

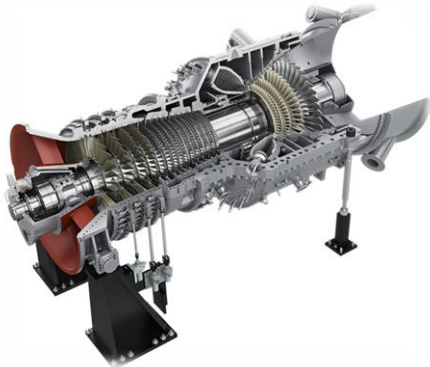
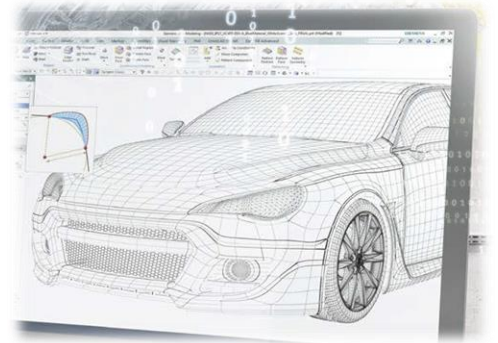
# Innovation in aircraft design: the role of hybrid electric aircraft

Dr. Andreas Reeh - Siemens eAircraft

Air Transport Colloquium – Antwerp, 6 December 2018

# What do you associate with Siemens?

**SIEMENS**  
*Ingenuity for life*





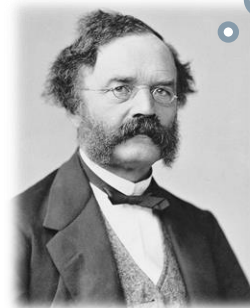
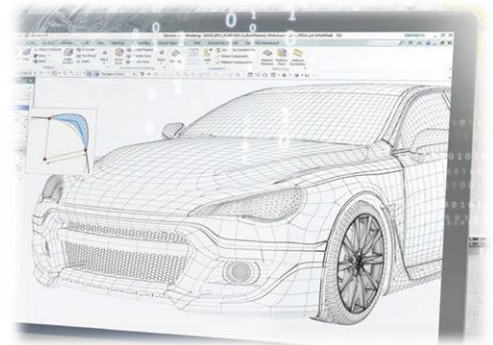
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- Electrification
- Digitalization
- Automation

Siemens  
and  
eAircraft?!

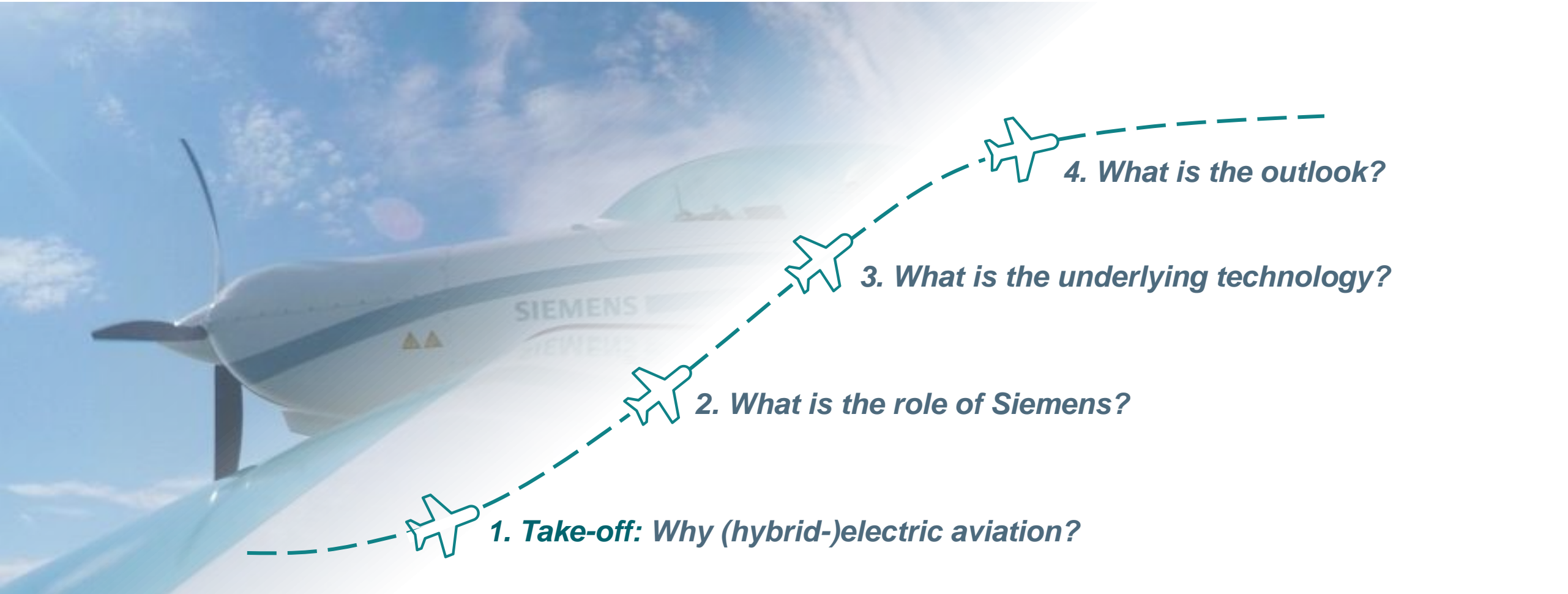


With our partners we have continually extended the boundaries of electric flight



# Hybrid-Electric Aircraft Propulsion

*Flight path for today's presentation*



# ***WHY* hybrid-electric aviation?**



Pull from airlines

## JetBlue-backed private jet company signs up for hybrid electric planes

Source: CNBC.com, 5/21/2018

## EasyJet makes progress with electric aircraft plan

Source: Reuters.com, 10/29/2018

## ***Air New Zealand and ATR explore the future of a regional aviation ecosystem including hybrid aircraft***

Source: AirNewZealand.co.nz, 11/9/2018

Pull from regulators and airports

## Norway aims for all short-haul flights to be 100% electric by 2040

Source: TheGuardian.com, 1/18/2018

**FIRST ELECTRIC-HYBRID PLANE TO  
TOUCH DOWN AT HEATHROW WITHIN 12  
YEARS**

Heathrow to launch race to land first electric-hybrid aircraft

Source: Independent.co.uk, 10/16/2018



**Pull from aircraft manufacturers**

## **Boeing-backed, hybrid-electric commuter plane to hit market in 2022**

Source: Reuters.com, 10/5/2017

## **Embraer sees 2024 commercial launch for Uber flying cabs**

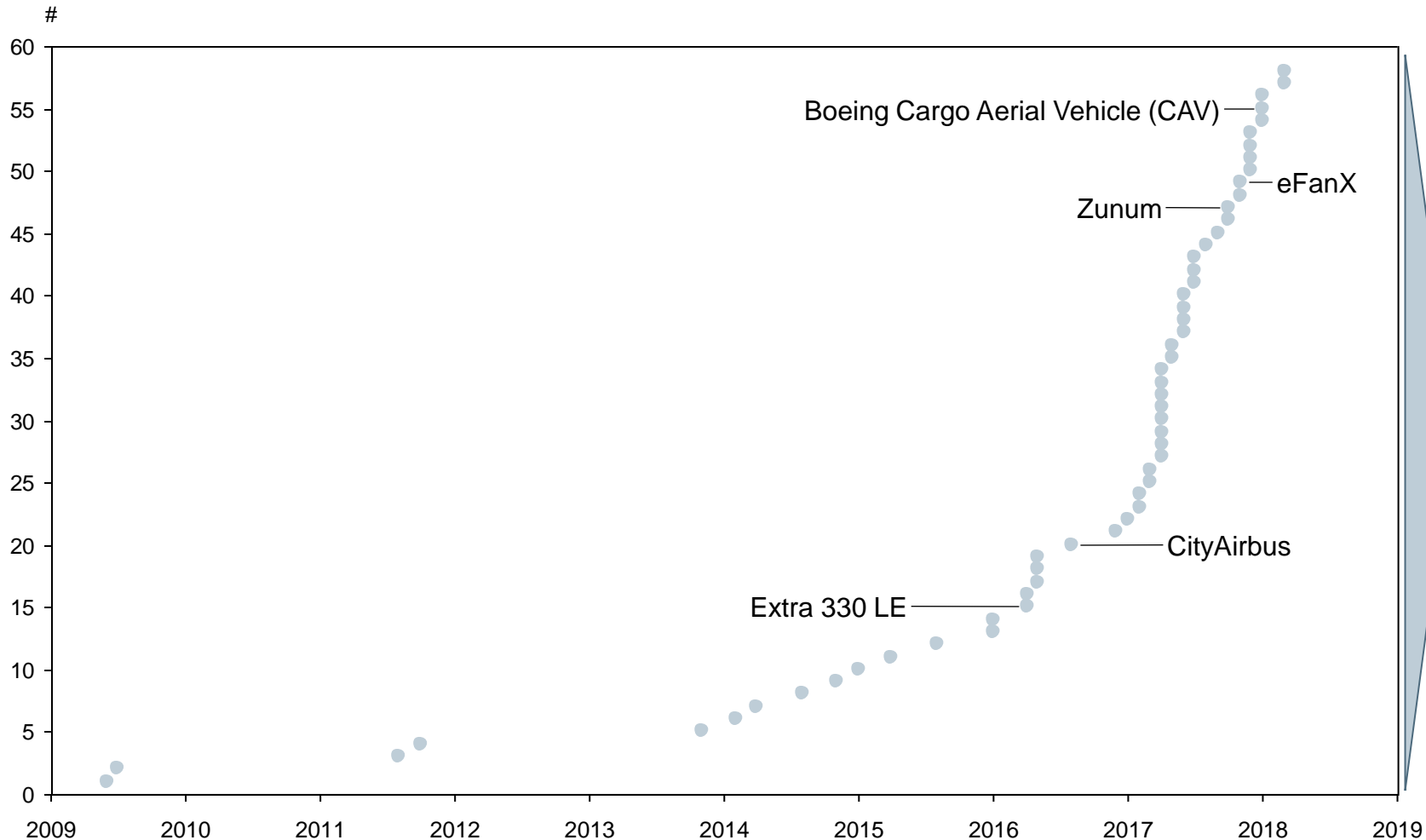
Source: Reuters.com, 12/15/2017

**The future is  
electric**

Source: Airbus.com, 7/17/2018

# Pull from the aviation industry – Rapidly increasing activities

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



## Significant investment 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)

# Technology push – The unexploited potential of electric aircraft propulsion

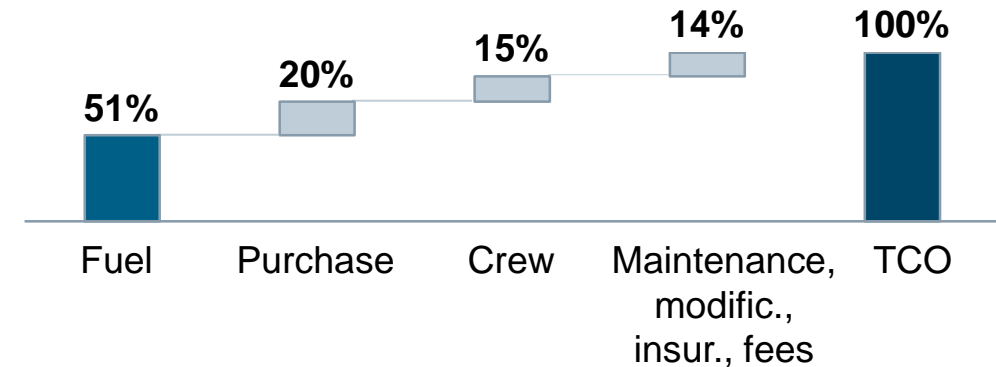
- Drive systems are going electric – on land, at sea and in the air
- Electric drive technology offers massive leaps in
  - Power density
  - Efficiency
  - Safety
- Aeropropulsion is attractive, technologically challenging, and requires verification and certification
- Key success factors
  - Distributed electric propulsion enabling more efficient aircraft configurations
  - Separation of power and thrust generation



## Reasons for hybrid-electric aviation

1. Reduction of total cost of ownership (reduction of fuel consumption)
2. Higher market acceptance (lower noise and CO<sub>2</sub> emissions)
3. Enabling new aircraft and air traffic concepts

### Total cost of ownership (example Boeing 737-800)<sup>1</sup>



→ Fuel, purchase and maintenance can be influenced

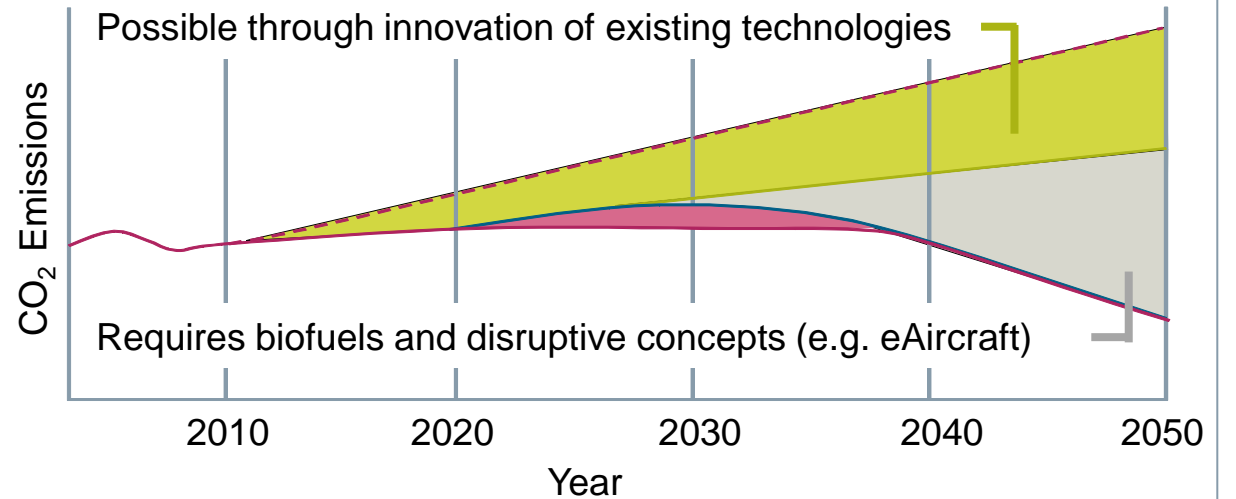
1) Source: eAircraft market evaluation



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### Projected emission goals: can only be reached with disruptive concepts<sup>1)</sup>



→ European Union's agreement "Flight-path 2050" requires 90 % emission reduction

<sup>1)</sup> IATA technology roadmap, June 2013

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## Electric propulsion leads to unprecedented design opportunities



1)



2)



3)



4)

1) [www.nasa.gov/centers/armstrong/Features/leaptech.html](http://www.nasa.gov/centers/armstrong/Features/leaptech.html) (December 2015)

3) City Airbus

2) <http://aviationweek.com/technology/quality-crowd-designed-uavs-surprises-airbus> (July 2015)

4) [www.nasa.gov/langley/ten-engine-electric-plane](http://www.nasa.gov/langley/ten-engine-electric-plane) (Dezember 2015)

# New aircraft - Diamond Aircraft and Siemens: Successful maiden flight of the world's first serial hybrid-electric twin engine plane



Technical feasibility of distributed propulsion system proven:

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



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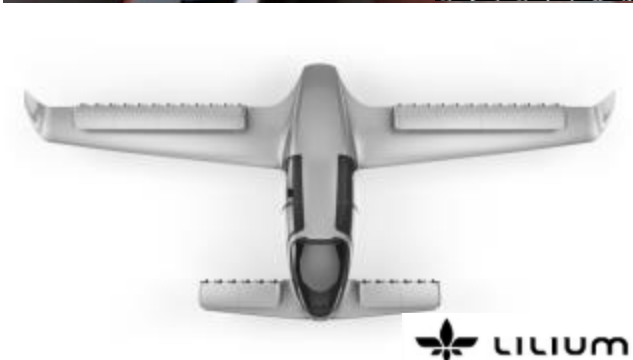
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1)

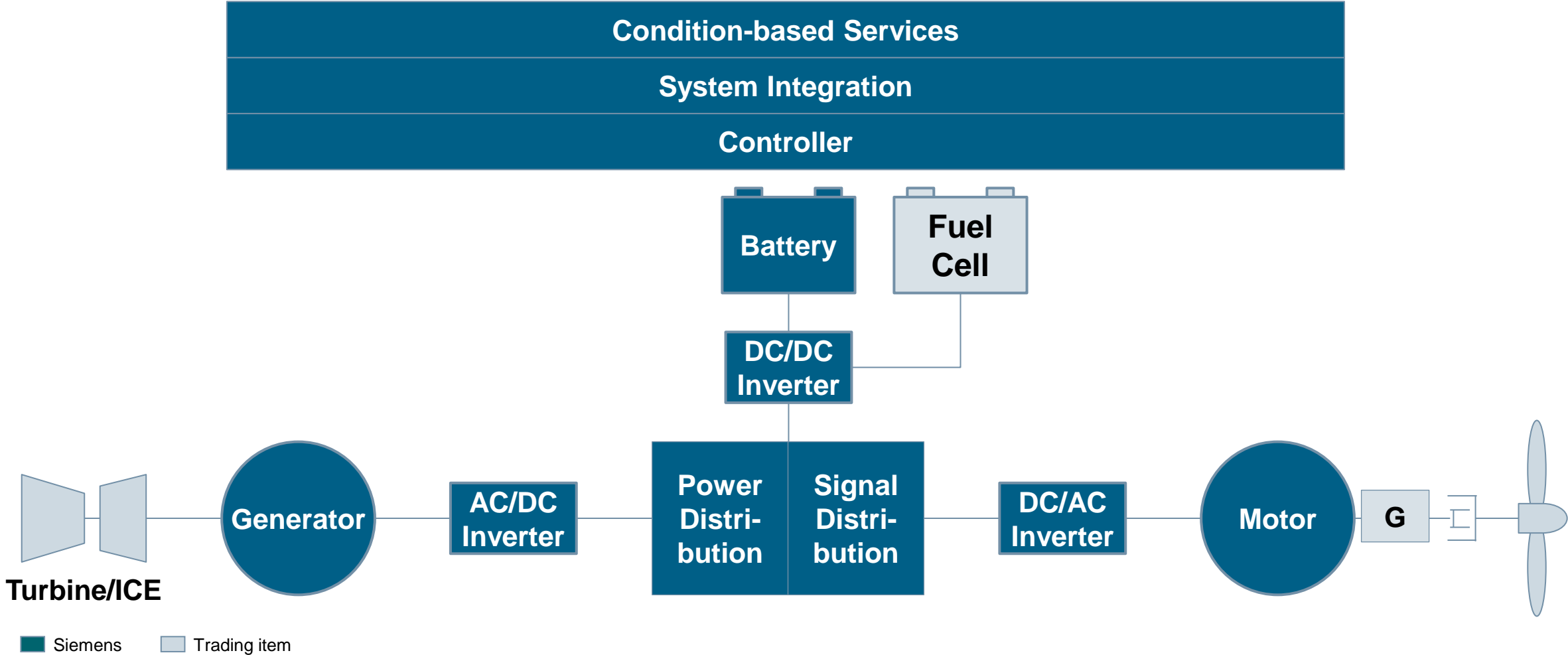
- Passenger transport in urban areas
- On-demand transport

1) Uber elevate



***WHAT* is the role of  
Siemens?**

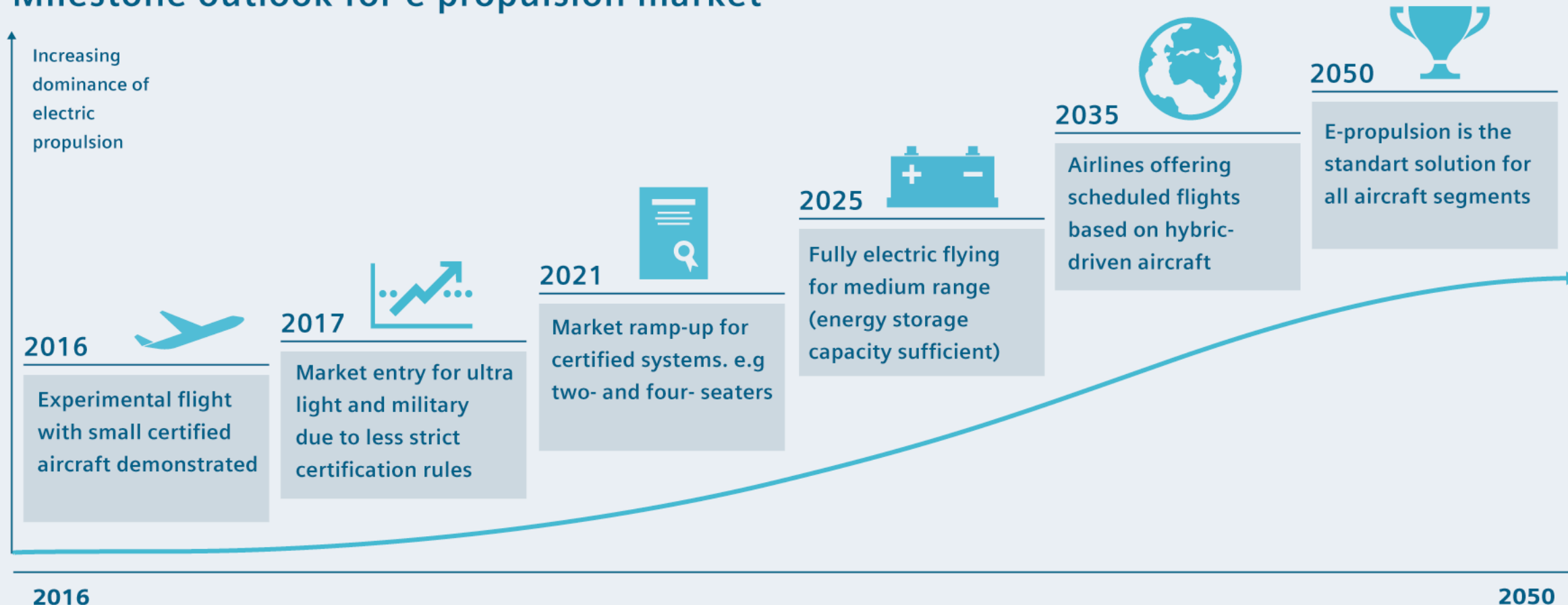
Our core portfolio – electric propulsion systems for applications with high power-to-mass requirements





# We expect e-propulsion to be the standard solution by 2050

## Milestone outlook for e propulsion market



Source: eAircraft market evaluation

**On April 7<sup>th</sup>, 2016, Airbus Group and Siemens AG have signed a long-term collaboration agreement in the field of hybrid electric propulsion systems**



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# SIEMENS

Siemens is determined to establish hybrid-electric propulsion systems for aircraft as a future business.

The Airbus Group logo is displayed in a blue color, with the word "AIRBUS" in a bold, sans-serif font and the word "GROUP" in a smaller, sans-serif font below it.

“We believe that by 2030 **passenger aircraft** below 100 seats could be propelled by **hybrid propulsion systems...**”

Airbus Group CEO Tom Enders

- Both companies take a significant joint development decision
- Demonstrate the technical **feasibility of various hybrid-electric propulsion systems by 2020**
- Assemble **joint development team** of some 200 employees
- Prototype propulsion systems ranging from a few **100 kW up to 10 MW** and more
- for short, local trips with aircraft below 100 seats, helicopters or UAVs up to classic short and medium-range journeys.
- Target: breakthrough innovation in **aerospace e-mobility**

***WHAT*** is the underlying  
technology?



# Airbus-Siemens Collaboration – The CityAirbus project

## CityAirbus

A multi-passenger, self-piloted electric vertical take-off and landing (VTOL) demonstrator designed for urban air mobility with cost efficiency, high-volume production and a low environmental footprint in mind.

**AUTONOMY**  
15 min

**ENGINES**  
• 8 fixed pitch propeller powered by direct drive engines  
• 8 x 100 KW electric motors

**SIZE**  
Compact size for best UAM compatibility

**BATTERIES**  
• 4 x 140 KW power in the batteries  
• 110 KWh energy in all four batteries

Boosted high HP propulsion units for efficiency, lowest acoustic footprint and safety

**CAPACITY**  
Design for up to 4 passengers

Avionics and Autopilot urban ATM

**CRUISE SPEED**  
120 Km/h

CityAirbus: Multi-passenger, self-piloted electric VTOL

2023 - fully certified CityAirbus becomes part of urban transport

### Making CityAirbus a reality



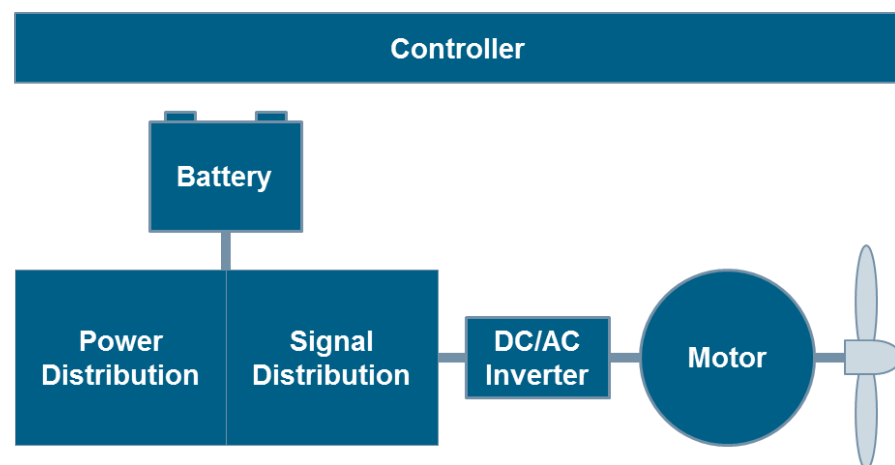
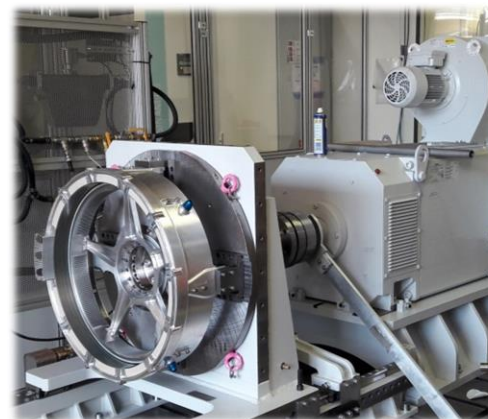
### The benefits of adding the third dimension to urban transport networks



**AIRBUS**

Source:  
[www.airbus.com/newsroom/press-releases](http://www.airbus.com/newsroom/press-releases)

# Airbus-Siemens Collaboration – The CityAirbus project



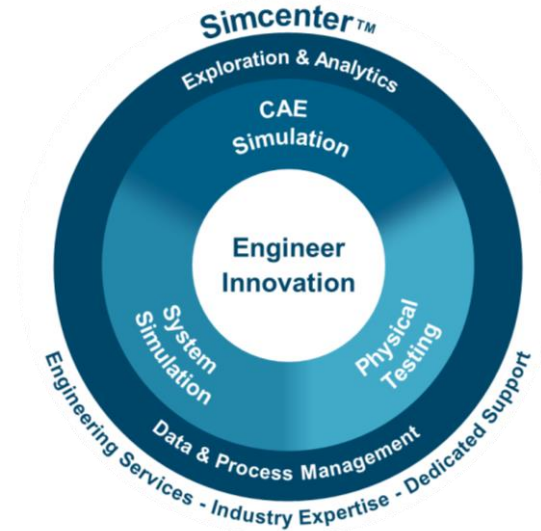
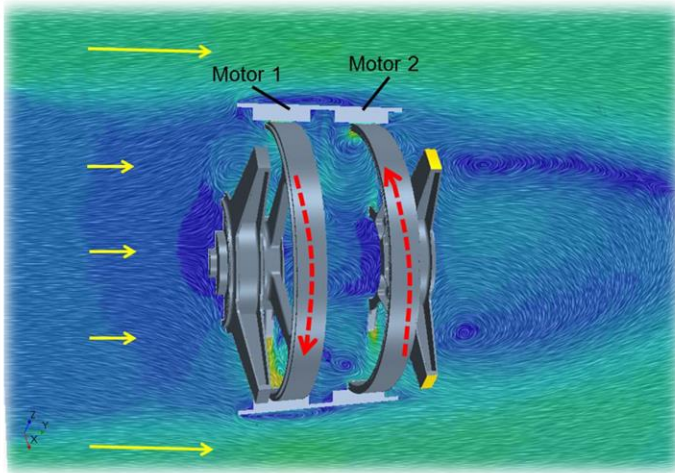
Electric Propulsion Unit (EPU)			
$P_{cont.}$	204 kW*	Torque-to-mass ratio	30 Nm/kg
$N_{max}$	1300 rpm	Power-to-mass ratio	4,2 kW/kg
$M_{cont.}$	1500 Nm	Direct drive with integrated rotor bearing	VTOL application
$\eta_{Motor}$	95% max	First time use of the SiC inverter	Low switching losses
$M_{motor}$	49 kg	NX toolchain development	Digital twin high fidelity design

\* First version with oversized motors due to risk mitigation

# SP200D

## Driving torque density

**SIEMENS**  
*Ingenuity for life*



Reality in 9 months and 19 days  
through the use of digital twin

### SP200D

**Record torque density 30 Nm/kg**

Designed for high-torque low-speed requirements.

Allows for slow rotating propellers,  
hence low noise.



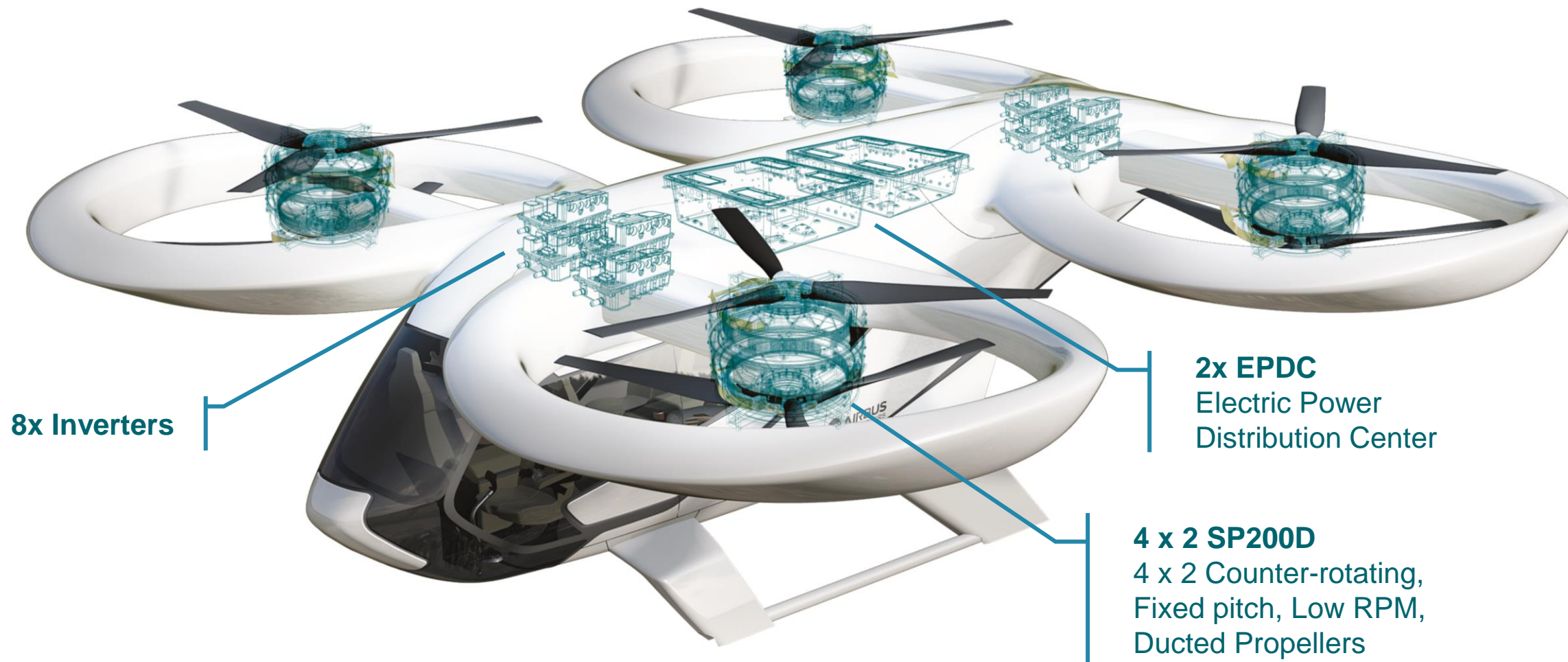
2 x SP200D coupled





## Siemens is powering the CityAirbus

**SIEMENS**  
*Ingenuity for life*

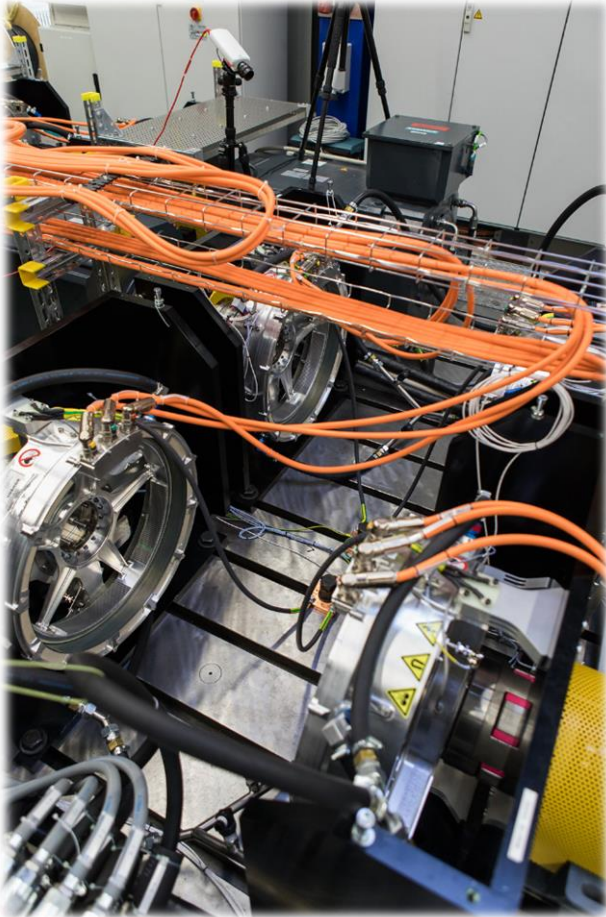




# Functional integration test – “Iron bird” set-up

8 electric propulsion units, 2 electric power distribution centers, 4 batteries

**SIEMENS**  
*Ingenuity for life*



SP200D motors



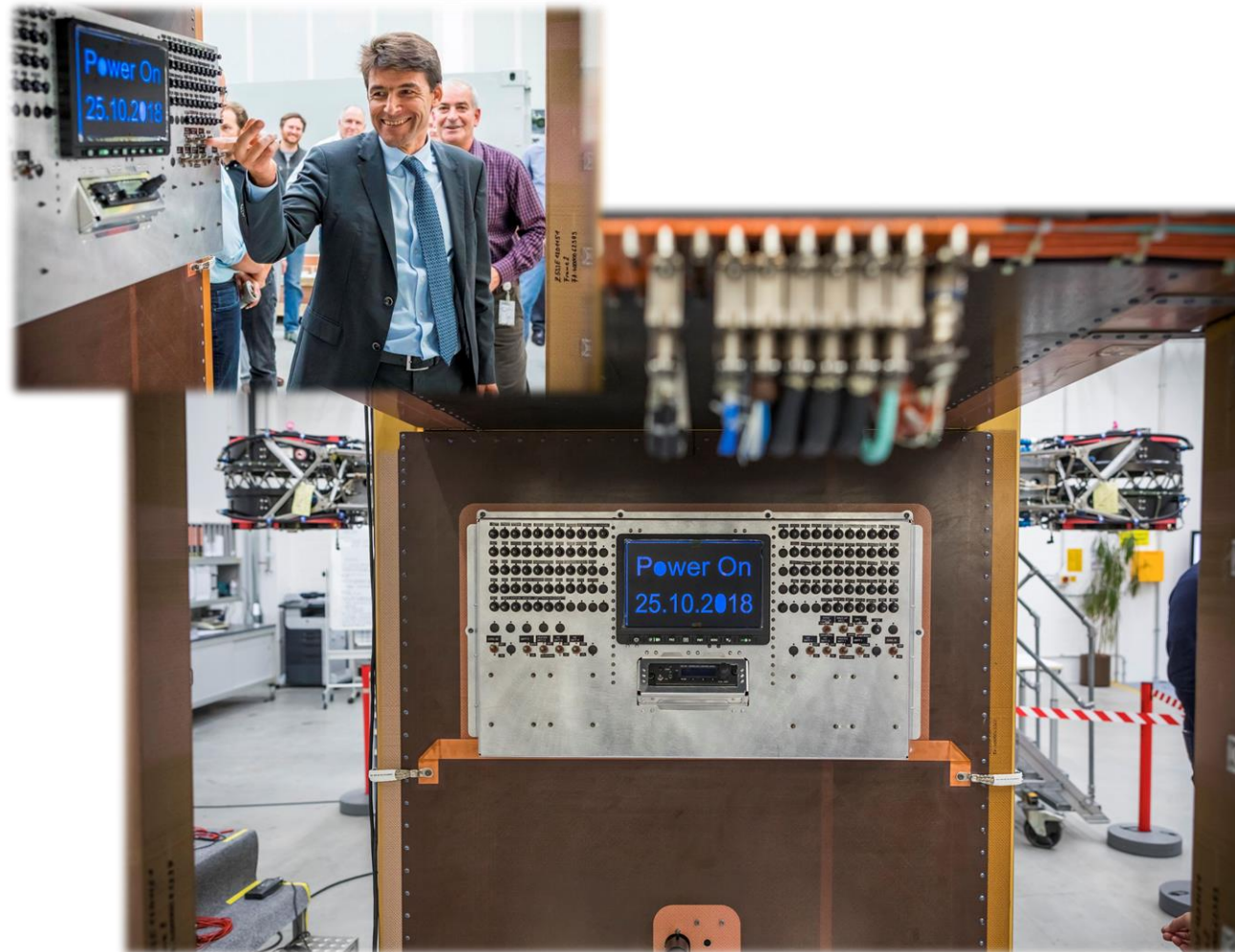
SiC inverters



City Airbus „Iron Bird“ set-up in Ottobrunn



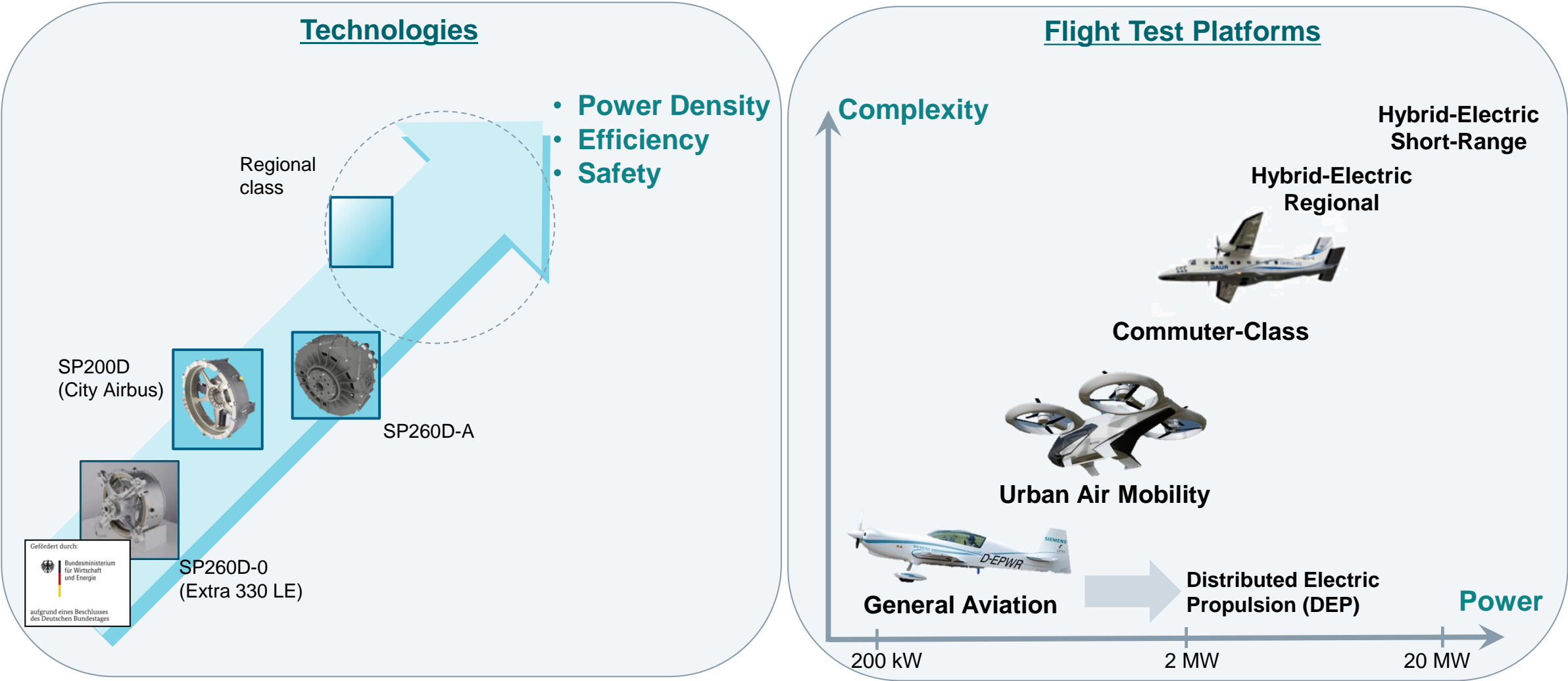
# Rotor testing at Airbus Helicopters and flight demonstrator high voltage power on in Donauwörth



City Airbus alpha flight demonstrator, Donauwörth

***WHAT* is the outlook?**

Further steps in research, development for systems mirroring increasing demands and complexity of platforms



# We develop hybrid electric propulsion systems for aircraft



Hybrid-electric propulsion is a **scalable technology**, making its way into

- **general aviation** by 2018 ... 2022
- **commercial aviation** (up to 100 passengers) by 2030

**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 consumption



Silent propulsion

Distributed propulsion



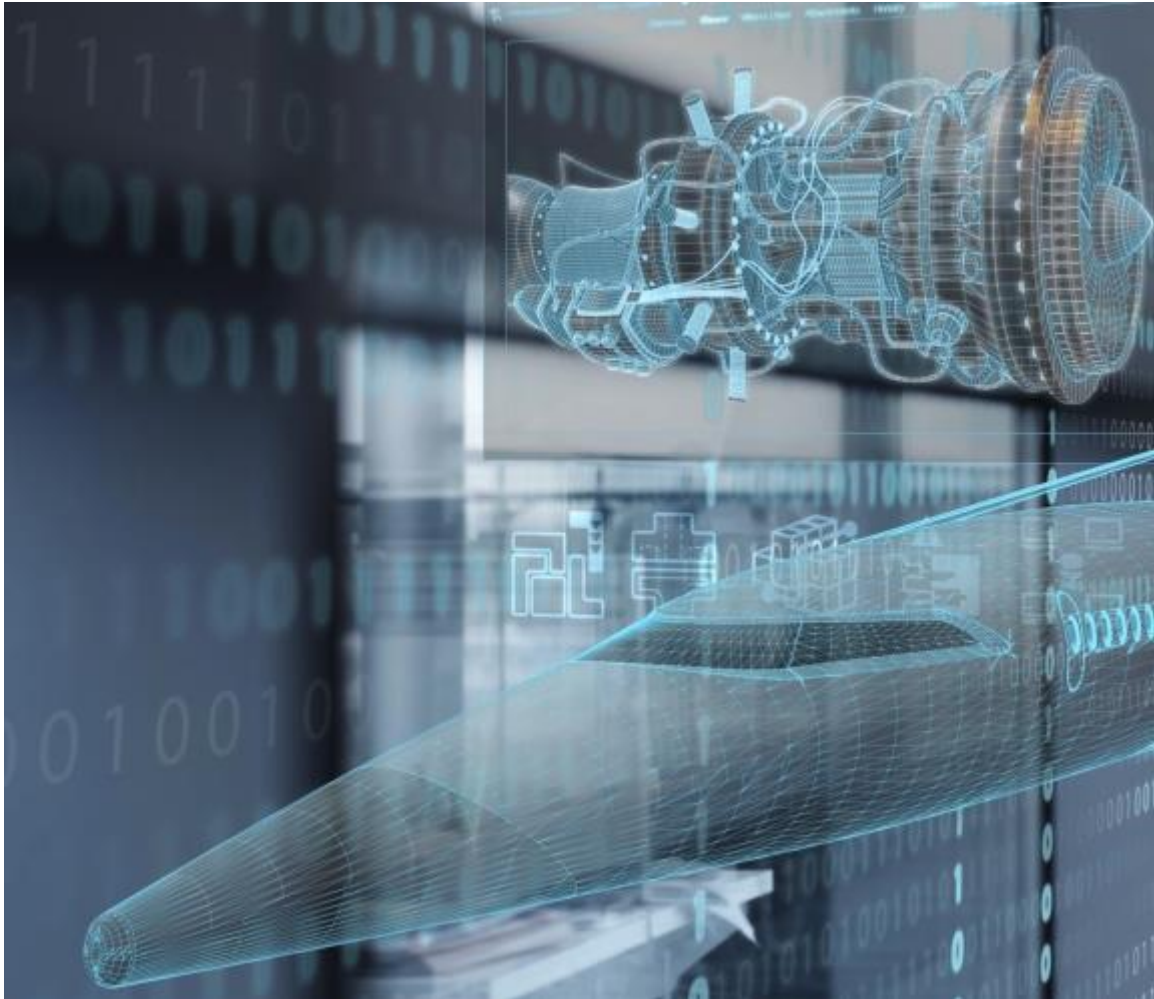
Increased aerodynamic efficiency

Vectorized thrust



STOL, VTOL

## Contact



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[www.siemens.com/eaircraft](http://www.siemens.com/eaircraft)