E-Aircraft System Programme

LuFo-V2 TELOS

Peter ROSTEK
21 March 2018
E-Aircraft Systems Programme – Integrated Project

Electric Aircraft Systems

Peter ROSTEK
E-Aircraft Systems Programme
Head of New Technologies and Concepts
Airbus - Corporate Technical Office
peter.rostek@airbus.com
E-Aircraft Systems Programme – Research and Development Projects

<table>
<thead>
<tr>
<th>Ground Demonstrators</th>
<th>Flight Demonstrators</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>QuadCruiser</strong></td>
<td>α</td>
</tr>
<tr>
<td>Commercial Drones – Low Power</td>
<td>β</td>
</tr>
<tr>
<td><strong>CityAirbus</strong></td>
<td>α</td>
</tr>
<tr>
<td>Urban Mobility – Medium Power</td>
<td>β</td>
</tr>
<tr>
<td><strong>E-Fan X</strong></td>
<td></td>
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<tr>
<td>Commercial Aircraft – High Power</td>
<td>FTB</td>
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<tr>
<td><strong>New Technologies and Concepts</strong></td>
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</tr>
<tr>
<td>Technology Bricks – All Power Classes</td>
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</tbody>
</table>
Why Electric Propulsion?

**Design Space**
- New Aircraft Configurations
- New Engine Cycles
- New Flight Operations

**Mega Trends**
- Urban Air Mobility
- Personal Air Vehicles
- Inter City Traffic

**Environment**
- Agreed Emission Targets
- Imminent Pollution Fees
- Potential Kerosene Replacements
The key enabler for future products in commercial aviation is...
With current battery technology all electric propulsion is nearly impossible in commercial aviation!

A319: 800 nm / 140 PAX

Conventional Kerosene

- 30 kg Kerosene per PAX

All Electric

- 1000 kg Battery per PAX

Assumptions

<table>
<thead>
<tr>
<th></th>
<th>Assumptions</th>
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<tbody>
<tr>
<td>Energy Density of Kerosene</td>
<td>12000 Wh/kg</td>
</tr>
<tr>
<td>Energy Density of Battery</td>
<td>120 Wh/kg</td>
</tr>
<tr>
<td>Efficiency Factor of eMotor</td>
<td>3</td>
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</tbody>
</table>
How to build bridges between small applications and large applications?

We are far away from any large application interesting for Airbus.

All demonstrations/applications are starting small.

But how to grow big?
Each electric propulsion system is based on selected electric subsystems
Lightweight power networks on appropriate voltage levels (incl. installation rules)
Key Challenges – Thermal Management

Disruptive equipment cooling technologies and appropriate thermal architecture concepts
LuFo-V2 TELOS - Thermo-Electrically Optimised Aircraft Propulsion Systems

- Develop the technological basis for a hybrid electric propulsion system on an appropriate power level (high power class)
- Target applications are regional range aircraft in a first step and short range aircraft in a second step (100-200PAX)
- Project Duration: 01.01.2016 – 31.12.2019

<table>
<thead>
<tr>
<th>Project Partner</th>
<th>Initial Budget [€]</th>
<th>Planned Upgrade [€]</th>
<th>New Budget [€]</th>
<th>Public Funding [€]</th>
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<tbody>
<tr>
<td>Airbus-EAS</td>
<td>2.500.000</td>
<td>6.500.000</td>
<td>9.000.000</td>
<td>3.780.000</td>
</tr>
<tr>
<td>Airbus-Operations</td>
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<td>2.000.000</td>
<td>840.000</td>
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<tr>
<td>SAG</td>
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<td>6.000.000</td>
<td>10.000.000</td>
<td>4.200.000</td>
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<tr>
<td>KIT</td>
<td>800.000</td>
<td>985.000</td>
<td>1.785.000</td>
<td>1.785.000</td>
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<tr>
<td>NMB</td>
<td>300.000</td>
<td></td>
<td>300.000</td>
<td>300.000</td>
</tr>
<tr>
<td>TUM</td>
<td>300.000</td>
<td></td>
<td>300.000</td>
<td>300.000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9.900.000</strong></td>
<td><strong>13.485.000</strong></td>
<td><strong>23.385.000</strong></td>
<td><strong>11.205.000</strong></td>
</tr>
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</table>
Possible Baseline: Propulsion system architecture to identify the potential of high temperature superconduction with a cryogenic cooling system
Conclusion

• The key enabler for future products in commercial aviation is electrification.

• Up to hybrid electric regional range aircraft conventional electrical systems might be sufficient.

• For hybrid electric short range aircraft we will need more disruptive technologies, such as high temperature superconduction and cryogenic cooling systems.
Some people can hardly wait to fly electric!
Cryogenic electric propulsion system for aircraft

Dr. Martin Boll
Ziehl VI Workshop 2018
Outline

• Siemens eAircraft in a nutshell  3
• Superconductivity to electrify the A 320 class  8
• A cryogenic electric propulsion system  19
Siemens eAircraft in a nutshell
Roadmap

Hybrid-electric flight – History and future

EAS House 2016

20MW

2MW

200kW

20kW

New Single Aisle Aircraft

AIRBUS
Airbus-Siemens Collaboration
Siemens SP200D EPU Direct Drive

City Airbus, full size demonstrator planned for End of 2018

<table>
<thead>
<tr>
<th>Electric Propulsion Unit EPU Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P&lt;sub&gt;cont&lt;/sub&gt;</strong></td>
</tr>
<tr>
<td><strong>N&lt;sub&gt;max&lt;/sub&gt;</strong></td>
</tr>
<tr>
<td><strong>M&lt;sub&gt;cont&lt;/sub&gt;</strong></td>
</tr>
<tr>
<td><strong>U&lt;sub&gt;zk&lt;/sub&gt;</strong></td>
</tr>
<tr>
<td><strong>η&lt;sub&gt;Motor&lt;/sub&gt;</strong></td>
</tr>
<tr>
<td><strong>M&lt;sub&gt;motor, drive, propeller bearing&lt;/sub&gt;</strong></td>
</tr>
</tbody>
</table>

* First version with oversized motors due to risk mitigation
Superconductivity to electrify the A320 class
Roadmap

Hybrid-electric flight – History and future

EAS House 2016

20MW
2MW
200kW
20kW

New Single Aisle Aircraft

First flight

Cri-Cri 2010
e-Genius 2011
DA36 2011
E-Star 2013
DA36 2013
E-Star 2 2014
E-Fan 1.0 2016
E-Fan 1.1 2016
E-Fan 1.2 2016
Siemens Extra 330LE 2016
Vahana 2017
CityAirbus 2018
E-Fan X 2020
20XX

AIRBUS
### Pathfinder: Electrifying the Airbus A320 class

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Number of passengers</td>
<td>189</td>
</tr>
<tr>
<td>Maximum take off weight (TOW)</td>
<td>90,000 kg</td>
</tr>
<tr>
<td>Kerosene consumption (cruise)</td>
<td>2700 liters/hour</td>
</tr>
<tr>
<td>Take-off thrust</td>
<td>2 x 147.5 kN (PW1133)</td>
</tr>
<tr>
<td>Take off mechanical power</td>
<td>2 x 22 MW</td>
</tr>
<tr>
<td>Weight per propulsion unit</td>
<td>2.86 t</td>
</tr>
<tr>
<td>Power/weight ratio prop. system</td>
<td>~ 7.7 kW/kg</td>
</tr>
<tr>
<td>Contribution to max TOF</td>
<td>6%</td>
</tr>
</tbody>
</table>

Electric propulsion: Kerosene consumption per PAX needs to be improved in order to meet CO₂ reduction goals of European Flightpath 2050 (-75%).
40 MW full serial hybrid: Technical challenges

**A320 neo, today**

- $\alpha_i$ [kW/kg]: $\sim 7.7$ kW/kg
- % of MTOW: 6%

**Normal conducting components**

- $\alpha_i$ [kW/kg]: $\sim 1.8$ kW/kg
- % of MTOW: 27%

Benefits of (distributed) electric propulsion: Aerodynamics, structural, separation of power and thrust generation → Gas turbine operated in its optimal point, but…
Implications for a comprehensive R&D strategy

1) Success by gradual improvement of currently available electric drive-train technology is unlikely.

2) In order to be successful, significantly enhanced technology has to be developed for all main system components.

3) A holistic system approach is essential in order to identify the key focus areas of a comprehensive R&D strategy.
A cryogenic electric propulsion system
Futuristic approach: Cryogenic Electric Propulsion System (CEPS)
Activities on superconductivity within TELOS

- Turbine / ICE
- HTS Generator
- Rotor
- Stator
- AC Power Generation
- Fuel + pumping
- LH₂/LX
- Electrical backup
- Battery
- Battery/SMES
- Converter
- Current Lead
- DC/DC
- H₂
- AC Power Distribution
- Propulsion
- Power Distribution
- H₂
- (SC)CB
- (SC)FCL
- Converter
- (SC)CB
- (SC)FCL
- AC
- DC
- AC
- DC
- AC
- DC
- AC
- DC
- M
- M
- Current Lead
- Dr. Martin Boll, eAircraft
- Unrestricted © Siemens AG 2018
- Page 13
- 2018-03-21
Required enabling technologies

1) Lightweight & fast rotating HTS generators & motors
   • HTS materials (High performance & reliable process)
   • Lightweight materials for cryogenic engineering (e.g. additive manufacturing)
   • Accompanying development of models for digital twin
   • N+2 SC machine materials: Cryogenic stator & HTS Bulk materials

2) Superconducting power distribution

3) Accompanying development of SC component models for system modelling

4) Power electronics operable in cryogenic environment

5) Lightweight & reliable cryogenic storage and distribution

Siemens HTS-III Machine
4 MW @ 120 rpm
40 MW full serial hybrid: Leverage through superconductivity

**A320 neo, today**

\[ \alpha_i \text{ [kW/kg]} \approx 7.7 \text{ kW/kg} \]

\% of MTOW 6%

**Normal conducting components**

\[ \alpha_i \text{ [kW/kg]} \approx 1.8 \text{ kW/kg} \]

\% of MTOW 27%

**Cryogenic propulsion system \sim 2035**

\[ \alpha_i \text{ [kW/kg]} \approx \text{ ?? kW/kg} \]

\% of MTOW \text{ ?? %}
Thank you for your attention!

Dr. Martin Boll
Project manager N+2 superconducting technologies for aviation
CT N47P AIR AS ELM1
Willy-Messerschmidt Str.1
82024 Taufkirchen
Phone: +49 1743384933

E-mail:
martin.boll@siemens.com

www.siemens.com/presse/elektromotor-flugzeug