Electric flight: lessons learned, trends, battery systems

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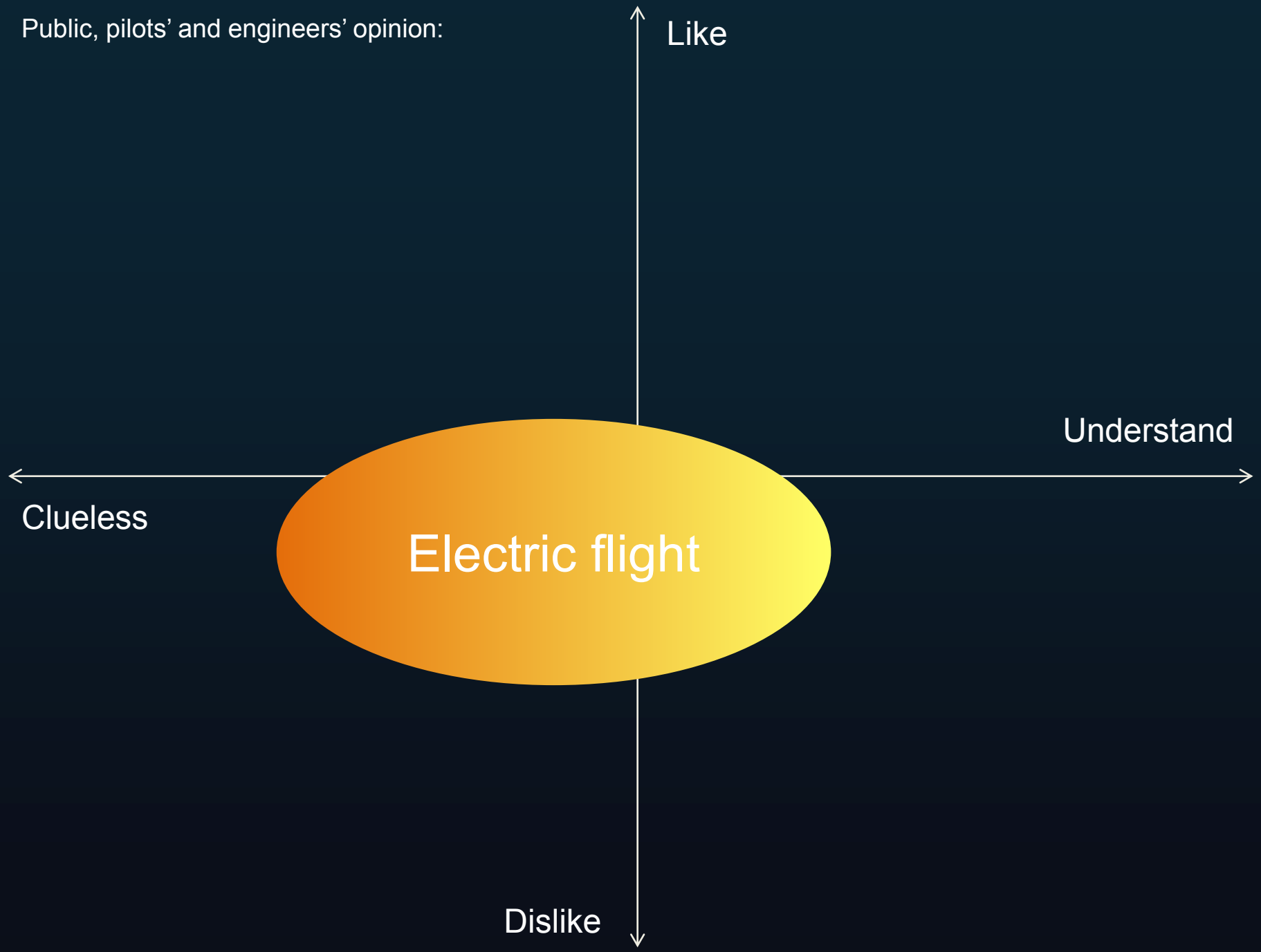
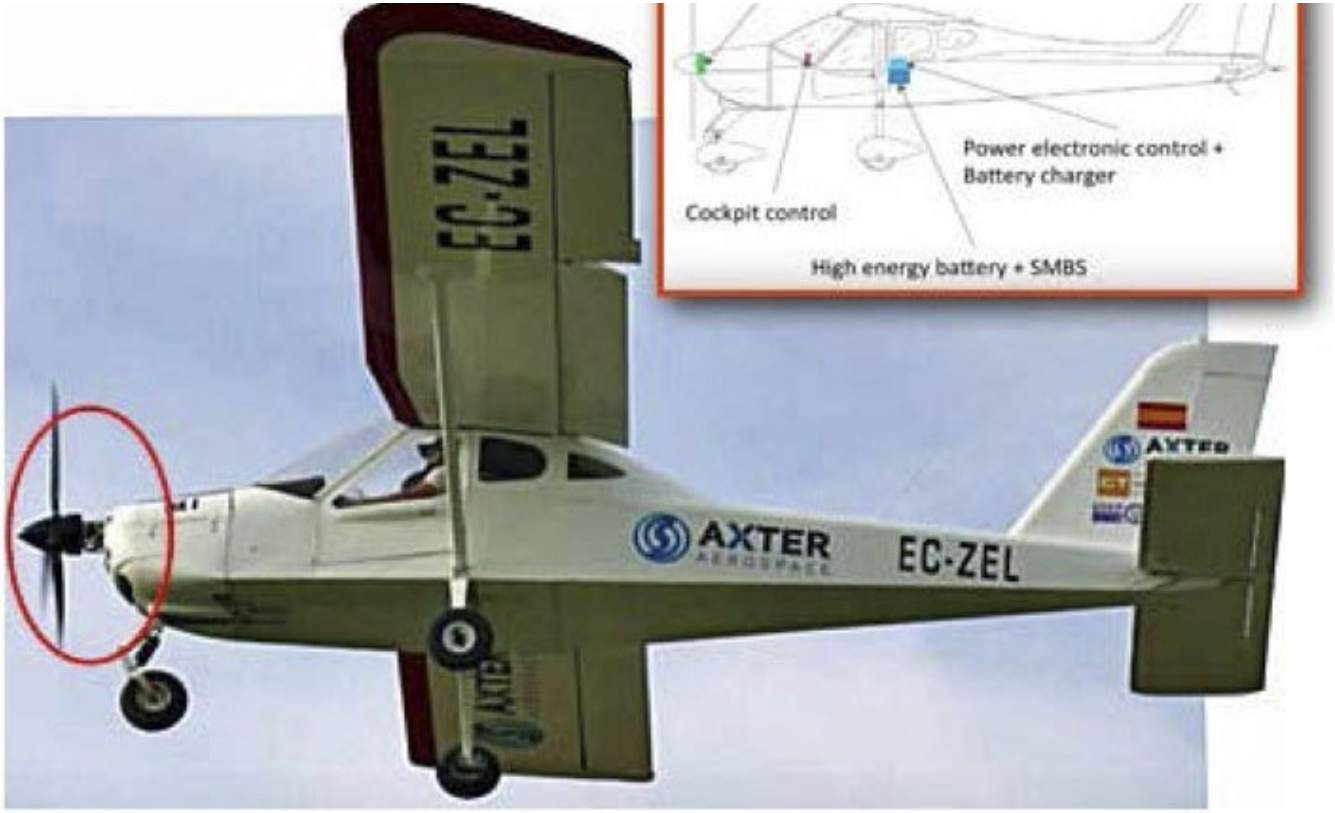
EASA GA Workshop ı Köln ı 21 October, 2015

Public, pilots’ and engineers’ opinion:


Public, pilots' and engineers' opinion:
Like
Understand
Clueless
Electric flight
Dislike

BOEING
Boeing Fuel Cell Demonstrator
(HK36 Super Dimona)
BAE SYSTEMS
Boeing Phantom Works
EC-DD3

EADS
Diamond
SIEMENS
EXPERIMENTAL
RWY10→
←A→ RWY28→

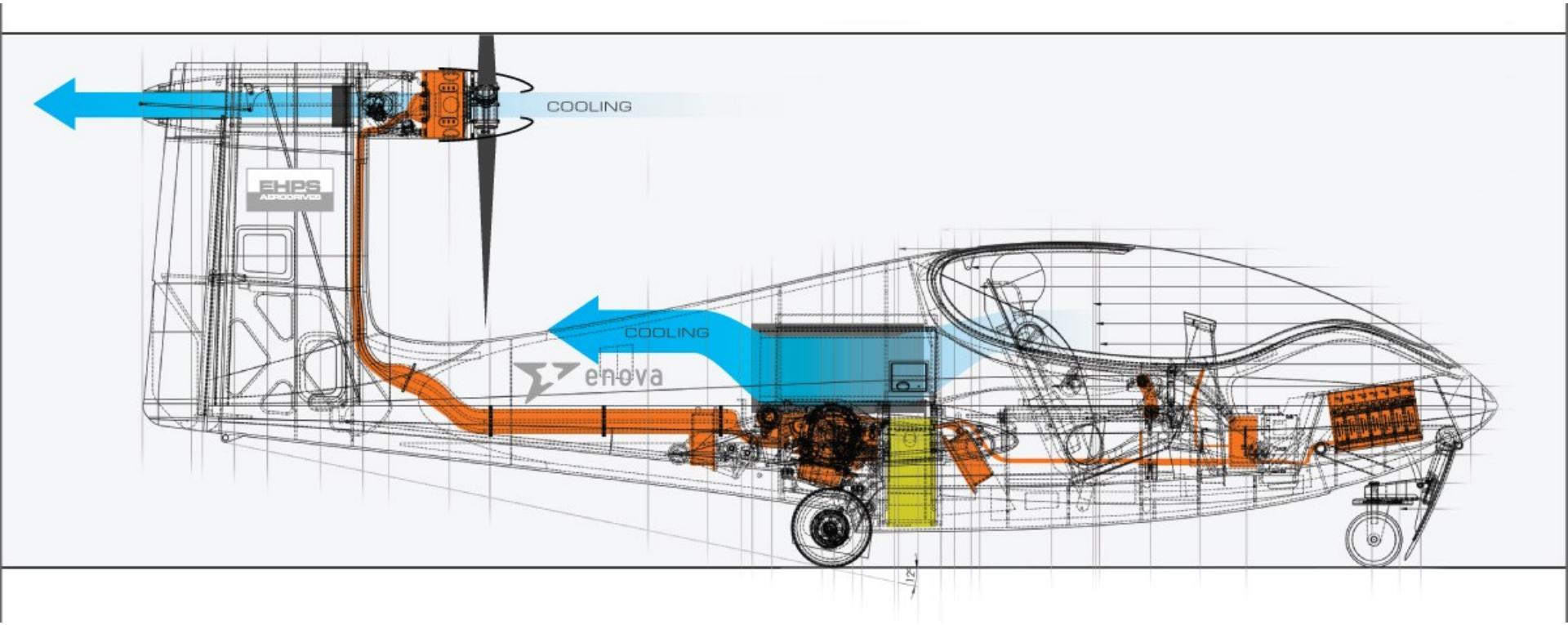

EC-ZEL
AXTER
AEROSPACE
EC-ZEL
Power electronic control +
Battery charger
Cockpit control
High energy battery + SMBS

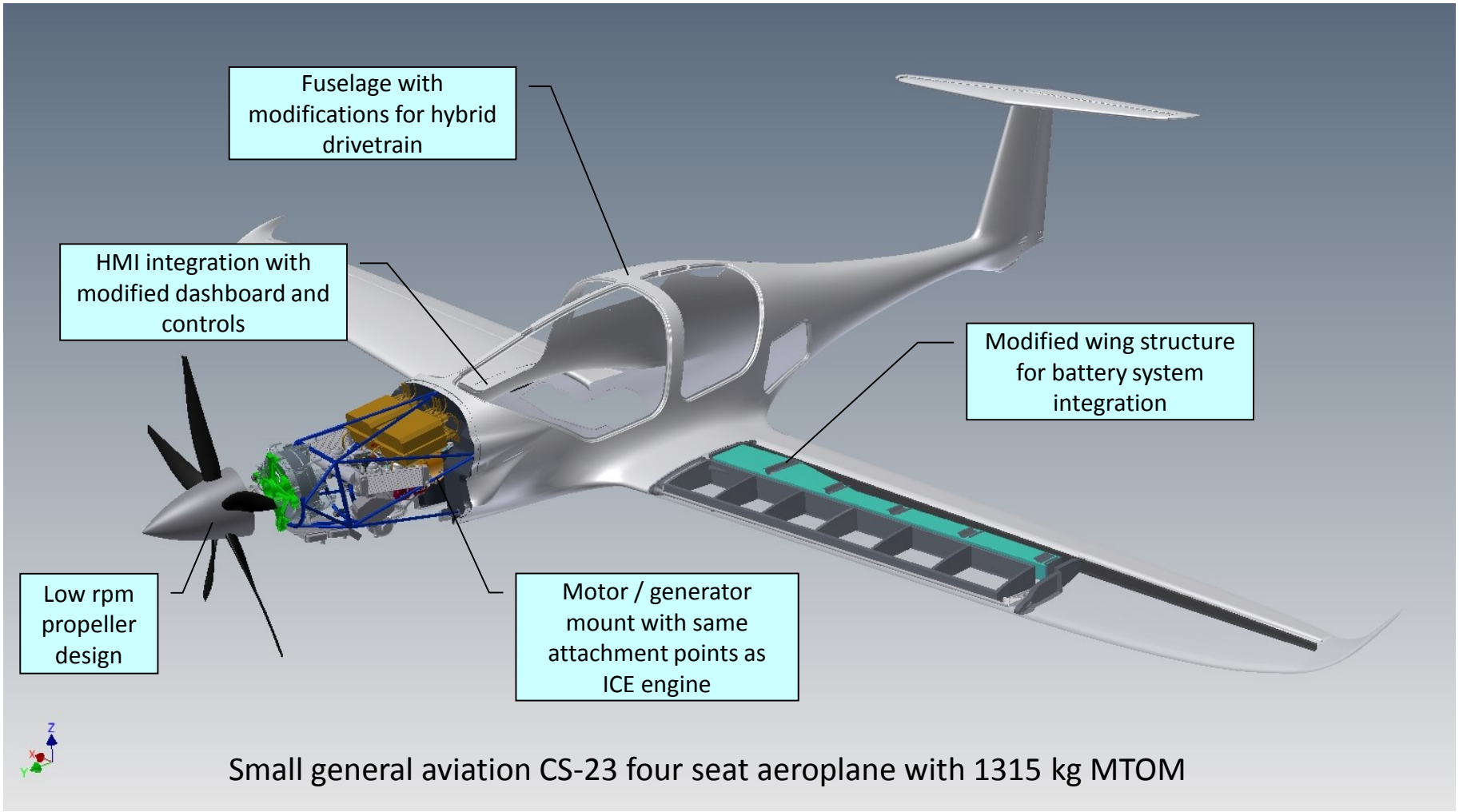
AIR ARRAY
BEWARE OF PROPELLER
DON'T TOUCH
DON'T TOUCH

AeroVironment
AeroVironment

CAUTION FAN
EXCALIBUR

D-KDLR

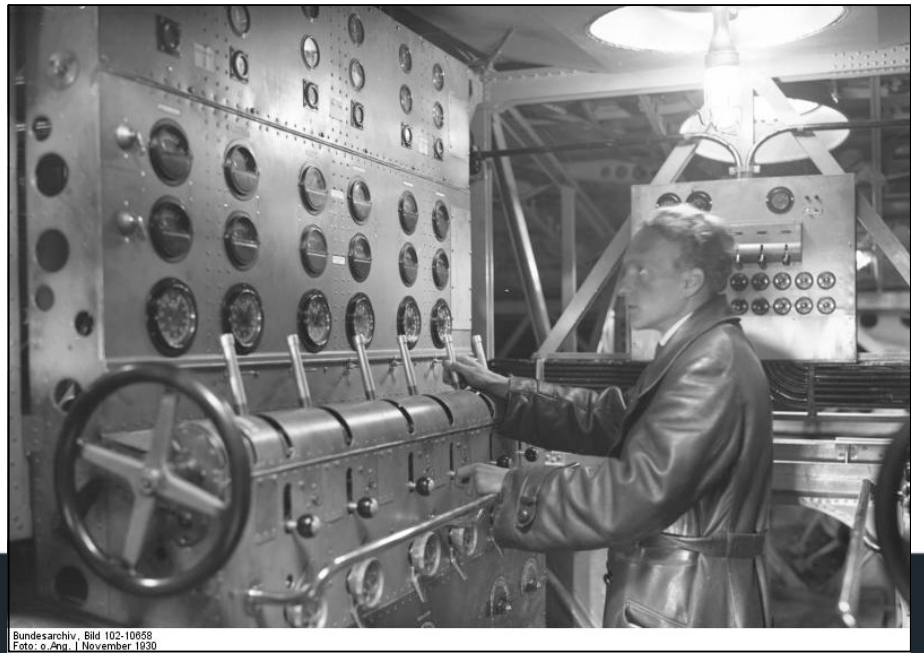

COOLING
COOLING
enova



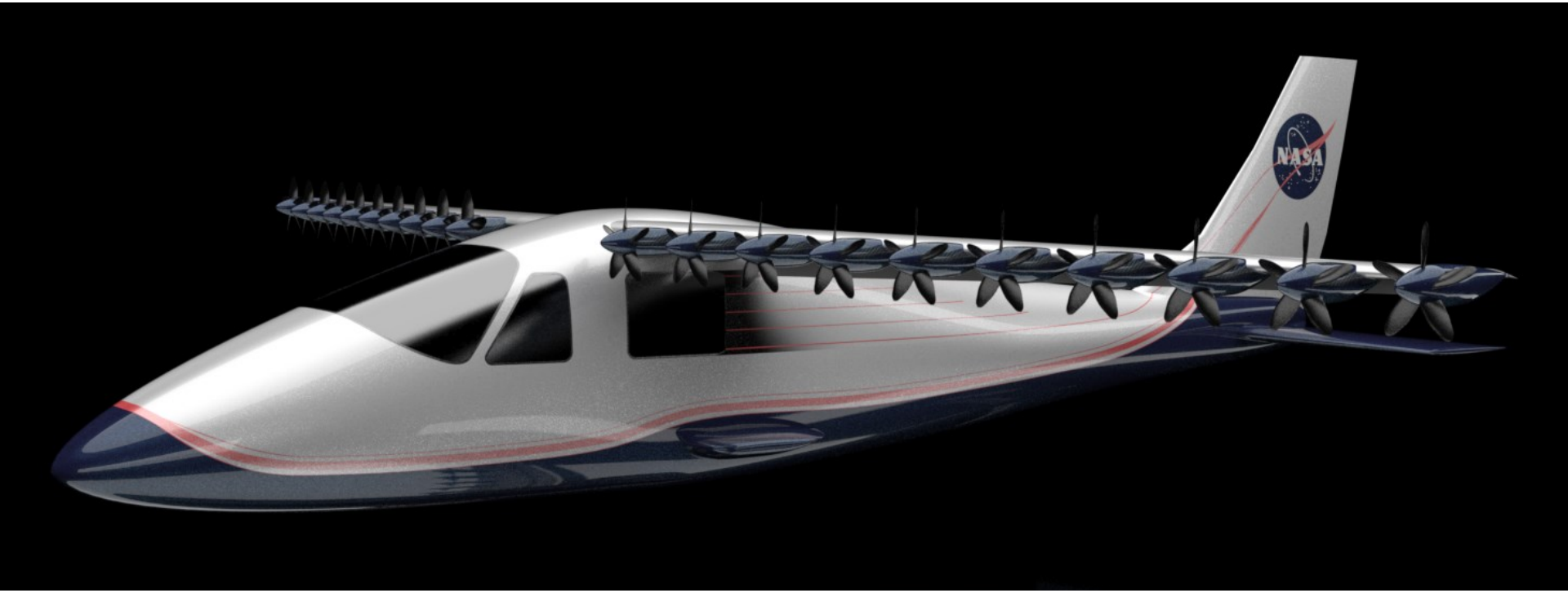
Small general aviation CS-23 four seat aeroplane with 1315 kg MTOM

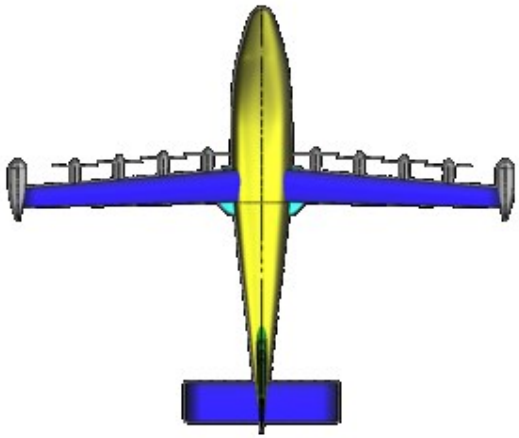
TF-X
TERRAFUGIA
DrivenToFly.com

Bundesarchiv, Bild 102-08049
Foto: o.Ang. | Juli 1929



Bundesarchiv, Bild 102-10658
Foto: o.Ang. | November 1930

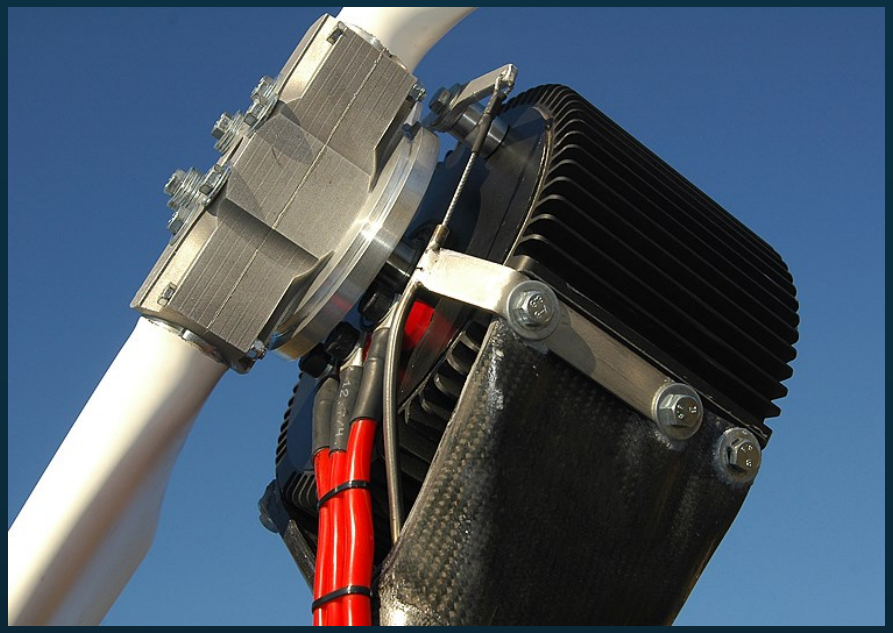

NASA

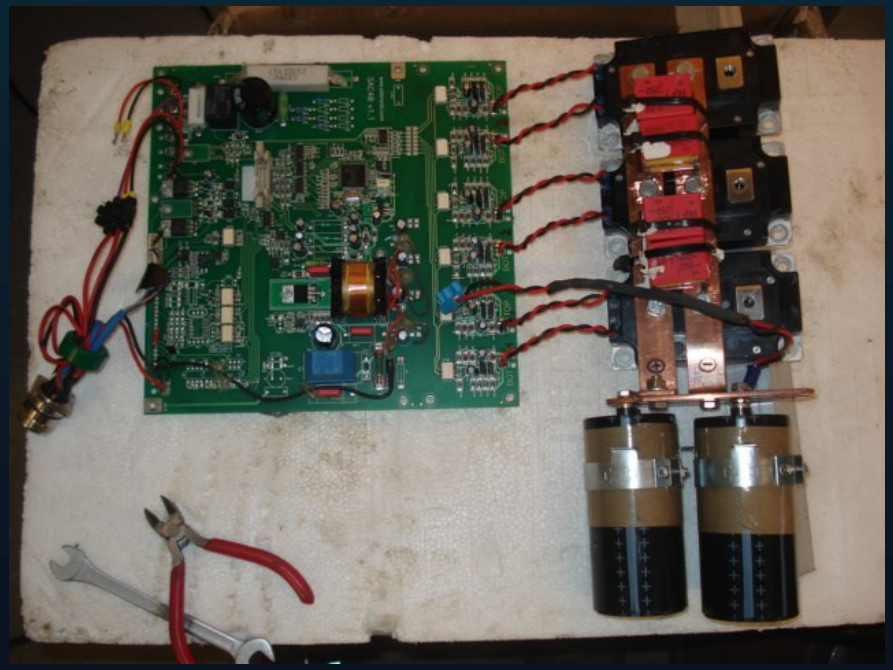


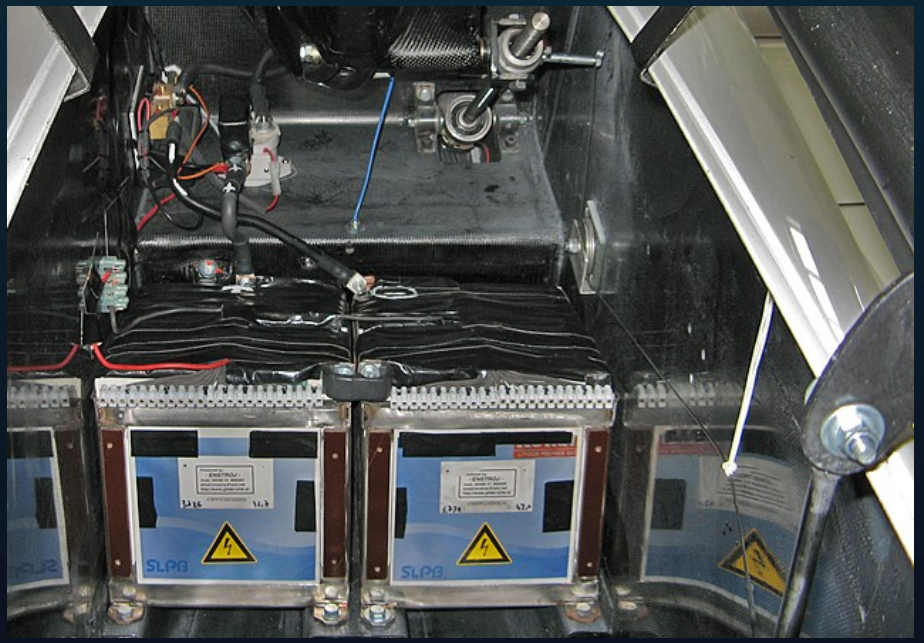
Electric Propulsion Penalties
Energy Storage Weight (50x worse than aviation fuel) Energy Storage Cost (Tesla 65 kWh battery is ~$25,000) Certification Uncertainties and Absence of Standards
Electric Propulsion Benefits
~2x efficiency of turbine engines, 3-4x efficiency of piston engines High efficiency across >50% rpm range 6x the motor power to weight of piston engines None air breathing - No power lapse with altitude or on hot days Extremely Quiet Zero vehicle emissions 10x lower energy costs
Electric Propulsion Integration Benefits
Scale independence of efficiency and power to weight Power to weight and efficiency don't degrade at smaller sizes Extremely compact High reliability – few moving parts

First ever 2-seat electric airplane

2007: Taurus Electro	
30 kW	LiPo
800 m	90 km/h, 20 min







SLPB
SLPB

DANGER
HIGH VOLTAGE

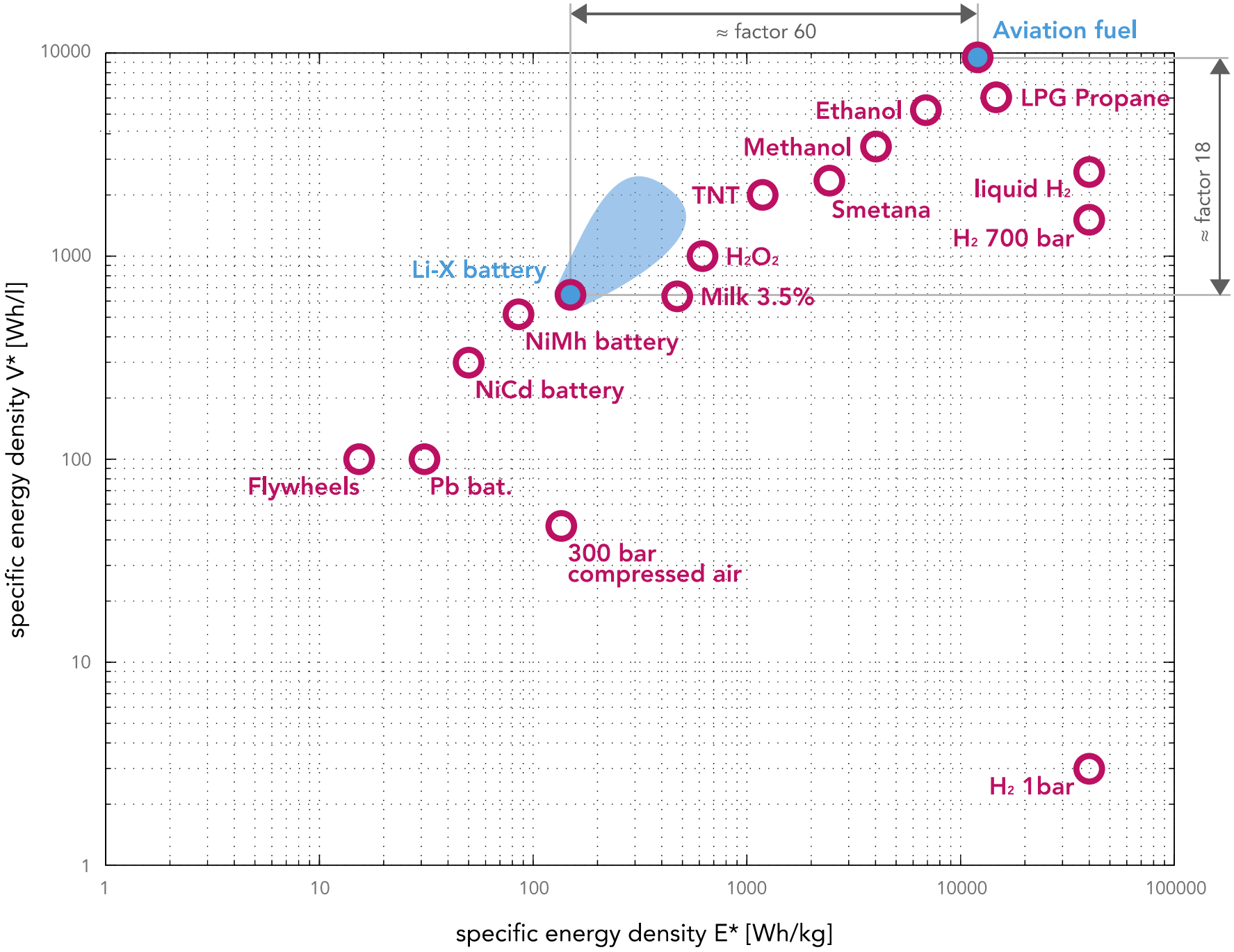
S5-PII04
ELECTRO
TAURUS
PIPISTREL

Taurus Electro	Taurus Electro G2
30 kW	40 kW
346 kg	332 kg
take-off: 250 m	take-off: 170 m
2.0 m/s	2.8 m/s
800 m	2000 m

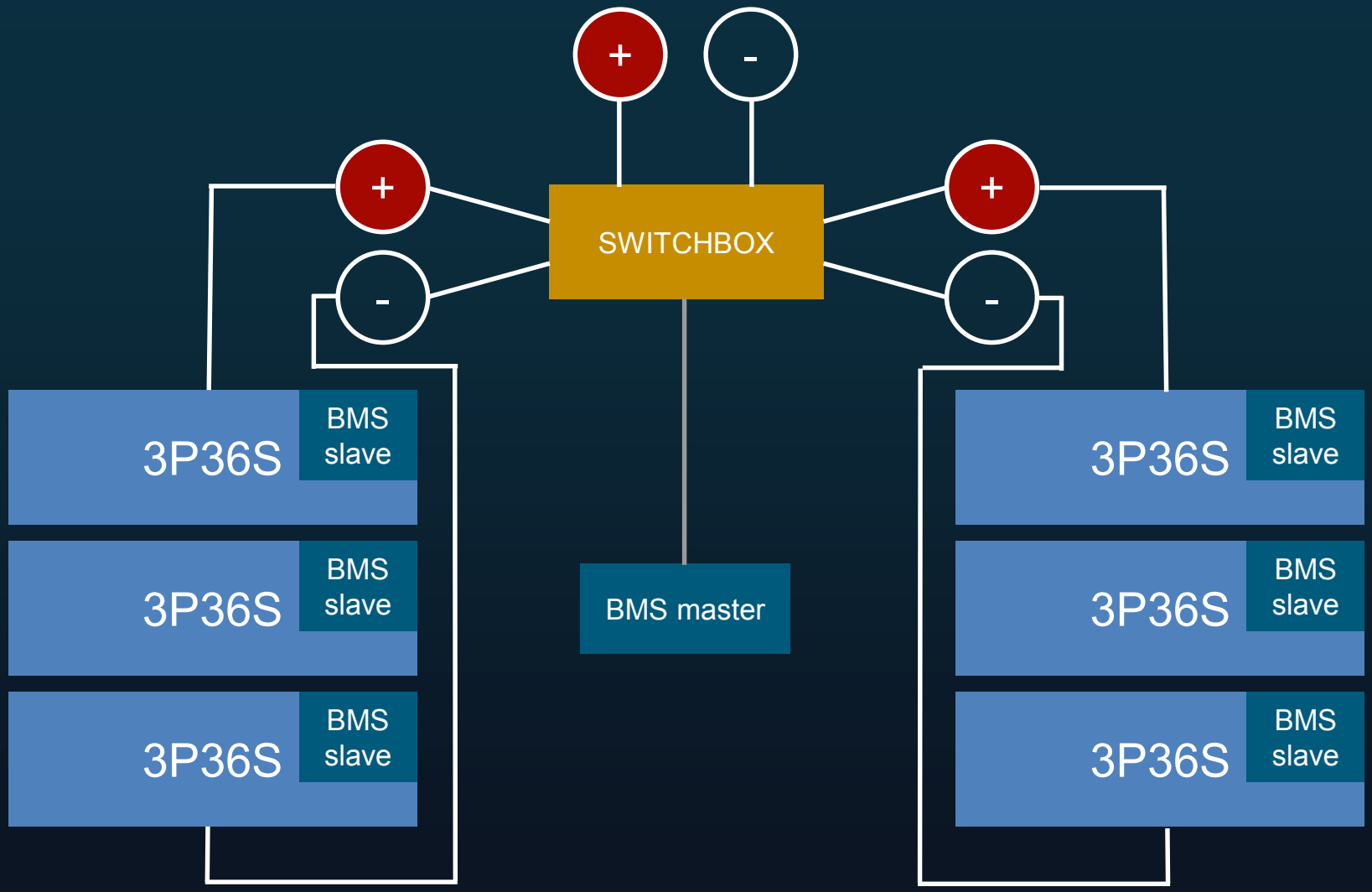
H2FLY
ulm

2000 hour lifetime	
ALPHATrainer	**ALPHAElectro**
10.2 l/hr	14 kWh / hr
29,580 EUR	8,120 EUR
Engine overhaul	Battery refurbisment
10,200 EUR	11,500 EUR
TOTAL	
39,780 EUR	19,620 EUR

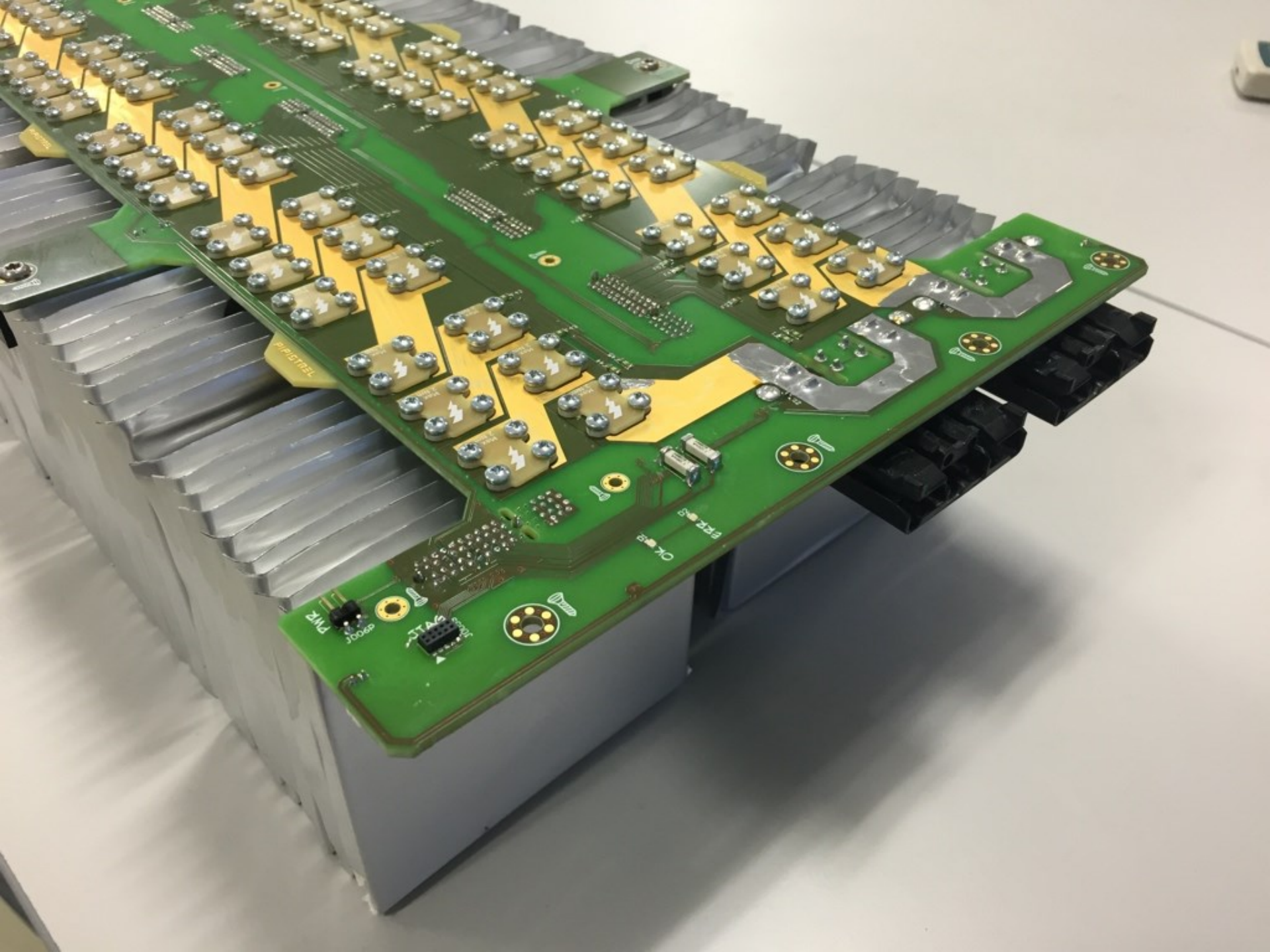
2000 hour lifetime	
“Average Trainer”	**Electric**Trainer
17 l/hr (2.15 EUR/l)	14 kWh / hr
73,100 EUR	8,120 EUR
Engine overhaul	Battery refurbishment
16,500 EUR	11,500 EUR
TOTAL	
89,600 EUR	19,620 EUR


≈ factor 60
Aviation fuel
LPG Propane
Ethanol
Methanol
Smetana
TNT
liquid H₂
H₂ 700 bar
≈ factor 18
H₂O₂
Li-X battery
Milk 3.5%
NiMh battery
NiCd battery
Flywheels
Pb bat.
300 bar
compressed air
H₂ 1bar
10000
1000
100
10
1
1
10
100
1000
10000
100000
specific energy density V* [Wh/l]
specific energy density E* [Wh/kg]

SIEMENS

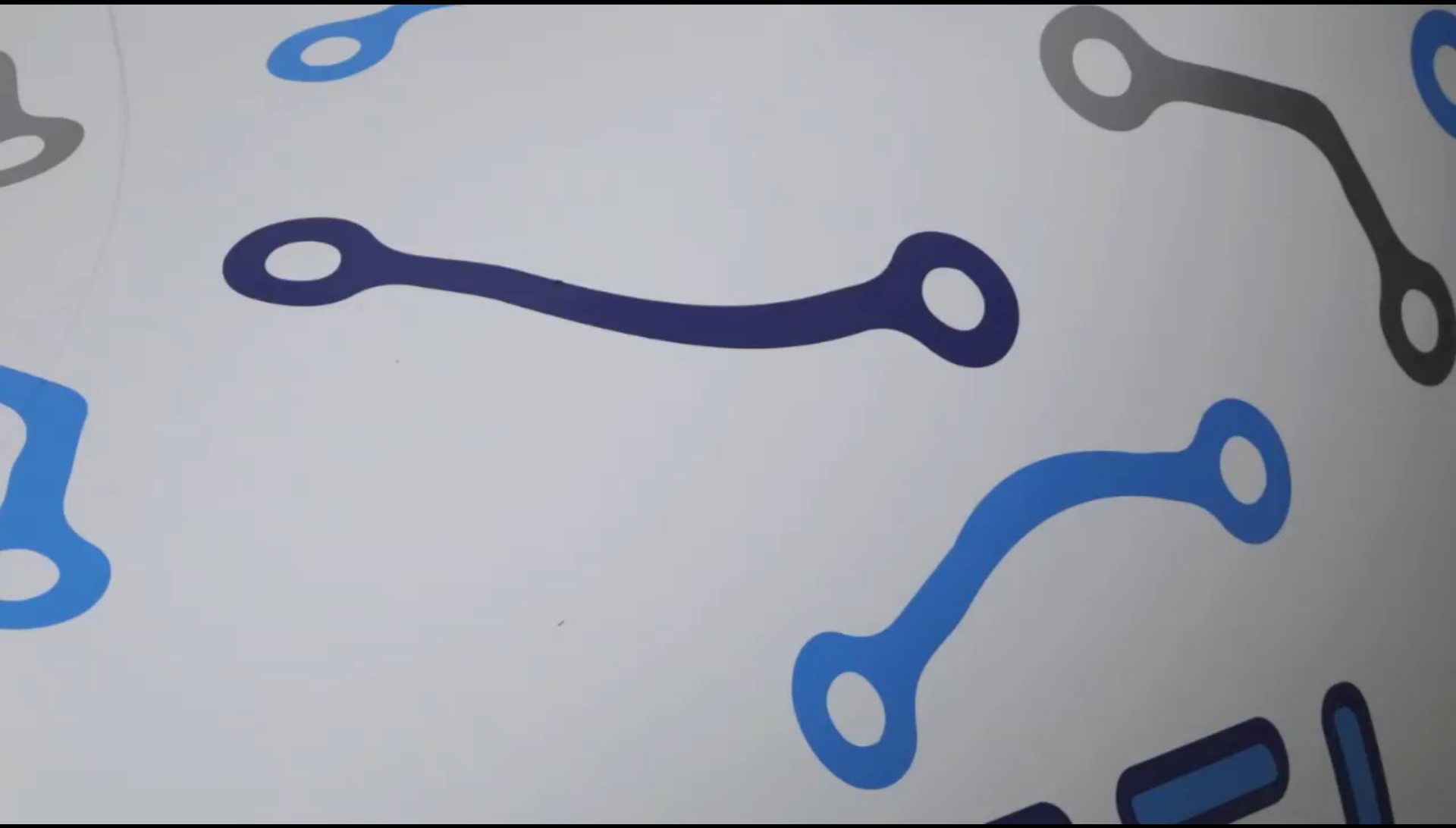

+
-
+
-
SWITCHBOX
+
-
3P36S
BMS slave
3P36S
BMS slave
3P36S
BMS slave
BMS master
3P36S
BMS slave
3P36S
BMS slave
3P36S
BMS slave

4

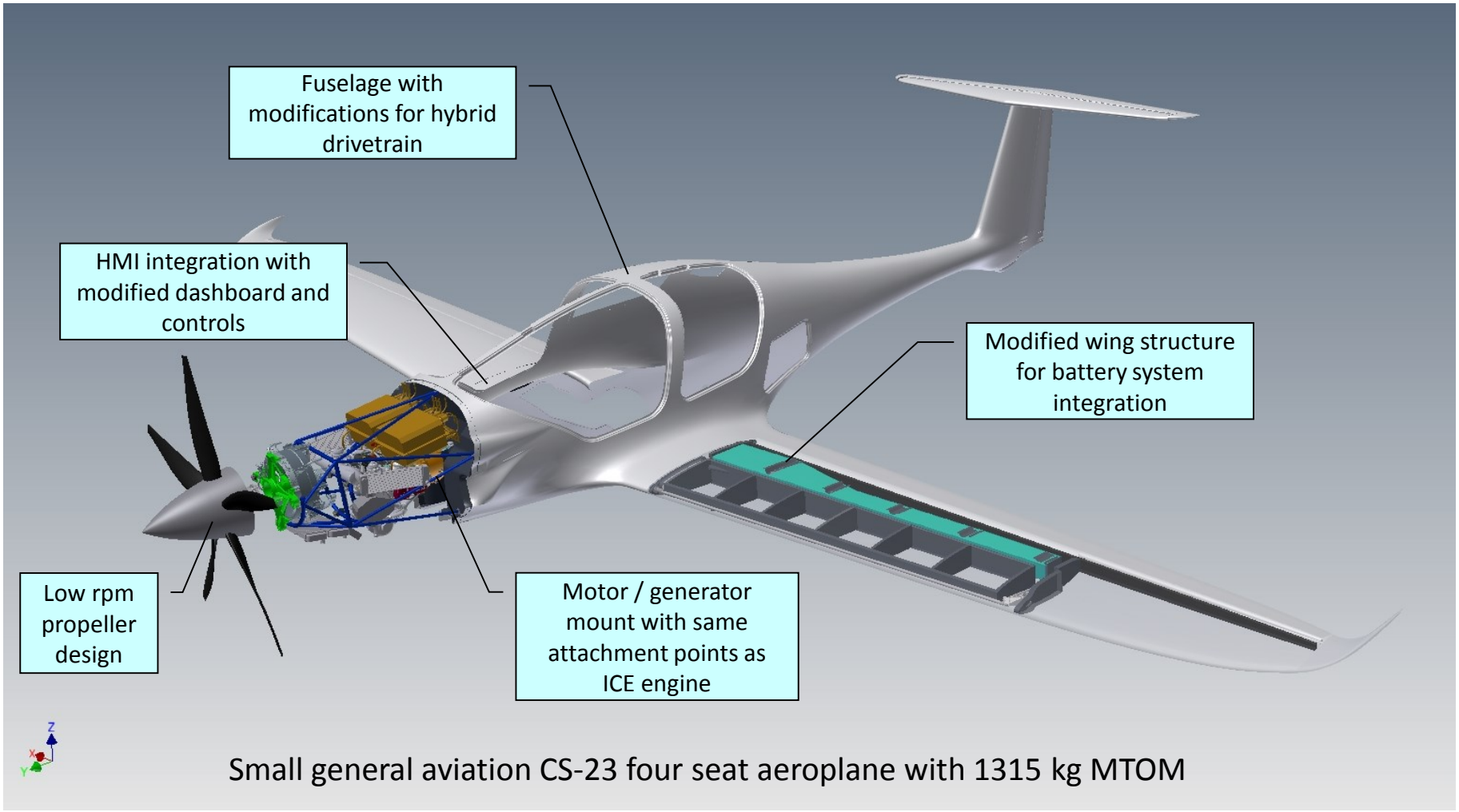

PWR
JTAG
ERR
OK

86Wh

SIEMENS



Hypstair Powertrain Components Installation (Siemens & Pipistrel)



Small general aviation CS-23 four seat aeroplane with 1315 kg MTOM

Sources for Certification Basis; Electric Flight

- EASA SC for electric powered
- CS-22 motorgliders
- EASA CS-LSA Issue 1 (referring to ASTM F2840)

- DO-311(A) Minimum Operational Performance Standards for Rechargeable Lithium Battery Systems

- SAE J2464 Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System Safety and Battery Abuse Testing

- LBA SC Brennstoffzellen 3. Ausgabe April 2012

- ASTM F44.40 WG Integration
- ASTM F39.05 WG EPU&HEPU

- CS-E
- AC23.1309 System Safety Analysis and Assessment for Part 23 Airplanes
- -AC23.1311 Installation of Electronic Display in Part 23 Airplanes
- AC23.1521 – Type Certification of Automobile Gasoline in Part 23 Airplanes with Reciprocating Engines
- AC23-2 Flammability Tests

- ARP-4754 / ED-79 System Development Process
- ARP-4761 Safety Assessment
- DO-160 Environmental conditions and test procedures
- DO-254/ED-80 Electronic HW Development Process
- DO-264
- DO-200A / DO-201A Airborne Databases
- DO-178B / ED-12 Software considerations in Airborne Systems and Equipment Certification

Safety related to energy storage

Enclosures, care, fire hazards of batteries vs. fuel.

Systems integration & Intercommunication.

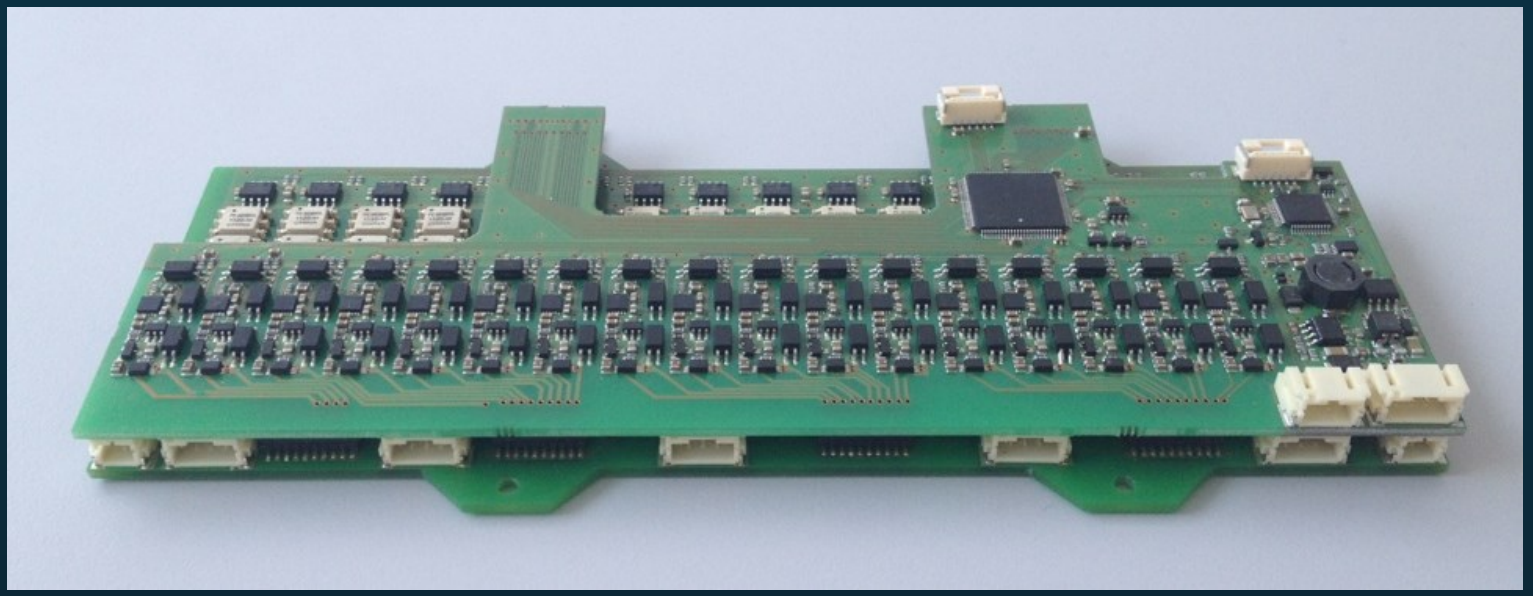
Making everything sing together, databus - how and why.

Software Certification and HMI.

Battling the data jungle. Knowledge proliferation.

BMS.

Pipistrel's proprietary BMS features, including cell failure forecasting.



Active voltage balancing & BMS integration in Battery System

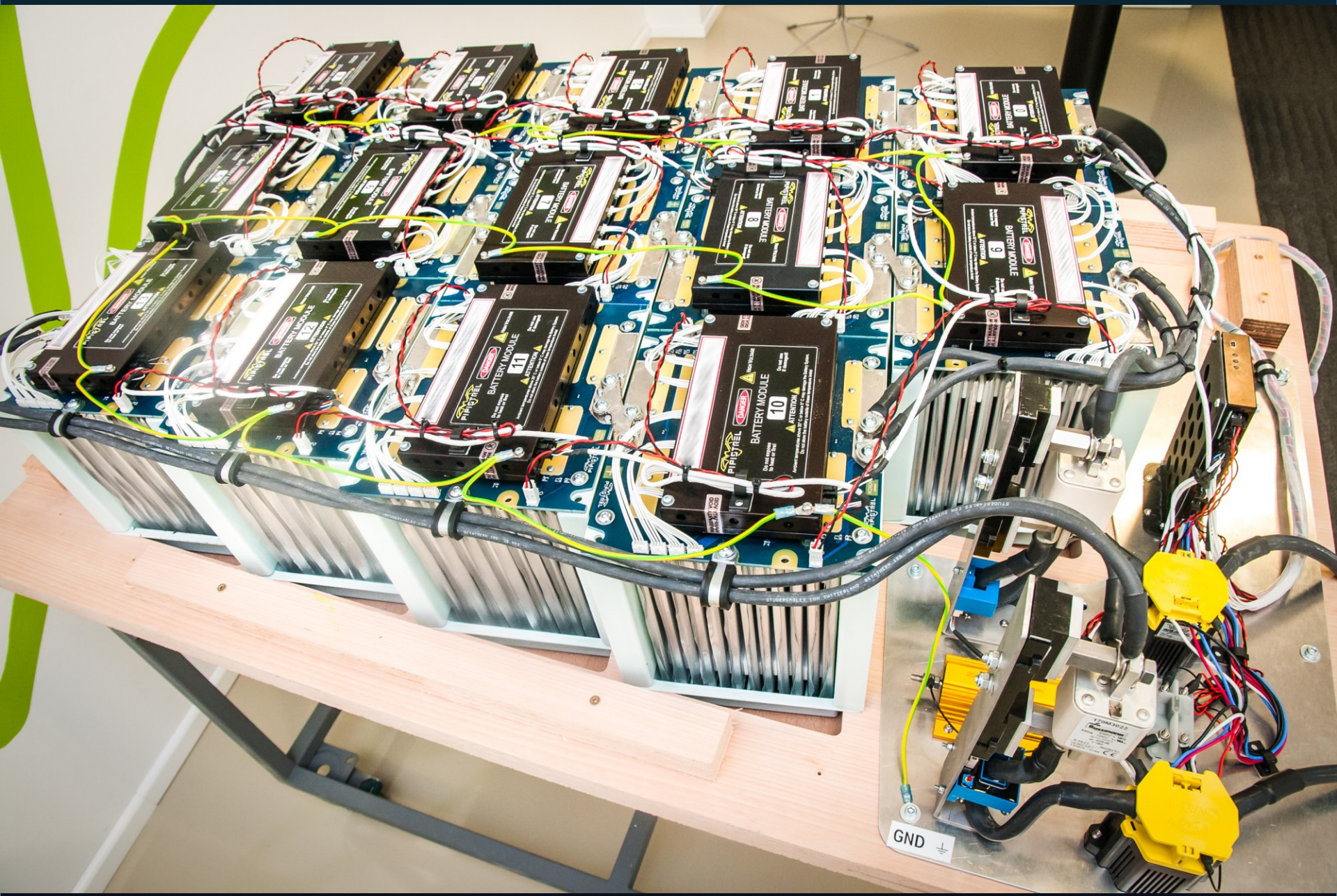
Active cell voltage balancing much faster, more efficient, safer than passive. Effectively increases battery capacity. Can utilize broad voltage spectrum 3.0 - 4.2 V safely.

Keeping cell voltage balanced also while charging

Reduces time from plug-in to flight. Tolerance for delta-voltage between cells is 0.03 V.

Individual cell failure model-based prediction

Monitoring behavior of all cells, all the time, serves as input to the cell failure predictiion algorithm. Know when your cell will fail in advance.


BATTERY MODULE
11
BATTERY MODULE
10
BATTERY MODULE
9
GND

What is the future?

How do we get there?