PARE

PERSPECTIVES FOR AERONAUTICAL RESEARCH IN EUROPE

Future Aircraft Design and Noise Impact
22nd Workshop of the Aeroacoustics Specialists Committee of the CEAS

PARE preliminary analysis of ACARE Challenge 3 environmental impact goals (towards quiter and cleaner environment in aviation sector)

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PARE - Perspectives for the Aeronautical Research in Europe

PARE' Concept

- Assess the rate of progress relative to the 23 Flightpath 2050 goals and those which need greater support, as well as make recommendations relevant to achieve those goals;
- Compare with the progress outside the EU to assess the competitive/collaborative status;
- To identify and foster the participation of aviation and aviation-related stakeholders in EU research and innovation activities considering, among other aspects, the potential for further contributions from the acceding, candidate and associated countries;
- Include technologies outside the aeronautical sector that could have benefit in aeronautics;
- Focus on the significant potential to increase the participation of women, not only increasing the number of engineers but also bringing additional complementary skills.

PARE

List of participants

#	Participant Legal Name	Country
1	INSTITUTO SUPERIOR TECNICO	Portugal
2	INOVAMAIS - SERVICOS DE CONSULTADORIA EM INOVACAO TECNOLOGICA S.A	Portugal
3	ZAPOROZHYE MACHINE-BUILDING DESIGN BUREAU PROGRESS STATE ENTERPRISE NAMED AFTER ACADEMICIAN A.G. IVCHENKO	Ukraine
4	AIRBUS DEFENCE AND SPACE SAS	France
5	UNIVERSIDAD POLITECNICA DE MADRID	Spain
6	VARTA MICRO INNOVATION GMBH	Austria
7	UNIVERSITATEA POLITEHNICA DIN BUCURESTI	Romania
8	NATIONAL AVIATION UNIVERSITY	Ukraine
9	FerroNATS Air Traffic Services S.A.	Spain
10	INNPULS SPOLKA Z OGRANICZONA ODPOWIEDZIALNOSCIA	Poland
11	UNIVERSITA DEGLI STUDI DI SALERNO	Italy
12	Izmir Katip Celebi Universitesi	Turkey
13	Quasar Human Capital, Unipessoal Lda	Portugal
14	VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS VIESOJI ISTAIGA	Lithuania
15	SATA Internacional	Portugal

Key challenges of a strategic research and innovation agenda *Flightpath 2050*

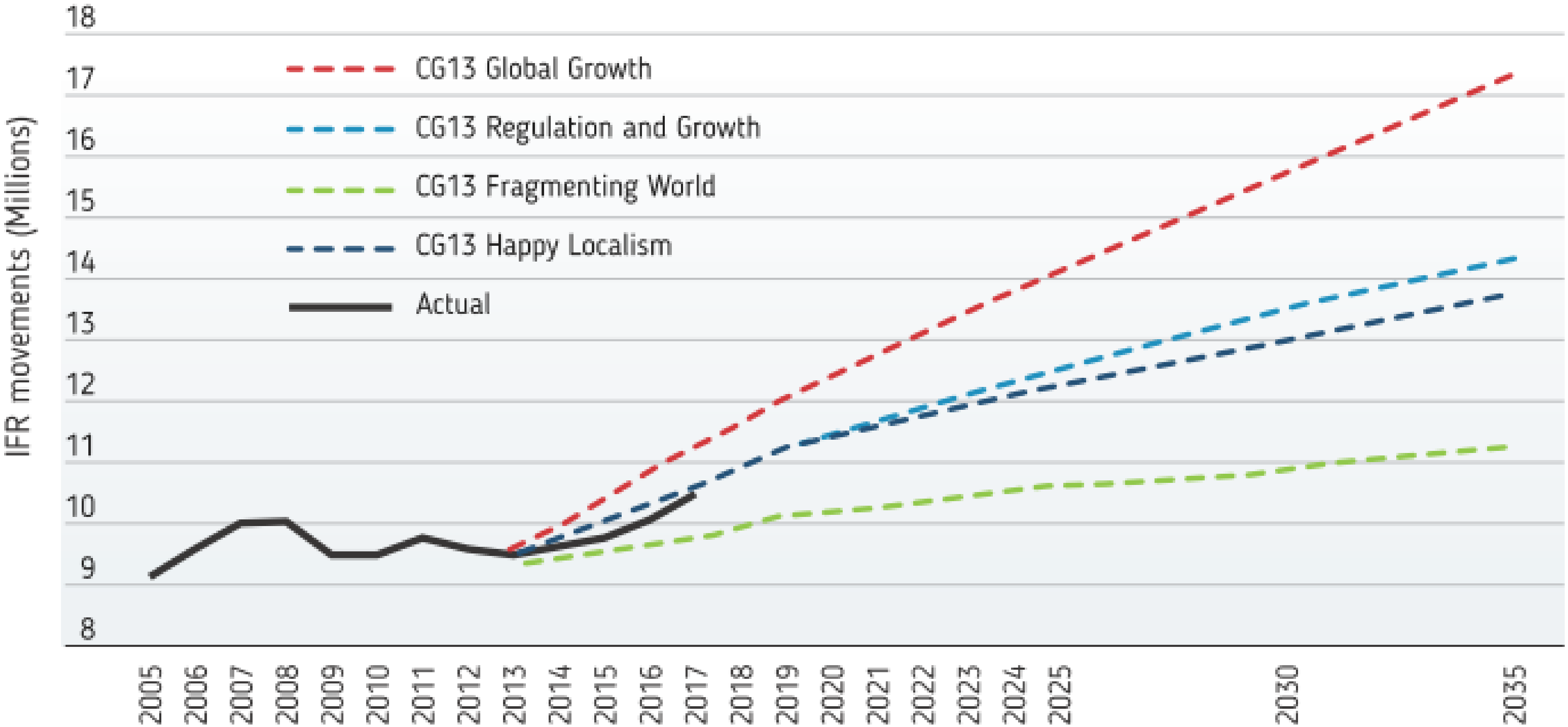
Comparison of long-term goals for environmental impact factors of aviation between ICAO Policy, EU and USA Research and Development agenda

Environmental impact factor from aviation	**ICAO Policy Goals** (A39-Resolutions)	**EU ACARE Goals 9** (*FP2050* till 2050)	**US FAA and NASA Goals** (*NSTC2010* and *CLEEN II* till 2035)
Noise	***Limit or reduce the number of people affected*** *by significant aircraft noise*	**perceived noise emission** of flying aircraft ***is reduced by 65%***	***52 dB reduction*** relative to cumulative margin of ICAO/FAA Stage 4 noise limit (a 25-year goal, by enabling N+3 aircraft and engines)
NO_x emissions	***Limit or reduce the impact of aviation emissions*** *on local air quality*	***90% reduction*** in NO_x emissions	**80%** ***reduction*** in NO_x emissions (for cruise relative to 2005 best in class and for LTO relative to ICAO CAEP/6 standard)
Greenhouse gas emissions and fuel/energy consumption	***Limit or reduce the impact of aviation greenhouse gas emissions*** *on the global climate*: a ***reduction in net aviation CO_2 emissions of 50%*** by 2050, relative to 2005 levels	***75% reduction in CO_2 emissions*** per passenger kilometre	***60% reduction in Aircraft Fuel/Energy Consumption*** (*CO_2 emissions per passenger kilometre?*) relative to 2000 best in class

The goals and action areas for *Challenge 3* of the ACARE perspectives

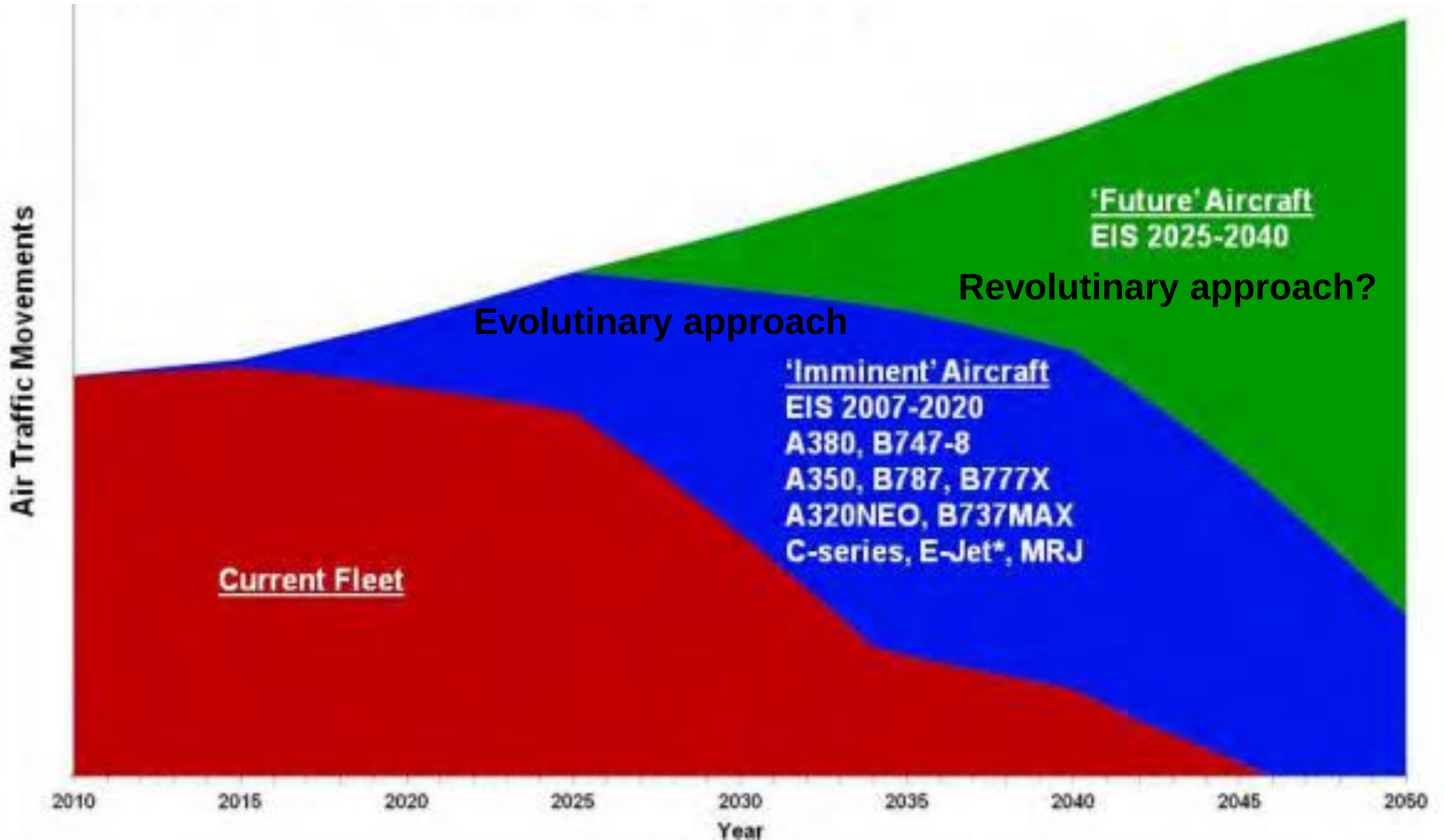
In principle for ***Goal 9*** the **vehicle design improvements** are considered mostly (plus biofuels)

Flight traffic scenario in EU till 2050
(Eurocontrol 2018 analysis)

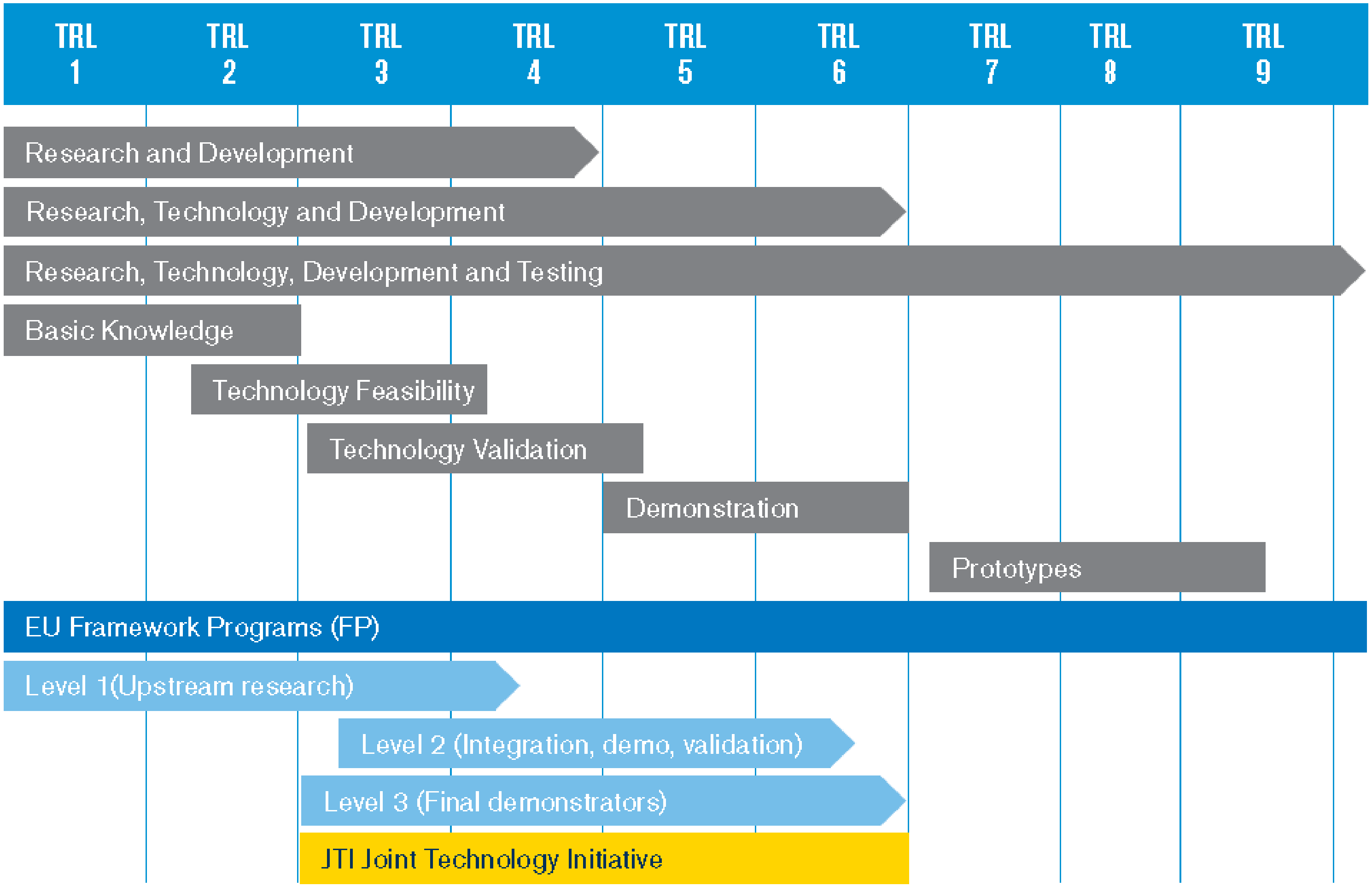


- In 2017, strong growth saw traffic back on the most-likely scenario from the 2013 forecast of Eurocontrol

Predictions of fleet transition from current aircraft to imminent/future aircraft 2010-2050

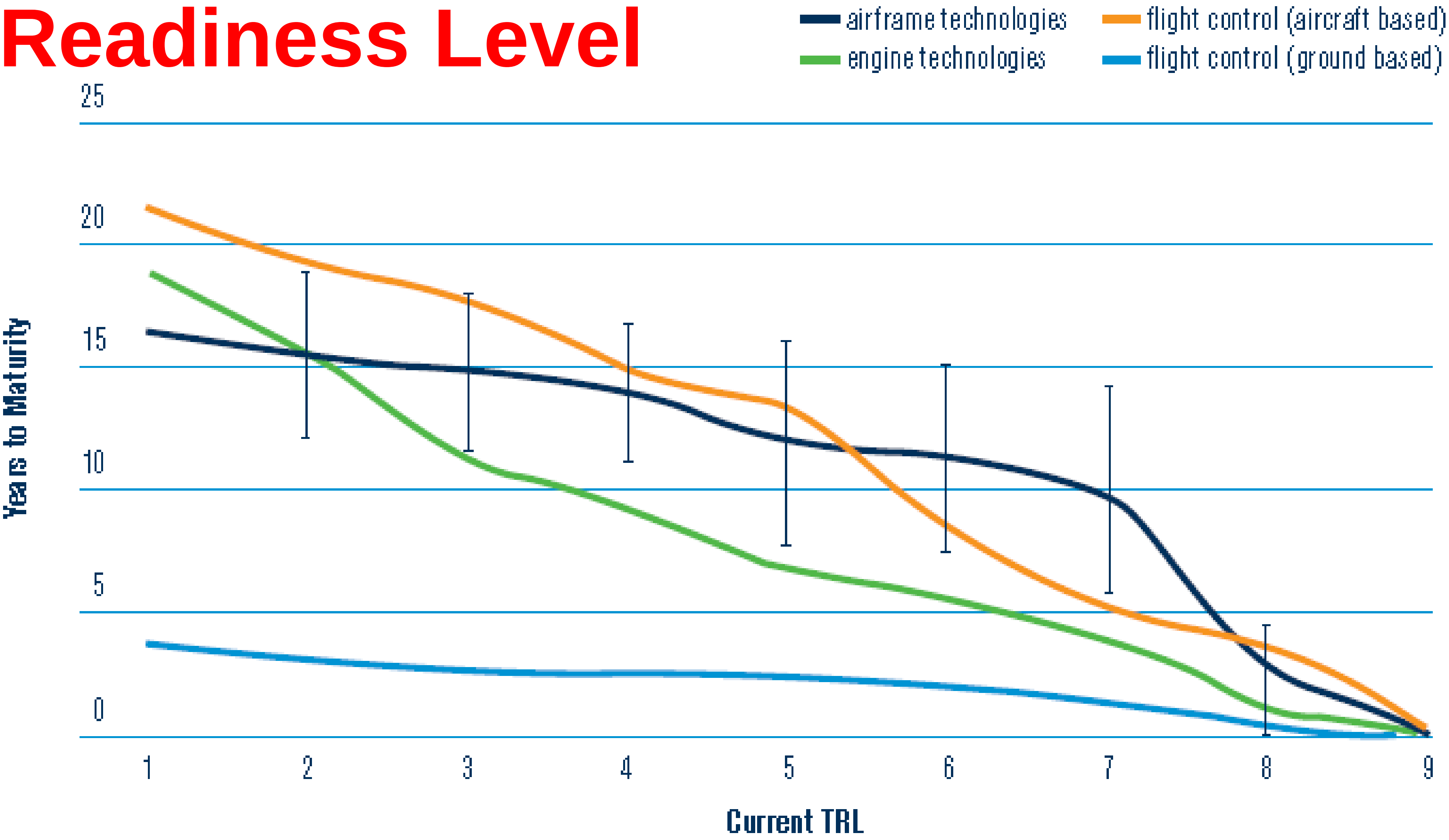


The EU Framework Program, with its three levels and the intended research objective



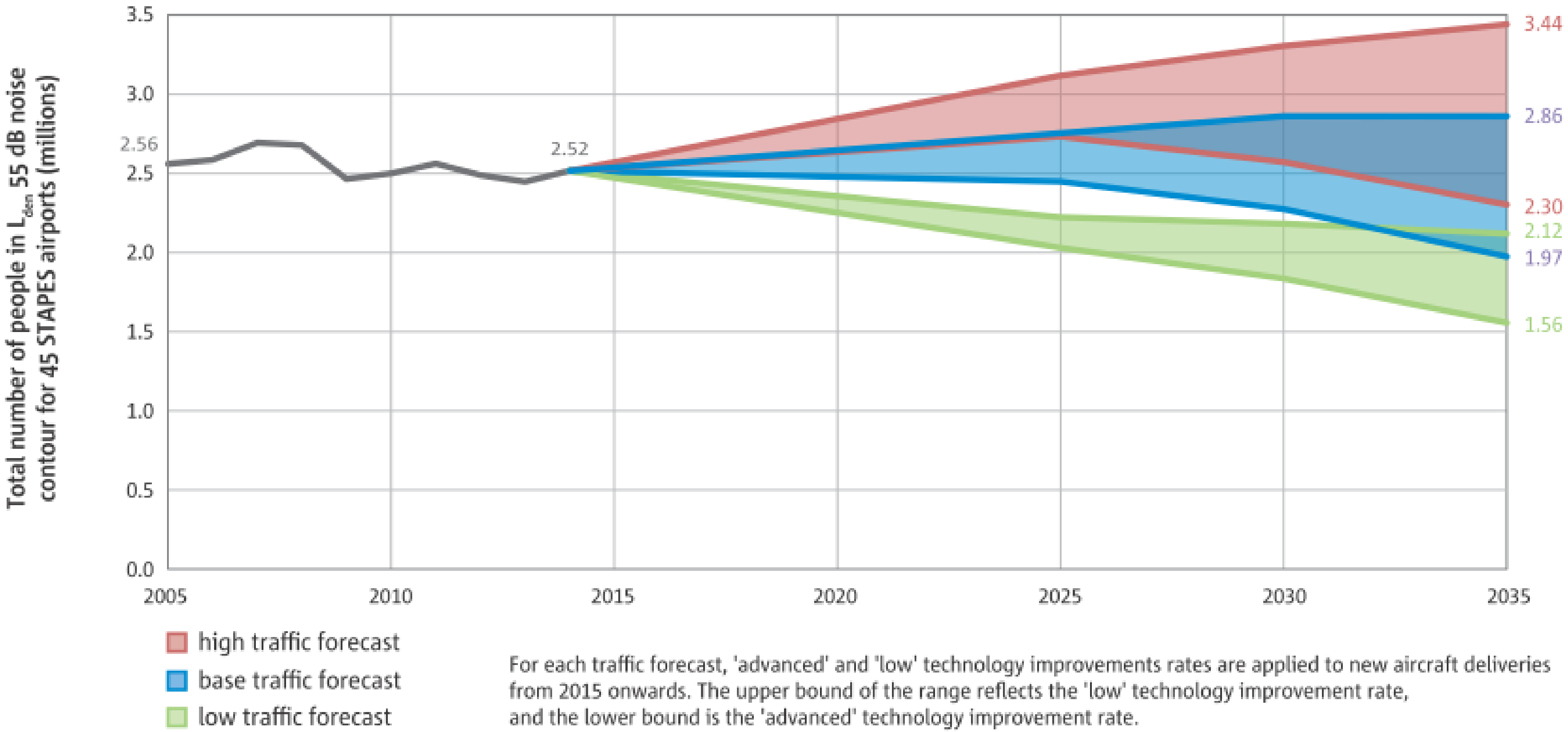
- TRL scale was introduced into the EU funded projects arena in 2014 as part of the Horizon 2020 framework program

Maturation Timeline for Technology Readiness Level



[IATA Technology Roadmap, 4th Edition, June 2013, IATA Technology Roadmap, 4th Edition, June 2013]

Future technology improvements could stabilize overall aircraft noise exposure in the 2035 timeframe

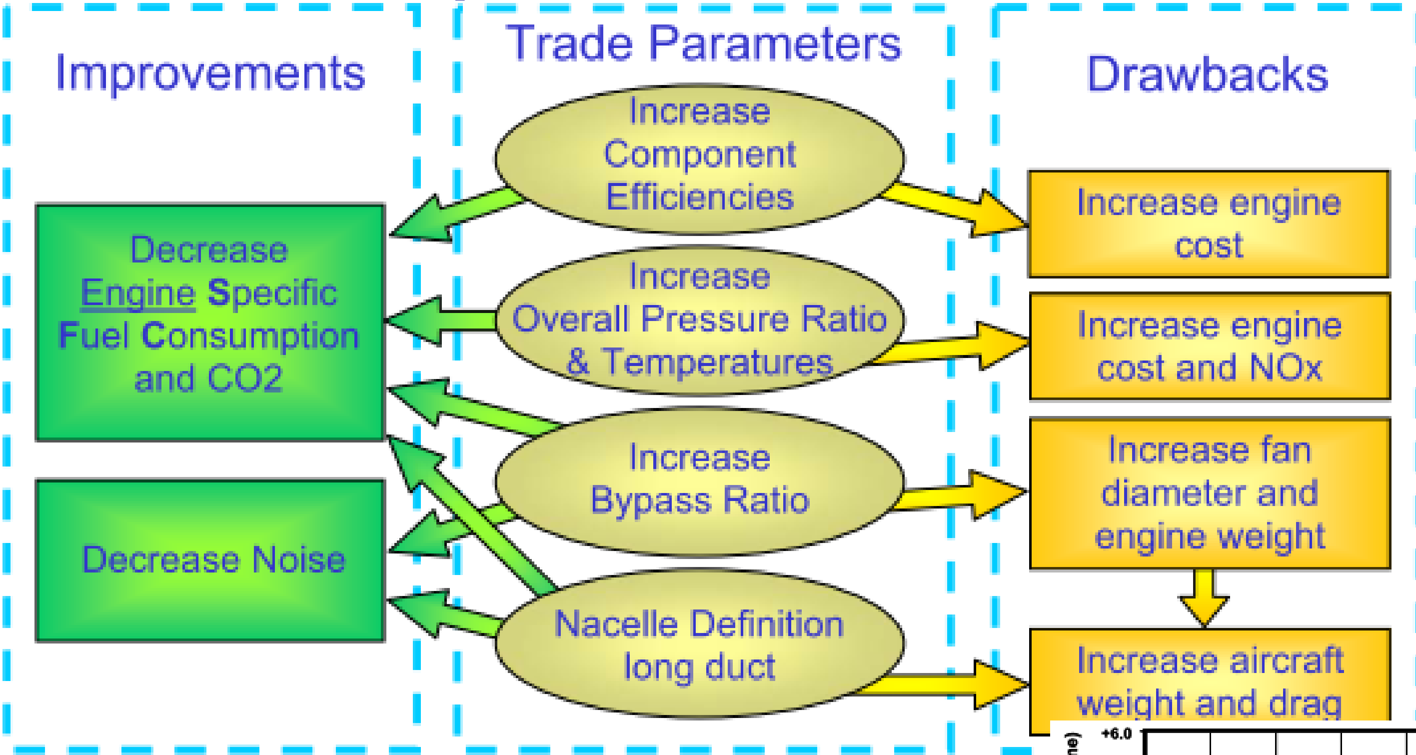


CAEP IEP2 Aircraft Noise Goals for short-medium (2020) and long (2030) term

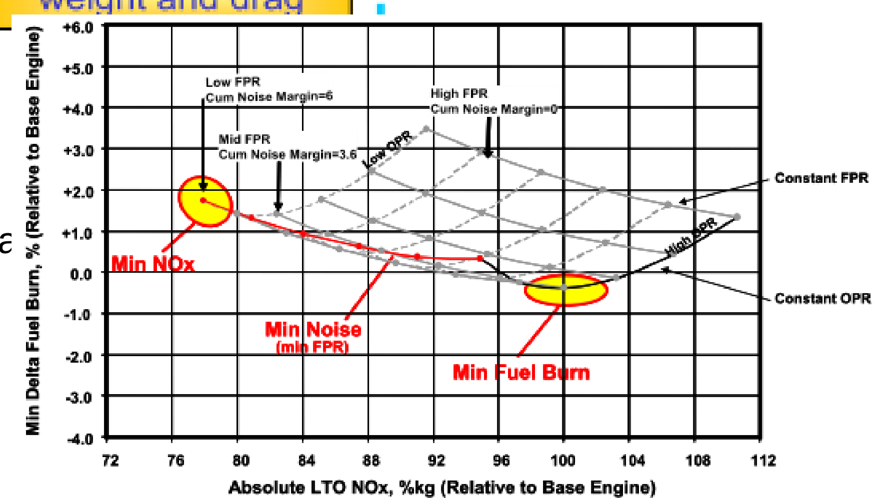
Aircraft type	Reference		Mid Term Goal (2020) TRL6			Long term goal (2030) TRL6		
	cumulative margin (EPNdB) v chapter 4	Bypass ratio	cumulative margin (EPNdB) v chapter 4	reduction EPNdB: Total (BPR,NRT)	Bypass ratio	cumulative margin (EPNdB) v chapter 4	reduction EPNdB: Total (BPR,NRT)	Bypass ratio
Regional jet	4	5.0	14	10.0 (6.0 ,4.0)	7 ± 1	21.5±4.0	17.5 (12.0, 5.5)	9 ± 1
Small-medium range (turbofan)	5	5.0	22.5	17.5(12.0, 5.5)	9 ± 1	30.0 ±4.0	25.0(18.0 , 7.0)	13 ± 1
Small-medium range (CROR)	5	–	–	–	–	7.5 → 15.5	8.5	–
Long range twin (Turbofan)	6	6.0	22	16.0 (10.5, 5.5)	10 ± 1	28.0 ±4.0	22.0 (15.0, 7.0)	13 ± 1
Long range quad (Turbofan)	5	5.0	22.5	17.5 (12.0, 5.5)	9 ± 1	27.0 ±4.0	22.0 (15.0, 7.0)	11 ± 1

- The CAEP Panel had previously concluded that the two primary paths to aircraft noise reduction were increasing Bypass Ratio (BPR) of the propulsion system cycle, and component noise reduction technologies (NRT).

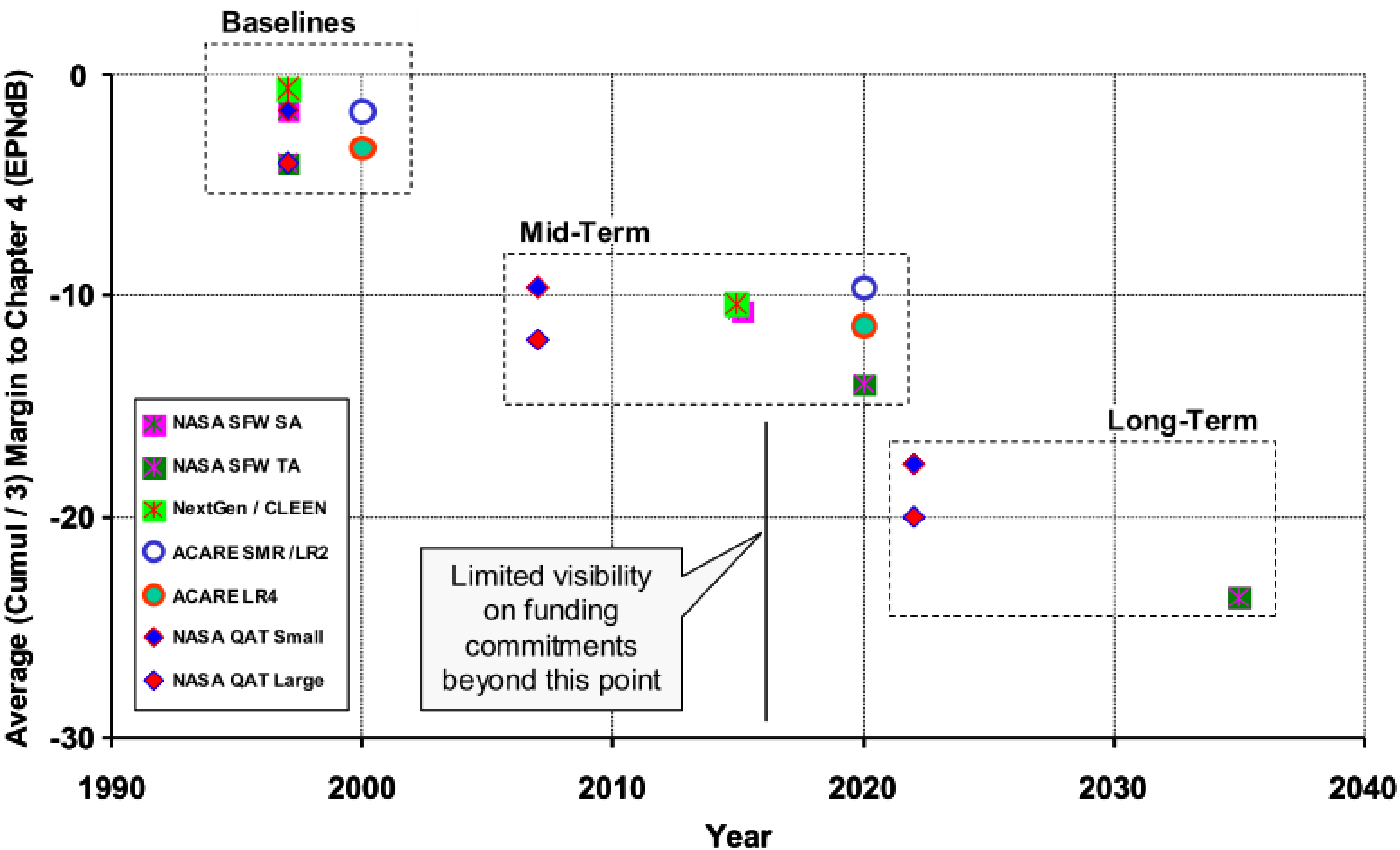
BPR beyond the demonstrated level of 9 (Environmental trade-offs)



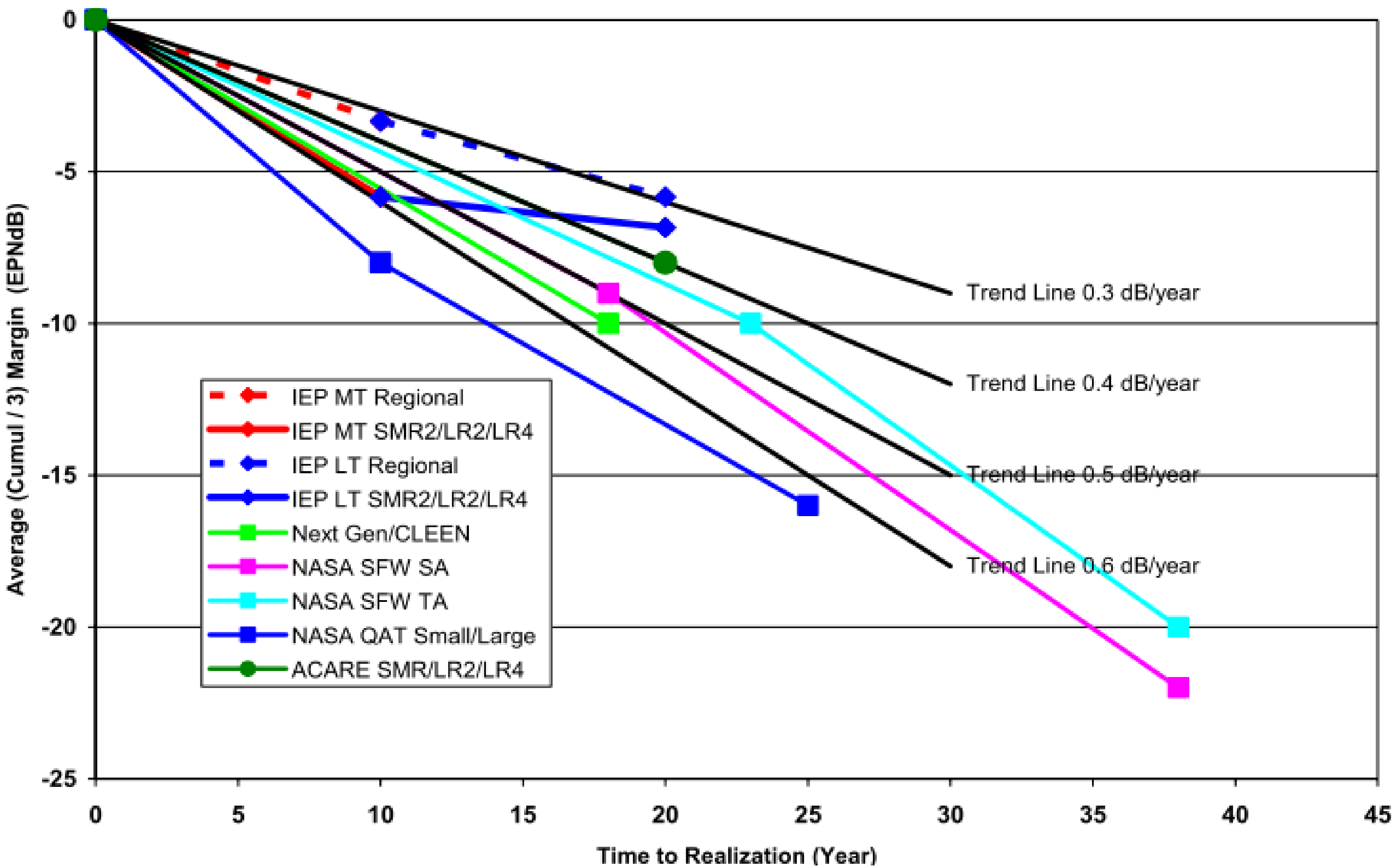
- Nacelle weight and drag as fan diameter increases
- Engine-out drag and consequent effect on tail control surfa
- Landing gear length for nacelle ground clearance
- Core size limitations and auxiliary bleed requirements
- Fan stall and stability control during extreme shifts in operating line from sea level to cruise.



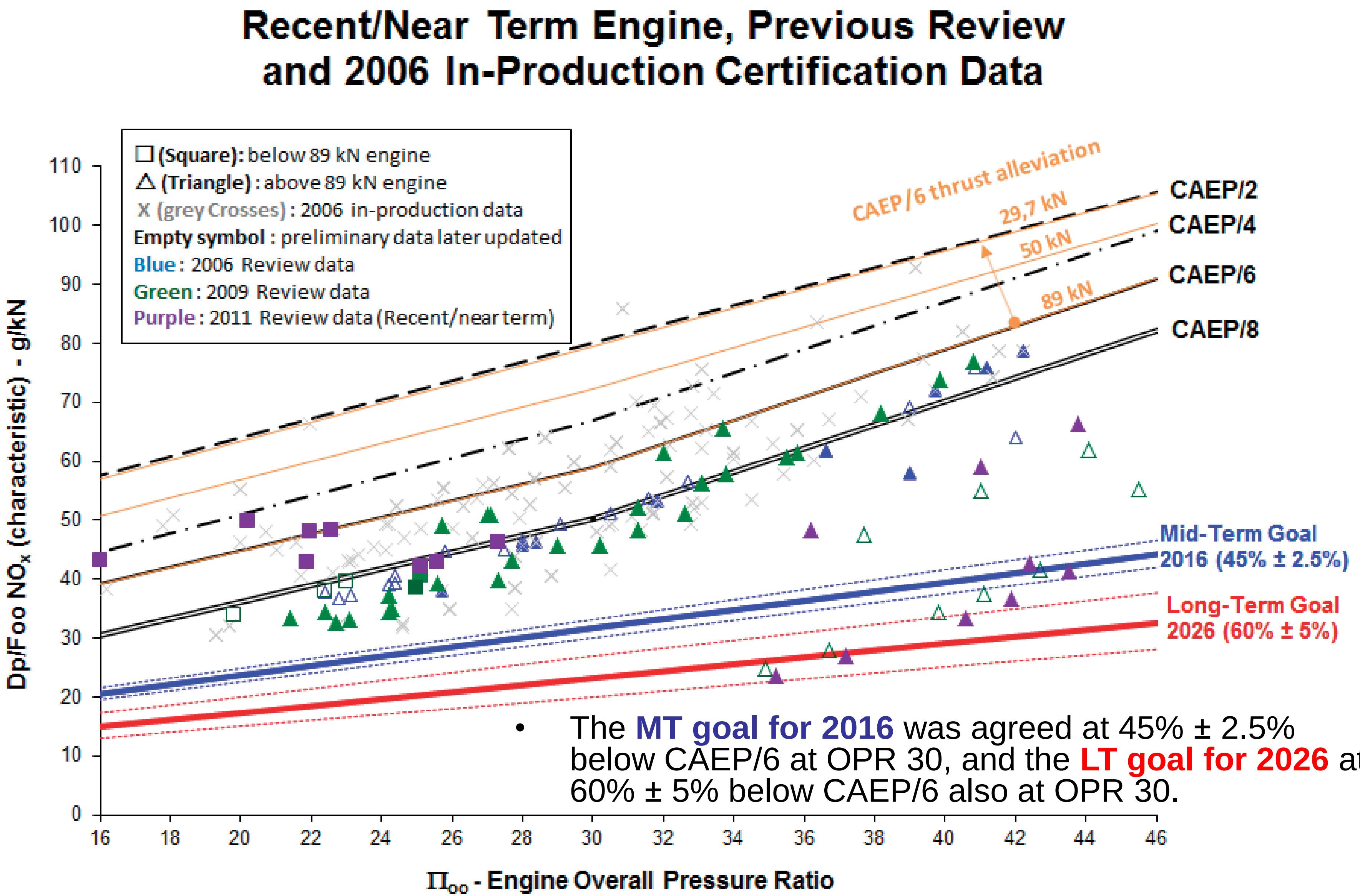
Comparison of US and EU research goals



IEP2 predicted noise reduction target versus US and EU research goals

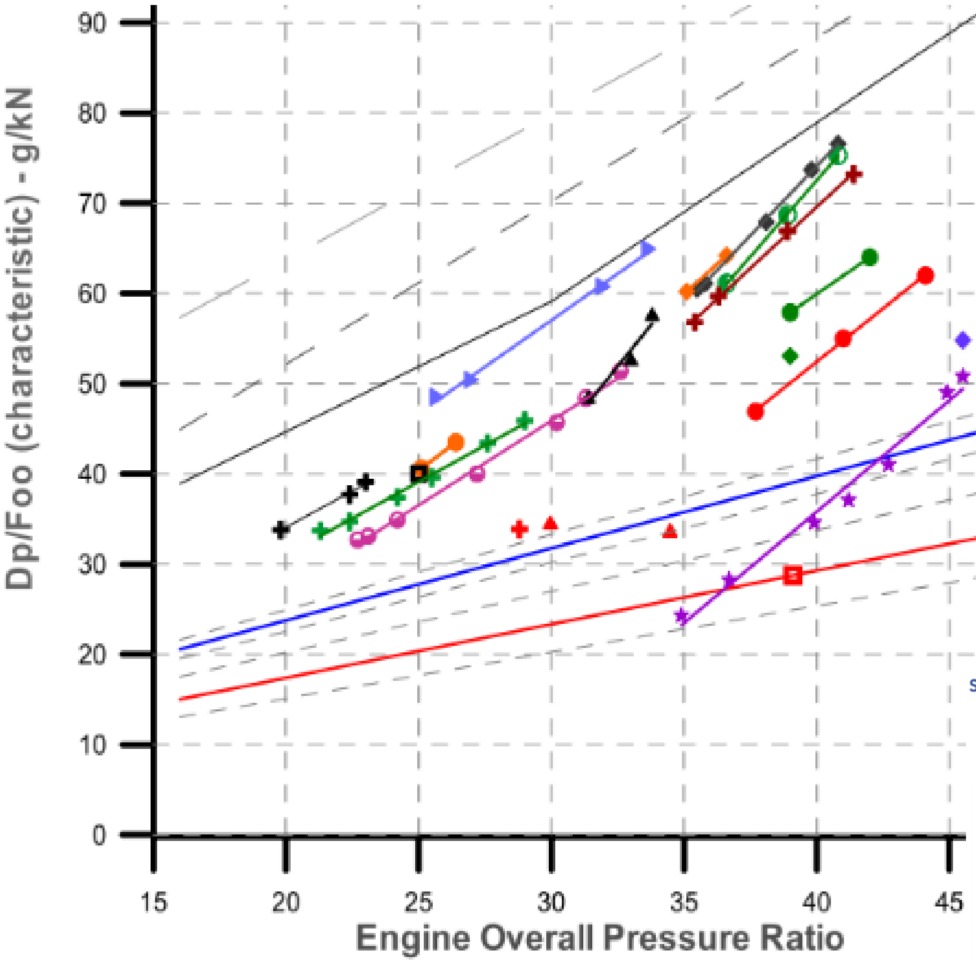


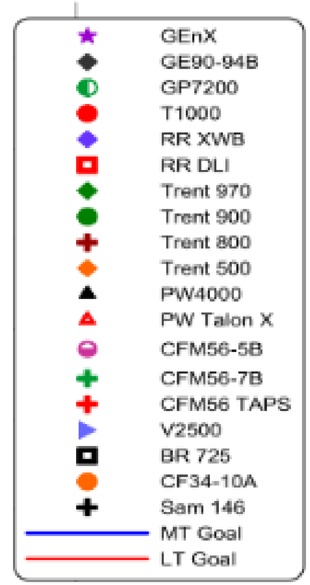
NO_x: ICAO certification standards via the 2016 MT & 2026 LT goals



- The **MT goal for 2016** was agreed at 45% ± 2.5% below CAEP/6 at OPR 30, and the **LT goal for 2026** at 60% ± 5% below CAEP/6 also at OPR 30.

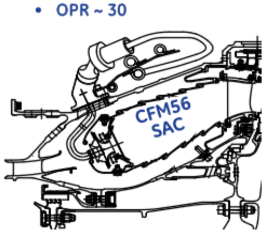
2009 Review data with RQL (rich-quench-lean concept) combustors in grey and new mid-OPR engines.



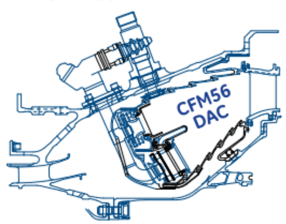


Generation staged DLI

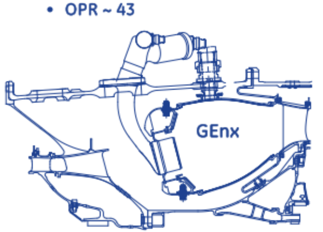
Single Annular Combustor (SAC)
- Rich burning (tech insertion)
- No staging
- 75% of CAEP/6 NOx
- OPR ~ 30



Double Annular Combustor (DAC)
- Lean burning
- Radial & circumferential staging
- 65% of CAEP/6 NOx
- OPR ~ 30



Twin Annular Premixing Swirler (TAPS I)
- Lean burning
- Staging within swirler
- 50% of CAEP/6 NOx
- OPR ~ 43



GE TAPS combustors

Lower NOx

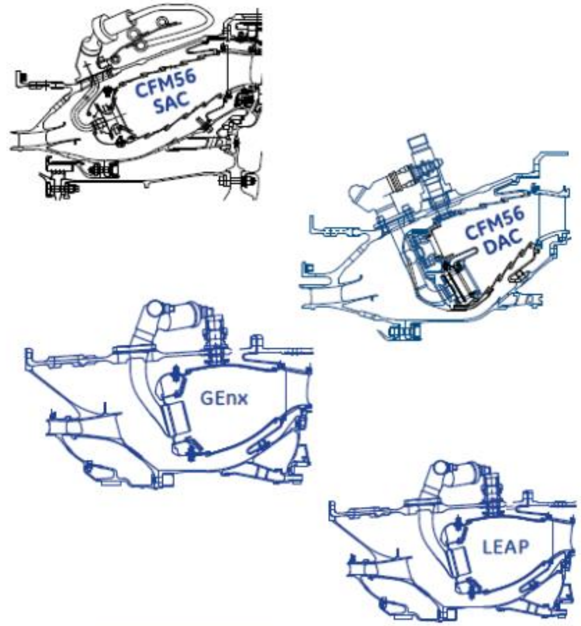
Single Annular Combustor (SAC)
- Rich burning (tech insertion)
- No staging
- 75% of CAEP/6 NOx
- OPR ~ 30

Double Annular Combustor (DAC)
- Lean burning
- Radial & circumferential staging
- 65% of CAEP/6 NOx
- OPR ~ 30

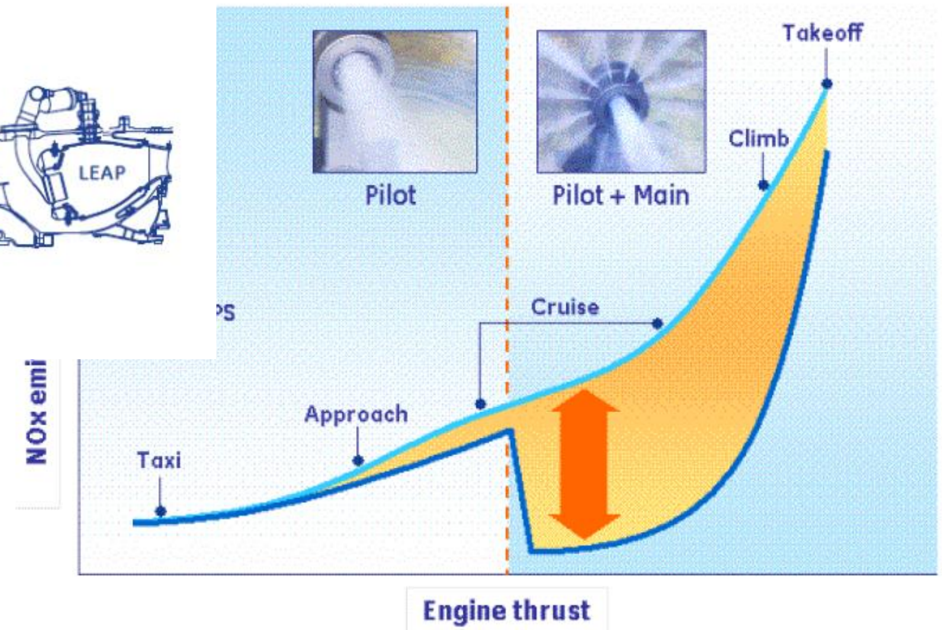
Twin Annular Premixing Swirler (TAPS I)
- Lean burning
- Staging within swirler
- 50% of CAEP/6 NOx
- OPR ~ 43

TAPS II (FAA CLEEN, NASA N+1)
- Lean burning
- 40% of CAEP/6 NOx
- OPR ~ 40

NASA N+2 (TAPS)
- Lean burning
- 25% of CAEP/6 NOx
- 45+ OPR



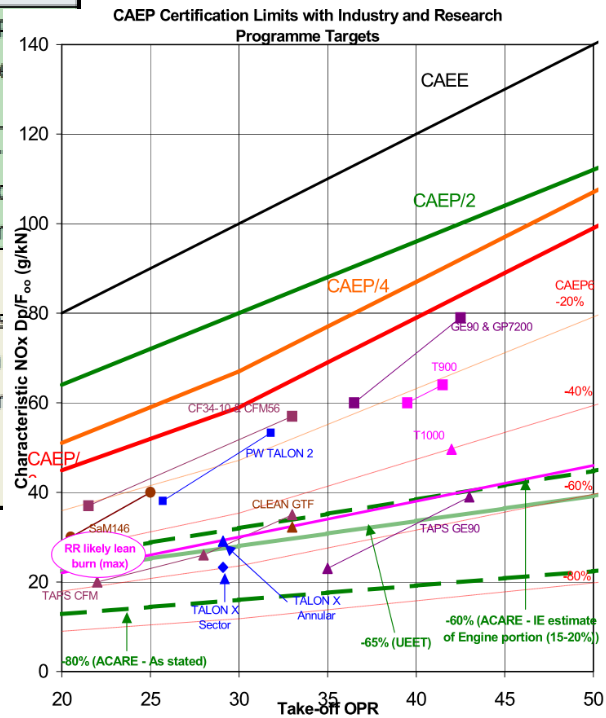
Scalable technologies



- Controlling temperature with Lean-Burn is key to minimizing NOx: the TAPS combustor will provide even more significant reductions as shown in Figure during high altitude climb and cruise conditions, where approximately 90% of NOx emissions are emitted.

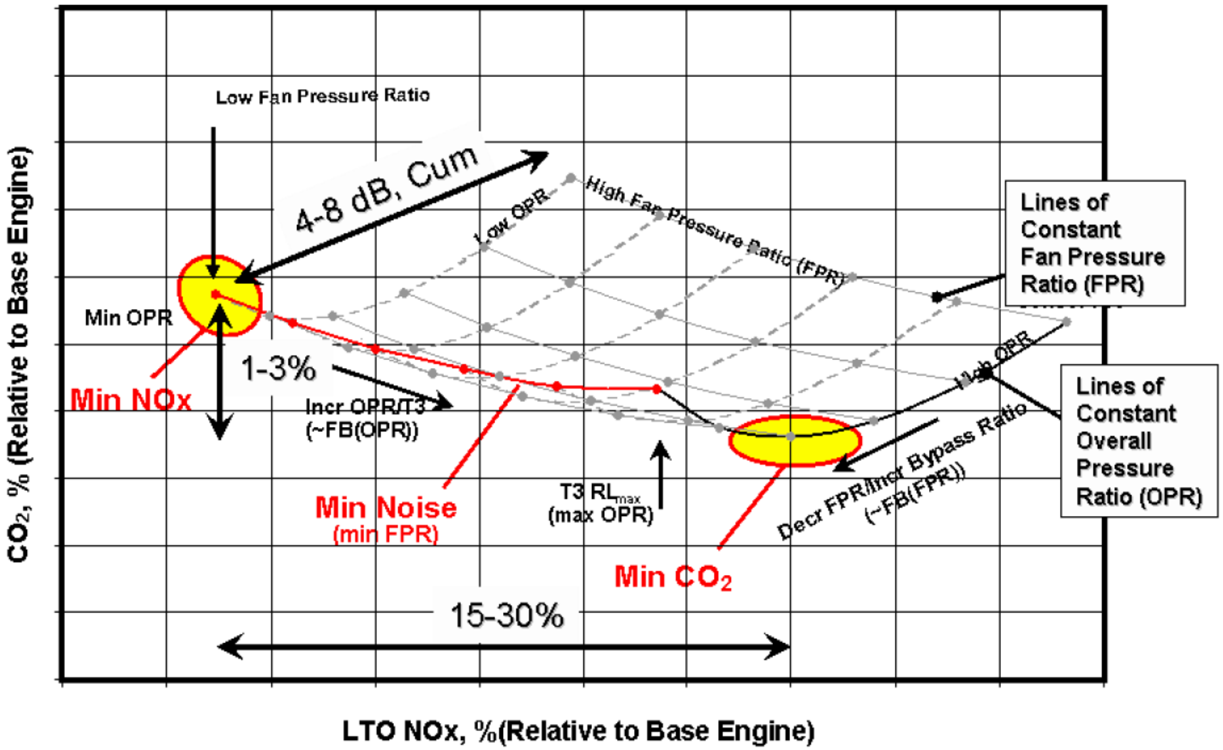
FORUM-AE assessment against ACARE emissions goals

	Reference 2000	ACARE 2020 Goals (at TRL6)		ACARE 2050 Goals (at TRL6)	
		High Level	detailed (SRA)	High Level	detailed (SRIA)
CO2	*Representative technology of aircraft & engine with 2000 EIS, & representative 2000 ATM*	"-50% per pass km"	aircraft: -20% to -25% engine: -15% to -20% ATM: -5% to -10%	"-75% per pass km"	aircraft & engine: -68% ATM: -12% Other: -12%
NOx (LTO)		"-80%"	engine: -60% CAEP6 ; complement achieved by aircraft + ATM	"-90%"	engine: -75% CAEP complement achieve aircraft + ATM
NOx (Cruise)		"-80%"	Achieved through -50% Fuel Burn & -60% cruise EINOx reduction	"-90%"	Achieved through - Fuel Burn & further EINOx reductio
Other emissions		"damaging emissions reduced"	emissions qualitatively reduced (particles, CO, UHC) and better understanding of impacts	"emissions-free taxiing" + qualitative reduction	knowlegde of emiss (particles, VOC) a better understandi impacts



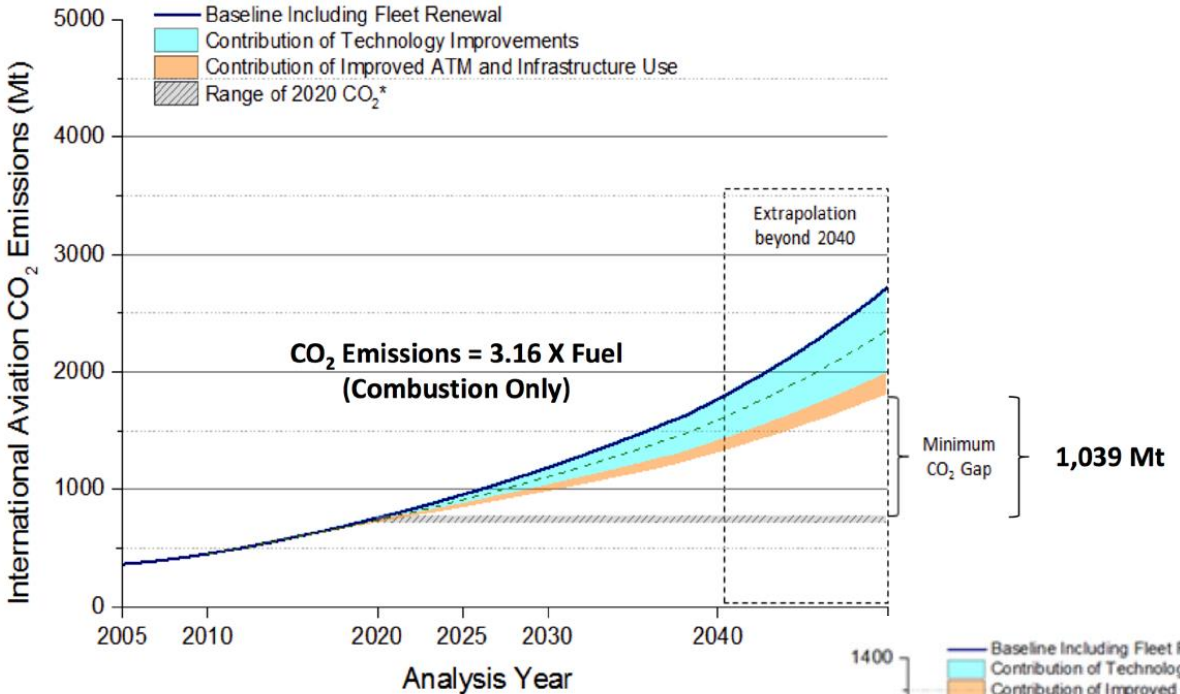
- It is important to recall that the ACARE objectives should be achieved through: a) aircraft technology, b) engine and combustion technology, c) ATM and flight optimisation.

Aero-engine optimisation trades for new engine design

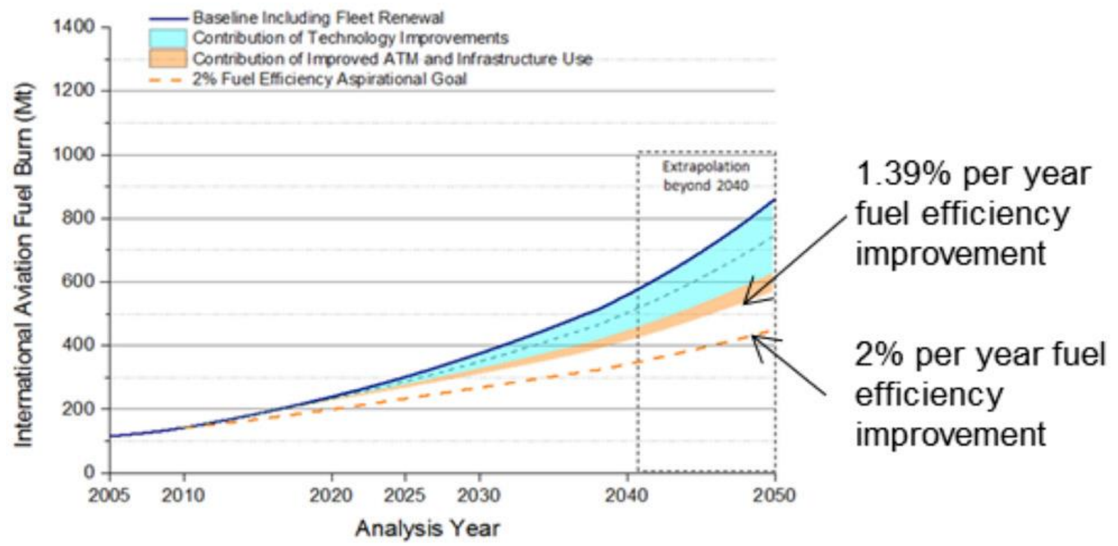


- Figure demonstrates the trades driving new engine design with respect to optimum fuel burn (CO2), minimum noise (by minimum fan pressure ratio FPR) and minimum NOx (by minimum OPR). The difference in LTO NOx levels between the best design for low NOx and best design for low CO2 can be up to 30%. Also, noise reduction obligations for new aircraft as introduced at some airports can lead to a divergence from the optimum engine design for lowest CO2

CO_2 & Fuel Burn Trends from International Aviation, 2005 to 2050

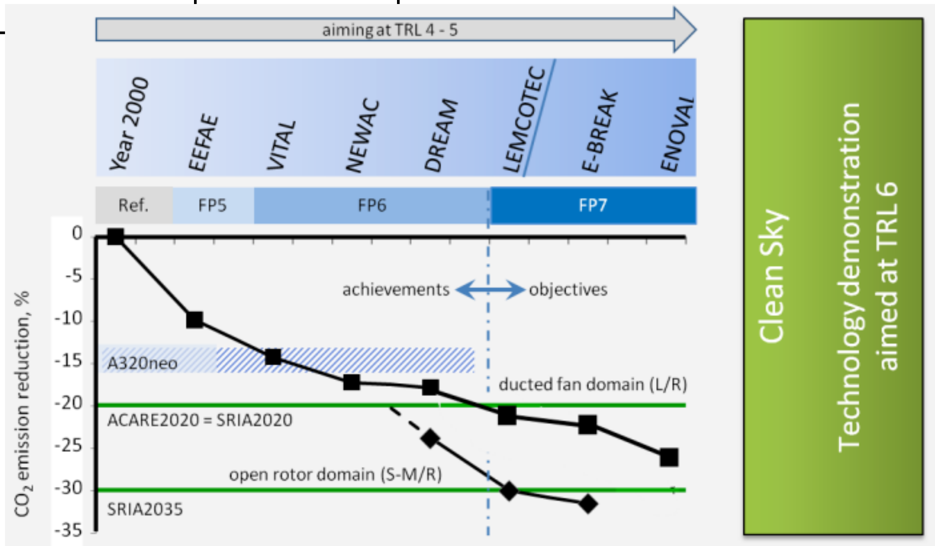


*Actual carbon neutral line is within this range
Dashed line in technology contribution sliver represents the "Low Aircraft Technology Scenario."
Note: Results were modelled for 2005, 2006, 2010, 2020, 2025, 2030, and 2040 then extrapolated to 2050.

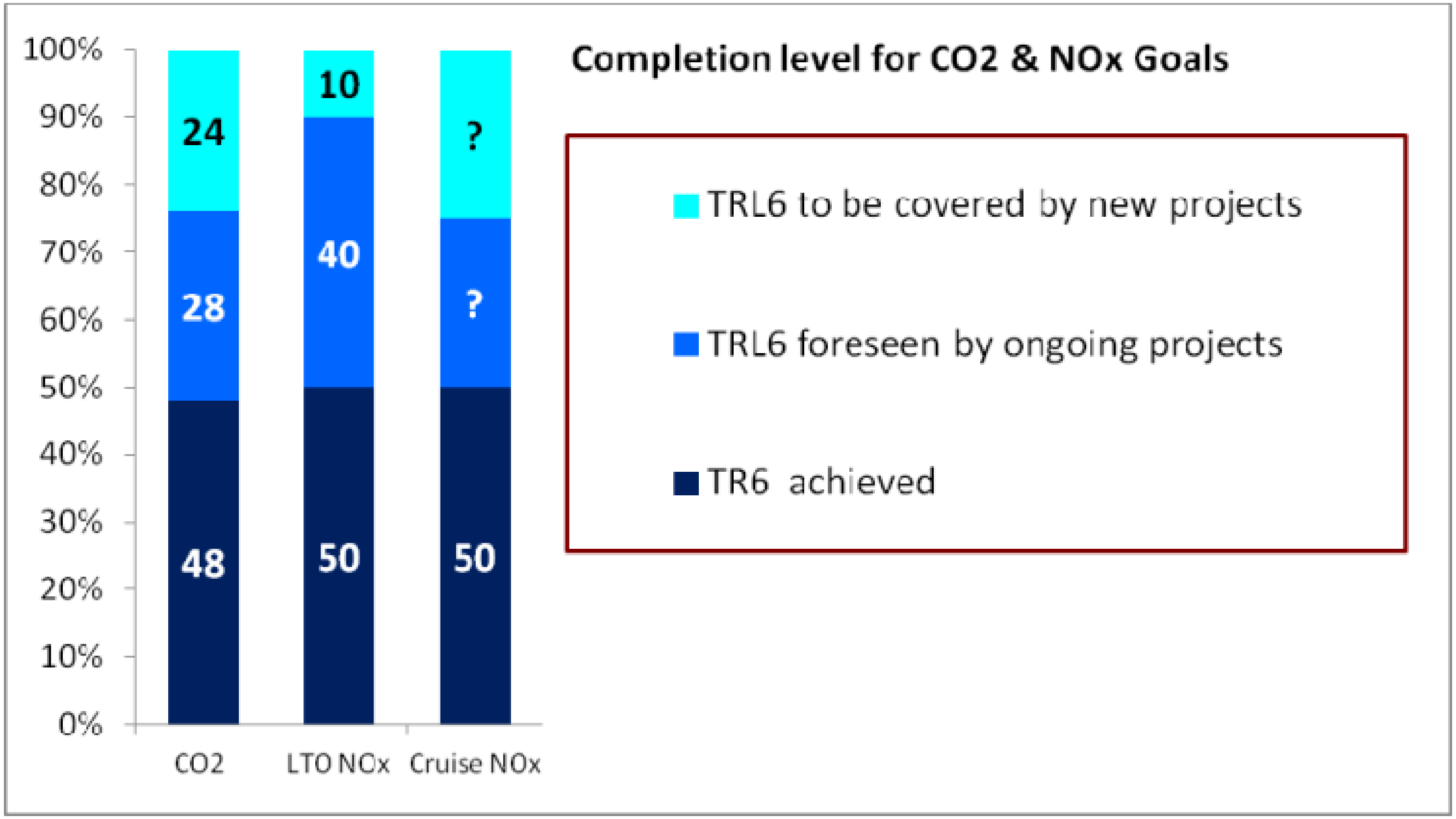


Clean Sky concept aircraft

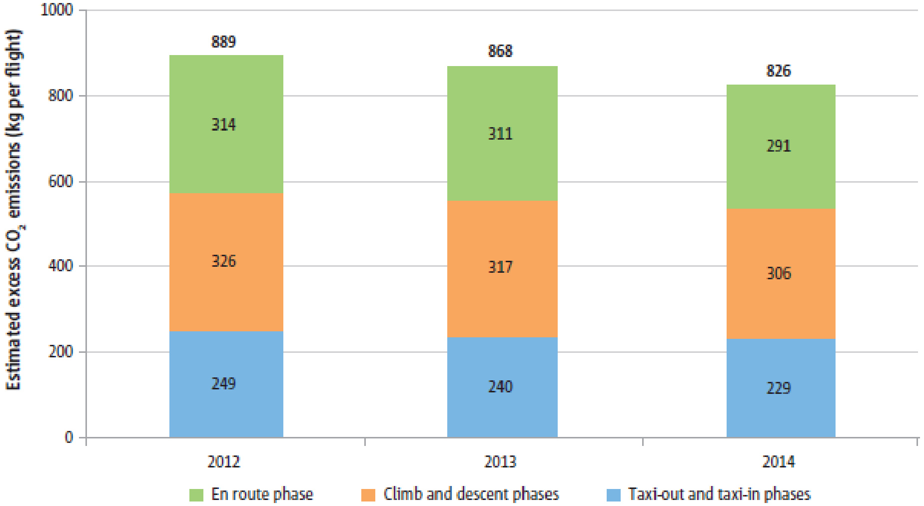
Clean Sky concept aircraft	**CO_2**
High Sweep bizjet aircraft, HSBJ 2020	-19%
Regional Turboprop aircraft, TP90 2020	-30%
Regional Geared Turbofan aircraft, GTF130 2020	-21%
Short-Medium Range aircraft (CROR engine), APL 2 2020	-34%
Long Range aircraft (Advanced Turbofan), APL3 2020	-18%
Twin Engine Heavy rotorcraft, TEH 2020	-22%



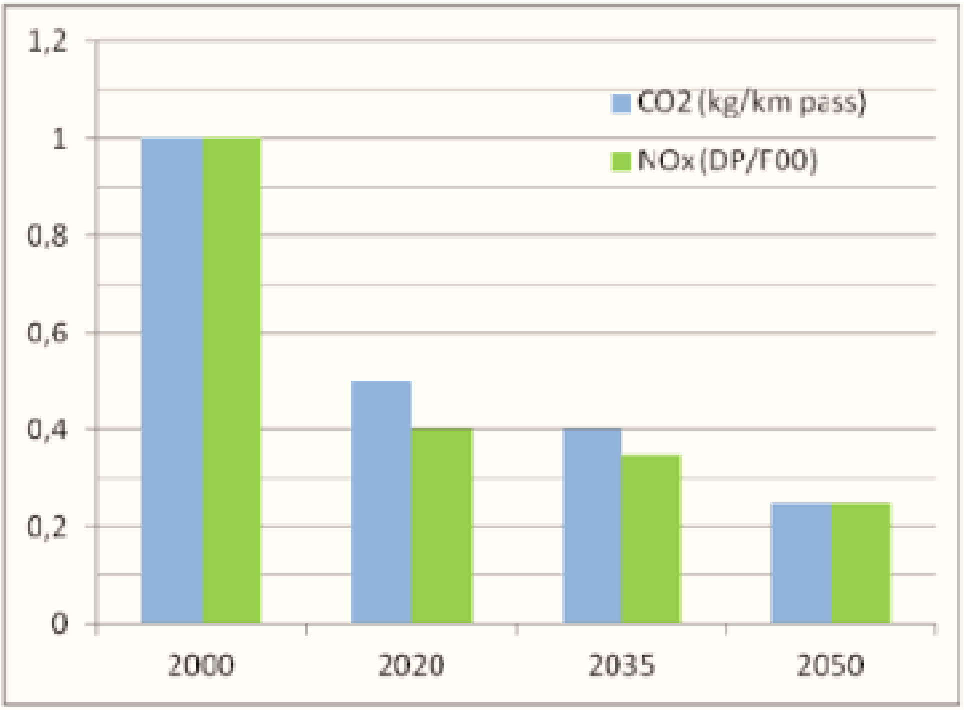
FORUM-AE 2015 assessment of progress towards ACARE 2020 goal



Aircraft CO_2 emissions reduction

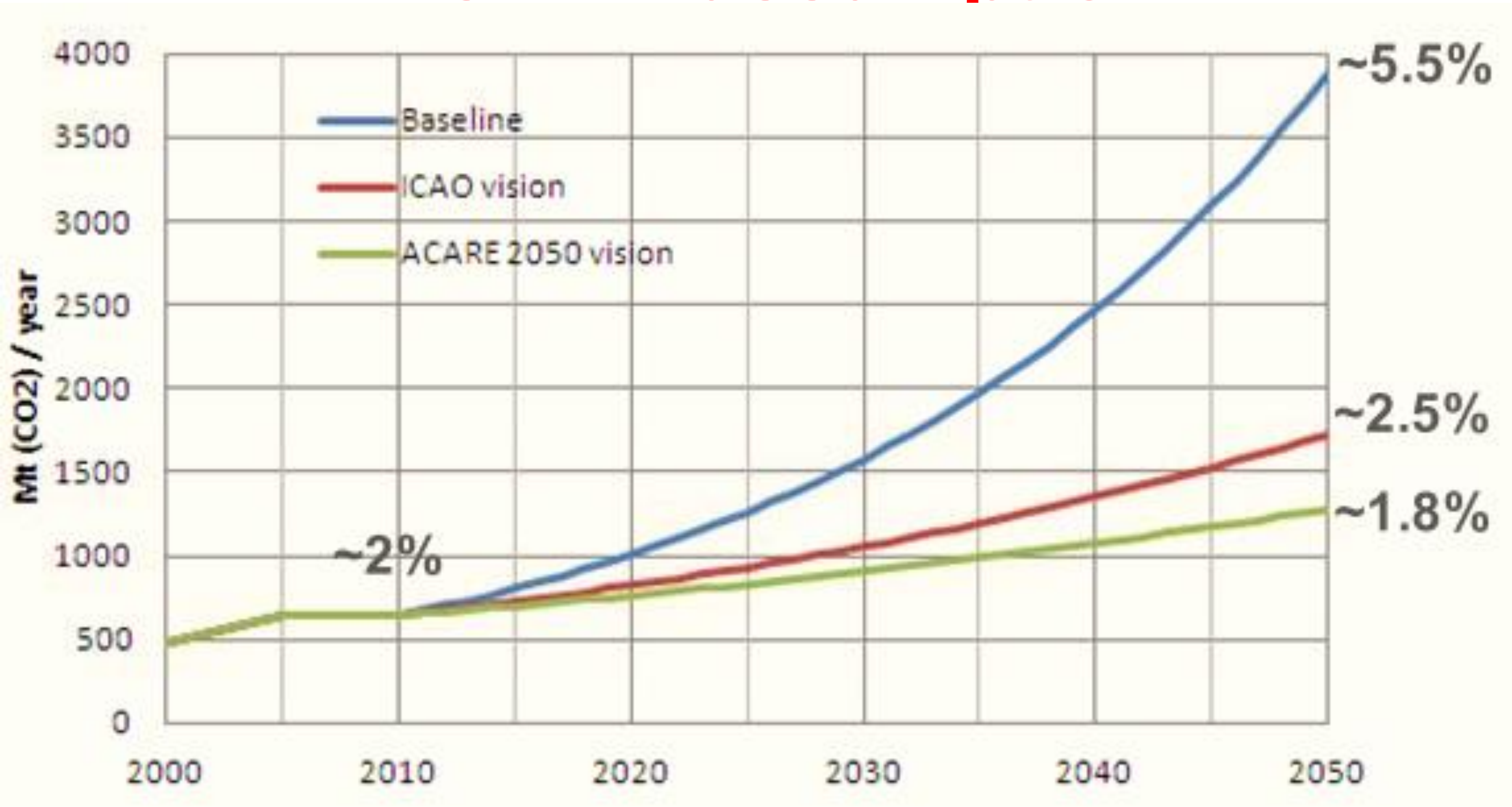


- Estimated excess CO_2 emissions per flight are decreasing in taxi, take-off, climb/descent and en route phases

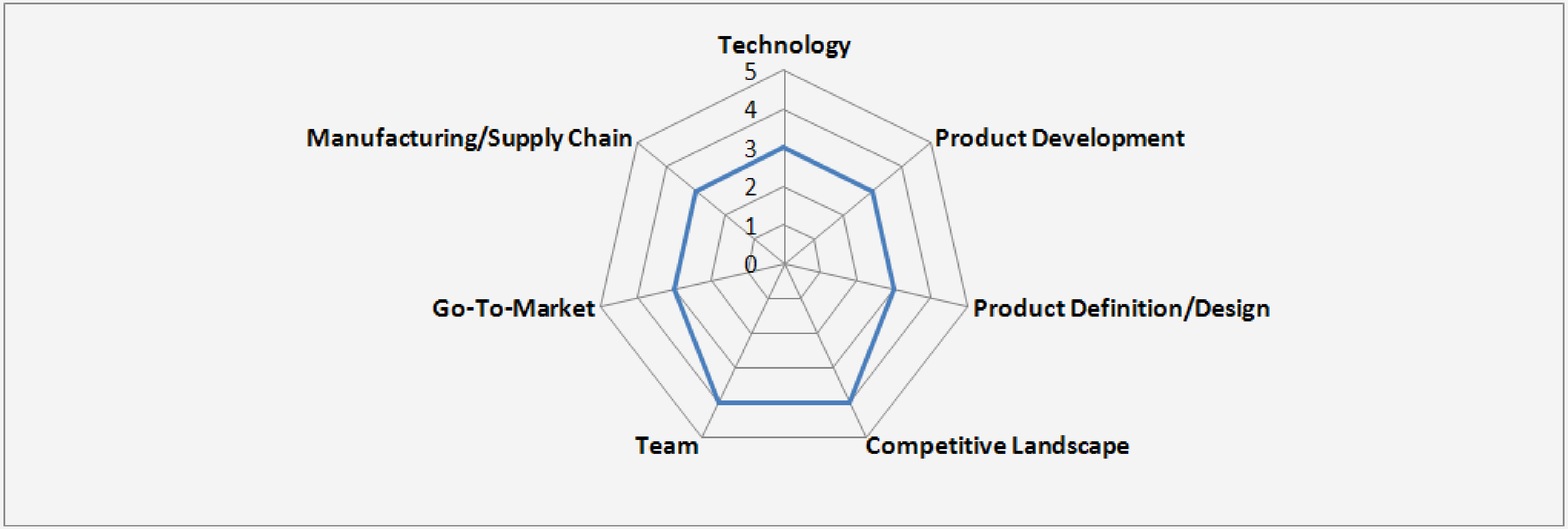


ACARE CO_2 & NOx goals calendar (using CAEP6 margin for NOx)

Global aviation CO_2 forecast with ACARE assumption



Preliminary TRL assessment for Goal 9 of Challenge 3



- NYSERDA (TRL/CRL) Calculator results for analysis and assessment of **ACARE Challenge 3 Goal 9** "Reduction of Noise and Emissions" (mid-term goals)

Preliminary recommendations from PARE project

- 9.1: Support a broad research effort to reduce aircraft noise (a) at the source (b) through operating procedures and (c) taking into account psychoacoustic effects
- 9.2: Besides struggling with short term solutions to an increasingly pressing noise problem a modest effort should be made towards a long-term definitive solution: aircraft in audible outside airport boundaries

Preliminary recommendations from PARE project

- 9.3: Formulate a set of trade-offs between (a) different types of emissions (CO_2, NO_x, particles and water vapor) in (b) local airports and global cruise flights.
- 9.4: Besides struggling with short-term emissions problems put a modest effort towards a long-term definitive solution: the hydrogen and electric powered aircraft.

Preliminary recommendations from PARE project

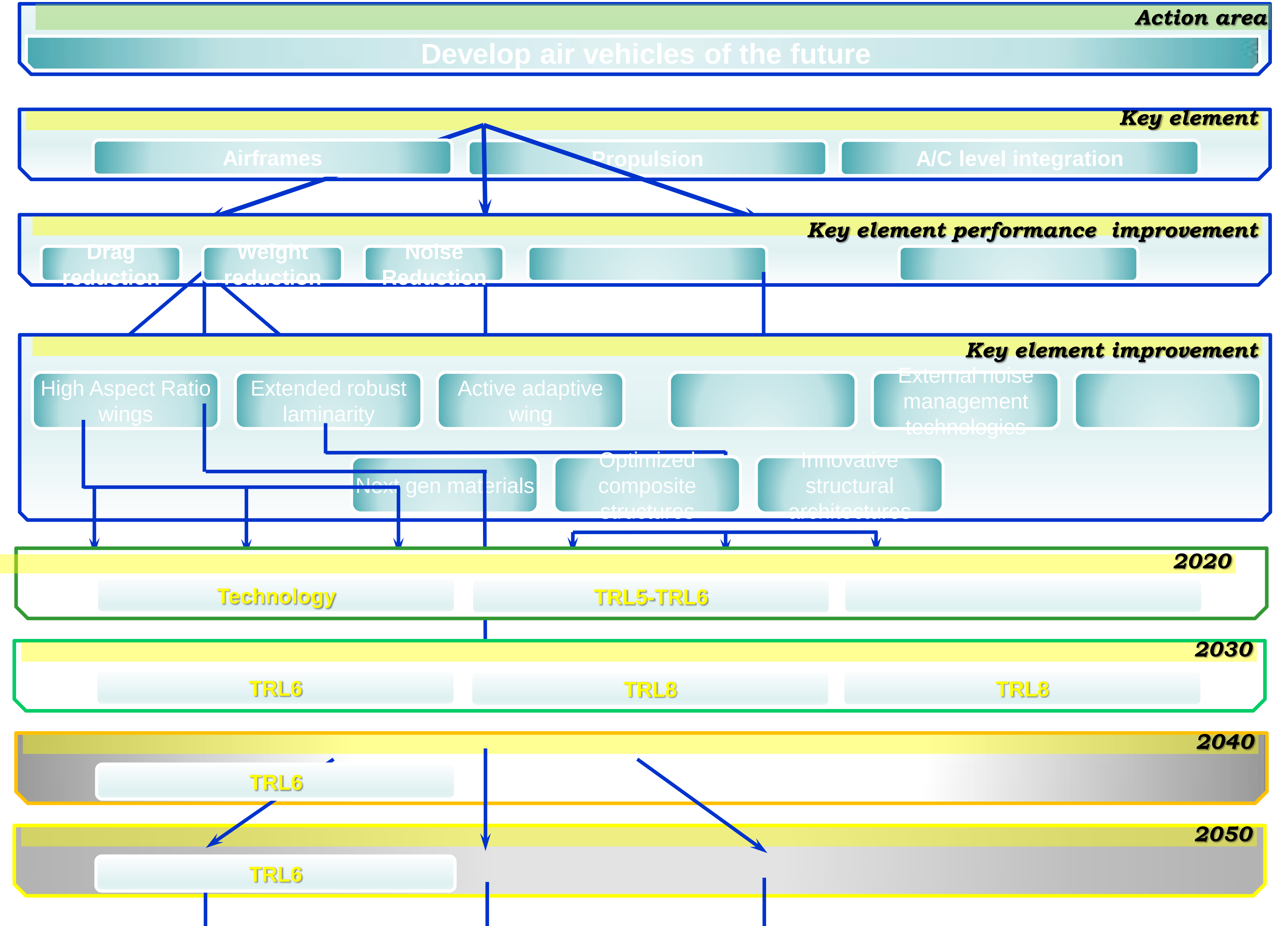
- 9.5. To renovate coordination efforts for all specific subjects of the dominant environmental problems:

- X-Noise

- FORUM-AE

- **CORE jet fuel**

- 9.6. PM-emission should be included in goals like NO_x and CO_2


Action area
Develop air vehicles of the future
Key element
Airframes
Propulsion
A/C level integration
Key element performance improvement
Drag reduction
Weight reduction
Noise Reduction
Key element improvement
High Aspect Ratio wings
Extended robust laminarity
Active adaptive wing
External noise management technologies
Next gen materials
Optimized composite structures
Innovative structural architectures
2020
Technology
TRL5-TRL6
2030
TRL6
TRL8
TRL8
2040
TRL6
2050
TRL6