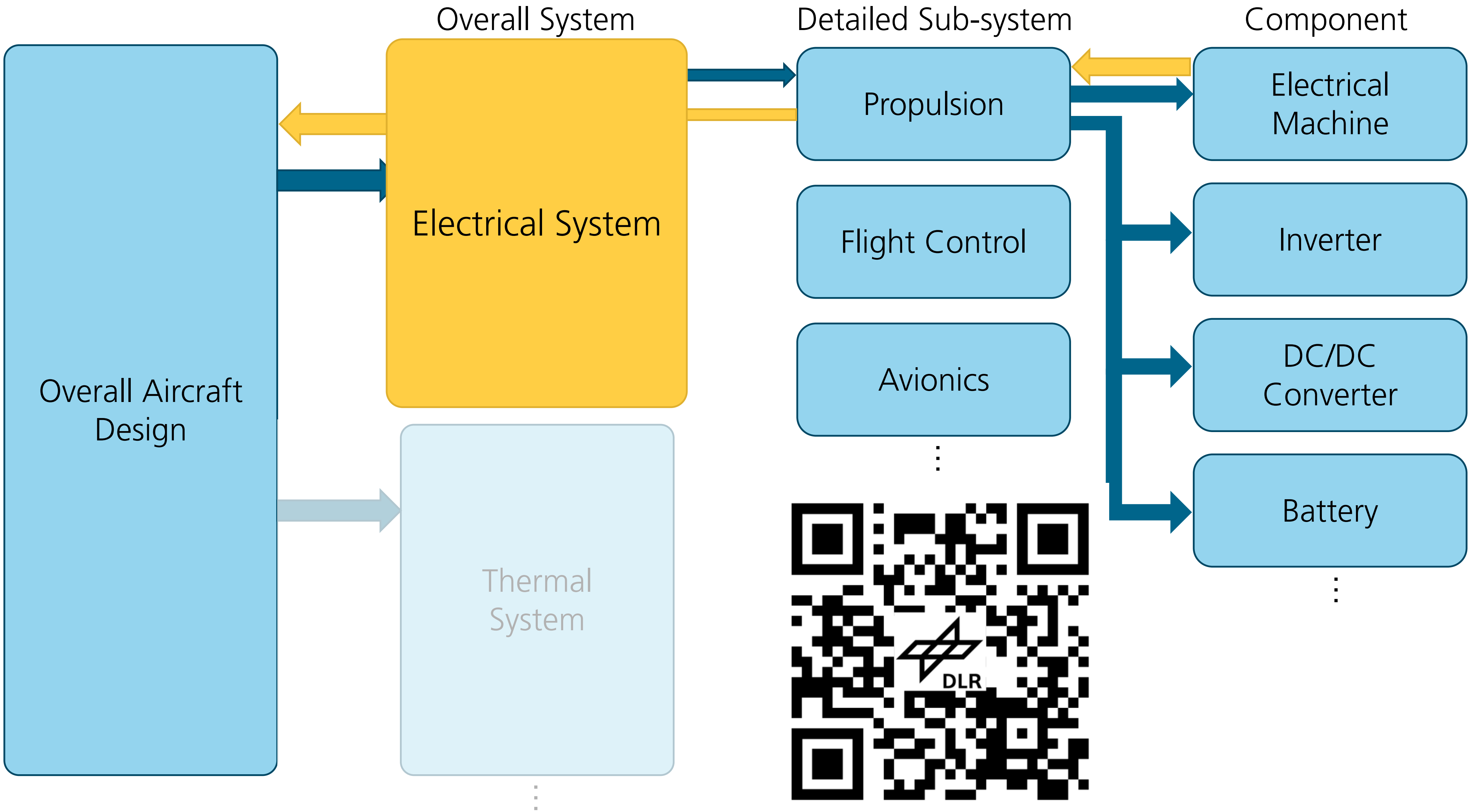
ARCHITECTURAL DESIGN DECISIONS FOR THE ELECTRIC POWER SYSTEM IN FUTURE ELECTRIC AIRCRAFT

Dr.-Ing. Andrea Reindl | Institute of System Architectures in Aeronautics | DLR Oberpfaffenhofen

DLR

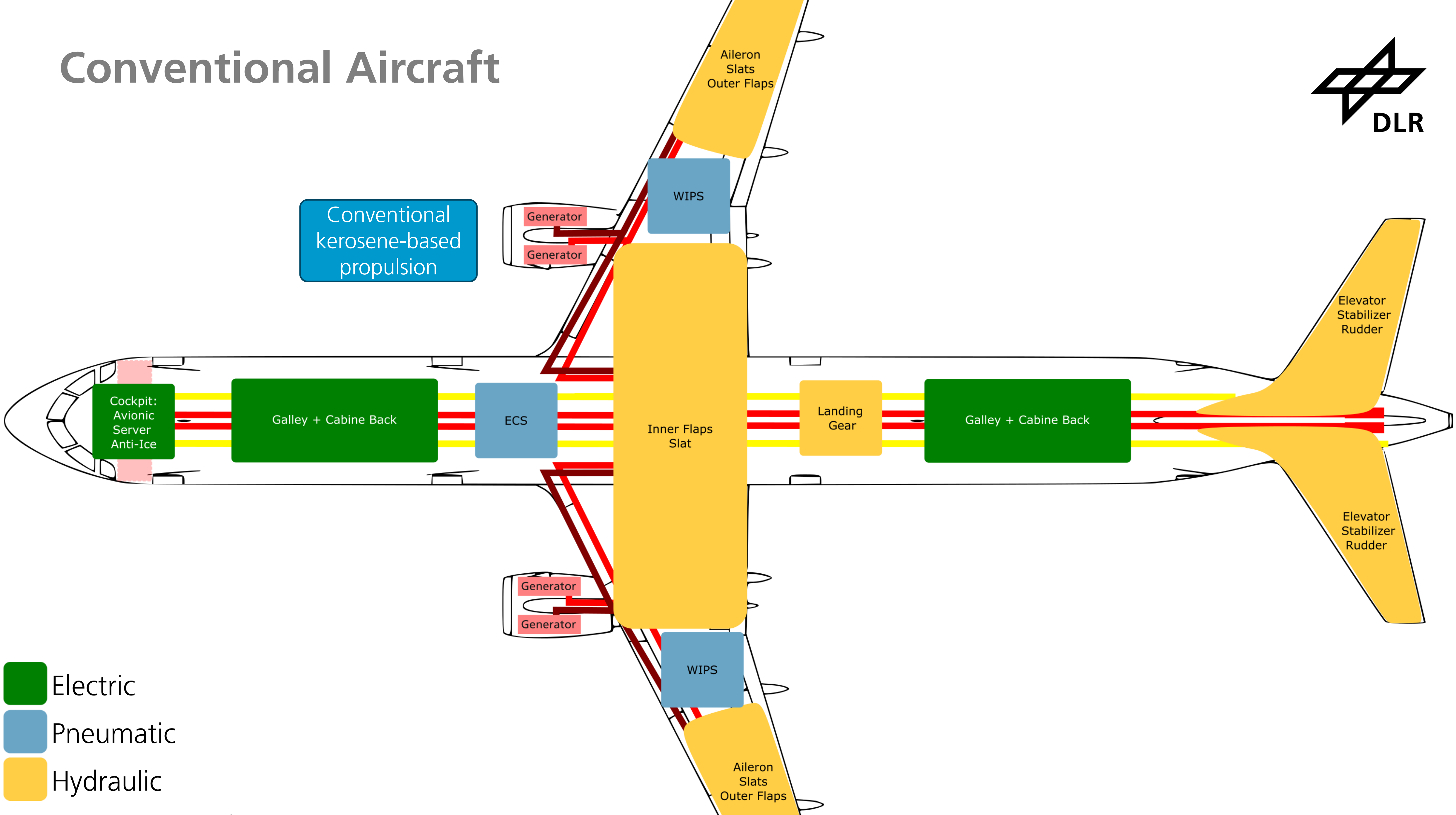
Design of **future aircraft concepts** with the aim of reducing **climate impact**, improving **efficiency** and being **economically viable**

How does the pre-design process work?

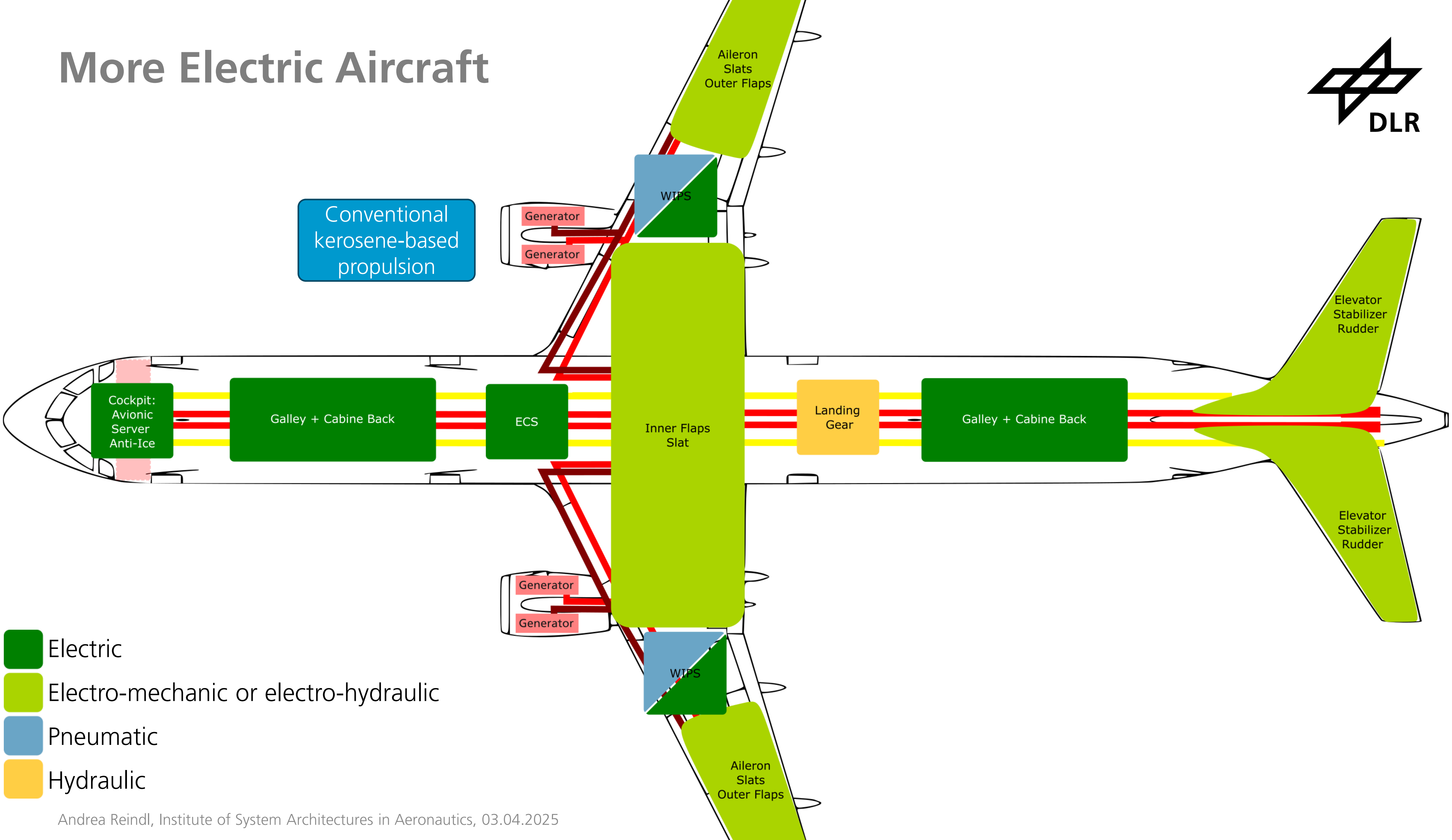


DLR Project - EXACT

Conventional Aircraft

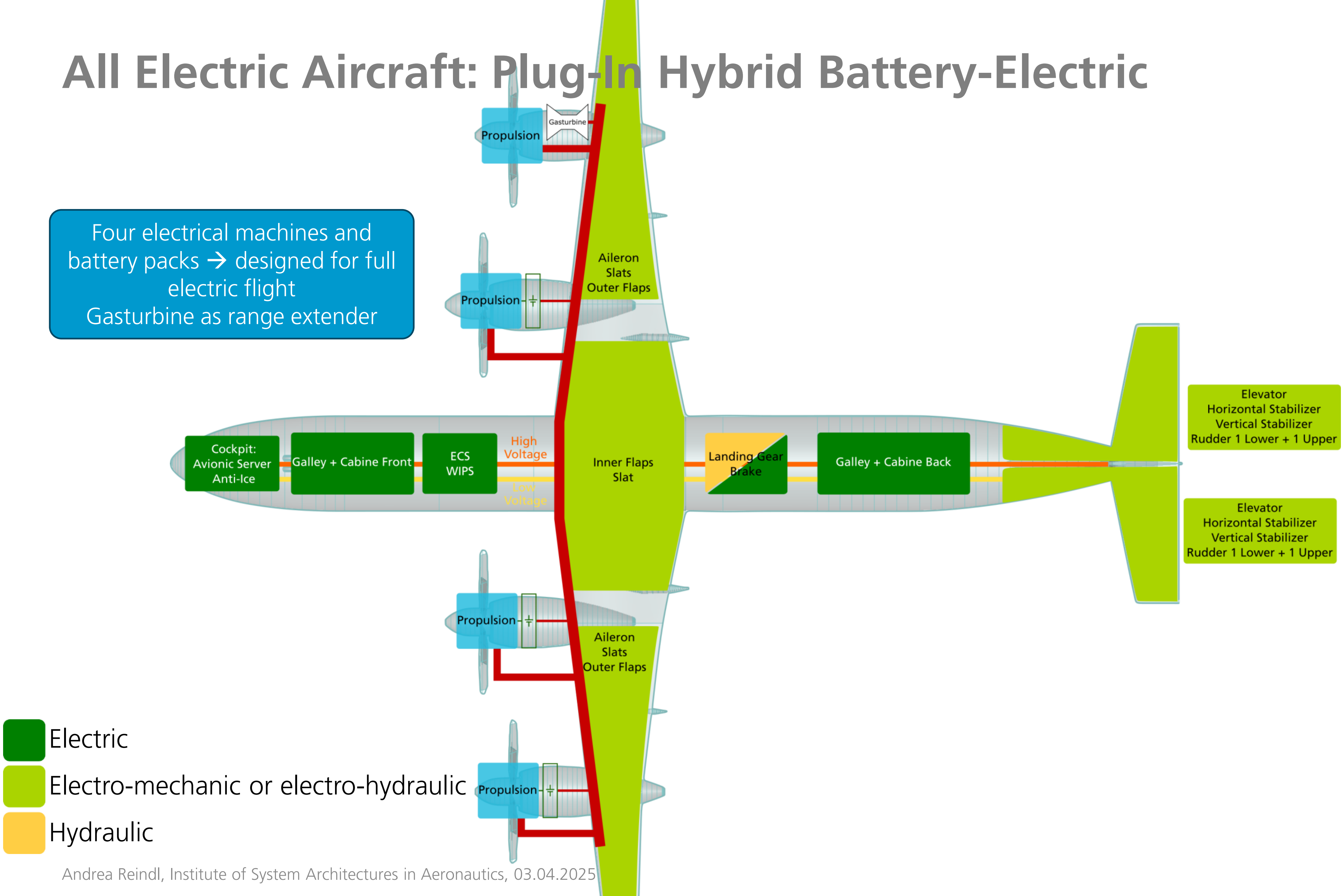


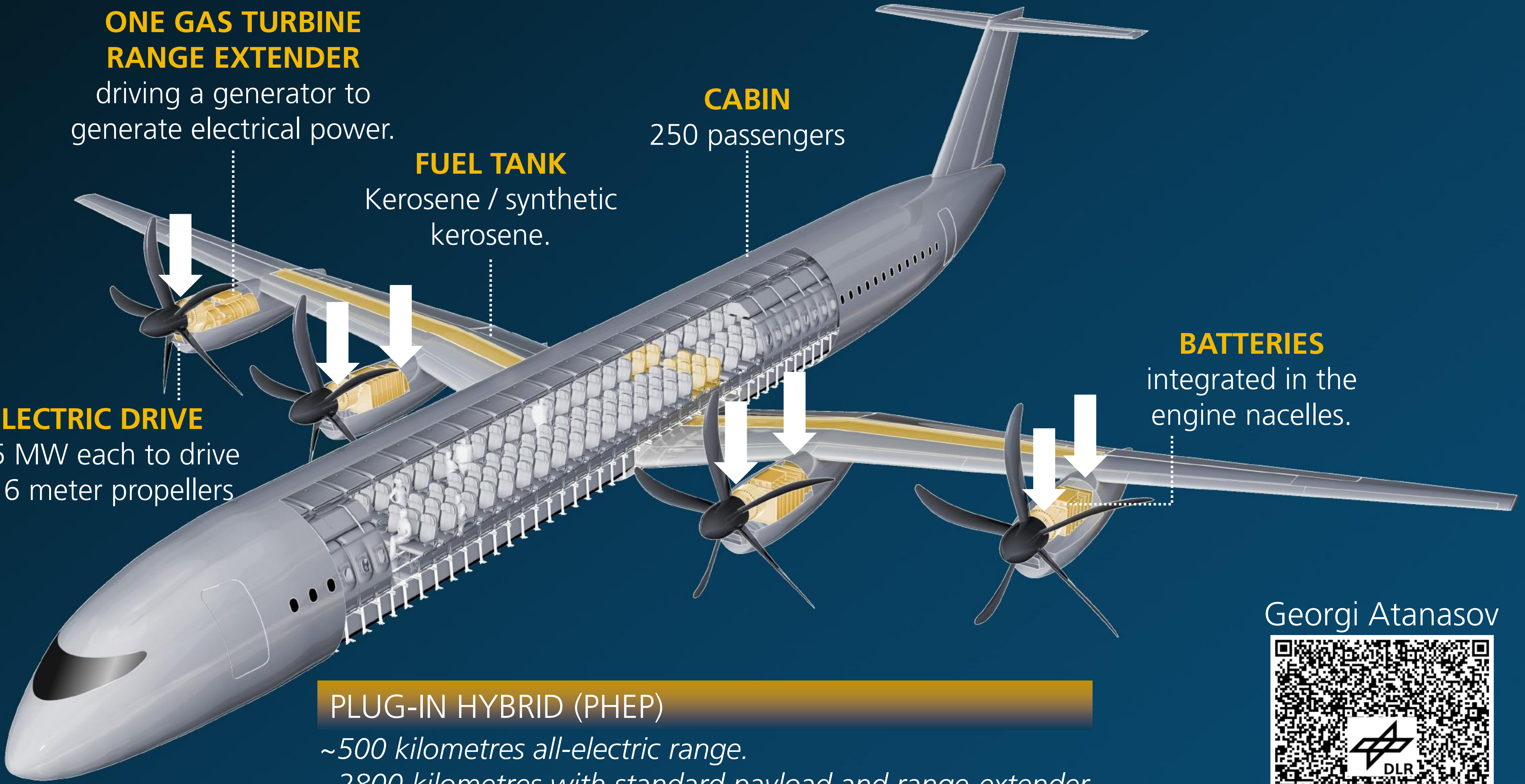
More Electric Aircraft



All Electric Aircraft: Plug-In Hybrid Battery-Electric

Four electrical machines and battery packs → designed for full electric flight
Gasturbine as range extender





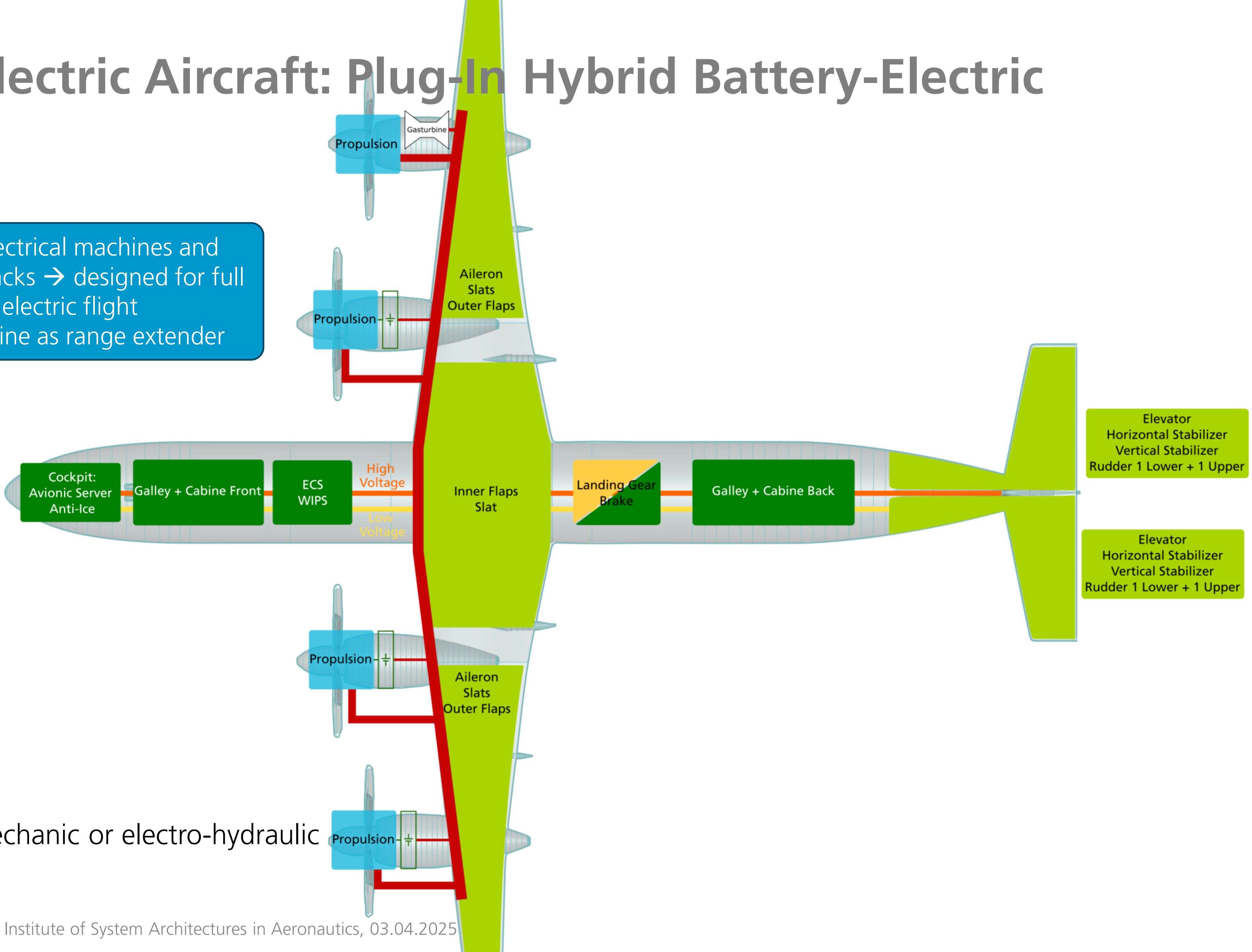
PLUG-IN HYBRID (PHEP)

~500 kilometres all-electric range.
~2800 kilometres with standard payload and range-extender
Cruising speed: ~750 kilometres per hour
Energy consumption: ~9 kWh/Passenger/100 km

Georgi Atanasov

All Electric Aircraft: Plug-In Hybrid Battery-Electric

Four electrical machines and battery packs → designed for full electric flight
Gasturbine as range extender



Electric
Electro-mechanic or electro-hydraulic
Hydraulic

POWER RATING ELECTRICAL SYSTEM

DLR

CONVENTIONAL

Type	A320	A321	A380
Maximum passenger capacity	180	220	853
Installed electrical power	~100 kW	~150 kW	~600-800 kW

MORE ELECTRIC AIRCRAFT

Type	A350	B787	A321 (under research)
Maximum passenger capacity	440	250	220
Installed electrical power	~1000-1400 kW	~1500 kW	~700 kW

ALL ELECTRIC AIRCRAFT

Type	EXACT PHEP (under research)
Maximum passenger capacity	250
Installed electrical power	~17.5 MW = 17500 kW

Andrea Reindl, Institute of System Architectures in Aeronautics, 03.04.2025

WEIGHT ELECTRICAL SYSTEM EXISTING AIRCRAFT

CONVENTIONAL

A320
~100 kW
Electric Generation: ~400 kg
Electric Distribution: ~1040 kg

A321
~150 kW
Electric Generation: ~400 kg
Electric Distribution: ~1200 kg

Wish list:
As light, efficient, reliable and safe as possible

A321
~700 kW
?

EXACT PHEP
~17.5 MW = 17500 kW
?

Method of Procedure

Analyze the **state of the art** and **map** it to the selected aircraft configuration

Conventional Approach

Focus on **new** aircraft configuration and the **technical innovations** and associated advantages for the system level

Disruptive Approach

Compare the **advantages** of the **conventional approach** with the **disadvantages** of the **disruptive approach** and derive a **hybrid** of both approaches.

Baseline Approach

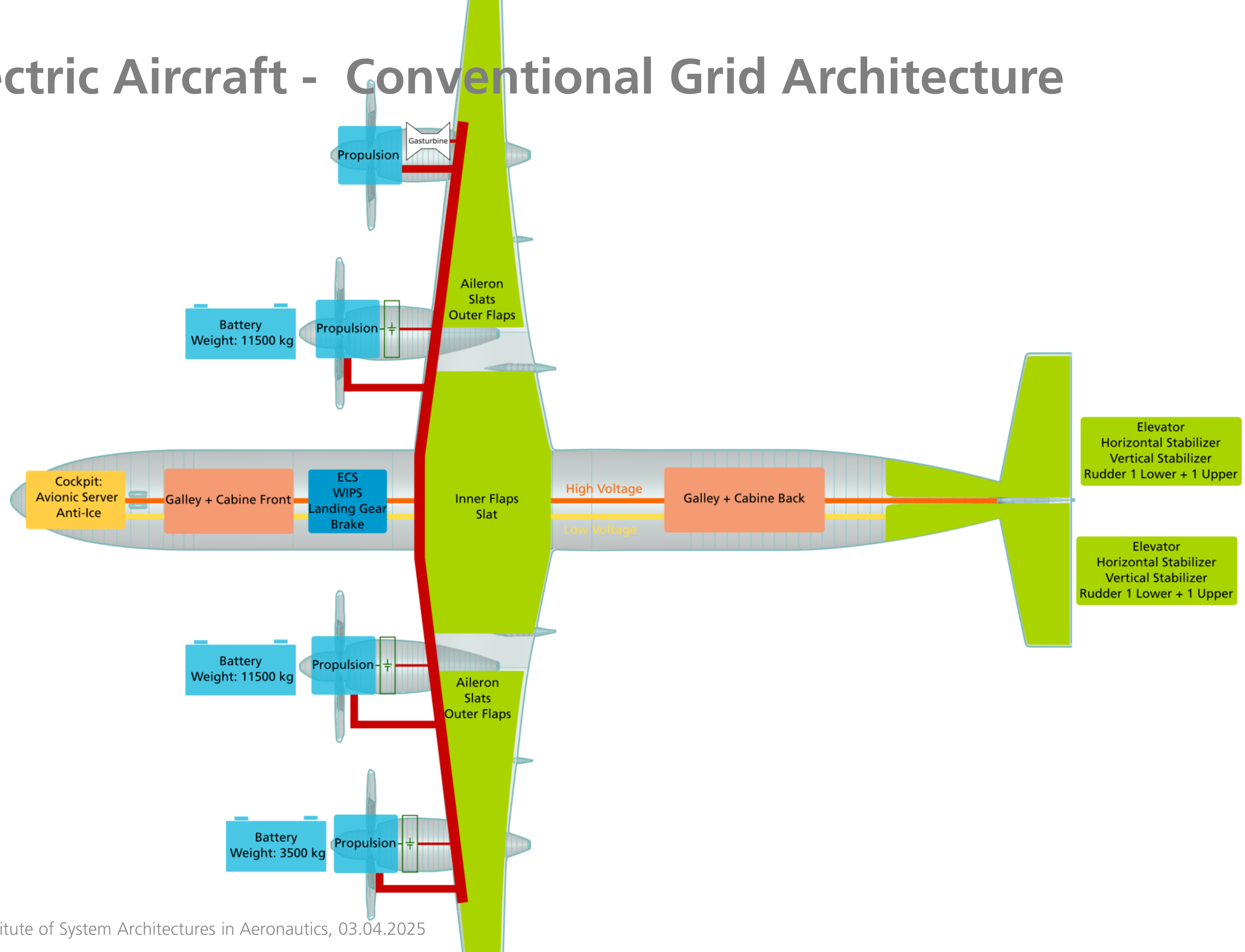
Method of Procedure

Analyze the **state of the art** and **map** it to the selected aircraft configuration

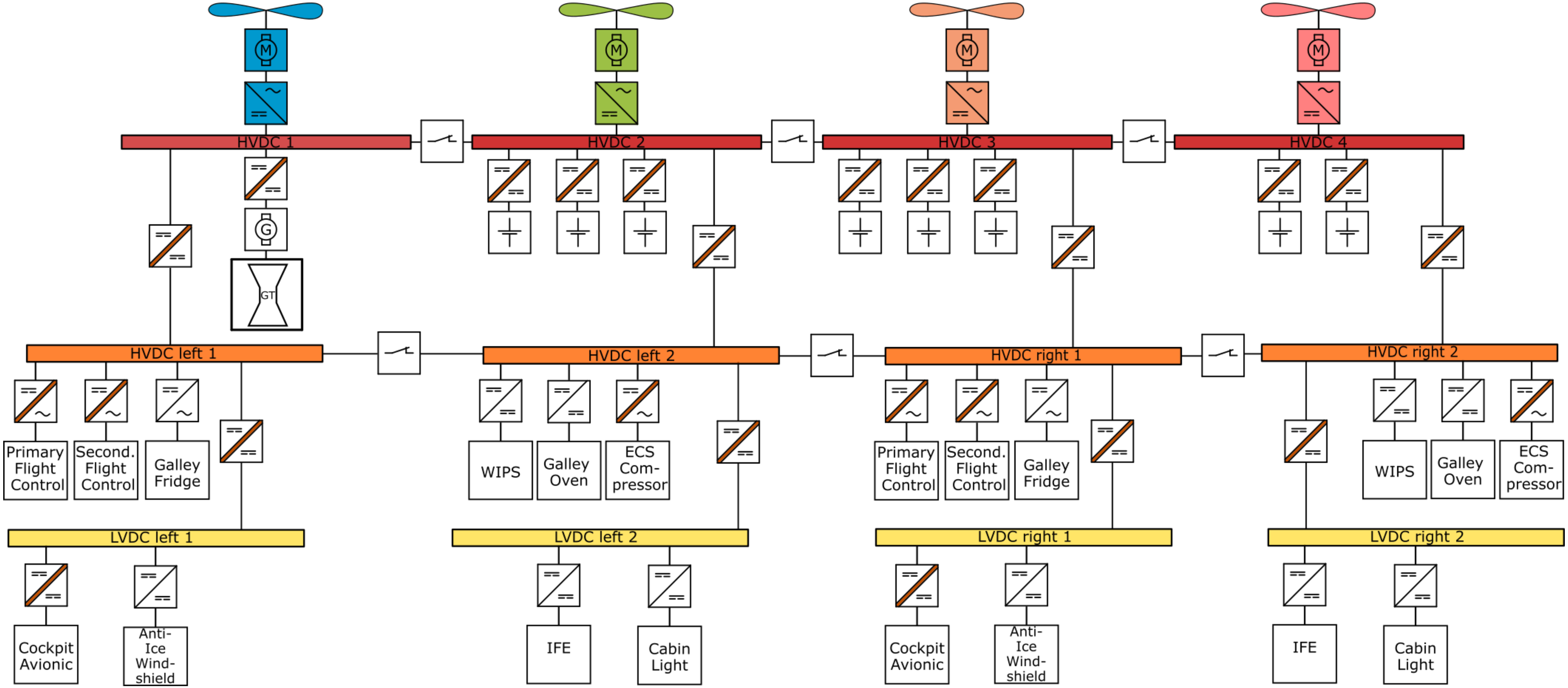
↓

Conventional Approach

All Electric Aircraft - Conventional Grid Architecture

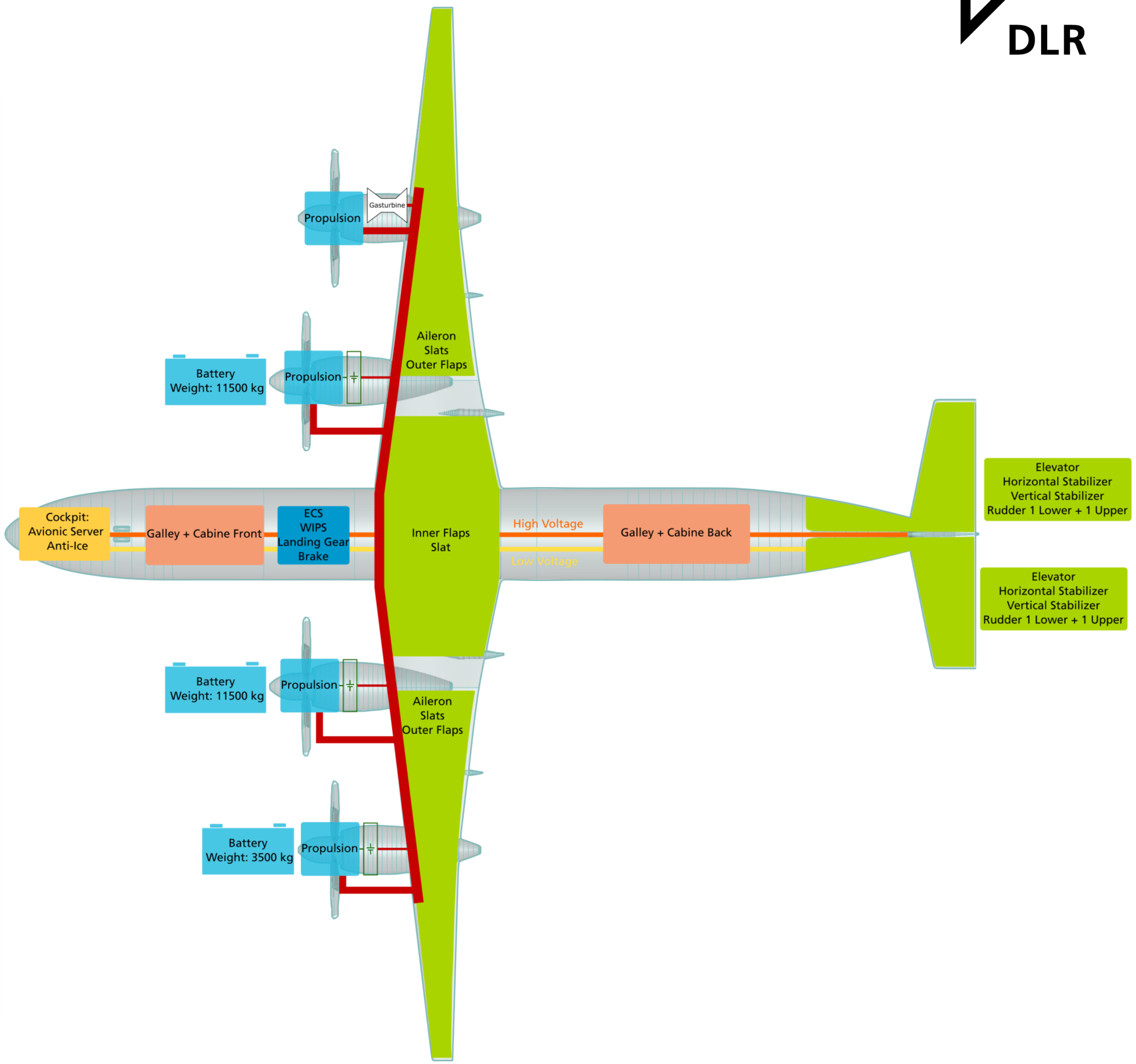


All Electric Aircraft – Conventional Grid Architecture



All Electric Aircraft - Conventional Approach: Connected Grid

- \+ Failure of one engine: available battery capacity is used to operate and overpower functional e-machines → availability
- \+ Failure of a single battery pack has little effect on the system
- \+ Batteries are placed in the narcelles: the fire load is separated from the remaining aircraft in case of a thermal runaway
- – Fault currents and line faults affect the entire system to some extent: complex protective mechanisms, bulky circuit breakers
- – Galvanic isolation is required at several points → heavy transformers, less efficiency
- – High voltage DC disconnection: risk of arcs is very high
- – Many components connected in parallel: high fault discharge currents



Method of Procedure

DLR

Analyze the **state of the art** and **map** it to the selected aircraft configuration

Conventional Approach: Connected Grid

Method of Procedure

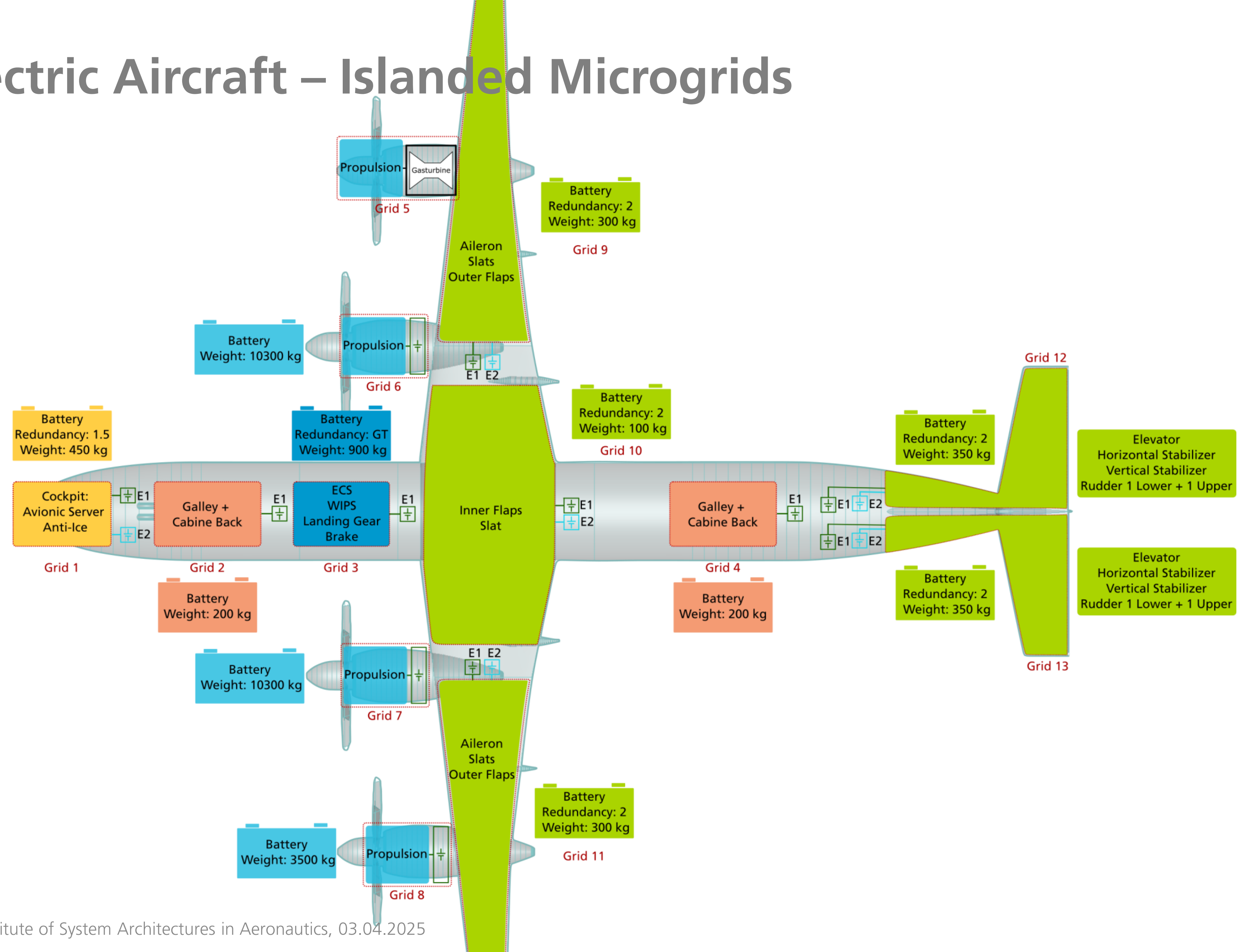
Analyze the **state of the art** and **map** it to the selected aircraft configuration

Conventional Approach: Connected Grid

Focus on **new** aircraft configuration and the **technical innovations** and associated advantages for the system level

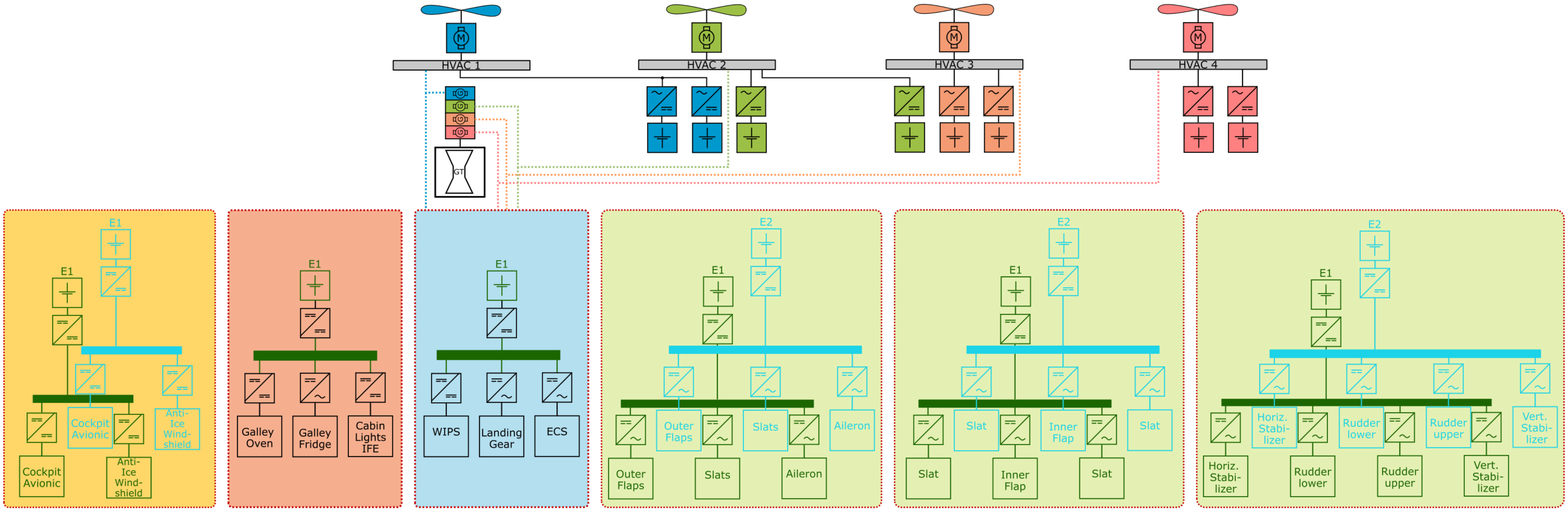
Disruptive Approach

All Electric Aircraft – Islanded Microgrids



Andrea Reindl, Institute of System Architectures in Aeronautics, 03.04.2025

All Electric Aircraft – Islanded Microgrids



Cockpit

Galley + Cabin
2 grids: front & back

WIPS, ECS
Landing Gear

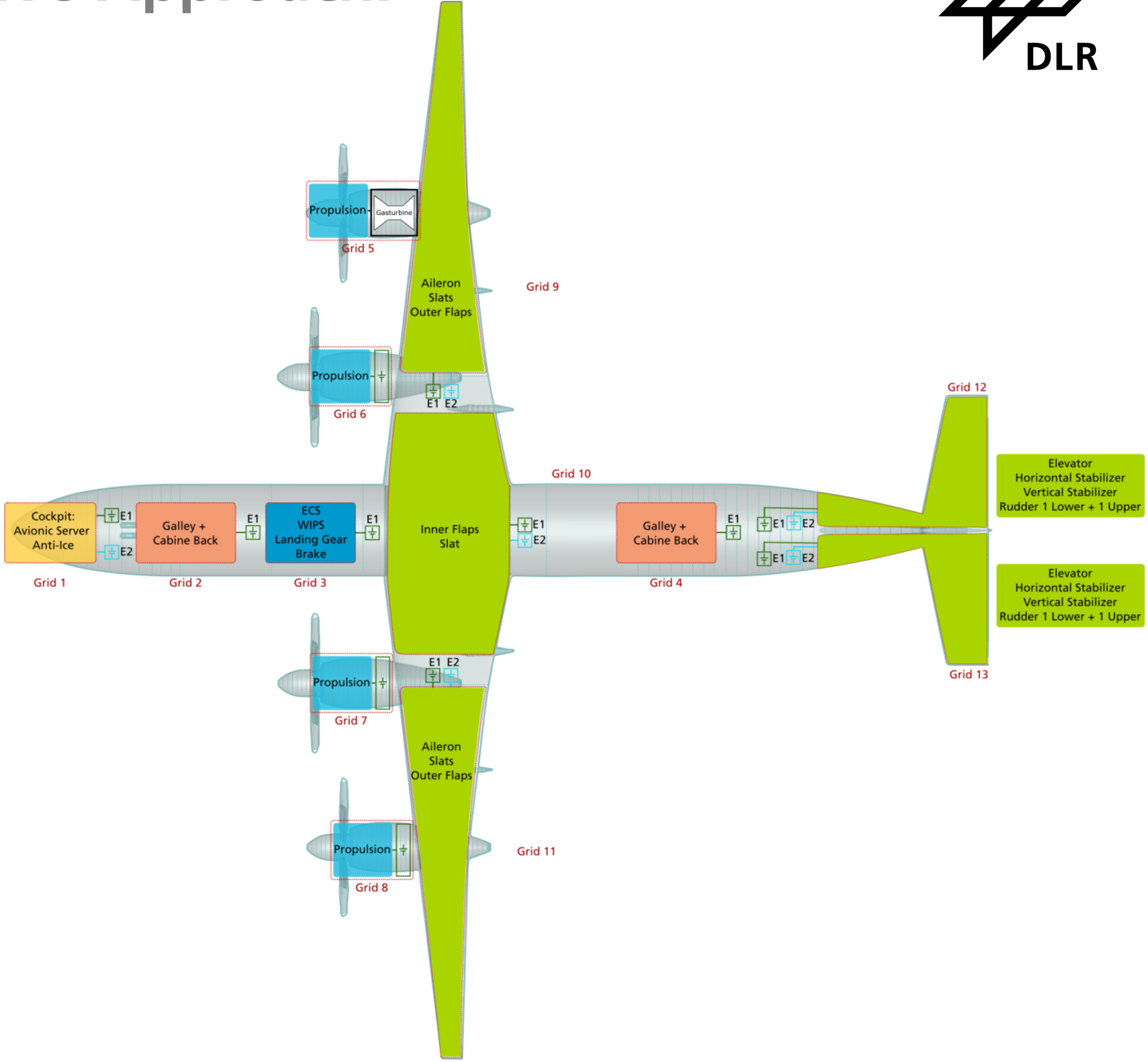
Flight Control: Flaps, Slats, Aileron
2 grids: right & left

Secondary Flight Control
Inner Flap, Slats

Primary Flight Control Tail Plane
2 grids: left & right

All Electric Aircraft - Disruptive Approach: Islanded Grid

+ Batteries isolated from each other → improved fail-safety
+ Fault current amplitude is lower → fewer components connected in parallel
+ Less galvanic isolation required
+ Shorter cable lengths, improved EMC → less complex filters
+ Separation of critical and non-critical grids
+ Decreased total weight: increased battery weight, decreased cable weight
+ Severity and impact of faults, e.g. single line faults is reduced → increases availability
– Batteries are distributed throughout the aircraft
– Failure of one engine → battery capacity can **not** be used



Method of Procedure

Analyze the **state of the art** and **map** it to the selected aircraft configuration

Conventional Approach: Connected Grid

Focus on **new** aircraft configuration and the **technical innovations** and associated advantages for the system level

Disruptive Approach: Islanded Microgrids

Method of Procedure

DLR

Analyze the **state of the art** and **map** it to the selected aircraft configuration

↓

Conventional Approach: Connected Grid

Focus on **new** aircraft configuration and the **technical innovations** and associated advantages for the system level

↓

Disruptive Approach: Islanded Microgrids

Compare the **advantages** of the **conventional approach** with the **disadvantages** of the **disruptive approach** and derive a **hybrid** of both approaches.

↓

Baseline Approach

Features Hybrid Approach

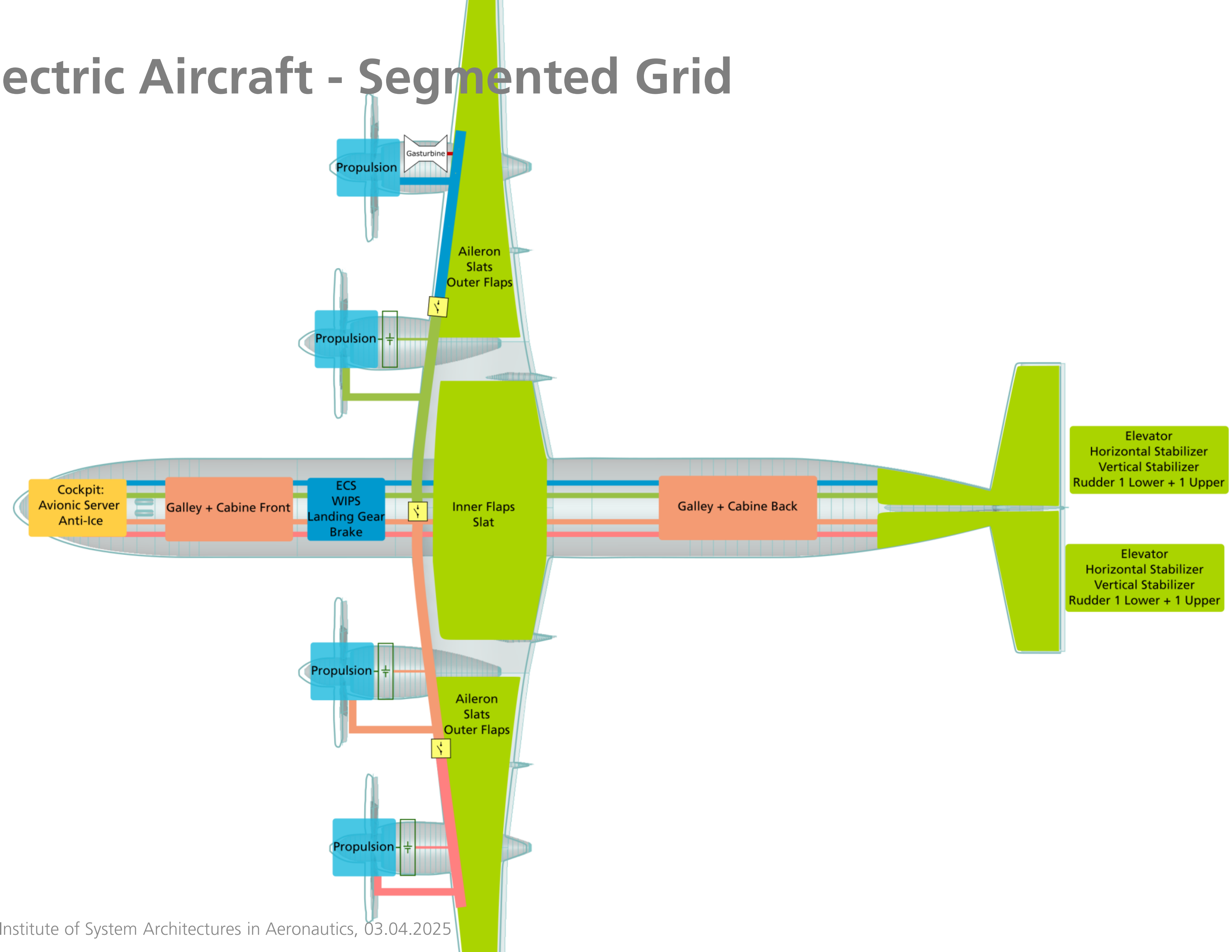
The objective is a grid architecture that offers these advantages additionally

+ Failure of one engine: available battery capacity is used to operate and overpower functional e-machines → availability
+ Failure of a single battery pack has little effect on the system
+ Batteries are placed in the narcelles: the fire load is separated from the remaining aircraft in case of a thermal runaway

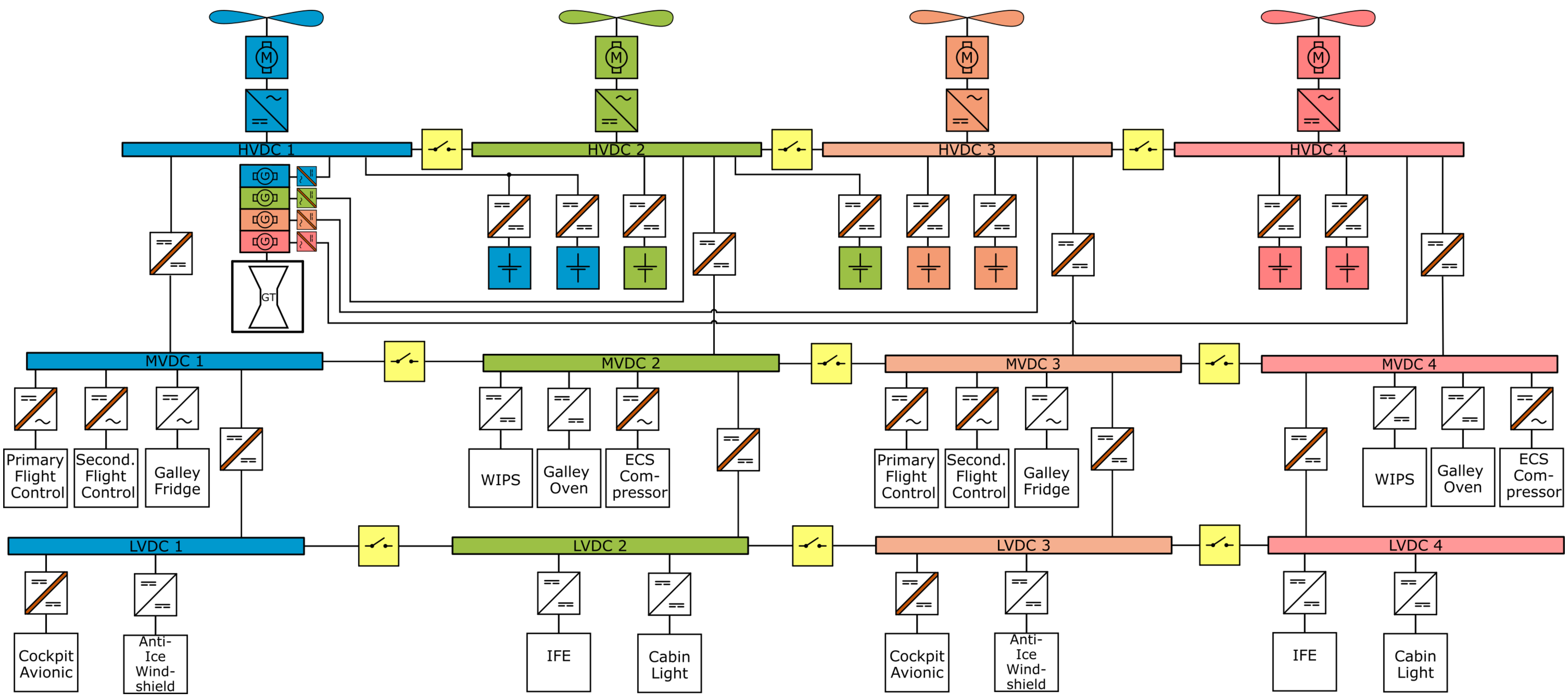
while overcoming the following disadvantages

– Batteries are distributed throughout the aircraft
– Failure of one engine → battery capacity can **not** be used

All Electric Aircraft - Segmented Grid

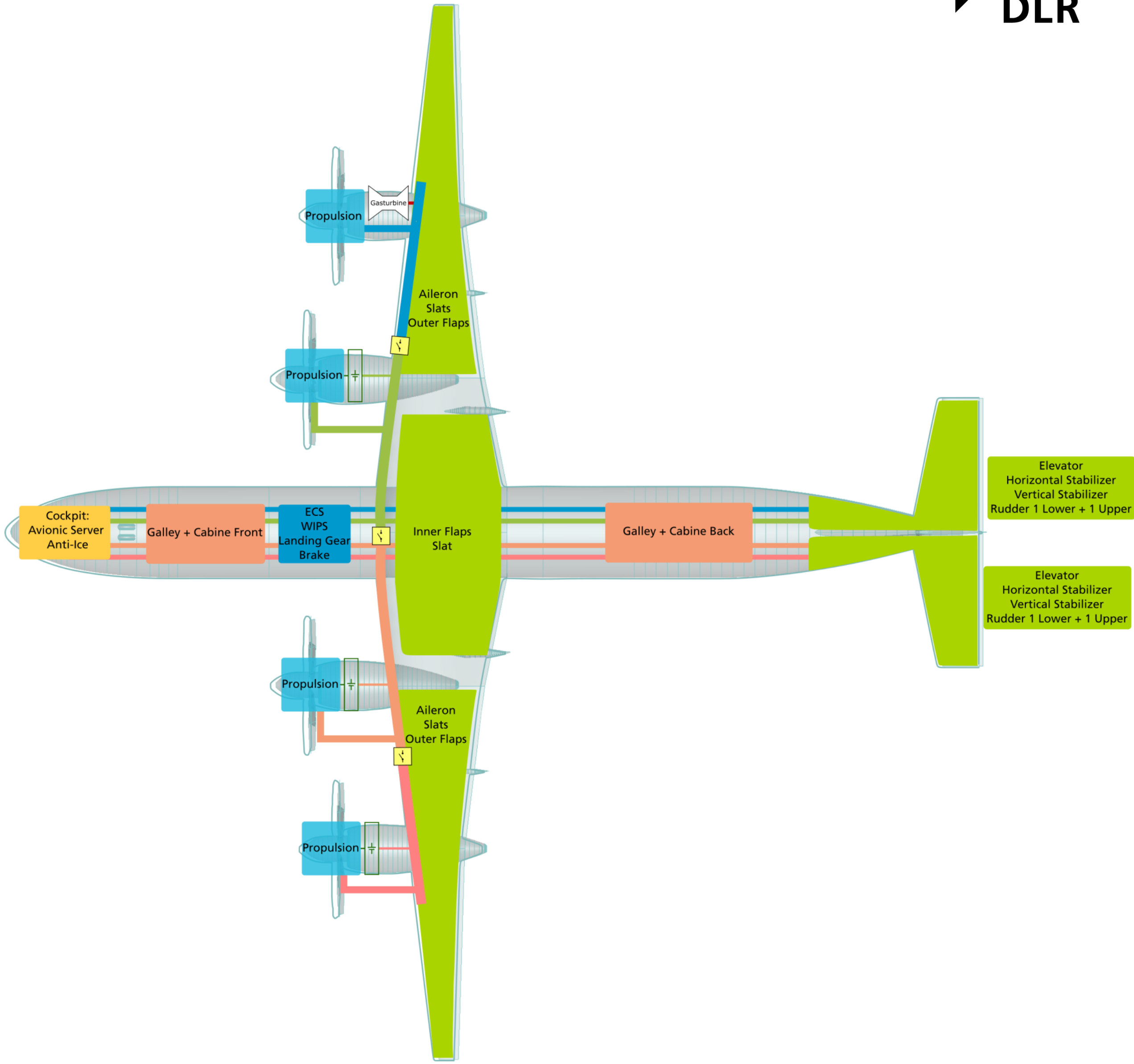


All Electric Aircraft - Segmented Grid



All Electric Aircraft - Baseline Approach: Segmented Grid

- \+ Failure of one engine: available battery capacity is used to operate and overpower functional e-machines → availability
- \+ Failure of a single battery pack has little effect on the system
- \+ Batteries are placed in the narcelles: the fire load is separated from the remaining aircraft in case of a thermal runaway
- \+ Batteries isolated from each other → improved fail-safety
- \+ Severity and impact of faults, e.g. single line faults is reduced → increases availability
- \+ High voltage DC connection → minor risk
- \+ Less components connected in parallel: lower fault discharge currents
- – Fault currents and line faults only affect the sub-system
- – Galvanic isolation is required at several points → heavy transformers, less efficiency
- – No separation of critical and non-critical grids



Conclusion

Analyze the **state of the art** and **map** it to the selected aircraft configuration

Conventional Approach: Connected Grid

Focus on **new** aircraft configuration and the **technical innovations** and associated advantages for the system level

Disruptive Approach: Islanded Microgrids

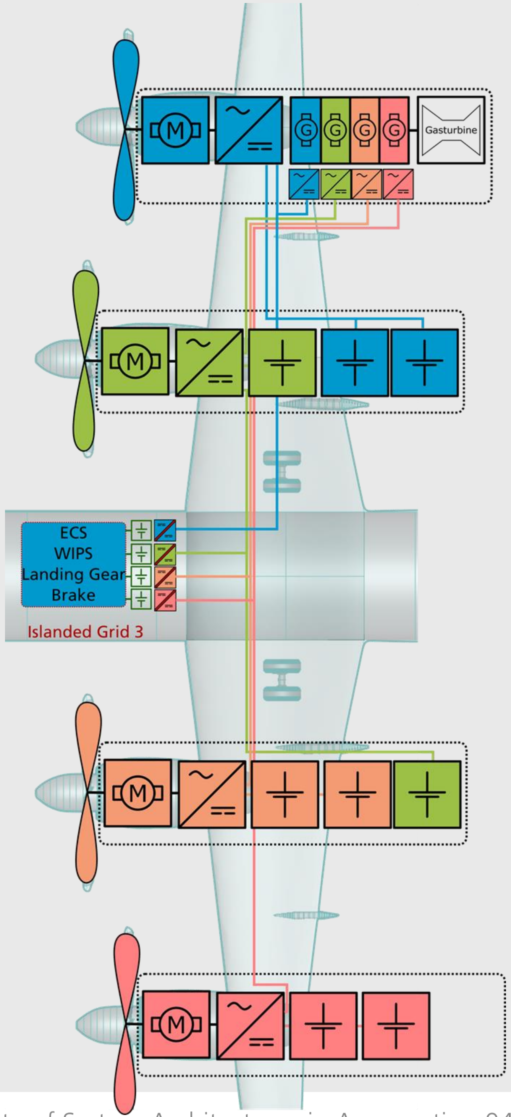
Compare the **advantages** of the **conventional approach** with the **disadvantages** of the **disruptive approach** and derive a **hybrid** of both approaches.

Baseline Approach: Segmented Grid

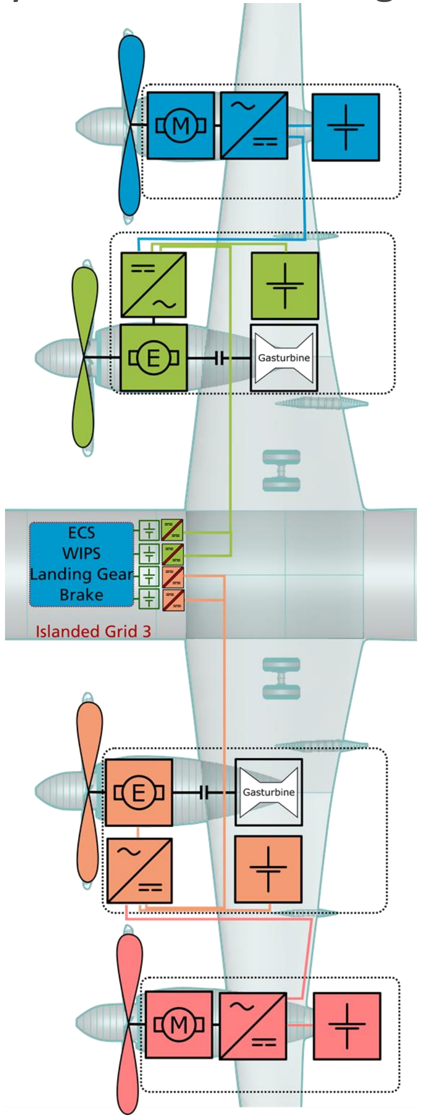
Preliminary design: basic models for weight study following electric simulation

Power Train Configurations

Plug-in Hybrid Electric Configuration - Baseline



Plug-in Parallel Hybrid Electric Configuration - Disruptive



Andrea Reindl, Institute of System Architectures in Aeronautics, 04/03/2025

Design of the Electrical Architecture of Future Electric Aircraft

- More Electric Aircraft
- All Electric Aircraft
- Propulsion Architecture of All Electric Aircraft

Contact
Dr.-Ing. Andrea Reindl
Institute of System Architectures in Aeronautics
andrea.reindl@dlr.de

Electrical System Architectures Comparison

	Segmented Grid	Islanded Grid
Battery Weight	→	↑
Wiring System Weight	→	↓
Protection Scheme Weight	↓	↓ ↓
Availability Propulsion	→	↓
Availability On-board system	↑	↑