ENGINE Demonstration Programmes in Clean Sky & Clean Sky 2

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SAGE & ENGINES ITD Project Officer

1. Open-Rotor Architectures
   - CS1-SAGE1 – RRUK
   - CS1-SAGE2 – SNECMA
   - CS2-LPA-(ENG-WP1) - SNECMA

2. Large VHBR Turbofans Architectures – LR Aircraft
   - CS1-SAGE3 – RRUK
   - CS1-SAGE6 – RRUK (Lean Burn)
   - CS2-ENG-WP5 – RRUK
   - CS2-ENG-WP6 – RRUK

3. VHBR Turbofans – SMR Aircraft
   - CS2-ENG-WP2 – SNECMA - UHPE

4. Geared Turbofans – SMR Aircraft
   - CS1-SAGE4 – MTU
   - CS2-ENG-WP4 – MTU

5. Turboshaft Engines - Helicopters
   - CS1-SAGE5 - TURBOMECA

6. TurboProp Engines – Regional/SAT
   - CS2-ENG-WP3 TURBOMECA
   - CS2-ENG-WP8 GE Avio

7. Small Piston Engines – Small Air Transport (SAT)
   - CS2-ENG-WP7 - SMA
1. Open Rotor Architectures
Objective: to build and ground test a full-scale Geared Pusher Open Rotor engine

Main benefit of the Open Rotor concept:
30% CO2 emissions reduction compared to the CFM56®* engine

Open Rotor GTD will run in 2016 on a brand new Safran Open Air Test Bench.

* CFM56 engines are a product of CFM International, a 50/50 joint company between Snecma (Safran) and GE.
• Flight Test Demonstrator Contra rotating Open Rotor for SMR aircraft: a breakthrough to reach the optimal performance

Top objectives

Performance

Architecture & Technologies

Aircraft/Propulsion System Integration

Data Exploitation

Snecma proprietary data
2. Large Turbofan Architectures
Delivered both Ground and Flight Tests

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Environmental targets (wrt reference)</th>
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<tbody>
<tr>
<td></td>
<td>CO2 [%]</td>
</tr>
<tr>
<td>Composite fan system</td>
<td>-1 to -3</td>
</tr>
<tr>
<td>Advanced integrated externals</td>
<td>-0.5 to -1.5</td>
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<tr>
<td>Low weight low pressure turbine</td>
<td>-1 to -2</td>
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A wealth of Hardware delivered through the Rolls-Royce led SAGE 3 – Advanced Low Pressure System engine programme
CS1 – SAGE6 – Rolls-Royce

**NO\textsubscript{x} Emissions Targets**

- NOx LTO <40% CAEP6
- Cruise EINOx <12g/kg

**Advanced/Active Control System**

Hardware being delivered for both Ground and Flight Tests of the Advanced Low Emissions Combustion System Engine programme

2016 to deliver both Ground and Flight Tests
Aim: System integration and delivery of whole-engine demonstration through ground and flight-based testing

Building on the success of the ALPS Engine from Clean Sky SAGE 3

Advance3 Core for the UltraFan™ Demonstration planned for 2016

- Efficiency relative to Trent 700: 20%+
- ByPass Ratio: 15+

Rolls-Royce Ultrafan™ Demonstrator Planned EIS 2025+

Enabling Technologies
- Lightweight Externals
- Lightweight High Efficiency Compressors
- Lightweight High Efficiency Turbines
- Powergear box
- Lightweight Cti Fan blades
- Control, EHM & Systems Integration
- Lean Burn Combustor
- Advance Core Architecture
- Optimised Powerplant & Nacelles
- Composite Containment Casing

Demonstrators
3. VHBR Turbofans
Ultra High Propulsive Efficiency for SMR aircraft: towards enhanced performance

Main Technology Objectives
- to validate LP modules & nacelle technologies

Key Technologies
- Low pressure ratio fan / variable area fan nozzle
- Low weight / low drag fixed or rotating structures and nacelle.
- High power gear box
- High efficiency LP turbine & LP compressor
- Engine / aircraft specific integration

Potential Partner participation:
- Fixed structures in propulsive system, low pressure turbine components, controls and systems components, shafts, bearings

Snecma proprietary data
4. Geared Turbofans
Clean Sky SAGE 4 Demonstrator is ready to test ...

Compressor Technology
- Surface treatment
  - Erosion protection
- New Materials (CFRP)
- Additive Manufacturing
- New measurement methods

Turbine Technology
- Improved outer cavity design
- Advanced case design
- New IAS designs
- Smart ACC
- Optimized airfoil shape
- Improved trim balancing
- Frequency mistuned airfoils
- CMC segments
- TiAl blade technology

Avio Aero
- Integrated Drive System Technology
tested on a specific transmission test bench

All-electric VGV-Aktuator (SENER)

MTU

Life lightweight TEC

dB Acoustic liner
Future Geared Fan Engines

Performance Parameters

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<tr>
<th>η</th>
<th>lb</th>
<th>Life</th>
<th>€</th>
<th>dB</th>
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Clean Sky 2 Notional Engine Concept

<table>
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<tr>
<th>BPR</th>
<th>OPR</th>
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<tr>
<td>14-20</td>
<td>60+</td>
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Source: ENOVAL

Clean Sky 2
Advanced Technology Projects

Compression System

Expansion System

Design Materials Manufacturing

Proof of technology maturity in Clean Sky 2 validation vehicles

2 shaft compressor rig

Engine demonstrator

Clean Sky Joint Undertaking
5. Turboshift Engines
CS1 – SAGE5 – Turbomeca

- **Design a totally new core engine called** for 800-1000 kW range allowing to:
  - Reduce by 15% Fuel Consumption
  - Reduce overall dimension and weight
  - Highlight possible production and maintenance cost reduction axis

- **SAGE 5 demonstrates new technologies for compressor, combustor, HP turbine, LP turbine and innovative architecture through**:
  - partial testing campaign of innovative technologies separately
  - Core engine demonstrator

- **Reach a TRL level 6 for each technology**

Turboshaft engine development → full-scale engine demonstration

- Project launch
  - 1 Sept 2009

- Preliminary DR
  - Feb. 2010

- Engine test
  - Feb 2013

- Critical DR
  - July 2011

- Demo spec.
- Prelim. design
- Partner selection
- Detail design
- Manufacture
- Build and test

15% Fuel consumption reduction demonstrated
6. Turboprop Engines
• Ground demonstration of a full Integrated Power Plant System
  – Including Air Intake & nacelle
  – Taking advantage of the FADEC for enhanced system controls capabilities

• The core generator is derived from the ARDIDEN 3 Turboshaft engine
  – Engine adaptations will be studied for matching TP usage

• New propeller and Power Gear Box will be designed
Integrated Collaborative Partnership to Strengthen European Competitiveness in Small Air Transport Turboprop Engines Market

High Level Objectives (vs 2014 ref. engine)

+ 15% Fuel Efficiency
- 10% Total Operating Costs
- 10 dB Noise Reduction (contrib.)

Sub-systems Technology Development and Validation on

- Advanced Core with High OPR
- Low Re Turbine Design
- Integrated Low Noise Propulsive System
- Affordable Low Emission Combustor
7. Small Piston Engines
Light weight and efficient Jet-fueled reciprocating engine (200-350 kW)

1. Engine power density challenge
   a. Improvement of existing architectures & manufacturing (WP7.1.1)
   b. Research for breakthrough technologies - Target 2.5 kW/kg (WP7.1.4)
   c. Turbocharger - Key equipment (WP7.1.2)

2. Powerplant optimization
   a. Propeller for compression ignition engine (WP7.1.3)
   b. Aircraft engine installation / heat exchangers (WP7.1.5)
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Thank You for your Attention