ICAO Symposium on Aviation and Climate Change, “Destination Green”, 14 – 16 May 2013

Noise Technology Goals

Summary of the conclusions of the second CAEP Noise Technology Independent Expert Panel (IEP2)

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Remit

The **Independent Expert Panel (IEP2)** was directed to carry out the following, per CAEP-Memo/80, Attachment A, dated January 21, 2011:

Task 1 - Summarize the status of new *technological advances* (novel aircraft and engine concepts) (e.g., open rotor, geared turbofan, blended wing body, etc.) that can be brought to market within 10 years (mid-term, 2020) from the date of the review, as well as the 20-year (long term, 2030) prospects suggested by research progress, without disclosing commercially sensitive information;

Task 2 - Assess the possibility of noise reduction for each *technology* (novel aircraft and engine concepts);

Task 3 - Comment on the environmental efficiency, and other economic tradeoffs resulting from adopting the candidate technologies; and

Task 4 - Recommend updated mid-term and long-term technology goals for reducing aircraft noise relative to the defined baseline, also considering an improved definition of the realization factor when applied to noise technology development.

IER – Independent Experts Review

IEP – Independent Experts Panel; "1" – First Review/Panel; "2" – Second Review/Panel

Task 1 – Technological Advances

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- IEP2 decided to use a Technology Scenario for Noise (TSN) approach similar to the Fuel Burn IEP.

  TSN-1: Pressure on the aviation industry to reduce noise will remain the same as it is today. Evolution of the conventional tube and wing aircraft will continue but the pressure will be insufficient to achieve the higher Technology Readiness Level (TRL) required for unconventional noise-driven aircraft concepts by 2030.

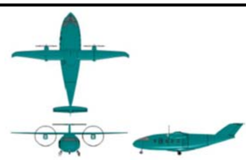
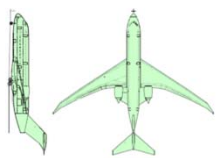
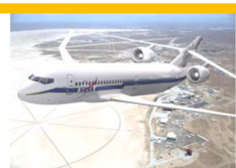
  TSN-2: Increased pressure to reduce noise, but balanced with reduced fuel burn and reduced emissions. Noise reduction would be a primary design objective that may require unconventional aircraft concepts, such as those that incorporate engine noise shielding.

- Reviewed NASA advanced aircraft studies and NACRE Pro-Green concepts (European project on "New Aircraft Concepts REsearch").

- Utilized independent systems analyses available from NASA Ultra High Bypass (UHB) turbofan and Open Rotor (CROR) studies.

- Interviewed several organizations who have conducted novel aircraft studies to determine feasibility for Entry Into Service (EIS) by 2030.

Sample of Novel Aircraft and Engine Concepts

Aircraft Concept	Picture	Mission	Reference	Fuel Burn (% below reference)	Noise (cum EPNdB under Chapter 4	NOx (% under CAEP/6)
NASA SFW General Electric 2035		20 pax 800 nm M=0.55 39,000’	B20/GE4600B	68.9	75	77
Novel Tube & Wing				**Reported Benefits**		
NASA ERA Boeing 2025		224 pax 8000 nm M=0.85 35,000’	B767 (1998 Technologies)	42.5	32	72
NACRE Proactive Green		Not Available	Single Aisle	-	4 below unshielded configurations	-
NASA ERA Lockheed Martin Box Wing		224 pax 8000 nm M=0.85 39,000’	1998 Technologies with Scaled Trent 800	>50	33 to 39	>85
NASA SFW MIT D8.1 Double Bubble		180 pax 3000 nm M=0.72 43,300’	B737-800	49	43	53

Selected for interviews by IEP2 to investigate feasibility for long-term 2030 EIS (entry into service), but deemed not likely.

Estimated by IEP2 to be feasible for long-term 2030 EIS based on interviews, but no current plans for product launch.

Task 2 – Noise Reduction Technologies

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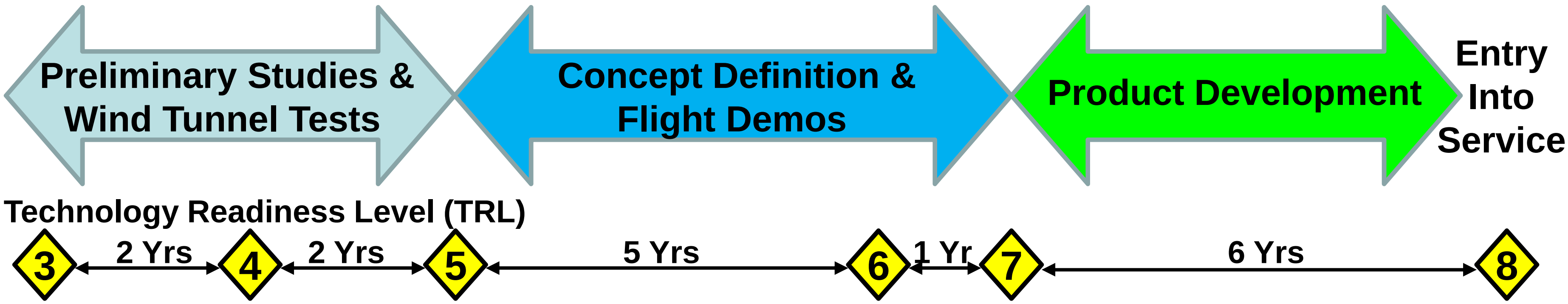
- The IEP2 revisited the noise reduction technologies (NRT) list from the first review. Several technologies shifted in time based on knowledge of current research activities.
- IEP2 used NASA studies on Short/Medium Range Twin (SMR2) Open Rotor and UHB turbofans to evaluate noise reduction technologies.
- TSN-2 concepts that used engine noise shielding were compared with each other to determine reasonable range of noise reduction benefits.

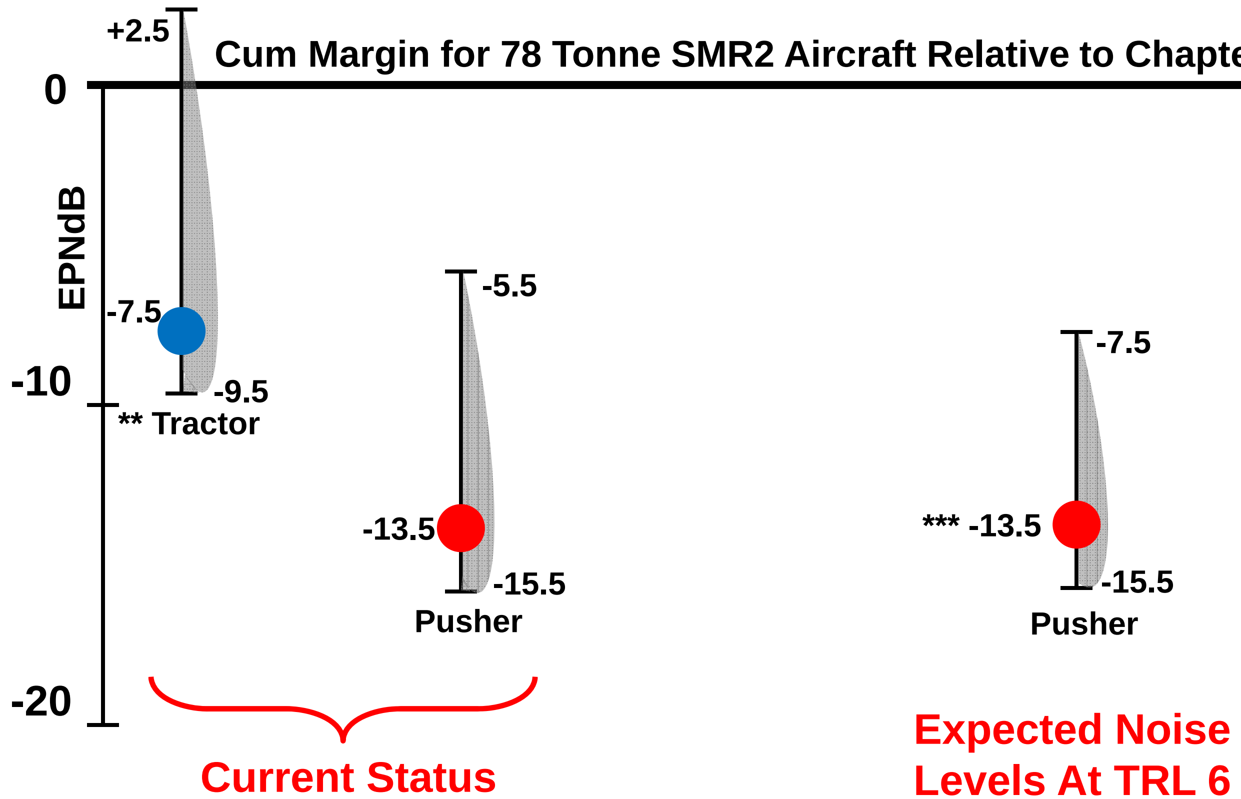
Noise Reduction Technologies

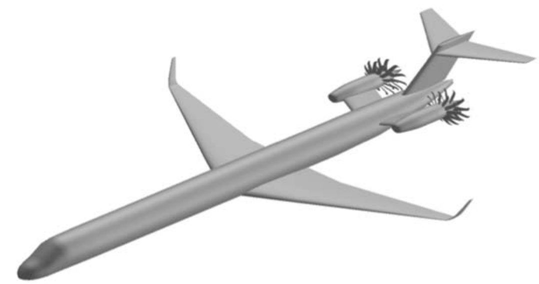
Small Twin Vehicles – Regional Jet to A321 size				
Component	**Technology**	**Medium Term** (TRL 8 by 2020)	**Long Term** (TRL 8 by 2030)	**Longer Term** (TRL 8 post 2030)
Fan	Rotor Sweep	X		
	Stator Sweep & Lean	X		
	Fan Speed Optimization	X		
	Variable Area Nozzle	X	X	
	Acoustically Lined “Soft”		X	
	Vane		X	
	Over The Rotor Treatment		X	
	Active Stator			X
	Active Blade Tone Control			X
	Zero Hub Fan			X
Jet	Fixed Geometry Chevrons	X		
	Variable Geometry		X	
	Chevrons	X		
	Higher BPR Cycle	X		
	Advanced Long-Duct Mixer		X	
	Fluidic Injection, Microjets		X	
	& High Frequency		X	
	Excitation		X	
	Bevelled Nozzle			
	Off-set nozzles			
Nacelle/Liner	Zero Splice Inlet	X		
	Scarf Inlet		X	
	Nose Lip Liner	X		
	High Temp. Lightweight	X		
	Liner			
	LDMF (CNA) Liner		X	
	HQ Tubes		X	
	Optimized Zone Liner		X	
	Aft Cowl Liner		X	
	Acoustic Splitter		X	
	Active/Adaptive Liner		X	

Small Twin Vehicles – Regional Jet to A321 size (continued)				
Component	**Technology**	**Medium Term** (TRL 8 by 2020)	**Long Term** (TRL 8 by 2030)	**Longer Term** (TRL 8 post 2030)
Turbine	Blade/Vane Ratio	X		
	Optimisation	X		
	Optimized Aerodynamics	X		
	Speed Optimisation		X	
	Over The Rotor			
	Treatment			
Combustor	Combustor Liner			
	(Baffles/Cavity Acoustic			
	Plugs/			
	Micro-Perforated Liner	X		
	Cavity Septum)		X	
	Staged injection			
Compressor	Blade/Vane Ratio	X		
Bleed Valve	Teeth Design	X		
	Exit Screen	X		
Landing	Fairing & Flaps	X		
Gear	Low-Noise Design	X		
	Flow Control		X	
Slats	Low-Noise Design		X	
	Slat Cove Filler		X	
Flaps	Low-Noise Design		X	
	Continuous Mold Line		X	
	Flap	X		
	Porous Side Edge			

Open Rotor Technology Development & Noise Predictions





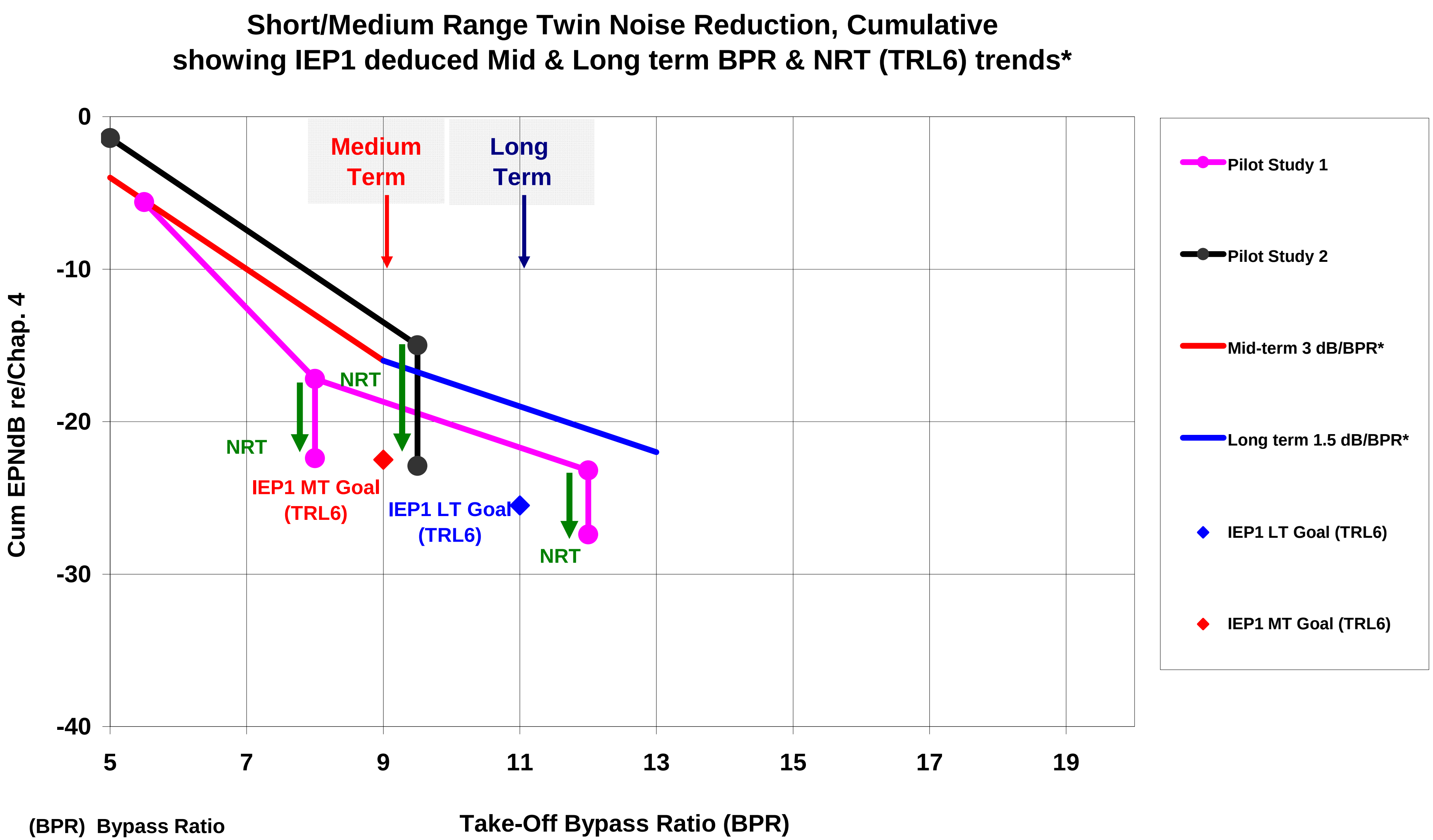


* Notional pusher configuration shown above.

** No known plans for higher TRL development of tractor configurations (wing mounted engines).

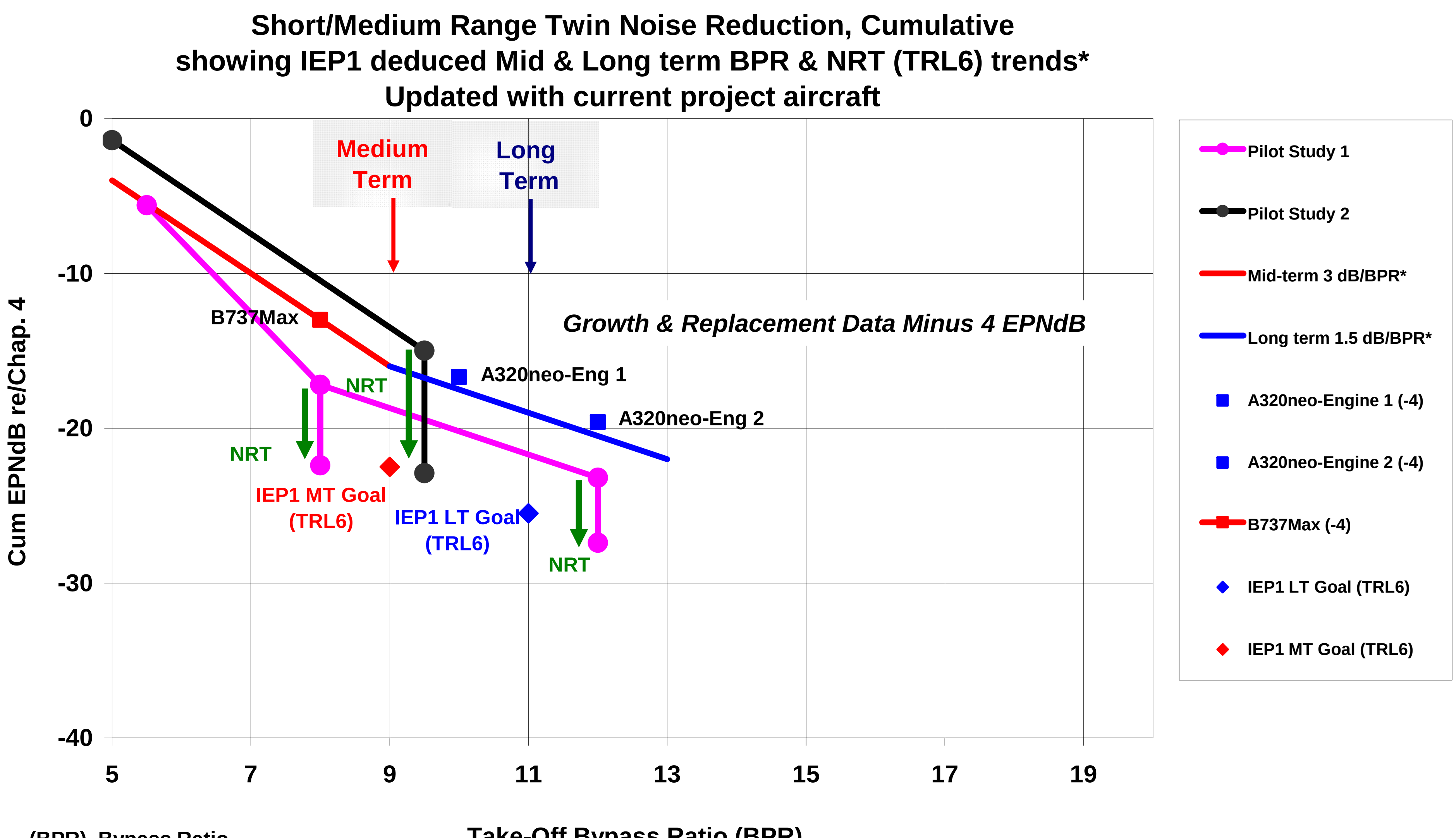
*** Nominal value judged by IEP2 to be the same from TRL4 to TRL6 based on experience from GE Un-Ducted Fan (UDF) flight tests.

Noise Trends with Bypass Ratio – SMR2



(BPR) Bypass Ratio
(NRT) Noise Reduction Technologies
(TRL) Technology Readiness Level

Noise Trends with Bypass Ratio – SMR2



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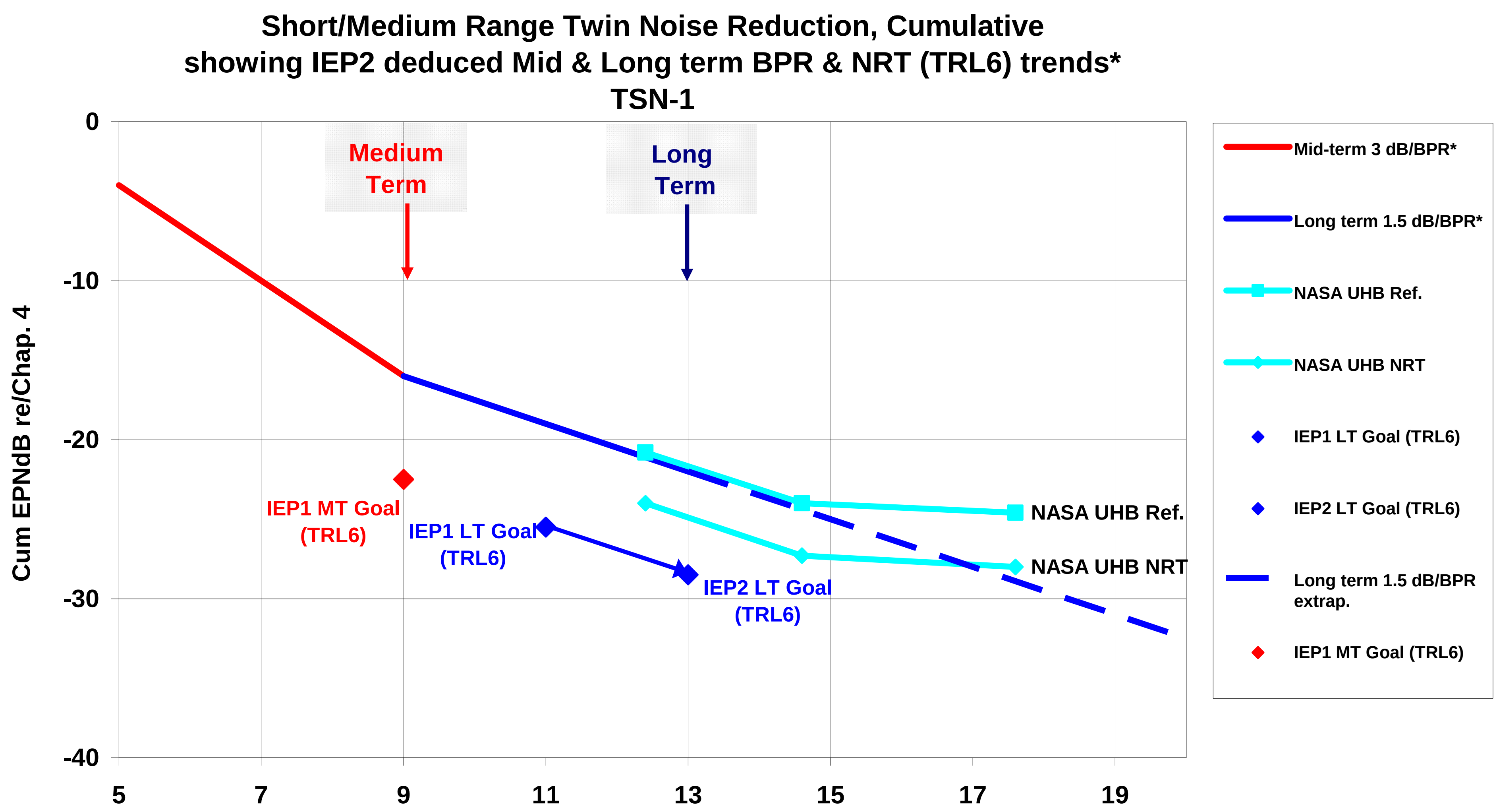
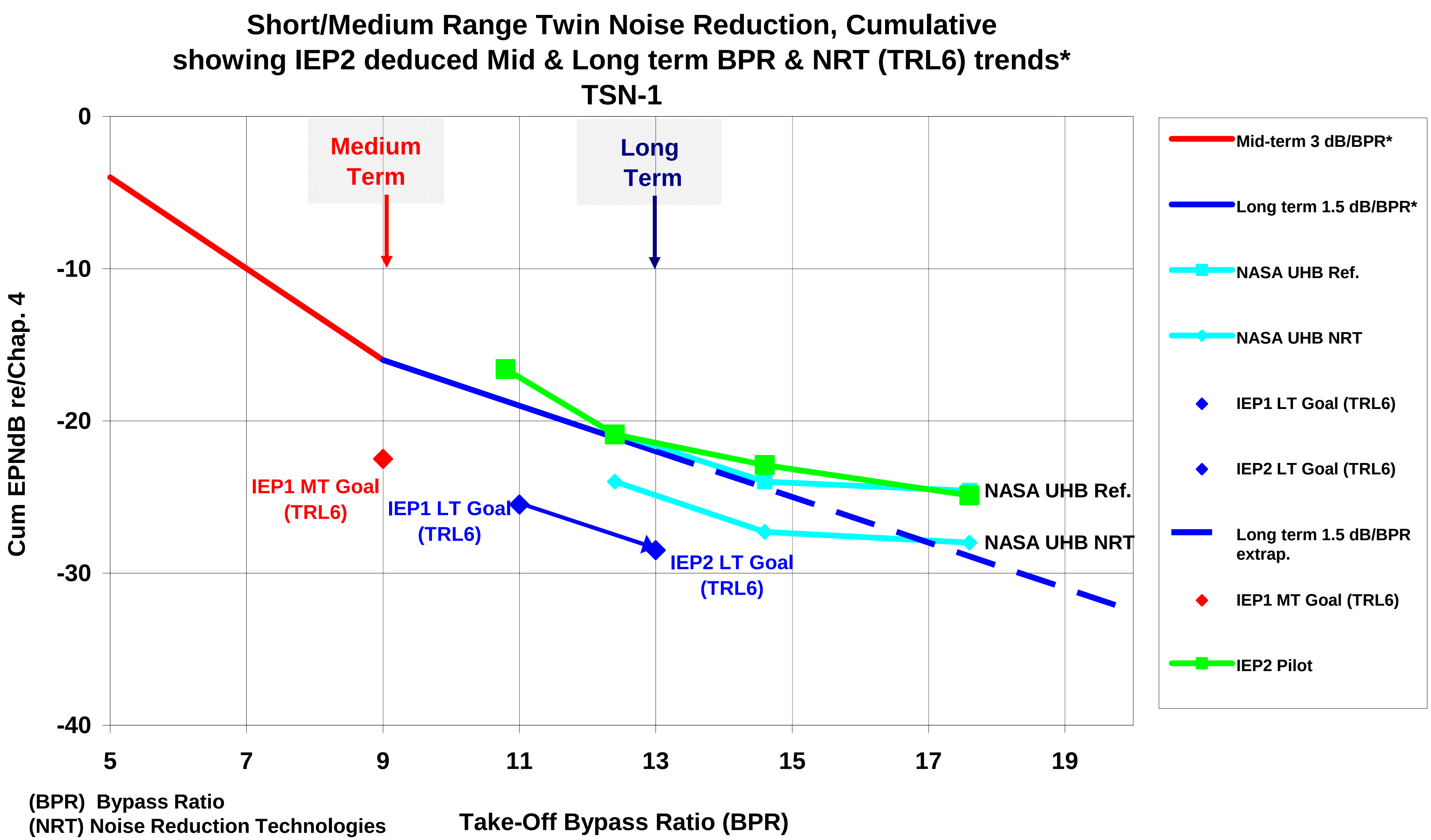
Noise Trends with Bypass Ratio – SMR2



(BPR) Bypass Ratio
(NRT) Noise Reduction Technologies
(TRL) Technology Readiness Level
(TSN) Technology Scenario for Noise
(UHB) Ultra High Bypass ratio

Noise Trends with Bypass Ratio – SMR2



(BPR) Bypass Ratio
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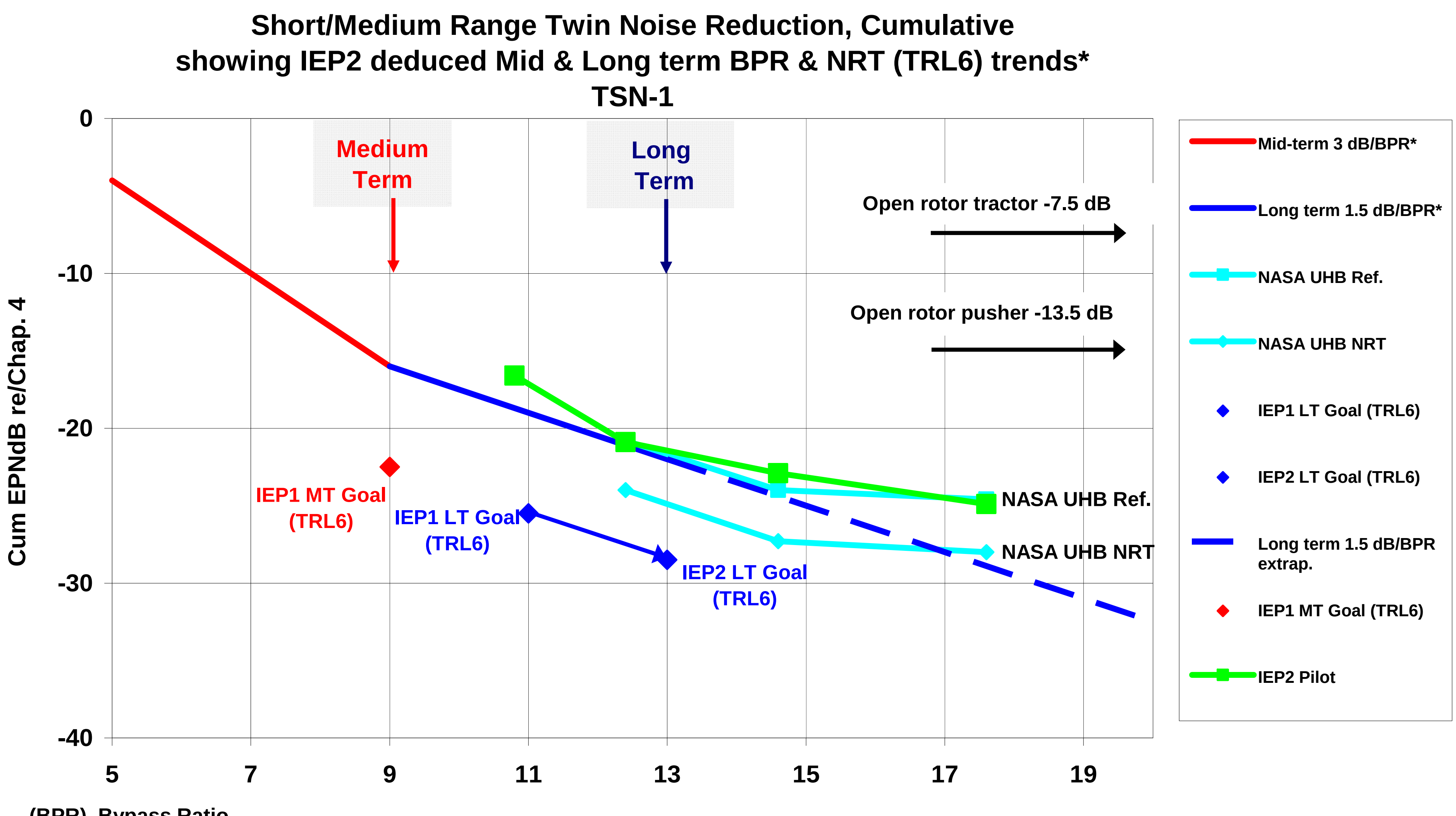
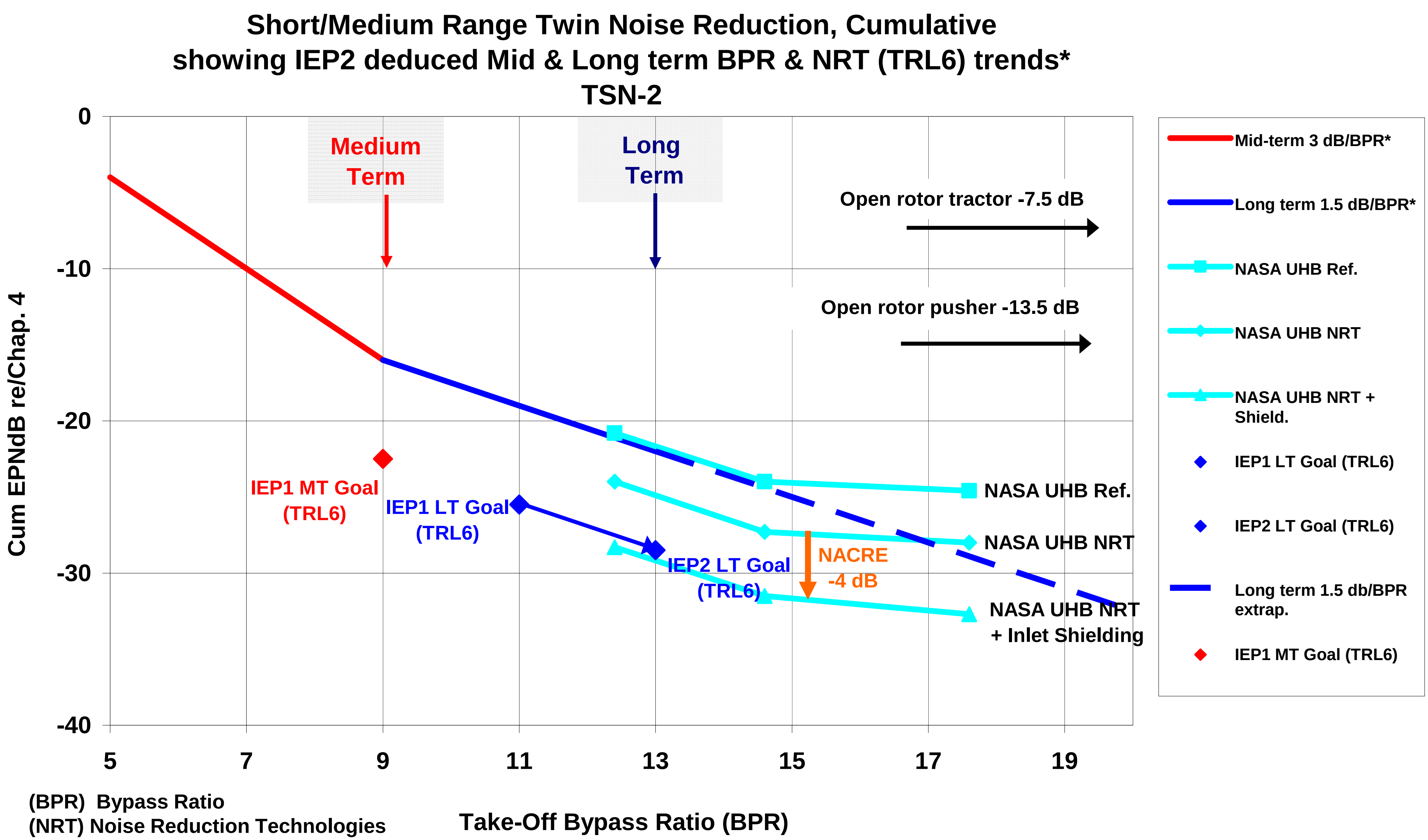
(TRL) Technology Readiness Level
(TSN) Technology Scenario for Noise
(UHB) Ultra High Bypass ratio

Noise Trends with Bypass Ratio – SMR2



(BPR) Bypass Ratio
(NRT) Noise Reduction Technologies
(TRL) Technology Readiness Level
(TSN) Technology Scenario for Noise
(UHB) Ultra High Bypass ratio
(CROR) Counter-Rotating Open Rotors

Noise Trends with Bypass Ratio – SMR2



(BPR) Bypass Ratio
(NRT) Noise Reduction Technologies
(TRL) Technology Readiness Level
(TSN) Technology Scenario for Noise
(UHB) Ultra High Bypass ratio

Task 3 – Tradeoffs

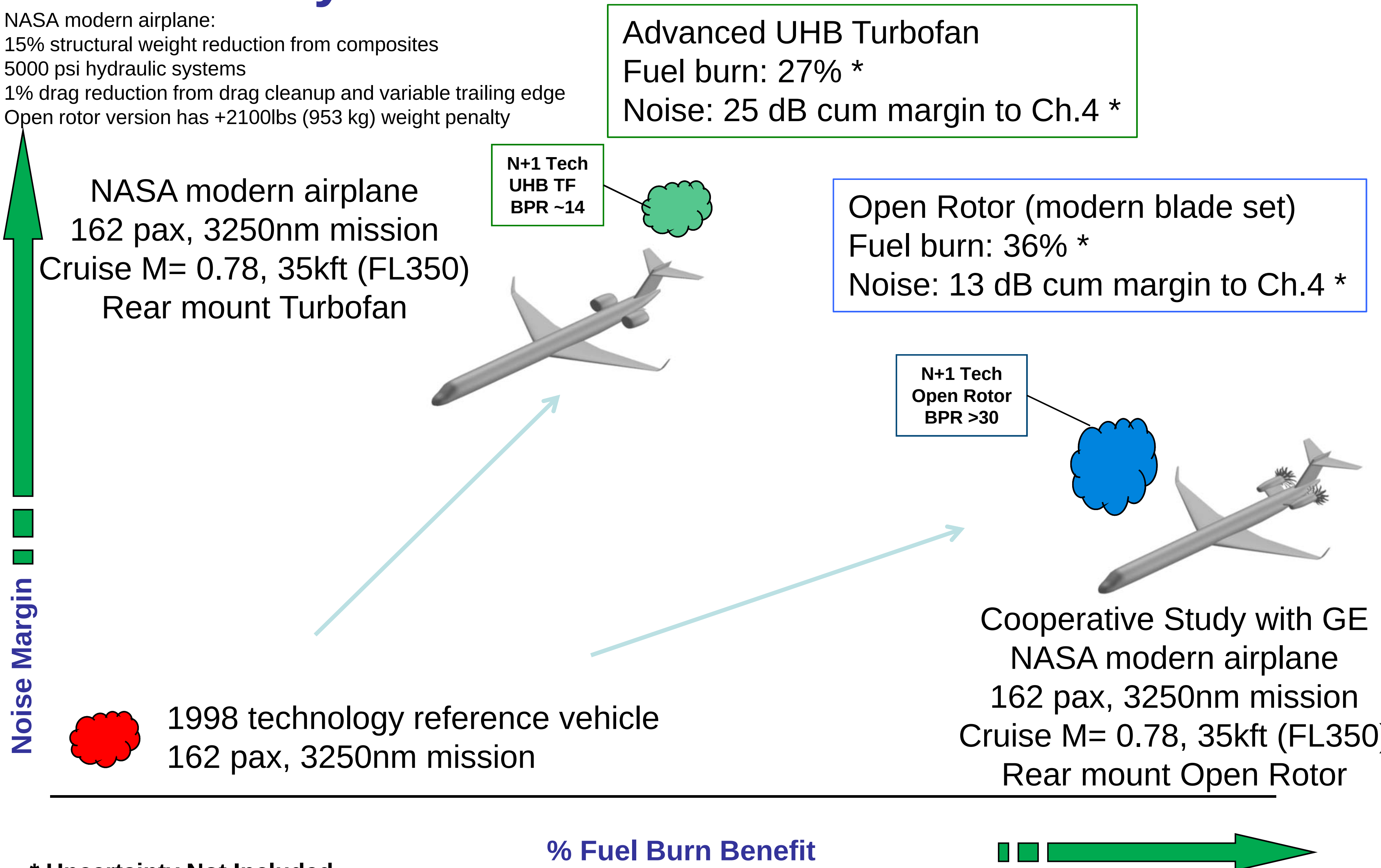
- Environmental Trade-offs (Noise/NO*x*/CO_2) linked to physical principles are key elements for optimization in design and other major areas (e.g. operations, regulations, research).

- Tradeoffs are very challenging to apprehend, due to complex, “remote and entangled” features and evolving issues:
  - Depends on progress in understanding quantitative trade-offs.
  - Would have required in-depth analyses, especially in little explored territory such as novel configurations. Not compatible with tight schedule.

- IEP used best available information from studies and new data to summarize and assess the effects of tradeoffs. Recent studies have been conducted with simultaneous goals for noise, emissions and fuel burn that included tradeoff assessments.

NASA Short Medium Range Twin (SMR2) Study Results – Fuel Burn vs. Noise

NASA modern airplane:
15% structural weight reduction from composites
5000 psi hydraulic systems
1% drag reduction from drag cleanup and variable trailing edge
Open rotor version has +2100lbs (953 kg) weight penalty

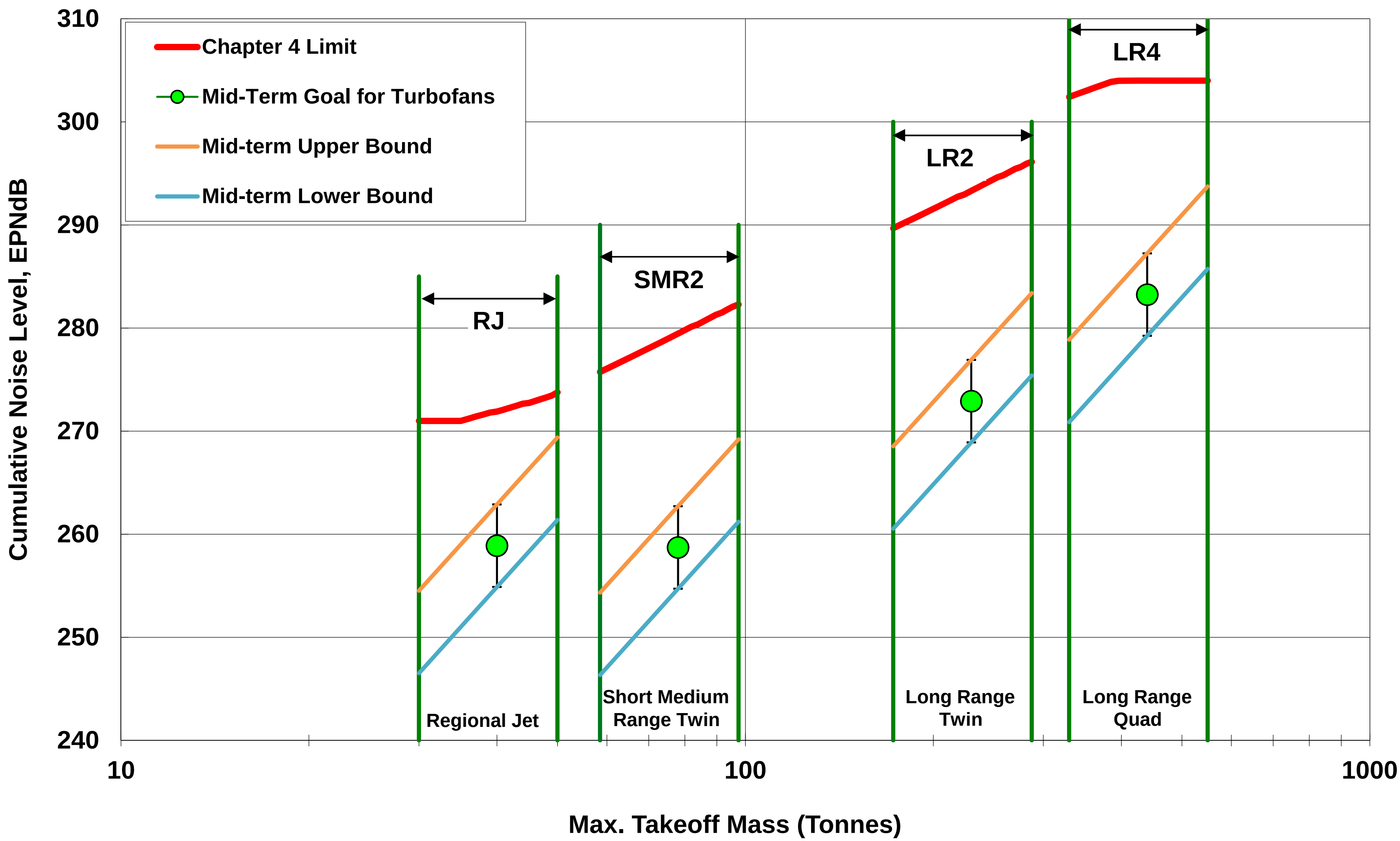


*** Uncertainty Not Included**

Task 4 - Goals

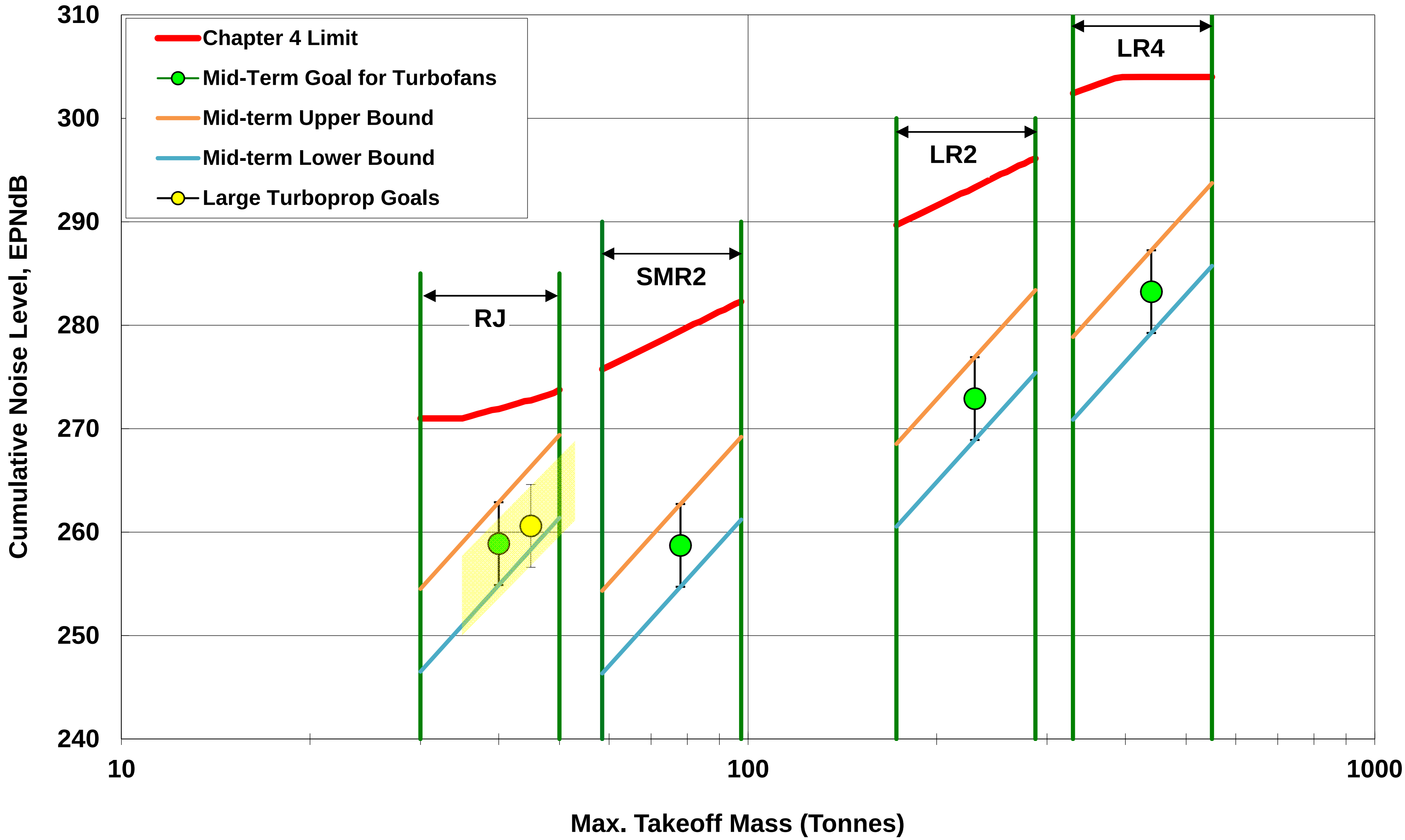
- **Updated Noise Goals**
- **En Route Noise**

Mid Term (2020) Cumulative Noise Goals at TRL 8

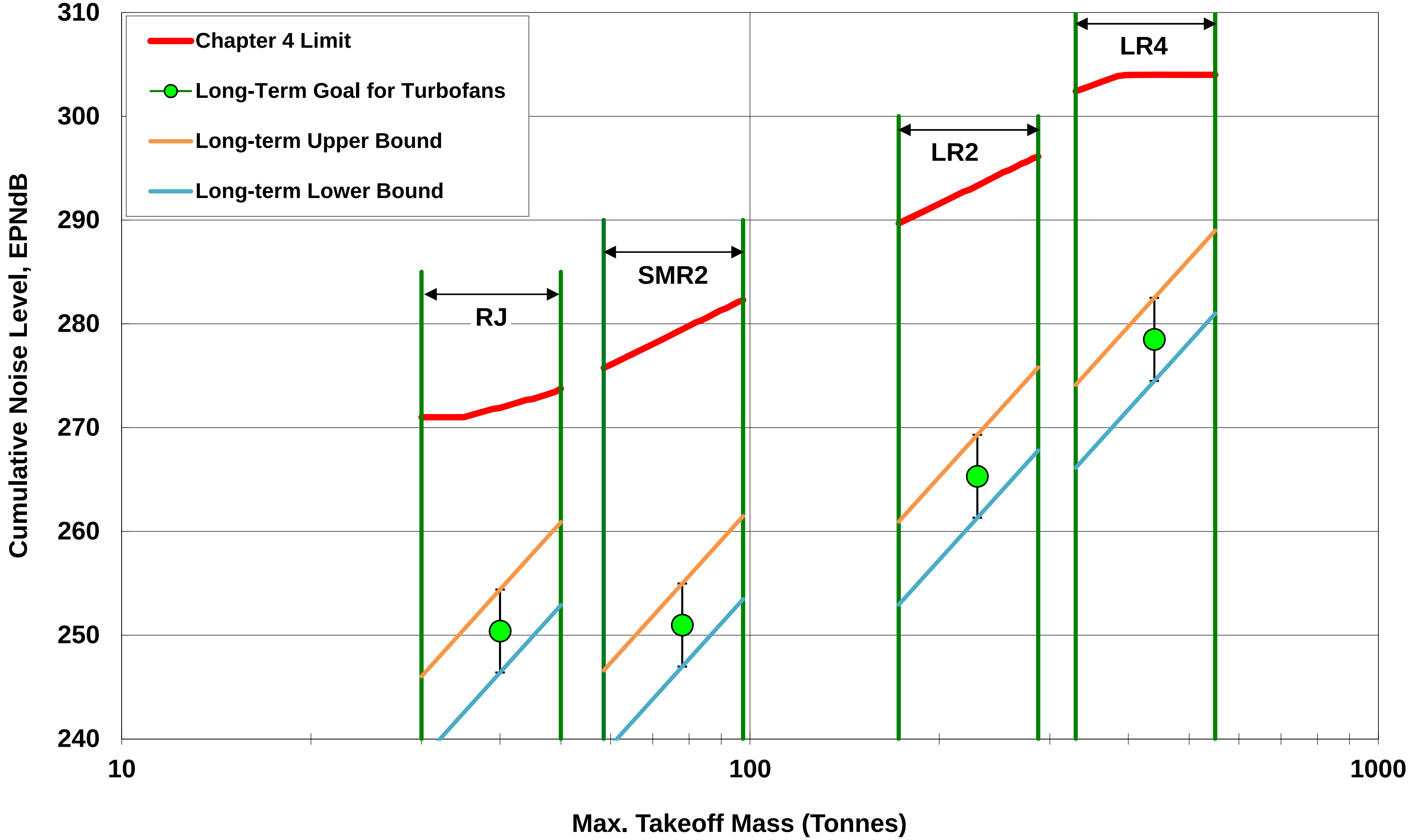


Mid Term (2020) Cumulative Noise Goals at TRL 8

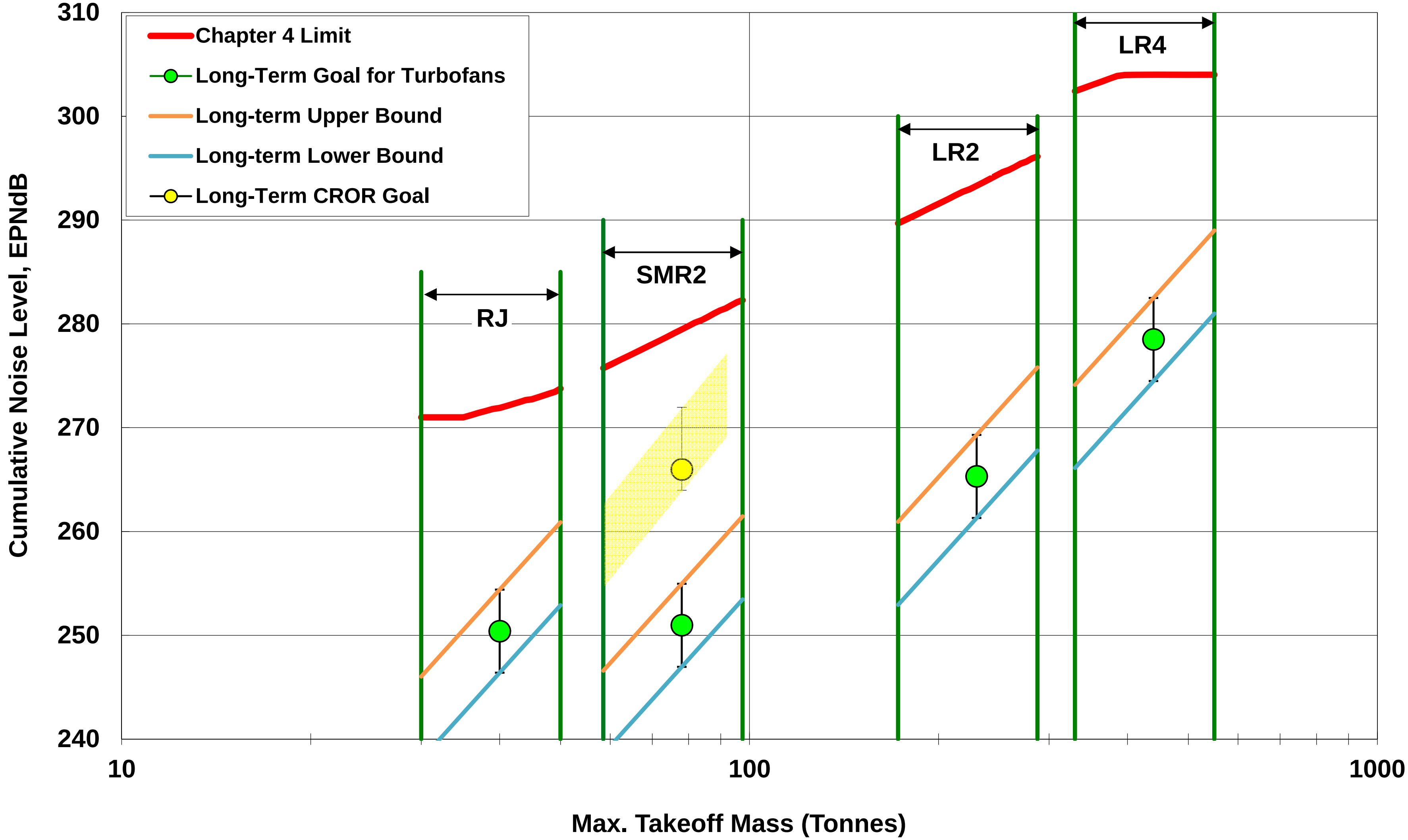
Add Large Turboprops



Long Term (2030) Cumulative Noise Goals at TRL 6
Turbofans Only



Long Term (2030) Cumulative Noise Goals at TRL 6
Add Open Rotor (CROR) for SMR2



Cumulative Noise Margin Goals Relative to Chapter 4, Mid-Term (2020)

Mid-term turbofan goals have not been changed from IEP1 review. Goals have been added for large turboprops. Also, the uncertainty values for noise estimates have been rounded to ±4 EPNdB.

Aircraft Category	BPR Goal	NR TRL6	NR TRL8	Cum Ref	Cum Goal TRL6	Cum Goal TRL8
Regional Jet (RJ)						
40 tonnes (nominal)	7±1	10	9	4	14	13±4
50 tonnes (max)	7±1	10	9	-0.5	9.5	8.5±4
Large Turboprops						
45 tonnes (nominal)	-	9.5	9	3	12.5	12±4
53 tonnes (max)	-	9.5	9	0.5	10	9.5±4
Short Medium Range Twin (SMR2)						
Turbofans: 78 tonnes (nominal)	9±1	17.5	16	5	22.5	21±4
98 tonnes (max)	9±1	17.5	16	1.5	19	17.5±4
CROR: 78 tonnes (nominal)	-	-	-	-	-	-
91 tonnes (max)	-	-	-	-	-	-
Long Range Twin (LR2)						
230 tonnes (nominal)	10±1	16	14.5	6	22	20.5±4
290 tonnes (max)	10±1	16	14.5	2.5	18.5	17±4
Long Range Quad (LR4)						
440 tonnes (nominal)	9±1	17.5	16	5	22.5	21±4
550 tonnes (max)	9±1	17.5	16	-1.5	16	14.5±4

Cumulative Noise Margin Goals Relative to Chapter 4, Long-Term (2030)

Long-term goals have only been updated for SMR2 and LR2. 3 dB increase from the IEP1 review for turbofans is due to BPR increase from 11 to 13. Goals have been added for SMR2 aft mounted CROR.

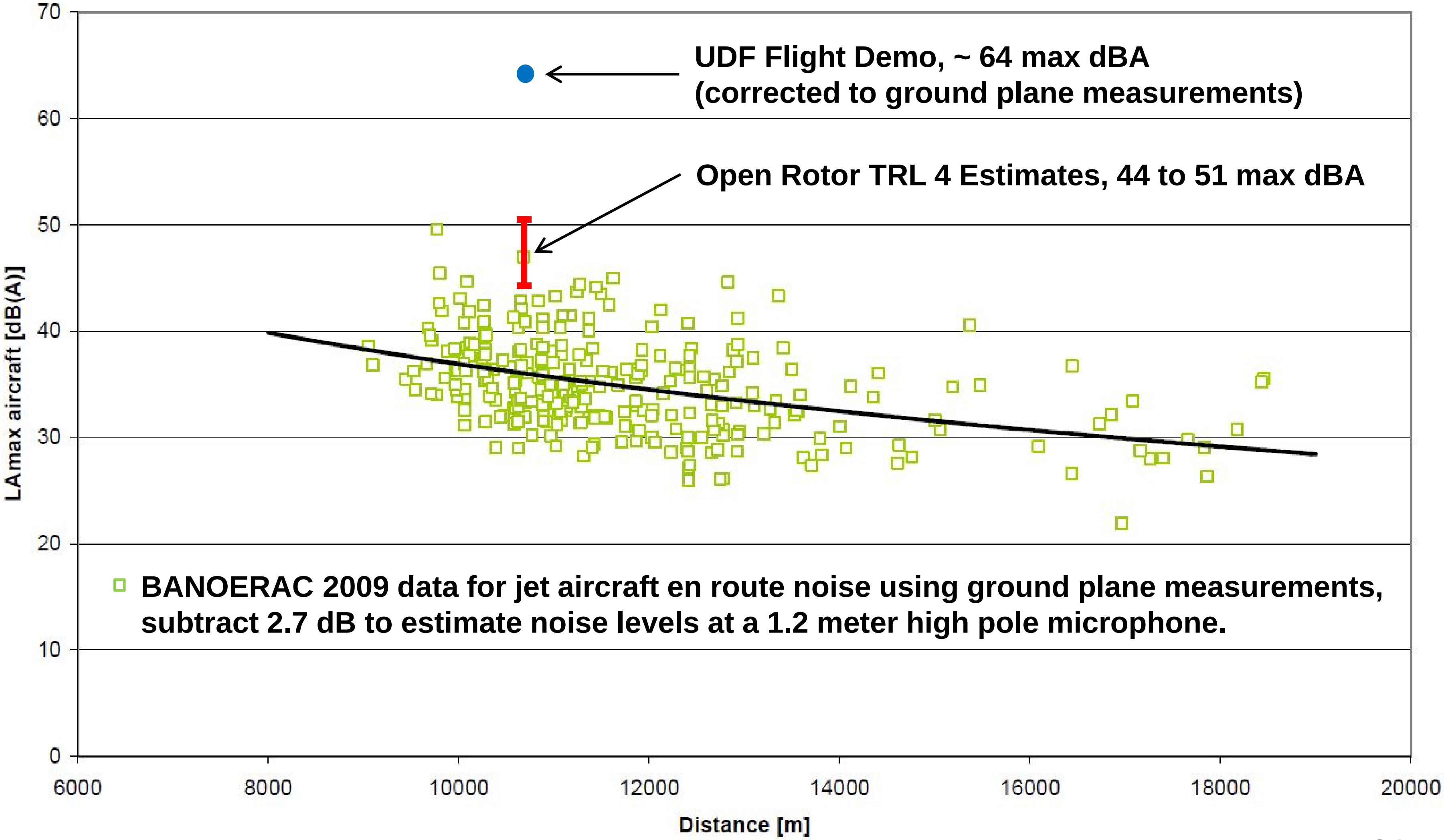
Aircraft Category	BPR Goal	NR TRL6	NR TRL8	Cum Ref	Cum Goal TRL6	Cum Goal TRL8
Regional Jet (RJ)						
40 tonnes (nominal)	9±1	17.5	-	4	21.5±4	-
50 tonnes (max)	9±1	17.5	-	-0.5	17±4	-
Large Turboprops						
45 tonnes (nominal)	-	-	-	-	-	-
53 tonnes (max)	-	-	-	-	-	-
Short Medium Range Twin (SMR2)						
Turbofans: 78 tonnes (nominal)	13±1	25	-	5	30±4	-
98 tonnes (max)	13±1	25	-	1.5	26.5±4	-
CROR: 78 tonnes (nominal)	-	8.5	-	5	* 13.5+2/-6	-
91 tonnes (max)	-	8.5	-	2	** 10.5+2/-6	-
Long Range Twin (LR2)						
230 tonnes (nominal)	13±1	22	-	6	28±4	-
290 tonnes (max)	13±1	22	-	2.5	24.5±4	-
Long Range Quad (LR4)						
440 tonnes (nominal)	11±1	22	-	5	27±4	-
550 tonnes (max)	11±1	22	-	-1.5	20.5±4	-

* CROR cumulative margin with uncertainties range from 7.5 to 15.5 EPNdB for 78 tonne nominal weight aircraft.

** CROR cumulative margin with uncertainties range from 4.5 to 12.5 EPNdB for 91 tonne maximum weight aircraft .

CROR En Route Noise Estimates

Open Rotor ground noise from 35,000 ft. cruise is estimated to be near the upper portion of data scatter from current jet powered aircraft



Conclusions (1/4)

- Reference aircraft and noise levels from IEP1 can be used as reference for IEP2 for Mid-Term (2020) and Long-Term (2030) goals.

- Novel aircraft concept studies are available that have considered environmental efficiencies and economic tradeoffs during conceptual design, and offer a balanced approach to reducing noise, emissions and fuel burn.

- IEP2 expects TSN-1 to prevail over the more aggressive TSN-2 (technology scenarios for noise). TSN-2 is feasible with increased resource investments and could provide additional noise reduction by 2030. The MIT "Double Bubble D8" concept aircraft is a good example.

Conclusions (2/4)

- Novel aircraft concepts may enable steeper approach glide slopes and significant noise reduction.
- Noise reduction technologies have been updated from the IEP1 review and were applied to novel aircraft.
- The Realization Factor (RF) used by IEP1 cannot be applied to novel aircraft concepts that have not been developed and tested beyond TRL6.
- IEP2 pilot studies indicate alternative noise correlations for turbofans are possible based on specific thrust and other overall aircraft parameters. This approach helps predict aircraft noise levels with higher BPR engines where previous correlations are less reliable.
- Novel aircraft can be developed by 2030 in SMR2/LR2 categories using Ultra High Bypass (UHB) engines. Examples of engines include counter-rotating open rotors (CROR) and geared turbofans (GTF).

Conclusions (3/4)

- Wing mounted (tractor) Open Rotors are expected to be about 6 EPNdB cum louder than aft mounted pusher configurations.
- A skewed uncertainty distribution is recommended for CROR.
- En route noise from CROR aircraft with modern technologies cruising at 35,000 feet is expected to be significantly quieter than Un-Ducted Fan (UDF) flight tests from the 1980's.
  - i) Projections using TRL4 wind tunnel data predict ground noise levels to be 13 to 20 dBA quieter.
  - ii) Comparisons with 2009 background noise measurements in Europe show the CROR flyover noise levels would be near the upper band of the turbofan noise levels.
  - iii) Ongoing research in Europe on Open Rotor en route noise not yet available.

Conclusions (4/4)

Noise Goals for Short-Medium Range Twins and Large Turboprops

- SMR2 CROR (pusher): TRL6 long-term cum noise goal under Chapter 4:

  13.5 +2/-6 EPNdB (7.5 to 15.5) for nominal weight, 78 tonne aircraft

  10.5 +2/-6 EPNdB (4.5 to 12.5) for maximum weight, 91 tonne aircraft

- SMR2 UHB Turbofans:TRL6 long-term cum noise goal under Chapter 4:

  30.0 ±4 EPNdB (26 to 34) for nominal weight, 78 tonne aircraft

  26.5 ±4 EPNdB (22.5 to 30.5) for maximum weight, 98 tonne aircraft

- Large Turboprops: TRL8 mid-term cum noise goal under Chapter 4:

  12.0 ±4 EPNdB (8 to 16) for nominal weight, 45 tonne aircraft

  9.5 ±4 EPNdB (5.5 to 13.5) for maximum weight, 53 tonne aircraft

Final report and acknowledgements

Destination Green

The final report for this work is available from ICAO: Noise Technology Independent Expert Panel (IEP2); Working Group 1 (Noise Technical); CAEP/9-WP/16; November 30, 2012.

2nd CAEP Noise Technology
Independent Experts
Goals Review

The IEP2 is grateful for the work done by organizations supporting independent studies for advanced aircraft. The following people were instrumental to the success of this work:

Jeff Berton, NASA Glenn
Casey Burley, NASA Langley
Elena De La Rosa Blanco, FAA Contractor
Mark Guynn, NASA Langley
William Haller, NASA Glenn
Eric Hendricks, NASA Glenn
Doug Nark, NASA Langley
David Stephens, NASA Glenn
Mike Tong, NASA Glenn
Dale Van Zante, NASA Glenn