IMOTHEP
GETTING HYBRID ELECTRIC

Study of a Regional Turboprop Aircraft with Hybrid-Electric Turboshaft Assistance

A. L. Habermann, F. Peter, P. Maas, M. Kolb, C. Rischmüller,
H. Kellermann, A. Seitz / BHL

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Motivation

IMOTHEP
GETTING HYBRID ELECTRIC

PROJECT

A clear view of the potential benefits of hybrid-electric propulsion

In-depth analysis of power train technologies with innovative propulsion architecture

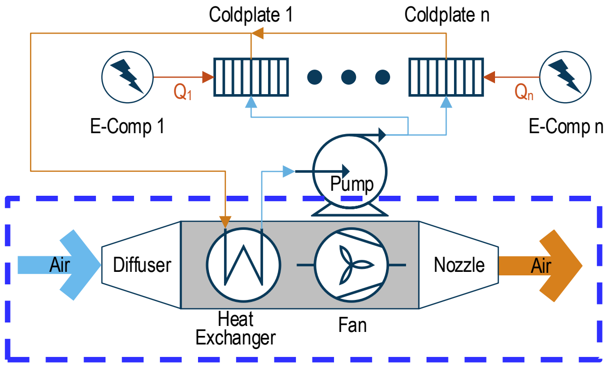
Bauhaus Luftfahrt
The Aviation Think Tank

REGIONAL AIRCRAFT STUDY

Fuel reduction potential of a regional aircraft

Two-fold parallel-hybrid electric propulsion architecture and innovative thermal management system

Aircraft Concept Overview



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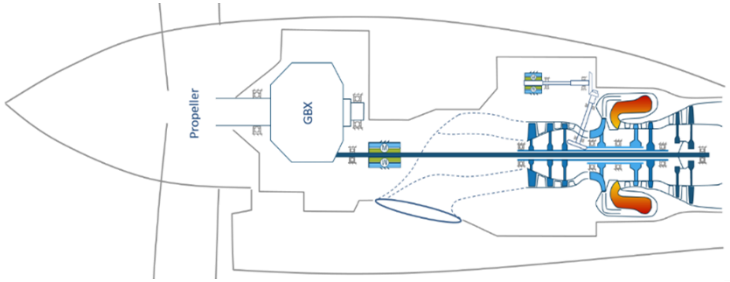
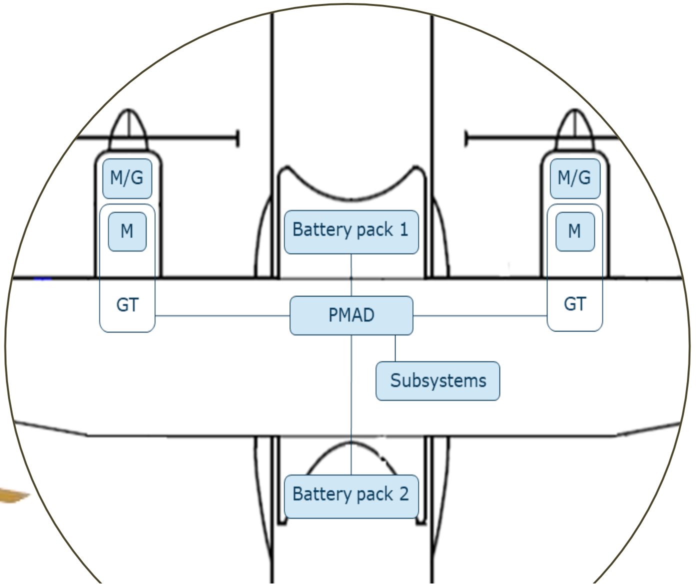
RAM AIR + WING SURFACE INTEGRATED HEAT EXCHANGER

Kellermann, H. et al. Design and Optimization of Ram Air–Based Thermal Management Systems for Hybrid-Electric Aircraft. Aerospace 2021, 8, 3.
Kellermann, H. et al. Assessment of Aircraft Surface Heat Exchanger Potential. Aerospace 2020, 7, 1.

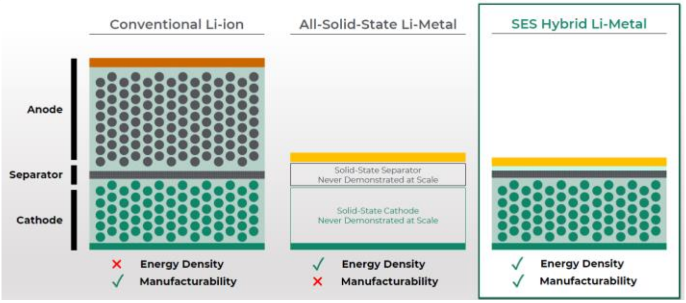


ELECTRICALLY-ASSISTED TURBOSHAFT

Maas, P. et al. Performance investigations of a cycle- and mechanically-integrated parallel hybrid-electric turboshaft. EASN Conference 2022.



HYBRID-ELECTRIC POWERTRAIN



HYBRID LI-METAL BATTERY

SES, Hybrid Li-Metall Batteries. Data Week 2021, 2021.

Reference Aircraft Approach

- 30 % Typical mission block fuel

- 17 % Typical mission block fuel

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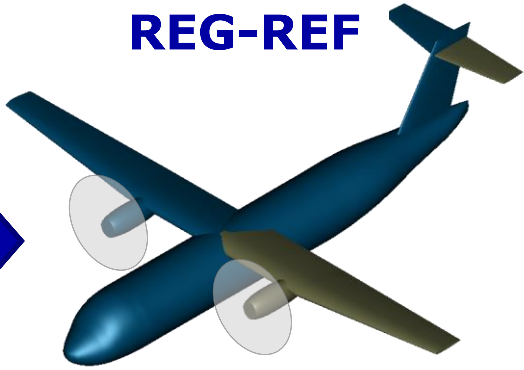
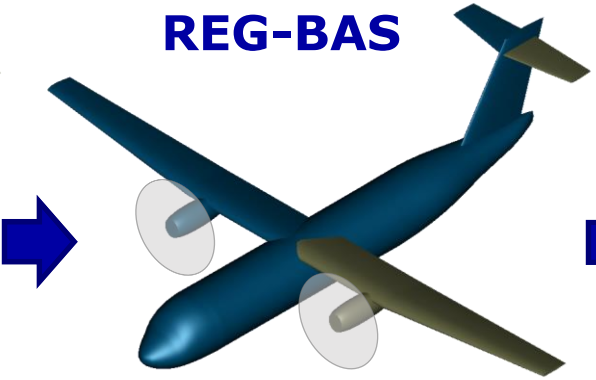
ATR 42-600

Source: atraircraft.com

REG-REF



REG-BAS



REG-CON

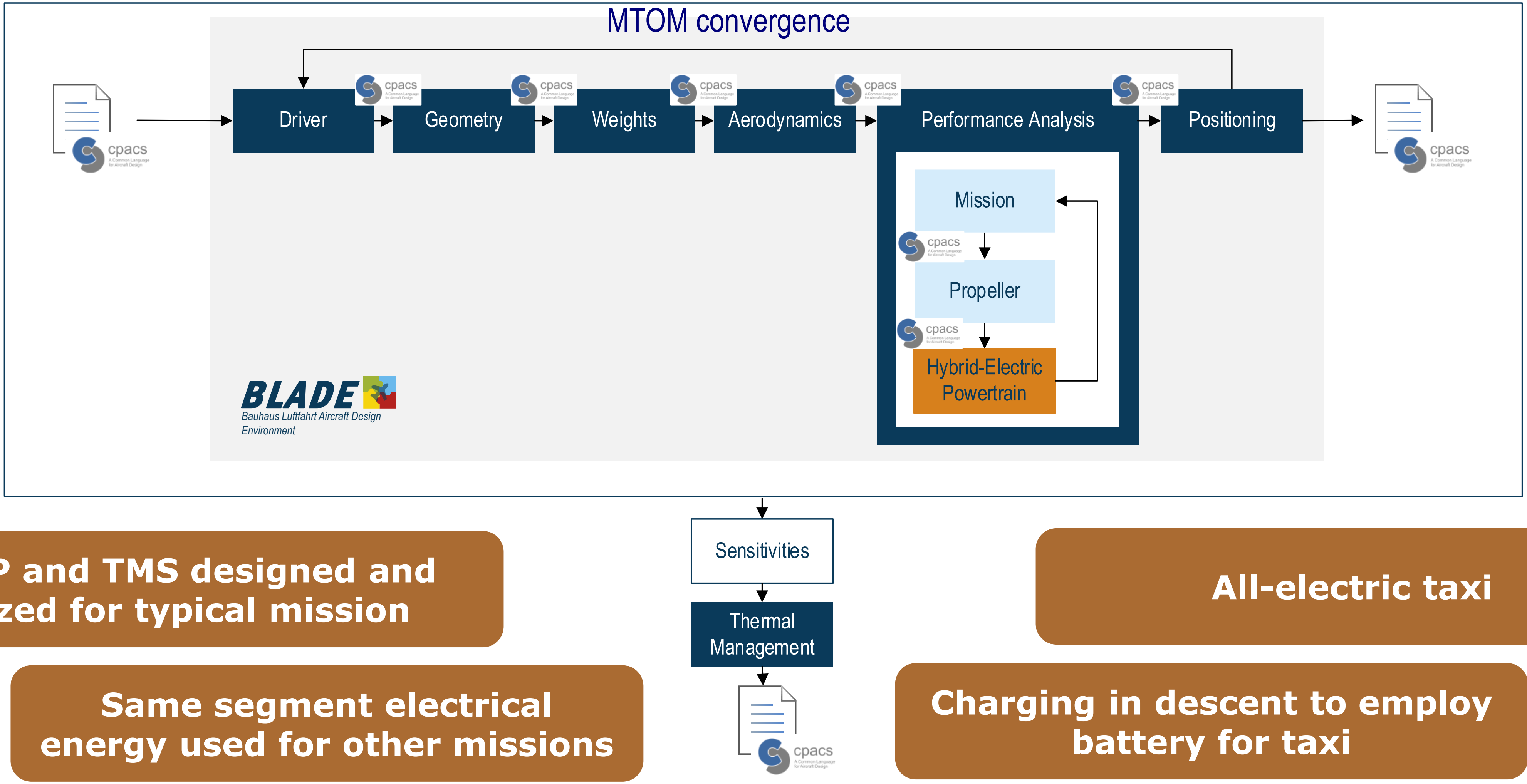
- Year 2000 reference aircraft
- Project-specific TLAR

- Year 2035+ reference aircraft
- Advanced technologies and MEA subsystems

- Hybrid-electric power train and innovative TMS
- Battery-sourced subsystems

TLAR	PAX	Design Mission	Typical Mission	Max Cruise Mach @FL150, ISA
Value	40 @106kg/PAX	600 nmi	200 nmi	0.40

HEP Aircraft Design Strategy



HEP and TMS designed and sized for typical mission

Same segment electrical energy used for other missions

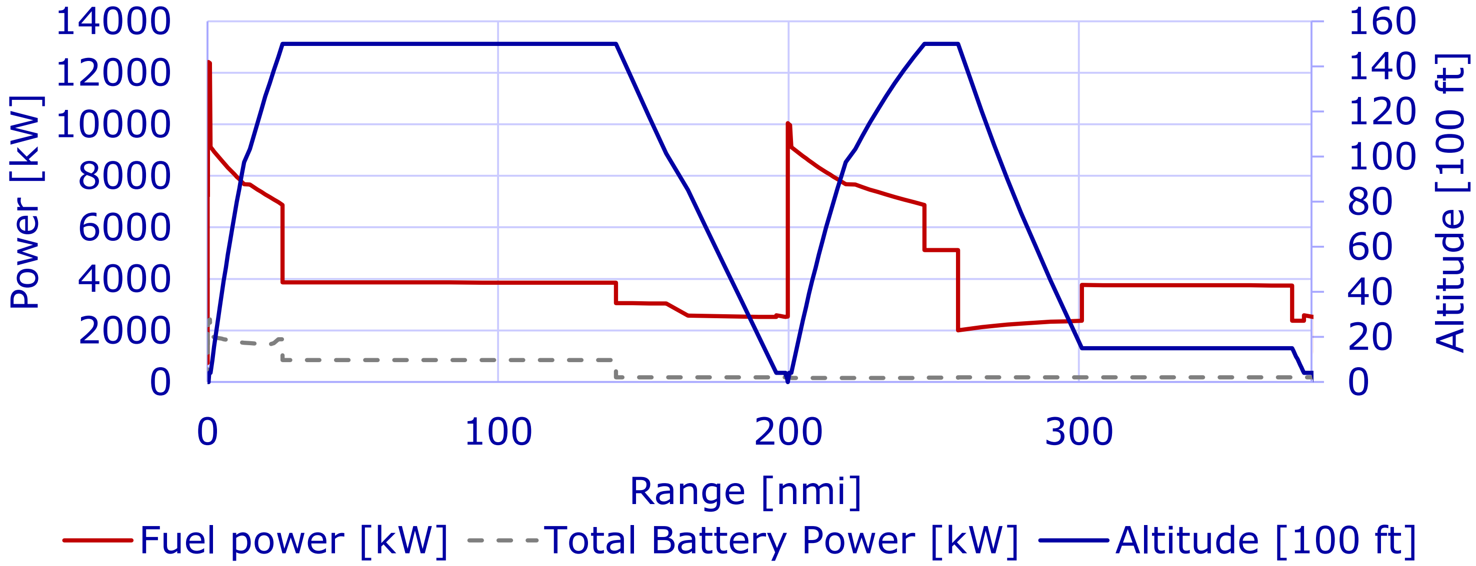
All-electric taxi

Charging in descent to employ battery for taxi

Electric power distribution optimization

Hybridization Strategies

Constant hybridization degree and power split for each mission segment



Battery weight drives aircraft performance

Hybridization strategy decides on fuel burn reduction potential

Degree of power hybridization[1]:

$$H_P = \frac{P_{sup,el}}{P_{sup,tot}} = \frac{P_{Bat,prop}}{P_{Bat,prop} + P_{Fuel}}$$

Power split:

$$S_P = \frac{P_{MotorA}}{P_{MotorA} + P_{MotorB}}$$

Motor A: Power shaft assistance
Motor B: High-pressure shaft assistance

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1 Seitz et al., Conceptual study of a mechanically integrated parallel hybrid electric turbofan. J Aero Eng 2018; 232: 2688-2712.

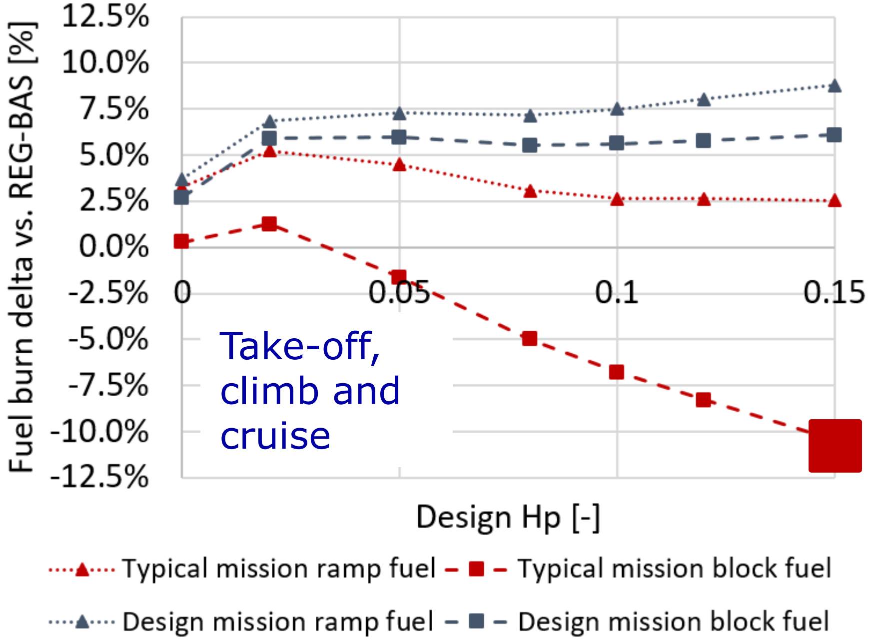
Mixed Hybridization Strategy

Fuel burn improvement achievable for typical mission block fuel

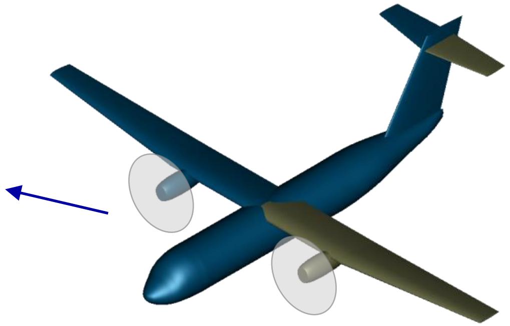
Charging in descent for all-electric taxi-in no significant effect

Power split optimization increases operational flexibility

Battery-sourced non-propulsive subsystem architecture not beneficial



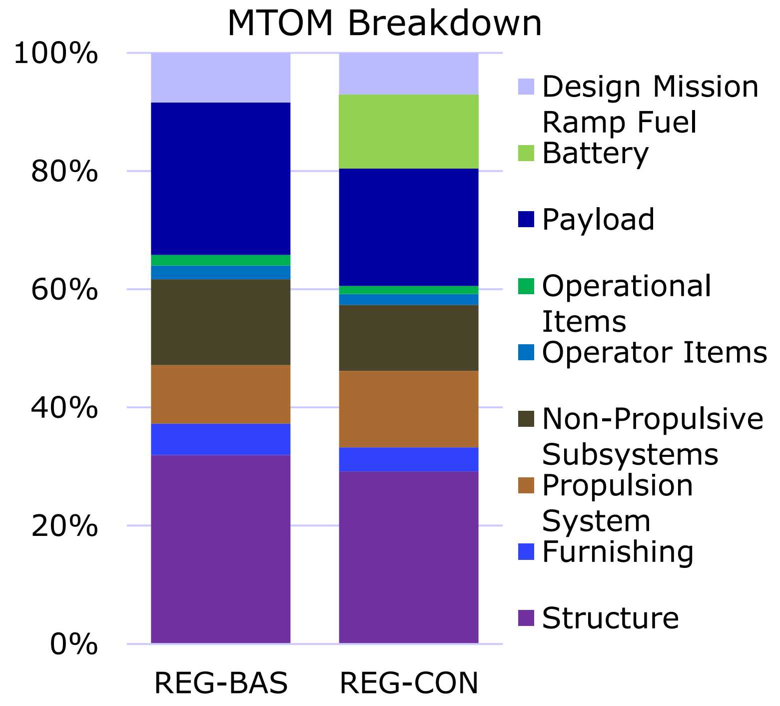
Take-off, climb and cruise

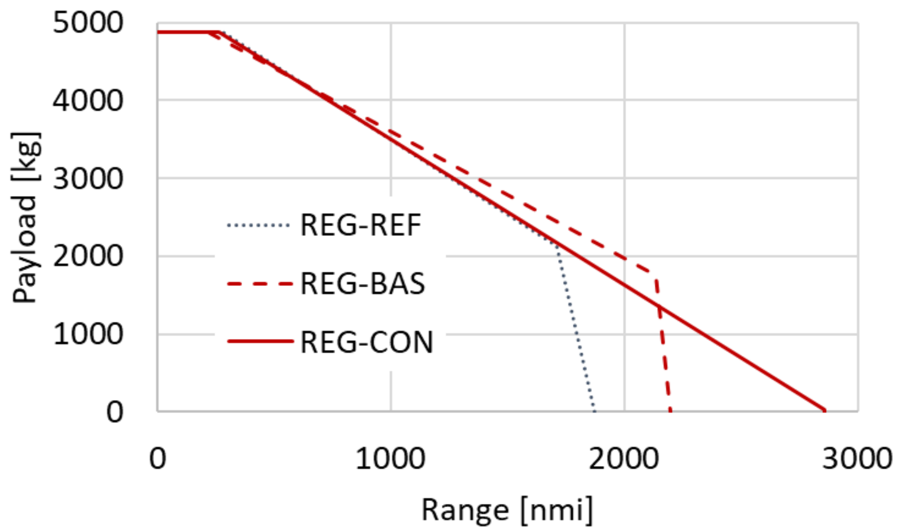


Final REG-CON

REG-CON Aircraft Sizing Results

	REG-CON	REG-CON vs. REG-BAS
MTOM [kg]	21300	+ 30.0 %
OEM [kg]	15570	+ 44.0 %
Typical mission block fuel w/o TMS [kg]	**322**	**- 10.5 %**
Typical mission block fuel with TMS [kg]	**325**	**- 9.6 %**
Battery mass [kg]	2670	-
Battery cell/pack gravimetric energy density [Wh/kg]	545/405	-
TSFC mid-cruise [g/kN/s]	6.94	- 34 %
L/D mid-cruise [-]	15.4	+ 5.9 %





TMS leads to a 0.8 % block fuel increase

Battery cell gravimetric energy density improvement required for higher benefit

Conclusions

Regional HEP configuration can achieve fuel burn reduction in typical mission block fuel

Innovative TMS shows synergistic effect with turboprop configuration

Battery performance limits the fuel burn reduction potential of the configuration

Non-propulsive subsystems should be sourced by another energy source than the battery

Contact:
anais.habermann@bauhaus-luftfahrt.net