Development of NOVA Aircraft Configurations for Large Engine Integration Studies

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Targeted architectures for UHBR

✓ Baseline
  - UHBR engine
  - Wide lifting fuselage
  - High AR wing
  - Downward oriented winglets

✓ Gull wing
  - Increased inner wing dihedral to limit landing gear length

✓ Podded
  - Engines mounted on aft fuselage side

✓ BLI
  - Engine inlet ingesting the fuselage boundary layer
NOVA
BLI configuration

✓ By embedding the engine into the fuselage, savings in fuel (due to reduced wetted area and jet/wake losses) and mass are expected

✓ **Deliberately « aggressive » design:**
  ✓ engine~40% buried
  ✓ short inlet (inlet length/fan diameter ratio~1)

When ingesting the fuselage boundary layer, the engines tend to minimize the aircraft footprint in the surrounding airflow, indicating better thrust-drag balance
Power saving VS stream-wise force

\[ PSC = \frac{P_{Podded} - P_{BLI}}{P_{Podded}} \]

5.2%
1. Introduction
   Context; why new engine integration concepts?

2. Boundary Layer Ingestion

3. Towards Distributed, Hybrid Electric Propulsion

4. Conclusions
• Links between BLI and Distributed Propulsion:
  • Efficiency $\uparrow$ with fraction of BL ingested ($D_w/D_A$)
  • Many architectures can be envisaged:

![Diagram of distributed propulsion architectures](image)

(Source: A. Steiner et al., BHL, ICASE2012)

• Distributed propulsion has additional advantages:
  • Redundancy/reconfiguration (safety)
  • Use differential thrust for control

• Links between Distributed Propulsion and (Hybrid) Electric:
  • Electric ducted fan is a enabling technology for multifan and “massively” Distributed Propulsion architectures
  • Distributed propulsion calls for separation of thrust and power production functions, making the use of hybrid energy source more natural.
Distributed Electric Propulsion studies in the AMPERE Project
Technologies and associated A/C concepts roadmap

Key technologies

- High power EDF
- Distributed propulsion
- High automation

- Med power motors
- Distributed Propulsion
- Hybrid energy
- High automation

- Low power EDF
- Distributed Propulsion
- Energy using H₂ FC
- High to full automation

- Low power EDF
- Conv. configuration
- Trad energy

- Conv. Elec. engine
- Conv. configuration
- Traditional energy

Regional Aircraft
100 seat & +

TRL8- 2011
TRL8- 2014
TRL6/7- 2020
TRL6/7- 2025 ?
TRL8- 2014
TRL8- 2020
TRL8- 2025 ?

Commercial aviation

PPlane « Fully automated »

OdM

Small Air Transport
(Single pilot operations)

APBEA
« Easy to fly »

APBEA « Easy to fly »

eFan
(Airbus Group)

TRL8- 2014

Leisure & Training

eFan 2.0 (Airbus Group)

Cri-Cri E - Cristaline

TRL8- 2011

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Objective: Increase maturity of DEP technology
- Aerodynamics of Electric Ducted Fan (EDF) integration
- A/C Control/command through EDF and conventional moving surfaces (considering potential resizing)

Means: Numerical and experimental approaches
- Aerodynamic design of EDF integration
- Wind tunnel experiments
  - L2 very low speed WT (Lille, France)
  - Powered 1:5 scale Mock-up with on the shelf components
- Control Law definition using both control surfaces and EDF
- 6DoF Simulation tool using aerodynamic model and Control law for robustness analysis and demonstration
AMPERE
Aircraft Pre-design

Estimated MTOW ~2400 kg

Example of arrangement of electrical propulsion architecture

Estimated weight of advanced power architecture (Propulsion) ~890 kg
Numerical investigation of DEP with blowing effect (2D)

Preliminary investigations

Clark Y

NACA 23012

\( h/c = 10\% \)  (\( \approx \) EDF with 40mm diameter)
\( h/c = 12.5\% \)  (\( \approx \) EDF with 50mm diameter)
Compared to
\( h/c = 4\% \)  (=reference from previous study)

Actuator disk ➔
Imposed pressure variation

Engine location sensitivity analysis

Selection criteria upon \( Cz_{\text{max}} \), stall behavior (stability and progressivity)

\[ \text{Mach} = 0.055 \text{-force= 500.0 [Pa]} \text{ alpha= 20.0} \]

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CFD RANS 2D
Numerical investigation of DEP with blowing effect (3D)

- CFD 3D computations, viscous, stationary (RANS), on a wing section with 1 EDF (which models a wing with an infinity of EDF)

- Fan modelled by an actuator disk (pressure gap)

- Guide vanes integrated into computations

- 3D effects integrated to handle «squaring the circle» issue (to go from a circle section to a square one)

\[ C_{z_{\text{max}}} = 1.2 \]

\[ C_{z_{\text{max}}} = 2.9 \]

\[ C_{z_{\text{max}}} = 4.7 \]

\[ C_{z_{\text{max}}} \text{ in 3D close to 4.7 instead of 5.7 with 2D CFD assessment} \]
Tests were ended early 2017
Analysis on going
1. **Introduction**  
   Context; why new engine integration concepts?

2. **Boundary Layer Ingestion**

3. **Towards Distributed, Hybrid Electric Propulsion**

4. **Conclusions:**  
   Future challenges of BLI and DEP
Conclusions: Main challenges of BLI

- Experimental proof of benefits in transonic conditions
- Design fan/OGV tolerant to distortion
- Aero-elastic behaviour of the fan with distortion
- Design air inlet suitable for all operating conditions (Active Flow Control)
- Impact of BLI engine integration architecture on structure and mass
- Aero-acoustic characterisation of BLI configuration
Conclusions: Main challenges of Distributed Propulsion

- Performance in transonic conditions
- Experimental proof of benefits at Low-Speed (Take-off and Landing)
- Impact of DP architecture on structure and mass

- Engine integration issues
  - Thermal aspects for large passenger Aircraft
  - Electromagnetic compatibility
Thanks for your attention.
Any questions?