Clean Sky

Innovation Takes Off

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Clean Sky 2

European Research in Aeronautics - the Clean Sky Joint Undertaking

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Manchester, UK.

Innovation Takes Off

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Clean Sky 2

Introduction

Europe's largest Aeronautics Research Programme

- One of 6 EC Joint Technology Initiatives: **Public-Private Partnership** (PPP) in terms of funding and governance.

- **Clean Sky 1** started in 2008 under FP7, up to 2017;
- continuation decision in 2014 for **Clean Sky 2** under H2020, to 2024
- ***Clean Sky 1:*** **1.6 Bn€ budget / 800 M€ funding / 200 M€ for CfPs**
- ***Clean Sky 2:*** **4.0 Bn€ budget/ 1.8 Bn€ funding / 550 M€ for CfPs**
- Programme managed by a dedicated body: the "Joint Undertaking"

Outline

- Part I -

… a “Joint Undertaking” …

- Part II -

The Research Programme
Clean Sky 1 and Clean Sky 2 Technologies

- Part III -

Clean Sky 3 ?

Outline

- Part I -

… a "***Joint*** Undertaking" …

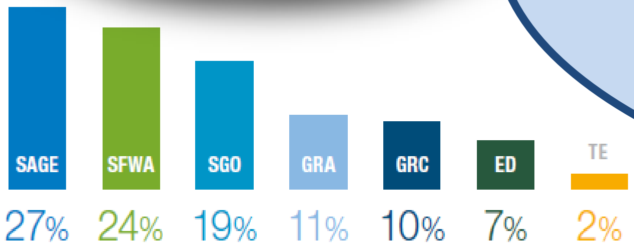
… a ***Joint*** Technology Initiative …

… a Public-Private ***Partnerschip*** …

Clean Sky : the European Aviation Partnership

Public Private Partnership
2008 - 2017

800 M€ Total EU Funding → 1.6 B€ total cost



> 500 Partners through Open Calls

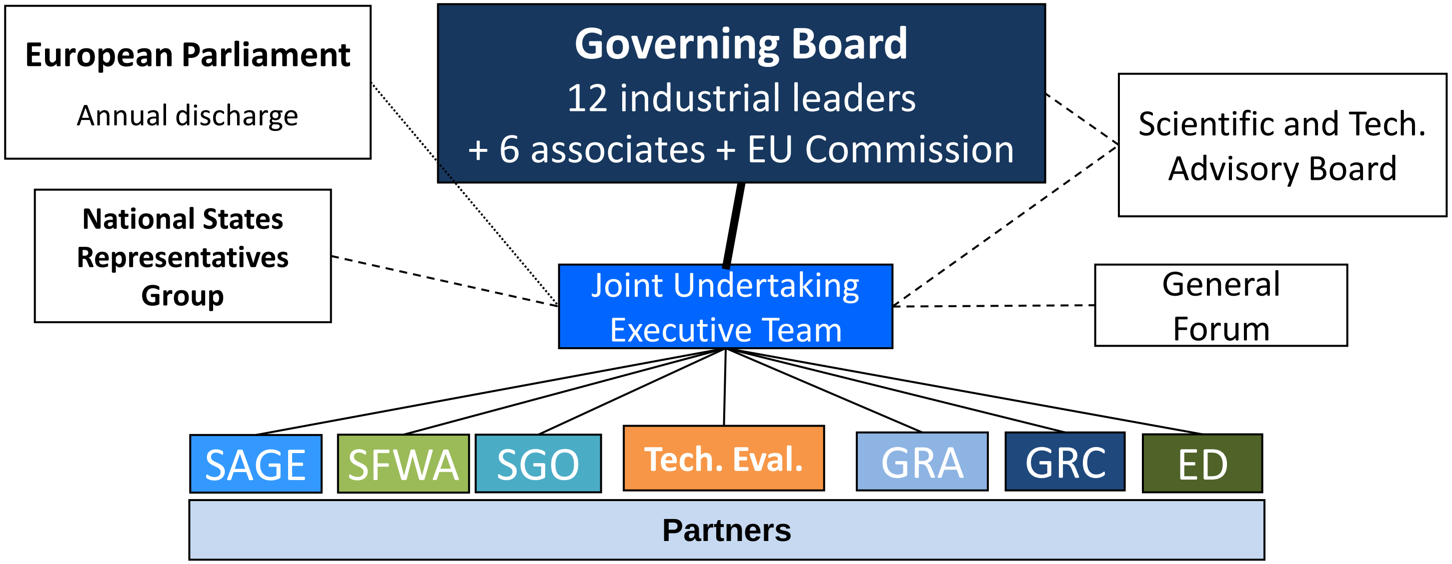
65 Associates

12 ITD Leaders

Up to 50%

Up to 25%

Not less than 25%



European Parliament
Annual discharge

Governing Board
12 industrial leaders
+ 6 associates + EU Commission

Scientific and Tech. Advisory Board

National States Representatives Group

Joint Undertaking Executive Team

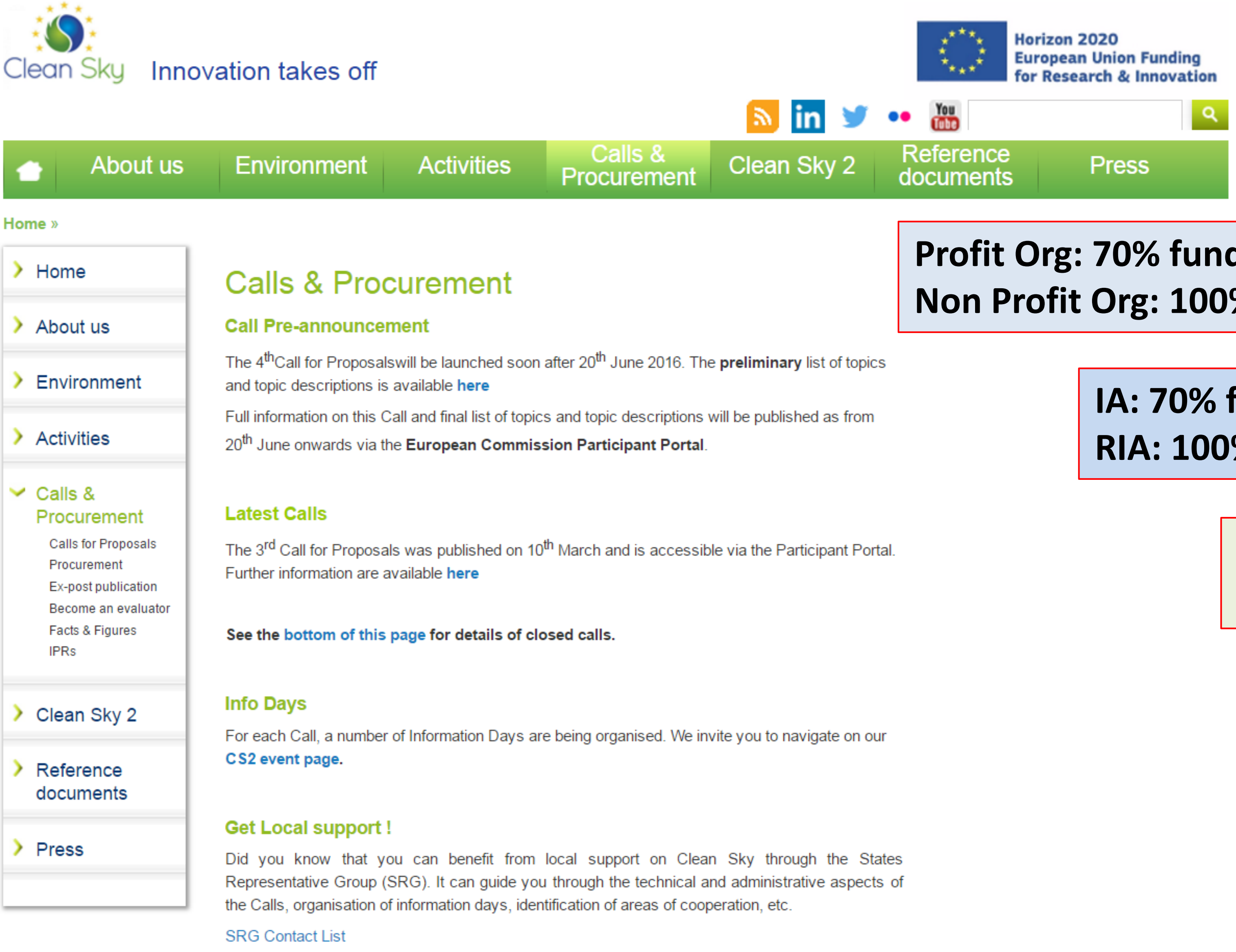
General Forum

SAGE | SFWA | SGO | **Tech. Eval.** | GRA | GRC | ED

Partners

~ 600 participants (members + partners) to date

Clean Sky / Clean Sky 2 Open Calls



Calls & Procurement

Call Pre-announcement

The 4thCall for Proposalswill be launched soon after 20th June 2016. The **preliminary** list of topics and topic descriptions is available **here**

Full information on this Call and final list of topics and topic descriptions will be published as from 20th June onwards via the **European Commission Participant Portal**.

Latest Calls

The 3rd Call for Proposals was published on 10th March and is accessible via the Participant Portal. Further information are available **here**

See the bottom of this page for details of closed calls.

Info Days

For each Call, a number of Information Days are being organised. We invite you to navigate on our **CS2 event page**.

Get Local support !

Did you know that you can benefit from local support on Clean Sky through the States Representative Group (SRG). It can guide you through the technical and administrative aspects of the Calls, organisation of information days, identification of areas of cooperation, etc.

SRG Contact List

Profit Org: 70% funding rate
Non Profit Org: 100% funding rate

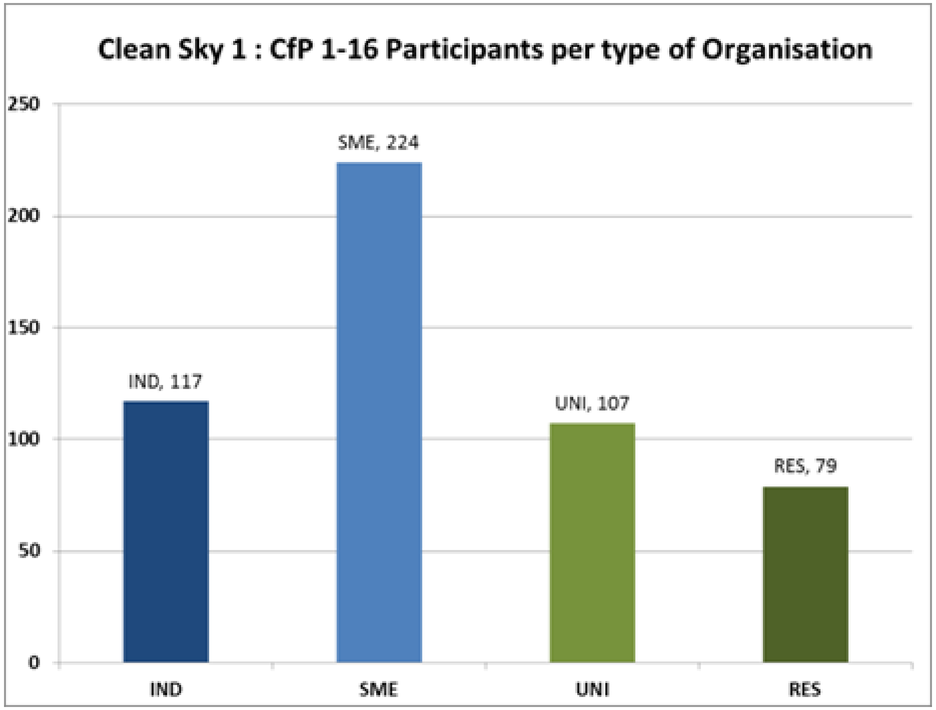
IA: 70% funding rate
RIA: 100% funding rate

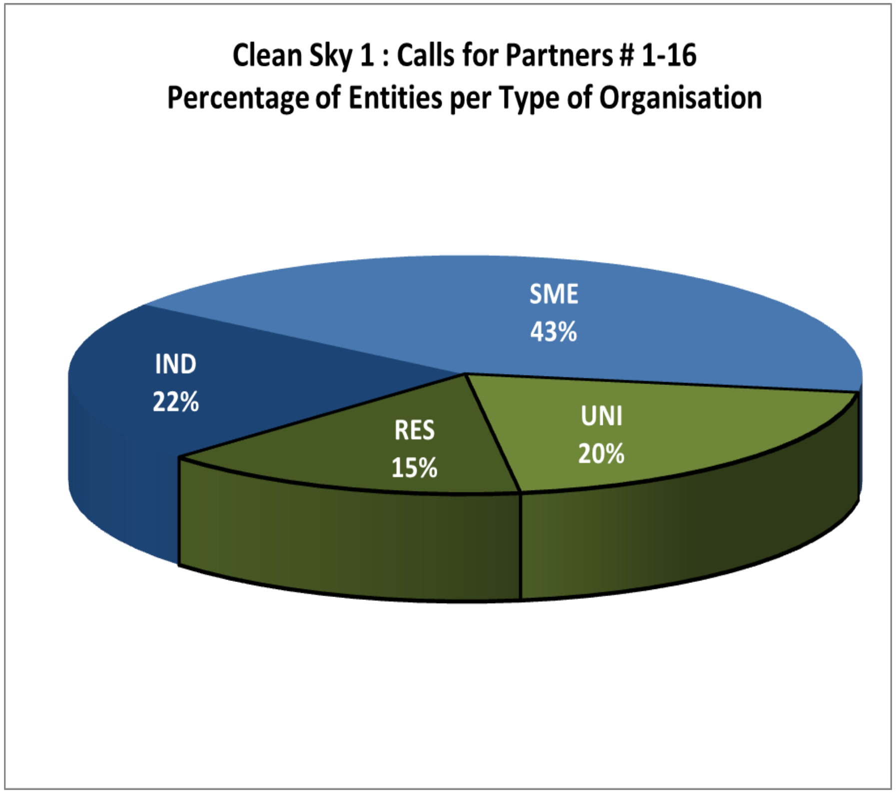
25% Flat Rate for Overheads

Facts & Figures – Clean Sky 1

SMEs, Academia and RTOs (Research and Technology Organisations)

Statistics over 16 CfP Calls :





- Academia and Research Centers obtained 35% of participation,

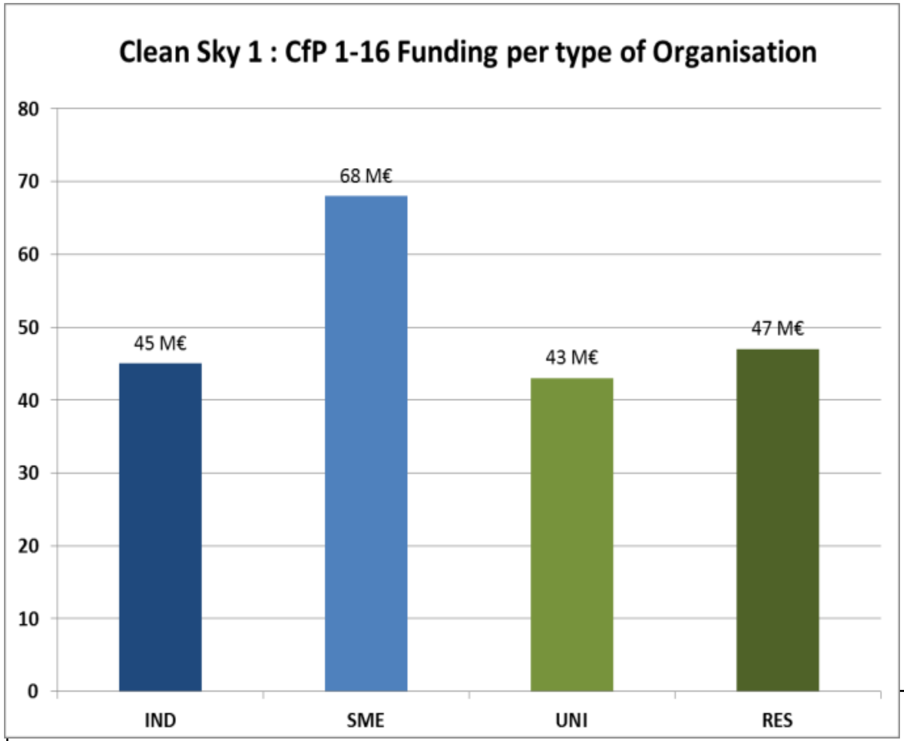
i.e. 107 Universities and 79 Res. Centers, sometimes involved in several different projects.

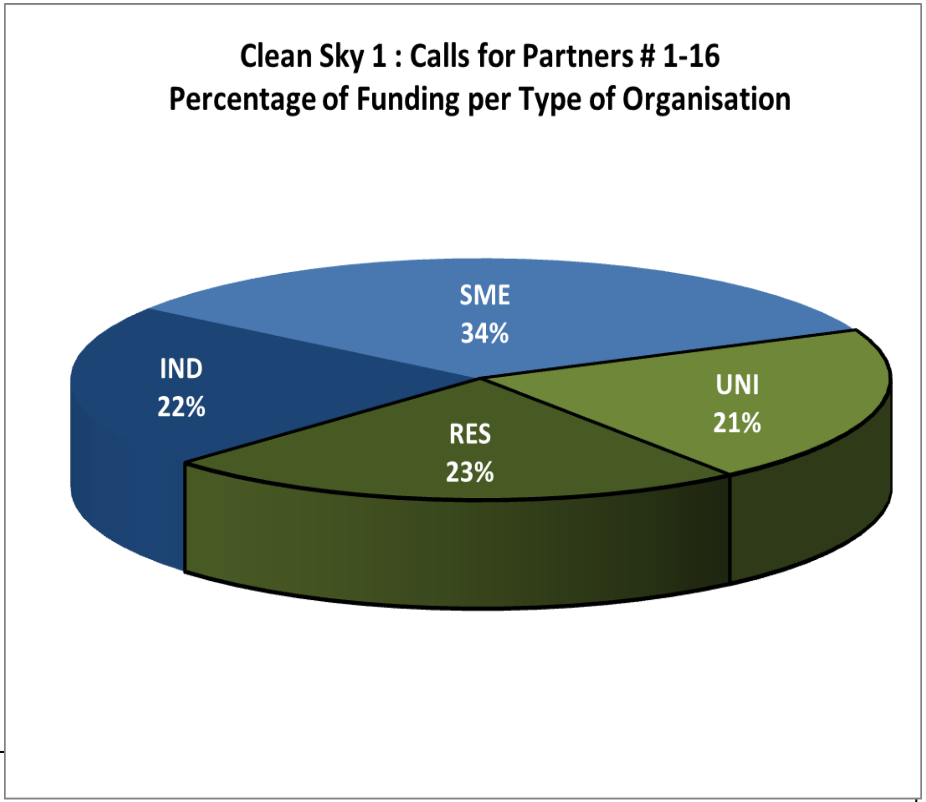
- SME’s obtained 43% of participation.

Facts & Figures – Clean Sky 1

SMEs, Academia and RTOs (Research and Technology Organisations)

Statistics over 16 CfP Calls :

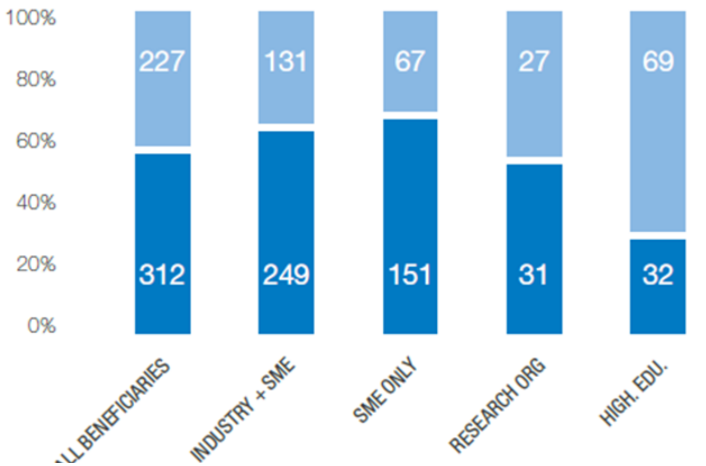




- **Academia and Research Centers obtained 90 M€**, i.e. 44%, twice the funding received by IND.
- **SME**’s obtained 68 M€, i.e. 34%.
- The overall funding of the 16 Calls for Proposals calls was **203 M€ - 482 Projects**

Facts & Figures – Clean Sky 1

New beneficiaries in Clean Sky



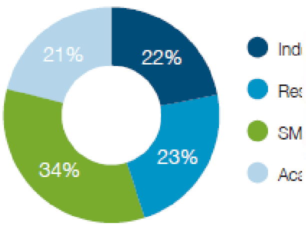
Number of Calls	Eligible Proposals	Funded projects	Average Project value
16	1519	482	€600 000

Average Funding Rate : 69%

Success rate of applicants : 32 %

Distribution of Funding for Partners

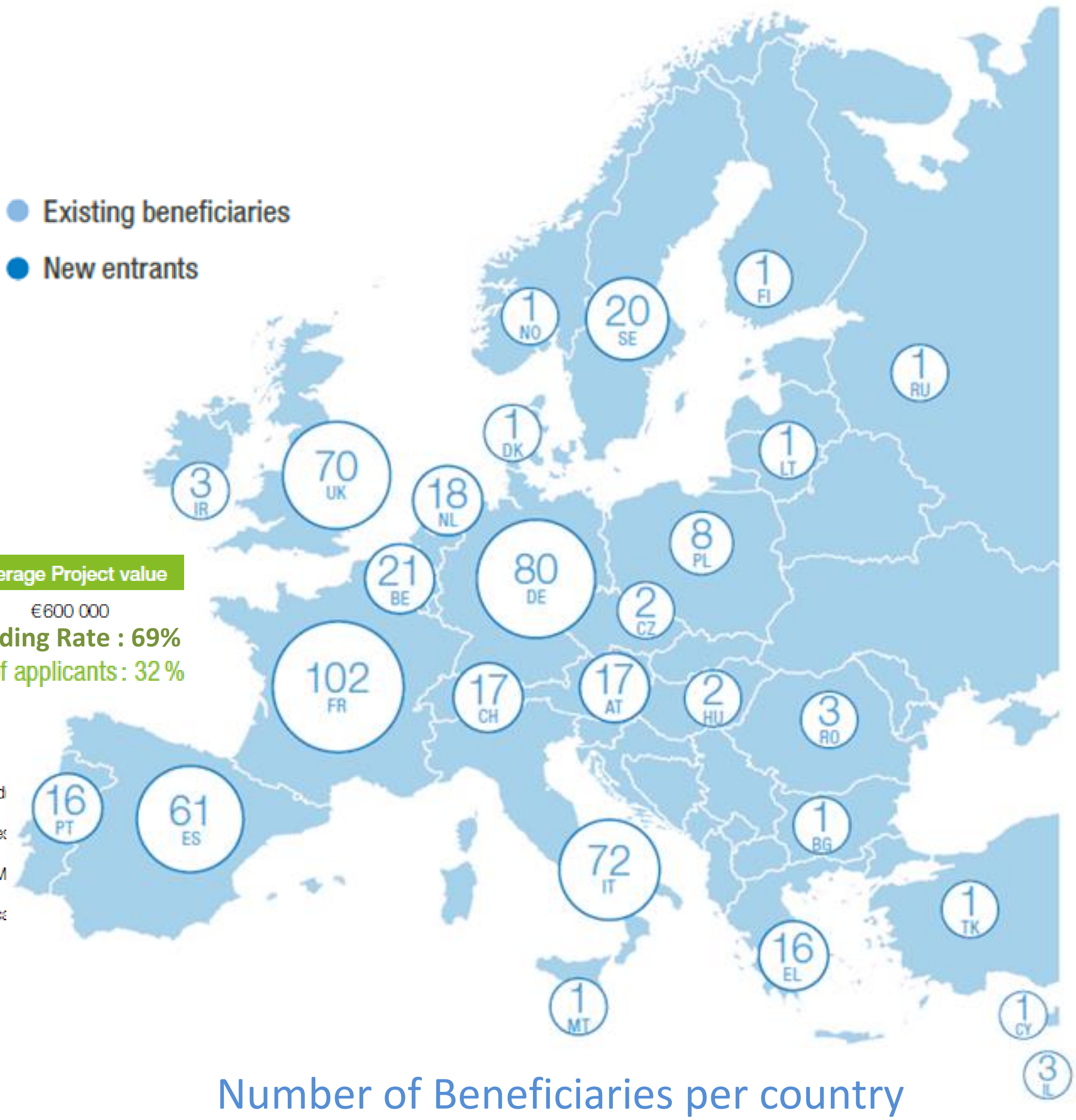
Applying as a single entity is possible under Clean Sky rules. This was the case for 41% of the funded projects. The maximum funding rate for Partners ranges from 50% up to 75% of project value, depending on the participant category (for example, SMEs, research centres and academia are eligible for 75%).



SME Statistics

SMEs are actively involved in Clean Sky through Calls for Partners (CfPs)

SMEs CfPs funding share	34%
SME average size of topics	600 k€
SME % of mono-beneficiary	41%



Number of Beneficiaries per country

Clean Sky 2

- Up to 40% of EU funding available for CS2 Leaders
- **At least 60% of EU funding open to competition:**

  Up to 30% for Core Partners (becoming Members once selected)

  At least 30% for CfP (i.e. *Partners* as in CS) plus CfTs : ~ 550 M€
- **Meaning >1bn€ of EU funding in play, via open Calls**

Industry, SMEs, Academia, and Research Organizations eligible both for participation as Core Partners or Partners.
Participation may also take place via suitable Clusters / Consortia.

800 - 1000 Participants expected across all tiers of the industrial supply chain and “R&I Chain”, with large investment leverage effect

Clean Sky 2 leaders

AIRBUS AN EADS COMPANY
AIRBUS HELICOPTERS
AgustaWestland A Finmeccanica Company
Alenia Aermacchi A Finmeccanica Company
DASSAULT AVIATION
DLR
AIRBUS DEFENCE & SPACE
evektor
Fraunhofer
LIEBHERR
MTU Aero Engines
PIAGGIO AERO
Rolls-Royce
SAFRAN AEROSPACE·DEFENCE·SECURITY
SAAB
THALES

- 175 Core Partners (incl. Aff. and Third Parties) after CPW01-04 (67 Projects)

- CS2DP: 549m€ in total for Partners
- CfP01-06: 279m€ launched, 243m€ granted, 202 Projects, more than 400 Partners
- CfP07-11: 306m€ available until 2020 (1 call per year)
- (246m€ for industrial/demonstration (demonstrator linked) topics, 60m€ for Thematic Topics)

Clean Sky JOINT UNDERTAKING

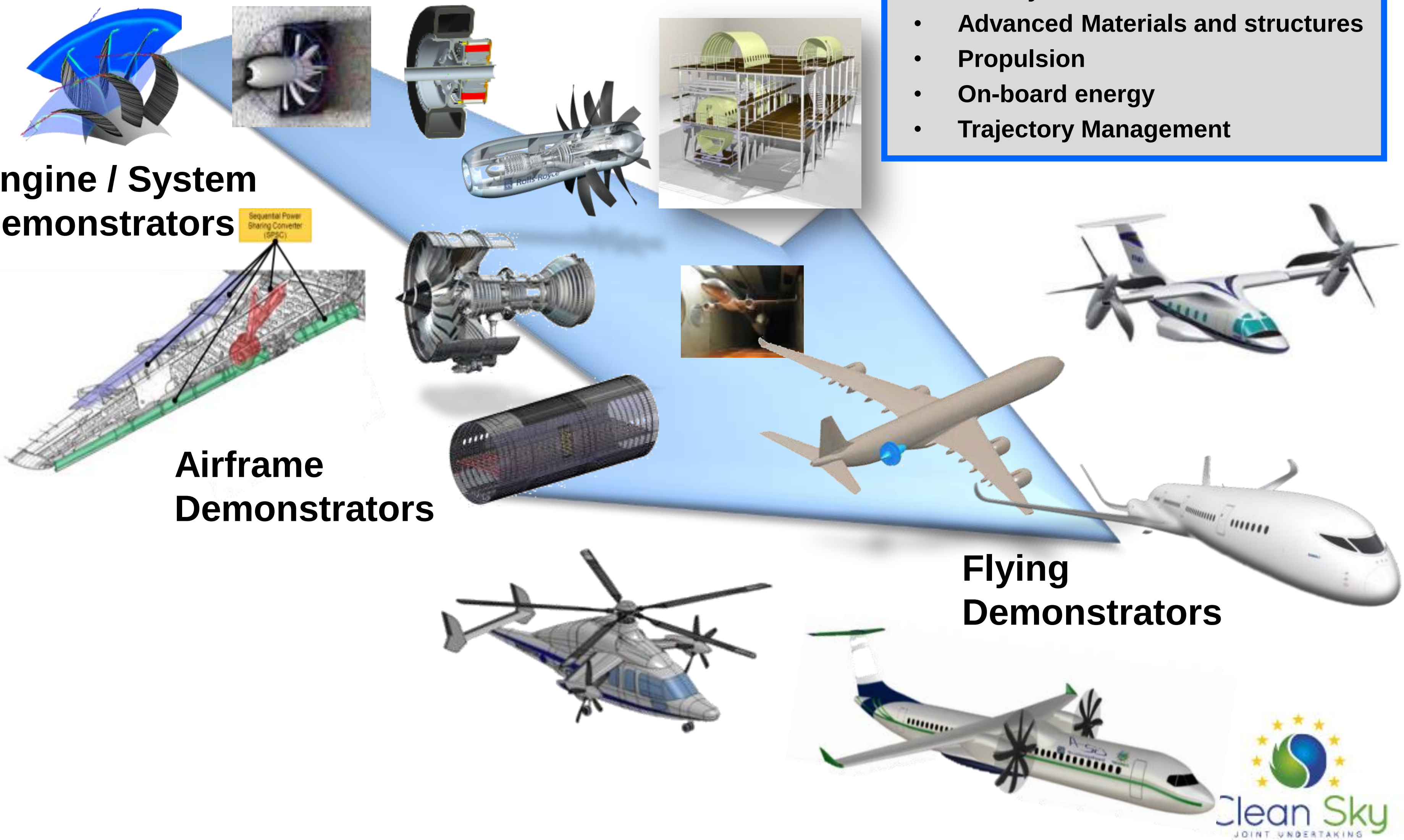
Outline

- Part II -

… Integrating breakthrough Technologies
Up to full scale Demonstrators …

Clean Sky 1 & Clean Sky 2

Taking Technology to Full-Scale Demonstration



Design Studies, Rig Testing, Modelling

- Aerodynamics
- Advanced Materials and structures
- Propulsion
- On-board energy
- Trajectory Management

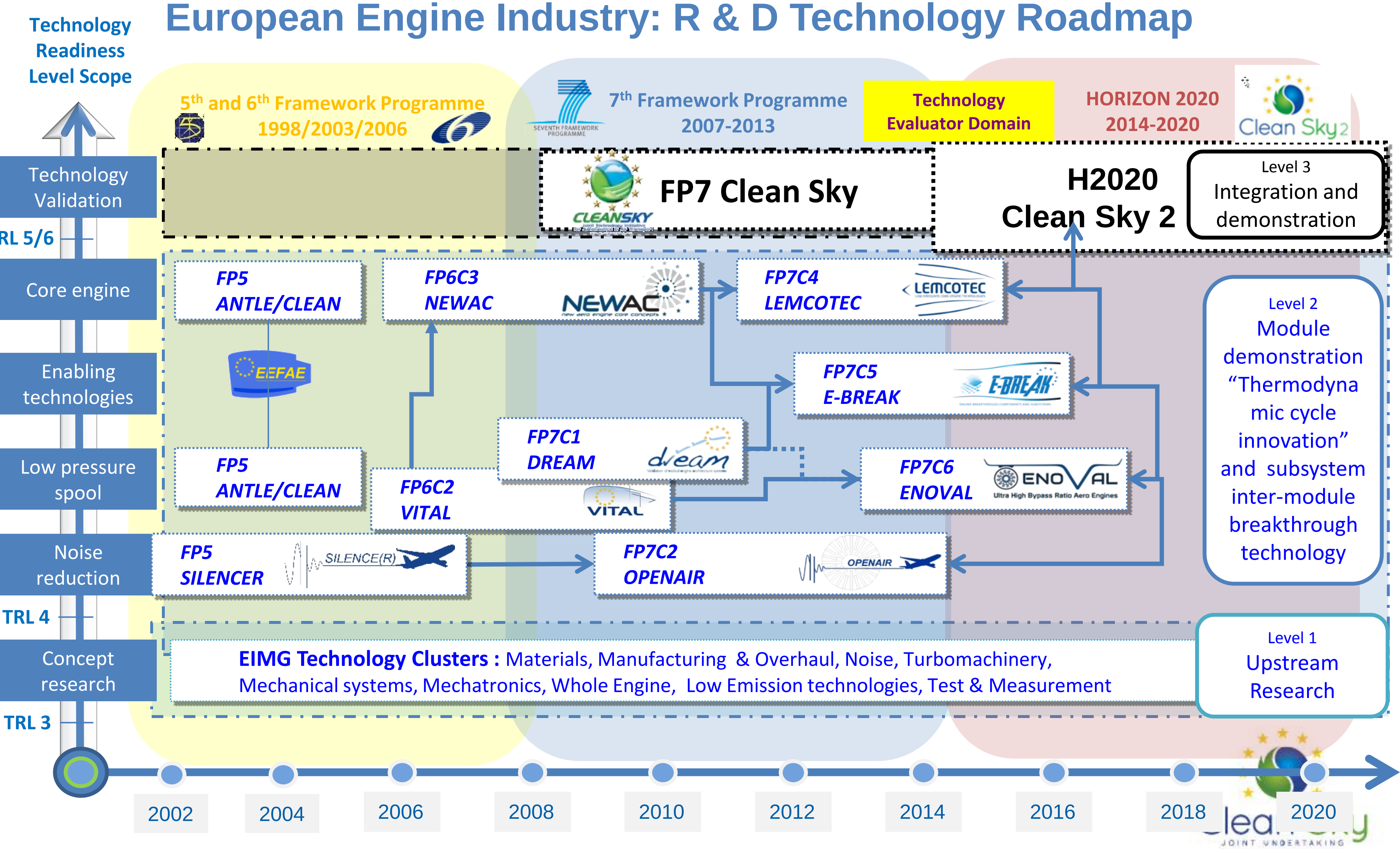
Engine / System Demonstrators

Airframe Demonstrators

Flying Demonstrators

Technology Roadmap example: Engine Technologies

European Engine Industry: R & D Technology Roadmap



Technology Readiness Level Scope

- Technology Validation
- TRL 5/6
- Core engine
- Enabling technologies
- Low pressure spool
- Noise reduction
- TRL 4
- Concept research
- TRL 3

5th and 6th Framework Programme 1998/2003/2006

7th Framework Programme 2007-2013

Technology Evaluator Domain

HORIZON 2020 2014-2020

FP7 Clean Sky

H2020 Clean Sky 2

Level 3
Integration and demonstration

FP5 ANTLE/CLEAN

FP6C3 NEWAC

FP7C4 LEMCOTEC

EEFAE

FP7C5 E-BREAK

FP7C1 DREAM

FP5 ANTLE/CLEAN

FP6C2 VITAL

FP7C6 ENOVAL

FP5 SILENCER

FP7C2 OPENAIR

Level 2
Module demonstration "Thermodynamic cycle innovation" and subsystem inter-module breakthrough technology

EIMG Technology Clusters : Materials, Manufacturing & Overhaul, Noise, Turbomachinery, Mechanical systems, Mechatronics, Whole Engine, Low Emission technologies, Test & Measurement

Level 1
Upstream Research

Outline

- Part II -

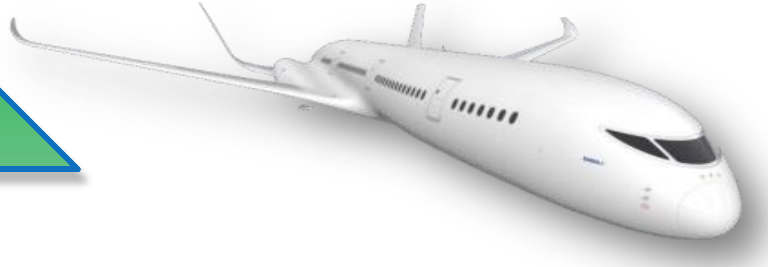
… Integrating breakthrough Technologies
Up to full scale Demonstrators …

- **Environmental Objectives**
- **Programme Structure**
- **Technologies and Demonstrators**
- **Assessment : the Technology Evaluator**

ACARE 2020 / 2050 Environmental targets

Reduce perceived external noise by

- 50% by 2020
- 65% by 2050



Reduce NO_X emissions by

- 80% by 2020
- 90% by 2050

Important Trade-offs for all stakeholders

Reduce fuel consumption and CO_2 emissions by

- 50% by 2020
- 75% by 2050

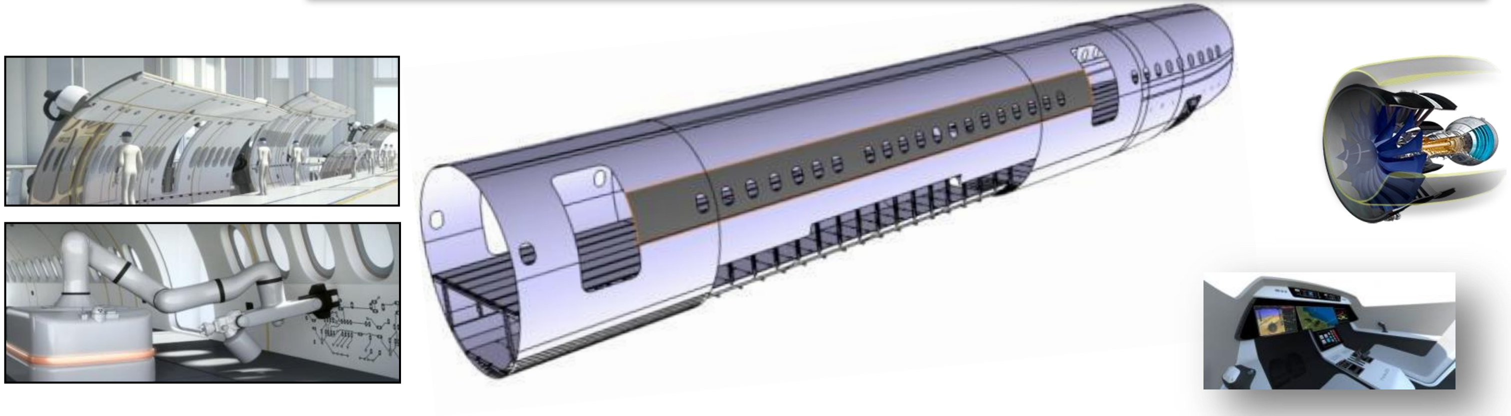
Vision 2020 and Flightpath 2050 targets are for new aircraft technology relative to 2000 performance

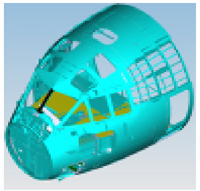
Addressing H2020 Transport Challenge Areas

Energy Efficiency & Environment

Enabling Safe & Seamless Mobility

Building industrial leadership in Europe





Clean Sky
JOINT UNDERTAKING

Outline

- Part II -

… Integrating breakthrough Technologies
Up to full scale Demonstrators …

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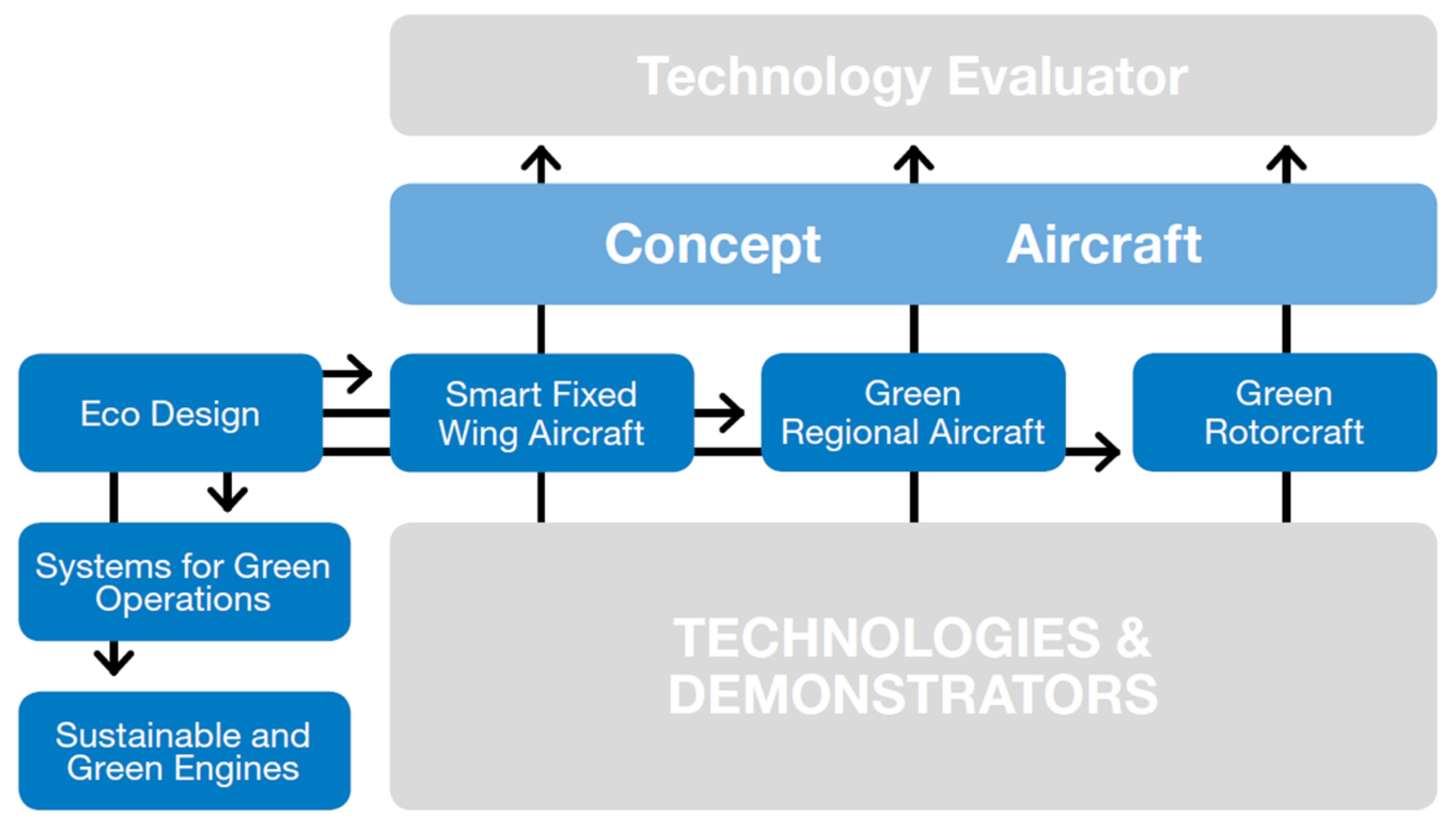
- **Programme Structure**
- **Technologies and Demonstrators**
- **Assessment : the Technology Evaluator**

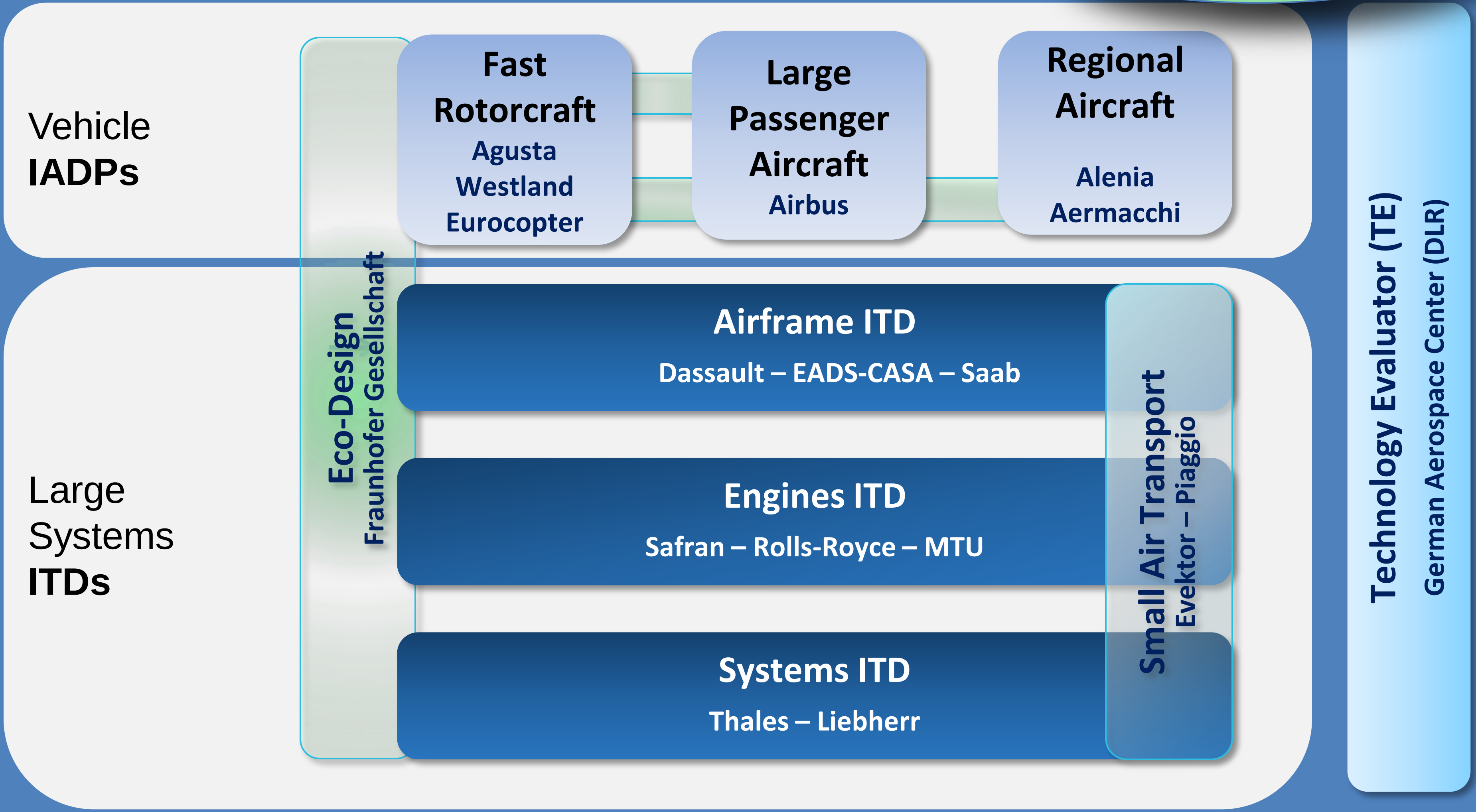
Clean Sky 1 Programme Set-up

EU Funding
0.8bn€



Clean Sky 2 Programme Set-up

EU Funding
1.8bn€



Vehicle
IADPs

Fast Rotorcraft
Agusta Westland
Eurocopter

Large Passenger Aircraft
Airbus

Regional Aircraft
Alenia Aermacchi

Large Systems
ITDs

Eco-Design
Fraunhofer Gesellschaft

Airframe ITD
Dassault – EADS-CASA – Saab

Engines ITD
Safran – Rolls-Royce – MTU

Systems ITD
Thales – Liebherr

Small Air Transport
Evektor – Piaggio

Technology Evaluator (TE)
German Aerospace Center (DLR)

Outline

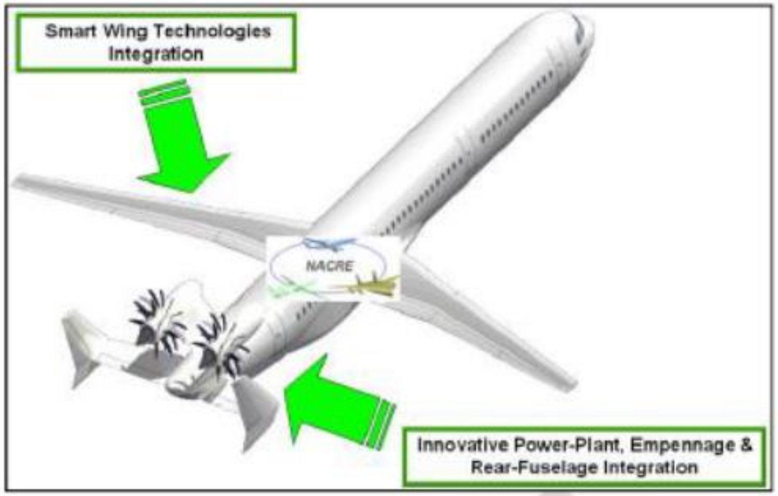
- Part II -

… Integrating breakthrough Technologies
Up to full scale Demonstrators …

- Environmental Objectives
- Programme Structure
- **Technologies and Demonstrators**
- Assessment : the Technology Evaluator

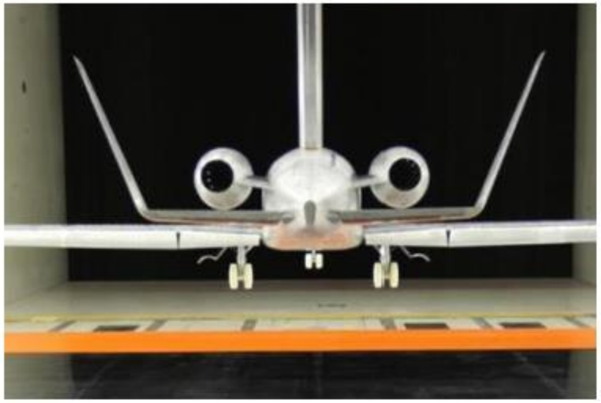
CS1 - SFWA Overview

- Integration of :
  - ✓ Passive and active flow and load control technologies into new ***Smart Wing*** concepts
  - ✓ ***Innovative Power-Plant*** *and* ***Empennage and Rear-Fuselage*** concepts
- ***For Large passengers aircrafts*** (with a capacity typically larger than 150 passengers)
- ***For Business Jets***



CS1 - SFWA Overview

Wind Tunnel Tests



TRL4 – Dec 2014 & April 2015
LSBJ Aero-acoustic tests at DNW

TRL5 – Nov 2016
Flutter tests at ONERA

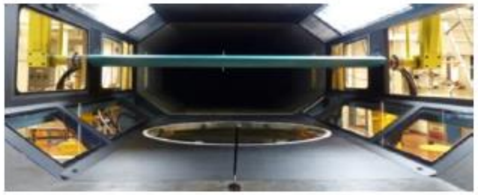
Full Scale Ground/ Flight Tests

TRL5 – May 2015
Vibration Control Demonstrator
at Dassault Aviation

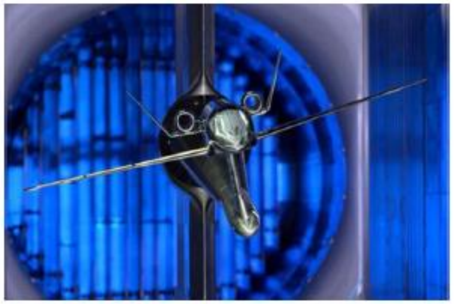
TRL5 – Oct/Nov 2016
SHIELD Noise shielding
at Dassault Aviation

CS1 - SFWA Overview

Wind Tunnel Tests



TRL 3-4 – Dec 2015
Integrated Active Component Demonstrator
(NLR, Fokker, TU Delft, Twente Univ.)



TRL 4-5 – Oct 2015
High Speed WTT on LSBJ at ETW

TRL 4 – Jan 2013
CROR WTT at DNW

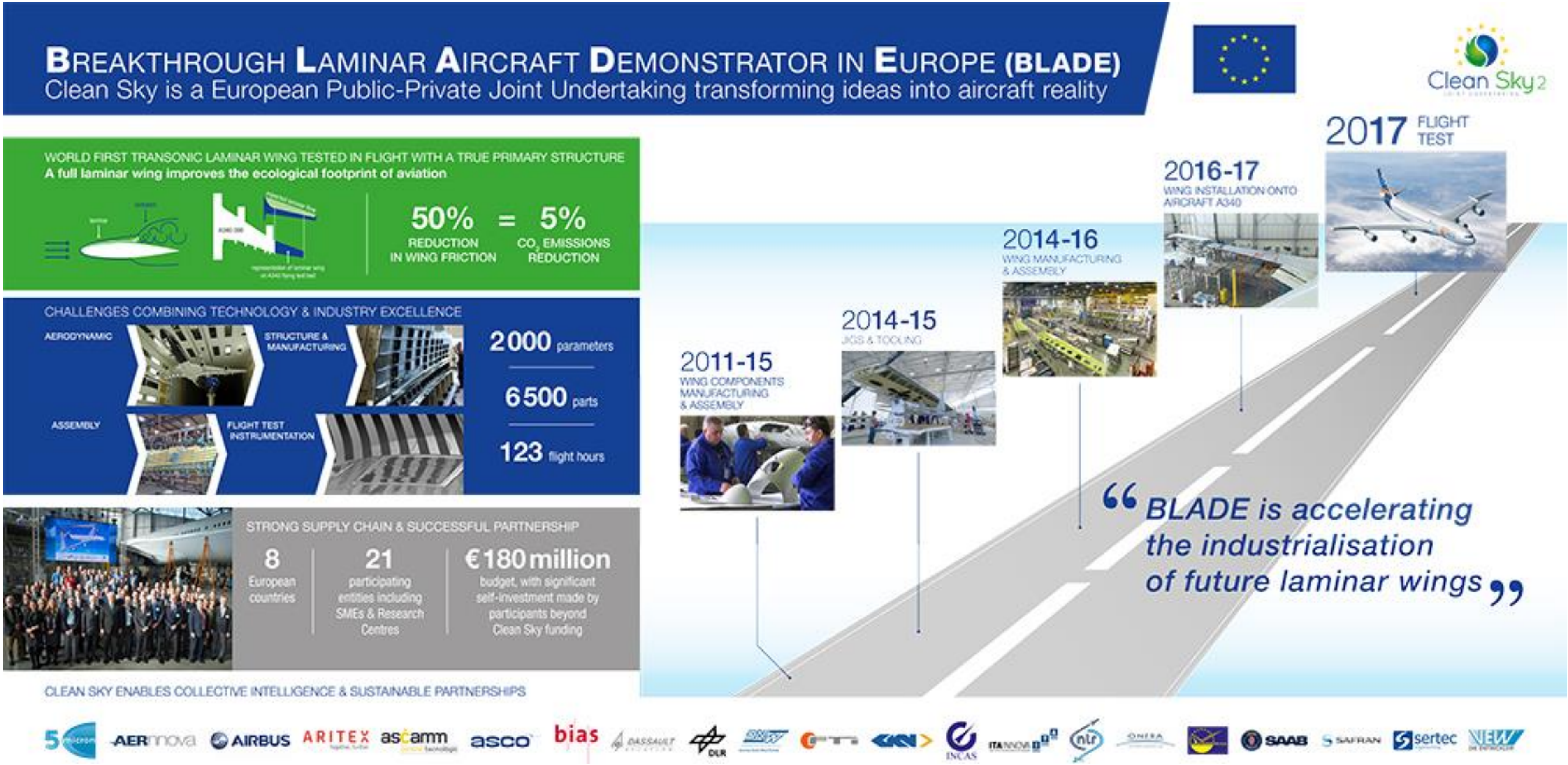
Full Scale Ground/ Flight Tests

TRL 4-5 – Dec 2014 NLF Ground Based Demonstrator (GKN) – Dec 2014

TRL 5 – Dec 2016 BLADE Wings installation (Airbus)

Clean Sky

Laminar Wing : The BLADE Project



BREAKTHROUGH LAMINAR AIRCRAFT DEMONSTRATOR IN EUROPE (BLADE)

Clean Sky is a European Public-Private Joint Undertaking transforming ideas into aircraft reality

WORLD FIRST TRANSONIC LAMINAR WING TESTED IN FLIGHT WITH A TRUE PRIMARY STRUCTURE

A full laminar wing improves the ecological footprint of aviation

50% REDUCTION IN WING FRICTION = 5% CO_2 EMISSIONS REDUCTION

CHALLENGES COMBINING TECHNOLOGY & INDUSTRY EXCELLENCE

- AERODYNAMIC
- STRUCTURE & MANUFACTURING
- ASSEMBLY
- FLIGHT TEST INSTRUMENTATION

2000 parameters

6500 parts

123 flight hours

STRONG SUPPLY CHAIN & SUCCESSFUL PARTNERSHIP

8 European countries

21 participating entities including SMEs & Research Centres

€180 million budget, with significant self-investment made by participants beyond Clean Sky funding

CLEAN SKY ENABLES COLLECTIVE INTELLIGENCE & SUSTAINABLE PARTNERSHIPS

2011-15 WING COMPONENTS MANUFACTURING & ASSEMBLY

2014-15 JIGS & TOOLING

2014-16 WING MANUFACTURING & ASSEMBLY

2016-17 WING INSTALLATION ONTO AIRCRAFT A340

2017 FLIGHT TEST

> *“BLADE is accelerating the industrialisation of future laminar wings”*

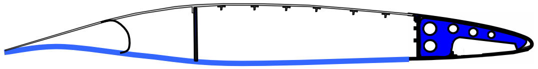
Clean Sky
JOINT UNDERTAKING

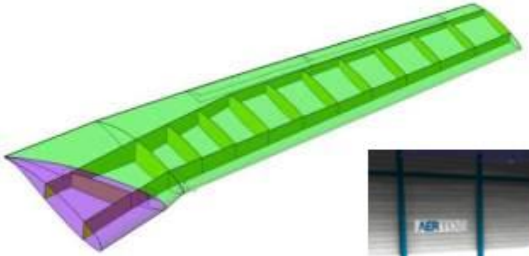
Laminar Wing : The BLADE Project

A340 flight test platform: Integration in Tarbes

Natural Laminar Flow Wing

- Proof of natural laminar wing concept by WT testing
- Use of novel materials and structural concepts
- Large scale flight test demonstration of the laminar wing

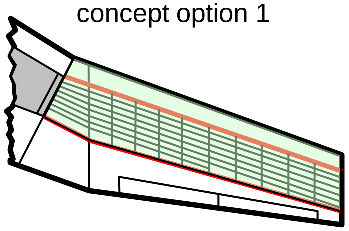




Laminar Wing Ground test demonstrator to address structural, system and manufacturing aspects

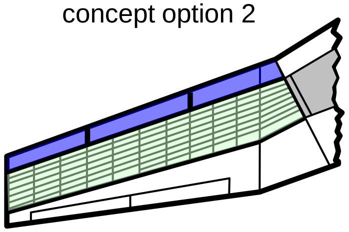
Starboard wing

Laminar wing structure concept option 1



Port wing

Laminar wing structure concept option 2



Smart Wing semi-assembly ground transportation (Aernnova)

Current manufacturing of the Smart Wing integrated upper panel (SAAB)

Laminar Wing aerodynamic layout and performance

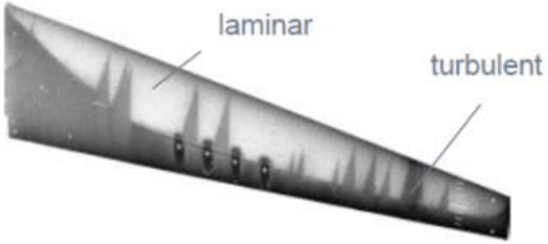
Clean Sky
JOINT UNDERTAKING

Laminar Wing Flight Tests

2014 – 2015
Wind tunnel tests. Laminar wing & Krueger flap demonstrator

2016
First aircraft parts

2017
Flight tests on Airbus A340



Expected Benefits

Minimise drag with laminar flow

-5% fuel burn saving
compared to current aircraft generation

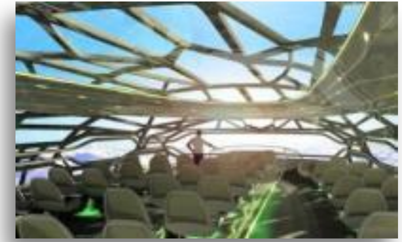
CS 2 - Large Passenger Aircraft

Large Passenger Aircraft Platform – Integration Topics

„Platform 1 - OAD“

Advanced Engine and Aircraft Configurations

„Platform 2 - OPD“



Innovative Physical Integration Cabin-System-Structure

„Platform 3 - OSD“

Next Gen. Electrical A/C Systems, Cockpit Systems & Avionics

Platform 1 Advanced Engine and Aircraft Configurations

Open Rotor demo in flight

Advanced engine integration driven rear fuselage

Validation of dynamically scaled flight testing

Hybrid laminar flow control large scale demonstration

Hybrid propulsion

Platform 2 Innovative Physical Integration Cabin-System-Structure

Integrated product architecture

Pre-Production Line Technologies

Platform 3 Next Gen. Electrical Aircraft A/C Systems, Cockpits & Avionics

Enhanced flight operations and functions

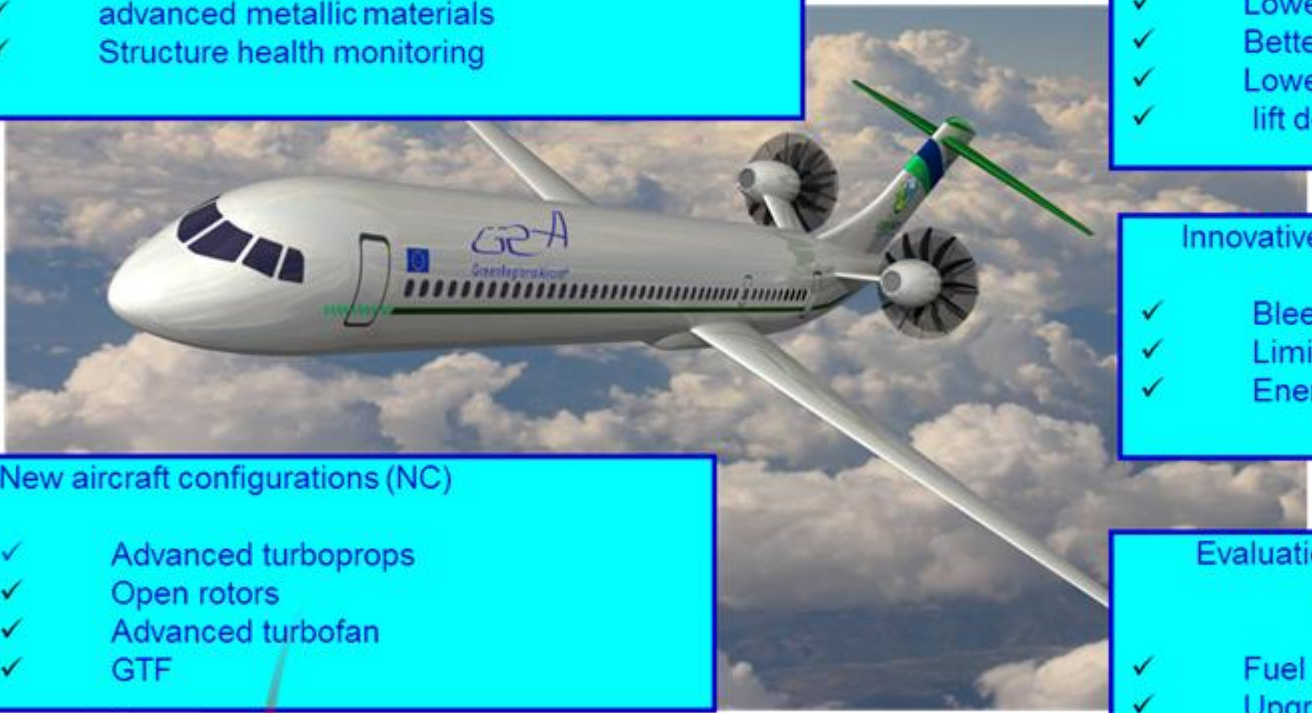
Avionic backbone technologies development and integration

Next generation cockpit ground demonstrator

Next generation cockpit features flight demonstration

“Pilot case” demonstrators

CS 1 - GRA Overview



Innovative structures (Low Weight Configuration)

✓ multifunctional composites
✓ advanced metallic materials
✓ Structure health monitoring

Advanced aerodynamics (Low Noise Configuration)

✓ Lower Fuel Consumption
✓ Better climb performance
✓ Lower Airframe noise from high
✓ lift devices and landing gear

Innovative systems (All Electrical Aircraft)

✓ Bleed less architectures
✓ Limited hydraulics
✓ Energy management

New aircraft configurations (NC)

✓ Advanced turboprops
✓ Open rotors
✓ Advanced turbofan
✓ GTF

Evaluation of new avionics architecture in MTM domain for

✓ Fuel & noise reduction
✓ Upgraded capabilities for MTM
✓ Lower Maintenance costs

CS 1 - GRA Overview

ATR-72 Flight Demonstration :

CFRP Stiffened Crown panel mounted for acoustic and vibration demonstration, **8 July 2015**

ATR first flight, Crown Panel

Alenia, ATR, Fraunhofer

TRL 5/6 - 9 July 2015

Objectives & Main outcomes:

- Innovative sensorized EPOXY CFRP fuselage "crown" panel
- Integrated Technology Demonstrator of Alenia (research, development, design, manufacturing and optical fibres sensor instrumentation), ATR (installation and operation; test aircraft), and Fraunhofer (panel piezo-electric sensor instrumentation),
- Aim of flight test campaign was to support the development of innovative EPOXY CFRP panel with embedded layer to provide additional acoustic damping, as well as two different technologies for Structural Health Monitoring (SHM)

Expected benefits:

- They concern weight, internal noise, assembly costs and structural health monitoring

ATR72 Flight Test Bed on 9 July 2015

Preparation for the Flight Tests

CS 1 - GRA Overview

All-Electric Aircraft demonstrator

Alenia, ATR, Partners

TRL 5 - February 2016

Objectives:

- The ATR 72 FTB (flying test bed) A/C will be modified at the end of the structural test campaign for the AEA Technologies in flight demonstration

Main features:

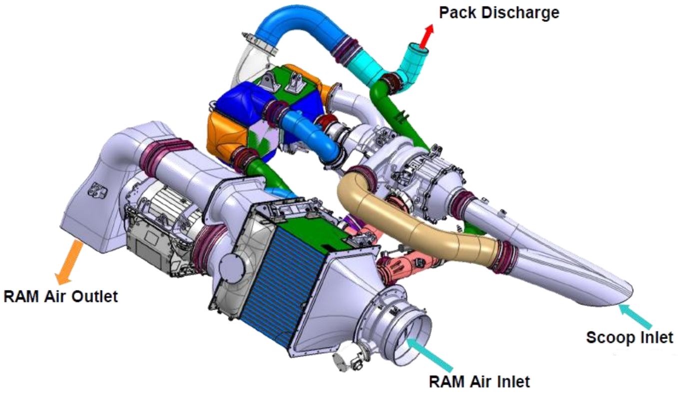
- EPGS: Electrical Power
- Installation of 270 HVDC Generation distribution including Electrical Power Center (EPC) and Simulated Resistive Electrical Load (SREL)
- E-ECS (Electric Environmental Control System) (35 kW), with a dedicated control rack
- EMAs: Installation of two electrical actuators (one for FCS, one for LG (each mounted on a dedicated test bench, both located in Cabin)

An FTI/Flight Test Station (FTES) will also be installed in the cabin.

Expected benefits:

- Implementation of more electric aircraft architecture

ATR 72 Flying Test Bed



CS 1 - GRA Overview

Fuselage demonstrator One Piece Barrel

Alenia Aermacchi, DEMA, Hellenic Aerospace Industry, Fraunhofer-Gesellschaft IBP

TRL 5 - June 2016

Main features:

The fuselage demonstrator has 2 components:

- The fabrication of the fuselage barrel as a Composite 'one piece barrel'
- The testing of this barrel for fatigue and static behaviour

Main benefits:

- New fuselage concept architecture

One Piece Barrel Demonstrator

Cockpit demonstrator

Airbus Defence & Space

TRL 5 - September 2016

Main features:

- A second cockpit ground demonstrator has been prepared, and has achieved a major step towards the internal target of 10% weight saving

Main outcomes:

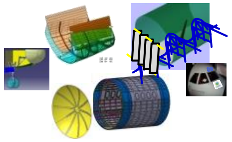
- Different frame materials are under investigation to identify the best material for acoustic, fatigue and crash behaviour

Cockpit demonstrator

CS 2 - Regional a/c IADP

FP-7

CS1 GRA



CLEAN SKY 2 "REGIONAL"

NG HE Regional A/C

Flightpath2050 mid-term

Regional a/c IADP | **Airframe ITD** | **A/C Syst&Eq. ITD** | **Engines ITD**

Technology Waves

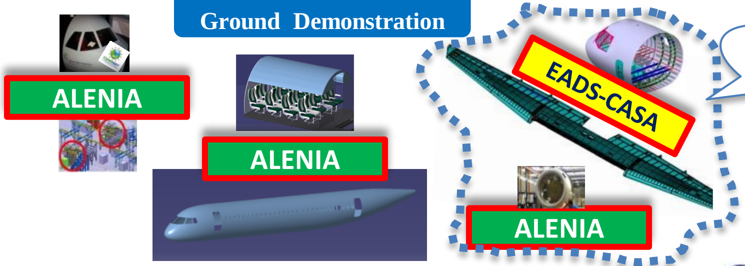
WV1 ADAPTIVE WING	(Liquid Infusion, Morphing, HLD, Winglets, NLF, Drag Reduction,…)
WV2 REGIONAL AVIONICS	(FMS, HMI, Health Monitoring,…)
WV3 COCKPIT	(Advanced Composite Materials, Systems)
WV4 INNOVATIVE FCS	(Flight-By-Wire, EMA,…)
WV5 ENERGY OPTIMIZED REGIONAL A/C	(Low Power WIPS, Electrical Landing Gears, EPGDS, E-ECS,…)
WV6 FUSELAGE STRUCTURE	(Advanced Composite Materials, Advanced Manufacturing, …)
WV7 PAX CABIN	(Human Centered Design, Green Materials, …)
WV8 NACELLES FOR REGIONAL A/C(Jet and TP)	(Nacelles Materials, Ice Protection, Drag Reduction,…)

Flight Demonstration

ALENIA

EADS-CASA

Ground Demonstration



ALENIA

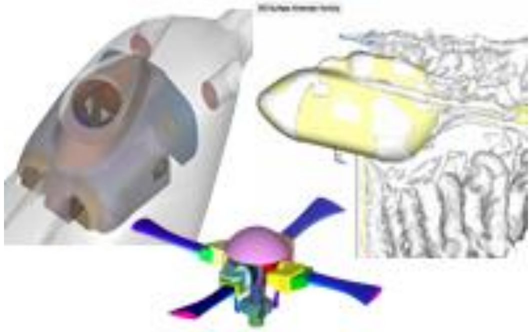
ALENIA

EADS-CASA

ALENIA

Airframe ITD

CS 1 - GRC Overview

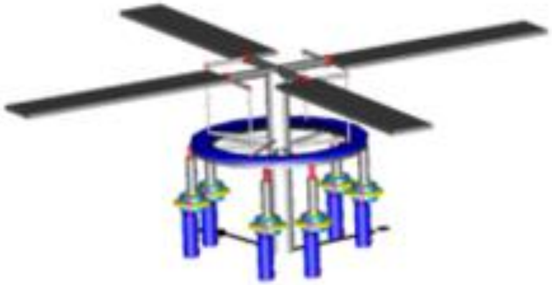


GRC2: Reduced Drag of R/C

GRC1: Innovative Rotor Blades

GRC6: Eco-friendly design

GRC3: More electrical Rotorcraft



GRC4: Diesel engine on light helicopter

GRC5: Optimised Flight path

Clean Sky
JOINT UNDERTAKING

CS 1 - GRC Overview

Demonstration of Diesel powered light helicopter

Airbus Helicopters, Marignane

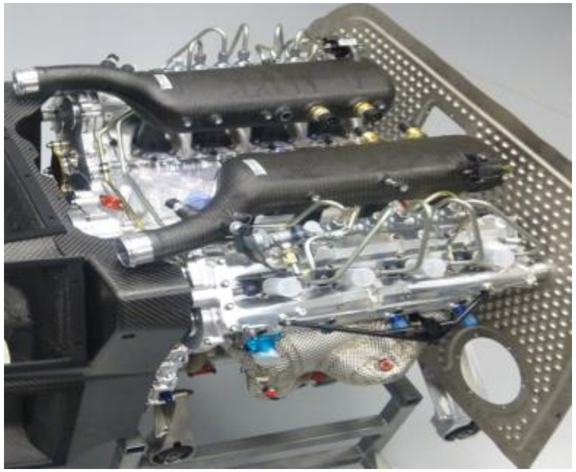
TRL 5/6 - Iron Bird tests - February 2014 - Flight tests - November 2015

Objectives:

- A flying demonstrator based on an EC120 serial helicopter and fitted with a newly designed High Compression Engine (HCE, a reciprocating engine using Kerosene) has been developed by Airbus Helicopters in the frame of GRC 4
- For this research project, Airbus Helicopters teamed up with TEOS Powertrain Engineering, France (leader of the Consortium), and AustroEngine GmbH, Austria (partners of the project HIPE 440 selected in 2011)

Main features & benefits:

- In the power class related to EC120 engines (300 to 400kW), the main advantages of HCEs compared to turboshaft engines are the lower specific fuel consumption, lower CO_2 emissions, and higher performance in hot/high conditions thanks to the superchargers. Target Mass-to-power ratio < 0.8 kg/kW



©Airbus Helicopters/Jerome Deulin

CS 1 - GRC Overview

Active Gurney Flap
AgustaWestland

Flight tests, TRL 6 - March 2016

Next-generation helicopters will consider adaptive and innovative components within their rotor blades in order to obtain performance benefits.

AgustaWestland and its partners are developing and testing an Active Gurney Flap system through a series of progressive tests consisting of:

- Model Rotor test (controlled environment test)
- 2D Static Test, University Twente (initial fully sized blade data)
- 2D Dynamic Test (at CIRA IWT1) (blade representative testing, controlled environment)
- Whirl Tower (full scale rotor; full systems capability test ahead of flight)
- Flight test on an AW139 helicopter TRL 6

Expected benefits:

- Demonstration of advanced Rotor Blade concept

Active Gurney Flap tests

CS 1 - GRC Overview

Electric Tail Demonstration

AgustaWestland, University of Bristol

TRL 5 - September 2016

Main features:

- Electrification of the tail rotor drive function
- The 'Electric Tail Demonstrator', based on concepts explored by the ELETAD project, incorporates the high power/weight ratio laboratory motor design into a high integrity aircraft system capable of installation and dynamic evaluation on an aircraft tail demonstration rig

Main outcomes:

- The Electric Tail Demonstrator system is currently TRL3, with the key motor parts from ELETAD that are at TRL 4
- The ground demonstration will dynamically evaluate the system representing flight mission profiles, reaching TRL 5

Expected benefits:

- Assessment of innovative helicopter tail Rotor architectures

Dedicated ground test bench

CS 1 - GRC Overview

Demonstration of Helicopter Low Noise Procedures
AgustaWestland

TRL 6 - May 2016

Main objectives:

- Gain confidence in the acoustic benefits of steep departure and approach procedures with respect to conventional ones, based on correlation with AW139 prototype flight acoustic measurements on-board and on-ground
- Involvement of partner project MANOEUVRES, to improve the acoustic prediction capability for manoeuvring unsteady conditions, and to propose the concept of a Pilot Acoustic Indicator, able to provide on-board noise predictions allowing the adaption of the flight path

AW 139 Helicopter Demonstrator

Main outcomes:

- After completing pilot handling, guidance and workload validation of the VFR environment friendly paths, using an engineering simulator AWARE, demonstration in flight of the noise abatement for this project in Q2 2016

Passive Optimized Blade
Airbus Helicopters

TRL 6 - June 2016

Main features:

- New rotor blades optimised for efficiency and noise signature, compatible with variable speed rotor. Modelling and predictions to be compared with full-scale testing on whirl tower and in flight

Expected benefits:

- Demonstration of advanced Rotor Blade concept

Main Rotor Whirl Tower

Demonstration of Helicopter Low Noise Procedures
Airbus Helicopters

Objectives:

- The low-noise IFR (Instrument Flight Rules) approach procedures were flown using accurate lateral and vertical guidance provided by EGNOS (European Geostationary Navigation Overlay Service), the European Satellite-Based Augmentation System (SBAS), and in the presence of airplane traffic, which proved the suitability of these helicopter-specific procedures to achieve Simultaneous Non Interfering (SNI) aircraft and rotorcraft IFR operations at a medium-size commercial airport

Main features & benefits:

- The procedures are based on the noise optimised flight paths successfully validated in 2013 with an H155 and have demonstrated noise footprint reductions of up to 50%
- Detailed design and integration of the procedures in Toulouse airspace was performed by partner project GARDEN (coordinated by Egis Avia)

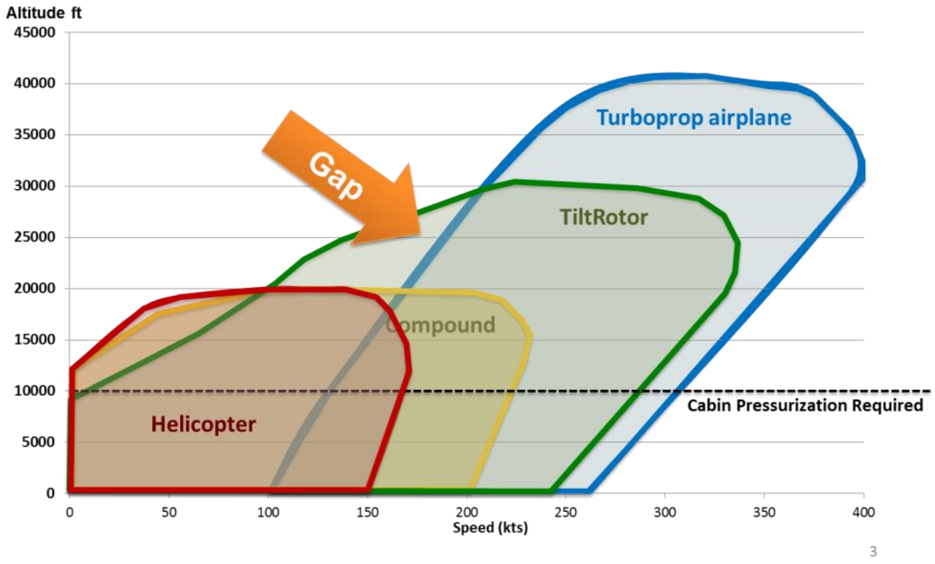
TRL 6 - May 2015

H175 helicopter,
heliport of Toulouse-Blagnac

CS 2 - Fast Rotorcraft IADP

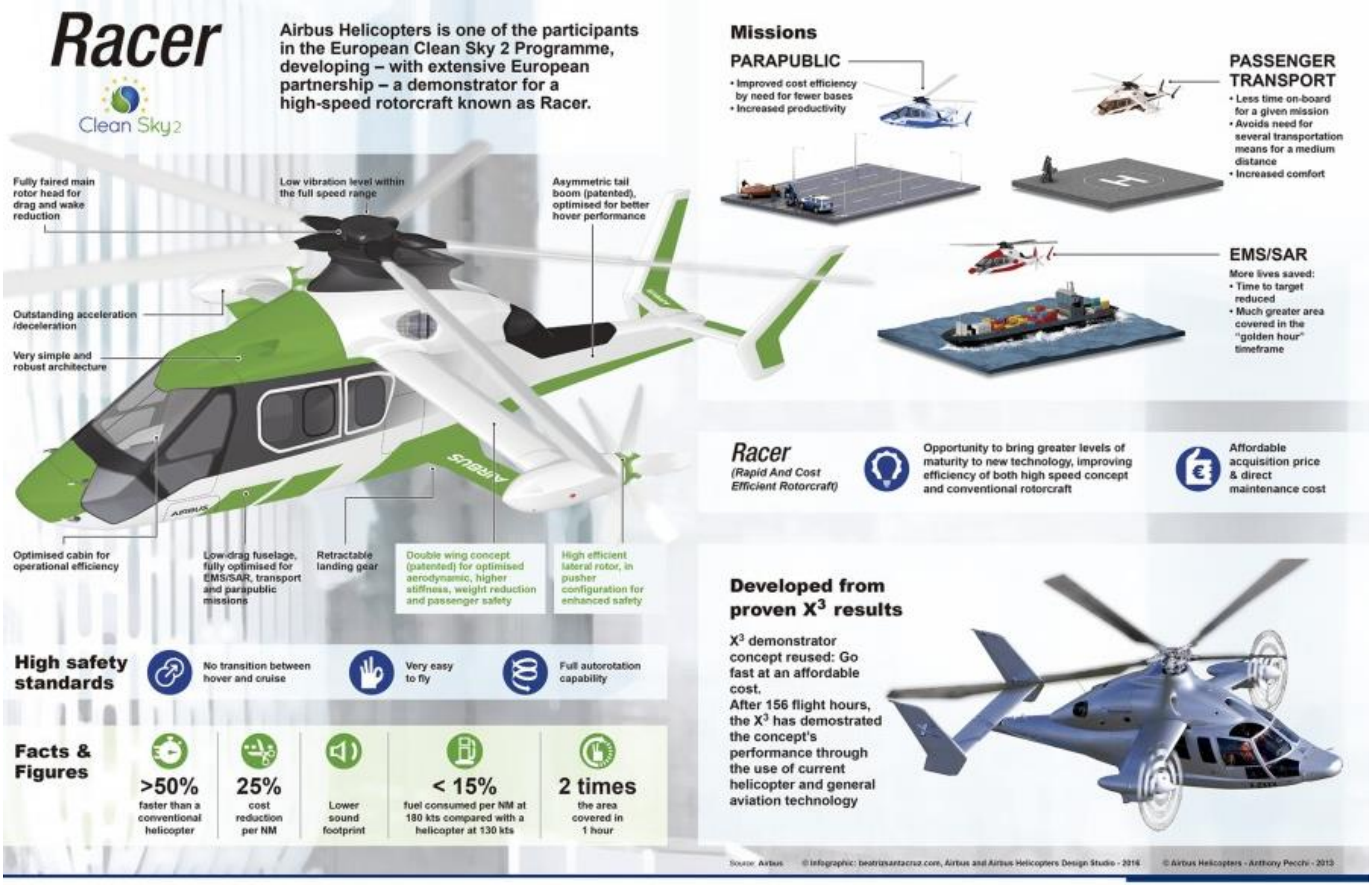
Tiltrotor (AW)

Compound (A-H)



Clean Sky
JOINT UNDERTAKING

CS 2 - Fast Rotorcraft IADP



Racer

Clean Sky 2

Airbus Helicopters is one of the participants in the European Clean Sky 2 Programme, developing – with extensive European partnership – a demonstrator for a high-speed rotorcraft known as Racer.

Fully faired main rotor head for drag and wake reduction

Low vibration level within the full speed range

Asymmetric tail boom (patented), optimised for better hover performance

Outstanding acceleration /deceleration

Very simple and robust architecture

Optimised cabin for operational efficiency

Low-drag fuselage, fully optimised for EMS/SAR, transport and parapublic missions

Retractable landing gear

Double wing concept (patented) for optimised aerodynamic, higher stiffness, weight reduction and passenger safety

High efficient lateral rotor, in pusher configuration for enhanced safety

High safety standards

No transition between hover and cruise

Very easy to fly

Full autorotation capability

Facts & Figures

>50%	25%		< 15%	2 times
faster than a conventional helicopter	cost reduction per NM	Lower sound footprint	fuel consumed per NM at 180 kts compared with a helicopter at 130 kts	the area covered in 1 hour

Missions

PARAPUBLIC

- Improved cost efficiency by need for fewer bases
- Increased productivity

PASSENGER TRANSPORT

- Less time on-board for a given mission
- Avoids need for several transportation means for a medium distance
- Increased comfort

EMS/SAR

More lives saved:

- Time to target reduced
- Much greater area covered in the "golden hour" timeframe

Racer

(Rapid And Cost Efficient Rotorcraft)

Opportunity to bring greater levels of maturity to new technology, improving efficiency of both high speed concept and conventional rotorcraft

Affordable acquisition price & direct maintenance cost

Developed from proven X³ results

X³ demonstrator concept reused: Go fast at an affordable cost.

After 156 flight hours, the X³ has demonstrated the concept's performance through the use of current helicopter and general aviation technology

Source: Airbus © Infographic: beatrizsantacruz.com, Airbus and Airbus Helicopters Design Studio - 2016 © Airbus Helicopters - Anthony Pecchi - 2013

CS 1 - SGO Overview

Management of Aircraft Energy

- The use of all-electric equipment system architectures will allow a more fuel-efficient use of secondary power, from electrical generation and distribution to electrical aircraft systems.
- Thermal management will address many levels, particularly relating to electric aircraft, from hot spots in large power electronics to motor drive system cooling, to overall aircraft solutions.

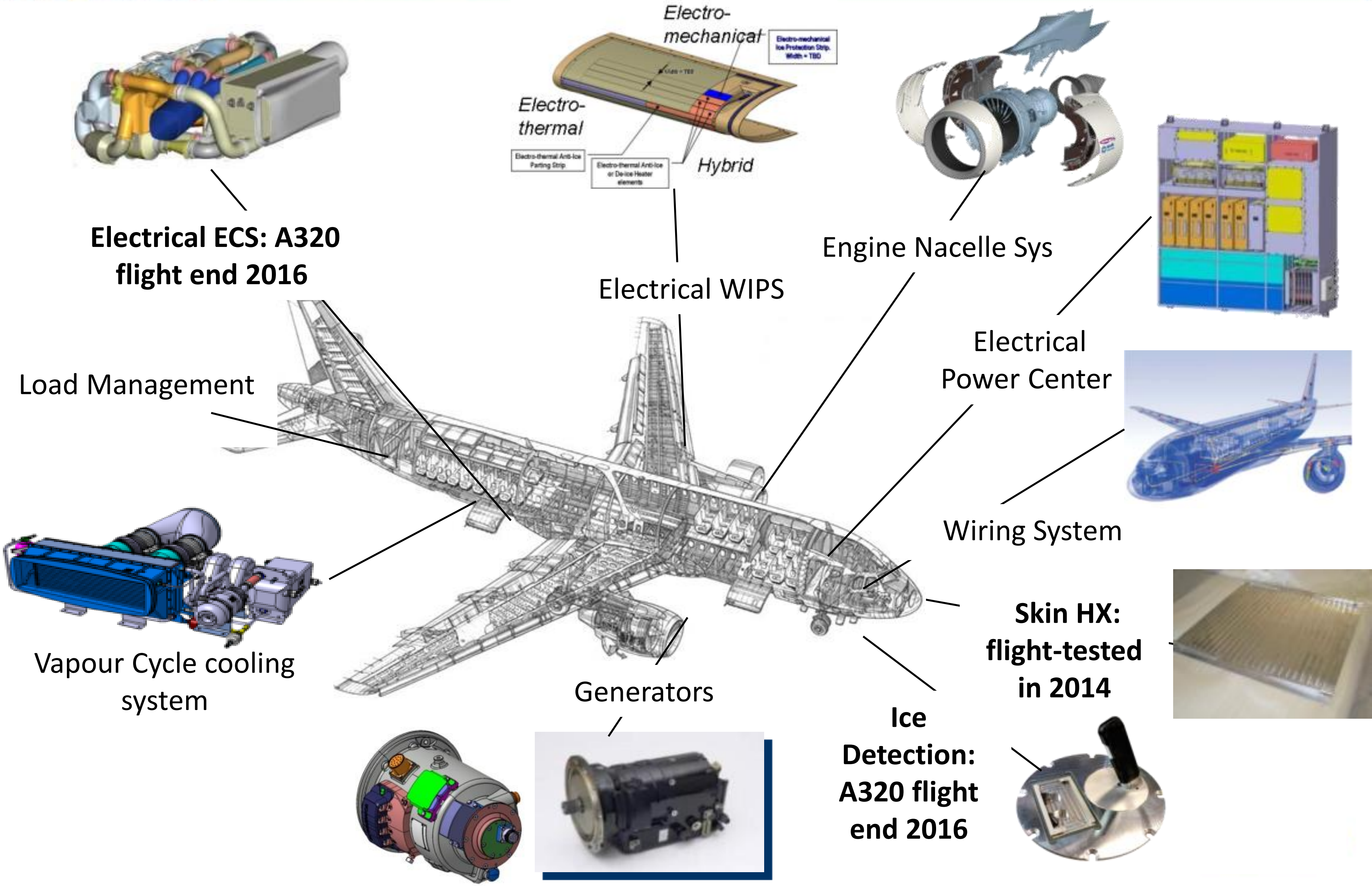
Management of Trajectory and Mission

- Systems and procedures will be designed to perform high precision optimised trajectories to minimise noise and emissions impact in airport areas.
- New aircraft systems for Smart Ground Operations will optimise use of engine power when aircraft is on ground and provide silent taxing capabilities
- Aircraft will be able to fly green missions from start to finish, thanks to technologies which allow to avoid fuel consuming meteorological hazards and to adapt flight path to known
local conditions

➔**Validation by ground based rigs and flight testing**

Clean Sky
JOINT UNDERTAKING

SGO : Management of aircraft energy



Electrical ECS: A320 flight end 2016

Electrical WIPS

Engine Nacelle Sys

Electrical Power Center

Load Management

Wiring System

Vapour Cycle cooling system

Generators

Skin HX: flight-tested in 2014

Ice Detection: A320 flight end 2016

CS2 - Systems (1/2)

Avionics extended cockpit

Workload,
HSI,
monitoring

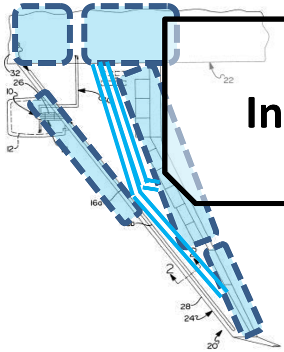
Computing I/O
Network
Sensors

Functions

Flight
Management
Systems

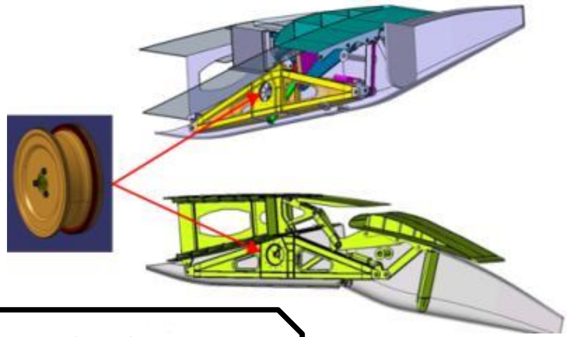
Future Displays,
Head-up, Human
factors assessments,
eyes-out piloting…

Innovative Electrical Wing



Smart
Integrated
Wing

Innovative
Electrical
Wing

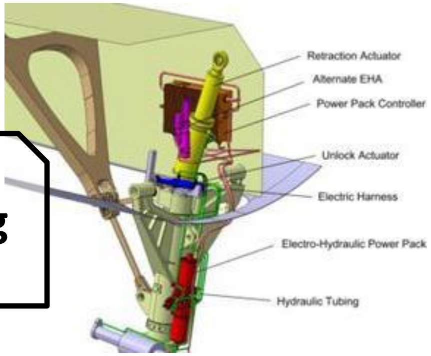


Flash FAL
Track

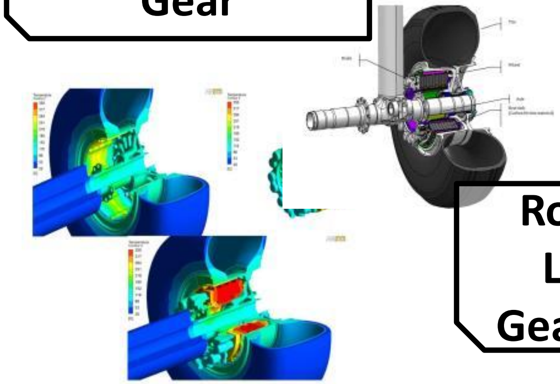
CS 2 - Systems (2/2)

Landing Gears Systems

Electrical Nose Landing Gear



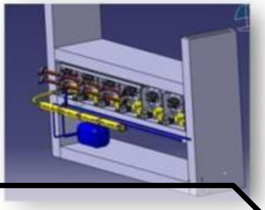
Main Landing Gear



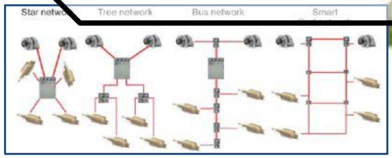
Rotorcraft Landing Gear System

Electrical Chain

Power Generation

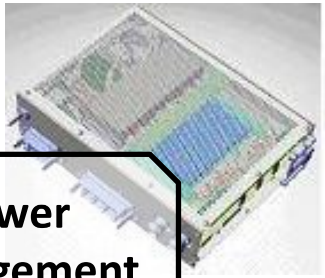


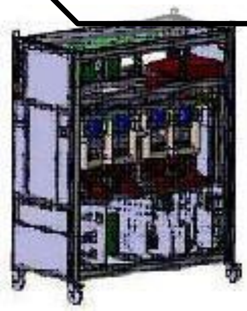
Power Distribution



Conversion

Power Management





Clean Sky
JOINT UNDERTAKING

CS1 – SAGE Overview

Advanced Low Pressure System (ALPS) first flight

Rolls-Royce

TRL 6 - October 2014

Objectives:

- Rolls-Royce's goals to deliver a 20% fuel efficiency improvement, compared to the first generation of Trent engines for the Advance and UltraFan™ engines (for a timeframe of 2020 and 2025), are pursued through the Advanced Low Pressure System (ALPS), part of the SAGE 3 ITD. One of the most striking advances has been the testing of the composite fan that will be incorporated into both engine designs

Main outcome:

- The CTi (Carbon Titanium) fan blade and associated composite engine casings deliver a weight saving of around 1,500 lb on a twin engine aircraft. Composite panels containing electrical harnesses and pipework fit around the fancase, reducing weight and simplifying maintenance
- Testing in 2014 consisted of first test bed runs in Derby, UK, to crosswind testing at the Rolls-Royce facility at the John C. Stennis Space Centre, Mississippi, and most recently full flight tests on a Rolls-Royce Boeing 747 flying test bed at Tucson, Arizona, where one of the four RB211 engines was replaced with a Trent 1000 "donor" engine with CTi blades
- A total of six flights took place over eleven days in October 2014

Clean Sky
JOINT UNDERTAKING

CS1 – SAGE Overview

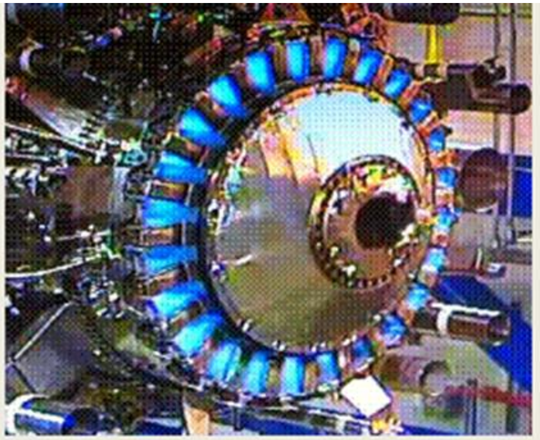
Lean Burn Demonstrator
Rolls-Royce

TRL 5 - June 2016

Objectives & features:

The Lean Burn Programme objective is to deliver a verified generic Lean Burn System against a set of validated requirements complying with regulatory and company demands for emissions and safety, and with acceptable reliability at minimum life cycle cost and weight.

- The test programme is based on Trent 1000 donor engines (ALECSYS) for engine ground testing
- Emissions capability at representative future cycles has been demonstrated in a dedicated core engine experiment on the EFE (Environmentally Friendly Engine) vehicle
- The programme is also envisaging a full scale flight test campaign on a B747 flying test bed
- The programme is scheduled to achieve TRL 5/MCRL 4 by mid-2016



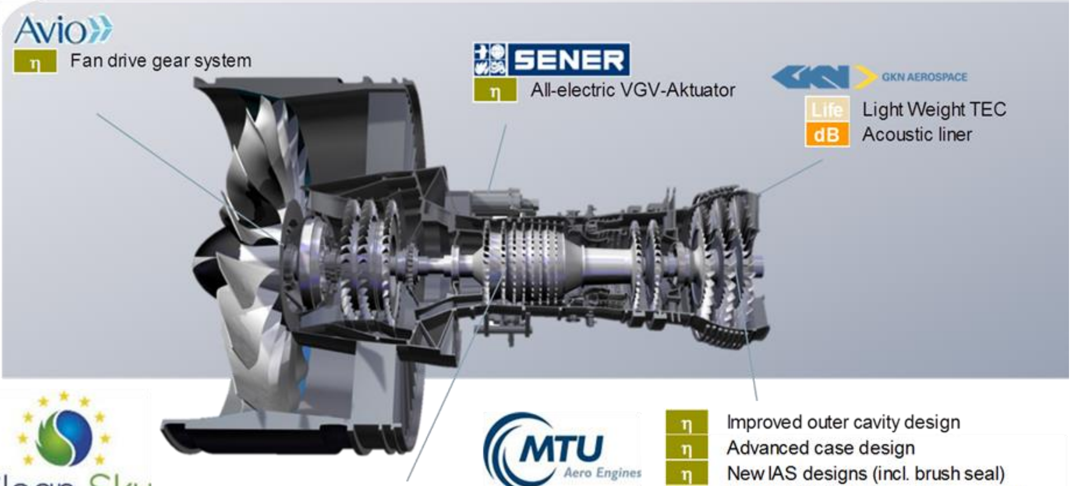
CS1 – SAGE Overview

Geared Turbofan Demonstrator
MTU

Main objectives:

- Advanced Geared Turbofan Demonstrator, with MTU and Partners' contribution with innovative technologies concerning materials and manufacturing processes
- Engine components concerned:
  - New highly efficient high-pressure compressor
  - Lightweight, high speed low-pressure turbine
  - Advanced lightweight and efficient turbine structures
  - Lightweight and reliable fan drive gear system
  - New systems for a more electric engine

Clean Sky SAGE 4 Demonstrator – materializing 2nd generation GTF



Avio
η Fan drive gear system

SENER
η All-electric VGV-Aktuator

GKN AEROSPACE
Life Light Weight TEC
dB Acoustic liner

Clean Sky
SAGE 4 Demonstrator

MTU Aero Engines

lb	CFRP sealing carrier
Life	Erosion protection / Superpolish
€	SLM Inner Air Seal Carrier
€	SLM Variable Guide Vane
	BSSM-C St. 1 + 3

η	Improved outer cavity design
η	Advanced case design
η	New IAS designs (incl. brush seal)
η	Smart ACC (w/o closed loop control)
η	Airfoil with reduced T/E thickness
η	Improved trim balance weight
lb	Impulse mistuned blades
lb	Ceramic matrix composite segm.
Life	TiAl blades

CS1 – SAGE Overview

First rotation of TECH800

Turbomeca

TRL 5 - April 2013

Objectives:

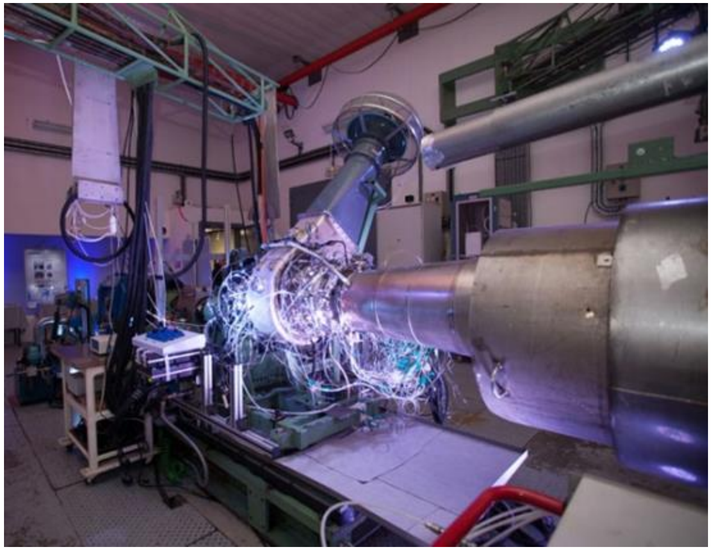
- Core turboshaft engine demonstrators in the power range 1,000-2,000 SHP

Main features:

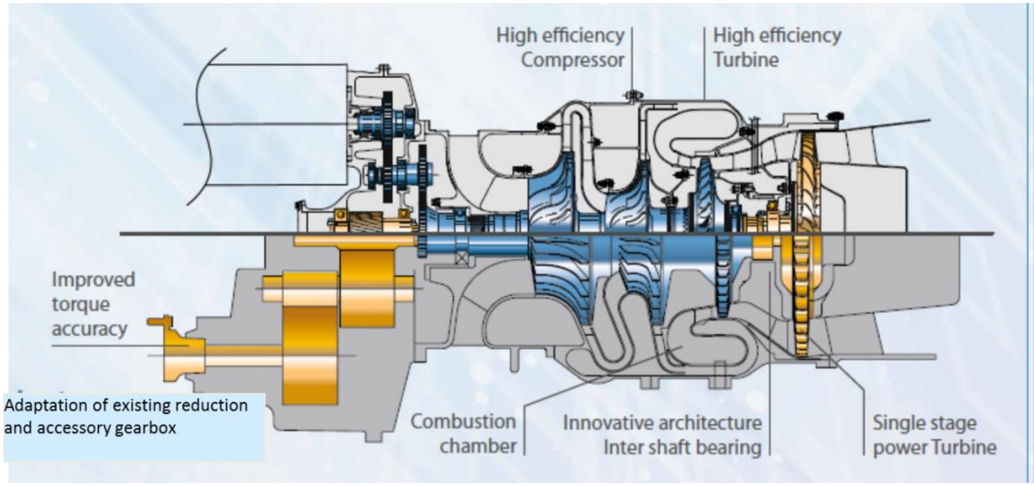
- High efficiency compressor, combustion chamber, high-pressure, and low-pressure turbine

Main outcomes:

- Turbomeca developed the technologies with support of several partners
- Full scale and life cycle validation achieved



Tests completed.
15% SFC Reduction demonstrated.
New Product emerging from technology development: ARRANO, selected for new H160 helicopter



CS1 – SAGE Overview

CROR Ground test demonstrator, Istres

Safran, Snecma

TRL 5 - From September 2016

Objectives & benefits:

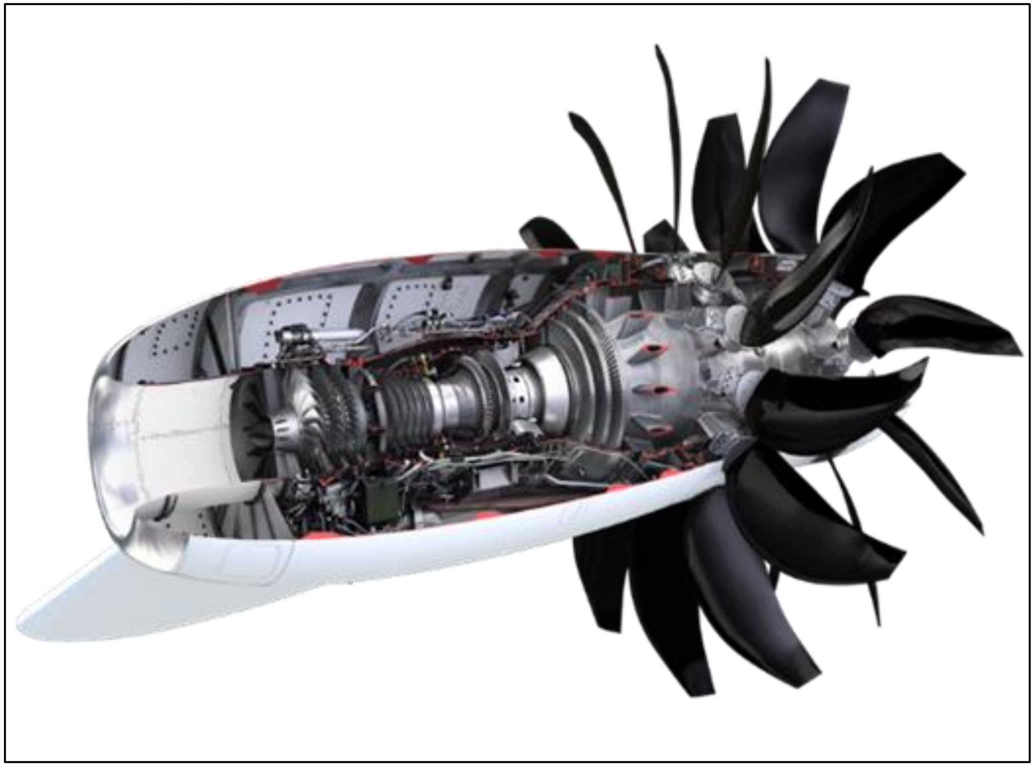
- The Contra Rotating Open Rotor (based on a geared unducted architecture) is an aircraft engine offering a 30% fuel burn reduction compared to the the year 2000 turbofan reference engine, allowing a significant decrease of the CO_2 emissions

Main features:

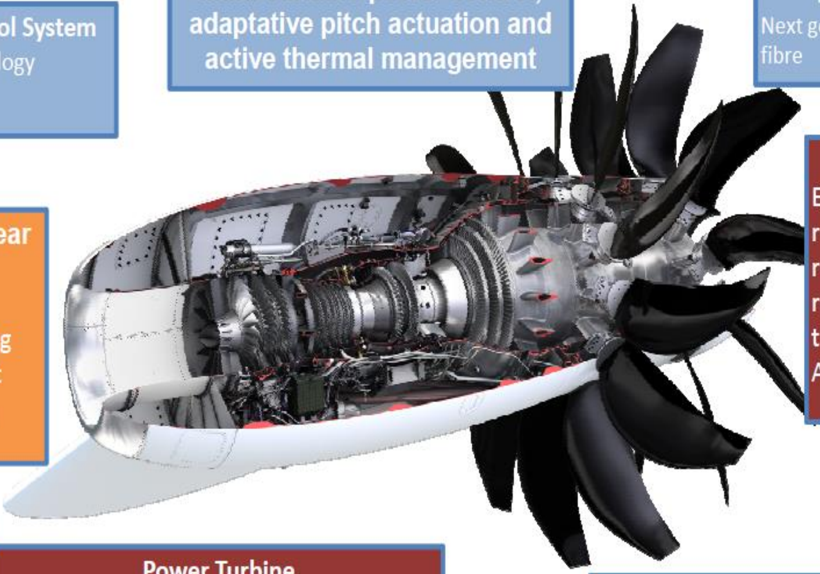
- The Open Rotor configuration aims at meeting several technological challenges such as a new propulsion mode, an innovative aerodynamic configuration and unprecedented manufacturing processes
- The main innovative elements of the design concern the blades of the propellers, the blade pitch change mechanism, the gearbox and the rotating structure

Main outcomes:

- By intensive aero-acoustic wind tunnel testing of several design optimisations, Safran demonstrated that this architecture is compliant with the new noise standards for certification (chapter 14) and consistent with expected performance level
- Safran is leading the SAGE 2 Consortium (including several Partners) which aims at delivering and ground testing a full-scale Open Rotor engine on a brand-new Safran open-air facility located in Istres



Contra-Rotating Open Rotor



SAFRAN

Propeller Pitch Control System
Reliable Fail Safe Technology

SAFRAN

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

SAFRAN

Lightweight Counter-rotating propellers
Next generation 3D woven carbon fibre

Lightweight front and rear rotating frames
Robust design to address certification issues of rotating casing, controlling leakage at interfaces and reducing the weight.

GKN AEROSPACE

Power Gear Box
Enabling technologies to achieve reliability and power/envelope ratios required to the counter-rotating reduction gearbox for the installation on Open Rotor Architectures.

Avio Aero

Power Turbine
Embedding new technologies in order to reduce module weight and increase efficiency

Avio Aero

Nacelle Components
Allowing rotating nacelles
Oil Cooling System

LEONARDO SAFRAN

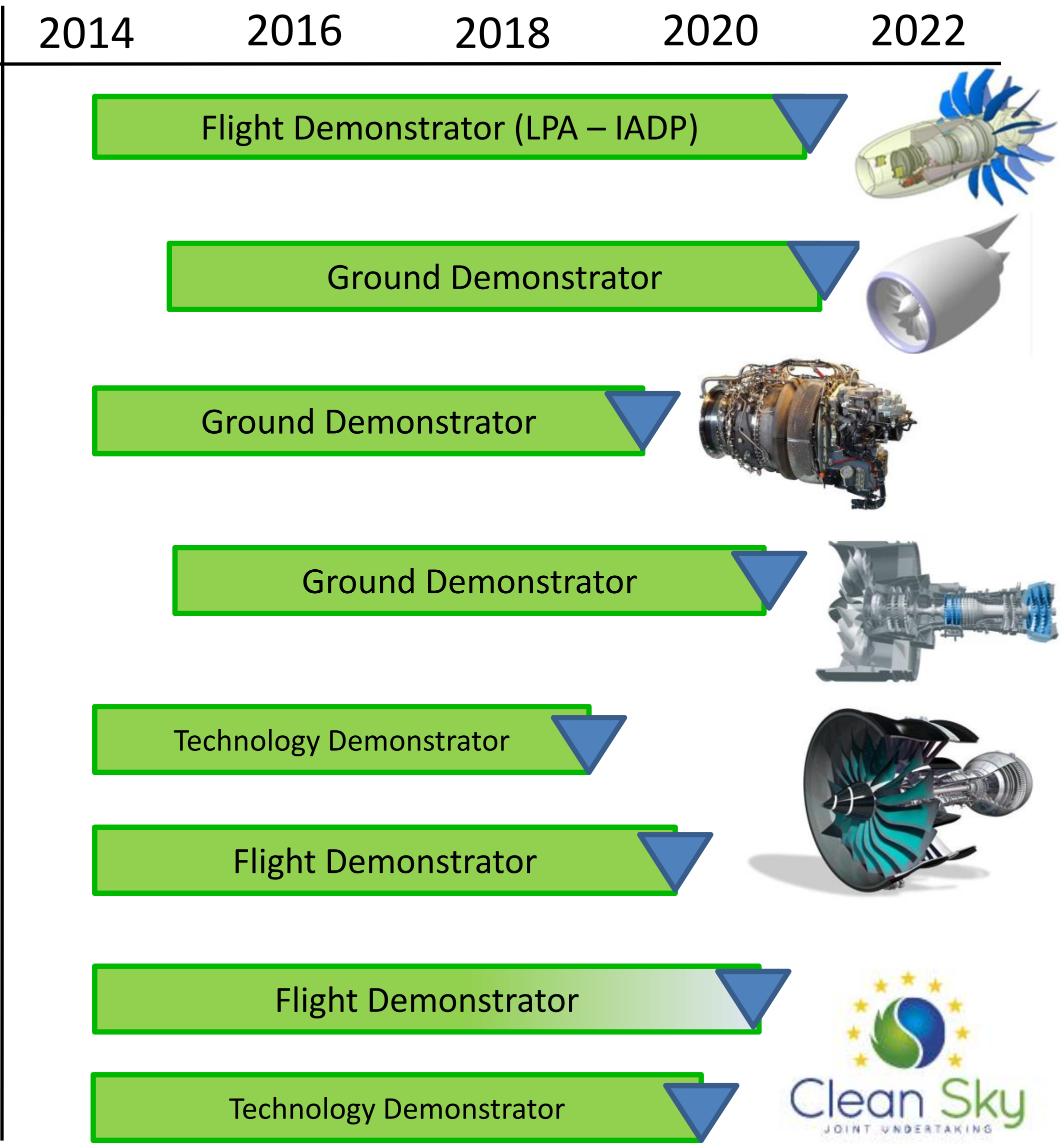
Clean Sky

Clean Sky
JOINT UNDERTAKING

Contra-Rotating Open Rotor GTD

CS 2 - Engines ITD

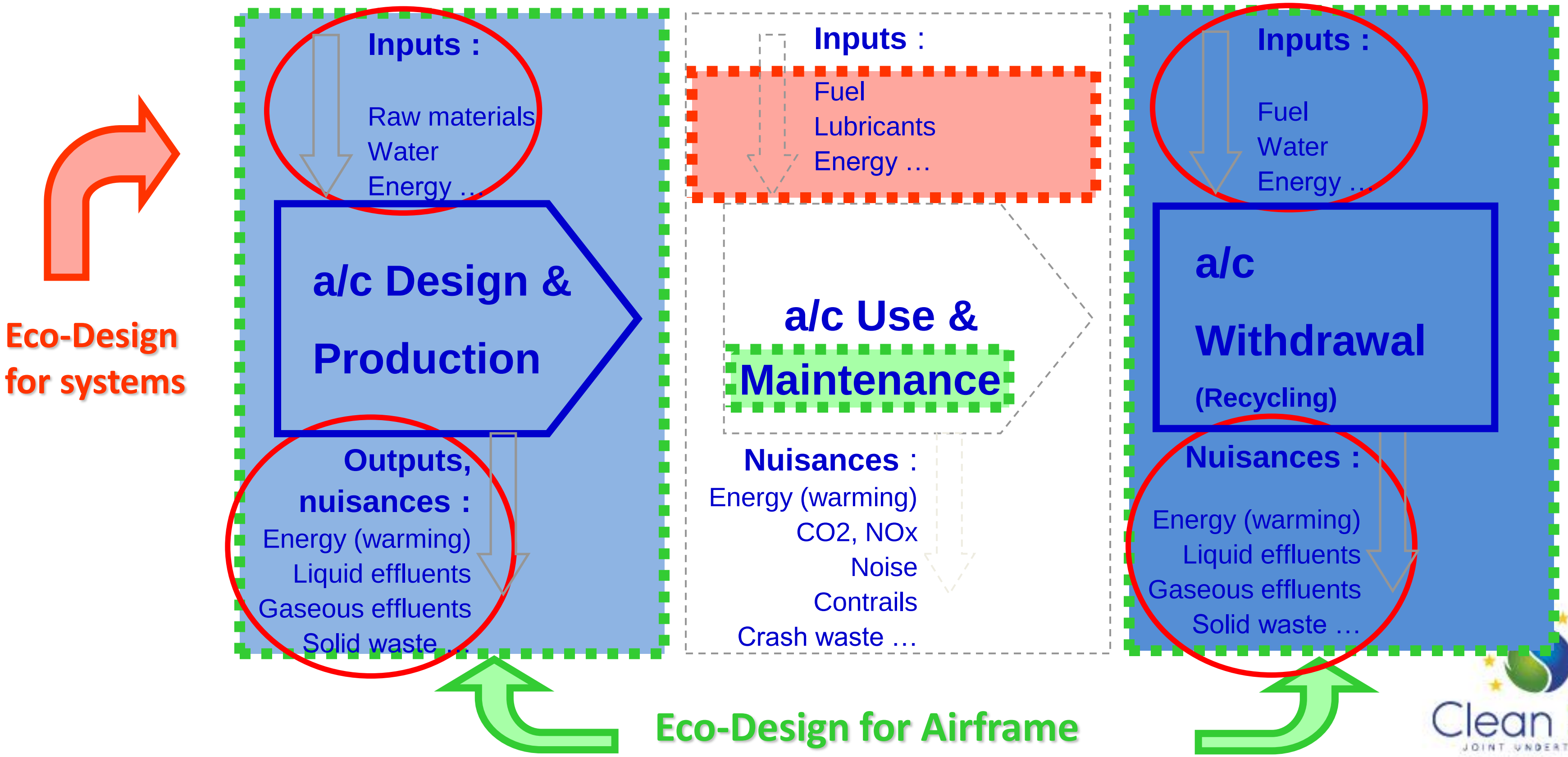
WP1	Open Rotor Flight Test	SNECMA	Flight Demonstrator (LPA – IADP)
WP2	UHPE demonstrator	SNECMA	Ground Demonstrator
WP3	Business Aviation Regional Turboprop	TM	Ground Demonstrator
WP4	Geared engine Configuration (HPC-LPT)	MTU	Ground Demonstrator
WP5	VHBR Turbofan Middle of Market	RR	Technology Demonstrator
WP6	VHBR Turbofan Long Range	RR	Flight Demonstrator
WP7	Small Aircraft Engine	SMA	Flight Demonstrator
WP8	Small Turboprop for SAT	Avio	Technology Demonstrator



Clean Sky
JOINT UNDERTAKING

CS 1 - Eco-Design Overview

- To design airframe for decreasing inputs, outputs and nuisances during a/c design & production and withdrawal phases: for Airframe Application (EDA)
- To design architectures of a/c systems, towards the more/all electrical a/c, with the objective of reducing use of non-renewable and noxious fluids/ materials during operations and maintenance: for Systems Application (EDS)



Eco-Design for systems

Inputs :

Raw materials
Water
Energy …

a/c Design & Production

Outputs, nuisances :
Energy (warming)
Liquid effluents
Gaseous effluents
Solid waste …

Inputs :

Fuel
Lubricants
Energy …

a/c Use & Maintenance

Nuisances :
Energy (warming)
CO2, NOx
Noise
Contrails
Crash waste …

Inputs :

Fuel
Water
Energy …

a/c Withdrawal
(Recycling)

Nuisances :

Energy (warming)
Liquid effluents
Gaseous effluents
Solid waste …

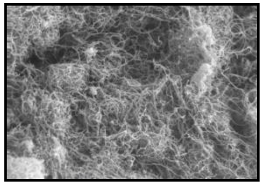
Eco-Design for Airframe

Clean Sky
JOINT UNDERTAKING

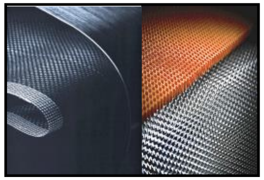
Eco-Design for Airframe Technical Areas

Area 4 : end of life management

Elimination
Recycling



Area 1 : new materials & surfaces

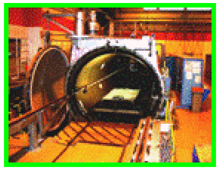


Raw Materials

Eco-Design
for Airframe

Manufacturing

Product



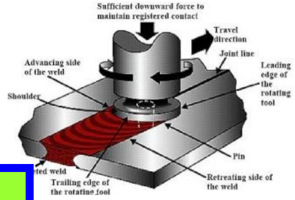
Area 2 : green manufacturing

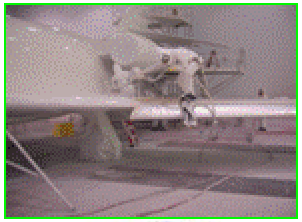
Green Repair

Maintenance

Use

Area 3 : long life structure





General objectives : Eco-Design and Green Manufacturing

Clean Sky
JOINT UNDERTAKING

Airframe : From *Clean Sky* towards *Clean Sky 2*

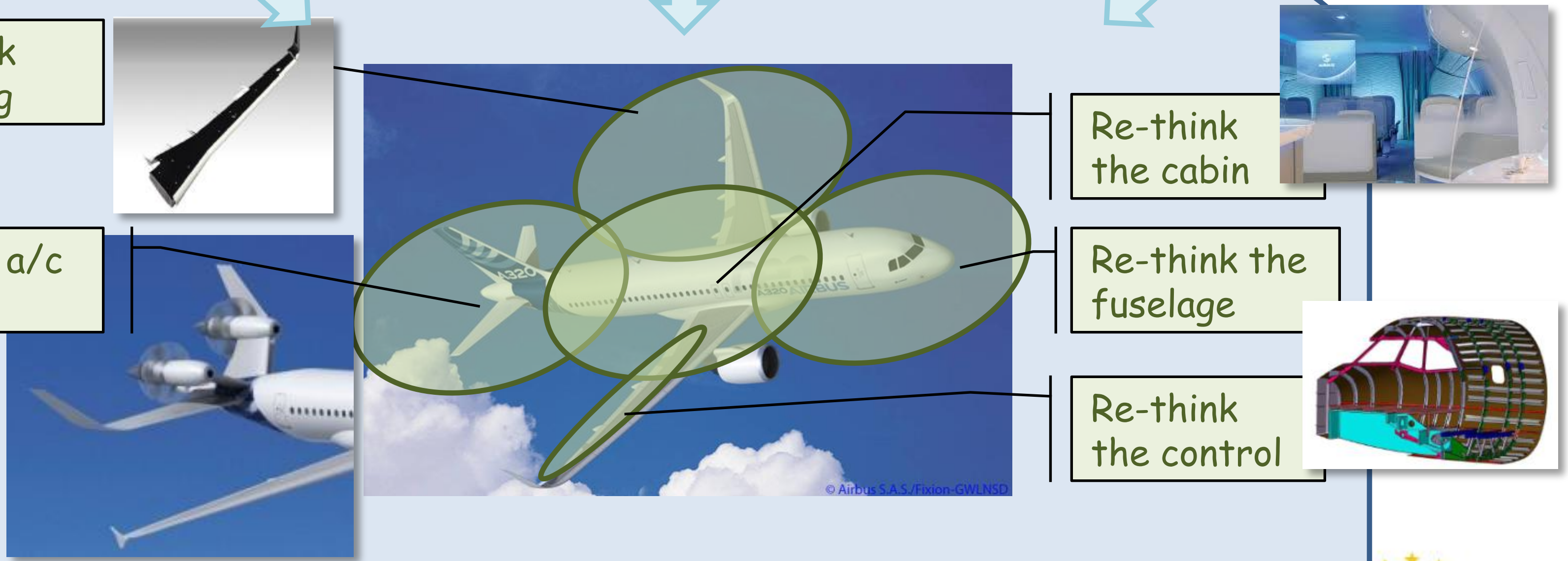
eco DESIGN

GreenRegionalAircraft

- Greener Airframe Technologies
- More Electrical a/c architectures

- More efficient wing
- Novel Propulsion Integration Strategy
- Optimized control surfaces

- Integrated Structures
- Smart high lift devices



© Airbus S.A.S./Fixion-GWLNSD

Re-think the wing

Re-think the a/c architecture

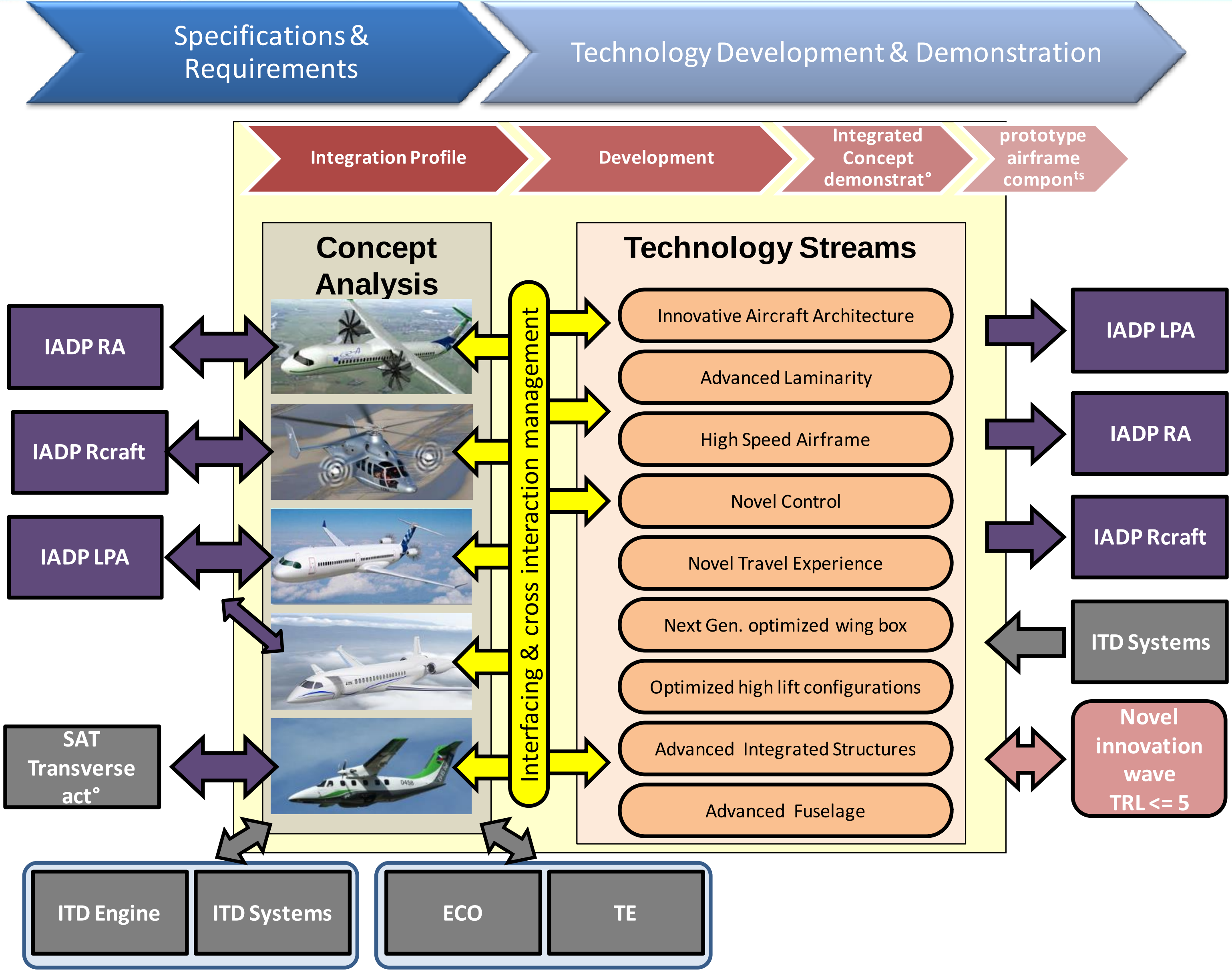
Re-think the cabin

Re-think the fuselage

Re-think the control

Step changes in the "efficiency" of all airframe elements by the means of a systematic "re-thinking"

CS 2 - AIRFRAME ITD



Specifications & Requirements

Technology Development & Demonstration

Integration Profile

Development

Integrated Concept demonstrat°

prototype airframe compon^ts

Concept Analysis

Interfacing & cross interaction management

Technology Streams

- Innovative Aircraft Architecture
- Advanced Laminarity
- High Speed Airframe
- Novel Control
- Novel Travel Experience
- Next Gen. optimized wing box
- Optimized high lift configurations
- Advanced Integrated Structures
- Advanced Fuselage

IADP RA

IADP Rcraft

IADP LPA

SAT Transverse act°

IADP LPA

IADP RA

IADP Rcraft

ITD Systems

Novel innovation wave TRL <= 5

ITD Engine

ITD Systems

ECO

TE

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Outline

- Part II -

… Integrating breakthrough Technologies
Up to full scale Demonstrators …

- Environmental Objectives
- Programme Structure
- Technologies and Demonstrators
- **Assessment : the Technology Evaluator**

Technology Evaluator

Mission level

Comparison of impacts (on noise & emissions) stemming from 2000 aircraft / rotorcraft with 2020 Clean Sky aircraft / rotorcraft in representative reference missions;

Difficulty: partly no comparable 2000 r/c available

Solution: selection & elaboration of 2000 counterparts

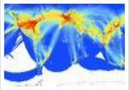
Airport level

Comparison of impacts (on noise & emissions & capacity) stemming from 2000 fleet with 2020 Clean Sky fleet on airports (one typical day) for a 2020 traffic scenario

Difficulty: only about 80% of 2000 fleet survives until 2020

Solution: application at a mix of airports

ATS level



Comparison of impacts (on noise & emissions) stemming from 2000 global fleet and movements with 2020 fleet with Clean Sky technologies for a 2020 traffic scenario

Difficulty: limited market penetration of CS tech in 2020 and unpredictable difference between natural and CS evolution
Solution: 3-point assessment with focus on potentials

Technology Evaluator

Large Commercial Concept Aircraft

Short/medium-range (SMR) aircraft, [APL2]

This concept aircraft includes the 'smart' laminar-flow wing. It will incorporate the Contra Rotating Open Rotor (CROR) engine concept, developed within the Clean Sky programme.

Flight-testing of a representative Laminar Wing and of a full-size CROR engine demonstrator are now planned beyond the framework of the programme and moved to the Clean Sky 2 programme.

Advanced systems and new flight trajectories already matured to appropriate level are included in the architecture.

Incorporating these technologies and configurations:

- SFWA Natural Laminar Flow (NLF) wing
- Snecma conceptual CROR engines
- SGO MTM (Management of Trajectory and Mission) Optimized trajectories, in the FMS (Flight Management System):
  - A-IGS (Adaptive-Increased Glide Slope)
  - MCDP (Multi Criteria Departure Procedure)

Long-range aircraft (LR), next generation large turbofan [APL3]

The long-range aircraft concept will provide the vehicle-level platform to integrate the next-generation large three-shaft turbofan engine using Clean Sky technologies. The focus of Clean Sky in this aircraft category is predominantly on improved engines and systems.

Incorporating these technologies and configurations:

- SAGE 3 Rolls-Royce Advanced Turbofan engines
- SAGE 6 Rolls-Royce lean burn system (combustor)
- SGO MTM (Management of Trajectory and Mission) Optimized trajectories, in the FMS (Flight Management System):
  - A-IGS (Adaptive-Increased Glide Slope)
  - MCDP (Multi Criteria Departure Procedure)

	CO2	NOx	Noise area	Noise	Perceived noise
Average value 500 – 2600NM, 75 dB take-off					
Short/Medium range	-41%	-42%	-68%	-5.1 dB	-30%
Average value 1000 – 7000NM, 75 dB take-off					
Long Range	-19%	-39%	-67%	-5,7 dB	-67%

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Technology Evaluator

	CO2	NOx	Noise area	Noise	Perceived noise
Average value 100 – 500NM, 75 dB landing					
Regional, Turboprop	-25%	-46%	-93%	-36.8 dB	-92%
Average value 300 – 1000NM, 75 dB take-off					
Regional, Geared Turbofan	-27%	-38%	-86%	-15.7 dB	-66%

Rotorcraft Class	Selected TE Mission	CO2	NOx	Noise Area (noise level > 77 dB)
Single Engine Light	Passenger	-20%	-54 %	Reduction over -50%
Twin Engine Light	EMS & Law	-13%	-44%	-55%
Twin Engine Medium	SAR & Fire	-11%	-45%	-50%
Twin Engine Heavy	Oil & Gas	-21%	-55%	n/a
High Compression Engine	Passenger & Training	-58%	-64%	n/a

Outline

- Part III -

Clean Sky 1
\+ Clean Sky 2

= Clean Sky 3 ?

Clean Sky 3 ?

- Mid-Term Evaluation of H2020 and JTI’s
  - High-Level Group H2020 (P. Lamy)
  - MTE Panel of JTI’s

- Position Papers
  - EIMG
  - Pegasus
  - EASN
  - EREA
  - …

Clean Sky 3 ?

Discussions started at EU level :

- Europe’s “missions”
  - Health issues
  - Migration issues
  - About Technology issues :
    - “Plastic-free” Europe …
    - Steel production at zero CO2 …
    - …

Clean Sky 3 ?

Advanced Aircraft Configurations :

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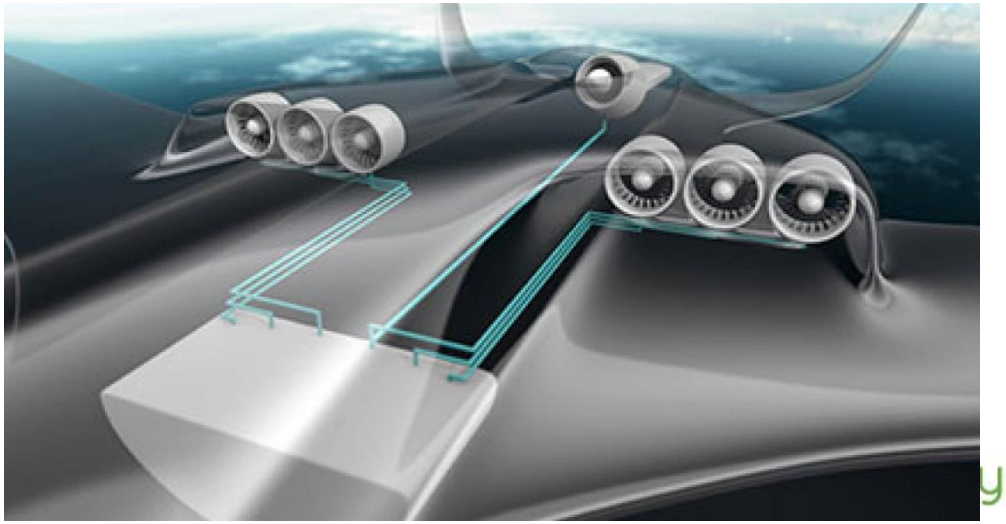


Clean Sky 3 ?

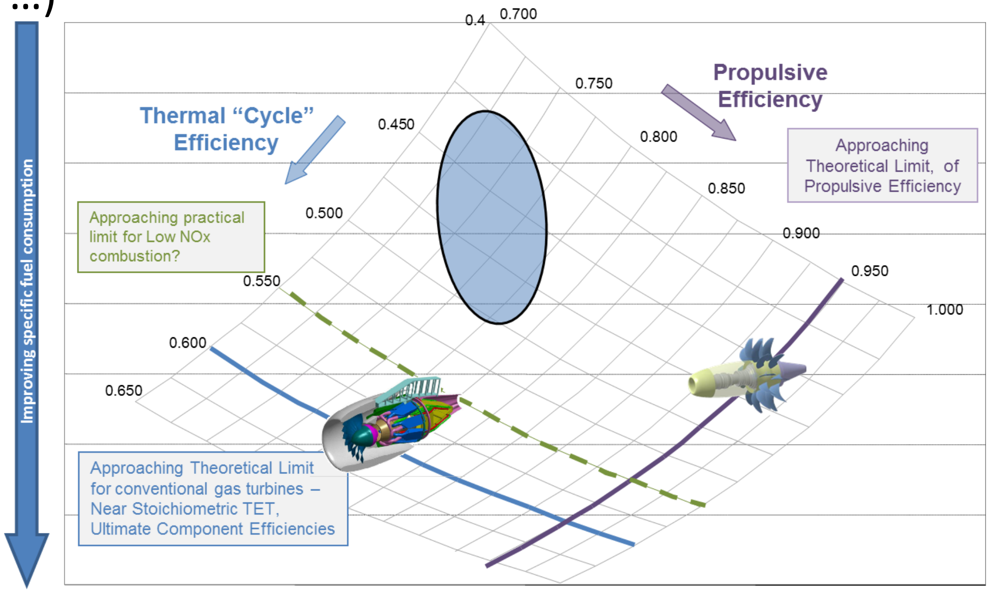
Radical Aircraft Configurations :

Clean Sky 3 ?

Engines :

- Propulsive efficiency (Unducted Fans, Variable Pitch Fans, …)
- Thermal efficiency (Advanced cycles, Intercooled, …)
- Combustion efficiency (incl. Lean Burn …)

- Manufacturing Methods
  - Additive Manufacturing, …
- Materials
  - Superalloys
  - Composites
  - TiAL
  - CMC, …
- Engine Integration
  - Boundary Layer Ingestion
  - Hybrid Propulsion / Electric Propulsion
  - Fuel Cells
- Alternative Fuels
  - Bio, Synthetic, …



Conclusions

- Although we may be nearing the asymptote of performance improvement of air vehicles and conventional propulsion systems, many technical challenges still lie ahead of us and substantial improvements are still possible, in particular with breakthrough configurations.
- There is a strong need to invest and support research towards highly innovative solutions and breakthrough configurations to sustain the future of aviation.
- Considering the growth rate of air traffic in the next decades, the environmental impact must be taken care of.
- Aeronautics remains one of the EU flagship industry at the forefront of technology, and competitiveness must be maintained/improved.

Perspective …

“Europe may not have
a single NASA-like organization
to act as a focal point
for Aeronautics Research,
but it does have Clean Sky …”

Graham Warwick,
Aviation Week,
July 2014.

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Thank You for your Attention

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