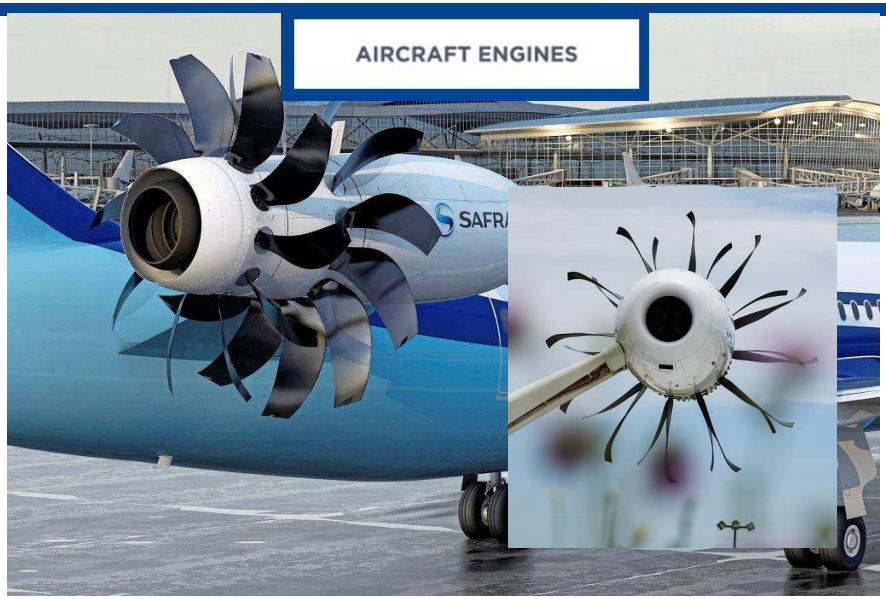

OPEN-ROTOR ENGINES

ARCHITECTURES & FULL SCALE DEMONSTRATOR BY SAFRAN

NICOLAS TANTOT, MARIO LAMBEY, ARNAUD LEBRUN, ANTHONY BINDER

SAFRAN

AEROSPACE TECHNOLOGY CONGRESS 2019
SUSTAINABLE AEROSPACE INNOVATION IN A GLOBALISED WORLD
STOCKHOLM WATERFRONT CONGRESS CENTRE, 8-9 OCT 2019

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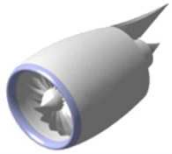
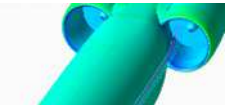
NG Propulsion – 4D Technology Watch





Unducted — Ducted — Embedded

Not electrified — Fully electrified

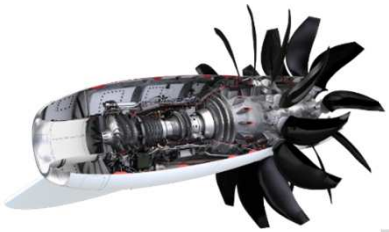
Conventional cycle — Unconventional cycle

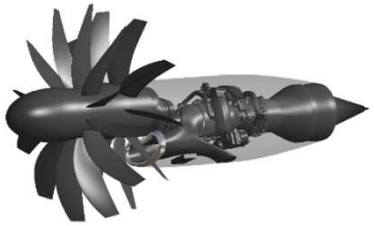
Conventional fuel — Unconventional fuel

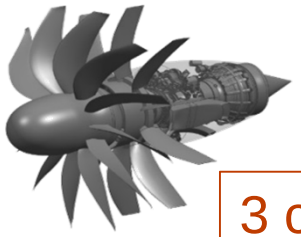
More efficient engine required

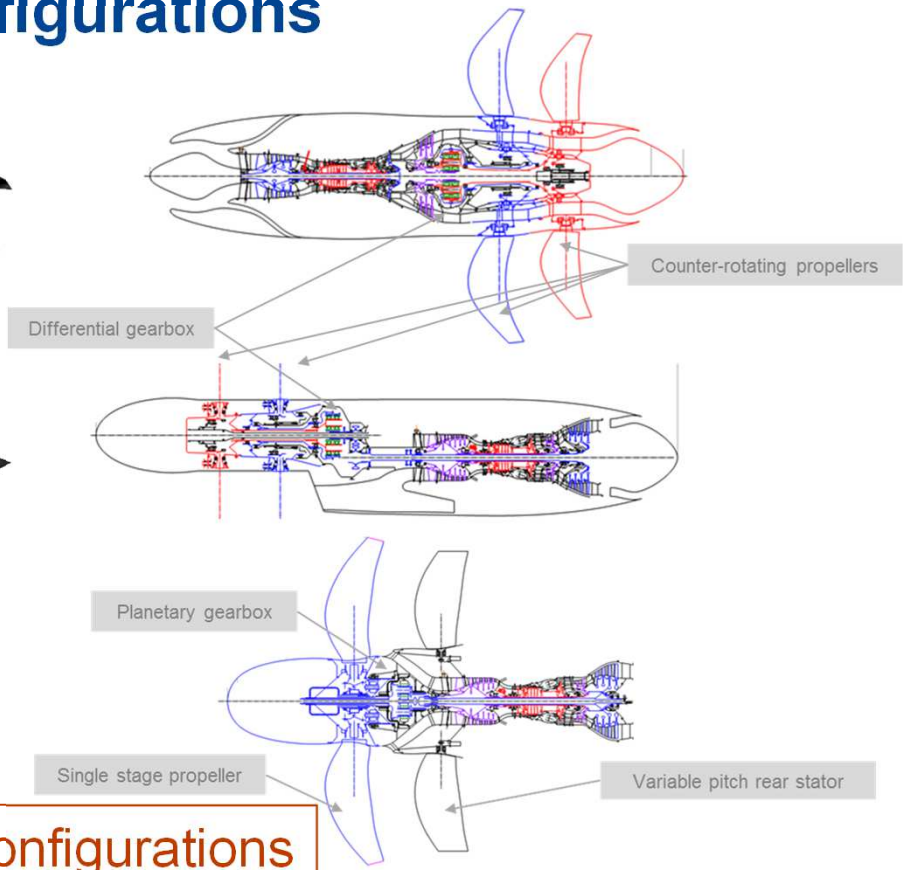
Open-Rotor Engines – Configurations

Counter rotating propellers (CROR, UDF)	Pusher config.
	Puller config.
Recovery vane (ORAS, USF)	Puller config.



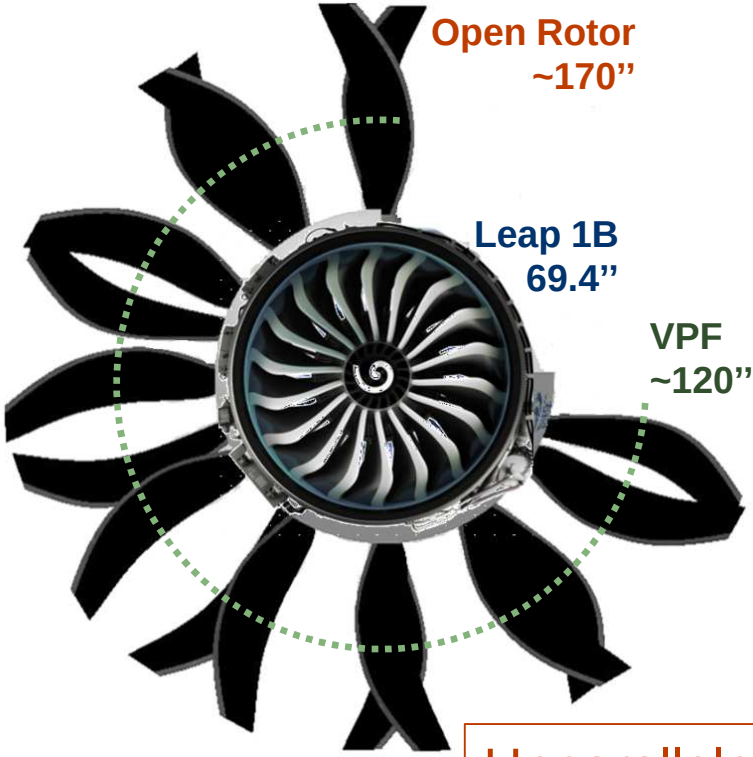


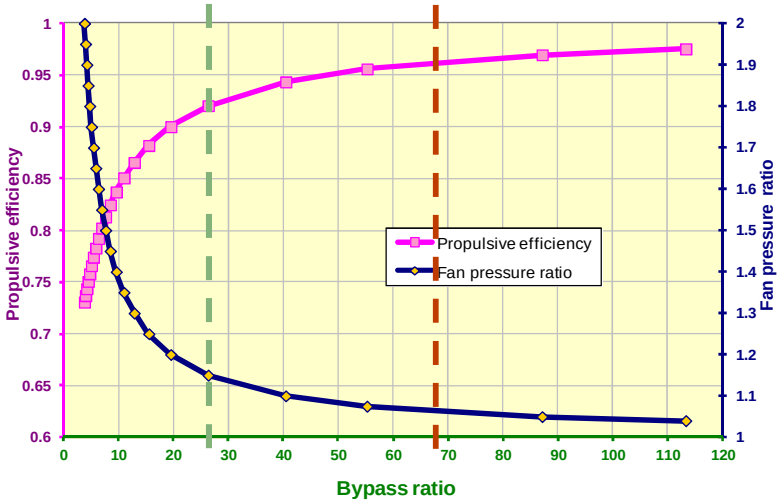




3 configurations

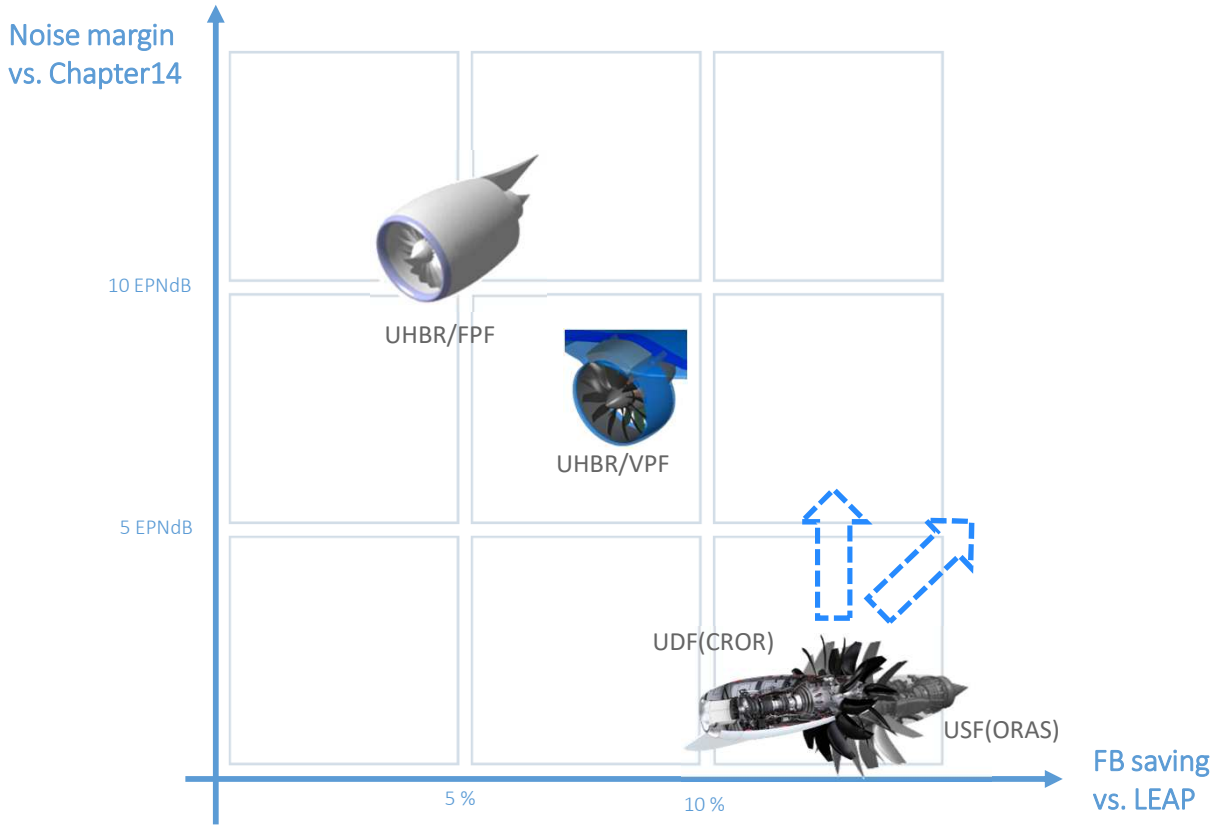
Open-Rotor Engines – Distinctive Features



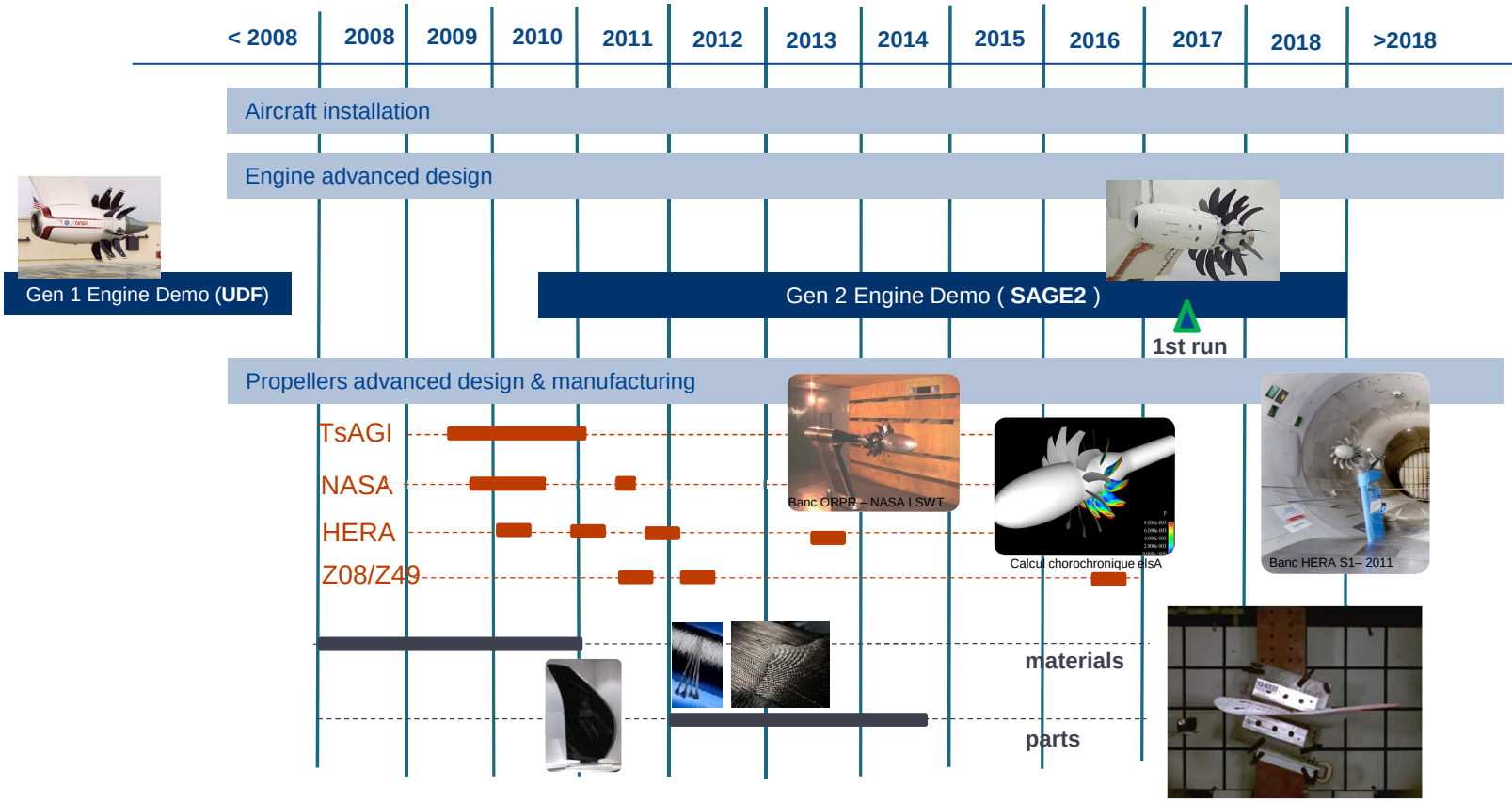


Unparalleled SFC

Open-Rotor Engines – A/C Noise vs. A/C Fuel Burn



Open-Rotor Engines – Engine & Propellers Maturation Plan



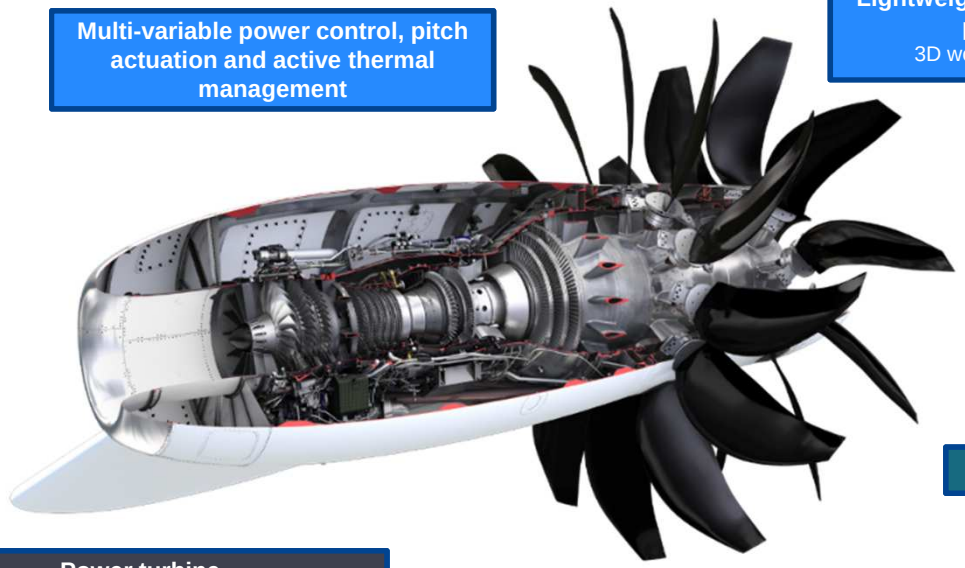
Open-Rotor Engines – SAGE2 Demonstration (1/3)

❑ On board, key technologies

Multi-variable power control, pitch actuation and active thermal management

Lightweight counter-rotating propellers
3D woven carbon fibre

Propellers Pitch Control System



Lightweight front and rear rotating frames

Rotating nacelle cowls

Power turbine

Differential power gearbox
(1 input, 2 outputs)
Reduction ratio: 8
Power: 14MW

Clean Sky

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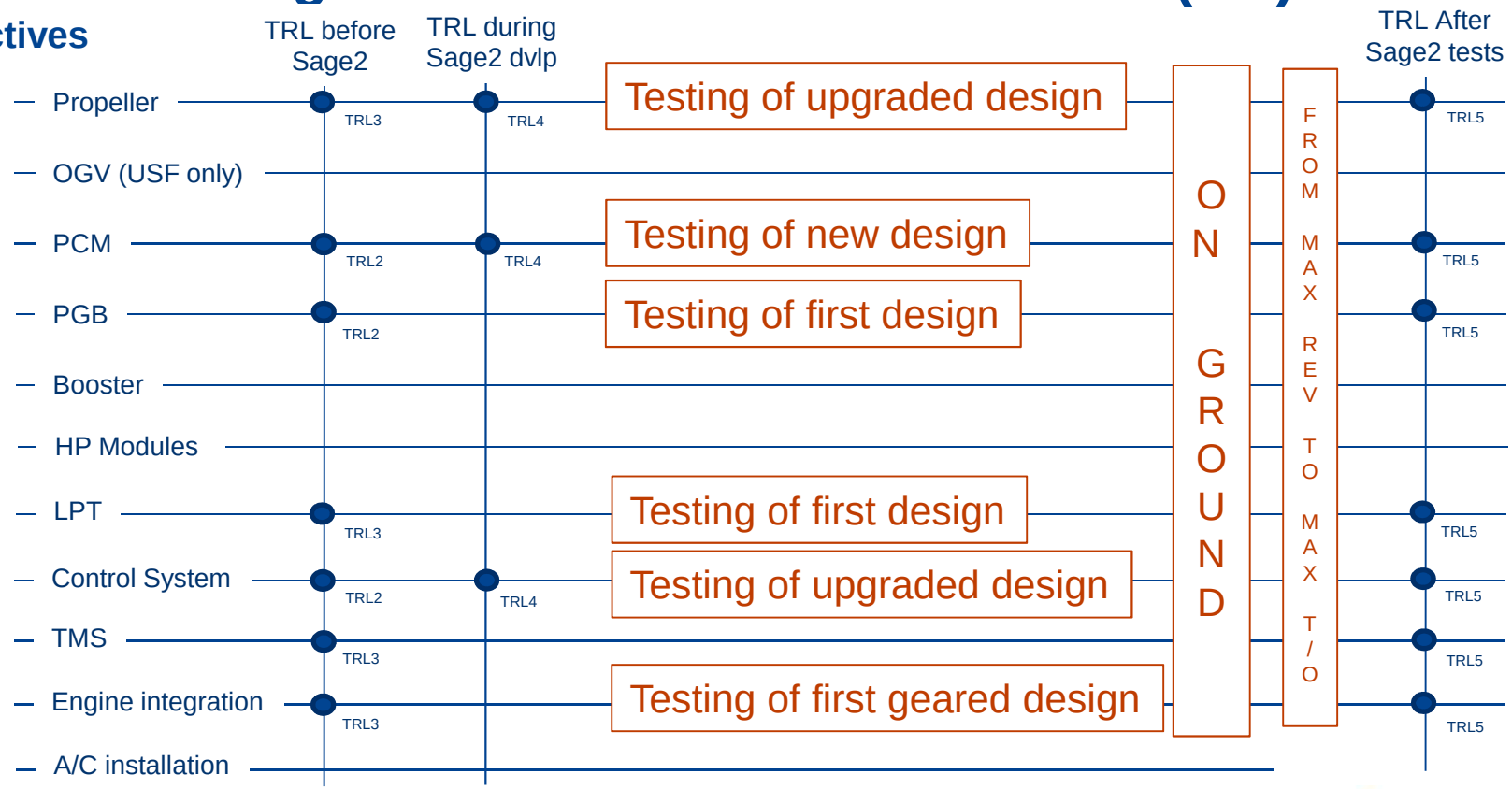
Open-Rotor Engines – SAGE2 Demonstration (2/3)

❑ Objectives



Open-Rotor Engines – SAGE2 Demonstration (3/3)

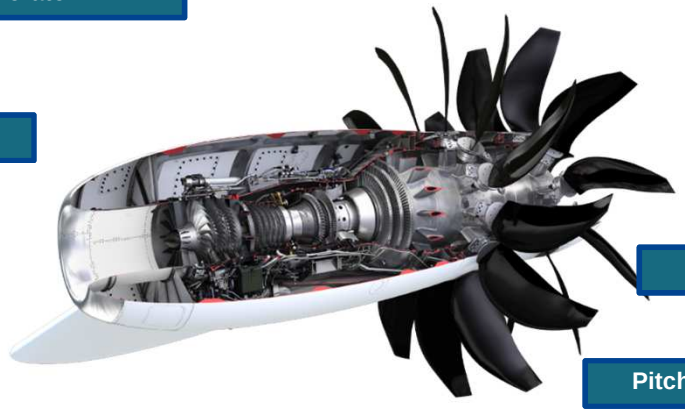
Test campaign

- At SAE Flight Test Center (Istres, south of France)
- Engine installed on bench: 27 March 2017
- First engine start: 30 May 2017
- Last test: 13 December 2017
- 100+ starts
- 70+ hrs of running
- All ratings achieved, MaxRev included
- Operating limits explored
- Fast transient operation executed
- Propulsor vibrations survey, propellers aero mapping, …performed

Test program executed

Open-Rotor Engines – Post SAGE2 Maturation Activities

- Additional/more stringent requirements to comply with
- Design & manufacturing to optimize



Noise: cabin & community

Bird ingestion

Weight

De-icing

Gas generator

Other certification requirements

Power Turbine

Power gearbox

Maintainability

Thermal management system

Propellers

Control system

Installation on aircraft

Pitch control mechanism

Sizing loads

Pylon blowing

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Open-Rotor Engines – Status & Way Forward

- **New propulsion solutions required for more environment friendly air transportation**
- **Open rotor engine configuration being the only one having a double digit fuel burn reduction potential**
- **Great potential confirmed by gradual architecture & technology maturation by Safran**
  - Key technologies matured up to expected level
  - Integration of this architecture validated
  - Compliance with Chapter 14 ICAO regulation achieved

- **R&T effort by Safran on Open rotor engine still on-going**
  - Including electric hybridization & fuel change

Appendix – Glossary

- CROR: Counter-Rotating Open-Rotor
- FPF: Fixed Pitch Fan
- HP: High Pressure
- OGV: Outlet Guide Vane
- ORAS: Open Rotor And Stator
- PGB: Power Gear-Box
- PCM: Pitch Control Mechanism
- SAGE: Sustainable And Green Engine
- TMS: Thermal Management System
- UDF: Un-Ducted Fan
- UHBR: Ultra High By-pass Ratio
- USF: Unducted Single Fan
- VPF: Variable Pitch Fan

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