

eAircraft: Hybrid-elektrische Antriebe für Luftfahrzeuge

Dr. Frank Anton, Siemens AG, Corporate Technology
14. Tag der Deutschen Luft- und Raumfahrtregionen, Potsdam, 10. September 2019

We develop hybrid electric propulsion systems for aircraft



Hybrid-electric propulsion is a **scalable technology**
eVTOL potentially large number → economy of scale

Enabler to reduce total cost of ownership and environmental impact:

Hybrid electric propulsion



Useful range

Separation of power generation
and thrust generation



Decreased fuel flow & emission



Silent propulsion

Distributed propulsion



Increased aerodynamic efficiency

Vectorized thrust



eSTOL, eVTOL

The eAircraft portfolio has been designed to meet aerospace requirements and is now on the way to industrialization & certification

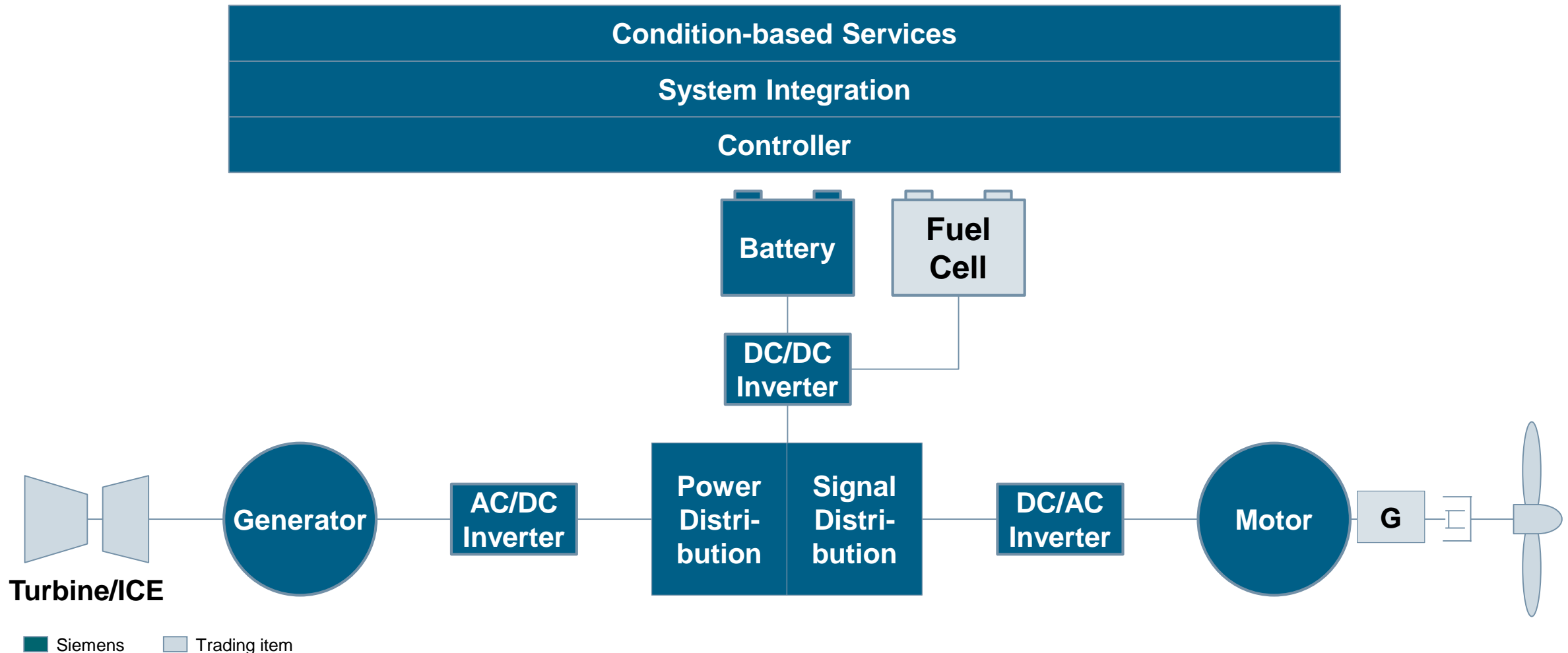


The eAircraft portfolio has been shaped by close collaboration with partners such as Airbus.

In the lower power classes, the systems have already been tested in flight and are being installed in first commercial applications.

In the high power classes, a 2 MW lab demonstrator is currently awaiting test results and a design of a 10 MW generator based on superconducting technology exists as digital twin.

Our core portfolio – electric propulsion units (EPU) for applications with high power/weight requirements



With our partners we have continually extended the boundaries of eFlight.
The year 2016 marks the beginning of real electric flight applications.

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2011

2013



Maiden flights of the DA36 e-Star, world's first hybrid-electric aircraft, and improved eStar 2, with Airbus and Diamond Aircraft

2014



Maiden flight of the fully electric WattsUp trainer with Pipistrel

2016



Magnus e-Fusion, sub-100kW class

1/4 Megawatt

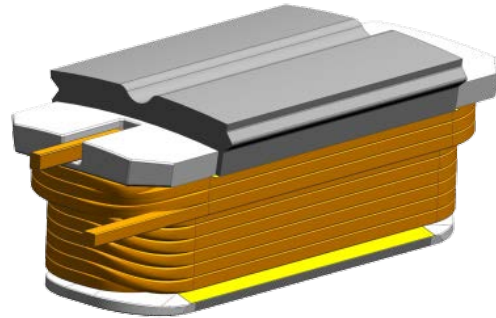
2016



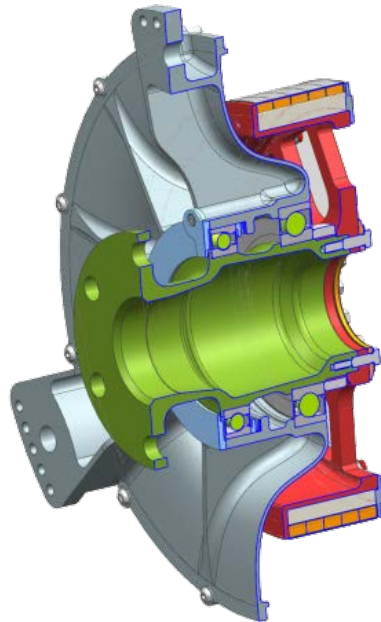
Extra 330LE

Wholistic toolchain for system development

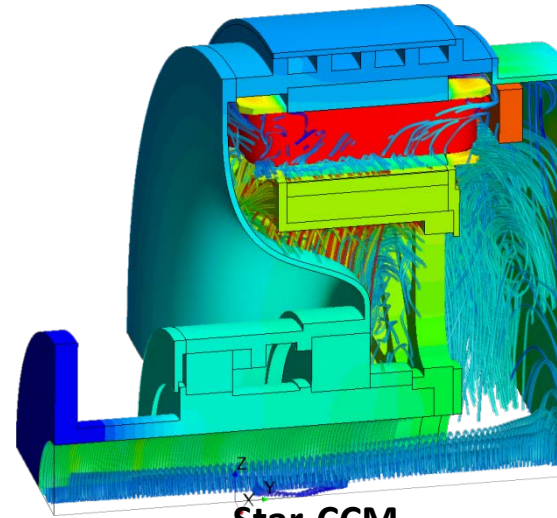
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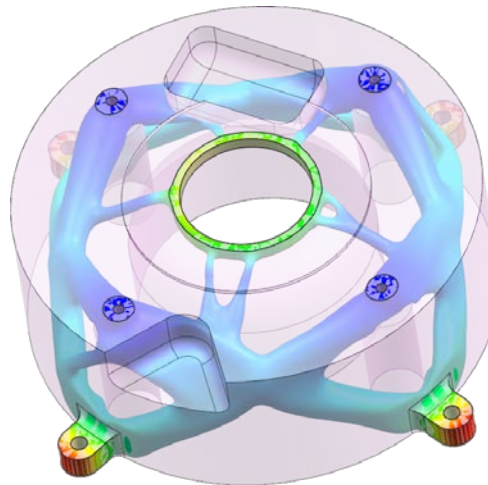
NX 12.0
Part Modeling



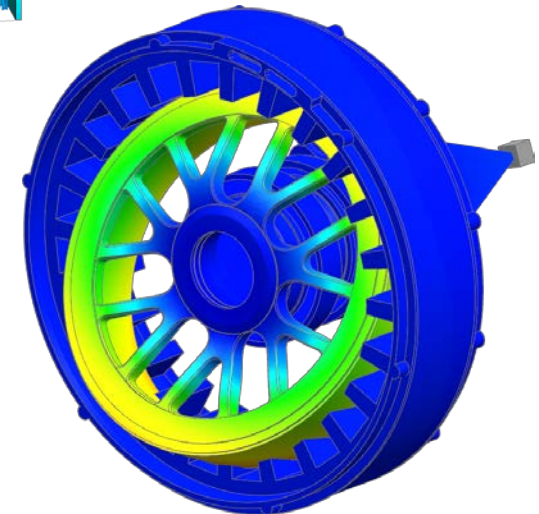
NX 12.0
Assembly Modeling



Star-CCM
Fluid Dynamics

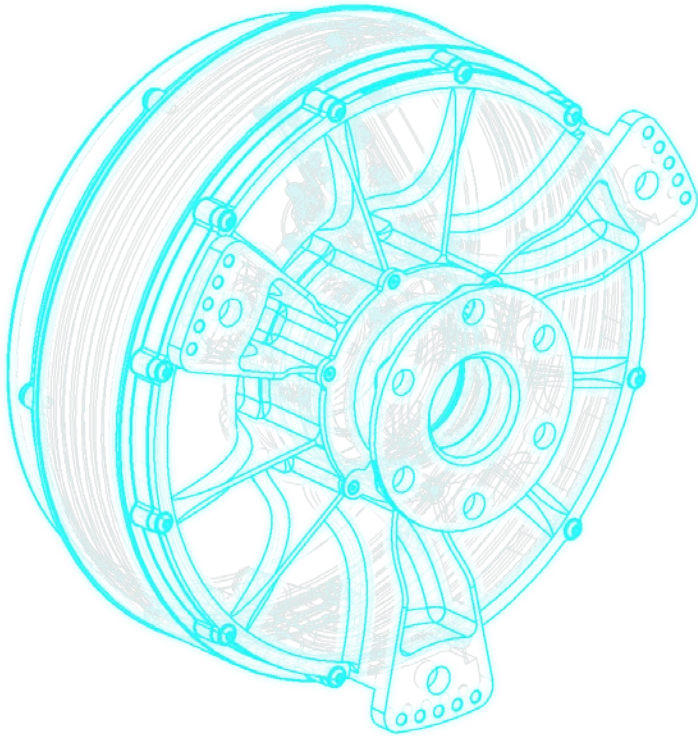


NX 12.0
Topology Optimization
September 10th, 2019



NX Nastran
FEM Analysis

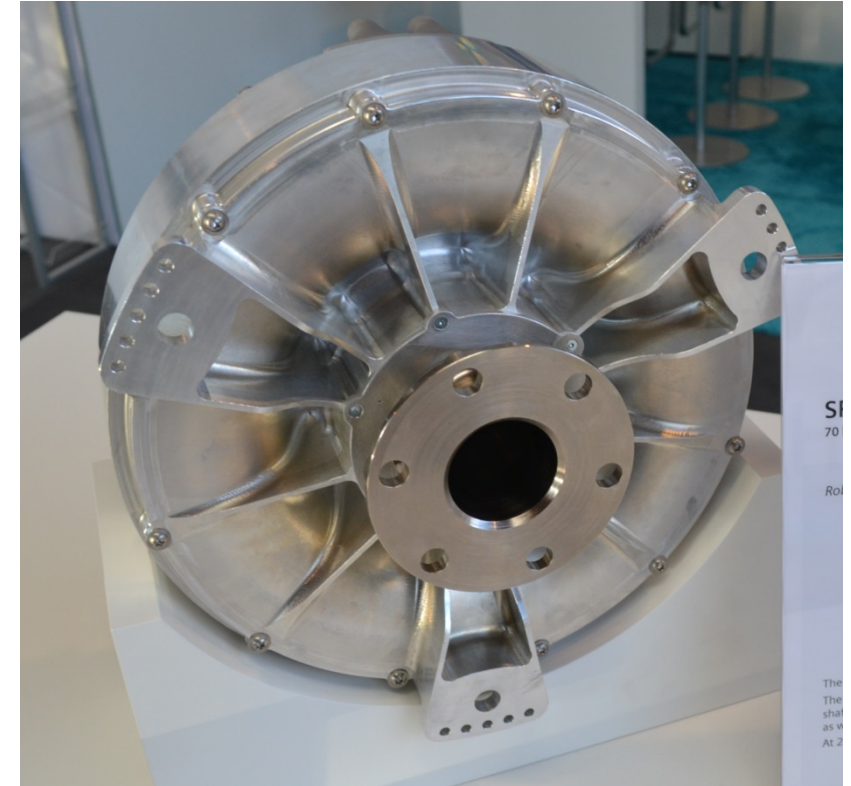
Concept to real-world object



Virtual concept



Virtual product



Real product

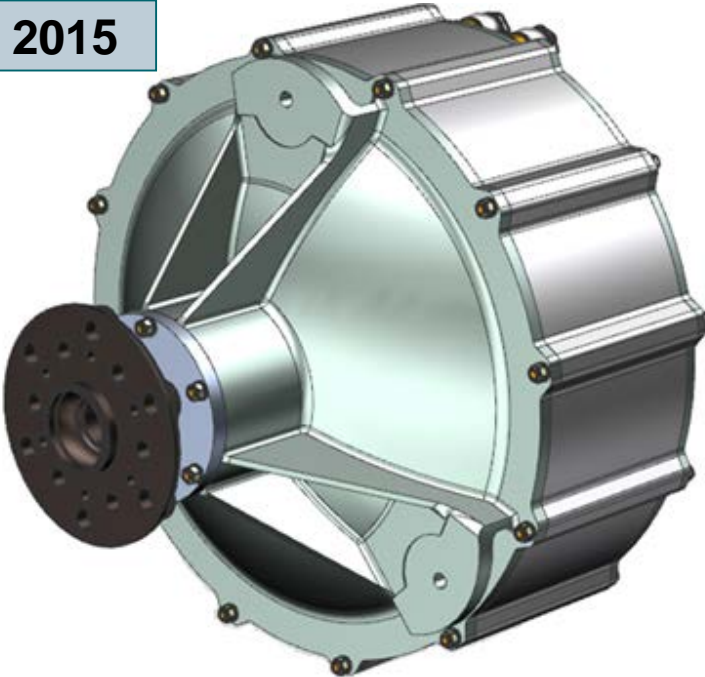
**eFusion - more than 300 emission free flight hours.
Diverse technologies on several test platforms in flight testing.**

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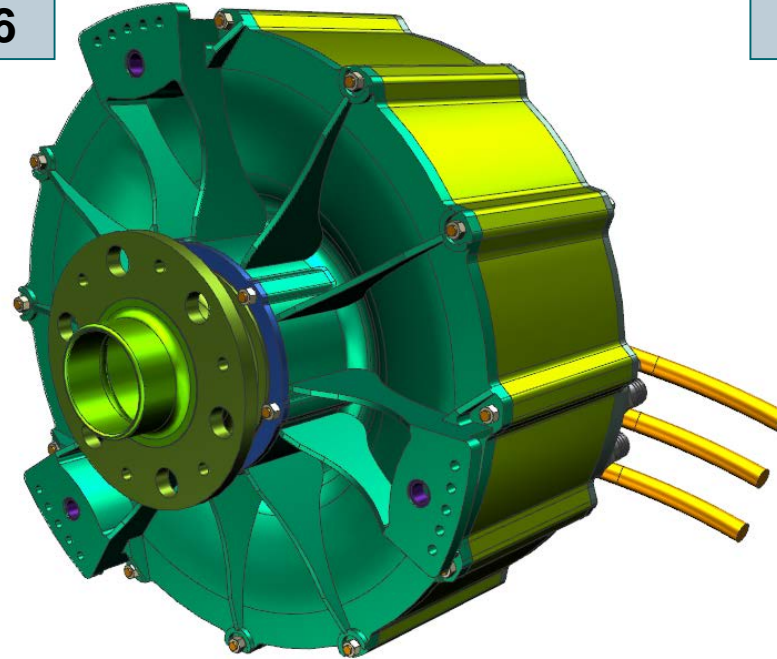
Progression of SP70D Motor

SP45D



SP55D

2016



SP70D

2018



	SP45D	SP55D	SP70D
Continuous Power	45	55	70
Peak Power	60	72	92
Rotational Speed	2500	3000	2600
Weight	28 kg	27 kg	26 kg



A Magnus eFusion with Siemens Electric Propulsion System crashed on May 31st, 2018 near Pécs, Hungary.

The pilot and a technical observer were killed in the incident.

The electric propulsion technology was operating faultlessly.

- **The technical investigation has not revealed any evidence of malfunction of the structure or any system of the aircraft.**
- **According to data available, there is no sign of smoke or fire during the flight. The fire started after the aircraft crashed to ground.**
- **During the flight the displays related to the electric propulsion system showed normal operations.**

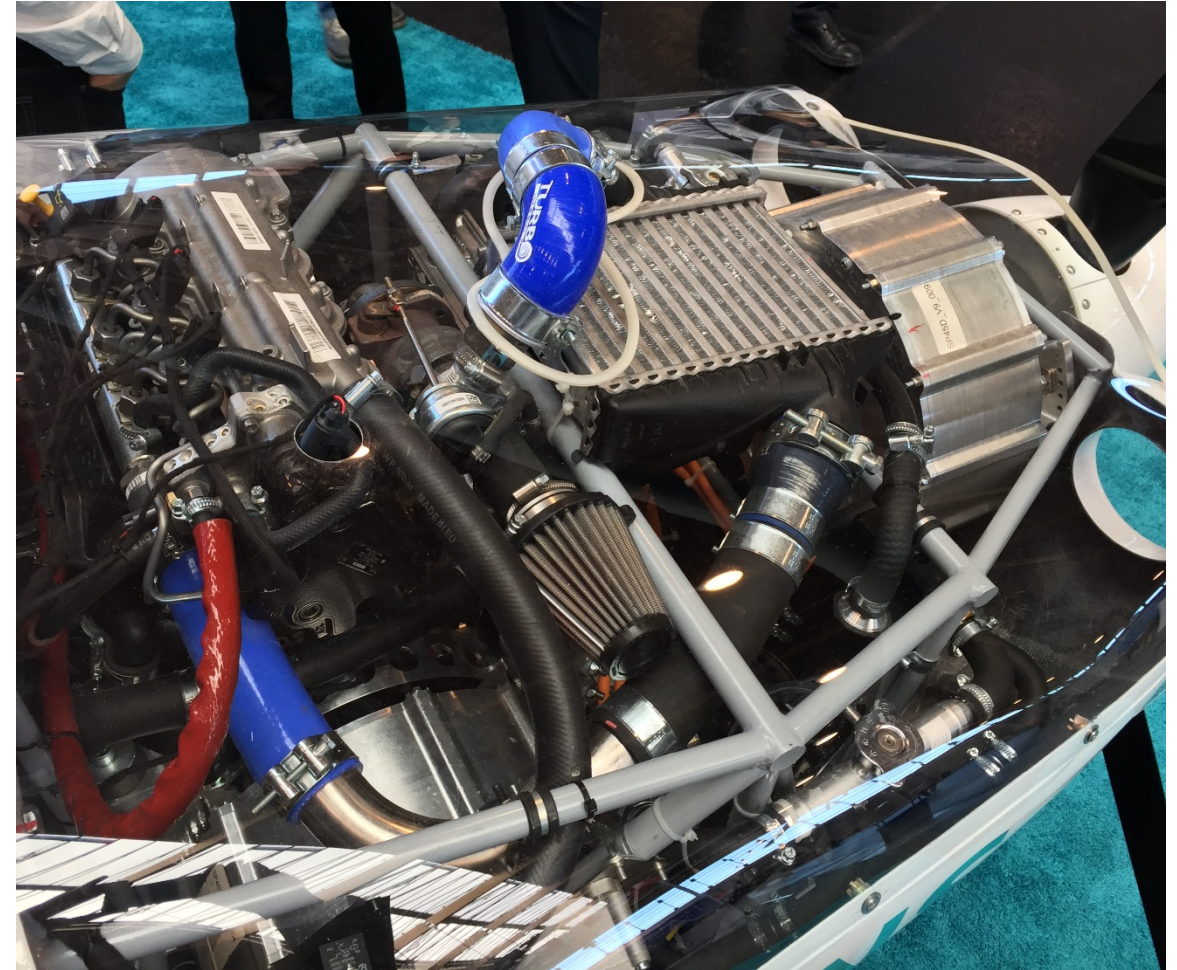
Our deepest thoughts are with the casualties' families.

Magnus eFusion Hybrid-Electric configuration

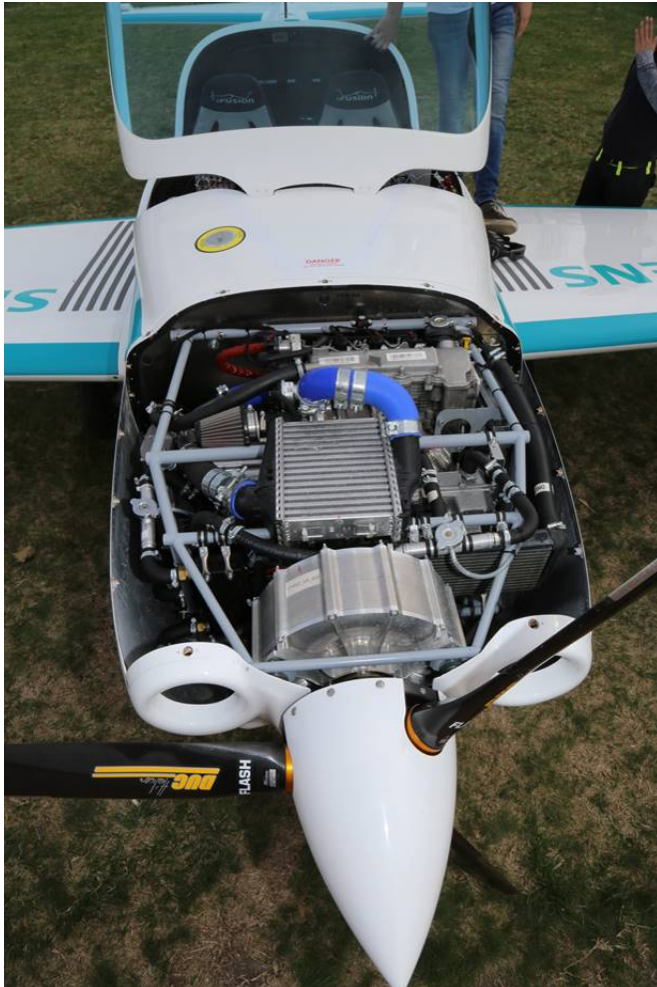
First Flight April 11th, 2018

- aerokurier award at Aero 2019

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Maiden flight – hybrid-electric eFusion April 2018



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Sun Flyer 2 Completes First Flight with Siemens Electric Propulsion System (12 FEB 2019)



- Planned use of SP70D in FAA certified aircraft
- Business case for 2 and 4 seat electric training aircrafts



Flight Design F2e completes first flight with Siemens Electric Propulsion System (29 MAY 2019)

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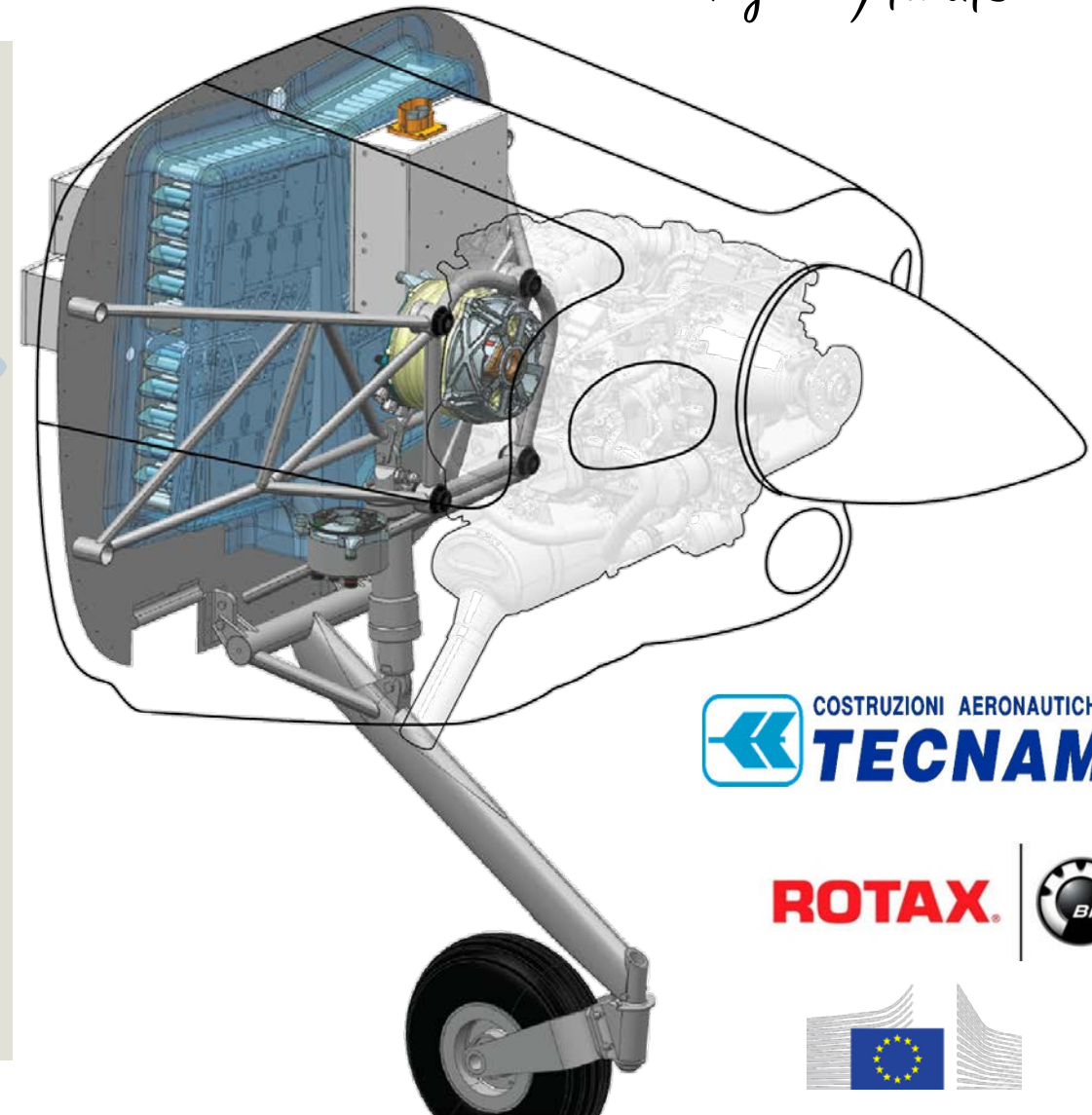
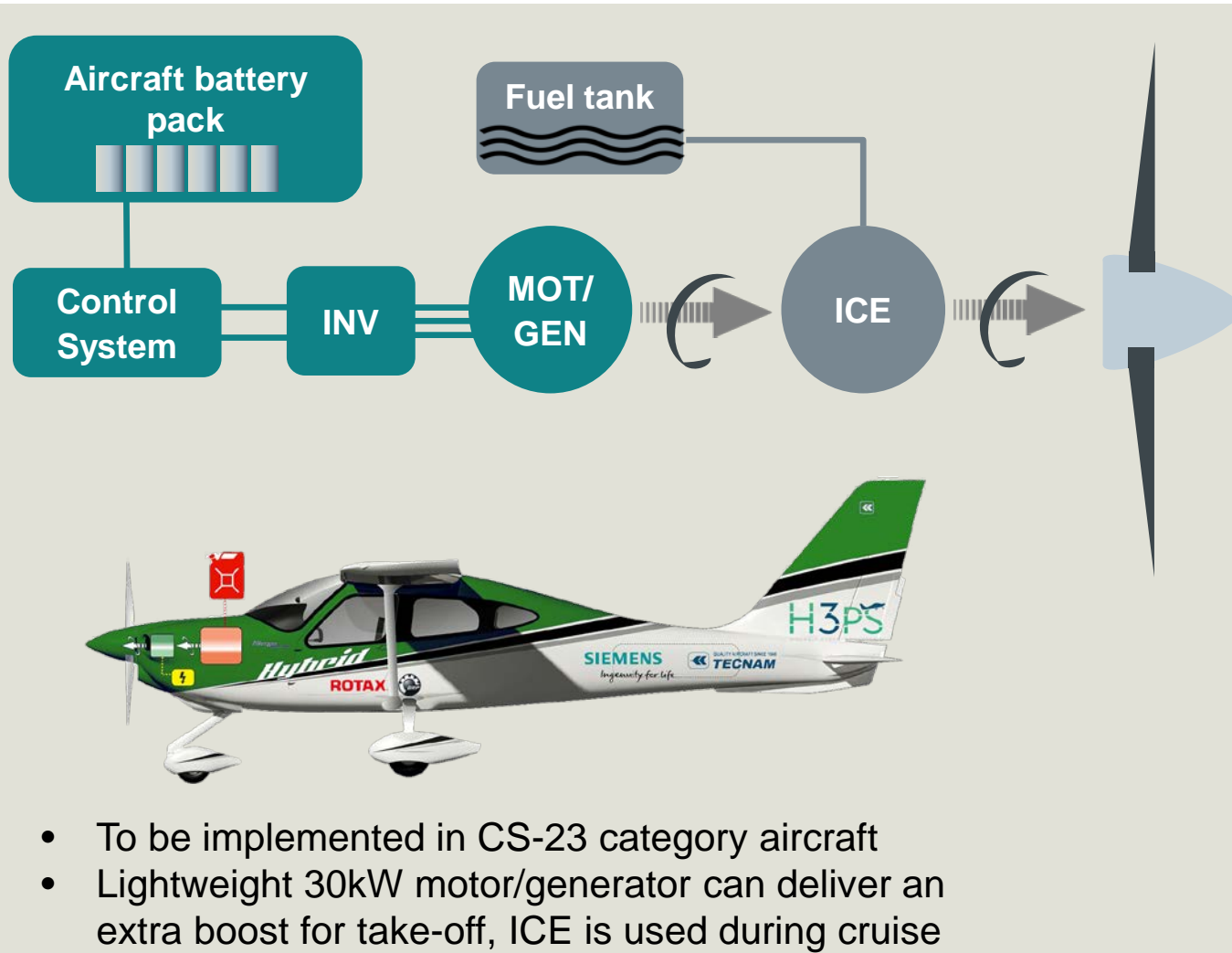
- First Flight Design prototype for low noise emission trainers to be developed
- Modular concept for easy installation of new components like energy storage



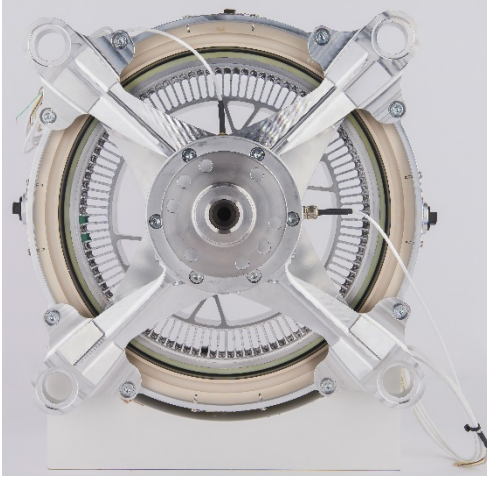
Parallel hybrid system

H3PS - High Power High Scalability Aircraft Hybrid Powertrain

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SP260D-A is the next development step towards a Safe and redundant design with excellent performance-to-weight ratio



SP260D-0

Direct Drive Permanent Magnet
MTOP 260 kW @ 2500 RPM
Torque 977 Nm
UDC 580 V
Oil cooled @ 90 °C
Efficiency 95%

50 kg
5.2 kW/kg

Weight
Power Density

44kg
5.9 kW/kg

SP260D-A



to be certified!

Developed for maximal Power Density
Redundant 3 Phase Windings

Implemented in Extra 330LE

Achievements:

- Electric Aircraft Speed Records
- Electric Aircraft Climbing Records
- First All-Electric Glider Towing

Extra 330LE

FAI Official World Record Flights at Dinslaken Schwarze Heide Airfield



**November 25th, 2016: FAI time to climb world record
eAircraft 500...1000 kg
3000 m in 4 min 22 sec
Pilot: Walter Extra**



**March 23rd, 2017: FAI speed world record
337.5 km/h (eAircraft <1000 kg)
Pilot: Walter Extra
342.8 km/h (eAircraft >1000 kg)
Pilot: Walter Kampsmann**

World's strongest electric aircraft Extra 330LE with SP260D propulsion system towed FFVV Swift glider and showed aerobatics at Paris Air Show 2017

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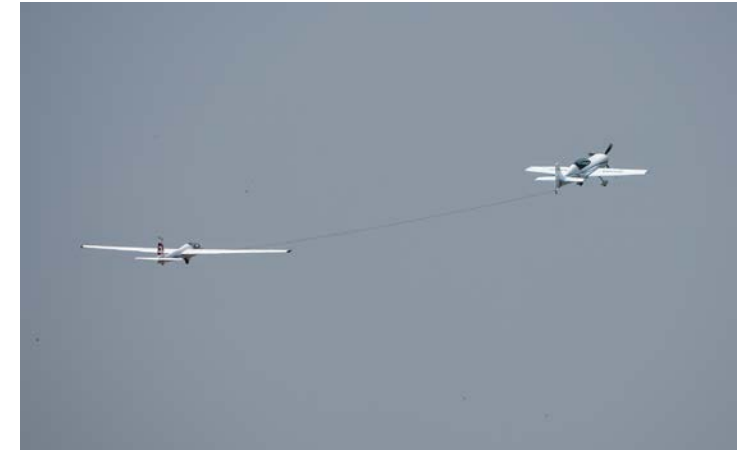
Pilots:
Nicolas Honnons, Swift
Ulrich Schell, Extra 330LE

World's strongest electric aircraft Extra 330LE with SP260D propulsion system towed FFVV Swift glider and showed aerobatics at Paris Air Show 2017



"Demonstrators are key to new technology,... the only way we can learn ... is by testing vehicles in flight."

said Mark Cousin, Airbus, at Paris Le Bourget 2017





- 4-seat hybrid-electric cruise aircraft by Swiss company Smartflyer
- Powered by one SP260D and a Siemens inverter, combined with Rotax engine as range extender
- First flight envisaged 2020/2021

The Swiss development company smartflyer AG shows what the hybrid-electric future of General Aviation looks like. The Siemens SP260D does not drive the propeller at the front of the aircraft, but on the fin. A configuration that is only possible due to the high power density of electric motors.

The increase in efficiency of the aircraft results from the free flow of the wake flow (push) of the large propeller. The high torque of the Siemens SP260D electric motor permits a low speed of 1800 RPM for the take-off phase, thereby reducing noise.

The smartflyer is a touring aircraft with a range of 750 km, which cannot be achieved with today's battery technology purely electrically. A range extender produces the necessary energy during the flight. The Rotax 914 aircraft engine drives a generator which charges the batteries in horizontal flight.

The serial hybrid drive is complex, but offers more safety than conventional drives. The SP260D with its two independent winding circuits and inverters integrates two motors on one propeller. The energy for the horizontal flight can be supplied directly from one of the four battery boxes or from the Range Extender.

Further reading:

https://www.smartflyer.ch/wp-content/uploads/2018/02/artikel_rundschau.pdf

Eviation Alice



- 9-seat all-electric commuter aircraft by Israeli company Eviation
- Powered by 3 Siemens SP260D motors with associated inverters
- First flight planned for summer 2019

Inspired by the new design possibilities that emerged by replacing turbine engines with all electric motors, Eviation and its team have reimagined what sleek, stylish and cost effective air mobility can be.

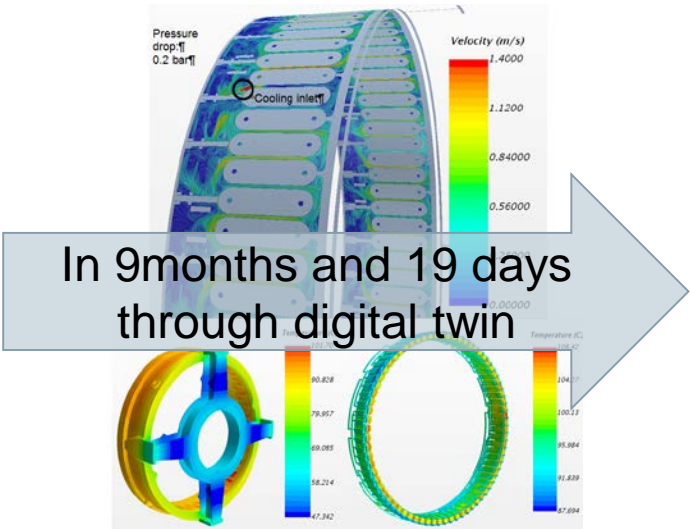
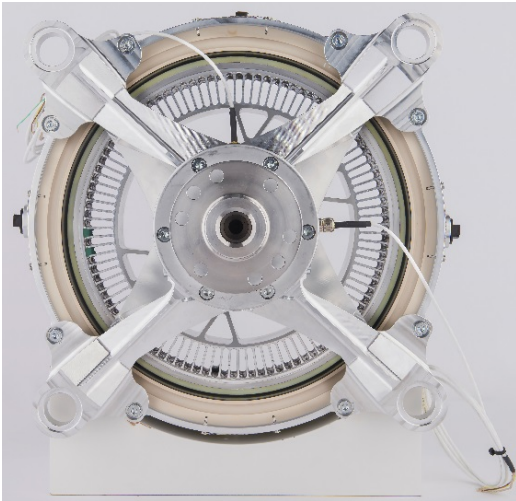
The fully operational all-electric regional commuter Alice will be capable of flying with nine passengers at 220 knots to a range of 650 miles on a single charge. The plane features innovations in thermal management and autonomous landing, as well as distributed electric propulsion, industry-leading battery technology and cutting-edge composite body frames.

The Alice will be displayed at the upcoming Paris Air Show and will conduct its first flight later this year.

Official press release:

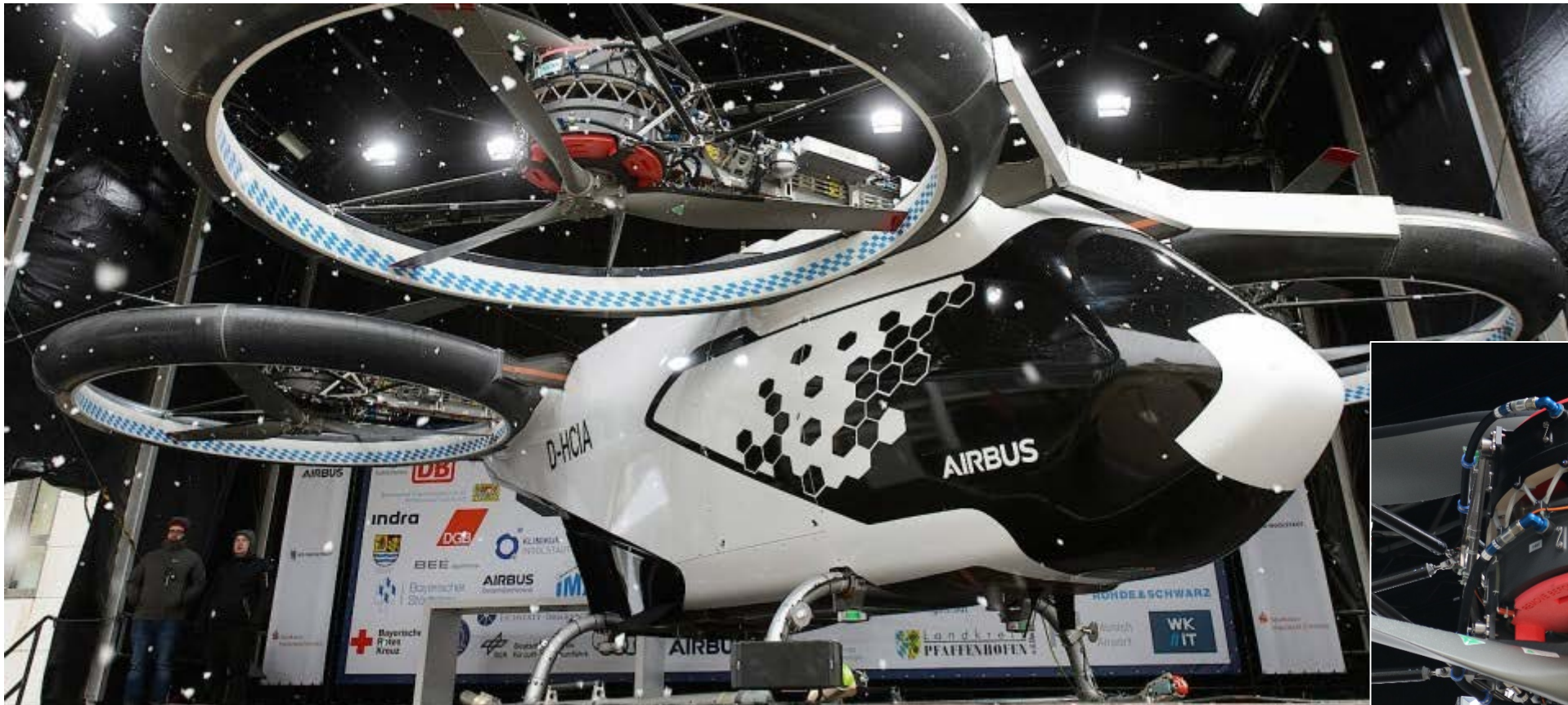
<https://www.prnewswire.com/news-releases/electric-airplane-manufacturer-eviation-partners-with-siemens-in-joint-development-of-electric-propulsion-systems-for-eviations-all-electric-alice-300798530.html>

CityAirbus uses Siemens SP200D EPU Direct Drive: Based on SP260 technology - 50% increase in Torque to Mass Ratio

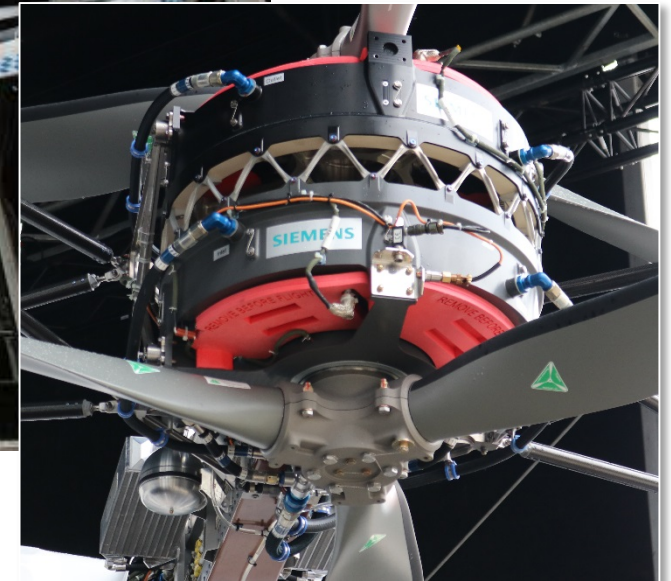


	SP260D2015		SP200D2017
Continuous Power	260 kW		204 kW
Rotational Speed	2500 RPM non-geared		1300 RPM non-geared
Continuous Torque	1000 Nm		1500 Nm
Mass	50 kg		49 kg
Torque to Mass Ratio	20 Nm/kg	<div> <div></div> <div>Increase by 50%</div> </div>	30.6 Nm/kg
Inverter Type	Si		SiC

Airbus is communicating the CityAirbus project



Presentation of City Airbus demonstrator in Ingolstadt, 11.03.2019



Study of DLR, MTU, RUAG and Siemens: Dornier Do228hep demonstrator could be flying testbed for hybrid-electric propulsion in commuter class



Substitution of one turboprop unit by an electric propulsion unit and an optimized propeller

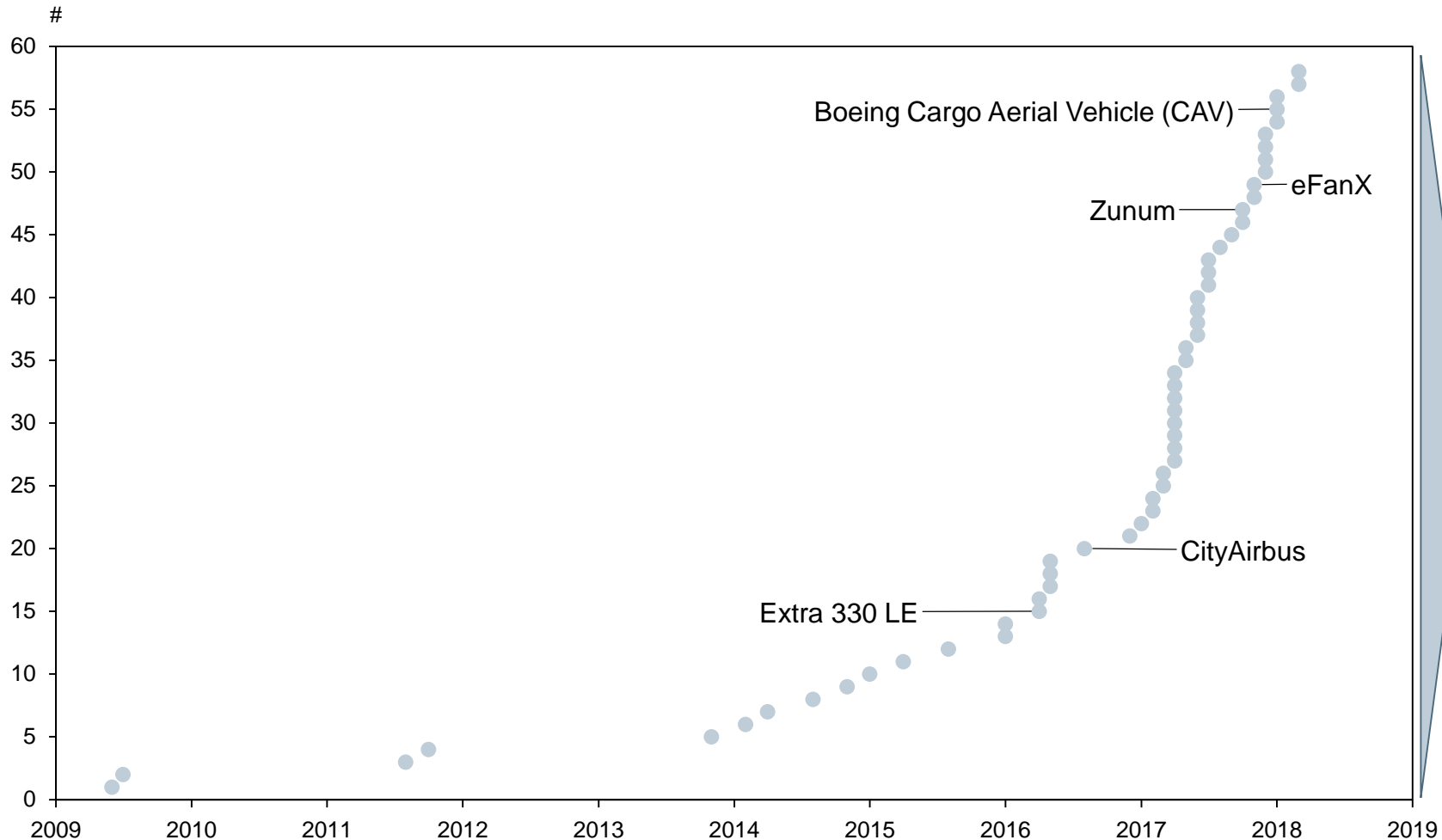
Integration of a gas turbine and an electric generator for hybrid-electric operation



Integration of batteries for energy storage

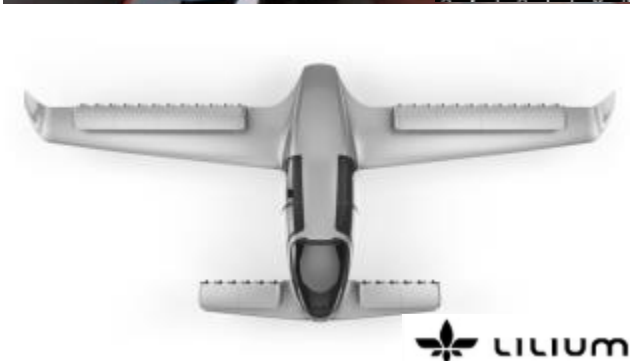
Industry activity in hybrid-electric aviation rapidly increasing

Number of (hybrid-)electric projects announced (cumulative)



Significant invests developing

- Explosion of announced projects in 2017
- Significant funding of startup companies, e.g.
 - Lilium (90' EUR, 2017)
 - Volocopter (31' EUR, 2017)
 - Joby Aviation (100' EUR, 2018)
- Growing investment activity of incumbents, e.g. Boeing (Aurora Flight Sciences and Zunum) or Geely (Terrafugia)



Diamond Aircraft and Siemens: Successful Maiden Flight of world's first Serial Hybrid-Electric Twin Engine Plane



- Distributed propulsion:
- Two electrically driven free-stream propellers
 - One electrical generator driven by a jet fuel piston engine
 - Battery



Diamond Aircraft and Siemens: Successful Maiden Flight of world's first Serial Hybrid-Electric Twin Engine Plane



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Distributed Electric Propulsion: The IBEFA consortium is investigating the feasibility of a Multi-Propeller Hybrid-Electric Low-Noise General Aviation Plane.

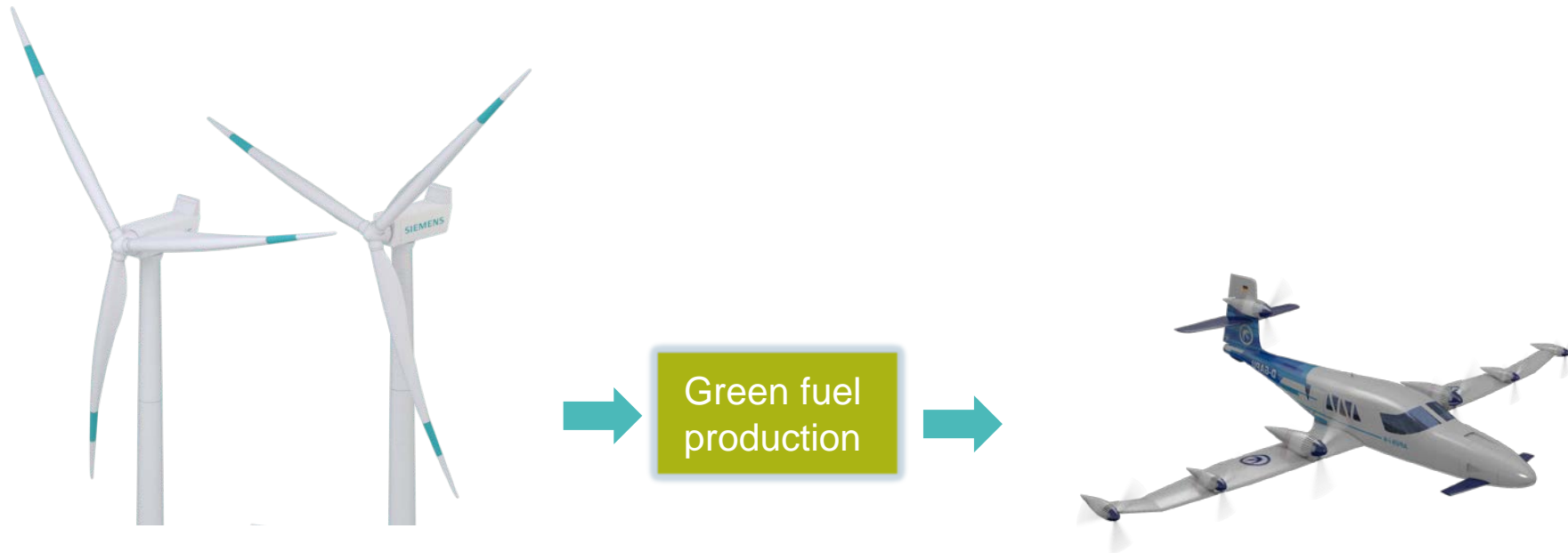
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Chance: Nachhaltige, innovative E-Mobility

Windenergie → Power-to-Green Fuel → Hybrid-Elektrisches leises Flugzeug

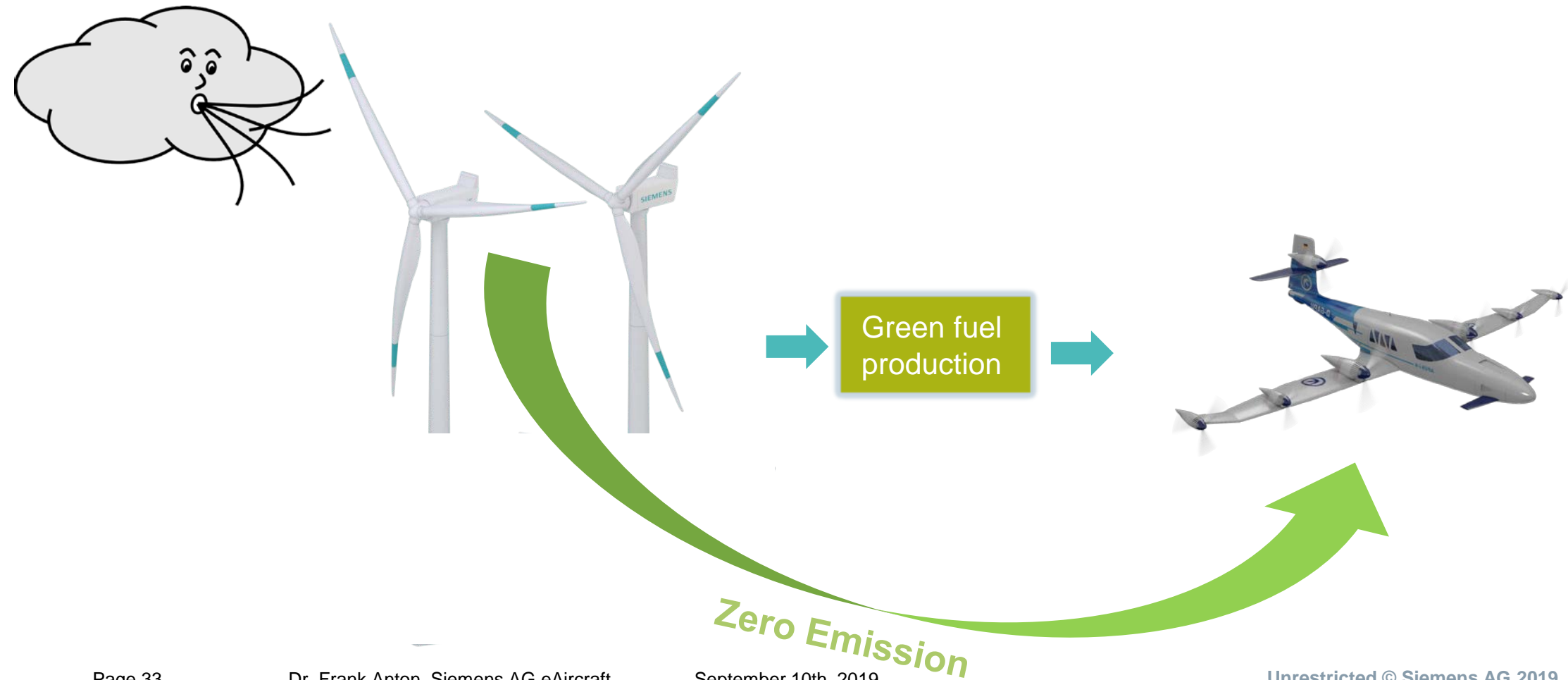
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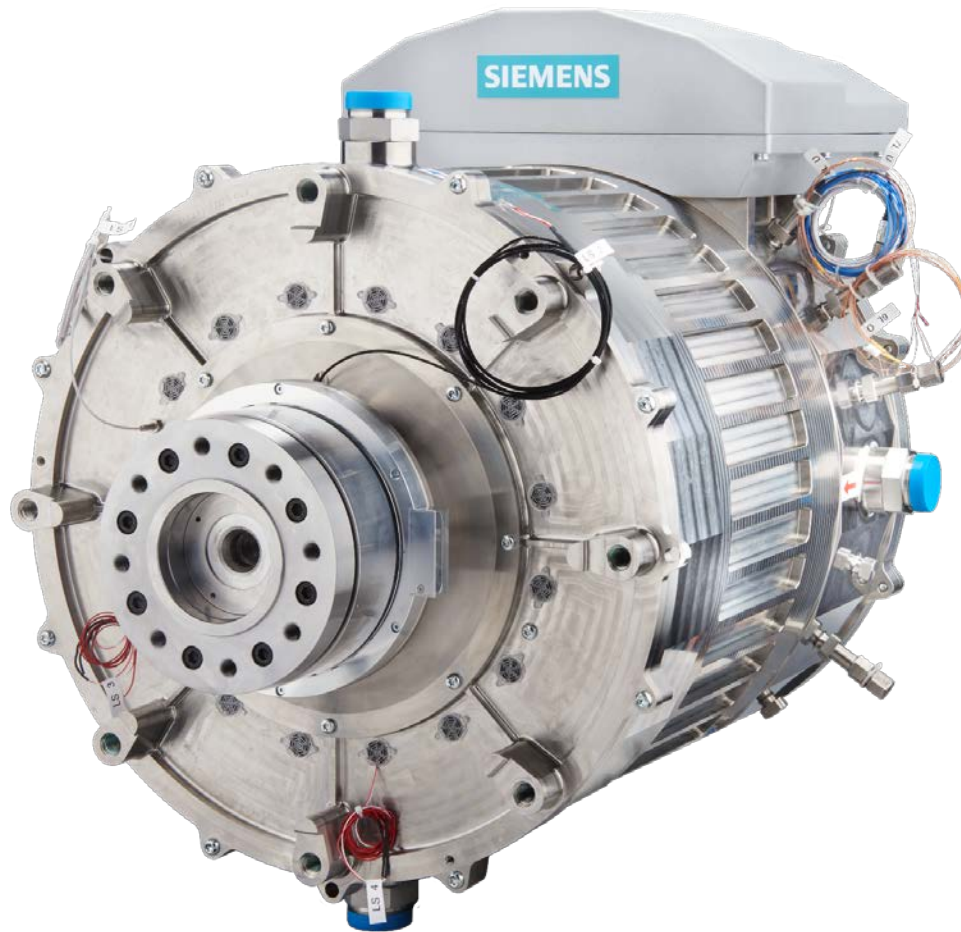
Chance: Nachhaltige, innovative E-Mobility

Windenergie → Power-to-Green Fuel → Hybrid-Elektrisches leises Flugzeug

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SP2000D



$P_{\max, \text{cont}}$	2,000 KW
N	6,500 rpm
M_{cont}	3,000 Nm
U_{DC}	3,000 V
m_{total}	261 kg
Cooling	Direct liquid cooling
Length	589 mm
Diameter	520 mm



All values are design values and currently under test.



Siemens sells electric aircraft-propulsion business to Rolls-Royce



Agreement signed on June 18th, 2019: Rolls-Royce to acquire eAircraft

Sale to accelerate development of sustainable air transport

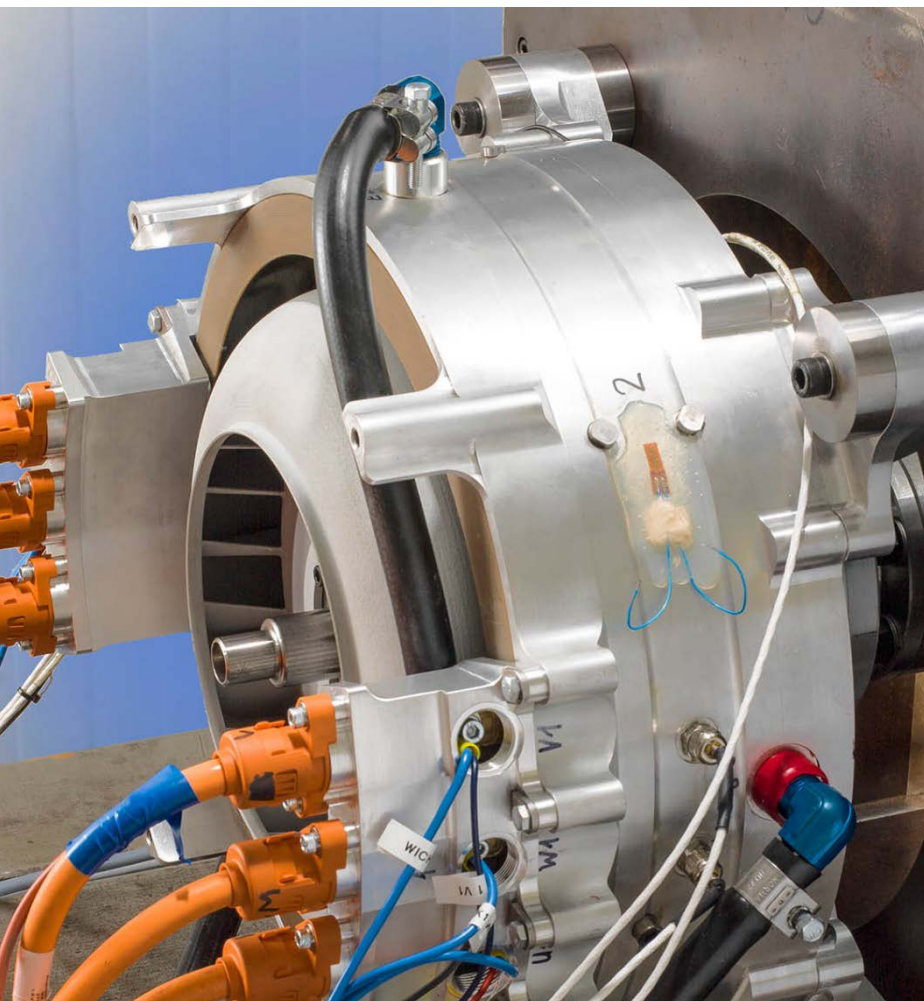
Rolls-Royce intends to become the leading supplier of electric and hybrid-electric propulsion systems for aircraft

Siemens will continue to support the transition to electric aviation with its digital solutions portfolio

Closing expected in late 2019



Thank you for your attention



Dr. Frank Anton
Senior Vice President eAircraft Transfer

Siemens AG, Corporate Technology



CT REE
Guenther-Scharowsky-Strasse 1
D-91058 Erlangen
Phone: +49-9131-737 320

frank.anton@siemens.com