Technology Impacts on Community Noise and Carbon Footprints of Subsonic Transports

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National Aeronautics and Space Administration

"expand the trade space and simultaneously reduce noise, NOX and carbon footprints of aviation"

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Sustainable Aerospace Innovation
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Famous “Quote” about engineers

Arguing with an engineer is like wrestling
with a pig in the mud, after about 3 hours
you realize the pig likes it

TECHNOLOGY BENEFITS*	TECHNOLOGY GENERATIONS (Technology Readiness Level = 4-6) v2013.1		
	N+1 (2015)	N+2 (2020**)	N+3 (2025)
Noise (cum margin rel. to Stage 4)	-32 dB	-42 dB	-52 dB
LTO NOx Emissions (rel. to CAEP 6)	-60%	-75%	-80%
Cruise NOx Emissions (rel. to 2005 best in class)	-55%	-70%	-80%
Aircraft Fuel/Energy Consumption‡ (rel. to 2005 best in class)	-33%	-50%	-60%

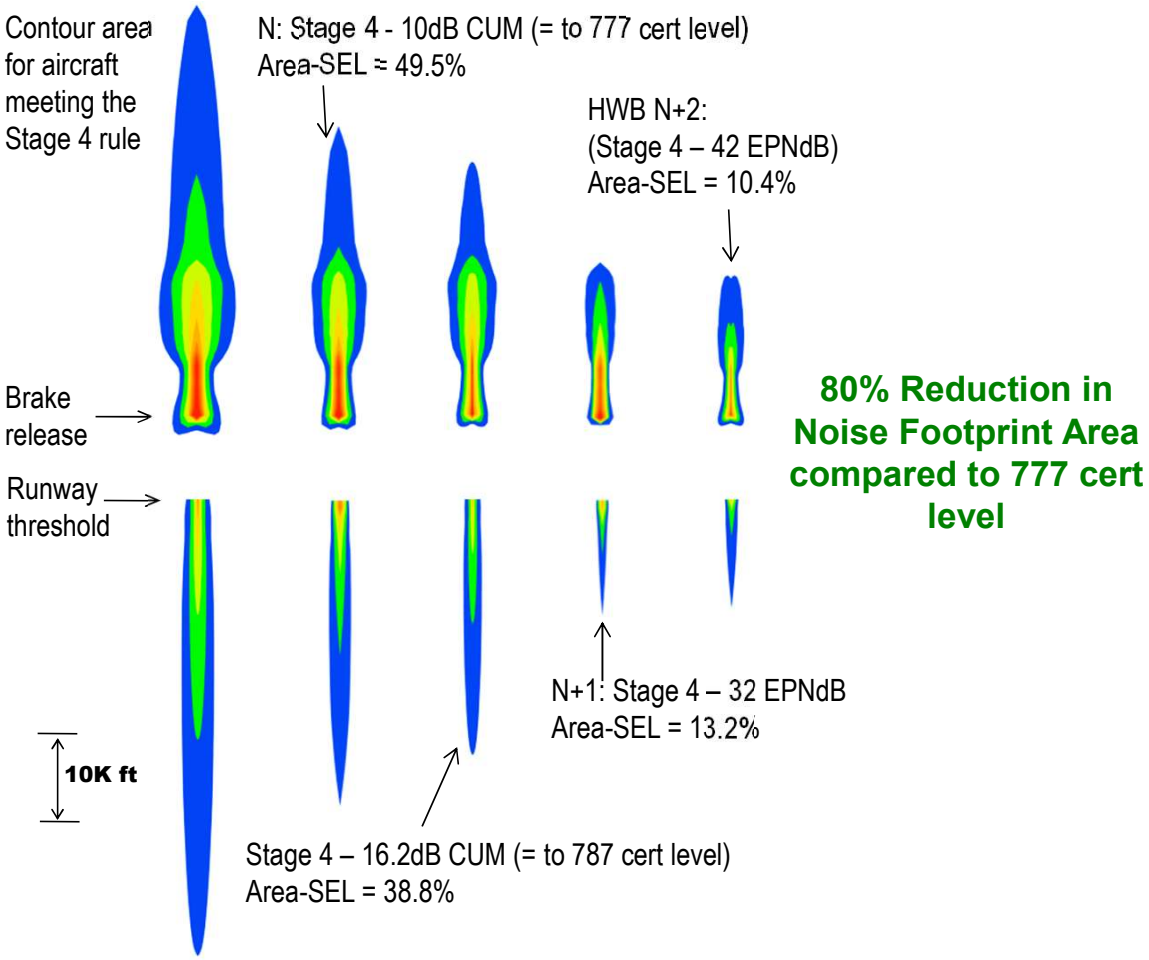
* Projected benefits once technologies are matured and implemented by industry. Benefits vary by vehicle size and mission. N+1 and N+3 values are referenced to a 737-800 with CFM56-7B engines. N+2 values are referenced to a 777-200 with GE90 engines.

** ERA's time-phased approach includes advancing "long-pole" technologies to TRL 6 by 2015

‡ CO_2 emission benefits dependent on life-cycle CO_2e per MJ for fuel and/or energy source used

Subsonic transport scorecard

N+2 Time Frame Focus



80% Reduction in Noise Footprint Area compared to 777 cert level

Grand challenge

Reduce the impact of aviation on community noise

The role of technology demonstrators

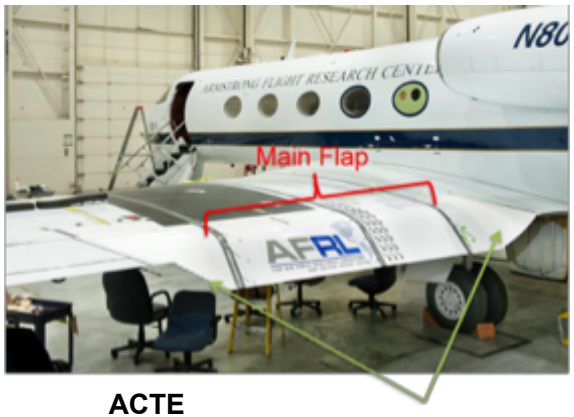
- Separate the real from the imagined
- Advance/accelerate the technology readiness level
- Establish technical “performance” expectations
- Increase manufacturing readiness
- Address integration challenges & ”ilities”
- Inspire the next generation

Environmentally Responsible Aviation
Focused research - Noise & Carbon & NOX Footprint

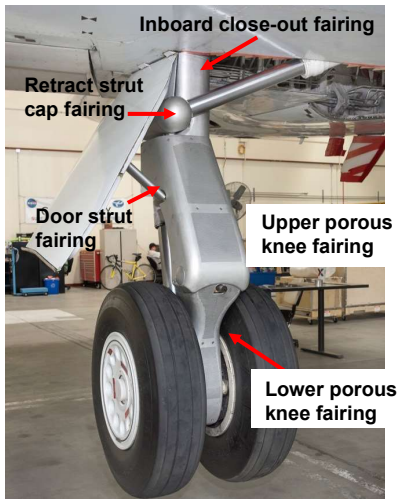
	Integrated Technology Demonstrators 2010-16	Partner
CFP	AFC Enabled Vertical Tail and Advanced Wing Flight Experiment	Boeing
CFP	Damage Arresting Composites Demonstration (Large Scale Structural Tests)	Boeing
NFP	Adaptive Compliant Trailing Edge Flight Test (w/AFRL)	FlexSys
CFP	Highly Loaded Front Block Compressor Demonstration (WT Tests)	General Electric
NFP & CFP	2nd Generation UHB Propulsor Integration (Design, WT Tests, w/FAA)	Pratt & Whitney
NOx	Fuel Flexible, Low NOX Combustor Integration (Design, Rig Tests)	Pratt & Whitney
NFP	Landing Gear and Flap Edge Noise Reduction Flight Tests	Gulfstream/ Inhouse
NFP & CFP	UHB Integration on Hybrid Wing Body Aircraft (Design, WT Tests)	Boeing
NFP & CFP	Advanced Open Rotor Design and WT Testing for Low Noise	Boeing/General Electric/Inhouse
NFP & CFP	Hybrid Wing Body Low-Speed, Flight Testing & Noise Reduction WT Testing	Boeing/Inhouse

Recent NR Technology Maturation Efforts
Adaptive Compliant Trailing Edge/Main Landing Gear

- **Adaptive Compliant Trailing Edge (ACTE)**
  - Technology developed jointly by the U. S. Air Force Research Laboratory (AFRL), FlexSys, Inc., and the NASA ERA project
  - Eliminates flap side edges and bracket assemblies
- **MLG NR Technologies**
  - MLG fairings
    - Upper porous knee fairing → 7,735 holes of 0.080" (2mm) diameter
    - Lower porous knee fairing → 3,597 holes of 0.080" (2mm) diameter
    - Total of 11,332 drilled holes
  - Chevron/batting plate cavity treatment
  - Mesh cavity treatment



ACTE



MLG fairings

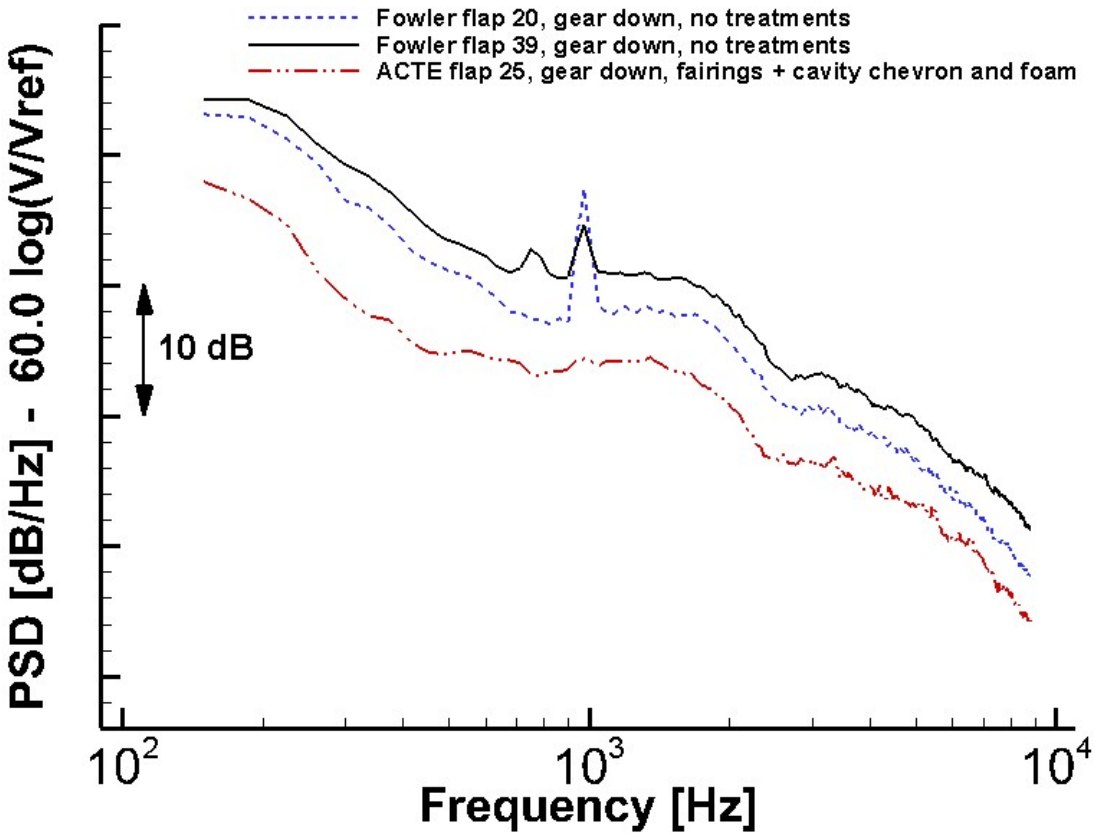
Untreated MLG

Chevron/foam cavity treatment

Mesh cavity treatment

Recent NR Technology Maturation Efforts
Adaptive Compliant Trailing Edge/Main Landing Gear

Total Reduction in Airframe Noise



Recent NR Technology Maturation Efforts
Low Drag Acoustic Liner

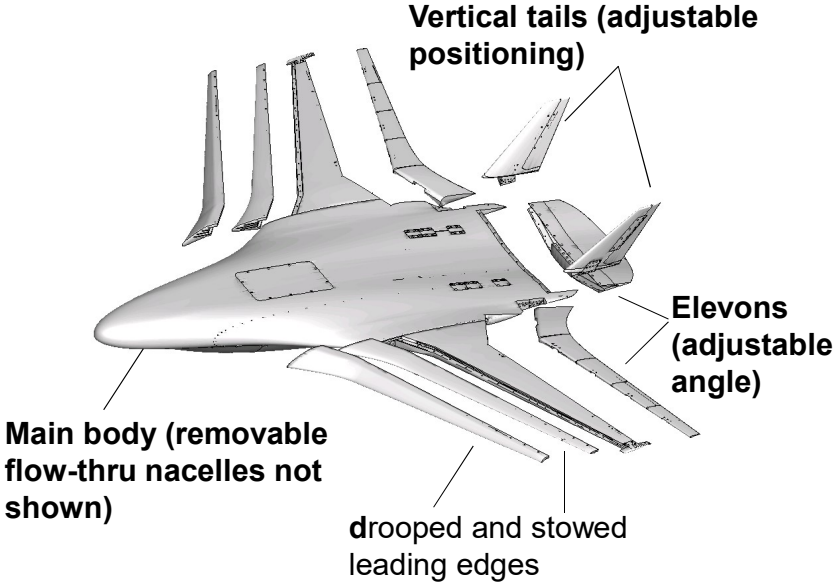
Quiet Technology Demonstrator 3

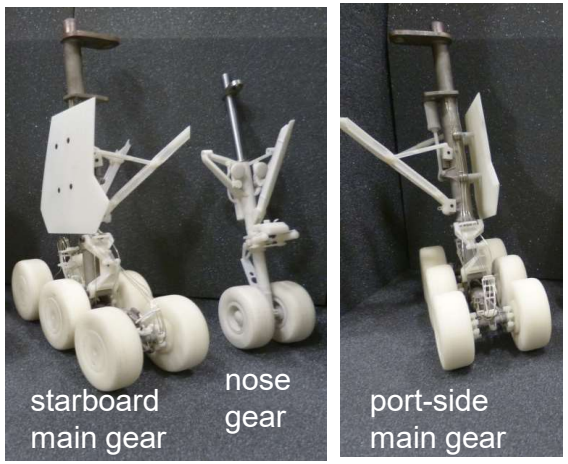
- 31 hours of total flight test time
- Half dedicated to flights over phased array located at Moses Lake, WA

Low Drag Acoustic Liner

- 7 years development time in NASA facilities
- 30 percent less drag than conventional acoustic liner
- 0.5 to 1 EPNdB aircraft level noise reduction
- Enables shorter inlets desired for adv. UHB engines

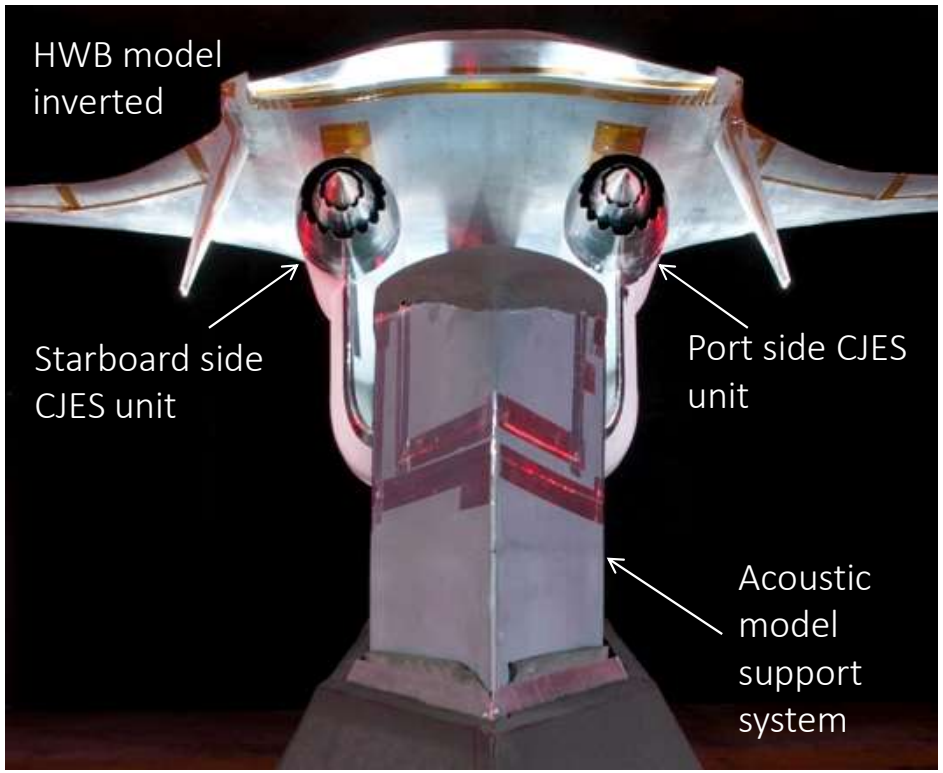
Recent NR Technology Maturation Efforts
Hybrid Wing Body Technology



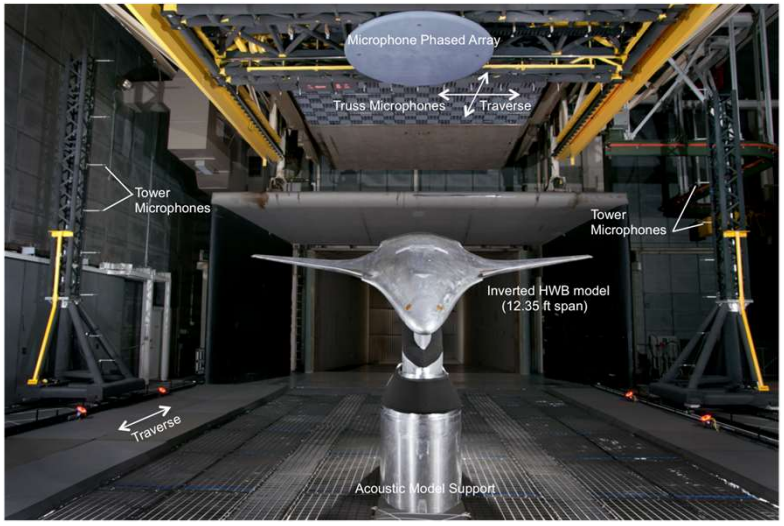


14x22 foot Wind Tunnel - 5.8% scale model (12.35 ft span)
Modular components (control surfaces and landing gear)
High fidelity of geometric details
Design Basis – MIT Silent Aircraft Initiative with design tweaks by Boeing

Recent NR Technology Maturation Efforts
Hybrid Wing Body Technology



- Noise measurements were obtained from Tower and Truss microphones, and from Microphone Phased Array at key streamwise locations.
- CJESimulators - Both units generate high temperature dual stream jet exhausts to simulate the HWB BPR-10 engine cycle jet noise
- BENSimulators – Emit uniform level broadband noise from scaled nacelles



Recent NR Technology Maturation Efforts
Open Rotor Technology

Problem

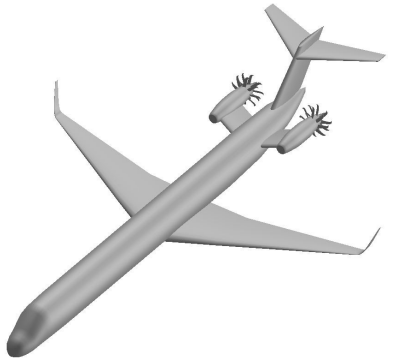
Open rotor (OR) propulsion systems possess the potential for dramatic reductions in fuel burn provided the new generation of blade geometries can provide an acceptable acoustic signature

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

Results

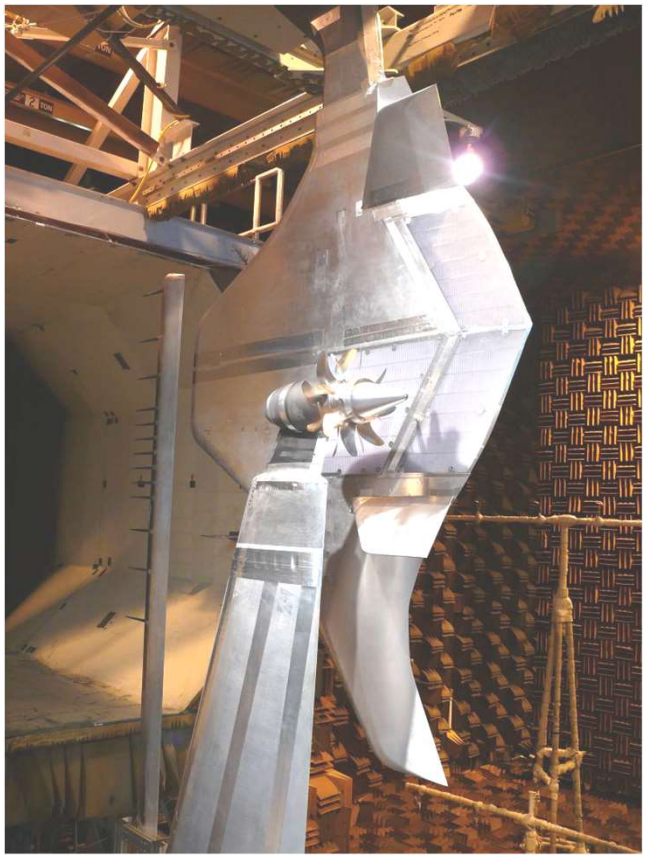
Fuel burn: the advanced OR powered aircraft is 12 percent more efficient than adv. UHB powered aircraft

Community noise: the advanced UHB powered aircraft makes about 1/2 the noise of the adv. OR powered aircraft



Single-aisle airplane w/rear-mounted open rotors

Recent NR Technology Maturation Efforts
Hybrid Wing Body + OR Technology



ERA Databases Continue to Inform Noise Assessments at A/C System Level (NASA models)

Recent A/C Assessments thru 2019	Result below Stage 4
• Hybrid Wing Body (300 seats)	40.4 to 50.9 dB cum.
• Mid Fuselage Nacelle (300 seats)	34.2 to 40.2 dB cum.
• Hybrid Wing Body w/OR (224 seats)	26.0 to 38.0 dB cum.
• Advanced Tube and Wing (300 seats)	24.3 to 30 dB cum.
• D8 “Double Bubble” (150 seats)	9 to 15 dB cum.
• Advanced T & W (open rotor, 150 seats)	about 13 dB cum.
• Transonic Truss Braced Wing (150 seats)	Work in progress

Published Results

Continuous upgrades to ANOPP and ANOPP II via new and improved modules and ongoing Noise Reduction (NR) technology maturation efforts

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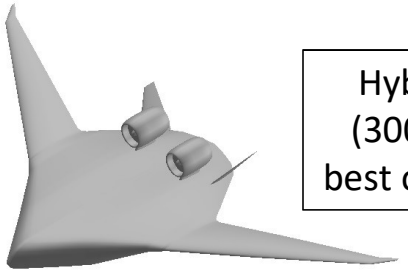
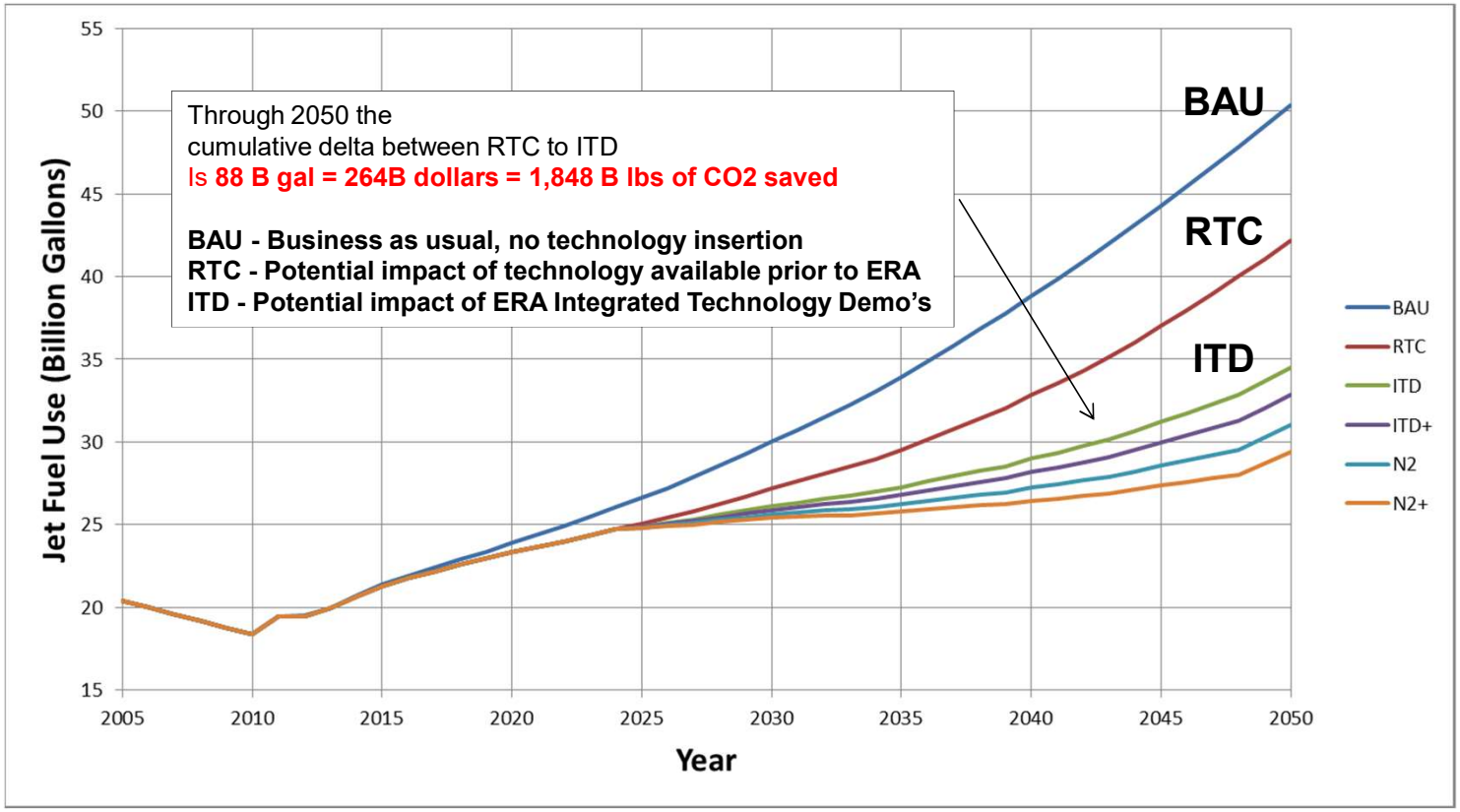


Hybrid Wing Body (300 passengers) is best overall performer

Subsonic transport scorecard w / score

N+2 Time Frame Focus Aricraft Level



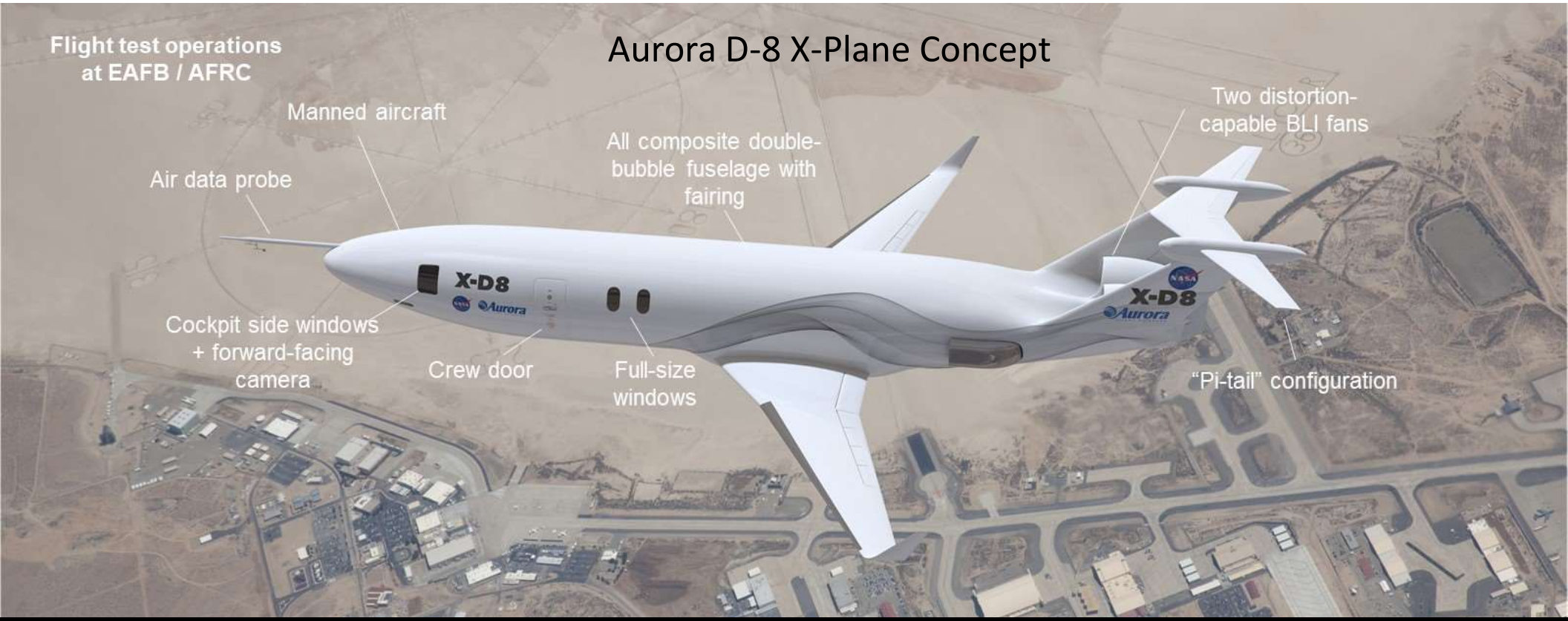
Subsonic transport scorecard w / score

N+2 Time Frame Focus Fleet Level

Notes – The ITD "what-if" scenario assumes ITD technology begins to transition into the fleet in 2025 to advanced tube and wing aircraft designs only

NASA X-PLANE STUDIES 2016 to current

Aurora D-8 X-Plane Concept



Objectives

- Demonstrate the operability of the D8 integrated double-bubble fuselage & boundary layer ingesting engines
- Verify feasibility of D8 conceptual design (lightweight structures, fabrication methods, ease of operations, lifecycle cost savings)
- Substantiate the fuel savings, noise reduction, and emissions reduction of the D8 configuration

Objectives

- Validation Of Aerodynamic Performance (L/D)
- Validation Of Engine Noise Shielding (Takeoff & Landing)
- Demonstrate Damage Tolerant Composite Center-body For Flight Loads And Proof Loads During Ground Testing
- Validate Full-Flight Envelope Stability & Control Assessment
- Validate Flight Control Secondary Power Requirements

Boeing TTBW X-Plane Concept

Objectives

- Demonstrate aerodynamic and structural benefits of Transonic Truss-Braced Wing (TTBW) technology
- Validate cruise performance can be achieved that enables fuel burn reduction goals
- Demonstrate a certification path for non-traditional structures

Objectives

- Demonstrate at full-scale flight the combination of BWB-X integrated technologies (pitch-pivot landing gear, semi-buried propulsion, BWB aerodynamics, BWB flight controls, BWB acoustics) has the ability to evolve into the disruptive Ascent 1000 Vision System aircraft
- Substantiate the performance benefit projections of *(-60% fuel burn*, *-86% NOx*) of the Ascent 1000 112 seat aircraft compared to the ERJ-190AR with *-39 dB cum to stage 4* noise reduction.
- Prove the viability of manufacturing processes and operational benefits in the ATM leading to Ascent 1000 product development; opening new US manufacturing market

NASA Electrified Aircraft Propulsion 1 MW-class Flying Powertrain Demonstrator STUDIES 2018 to current

NASA Electrified Aircraft Propulsion 1MW-Class Flying Powertrain Demonstrator Studies

- AmpAire
- Boeing
- General Electric
- United Technologies
- Wright Electric
- Other 2019 awards possible

QUESTIONS & COMMENTS

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