

University of Stuttgart
Institute of Aircraft Design



Eco4
a new generation
hybrid-electric
four place aircraft

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E-Flight Forum
Beijing
8-10 Nov2017

The Challenge for Electric Flight

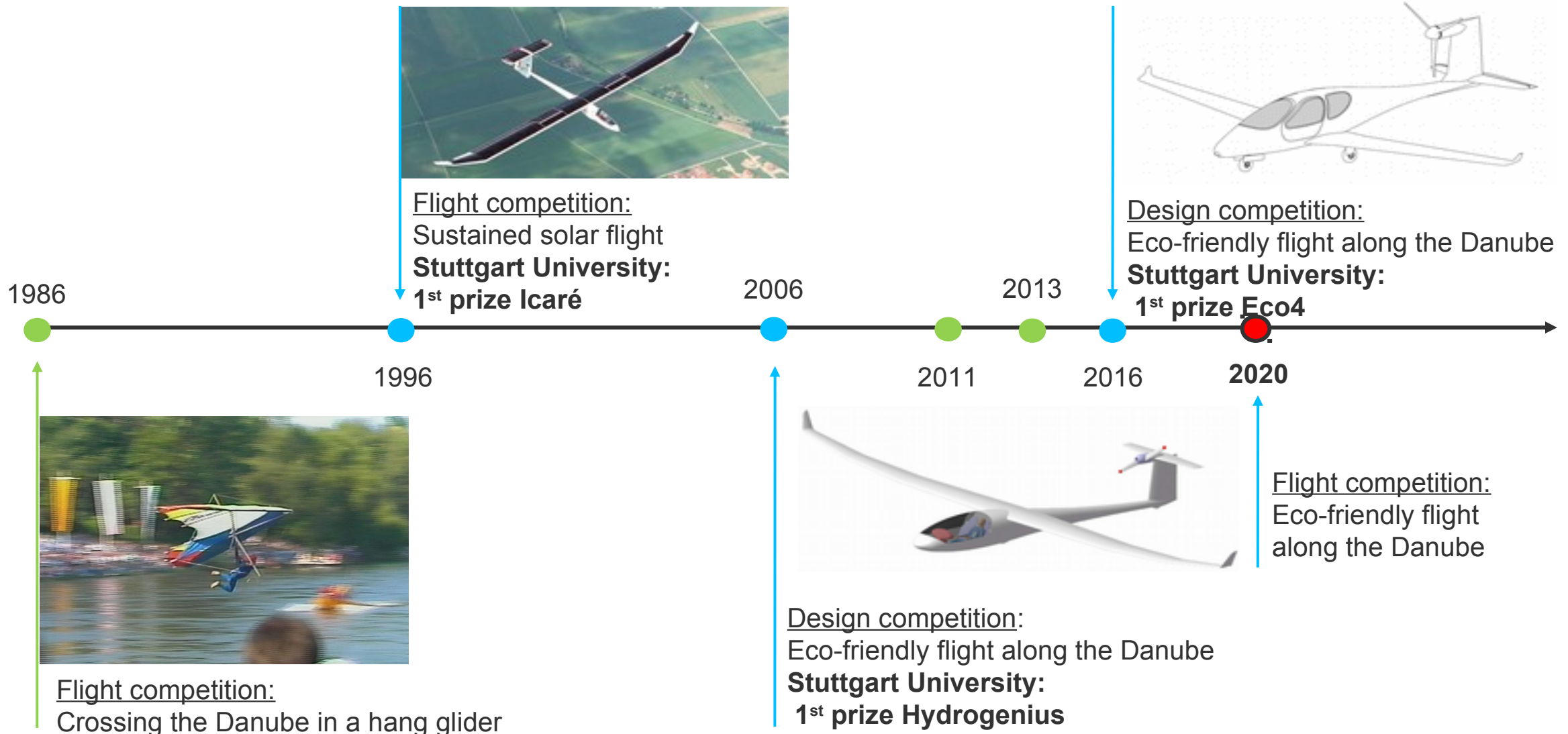
How to scale the technology?

- The energy density of today's batteries allows for development of viable General Aviation products



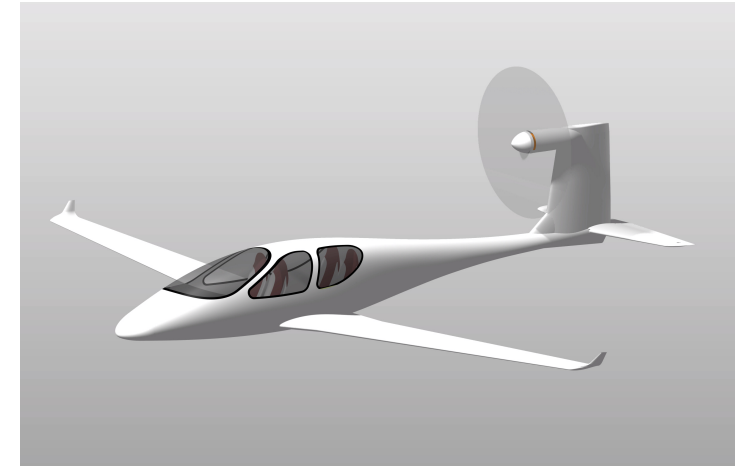
Eco4 – a hybrid-electric product

Designed for the Berblinger Competition



Eco4 – a hybrid-electric product

1st Prize in the Berblinger Competition 2016



Eco4 – a hybrid-electric product

Designed for the Berblinger competition – design requirements



- Requirements directly from the task:

Flight performance I

Maximum range	3000 km (1600 nm)
Energy consumption	As low as possible
Noise	As low as possible

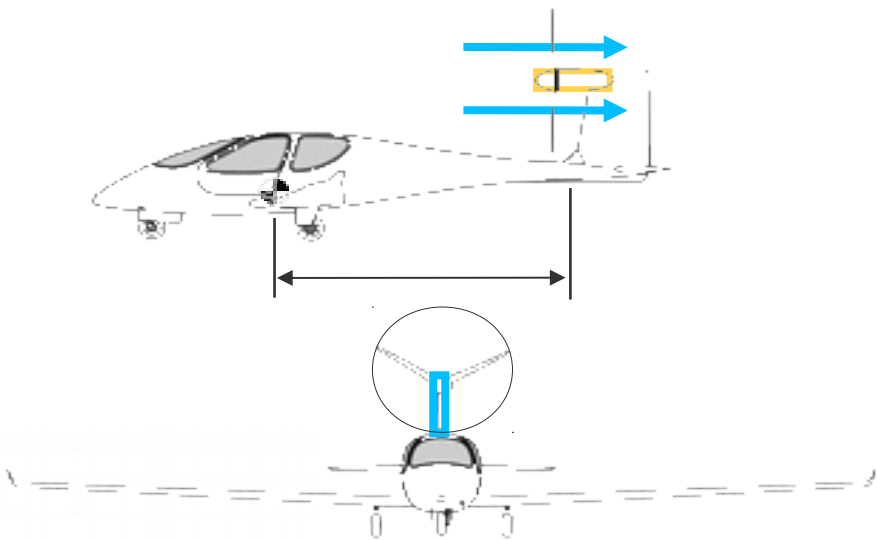
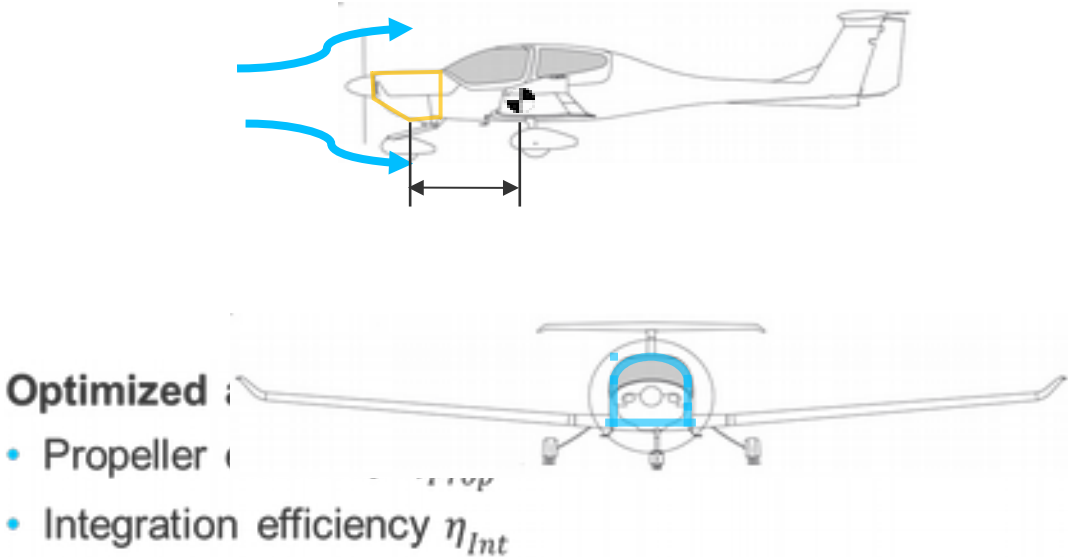
- Requirements to ensure practicability:

Flight performance II

Cruise speed	> 120 knots
Capacity	1 + 3
Take-off field length	< 600 m (< 2000 ft)
Rate of climb	> 5 m/s (> 1000 ft/min)
Stall speed	< 110 km/h (< 60 knots)

Eco4 – a hybrid-electric product

Why go electric?

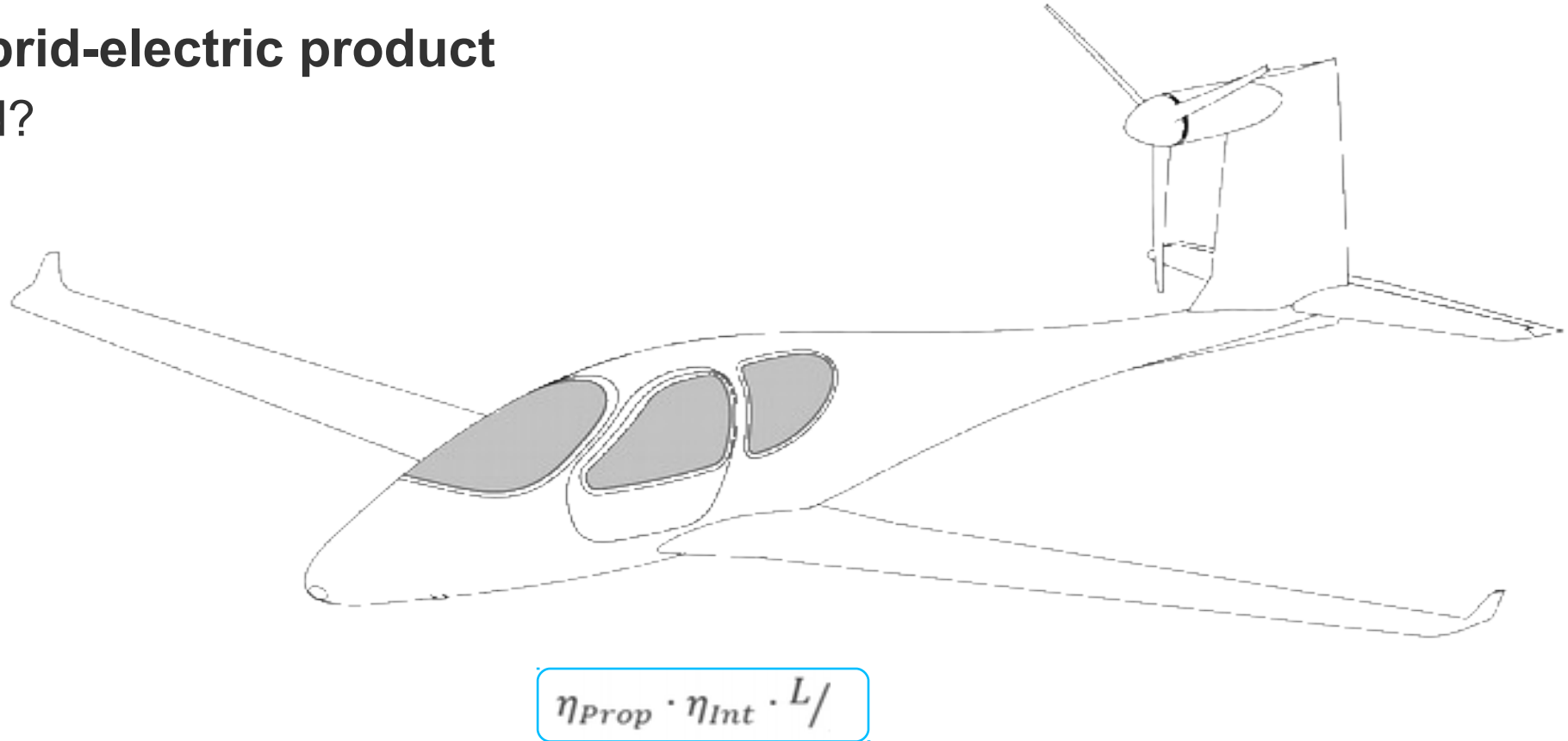


$$\eta_{Prop} \cdot \eta_{Int} \cdot L/$$

Application	Conventional	Electric	Difference [%]
2 PAX, 83 knots	12 (Valentin Taifun)	23 (e-Genius)	+91%
4 PAX, 120 knots	10 (Diamond DA40)	18 (Eco4*)	+80%

Eco4 – a hybrid-electric product

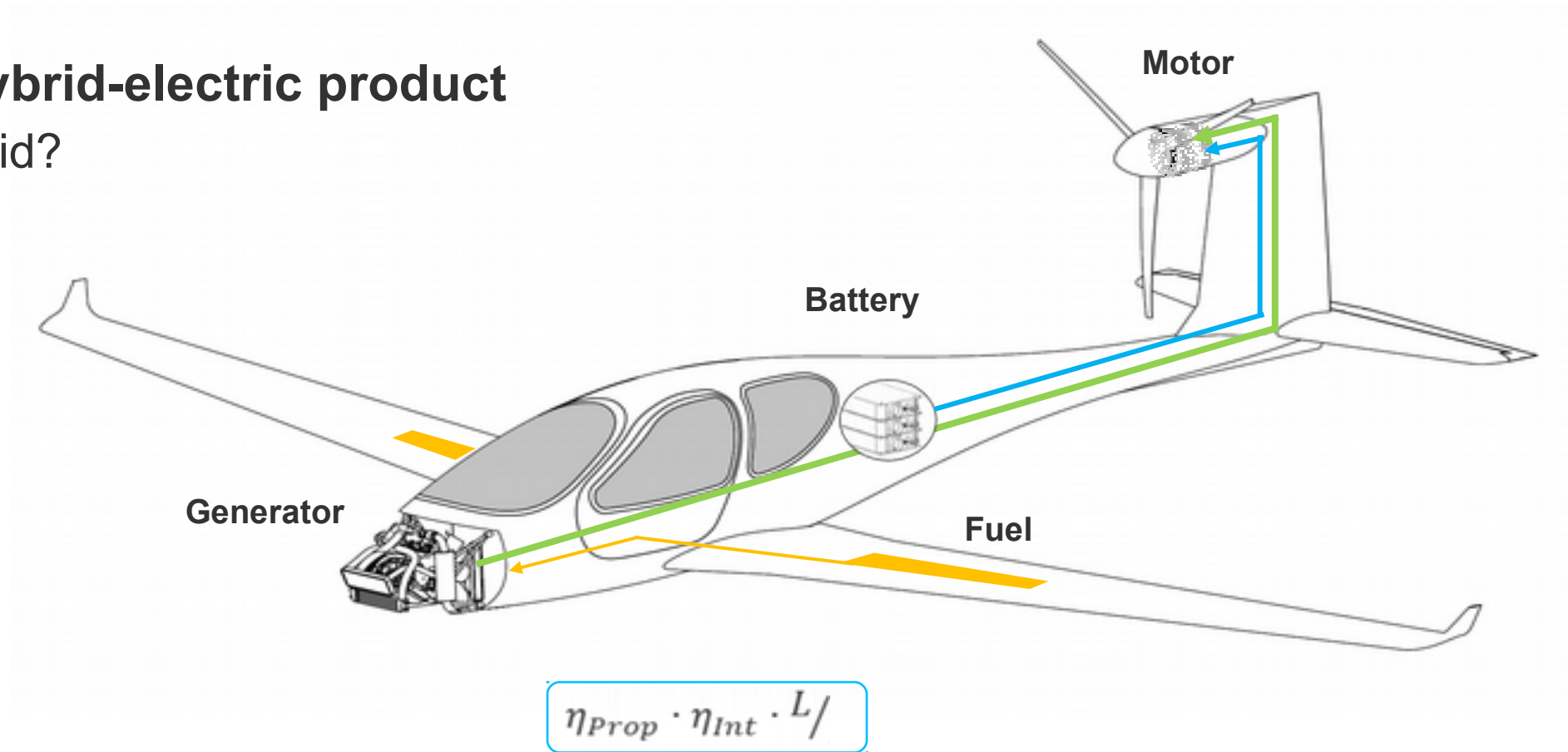
Why go hybrid?



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Eco4 – a hybrid-electric product

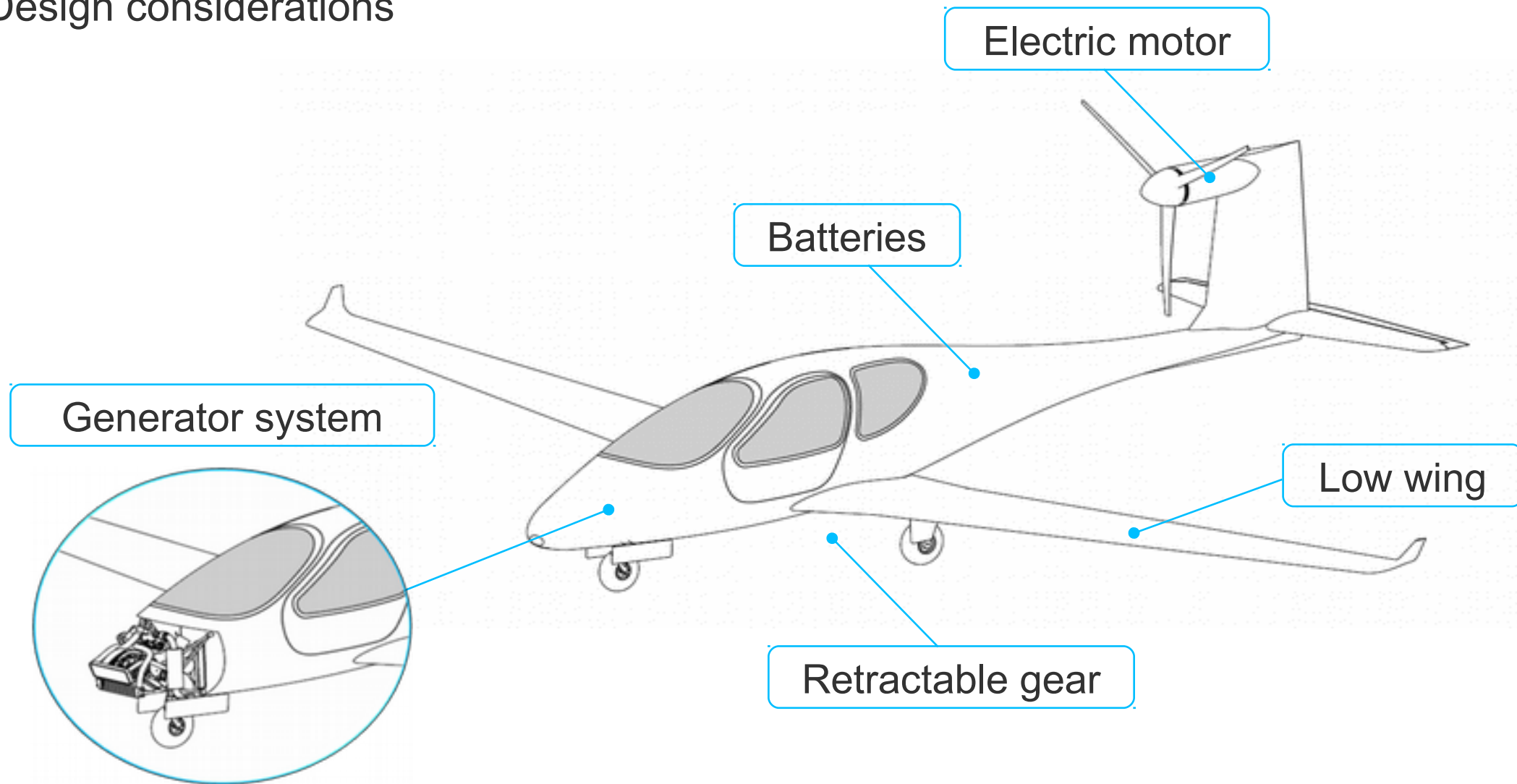
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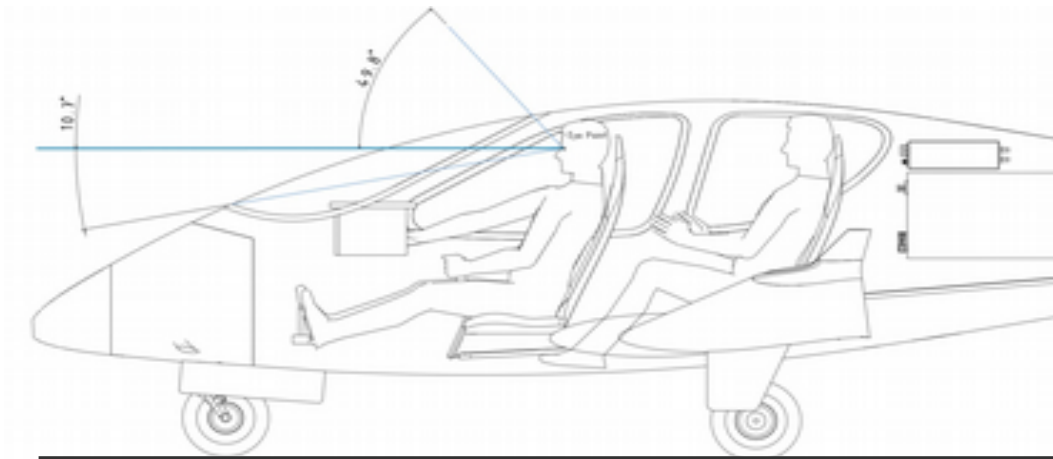
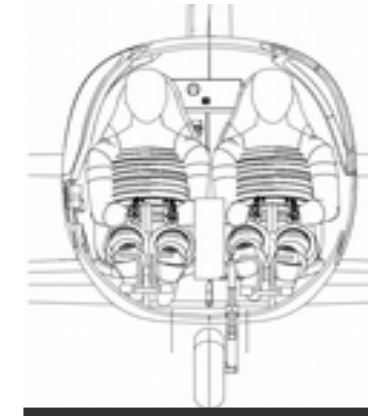
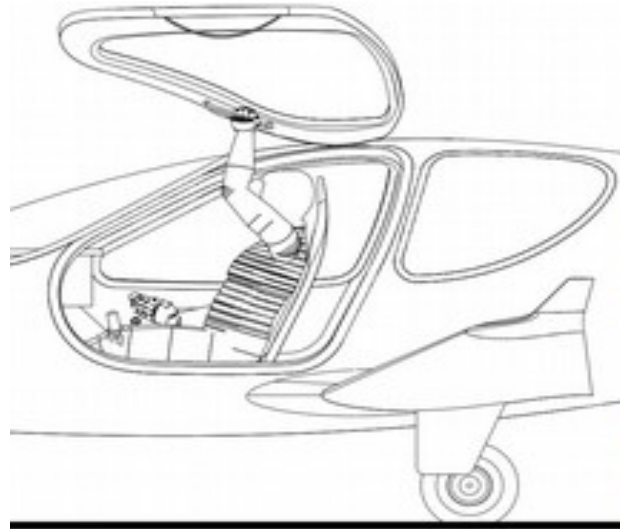
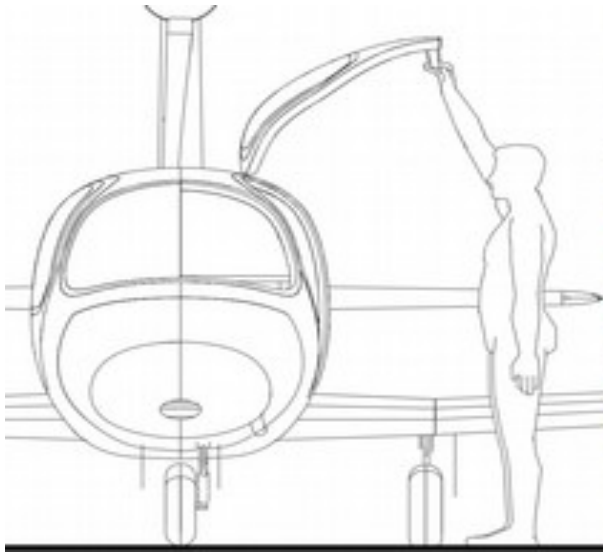
Eco4 – a hybrid-electric product

Design considerations



Eco4 – a hybrid-electric product

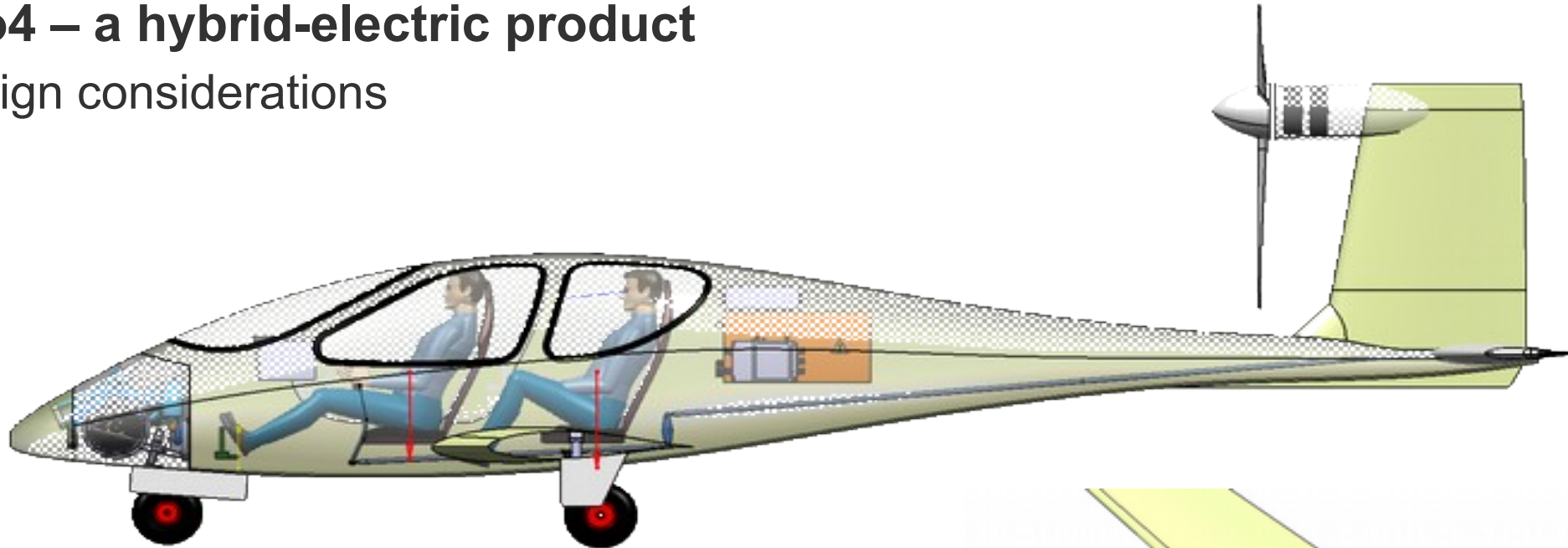
Design considerations



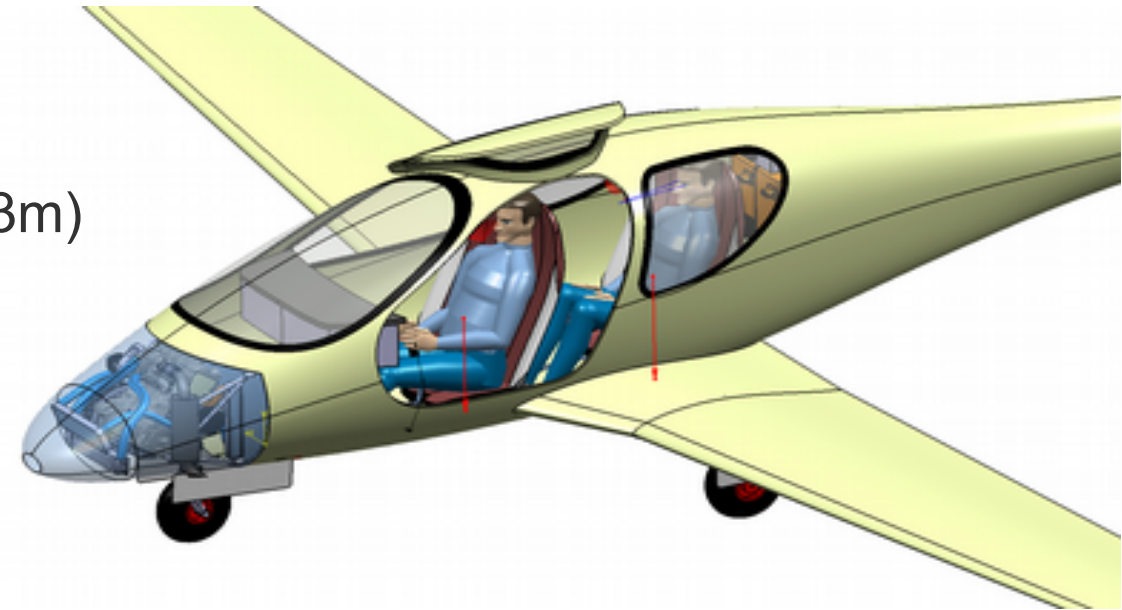
- Cabin design including state-of-the-art ergonomics and anthropometry
- Cabin designed for a wide range of pilots and passengers

Eco4 – a hybrid-electric product

Design considerations

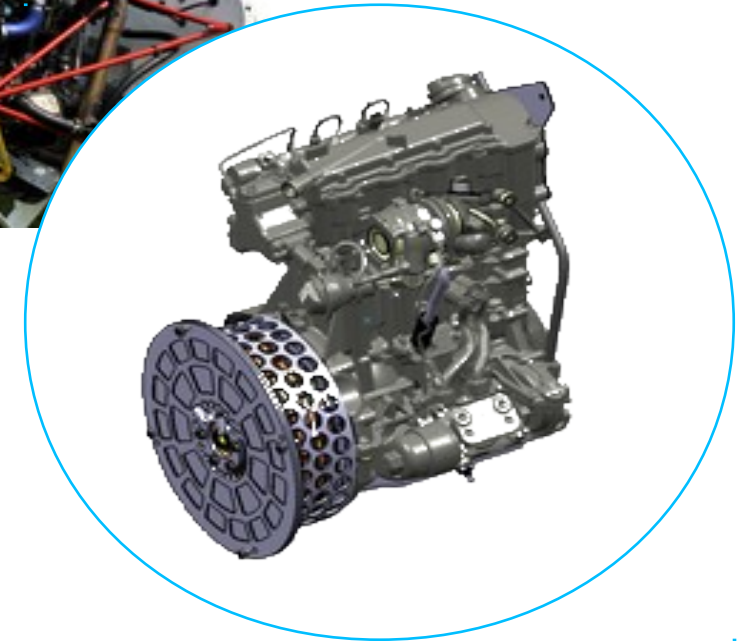
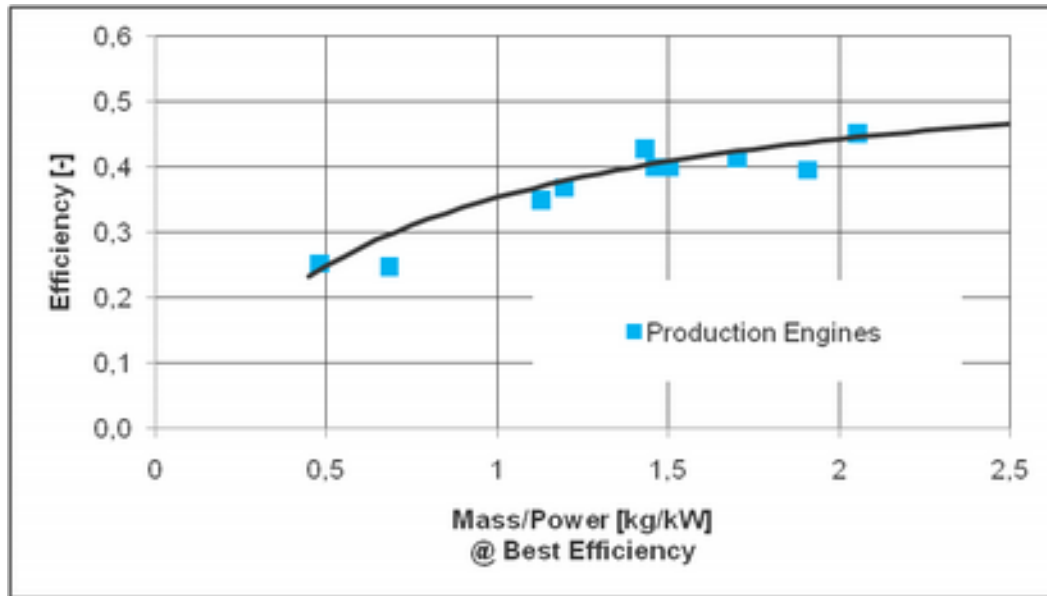


- Cabin view for 95 percentile pilot + passenger (>1,83m)
- Access to the cabin via two front doors
- Access to passenger seats via folding pilot seats



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Choice of combustion engine



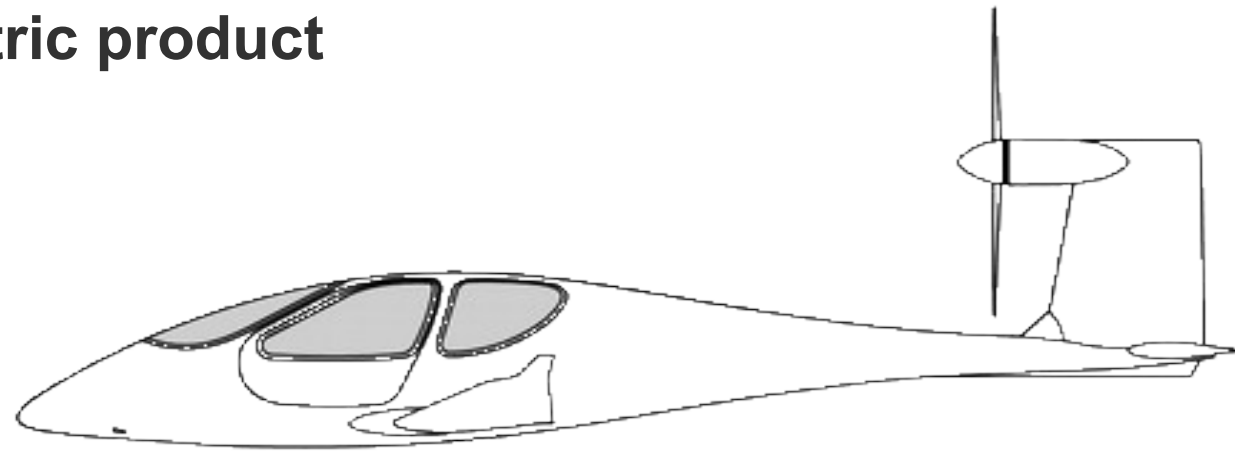
- Rising efficiency as mass-to-power-ratio increases

➡ Eco4 benefits from an efficient, but relatively heavy combustion engine

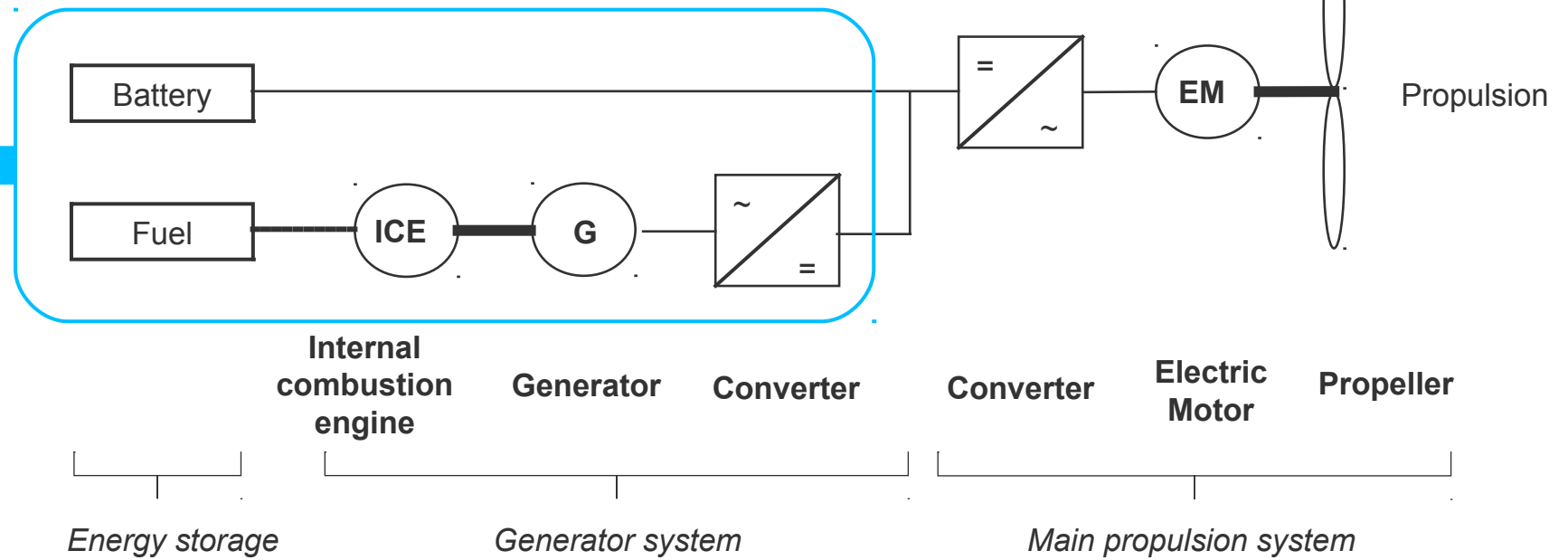
- 3 cylinders, common rail
- max. power: 58 kW

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Systems architecture

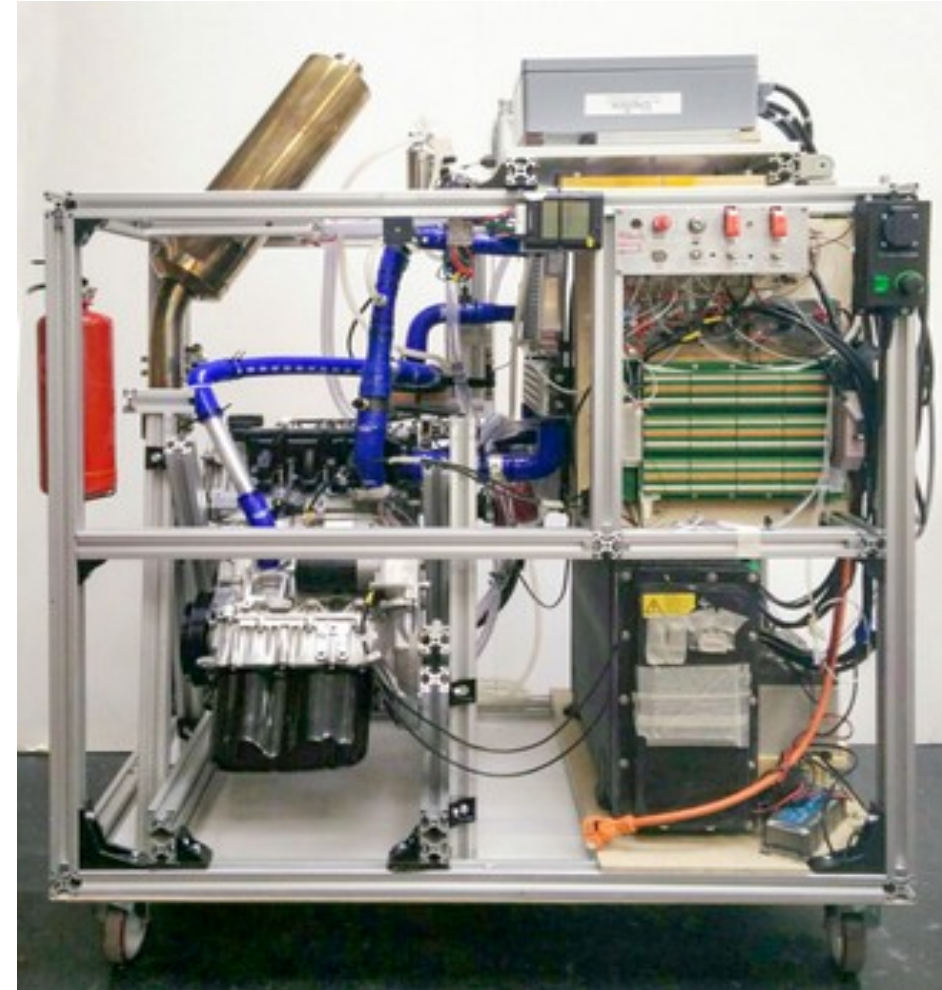
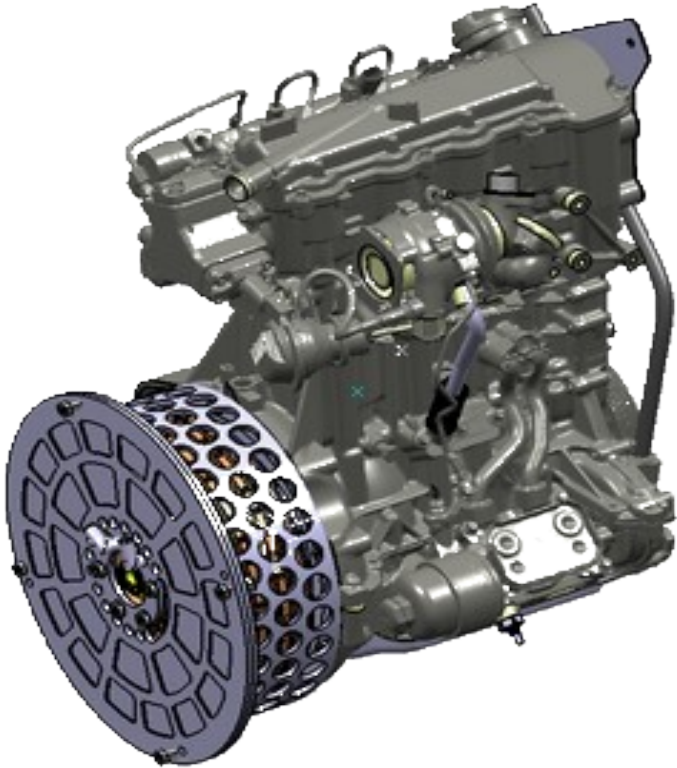


Power Management
Unit



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The GenSet – ground testing has started



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E-Genius – our test platform for the GenSet



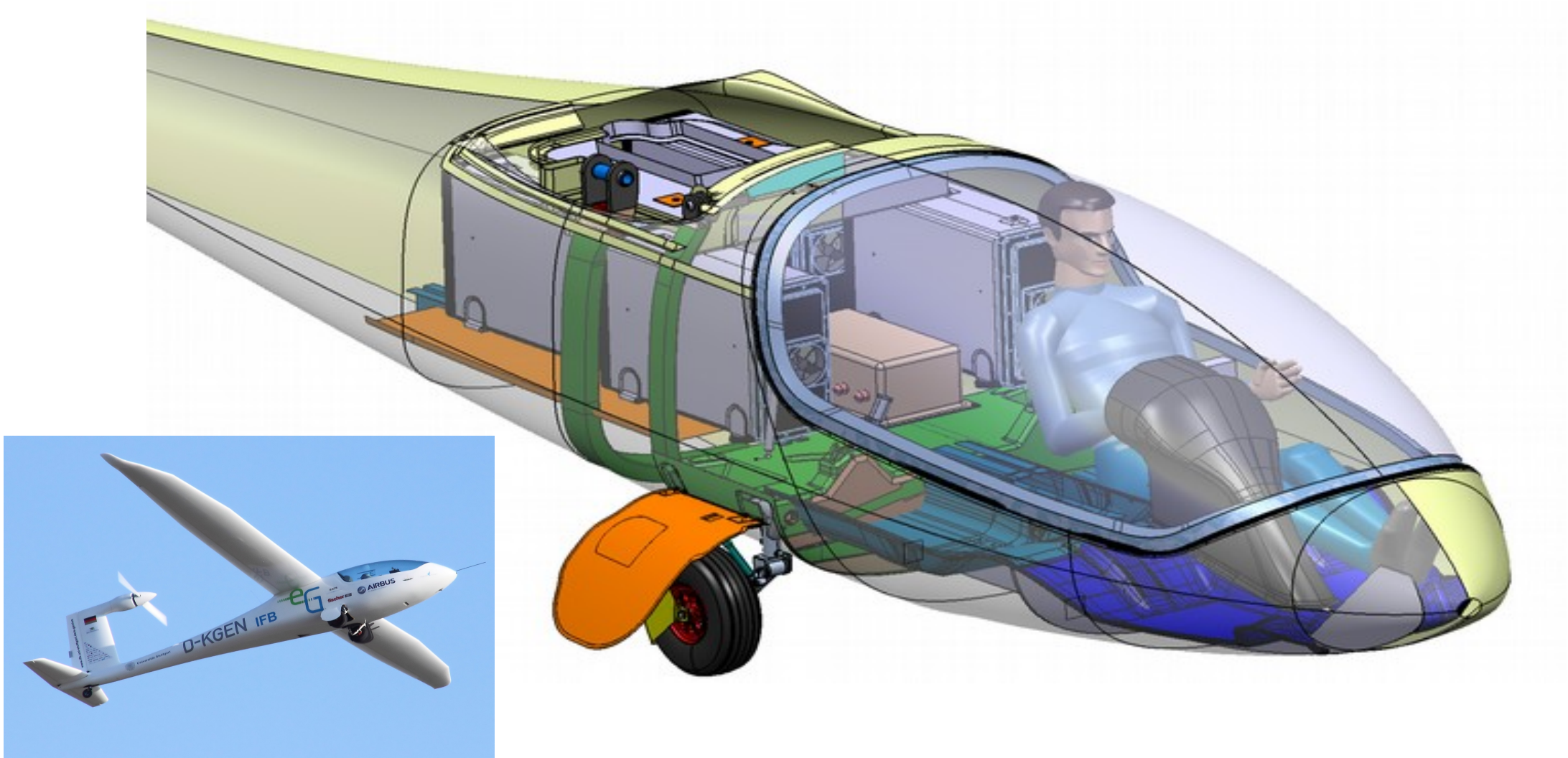
Span width:	16,86 m
Length:	8,10 m
Wing area:	14,1 m ²
Payload:	>180 kg
Max. take of weight:	950 kg
Shaft power:	30 kW (cont.) 70 kW (peak)
Usable battery capacity:	49 kWh
Cruising flight:	140-200 km/h
Climb rate:	>4 m/s
Take-off distance:	450 m
Landing distance:	350 m
Glide ratio:	1:34
Climb rate at Start:	5,5 m/s
Range (FL100, 150km/h)	400 km + 30 min reserve

✦ 2 new world records flown on 1 November 2017:

- Speed over 15km (235 km/h)
- Speed over 100km (222 km/h)

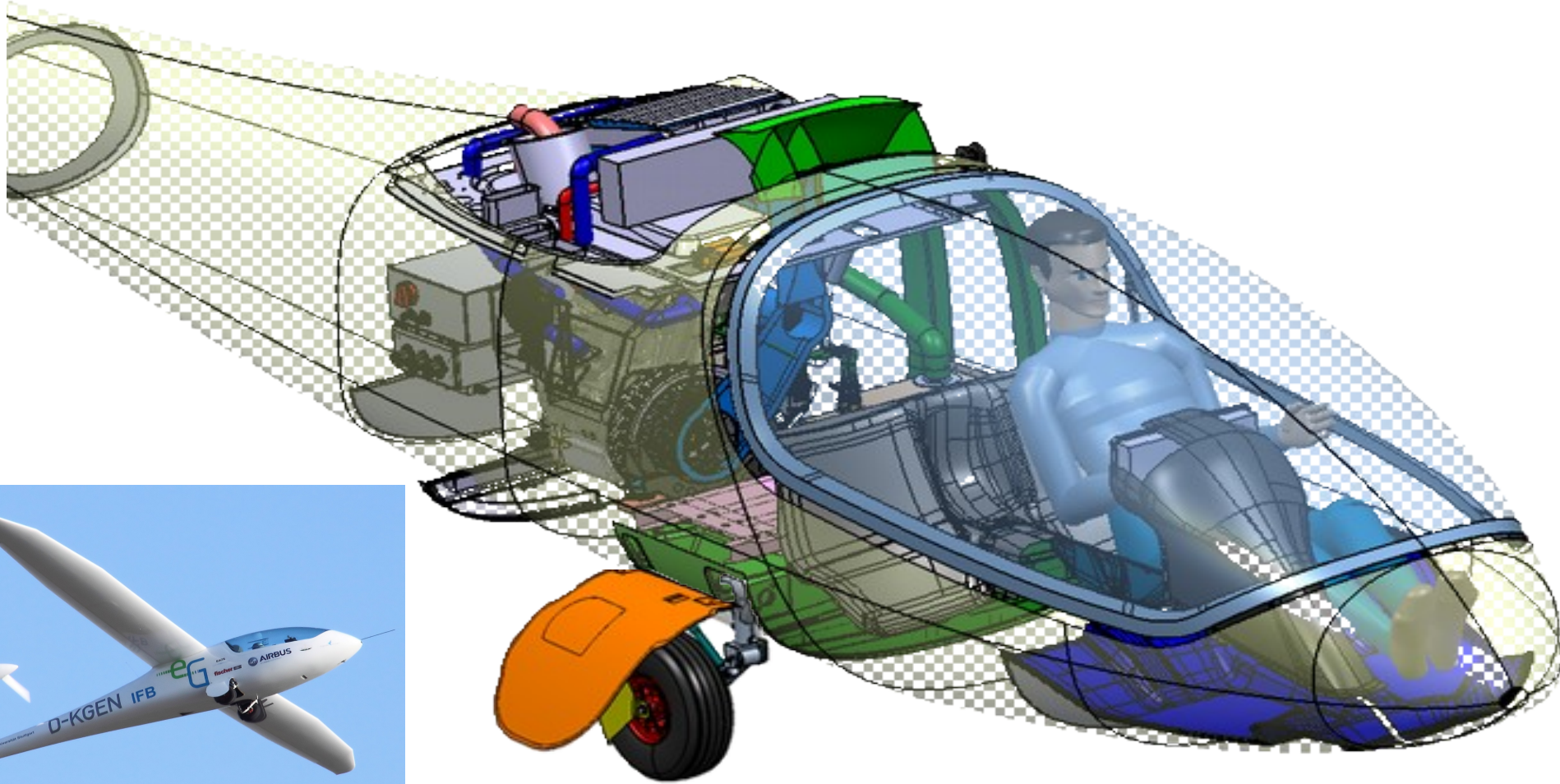
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e-Genius: Battery Powered



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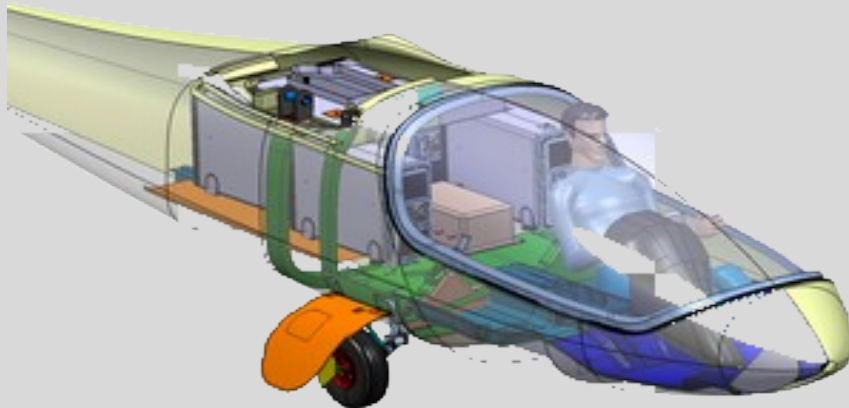
e-Genius: High Performance Hybrid



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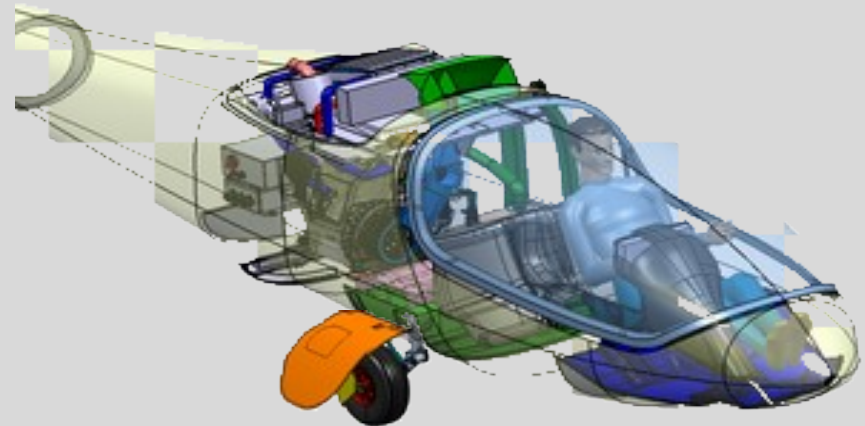
Proof of concept in the e-Genius

e-Genius battery powered



- ➡ Powered by batteries
- Max. range 400 km (+ 30 min)
- Cruise speed: 150 km/h

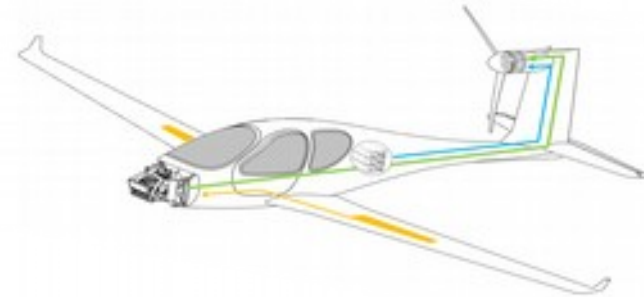
e-Genius HPH (hybrid)



- ➡ Powered by generator
- Max. range > 2000 km
- Cruise speed: 170 km/h
- **Fuel consumption 3.0 l/100km**
(on aircraft level)

Eco4 – a hybrid-electric product

Comparison to DA40 D



	DA-40 D	Eco4
Maximum Take-Off Mass	1150 kg	1200 kg
Take-off power	99 kW	130 kW
Take-off field length	2080 ft	2000 ft
Climb rate	650 ft/min	1000 ft/min
Cruise speed	120 knots	120 knots
Max. range with 3 persons on board (each 90 kg)	650 nm	1600 nm
Max. range with 4 persons on board (each 80 kg)	230 nm	1200 nm
Fuel flow @ 120 knots	18 liters/hour @ 5000 ft. ISA Std.	11 liters/hour @ 5000 ft. ISA Std.

 **increased range!**

 **- 40% fuel flow**

- + increased reliability of electric motor
- + no idling on ground or in descent
- + silent take-off and landing

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Is there a market?

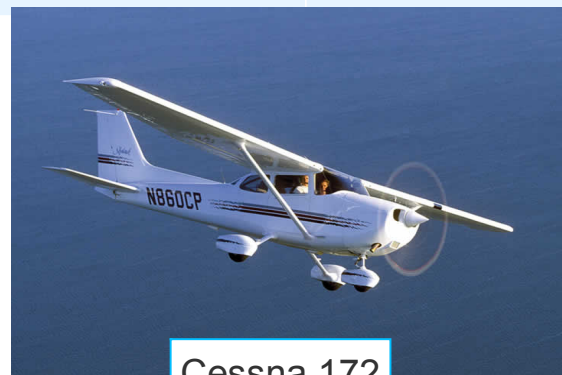
- Four seater with ~120 knots cruise speed

Type	Unit cost	2016 Unit sold*	2016 Annual billing	Unit sold since 1997	Production since
DA-40	\$420,000	48	20.2 M\$	1,935	2002
Cessna 172	\$307,500	126	38.7 M\$	5,373	1956
Cessna 182	\$480,000	133	63.8 M\$	3,546	1956
PA-28	\$467,000	54	25.2 M\$	1,359	1961
Tecnam P2010	\$220,000	22	4.8 M\$	42	2015
Total	-	383	152,7 M\$	12,255	-

* = source: GAMA Databook 2016



DA-40



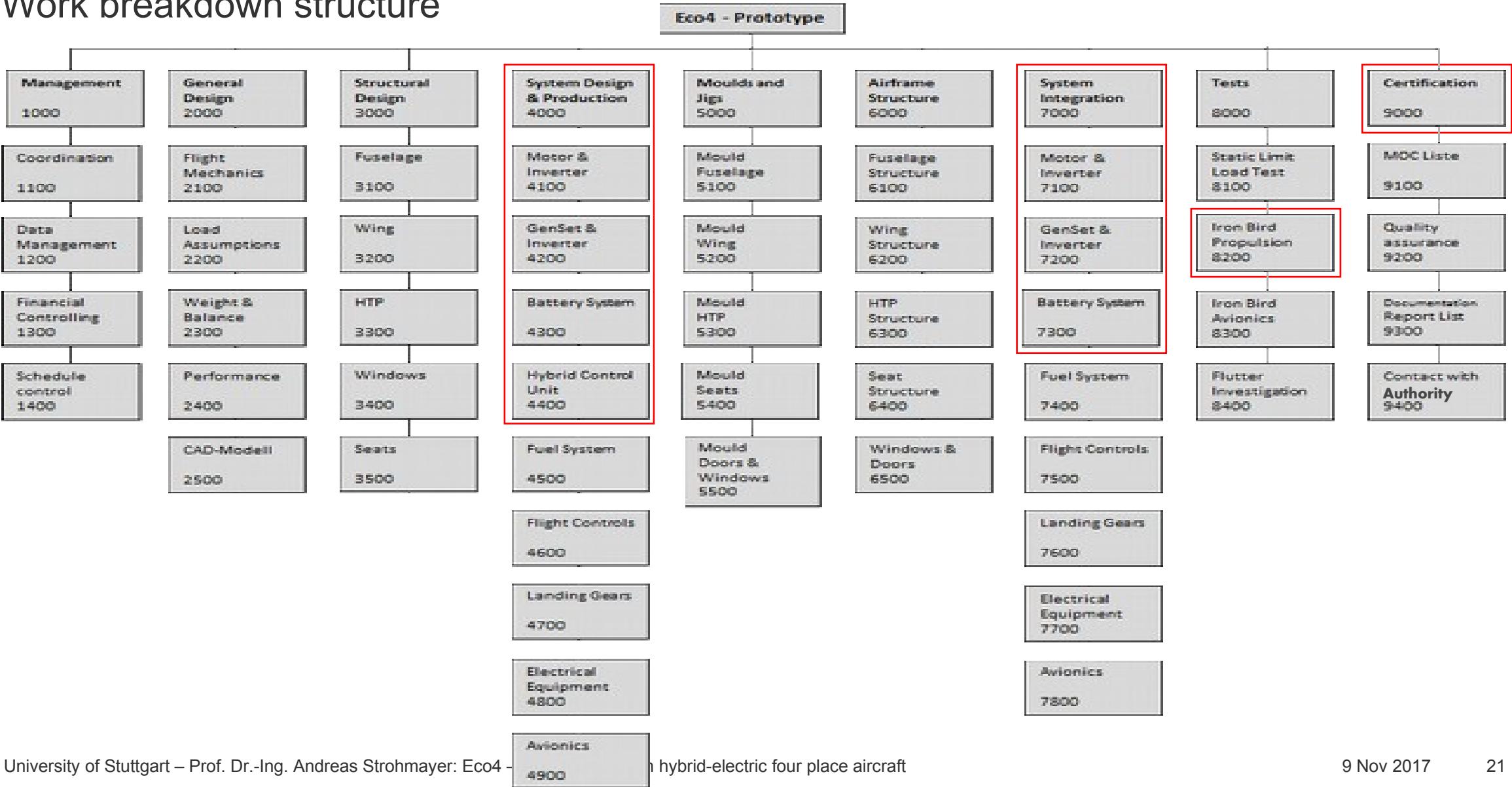
Cessna 172



PA-28

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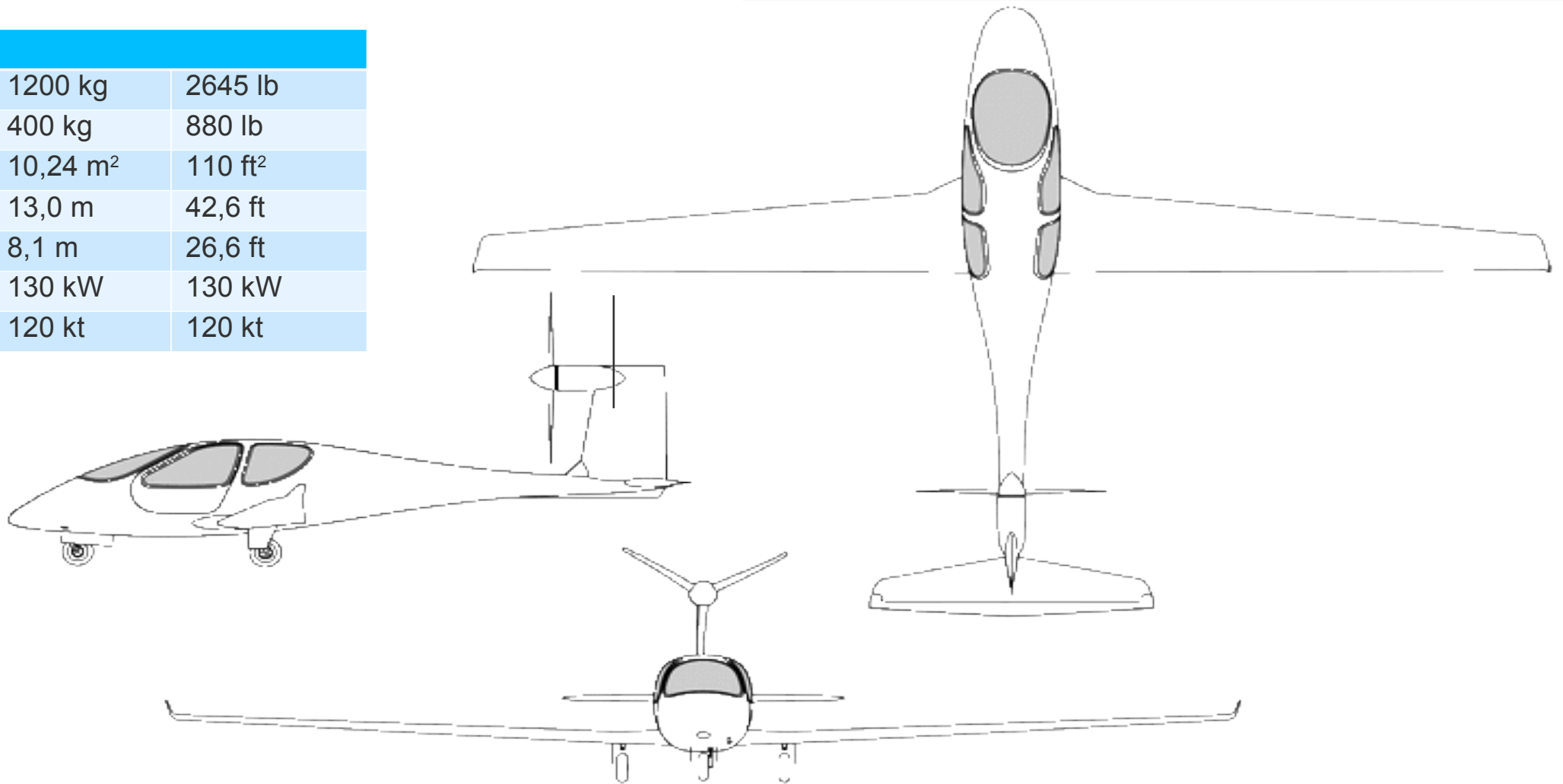
Work breakdown structure

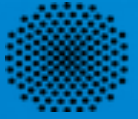


Eco4 – a hybrid-electric product

Key technical data

Data		
MTOM	1200 kg	2645 lb
Payload	400 kg	880 lb
Wing area	10,24 m ²	110 ft ²
Wing span	13,0 m	42,6 ft
Length	8,1 m	26,6 ft
Power @ T/O	130 kW	130 kW
Cruise speed	120 kt	120 kt





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