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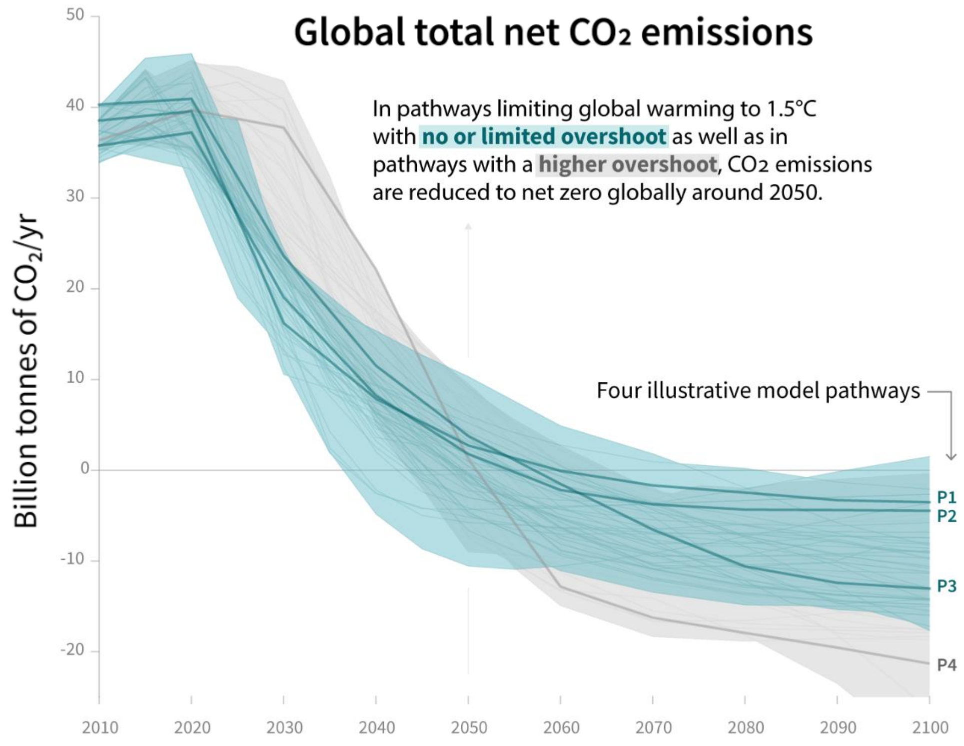
Energy & Propulsion System Integration – Key Driver of Advanced Aircraft Design

Arne Seitz

3rd ECATS Conference, Session V „Propulsion Integration“
14 October 2020

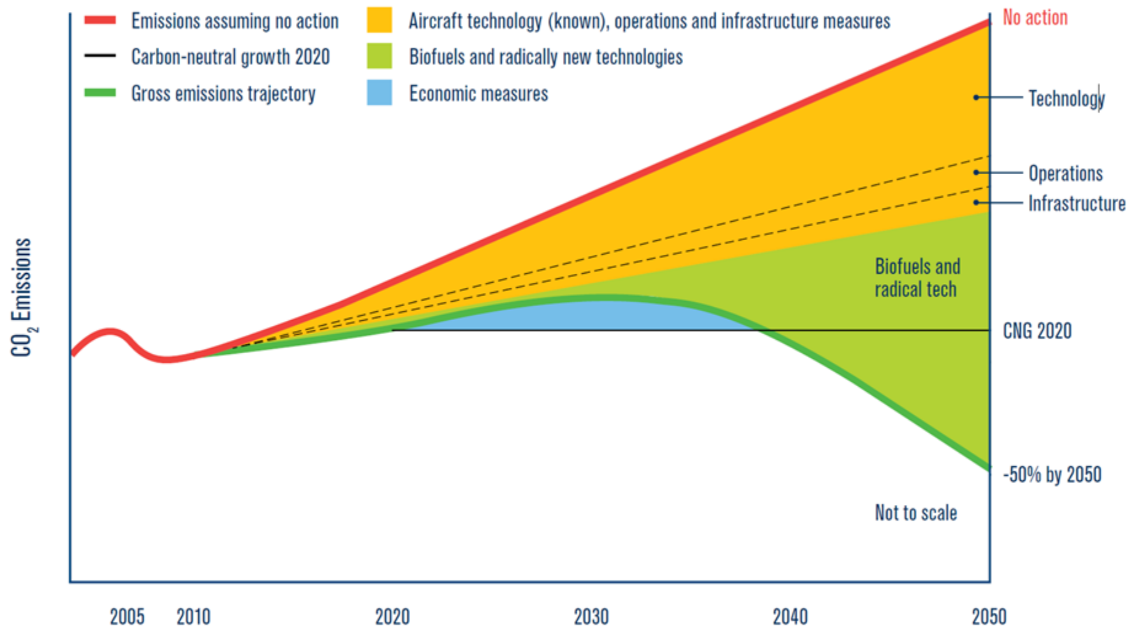
The Global Challenge

Pathways to 1.5°C global warming limit



Source: IPCC Special Report on Global Warming of 1.5C (2018), https://www.ipcc.ch/sr15/

International CO_2 targets in aviation



Source: IATA Technology Roadmap, 2013

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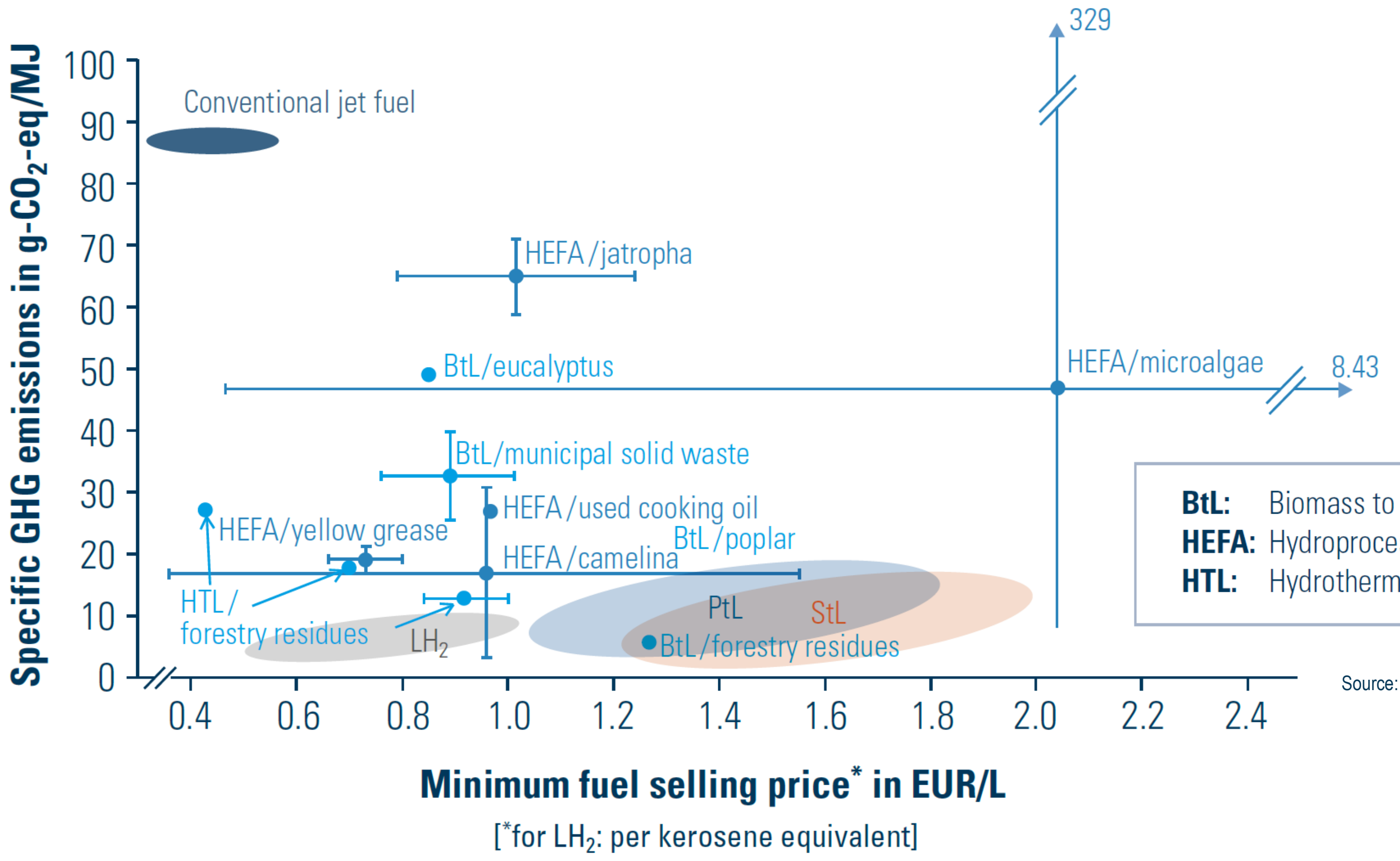
Alternative Fuel Options



BtL: Biomass to liquid
HEFA: Hydroprocessed esters and fatty acids
HTL: Hydrothermal liquefaction
LH_2: Liquid hydrogen
PtL: Power to liquid
StL: Sunlight to liquid

Source: Bauhaus Luftfahrt "Yearbook 2019" (2020), www.Bauhaus-Luftfahrt.net.

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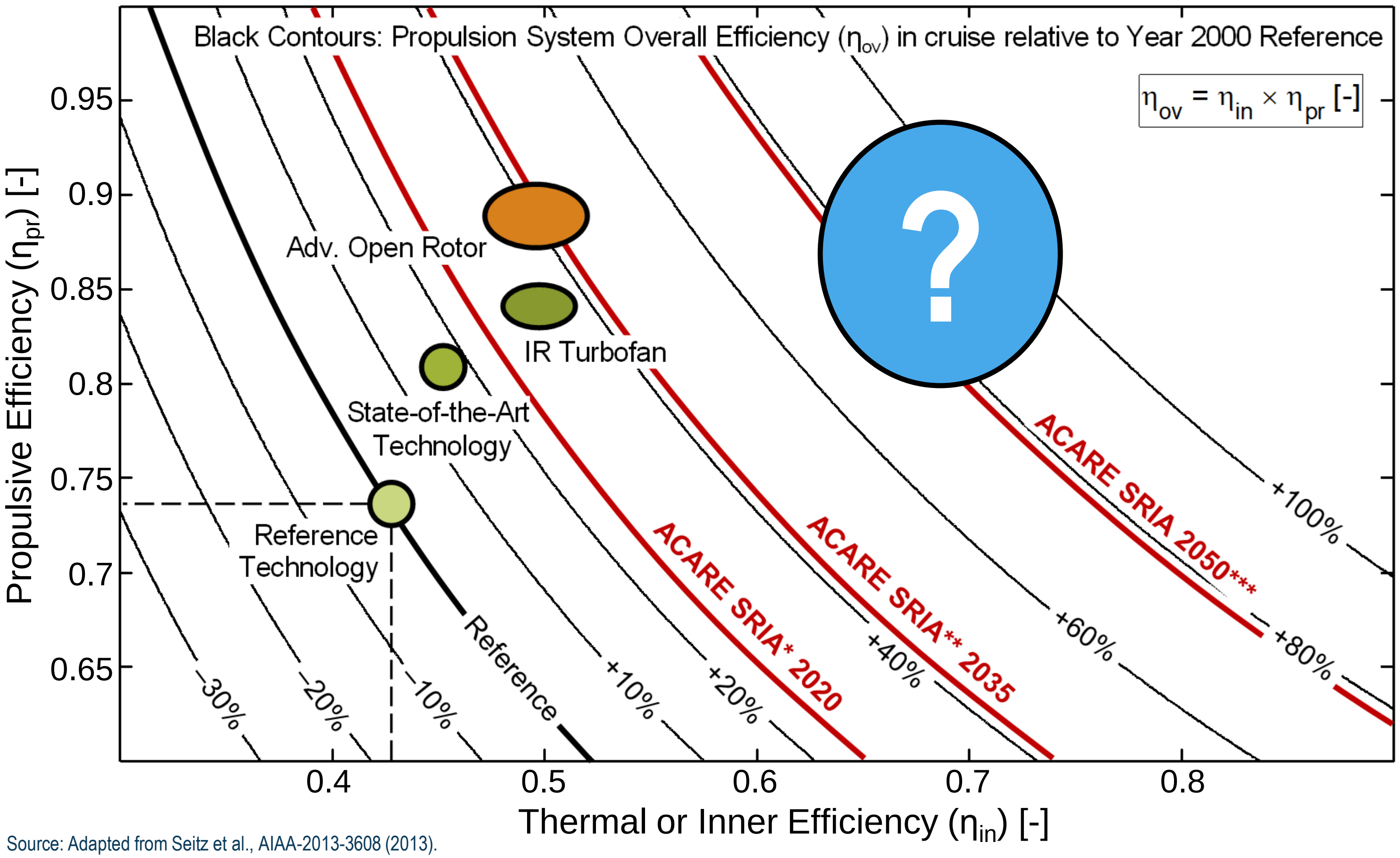
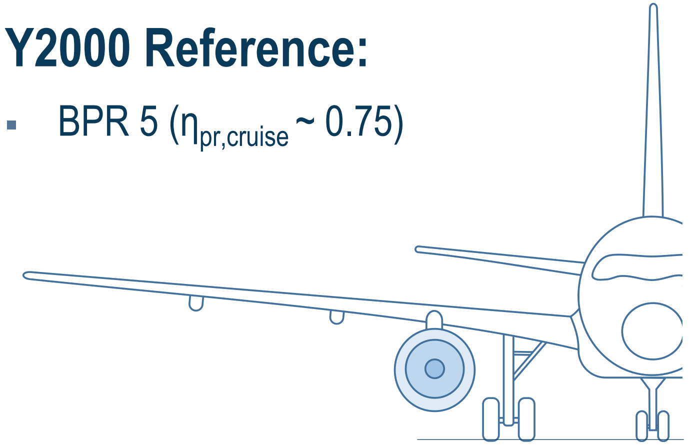
Target Directions for Propulsion System Efficiency Improvement



Source: Adapted from Seitz et al., AIAA-2013-3608 (2013).

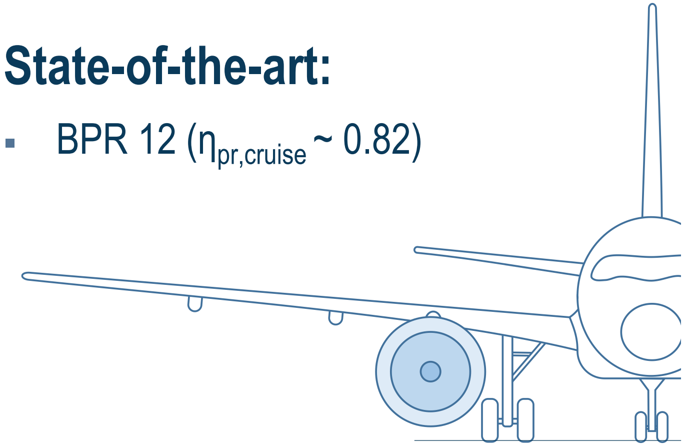
Y2000 Reference:

- BPR 5 ($\eta_{pr,cruise}$ ~ 0.75)



State-of-the-art:

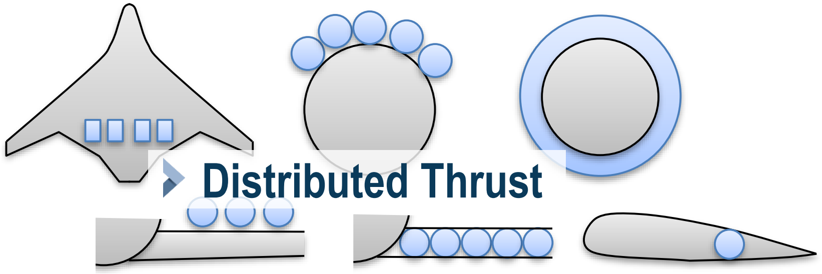
- BPR 12 ($\eta_{pr,cruise}$ ~ 0.82)

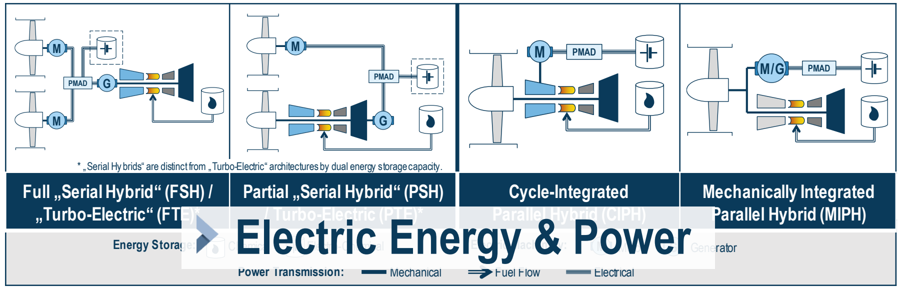


Perspectives Beyond Simply Increasing Fan Diameter

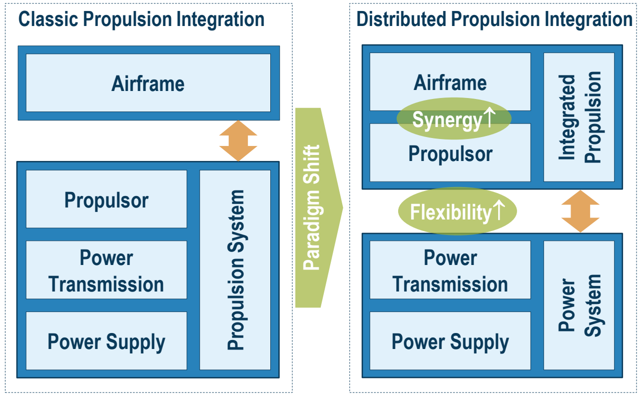
Key ingredients for advanced propulsion integration

- Implementation of low specific thrust
- Realisation of functional synergies between propulsion and airframe
- Utilisation of alternative energy & power transmission
- Efficient management of the thermal household

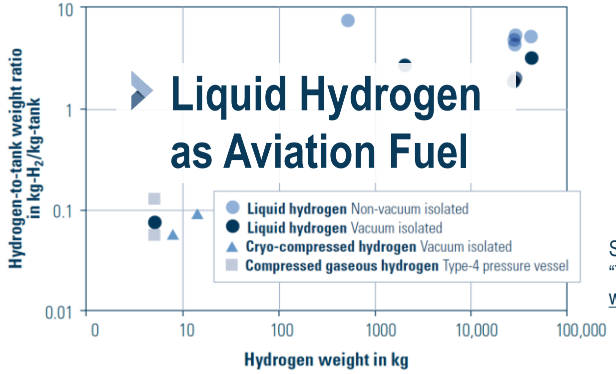




Departing from Cayley‘s Design Paradigm



Source: Steiner et al., ICAS Congress, Paper ID 803, Brisbane, Australia, 2012.



Source: Bauhaus Luftfahrt "Yearbook 2019" (2020), www.Bauhaus-Luftfahrt.net.

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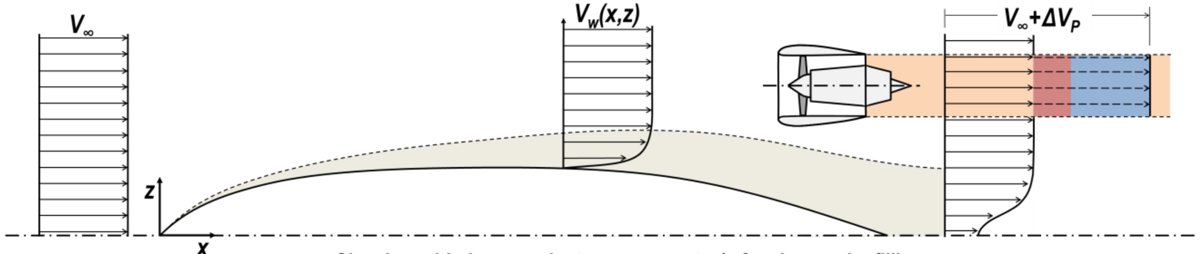
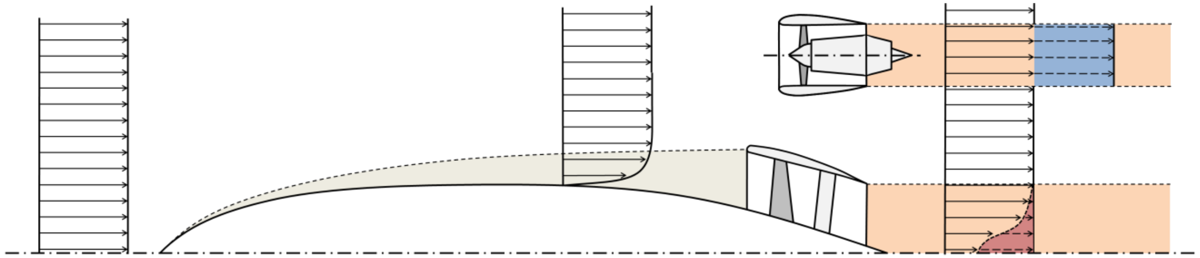
Introduction to Wake-Filling Propulsion Integration



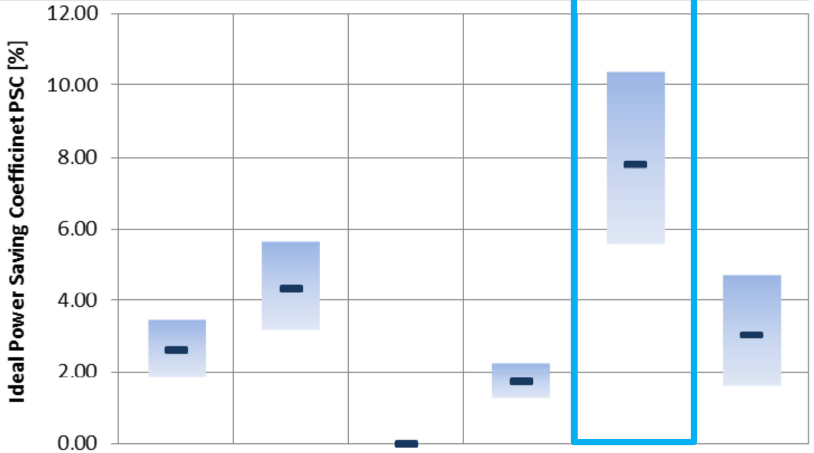
Classic podded power plant arrangement w/o fuselage wake-filling



Propulsive fuselage device applied to ideal fuselage wake-filling only, required residual aircraft thrust provided by podded power plants

Source: Seitz and Gologan, 4th CEAS Air & Space Conference, Paper No. 257, Linköping, Sweden, 2013.

	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
$C_{D0,ing}/C_{D0}$	0.12	0.18	0.20	0.30	0.00	0.00	0.08	0.12	0.35	0.55	0.10	0.25
C_{D0}/C_D	0.55	0.65	0.55	0.65	0.55	0.65	0.55	0.65	0.55	0.65	0.55	0.65
D_{ing}/T	0.06	0.12	0.11	0.20	0.00	0.00	0.04	0.08	0.19	0.36	0.06	0.16
PSC	1.86	3.46	3.19	5.66	0.00	0.00	1.28	2.26	5.58	10.37	1.60	4.71
Score	1		2		0		1		3		1	



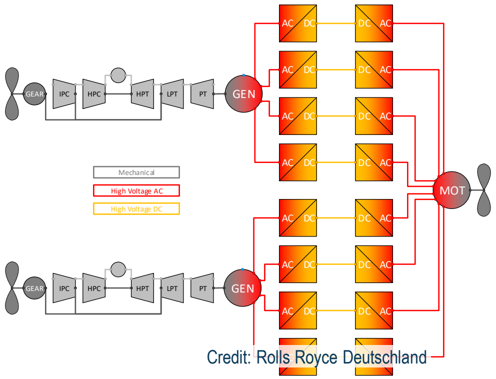
The “Propulsive Fuselage“ Approach

Source: Steiner et al., ICAS Congress, Paper ID 803, Brisbane, Australia, 2012.

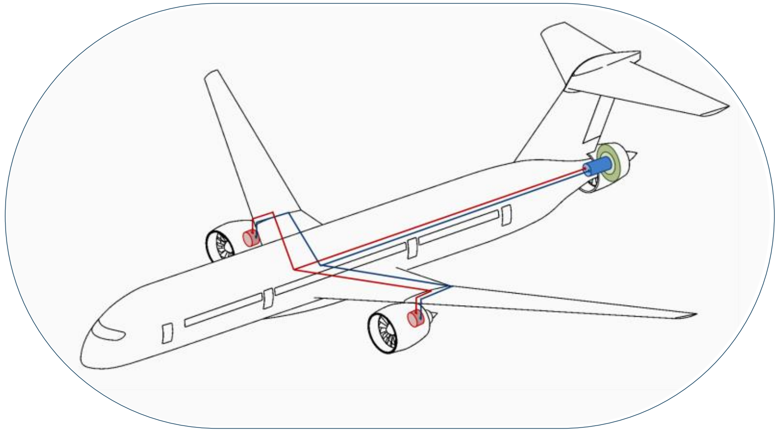
H2020 „CENTRELINE“ – Research Focal Points

AIRBUS · ARTTIC · Bauhaus Luftfahrt · Chalmers · MTU Aero Engines · Politechnika Warszawska · Rolls-Royce · TU Delft · University of Cambridge

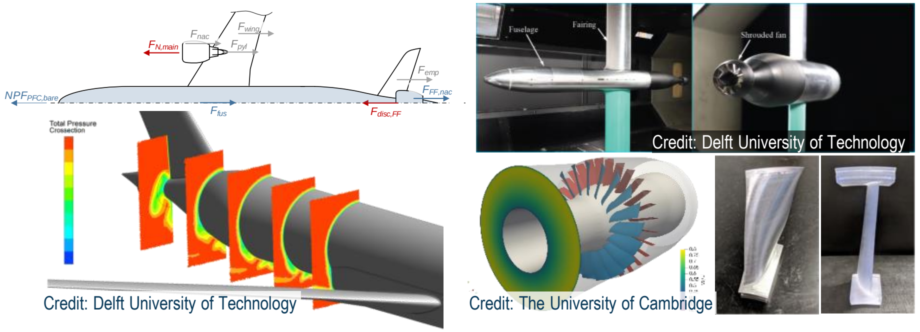
- Fuselage fan turbo-electric drive train design



Credit: Rolls Royce Deutschland



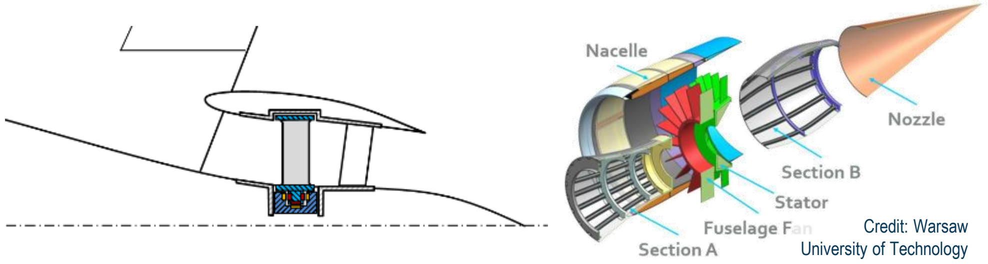
- Understanding of the aerodynamic effects of fuselage wake-filling propulsion integration



Credit: Delft University of Technology
Credit: Delft University of Technology
Credit: The University of Cambridge

- Multi-disciplinary aircraft design integration and optimisation

- Aero-structural integration of the BLI propulsor



Credit: Warsaw University of Technology

Sources: Please visit the CENTRELINE project website: www.centreline.eu

This work is supported by the European Commission within the Horizon 2020 Research and Innovation Programme under Grant Agreement No. 723242.

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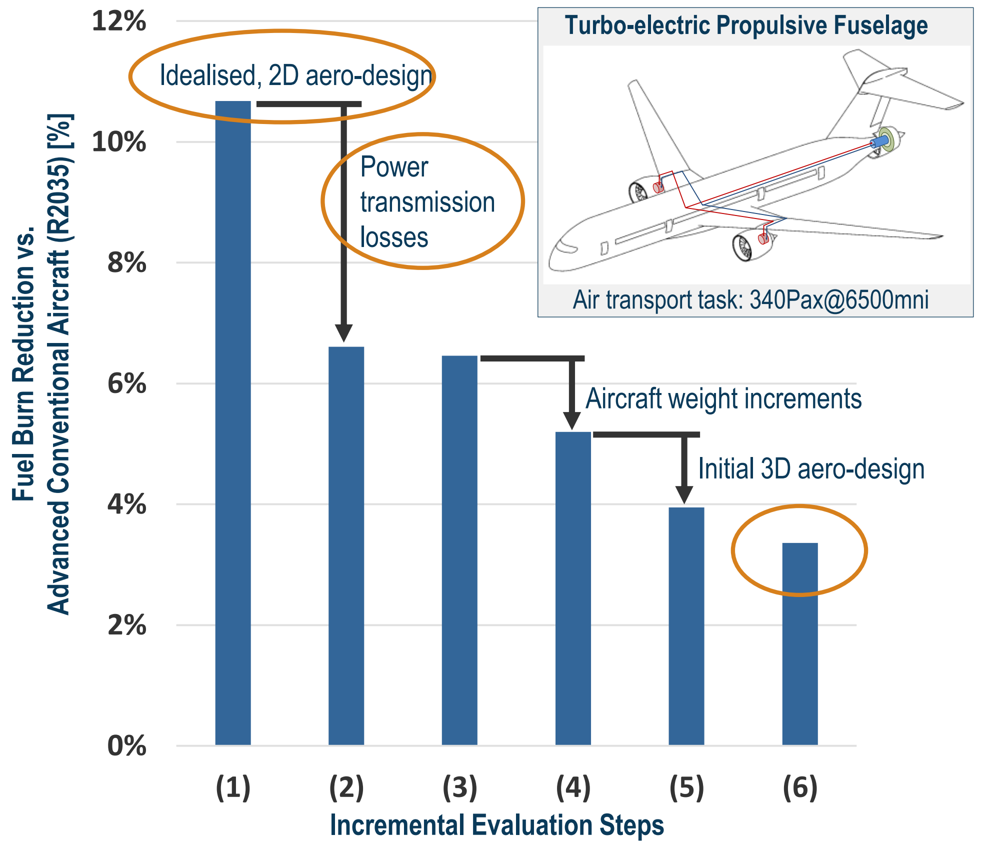
Fuel Evaluation of Turbo-electric Propulsive Fuselage

CENTRELINE

AIRBUS ARTTIC Bauhaus Luftfahrt CHALMERS MTU Politechnika Warszawska Rolls-Royce TU Delft University of Cambridge

Stack-up of effects analysis

- **(1)** Base scenario: Identical residual drags (PFC vs. REF), ideal power transmission to fuselage fan, all identical fan aerodynamic efficiencies, axisymmetric bare PFC
- **(2)** Losses due to FF turbo-electric transmission
- **(3)** Fuselage fan efficiency penalty: axisymmetric inflow distortion
- **(4)** PFC aircraft component weight changes
- **(5)** Initial 3D aero-design incl. fuselage upsweep
- **(6)** Estimated fuselage fan efficiency penalty: full inflow distortion



Source: Seitz, A., Presentation at 10th EASN International Conference, 02-04 September 2020.

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Energy & Propulsion Integrated for a Future Long Range Aircraft

- Liquid Hydrogen Fuel
- Fuselage boundary layer ingestion
- Radical heat engines & power transmission
- Ultra-efficient wing

Thank you!

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