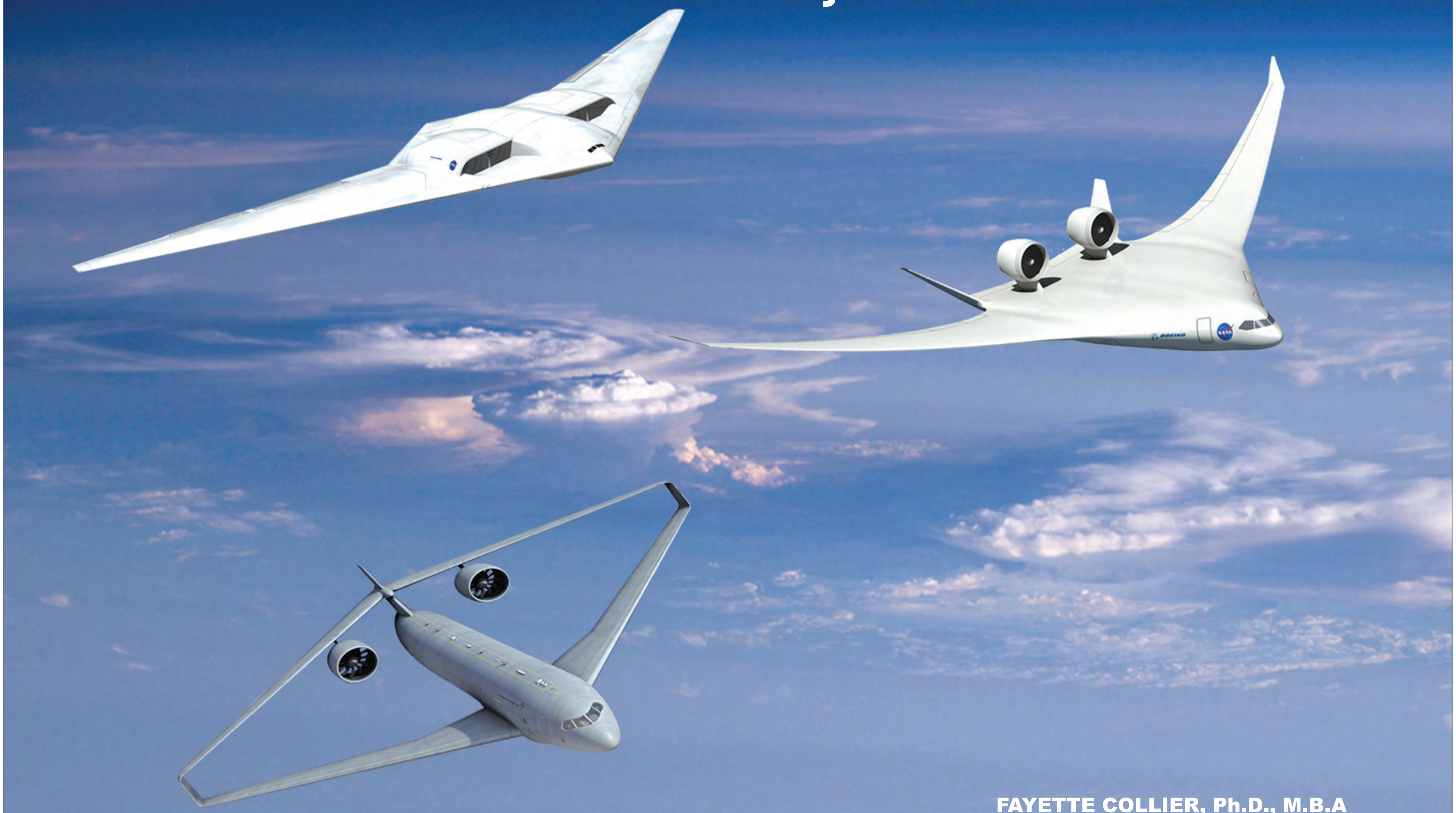
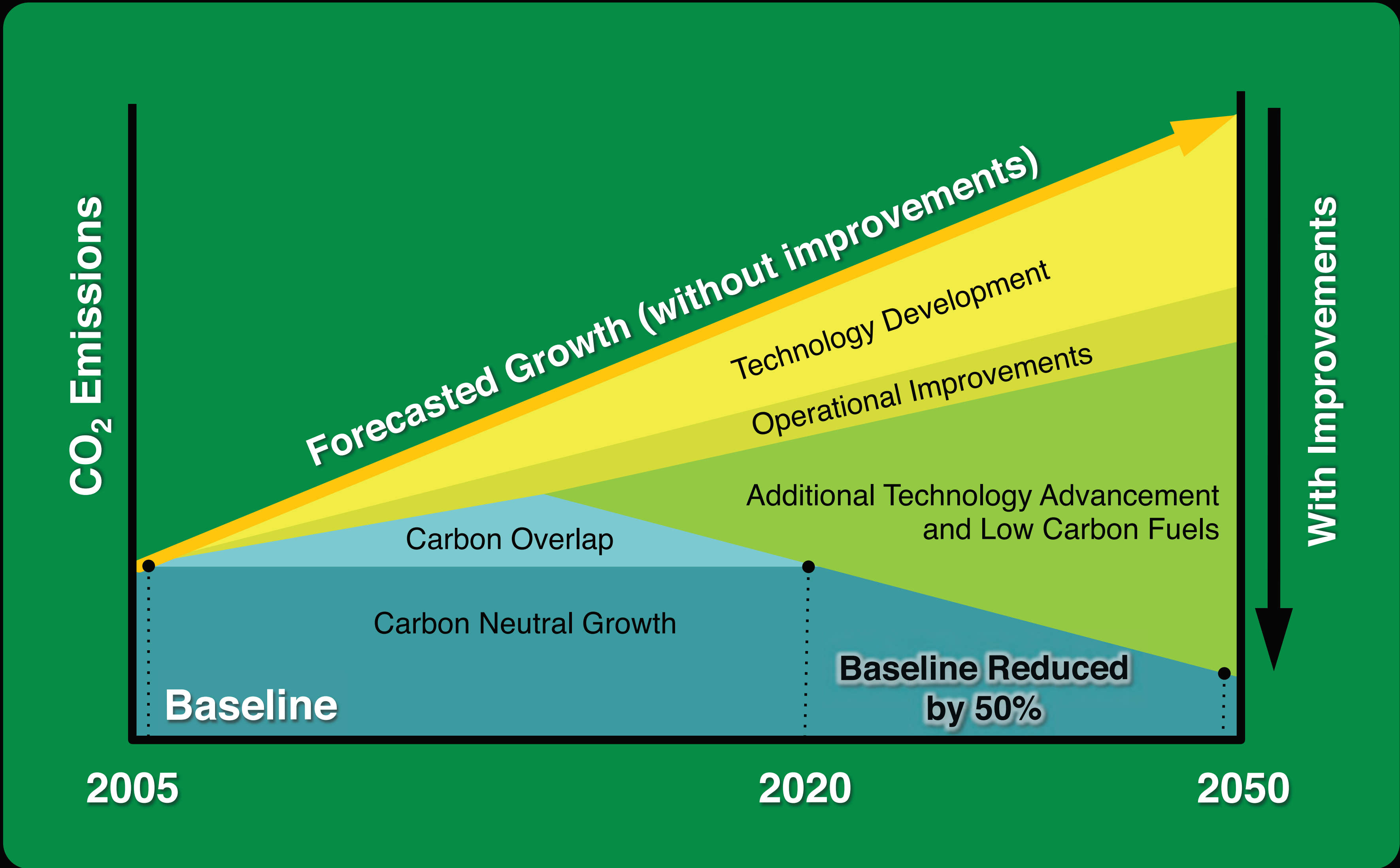
Environmentally Responsible Aviation
A NASA Aeronautics Project



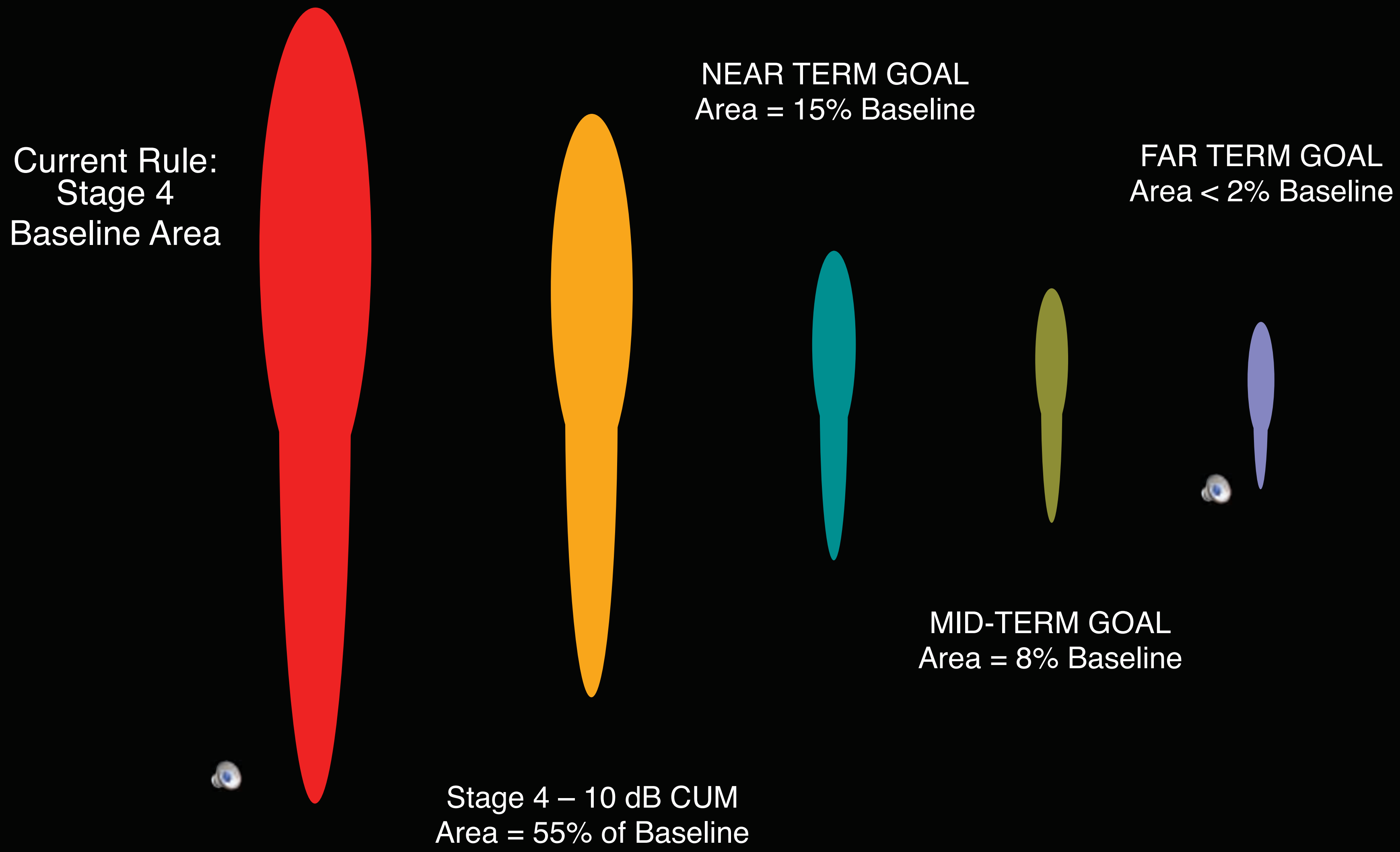
FAYETTE COLLIER, Ph.D., M.B.A
Project Manager.

Challenge: Significant Carbon Emissions Reduction



Source = IATA/FAA/AEE 2010

Challenge: Significant Community Noise Reduction



Traceability from National R&D Plan to ERA Project Technical Focus Areas

National R&D Plan

Energy and Environment	Enhance Mobility	National Security

Vehicle System Focus - Investigate vehicle concepts that enable simultaneous reduction noise, emissions, fuel burn

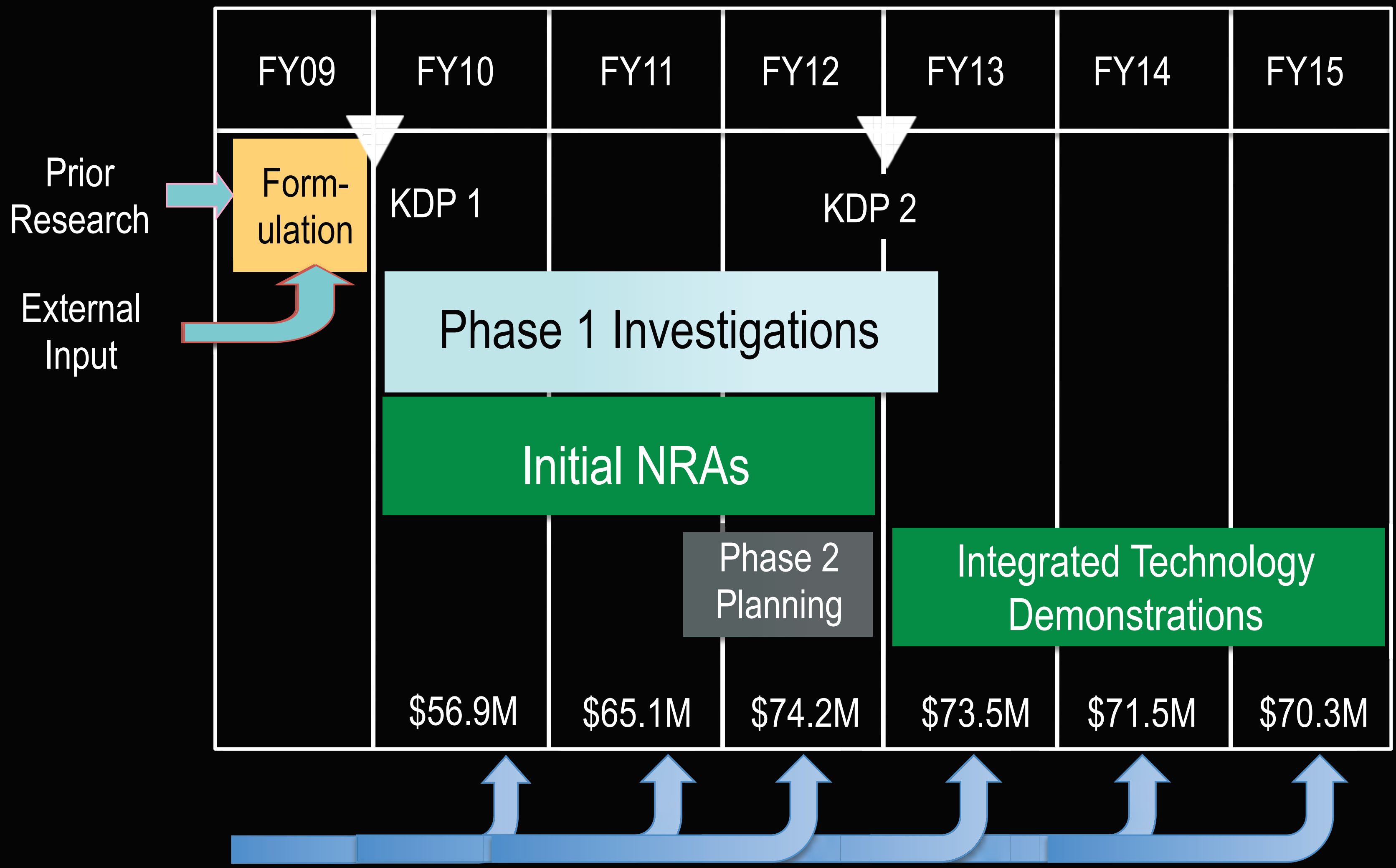
-75% LTO & -70% Cruise NOx Emissions	42dB below Stage 4 Community Noise	-50% Aircraft Fuel/ Energy Consumption

Technical Focus Areas - *Accelerate* technology maturation through integrated system research

Innovative Flow Control Concepts for Drag Reduction	Advanced Composites for Weight Reduction	Advanced UHB Engines for SFC & Noise Reduction	Advanced Combustors for Oxides of Nitrogen reductions	Airframe & Engine Integration for Community Noise Reduction

Project Flow and Budget

With Key Decision Points



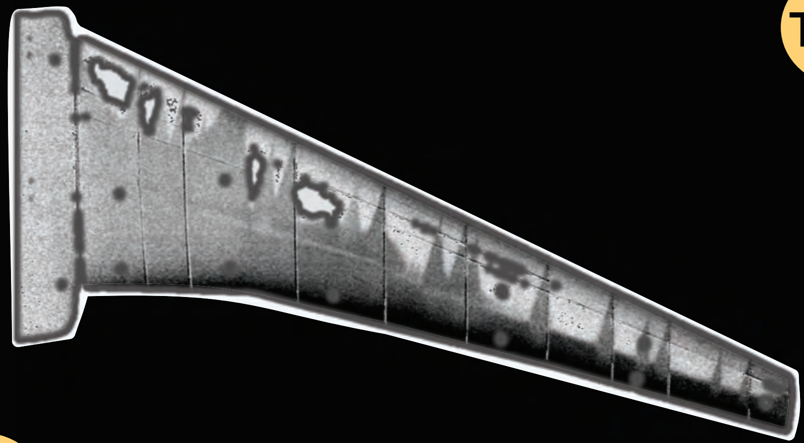
Technical input from Fundamental Programs, NRAs, Industry, Academia, Other Gov't Agencies

ERA FY 10-12 are actual full cost
ERA FY 13-15 budget numbers from President's FY13 budget

ERA Phase I Investigations

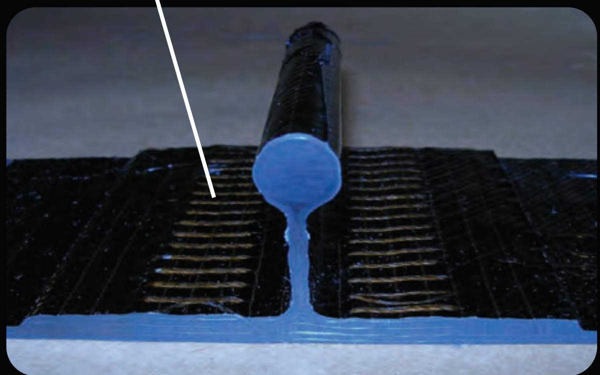
Reduce Mission Fuel Burn and Community Noise

TFA1 DRAG REDUCTION – Via Flow Control



TFA2 WEIGHT REDUCTION

PRSEUS – Pultruded Rod Stitched Efficient Unitized Structure



TFA3 SFC/NOISE REDUCTION

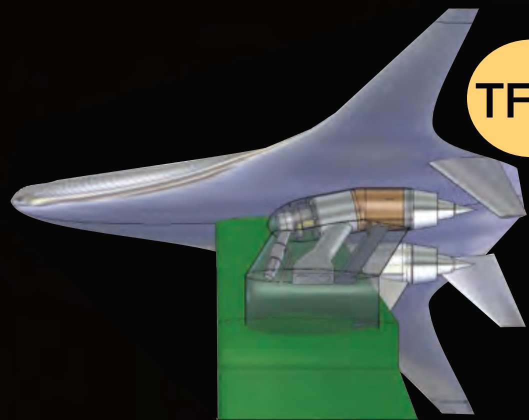
Advanced Cores and Development of Integration of Advanced UHB Engines

ERA Phase I Investigations

Reduce Mission Fuel Burn and Community Noise

TFA5 **AIRFRAME NOISE**
High-lift Systems and Landing Gear

TFA5 **PROPULSION NOISE**
Fan, Core and Jet Noise



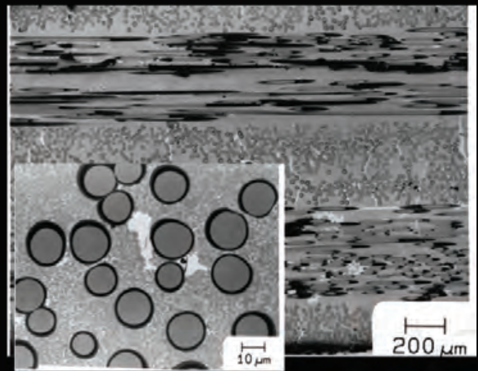
TFA5 **PROPULSION AIRFRAME AEROACUSTICS**
Airframe/Propulsion Interaction & Shielding

ERA Phase I Investigations

Reduce LTO and Cruise NOX, and Reduce Fuel Burn

TFA4 CMC COMBUSTOR LINER

For higher engine temps

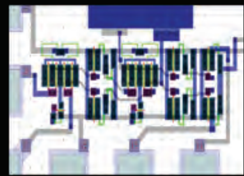


SIC CMC Concepts

CMC combustor liner

TFA4 INSTABILITY CONTROL

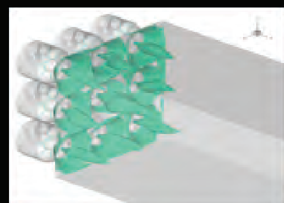
Suppress combustor instabilities



High Temperature SiC electronics circuits and dynamic pressure sensors

Fuel Modulation for high frequency fuel delivery systems

TFA4 LOW NOX, FUEL FLEXIBLE DESIGN/TEST



Innovative Injector Concept

ASCR Combustion Rig

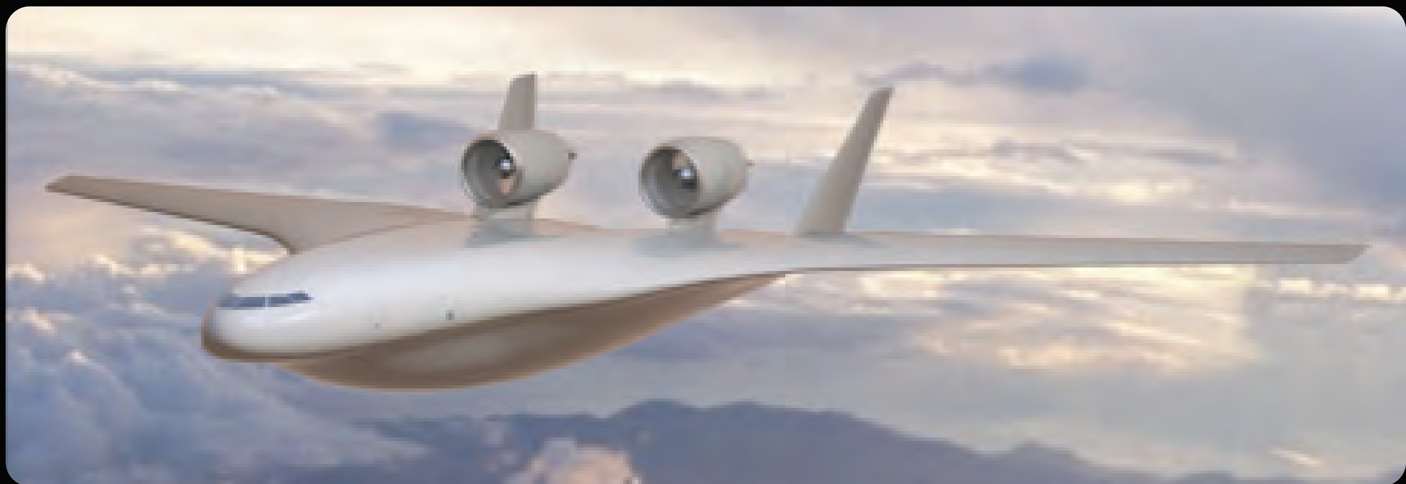
ERA Phase I Investigations

Advanced Vehicle Concept Study

- Task 1 - Define /Development Future Scenario
- Task 2 - Develop a conceptual design of a 2025 EIS subsonic transport – passenger and/or cargo
- Task 3 - Develop associated tech maturation plans
- Task 4 - FY 2013 – 2015 Critical Technology Demonstrations
- Task 5 - Conceptual Design of a Subscale Testbed Vehicle

ERA Phase I Investigations
Advanced Vehicle Concept Study

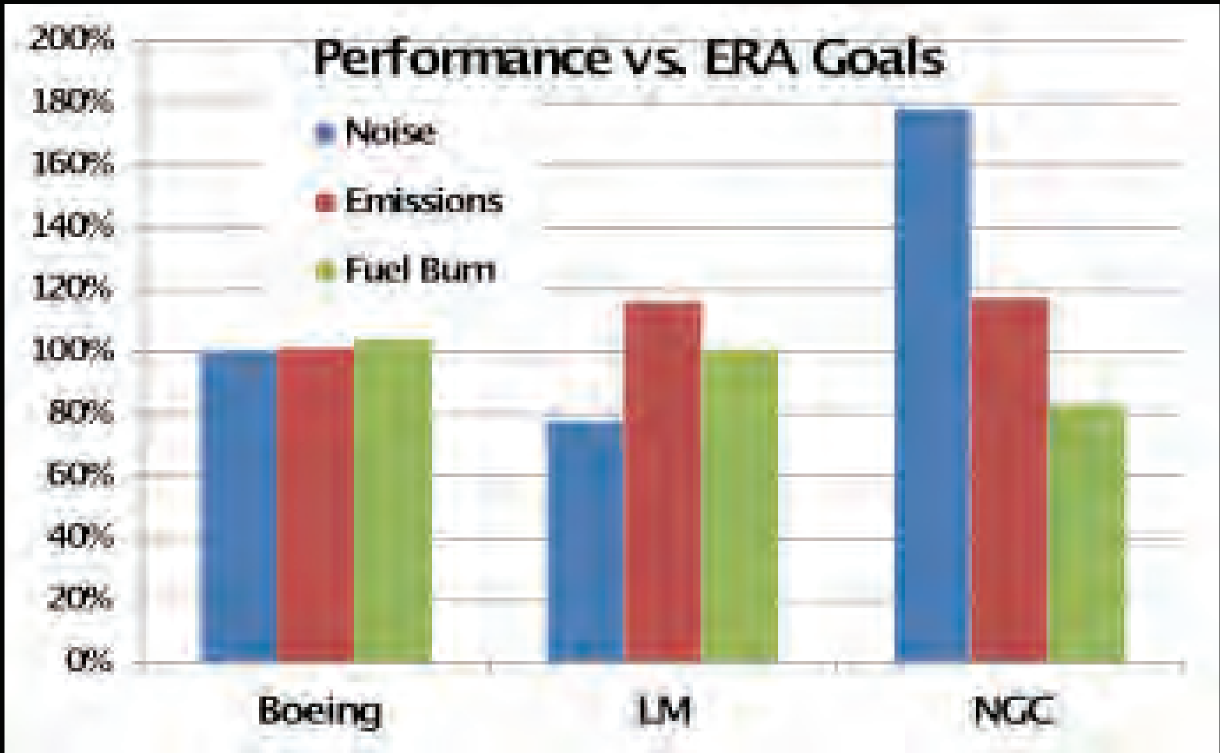




ERA Phase I Investigations

Advanced Vehicle Concept Study Summary Results

Vehicle Performance

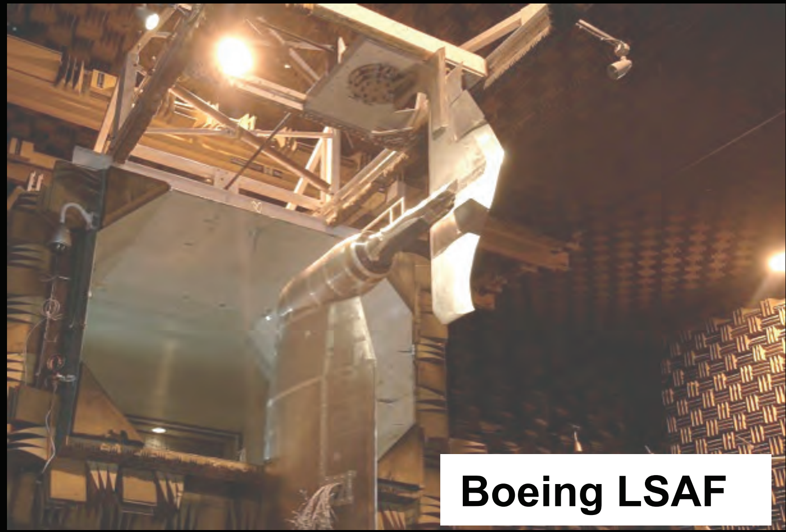


Key Technologies Identified

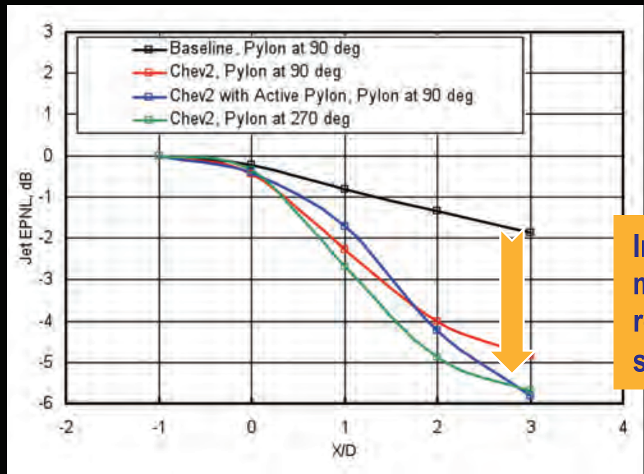
- Laminar flow control
- Advanced unitized composite structures
- Advanced UHB Engines

Progress - Community Noise Reduction
NASA / Boeing HWB Aeroacoustic Experiment

- HWB with BPR 7 engines. Well known engine database provides link to reference SOA conventional aircraft.
- Experiment included:
  - Broadband source for approximation of non-jet engine noise source shielding
  - HWB airframe noise characterization
  - Extensive jet shielding database for difficult distributed jet noise source. Extensive nozzle design parameters investigated.



Czech, M.J., Thomas, R.H., and Elkoby, R., "Propulsion Airframe Aeroacoustic Integration Effects for a Hybrid Wing Body Configuration," *International Journal Of Aeroacoustics*, Vol. 11, Number 3+4, 2012.

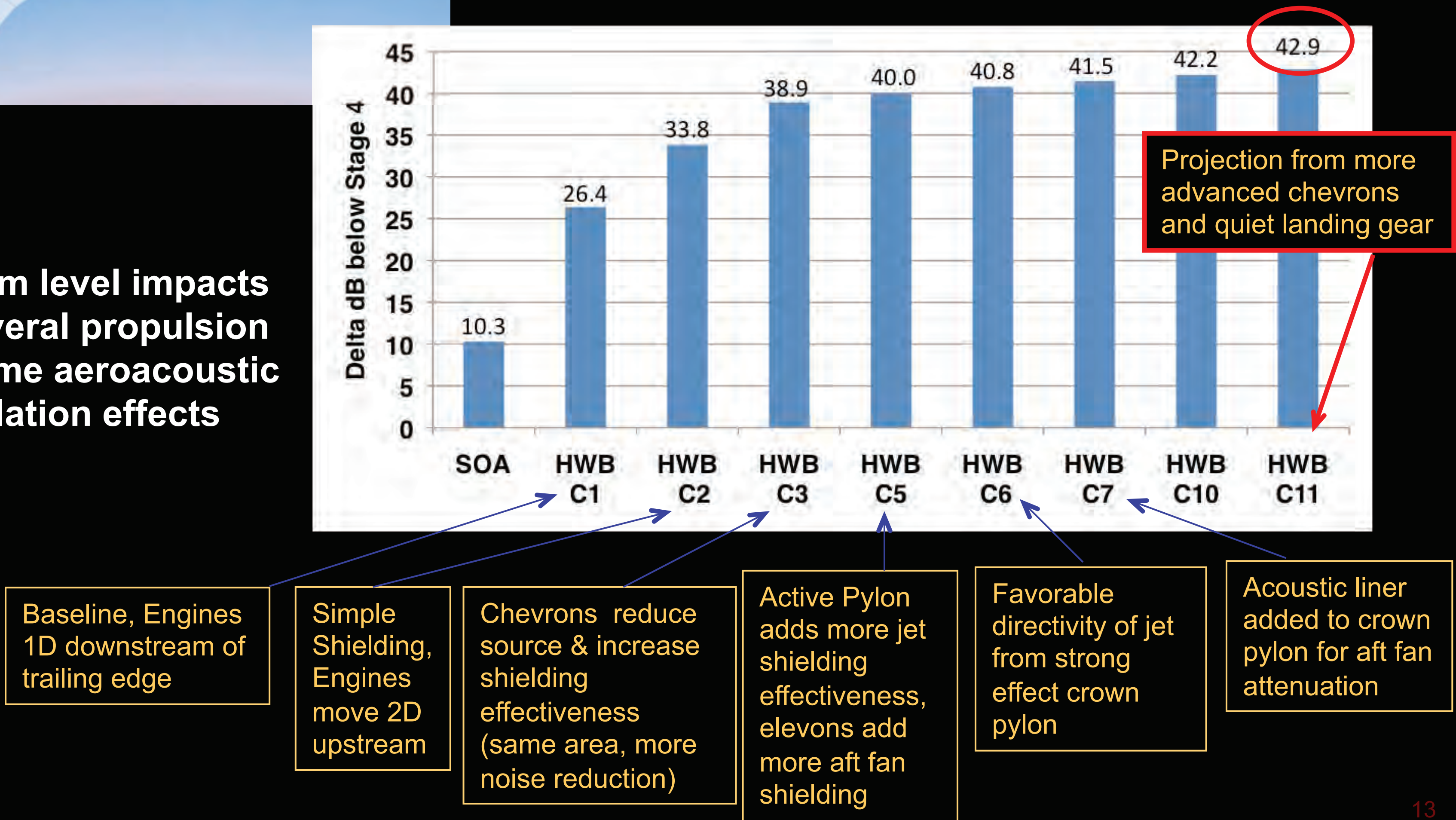


Increasing slope means more noise reduction with the same surface area

Progress - Community Noise Reduction Technical Roadmap to Goal

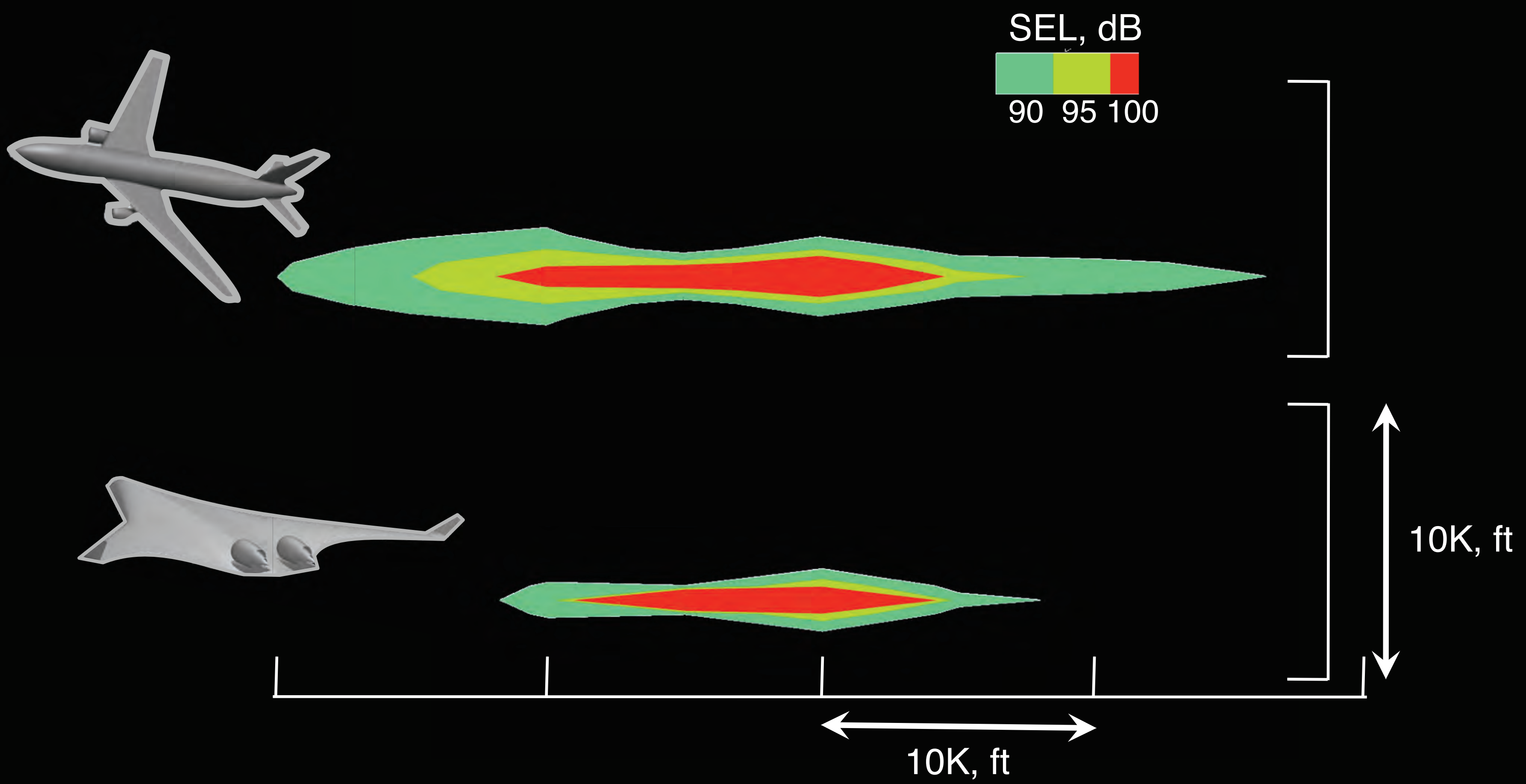
Thomas, R.H., Burley, C.L., and Olson, E.D., "Hybrid Wing Body Aircraft System Noise Assessment with Propulsion Airframe Aeroacoustic Experiments," *International Journal Of Aeroacoustics*, Vol. 11, Number 3+4, 2012.

System level impacts of several propulsion airframe aeroacoustic installation effects



Progress – Community Noise Reduction Conventional Airframe and Advanced HWB Airframe

POTENTIAL NOISE IMPACT - TAKEOFF AND LANDING CYCLE



80% Reduction in Ground Area

Progress – Community Noise Reduction

Advanced UHB versus Advanced Open Rotor

Problem

Open rotor (OR) propulsion systems possess the potential for dramatic reductions in fuel burn provided the new generation of blade geometries can provide an acceptable acoustic signature

Objective

Determine fuel burn reduction attributable to advanced open rotor

Approach - Assess fuel burn & community noise characteristics of advanced open rotor and UHB powered, single-aisle transports

- Advanced airframe technologies included in the overall assessment
- GE and NASA collaborated on
  - open rotor acoustic prediction methodology
  - extensive wind tunnel test campaign (w/FAA)
  - engine cycle decks

Results

- Fuel burn: the advanced OR powered aircraft is 12 percent more efficient than adv. UHB powered aircraft
- Community noise: the advanced UHB powered aircraft makes about 1/2 the noise of the adv. OR powered aircraft

Significance

Results provide industry and regulatory community data from which to make informed decisions on open rotor fuel efficiency and noise trade-offs

Single-aisle airplane w/rear-mounted open rotors

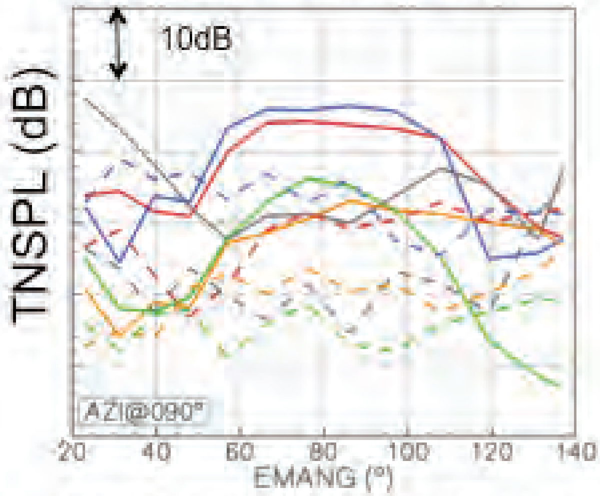
Open Rotor Propulsion Rig installed in GRC's 8x6 (left) and 9x15 (right) Wind Tunnels

Vehicle Level Assessment	UHB Powered	OR Powered
Fuel Burn	-27%	-36%
Cumulative Noise Margin below Chapter 4	-24 dB	-13 dB

Reference: 1998 Aircraft Technology Levels

Progress – Community Noise Reduction
Adv. Open Rotor and Advanced HWB Airframe

Substantial Noise Reduction Possible at Baseline Position Upstream of Trailing Edge (first five tones shown)



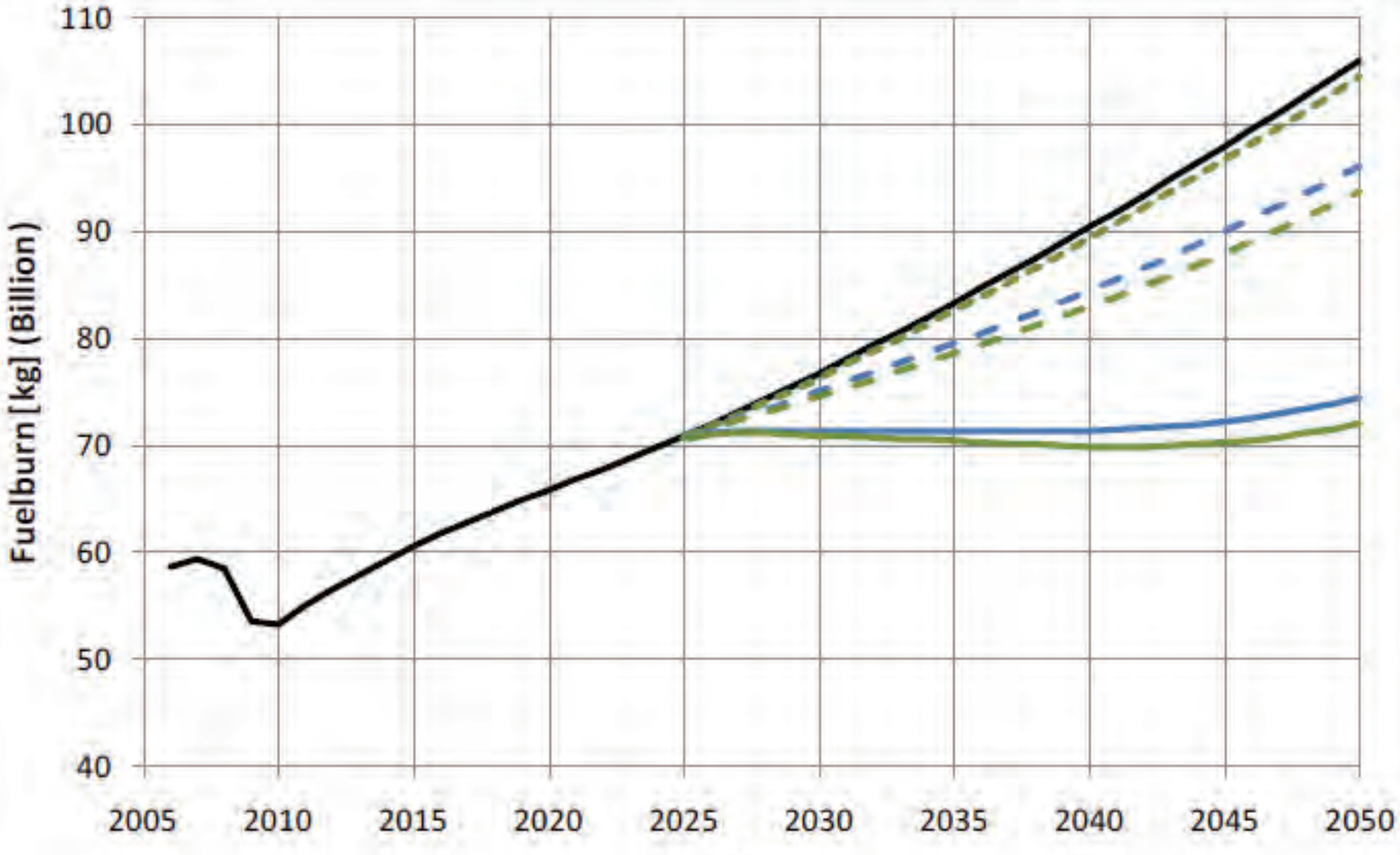
Czech, M.J., and Thomas, R.H., "Experimental Studies of Open Rotor Installation Effects," presented at the AIAA 3rd Atmospheric Environments Conference, June, 2011.

- NASA/Boeing Experiment for Installation Effects Including:
  - 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
- NASA projection of best open rotor source levels in 2025

- Boeing Vehicle Model, NASA GRC Engine Model, and a NASA LaRC Flight Path Analysis
- All Elements Combined in a NASA System Noise Assessment of Open Rotor HWB (planned for 2013 Aeroacoustics Conference)

Projected Integrated Portfolio Benefits

Fleet Wide Mission Fuel Burned Reduction



From Mavris, Schutte, Jimenez, Pfaender, etc.
Georgia Tech, AIAA 2011-6882, etc.

436 Billion kg Fuel Saved