FUTure PRopulsion and INTegration
towards a hybrid-electric 50-seat regional aircraft

Current Status of FUTPRINT50

EASIER Workshop | 1 June 2021 | online

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FutPrInt50

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This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 875551

European Commission

Content Overview

FUTPRINT50

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Objectives of FutPrInt50

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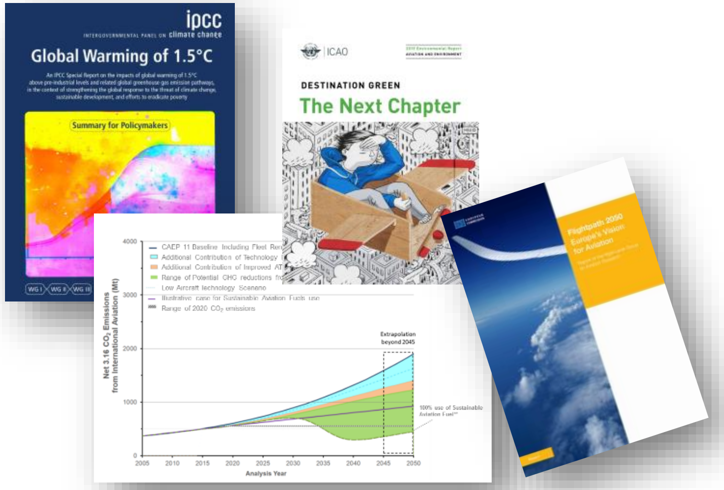
Objectives



Aviation is a key component **for development and resilience.**
It is deeply integrated into a worldwide **intermodal transport network.**

Clean Aviation
to support **sustainable development.**

FUTPRINT50

Future propulsion and integration: towards a hybrid-electric 50-seat regional aircraft

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Objectives

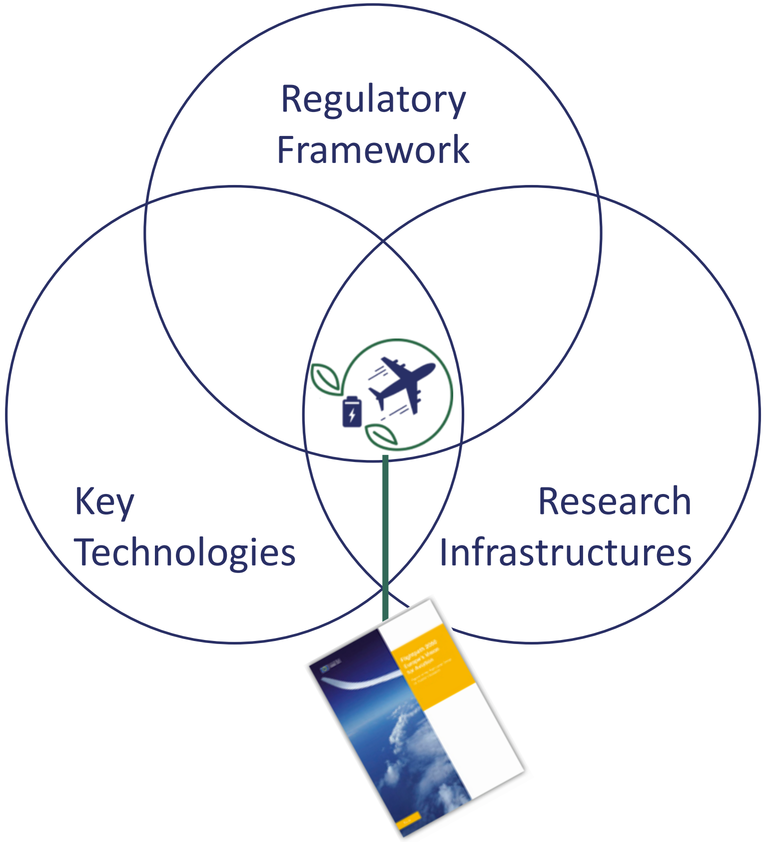
Hybrid-Electric
≤ 50 PAX
EIS 2035/2040

Open-source tools & models

In-depth state-of-art feasibility study

Disruptive key technologies:

- Energy storage
- Energy harvesting
- Thermal management



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Mission Statement

*“To develop a **synergetic** aircraft design for a commercial **hybrid-electric regional** aircraft up to 50 seats for entry into service by **2035/2040**, to identify key enabling **technologies** and a roadmap for **regulatory aspects**. The clean sheet aircraft design shall help **accelerate and integrate** hybrid-electric aircraft and technologies to achieve a **sustainable competitive aviation** growth, as well as acting as a disruptor to **regulators**, **air traffic management** and **energy suppliers**.”*

The clean sheet aircraft design shall

- have class-leading emissions and noise,
- include technologies that ensure (operational) safety,
- offer competitive operational cost,
- offer operational improvements during exploitation compared to current regional aircraft,
- not enforce expensive changes to the current infrastructure.

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Requirements Specification & Design Methodology

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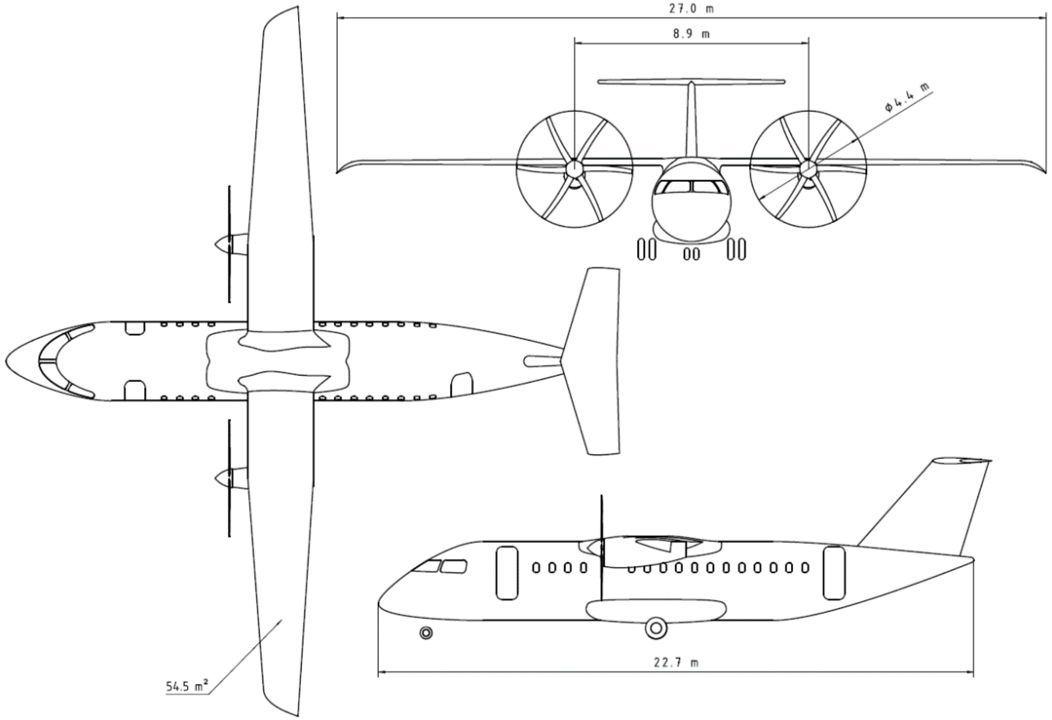
Conventional Reference Aircraft (2040)

- Designed in SUAVE, the tool environment we will use for future hybrid-electric aircraft designs
- Will serve as reference for future hybrid-electric aircraft designs
  - Flight performance
  - Direct operating costs

MRM	11700 kg
Payload	5300 kg
Mission fuel	377 kg
Reserve fuel	344 kg
TOW	17720 kg
Rate of climb (start)	1917 ft/min
Rate of climb (end)	966 ft/min
Time to climb to FL170	9.6 min
Cruise fuel flow	460 kg/h



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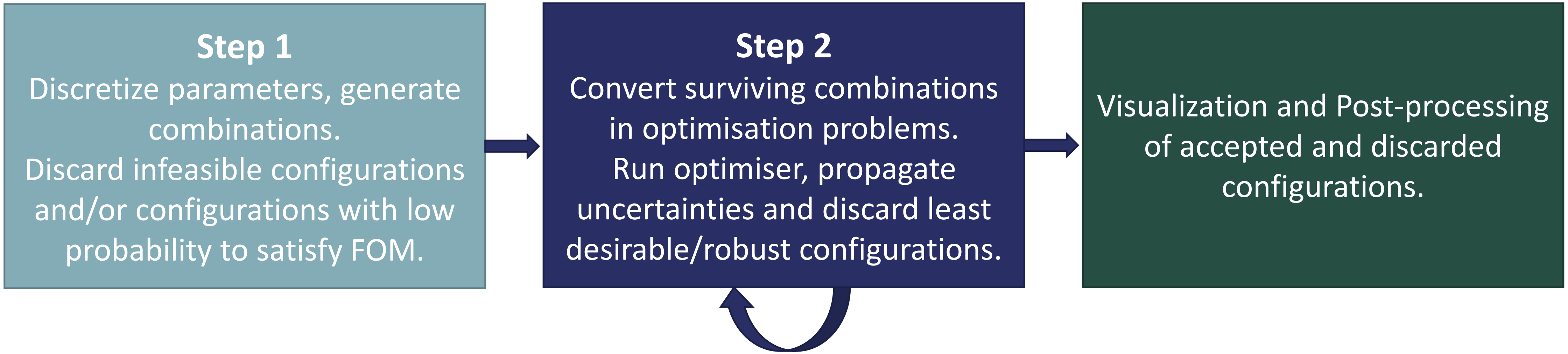
Design Methodology

Probabilistic set-based design with optimization

- Step 1: **Probability** to discard undesirable and unfeasible design configurations
- Step 2: **Optimisation with uncertainty propagation** to identify the optimum of each configuration and further refine the knowledge in them



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Aircraft Energy System Analysis

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Aircraft Energy System Analysis: Energy Storage

- Sizing tool of the battery model is a top layer of the battery pack
- It helps to define the optimal parameters of the battery pack, for a given usage pattern

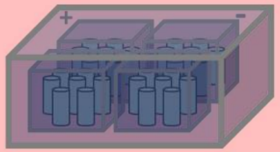
Sizing parameters

- Cell type / chemistry
- Cooling-heating techno (direct/indirect?)
- Expected lifetime (year)
- Sizing profiles :
  - $P_{elec\_over\_24h\_(W)} = f(t_{\_(s)})$
  - $T_{amb\_over\_24h\_(°C)} = f(t_{\_(s)})$
- Pack voltage limits :
  - Udc min
  - Udc max

Pack Sizing Tool

Iterative simulations

BATTERY PACK MODEL



Optimal pack sizing parameters

- N cells in series
- N cells in parallel
- Cell SOH at durablitity target

Ouput Characteristics

- Pack mass
- Pack volume

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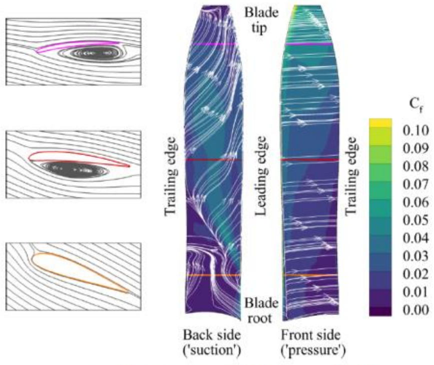
Aircraft Energy System Analysis: Energy Harvesting

- Numerical analyses of isolated propellers in propulsive and regenerative conditions
- Wind-tunnel experiment with isolated propeller
- Wind-tunnel experiment with installed tip-mounted propeller configuration
- Just started: development of novel techniques for acoustic data processing (wavelet decomposition)



(c) $J = 1.15$, $T_C = -0.108$, $P_C = -0.043$

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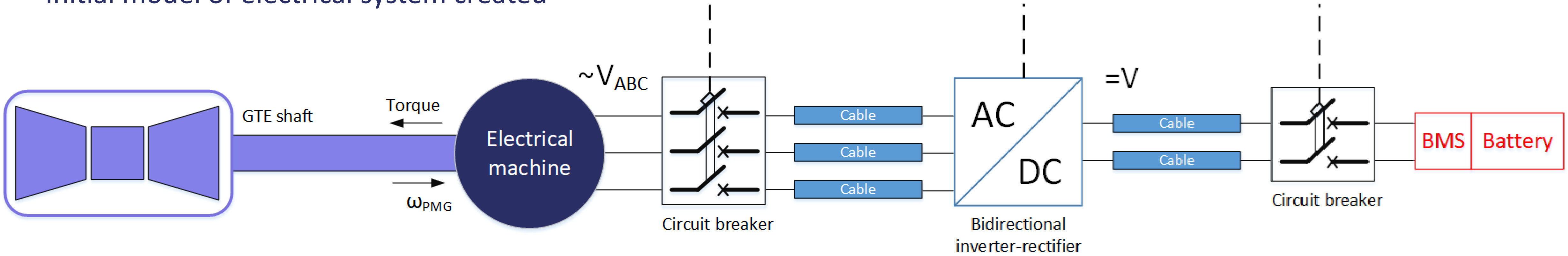
Aircraft Energy System Analysis: Electrical System Models

Goal

- To develop a library of Electrical System component models

Achievements

- Various electrical system architectures mapped
- Dynamic inputs/outputs of electrical components proposed
- Initial model of electrical system created



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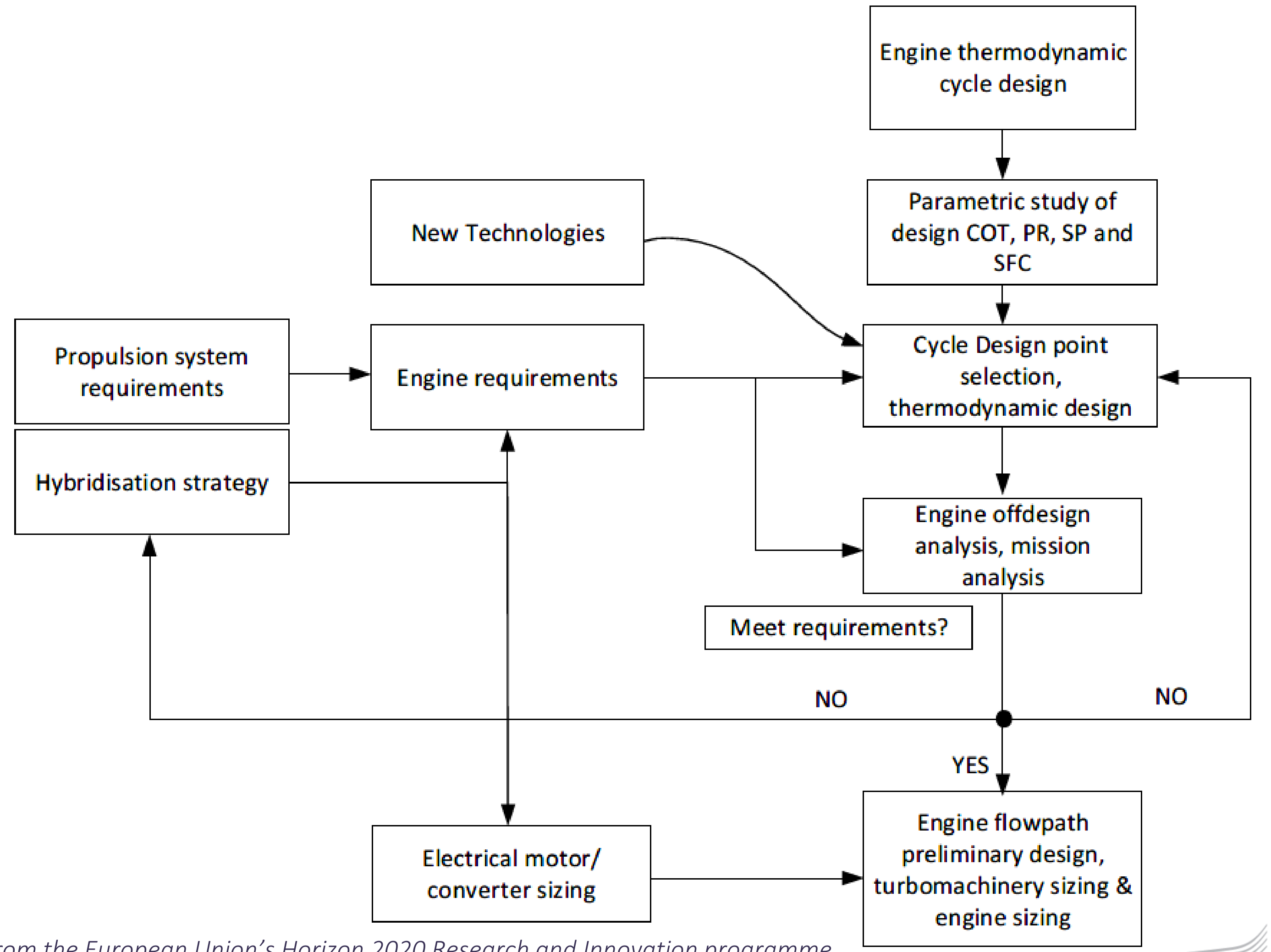
Aircraft Energy System Analysis: Prime Mover Design

Prime mover design flowchart

- Thermodynamic cycle design
- Hybrid engine requirements
- Off-design analysis
- Turbomachinery design
- Engine sizing



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Aircraft Level Architecture Analysis

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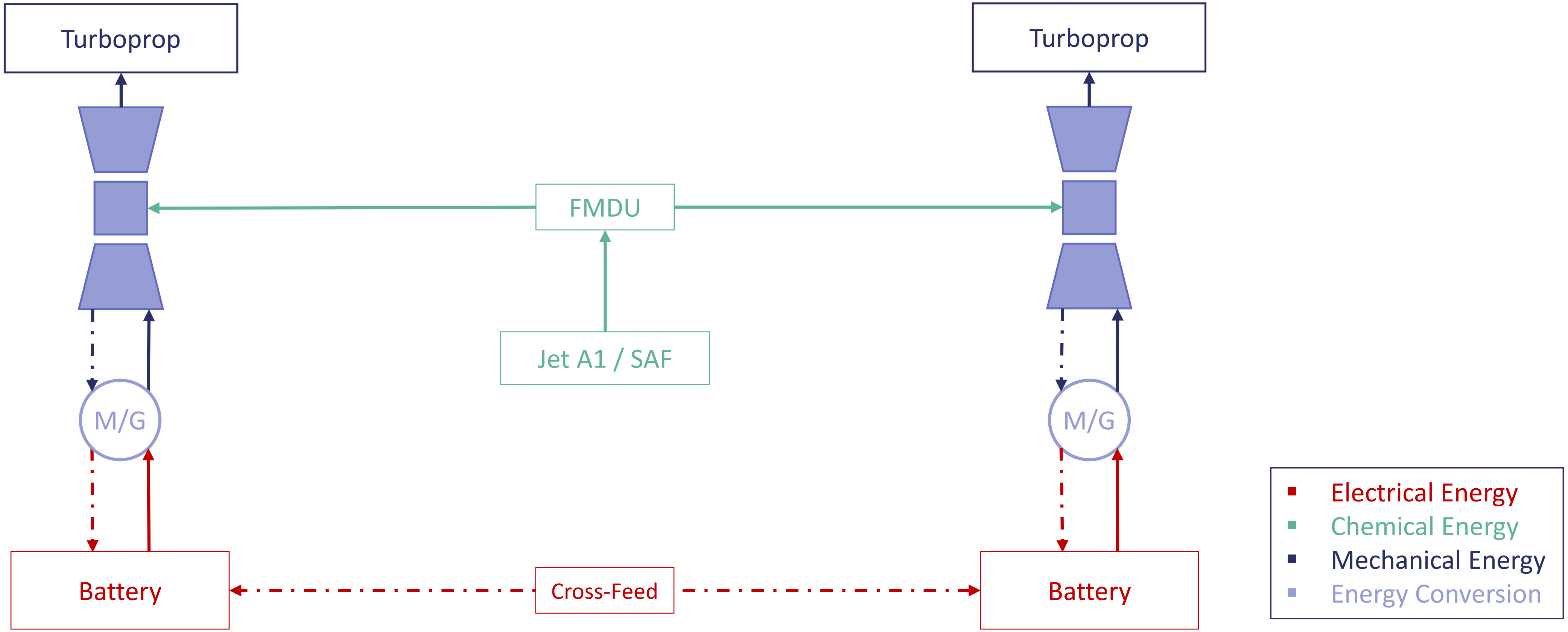
Aircraft Level Architecture Analysis: Hybrid-Electric Architectures

- Selection of relevant hybrid-electric architectures → example: parallel hybrid



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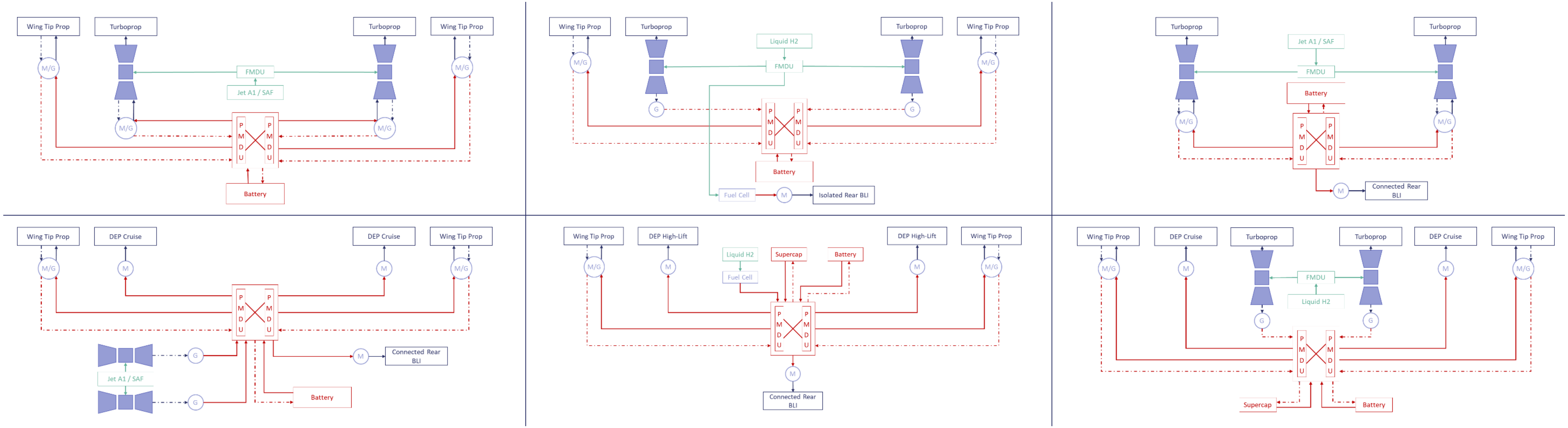
Aircraft Level Architecture Analysis: Hybrid-Electric Architectures

- Selection of relevant hybrid-electric architectures



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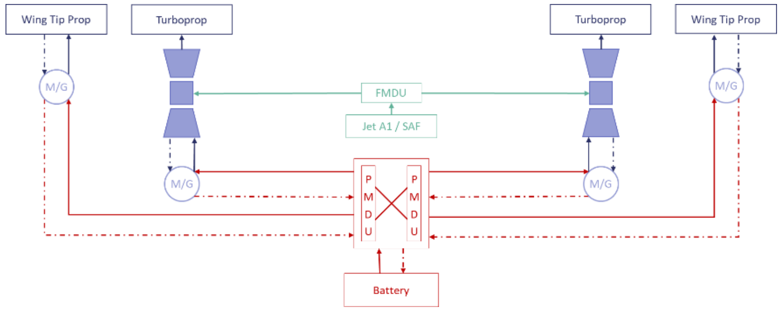
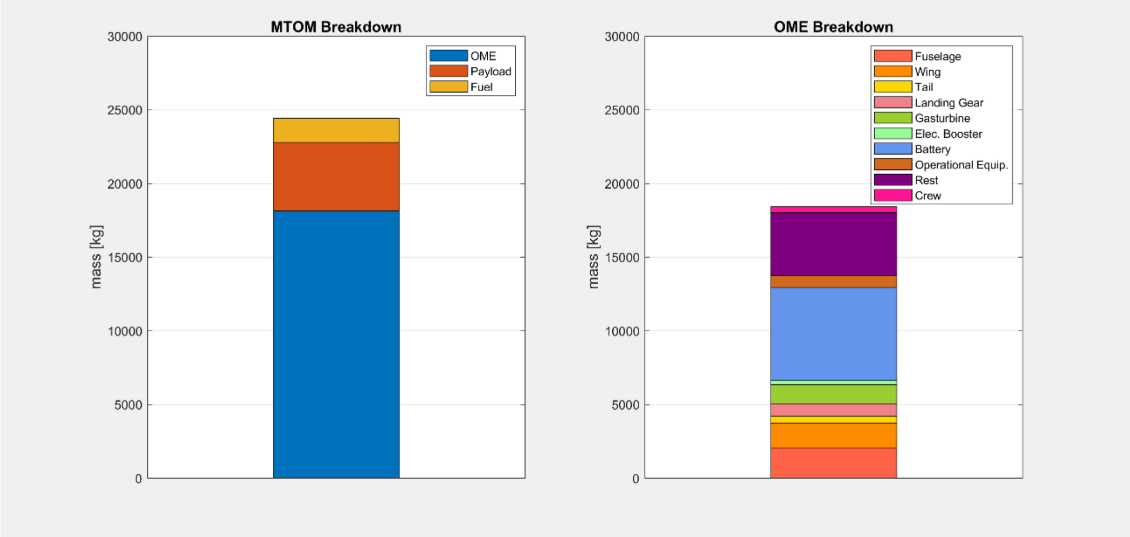
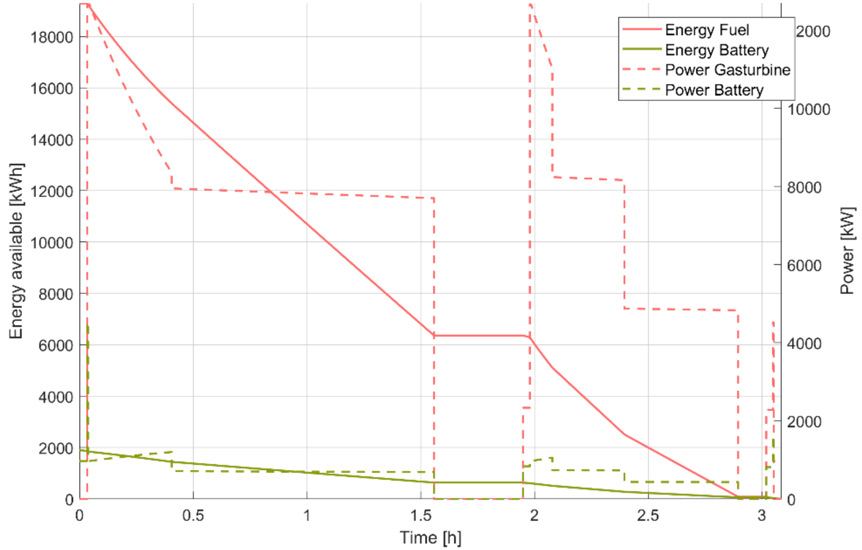
Aircraft Level Architecture Analysis: Initial Sizing

- Initial sizing of all relevant architectures
  - Mass estimations of components
  - Flight performance data over the entire mission
  - Energy and power distribution
- Parameter studies over hybridisation factors and booster intensity







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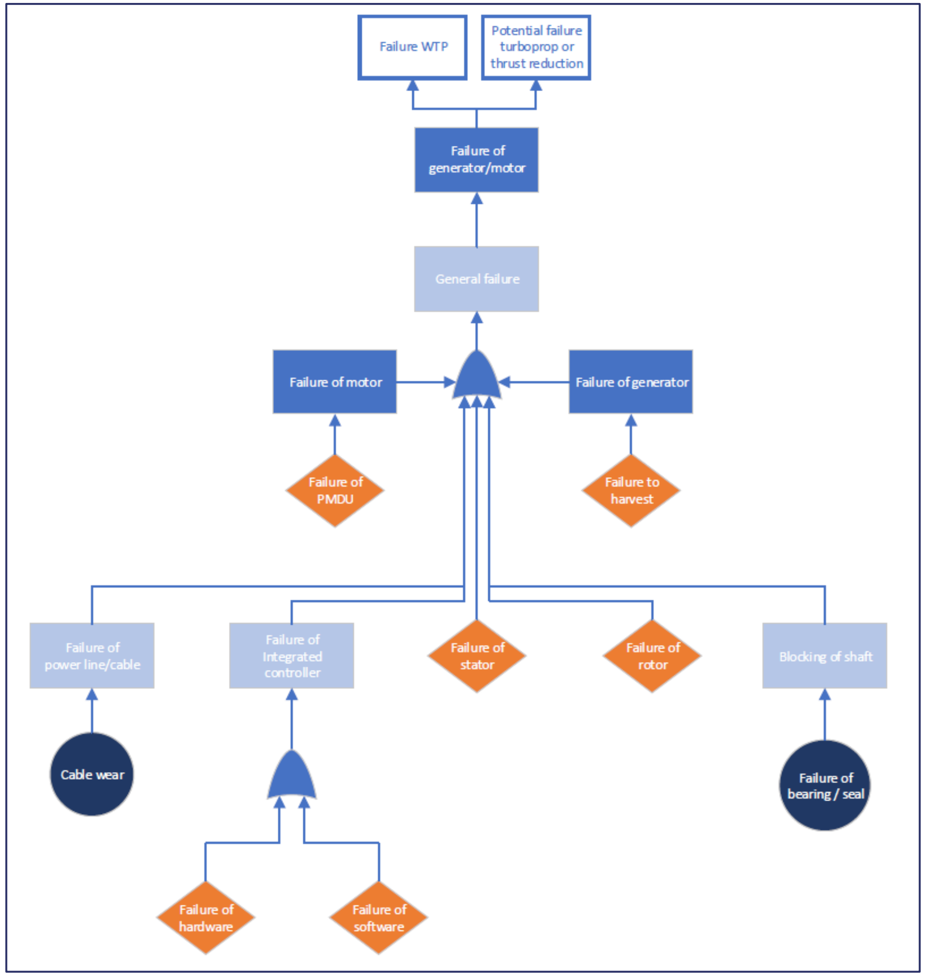
Aircraft Level Architecture Analysis: Initial Sizing

Component failure scenarios

- Functional hazard assessment
- Fault tree analysis

72 ENGINE TURBINE/TURBO PROP DUCTED FAN/UNDUCTED FAN							
ATA Chapter	**Function**	**Functional Failure**	**Flight Phase**	**Effect on Aircraft. Crew, and Other**	**Indication to Pilot**	**Condition Classification**	**Required Safety**
-00 General							
-10 Reduction Gear, Shaft Section (Turbo-Prop and/or Front Mounted Gear Driven Propulsor)							
	Provide coupling between TP and M/G	Severance of coupling	T	I) Reduced power available	Decrease in acc. Rate	Catastrophic	<1E-9
	Provide coupling between TP and M/G	Severance of coupling	F/L	I) Reduced power available		Hazardous	<1E-7
-20 Air Inlet Section							
-30 Compressor Section							
-40 Combustion Section							
-50 Turbine Section							
-60 Accessory Drives							
	Generate power for battery charging	loss of charging function	F/L	II) Diversion to airport	Alarm function shall be present	Major	<1E-5
	Provide power	Loss of both M/G	T	I) Reduced power available, still enough for take-off	Decrease in acc. Rate	Catastrophic	<1E-9
	Provide power	Loss of both M/G	F/L	I) Reduced power available, still enough for missed approach		Hazardous	<1E-7
-70 By-pass Section							
-80 Propulsor Section (Rear Mounted)							



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Next Steps

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Next Steps

- Development of more sophisticated models of electric energy systems
- Detailed design and sizing of components
- Development of integrated tool environment
- Technology validation and roadmaps

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Acknowledgement

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