

Overview of the Space Launch System Ascent Aeroacoustic Environment Test Program

5 January, 2016

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NASA/George C. Marshall Space Flight Center

54th AIAA Aerospace Sciences Meeting

4-8 January, 2016

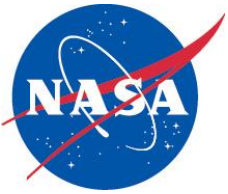
San Diego, California



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

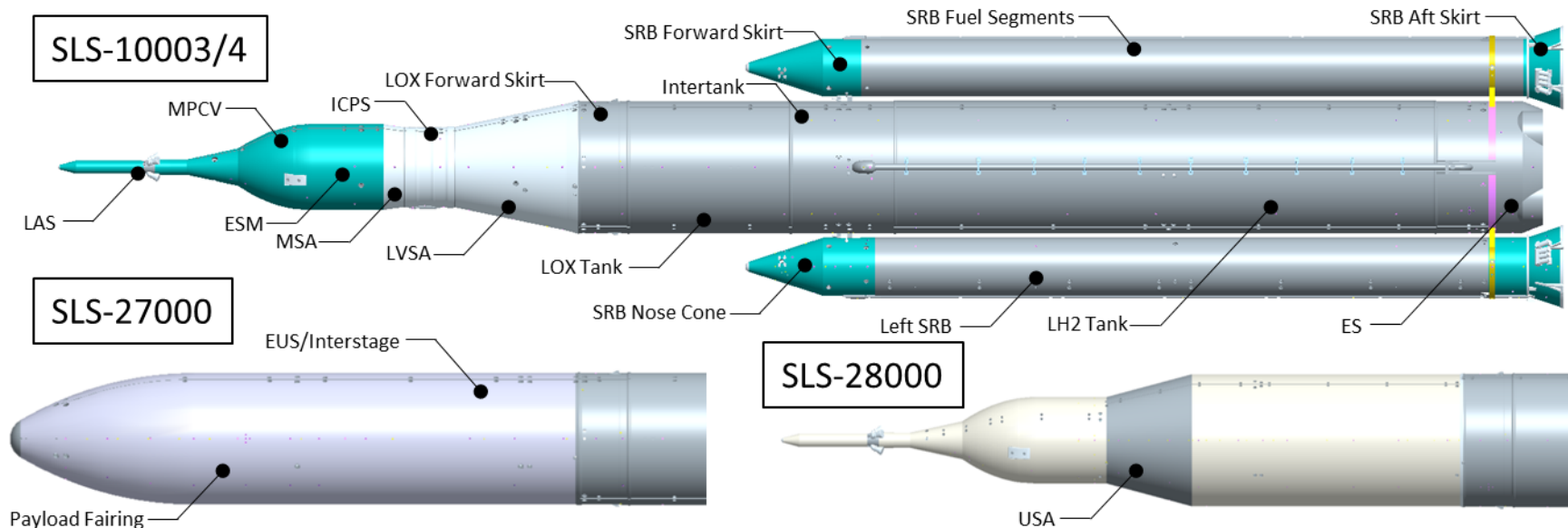


◆ 2.5% Full Stack

- Block 1 SLS-10003 OML with updates for -10004 OML
- Block 1B SLS-27000 (cargo) OML
- Five NESC nose caps, 21 BMO and AMO

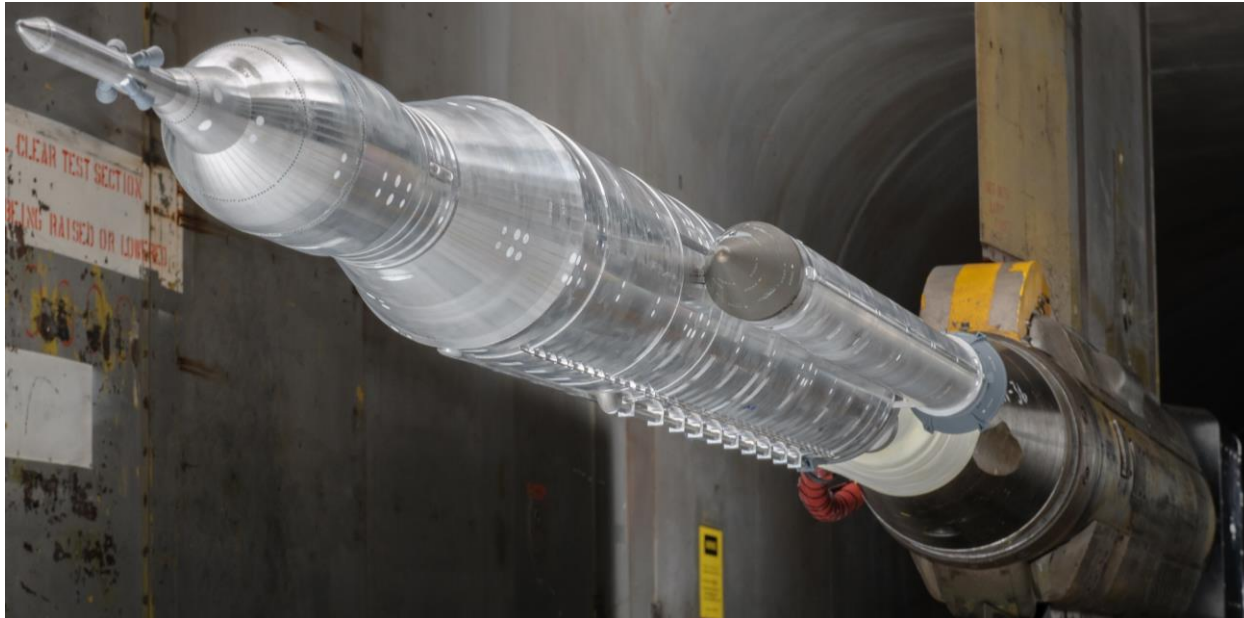
◆ 4% Forebody (truncated at SRB tip)

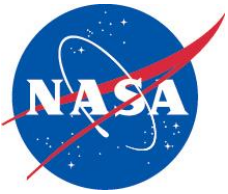
- Block 1 SLS-10003 OML with updates for -10004 OML
- Block 1B SLS-28000 (crew) OML





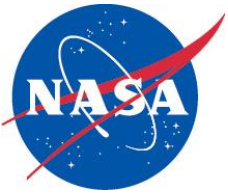
2.5% Models



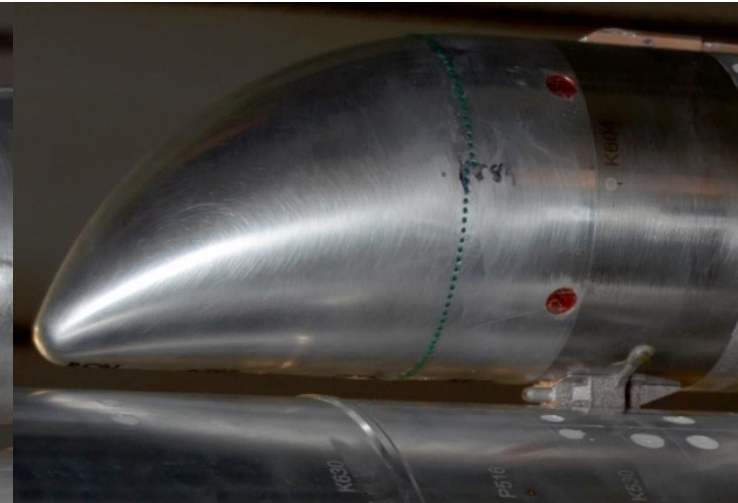
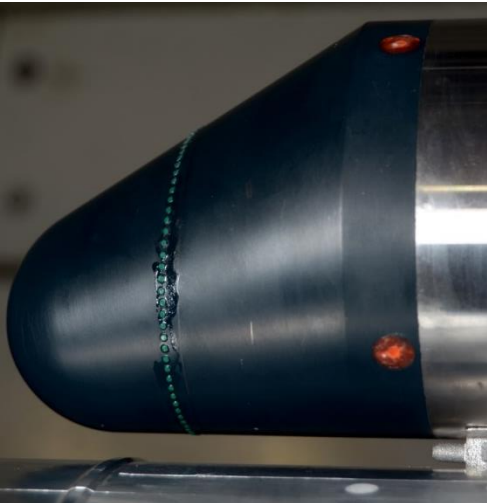
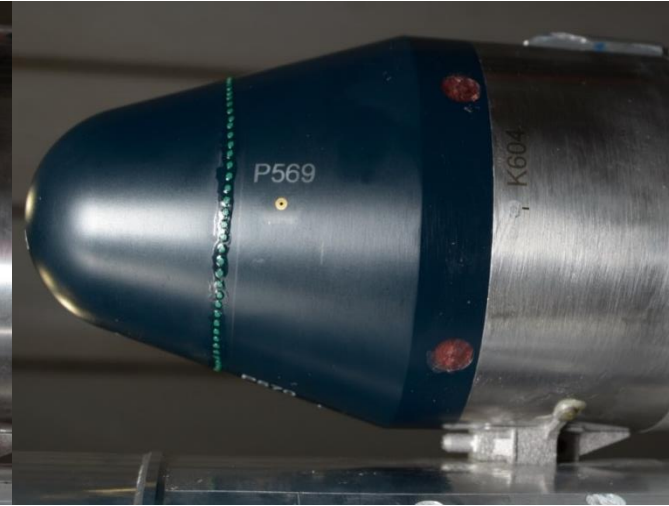
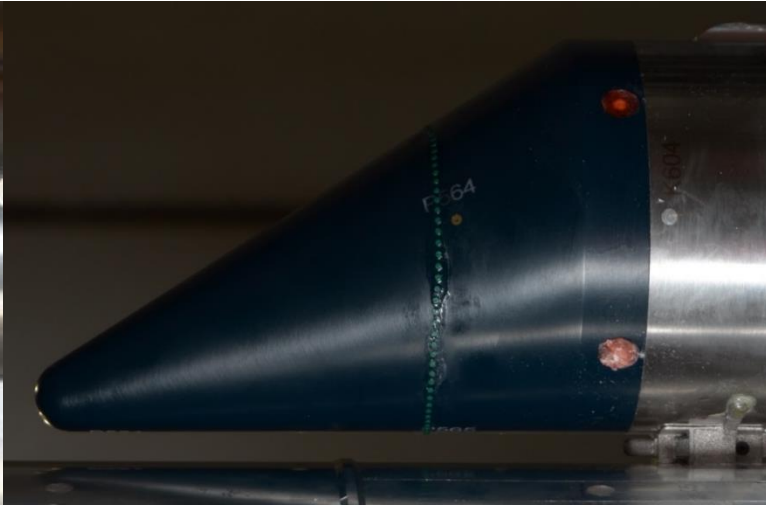


4% Models



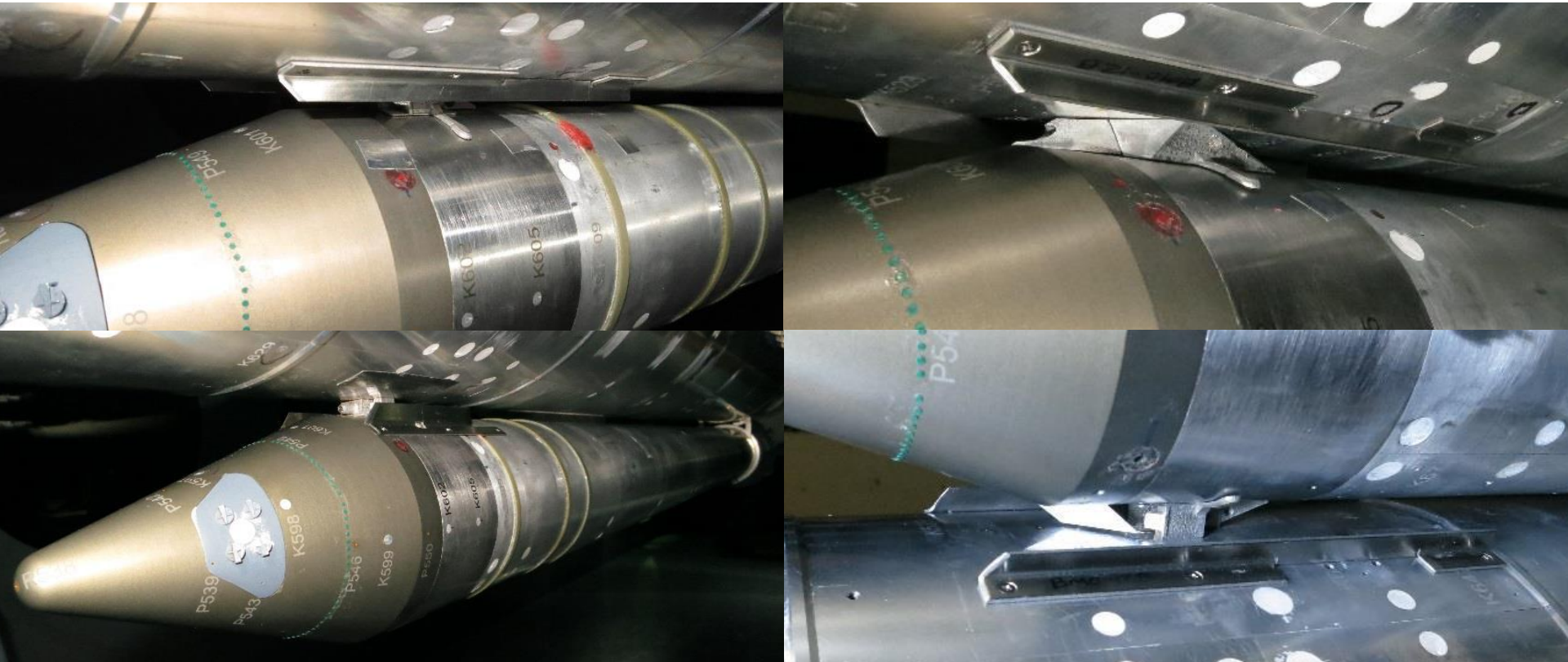


NESC Booster Nose Caps





AMO and BMOs



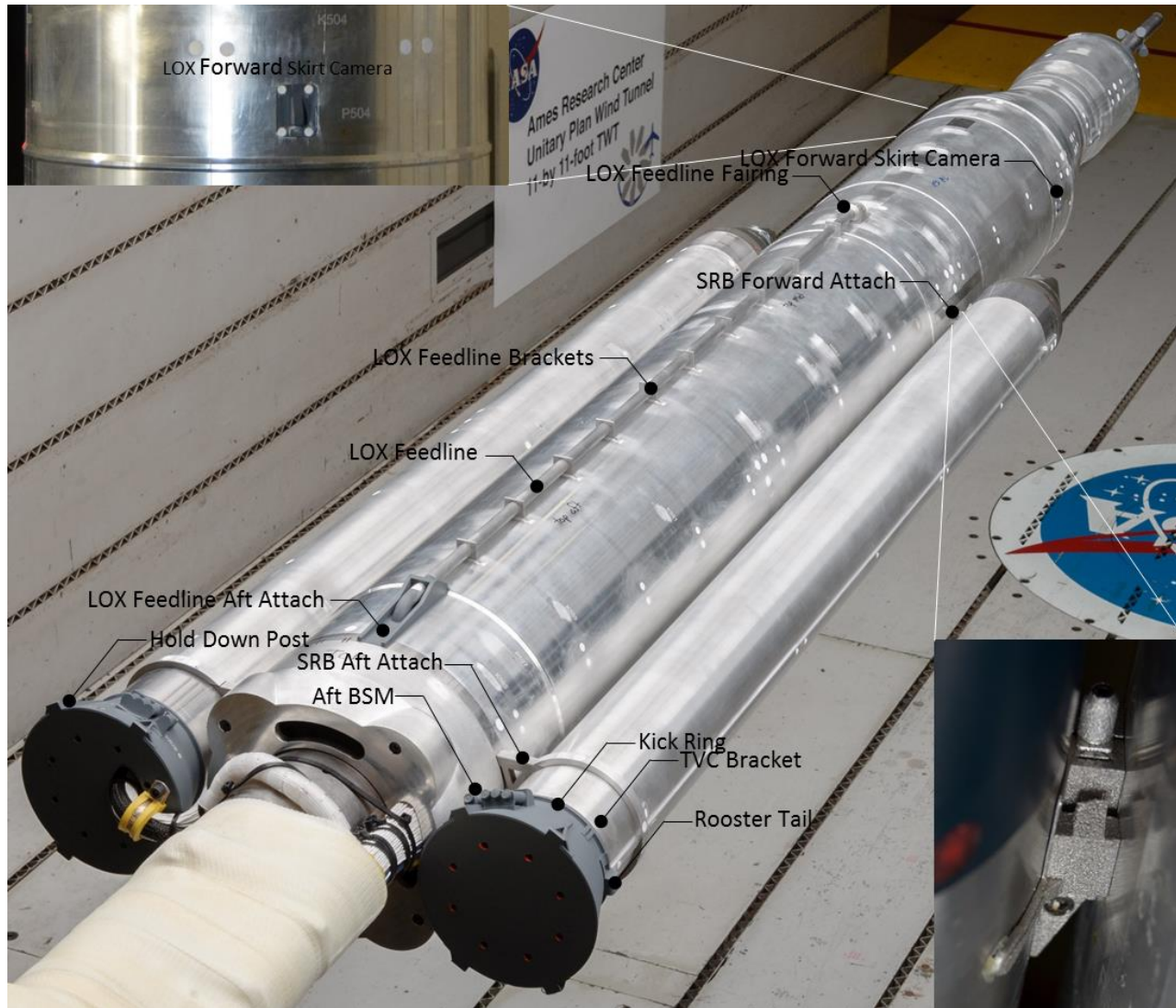


Full Stack Protuberances



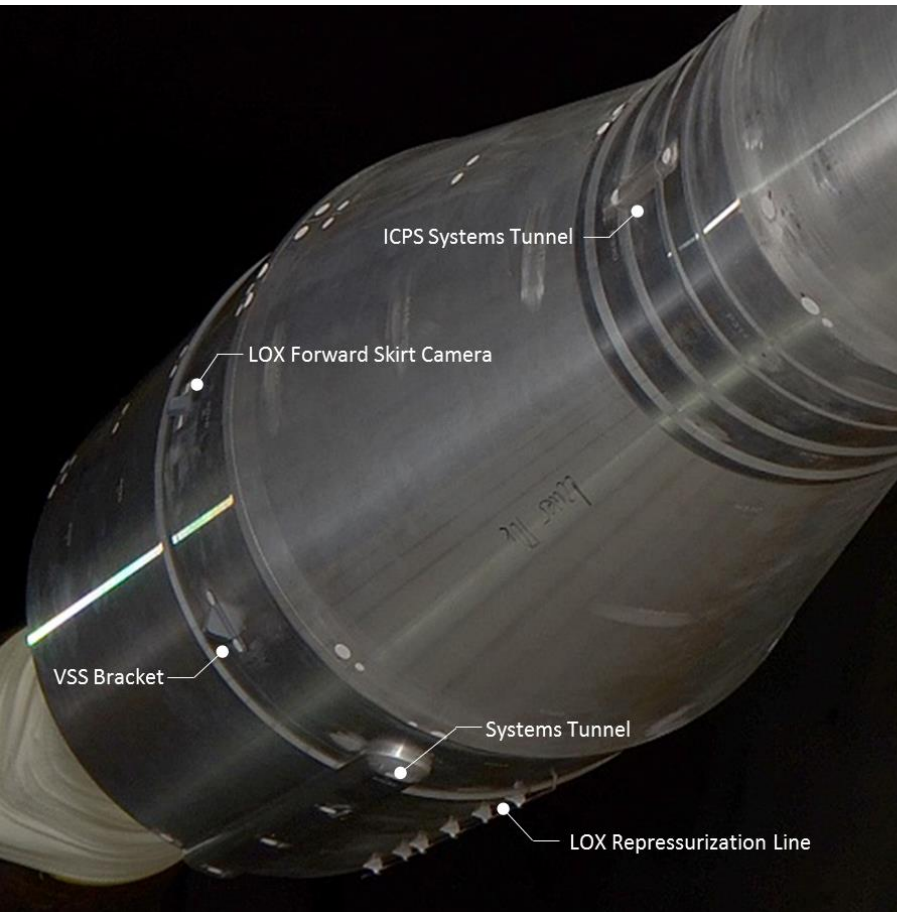


Full Stack Protuberances





Forebody Protuberances



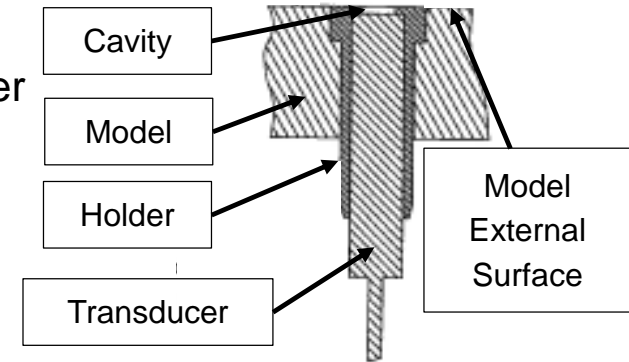


Instrumentation



◆ Dynamic Transducers

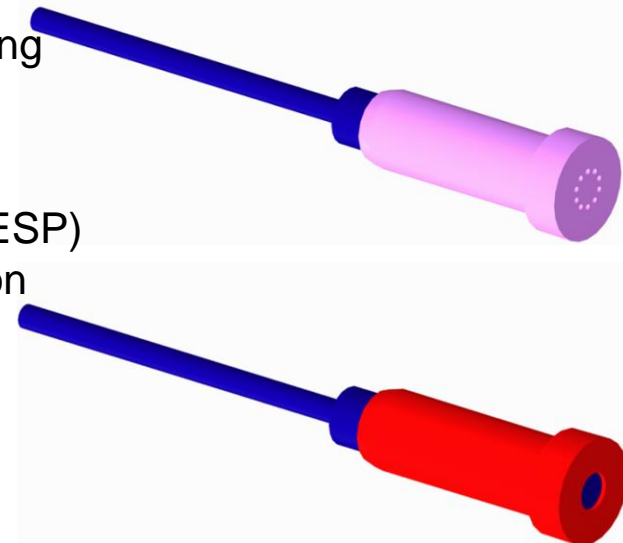
- Kulite Semiconductor Inc. XCL-072-5D and -15D ultra-miniature high frequency pressure transducer
- Included individual temperature compensation modules and Omnetics connectors
- Mounted via individually contoured holders
- Five cross-correlation patches
- Primarily newly purchased with additional needs 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





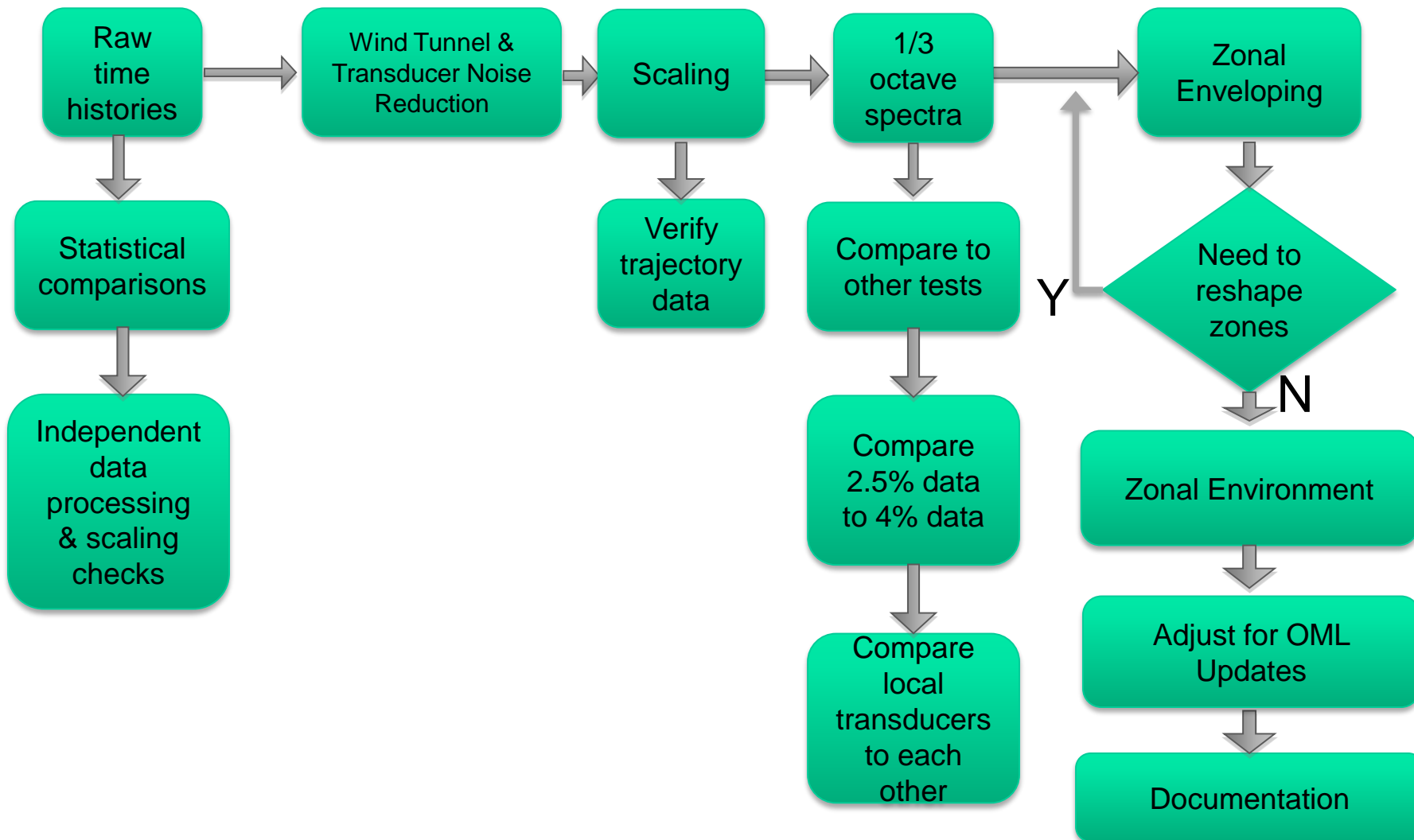
Test Overview



- ◆ **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: $\alpha/\beta = 0^\circ, \pm 1^\circ, \pm 2^\circ, \pm 2.83^\circ, \pm 4^\circ, \pm 6^\circ$**
- ◆ **Mach Sweep: At $\alpha/\beta = 0^\circ$ 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: $|\Delta C'_p|_{flight} = |\Delta C'_p|_{tunnel}$ where $\Delta C'_p = p'_{rms}/q_\infty$
- Therefore: $FPL_{flight} = FPL_{tunnel} + 20\log_{10}\left(\frac{q_{\infty,flight}}{q_{\infty,tunnel}}\right)$

◆ Frequency

- Assume: $|St|_{flight} = |St|_{tunnel}$ where $St = f l / U$
- Therefore: $f_{flight} = f_{tunnel} \left(\frac{l_{tunnel}}{l_{flight}}\right) \sqrt{\frac{T_{flight}}{T_{tunnel}}}$



Results



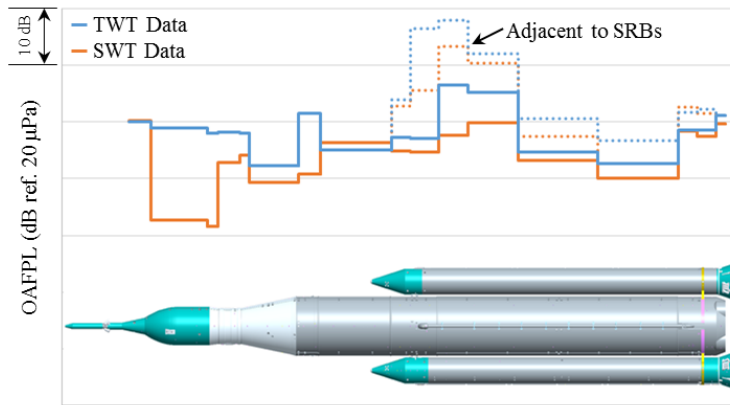
- ◆ **Data shown for baseline configurations**
 - Standard SRB nose caps
 - No AMO or BMO

- ◆ **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
 - $\alpha \leq 4.47^\circ$

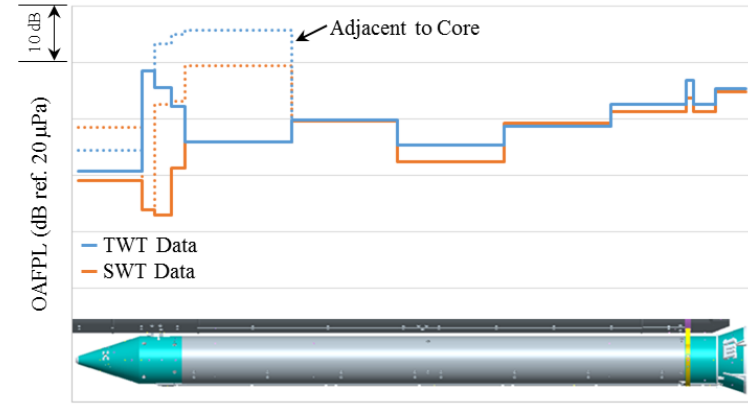
- ◆ **Protuberance environments shown in the paper**



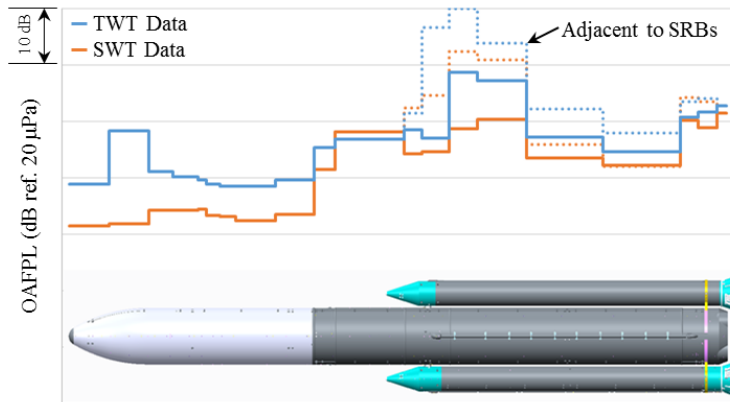
General Acreage Environments



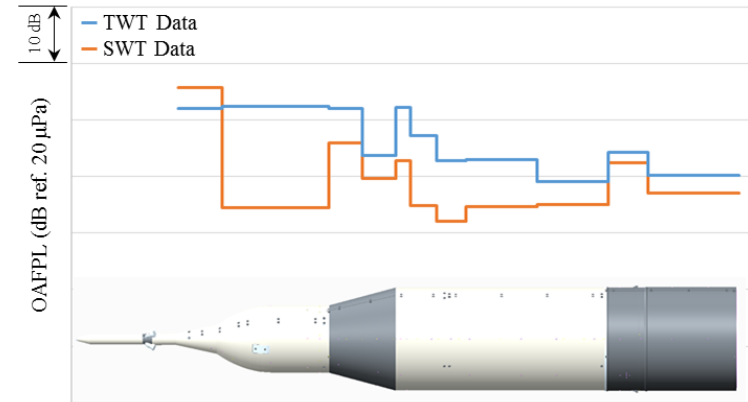
Vehicle Station



Vehicle Station



Vehicle Station



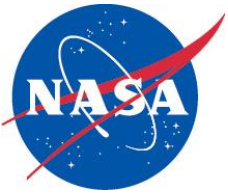
Vehicle Station



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?