INTEGRATION STRATEGIES FOR A FUEL-DRIVEN RANGE EXTENDER ON A 19-SEATER BATTERY-ELECTRIC AIRCRAFT

Philip Balack, German Aerospace Center DLR

Institute of System Architectures in Aeronautics, Hamburg

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DLR

TELEM Project

- LuFoVI program
- 2021-2024
- Exploration and maturation of technologies for electric flight
- Leadership: Rolls-Royce Electrical

Deutsches Zentrum für Luft- und Raumfahrt

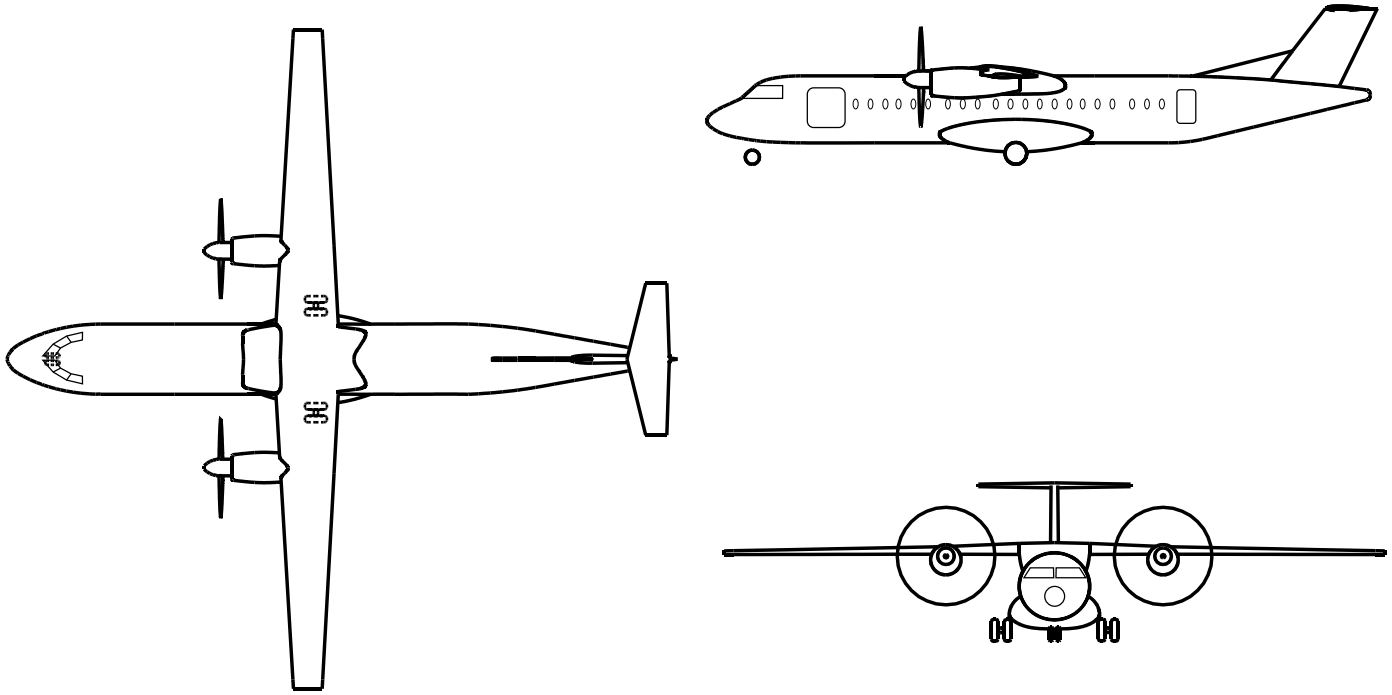
Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

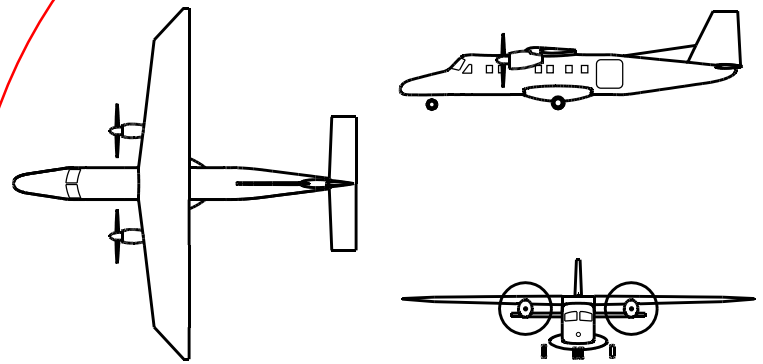
Conceptual Design Phase

- Design of hybrid-electric aircraft for two aircraft classes



70-Seater Regional Aircraft

1000nm Design Range

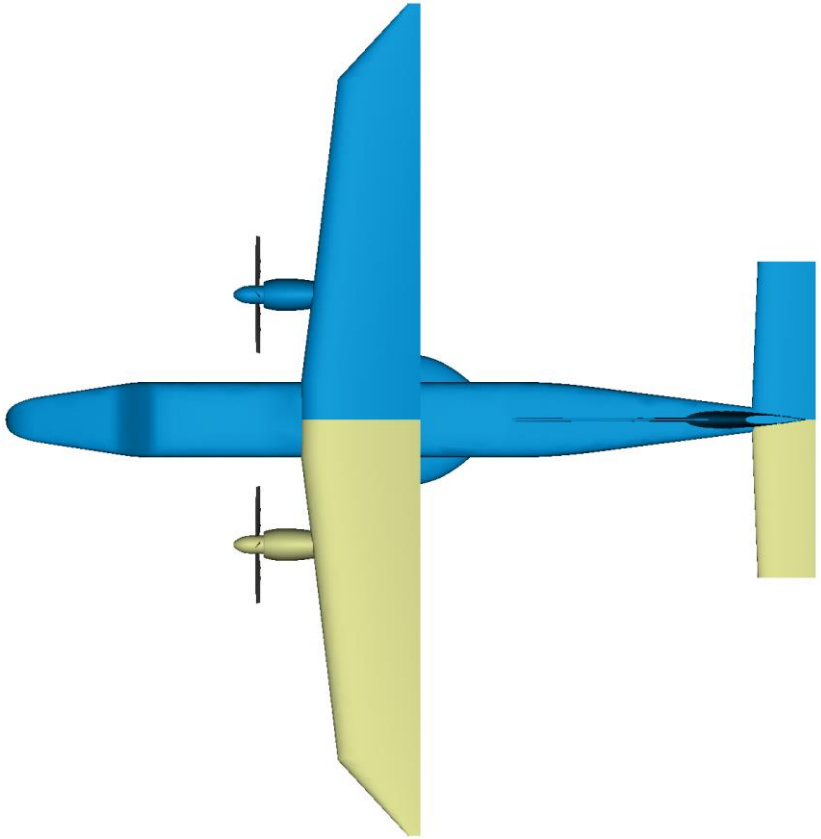


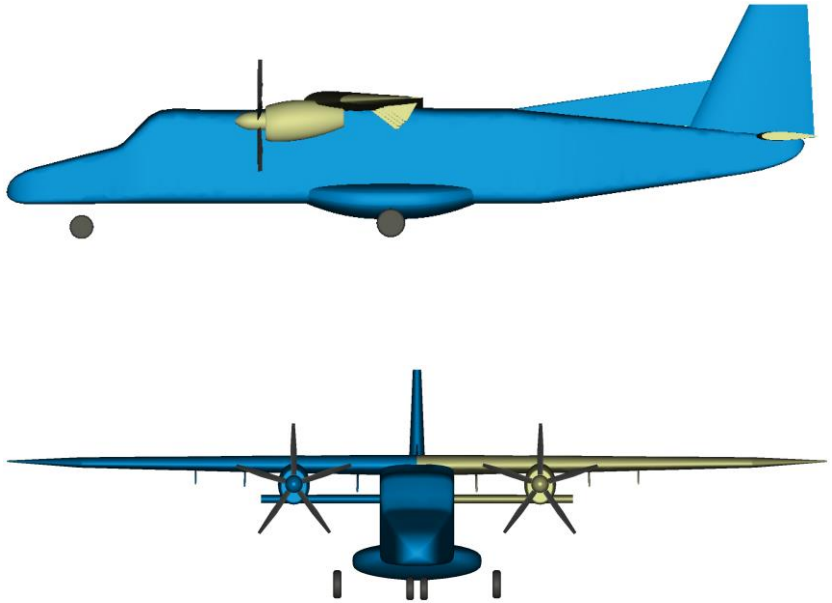
19-Seater Commuter

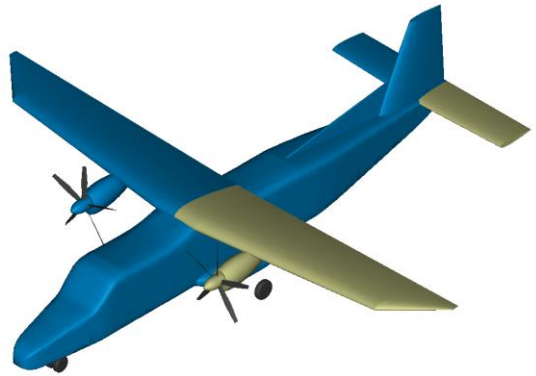
400nm Design Range

19-Seater Class Reference Aircraft

- Dornier 228-212
  - Conceptual model, including aero+engine performance, weights etc.





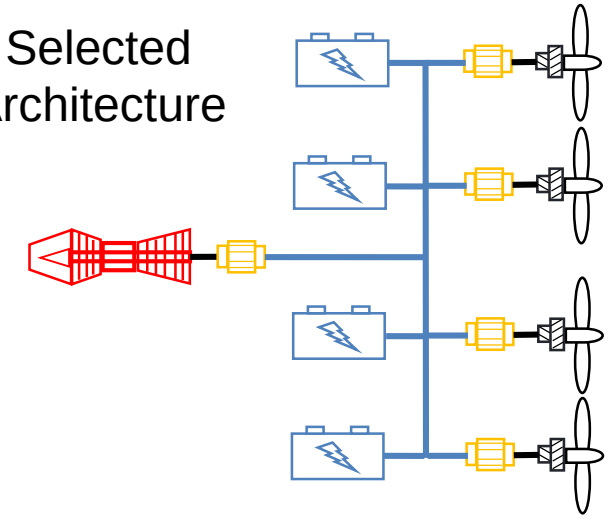


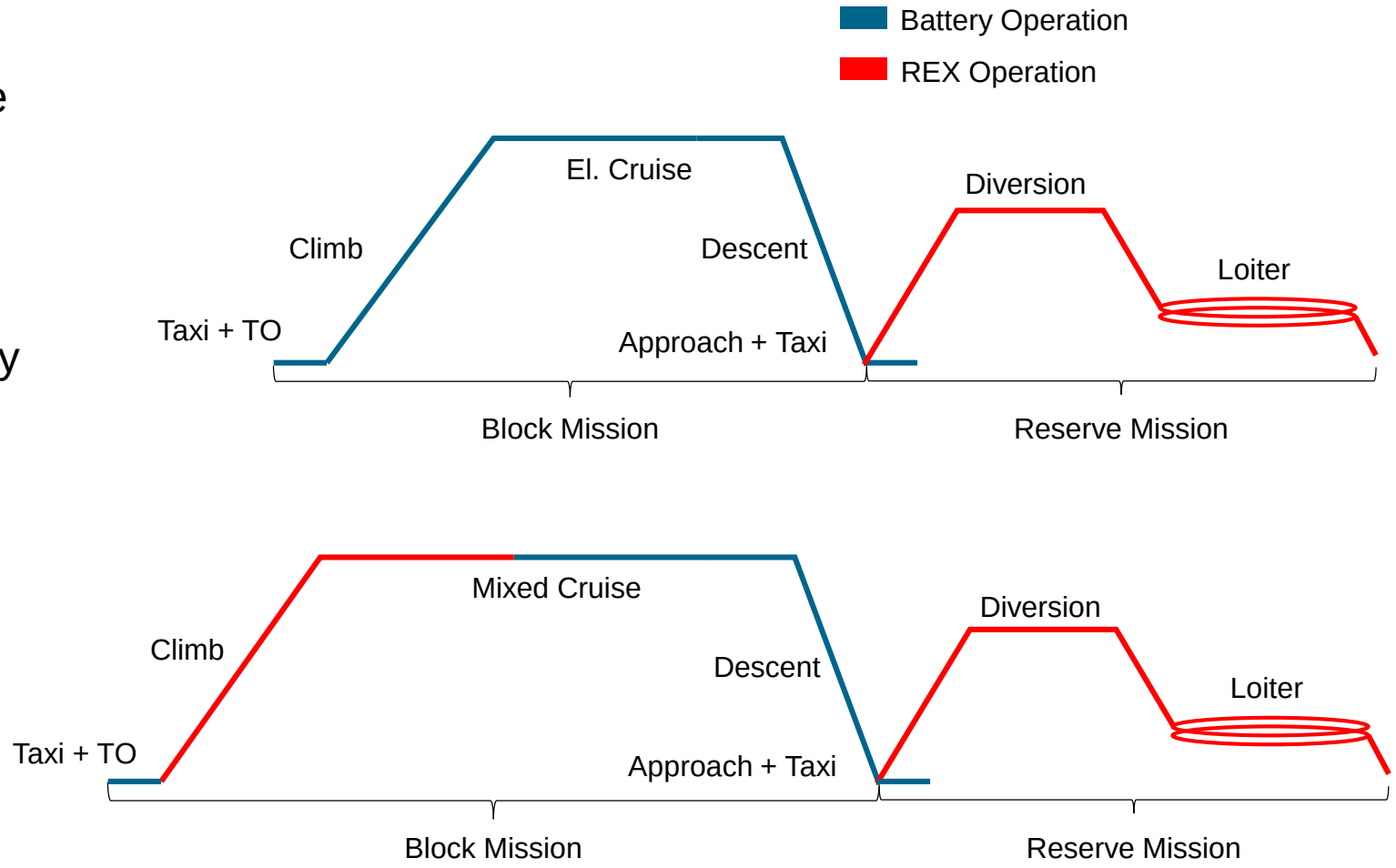
Only high-wing, lower-speed, utility type 19-seater aircraft still in production
(e.g. DHC-6 Viking Twin-Otter, Let L-410NG, PZL M-28 „Skytruck“, Harbin Y-12F, Do228-NG until recently)

Plug-In Concept / Serial Hybrid-Electric

- Fully battery-electric operation
- Kerosene-fueled turboshaft range extender (REX) for reserves and increased range
- Main enabler for higher energy efficiency and lower green-house gas emissions with electric energy coming from renewable sources

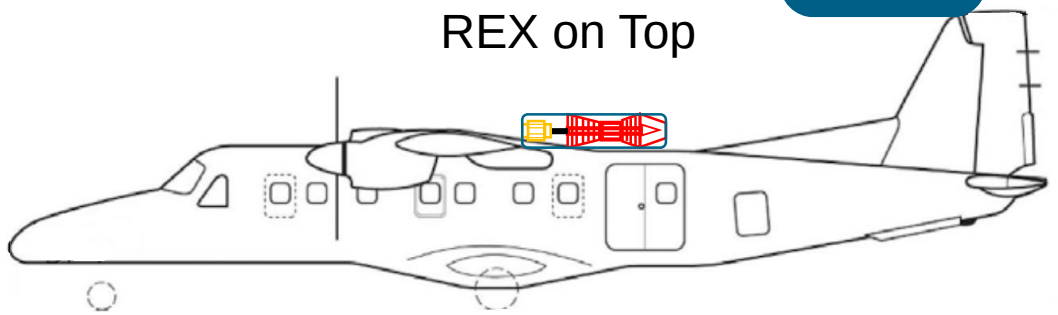
Selected Architecture



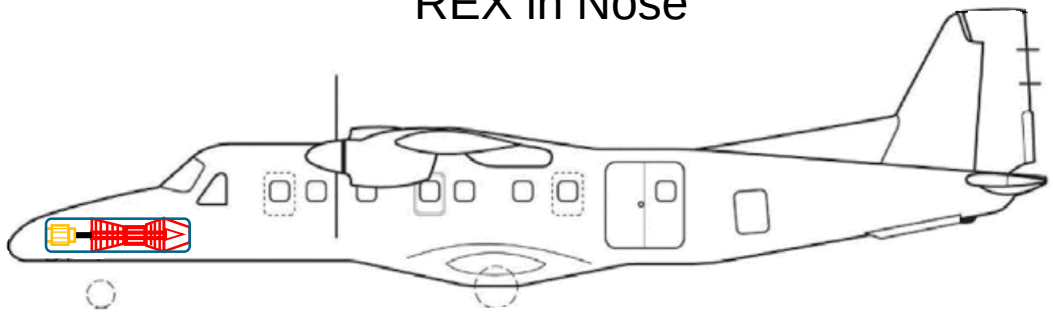


Options for REX Integration on a typical High-Wing Commuter Aircraft

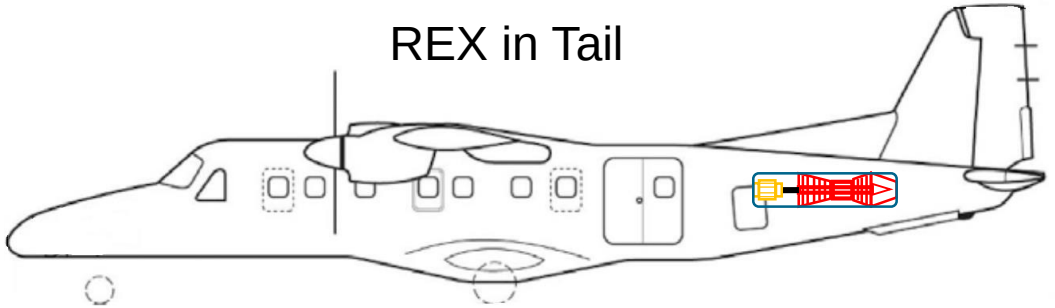
REX on Top



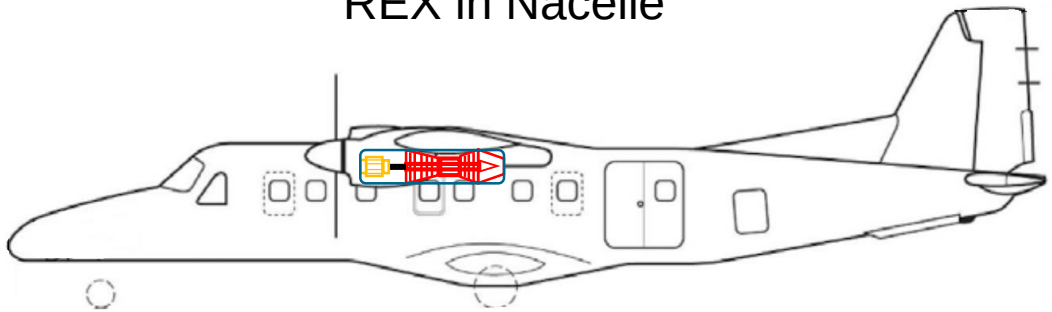
REX in Nose



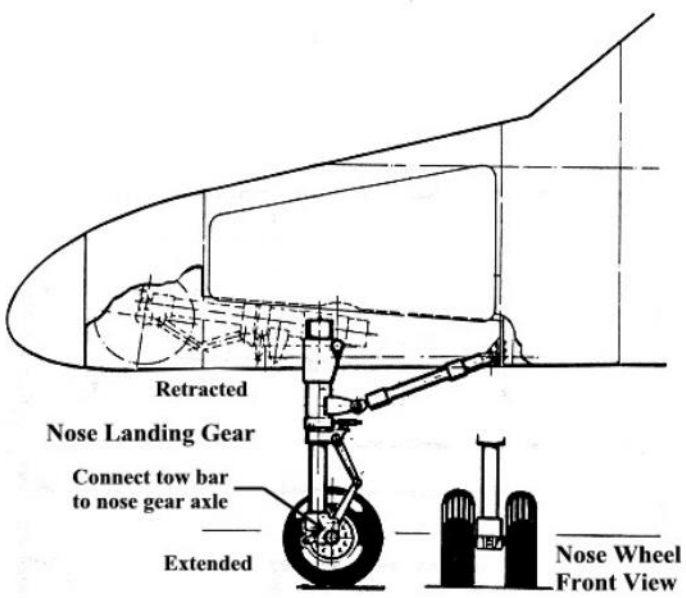
REX in Tail



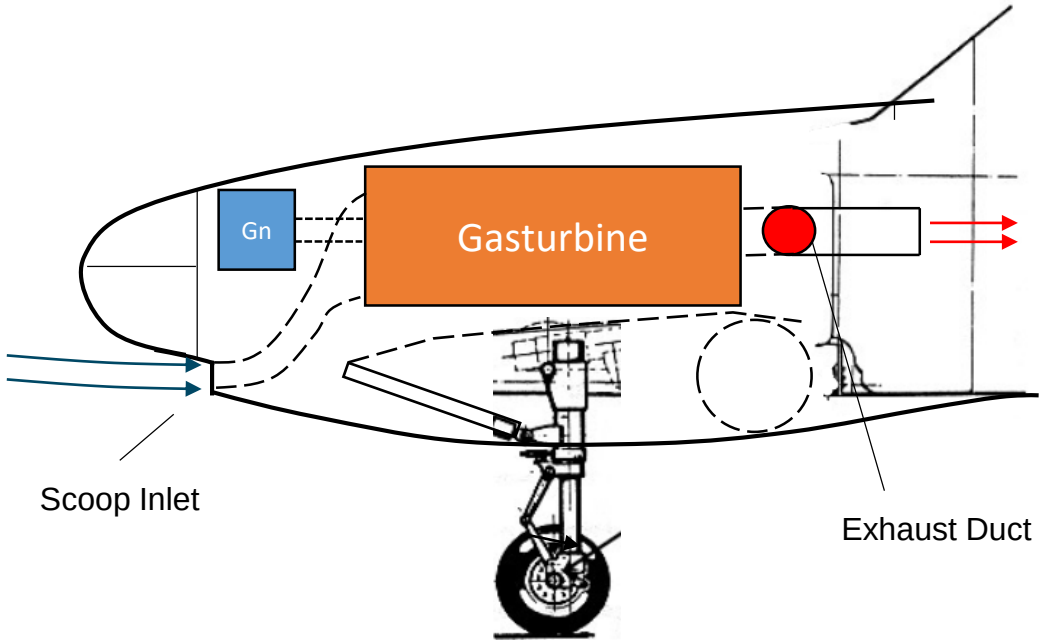
REX in Nacelle



REX in the Nose / Exemplary Integration



Original Do228

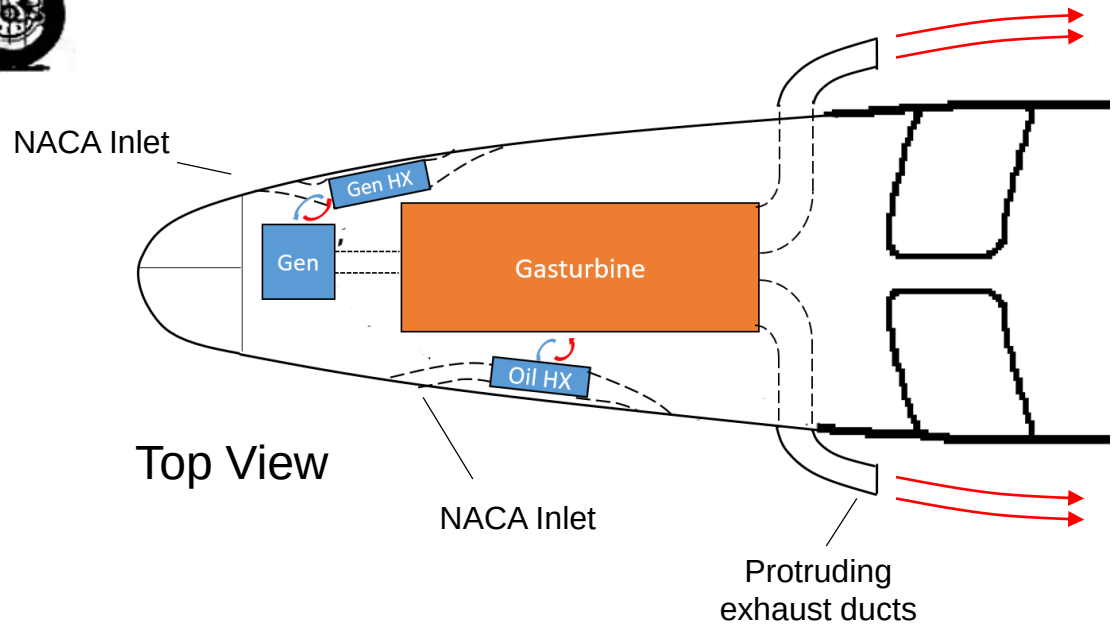


REX Specification

Gasturbine	Length	1.45m
	Diameter	0.57m
	Power	1400kW
Generator	Length	0.3m
	Diameter	0.3m
	Power	1350kW

⇨ Keeping the retractable landing gear (opposite orientation)

⇨ Fairing around the tire to lower the engine cowling (least interference with pilot sight)



Top View

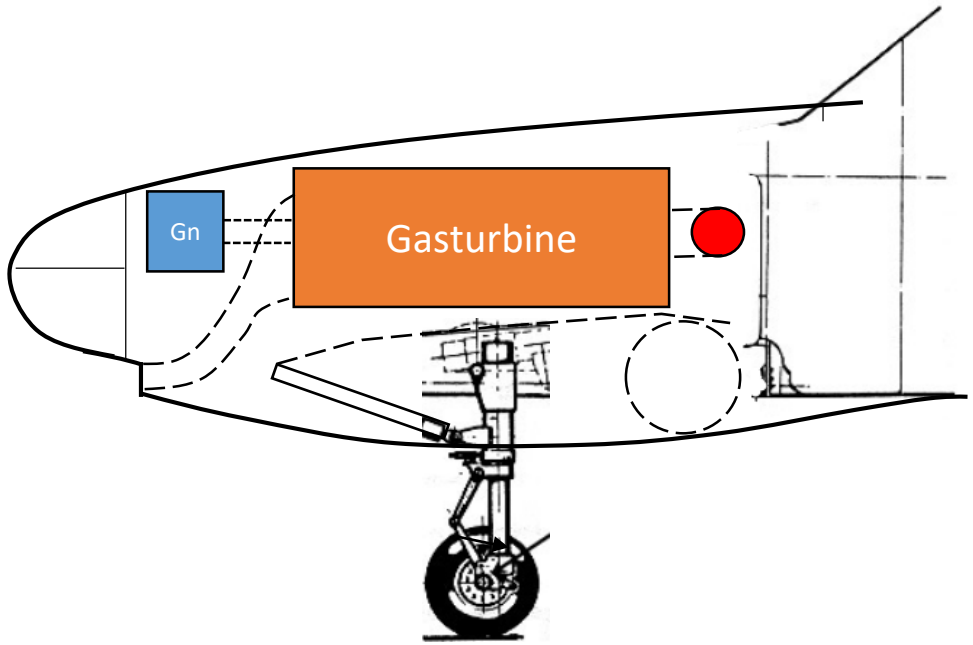
REX in the Nose

Pros

- Best safety in case of disc burst
- Best maintenance access
- Smallest empennage
- Low effort for all battery-electric conversion

Cons

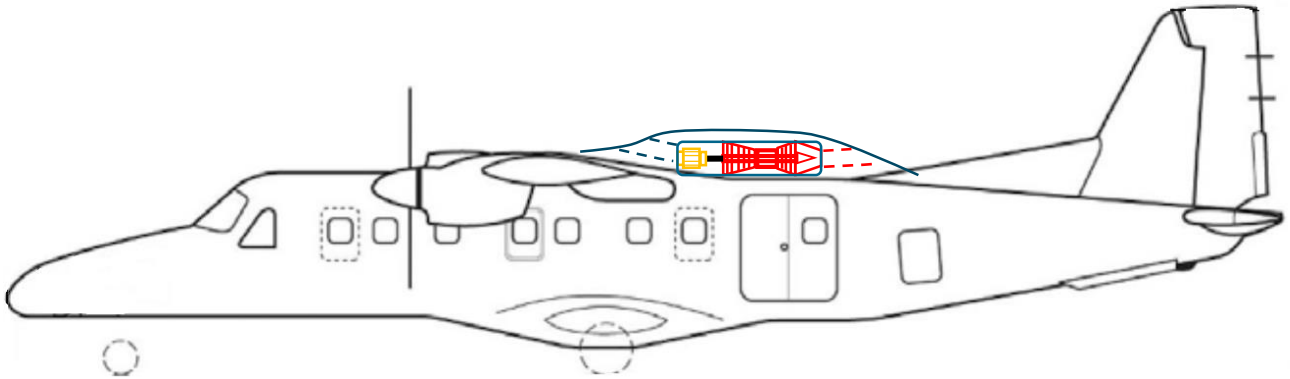
- Aerodynamic integration „ok“ (pro-truding exhaust outlets)
- Longer nose required
- Nose baggage compartment lost
- Pilot sight may be reduced



REX on Top

Pros

- Integration close to the overall center of gravity
- Simple fuel system
- Low risk for FOD (best for seaplane app.)
- Low effort for all battery-electric conversion
- Baggage compartments untouched



Cons

- Worst maintenance access
- Difficult aerodynamics
  - V- or H-tail necessary due to hot exhaust gas
  - Problematic air feed at high angles of attack
  - Largest drag increase when REX is turned off
- Worst disc burst impact
- Worst in terms of cabin noise

REX in Nacelle Configuration

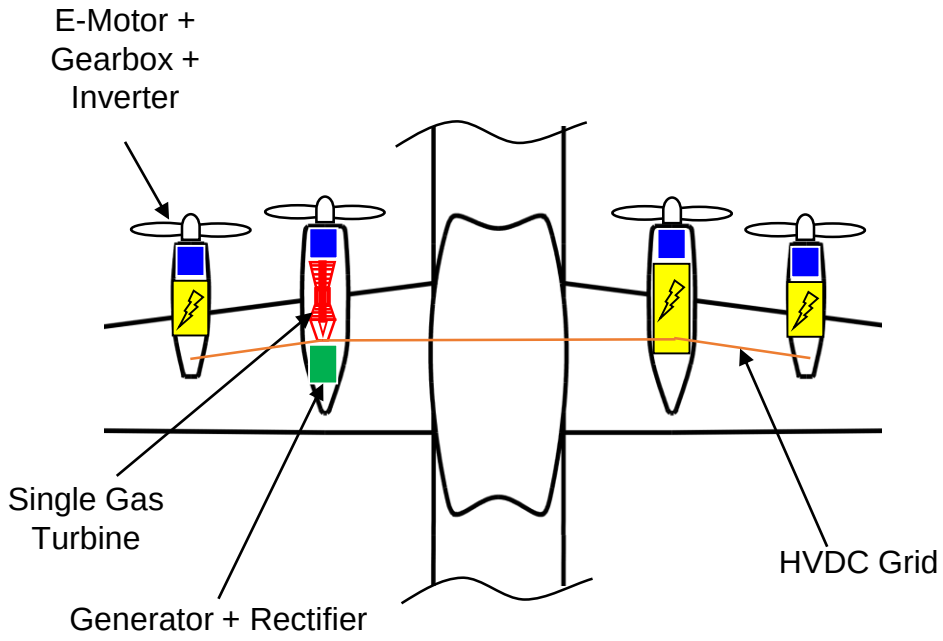
Pros

- Integration closer to the overall center of gravity
- Good maintenance access
- Best / simplest fuel system
- Good air feed and acceptable exhaust gas handling (unsymmetrical but relatively straight ducting)
- Baggage compartments untouched

Cons

- Unsymmetrical battery integration / unsymmetrical REX thrust
- Two/three different types of nacelles
- Larger effort for all battery-electric conversion

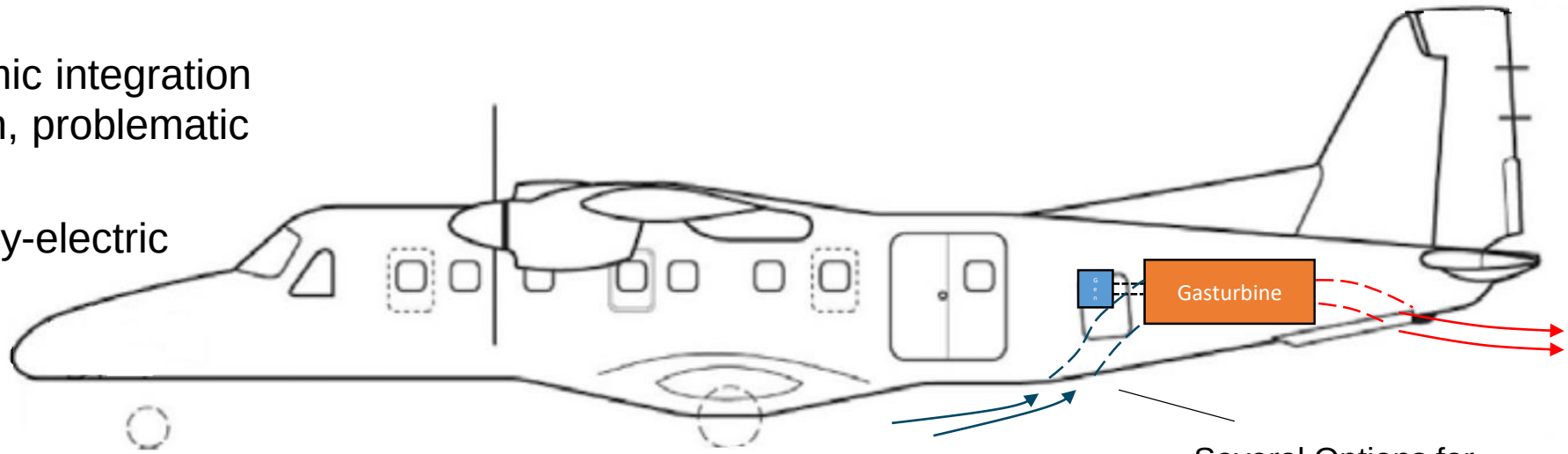
⇨ Better for configurations with two REX´s or parallel-hybrid architecture



REX in Tail

Pros

- Utilization of space inside the fuselage
- Little disc burst impact
- Acceptable aerodynamic integration (Best exhaust flowpath, problematic intake)
- Low effort for all battery-electric conversion
- Acceptable weight and balance situation



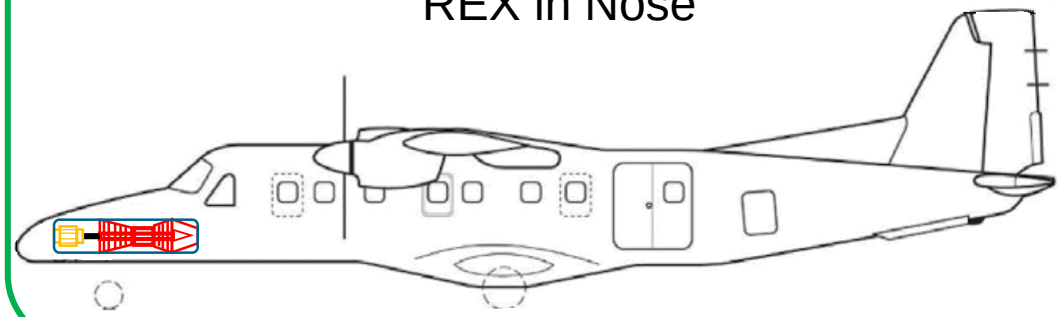
Several Options for Intake Design
Lower Side / Top Side / Right Hand + Left Hand)

Cons

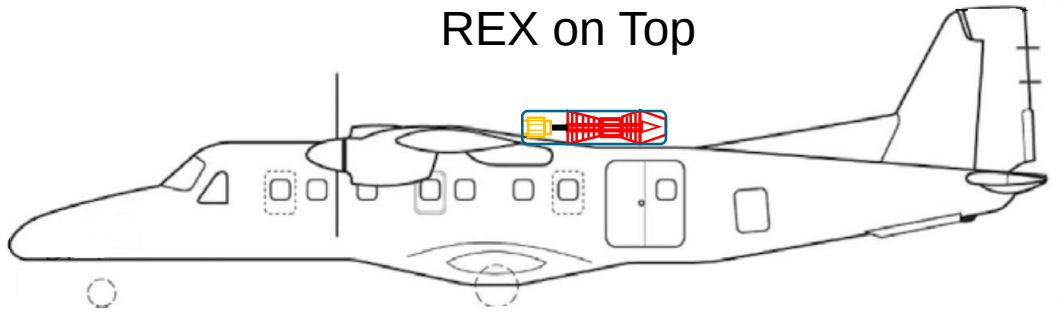
- Largest tailplane due to overall cog-shift towards the tail
- More effort for ensuring safety / redundancy of flight controls in case of disc burst
- Tailstrike issue if intake is on the lower side

Selected Options for Quantitative Assessment

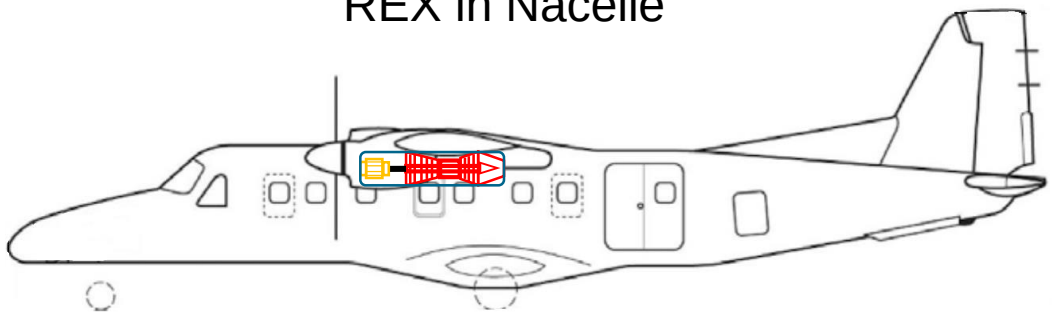
REX in Nose



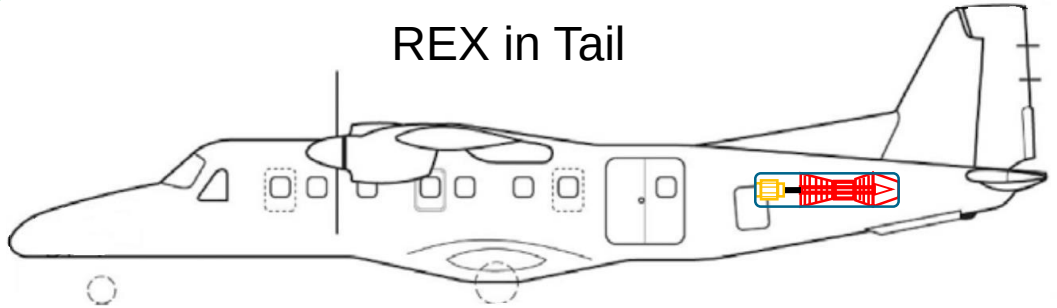
REX on Top



REX in Nacelle



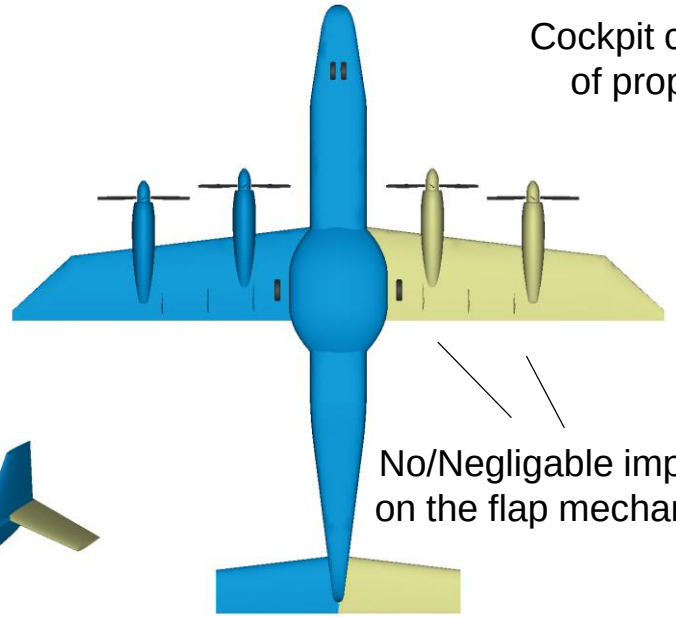
REX in Tail



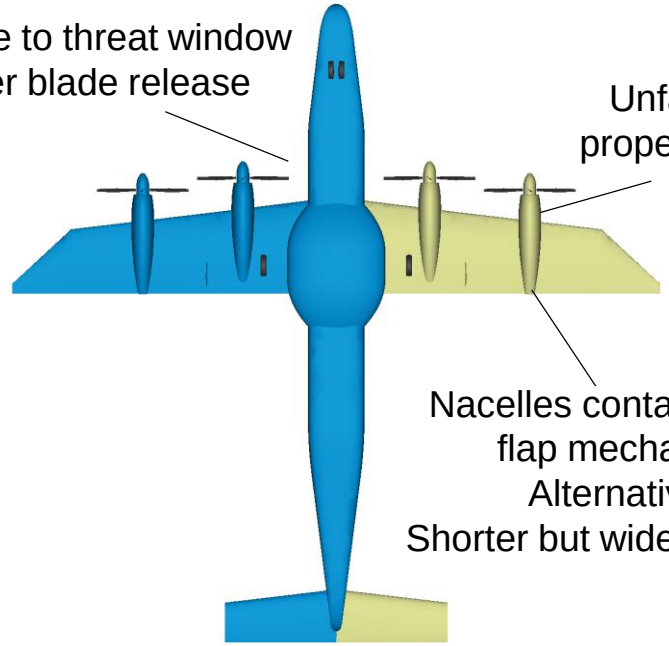
Study: REX in Tail vs. in Nose

REX in Tail

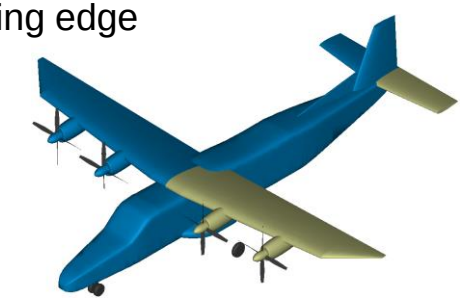
REX in Nose



Cockpit close to threat window of propeller blade release



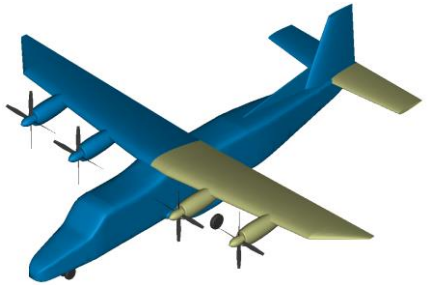
Unfavourable distance betw. propeller and wing leading edge



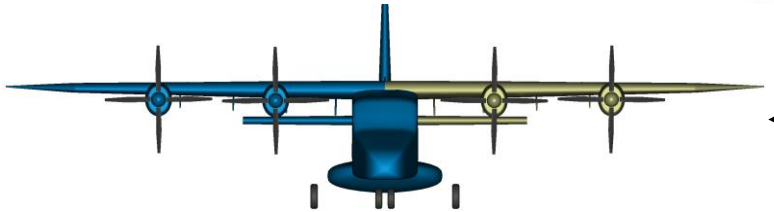
REX in Nose

No/Negligable impact on the flap mechanics

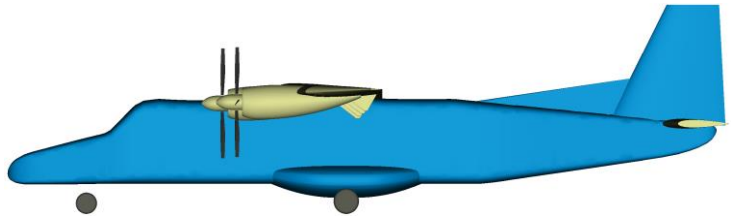
Nacelles containing the flap mechanics
Alternative:
Shorter but wider nacelles

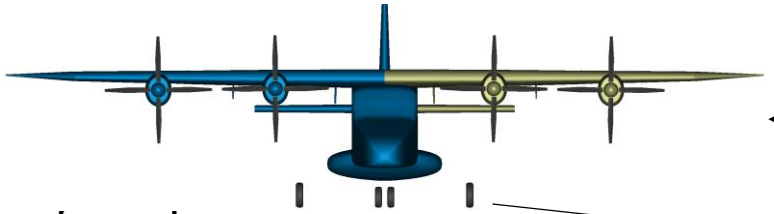


REX in Tail

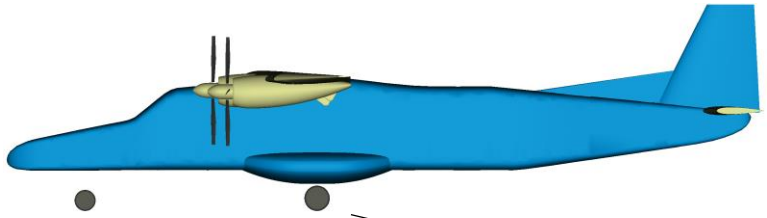


REX in Tail





REX in Nose



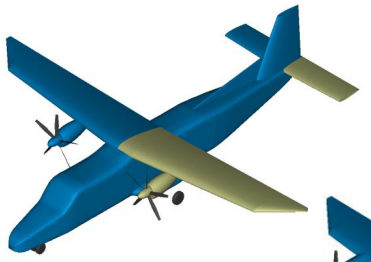
REX in Tail preferred

Wider Main Gear Track for REX in Nose
-> Difficult integration

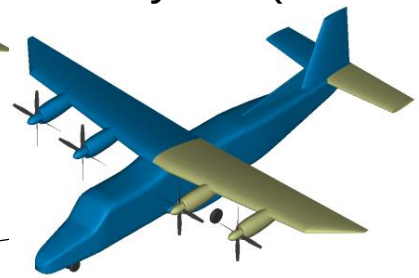
Longer Landing Gear

Fleet-level Assessment

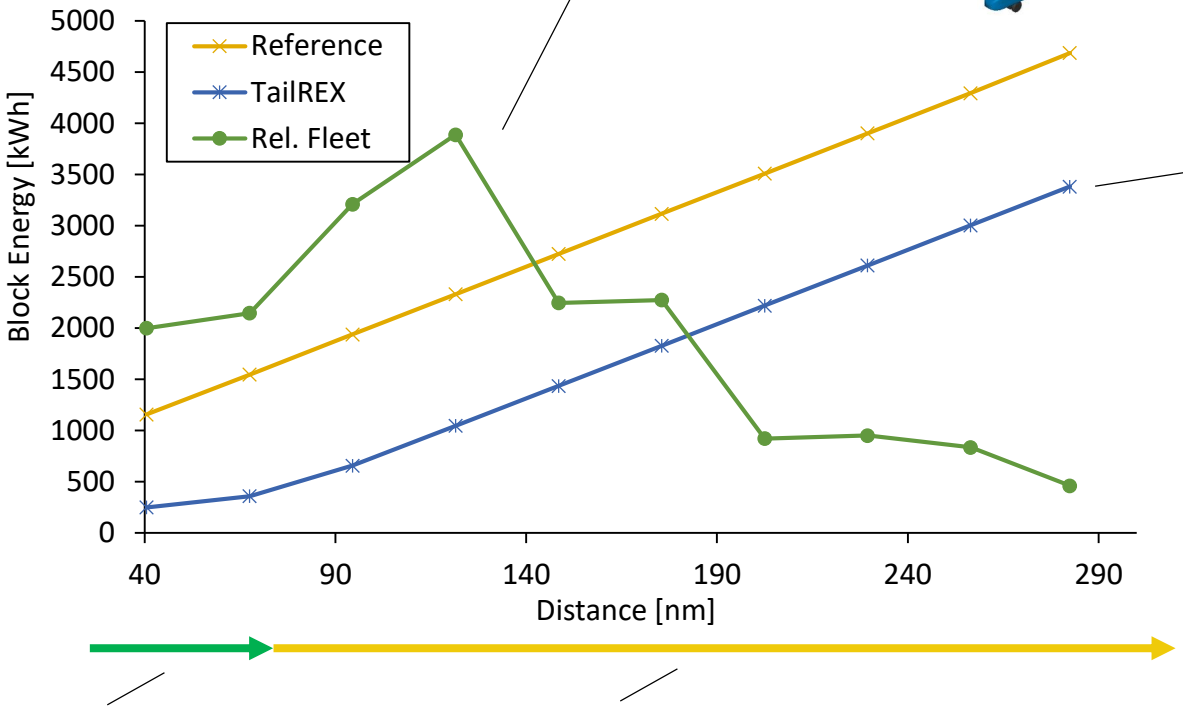
Reference



Hybrid (Tail REX)



Relative Fleet Distribution



Electric up to approx. 76 nm (141 km)

Hybrid operation

Benefit on fleet level

-53% Fleet energy

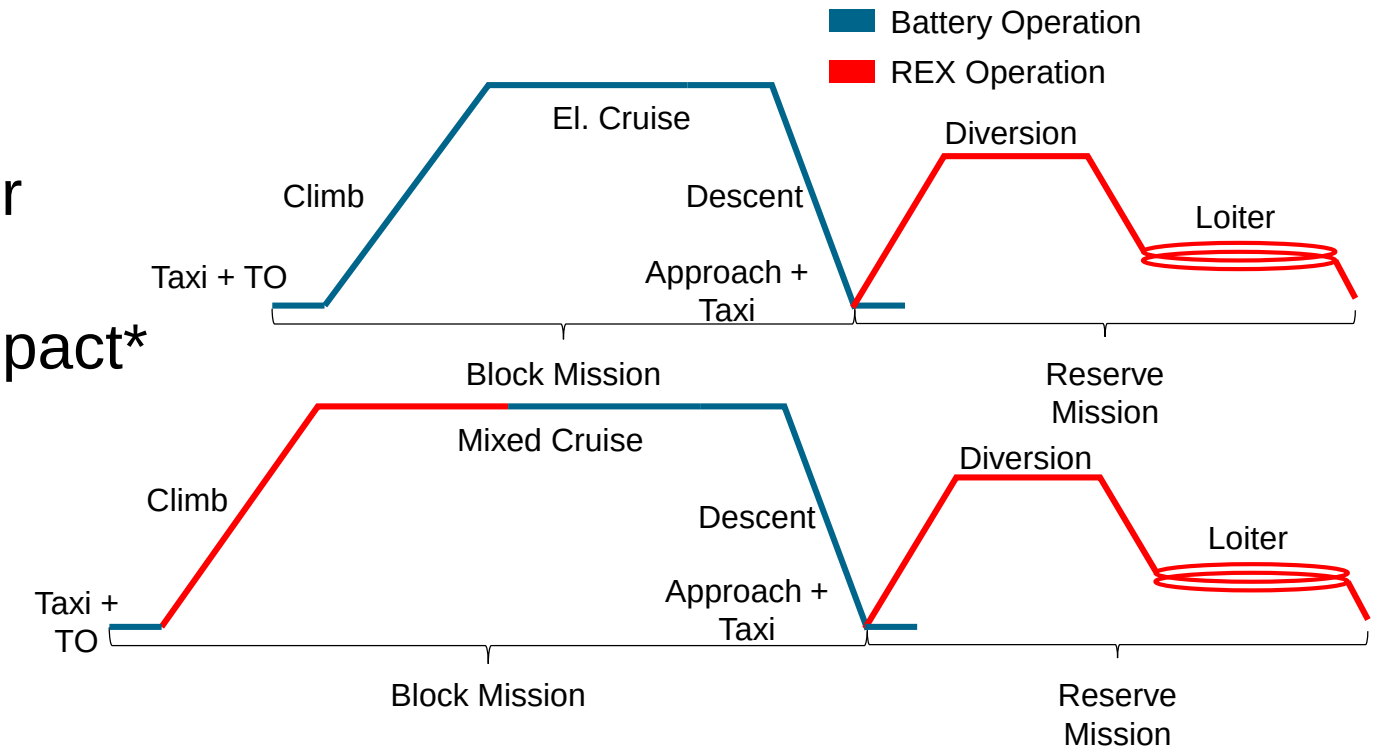
-69% Fleet fuel

Assumptions Pack:

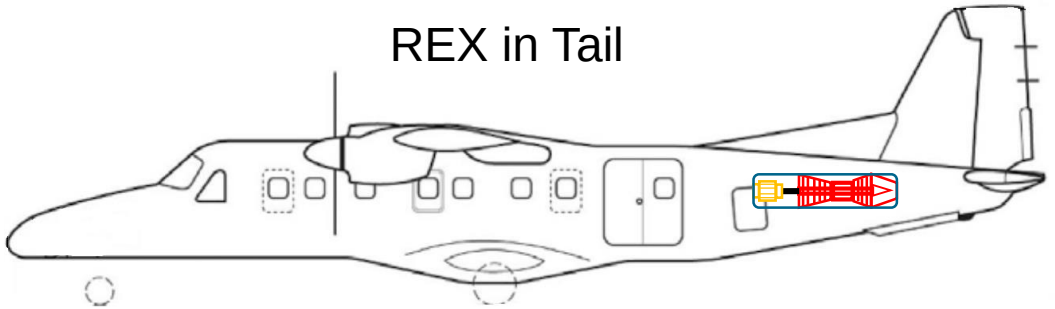
- State-of-the-art technology (Aluminium structures + Gas turbine)
- Max 8618 kg MTOM (CS23 limit) i.e. + 34% vs. Reference
- Slightly less STOL capability (higher wing loading-, stall speed)
- Constant wing aspect ratio (9)
- Battery:
  - 320 Wh/kg (Pack level)
  - 10%-90% SoC Range
- Geared Electric Motor: 10kW/kg, 98% Eff.
- Generator: 16kW/kg, 98.5% Eff.
- Power Electronics: 60kW/kg, 98.5% Eff.

Conclusion

- The Plug-In hybrid-electric concept is the main enabler for desired energy savings and reduction in climate impact*



- The optimal integration of the range extender is a compromise and may not be the one giving the best energy efficiency



*Given that the elecric energy is provided by renewable energy sources

Thank you for your attention!

Contact:

Philip Balack

DLR Institute of System Architectures in Aeronautics, Hamburg

Philip.Balack@dlr.de