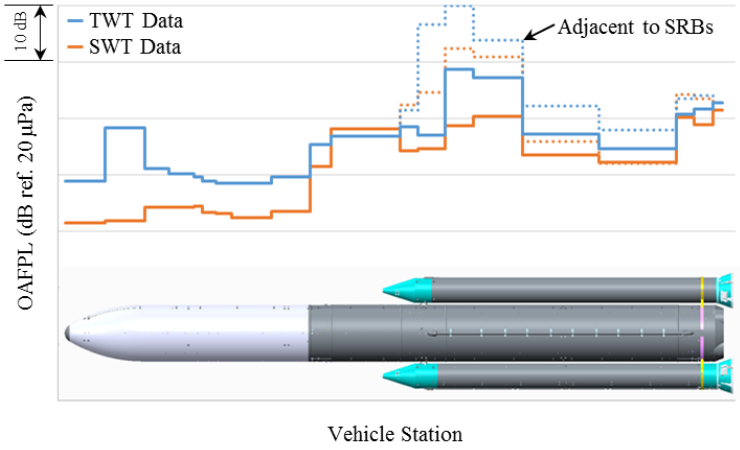
Results

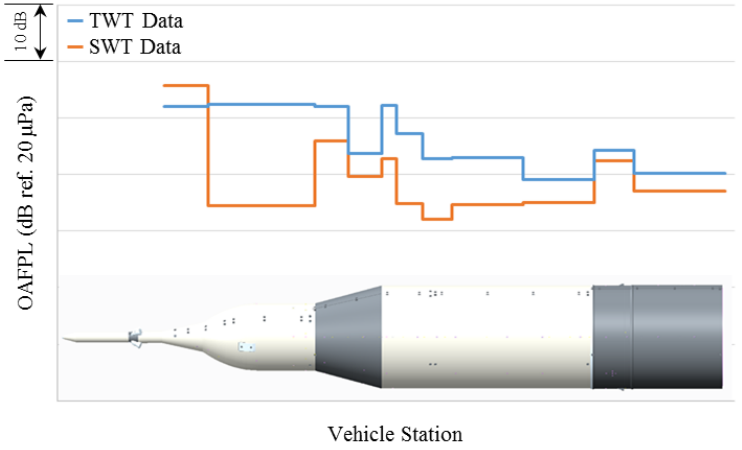
- **Data shown for baseline configurations**
  - Standard SRB nose caps
  - No AMO or BMO
- **Full bandwidth zonal overall fluctuating pressure levels (OAFPL) as function of vehicle station (10-2000 Hz full scale)**
  - TWT Data: Mach = 0.7 – 1.4
  - SWT Data: Mach = 1.55 – 2.5
  - $\alpha \leq 4.47°$
- **Protuberance environments shown in the paper**

General Acreage Environments



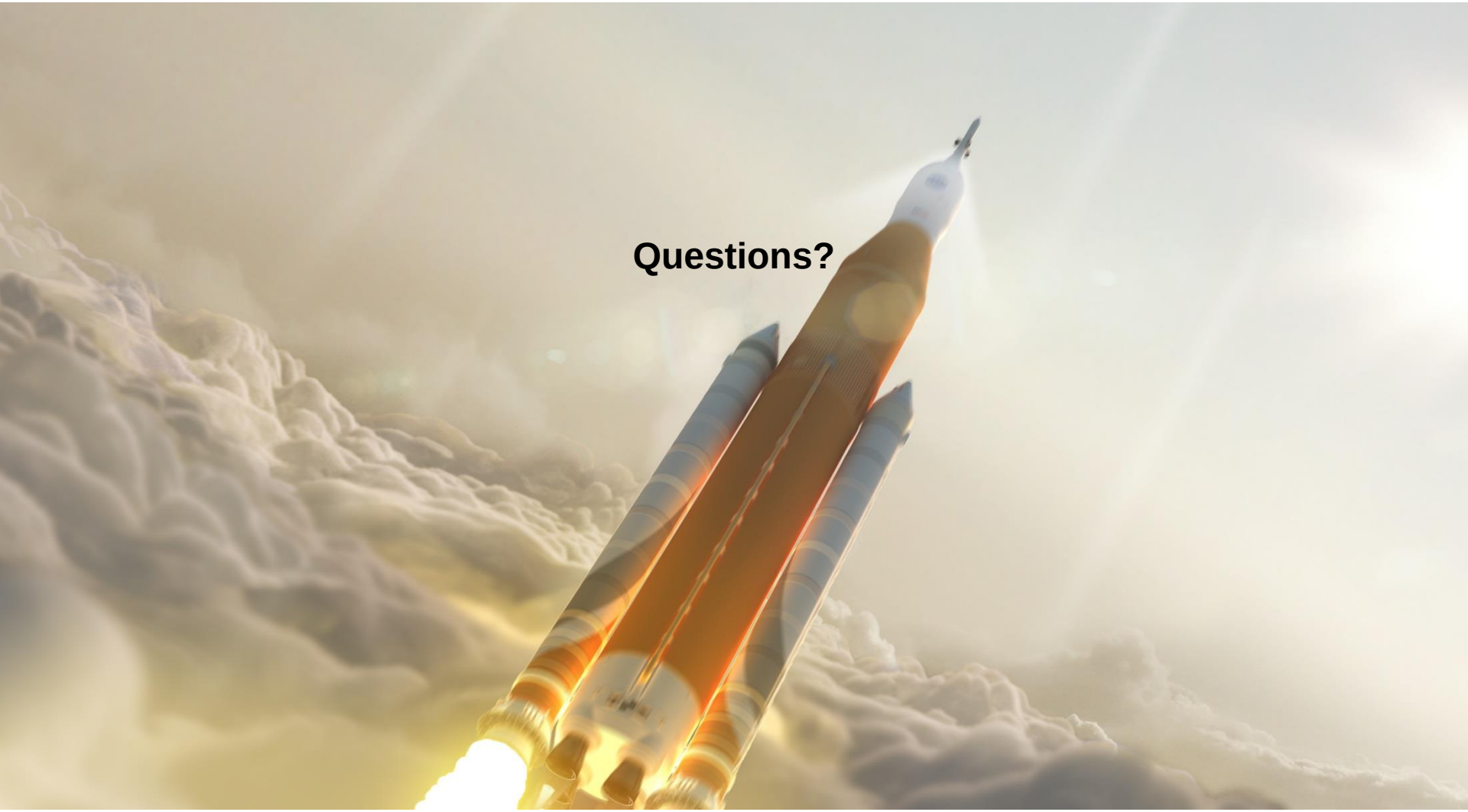






Conclusions

- **All primary and secondary test objectives were accomplished with minimal transducer loss**
- **Primary Objective: Data have been used to successfully develop ascent aeroacoustic environments**
  - SLS-10005 Block 1 design environments released July 2014
  - SLS-27004, SLS-27502, and SLS-28004 preliminary environments released August 2015
- **Secondary Objectives: Data are being used for compartment venting environment determination, static CFD substantiation, unsteady CFD development**
- **Data are advancing the understanding of complex multi-body flow fields**


Questions?