Status of Hybrid Wing Body Community Noise Assessments

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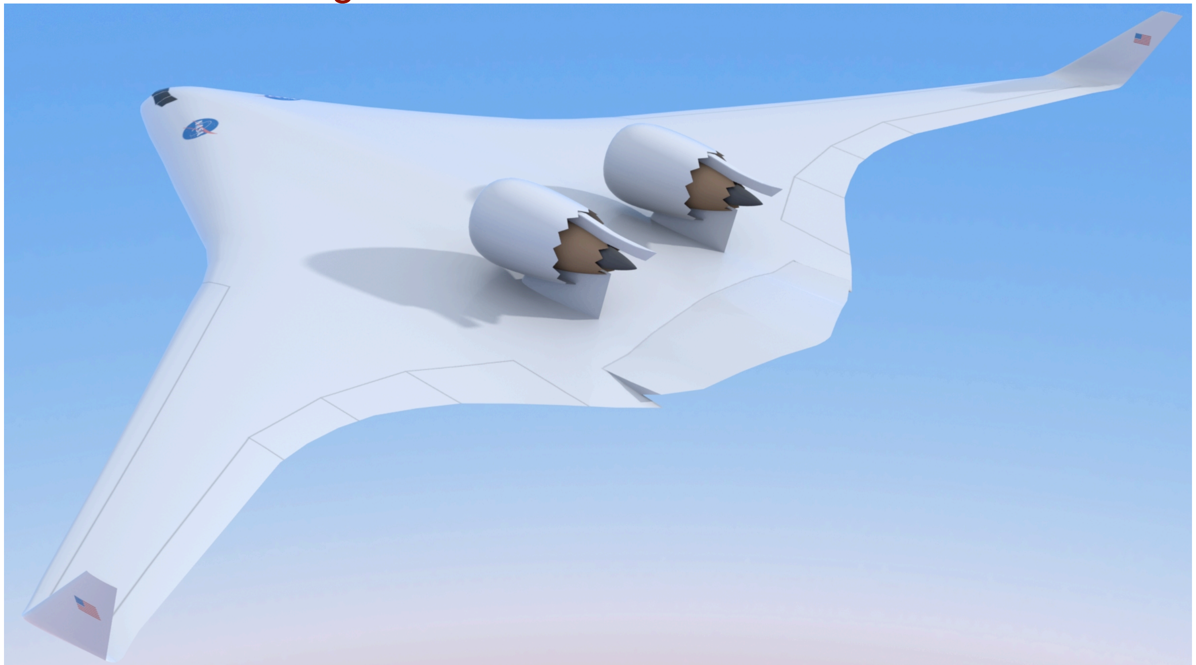
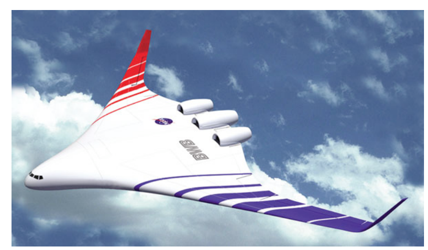


Introduction

Acknowledgments:

- Mr. Craig Nickol, Dr. Frank Gern, Mr. Jeff Berton, NASA
- PAA Experimental Data on separate task: Dr. Michael Czech, Dr. Leon Brusniak, Mr. Ronen Elkoby and the LSAF Team, The Boeing Company
- Mr. John Rawls Jr., Lockheed Martin Engineering Services

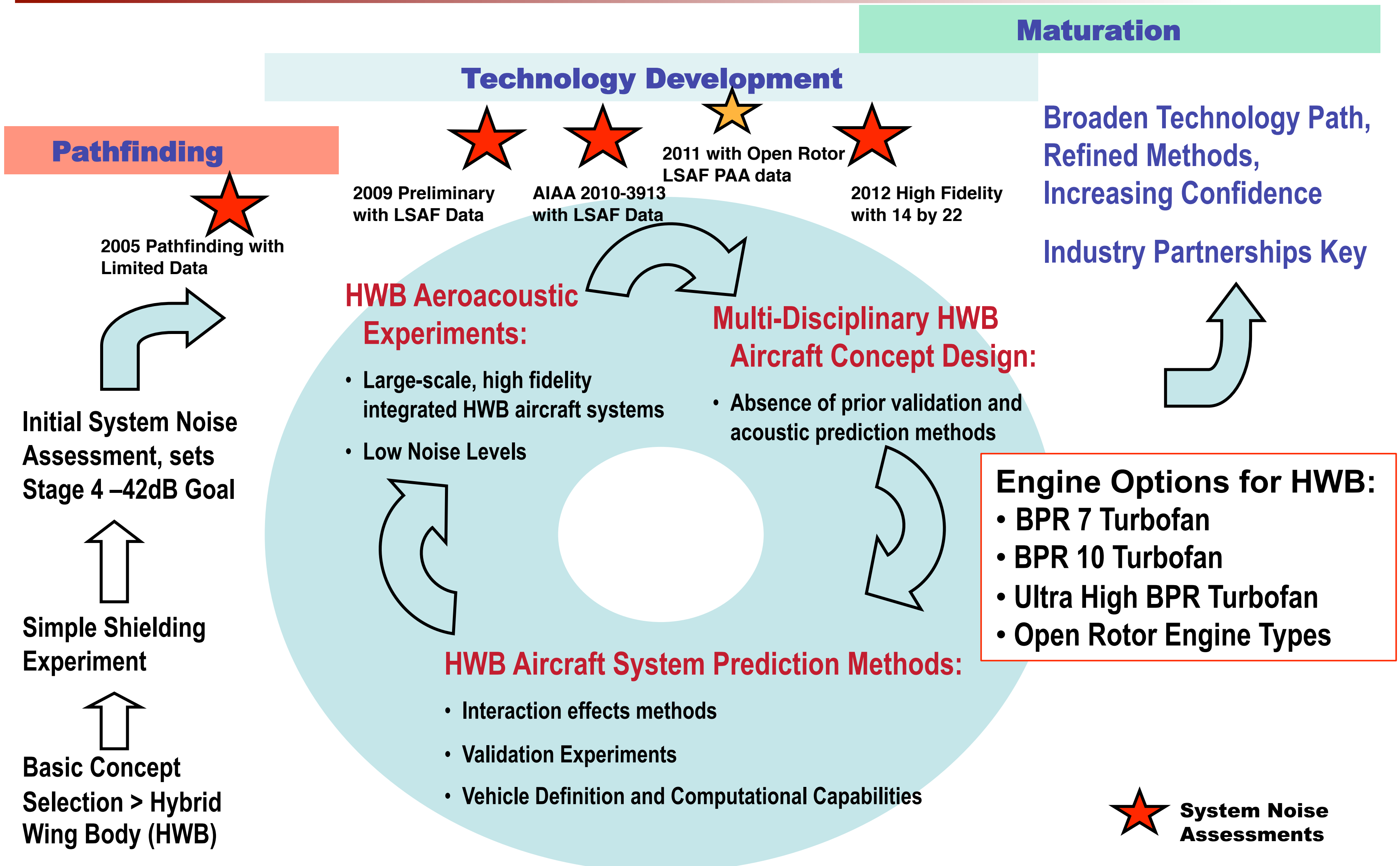
PAA Definition: Aeroacoustic effects associated with the integration of the propulsion and airframe systems (acoustic and flow interactions)



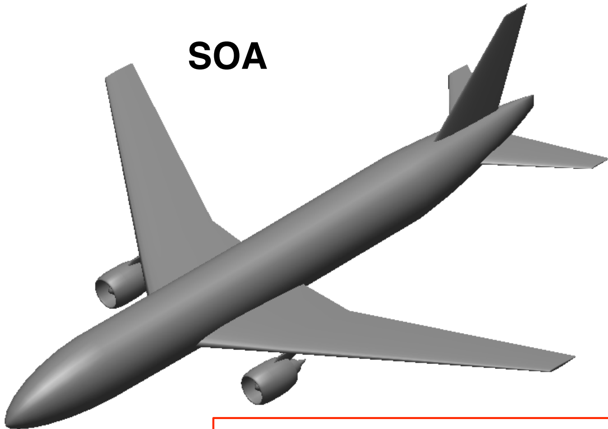
Outline

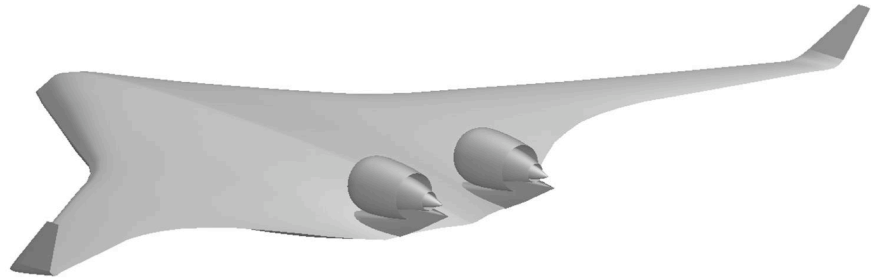
- NASA N+2 Noise Goal Roadmap
- HWB with BPR 7 Turbofan (ref: AIAA 2010-3913 Thomas, Burley, and Olson)
    - Assessment Process Including PAA Experiment
    - HWB Configurations
    - System Noise Impacts
    - Summary & Future Directions – HWB with UHB Turbofan
- Current Study In Progress – HWB with Open Rotor
    - LSAF PAA Experiment
    - Assessment Process
- Summary

NASA N+2 Acoustics Goal Roadmap



Review 2010 Assessment - Aircraft Models and Framework





Both aircraft use equivalent technology levels and are sized for same payload, same 7500 NM mission, meet FAA airworthiness standards, and same GE90-like engine used on both aircraft

	777-like SOA	HWB NASA Best
Weight-takeoff (lbs)	656,000	590,436
Weight-landing (lbs)	459,200	413,305
Max Fuel (lbs)	284,279	227,081
Engine SFC (lbm/hr/lbf)	0.557	0.549
L/D (start of cruise)	19.5	23.0
Thrust per Engine (static sea level)	86,783	81,298
Takoff Field-Length (ft)	8648	8633

Aircraft System Noise Prediction Method

- NASA Aircraft Noise Prediction Program (ANOPP-Lv 27)
  - SOA and HWB flight definition from FLOPS
  - GE90-like relative engine noise sources match data (ref. Gliebe, 2003)
  - Total SOA prediction calibrated to match EPNL data for this aircraft

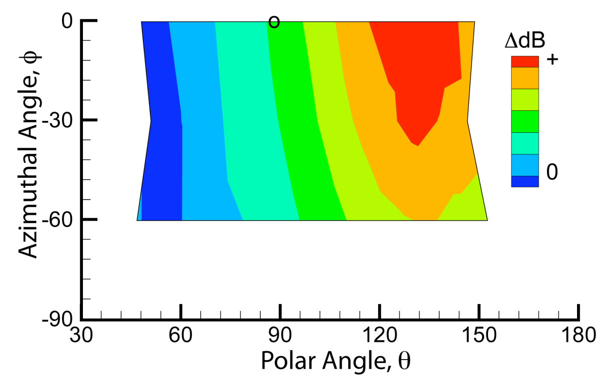
ANOPP

Aircraft Flight Definition ← **FLight OPtimization System (FLOPS)**

Source Noise
Jet: ST2JET
Fan: Boeing method
Duct Treatment: GE
Core: SAE
Airframe: Boeing, Fink (t.e.)

← **Numerical Propulsion System Simulation (NPSS)**

PAA Effects ← **Experimental Data from LSAF (ref AIAA 2010-3912)**

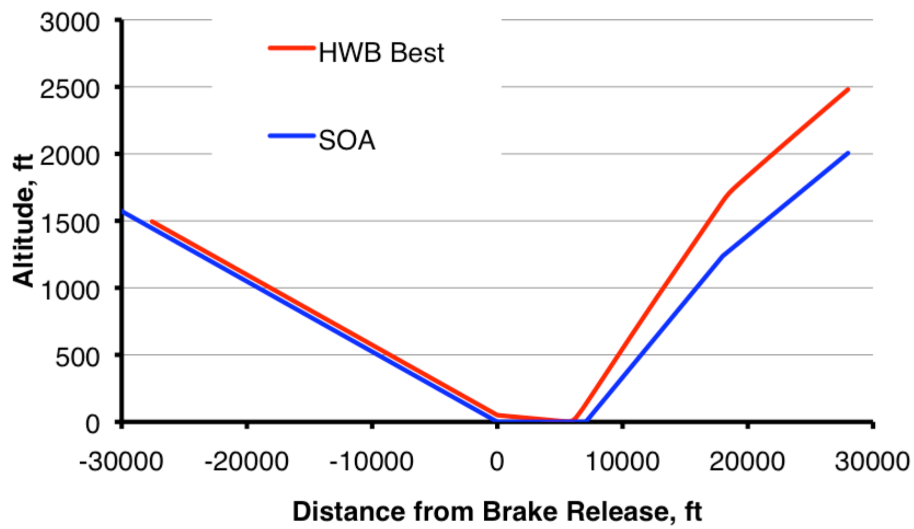


Propagation & Noise Metrics

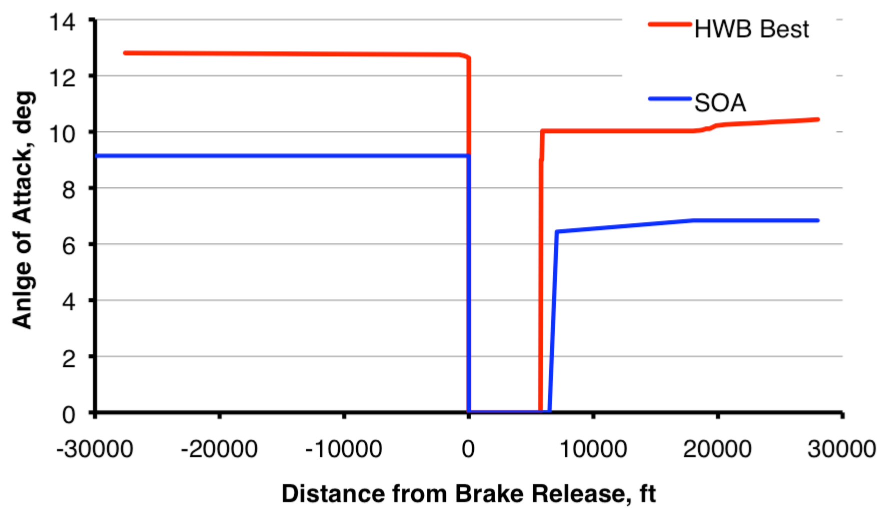
↓

EPNL predicted at FAR 36 locations

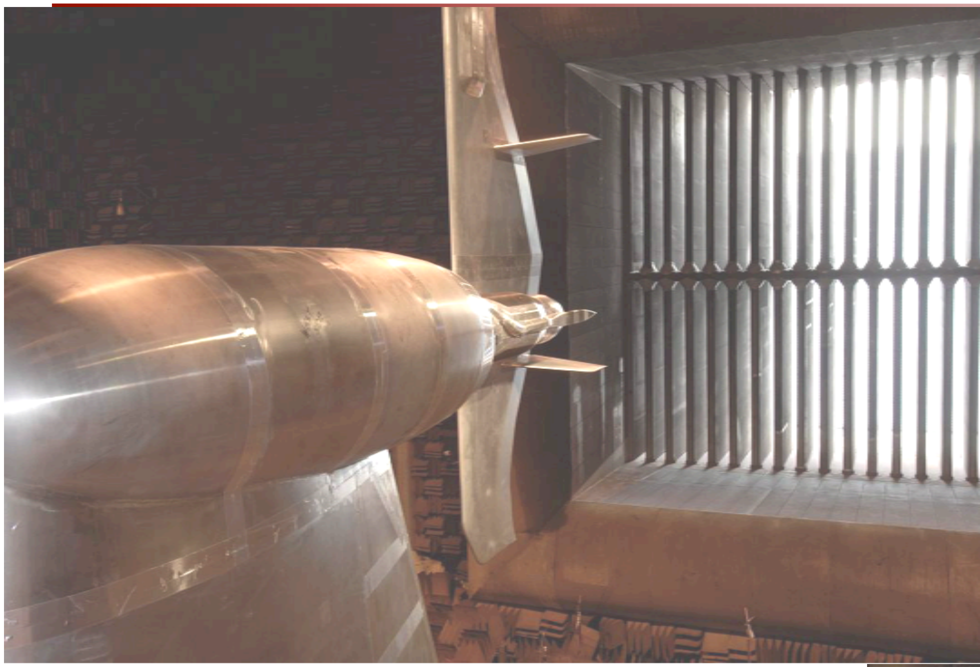
Flight Path Profiles



Approach → **Takeoff** →



Technology and Experimental Data for Key PAA Effects



Ref: Czech, Thomas, and Elkoby, "Propulsion Airframe Aeroacoustics Integration Effects for a Hybrid Wing Body Aircraft Configuration," AIAA 2010-3912

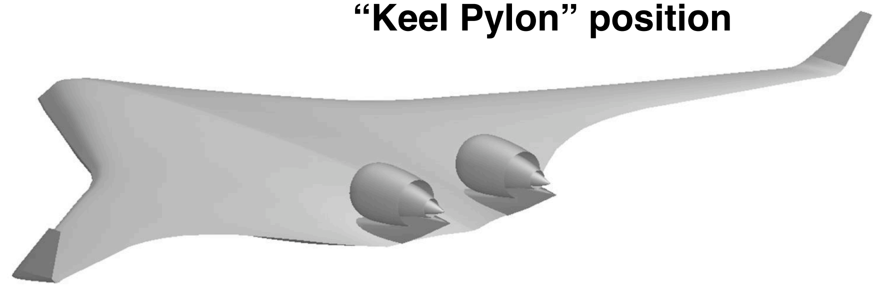
HWB Experiment Improves Basic Understanding of Aeroacoustic Sources and Parameters:

- **Effects from Verticals and Elevons**
- **Jet-Airframe shielding including source modification**
- **Broadband point source shielding with flow effect**

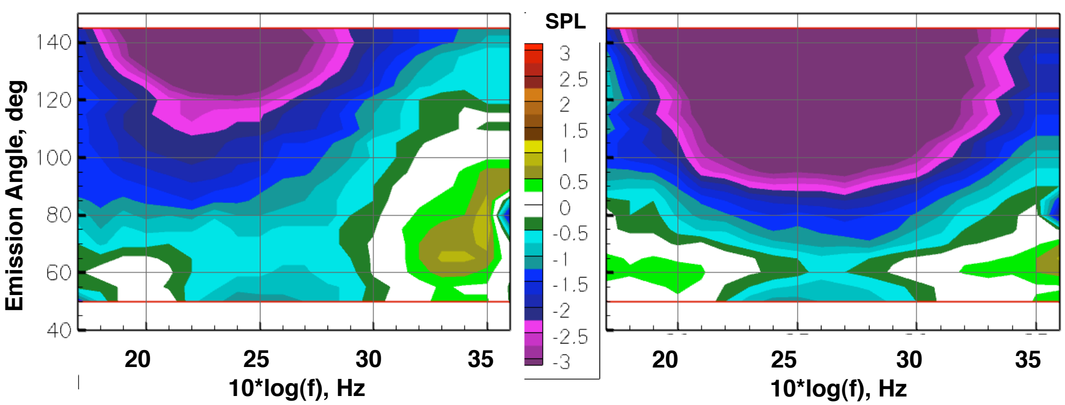
Effect of Pylon Orientation Relative to Observer

"Crown Pylon" position

"Keel Pylon" position



SPL difference between crown pylon and keel position (from ref AIAA 2010-3912)



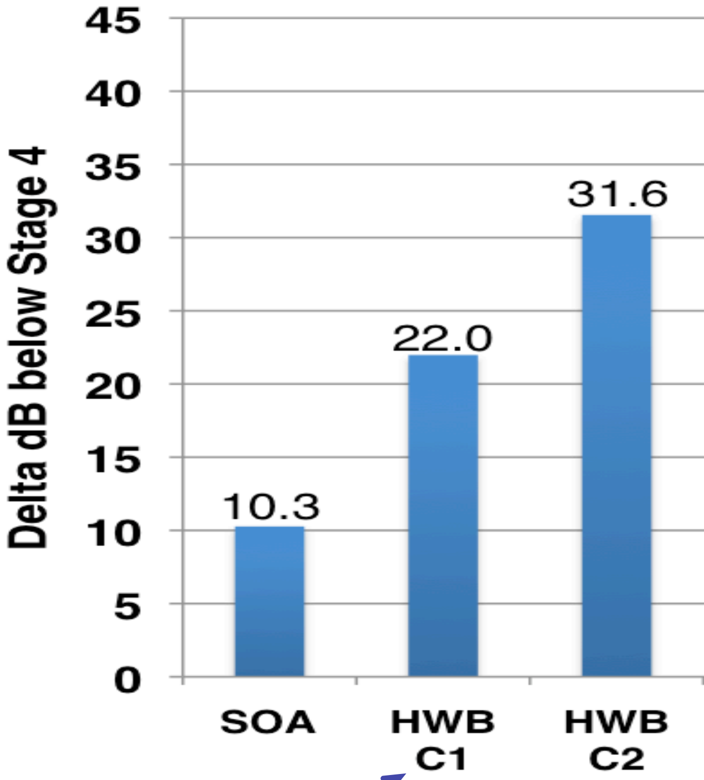
Crown rel. to Keel at Cutback

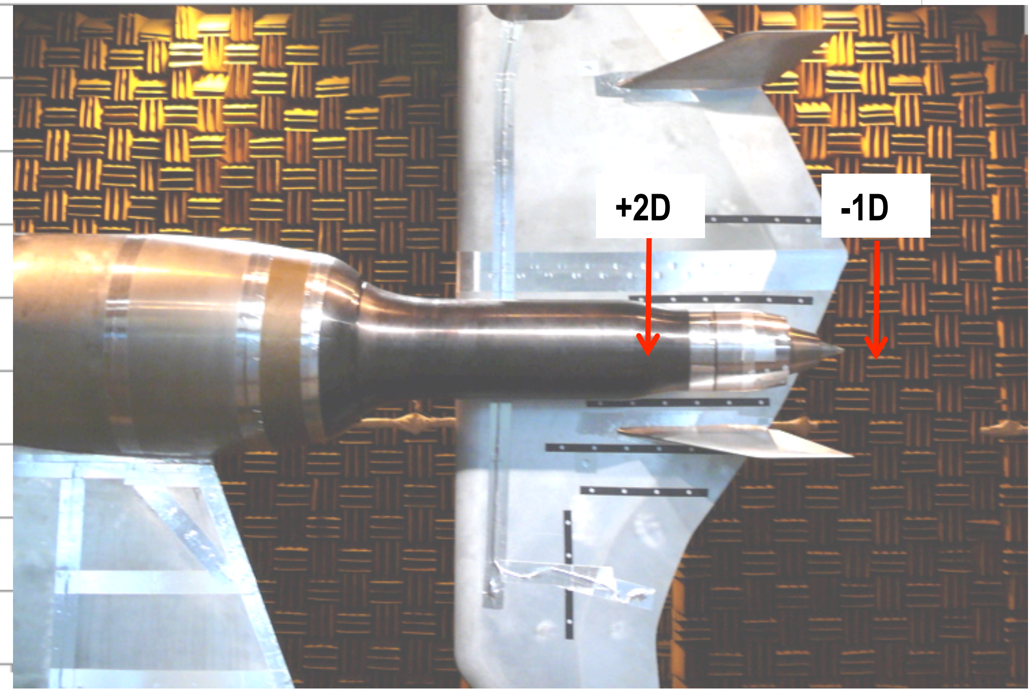
Crown rel. to Keel at Sideline

- Effect of pylon orientation increases with power setting
- Azimuthal orientation of pylon has up to 8dB effect in aft arc

Effect of pylon on key jet noise source included through experimental information

PAA Technology Effects on System Noise Levels



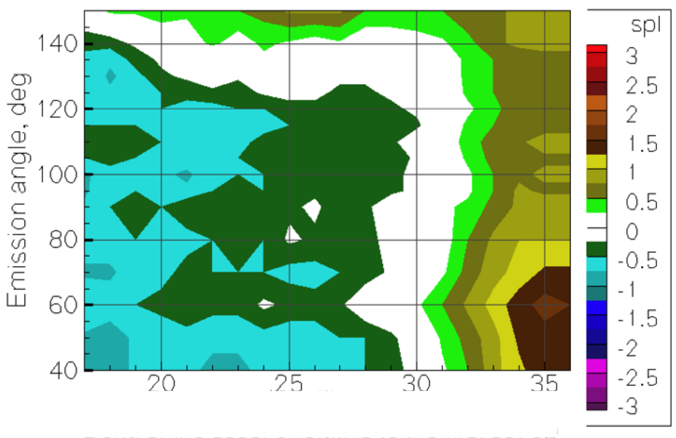


Baseline, Engines 1D downstream of trailing edge

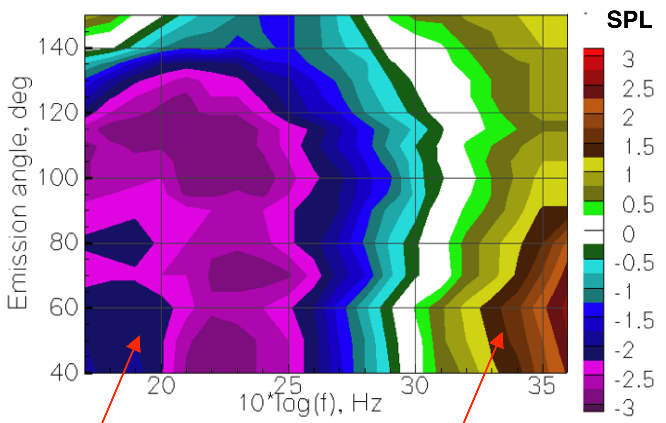
Simple Shielding, engines move 2D upstream

Jet noise changes with chevrons

Spectral changes with Chev1
Mild design



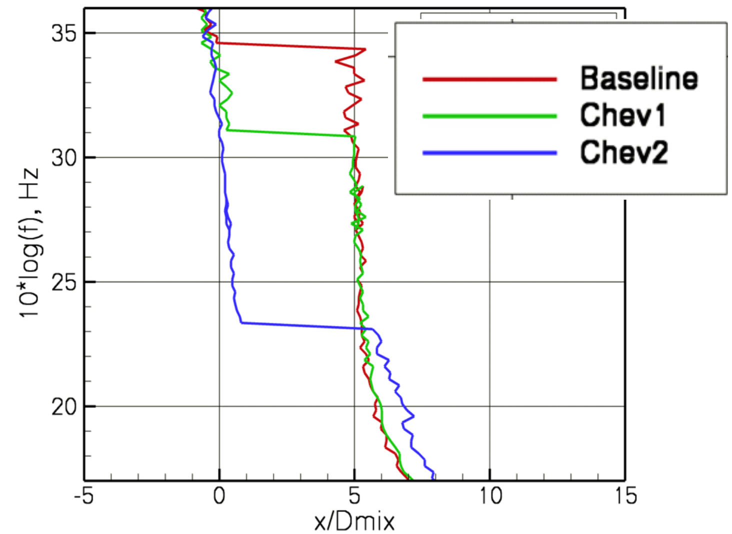
Spectral changes with Chev2
Aggressive design



Low frequency reduction

High frequency increase

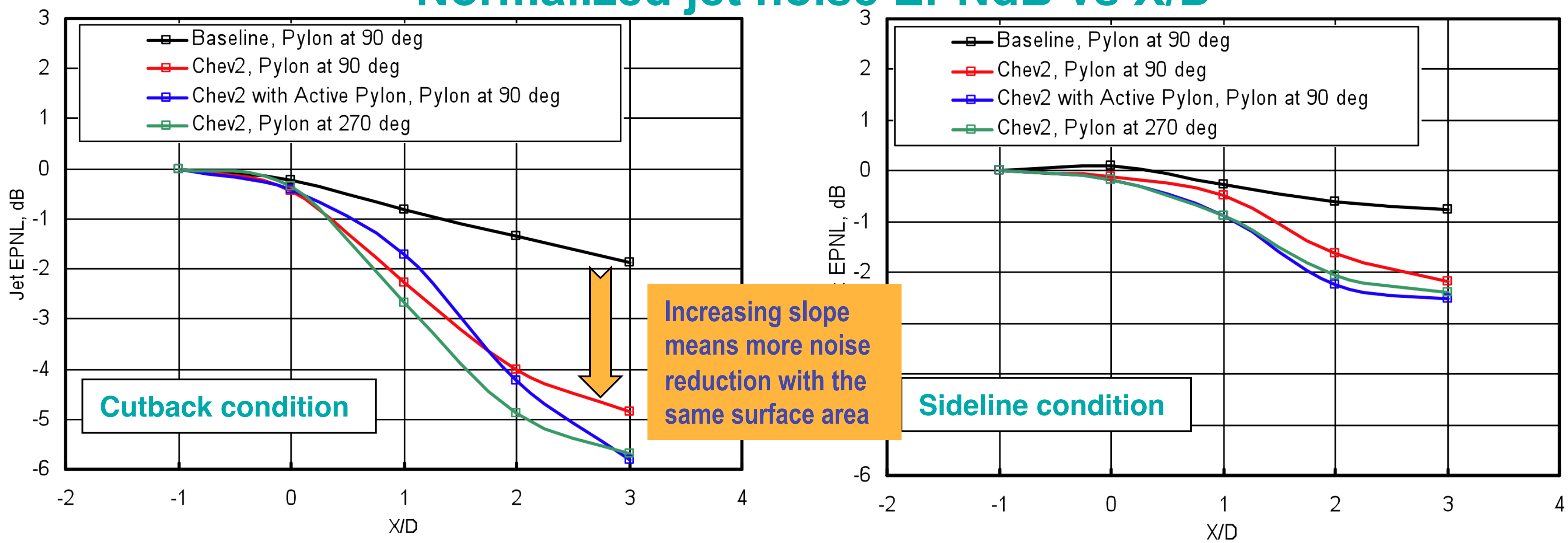
Peak source location changes



- Chevrons relocate peak sources towards the nozzle exit except at very low frequencies
- Movement of sources with chevrons is favorable for shielding

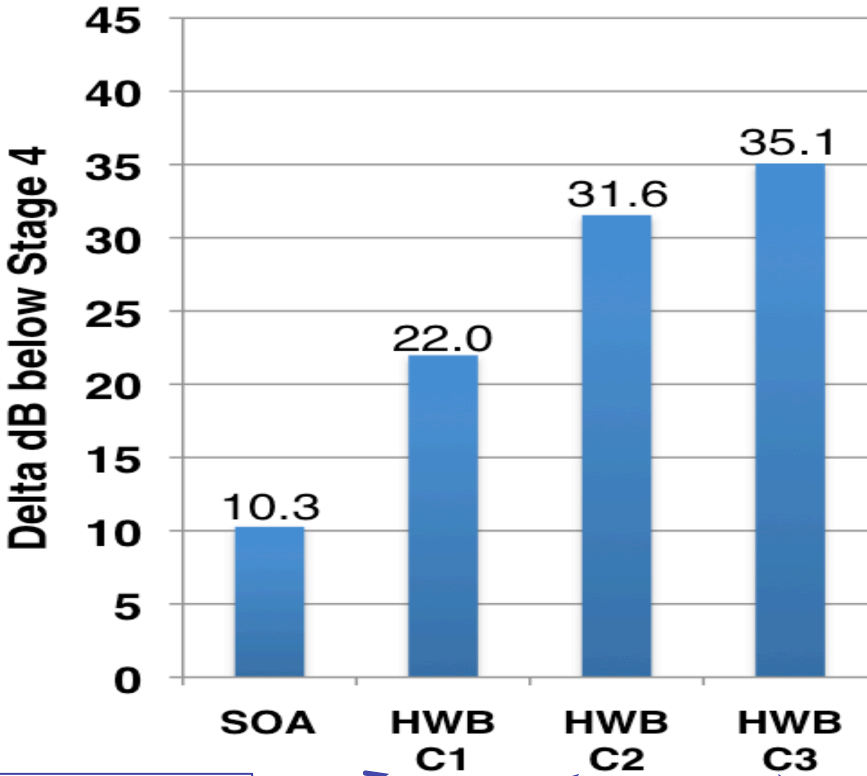
Shielding Effectiveness

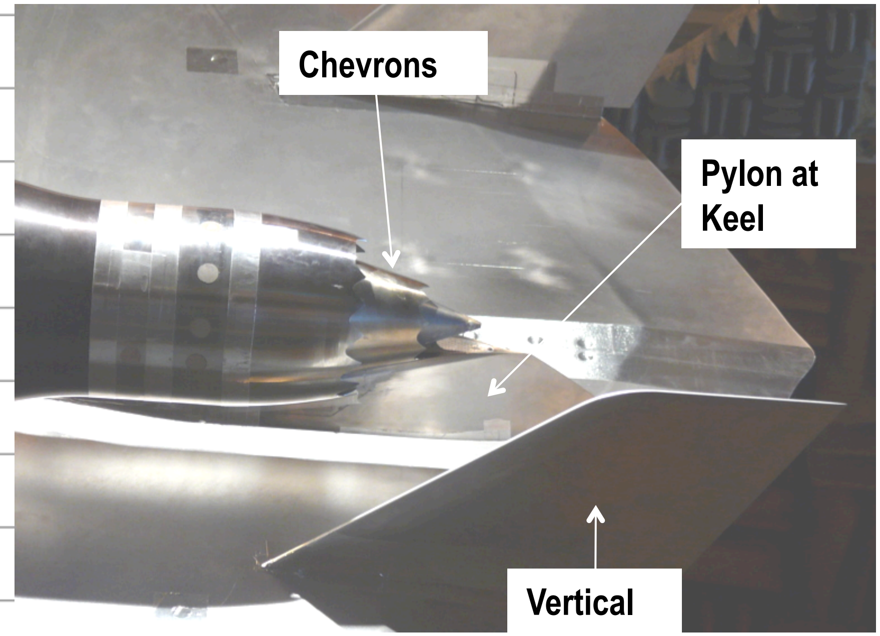
Normalized jet noise EPNdB vs X/D



- Jet noise EPNdB varies significantly as a function of engine location. Isolated nozzle is the reference.
- The baseline nozzle with pylon offers reductions of ~1 to 2dB of EPNdB
- Shielding effectiveness significantly enhanced with the chevron nozzle
- Jet noise EPNdB decreased by up to 5dB at x/D=2 and cutback power

PAA Technology Effects on System Noise Levels



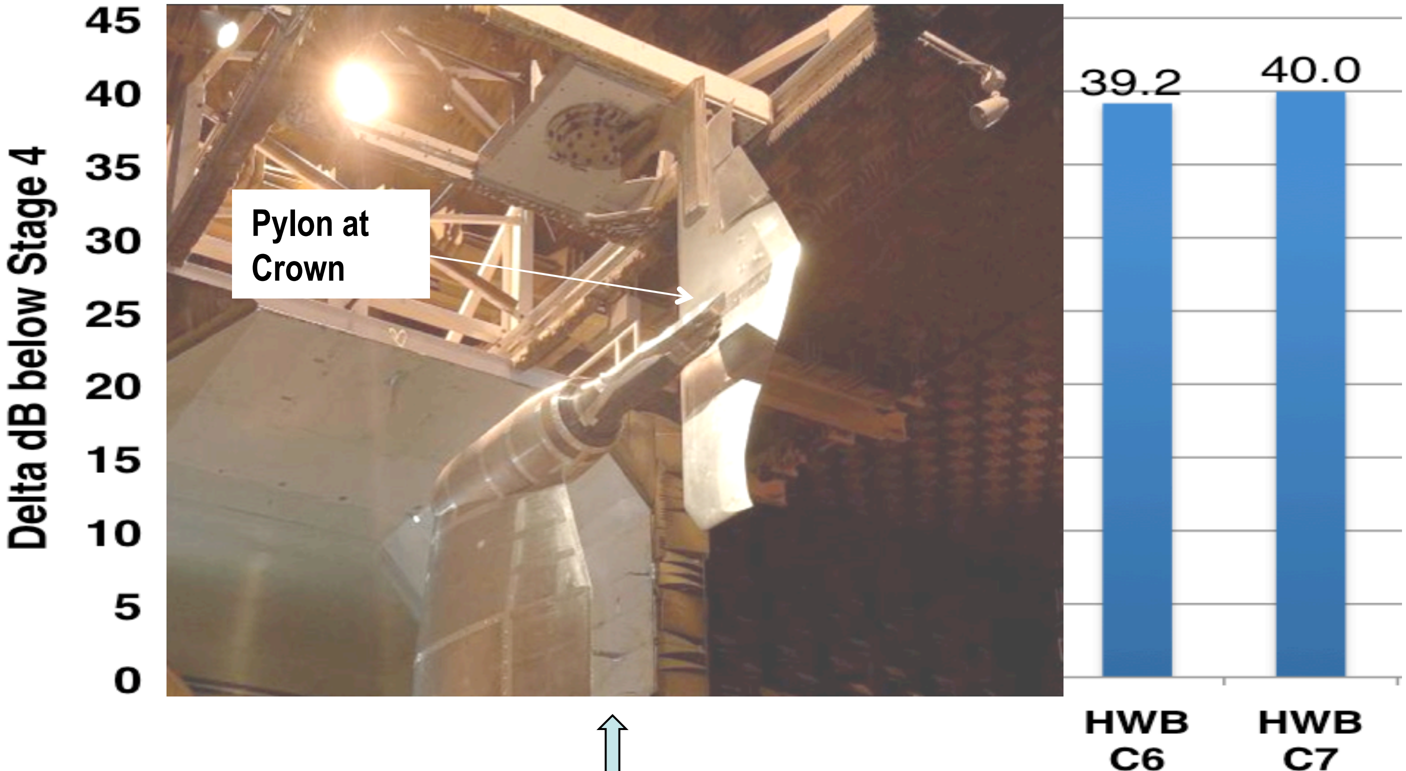


Baseline, engines 1D downstream of trailing edge

Simple Shielding, engines move 2D upstream

2D, chevrons to reduce jet source & increase shielding effectiveness

PAA Technology Effects on System Noise Levels



Favorable directivity of jet from strong effect crown pylon

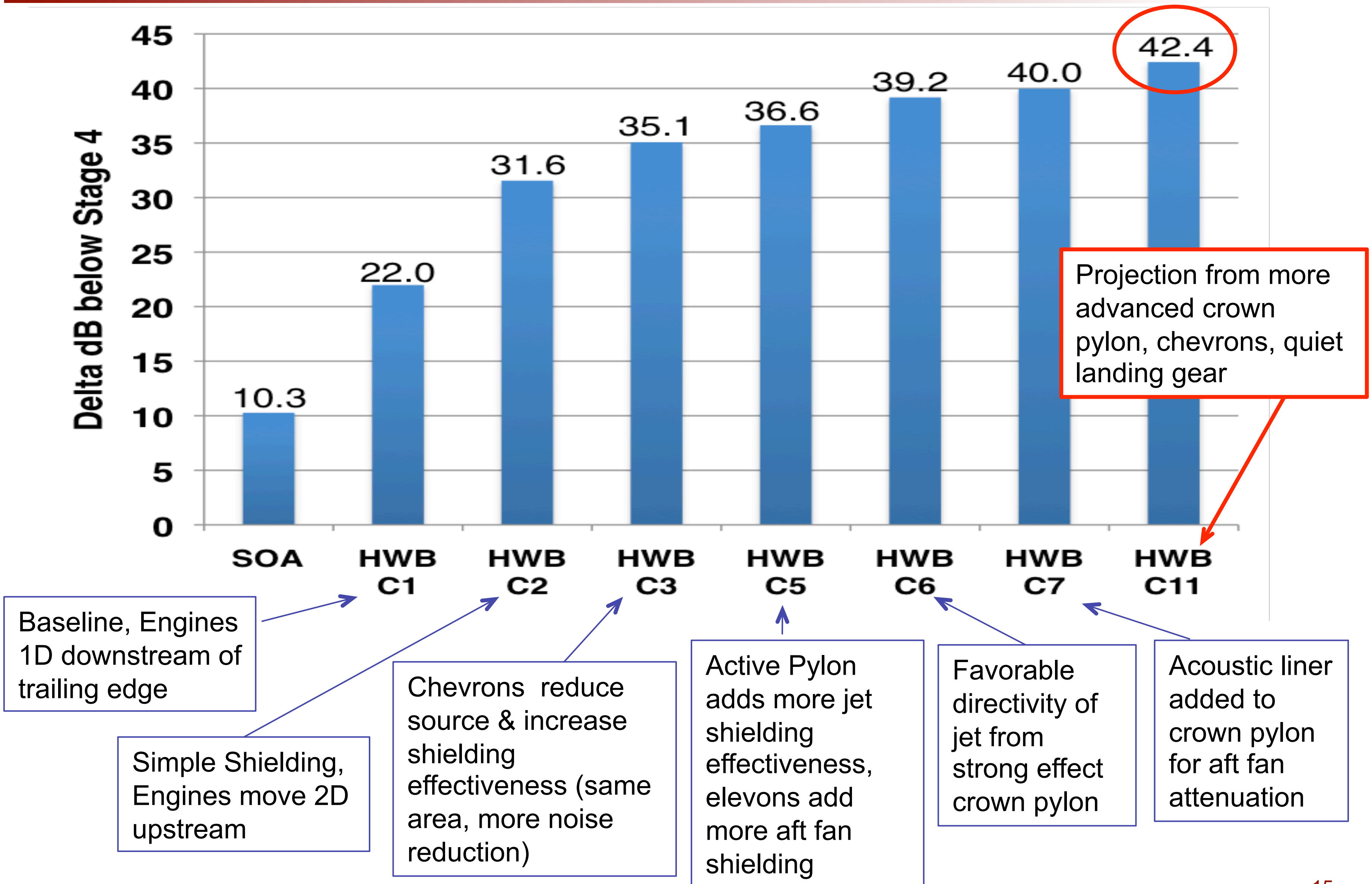
Acoustic liner added to crown pylon for aft fan attenuation

Keel Pylon

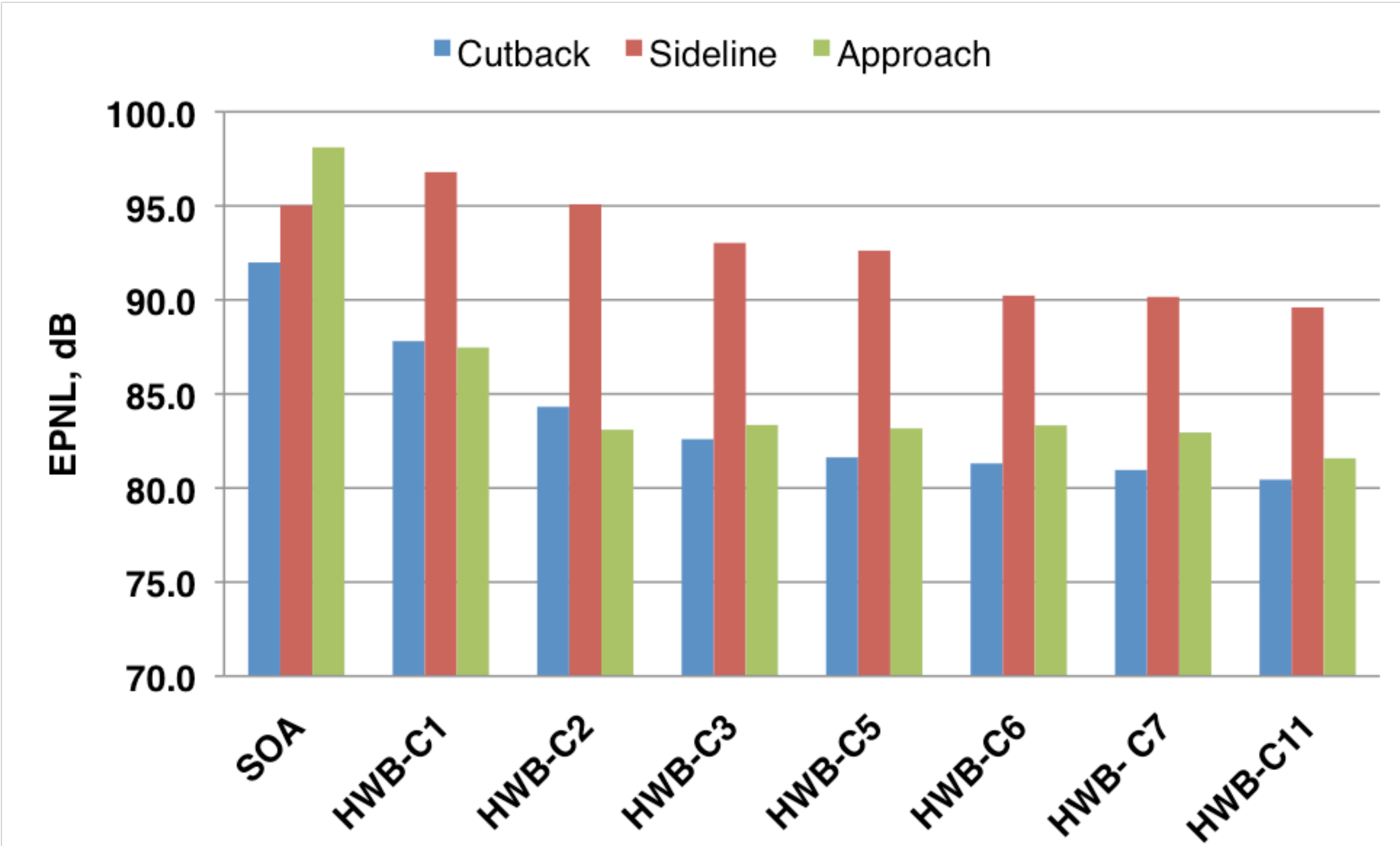
Crown Pylon

Pylon rotated from keel to crown position

PAA Technology Effects on System Noise Levels

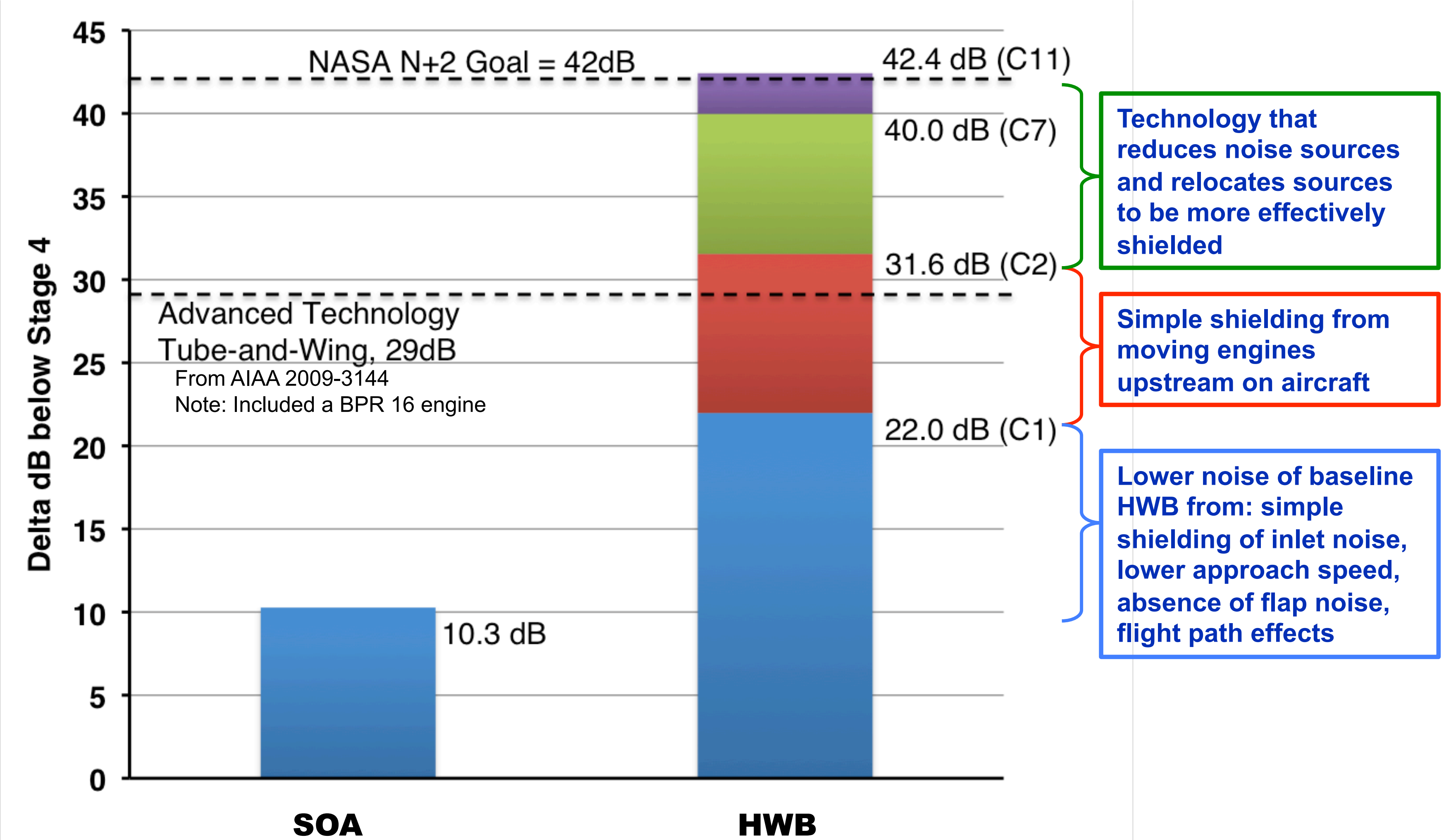


EPNL Impacts of HWB Configurations



- **HWB configuration results in a new distribution between 3 cert points**
- **Technology reduces all 3 cert points without changing basic distribution**

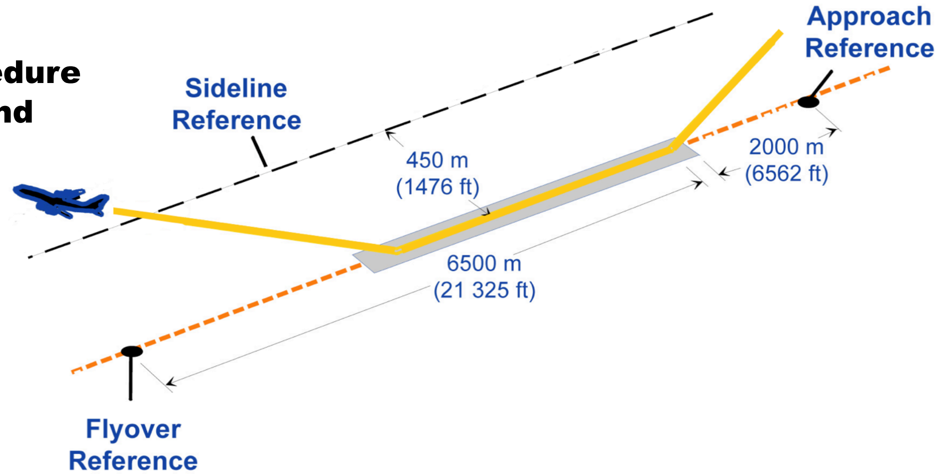
Perspective on 42.4 dB Cumulative Level

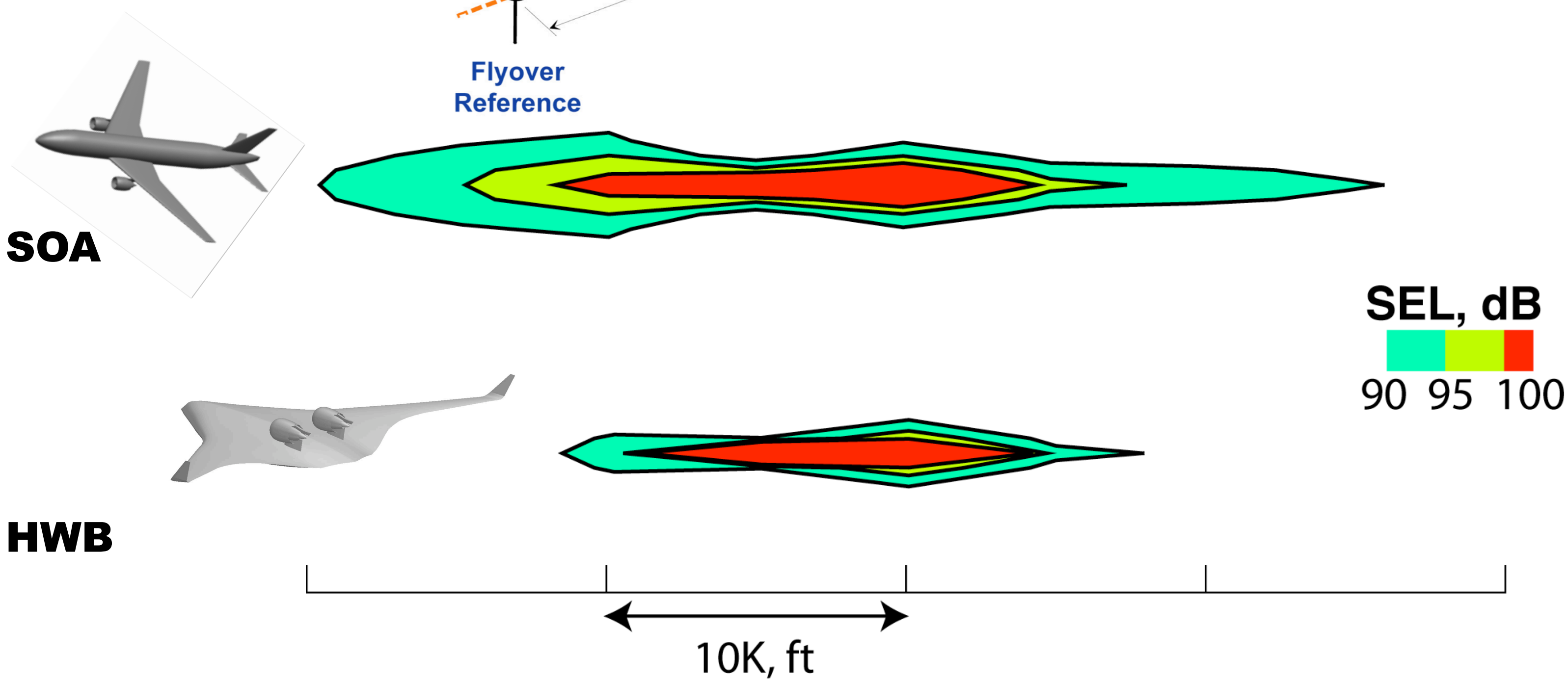


An integrated systems approach key to achieving NASA's N+2 goal of 42 dB

Sound Exposure Level (SEL) Contour

For a simulated certification procedure (FAR 36) takeoff and landing





Impact is a 66% reduction in ground area

Summary of 2010 Assessment of HWB with BPR 7

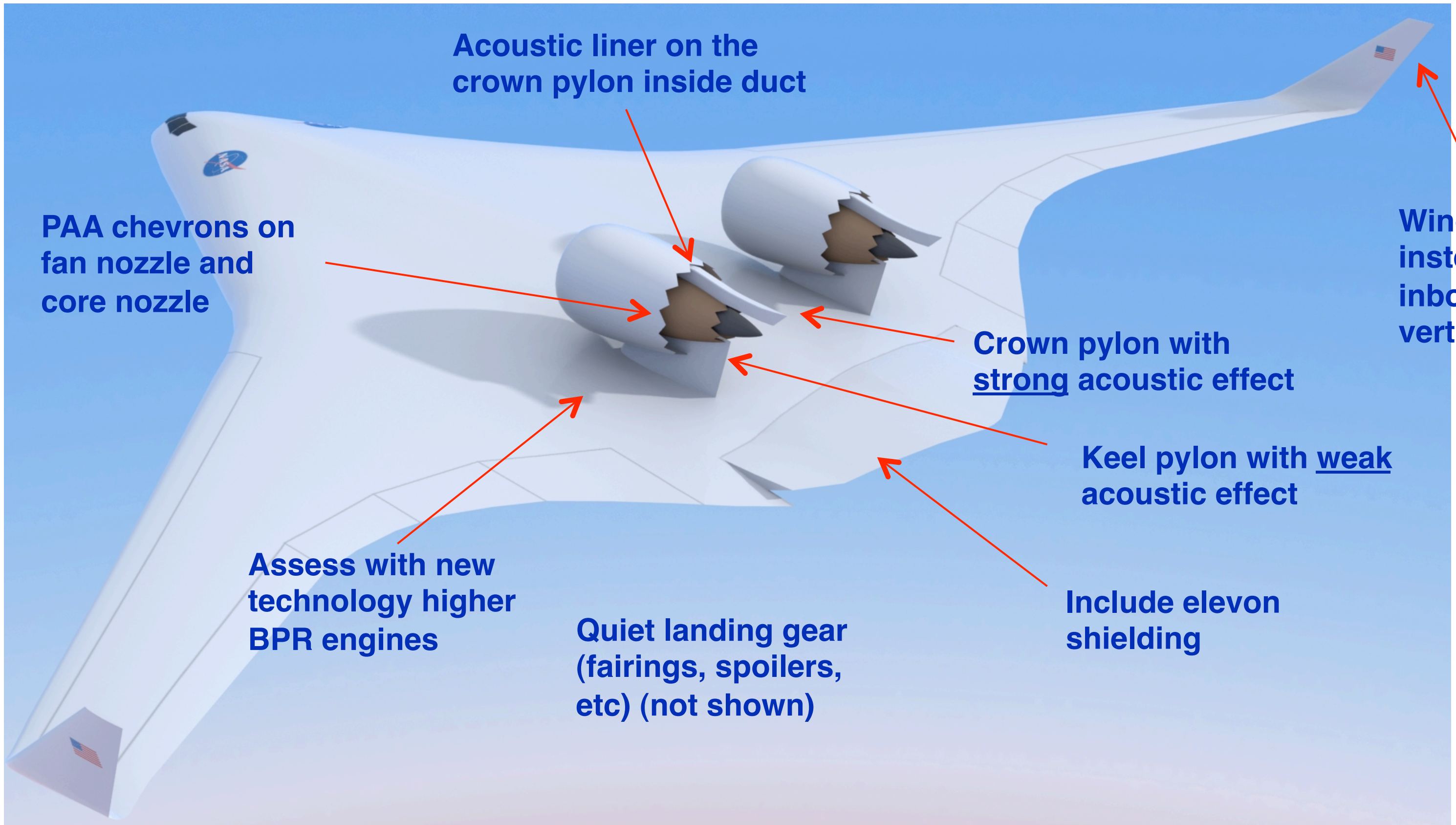
(from ref AIAA 2010-3913 Thomas, Burley, and Olson)

- **A rigorous HWB system noise assessment with key elements:**
  - **NASA ANOPP system noise method**
  - **NASA updated HWB aircraft model and flight path**
  - **Boeing/NASA PAA LSAF (2009) experimental results**
- **42.4 dB cumulative assessed on the HWB with relatively near term technologies:**
  - **Existing GE90-like engine (BPR 7)**
  - **PAA chevron nozzle and crown pylon technology configurations**
  - **Acoustic liner applied on the crown pylon**
  - **Quiet landing gear technology**
  - **Reduced approach flight speed**

Results in higher confidence assessment compared to earlier pathfinding assessments

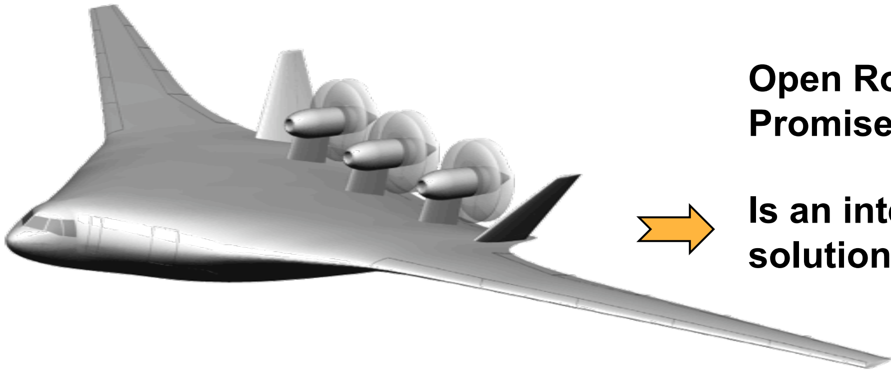
Future Directions – HWB with UHB Turbofan

- Better suppression map with more realistic fan noise simulation
- Flight path and aircraft model
- Maturation of specific PAA and aircraft system technology targeted for noise reduction



Critical step toward higher fidelity HWB aeroacoustic capabilities

Assessment of HWB with Open Rotor



Boeing R&T Image

Open Rotor Isolated Engine Fuel Burn Reduction Promise….with a Known Noise Challenge

Is an integrated HWB/Open Rotor aircraft system another solution to meet the ERA goals simultaneously?

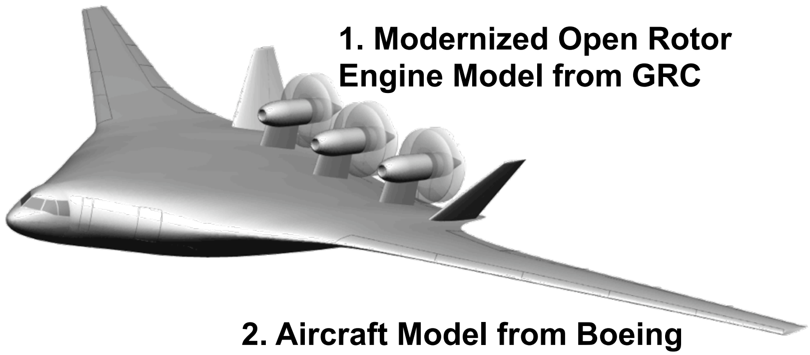
ERA Goal

	N+1 = 2015** Technology Benefits Relative to a Single Aisle Reference Configuration	N+2 = 2020** Technology Benefits Relative to a Large Twin Aisle Reference Configuration	N+3 = 2025** Technology Benefits
Noise (cum below Stage 4)	-32 dB	-42 dB	-71 dB
LTO NO_x Emissions (below CAEP 6)	-60%	-75%	better than -75%
Performance: Aircraft Fuel Burn	-33%	-50%	better than -70%
Performance: Field Length	-33%	-50%	exploit metro-plex* concepts

**Technology Readiness Level for key technologies = 4-6. ERA will undertake a time phased approach, TRL 6 by 2015 for "long-pole" technologies

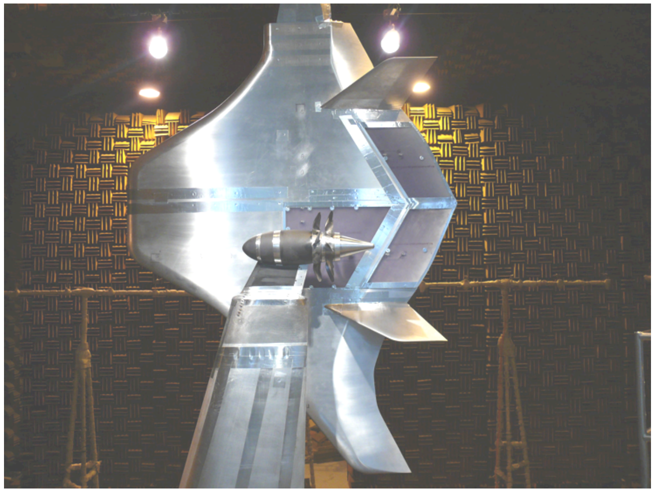
* Concepts that enable optimal use of runways at multiple airports within the metropolitan area

NASA Open Rotor System Noise Assessment Process Elements

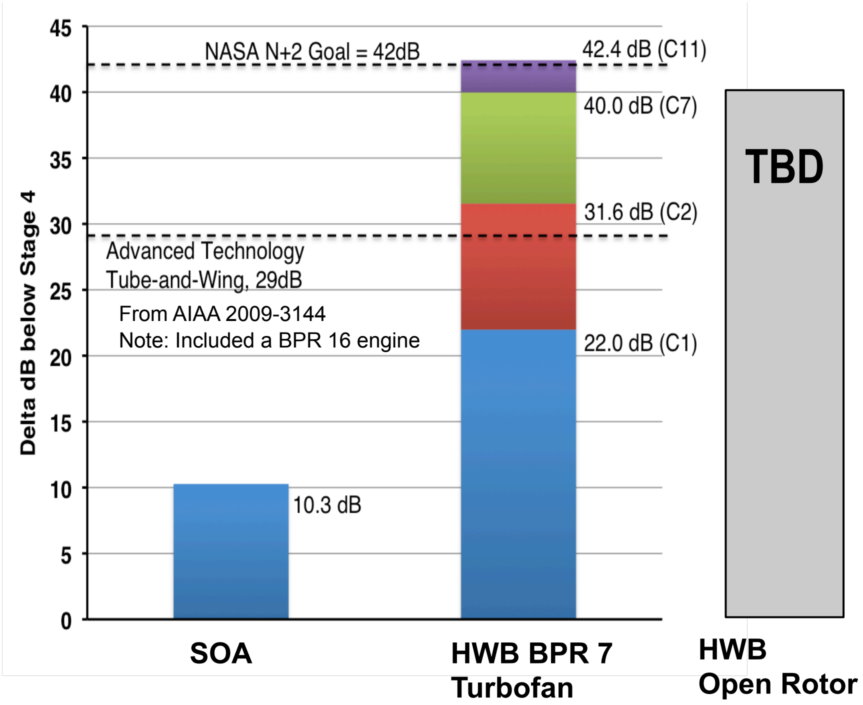


1. Modernized Open Rotor Engine Model from GRC

2. Aircraft Model from Boeing R&T task (Frank Gern TM)



3. Results from NASA/Boeing Open Rotor PAA Experiment



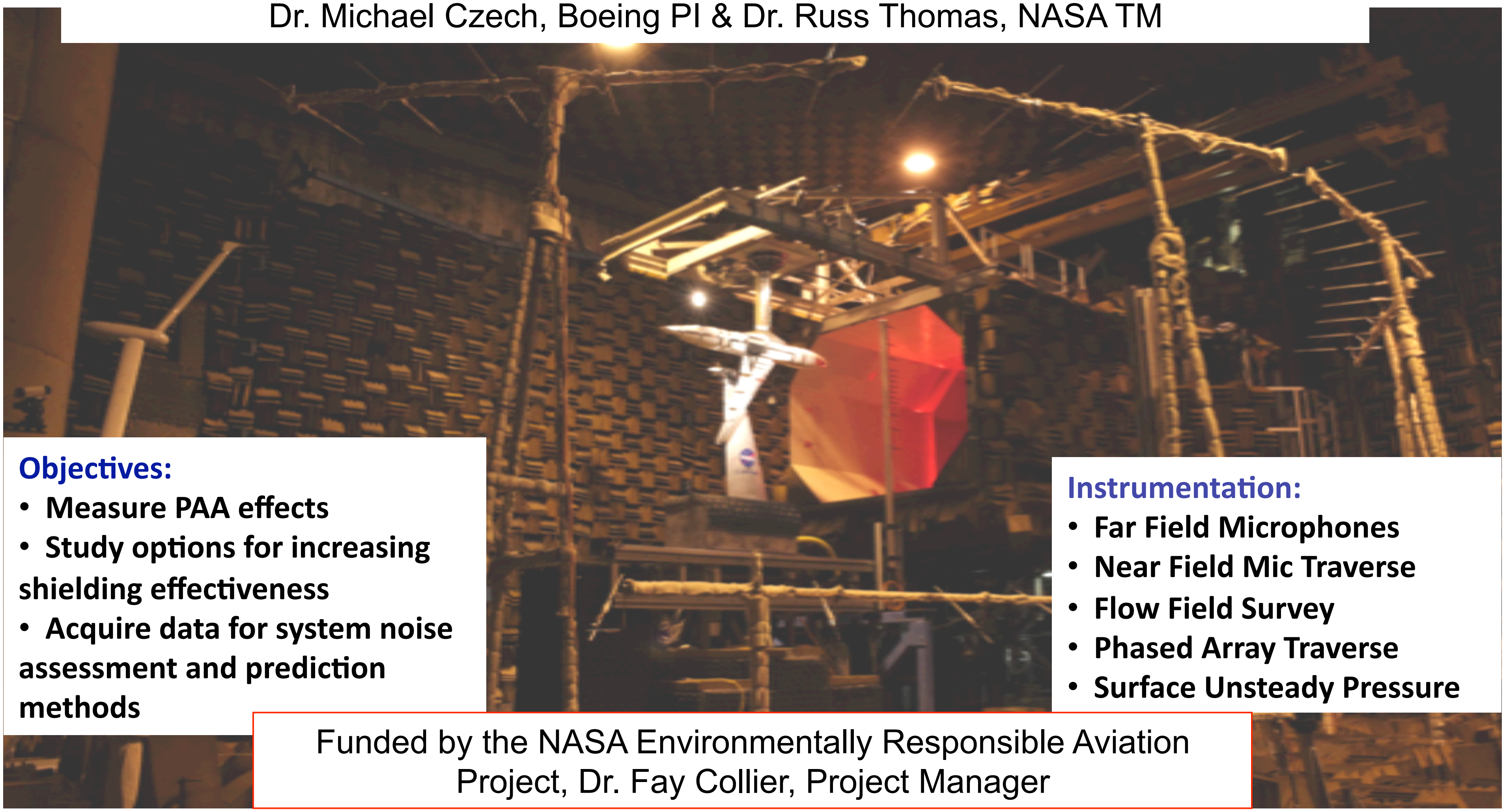
4. System Noise Assessment (Thomas, Burley, Olson, Gern, et al):
- certification points
- include technology options from experiment
- flight path variables

Rigorous systems noise assessments a key to achieving NASA's N+2 goal of 42 dB simultaneously with other goals

NASA/Boeing Open Rotor PAA Experiment

Experiment of open rotor PAA effects for both HWB and Tube-and-Wing aircraft types in Boeing's LSAF completed November 15, 2010

Dr. Michael Czech, Boeing PI & Dr. Russ Thomas, NASA TM

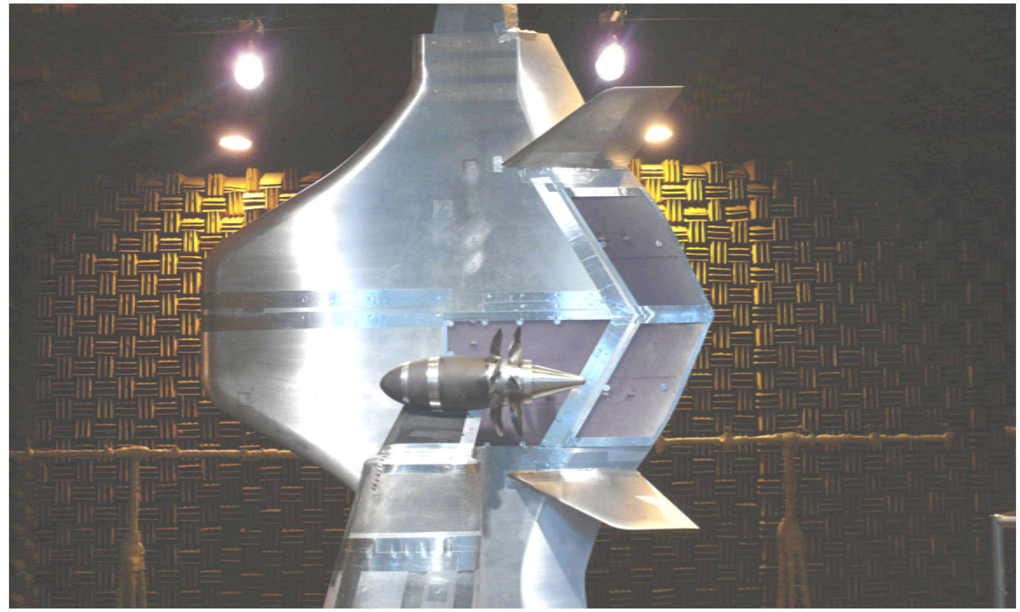


Objectives:
- **Measure PAA effects**
- **Study options for increasing shielding effectiveness**
- **Acquire data for system noise assessment and prediction methods**

Instrumentation:
- **Far Field Microphones**
- **Near Field Mic Traverse**
- **Flow Field Survey**
- **Phased Array Traverse**
- **Surface Unsteady Pressure**

Funded by the NASA Environmentally Responsible Aviation Project, Dr. Fay Collier, Project Manager

NASA/Boeing Open Rotor PAA Experiment



Experimental Parameter Summary:
- rotor speed variation
- wind tunnel Mach variation

- rotor to airframe relative position, axial and vertical
- off-center and centerline positions
- inboard verticals, size and cant angle
- elevon deflection

Summary

- ANOPP System Noise Assessment Process for HWB Aircraft Assembled
  - Engine System Model
  - Aircraft System Model
  - PAA Experimental Data for Key Aircraft Integration Effects

- Rigorous System Noise Assessment of HWB with BPR 7 Turbofan Completed in 2010
  - Technology Path Developed
  - 42 dB Assessed Level with High Confidence on Critical Noise Sources

- Leads to High Fidelity 14 X 22 N2A HWB Experiment and Validation in 2012

- Key Elements in Progress Toward Assessment of HWB with Open Rotor
  - Engine System Model – In Progress by GRC Systems Team
  - Aircraft System Model – In Progress on Boeing R&T task
  - PAA Open Rotor Experiment – Completed on Boeing Task
  - PAA Open Rotor Data Analysis – Initiated
  - ANOPP Based System Noise Process – In Progress

For HWB aircraft concept, there has been rapid progress in technology and assessments to meet the noise goal of the N+2 goals

NASA