E-FAN
The first purpose-built, electrically powered trainer aircraft

AIRBUS Group – SAFRAN – ZODIAC
05/02/2015 - TOULOUSE
**Agenda**

- History and Origin of the project
- E-Fan 2.0 objectives
- Partnership
- Requirements
- Challenges

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- Electrical System Devices
- High Voltage Electrical System
- Skills
- Technical Challenges

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- Electric Propulsion Challenges
- eFAN eIPS 2.0 Concept
The “E-FAN Family” concept

2010

2012

2014

2017

World’s first fully electric four engine aerobatic plane

First purpose-built electric powered training aircraft

Industrialized version of E-FAN 1.0

=> Electrization of a thermical plane

=> Flying test bed

=> Commercial version of a full-electrical training plane

E-FAN: Development of an electrically-powered aircraft
E-FAN 2.0: Main objectives & challenges

- 4 objectives:
  - Competitive aircraft
    - Response to a market need for ab-initio trainings
    - Competitive price in Total Cost of Ownership (TCO)
  - Certifiable aircraft: regulatory acceptance of electric propulsion
  - Aircraft suitable for production: structuring of an industrial sector
  - Acceptability of new learning methods by all the stakeholders (teachers, pilots, regulatory authorities)

- 4 challenges:

<table>
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<tr>
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<th>Avion Thermal Aircraft</th>
<th>Project goals</th>
</tr>
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<tbody>
<tr>
<td><strong>Weight</strong></td>
<td>&lt;600 kg (LSA certification)</td>
<td>&lt;600 kg (LSA** certification)</td>
</tr>
<tr>
<td><strong>TCO</strong></td>
<td>100 à 120 €/h</td>
<td>Less than 90 €/h (low energy cost, minimizing immobilization with low maintenance)</td>
</tr>
<tr>
<td><strong>Autonomy</strong></td>
<td>4 - 5 hours</td>
<td>1h + 15 min for security reasons</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>10 hours / day</td>
<td>5 hours / day (quick charge in 45 min)</td>
</tr>
<tr>
<td></td>
<td>scheduled maintenance every 50h</td>
<td>Yearly scheduled maintenance***</td>
</tr>
</tbody>
</table>

* Restricted certificate of airworthiness ** Light Sport Aircraft *** Based on the use of 300 hours per year
Towards production

June 2011

E-FAN 1.0
Flying Demonstrator

July 2014

Design

Pré-Industrialization

2017

E-FAN 2.0

Creation of VoltAir, 100% Airbus Group Subsidiaries

100% electrical engine

2 seats side-by-side

Initial training

Battery management system

Fixed gear
E-FAN 2.0: Partners

Consortium of 10 partners for industrial production

- 6 industrial partners: Airbus Group (with Daher-Socata as key subcontractor), Zodiac Aerospace, Safran, ACS, Evtronic, Serma Technologies;

- 4 research organizations / schools: CEA Tech, ENAC, ENSAM, ISAE, INSA.
ASTM 2840

This specification provides designers and manufacturers of electric propulsion for light sport aircraft design references and criteria to use in designing and manufacturing EPUs

- This specification covers minimum requirements for the design and manufacture of Electric Propulsion Units (EPU) for light sport aircraft, VFR use. The EPU shall as a minimum consist of the electric motor, associated controllers, disconnects and wiring, an Energy Storage Device (ESD) such as a battery or capacitor, or both, and EPU monitoring gauges and meters. Optional onboard charging devices, in-flight charging devices or other technology may be included.

- § 5 : Data requirement : data recorder & storing, drawings, reference, M&P, operating manuel, maintenance manuel

- § 6 : Design Criteria : Material, Fire, Crash, vibration, SW

- § 7 : Qualification tests : durability, endurance, reliability (for each component of EPU and for the EPU system)

- § 8 : Manufacturing Requirements

Applicable to Airbus Group, SAFRAN, ZODIAC
### Example of Top Level Requirement

<table>
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<td>Regulatory requirements</td>
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<td>Operating environment and limitations</td>
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<td>Mission capability and performance</td>
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<td>Physical characteristics</td>
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<tr>
<td>Cabin &amp; comfort</td>
<td>8</td>
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<tr>
<td>Ergonomy/HMI</td>
<td>10</td>
</tr>
<tr>
<td>Safety</td>
<td>3</td>
</tr>
<tr>
<td>Reliability</td>
<td>7</td>
</tr>
<tr>
<td>Availability</td>
<td>1</td>
</tr>
<tr>
<td>Maintainability</td>
<td>5</td>
</tr>
<tr>
<td>Service life and utilization characteristics</td>
<td>5</td>
</tr>
<tr>
<td>Total Cost of Ownership (TCO)</td>
<td>10</td>
</tr>
<tr>
<td>Rescue and emergency equipment</td>
<td>1</td>
</tr>
<tr>
<td>Commercial options</td>
<td>2</td>
</tr>
</tbody>
</table>

#### Regulatory:
- MTOW = 600 kg (LSA)
- \( V_s \leq 83 \text{ km/h} \)
- Load Factor:
  - Positive limit load factor : +4 g
  - Negative limit load factor : -2 g
- The system shall be designed for flight in heavy rain
- Rate of climb at VY shall exceed 95 m/min (312 fpm)

#### Market:
- Operating temperatures : ISA -30 to ISA +25
- Autonomy 1 hour + 15 min reserve
- Nb Rotation : 6 per day
- Average yearly utilization : 300 FH/year
- Cabin size : fit with EU and US market
- Heating system to ensure a cabin temperature of 15°C under an OAT of -10°C
- Transition between thermal and electrical easy
- No more than 30 min to remove or install Line Replaceable Units (LRU)
- No additional calendar scheduled maintenance, except those mandated by A/C manufacturers
# E-FAN 2.0: Main innovations & challenges

<table>
<thead>
<tr>
<th>Area of work</th>
<th>E-FAN 1.0 demonstrator</th>
<th>Project innovations</th>
<th>Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy storage</td>
<td>Energy density: 100 Wh/kg 130 kg of Li-Ion batteries Energy delivered: 13 kWh</td>
<td><strong>Energy density &gt; 200 Wh/kg</strong> 200 kg max of Li-Ion batteries Typical energy: 40 kWh</td>
<td>Mechanical integration / Packaging Electrochemistry and Materials <strong>Intelligent energy management / Safety</strong></td>
</tr>
<tr>
<td>Recharge</td>
<td>Slow recharge in about 2h</td>
<td>Quick recharge in 45 min</td>
<td>Heating / cooling batteries Preservation durability / safety</td>
</tr>
<tr>
<td>Engine specification</td>
<td>Electric motor and fan ducted</td>
<td>Optimization of the propulsion system (efficiency, cooling, acoustic)</td>
<td><strong>Cooling and electromagnetism management</strong> <strong>Internal aerodynamics</strong> <strong>Noise control and management</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>High energy density (approx. 5kW/kg on the pack)</td>
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<td>Taxiing</td>
<td>Remote engine with transmission to the wheel</td>
<td>New system to integrate into a fixed gear</td>
<td>Design / Integration motor/wheel Robustness and reliability under conditions of use</td>
</tr>
<tr>
<td>IHM / Avionics</td>
<td>Customization of a classic dashboard</td>
<td>Modern cockpit compatible with the training demands and the transition to a thermal plane</td>
<td>Ability to simplify the management of electric propulsion and autonomy</td>
</tr>
<tr>
<td>Weight</td>
<td>Current weight: 650 kg (incl. 130 kg of batteries)</td>
<td>Weight to reach: 600 kg incl. 200 kg of batteries (reduction of 120 kg)</td>
<td>Batteries mass: 200 kg max Lighter engines, structure and system</td>
</tr>
<tr>
<td>Aircraft system</td>
<td>No redundancy or system reconfiguration</td>
<td>Combine the high requirements of reliability and security with high mass and cost constraints</td>
<td>Complex system in a constrained environment</td>
</tr>
</tbody>
</table>
ZODIAC AEROSPACE WP
ZODIAC AEROSPACE PACKAGE

1. Energy Storage Device (ESD):
   - Including cells, Battery Management System, Continuous load evaluation, packaging & assembly
   - Activities:
     - Design, prototype assembly, testing in flight and on ground for the battery charger function
     - Support AGI for the certification activities

2. High voltage electrical system:
   - High voltage distribution system (270 VDC & 350VDC)
   - Activities:
     - Design, prototype assembly and testing
     - Support AGI for the certification activities

Competencies to develop:
   - Acquire a global understanding of a full electrical A/C - (support the trade off s leaded by AGI/Socata)
   - Acquire a first experience in hpw certified a a full electrical A/C
   - Develop a battery system integrating COTS cells
CHALLENGES

**Energy Storage Device:**
1. Worldwide benchmark and selection of the Cells
2. Performances des cellules disponibles à ce jour (densité d’énergie)
3. Safety
4. Accuracy of the continuous load evaluation
5. Mechanical Integration directly in the wing box:

**High voltage electrical distribution system**
1. HVDC level
2. HVDC integration (EMI, Safety, short circuit protection)
PROPULSION CHALLENGES

- Electrical Motor
  - Mass and Performance
  - Integration
  - Cooling

- Power Electronics
  - Mass and Performances
  - Integration
  - Cooling

- Ducted Fan
  - Mass and Aero Dynamic Performances
  - Integration
  - Speed

- Nacelle
  - Mass and Aero Dynamic Performances
  - Integration
eFAN eIPS 2.0 Concept

- Reliable, Cost Improved Solution
- Low Drag Nacelle
- Advanced Aircooled Integrated Electronics and Electrical Motor
  - 2 Synchronous Brushless Electrical Motors
  - High Efficiency Distributed Power Electronics
- High Aerodynamic Efficiency Fan
- Easy Maintenance

Integration and Assembly

Project Management

FAN and Aerodynamics

Power Electronics

Nacelle

Electrical Motor

SAFRAN

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SAFRAN
Thanks for your attention

AIRBUS Group: emmanuel.joubert@airbus.com
SAFRAN: christophe.claisse@safran.com
ZODIAC: Thierry.RougeCarrassat@zodiacaerospace.com