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Neue Wege.

(Hybrid) Electric Transport Aircraft

Prof. Dr. Mirko Hornung

e-Flight Forum, Beijing, 9th November 2017

Agenda

>>Universally Electric Aircraft

>>Hybridization Options

>>Boundary Layer Ingestion

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>> Hybridization Options

>> Boundary Layer Ingestion

Bauhaus Luftfahrt – Ce-Liner

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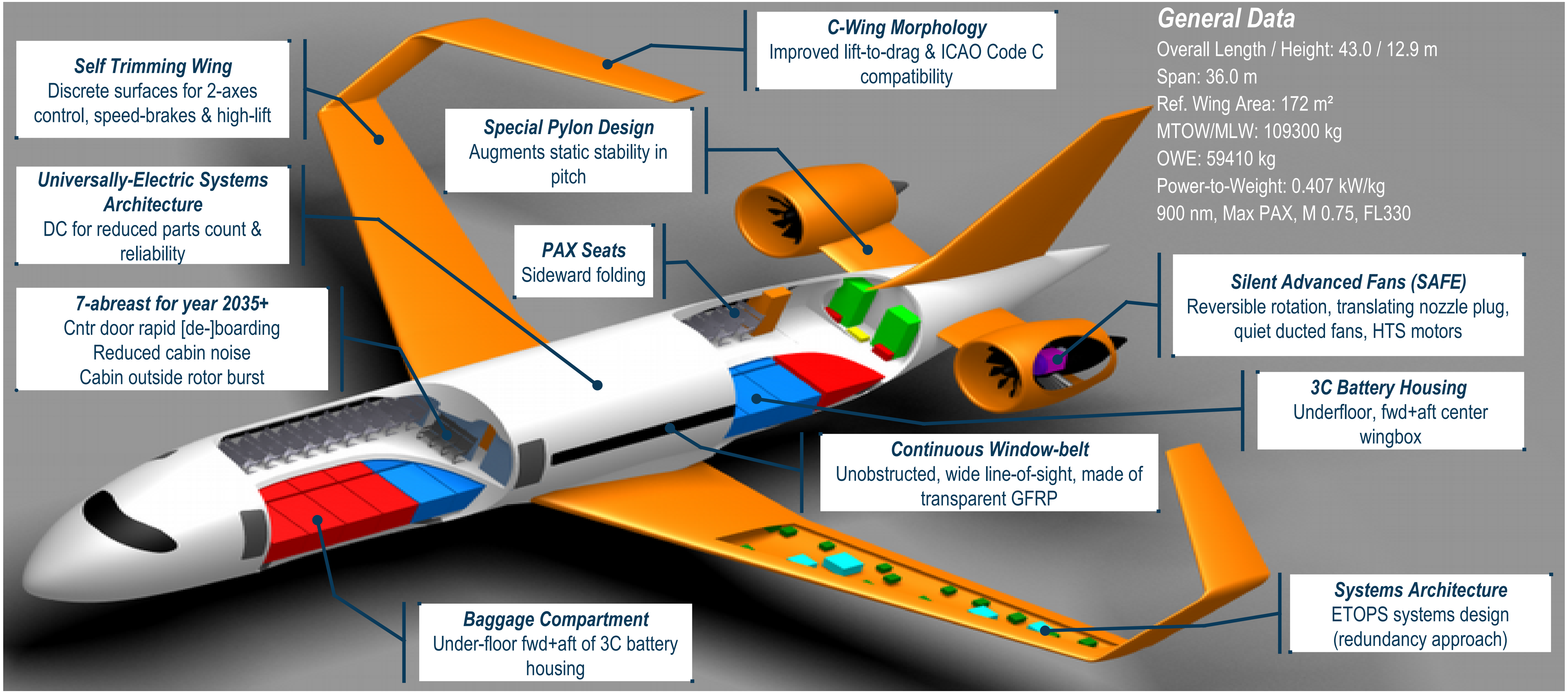

Benchmarking Ce-Liner

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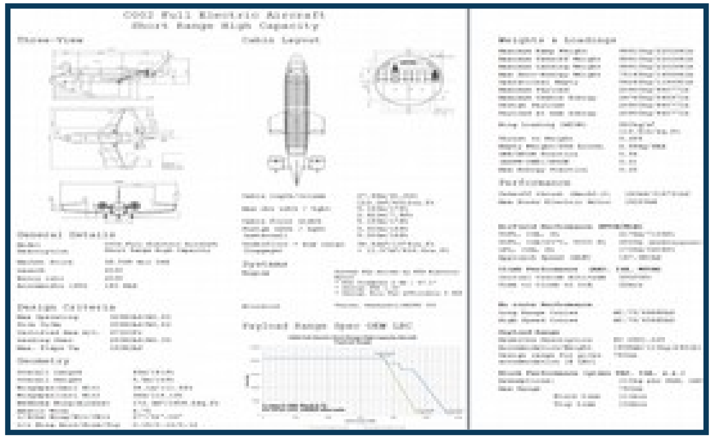

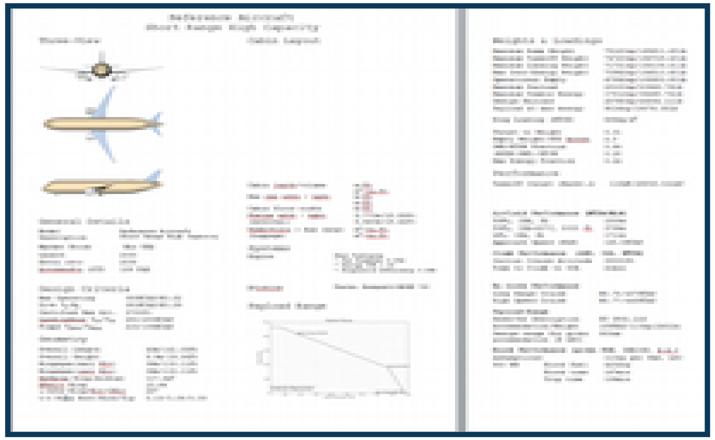

Aircraft Properties	Units	Ce-Liner	B787-3+	Δ (B787-3+)
MTOW	[kg]	109300	73700	+49.1%
MLW	[kg]	109300	70360	N/A
OEW / MTOW	[%]	54.4	65.4	-16.8%
OWE / PAX	kg/PAX	314	253	+24.0%
Max Energy(Fuel) Weight / MTOW	[%]	27.5	24.3	+13.2%
Reference Area (Sref)	[m²]	172.3	115.2	+49.6%
Aspect Ratio (planar wing)	[-]	7.1	10.8	-34.2%
MTOW / Sref	[kg/m²]	635	636	~0.0%
Power / MTOW	[kW/kg]	0.407	N/A	N/A
Thrust / MTOW (M0.20, SL)	[-]	0.233	0.310	-24.8%
TOFL@ISA,SL	[m]	2245	1830	+22.7%
LFL@ISA,SL	[m]	1875	1770	+5.9%
Approach Speed (MLW)	KCAS	149	146	+2.1%
Des.Range, LRC, ICA, Max-PAX	[nm]	900 nm, M0.75, FL330		
(L/D) @ LRC, TOC, ISA+10°C	(-)	20.5	18.4	+11.4%
ESAR, 900 nm, LRC, ISA+10°C	[km/kWh]	**0.0473**	**0.0374**	**+26.4%**

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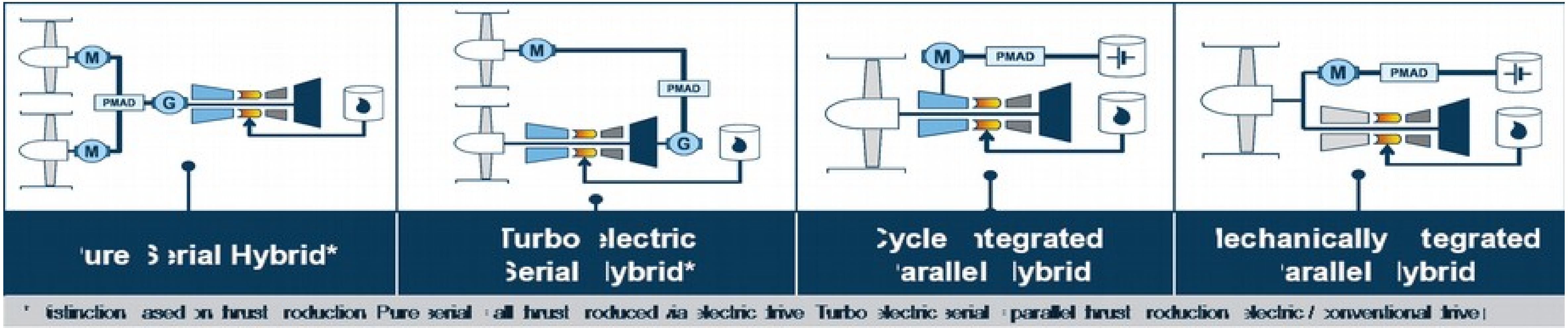
>> **Hybridization Options**

>> Boundary Layer Ingestion

Basic Approaches to Hybrid Electric Propulsion

>> Four Basic Approaches to Hybrid Electric Propulsion



>> Important system descriptors

> Degree of power hybridization H_P

$$H_P = \frac{P_{supply,elec}}{P_{supply,tot}} = \frac{P_{supply,elec}}{P_{supply,elec} + P_{supply,fuel}}$$

> Degree of energy hybridisation H_E

$$H_E = \frac{E_{supply,elec}}{E_{supply,tot}} = \frac{E_{supply,elec}}{E_{supply,elec} + E_{supply,fuel}}$$

Parallel Hybrid (A/C Level)

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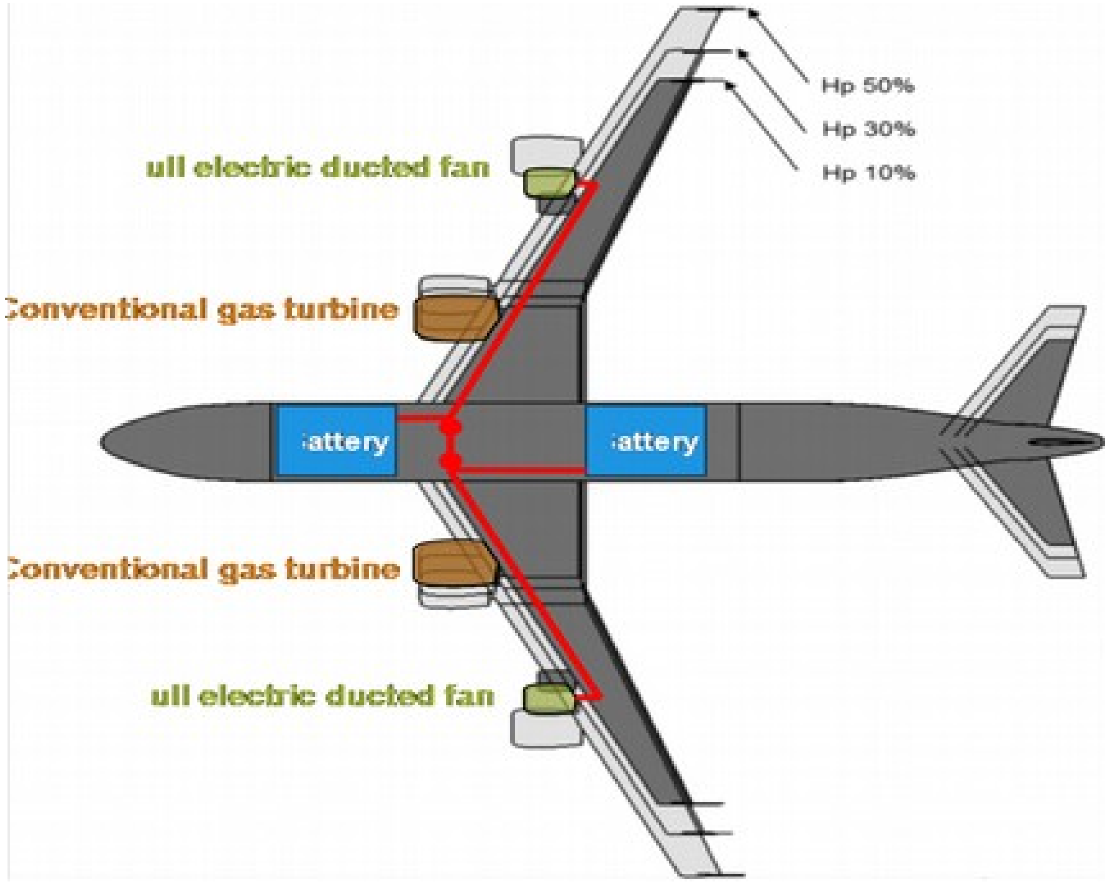
- >> ***Hybrid-electric propulsion system with 4 propulsors***
  - > 2 conventional gas turbines
  - > 2 electrically powered ducted fans
  - > No direct coupling between different energy carriers/propulsion systems
- >> ***Battery supplied electric system used as assistance system***
- >> ***Expected advantages***
  - > Downsizing of gas turbines
  - > Electric cruise capability
  - > Increased operational behavior compared to integrated parallel hybrid topologies → No coupling of propulsors



Hybridization Strategy

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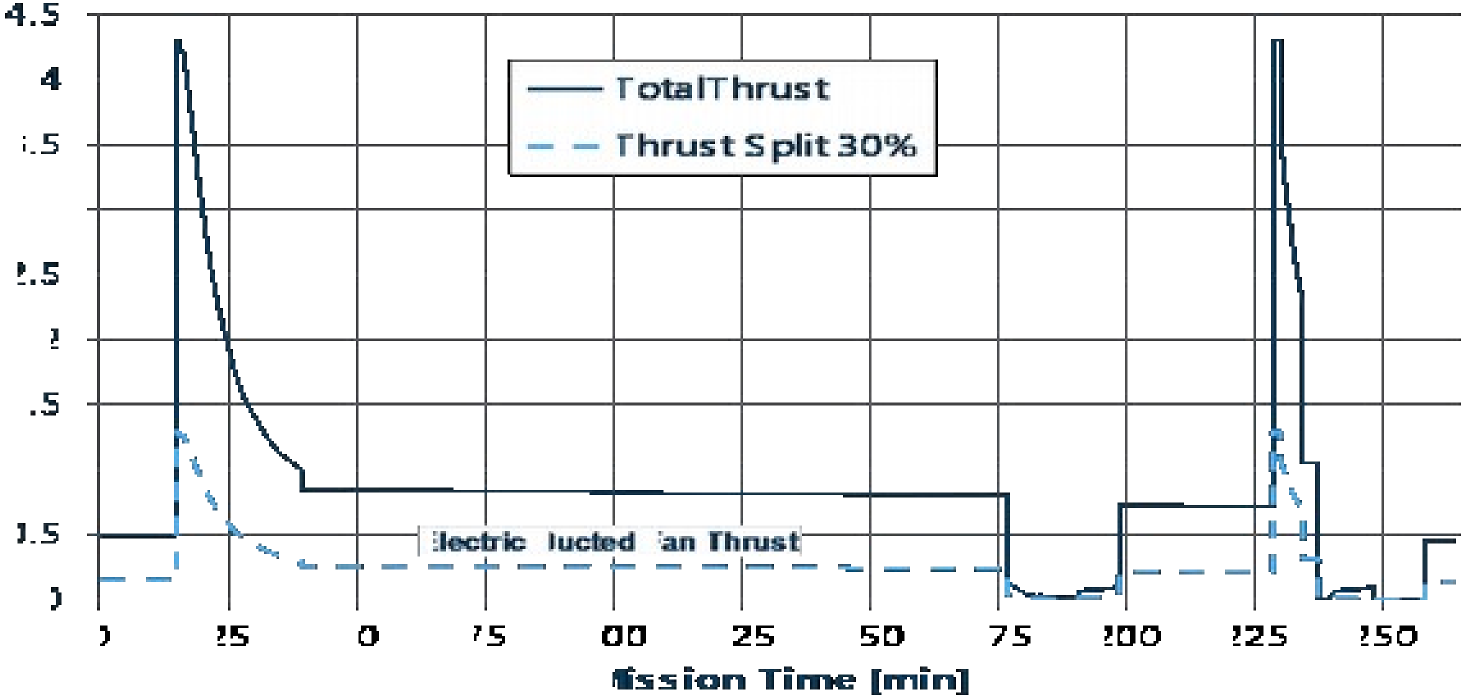
- **>>** *Electric support given by constant thrust split between conventional and electric supplied propulsors over the entire mission*
- **>>** *Normalized power profile used to determine fuel and battery demand*
- **>>** *Aircraft level assessment performed with the help of trade factors*



Initial Aircraft Level Results

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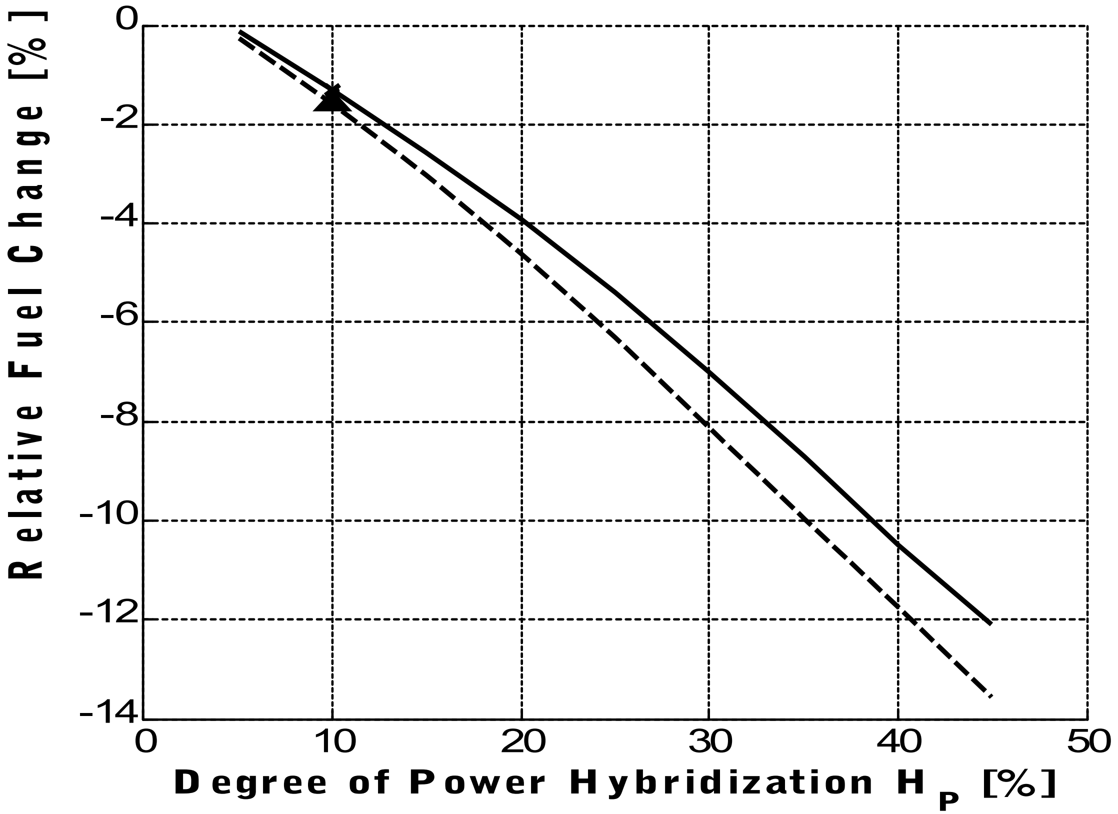
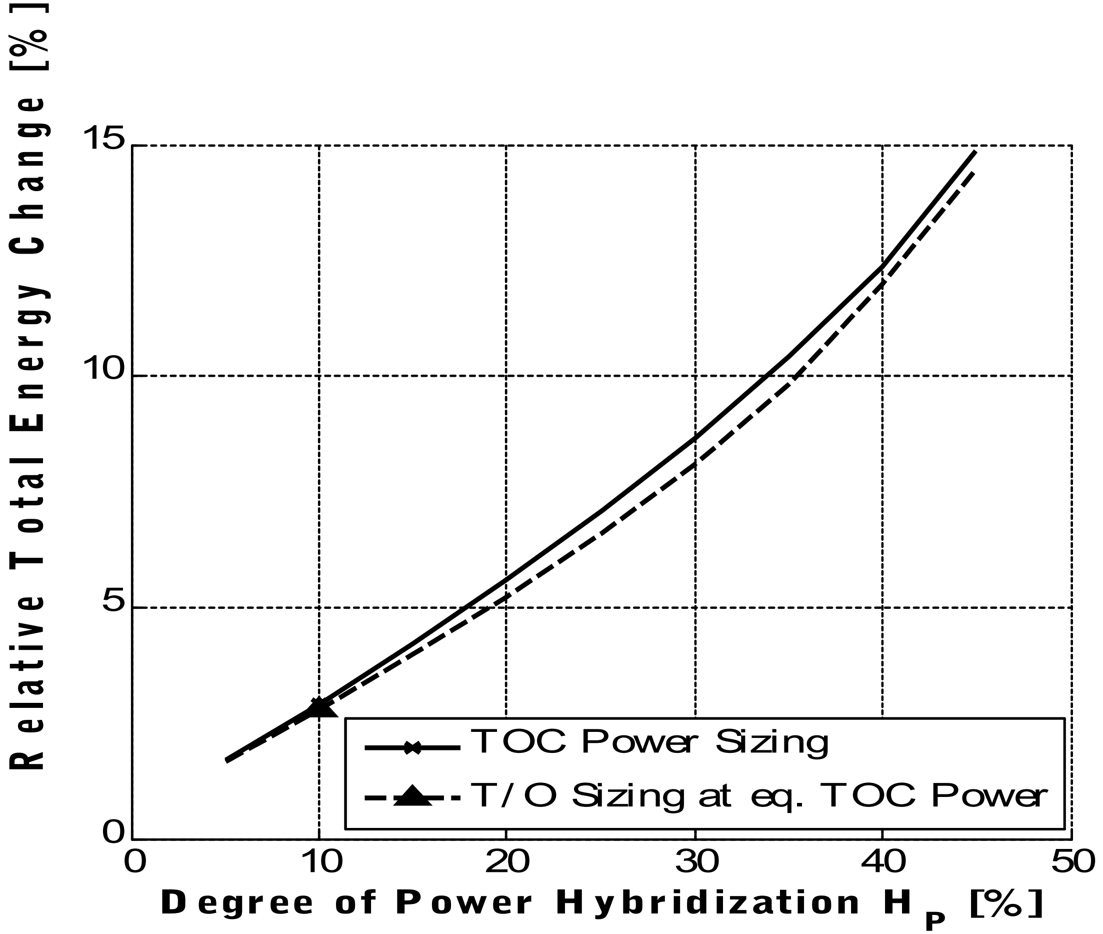
>> *Impact of different values of degree of power hybridizations and electric motor sizing points on the in-flight fuel burn and mission energy*





Initial Aircraft Level Results and Sensitivities I

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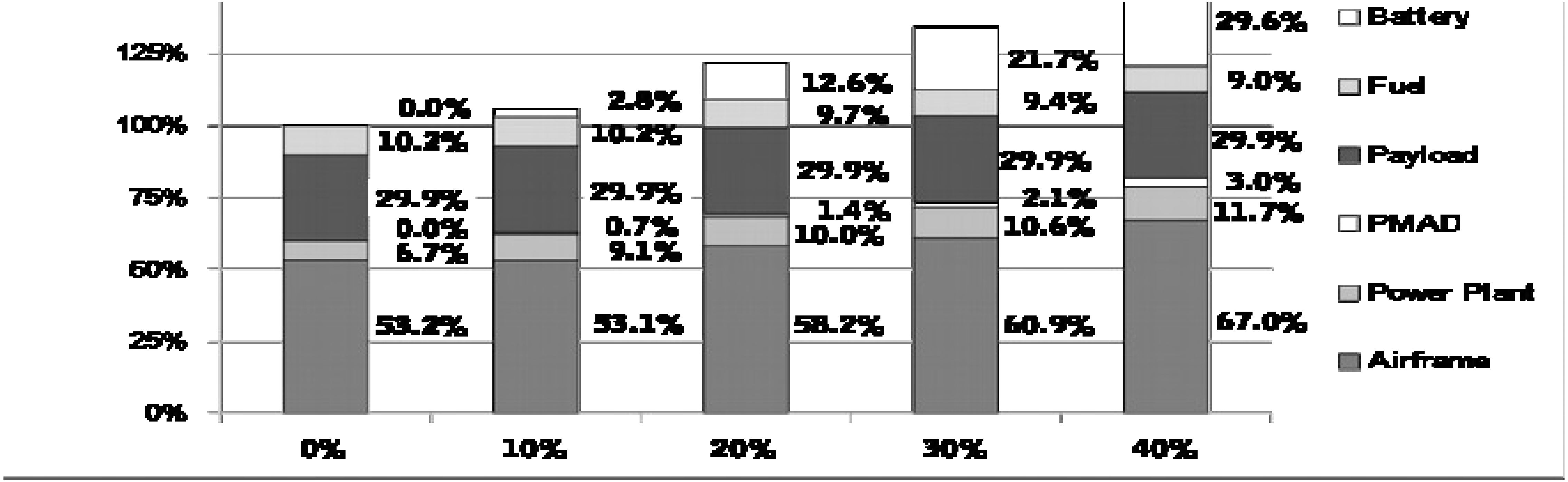
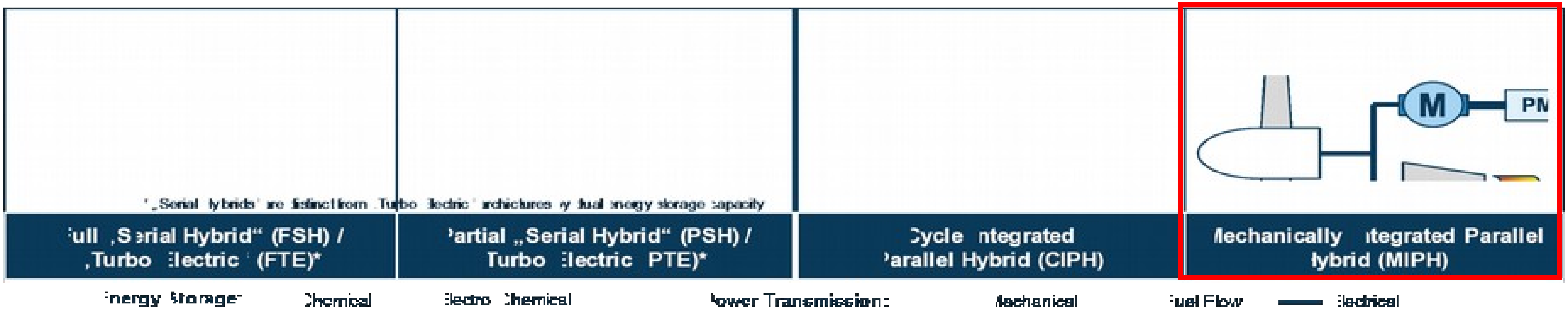
>> *Assuming a 1000 Wh/kg battery for different values of degree of power hybridization for a 1300nm and 180 PAX mission results in*

> up to 50% higher MTOW

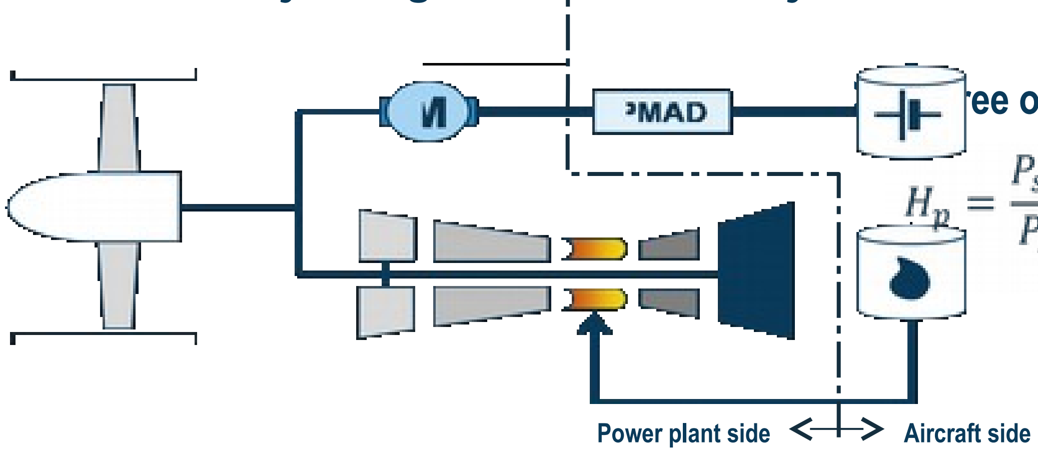
> up to 11.7% lower in-flight fuel burn, but 12.4% higher mission energy demand



Hybrid-electric Propulsion Landscape



>> Mechanically Integrated Parallel Hybrid:



ree of Power Hybridisation:

$$H_p = \frac{P_{supply,elec}}{P_{supply,tot}} = \frac{P_{Batt}}{P_{Batt} + P_{fuel}}$$

The Cloud of MIPH Concepts

>> MIPH application:

> UHBR short range GTF

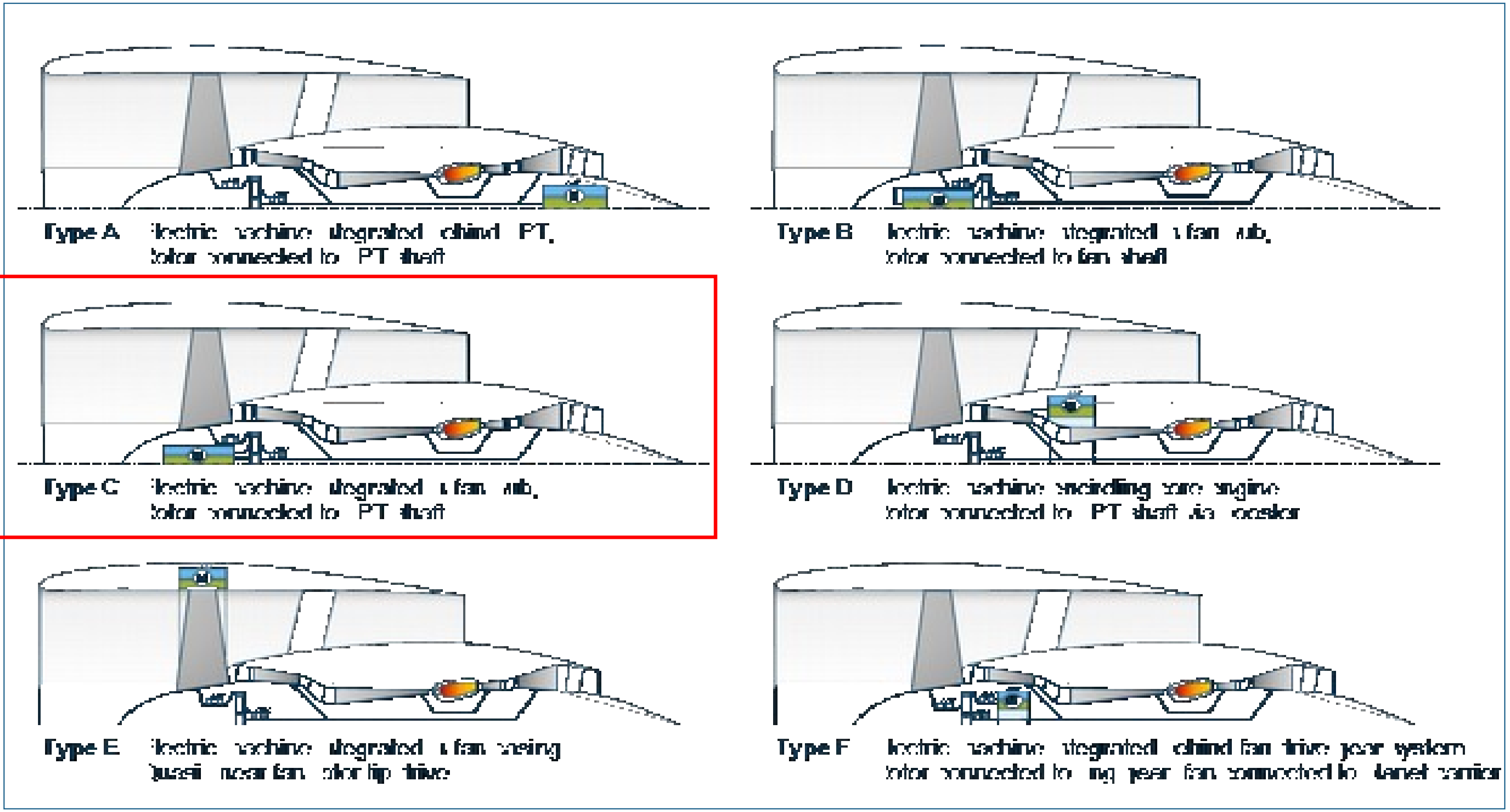
> 20klbf thrust class

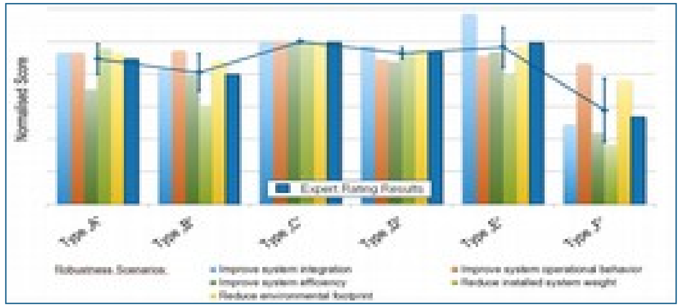
Selected concept

+ High speed electric motor

+ Thermal environment for electrics

+ Overall most robust solution





MIPH: Power Plant Performance

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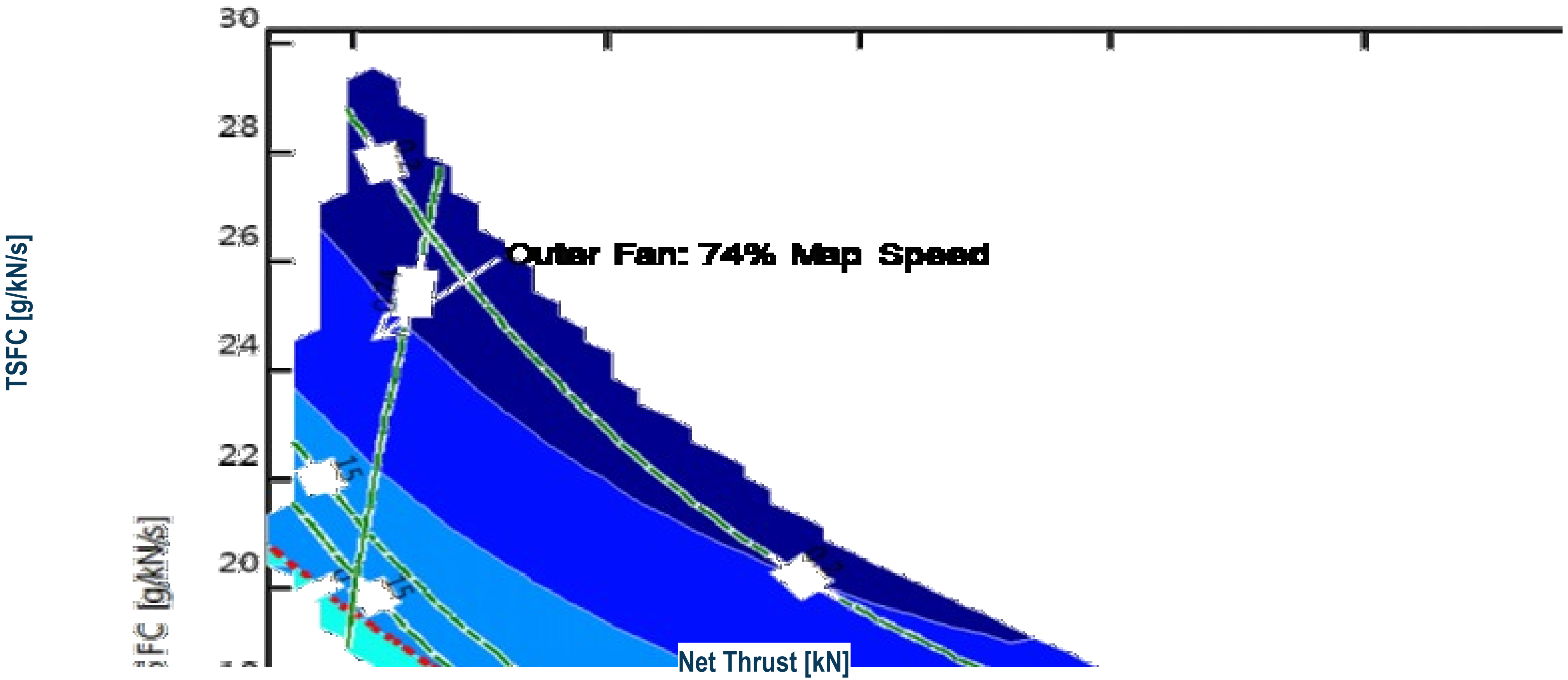
>> Cruise part power characteristics for S/R GTF application ($H_{P,des}$=0.1)



MIPH: Electric Motor Sizing

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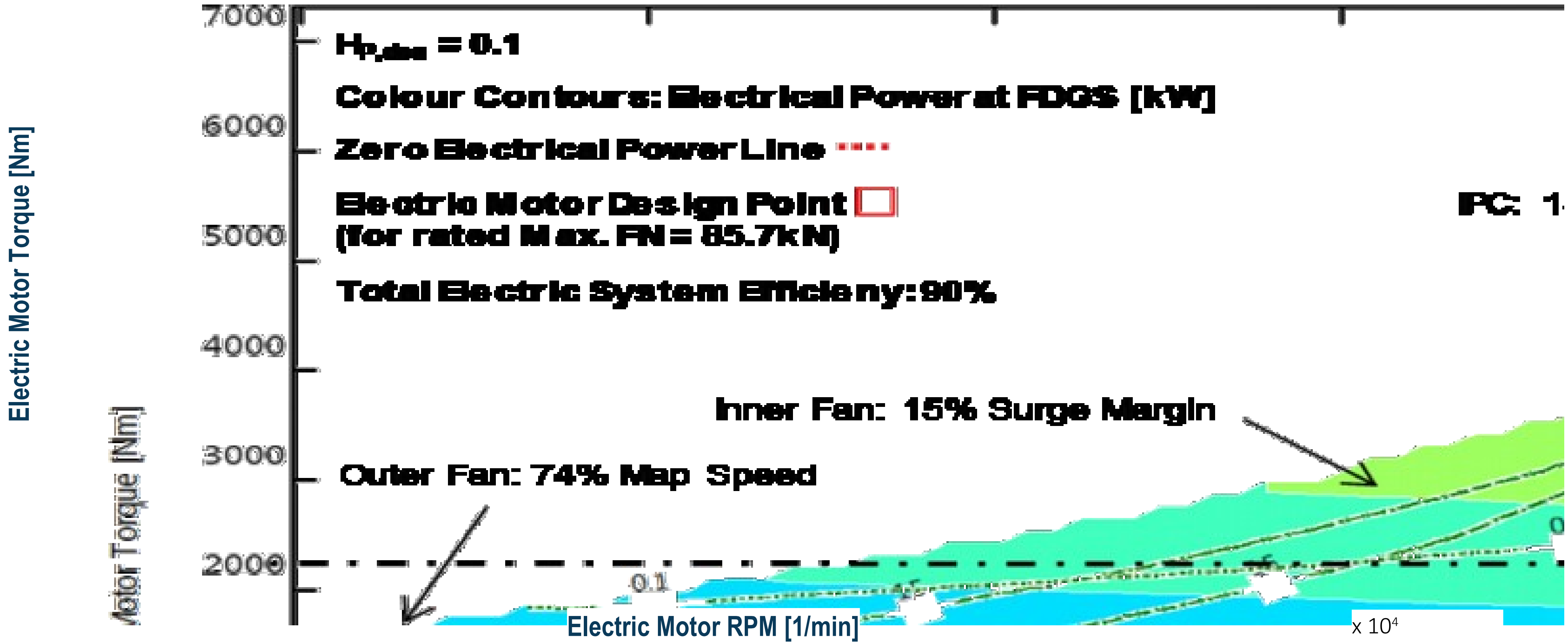
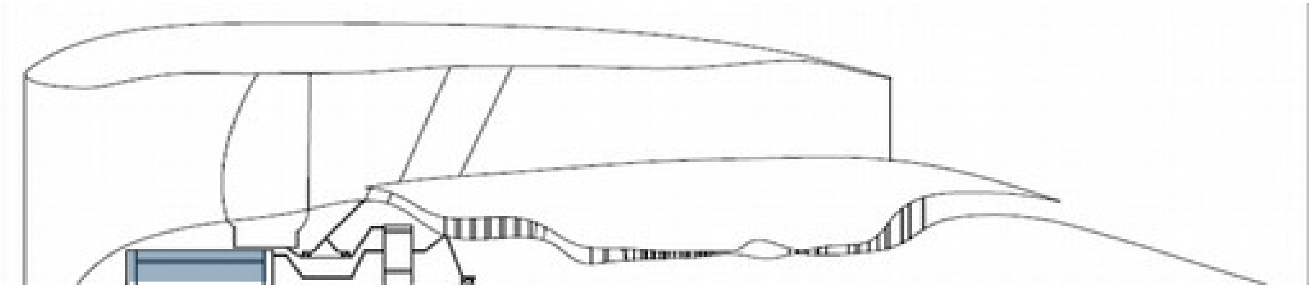
>> Sizing point take-off for ENOVAL S/M range application ($H_{P,des}$=0.1)



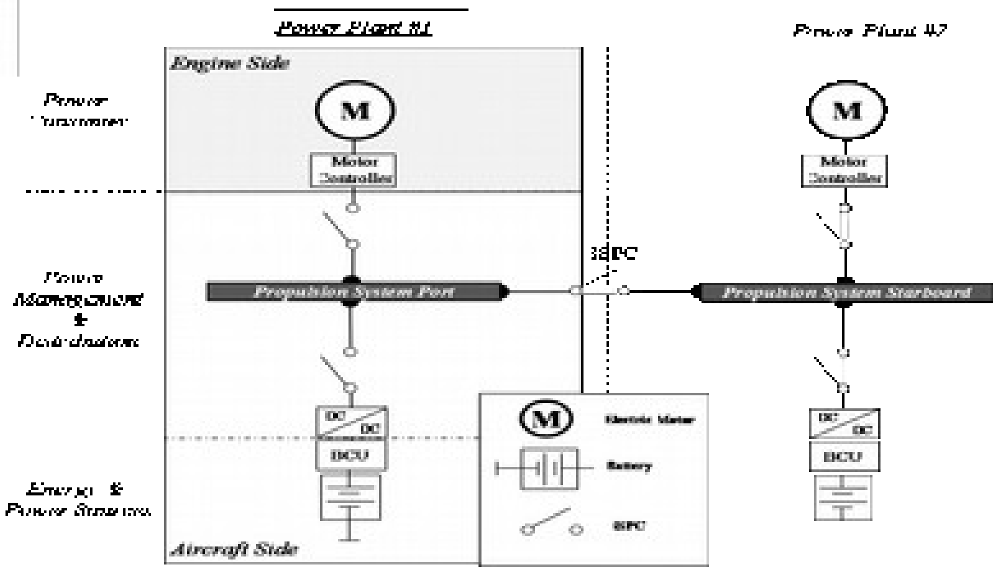
MIPH: Detailed Concept Sketch

>> Basic flow path of mechanically integrated parallel hybrid power plant

- > $H_{P,des} = 0.1$
- > 2MW electric motor

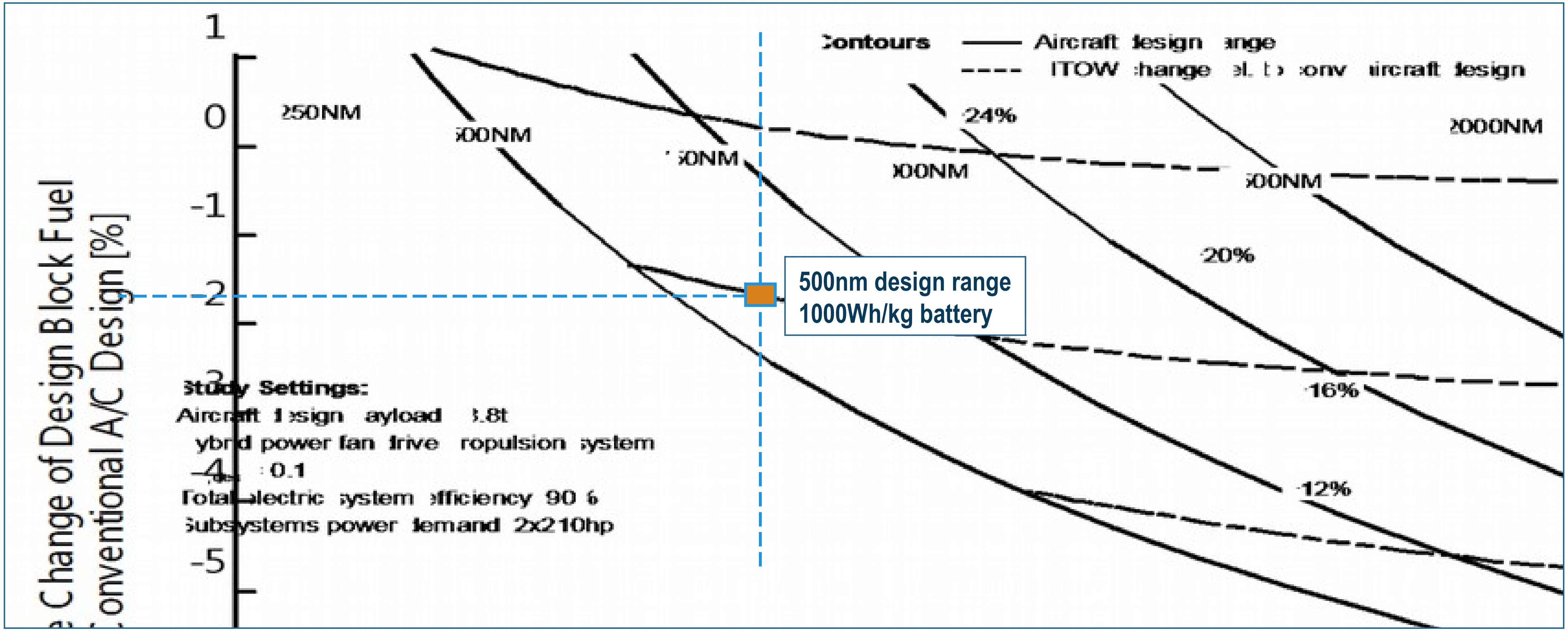


>> Layout of electrical system architecture:



MIPH: Design Block Fuel Assessment

>> Mechanically integrated parallel hybrid vs. advanced turbofan technology



MIPH: Aircraft Integrated Weights

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>> *Weight breakdowns for MIPH and advanced turbofan technology powered aircraft, designed for a 500NM stage length:*

Weight Item	Conventionally powered A/C	MIPH turbofan powered A/C [1]	Delta [%]
Airframe structures and systems	30811	33126	+7.5
Power plant systems [2]	6822	7780	+14.0
Electric systems architecture	n/a	2270	n/a
Battery system	n/a	5330	n/a
OWE	37633	48506	+28.9
Payload	18775	18775	±0.0
Design fuel	3839	3706	-3.5
MTOW	60247	70986	+17.8

[1] 1000Wh/kg battery system specific energy
[2] weight of electric motors included in electric systems architecture

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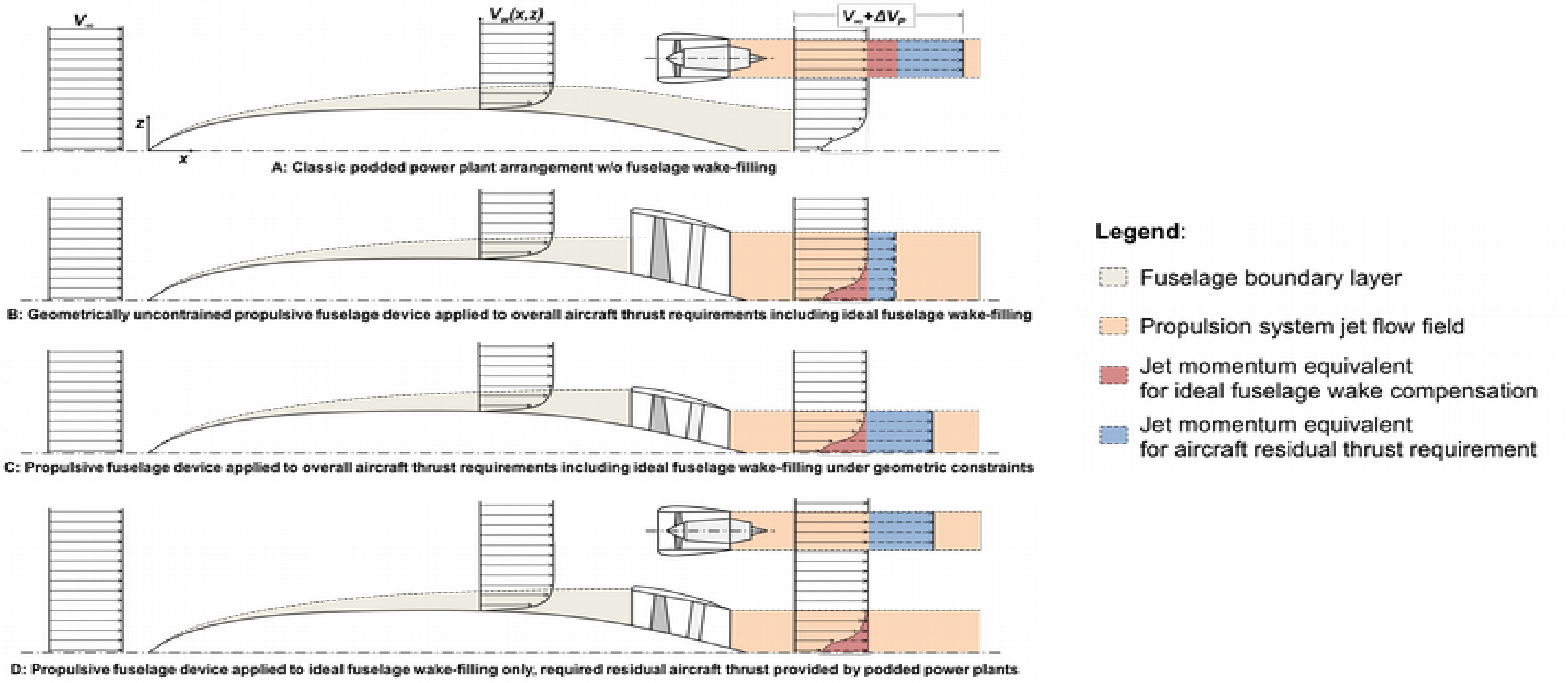
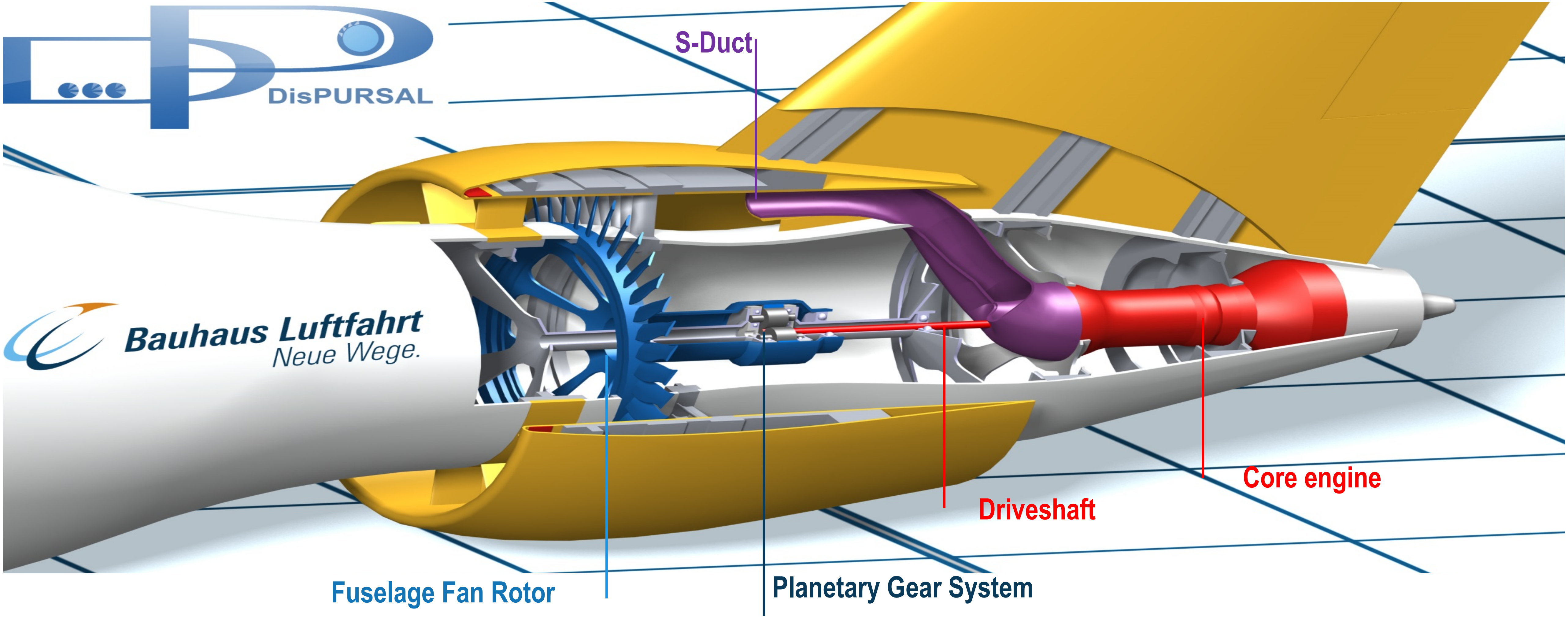
The Principle of Aircraft Wake Filling



Ref.: Seitz and Gologan (2013)

Fuselage Fan Propulsion System Integration



Basic Approaches to Hybrid Electric Propulsion

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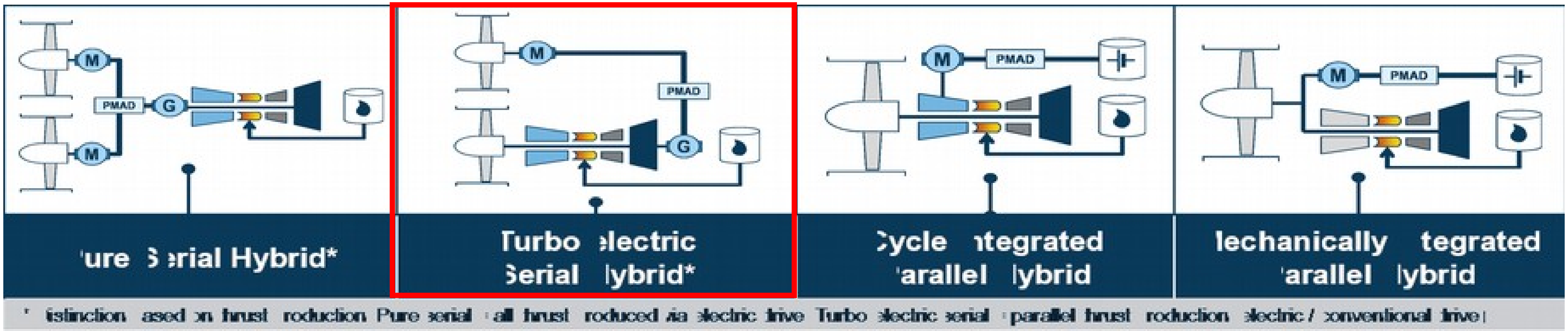
>> Four Basic Approaches to Hybrid Electric Propulsion



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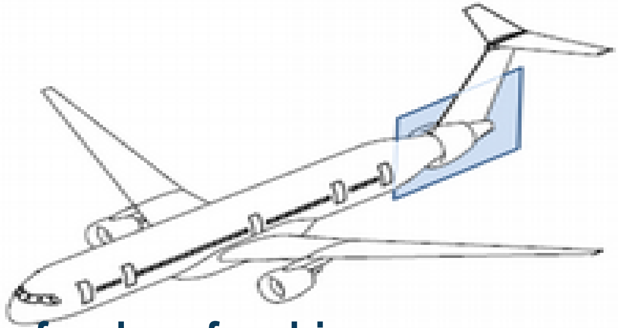
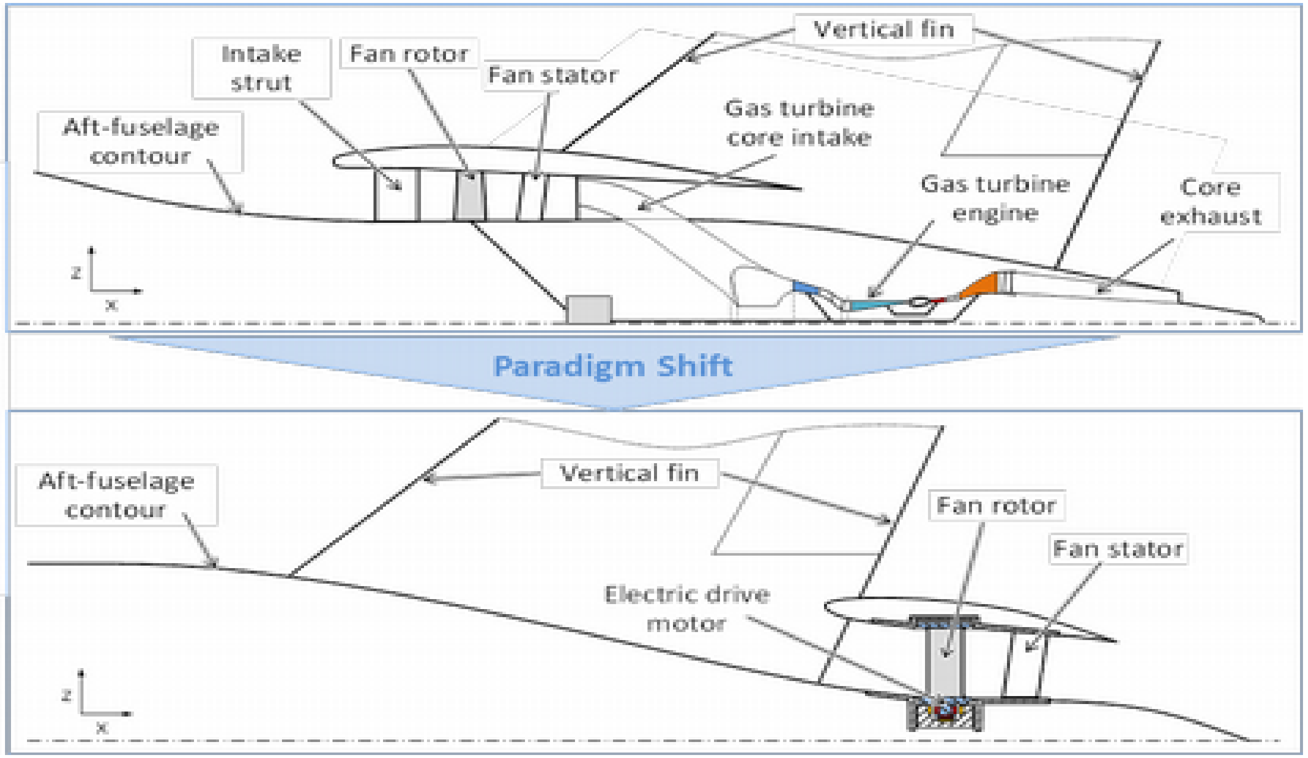
Synergistic Propulsion-Airframe Integration

>> Wake-filling aft-fuselage propulsion integration with turbo-electric design paradigm shift

- > Mechnical fuselage fan drive
- > DisPURSAL: –9% Design Fuel





- > Turbo-electric fuselage fan drive
- > Init. Estimate: –11% Design Fuel

Ref.: Seitz, A. „Power Train Options for a Propulsive Fuselage Aircraft Layout, Presentation at MEA-USA Conference, Seattle, August 2016

Contact

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