



System Noise Technology Roadmaps for a Transonic Truss- Braced Wing and Peer Conventional Configuration

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Outline



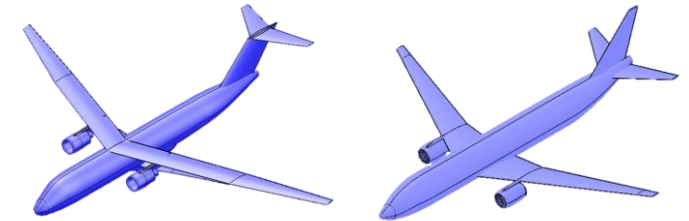
- Concept Overview
- Baseline Noise Prediction
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 - Results
- Noise Technology Roadmap
 - Process
 - Results
- Conclusions/Future Work

The Advanced Air Transport Technology Project is gratefully acknowledged for funding this work.

Concept Overview



- Two single-aisle concepts
 - 2035 entry into service (EIS)
 - Transonic Truss-Braced Wing¹ (TTBW)
 - Conventional Configuration² (CC)
- Minimum block fuel designs
- Two-spool, direct-drive engine
- High-lift and landing gear geometry scaled from:
 - Boeing contractor reports³
 - Other available single-aisle aircraft designs



Metric	TTBW	CC
Design Range [NM]	3500	
Cruise Mach	0.8	
Passengers	154 (2 class)	154 (3 class)
Thrust [lb] (Sea Level Static)	23,200	21,800
Span [ft]	158.1	123.7
Aspect Ratio	19.6	13.1
Gross Takeoff Weight (GTOW) [lb]	135,600	136,200
Max Landing Weight (MLW) [lb]	116,600	114,400

¹AIAA Paper 2020-0011

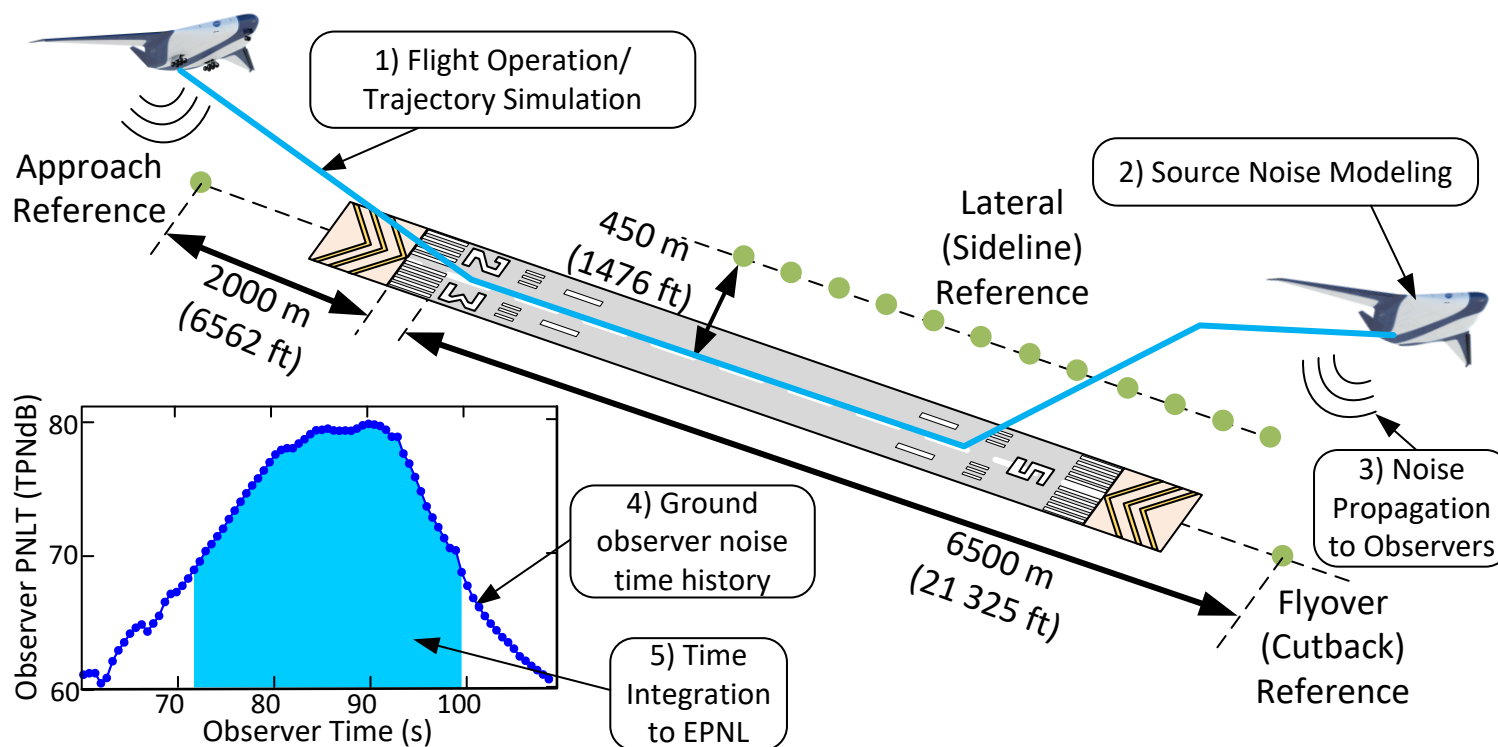
²AIAA Paper 2016-1027

³Droney, C. and Zidovetzki, E. SUGAR Phase IV Mach 0.80 Transonic Truss-Braced Wing Concept Data Package. Unpublished NASA Contractor Report.

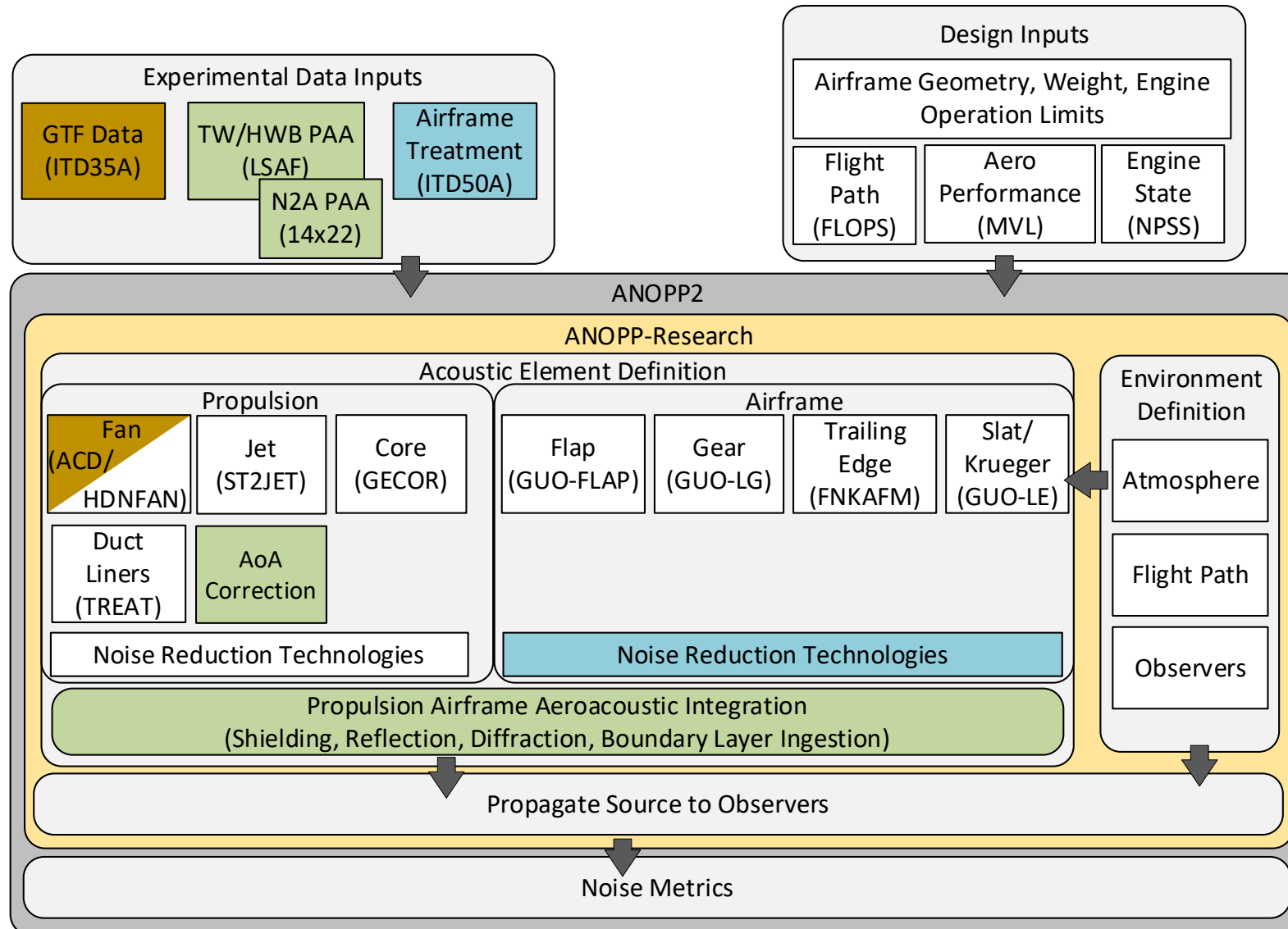
Motivation and Metric



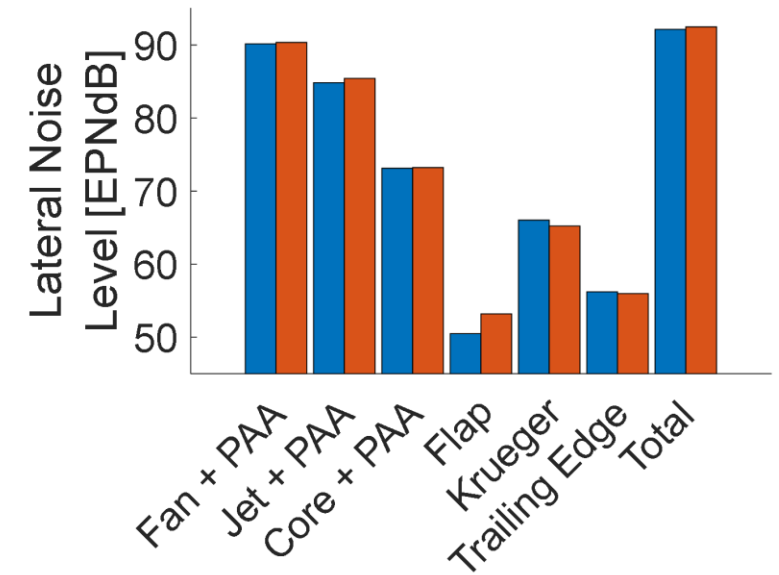
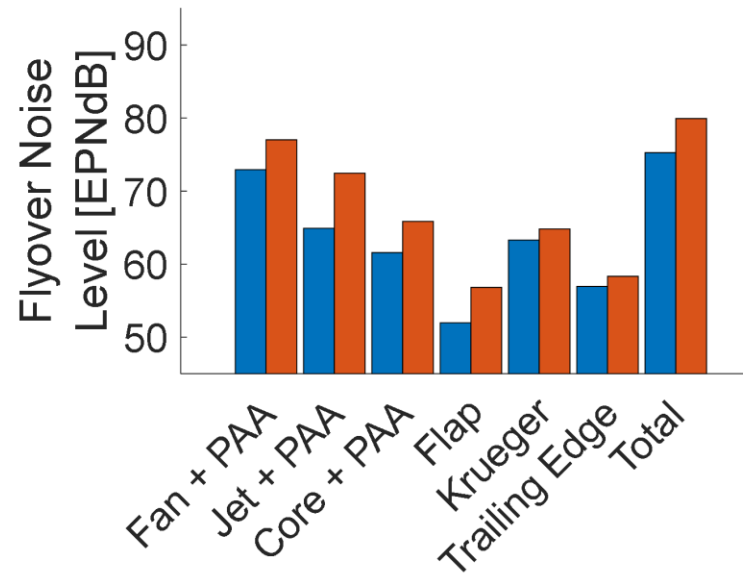
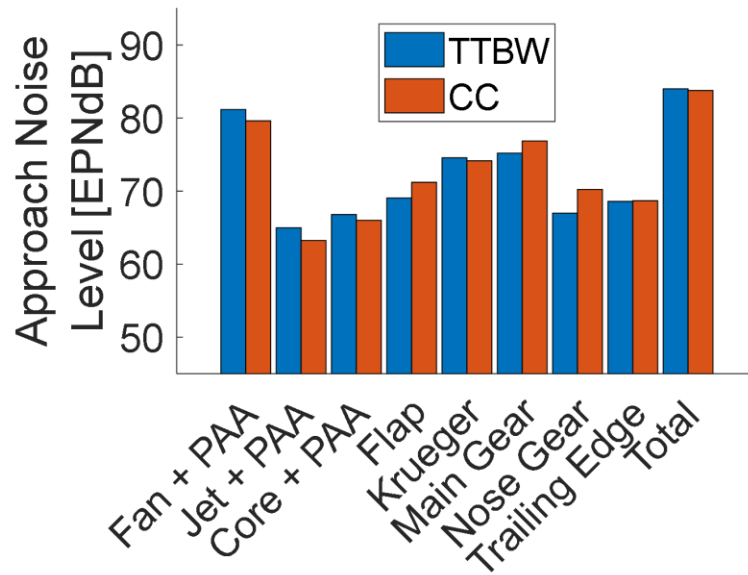
- NASA targeting noise reduction of 35 EPNdB below Stage 5 minimum margin for vehicles with EIS 2025-2035
- Both concepts assessed relative to NASA noise goal and each other using effective perceived noise level (EPNL) and noise certification flight conditions



ANOPP-Research Noise Prediction Process



Baseline Results



Configuration	Approach Level [EPNdB]	Flyover Level [EPNdB]	Lateral Level [EPNdB]	Cumulative Margin [EPNdB]
TTBW	84.0	75.3	92.1	18.0
CC	83.8	79.9	92.5	13.3

- Fan noise element with propulsion airframe aeroacoustic (PAA) effects leading source for all three certification points
- Similar engine source ranking, as expected
- TTBW has a large advantage at flyover
- Krueger and main gear are primary airframe sources
- Airframe ranking differs from combination of source strength and operation

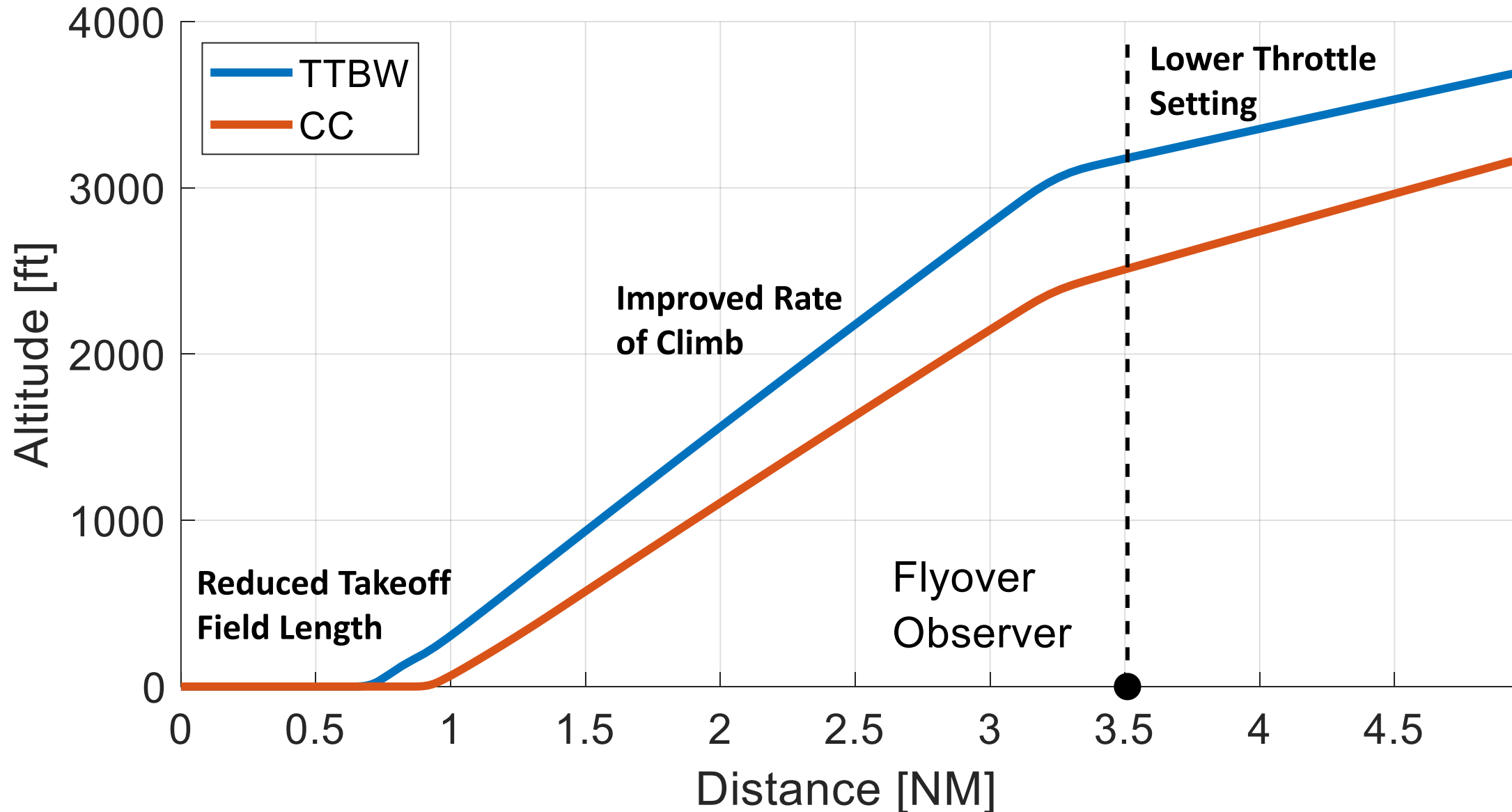
Airframe Subsystem Noise Comparison



- TTBW airframe sources are louder than CC
 - Krueger – double panel count re CC
 - Main gear – body-mounted, local flow
 - Trailing edge – longer wingspan, strut
- TTBW airframe noise comparable to CC due to low-speed performance
 - Lower approach speed
 - Higher flyover altitude

Airframe Subsystem Noise Levels									
Concept	Approach			Flyover		Lateral			CUM Airframe Level [EPNdB]
	Level [EPNdB]	Speed [kn]	MLW [klb]	Level [EPNdB]	Altitude [ft]	Level [EPNdB]	Speed [kn]	GTOW [klb]	
TTBW	79.2	127	116.6	64.8	3,180	66.8	155	135.6	210.8
CC	80.3	141	114.4	66.6	2,540	66.2	164	136.2	213.1

TTBW Flight Path Advantages



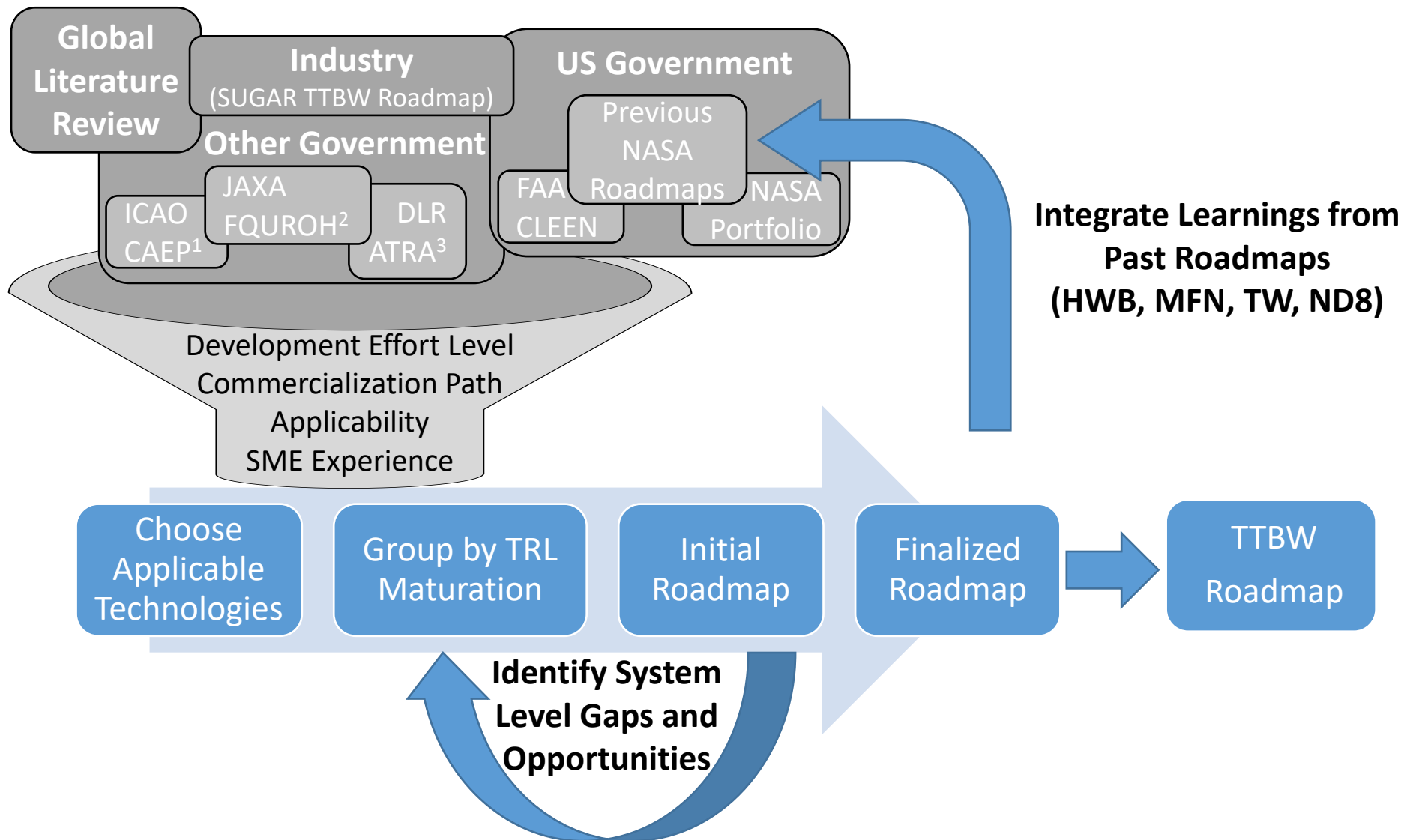
Propulsive Airframe Aeroacoustic Effects



- TTBW has a significant PAA penalty (louder), but improves relative to conventional configuration due to:
 - High wing configuration (better lateral shielding)
 - Strut shielding
 - Smaller chord wing
- Opportunity to further reduce penalty through:
 - Noise reduction technologies
 - Improved PAA modeling tools and optimization
 - Other unconventional single-aisle configurations

Concept	Approach [EPNdB]	Flyover [EPNdB]	Lateral [EPNdB]	Cumulative Penalty [EPNdB]
CC	0.8	1.8	2.0	4.6
TTBW	1.0	2.0	1.0	4.0

Noise Technology Roadmap Process



¹ICAO Document 10017

²AIAA Papers 2017-4033, 2018-4085

³AIAA Paper 2021-2160

Technology Readiness Level Grouping Criteria



Estimated Technology Readiness Level 5-6 Date

2028 Cutoff
(for EIS 2035)

Mid Term



Landing Gear
Door Liner¹



Partial Main and
Nose Gear
Fairings²

Potential Mid Term



Pod Main Landing
Gear

Adequately resourced to meet
insertion TRL by cutoff

Potential Mid Term



Pod Main Landing
Gear³

Additional
Resources

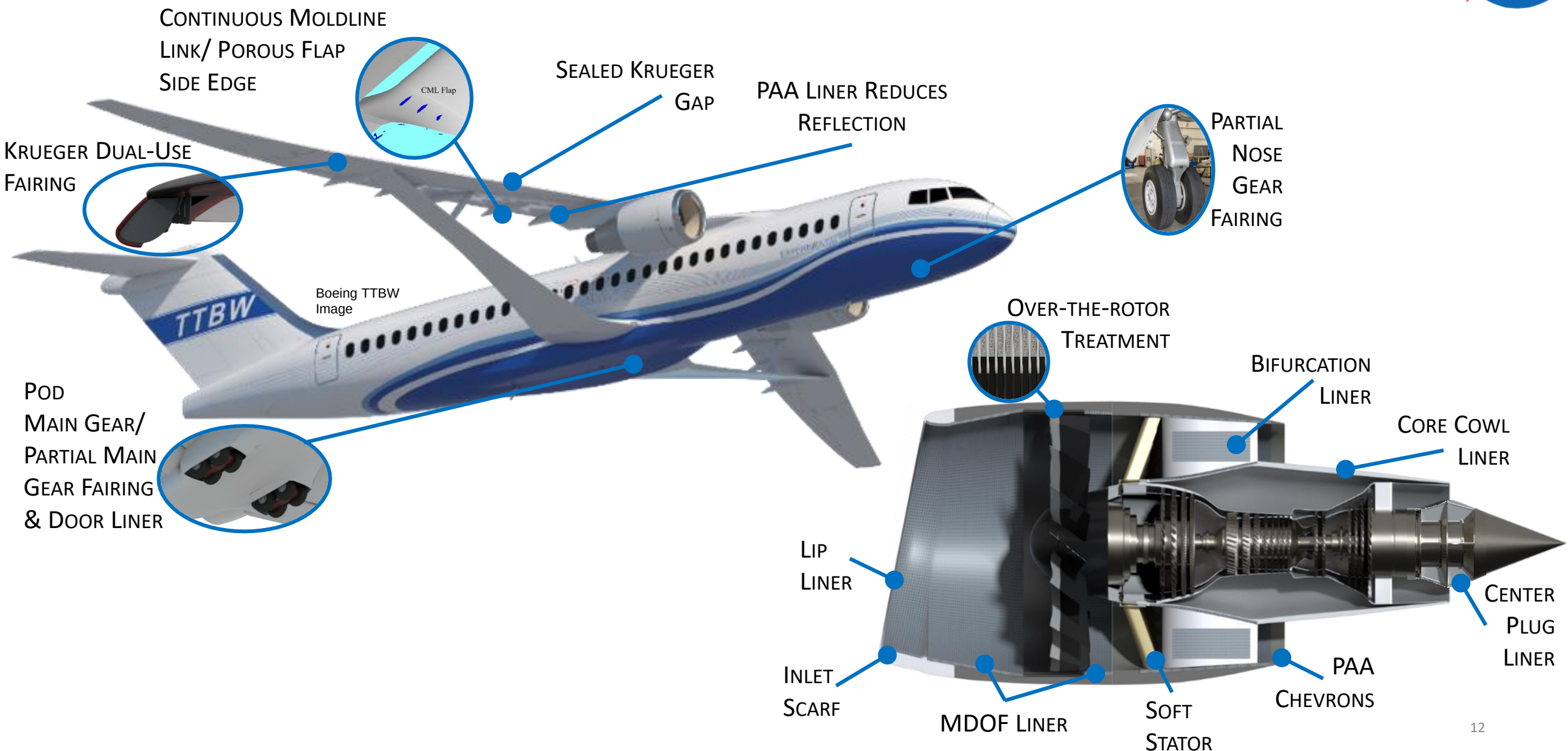
Requires additional resources to accelerate
TRL maturation and insert by cutoff

¹Ileri, L. and Orton, A. CLEEN III Progress & Acoustic Work Packages, NASA Acoustics Technical Working Group Meeting, October 2021.

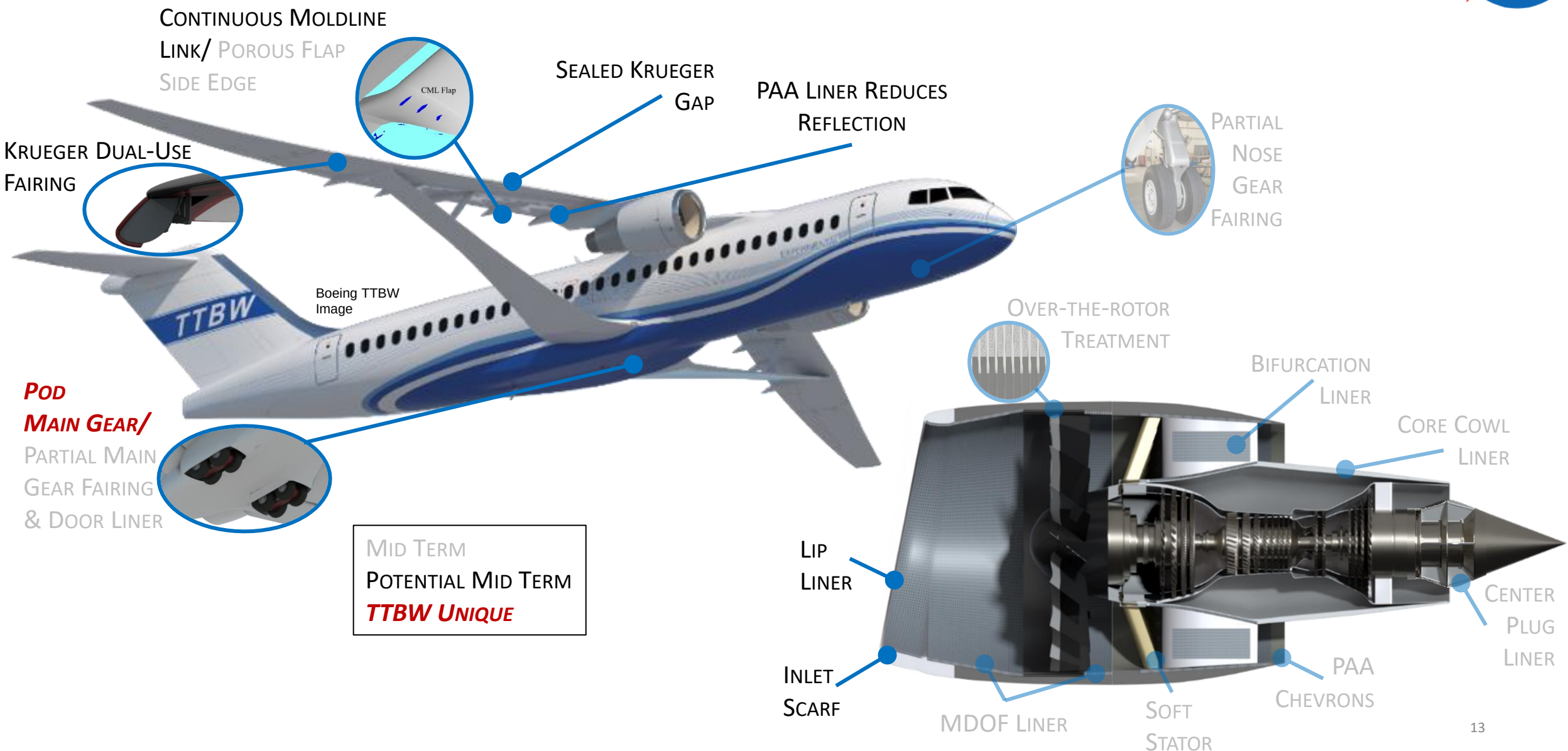
²AIAA Paper 2018-2972

³AIAA Paper 2016-3039

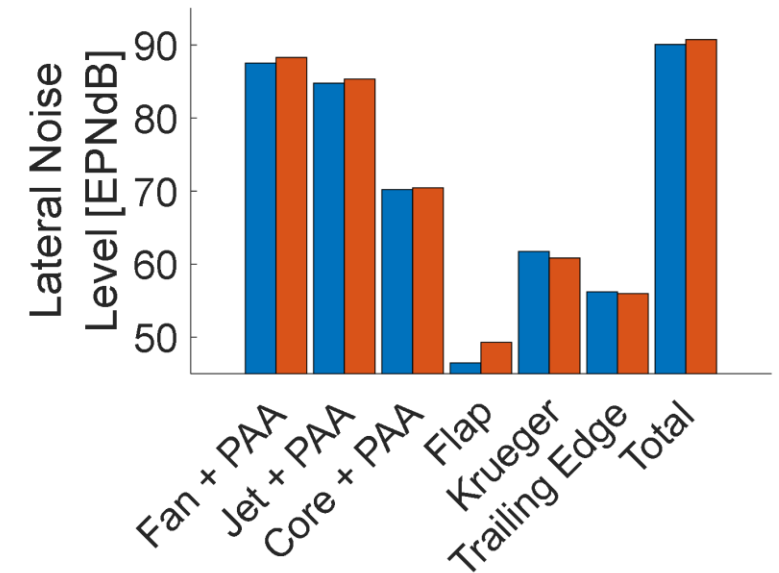
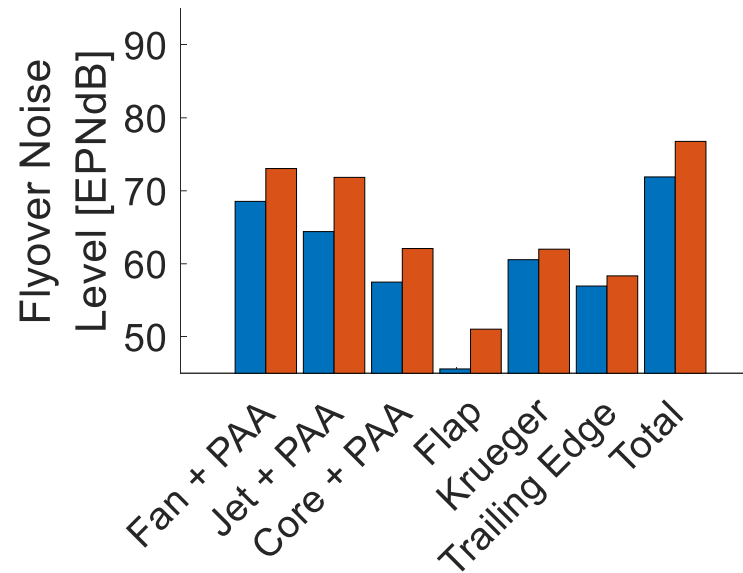
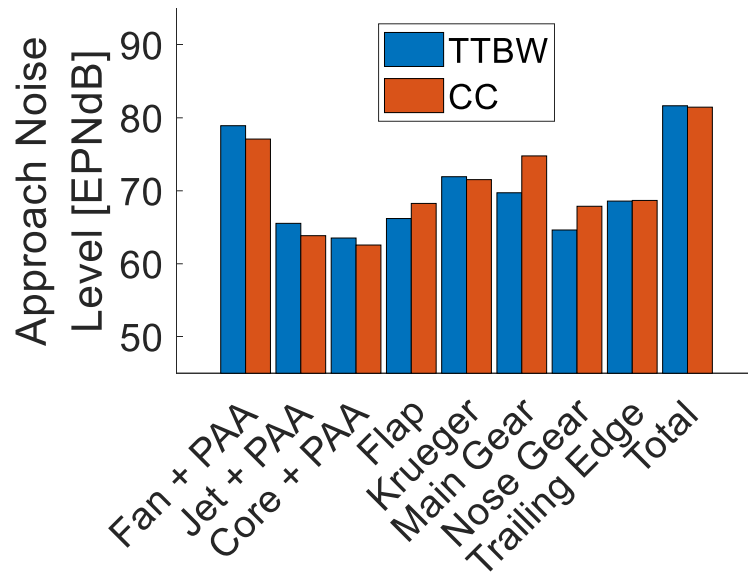
Roadmap Technologies



Roadmap Technologies



Roadmap Results



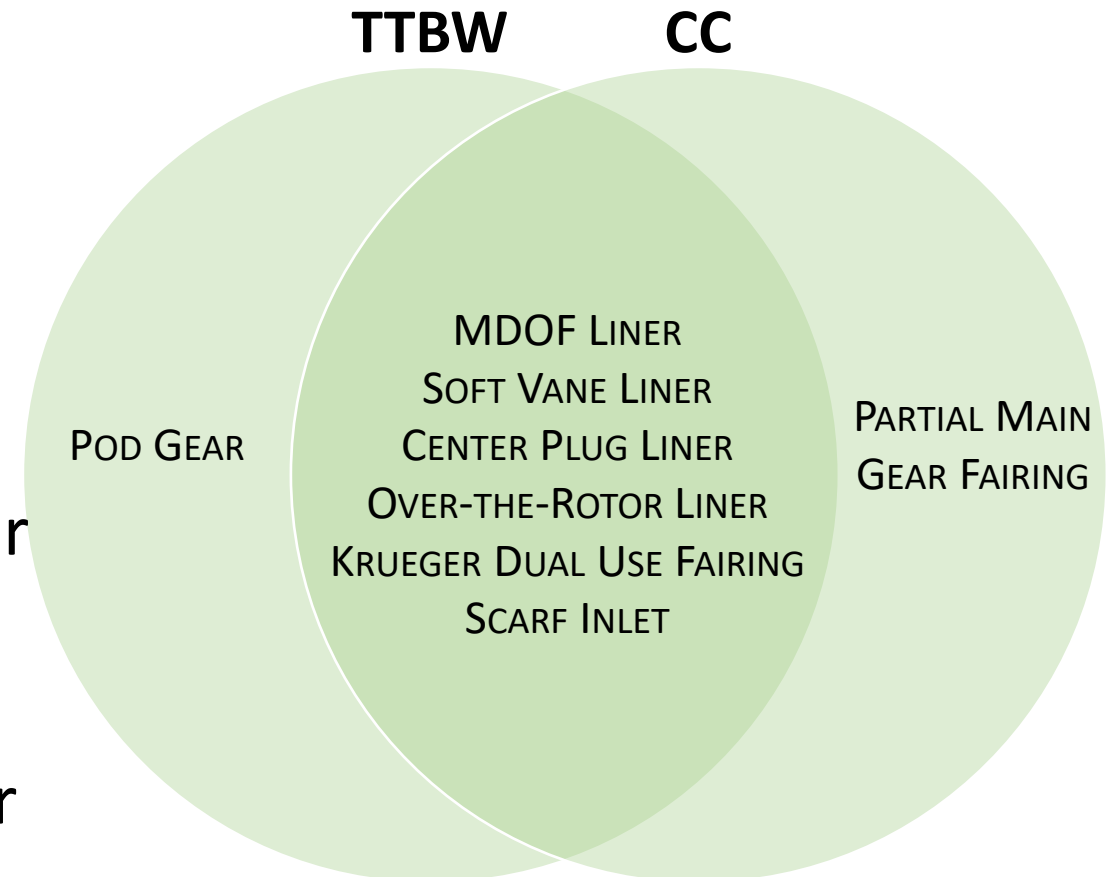
Configuration	Approach Level [EPNdB]	Flyover Level [EPNdB]	Lateral Level [EPNdB]	Cumulative Margin [EPNdB]
TTBW	81.7	71.9	90.1	25.8
CC	81.5	76.8	90.7	20.5

- Fan noise element with PAA effects **still the leading source** for all three certification points
- Noise reduction technologies provide cumulative reductions of:
 - 7.8 EPNdB for the TTBW
 - 7.2 EPNdB for the CC

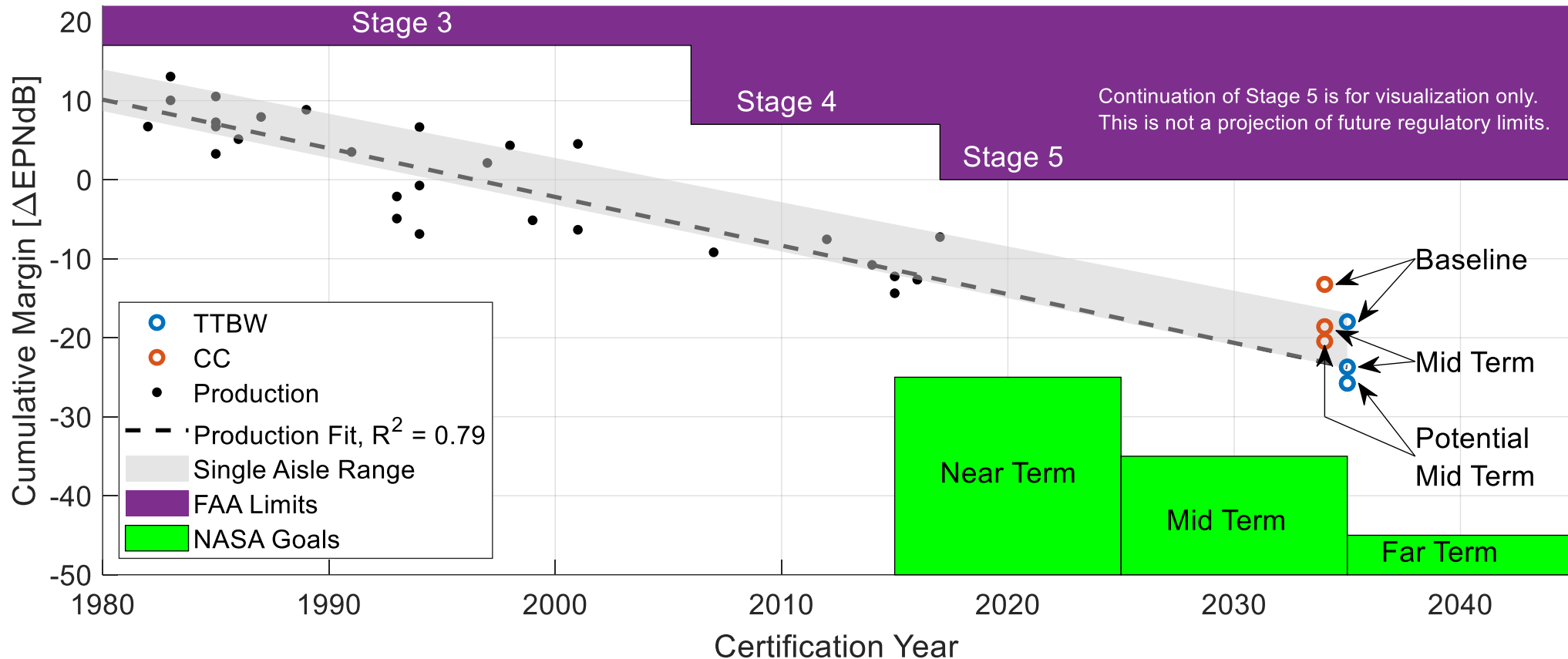
Technologies with High System Benefit



- Technologies with high system level benefit (> 0.5 EPNdB, cum.) typically affect dominant sources:
 - Fan
 - Krueger
 - Main landing gear
- TTBW typically gets the same or better noise reduction re CC
- Pod gear provides significantly more noise reduction than partial main gear fairing



Context for Current Results

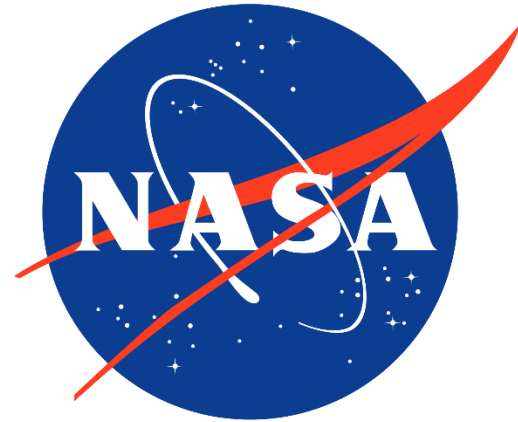


- Single-aisle range bounded by curve fits to A320 and B737 families
- TTBW maintains a ~5 EPNdB advantage regardless of noise reduction package
- Potential mid term below production fit
- Additional innovation and technologies needed to meet NASA Mid Term goal

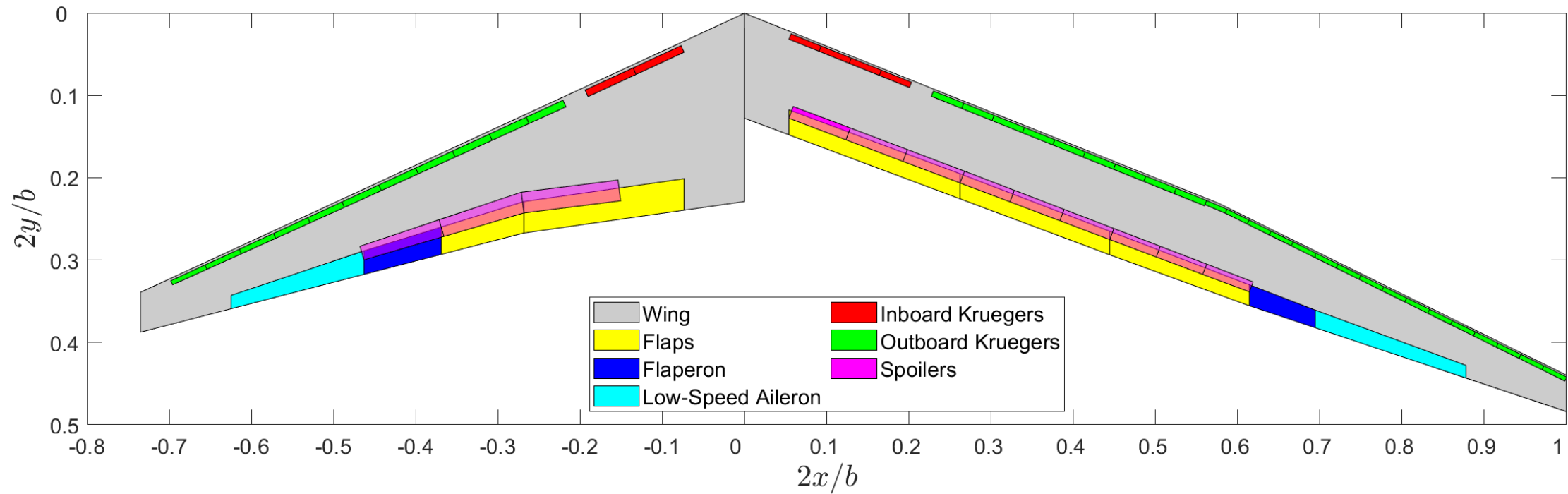
Conclusions & Future Work



- TTBW differentiates from the CC by quieter baseline noise from:
 - Better low-speed performance (approach velocity, takeoff climb rate)
 - Improved PAA effects
- Only the full NASA TTBW noise reduction roadmap is nominally below the production curve fit
- TTBW unique aspects may spur innovation (e.g., pod gear) needed to reach NASA goal
- Fan noise technologies were particularly effective on both vehicles
- Strong correlation between technology effectiveness between vehicles
- Uncertainty quantification needed for confidence in interpreting results
- Improvements to source and technology prediction models/effects
 - Fan source and acoustic liner methods
 - Use of recently developed PAA scattering code(s)¹
 - Landing gear door liner, core cowl liner



High Lift Planform



Roadmap One-Off Technology Impacts



Mid Term

Technology	Element	TTBW [EPNdB, cum.]	CC [EPNdB, cum.]
MDOF Liner	Fan	1.5	1.2
Over-the-Rotor Liner	Fan	1.4	1.3
Soft Vane	Fan	0.8	0.6
Center Plug Liner	Core	0.7	0.5
Core Cowl Liner	Aft Fan	0.4	0.4
PAA Chevrons	Jet	0.3	0.3
Bifurcation Liner	Aft Fan	0.2	0.3
Partial Main Gear Fairing	Main Gear	0.1	0.5
Porous Flap Side Edge	Flap	0.2	0.2
Partial Nose Gear Fairing	Nose Gear	0.1	0.1
Landing Gear Door Liner	Main Gear	< 0.05	0.1
Total		5.7	5.4

Potential Mid Term

Technology	Element	TTBW [EPNdB, cum.]	CC [EPNdB, cum.]
Krueger Dual Use Fairing	Leading Edge	0.7	0.5
Scarf Inlet	Forward Fan Directivity	0.6	0.7
Pod Landing Gear	Main Gear	0.5	-----
Lip Liner	Forward Fan	0.4	0.4
PAA Wing Liner	Aft Fan/Core Reflection	0.1	0.2
Continuous Moldline Link	Flap	0.2	0.3
Sealed Krueger Gap	Leading Edge	<0.05	<0.05
Total		2.1	1.9