

Overview of the Hybrid Wing Body Aeroacoustic test in NASA Langley 14- by 22-Foot Subsonic Tunnel

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NASA Environmentally Responsible Aviation (ERA) Project

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HWB Aeroacoustic Test : A multi-year effort



2008-2010:

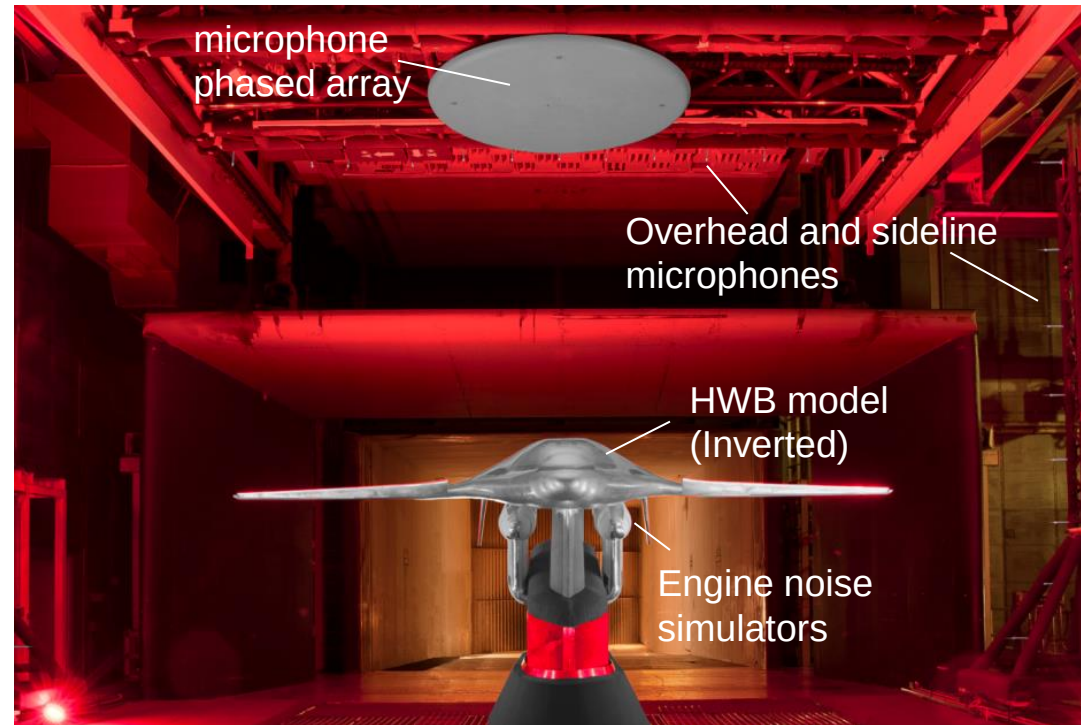
NASA Research Announcement for design of HWB configuration to meet NASA/ERA noise reduction goals.

2011: Delivery of full span model of N2A-EXTE HWB configuration.

2010-2012:

Development of:

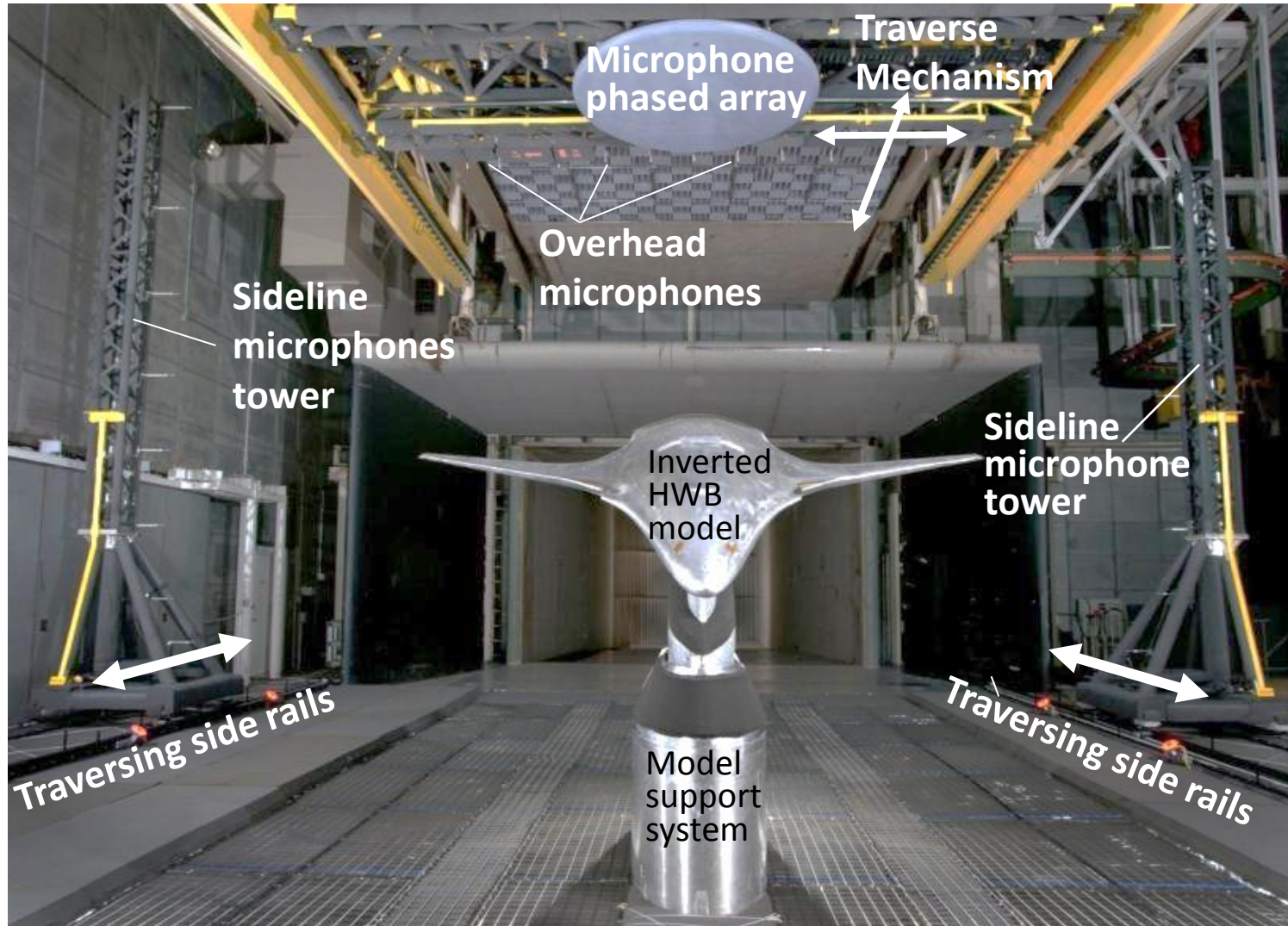
- engine noise simulators for jet and turbomachinery broadband noise.
- phased microphone array.
- the HWB model support system.
- Data Acquisition System for control of the microphones' traverse system and simultaneous acquisition of over 160 microphone and unsteady surface pressure sensor channels.
- Substantial infrastructure and testing capability upgrades to 14x22-Ft Subsonic Tunnel (instrumentation traverse system, acoustic treatment, propane fuel and controls, etc.)



Upgrades to 14 by 22-Foot Subsonic Tunnel



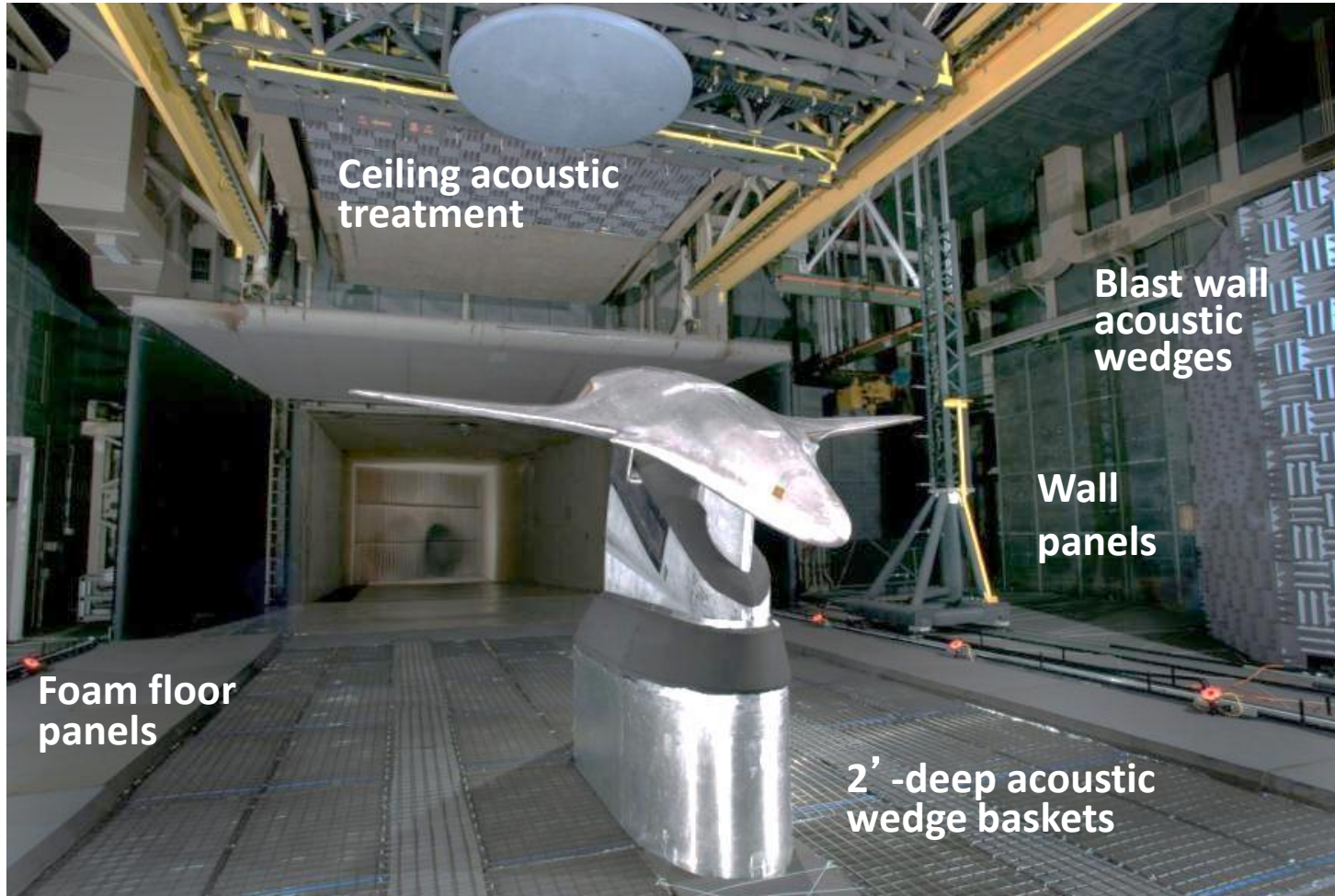
- Phased microphone array and microphone traverse systems .



Upgrades to 14 by 22-Foot Subsonic Tunnel



- New acoustic treatment and modification of test section blast wall



Upgrades to 14 by 22-Foot Subsonic Tunnel



- Fuel system installation for jet engine noise simulator capability.



2500 gallon liquid
propane storage tank



500 gallon
run tank



Two portable valve pallets
underneath wind tunnel
control propane delivery to
CJES units

HWB Acoustic Test Team (partial list)



Principal Investigator: Thomas Brooks

Co- PI, Main contact for BENS: Florence Hutcheson

Co-PI, Main contact for CJES: Michael Doty

Test Directors: Dan Hoad, Stephanie Heath

HWB Noise Assessment: Casey Burley, C. Nickol, D. Vicroy

Data Acquisition System: Lawrence Becker

Instrumentation and Data Management: William Humphreys

Test Data Reduction and Analysis: Chris Bahr and Taylor Spalt

CJES Development: Henry Haskin

Data Processing and Analysis: Daniel Stead, Stuart Pope, Jerry Plassman

Acoustic and Photogrammetric Instrumentation : Scott Bartram, Benny Lunsford, Jaye Moen, Dennis Kuchta

Programmatic Support: Environmentally Responsible Aviation Project team

NASA 14 x 22 Ft Tunnel testing team and many other colleagues ...





HWB Aeroacoustic Test - Objectives and Sequence

HWB Aeroacoustic Test Objectives



- Provide high-quality acoustic data for a Hybrid Wing Body (HWB) aircraft
 - assess the NASA/ERA noise goal of 42 cumulative EPNdB below Stage 4 levels
- Determine spectra, level, and directivity of HWB components and effects of shielding parameters on noise emission
- Form database for validating system noise analysis codes (ex: NASA's ANOPP2) and developing/improving prediction capabilities

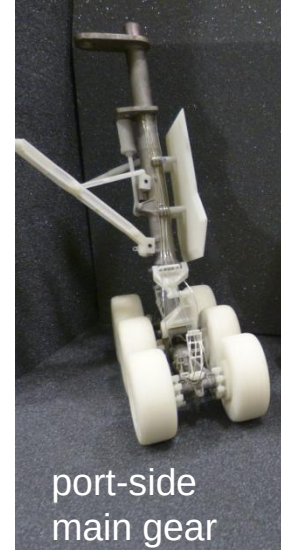
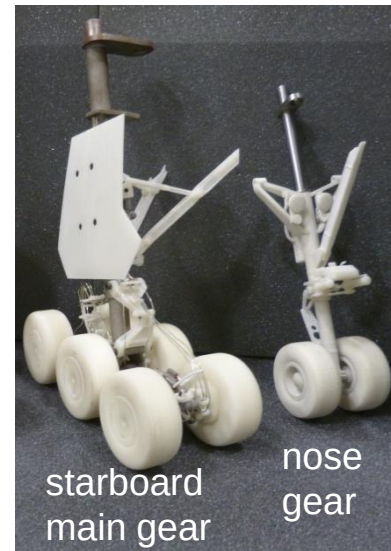
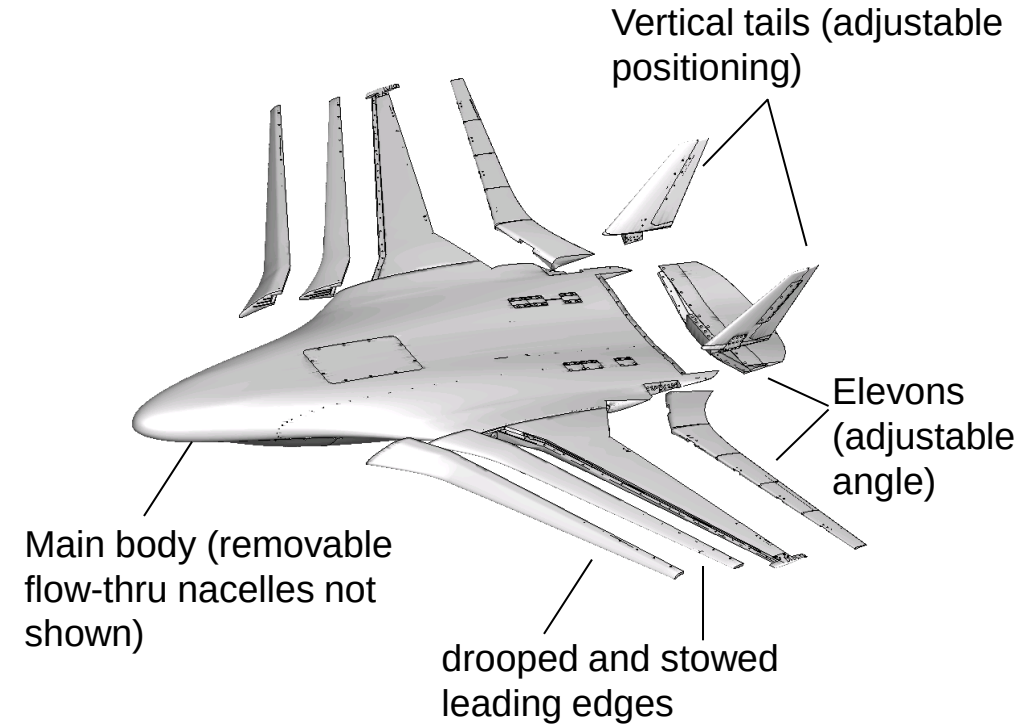


- **HWB test data**
 - Shielding of turbomachinery noise (broadband component):
 - HWB airframe model with Broadband Engine Noise Simulators (BENS)
 - Jet noise and its shielding:
 - HWB airframe model with Compact Jet Engine Simulators (CJES)
 - Airframe noise from HWB components
 - HWB airframe model alone
- **Acoustic characterization of 14 x 22 test section**
 - Data acquired to identify reflections and room reverberance in test environment
 - Background noise data for a range of flow speeds and microphone locations



HWB Test Model and Engine Noise Simulators

HWB (N2A-EXTE) Airframe Model



- 5.8% scale (12.35 ft span)
- modular components (control surfaces and landing gear)
- high fidelity of geometric details
- Designed by a team led by Boeing under a NASA Research Announcement

HWB (N2A-EXTE) Airframe Model

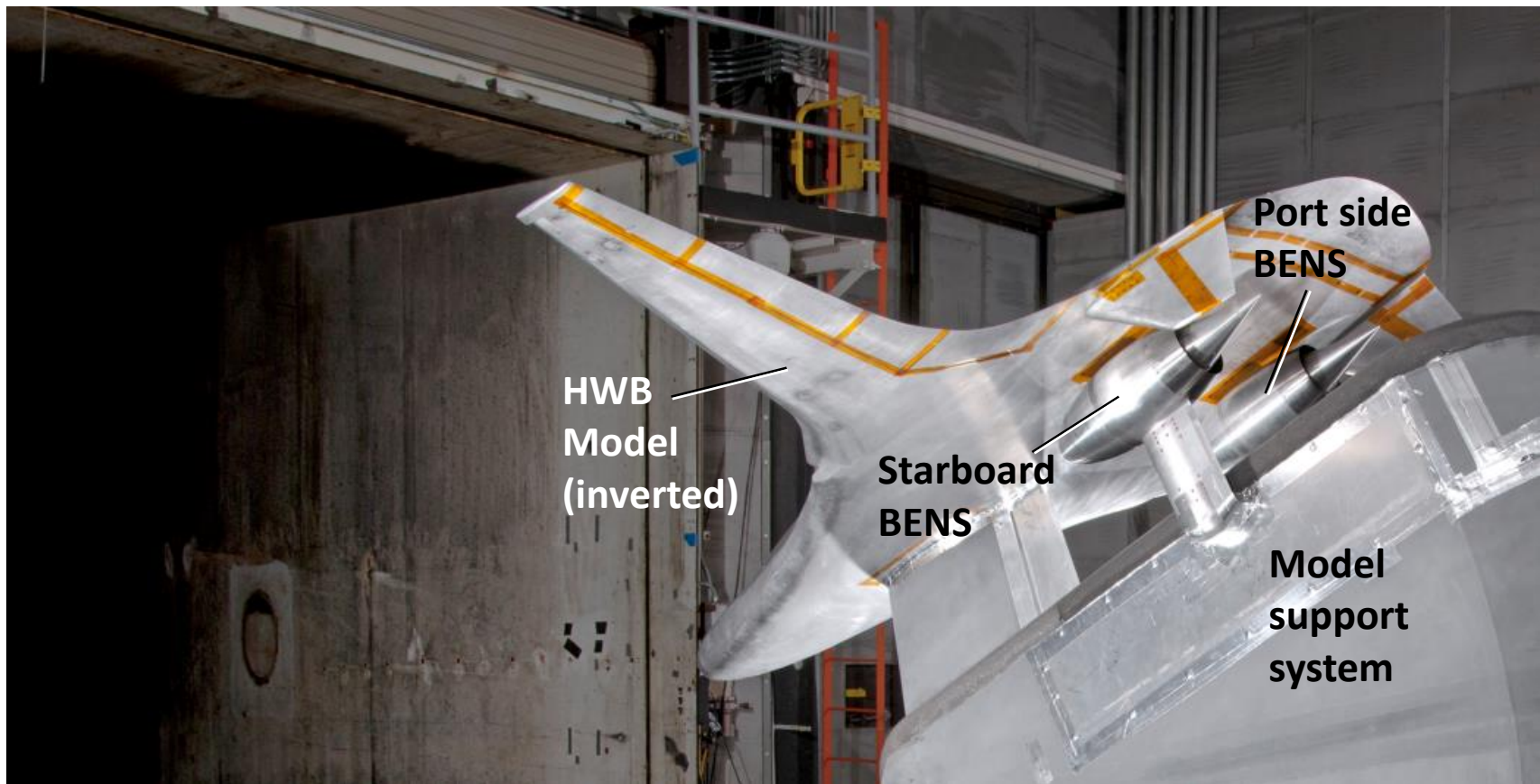


HWB model in 14'x22'test section with 30° roll and configured for airframe noise testing

Broadband Engine Noise Simulators (BENS)



- Use to determine insertion loss due to shielding by HWB airframe of turbomachinery broadband noise.
- Emit uniform-level broadband noise from scaled nacelles

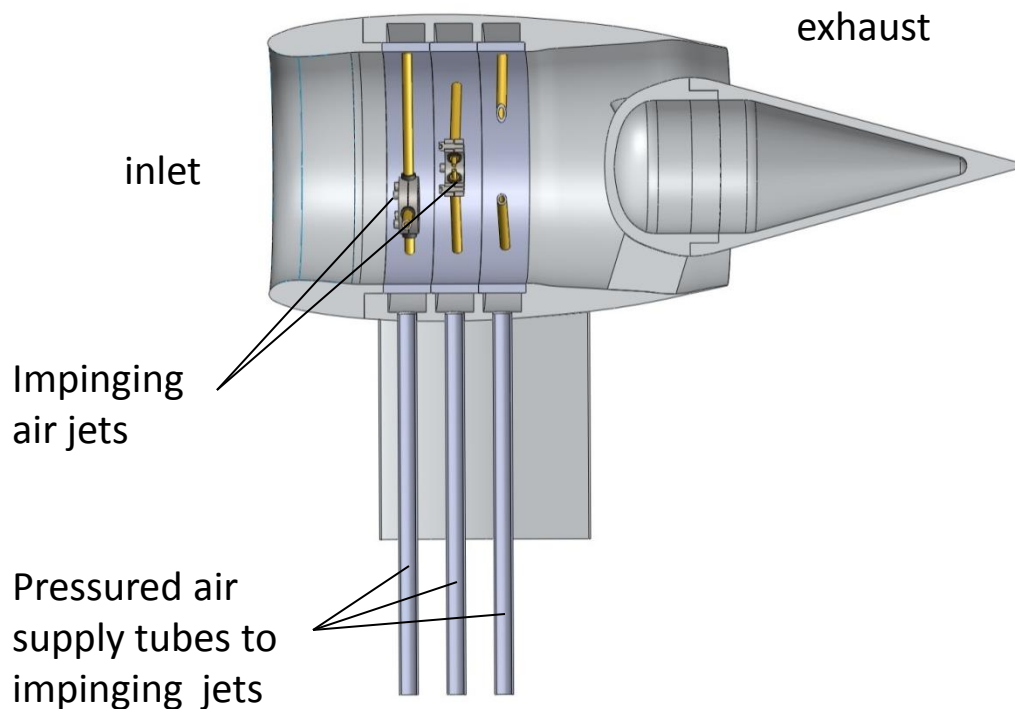


HWB model in 14'x22' test section - BENS in baseline position w.r.t. HWB fuselage

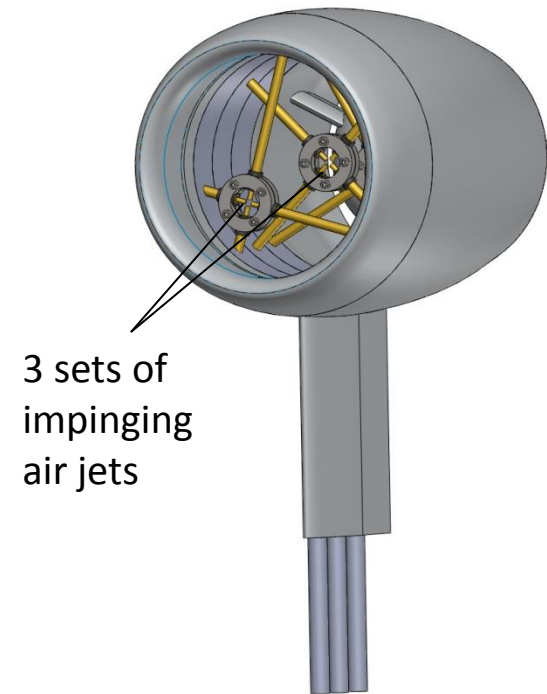
Broadband Engine Noise Simulators (BENS)



- Noise generated by 3 sets of impinging air jets positioned in the open interior of specifically designed engine nacelles.



BENS cross section

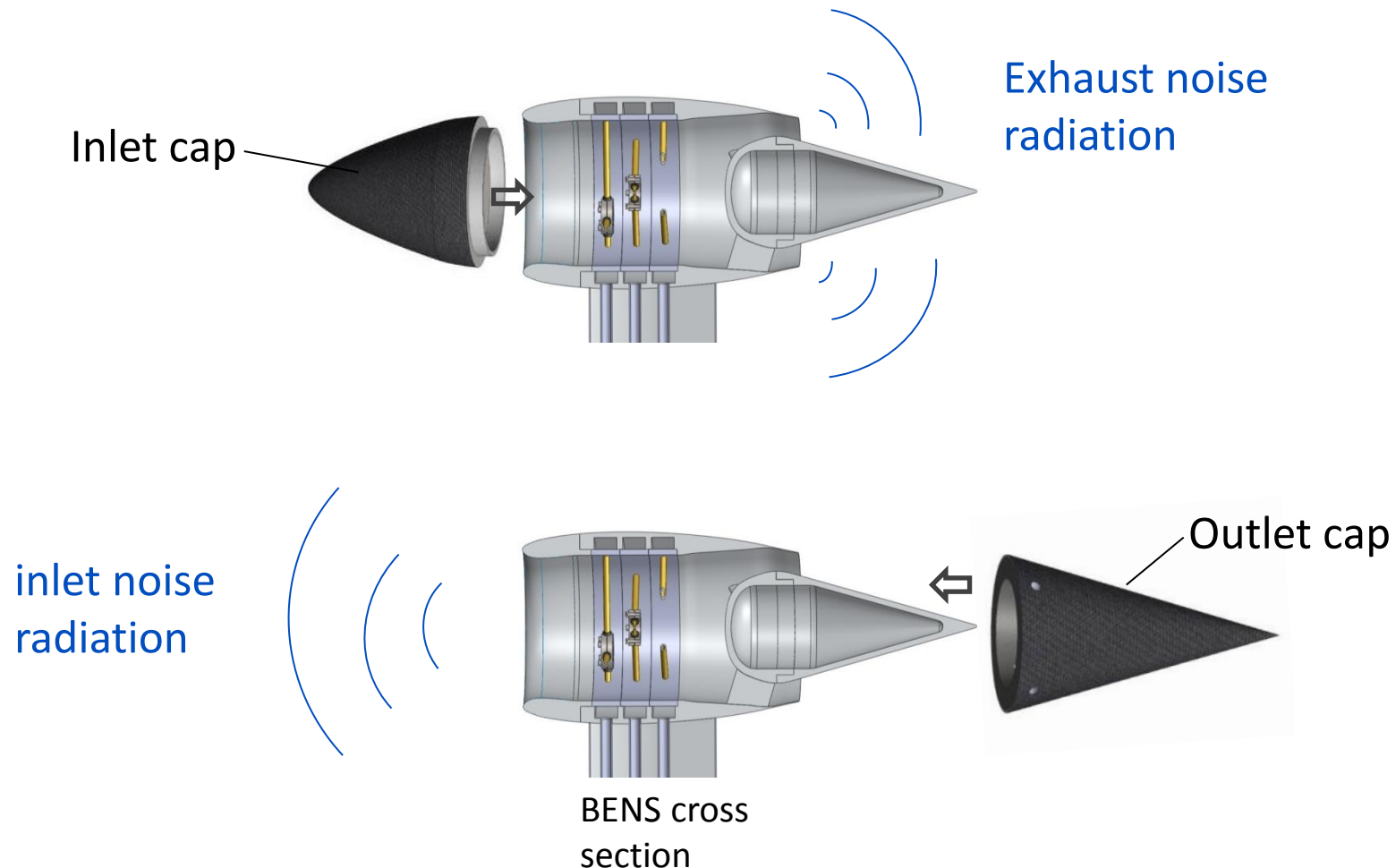


BENS – view of inlet

Broadband Engine Noise Simulators (BENS)



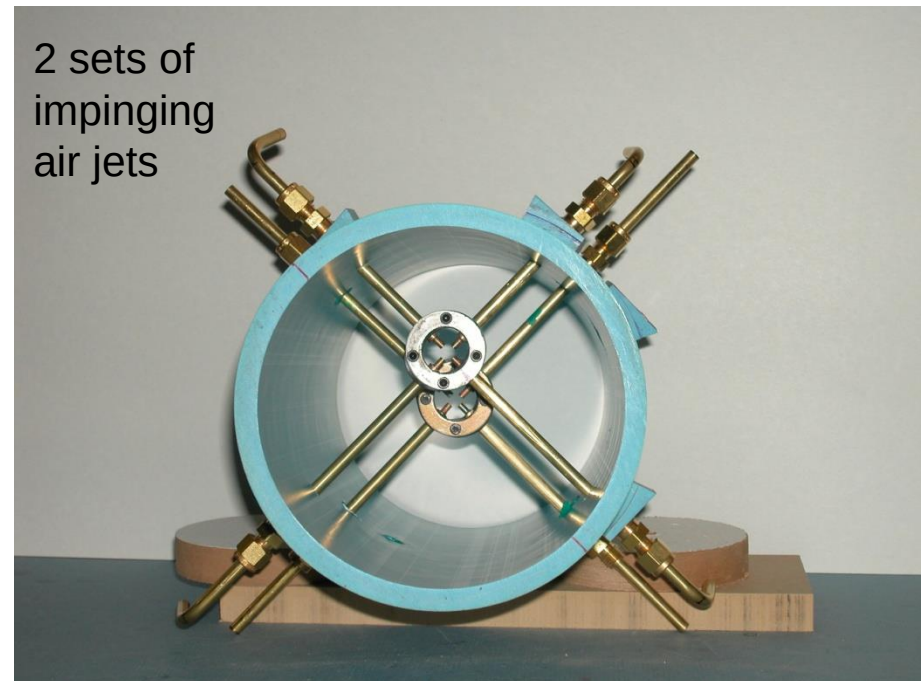
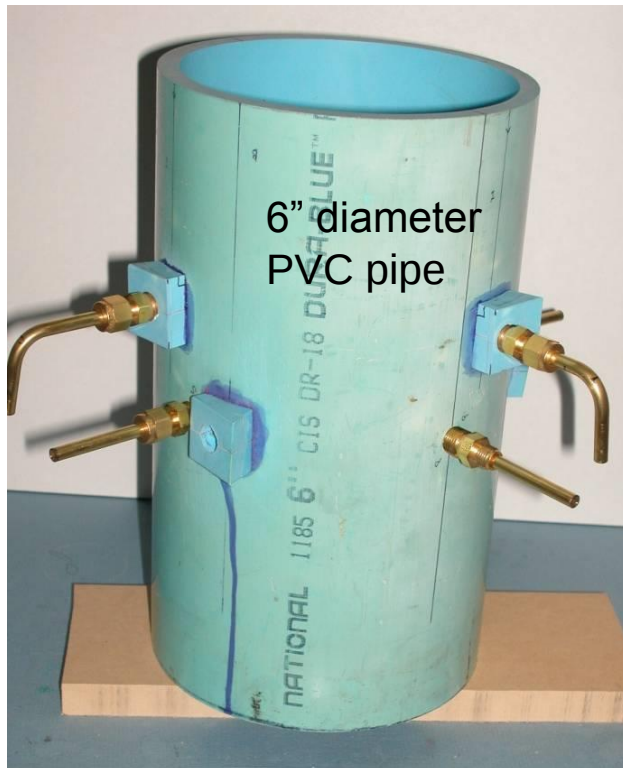
- Shielding of noise radiation from BENS inlet and exhaust were examined separately.



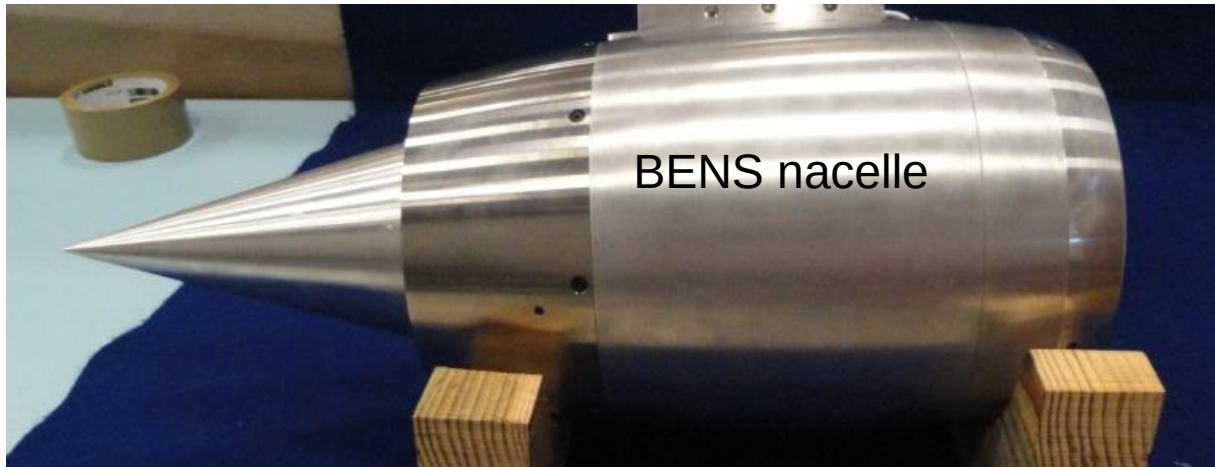
BENS – Initial Prototype



- Initial prototype developed to assess feasibility of concept:
 - Impinging jet design
 - Noise level and frequency range



BENS – Final Product

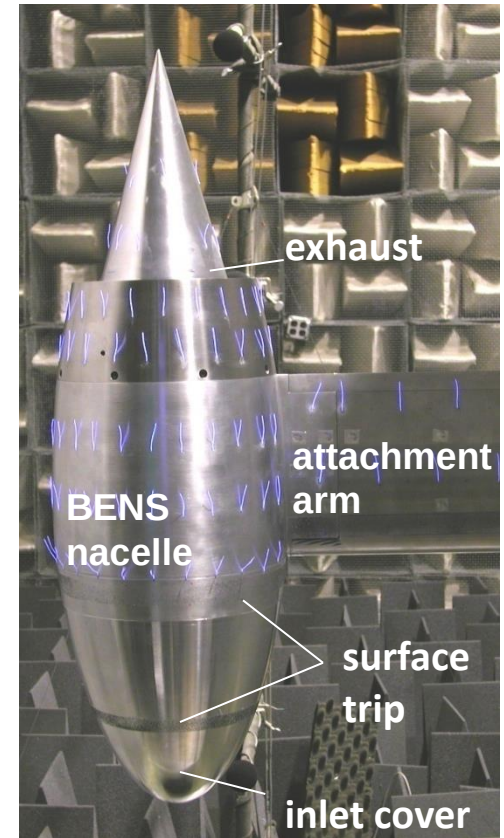


View from the inlet

BENS – Preliminary Testing



- Verify flow behavior when inlet or outlet caps are on:
 - determine surface trip requirements.
- Establish BENS noise output characteristics and requirements:
 - Determine optimum pressure requirements.
 - Verify linearity between embedded pressure sensor signals and far field microphone signals for flow On and Off conditions.
 - Evaluate signal to noise ratio (BENS noise output versus 14x22 background noise levels).

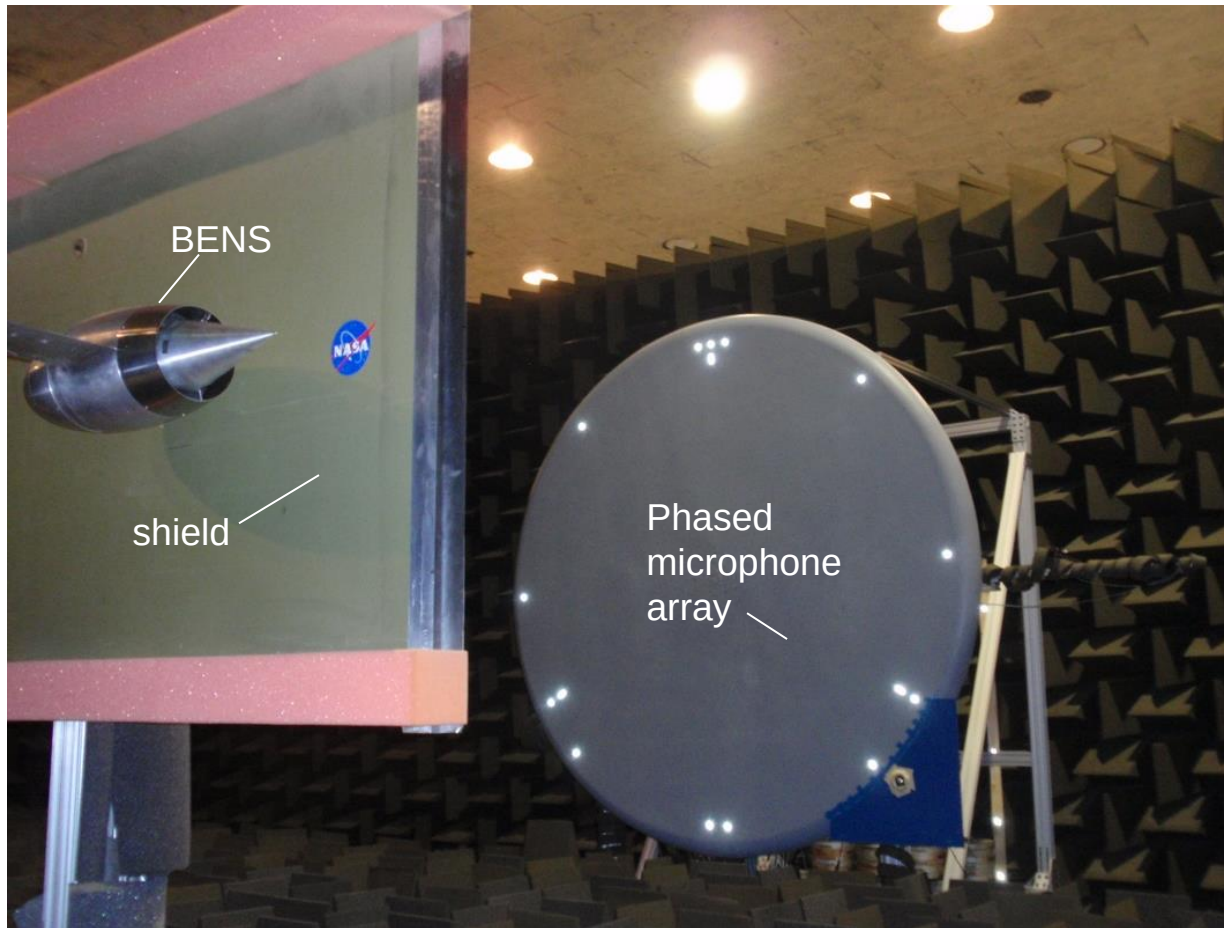


**BENS testing in NASA
Quiet Flow Facility**

BENS – Preliminary Testing



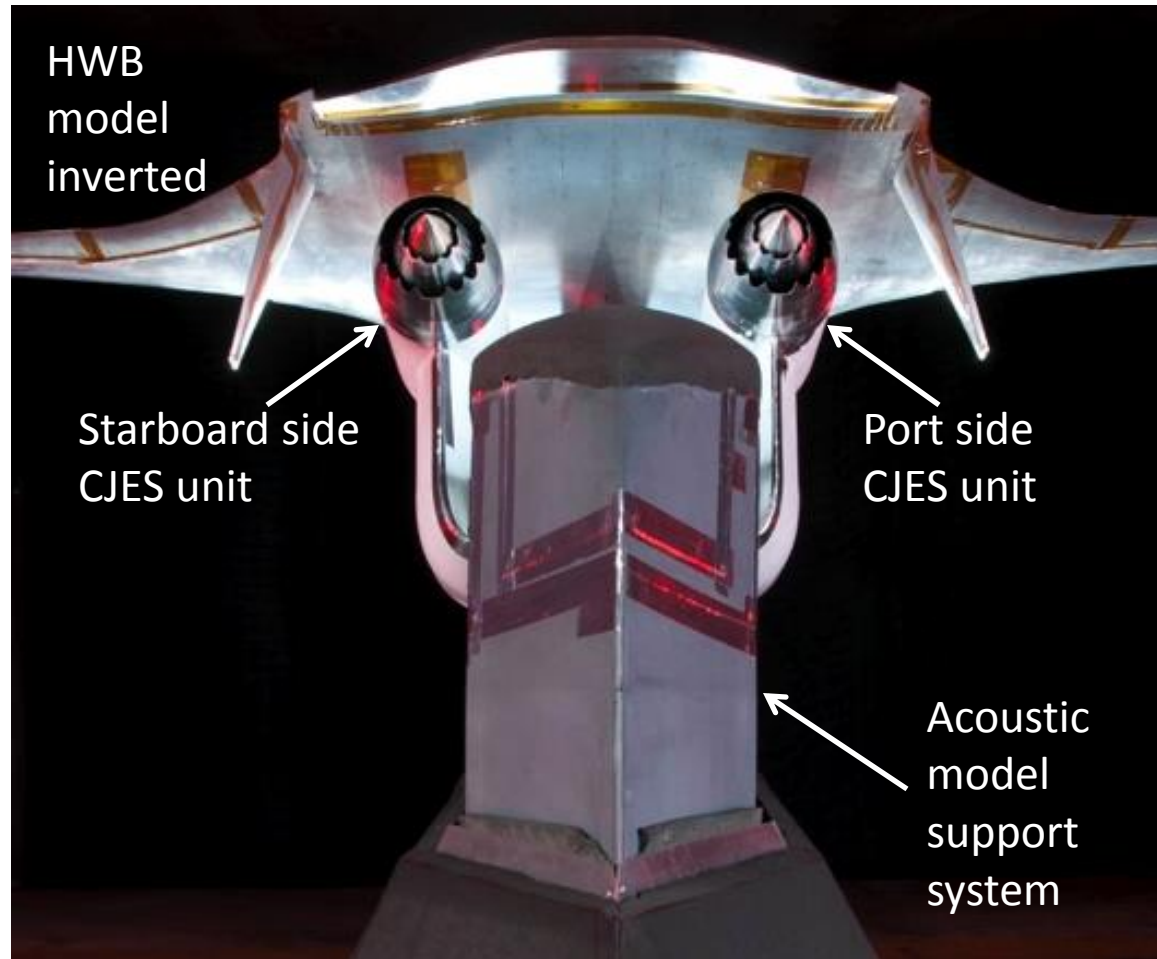
- Collect phased array data with and w/o shield to test microphone array and data acquisition system.



Compact Jet Engine Simulators (CJES)

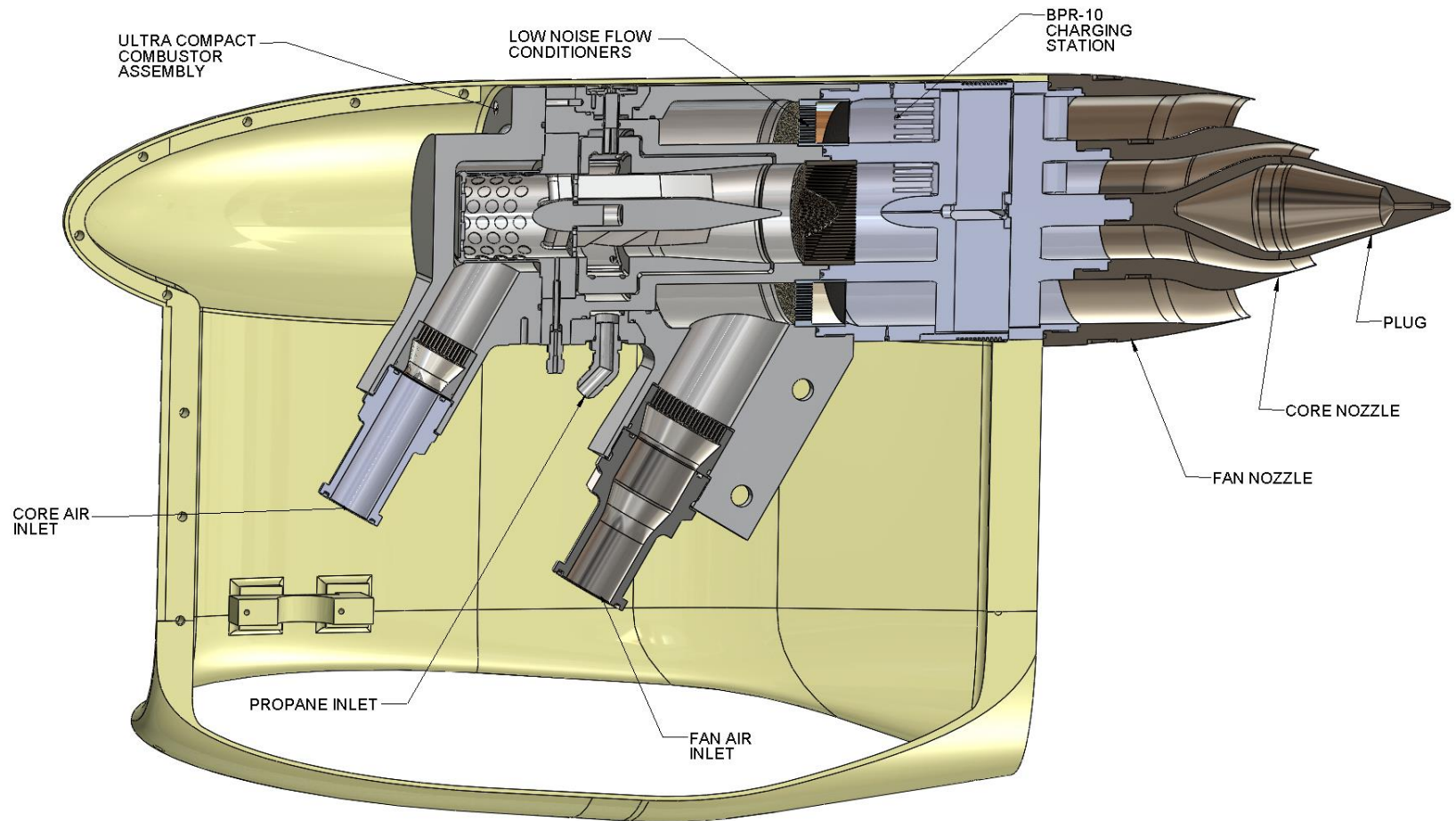


- Both units generate high temperature dual stream jet exhausts to simulate the HWB BPR-10 engine cycle jet noise



CJES units in baseline (shielded) position wrt HWB fuselage

Compact Jet Engine Simulators (CJES)

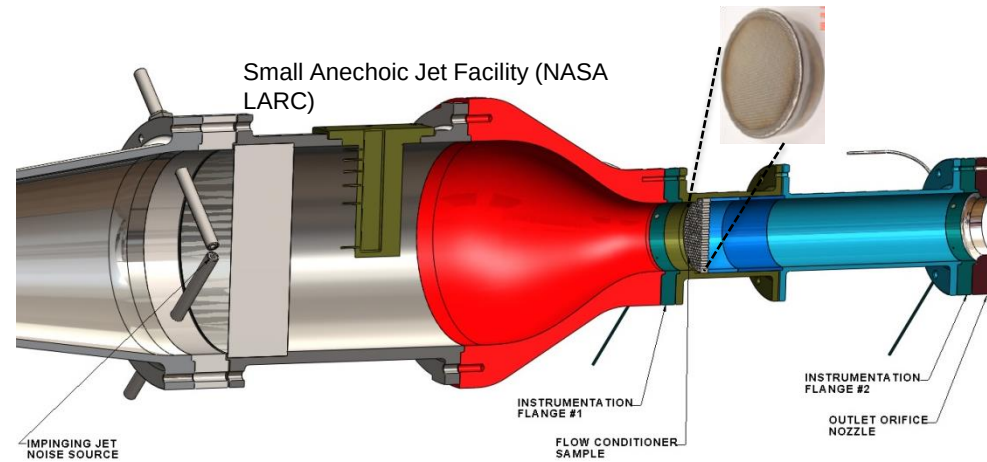


- Each CJES unit consists of a core and fan (bypass) stream simulating various cycle points of a turbofan engine (BPR-10 in this case)
- Gaseous propane is used to generate representative temperatures, up to ~ 1150° F for current test conditions

CJES – Preliminary Testing



Flow conditioners for CJES Rig Noise Reduction (AIAA 2011-2791)



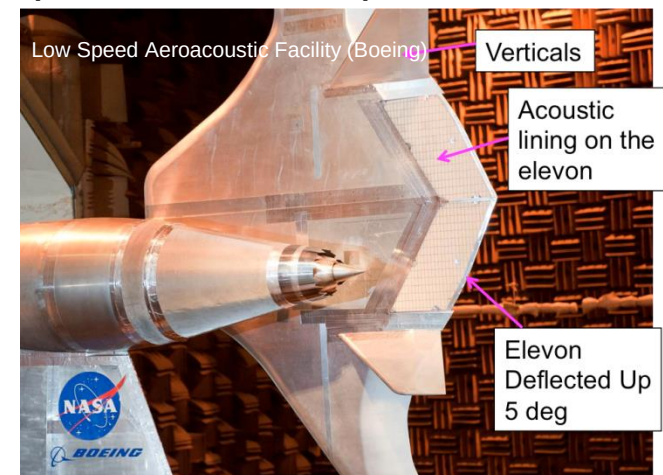
□ Twin jet aeroacoustic testing (AIAA 2012-2157)



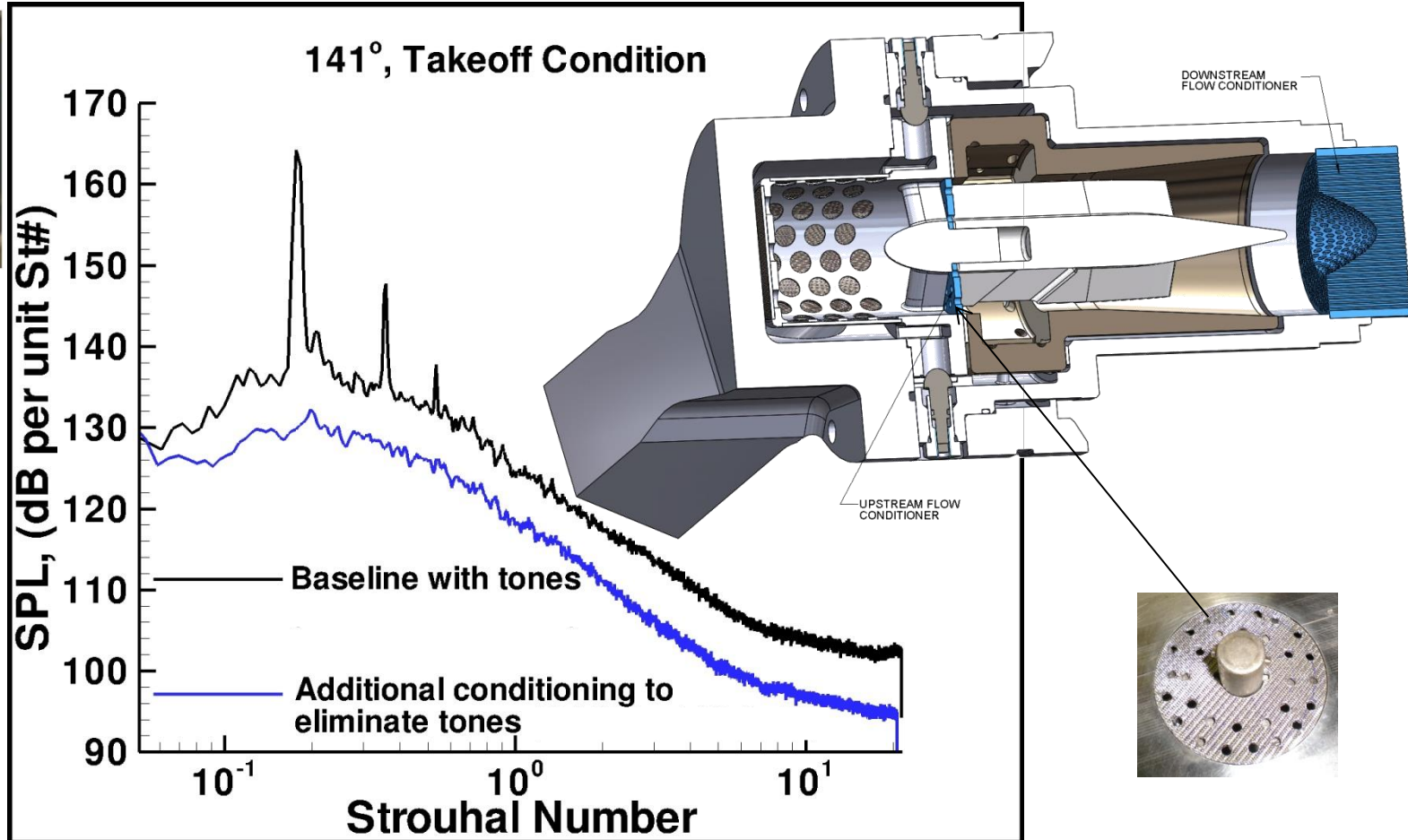
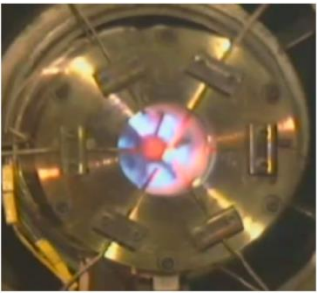
CJES and Ultra Compact Combustor Checkout Testing (AIAA 2013-2035)



Low Noise Nozzle Development (AIAA 2013-541)



Combustion Instability

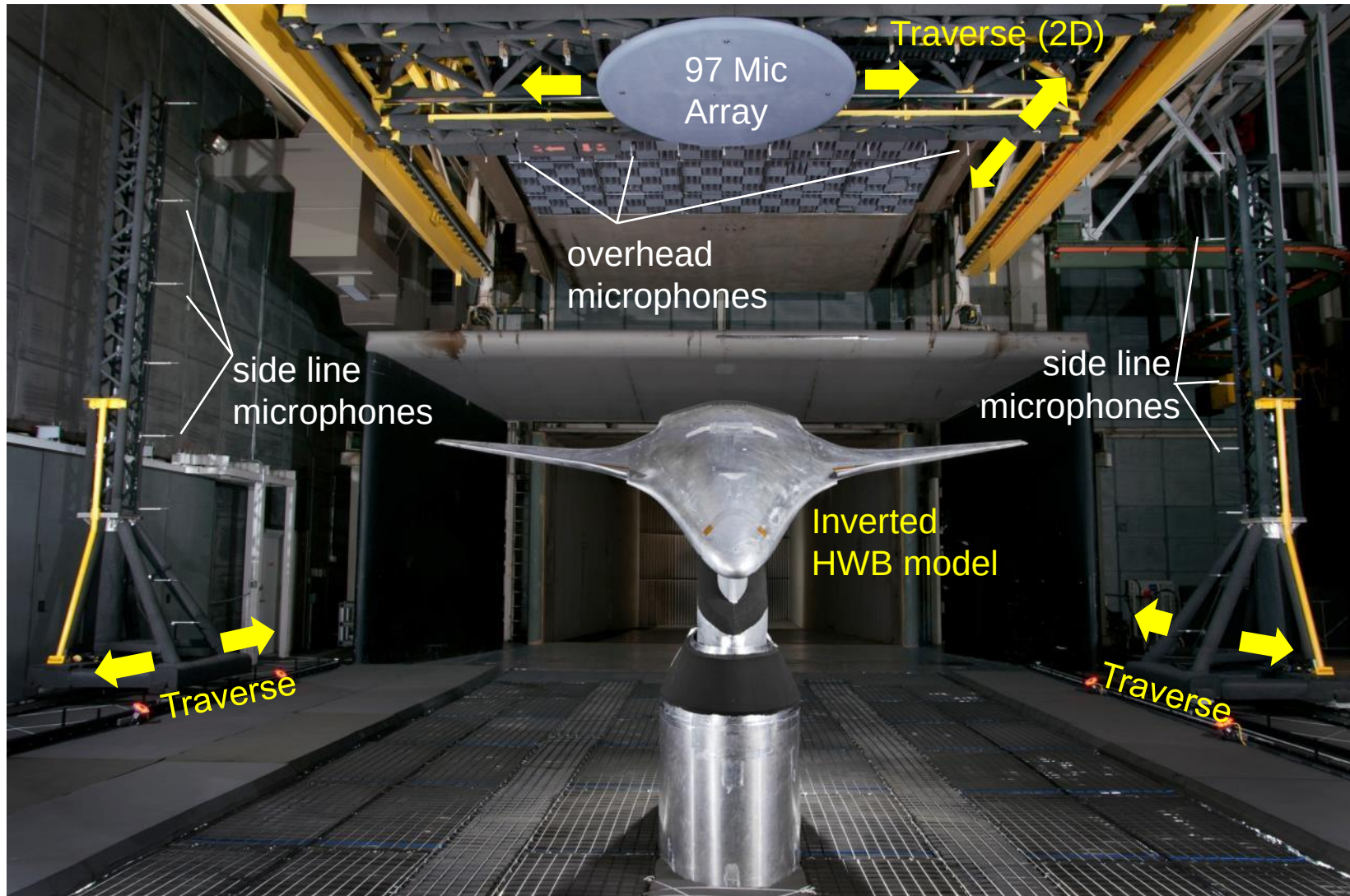


- Combustion-driven acoustic instability generating tones ~ 25 dB above broadband
- Tones eliminated with combination of non-uniform flow conditioner to break up reflected acoustic wave and upstream screen to change effective combustor length



Acoustic Test Set-up and Data Presentation

Acoustic Test Set-up



- Noise measurements were obtained from sideline and overhead microphones, and from phased microphone array at key streamwise locations.

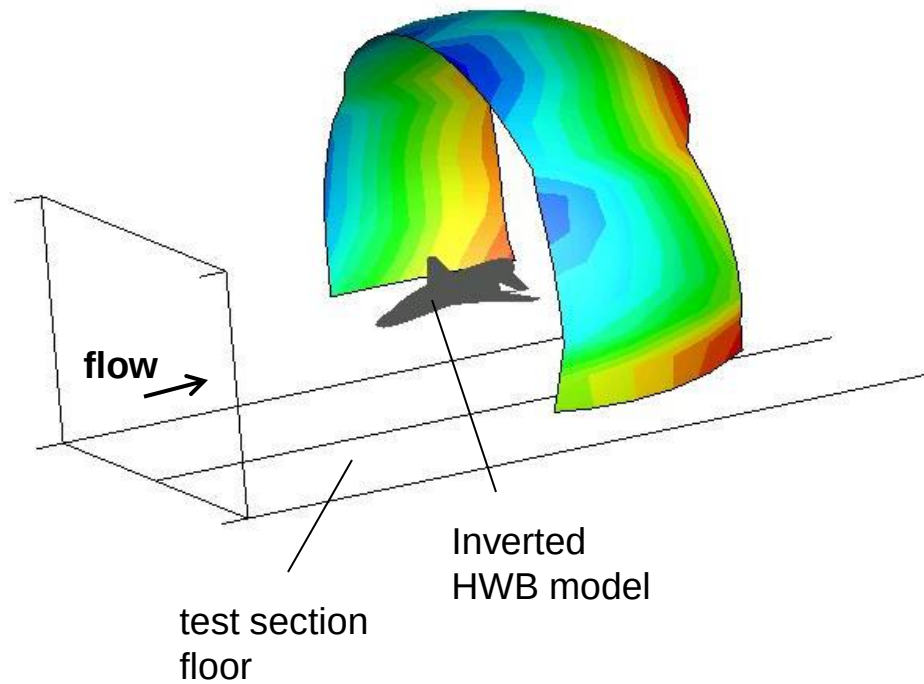
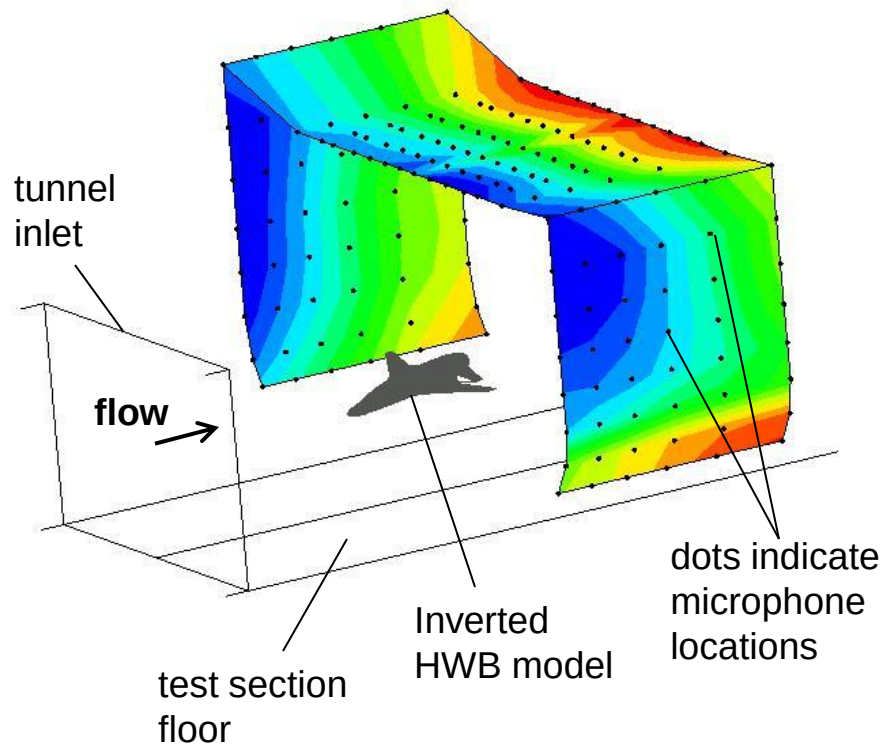
Test Data Presentation



Corrected SPL contour levels over area traversed by the truss and tower microphones



Corresponding SPL levels on a hemisphere



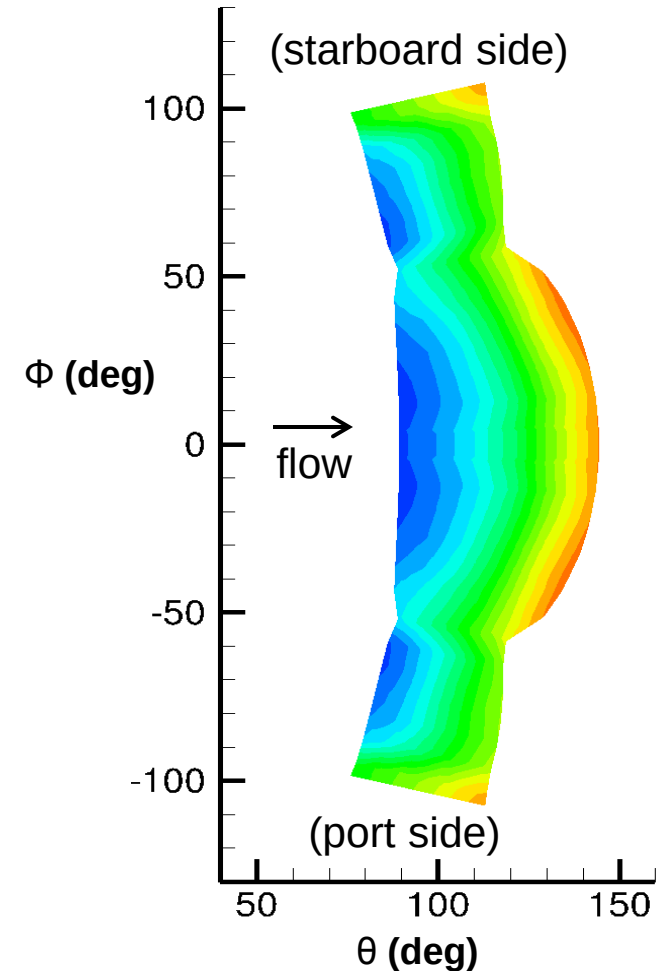
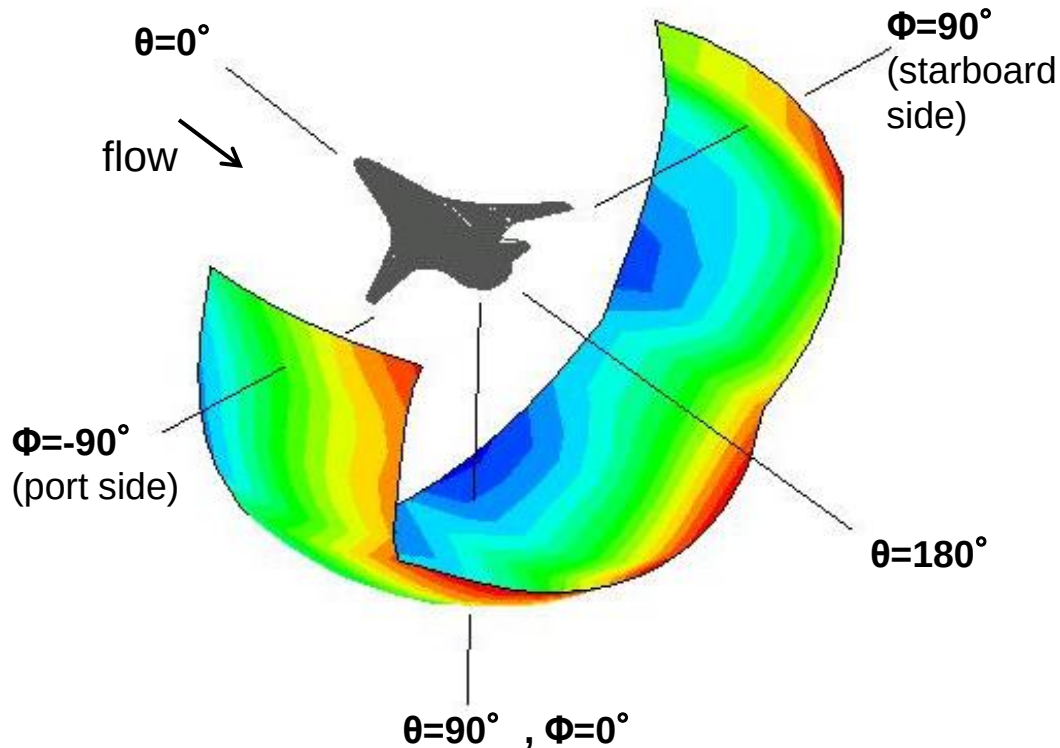
Test data and results presentation



HWB rotated “right side up” with hemisphere (observers) towards ground.



Unfolded hemisphere: (θ - Φ) plot





Test Data and Sample Results

Test Data and Sample Results



- **HWB test data**

- Shielding of broadband component of turbomachinery noise

- Jet noise and its shielding

- Airframe noise from HWB components

Exhaust BENS data acquired for:

- **3 flight-simulation configurations (398 data points)**
Take-Off and 2 Approach conditions
- **Alternate vertical tail configurations (188 data points)**
2 geometries, 2 cant angles, 2 streamwise placements
- **Alternate BENS nacelle streamwise positions (118 data points)**

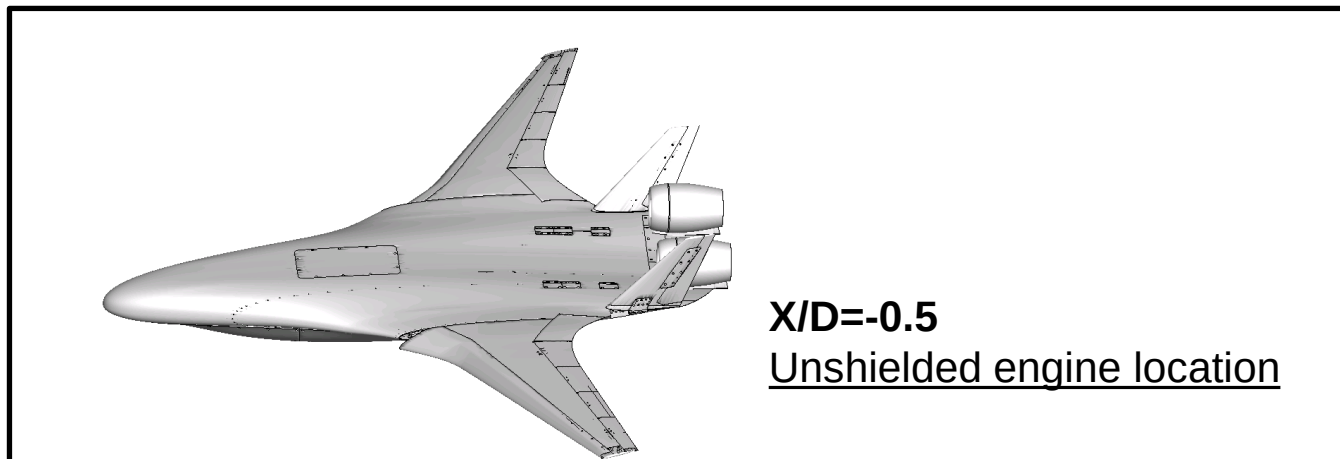
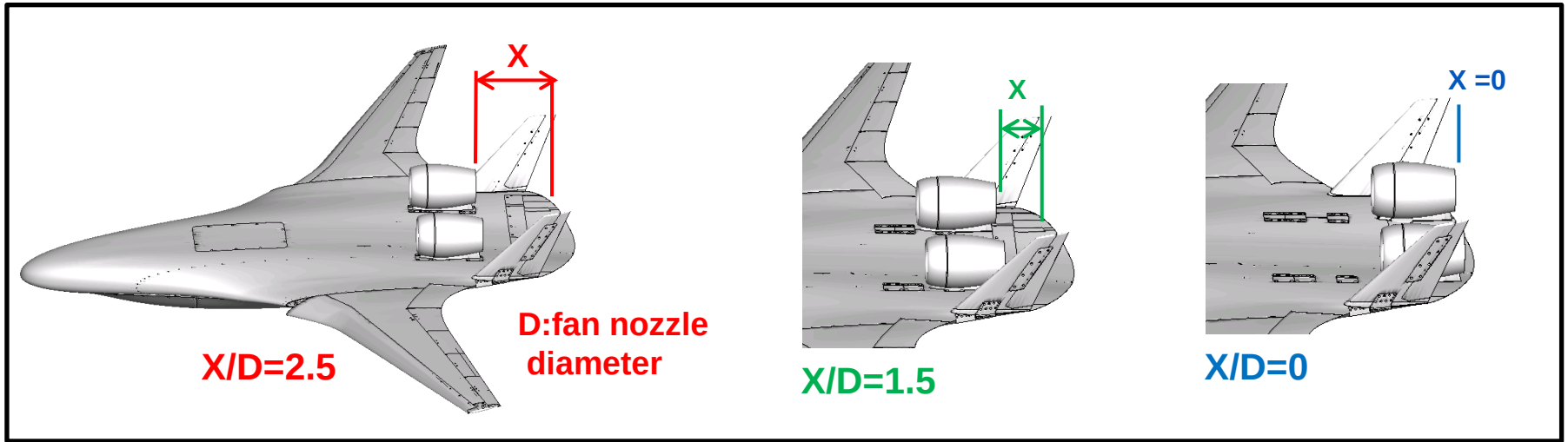
Inlet BENS data acquired for:

- **Two Leading Edge (LE) configurations (145 data points)**
Drooped LE and Stowed LE

Effect of Engine Location on Shielding



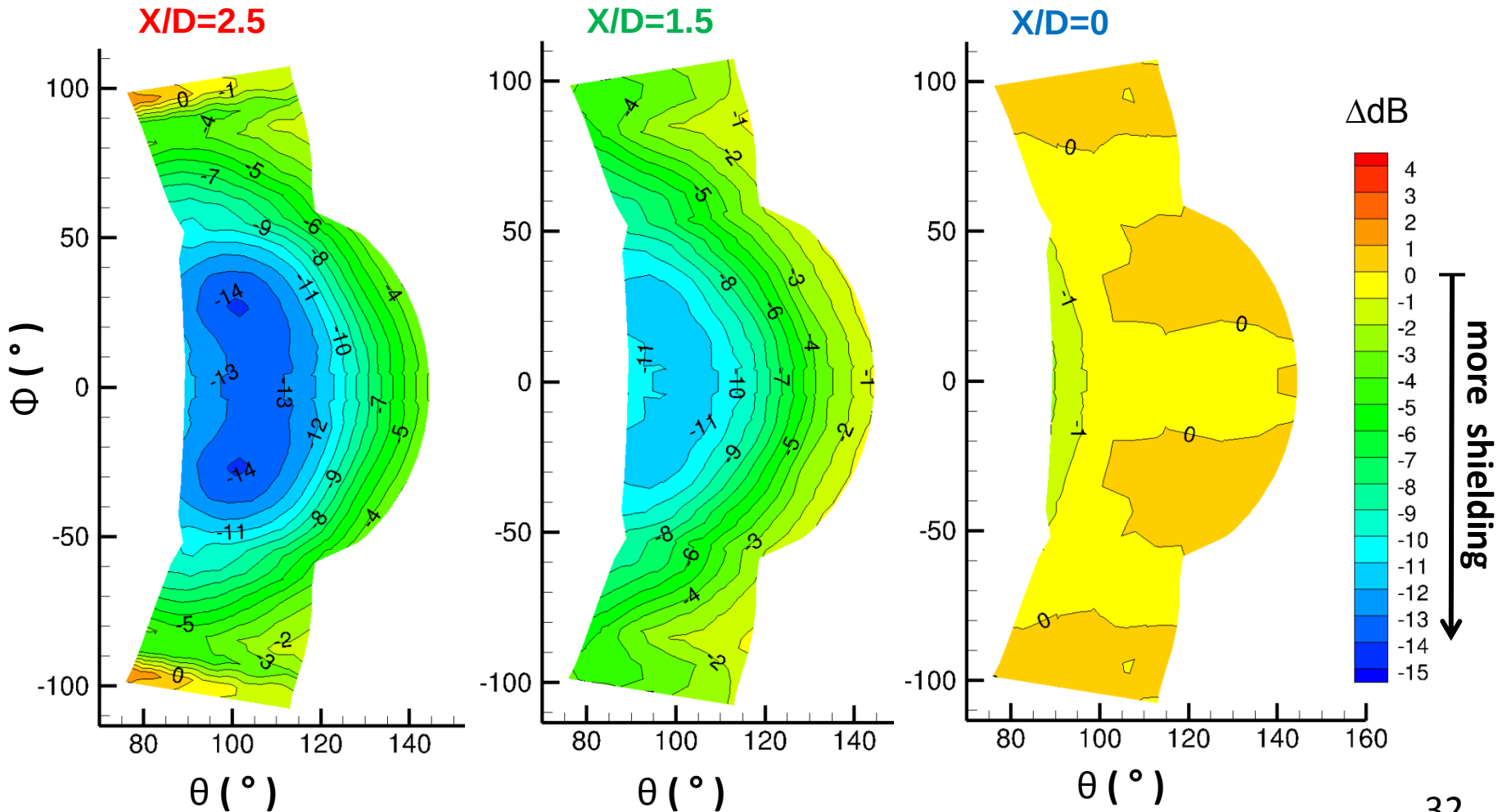
Shielding (ΔdB) =



Effects of Engine Location on Shielding



ΔdB due to shielding
Mach=0.19 $f_{1/3} = 31.5\text{kHz}$



Test Data and Sample Results



- **HWB test data**

- Shielding of turbomachinery noise (broadband component):

- Jet noise and its shielding

- Airframe noise from HWB components

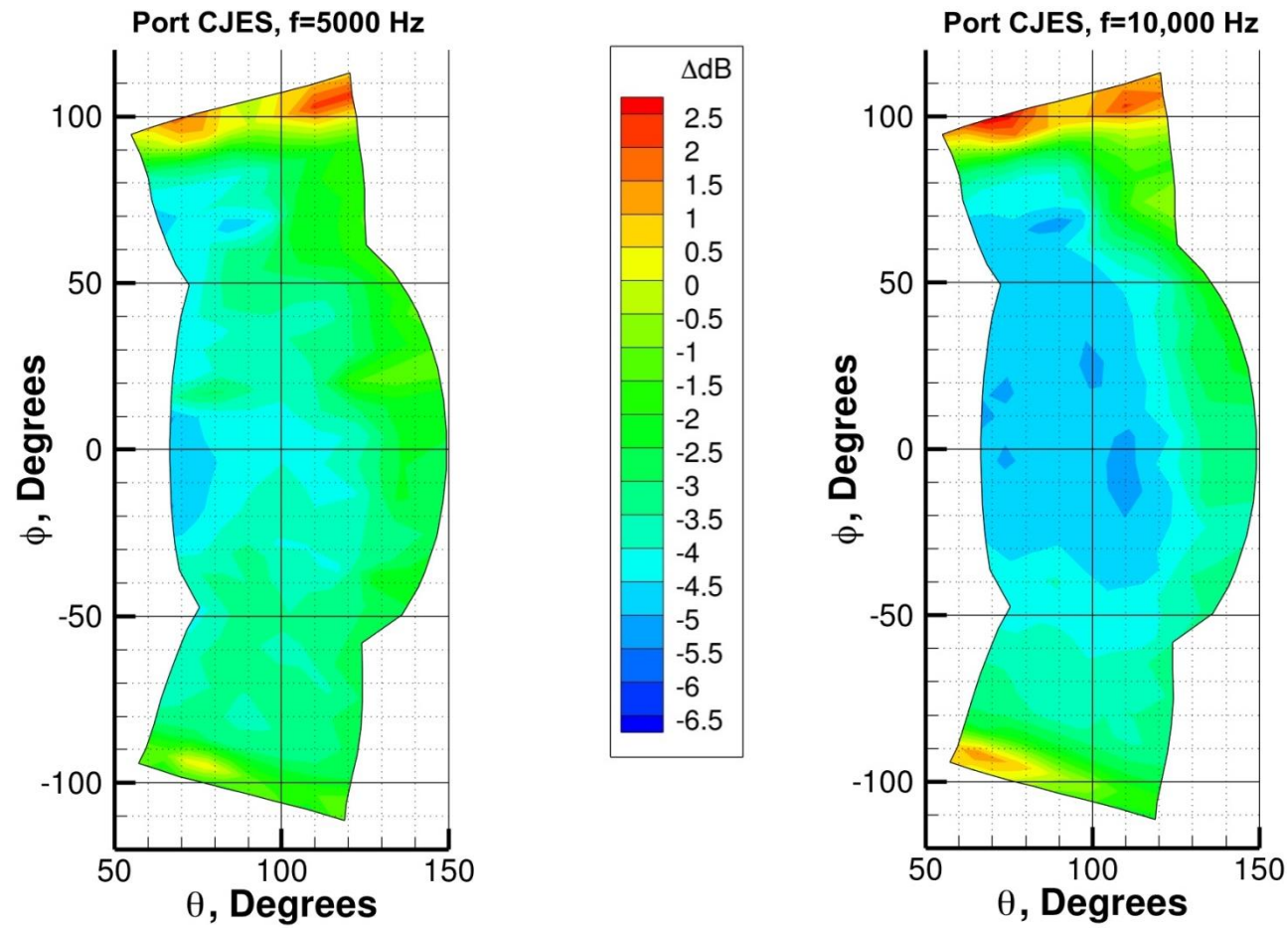


- **3 flight-simulation configurations (41 data points)**
Approach, Cutback, and Takeoff
- **Round axisym. nozzle set vs low-noise chevron nozzle set (36 data points)**
- **Alternate CJES streamwise positions (27 data points)**
- **Single vs twin jet configurations (27 data points)**
- **Various angle of attack configurations (37 data points)**
- **Alternate vertical tail configurations (25 data points)**
No verticals; narrow chord / 10° cant / aft position (baseline); narrow chord / 10° / forward position

HWB-CJES Shielding Results



Δ dB Contours for $x/D=2.5 - x/D=-0.5$
Round Nozzles



Test Data and Sample Results



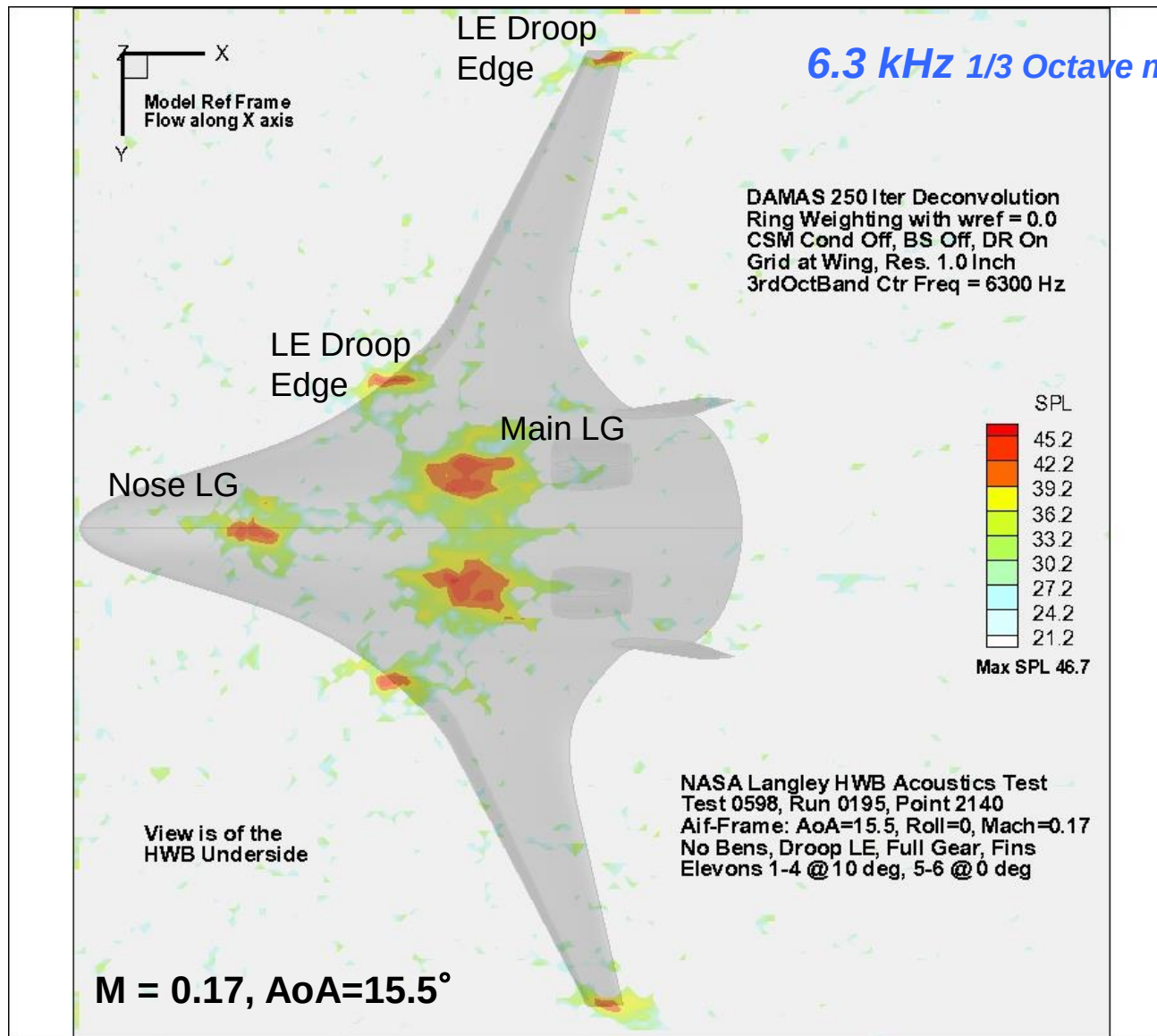
- **N2A-EXTE HWB test data**
 - Shielding of turbomachinery noise (broadband component)
 - Jet noise and its shielding
 - Airframe noise from HWB components

Airframe Noise Test Data



- Airframe noise results by phased array (w DAMAS processing) and with sideline / overhead single-microphones
- Airframe parameter variations
 - Mach: 0.17, 0.19, 0.21
 - AoA: 0°, 13°, 15.5°.
 - Landing gear: main gear and nose gear combinations: *separate, both, none*
 - HWB model 'rolled' 30° to increase extent of azimuthal directivity measurement
 - Azimuthal angle range: 0, 25° and with model rolled: 30°, 55°.
 - Different combinations of 6 elevon settings
 - Vertical tails:
 - None
 - Baseline (aft position at 10° cant)
 - Leading edge: drooped and stowed

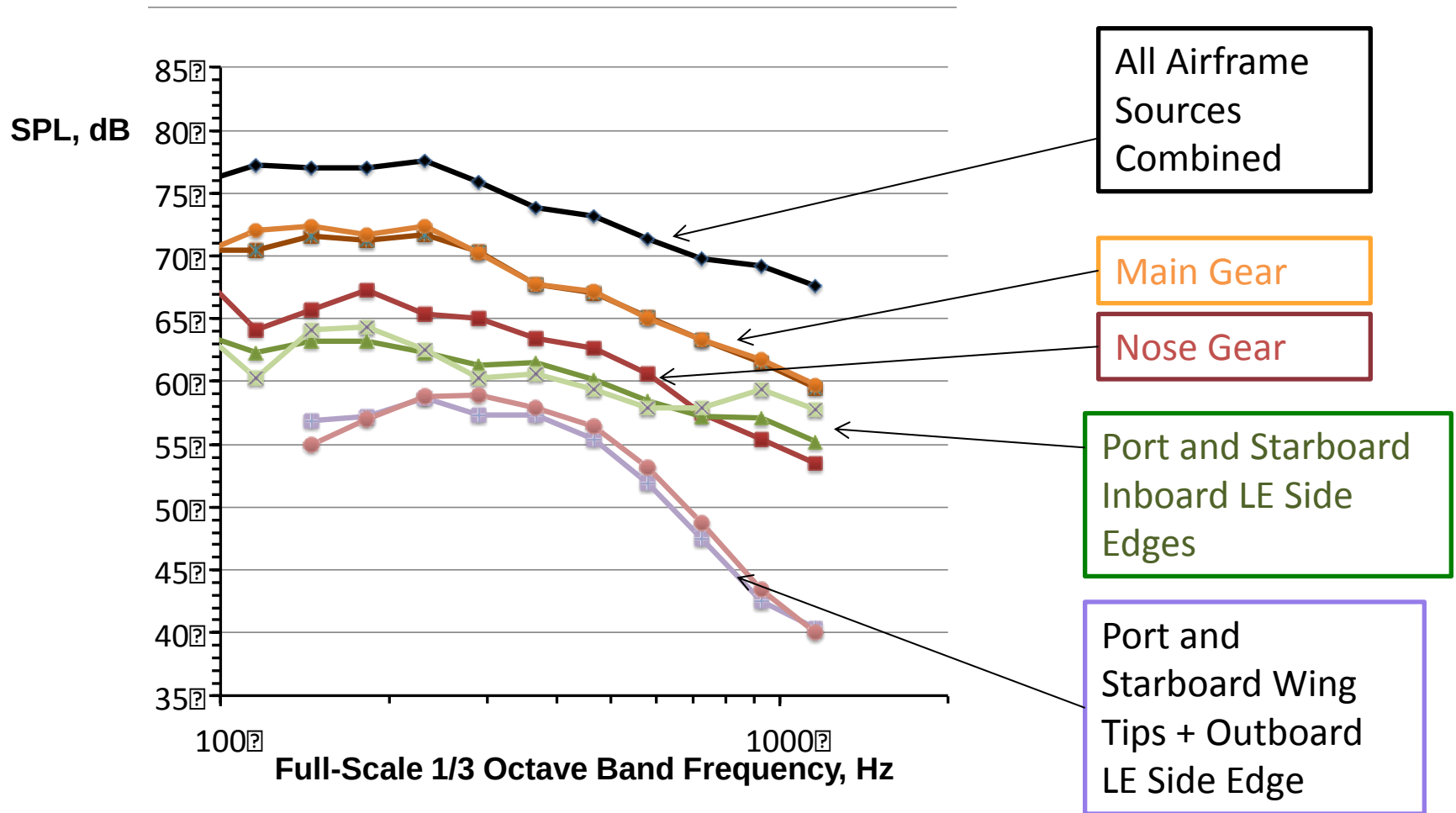
Airframe Noise Source Distribution by DAMAS-Array



Airframe Noise Component Ranking



- Airframe source identification
- Approach Condition: $\text{AoA}=15.5^\circ$, $R=245.7$ ft, $M=0.21$, $\theta=73.5^\circ$, $\phi=0^\circ$





N2A-EXTE HWB Noise Assessment



- **Test data used as input to ANOPP2 to perform the noise assessment:**
 - Jet noise, airframe noise and engine shielding effects measurements
- **Assessment performed for :**
 - Baseline N2A-EXTE airframe configuration
 - Reduced approach flight speed
 - Modified landing gear designs with fairings
 - Modified vertical tail placement
 - Drooped leading edge
 - Over-the-Rotor liner and Soft-Vane fan technologies
- **Cumulative noise assessed at 38.7 EPNdB below Stage 4 for “best” configuration.**

Large and successful multi-year effort:

- Concept study and fabrication of HWB full-span high-fidelity model
- Development of complex instrumentation and test hardware (engine noise simulators, phased microphone array, traverse and data acquisition systems, etc.)
- Noise spectra and directivity for :
 - Jet noise and its shielding
 - Airframe noise
 - Broadband turbomachinery noise shielding
- Comprehensive aeroacoustic database on full-span high-fidelity HWB model:
 - for system noise analysis and validation/development of prediction capabilities
 - addresses noise exposure metrics and noise reduction methodology for a HWB vehicle.
- Major upgrades to testing capabilities of NASA 14 by 22-Foot Subsonic Tunnel.



Thank you for your Attention!



Backup – other...



- Acoustic and associated data from the Hybrid Wing Body Acoustic Test within the 14- by 22-Foot Subsonic Tunnel are being prepared for release
- Over the next 12 months a selected subset of data from the test will become publicly available and could be provided upon formal request