Annex II:
8th Call for Proposals (CFP08) -
List and Full Description of Topics

Call Text
[PP1]

- 28 February 2018 -

The present preliminary version of the Call Text is released **for information only** and addressed to any interested party prior to the official launch of the Call anticipated in April 2018. The final call text document serving as the foundation for any application to this Call will be published via the H2020 Participant Portal.
The content is a non-legally binding preliminary version and may still be subject to modifications until its official publication.

Revision History Table		
Version n°	**Issue Date**	**Reason for change**
PP1	28/02/2018	Pre-publication of the preliminary version of the Call text [via the CSJU Website]

Important notice on Q&As

Question and Answers will open **as from the Call Opening date** (mid-April 2018) via the Participant Portal of the European Commission.

In case of questions on the Call (either administrative or technical), applicants are invited to contact the JU using the **dedicated Call functional mailbox**: *email address will be published on the Participant Portal of the European Commission.*

Note that questions received up **until 01/06/2018, 17:00 (Brussels Time)** will be answered after analysis and published in Q&A when appropriate. In total, three publications of Q/As are foreseen: 12/04/2018, 15/05/2018 and 15/06/2018 (estimated dates).

The Q/As will made available via the Participant Portal of the European Commission.

CfP08 Info Day(s)

More Information available on the Clean Sky 2 website: www.cleansky.eu

INDEX

PART A: Call topics launched within the complementary framework of IADP/ITD/TA

PART B: Thematic Topics

List of Topics for Calls for Partners (CFP08) – Part A

Identification Code	Title	Type of Action	Value (Funding in M€)	Topic Leader
JTI-CS2-2018-CFP08-LPA-01-47	High Performance Electrical Components for Bleed Control	IA	0.90	Safran
JTI-CS2-2018-CFP08-LPA-01-48	Advanced Pitch Control Mechanism TRL4 Demonstration	IA	3.50	Safran
JTI-CS2-2018-CFP08-LPA-01-49	Oil Transfer Bearing for Advanced Pitch Change Mechanism	IA	2.50	Safran
JTI-CS2-2018-CFP08-LPA-01-50	Development and manufacturing of innovative tooling for composite parts	IA	1.00	Aernnova
JTI-CS2-2018-CFP08-LPA-01-51	Design and manufacturing of a large-scale HLFC wing model for a transonic WTT	IA	1.70	ONERA
JTI-CS2-2018-CFP08-LPA-01-52	Thermo-mechanical design validation of compact heat exchanger by thermal cycling life prediction	IA	1.20	Liebherr
JTI-CS2-2018-CFP08-LPA-01-53	Compact Matrix Air Oil Heat Exchanger	IA	0.70	Rolls-Royce
JTI-CS2-2018-CFP08-LPA-01-54	Development of Measurement Techniques for Visualisation and Evaluation of Reverse Flow Interactions with Fan	RIA	1.60	Rolls-Royce
JTI-CS2-2018-CFP08-LPA-01-55	Harsh Environment Electric Actuations	IA	0.60	Rolls-Royce
JTI-CS2-2018-CFP08-LPA-01-56	AC Cabling - Hybrid Electric	IA	0.75	Rolls-Royce
JTI-CS2-2018-CFP08-LPA-01-57	Aerospace standard Lightweight SSPC for High voltage >1kA application.	RIA	0.90	Rolls-Royce
JTI-CS2-2018-CFP08-LPA-01-58	Innovative Power and data transfer solutions for nacelle	IA	0.45	Airbus
JTI-CS2-2018-CFP08-LPA-02-23	Development and execution of new test procedures for thermoplastic aircraft fuselage panels	IA	0.50	Aernnova
JTI-CS2-2018-CFP08-LPA-02-24	Generic added structures on shells made from thermoplastic sheet material	IA	0.80	Diehl
JTI-CS2-2018-CFP08-LPA-02-25	Micro mechanical characteristics of a PEKK Co-consolidation / welded joint	IA	0.85	Fokker
JTI-CS2-2018-CFP08-LPA-02-26	Power Network with Electrical Switching	IA	1.10	Fokker
JTI-CS2-2018-CFP08-LPA-03-15	Pilot monitoring and speech to text in service data collection	IA	0.70	Honeywell
JTI-CS2-2018-CFP08-LPA: 17 topics			19.75	
JTI-CS2-2018-CFP08-REG-01-16	Innovative recirculation / air treatment system	IA	1.40	Leonardo Aircraft
JTI-CS2-2018-CFP08-REG-01-17	Full scale innovative pressure bulkheads for Regional Aircraft Fuselage barrel on-ground demonstrators	IA	1.00	Leonardo Aircraft

Identification Code	Title	Type of Action	Value (Funding in M€)	Topic Leader
JTI-CS2-2018-CFP08-REG-02-05	High fidelity power effects aerodynamics at High Reynolds conditions in Regional turboprop configuration	RIA	1.00	Airbus Defence & Space
JTI-CS2-2018-CFP08-REG-03-01	Laminar Flow robustness and Load control effectiveness evaluation for a Regional Turboprop wing	RIA	1.30	CIRA
JTI-CS2-2018-CFP08-REG: 4 topics			**4.70**	
JTI-CS2-2018-CfP08-FRC-01-18	Adoption of a "Digital Transformation" approach to improve NGCTR design and simulation	RIA	1.75	Leonardo Helicopters
JTI-CS2-2018-CfP08-FRC-01-19	Certification by Simulation for Rotorcraft Flight Aspects (CSRFA)	IA	3.00	Leonardo Helicopters
JTI-CS2-2018-CfP08-FRC-01-20	Design, development and flight qualification of a supercritical composite shaft drive line for tiltrotor main drive system	IA	0.40	Leonardo Helicopters
JTI-CS2-2018-CfP08-FRC-01-21	Development of effective engine air intake protection system for Tilt Rotor	IA	2.50	Leonardo Helicopters
JTI-CS2-2018-CfP08-FRC-01-22	Engine exhaust wake flow regulator for Tilt Rotor.	IA	1.60	Leonardo Helicopters
JTI-CS2-2018-CfP08-FRC-01-23	Experimental characterization and optimization of the RH and LH Engine intakes configuration of the next generation Tilt Rotor	RIA	3.50	Leonardo Helicopters
JTI-CS2-2018-CfP08-FRC-01-24	High efficiency full electrical low pressure Compartment Pressure Control System for tilt-rotor applications	IA	1.20	Leonardo Helicopters
JTI-CS2-2018-CFP08-FRC: 7 topics			**13.95**	
JTI-CS2-2018-CFP08-AIR-01-37	Composite mould tool based on 3D printing	RIA	0.8	SAAB
JTI-CS2-2018-CFP08-AIR-01-38	Innovative test rig for the investigation of gust loads in transonic flow conditions	RIA	1	ONERA
JTI-CS2-2018-CFP08-AIR-01-39	In-Seat Ventilation & Supply for Personalized Comfort Control on Board an Aircraft	IA	0.45	Airbus
JTI-CS2-2018-CFP08-AIR-02-60	Full Scale Innovative Integrated Tooling for Composite Material Wing Box [SAT]	IA	0.95	Israel Aircraft Industries
JTI-CS2-2018-CFP08-AIR-02-61	Development and Optimization of Bonding Assembly Technology for a Composite Material Wingbox [SAT]	IA	0.9	Israel Aircraft Industries
JTI-CS2-2018-CFP08-AIR-02-63	Enhanced Low Cost Complex Composite Structures	IA	0.75	Airbus Defense & Space
JTI-CS2-2018-CFP08-AIR-02-65	Design of special welding head for FSW process with automatic adjustable pin and welding force control system [SAT]	IA	0.7	PZL MIELEC
JTI-CS2-2018-CFP08-AIR-02-64	Cold Spray of metallic coatings on polymer and composite materials [SAT]	IA	0.7	PZL MIELEC
JTI-CS2-2018-CFP08-AIR-02-67	Model based development of an innovative ECS air distribution system for ground testing with a Cabin Demonstrator	RIA	1.3	Fraunhofer

Identification Code	Title	Type of Action	Value (Funding in M€)	Topic Leader
JTI-CS2-2018-CFP08-AIR-02-66	**Evaluation and modelling of comfort driving parameters in a Cabin Demonstrator**	RIA	1.1	Fraunhofer
JTI-CS2-2018-CFP08-AIR-03-01	**Bio contamination survey**	RIA	0.5	Dassault Aviation
JTI-CS2-2018-CFP08-AIR-03-02	**Non destructive testing (NDT) of bonded assemblies**	IA	0.6	Dassault Aviation
JTI-CS2-2018-CFP08-AIR-03-03	**Sizing for recycled carbon fibres to optimise adhesion in organic/inorganic composite materials**	RIA	0.5	Fraunhofer
JTI-CS2-2018-CFP08-AIR-03-04	**Development of an anaerobic digester prototype for aircraft use**	RIA	0.4	Fraunhofer
JTI-CS2-2018-CFP08-AIR-03-05	**Development and evaluation of a manufacturing process for a lightweight aircraft wheel made of CFRP**	IA	0.45	Fraunhofer
JTI-CS2-2018-CFP08-AIR: 16 topics			**11.50**	
JTI-CS2-2018-CfP08-ENG-01-32	**Optimized UHPE flow path cooling design and testing using advanced manufacturing techniques**	IA	1.00	GE Deutschland
JTI-CS2-2018-CfP08-ENG-01-33	**Analysis of high frequency vibrations from a Gear Box in an Engine environment by SEA (Statistical Energy Analysis).**	RIA	0.85	Safran
JTI-CS2-2018-CfP08-ENG-01-34	**Characterization of flow through rotating labyrinth seals**	RIA	0.60	Safran
JTI-CS2-2018-CfP08-ENG-01-35	**Oil flow 4 channels regulation valves**	IA	1.40	Safran
JTI-CS2-2018-CfP08-ENG-01-36	**Optimizing impingement cooling**	RIA	0.60	Safran
JTI-CS2-2018-CfP08-ENG-01-37	**Aerodynamic SACOC upgrade**	RIA	0.65	Safran
JTI-CS2-2018-CfP08-ENG-01-38	**Low NOx / Low soot injection system design for spinning combustion technology**	RIA	0.60	Safran
JTI-CS2-2018-CfP08-ENG-02-09	**Development and verification of microstructure, residual stress and deformation simulation capability for additive free-form deposition using multiple superalloys**	RIA	0.80	GKN Aerospace
JTI-CS2-2018-CfP08-ENG-03-23	**Probabilistic simulation of defect probability in titanium fusion processes**	RIA	0.60	GKN Aerospace
JTI-CS2-2018-CfP08-ENG-03-24	**VHCF material model for case hardened gear steels for application in an epicyclic power gearbox**	RIA	2.40	Rolls-Royce
JTI-CS2-2018-CfP08-ENG-03-25	**Development of design methodologies for thermal management and scavenge / sealing interactions in future ventless UltraFan bearing chambers**	RIA	1.70	Rolls-Royce
JTI-CS2-2018-CFP08-ENG: 11 topics			**11.20**	
JTI-CS2-2018-CFP08-SYS-02-46	**Modeling of friction effects caused by surface contact with high pressure and rapid movement**	**RIA**	**0.70**	**Liebherr**

Identification Code	Title	Type of Action	Value (Funding in M€)	Topic Leader
JTI-CS2-2018-CFP08-SYS-02-47	New grip generation for active inceptor	IA	0.50	Safran
JTI-CS2-2018-CFP08-SYS-02-48	Long stroke linear piezo actuators	IA	0.80	Safran
JTI-CS2-2018-CFP08-SYS-02-49	Health Monitoring for EHA fluid	IA	0.50	Safran
JTI-CS2-2018-CFP08-SYS-02-50	CFRP electrically heated tools for high pressure RTM	IA	0.75	Fokker Landing Gear
JTI-CS2-2018-CFP08-SYS-02-51	Innovative quality inspection methods for CFRP primary structural parts	IA	0.75	Fokker Landing Gear
JTI-CS2-2018-CFP08-SYS-02-52	Innovative Composite Material Qualification Methodologies	IA	1.00	Fokker Landing Gear
JTI-CS2-2018-CFP08-SYS-02-53	Development of an optimized DC-DC converter for a smart electrical system	IA	0.70	Safran
JTI-CS2-2018-CFP08-SYS-02-54	Development of a HVDC current limiter	IA	0.65	Zodiac Aero Electric
JTI-CS2-2018-CFP08-SYS-02-55	Air treatment system for airborne microbe removal from air circulation or chambers	RIA	0.65	United Technologies Research Centre
JTI-CS2-2018-CFP08-SYS-02-66	Winglet tab EMA validation and ECUs for flight control systems completion in new electrical wing	RIA	0.90	CESA
JTI-CS2-2018-CFP08-SYS-03-17	Improved Thermal Properties of Computing Platforms for Next-Generation Avionics [SAT]	RIA	0.80	Honeywell International
JTI-CS2-2018-CFP08-SYS-03-18	Development and testing of innovative Cr free anodic layers removal solution	RIA	0.50	Liebherr
JTI-CS2-2018-CFP08-SYS: 13 topics			9.20	

List of Topics for Calls for Partners (CFP08) – Part B

Identification Code	Title	Type of Action	Value (Funding in M€)
JTI-CS2-2018-CFP08-TT-01	Concept Design of a 19-seat Commuter Aircraft with Hybrid-Electric Powertrain	RIA	0.80
JTI-CS2-2018-CFP08-TT-02	Innovative NOx Reduction Technologies	RIA	1.00
JTI-CS2-2018-CFP08-TT-03	End-to-End impact scenarios for hybrid-electric propulsion concepts in short range / regional commercial air transport	RIA	0.40
JTI-CS2-2018-CFP08-TT-04	Cognitive Computing potential for cockpit operations	RIA	0.80

PART A: Call topics launched within the complementary framework of IADP/ITD/TA

1. Overview of number of topics and total indicative funding value per SPD

CfP08 Call Overview

SPD Area	No. of topics	Ind. topic Funding (M€)
IADP Large Passenger Aircraft	17	19.75
IADP Regional Aircraft	4	4.70
IADP Fast Rotorcraft	7	13.95
ITD Airframe	16	11.50
ITD Engines	11	11.20
ITD Systems	13	9.20
Small Air Transport (SAT)*	[5]	[4.05]
ECO Design	[0]	[0]
Technology Evaluator	[0]	[0]
TOTAL	68	70.30

* SAT related topics are proposed and embedded in the concerned SPDs as follows: AIR: 4 SAT topics, 3.25 M€ and SYS: 1 SAT topic, 0.80 M€

2. Call Rules

Before submitting any proposals to the topics proposed in the Clean Sky 2 Call for Proposals, all applicants shall refer to the applicable rules as presented in the "*Rules for submission, evaluation, selection, award and review procedures of Calls for Proposals*" and the "*Work Plan 2018-2019".*

3. Programme Scene setter/Objectives

In accordance with Article 2 of the COUNCIL REGULATION (EU) No 558/2014 of 6 May 2014 the **Clean Sky 2 high-level (environmental) objectives are**:

"(*b) to contribute to improving the environmental impact of aeronautical technologies, including those relating to small aviation, as well as to developing a strong and globally competitive aeronautical industry and supply chain in Europe.*
This can be realised through speeding up the development of cleaner air transport technologies for earliest possible deployment, and in particular the integration, demonstration and validation of technologies capable of:

(i) increasing aircraft fuel efficiency, thus reducing CO2 emissions by 20 to 30 % compared to 'state-of-the-art' aircraft entering into service as from 2014;
(ii) reducing aircraft NOx and noise emissions by 20 to 30 % compared to 'state-of-the-art' aircraft entering into service as from 2014."

These Programme's high-level (environmental) objectives have been translated into **targeted vehicle performance levels,** see table below. Each conceptual aircraft summarises the key enabling technologies, including engines, developed in Clean Sky 2.

Conceptual aircraft / air transport type	Reference a/c*	Window[1]	ΔCO_2	ΔNO_x	Δ Noise	Target[2] TRL @ CS2 close
Advanced Long-range (LR)	LR 2014 ref	2030	20%	20%	20%	4
Ultra advanced LR	LR 2014 ref	2035+	30%	30%	30%	3
Advanced Short/Medium-range (SMR)	SMR 2014 ref	2030	20%	20%	20%	5
Ultra-advanced SMR	SMR 2014 ref	2035+	30%	30%	30%	4
Innovative Turboprop [TP], 130 pax	2014 130 pax ref	2035+	19 to 25%	19 to 25%	20 to 30%	4
Advanced TP, 90 pax	2014 TP ref[4]	2025+	35 to 40%	> 50%	60 to 70%	5
Regional Multimission TP, 70 pax	2014 Multi-mission	2025+	20 to 30%	20 to 30%	20 to 30%	6
19-pax Commuter	2014 19 pax a/c	2025	20%	20%	20%	4-5
Low Sweep Business Jet	2014 SoA Business a/c	2035	> 30%	> 30%	> 30%	≥ 4
Compound helicopter[3]	TEM 2020 ref (CS1)	2030	20%	20%	20%	6
Next-Generation Tiltrotor	AW139	2025	50%	14%	30%	5

*The reference aircraft will be further specified and confirmed through the Technology Evaluator assessment work.
[1]All key enabling technologies at TRL 6 with a potential entry into service five years later.
[2]Key enabling technologies at major system level. The target TRL indicates the level of maturity and the level of challenge in maturing towards potential uptake into marketable innovations.
[3]Assessment v. comparable passenger journey, not a/c mission.
[4] ATR 72 airplane, latest SOA Regional A/C in-service in 2014 (technological standard of years 2000), scaled to 90 Pax.

To integrate, demonstrate and validate the most promising technologies capable of contributing to the CS2 high-level and programme specific objectives, the CS2 technology and demonstration activity is structured in **key (technology) themes,** further subdivided in a number of **demonstration areas**, as depicted below. A demonstration area may contribute to one or more objectives and also may involve more than one ITD/IADP.

Ref-Code	Theme	Demonstration area
1A	Breakthroughs in Propulsion Efficiency (incl. Propulsion-Airframe Integration)	Advanced Engine/Airframe Architectures
1B		Ultra-high Bypass and High Propulsive Efficiency Geared Turbofans
1C		Hybrid Electric Propulsion
1D		Boundary Layer Ingestion
1E		Small Aircraft, Regional and Business Aviation Turboprop
2A	Advances in Wings, Aerodynamics and Flight Dynamics	Advanced Laminar Flow Technologies
2B		Regional Aircraft Wing Optimization
3A	Innovative Structural / Functional Design - and Production System	Advanced Manufacturing
3B		Cabin & Fuselage
3C		Innovative Solutions for Business Jets
4A	Next Generation Cockpit Systems and Aircraft Operations	Cockpit & Avionics
4B		Advanced MRO
5A	Novel Aircraft Configurations and Capabilities	Next-Generation Civil Tiltrotor
5B		RACER Compound Helicopter
6A	Aircraft Non-Propulsive Energy and Control Systems	Electrical Systems
6B		Landing Systems
6C		Non-Propulsive Energy Optimization for Large Aircraft
7A	Optimal Cabin and Passenger Environment	Environmental Control System
7B		Innovative Cabin Passenger/Payload Systems
8A	Eco-Design	
9A	Enabling Technologies	
	Technology Evaluator	

The individual topic descriptions provide more detailed information about the link/contribution to the high-level objectives.

4. Clean Sky 2 – Large Passenger Aircraft IAPD

I. JTI-CS2-2018-CfP08-LPA-01-47: High Performance Electrical Components for Bleed Control

Type of action (RIA/IA/CSA)	IA		
Programme Area	LPA		
(CS2 JTP 2015) WP Ref.	WP 1.1.10		
Indicative Funding Topic Value (in k€)	900		
Topic Leader	Safran	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	30	**Indicative Start Date (at the earliest)**[1]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-LPA-01-47	**High Performance Electrical Components for Bleed Control**
Short description	
This topic aims at developing of high performance, high reliability, low cost, low weight electrical bleed control valves and electrical inlet guide vane actuator, in order to be able to control the APU bleedflow of an innovative Non Propulsive Energy generation system.	

Links to the Clean Sky 2 Programme High-level Objectives[2]				
This topic is located in the demonstration area:	Non-Propulsive Energy Optimization for Large Aircraft			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Long-range, Advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

[1] The start date corresponds to actual start date with all legal documents in place.
[2] For further info see Chapter 1 “Introduction to the Programme Scene Setter / Objectives” with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

High Performance Electrical Components for Bleed Control studies present significant opportunities of weight reduction and optimized maintenance through the suppression of the need for pressurized fluid for actuation.

With the development of full electrical architectures in order to support the needs of More Electric Aircraft and future Non propulsive Energy Generation system, it is necessary to consider enhanced electrical bleed control valve and inlet guide vane actuators, in terms of reliability (targeted MTBF: 50 000 h), with weight, volume and costs competitive with hydraulic / pneumatic technologies.

The introduction of EMA technology on previous Power On Demand Systems has enabled the demonstration of the feasability of an electrical actuated bleedflow control, offering electrification of the bleed control function.

Yet, the implementation of electronic components in APU engine environment is introducing new risks associated with the impacts on reliability of such hardware in realistic (hot > 125°C) conditions. To overcome this, architectures are being developed to minimize the amount of sensitive hardware and propose new cooling architectures.

It is envisaged that with the advent of High Performance Electrical Components for Bleed Control Advanced Health monitoring will be made possible on the bleed flow control, ensuring better dispatch of the Aircraft.

This Work Package focusses upon the electrical actuators associated with the system depicted below. The diagram illustrates the interactions between the different items being developed through this CFP.

Preliminary studies of the applications indicate the following approximate specification points:

- Bleed flow for demonstration: 2 kg/s
- EMA stroke: 2”
- EMA force: 800 N
- Bleed valve dynamics (Open/close): 0.5 to 1.5 s

The Work Package contributors will be experts in the field of pneumatic and control systems, including the disciplines of electronics, digital control, mechanical and thermal engineering, and in the selection of components and specification and/or manufacture of components such as valves, actuators and control units for high reliability applications. The objective will be to validate designs against the severe operating requirements of the application, especially reliability aspects.

The primary objective is the development of two components: EMA for inlet guide vanes and electrical bleed control valve, as far as the demonstration of their reliability in harsh environment.

The particular challenges surround the required robustness and reliability in the harsh environment, being integrated with the electrical components, combined with the stringent requirements for size, weight, efficiency and compatibility with aeronautical performance standards.

2. Scope of work

Tasks		
Ref. No.	***Title - Description***	***Due Date***
T2.1	Initial Requirements Capture – define requirements and interfaces through discussion with stakeholders	T0+1
T2.2	Component selection – perform initial performance analyses to enable baseline selection of components to meet the main performance requirements.	T0+3
T2.3	Components architecture definition	T0+6
T2.4	Functional modelling and failure mode analysis (FMEA)	T0+9
T2.5	Module Functional definition	T0+9
T2.6	Supply chain identification and industrialization assessment	T0+10
T2.7	Inlet guide vane actuator Preliminary Design and performance prediction	T0+12
T2.8	Bleed Control Valve Preliminary Design and performance prediction	T0+12
T2.9	Bleed Control Valve Detailed Design	T0+18
T2.9	Inlet guide vane actuator Detailed Design	T0+18
T2.10	Module manufacture	T0+24
T2.11	Module electrical and thermal performance characterisation and environmental test	T0+27
T2.12	Integration support	T0+30

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title – Description***	***Type****	***Due Date***
D2.1	Preliminary Requirements Specification	R	T0+3
D2.2	Module Architecture Report	R	T0+6
D2.3	Industrialisation Assessment Report	R	T0+12
D2.6	Test report	R	T0+27
D2.7	Two components shipsets for integration	HW	T0+27
D2.8	Final report (incl. reliability prediction)	R	T0+30
Milestones (when appropriate)			
Ref. No.	***Title – Description***	***Type****	***Due Date***
D2.4	Preliminary Design Review	D	T0+12
D2.5	Detailed Design and Manufacturing Review	D	T0+18

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Specialist in pneumatics systems & control systems
- Links with, or internal, design & industrial capacity in power electronics
- Mechanical design of actuators
- Knowledge of aeronautical constraints (environments)
- Test & analysis capability to support detailed behavioural characterisation of power components

and their failures, including electrical, electromagnetic, thermal and combined effects

5. Abbreviations

AC	Alternating Current
FPGA	Field Programmable Gate Array
CPU	Central Processing Unit
EMA	ElectroMechanical Actuator
HW	Hardware
IGV	Inlet Guide Vane

II. JTI-CS2-2018-CfP08-LPA-01-48: Advanced Pitch Control Mechanism TRL4 Demonstration

Type of action (RIA/IA/CSA)	IA		
Programme Area	LPA		
(CS2 JTP 2015) WP Ref.	WP 1.1.3		
Indicative Funding Topic Value (in k€)	3500		
Topic Leader	SAFRAN	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	48	**Indicative Start Date (at the earliest)**[3]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-LPA-01-48	**Advanced Pitch Control Mechanism TRL4 Demonstration**
Short description	
Future engine architectures require advanced performance pitch control mechanism featuring reduced mass; enhanced stiffness; improved maintainability; high accuracy and increased actuation capability. The project intends to identify most relevant concept; to design it from concept to detailed design; to manufacture, assemble and test it in representative testing conditions (vibration, endurance, performance, actuation; etc)	

Links to the Clean Sky 2 Programme High-level Objectives[4]				
This topic is located in the demonstration area:	Advanced Engine/Airframe Architectures			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

[3] The start date corresponds to actual start date with all legal documents in place.
[4] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

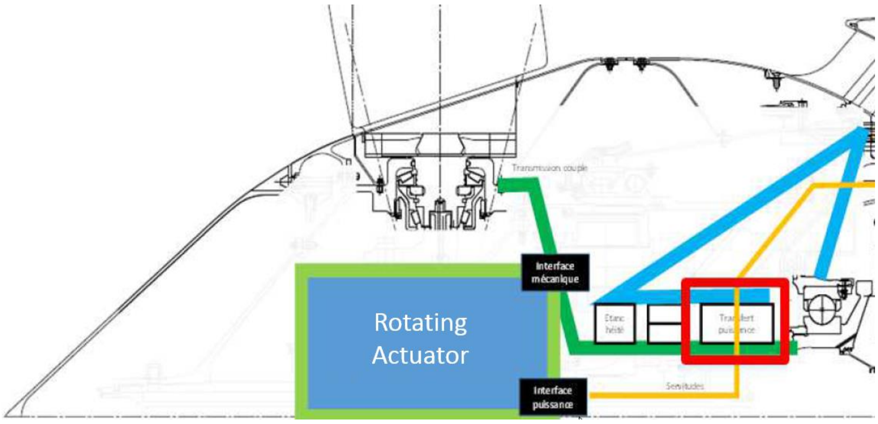


Figure 1 Advanced PCM in forward engine rotating environment

Future engine architectures like open rotor or advanced turbofan may need additional fan or propeller blade controllability in order to cope with high performance and operability objectives.
In order to do so; adjustable pitch fan/propeller blades are required to achieve this goal.
In the past; such pitch control system or mechanism is already known as it has been required in order to enable propellers to cope with wide speed range. Various technologies have been used to do so in the past decades; either pure mechanical not controlled system or complex hydraulic systems and even more recently electrical systems.
Recently; Safran Aircraft Engines went through a ten years research project in Cleansky during which an open rotor engine called SAGE2 engine has been designed; manufactured; assembled and tested. This engine incorporated two PCM; one in each rotor; to enable independent control of each propeller blade stage.
SAGE2 PCM will be briefely described in the document; they are both similar and based on static hydraulic actuators transferring motion and loads thanks to bearings and rods. That is the main difference with the cfp PCM which is integrated under the fan blades. That kind of integration involve the use of a rotating actuator.
The objectives of the current CfP is to provide and advanced PCM technology located in rotating environment; based on historical technology background as well as more recent SAGE2 technology demonstration; in order to provide more fuel efficient; more reliable; lighter future engines featuring blade pitch control.
This rotating PCM study is a major technological breakthrough regarding the development of all the LPA demonstrators: UHBR (variable and geared fan), BLI (active variable fan) and USF (variable open fan).

The most important advantages of a variable pitch fan are:

- The reverse capability : mass gain → fuel burn reduction
- The fan adjustment capability on forward range :
    - → Noise reduction
    - → Power adjustment → fuel burn reduction

2. Scope of work

The scope of work is based on TRL4 demonstration of a new PCM technology with advanced performance pitch control mechanism featuring reduced mass; enhanced stiffness; improved maintainability; high accuracy and increased actuation capability. The project intends to identify most relevant concept; to design it from concept to detailed design; to manufacture, assemble and test it in representative testing conditions (vibration, endurance, performance, etc).

TRL4 is intended as PCM validation in relevant environment. Fidelity of breadboard technology is to be increased significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment.

The Pitch Actuation sub components have been split into several lower levels functions described below:

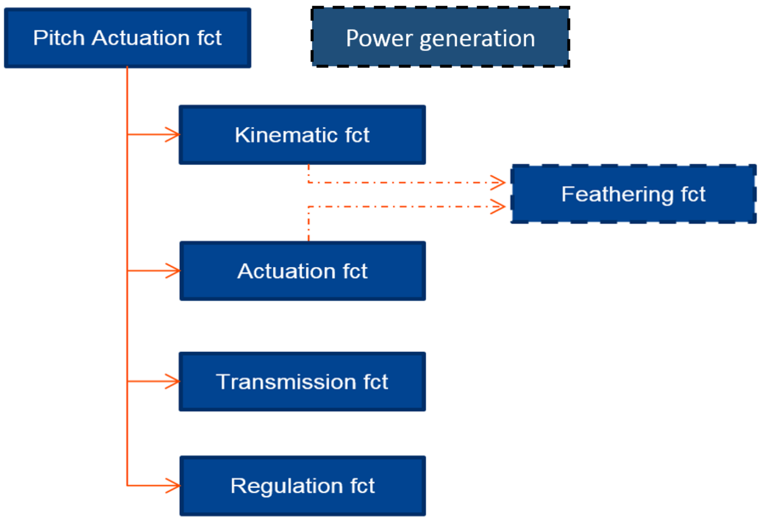


Figure 2 PCM functions breakdown

The main functions of Pitch Actuation Mechanism are listed below:

- Control blade pitch based on power provided at PCM interface with specified total and relative accuracy.
- Provide blade pitch value thanks to dedicated sensor to engine control system.
- Limit the blade pitch range according aircraft operating mode (flight fine stop function).
- Limit the blade pitch speed range.
- Ensure blade feathering capability (replace conventional direct counterweight).

Note: even though power generation is not a PCM function; it is required to the applicant to evaluate the impact of power requirements and make proposal if relevant to general objectives.

As background description; please find below how the functions are performed on either conventionnal (typical XXth century propeller) or SAGE2 open rotor:

	Kinematics	Actuation	Transmission	Feathering	Control System
Conventional PCM	Gears or rods	Hydraulic actuator in rotating environment	OTB	Direct counterweight	Mechanical or electrical
SAGE2 open rotor	Rods	Hydraulic actuator in stator environment	Bearing	Direct counterweight	Electrical *No flight fine stop*
Advanced PCM	TBD	Actuator in rotating environment	TBD	TBD	Electrical *With flight fine stop*

Table 1 PCM functions technologies

Advanced PCM maturation work plan is typically spread over 3-4 years in order to achieve TRL4 demonstration. The main tasks are developed below:

Tasks		
Ref. No.	***Title - Description***	***Due Date***
PCM_Task_01	Specification and Risk Analysis	Q2 2019
PCM_Task_02	Conceptual integrated PCM design	Q3 2019
PCM_Task_03	Preliminary integrated PCM design Preliminary test plan.	Q2 2020
PCM_Task_04	Detailed integrated PCM design: same as PDR at detailed level for final validation. Detailed test plan.	Q4 2020
PCM_Task_05	N/A	N/A
PCM_Task_06	PCM manufacturing	Q3 2021
PCM_Task_07	PCM individual components testing	Q3 2021
PCM_Task_08	N/A	N/A
PCM_Task_09	PCM assembly (PCM and PCM rig)	Q4 2021
PCM_Task_10	N/A	N/A
PCM_Task_11	PCM rig commissioning	Q2 2022
PCM_Task_12	PCM acceptance and qualification testing	Q3 2022
PCM_Task_13	N/A	N/A
PCM_Task_14	N/A	N/A
PCM_Task_15	PCM investigations; lessons learned and way forward analysis	Q4 2022

High level requirements for advanced PCM demonstration:

- Rotor speed: from 700 to 1200RPM.
- Available volume: preliminary 2D design box: [length; radius] = [750; 250] mm.
- Actuation capability: 1500Nm at max actuation blade request for a 12 blade fan/propeller.
- Pitch range: [-30; +90]deg; max operating actuation at TO ~40deg.
- Pitch rate: nominal/limit/ultimate: 15/30/60deg/s.
- Mass : 200kg +/-40kg
- Thermal environment:
  - Minimal surviving temperature: -55°C.
  - Minimal operating temperature: -40°C.

- Normal operating condition: 120°C.
  - Limit operation condition: 150°C.
  - Ultimate operation condition: 180°C.
- Stiffness: 60Nm/rad for each 1Nm blade actuation capability.

Thus for 1000Nm max blade actuation → 60000Nm/rad stiffeness requirement.

- Accuracy:
  - Absolute accuracy (between request and individual blade): +/-0.5deg.
  - Relative accuracy (between one blade to one another): +/-0.1deg.
- Loads:
  - Vibration: demonstration according DO-160G – vibration category T.
  - Acceleration loads: x engine axis; z vertical axis; y lateral axis:
    - Limit: Nz[-1.8;3.8]g ; Ny[-2;2]g ; Nx[-1.3;1.3]g
    - Ultimate: Nz[-4;6]g ; Ny[-3;3]g ; Nx[-9;9]g
- Power:
  - Hydraulic: oil (MIL-PRF-23699 "type II" grade STD or HTS) at indicative 120 to 206 bars; 3700L/hr.
  - Electrical: indicative 115VAC/400Hz or 115VAC/VF.
- Life:
  - Targeted engine life: 60 000hr and 36 000 cycles.
  - PCM demonstrator life: 1000hr and 500 cycles.
    To be considered for design criteria; not to be considered as endurance specification.
- Maintainability:
  - Targeted MTBO: 10 000 hrs.
  - Targeted MTBF: 60 000hrs.
  - Capability to disassemble and replace PCM in engine rotor: 2 hours.

Note: all above general specifications are listed in order to provide high level of preliminary specification that will be reviewed and detailed during CfP work based on detailed specification datasheet provided by SAE.

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
PCM_Del_01	Specification and Risk Analysis Review Presentation Specification and Risk Analysis Design Report Content: • High-level specifications • Assumptions / states of the art, red lines	R	Q2 2019

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
PCM_Del_02	Concept Review Presentation: • High-level specifications • Assumptions / states of the art, red lines • Preliminary PCM section • Major choices regarding technology, architecture, materials: • experience and Technological Demonstration Program • Systems; preliminary; any new features • Weight • Comparative score card Level of maturity of the proposed technologies and selection • Maturation plan for the innovating technologies • Maintainability • Risks and risk reduction plans, • Preliminary development plan Concept Design Report	R	Q3 2019
PCM_Del_03	Preliminary Review Presentation: • Technical Specification (feasibility; compatibility) • PCM concept (function and performance description; interfaces description) • Substantiation (PCM substantiation plan; trade-offs made; experience and feedbacks; performance demonstration; recommendations answers) • Development plan (activities sequence; production and assembly schedule; partial tests plan; innovative and back up technologies; means of compliance; PCM rig design). • Industrial feasibility • Maintainability and reparability studies. • Recurrent costs. • Risk analysis. Preliminary Design Report	R	Q2 2020
PCM_Del_04	Detailed Review Presentation: • Same as PDR at detailed/final stage. Detailed Design Report	R	Q4 2020
PCM_Del_05	TRL3 Review Presentation: • Design capability • Design validation status • Production capability • Handling capability • Manufacturing capability TRL3 Design Report	R	Q4 2020

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
PCM_Del_06	Manufacturing Review: • Detailed and assembly drawings. • Assembly process. • Bill of Material and Hardware. • Control report. • Concessions status and strategy. • Recommendations answers. Manufacturing Report	D	Q3 2021
PCM_Del_07	Component Testing Review Component Testing Report	D	Q2 2021
PCM_Del_08	Component tested hardware: key component after testing (sensor; bearing; seal).	HW	Q3 2021
PCM_Del_09	Assembly Review: same as manufacturing at complete hardware stage level. Assembly Report (PCM and PCM rig)	D	Q4 2021
PCM_Del_10	N/A	N/A	N/A
PCM_Del_11	PCM test rig commissioning report	D	Q2 2022
PCM_Del_12	Acceptance Test Review : • Electrical bonding test. • Displacement sensor calibration test. • Green run test. • Internal friction test. • Internal leakages test – static and dynamic (if relevant). • Cooling flow test (if relevant). • Proof pressure test (if relevant). • Any other relevant acceptance test related to PCM architecture. Acceptance Test ReportQualification Test Review : • Electrical test. • Performance test. • Endurance test (min 100hr). • Proof pressure test (if relevant). • Dielectric rigidity test. • Vibration test. • Any other relevant qualification test related to PCM architecture. Qualification Test Report	D	Q3 2022
PCM_Del_13	TRL4 Review : same as TRL3 at TRL3 stage. TRL4 Design Report	R	Q2 2022
PCM_Del_14	Tested PCM hardware (min 1 complete PCM)	HW	Q3 2022
PCM_Del_14	PCM investigations; lessons learned and way forward analysis report	R	Q4 2022

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
PCM_MS_01	Specification Review	R	Q2 2019
PCM_MS_02	COR	R	Q3 2019
PCM_MS_03	PDR	R	Q2 2020
PCM_MS_04	CDR	R	Q4 2020
PCM_MS_05	TRL3 review	R	Q4 2020
PCM_MS_06	Manufacturing Review	R	Q3 2021
PCM_MS_07	Component Testing Review	R, HW	Q2 2021
PCM_MS_08	N/A	N/A	N/A
PCM_MS_09	Assembly Review (PCM and PCM rig)	R	Q4 2021
PCM_MS_10	N/A	N/A	N/A
PCM_MS_11	PCM Rig Commissioning Review	R	Q2 2022
PCM_MS_12	Acceptance and Qualification Test Review	R	Q3 2022
PCM_MS_13	TRL4 Review	R	Q3 2022
PCM_MS_14	Tested PCM Commissioning	R, HW	Q3 2022
PCM_MS_15	PCM investigations; lessons learned and way forward analysis review	R	Q4 2022

Safran will provide detailed specifications and provide feedback during design reviews.
Face-to-face meetings are expected for each deliverable/review as well as during Quaterly progress reviews. Monthly phone calls will be established for project progress follow-up and technical interactions.

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Architecture design: safety; fault; reliability management; control-command-monitoring skills.
- Mechanical design: static; dynamic; kinematics; friction analysis; thermal manangement.
- Hydraulic design: fluid simulation; thermal management.
- Electrical design: actuator sizing; conversion management ; thermal management.
- Manufacturing and assembly: provisionning (raw material and components like sensors; bearings; seals etc); machining; controlling of PCM components and sub assembly.
- Testing and inspecting: provisionning and testing individual components (such as motion sensor); testing PCM system (mechanical testing; hydraulic testing; vibration testing; electrical testing).

5. Abbreviations

BLI	Boundary layer ingestion
CDR	Critical Design Review
COR	Concept Review
FCT	Function
HP	high pressure
LTB	Load Transfer bearing (in front propeller PCM)
LVDT	Linear Variable Displacement Transducer
MTBF	Mean Time Between Failure
MTBO	Mean Time Between Overhaul

N/A	Not Applicable
OTB	Oil Transfer Bearing
PCM	Pitch Change Mechanism
PCU	Pitch Control Unit
PDR	Preliminary Design Review
REACH	Registration, Evaluation, Authorisation and Restriction of Chemical Substances
RSB	Radial Shaft Bearing
SAE	Safran Aircraft Engines
TBC	To Be Confirmed
TBD	To be defined
UHBR	Ultra High By pass Ratio
VAC	Volt Alternating Current
VF	Variable Frequency
VPF	Variable Pitch Fan

III. JTI-CS2-2018-CfP08-LPA-01-49: Advanced Oil Transfer Bearing TRL4 Demonstration

Type of action (RIA/IA/CSA)	IA		
Programme Area	LPA		
(CS2 JTP 2015) WP Ref.	WP 1.1.3.4.7		
Indicative Funding Topic Value (in k€)	2500		
Topic Leader	SAFRAN	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	36	**Indicative Start Date (at the earliest)**[5]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-LPA-01-49	**Advanced Oil Transfer Bearing TRL4 Demonstration**
Short description	
Future aeroengine architectures are likely to feature main power gearbox, as power transfer element between low pressure turbine and low pressure compressor, and may require performance pitch control mechanism. Both features, that may coexist or be implemented separately, are based on high energy oil transfers to rotating parts. One key feature to concept competitiveness is the availability of an advanced Oil Transfer Bearing ensuring this transmission function, and featuring reduced mass, enhanced stiffness, improved maintainability, high accuracy and increased actuation capability. The project intends to identify most relevant concept; to design it from concept to detailed design; to manufacture, assemble and test it in representative testing conditions (vibration, endurance, performance, actuation; etc)	

Links to the Clean Sky 2 Programme High-level Objectives[6]				
This topic is located in the demonstration area:	Advanced Engine/Airframe Architectures			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

[5] The start date corresponds to actual start date with all legal documents in place.

[6] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

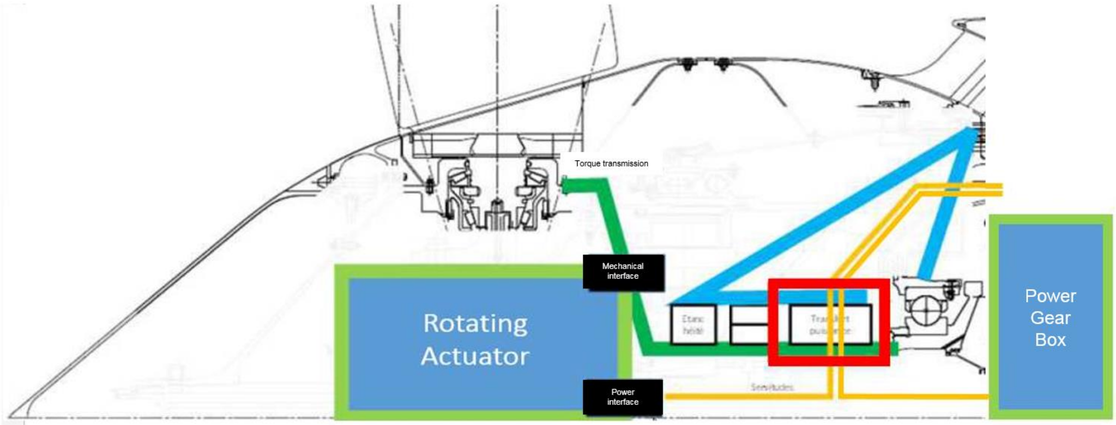


Figure 3 Advanced OTB (red circled) in forward engine rotating environment

Future engine architectures like open rotor or advanced turbofan are likely to feature main power gearbox, as power transfer element between low pressure turbine and low pressure compressor, and may need additional fan or propeller blade controllability in order to cope with high performance and operability objectives.
In order to do so; adjustable pitch fan/propeller blades are required to achieve this goal, in combination with main power gearbox.

One key feature to this architectural feasibility is the ability to transfer high energy oil to rotating parts:

- Either to perform pitch change actuation
- And/or to contribute to main power gearbox lubrication

Regarding the pitch change actuation:
In the past, pitch control system or mechanism based on OTB technology have been implemented as this concept has been required in order to enable propellers to cope with wide speed range. For instance, SNECMA-RollsRoyce Tyne engine has been featuring OTB technology integrated in between the gas turbine and the power gearbox.
Recently, Safran Aircraft Engines went through a ten years research project in Clean Sky during which an open rotor engine called SAGE2 engine has been designed, manufactured, assembled and tested. This engine incorporated two PCM; one in each rotor; to enable independent control of each propeller blade stage. The transfer technology was performed thanks to large and heavy load transfer bearing.
SAGE2 load transfer bearing will be briefly described in the document; they are both similar and ensuring the transmission of stator actuator motion and loads to rotating kinematics.
The objectives of the current CfP is to provide and advanced OTB technology located in rotating environment, based on historical technology background as well as more recent SAGE2 technology demonstration, in order to provide more fuel efficient, more reliable, lighter future engines featuring power transfer to rotating environment.
This need is to be understood in the light of a dual requirement: ability to transfer actuation power (variable pitch system target), and ability to transfer lubricant (main power gearbox target).

2. Scope of work

The scope of work is based on TRL4 demonstration of a new OTB technology with advanced performance OTB featuring reduced mass, enhanced stiffness, improved maintainability, low leakage and power dissipation.

The project intends to identify most relevant concept, to design it from concept to detailed design, to manufacture, assemble and test it in representative testing conditions (vibration, endurance, performance, leakage, etc).

Compliance with the 2 functions (gearbox lubrication and power transfer for actuation) must be demonstrated by tests or analysis based on test or experience on similar designs.

TRL4 is intended as OTB validation in relevant environment. Fidelity of breadboard technology is to be increased significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment.

In the context of pitch change actuation, the main functions of the system are listed below:

- Provide actuation power to rotating PCM.
- Limit power dissipation.
- Cope with engine loads and stator/rotor relative displacements.

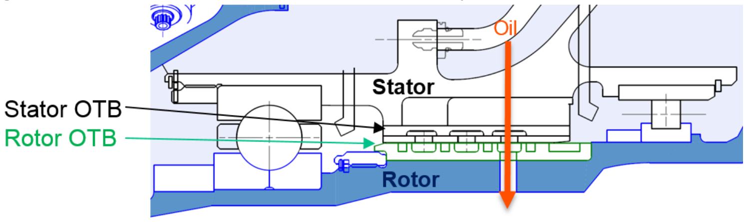


Figure 4 Conceptual SAE OTB design

Note: even though power generation is not a OTB function; it is required to the applicant to evaluate the impact of power requirements and make proposal if relevant to general objectives.

Advanced OTB maturation work plan is typically spread over 3-4 years in order to achieve TRL4 demonstration. The main tasks are developed below:

Tasks		
Ref. No.	***Title - Description***	***Due Date***
OTB_Task_01	Specification and Risk Analysis	Q2 2019
OTB_Task_02	Conceptual integrated OTB design	Q3 2019
OTB_Task_03	Preliminary integrated OTB design Preliminary test plan.	Q1 2020
OTB_Task_04	Detailed integrated OTB design: same as PDR at detailed level for final validation. Detailed test plan.	Q3 2020
OTB_Task_05	N/A	N/A
OTB_Task_06	OTB manufacturing	Q1 2021
OTB_Task_07	OTB individual components testing	Q1 2021
OTB_Task_08	N/A	N/A
OTB_Task_09	OTB assembly (OTB and OTB rig)	Q1 2021

Tasks		
Ref. No.	***Title - Description***	***Due Date***
OTB_Task_10	N/A	N/A
OTB_Task_11	OTB rig commissioning	Q2 2021
OTB_Task_12	OTB acceptance and qualification testing	Q2 2021
OTB_Task_13	N/A	N/A
OTB_Task_14	N/A	N/A
OTB_Task_15	OTB investigations; lessons learned and way forward analysis	Q4 2021

High level requirements for advanced OTB demonstration:

- Rotor speed: from 700 to 4000 rpm.
- Available volume: preliminary 2D design box:
  - Radius [50-200]mm range.
  - Length [100-150]mm range
- Power lines: between 1 and 4, depending on functional scope (pitch actuation only, gearbox lubrication only, both functions).
- Thermal environment:
  - Minimal surviving temperature: -55°C.
  - Minimal operating temperature: -40°C.
  - Normal operating condition: 120°C.
  - Limit operation condition: 150°C.
  - Ultimate operation condition: 180°C.
- Leakage levels: 200L/hr max.
- Loads:
  - Vibration: demonstration according DO-160G – vibration category T.
  - Acceleration loads: x engine axis; z vertical axis; y lateral axis:
    - Limit: Nz[-1.8;3.8]g ; Ny[-2;2]g ; Nx[-1.3;1.3]g
    - Ultimate: Nz[-4;6]g ; Ny[-3;3]g ; Nx[-9;9]g
- Power:
  - Hydraulic: oil (MIL-PRF-23699 "type II" grade STD or HTS)
  - Actuation function : oil at indicative pressure 50 to 210 bars; up to 4000L/hr massflow rate.
  - Lubrication function : oil at indicative pressure 8 bars ; 7000 L/hr massflow rate
- Life:
  - Targeted engine life: 60 000hr and 36 000 cycles.
  - OTB demonstrator life: 1000hr and 500 cycles.

    To be considered for design criteria; not to be considered as endurance specification.
- Maintainability:
  - Targeted MTBO: 10 000 hrs.
  - Targeted MTBF: 60 000hrs.
  - Capability to disassemble and replace OTB in engine rotor: 2 hours.

Note: all above general specifications are listed in order to provide high level of preliminary specification that will be reviewed and detailed during CfP work based on detailed specification datasheet provided by SAE.

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
OTB_Del_01	Specification and Risk Analysis Review Presentation Specification and Risk Analysis Design Report Content: • High-level specifications • Assumptions / states of the art, red lines	R	Q2 2019
OTB_Del_02	Concept Review Presentation: • High-level specifications • Assumptions / states of the art, red lines • Preliminary OTB section • Major choices regarding technology, architecture, materials: • experience and Technological Demonstration Program • Systems; preliminary; any new features • Weight • Comparative score card Level of maturity of the proposed technologies and selection • Maturation plan for the innovating technologies • Maintainability • Risks and risk reduction plans, • Preliminary development plan Concept Design Report	R	Q3 2019
OTB_Del_03	Preliminary Review Presentation: • Technical Specification (feasibility; compatibility) • OTB concept (function and performance description; interfaces description) • Substantiation (OTB substantiation plan; trade-offs made; experience and feedbacks; performance demonstration; recommendations answers) • Development plan (activities sequence; production and assembly schedule; partial tests plan; innovative and back up technologies; means of compliance; OTB rig design). • Industrial feasibility • Maintainability and reparability studies. • Recurrent costs. • Risk analysis. Preliminary Design Report	R	Q1 2020
OTB_Del_04	Detailed Review Presentation: • Same as PDR at detailed/final stage. Detailed Design Report	R	Q3 2020
OTB_Del_05	TRL3 Review Presentation:	R	Q3 2020

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
	• Design capability • Design validation status • Production capability • Handling capability • Manufacturing capability TRL3 Design Report		
OTB_Del_06	Manufacturing Review: • Detailed and assembly drawings. • Assembly process. • Bill of Material and Hardware. • Control report. • Concessions status and strategy. • Recommendations answers. Manufacturing Report	D	Q1 2021
OTB_Del_07	Component Testing Review Component Testing Report	D	Q1 2021
OTB_Del_08	Component tested hardware: key component after testing (sensor; bearing; seal).	HW	Q1 2021
OTB_Del_09	Assembly Review: same as manufacturing at complete hardware stage level. Assembly Report (OTB and OTB rig)	D	Q1 2021
OTB_Del_10	N/A	N/A	N/A
OTB_Del_11	OTB test rig commissioning report	D	Q2 2021
OTB_Del_12	Acceptance Test Review : • Electrical bonding test. • Displacement sensor calibration test. • Green run test. • Internal friction test. • Internal leakages test – static and dynamic (if relevant). • Cooling flow test (if relevant). • Proof pressure test (if relevant). • Any other relevant acceptance test related to OTB architecture. Acceptance Test Report Qualification Test Review : • Electrical test. • Performance test. • Endurance test (min 100hr). • Proof pressure test (if relevant). • Dielectric rigidity test. • Vibration test. • Any other relevant qualification test related to OTB architecture. Qualification Test Report	D	Q2 2021

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
OTB_Del_13	TRL4 Review: same as TRL3 at TRL3 stage. TRL4 Design Report	R	Q2 2021
OTB_Del_14	Tested OTB hardware (min 1 complete OTB)	HW	Q2 2021
OTB_Del_14	OTB investigations; lessons learned and way forward analysis report	R	Q4 2021

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
OTB_MS_01	Specification Review	R	Q2 2019
OTB_MS_02	COR	R	Q3 2019
OTB_MS_03	PDR	R	Q1 2020
OTB_MS_04	CDR	R	Q4 2020
OTB_MS_05	TRL3 review	R	Q4 2020
OTB_MS_06	Manufacturing Review	R	Q1 2021
OTB_MS_07	Component Testing Review	R, HW	Q1 2021
OTB_MS_08	N/A	N/A	Q1 2021
OTB_MS_09	Assembly Review (OTB and OTB rig)	R	Q1 2021
OTB_MS_10	N/A	N/A	N/A
OTB_MS_11	OTB Rig Commissioning Review	R	Q1 2021
OTB_MS_12	Acceptance and Qualification Test Review	R	Q2 2021
OTB_MS_13	TRL4 Review	R	Q2 2021
OTB_MS_14	Tested OTB Commissioning	R, HW	Q2 2021
OTB_MS_15	OTB investigations; lessons learned and way forward analysis review	R	Q4 2021

Safran will provide detailed specifications and provide feedback during design reviews.
Face-to-face meetings are expected for each deliverable/review as well as during Quarterly progress reviews. Monthly phone calls will be established for project progress follow-up and technical interactions.

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Architecture design: safety, fault, reliability management, control-command-monitoring skills.
- Mechanical design: static, dynamic, kinematics, friction analysis, thermal manangement.
- Hydraulic design: fluid simulation,thermal management.
- Manufacturing and assembly: provisionning (raw material and components like sensors, bearings, seals etc), machining, controlling of OTB components and sub assembly.
- Testing and inspecting: provisionning and testing individual components (such as motion sensor), testing OTB system (mechanical testing, hydraulic testing,vibration testing, electrical testing).

5. Abbreviations

CDR	Critical Design Review
COR	Concept Review
FCT	Function

HP	high pressure
LTB	Load Transfer bearing
LVDT	Linear Variable Displacement Transducer
MTBF	Mean Time Between Failure
MTBO	Mean Time Between Overhaul
N/A	Not Applicable
OTB	Oil Transfer Bearing
PCM	Pitch Change Mechanism
PCU	Pitch Control Unit
PDR	Preliminary Design Review
PGB	Power Gear Box
REACH	Registration, Evaluation, Authorisation and Restriction of Chemical Substances
RSB	Radial Shaft Bearing
SAE	Safran Aircraft Engines
TBC	To Be Confirmed
TBD	To be defined
VAC	Volt Alternating Current
VF	Variable Frequency

IV. JTI-CS2-2018-CfP08-LPA-01-50: Development and manufacturing of innovative tooling for composite parts

Type of action (RIA/IA/CSA)	IA		
Programme Area	LPA		
(CS2 JTP 2015) WP Ref.	WP 1.4.4		
Indicative Funding Topic Value (in k€)	1000		
Topic Leader*	Aernnova	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	30	**Indicative Start Date (at the earliest)**[7]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-LPA-01-50	**Development and manufacturing of innovative tooling for composite parts**

Short description

The development of this tooling should be innovative in order to implement the best performances in:
- Eco-design for of the tooling manufactured, employing low cost/natural material
- Time and energy saving innovations in manufacturing of the future parts, for example by implementation of a more efficient heating system
- Use of innovative materials with automation (Hi-tape, NCF, etc.)
- Production time savings to reduce the cost and production lead times. Focusing on the heating and cooling system both for the tooling and to the element. Reducing the temperature changing times will significantly drop the times during the manufacture of the piece, being one of the key parts of the process. Given the faster system is at least as efficient as the one currently used in terms of energy, the cost of the manufacturing will also decrease.

Always ensuring that each one of the single parts manufactured with the prototype tooling fit with the Aeronautical quality standards

Links to the Clean Sky 2 Programme High-level Objectives[8]				
This topic is located in the demonstration area:	Advanced Laminar Flow Technologies			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Long-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

[7] The start date corresponds to actual start date with all legal documents in place.
[8] For further info see Chapter 1 “Introduction to the Programme Scene Setter / Objectives” with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

This topic aims to design and manufacture the tooling necessary for the manufacturing of a leading edge, including HLFC system for a WING structure. The technology of the manufacturing will be RTM. Therefore, the Applicant would manufacture the RTM tool and any other tooling needed in the process, both for manufacturing and validating purposes.

The related elementary parts will be assembled in a TRL4 level of maturity prototype for a Wind Test panel.

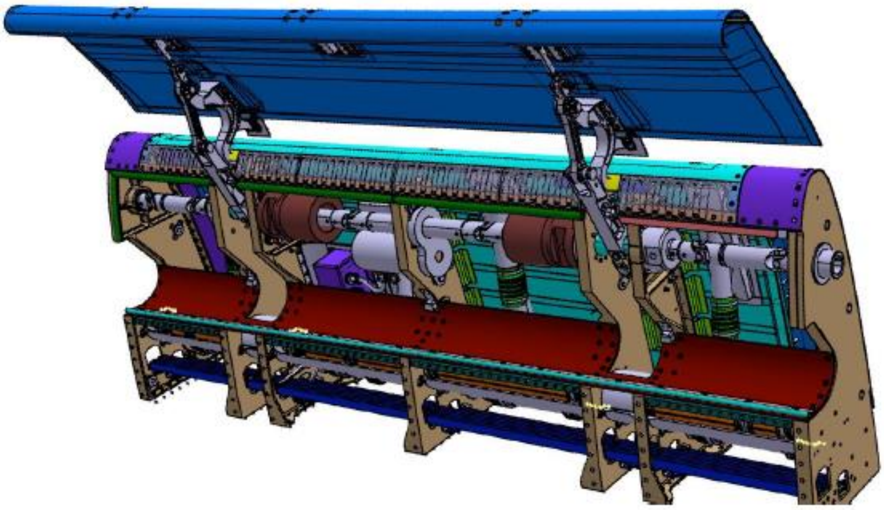


Figure 5: Example of structures of interest,
in this particular case the structure will be the LE of the WING

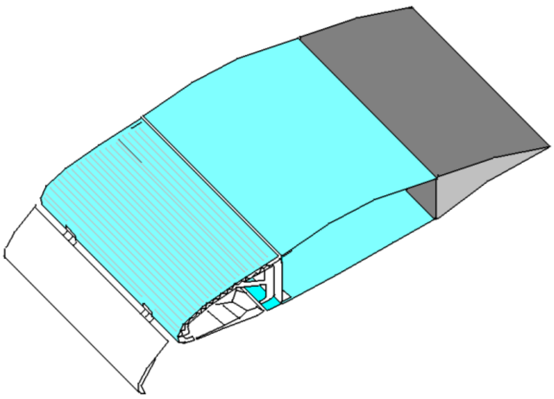


Figure2: Painted in blue the parts manufactured with HLFC technology. Painted grey ALM technology

2. Scope of work

The Topic Manager will settle the preliminary design of the tooling requested. The detailed requirements are still under definition, and will be made available at the beginning of the project by the topic manager once the preliminary design will be defined. The Applicant will be responsible of detailing the design and manufacturing the tooling, in concurrence with the Manager.
Requirements and features needed for the Prototype Manufacturing tooling and any other tooling will

be provided by the topic manager at the beginning of the project.
Final part will be compound by 5 meter length of a HLFC leading edge with upper HLFC skin integrated plus a trailing edge in one piece manufactured by ALM technology.

A smaller tooling is defined as the "trial tooling", in which numerous manufacturing trials are going to be done. This tooling has to be able to reproduce all the key parameters involved in the manufacturing process definition, an appropriated sized for the study and control of those parameters it will be necessary (300-600 mm). This tooling is required in order to follow a proper development of the manufacturing process, and the innovative technologies which will be added to the tooling, as the new heating system.

Manufacturing "trial tooling" and final tooling (5m) must cover the following features:

- Innovative temperature system with advanced sensors to self-regulate and monitor the temperature at all times
- Reduce overall energy consumption by optimizing the cycle and the heating strategy.
- Since the part might include metallic components, the tooling should take into account the different Coefficient of thermal expansion (CTE) that the part might present.
- The demoulding of the projected parts will be complex. Therefore, the tool needs to be divided in parts which could be singularly removed.
- Any complementary tooling used besides the requested RTM one, both to manufacture and to validate the process and/or the final parts will be included
- Hot-forming tooling for preform elementary parts.

This topic´s goal is to manufacture tooling capable of manufacture the Wing Leading Edge structure, included a HLFC system, with resin injection processes up to 180ºC, as in RTM. Geometrical tolerances permitted in the aerospace sector shall be respected.
Hi-tape, NCF or similar materials are requested in this part, so the tooling needs to be adapted for their use.

Some works have already been carried out in former research activities to investigate the use of new materials to develop reliable and automated manufacturing processes without paying attention to much on energy consumption lead time. The key innovation of topic should be the heating management system of the future tooling, which as above explained, could reduce significantly both the cost and the leading time of the manufacturing process. Any heating system are to be considered (Infrared, Microwave, Thermofluid, Induction, etc.), and the most suitable ones to further investigated and matured in the frame of this topic with the goal to optimize the efficiency of the manufacturing process. The tooling designed is foreseen to be part of a high-production ratio process, so the regularity in the manufactured parts and lead times is strongly required.

Focusing on the ALM technology requested for the trailing edge, this is also a major point in the requirements, due to the mixture of RTM and ALM technologies is quite innovative in terms of highly integrated manufacturing processes.

Manufacturing trials will be performed to ensure the quality of the automatic solution provided.
The main tasks of the applicants can be summarized as follows:

Tasks
Concurrent engineering with the Topic Manager to reach the detail design level.
Tradeoff for material selection, heating and thermal control systems and integration of different materials.
Defining the manufacturing process for the tooling
Manufacture of the tooling
Validation process according with aeronautical standards.
Delivery of the prototype tooling to the Topic Manager facilities.
ALM technology manufacturing for trailing edge specimen.

The applicant will work in close collaboration with the topic manager to validate the outcomes of the different activities.

3. Major Deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	***Title - Description***	***Type***	***Due Date***
D1	Tradeoffs report: – Materials – Systems – Integration	Report	To+9
D2	Manufacturing process definition	Report	To+21
D3	Manufacturing tooling report	Report	To+27
D4	Manufacturing and validation tooling	Report	To+29
D5	Final report: Conclusions and lesson learned	Report	To+30

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type***	***Due Date***
M1	Material tradeoffs	Report	To+9
M2	Manufacturing process defined	Report	To+21
M3	Prototype tooling manufactured	Hardware	To+28
M4	Prototype tooling validated	Report	To+29
M5	Prototype tooling delivered	Delivery	To+30

4. Special skills, Capabilities, Certification expected from the Applicant(s)

**(M) – Mandatory; (A) – Appreciated*

- Experience in design and manufacturing of manufacturing tooling for structures in conventional and innovative composite and metallic materials and components (M).
- Experience in management, coordination and development technological (Aeronautical) programs. (M).
- Proved experience in collaborating with reference aeronautical companies with industrial air vehicle developments.

- Experience in shared international R&T projects cooperating with industrial partners, institutions, technology centres, universities and OEMs (Original Equipment Manufacturer). (A)
- Quality System international standards (i.e. EN 9100:2009/ ISO 9001:2008/ ISO 14001:2004). (M)
- Capacity to repair or modify "in-shop" the prototype manufacturing tooling for components due to manufacturing deviations. (A).
- ALM technology knowledge and development capacity for big parts.
- Qualification as strategic supplier of manufacturing tooling on aeronautical elements. (A).
- Since the tooling is defined as a high-rate production tooling, experience in continuous production manufacturing (as in plastic infusion processes) (A)
- Experience and know-how with diverse tooling for both composites and metallic technologies, specifically OoA (RTM) for composites.
- Experience and know-how with tooling for manufacturing metallic components. (M)
- Into the eco design field, the Partner shall have the capability to monitor and decrease the use of hazardous substances regarding REACH regulation (M).
- The above mentioned requirements will be fixed in more details during the partner agreement phase-Negotiation Phase. This will also include the IP-process.

V. JTI-CS2-2018-CfP08-LPA-01-51: Design and manufacture of a large wing model equipped with active and passive HLFC technologies

Type of action (RIA/IA/CSA)	IA		
Programme Area	LPA		
(CS2 JTP 2015) WP Ref.	WP 1.4.4		
Indicative Funding Topic Value (in k€)	1700		
Topic Leader	ONERA	Type of Agreement	Implementation Agreement
Duration of the action (in Months)	24	Indicative Start Date (at the earliest)[9]	Q1 2019

Topic Identification Code	Title
JTI-CS2-2018-CfP08-LPA-01-51	Design and manufacture of a large wing model equipped with active and passive HLFC technologies
Short description	
The main purpose of this topic is to design and manufacture (instrumentation included) a large wing-model which will be equipped with wall-suction parts in the leading-edge region in order to perform Hybrid Laminar Flow Control (HLFC) by using active and passive suction systems. The ultimate objective (not included in the scope of this topic) is to perform Wind-Tunnel Tests (WTT) of the model inside a large transonic facility in order to prove the aerodynamic efficiency and the robustness of active and passive HLFC technologies under transonic flow conditions	

Links to the Clean Sky 2 Programme High-level Objectives[10]				
This topic is located in the demonstration area:	Advanced Laminar Flow Technologies			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Long-range, Ultra-advanced Long-range, Ultra-advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

[9] The start date corresponds to actual start date with all legal documents in place.
[10] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

Laminarity is one of the most important technological routes to a more efficient aircraft, because it significantly improves drag and therefore the aerodynamic performances. In the framework of Clean Sky 2 LPA-IADP (Platform 1), one of the main objectives of WP 1.4.4 is to improve the Technology Readiness Level (TRL) of Hybrid Laminar Flow Control (HLFC) technologies applied on wings towards TRL 4. Success at that level will be contingent upon information derived from a variety of sources including large scale Wind-Tunnel Tests (WTT), ground based demonstrators, numerical simulations and integration studies. The main purpose of the Topic is to design and manufacture a large wing-model that will be equipped with wall-suction parts in the leading-edge region (through perforated panels) in order to perform HLFC by using active and passive suction systems. The ultimate goal (not included in the scope of this CfP) is to perform WTT of the model inside a large transonic facility (ONERA S1MA) in order to prove the aerodynamic efficiency and the robustness of active and passive HLFC technologies under transonic flow conditions.

2. Scope of work

This particular Topic deals with the design and manufacture of a large wing model (instrumentation included) that will be equipped with wall-suction parts in the leading-edge region (through perforated panels) in order to perform HLFC by using active and passive suction systems under transonic conditions (M~0.85) and for high Reynolds number ($Re > 10x10^6$ /m). The overall model will have a maximum span of approximately 5m and a maximum aerodynamic chord of approximately 2m as illustrated in Figure 1. The global platform and sectional shape of the wing model (typical of long range aircraft) will be provided by the Topic Leader.

Two types of suction systems will be investigated to achieve the wall-suction through perforated panels: one active system based upon an external suction device (mainly a pump) and a passive system where suction results from variations of pressure distributions along the wing model. The active suction system will be under the responsibility of the operational team of the wind-tunnel and will be integrated outside the model. The suction panels (perforated panels) will be provided by the Topic Leader to the Applicant(s) who will assemble them to the model. The Apllicant(s) will have the responsibility of the design/production of all pneumatic pipes, connectors and suction chambers. For this purpose, guidelines would be provided by the Topic Leader but the Applicant(s) will have the freedom to suggest innovative passive devices to generate the requested suction mass-flow into the chambers.

The wing could be divided into three parts along the span direction, each being dedicated to a specific purpose: an inner section, a middle section and an outer section. Thus, from the root to the tip of the wing:

- The inner part will be dedicated to Attachment Line Transition (ALT) control using both passive Anti-Contamination Device (ACD) and active wall suction to investigate leading-edge turbulent contamination under transonic conditions.
- The middle part will be dedicated to demonstrating the effectiveness of active HLFC technology.
- The outer part will be dedicated to demonstrating the effectiveness of passive HLFC technology.

As illustrated in Figure 1, the model will be equipped with large areas with specific wall-treatment in order to enhance the contrast of Infra-Red (IR) measurements for transition detection. The model will also be equipped with some specific inserts dedicated to investigate the influence of surface defects on the transition location. Those inserts will enable to tackle the surface tolerance requirements along parts of HLFC wings. These inserts will be located between one of the suction panels and the corresponding IR area and will be equipped with an inovative solution to remotely adjust the geometry of the surface defects (gaps or steps for example).

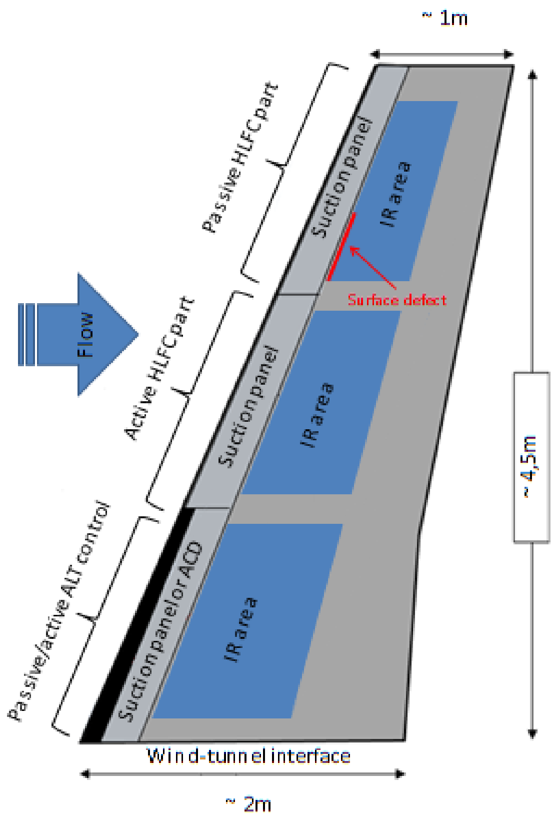


Figure 6 – Schematic view of the model

The Applicant(s) will be responsible for the design, manufacture and instrumentation of a model compliant with the wind-tunnel interface and loads requirements in close contact with the Topic Leader. As the WTT dynamic pressure will be higher than in the case of real flight, the requirements on surface quality under loads will have to be used as design constraints. The full range of surface quality requirements will be provided by the Topic Leader in the Negotiation phase of the process. For the same reason, the model will not be similar to a real wing structure in terms of stiffness distribution.

The scope of work is divided into 7 main tasks summarized in the following table and detailed below:

Tasks		
Ref. No.	***Title - Description***	***Due Date***
T1	Model Specifications Transcription	T0 + 1M
T2	Model Design	T0 + 6M
T3	Model Parts Manufacturing	T0 + 15M
T4	Model Parts Instrumentation	T0 + 15M
T5	Model Assembling and Checking	T0 + 18M
T6	Model Ground Tests	T0 + 18M
T7	Assistance during WTT	T0 + 24M

Task 1 – Model Specifications Transcription

The Applicant(s) will be in charge of the transcription of all inputs from the Topic Leader into model specifications.

Task 2 – Model Design

The Applicant(s) will be responsible for the complete 3D design of the model, with the exception of all suction panels and the suction system used for the inner and middle parts. The model will be compliant with the wind-tunnel interface given as inputs (CAD and/or drawings) by the Topic Leader at the beginning of the project. A full set of CAD models and drawings (parts, assembly and equipment) will be provided by the Applicant(s) in the Model Design Report (D1) including mounting and handling procedures. Stress analysis and displacement prediction will be justified by FEM computations on the model under critical/nominal aerodynamic loads and results will also be provided in the Model Design Report (D1). The FEM models will be provided by the Applicant(s) preferably in NASTRAN format. Interference with the ONERA S1MA operational team will be required to ensure compliance of the model/wind-tunnel interface.

Task 3 – Model Parts Manufacturing

The Applicant(s) will be responsible for the manufacture of all previously designed parts. The manufacturing process will be fully described (milling jigs, NC programming, raw-blocks purchasing). After manufacture, the Applicant(s) will perform intermediate geometrical and shape measurements for each parts. The quality of the surface exposed to the flow will be treated with care: the surface roughness of these parts must comply with the laminarity requirements and will be defined by the Topic Leader during the Negotiation phase of the project.

Task 4 – Model Parts Instrumentation

The wing will be equipped with several lines of pressure taps distributed along the chord on both sides of the model (~300 pressure taps for the entire model). Time-resolved pressor sensors (~30 for the entire model) will be integrated into the wall in very specific locations to enable buffet monitoring. Accelerometers (~6 for the entire model) and strain gauges (~10 for the entire model) will be integrated inside the model to enable vibration and stress monitoring, respectively. Flush-mounted hot-films sensors may also be integrated in order to monitor the ALT and will be provided by the Topic Leader. The model will be equipped with large areas of specific wall treatment (using low thermal conductivity and high IR emissivity material) in order to enhance the contrast of IR measurements. As illustrated in the schematic view of the model (Figure 1), these IR areas will extend from the downstream part of the suction panels to about 70% of the chord (on both sides of the model). Special attention will be paid to the junction between the model wall and those IR areas to avoid surface defaults (steps or gaps) and any degradation of the surface quality even during the WTT. The nominal operation and positioning of each sensor will be verified and described in the Model Checking Report (D2).

Task 5 – Model Assembling and Checking

All parts of the model will be assembled (and adjusted) at least once to check for the final shape and overall assembly. The toolings or jigs required to complete this final assembly will be designed and manufactured by the Applicant(s). Geometric measurements (shape, surface quality) and verification of the flow-control devices properties and equipment will be performed and described in the Model Checking Report (D2).

Task 6 – Model Ground Tests

Ground tests will be carried out on the model (fully assembled) before delivery and will consist in displacement measurements and surface quality inspection under static loads. Toolings, jigs and specific instrumentation required to perform these tests will be the responsibility of the Applicant(s). Results will be described and analysed in the Model Checking Report (D2). Ground Vibration Tests are not in the scope of this project and will be performed by a LPA-IADP member.

Task 7 – Assistance during WTT

The Applicant(s) will provide the necessary assistance during the WTT phase that will take place after the delivery of the model.

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, RM=Review Meeting, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1	Model Design Report (including drawings, CAD & FEM models)	R	T0 + 8M
D2	Model Checking Report	R	T0 + 18M
D3	Final Report	R	T0 + 24M

Milestones			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M1	Kick-Off Meeting	RM	T0 + 1M
M2	PDR of the Model	RM	T0 + 3M
M3	CDR of the Model	RM	T0 + 6M
M4	Model Final Assembly	HW/RM	T0 + 17M
M5	Model Ground-tests Validation	R/RM	T0 + 18M
M6	Model Delivery	HW	T0 + 18M
M7	Closure Meeting	RM	T0 + 24M

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- The Applicant(s) must have proven experience in the design and manufacture of large models intended for transonic WTT.
- The Applicant(s) must have experience in the manufacture of parts with a surface quality that comply with laminarity requirements included in the IR measurements areas.
- Experience in former HLFC European or collaborative programmes would be highly appreciated.
- An international standard quality management system would be appreciated.

5. Abbreviations

ACD	Anti Contamination Device
ALT	Attachment Line Transition
CDR	Critical Design Review
FEM	Finite Element Method
GVT	Ground Vibration Tests
IR	Infra-Red
PDR	Preliminary Design Review
TRL	Technology Readiness Level
WTT	Wind-Tunnel Tests

VI. JTI-CS2-2018-CfP08-LPA-01-52: Thermo-mechanical design validation of compact heat exchanger by thermal cycling life prediction

Type of action (RIA/IA/CSA)	IA		
Programme Area	LPA		
(CS2 JTP 2015) WP Ref.	WP 1.5		
Indicative Funding Topic Value (in k€)	1200		
Topic Leader	Liebherr	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	36	**Indicative Start Date (at the earliest)**[11]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-LPA-01-52	**Thermo-mechanical design validation of compact heat exchanger by thermal cycling life prediction**
Short description	
Compact heat exchangers featured in innovative bleed systems could be early damaged when used in severe operating conditions (temperature, pressure and vibrations) such as the ones to be encountered in UHBR nacelle. The objective of this topic is to gain knowledge on physics involved in heat exchanger deterioration. Hence, models which can deal with multi-scale and multi-disciplinary physics shall be built, communicating between each other, with the objective to accurately simulate real operational conditions. Furthermore, sensitivities analysis, design of experiments and probabilistic approach shall be coupled with these models. Finally, innovative virtual demonstration means shall be developed to replace experimental validation	

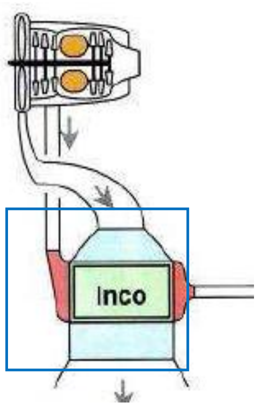
Links to the Clean Sky 2 Programme High-level Objectives[12]				
This topic is located in the demonstration area:	Advanced Engine/Airframe Architectures			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Long-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

[11] The start date corresponds to actual start date with all legal documents in place.

[12] For further info see Chapter 1 “Introduction to the Programme Scene Setter / Objectives” with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

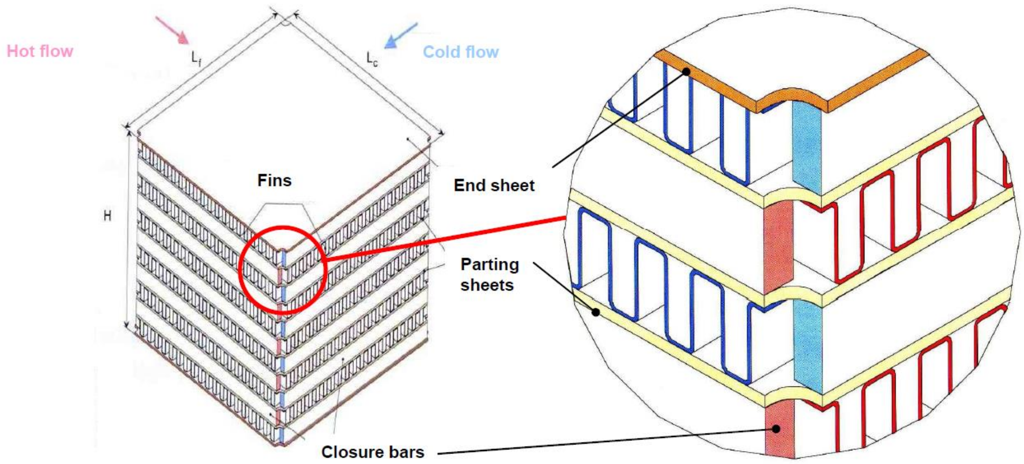
The bleed system is installed in the engine nacelle and therefore submitted to high environmental constrains: pressure, temperature and vibrations. These constrains will be especially high with the upcoming UBHR engine. The Topic Manager needs to ensure that the bleed system equipment will sustain this harsher environment. In particular, this topic focusses on the precooler which is the compact air-air heat exchanger of the air bleed system.

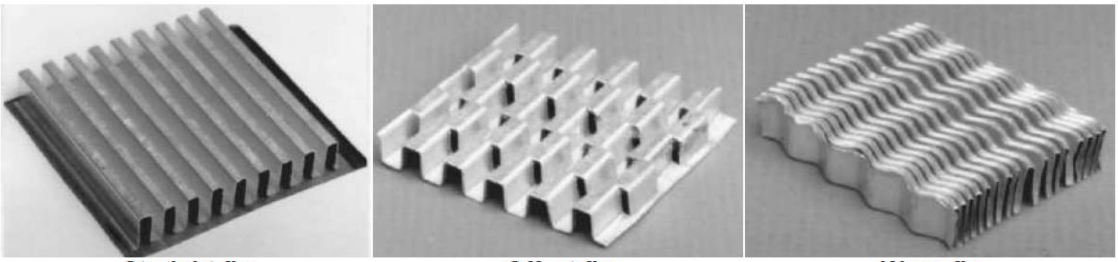


Precooler in the air bleed system

Compact air-air heat exchangers have been studied extensively over several decades by industrial and academics. Some of these works are now white paper and used daily in the conception of heat-exchanger **Error! Reference source not found.Error! Reference source not found.Error! Reference rce not found.**. They mainly deal with compact heat exchangers air to air plate fin.

The complete structure is composed of a core and headers. The core is composed of an alternating stack of layers in which respectively pass the hot air flow (**hot fins**) and the cold air flow (**cold fins**). To ensure the tightness between these layers, they are separated by **parting sheets** and sealed to be isolated from the outside by **closure bars**. The core is closed at its upper and lower parts with two **end sheets**. On the core are welded the headers or the frames to guide the inlet and outlet airflows. Today, the various types of fins which constitute the cores of heat exchangers are straight, offset and wavy fins.





Straight fin Offset fin Wavy fin

The design of the core is controlled to maximize the efficiency of the heat exchange. Thus, the definition of the stack, choosing the type of fins (materials and dimensions), is determined by taking into account the available space, pressure drops, flow rates and temperatures at the design point.
Compact welded heat exchangers are designed to be used in severe operating conditions (temperature, pressure). Cracks of the parting sheets and deformation of the fins could occur under complex thermo-mechanical fatigue failure, as a consequence of large strains due to harsher aerothermal cyclic constrains as the one expected in UHBR nacelle.
In order to validate precooler life duration expectancy, tests in a representative environment would be required. Unfortunately when dealing with high pressure, high temperature and high mass-flow rate, the competence to build an appropriate set-up of parameters and the capacity to perform such tests out of an engine environment become limited. In fact, these tests consist in temperature, flow and pressure variations cycling and are determined in order to represent duty cycles corresponding to the whole life of aircraft. Within a new engine development, the necessary temporal data are often not available to identify the right thermal and pressure cycles to be applied on the precooler.

Temporal data on temperature, pressure and air flow are required and of importance because precoolers are assembled with components that have different time constants and different thermal expansions so that complex thermomechanical stresses appear when exposed to in flight temperature variation. Furthermore, the geometry of these components is very different such as the headers and the core, and it is very complicated to perform predictive calculations on these assemblies. In fact, the analysis of these structures directly by a finite element method is currently impossible because of the size difference between the fins (of the order of a millimetre) and the precooler (about a hundred of a millimetre).
The solution used by the Topic Manager, to circumvent this problem, is to consider the core as a structure resulting from the periodic repetition along the three directions of a basic pattern (elementary cell).
Note that this strong hypothesis is true if we do not take into account:

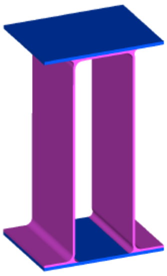
- the impact of the manufacturing process that alters the shape of fins according to their position in the core
- the edges of the core (closure bars and end sheets) where the repetition of the pattern stops

With this strategy, the modelling process becomes “indirect” with the following main steps:

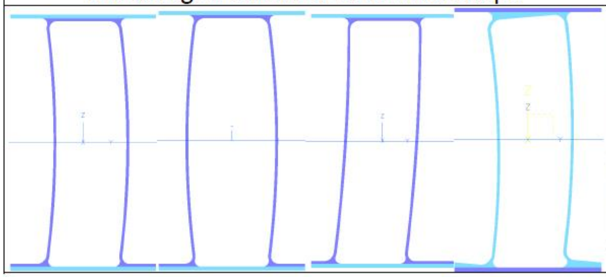
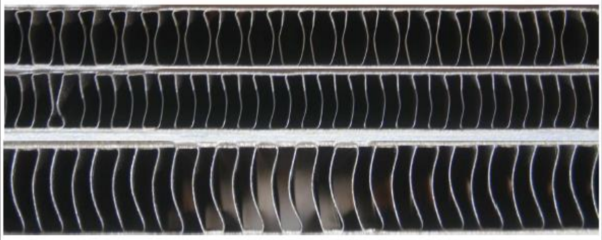
- Identifying, extracting and meshing the periodic elementary cell (with 3D solid elements)
- Calculating its effectives properties obtained from the micromechanical analysis
- Doing the global analysis via standard FE solution (the Topic Manager makes use of NX Nastran)
- Extracting local displacements, strains, and stresses within the unit cell from the global response using recovery relationships, but this is a manual time consuming approach.

The Topic Manager has developed a direct method between the microscopic and macroscopic scale based on an elementary pattern representative of the full core.

Elementary cells for straight and offset fins:

Straight fins	Offset fins
	

Moreover, the impact of deformed elementary cells has been studied.

Modeling of different deformed shape	Example of manufacturing defaults
	

The objective of the topic is therefore to study and develop new coupled multi-physics and multiscale simulations of the aero-thermo-mechanical solicitations involved inside the precooler, which will partially replace physical testing and enhance adaptation to evolving engine specifications.

[1] W.M. Kays, A.L. London, *"Compact Heat Exchangers"*, (Third Edition) Krieger Publishing Company, New York (1998)

[2] R.J.Manglik et A.E.Bergles, *"Heat transfer and pressure drop correlations for the Rectangular ofsset strip fin compact heat exchanger"*, Experimental Thermal and Fluid Science, vol. 10, pp.171-180, 1995

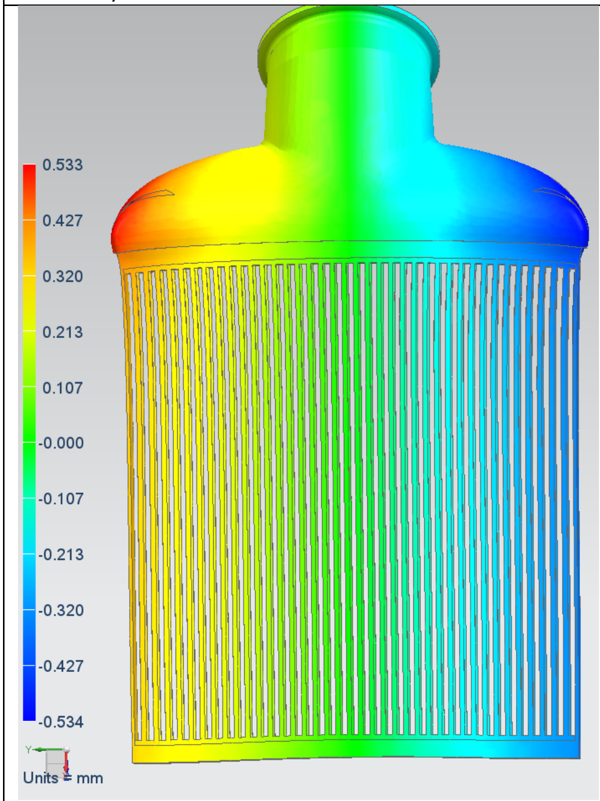
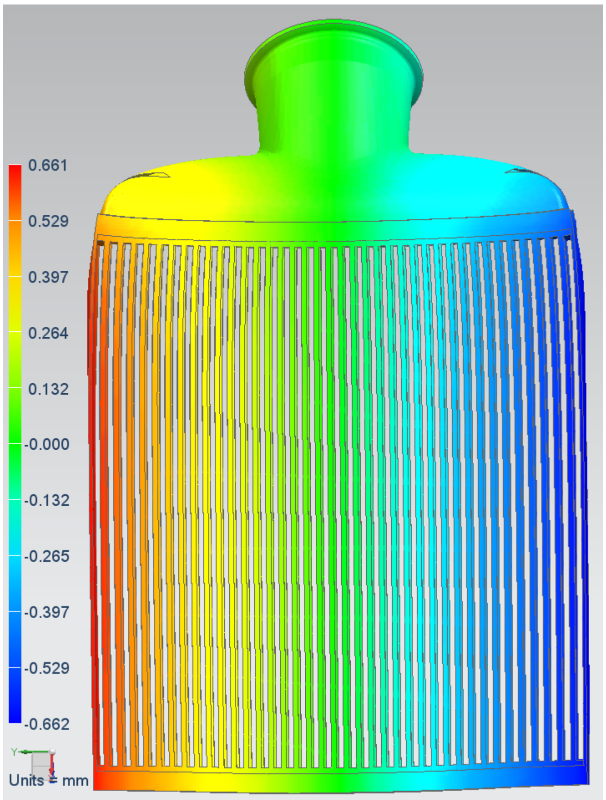
[3] A. Muley, J.B. Borghese, R.M. Manglik, J. Kundu, *"Experimental and numerical investigation of thermal-hydraulic characteristics of a wavy-channel compact heat exchanger"*, 12th International Heat Transfer Conference, Grenoble, 2002.

2. Scope of work

Tasks		
Ref. No.	***Title – Description***	***Due Date***
Task 1	Building of a multi-scale and multi-disciplinary model	T0+8
Task 2	Multiple simulations	T0+36
Task 3	Models validation by laboratory tests	T0+36
Task 4	Degradation law and accelerated test definition	T0+48

Task 1: Building of a multi-scale and multi-disciplinary model

The Topic Manager will provide the applicant a cartographic analysis of the degradation modes of a precooler. The Topic Manager already identified the main physical phenomena governing the degradation and confirmed strong couplings between physics. As an exemple, one phenomenon is the difference of thermal inertia between massive headers and the matrix made of thin sheets (50µm) during thermal cycling. Deformations, as presented in the below figures lead to local failures such as cracks of the parting sheets and deformation of the fins after large cyclic strain due to aerothermal cyclic loads. Cracks seem to be the consequence of complex thermo-mechanical fatigue failure. When crack propagates, a leakage could appear between the hot pass and the cold pass.

Hot header (450°C up to 600°C) / Cold matrix (-40°C up to 200°C)	Cold header (-40°C up to 200°C) / Hot matrix (450°C up to 600°C)
	

Based on this analysis, the applicant shall build multi-scale and multi-physiscs (aerodynamic, thermal & thermomechanical) models and to make them communicate between each other in order to better understand the physics inside the precooler.
The applicant shall reproduce, by multiphysics and multiscale simulations, the dynamical strains and stresses states leading to degradations.
The applicant shall also integrate complex material laws in these models.
The applicant shall use preferentially Star-CCM+ (Simcenter CFD) for the aerothermal CFD simulation, NX Thermal for thermal analysis and NX Nastran for thermomechanical Finite Element Analysis.
The Topic Manager will provide geometrical and available materials data but the applicant will have to perform characterization of metallic sheets to define complex material laws at high temperature.
The models developped shall enable the applicant to define a criterium to localize damage initiation and evaluate its evolution i.e. a degradation criterium (ex: cracks initiation and propagation, leakage, local variation of temperature due to leakage increase).

Task 2: Multiple simulations

The objectives of this task are:

- to perform sensitivities analysis to a range of parameters among:
  - a- Local deformation
  - b- Statistical dispersions:
    - o dispersions due to manufacturing inducing an initial stress state,
    - o dispersions of acting and boundary conditions (pressure, flow, temperature depending of time, and interface loads),
  - c- Header-matrix interaction depending of heating and cooling rates.
- to determine potential coupling of above parameters,
- to introduce probabilistic nature of some parameters. The applicant is free to use probabilistic method, reduction model or meta-model to construct response surfaces, in the models defined in Task 1.

The applicant shall upgrade/extend the model developped in Task 1 according to the sensitivity analysis: reduction model for non-sensitive parameters and probabilistic model for the influent parameters.
Based on the results of the sensitivities analysis, the applicant shall collaborate with the Topic Manager to determine the relevent tests or measurements in order to build the probability function of the more influent parameters.

Task 3: Models validation by laboratory tests

When dealing with mechanical parts having such multi-scales effects as precoolers (several hundreds of mm build with sheet of metal as thin as 50 µm), fatigue datasheets are not available and mechanical properties cannot be decorrelated from the manufacturing process (vacuum brazing). Thus, laboratory tests will be necessary to validate the models or at least to obtain some necessary inputs to build the model laws.
The applicant shall perform these tests on precooler representative coupons, according to the sensitivity analysis results (main parameters identified). The precooler coupons shall be defined by the applicant jointly with the Topic Manager and will be manufactured by the Topic Manager.
These tests will incrementally performed to validate each step of model construction jointly by the applicant and the Topic Manager.
To validate the degradation criterium define in task 1, the partners shall also propose a measurement methodology and apply it (instrumentation) to localize damage initiation on precooler coupons. It is expected that the damage inituation will be internal and thus not directly visible.

Task 4: Degradation law and accelerated test definition

Based on the multiple simulation results and on the laboratory tests, the applicant shall propose:

- a degradation law that could be used to correlate the cracks initiation and propagation to the parameters of the sensitivity analysis;
- a simplified and accurate simulation approach that can be easily implemented in the models used for precooler sizing;
- an accelerated test methodology which parameters could be correlated to bleed data and able to initiate and propagate the **same** fatigue cracks as in flight. This accelerated test will be performed by the Topic Manager after the end of the project and the measurement methodology and related set-up defined in Task 3 will be transferred to the Topic Manager to be used during this test.

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware, M=Model*

Deliverables			
Ref. No.	**Title – Description**	**Type***	**Due Date**
1	First multi-scale and multi-disciplinary model	M+R	T0+6
2	Multi-scale and multi-disciplinary model updated	M+R	T0+12
3	Sensitivity analysis results: influent parameters and response surface	M+R+D	T0+24
4	Model updated with probabilistic law and meta-model	M+R+D	T0+30
5	Correlated models with laboratory tests results	M+R+D	T0+32
6	Measurement methodology definition and measurement set-up delivery	R+HW	T0+36
7	Degradation law & accelerated test definition	R+D	T0+36

4. Special skills, Capabilities, Certification expected from the Applicant(s)

The applicant shall demonstrate their skills detailling their activities, own bibliographic references and descirption of past projects linked to the present topic.

Mandatory skills

- Demonstrated knowledge of CFD: thermal and aerodynamic simulations of CHX
- Demonstrated knowledge of finite elements methodology: model condensation or homogeneisation, thermomechanical simulation
- Demonstrated knowledge of probalistic approach in simulation
- Demonstrated knowledge of numerical design of experiments in simulation, metamodel construction and response surface methodology (RSM)
- Understanding of CHX design and manufacturing (including brazing metallurgy)

Capabilities

- In-house computing facilities
- In-house CFD & Finite Elements tools: Star-CCM+ (Simcenter CFD) for the aerothermal CFD simulation, NX Thermal for thermal analysis and NX Nastran for thermomechanical Finite Element Analysis
- Metallic sheet and brazed assembly characterization
- Testing facilities to test precooler coupons (temperature range: -40°C to 200°C on cold path and 250°C to 600°C on hot path, flow range: 0.5 kg/s, pressure: 0-5bars)

5. Abbreviations

CFD	Computational Fluid Dynamics
CHX	Compact Heat-Exchanger

VII. JTI-CS2-2018-CfP08-LPA-01-53: Compact Matrix Air Oil Heat Exchanger

Type of action (RIA/IA/CSA)	IA		
Programme Area	LPA		
(CS2 JTP 2015) WP Ref.	WP 1.5.2		
Indicative Funding Topic Value (in k€)	700		
Topic Leader	Rolls-Royce	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	36	**Indicative Start Date (at the earliest)**[13]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-LPA-01-53	**Compact Matrix Air Oil Heat Exchanger**
Short description	
UHBR engine development will place a significant demand on the aircraft and engine's heat management system. With the current size and shape of Matrix Air Oil Heat Exchanger technology, it is becoming difficult to locate them on ever more, space constrained engines. New technology is required that increases compactness and allows conforming shaped units to be produced by exploiting novel design, manufacturing methods and materials	

Links to the Clean Sky 2 Programme High-level Objectives[14]	
This topic is located in the demonstration area:	Advanced Engine/Airframe Architectures
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Long-range
With expected impacts related to the Programme high-level objectives:	

Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

[13] The start date corresponds to actual start date with all legal documents in place.
[14] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

Ultra-High By-Pass Ratio (UHBR) engine development, enabling a significant reduction in specific fuel consumption together with reduced emissions for the next generation of large passenger aircraft, will place a significant demand on the aircraft and engine's heat management system. For example the UHBR high power, high efficiency Power Gearbox (PGB), requires an optimised lubrication system with oil temperatures maintained within closely controlled limits.

Air cooling of the oil system, to within closely controlled limits, is a significant challenge in part due to the limited space available for heat exchangers. This combined with a need to minimise the cooling air flow drives the need for a novel heat exchanger solution.

The aim of this collaborative project is to identify and develop a heat exchanger solution using alternative materials and/or manufacturing methodology. A compact Matrix Air Oil Heat Exchanger (MAOHE) is needed with a characteristically low air side pressure drop. The relative high level of heat generation by the PGB and limited space availability will require a number of heat exchangers of high effectiveness. The limited space constrained envelopes available, for example around the engine core, may be better exploited with a curved shape of MAOHE rather than the more conventional solutions tending to be of rectangular form.

The curved shape may additionally drive the need for novel manufacturing methods. The design may utilise non-metallic materials that offer higher levels of thermal conductivity and lighter weight.

Working closely with the topic manager, the partner will design and develop the MAOHE to TRL6 and Manufacturing Capability Readiness Level (MCRL) 4, i.e. the manufacturing process is validated in a laboratory environment using representative development equipment.

The Work Break-down Structure (WBS) will be split into three Work Packages (WP's) as detailed below:

- WP1: Design and Thermal Model a MAOHE concept that offers a significant improvement in performance compared to current state of the art compact heat exchangers.
- WP2: Manufacturing/build and test a representative MAOHE prototype with sufficient suitability to perform design assurance testing in respect of functional performance.
- WP3: Refine/optimise MAOHE design, Build & Test to validate to TRL6.

It is envisaged that following the successful completion of the work packages, the MAOHE would be considered for incorporation on to a demonstrator engine flight test program.

The strategic theme falls under the umbrella of Clean Sky 2 LPA Platform 1 Work Package (WP) 1.5.2 Turbofan Powerplant Integration.

2. Scope of work

Tasks		
Ref. No.	***Title - Description***	***Due Date***
1	Design a MAOHE incorporating novel geometry and construction	T0+6
2	Create a thermal model of the proposed design using computation techniques	T0+9
3	Build a thermally representative MAOHE	T0+12
4	Performance test the MAOHE concept and validate the thermal model	T0+15
5	Refine MAOHE design and build an optimised MAOHE	T0+26
6	Test and validate the MAOHE in line with the Topic Managers requirements	T0+34

Task 1 : Design a MAOHE incorporating novel geometry and construction
Design a compact MAOHE capable of exchanging approximately 50 to 80kW of heat with a dry weight not exceeding 10kg. The design shall offer a significant improvement of effectiveness. The ambition is to reduce the cooling Air mass flow rate required and/or a 20% reduction of air side pressure drop compared to current state of the art heat exchangers designed for aerospace applications.

Task 2 : Create a thermal model of the proposed design using computation techniques
Develop a predictive model with capability for design and off-design performance predictions. Utilisation of the latest computation techniques will be required to accurately define thermal and fluid pressure drop performance from first principals or empirically derived data.
Both thermal performance and pressure drops shall be defined along with the following:

- Performance data representative of a nominal MAOHE (e.g. thermal performance correlations).
- Geometrical data of the Air and Oil circuit.
- Performance data to enable accounting of variability.
- Isothermal oil flow versus pressure drop characteristics for the full range of operating temperatures and flows.
- Isothermal air flow versus pressure drop characteristics for the full range of operating temperatures and flows.

Task 3 : Build a thermally representative MAOHE
This task would involve manufacturing a representative MAOHE with sufficient suitability to perform design assurance testing in respect of functional performance. The prototype part will utilise the design features and material types necessary to accurately measure thermal and pressure drop characteristics.

Task 4 : Performance test the MAOHE concept and validate the thermal model
The Partner will conduct functional performance tests of the MAOHE from task 3 in a representative environment. Produce test evidence to sufficiently characterise the design concept and validate the thermal model.

Task 5 : Refine MAOHE design and build an optimised MAOHE

- Develop manufacturing methods and design solution.
- Build a number of MAOHEs sufficient for rig test validation and development engine test purposes.
- Conduct mechanical analysis using FEA and other advantaged design tools.
- Produce evidence suitable to demonstrate MCRL4.
- Produce evidence suitable to demonstrate a Material Readiness Level (MRL) 6, i.e. that the material is validated by a component and/or sub-element testing, that its database is populated and production documentation issued in line with the topic manager’s processes.

Task 6 : Test and validate the MAOHE in line with the Topic Manager’s requirements

- The Partner will conduct full validation rig tests of the MAOHE to demonstrate performance and environmental durability in line with the topic manager’s requirements.
- Produce evidence suitable to demonstrate TRL6.

3. <u>Major Deliverables/ Milestones and schedule (estimate)</u>

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
1	Review of Concept Design	R	T0+6
2	Report on thermal modelling	R, D	T0+M9
4	Manufacture prototype MAOHE	HW	T0+12
5	Report on MAOHE Concept Testing	R, D	T0+15
6	Preliminary Design Review (PDR) of MAOHE Design	R	T0+18
7	Critical Design Review (CDR) of MAOHE Design	R	T0+21
8	MAOHE Engine Hardware manufactured	HW	T0+M26
9	Qualification Test Report for MAOHE	R,D	T0+34

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
1	MAOHE Concept Design Review passed	R	T0+6
2	MAOHE Thermal Modelling complete	R, D	T0+8
3	MAOHE Prototype manufactured	HW	T0+12
4	MAOHE Concept Testing complete	R, D	T0+14
5	MAOHE PDR Gate passed	R	T0+18
6	MAOHE CDR Gate passed	R	T0+21
7	MAOHE Qualification testing complete	R, D	T0+M33

4. Special skills, Capabilities, Certification expected from the Applicant(s)

The applicant shall

- Have substantial technical knowledge in the domain of the proposed tasks.
- Have proven capability in Heat Exchanger design and modelling methods that support the design of an optimised Novel Heat Exchanger.
- Have access to material data suitable for MAOHE aerospace application.
- Be knowledgable in the current state of the appropriate art manufacturing methods.
- Have proven DFMEA, PFMEA capabilities.
- Have proven risk management practices.
- Have a knowledge of aerospace certification expectations
- Test knowledge of heat exchangers in the following areas:
  - EUROCAE ED-14G – *Environmental Conditions and Test Procedures for Airbourne Equipment*
  - Vibration testing in accordance with CS-E-80.

5. Abbreviations

TRL	Technology Readiness Level
MCRL	Manufacturing Capability Readiness Level
MRL	Materials Readiness Level
MAOHE	Matrix Air Oil Heat Exchanger
PGB	Power Gearbox
FEA	Finite Element Analysis
DFMEA	Design Failure Modes Effect Analysis
PFMEA	Process Failure Modes Effect Analysis

VIII. JTI-CS2-2018-CfP08-LPA-01-54: Development of Measurement Techniques for Visualisation and Evaluation of Reverse Flow Interactions with Fan

Type of action (RIA or IA)	RIA		
Programme Area	LPA		
Joint Technical Programme (JTP) Ref.	WP1.5.2		
Indicative Funding Topic Value (in k€)	1600		
Topic Leader	Rolls-Royce	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	36	**Indicative Start Date (at the earliest)**[15]	Q1 2019

Identification	**Title**
JTI-CS2-2018-CfP08-LPA-01-54	**Development of Measurement Techniques for Visualisation and Evaluation of Reverse Flow Interactions with Fan**
Short description (3 lines)	
Reverse flows generated by the thrust reverser unit (TRU) are of significant complexity. In order to ensure reliable fan performance when the TRU is deployed, the flow topologies up- and down-stream of the fan module need to be investigated and understood. For this purpose, advanced measurement techniques for a novel level of visualisation and evaluation of reverse flow interactions with fan aerodynamics need to be developed	

Links to the Clean Sky 2 Programme High-level Objectives[16]				
This topic is located in the demonstration area:	Advanced Engine/Airframe Architectures			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Long-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

[15] The start date corresponds to actual start date with all legal documents in place.

[16] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

Reducing the fuel burn and weight of commercial aircraft is a major factor in the development of aircraft engines. In the quest for reducing thrust specific fuel consumption, the mass flow rate of fuel burned per unit thrust of an aircraft engine, designs are trending towards Ultra High By-Pass Ratios (UHBR) and lower fan pressure ratios. The increment of the fan size diameter, required to allow for higher by-pass ratios, drives the necessity for new technologies for the development of Short Slim Nacelles (SSN) aimed at reducing the penalty on weight and drag losses. Furthermore, special designs for the integration of bigger engines to the aircraft are needed to minimise the impact on aircraft performance.

The implementation of SSN represents a challenge for the integration of the different engine components such as the Thrust Reverse Unit (TRU) and Fan. The first is limited by the space in the nacelle cowl for housing the cascade grid, if a conventional cascade type TRU is used. On the other side, the fan performance might be influenced by the short nacelle, especially if a short intake is designed. Under TRU operation, the blockage in the by-pass duct produced by the TRU blockage door induces a backpressure field downstream of the fan, influencing its operability. Furthermore, the TRU plume may be re-ingested by the intake at certain flight conditions and influencing with that the fan operability as well. These interactions, up- and down-stream of the fan are at the same time affected by the aircraft installation. In order to ensure reliable fan performance when the TRU is deployed, the flow topologies up- and down-stream of the fan module need to be investigated and understood. For this purpose, advanced measurement techniques for a novel level of visualisation and evaluation of reverse flow interactions with the fan aerodynamics needs to be developed. This is essential for future applications and integration of SSN, as required for Ultra High By-Pass Ratio (UHBR) engines.

The aim of the project is to develop an advanced measurement technique for a novel level of visualisation and evaluation of reverse flow interaction with the fan aerodynamics. For this purpose, as a first step a TRU cascade type rig model should be designed for a UHBR-SSN application. The model will be tested under static and free-stream low speed conditions to analyse the flow in the bypass duct, in order to assess the distortions particularly at the OGV and fan stations induced by the blockage-backpressure field. Furthermore, a visualisation and assessment of the plume flow and its interaction with the intake should be planned. The second step would be an evaluation of the influence of both of these effects on an installed configuration.

A work package of the project should be dedicated to a numerical evaluation of the concept in order to support not only the analysis of the experiments, but also to develop a reduced order modelling of the cascade type TRU. For this purpose, a methodology for advanced CFD (Computational Fluid Dynamics) grid generation should be developed, followed by steady and unsteady RANS (Reynolds Averaged Navier Stokes) computations of the cases evaluated. Finally, a surrogate model, based on reduced order modelling, for the simulation of the TRU cascades should be developed.

The experimental and numerical analysis of the isolated and installed TRU will allow:

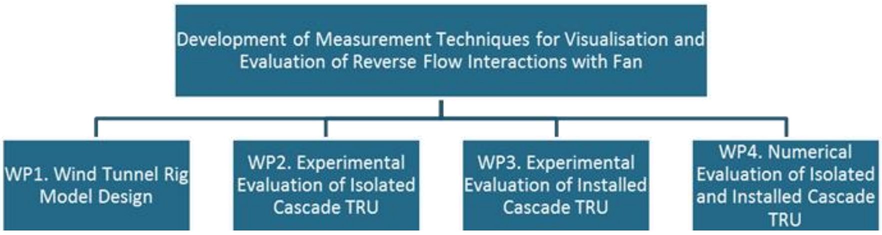
- Development of a novel visualisation technique for the evaluation of TRU flows and their interaction with the fan module.
- Development & verification of a methodology for numerical evaluation of TRU.
- Development of a reduced order model for TRU computations.

The main tasks can be described as follows:

- Development of TRU rig model for experimental evaluation.
- Development of a novel technique for Wind Tunnel (WT) flow visualisation.
- Definition of model (including instrumentation) and test cases for isolated configurations.
- Definition of model (including instrumentation) and test cases for installed configurations.
- Manufacturing/preparation of wind tunnel/CFD models.
- Wind Tunnel Test (WTT) development of isolated/installed cases.

- Numerical evaluation of TRU configurations.
- Development of surrogate model for simulation of cascade type TRU.
- Analysis of results.

The Work Break-down Structure (WBS) will be split into four main Work Packages (WP's) as detailed below:



The strategic theme falls under the umbrella of Clean Sky 2 LPA Platform 1 Work Package (WP) 1.5.2 Turbofan Powerplant Integration.

2. Scope of work

Tasks		
Ref. No.	***Title – Description***	***Due Date***
T1	Conceptual design phase: development of TRU rig model for experimental evaluation.	T0+9 months
T2	Development of a novel technique for WT flow visualisation.	T0+18 months
T3	Detailed design and manufacturing of WTT models	T0+18 months
T4	Calibration, commissioning and testing.	T0+24 months
T5	Concept evaluation and numerical methodology development.	T0+24 months
T6	Development of surrogate model for simulation of cascade type TRU.	T0+36 months
T7	Analysis of results.	T0+36 months

Task 1

This task covers the rig design of a cascade type TRU. Based on selected candidate models, an analysis of the candidates should be performed to extract scaling effects which should support the definition of the model to be tested. This task covers the analysis and definition of construction constraints for the manufacture of the rig. The expected scaling range of the models is considered to be higher than 1/12 of full scale. This task includes the creation of a Test Requirement Document.

Task 2

This task relates to the development of a novel measurement technique for the visualisation of turbulent flows in the bypass duct and TRU plume. The technique can be based on state of the art flow visualisation methods, such as Particle Image Velocimetry (PIV), Particle Tracking Velocimetry (PTV), Background Oriented Schlieren (BOS), or similar.

Task 3

This task relates to the detailed design and manufacturing of models and instrumentation.

Task 4
This task comprises:
- Instrumentation calibration
- Commissioning of rig and models
- Test of isolated configuration
- Test of installed configuration

Task 5
This task relates to the numerical evaluation of the isolated and installed TRU. This task includes the development of a CFD methodology for mesh generation of complex geometries and numerical evaluation of the TRU flows. The work package should include a deep study of mesh dependencies on numerical results. A variation of turbulence models should also be performed.

Task 6
Taking the experimental and numerical results obtained in Tasks 1 to 5, a surrogate model for the evaluation of cascades for TRU application should be developed. The task includes the development and implementation of the surrogate model on the CFD solver.

Task 7
This task relates to the analysis and reporting of the results obtained during the project.

3. Major deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title – Description***	***Type***	***Due Date***
D1	Work plan description on all tasks.	R	T0+1 months
D2	Test requirement Document	R	T0+6 months
D3	Definition of rig model	R, D	T0+9 months
D4	Definition of measurement techniques for novel flow visualisation	R	T0+18 months
D5	Models available for wind tunnel tests/CFD simulations	R, D	T0+18 months
D6	Wind tunnel test data	D	T0+24 months
D7	Report of wind tunnel test results	R	T0+25 months
D8	Methodology for CFD evaluation of TRU flows	R	T0+24 months
D9	Implementation of surrogate model for TRU cascade simulation	R	T0+36 months
D10	Final Project Report	R	T0+36 months

Milestones			
Ref. No.	***Title – Description***	***Type***	***Due Date***
M1	Work plan agreed	R	T0+1 months
M2	Preliminary Design review	R	T0+9 months
M3	Critical Design Review	R	T0+12 months
M4	Manufacturing Readiness Review	R	T0+15 months

Milestones			
Ref. No.	***Title – Description***	***Type***	***Due Date***
M5	Manufacturing Completition Review	R, HW	T0+18 months
M6	Test Readiness Review	R	T0+21 months
M7	Test Completition Review	R	T0+24 months
M8	CFD results available	R, D	T0+24 months
M9	Surrogated model available	R, D	T0+36 months
M10	Final report	R	T0+36 months

4. Special skills, Capabilities, Certification expected from the Applicant(s)

This package of work will require expertise in the field of experimental and numerical aerodynamics of engine nozzle jet flows.

The applicant shall:

- substantiate technical knowledge in the domain of the proposed tasks
- demonstrate experience in project participation, international cooperation, project and quality management
- show that knowledge is recognized in the scientific community

It would be necessary to have familiarity with the following special skills:

- expertise in aerodynamic CFD modelling
- experience in nozzle jet flows
- expertise in experimental methods, especially laser optical methods, for engine jet flows

5. Abbreviations

TRU	Thrust Reverser Unit
UHBR	Ultra High By-Pass Ratio
SSN	Short Slim Nacelle
OGV	Outlet Guide Vane
CRD	Computational Fluid Dynamics
RANS	Reynolds Averaged Navier Stokes
WT	Wind Tunnel
WTT	Wind Tunnel Test
WBS	Work Break-down Structure
WP	Work Package
PIV	Particle Image Velocimetry
PTV	Particle Tracking Velocimetry
BOS	Background Oriented Schlieren

IX. JTI-CS2-2018-CfP08-LPA-01-55: Harsh Environment Electric Actuators

Type of action (RIA/IA/CSA)	IA		
Programme Area	LPA		
(CS2 JTP 2015) WP Ref.	WP 1.5.2		
Indicative Funding Topic Value (in k€)	600		
Topic Leader	Rolls-Royce	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	24	**Indicative Start Date (at the earliest)**[17]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-LPA-01-55	**Harsh Environment Electric Actuators**
Short description	
Carry out an in depth study to review, develop, design, and manufacture electric motive force actuated slow and fast response electric actuators capable of operating in the engine core zone environment (up to 350°C surrounding air temperature, 400°C at the centre of the motor and 40g vibration up to 3KHz)	

Links to the Clean Sky 2 Programme High-level Objectives[18]				
This topic is located in the demonstration area:	Advanced Engine/Airframe Architectures			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Long-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

[17] The start date corresponds to actual start date with all legal documents in place.

[18] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

The fully optimised gas turbine engine effectors motive power system is unlikely to be delivered via a mix of fueldraulic and pneumatic muscle owing to the parasitic losses of such systems throughout the engines operating cycle. The most optimum solutions are likely to reside in a common electric motive power system across all of the engines systems that minimises parasitic losses throughout the operating cycle. Such a holistic configuration is in alignment with the aims of a more electric engine/aircraft theme within the Clean Sky 2 LPA Programme, and is also relevant to the Ultra High By-Pass Ratio (UHBR) family architecture.

This project will focus on designing and developing novel scale-able harsh environment electric actuator solutions, capable of withstanding temperatures beyond 160°C and increased levels of vibration compared to today's state of the art, suitable for close-coupled adoption onto all motive power systems of the gas turbine engine and distributed propulsion concepts such as hybrid-electric power transmission. These engine systems typically require 2-state and 3-state position control, modulating position control, and force regulating control against a range of loads (linear and rotational) and at a range of slew rates. Working closely with the Topic Manager the Partner will develop these harsh environment solutions to TRL5.

The Work Break-down Structure (WBS) will be split into two Work Packages (WP's) as detailed below:

WP1: Build on existing sub-concepts in the areas of wire joining methods, wire materials, wire insulation methods, coil encapsulation methods, and motor lamination methods relevant to harsh engine environments.

WP2: Incorporate the learning from WP1 into the build of a unit modified from an existing electric motor concept – design, build and prototype to TRL5.

The strategic theme falls under the umbrella of Clean Sky 2 LPA Platform 1 Work Package (WP) 1.5.2 Turbofan Powerplant Integration.

2. Scope of work

Tasks		
Ref. No.	***Title - Description***	***Due Date***
Task 1.1	Agree high level electrical interface specification for electric actuator.	T0 + 3
Task 1.2	Research and select magnet wire & lead out wire materials for high temperature high vibration environment.	T0 + 6
Task 1.3	Research and select soft magnet lamination materials and designs suitable for use in high temperature high vibration environments.	T0 + 6
Task 1.4	Joining Methods. Undertake trials to optimise wire joining methods.	T0 + 9
Task 1.5	Insulation Methods. Undertake trials to optimise wire insulation methods.	T0 + 9
Task 1.6	Impregnation Methods. Undertake trials to optimise coil impregnation methods.	T0 + 10
Task 1.7	Undertake preliminary design review with Topic Manager.	T0 + 12
Task 1.8	Undertake critical design review with Topic Manager.	T0 + 15
Task 1.9	Manufacture, assembly, and acceptance testing of development harsh environment electric actuator	T0 + 18
Task 1.10	Complete test programme for development electric actuator.	T0 + 24

Task 1.1: Agree high level electrical interface specification for electric actuator

The electric actuator may be used to position a valve element that itself has a closing torque load applied to it. The electric actuator will be required to fail safe (to a closed position), vary, and hold the position of the valve element to anywhere within the required range of motion. The speed and torque demands on the electric actuation system can be traded through gearing as required to optimally achieve the function. In this task the partner will work with the Topic Manager to agree the cardinal electrical interface requirements to which the actuator family shall be designed against.

Task 1.2: Research and select magnet wire & lead out wire materials for high temperature high vibration environment

The partner shall research, identify, and down-select suitable magnet wire and lead wire materials that are considered to be able to be demonstrated to have robustness in a harsh environment (up to 350°C surrounding air temperature, 400°C at the centre of the coil, and 3KHz vibration levels whilst operational).

Task 1.3: Research and select soft magnet lamination materials and designs suitable for use in high temperature high vibration environments

The partner shall research, identify, and down-select suitable soft magnet lamination materials that are considered to be able to be demonstrated to have robustness in an engine harsh environment (up to 350°C surrounding air temperature, 400°C at the centre of the coil, and 3KHz vibration levels whilst operational).

Task 1.4: Joining Methods. Undertake trials to optimise wire joining methods

The partner shall demonstrate repeatable, robust, and low variation (high Cpk (process capability)) performance in the recommended joining method of the selected magnet wire to the lead wire materials.

Task 1.5: Insulation Methods. Undertake trials to optimise wire insulation methods

The partner shall demonstrate via the test of sufficient articles that a repeatable, robust (high Cpk (process capability)) method of wire insulation has been identified. Covering coil to coil turns, coil to case, and channel to channel paths through the coil manufacturing process.

Task 1.6: Impregnation Methods. Undertake trials to optimise coil impregnation methods

The partner shall demonstrate that a rugged and low variation (high CpK) impregnation material and application method has been identified that is robust under operation in the harsh engine environment. Taking into consideration the thermal mis-matches of the constituent materials of the assembly, the operational environment and product duty cycle.

Task 1.7: Undertake preliminary design review with Topic Manager

In consideration of the learning from tasks 1.2 through 1.6 inclusive the Partner will propose a preliminary design solution and successfully conduct and close out with the Topic Manager a Preliminary Design Review of the preliminary electric actuator product family solution.

Task 1.8: Undertake critical design review with Topic Manager

Building upon the learning from tasks 1.2 through 1.6 inclusive and addressing the actions/recommendations from task 1.7 the Partner will propose a design solution and successfully conduct and close out with the Topic Manager a Critical Design Review of the electric actuator product family solution.

Task 1.9: Manufacture, assembly, and acceptance testing of development harsh environment electric actuator

Manufacture, assembly, and acceptance testing of development harsh environment electric actuator

Task 1.10: Complete test programme for development electric actuator

Agree, define, undertake and report upon the appropriate testing to verify the robust performance to specification of an example of the agreed design solution as agreed at completion of Task 1.8.

3. Major Deliverables/ Milestones and schedule (estimate)

*Type: R=Report, D=Data, HW=Hardware

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1.1	Appropriate materials for trials down-selected.	D, R	T0 + 6
D1.2	Joining, insulation, impregnation, and coil winding trials completed.	D, R	T0 + 10
D1.3	Electric Actuator Preliminary Design Review completed with Topic Manager.	D, R	T0 + 12
D1.4	Electric Actuator Critical Design Review completed with Topic Manager.	D, R	T0 +15
D1.5	Test report issued from development testing of example unit post the Critical Design Review.	D, R	T0 + 24

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M1.1	Optimal materials and manufacturing & assembly methods selected post completion of trials.	R	T0 + 10
M1.2	Preliminary Design Review completed.	R	T0 + 12
M1.3	Critical Design Review completed.	R	T0 + 15
M1.4	Manufacture, assembly, and acceptance testing of development harsh environment electric actuator completed.	HW	T0 + 18
M1.5	Development test trials of harsh environment electric actuator completed.	HW, D	T0 + 22
M1.6	Test Report from development test trials of harsh environment electric actuator issued.	R, D	T0 + 24

4. Special skills, Capabilities, Certification expected from the Applicant(s)

The applicant shall

- Have substantial technical knowledge in the domain of the proposed tasks.
- Have proven capability in electro-magnetic modelling methods that support the design of robust electric actuators optimally sized to deliver the function at minimum power draw.
- Have an awareness of the temperature limiting features and components of existing electric actuation solutions.
- Be knowledgeable regarding suitable magnet and lead out wire materials applicable to harsh

environment electric actuators.

- Be knowledgeable in wire joining methods applicable to harsh environment electric actuators.
- Be knowledgeable in wire insulation methods applicable to harsh environment electric actuators.
- Be knowledgeable in coil impregnation methods applicable to harsh environment electric actuators.
- Be knowledgeable in coil winding methods applicable to harsh environment electric actuators.
- Be knowledgeable in materials selections to optimise the thermal balance of the coil wound assemblies.
- Have proven DFMEA, and PFMEA capabilities.
- Have proven risk management practices.

Certification Expectations

- Testing of development examples of electric actuators in the following areas:
    - Thermal cycling and thermal shock testing at varying operational duty cycles in accordance with CS-E-80.
    - Vibration testing in accordance with CS-E-80.
    - Simulated Operations Testing (under load conditions) at conditions to be agreed with the Topic Manager.
    - Salt/Fog, and hermeticity testing in accordance with CS-E-80.
    - Di-electric testing in accordance with CS-E-80.

5. Abbreviations

WBS	Work Break-down Structure
WP	Work Package
Cpk	Process Capability measure
DFMEA	Design Failure Modes Effect Analysis
PFMEA	Process Failure Modes Effect Analysis

X. JTI-CS2-2018-CfP08-LPA-01-56: Development of AC cabling technologies for >1kV aerospace applications

Type of action (RIA/IA/CSA)	IA		
Programme Area	LPA		
(CS2 JTP 2015) WP Ref.	WP 1.6.1		
Indicative Funding Topic Value (in k€)	750		
Topic Leader	Rolls-Royce	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	24	**Indicative Start Date (at the earliest)**[19]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-LPA-01-56	**Development of AC cabling technologies for >1kV aerospace applications**
Short description	
Build a simulation model to develop an understanding of the present capability of aerospace cables to withstand the demands of aerospace High Voltage (HV), high current, high frequency operation in an aerospace environment and identify an optimised aerospace cable for use with HV aerospace systems.	

Links to the Clean Sky 2 Programme High-level Objectives[20]				
This topic is located in the demonstration area:	Hybrid Electric Propulsion			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	▪ Ultra-advanced Long-range ▪ Advanced Long-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

[19] The start date corresponds to actual start date with all legal documents in place.

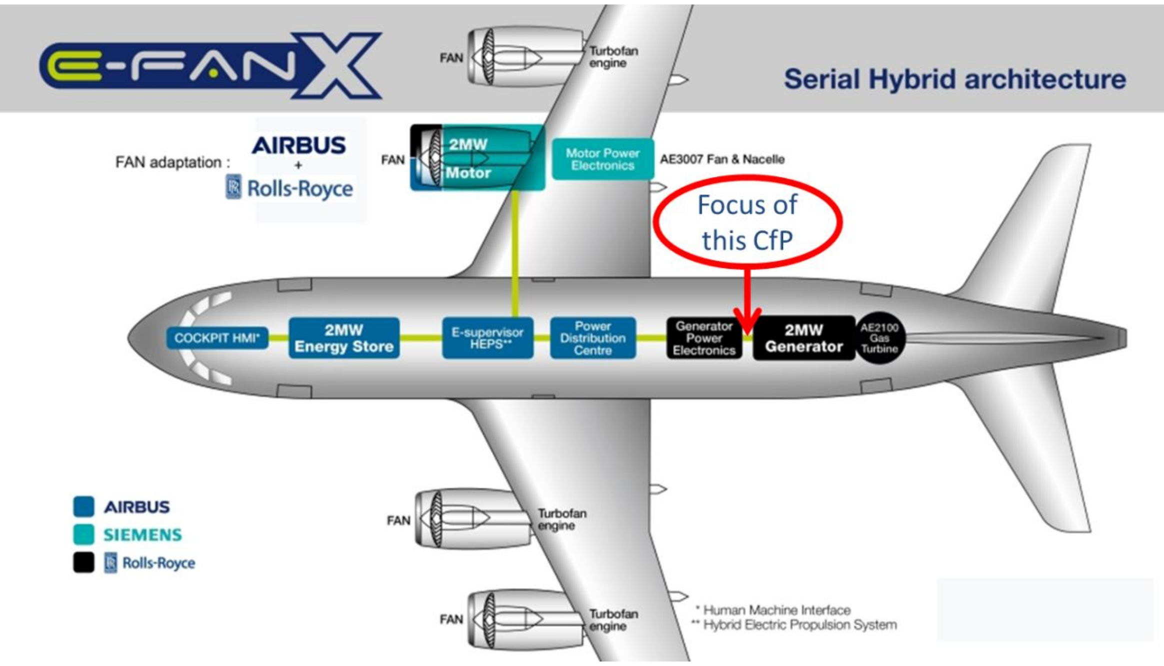
[20] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

The rise of hybridisation and electrification in proposed aerospace transport solutions is being driven by growing pressure on the industry to reduce its production of greenhouse gases, coupled by the development of enabling technologies that are making more-electric solutions a viable alternative to existing aircraft power and propulsion solutions.

Current proposals for future hybrid and fully electric propulsion systems require an increse in the operating voltage up to HV (>1000Vac). For hybrid systems, such as the E-FanX demonstrator shown below, the architecture will include a gas turbine and generator arrangement providing High Voltage Alternating Current (HVAC) to a converter, this feeds a Direct Current (DC) distribution network before more power electronics are used to drive Alternating Current (AC) motors.

The focus of this call is on the interconnecting AC cables between the power electronics and the motors/generators in general; these are likely to encounter some of the most hostile environments on the aircraft with high temperatures, high levels of contaminants and vibration and high altitude - all having detrimental effects on the cable, its insulation system and its terminations.



The Topic Leader is looking for collaborative research partner(s) to support a research and development activity focusing around the implications of working in an aerospace environment on HV, high frequency AC cabling. There are three work packages in this call:

- WP1: Capturing and understanding the implications of using HVAC in aerospace including failure modes, lifing, arcing.
- WP2: Development of a cable modelling tool which can be used to assess the suitability of cables for use in aerospace HVAC systems including the findings of WP1. Validation of the model will be carried out through physical testing on existing aerospace cables.
- WP3: Development, and demonstration of an optimised HVAC cable in a representative aerospace environment at full power.

This strategic theme covers work package WP1.6.1 –Alternative Energy Propulsion Architecture & Components within the Clean Sky 2 Large Passenger Aircraft (LPA) – Platform 1.

2. Scope of work

Requirements: >1MW, >10kHz switching and >1kHz fundamental, >1kVAC voltage rating, Development up to TRL 5

Tasks		
Ref. No.	***Title - Description***	***Due Date***
T1.1	Identification of potential failure cases within HVAC (High Voltage Alternating Current) cables in aerospace	T0 + 3
T1.2	State of the art assessment on cable materials and insulation co-ordination	T0 + 3
T1.3	FMEA of HVAC cables in aerospace	T0 + 4
T2.1	Develop initial model of HVAC cable systems based on T1.3	T0 + 8
T2.2	Design and build test rig - representative of a HVAC aerospace cabling system	T0 + 9
T2.3	Validation of T2.1 via testing of existing cables at full power	T0 + 12
T3.1	Design/optimisation of aerospace HVAC cable	T0 + 15
T3.2	Manufacture of aerospace HVAC cable samples	T0 + 18
T3.3	Validation of optimised aerospace HVAC cable design through testing	T0 + 23

WP1: To identify and understand the potential failure modes that can be expected within an Aerospace High Voltage (HV) system and their effect on cables. This should encompass electrical, mechanial and material considerations to give a full understanding of the cable, its operation and its environment.

- **Task T1.1**
  Identification of potential failure cases within HVAC (High Voltage Alternating Current) cables in aerospace
- **Task T1.2**
  State of the art assessment on cable materials and insulation co-ordination
- **Task T1.3**
  Carry out a Failure Modes and Effects Analysis (FMEA) of HVAC cables in aerospace

WP2: To develop and validate a model of aerospace HVAC cables encompassing lifing, frequency effects and the failure modes captured in WP1.

- **Task T2.1**
  Develop an aerospace HVAC cable model capable of representing electrical, mechanial, material considerations and the failure modes captured through WP1.
- **Task T2.2**
  Design and build test rig - representative of a HVAC aerospace cabling system
- **Task T2.3**
  Validation of T2.1 modeal via testing of existing cables at full power using test rig built as part of T2.2.

WP3: Development or optimisation of an aerospace HVAC cable using the knowledge gained from work packages 1 and 2.

- **Task T3.1**

Carry out the design and optimisation of an aerospace HVAC cable

- **Task T3.2**
  Manufacture aerospace HVAC cable samples based on the output of T3.1.
- **Task T3.3**
  Validation of the optimised cable and report detailing design detail and results.

3. Major Deliverables/ Milestones and schedule (estimate)

** Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1.1	Report on identified potential failure cases within HVAC cables in aerospace and state of the art assessment.	D, R	T0 + 4
D1.2	FMEA analysis of aerospace HVAC cables	D, R	T0 + 5
D2.1	Model validation report	R	T0 + 13
D3.1	Report capturing optimised aerospace HVAC cable design and test results.	D, R	T0+ 23
D3.2	Optimised validated cable samples available to RR	HW	T0+ 23

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M1.1	Review of identified potential failure modes	D	T0 + 4
M2.1	Demonstration of model	D	T0 + 9
M2.2	Review of rig design and test plans	D	T0 + 9
M2.3	Review of validated model	D	T0+13
M2.4	Commissioning of test rig	D	T0 +11
M3.1	Cable design complete	D	T0 +16
M3.2	Cable manufacture complete	D	T0 +19
M3.3	Cable testing complete	D	T0 +23

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Skill 1: Medium Voltage capabilities
- Skill 2: Understanding of insulation design, development and testing
- Skill 3: Understanding of cable and termination design
- Skill 4: Understanding of material interactions and compatibility testing

5. Abbreviations

HV	High Voltage
HVAC	High Voltage Alternating Current
kV	KiloVolts
AC	Alternating Current
DC	Direct Current

XI. JTI-CS2-2018-CfP08-LPA-01-57: Aerospace standard Lightweight SSPC for High voltage >1kA application

Type of action (RIA/IA/CSA)	RIA		
Programme Area	LPA		
(CS2 JTP 2015) WP Ref.	WP 1.6.1		
Indicative Funding Topic Value (in k€)	900		
Topic Leader	Rolls-Royce	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	24	**Indicative Start Date (at the earliest)**[21]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-LPA-01-57	**Aerospace standard Lightweight SSPC for High voltage >1kA application**
Short description	
Design and development of aerospace standard lightweight solid state protection component for >1kV and >1kA electrical architectures. Cooling and shielding should be integrated into the solution	

Links to the Clean Sky 2 Programme High-level Objectives[22]				
This topic is located in the demonstration area:	Hybrid Electric Propulsion			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	▪ Ultra-advanced Long-range ▪ Advanced Long-range ▪ Advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

[21] The start date corresponds to actual start date with all legal documents in place.
[22] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

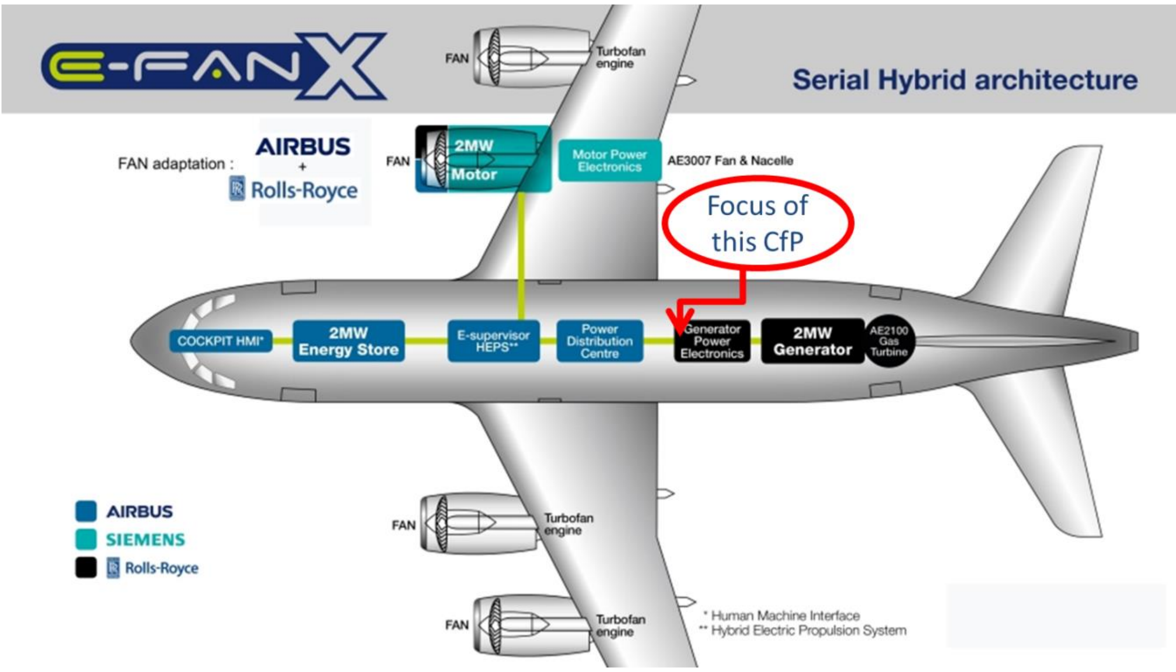
1. Background

The rise of hybridisation and electrification in proposed aerospace transport solutions is being driven by growing pressure on the industry to reduce its production of greenhouse gases, coupled by the development of enabling technologies that are making more-electric solutions a viable alternative to existing aircraft power and propulsion solutions.

The increasing electrical power levels being considered in research and demonstrator projects introduce a significant challenge for protection systems, particularly for Large Passenger Aircraft (LPA). For hybrid systems, such as the E-FanX demonstrator shown below, the architecture will include a gas turbine and generator arrangement providing High Voltage Alternating Current (HVAC) to a converter, this feeds a Direct Current (DC) distribution network before more power electronics are used to drive Alternating Current (AC) motors.

Operating voltages in excess of 1 kV are being more frequently referenced in the public domain, however, due to the harsher operating environment at altitude, high power systems will inevitably require higher operating currents which are likely to exceed 1 kA in some applications.

As with any electrical power distribution grid, hybrid and distributed propulsion architectures require protection solutions to cover all stages of power distribution – from primary higher voltage generation to lower voltage secondary distribution networks.



In combination with the increasing power requirements for protection equipment, DC (Direct Current) is being more frequently adopted and this introduces additional challenges, in particular the breaking of a high power circuit under fault conditions. Solid-state technology offers an opportunity to minimise system size and weight by electrically disconnecting two conductors using semiconductor materials; this removes the challenge associated with electrical arcing and increases the switching speeds possible (in comparison to conventional contactor based technologies).

The Topic Leader is looking for collaborative research partner(s) capable of supporting the development, to TRL 3/4, of a lightweight and efficient solid-state protection device, including intergrated isolation capability, to operate at a nominal voltage between at least 540 V DC (e.g. ±270 V) and up to or greater than 1 kV DC with a nominal current capacity between 500 A and up to or greater than 1 kA.
This call will be split into two work packages:

- WP1: Component development
- WP2: Thermal and Electromagnetic Interference (EMI) analysis

This strategic theme covers work package WP1.6.1 –Alternative Energy Propulsion Architecture & Components within The Clean Sky 2 Large Passenger Aircraft (LPA) – Platform 1.

2. Scope of work

Tasks		
Ref. No.	***Title - Description***	***Due Date***
T1.1	Protection device design trade study	T0 + 6
T1.2	Study into the scalability of solid-state devices for aerospace electrical protection.	T0 + 8
T1.3	Solid-state protection device prototyping and testing	T0 + 22
T2.1	Thermal modelling and simulation of solid-state protection device	T0 + 24
T2.2	EMI modelling and simulation of solid-state protection device	T0 + 24

WP1: To develop a high power solid-state protection device to TRL 3/4. This will include concept trade studies, modelling, prototyping, functional demonstration and scalability studies. The aim is to identify the applicability of solid-state technologies as a means of providing electrical protection in high power sections of future aerospace electrical networks.

- **Task 1.1**
  Perform a trade study to look at methods of maximising on-state efficiency of solid-state devices, versus cost and weight.
- **Task 1.2**
  Perform a study into the scalability of solid-state technology for electrical protection applications.
- **Task 1.3**
  Carry out conceptual design, development and functional testing of a prototype solid state protection device.

WP2: To identify the integration requirements of the solid-state devices from WP1, in particular looking at the thermal management/cooling demands and required EMI shielding to make the device compliant with Electromagnetic Compatibility (EMC) standards.

- **Task 2.1**
  Develop a thermal model of the solid-state device from WP1, and validate the simulation results using measured data from testing as part of Task 1.3.
- **Task 2.2**
  Develop an EMI model of the solid-state device from WP1, and validate the simulation results using measured data from testing as part of Task 1.3.

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1.1	Initial solid-state electrical protection device design	R	T0 + 7
D1.2	Report on trade study of maximising solid-state device efficiency, and the scalability of solid-state technology for electrical protection applications.	R	T0 + 9
D1.3	Design definition for high-power, lightweight and high efficiency solid-state electrical protection device.	R	T0 + 11
D1.4	Prototype hardware and report of testing results and analysis	HW, D	T0 + 22
D2.1	Report on development of thermal and EMI models, including simulation analysis and delivery of validated models.	R, D	T0 + 24

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M1.1	Requirements capture document	R	T0 + 2
M1.2	Mid-point review of protection device design	D	T0 + 7
M1.3	Review of prototype protection device design	D	T0 + 11
M2.1	Review of thermal and EMI models	D	T0 + 18

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Skill 1: Solid-state protection device design, development and testing capability required
- Skill 2: Understanding of influence of aerospace operating envionrments on requirements and design of solid-state devices

5. Abbreviations

kV	Kilo-Volts
TRL	Technology Readiness Level
DC	Direct Current
kA	Kilo-Amperes
V	Volts
A	Amperes
EMI	Electromagnetic Interference
EMC	Electromagnetic Compatibility

XII. JTI-CS2-2018-CfP08-LPA-01-58: Innovative Power and Data transfer solutions for nacelle

Type of action (RIA/IA/CSA)	IA		
Programme Area	LPA		
(CS2 JTP 2015) WP Ref.	WP 1.6.4		
Indicative Funding Topic Value (in k€)	450		
Topic Leader	Airbus	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	38	**Indicative Start Date (at the earliest)**[23]	Q1 2019

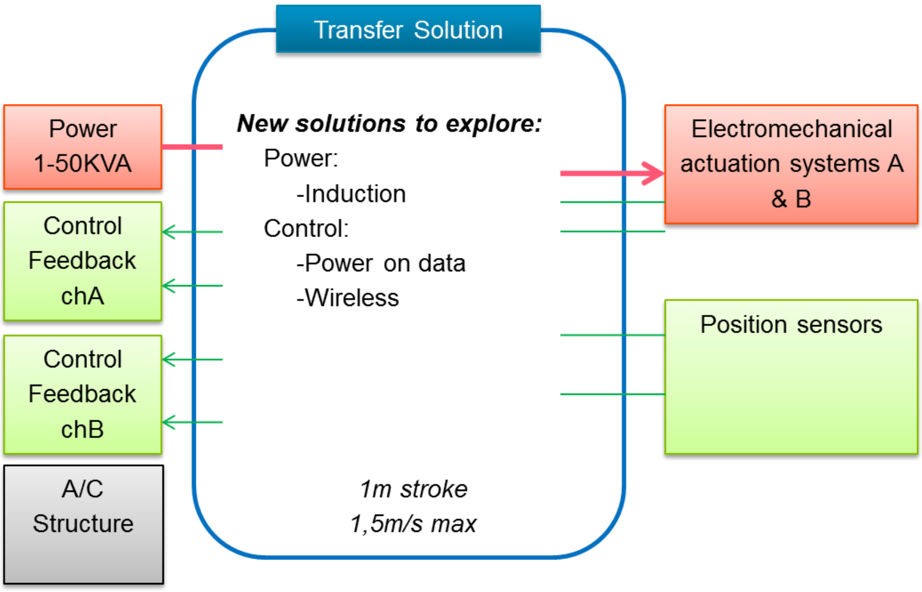
Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-LPA-01-58	**Innovative Power and data transfer solutions for nacelle**
Short description	
Future Ultra High by-pass Ratio engines are bringing new challenges in integration to airframe, especially nacelle short and slim aerolines. These new constrains lead to define new solutions for the nacelle thrust reverser unit kinematics, and requires new compact electrical solutions to transfer electrical power and data from the fixed part of the thrust reverser to the translating one. The proposed activity will consist in defining and testing new electrical power and data transfer solution compliant with those new requirements, with a target for a TRL6 level	

Links to the Clean Sky 2 Programme High-level Objectives[24]				
This topic is located in the demonstration area:	Advanced Engine/Airframe Architectures			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Long-range, Advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

[23] The start date corresponds to actual start date with all legal documents in place.
[24] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

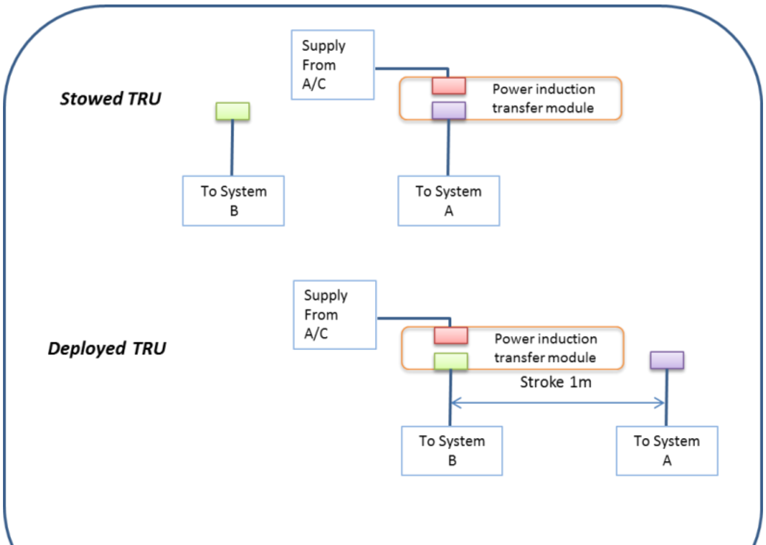
1. Background

Future Ultra High by-pass Ratio engines are bringing new challenges in integration to airframe, especially nacelle short and slim aero lines. These new constrains lead to define new solutions for the nacelle thrust reverser unit kinematics, and requires new compact electrical solutions to transfer electrical power and data from the fixed part of the thrust reverser to the translating one. The proposed activity will consist in defining and testing new electrical power and data transfer solution compliant with those new requirements, with a target for a TRL6 level.



Description of power transfer solution high level requirements:

- Transfer high power to system B (30 to 50 KVA maximum, during 1 to 10seconds, in both A/C to system and system to A/C directions) between 2 parts with no contact (5 to 20mm air gap) when thrust reverser is in deployed configuration, w/o disturbance of surrounding electrical systems (operation during Thrust reverser sequence on ground at landing)
- Transfer power to system A (1 to 5 KVA maximum, during 2 minutes maximum) between 2 parts with no contact (5 to 20mm air gap) when thrust reverser is in stowed configuration, w/o disturbance of surrounding electrical systems (operation on ground, A/C at taxi and engines of only)
- Operate 2 power cycles per flight considering 3 x 36000 flight cycles
- Be tolerant to relative displacements when operating (few millimeters in all direction, will be refined during the activity)
- Maintain power and current quality in a harsh environment (water/sand/dust contamination, high vibrations as per DO160 issue G curve W, wide temperature range -55°C to 100°C)
- Target high reliability MTBF > 100000 FH (close to connectors reliability)

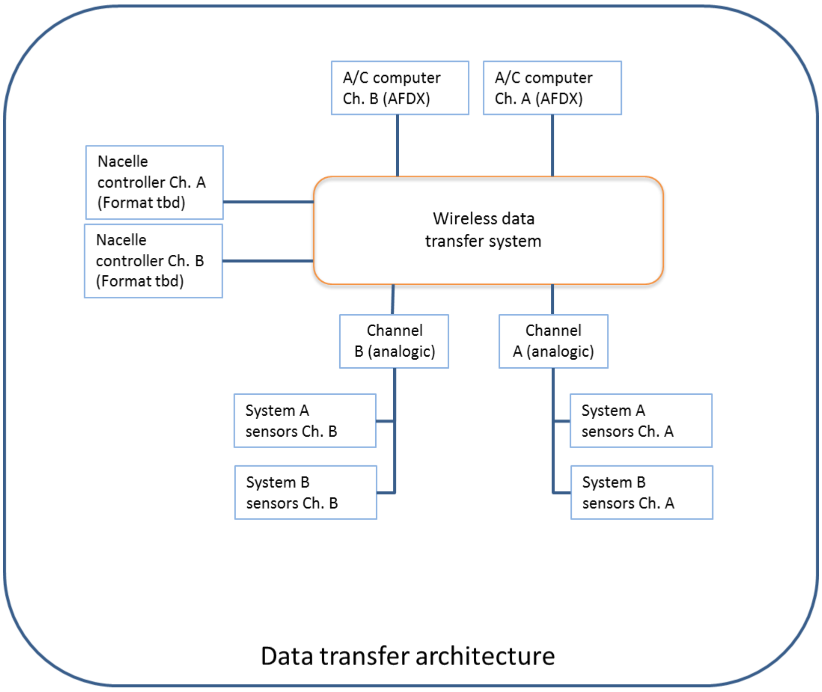


Power transfer sequences

Description of data transfer solution high level requirements:

- Main function is to transfer data between 2 parts with no contact (5 to 20mm air gap) when thrust reverser is in a determined stowed or deployed configuration and also during its translation (1.5m/s maximum speed, 1m stroke)
- Enable wireless data transfer between emission & reception modules located at a distance of 0.5m (TRU stowed) to 1.5m (TRU deployed) w/o disturbance of surrounding electrical systems
- Transfer numerical data generated of 2 channel by about 12 sensors (RVDT, PS) shared between 2 different systems
- Operate 1 cycle (1minute max) per flight considering 3 x 36000 flight cycles
- Be tolerant to relative displacements when operating (few millimeters in all direction, will be refined during the activity)
- Maintain data quality in a harsh environment (water/sand/dust contamination, high vibrations as per DO160 issue G curve W, wide temperature range -55°C to 100°C)
    - Target high reliability MTBF > 100000 FH (close to connectors reliability)

The data transfer solution shall include also the analogic to numeric conversion modules and from numeric to a known aeronautic format (AFDX, ARINC429, CAN)



Work breakdown Structure is proposed as following:

Airbus:

- Elaborate specification of the electrical transfer solution
- Functional analysis
- Space enveloppe
- Functional interfaces (mechanical & electrical)
- Design constrains (operability, reliability, safety, loads, speed, accelerations, vibration…)
- Environmental requirements
- Propose simplified qualification approach based on DO254 / ABD100
- Integrates the proposed solution in the targeted nacelle design (DMU)
- Analyse environmental data from flight test and refine technical specifcation for TRL6
- Verify compliance of the design proposed
- Assess technology readiness level for the integration part
- Provide test mean (Functional Iron bird environment)

Partner:

- Elaborates the technical solution compliant to Airbus specification => TRL 2, TRL3
- Develop Technical solution for power transfer (Resonance induction)
- Develop Technical solution for data transfer (Wireless)
- Follow Simplified qualification process
- Design (3D), size, qualify and test the solution => TRL4
- Provides a test hardware for Airbus functional Integration test (TRL5)
- Finalize test lab of the solution after Demonstrator flight test data (TRL6)

2. Scope of work

Tasks		
Ref. No.	***Title - Description***	***Due Date***
T_1	Analysis of the specification – transformation of high level requirements into detailed requirements	T0+2months
T_2	Identification of state of the art for similar components + list of potential concepts (TRL2)	T0+3months
T_3	Preliminary concepts proposals & pre-sizing – down-selection (TRL3)	T0+9months
T_4	Definition of selected concept and first performance test (prototype in a non-representative environment, demonstration of feasibility (TRL4)	T0+16months
T_5	Detailed definition of a product representative prototype & performance test at component level (TRL5)	T0+28months
T_6	Integration test of the prototype on a scale 1 half-nacelle and Functional Iron Bird (TRL6 part 1)	T0+30months
T_7	Environmental & endurance qualification to demonstrate compliance to products requirements (TRL6 part2)	T0+38months

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D_1	Development plan (including technology readiness roadmap)	R	T0
D_2	Specification compliance Mattrix & derived component requirements	R	T0+2months
D_3	State of Art analysis / list of potential concepts (TRL2 dossier)	R	T0+3months
D_4	TRL3 dossier (preliminary concept definition, downselection criteria, concept DMU, interface loads)	R + D	T0+9months
D_5	Concept Prototype test report	R	T0+15months
D_6	TRL4 dossier (Concept pre-sizing, test report, compliance, Behavioural electrical model)	R	T0+16 months
D_7	Product representative definition dossier (compliance to spec, DMU, Behavioural electrical model)	R + D	T0+20 months
D_8	Product representative prototype	HW	T0+26months
D_9	Product representative prototype performance test & report (TRL5)	R + D	T0+28months
D_10	Product representative prototype Integration test (nacelle scale + FIB) & report	R + D	T0+30months
D_11	Product representative prototype environmental test & endurance report	R + D	T0+36months
D_12	Final review (Maturity & compliance demonstration – TRL6)	R	T0+38months

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M_1	Kick of Meeting	R	T0
M_2	TRL3	R	T0+9months
M_3	TRL4	R	T0+16 months
M_4	TRL5	R	T0+28months
M_5	Product representative prototype acceptance review (before HW delivery to integration test benches)	R	T0+26months
M_6	TRL6	R	T0+38months

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Aeronautics equipments design & manufacturing for civil A/C applications (CS25 knowledge)
- Experience in civil A/C electrical systems and components definiton & qualification
- Experience in power electronics, power induction, data communications and wireless transmission applied to aeronautics and/or space industry
- Experience in Electromagnetic interference compatibility
- Knowledge of Engine and nacelle environmental condition
- Experience in analogic to numeric conversion modules definition, qualification and industrialisation for aeronautics
- Experience in systems engineering, systems performance tests and qualification tests (DO160)
- Airbus systems requirements knowledge (ABD100)

5. Abbreviations

A/C	Aircraft
PS	Proximity Sensor
RVDT	Rotary Variable Differential transformer
TRL	Technology Readiness Level

XIII. JTI-CS2-2018-CfP08-LPA-02-23: Development and execution of new test procedures for thermoplastic aircraft fuselage panels

Type of action (RIA/IA/CSA)	IA		
Programme Area	LPA		
(CS2 JTP 2015) WP Ref.	WP 2.1.4		
Indicative Funding Topic Value (in k€)	500		
Topic Leader*	AERNNOVA	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	30	**Indicative Start Date (at the earliest)**[25]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-LPA-02-23	**Development and execution of new test procedures for thermoplastic aircraft fuselage panels**
Short description	
The main objective of the topic is to validate the structural behavior of thermoplastic aircraft fuselage panels in relation to new analytical methods for out of autoclave thermoplastic curing processes by static testing of panels under representative loads conditions. The tests will ensure the improved understanding of the structural response of the developed concept and proper design solutions for future application.	

Links to the Clean Sky 2 Programme High-level Objectives[26]				
This topic is located in the demonstration area:		Cabin & Fuselage		
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter		Advanced Short/Medium-range		
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☒	☐

[25] The start date corresponds to actual start date with all legal documents in place.
[26] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

Activities allocated in work package 2.1 of platform 2 of the Clean Sky 2 LPA are dedicated to the concept development, design and manufacturing of a multifunctional fuselage demonstrator in thermoplastic materials

The thermoplastic material is a revolutionary advance in the manufacturing of structural components. Highly automated, function integrated manufacturing and near Final Assembly Line including cabin and systems ingredients are some of the advantages of this material.

The CS2 LPA is developing a big fuselage demonstrator based in thermoplastics materials. This topic is about validating out of autoclave thermoplastic curing processes by static testing of flat panels (potentially curved) under representative loads conditions.

Autoclave is a bottle neck in composite manufacturing, thus the avoidance of this manufacturing step will improve the production rate. Besides out of autoclave curing is promising from energy optimization being this another of the key reasons for this technology development.

Therefore this topic aims the validation of out of autoclave thermoplastic panels demonstrators. They will consist in a thermoplastic structure. The tests will ensure the structural response of the developed concept and the design solutions. The test campaign shall be carried out to complete the developments.

Test campaign shall also provide innovative tooling solutions in order to reduce the test development program schedule and costs while keeping the highest level of accuracy in its results with innovative on time-monitoring systems and thermoplastic structures inspection methodologies.

Special attention will be given to:

- Ensuring test loads application alignment systems/methodology.
- FEM capabilities to analyze the influence of the tooling design on the load redistribution during the test execution. Test simulation.
- New materials for test tooling design.
- Contact- less on-time inspection methodologies.
- Flexible and multi-purpose tooling solutions.
- Eco-design criteria and development for less material and energy utilization, enhance use of eco-materials and future recyclability

2. Scope of work

The scope of the work defined in this document is focused on providing test evidences of the behavior of thermoplastic composite parts. Hence Test Matrix to be presented follows the rules of the building block approach (see Figure 1) from structural details (level 2) up to subcomponent level (level 3). The scope and objectives of the two levels would be as follows:

Level 2 Tests (Structural Details):

Level 2 is focused on establishing allowables (point design) or calibration/validation of the analysis methodologies used on the strength prediction of the details presented in the design. The specimens are still relatively simple specimens. These may include examples skin/stringer combinations, stringer drop-offs, reinforcing ply drop offs, and bonded splices. To determine damage tolerance (Category 1 damages) and inspection criteria, the same specimens should be tested with barely visible and with easily detectable damage.

Level 3 Tests (Subcomponent):

Level 3 is focused on validating the design methodologies employed in the design of subcomponents. Specimen boundary and load introduction conditions are more representative of the actual structure than in the element tests. Biaxial loading can be applied. The level of specimen complexity allows incorporation of representative structural details. The level of specimen complexity allows for the testing of multi stiffened panels, panels with large cutouts, and damaged panels. Secondary loading effects should be seen in this level of specimen complexity. The resulting load distributions and local bending effects become observable and out-of-plane failure modes become more representative of full-scale structure.

The scope of the program is to test the design and structural capabilities of a manufactured flat demonstrator with potentially curved panel. Specimens will be tested only under Room Temperature conditions.

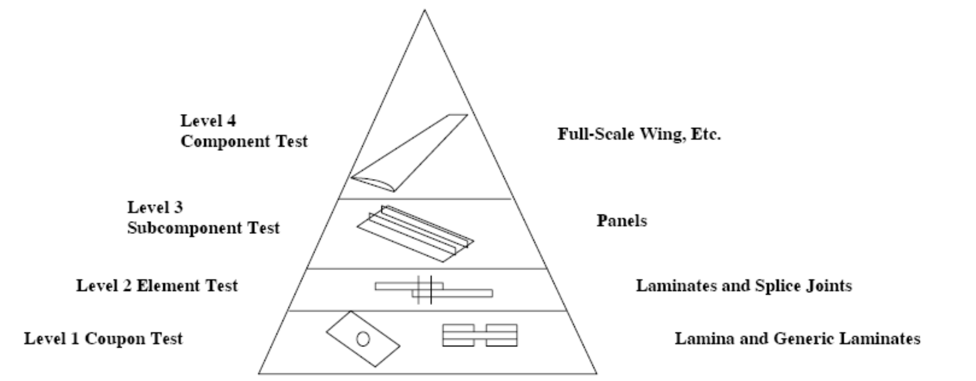


FIGURE 4.1(b) *The building block approach–test levels and examples of test articles.*

Figure 1: Building block approach

Hence, tasks can be divided in two subgroups:

Tasks		
Ref. No.	***Title – Description***	***Due Date***
Level 2 tests		
L2-Tk0	Test Plan preparation of Level 2 tests (in collaboration with the topic manager)	T0+3
L2-Tk1	Design and manufacturing of test tooling	T0+8
L2-Tk2	Level 2 testing	T0+15
L2-Tk3	Level 2 test report	T0+18
Level 3 tests		
L3-Tk0	Test Plan preparation of Level 3 tests (in collaboration with the topic manager)	T0+14
L3-Tk1	Design and manufacturing of test tooling	T0+19

Tasks		
Ref. No.	***Title – Description***	***Due Date***
L3-Tk2	Level 3 testing	T0+25
L3-Tk3	Level 3 test report	T0+30

Level 2 tests

Based on previous experience these level 2 tests are expected (final list and number of coupons to be confirmed during negotiation);

- ✓ Crippling
- ✓ CAI stringer
- ✓ Mouse hole

L2-Tk0 Test Plan preparation of Level 2 tests (in collaboration with the topic manager)

The applicant should participate in the development of the test plan for Level 2 tests in collaboration with the topic manager. Conceptual and preliminary design will be provided to the applicant. The test plan shall include the complete definition of the coupons (dimensions, loadings…). No bolted joints are expected.

L2-Tk1 Design and manufacturing of test tooling

The applicant shall perform the design and manufacturing of the test tooling after the acceptance of the test plan by the topic manager.

Requirements and features needed for the Level 2 manufacturing of the test tooling and any other tooling will be provided in accordance with the Topic Manager requirements, at the beginning of the project.

L2-T2 Level 2 testing

Tests will be performed under the conditions defined in the test plan (L2-Tk0 task). The experimental tests are carried out under quasi-static loading conditions. Those tests shall provide the behavior of the new thermoplastic material to ease the definition of the Level 3 coupon design. Conditioning of the test specimen prior to test and specific control of environmental parameters during test are not required (ambient temperature and humidity).

The applicant should design and prepare the experimental test setup, including the boundary conditions, actuation systems, sensors installation, instrumentation and positioning.

The following main capabilities are requested:

- Traceability of the coupons
- Non destructive inspections before and after the test (Ultrasonic, visual, dimensional)
- Load application monitoring
- Installation and continuous monitoring of strain gauges.
- Temperature and humidity control during the test.
- Any essential tool necessary for the development of the test

L2-Tk3 Level 2 test report

Final deliverable for Level 2 tests will consist of a test results report. Preliminary test data can be requested by the Topic Manager at any moment of the test campaign. Those preliminary results may help on the definition of the Level 3 Test campaign.

Level 3 tests

Preliminary dimensions of the panel to be tested (flat or curved) are: 2mx1.5m.

Loading conditions will be shear, compression and tension. The panel will be tested until structural failure under one of those conditions.

L3-Tk0 Test Plan preparation of Level 3 tests (in collaboration with the topic manager)
The applicant should participate in the development of the test plan for Level 3 tests in collaboration with the topic manager. Conceptual and preliminary design will be provided to the applicant. The test plan shall include the complete definition of the structural panel (dimensions, loadings…). No bolted joints are expected.

L3-Tk1 Design and manufacturing of test tooling
The applicant shall perform the design and manufacturing of the test tooling after the acceptance of the test plan by the topic manager.

Requirements and features needed for the Level 3 manufacturing tooling and any other tooling will be provided in accordance with the Topic Manager requirements, at the beginning of the project.

L3-Tk2 Level 3 testing
Tests will be performed under the conditions defined in the test plan (L3-Tk0 task). Three loading conditions will be defined: shear, compression and tension. The panel will be loaded until structural failure under one of those conditions.

The goal of the project is to predict the behavior of the level 3 panel demonstrator with the analytical analyses performed by the topic manager stress group.

The design process of the test rig must take into account different aspects:

- Rigidity of the test rig.
- Specimen-rig joining elements.
- Load application systems and devices.
- Test rig assembly and specimen to rig assembly.
- Verifications required such as: specimen positioning, load application direction, security measurements…
- Specimen required instrumentation.

The applicant should design and prepare the experimental test setup, including the boundary conditions, actuation systems, sensors installation, instrumentation and positioning.

The following main capabilities are requested:

- Traceability of the coupon
- Non destructive inspections before and after the test (Ultrasonic, visual, dimensional)
- Load application monitoring
- Installation and continuous monitoring of strain gauges.
- Temperature and humidity control during the test.
- Any essential tool necessary for the development of the test

L3-Tk3 Level 3 test report
Final deliverable for Level 3 tests will consist of a test results report. Preliminary test data can be requested by the Topic Manager at any moment of the test campaign.

As a general final remark, the Applicant(s) will interact with the Topic Manager during the analytical comparison phase, providing experimental test results in the best format for the correlation prior setting up conclusions.

Topic Manager will provide information (design documentation, general requirements, specifications…) and will prepare models for later comparison, and also will supply the specimen to be tested.

The applicant will lead and manage all the activities included in this document. Selected applicant will be the responsible for the test rig design, test rig elements manufacturing, test rig assembly at its facilities, required tests execution and test results delivery. All of these activities will be always performed under the supervision of the Topic Manager.

In conclusion, the Topic manager and the Applicant will closely work together all along the various phases:

- Test Plan Issue and conceptual preliminary design of the test rig (PDR)
- End of the design phase (CDR)
- Test readiness (TRR)
- Structural Test campaign execution and results acceptance
- Test Completion Review

The Applicant(s) will describe and propose in their proposal the most suitable and innovative test rig design for performing the required structural tests and generate the required documentation.

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1	Level 2 Test Plan proposal to be discussed with the topic manager	R	T0+3
D2	Level 2 Tooling Design Document (design and calculations of test set up)	R	T0+8
D3	Level 2 Test results report: set up description, equipment conformity certificates, test results	R	T0+18
D4	Level 3 Test Plan proposal to be discussed with the topic manager	R	T0+14
D5	Level 3 Tooling Design Document (design and calculations of test set up)	R	T0+19
D6	Level 3 Test results report: set up description, equipment conformity certificates, test results	R	T0+30

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M1	Level 2 Kick Of Meeting	R	T0
M2	Level 2 Critical Design Review: tooling and set up validation	R	T0+8
M3	Level 2 Test Readiness Review: tests start	R	T0+11
M4	Level 2 Test Report	R	T0+18
M5	Level 3 Kick Of Meeting	R	T0+11
M6	Level 4 Critical Design Review: tooling and set up validation	R	T0+19
M7	Level 5 Test Readiness Review: tests start	R	T0+22
M8	Level 6 Test Report	R	T0+30

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Applicants should have a strong knowledge and experience in mechanics, tooling design and composite components structural tests.
- It is required that the the test laboratory had developed a Quality System to assure the Quality of all Products and Services performed by the Test Lab for its Customers. Quality System International Standards (i.e. EN 9100:2009/ ISO 9001:2008/ ISO 14001:2004).

- Participation in international technological programs cooperating with reference aeronautical companies.
- Experience in management, coordination and tests execution developments of composite components.
- The tests must show high level of expertise and show a quality guaranteed management and testing process. Additionally different equipment is needed in all of the tests and the test lab must be expert in different fields such as structure tests, tooling design, advanced instrumentation and monitoring, advanced NDT techniques…
- Specifically, the applicant must have:
  - Design and analysis tools of the aeronautical industry (i.e. CATIA v5).
  - Testing equipment suitable for the tests execution, included in Scope of Work (level 2 and level 3 tests): universal test machines, load cells, hydraulic actuators, control system work stations, strain gage data acquisition channels, displacement transducers
  - Tools and methods for 3D non-contact displacement measurement, high speed video camera... for checking test behaviour.
  - Tools and methods for non-destructive inspection.
  - Experience in working with geometrical verification means as laser tracker.
  - Experience on technologies for reduction testing time and costs.
  - Laboratory flexibility in the design and the performance of structures tests.
- The above mentioned requirements will be discussed in more details during the partner agreement phase-Negotiation Phase. This will also include the IP management.

5. <u>Abbreviations</u>

FEM	Finite Element Model
LPA	Large Passenger Aircraft
NDT	Non destructive technologies

XIV. JTI-CS2-2018-CfP08-LPA-02-24: Generic added structures on thermoplastic fuselage shells

Type of action (RIA/IA/CSA)	IA		
Programme Area	LPA		
(CS2 JTP 2015) WP Ref.	WP 2.1.5		
Indicative Funding Topic Value (in k€)	800		
Topic Leader	Diehl Aircabin	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	24	**Indicative Start Date (at the earliest)**[27]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-LPA-02-24	**Generic added structures on thermoplastic fuselage shells**
Short description	
Lining panels for aircraft cabin interior are normally produced using glass-fiber reinforced sheet with epoxy resin. Any attachments are adhesively bonded afterwards. Within the Multifunctional Fuselage project the manufacturing of lining panels using thermoplastic sheets is investigated. Based on the benefits of the thermoplastic material methods to add these attachments by injection molding directly to the shell or using 3D-printing technology have to be developed and experimentally validated.	

Links to the Clean Sky 2 Programme High-level Objectives[28]				
This topic is located in the demonstration area:		Cabin & Fuselage		
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter		Advanced Short/Medium-range		
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☒	☐

[27] The start date corresponds to actual start date with all legal documents in place.
[28] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

Large Passenger Aircraft (LPA) Platform 2 – Multifunctional Fuselage Demonstrator

The objective of Large Passenger Aircraft (LPA) Platform 2 – Multifunctional Fuselage Demonstrator (MFFD) is to validate high potential combinations of airframe structures, cabin/cargo, and system elements using advanced materials and applying innovative design principles in combination with the most advanced system architecture in combination with the next generation cabin.

The overall objectives of the MFFD are:

- Enable a high production rate of a minimum of 60 aircraft per month
- Achieve a total fuselage weight reduction of 1000kg
- Achieve a reduction of recurring costs

The driver of this approach is to attain a significant fuel burn reduction by substantially reducting the overall aircraft energy consumption, apply low weight systems and system architecture/integration and to be able to cash in weight potentials in the structural design of the fuselage and the connected airframe structure. This must be achieved by the development and application of industry 4.0 opportunities such as design for manufacturing & autmation, automation, sensorization, and data analysis to demonstrate desired manufacturing cost effects.

The platform 2, work package 2.1 objective is the integration of cabin and systems with the primary aircraft structure to reduce weight and manufacturing cost and to enhance space for passengers and cargo by:

- Removing artifical separation of functions already at the aircraft pre-design stage
- Considering the aircraft manufacturing, assembly and installation in a high production rate setting right at the start.
- Achieve weight reductions which in turn contribute to the environmental challenge to reduce the CO_2 and NO_x footprint by 5 to 8%

WP2.1.5 Lower half of the Multifunctional Fuselage Demonstrator

In 2017, project activities started on the development of the lower half of the multifunctional fuselage demonstrator. This part of the project will develop, manufacture and deliver a 180° full scale multi-functional integrated thermoplastic fuselage shell, including cabin and cargo floor structure and relevant main interior and system elements.

The figure below provides a view on the diagonal cut concept with some characteristic features highlighted.

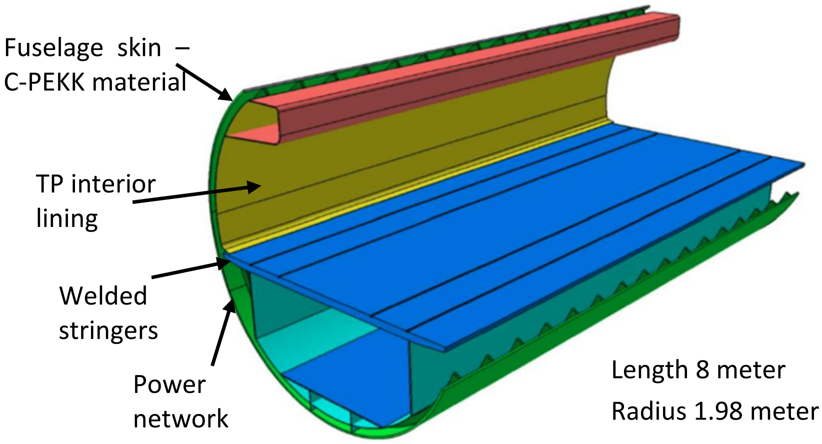


Figure 1: Multifunctional Fuselage Demonstrator

The applicants work will involve key aspects of the core partners activity on the MFFD and as such is linked to WP2.1.5. The work will be focused on the thermoplastic interior lining as part of the multifunctional fuselage demonstrator.

Interior lining with thermoset material

The state of art of interior connection shows a solution using different kinds of brackets. Sidewalls and ceiling panels are connected to fuselage with brackets made of Ultem and aluminium that are bolted to the frame. The counterpart is a bracket at the interior panel which enables quick mounting within the final assembly line. Between these two brackets normally a third one is used to align the structure bracket to the interior lining bracket. For each suspension point, a shock mount absorbs vibration and gives a tolerance to thermal expansion as well as loads coming from the fuselage.
The complexity of the panel brackets additionally leads to relatively large connector brackets and additional weight. In this regard, the quick solutions for final assembly line are based on more complex attachment of brackets at structural parts. At the moment sidewall and ceiling panels are made out of sandwich panels to ensure weight and stiffness. The process time to manufacture the panels is limited because of the use of thermoset material. The use of thermoplastic materials enables new solutions regarding cabin integration. A dustless assembly of shell interior parts will reduce the variety of bracket solutions leading to weight and cost saving. Furthermore, the thermoplastic welding has the potential to enable the pre-assembly of systems and assembling pre-equipped aircraft structures, leading to higher production rates, reduced and optimized installation efforts, weight savings, reduced production costs and operational efficiency. The coordinated and multi-specialist design between fuselage structure und interior parts then should lead to consistent mounting dimensions which are the basis for uniform interior solutions.

2. Scope of work

Within this project novel strategies for connecting linings elements to other structures have to be defined, evaluated and experimentally validated to emphasize the advantages of a fully thermoplastic fuselage and lining, which means that connecting elements are directly joined to the lining by pressing, injection molding or thermoplastic printing on the part without any additional adhesive. The objective of the work is to identify suitable materials and processing technologies contributing to the fuselage demonstrator. The processing technologies have to be enhanced to allow the manufacturing of a fully functionalized lining element within cycle times of max. 5 minutes. The technologies have to be demonstrated in relevant scale. Besides, the interfaces have to be characterized in terms of mechanics and morphology to proof the requirements in terms of load transfer. The applicant will use geometries and operating conditions prescribed by the topic leader that defines:

- Basic CAD-geometry of the demonstrator
- Values for state of the art systems as benchmark

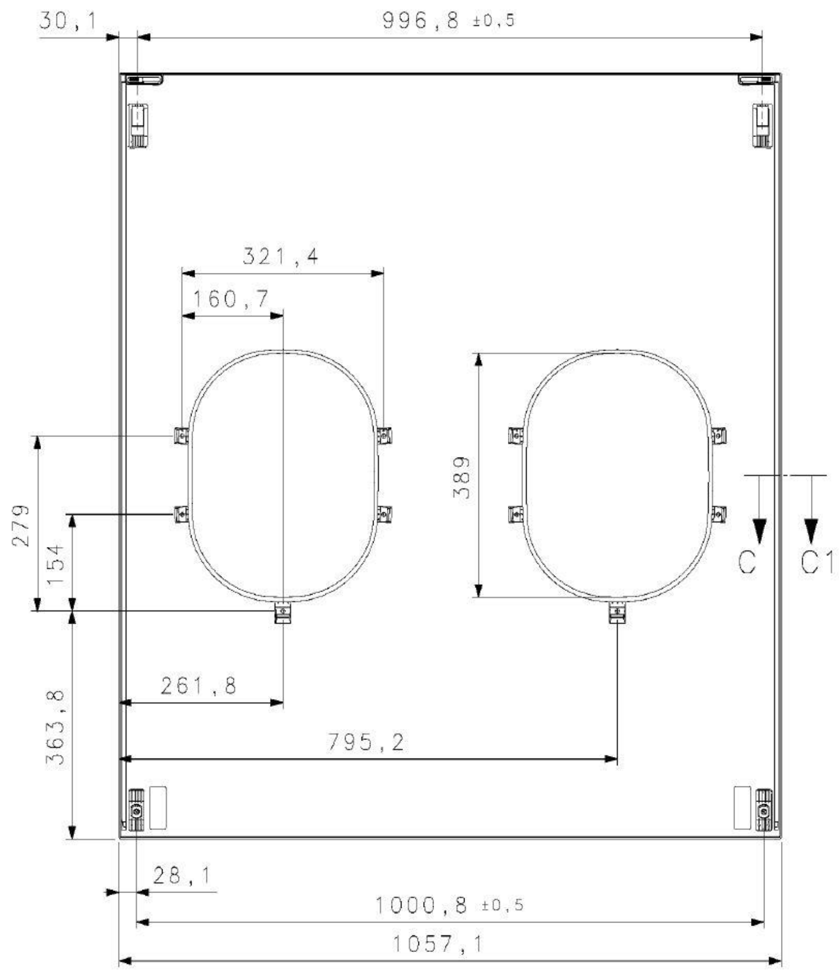


Figure 2: Dimensions of lining panel with attachment brackets

WP1: Identify suitable material combinations for functional elements on thermoplastic structures

For integration of net shaped and multi function integrated parts on thermoplastic composite elements in aircraft interiors, thermoplastic materials for cohesive joining on laminate surfaces must be identified. The materials have to ensure, that required adhesion on thermoplastic laminate is sufficient, especially in terms of shear and tensile strength or combination of both. The materials must fulfill in later component tests the aircraft requirements regarding FST (Flame Smoke Toxicity). Based on the chosen laminate material by the topic leader the applicant will select a set of thermoplastic polymers. These polymers have to be tested in laboratory scale test geometries. For this purpose, several test geometries for functional components have to be developed, manufactured and tested, e.g. screw domes for 3D-printing and ribs for injection molding. The suitability will be rated using different test methods. Properties are evaluated in mechanical tests (adhesion on laminate, tensile, shear) and warpage and shrinkage measurements. Maximum five materials will be chosen for the next steps. These materials will be investigated for best processing parameters and scope for injection molding and 3D-printing on laminates.

WP2: Development of a suitable processing for the customization of interior lining by 3D-printed elements

The applicant has to develop a novel processing approach to customize thermoplastic aircraft interior structures by 3D-printed elements, considering the constraints regarding processing time, adhesion strength, geometric accuracy and costs. The 3D-printing technology could enable a high degree of customization for small batch sizes. Applications for the 3D-printed elements are individual screw bosses, cable and sensor/actor fixing elements as well as individual mounting positions with different surface geometries.

Therefore, a technology has to be established, to print directly on a thermoplastic sheet without using any additional adhesives. The material choice and testing methods have to be based on WP1 and the 3D-printing process has to be included in a thermoforming and/or injection molding process chain to individualize the parts for specific mounting positions or equipment lines. This will be investigated in WP3 and WP4.

As a second method a two-step processing has to be developed and evaluated. Therefore, a 3D-printed component has to be joined with the thermoplastic base part in a welding or thermal joining process. The advantage of this method is that the 3D-printed parts could be produced batch wise in high quantities.

The parts produced by the new process should be able to be used as load transmission elements and therefore have to fulfill the aircraft interior specifications. The process development has to be evaluated by printing small scale demonstrators and a characterization of the interface between base structure and 3D-printed part.

WP3: Development of a suitable processing for injection molding on interior lining

The objective of this WP is to develop a combined processing for manufacturing linings and injection molding of functional elements. For manufacturing interior lining thermoforming of thermoplastic laminate or thermoplastic sandwich structure is required, followed by an injection molding step. With respect to the sandwich technology, experience with different core material (foam, honeycomb etc.) is required. Damage of core structures (compression strength: 0.5 N/mm^2) within the thermoplastic lining during injection molding must be avoided. For long flow path, reduced injection pressures, reduced sink marks and reduced warpage the possibility for foam injection molding must be evaluated. Upscaling for this process to enable injection molding on full parts of thermoplastic interior lining (up to 1100 mm x 1300 mm). The figure 2 can be used for comparison. Outcome of this task are design guidelines for planning the demonstrator part and demonstrator mold in Task 4. Design guidelines consist of possible geometries, possible flow path length and mold guidelines.

WP4: Process upscaling, mould manufacturing, manufacturing of demonstrator parts

In this task, the applicant shall use all data delivered by the topic leader and the design guidelines of task 3 to plan an appropriate big scale demonstrator in a relevant scale of minimum 600 mm x 600 mm. The demonstrator consists of a thermoformed thermoplastic composite laminate or sandwich panel combined with function elements by injection molding and individual 3D-printed elements. The mold concept must be able to clamp previously manufactured function integration parts by injection molding or 3-D-printing. Thereby separately manufactured elements for function integration can be used as inserts for the laminate in the compression molding step. The task contains planning the demonstrator part in close cooperation with topic leader and controlling the time schedule up to design freeze, manufacturing the mold and operation on a compression injection molding machine. Furthermore, the applicant has to prove the compatibility of the design with the previously selected 3D-printing process. A complete manufacturing cell for production of the demonstrator parts is required including the heating and transfer of the thermoplastic lining into the compression injection molding machine. Demonstrator parts must be manufactured with different processing parameters to study the influence of different processing temperatures, pressures and times on part quality. The demonstrator parts are tested according to WP 5 and costs for serial production will be evaluated.

WP5: Testing of laboratory specimens and demonstrators

The work package covers all test activities and has to be planned parallel to the relevant tasks. Tests have to be accomplished with the small-scale demonstrator parts to identify the appropriate process as well as with the big scale parts to evaluate the influence of the process upscaling on the part properties.

The applicant has to characterize the interface properties for the small and large-scale demonstrators under static and dynamic tensile, pressure and shear loading. Mechanical benchmark values are provided by topic manager. A benchmarking between the standard thermoset system, injection molding and 3d-printing must be performed.

Suitable testing fixtures have to be developed and manufactured. Special attention has to be drawn to dynamic fatigue crack growth within the joining zone.

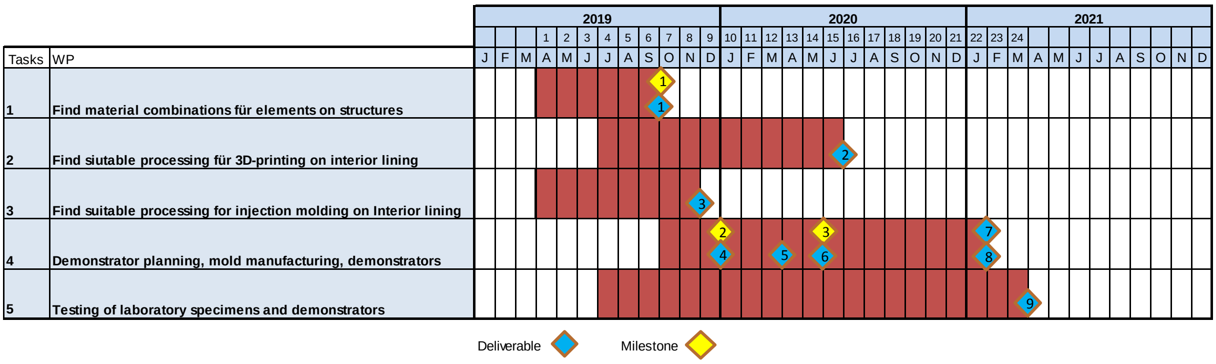
Tasks		
Ref. No.	***Title – Description***	***Due Date***
1	Find suitable material combinations for function elements on thermoplastic structures	T_0 + 6m
2	Find suitable processing for 3-D printing on interior lining	T_0 + 15m
3	Find suitable processing for injection molding on interior lining	T_0 + 8m
4	Planning demonstrator manufacturing, mold manufacturing, manufacturing of demonstrator parts	T_0 + 22m
5	Testing of laboratory specimens and demonstrators	T_0 + 24m

3. Major deliverables/ Milestones and schedule

Deliverables			
Ref. No.	Title - Description	Type	Due Date
1	Material combinations	Report	T0 + 6m
2	Description of technology for 3D-printing on TP-surface	Report	T0 + 15m
3	Interface properties for small-scale specimens	Report	T0 + 8m
4	Final mold design	CAD	T0 + 9m
5	Small-scale demonstrator 3D-printing	Hardware	T0 + 12m
6	Mold for thermoforming and injection molding	Hardware	T0 + 14m
7	Demonstrator parts 3D-printing	Hardware	T0 + 22m
8	Demonstrator parts injection molding	Hardware	T0 + 22m
9	Interface properties for demonstrator parts	Report	T0 + 23m

Milestones (when appropriate)			
Ref. No.	Title – Description	Type	Due Date
1	Material combinations evaluated, and project materials fixed	Report	T0 + 6m
2	Process chain for injection molding process developed / Design freeze demonstrator mold	Report	T0 + 9m
3	Mold and handling available	Hardware	T0 + 14m

Gantt Chart for deliverables and Milestones



4. Special skills, Capabilities, Certification expected from the Applicant(s)

3D-printing

- Experience, equipment and machinery for benchmarking powder and melt-based additive manufacturing technologies including technologies for short fiber regarding printing on thermoplastic surfaces and compatibility to a separate joining process
- Experience in 3D-printing conformal construction

Thermoplastic composites and injection molding

- Proven expertise in compression molding of high temperature thermoplastic composites
- Proven expertise in compression molding of high temperature thermoplastic sandwich composites
- Proven expertise in injection molding of high temperature thermoplastics
- Proven expertise in foam injection molding
- Proven expertise in injection molding on thermoplastic composites
- Proven expertise in injection molding on thermoplastic sandwich composites
- Proven expertise for the automated production of three-dimensional thermoplastic sandwich structures
- Manufacturing machines for thermoforming and foam injection molding of thermoplastic composites in laboratory and industrial scale

Demonstrator

- Proven experience with large scale thermoplastic parts
- Proven experience in designing demonstrator molds for thermoplastic composites
- Proven experience in individualization of thermoplastic sandwich structures by 3D-printing
- Proven experience in individualization of thermoplastic sandwich structures by injection

molding

- Manufacturing machines for thermoforming and injection molding of thermoplastic Composites
  - Vertical compression injection molding machine for processing inserts by gravity
  - Compression force up to 20.000 kN
  - Suitable for parts up to 1300 mm x 1100 mm
  - Suitable for mass temperatures up to 400 °C
  - Suitable for foam injection molding

Testing

- Mechanical testing (tensile / adhesion / bending)
- Testing capabilities for fatigue property evaluation
- Thermal analysis (DSC/DMA/TGA)
- Scanning electron microscopy

5. Abbreviations

MFFD	MultFunctional Fuselage Demonstrator
LPA	Large Passenger Aircraft
DSC	Differential Scanning Calorimetry
DMA	Dynamic Mechanical Analysis
TGA	Thermogravimetric Analysis
FST	Flame Smoke Toxicity
TP	Thermoplastic

XV. JTI-CS2-2018-CfP08-LPA-02-25: Micro mechanical characteristics of a PEKK Co-consolidation / welded joint for use in thermoplastic fuselages

Type of action (RIA/IA/CSA)	IA		
Programme Area	LPA		
(CS2 JTP 2015) WP Ref.	WP 2.1.5		
Indicative Funding Topic Value (in k€)	850		
Topic Leader	Fokker	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	30	**Indicative Start Date (at the earliest)29**	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-LPA-02-25	**Micro mechanical characteristics of a PEKK Co-consolidation / welded joint for use in thermoplastic fuselages**
Short description	
The topic aims to contribute to a more fundamental understanding of the longer term quality aspects of new joining technologies allowing a radical lead time reduction for joining processes to improve the overall effectiveness of fuselage assembly. To better understand the durability of these processes themes like healing/aging in PEKK joints, process window comparison of welded carbon PEKK joints and durability of PEKK compounds need to be investigated.	

Links to the Clean Sky 2 Programme High-level Objectives30	
This topic is located in the demonstration area:	Cabin & Fuselage
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Short/Medium-range

[29] The start date corresponds to actual start date with all legal documents in place.

[30] For further info see Chapter 1 “Introduction to the Programme Scene Setter / Objectives” with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☒	☐

1. Background

Large Passenger Aircraft (LPA) Platform 2 – Multifunctional Fuselage Demonstrator

The objective of Large Passenger Aircraft (LPA) Platform 2 – Multifunctional Fuselage Demonstrator (MFFD) is to validate high potential combinations of airframe structures, cabin/cargo, and system elements using advanced materials and applying innovative design principles in combination with the most advanced system architecture in combination with the next generation cabin.

The overall objectives of the MFFD are:

- Enable a high production rate of a minimum of 60 aircraft per month
- Achieve a total fuselage weight reduction of 1000kg
- Achieve a reduction of recurring costs

The driver of this approach is to attain a significant fuel burn reduction by substantially reducting the overall aircraft energy consumption, apply low weight systems and system architecture/integration and to be able to cash in weight potentials in the structural design of the fuselage and the connected airframe structure. This must be achieved by the development and application of industry 4.0 opportunities such as design for manufacturing & autmation, automation, sensorization, and data analysis to demonstrate desired manufacturing cost effects.

The platform 2, work package 2.1 objective is the integration of cabin and systems with the primary aircraft structure to reduce weight and manufacturing cost and to enhance space for passengers and cargo by:

- Removing artifical separation of functions already at the aircraft pre-design stage
- Considering the aircraft manufacturing, assembly and installation in a high production rate setting right at the start.
- Achieve weight reductions which in turn contribute to the environmental challenge to reduce the CO2 and NOx footprint by 5 to 8%

WP2.1.5 Lower half of the Multifunctional Fuselage Demonstrator

In 2017, project activities started on the development of the lower half of the multifunctional fuselage demonstrator. This part of the project will develop, manufacture and deliver a 180° full scale multi-functional integrated thermoplastic fuselage shell, incl. cabin and cargo floor structure and relevant main interior and system elements.

The applicants work will involve key aspects of the core partners activity on the MFFD and as such is linked to WP2.1.5.

The following figure provides a view on the diagonal cut concept with some characteristic features highlighted.

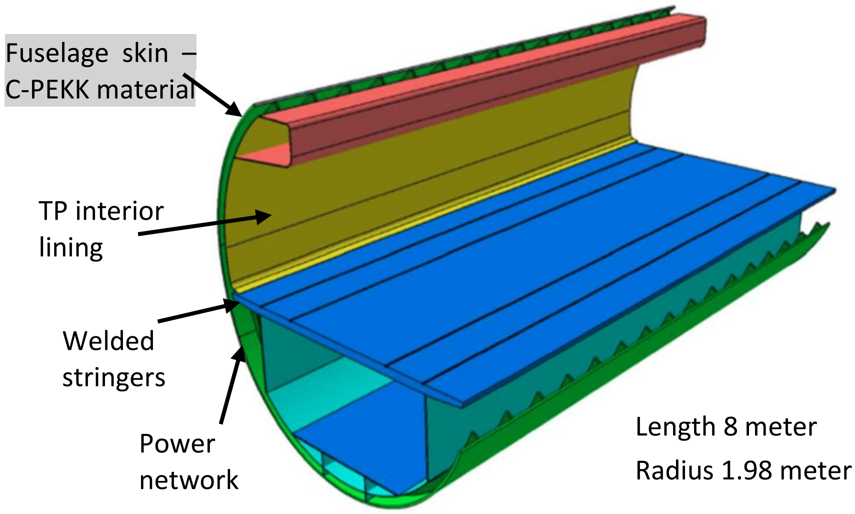


Figure 1: overview of the MultiFunctional Fuselage demonstrator lower half

Micro mechanical characteristics of a PEKK Co-consolidation / welded joint

The "Micro mechanical characteristics of a PEKK Co-consolidation / welded joint" topic aims to provide a more fundamental understanding of the longer term quality aspects of this type of joint and manufacturing processes. Achieving a high production rate results in an aim for short processing windows which in turn may influence the micro mechanical characteristics. The overall aim of this activity is to assess the relation between processing time/manufacturing process versus durability for various structural features. The outcome of this research will provide a better fundamental understanding which in turn results in valuable inputs for the design process. To support this aim the following aspects need to be addressed:

- Healing/aging in Carbon-PEKK joints
- Process window comparison of welded carbon PEKK joints
- Durability aspects of PEKK compounds

2. Scope of work

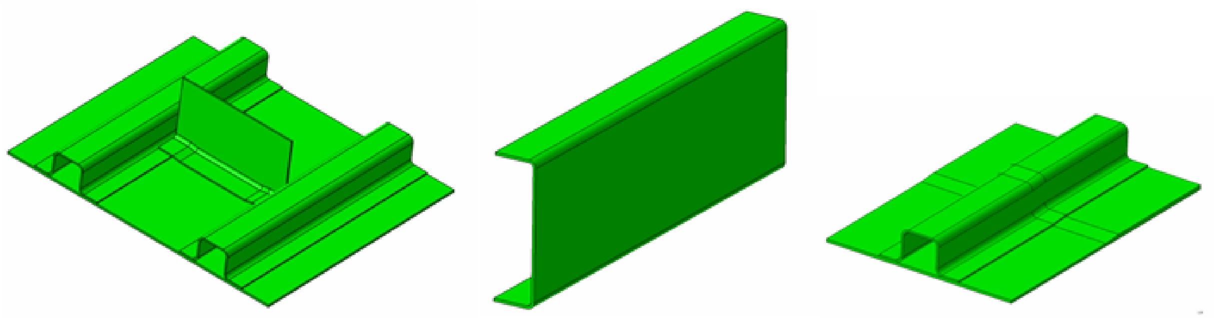
The three aspects, identified in the previous section, will be investigated in the 3 main work packages of the project. This section further outlines which tasks are involved. It is expected that all research is performed on small to medium sized coupons and as such the envisioned Technology Readiness Level at the end of the activity is 3, and if possible TRL4. For all of the work packages the applicant is expected to:

- Develop requirements and means of compliance, ASTM etc.
- Prepare a test plan, and test matrix
- Conduct reviews with the topic leader
- Manufacture test specimen
- Perform tests and prepare test reports and evaluate the results

In consultation with the topic leader the most complex test specimen can be provided by the topic leader.

WP1: Healing/aging in PEKK joints

The objective of this work package is to develop a sound understanding of the influencing parameters, on the joint durability for Carbon-PEKK materials that are joined/formed through melting processes. Examples of such structural features are depicted below.



A). Welded frame onto a fuselage shell

B). A press formed C-Frame/beam

C). Joggles in stringers using various welding processes

Figure 2. Examples of welded joints in a fuselage

The following sub-tasks are defined:

<u>WP1.1 Influence of surface condition of C-PEKK parts on the interface healing characteristics</u>

Healing of polymers may take place as the molecules diffuse across a damaged region, above their melting temperature. Therefore the influence of the surface condition of the PEKK parts on the healing of the interface need to be investigated. Different surface conditions should be studied: IR degraded surfaces, presence of release agent, resin rich/resin starved surfaces and effects of pre-treatment.
The typical test matrix would include single lap shear joints for shear tests and angle joints for tensile pull-off tests. Furthermore up to four different welding techniques should be examined: conduction welding, induction welding, resistance welding and ultrasonic welding.

<u>WP1.2 Aging effects on durability of C-PEKK parts made by various manufacturing methods</u>

The aging effects on joint durability of C-PEKK parts made by various manufacturing methods or configurations need to be investigated. The configurations must be relevant for an aircraft structure and the test matrix should contain at least: press formed parts, autoclave consolidated parts, and continuously formed parts, as indicated in figure 2-B. Critical environmental and aging conditions should be selected for strength testing in particular in the corner radius area. Specimen type can be selected depending on the manufacturing method and for the best response of the specimen to the degradation effects.

WP2: Process window comparison of welded carbon PEKK joints

The objective of this work package is to compare process windows of various welding techniques and to evaluate the suitability of the various techniques to a range of design features, see figure 2-A, and 2-C. The processing window of a welded joint is essentially a time dependent thermal profile at the interface. The specific window used influences the quality of the joint and in order to achieve a high production rate the influence of weld time on quality need to be well understood.

The typical test matrix would include single lap shear joints for shear tests, angle joints for tensile pull-off tests, and larger test articles that include joggles (figure 2-A, 2-C) loaded in shear. Furthermore up to four different welding techniques should be examined: conduction welding, induction welding, resistance welding and ultrasonic welding. In addition, C-PEKK from different suppliers and in different forms should be used.

WP3: Durability aspects of PEKK Compound

The objective of this work package is to examine the following durability aspects of a PEKK compound: Environmental Stress Cracking, and ratchetting (creep). The particular structural design feature is depicted in figure 3.

Figure 3. PEKK compound used to join a stringer to a skin (Butt joint)

WP3.1 Environmental Stress Cracking of PEKK

One of the potential causes of unexpected brittle fracture of thermoplastics is Environmental Stress Cracking (ESC). The simultaneous exposure to environmental conditions as experienced in an aircraft under the same stress may accelerate the crazing process and initiate crazes at a reduced stress level.

The objective of this work package is to investigate the potential environmental stress cracking behaviour and resistance to ESC in C-PEKK composites and compounds that are used in joints and parts in an aircraft environment. In consultation with the Topic Leader, the specific environmental conditions, stress levels, and test articles will be defined. The test matrix should at least contain the compound itself and joints as depicted below where two laminates are joined with a compound filler. It is important to note that only the compound should be studied that adequately represents the compound in the joint and therefore should have the same thermal history.

WP3.2 Ratchetting of PEKK compounds

Ratchetting can be defined as the un-symmetric cycles of stress between prescribed limits resulting in progressive 'creep' or 'ratchetting' behaviour in the direction of the mean stress. This micro-mechanical behaviour may occur when compound joints e.g. butt joints are used in aircraft structures at a location that generates heat. An example of such a location is the 'boiler room' in an aft fuselage section that houses an APU. At such a location, the temperature is rising and falling depending on the use of the APU.

The objective of this work package is to provide a better understanding of the micro-mechanical ratchetting behaviour of a butt-joint coupon made of Carbon-PEKK and to understand the influence of the development of residual stresses in the compound due to the manufacturing process and the hygrothermal cycles during service. The typical test specimen is depicted in figure 3 and loading conditions may include tension, shear, and bending. The hygrothermal cycle will be defined in consultation with the topic leader.

Tasks		
Ref. No.	Title - Description	Due Date
WP1	Healing/aging in PEKK joints	t0 +30
WP1.1	Influence of surface condition of C-PEKK parts on the interface healing characteristics	t0 +28
WP1.2	Aging effects on durability of C-PEKK parts made by various manufacturing methods	t0 +28
WP2	Process window comparison of welded carbon PEKK joints	t0 +30
WP3	Durability aspects of PEKK Compound	t0 +30
WP3.1	Environmental Stress Cracking of PEKK	t0 +28
WP3.2	Ratchetting of PEKK compounds	t0 +28

3. Major deliverables/ Milestones and schedule

Deliverables			
Ref. No.	Title - Description	Type*	Due Date
D1	Requirements definition, Test & Validation plans for WP1	Report	t0 +3
D2	Manufacture test specimen + reports for WP1	Hardware + report	t0 +5
D3	Test and evaluation reports for WP1	Report	t0 +28
D4	Requirements definition, Test & Validation plans for WP2	Report	t0 +4
D5	Manufacture test specimen + reports for WP2	Hardware + report	t0 +10
D6	Test and evaluation reports for WP2	Report	t0 +28
D7	Requirements definition, Test & Validation plans for WP3	Report	t0 +3
D8	Manufacture test specimen + reports for WP3	Hardware + report	t0 +7
D9	Test and evaluation reports for WP3	Report	t0 +28
D10	Final Evaluation report of all work packages	Report	t0 +30

Milestones (when appropriate)		
Ref. No.	Title – Description	Due Date
M1	Kick-off meeting	t0
M2	Requirements reviews meetings	t0 +2 / t0+4
M3	Test readiness reviews meetings	t0 +5 / t0 +7 / t0+10
M4	Intermediate review meeting	t0 +18
M5	Final Evaluation review meeting	t0 +28

Gantt Chart for Deliverables and Milestones

WP	ID	M 1	M 2	M 3	M 4	M 5	M 6	M 7	M 8	M 9	M 10	M 11	M 12	M 13	M 14	M 15	M 16	M 17	M 18	M 19	M 20	M 21	M 22	M 23	M 24	M 25	M 26	M 27	M 28	M 29	M 30
	Milestones	MS1	MS2			MS3													MS4										MS5		
WP1	D1	X	X																												
	D2			X	X	X																									
	D3						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
WP2	D4	X	X	X	X																										
	D5					X	X	X	X	X	X																				
	D6											X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
WP3	D7	X	X	X																											
	D8				X	X	X	X																							
	D9								X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	D10																													X	X

4. Special skills, Capabilities, Certification expected from the Applicant(s)

Special skills

- The applicant shall be able to demonstrate sound technical knowledge in the field of proposed contributions; the applicant shall be able to demonstrate that their knowledge is widely recognized.
- The applicant shall provide evidence to be able to cope with the required high level of adequate resources in qualified personnel, required tools and equipment.
- The activity will be managed with a Phase & Gate approach.
- Demonstrated experience in management, coordination and development of testing (Aeronautical) programs, including relevant ASTM requirements
- Experience with polymer mechanics, i.e.:
    - experience in time- and rate dependent behavior
    - modelling of composites (fibers with polymer)
    - mechanical characterization of polymers

Capabilities

- The applicant should have access to work-shop facilities in line with the proposed deliverables and associated activities. Typical equipment expected are:
    - Mechanical static and fatigue testing in specific environmental conditions
    - Thermal analysis (DSC/DMA/TGA)
    - Scanning Electron Microscope

5. Abbreviations

APU	Auxillary Power Unit
DMA	Dynamic Mechanical Analysis
DSC	Differential Scanning Calorimetry
ESC	Environmental stress cracking
IR	Infrared
FFD	MultFunctional Fuselage Demonstrator
SEM	Scanning Electron Microscopy
TGA	Thermogravimetric Analysis
TP	Thermoplastic
UD	Uni-directional

XVI. JTI-CS2-2018-CfP08-LPA-02-26: Multifunctional Aircraft Power Network with Electrical Switching

Type of action (RIA/IA/CSA)	IA		
Programme Area	LPA		
(CS2 JTP 2015) WP Ref.	WP 2.1.5		
Indicative Funding Topic Value (in k€)	1100		
Topic Leader	Fokker	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	30	**Indicative Start Date (at the earliest)31**	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-LPA-02-26	**Multifunctional Aircraft Power Network with Electrical Switching**
Short description	
The topic contributes to develop advanced electrical distribution system architectures to be integrated in the Multifunctional Fuselage Demonstrator. Design, Development, Manufacturing and Validation of a "Multifunctional Aircraft Power Network with Electrical Switching" shall deliver a hardware and software system with an achieved Technology Readiness Level of 4. The development includes the control of a data network and switching on the power buses controlled by the Bus Controller Unit (BCU). The scope of the project includes the BCU, Solid State Bus Tie Contactor (SSBTC), loads with representative impedances and integrated bus controlled switching, as well as the performance of these when integrated with the Multifunctional Fuselage Demonstrator (MFFD) bus.	

Links to the Clean Sky 2 Programme High-level Objectives32				
This topic is located in the demonstration area:	Cabin & Fuselage			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☒	☐

[31] The start date corresponds to actual start date with all legal documents in place.
[32] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

Large Passenger Aircraft (LPA) Platform 2 – Multifunctional Fuselage Demonstrator

The objective of Large Passenger Aircraft (LPA) Platform 2 – Multifunctional Fuselage Demonstrator (MFFD) is to validate high potential combinations of airframe structures, cabin/cargo, and system elements using advanced materials and applying innovative design principles in combination with the most advanced system architecture of the next generation cabin.

The overall objectives of the MFFD are:

- Enable a high production rate of a minimum of 60 aircraft per month
- Achieve a total fuselage weight reduction of 1000kg
- Achieve a reduction of recurring costs

The driver of this approach is to attain a significant fuel burn reduction by substantially reducting the overall aircraft energy consumption, apply low weight systems and system architecture/integration and to be able to cash in weight potentials in the structural design of the fuselage and the connected airframe structure. This must be achieved by the development and application of industry 4.0 opportunities such as design for manufacturing & automation, automation, sensorization, and data analysis to demonstrate desired manufacturing cost effects.

The platform 2, work package 2.1 objective is the integration of cabin and systems with the primary aircraft structure to reduce weight and manufacturing cost and to enhance space for passengers and cargo by:

- Removing artifical separation of functions already at the aircraft pre-design stage
- Considering the aircraft manufacturing, assembly and installation in a high production rate setting right at the start.
- Achieve weight reductions which in turn contribute to the environmental challenge to reduce the CO2 and NOx footprint by 5 to 8%

WP2.1.5 Lower half of the Multifunctional Fuselage Demonstrator

In 2017, project activities started on the development of the lower half of the multifunctional fuselage demonstrator. This part of the project will develop, manufacture and deliver a 180° full scale multi-functional integrated thermoplastic fuselage shell, including cabin and cargo floor structure and relevant main interior and system elements.

The figure below provides a view on the diagonal cut concept with some characteristic features highlighted.

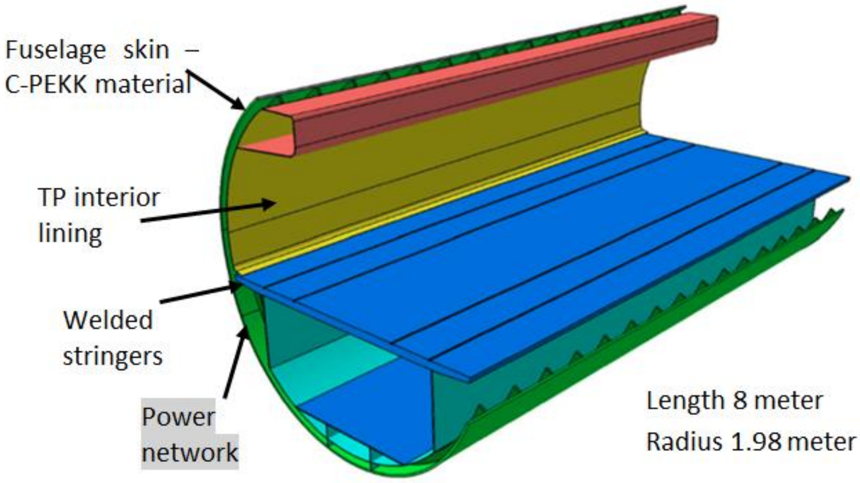


Figure 1: Multifunctional Fuselage Demonstrator

The applicants work will involve key aspects of the core partners activity on the MFFD and as such is linked to WP2.1.5.

Multifunctional Aircraft Power Network with Electrical Switching

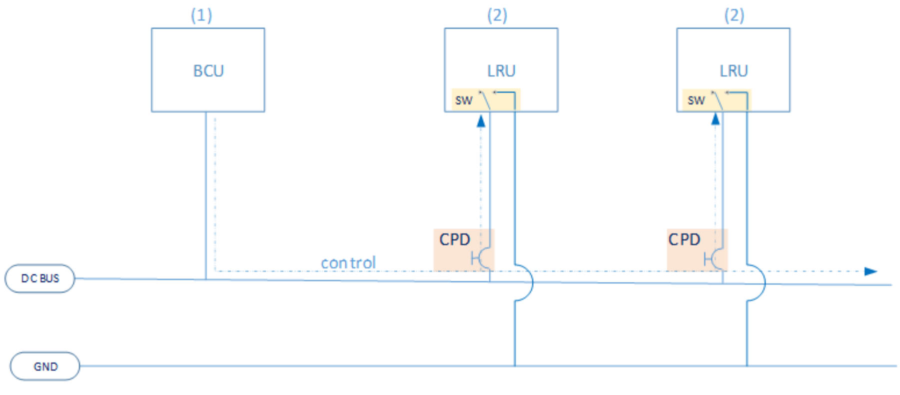
The "Multifunctional Aircraft Power network with electrical switching" forms an important aspect of the overall LPA aim to develop advanced system architectures. It involves integrating two functions which are currently separated into different systems into one system thereby offering a potential system weight reduction of at least 25%.

In the current state of the art electrical secondary power distribution utilizes software controlled remote Circuit Protection Devices (CPDs) which are centralized in secondary power distribution assemblies. These CPDs provide the function to protect the wires/cables connecting the loads. In additon the loads are connected with wires/cables which provide a separate communication functions. For a single aisle aircraft the length of these wires and cables may exceed over 50km.

The envisoned system would enable power distribution via a combined power and data network where as an alternative to the use of CPDs the switching of loads can be achieved though the use of switches within the loads themselves. This internal switching enables load shedding supporting capacity requirements, balancing and redundancy.

Benefits are the significant reduction of wires/cables and associated hardware.

Challenges will be reliability of the system, system component development, software development, integration into the aircraft system architecture, certification, power bus network architecture definition and robustness (bus failure prevention).



(1) BCU: Bus Control Unit
(2) LRU: Line Replaceable Unit, simple and same, with an internal switch.

Relevant to the demonstrator, the applicant is to provide functional hardware for prototype system demonstration purposes. The objective is to showcase the technology functionality, its relevance to leaner and greener aircraft, and overall modular concept.

Electrical interconnection hardware such as power bus wires, busbars and connectors, will be provided and installed by the topic leader.

The applicant is expected to deliver functional:

- At least 4 BCU (2 Buses for AC and 2 buses for DC)
- Remotely switchable electrical units with representative impedances (quantity and functionality to be agreed – but at least 6 for installation and 2 spares
- For validation tests only: 2 Solid State Bus Tie Contactors (SSBTC)

2. Scope of work

The development of the "Power Network with Electrical Switching" shall deliver a hardware and software system with an achieved Technology Readiness Level of 4.
The scope of this activity is to develop the communications architecture and technologies to support the transmission of data over an aircraft power bus. This network would be centered on the Bus Controller Unit, enabling functionality such as data communication to/from the loads, load shedding, and contactor addressing.
The main activities in this work are as follows

- System requirements definition.
- Modelling / co-design of bus network to optimise communications channel performance.
- Definition of an architecture to support robust communications to multiple sources/loads.
- Design and validation of the communication system based on the defined architecture
- Demonstration of the required application functionality in the power network.

The topic leader will provide the geometry of the LRU hardware and interfaces as forthcoming from the system integration activities.

Task 1: Requirements definition and conceptual model of bus Network

Task 1.1: Top level requirements definition

This task shall define the overall system requirements, based on interaction with the topic leader on the required system functionality. This shall include top level power capacity and quality, as well as needed total aircraft data network and the power bus requirements.

Task 1.2: Modelling of bus network

Based on the physically integrated bus structure and connections provided by the topic leader, the applicant shall develop physical models to explore the communications channel performance. Determination of the bus network design parameters will enable the impact of structural integration on the communications capability to be determined. Aspects such as bus impedance and power quality requirements (EMI, Susceptibility) shall be included.

Task 2: Software Development

Task 2.1: Architecture definition

This task shall develop the required power / communications architecture to enable the bus to carry multiple communications channels. An appropriate methodology for robust multi-channel communications shall be proposed, including a suitable communications protocol for this application, and an analysis of the overall communications bandwidth shall be performed.

Task 2.2: Communication system design

Based on the requirements, architecture design (power line, power sources, protections and loads) and additional design requirements, the communication system shall be designed and simulated. This task includes downselecting the PLC (Power Line Communication) modem that complies with the requirements (including latency), design the analog front end architecture and schematic. Additional capabilities such as error correction or multichannel shall be evaluated. Initial testing on a simplified power system shall be performed for initial validation purposes.

Task 3: Bus Control Hardware Development

In this task, a TRL4 demonstrator of the power distribution network control shall be developed, simulated and tested. This shall be based upon a representative power network topology, with the sources, loads, contactors, and bus controllers represented using emulated impedances (or real components where available). The Multifunctional Fuselage Demonstrator (MFFD) shall be used to validate the bus network model and communications channel performance of the integrated power bus and communication system.

The aim is to install this power distribution network onto the MFFD in advance of completion of task 3 (t0 +18). A second hardware system needs to be made to support further testing activities for the software development task. This system needs to be delivered to the topic leader upon completing the activity.

Tasks		
Ref. no.	Title - Description	Due Date
T1.1	Requirements Definition	t0 +2
T1.2	Modelling of bus network	t0 +6
T2.1	Architecture definition	t0 +18
T2.2	Communications system design	t0 +24
T3	Bus control hardware development	(t0 +18) t0 +30

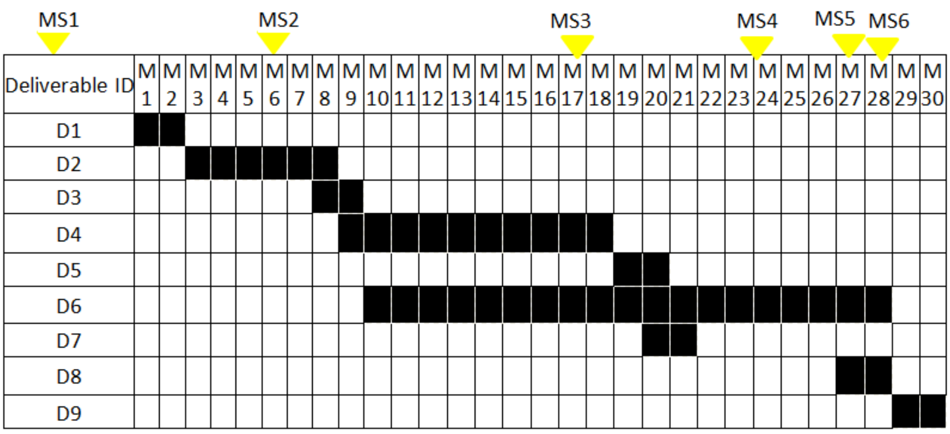
3. Major Deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	Title - Description	Type *	Due Date
D1	System (top level) requirements	R	t0 + 2
D2	Requirements and system architecture	R	t0 + 8
D3	TRL 3 validation plan and criteria	R	t0 + 9
D4	Integrated communication system 1)	HW	t0 + 18
D5	TRL 3 validation report	R	t0 + 20
D6	Bus network model + Schematic circuit of communication system	SW	t0 + 24
D7	TRL 4 validation plan and criteria	R	t0 + 21
D8	Integrated communication system 2)	HW	t0 + 28
D9	TRL 4 validation report + Final evaluation report	R	t0 + 30
NOTE 1): The hardware for the integrated communications systems network needs to be delivered to the MFFD. The topic leader is responsible for the power bus network electrical interconnection hardware, the applicant is responsible for functional power bus controller and the remotely switchable units, including software and system test plans. NOTE 2): This is a second hardware system to be delivered to the topic leader and will be used for TRL4 demonstration.			

**Type: R=Report, D=Data, HW=Hardware, SW=Software*

Milestones		
Ref. No.	Title – Description	Due Date
MS1	Kick-off meeting	t0
MS2	System Model and Requirements Review	t0 + 8
MS3	TRL3 Assessment Review	t0 + 18
MS4	Communication design finalized	t0 + 24
MS5	TRL4 testing completed	t0 + 27
MS6	TRL4 Assessment Review	t0 + 28

Gantt Chart for deliverables and Milestones



4. Special skills, Capabilities, Certification expected from the Applicant(s)

General skills

- The applicant shall be able to demonstrate sound technical knowledge in the field of proposed contributions; the applicant shall be able to demonstrate that their knowledge is widely recognized; the applicant shall furthermore have a strong industry background an experience in primary and secondary electrical power distribution systems, including electronic hardware and software development and manufacture.
- The applicant shall demonstrate experience in-depth project management in Time, Cost and Quality together with evidence of past experience in collaborative project participation.
- The applicant shall provide evidence to be able to cope with the required high level of adequate resources in qualified personnel, required tools and equipment.
- The activity will be managed with a Phase & Gate approach. The Topic leader will approve gates and authorize progress to subsequent phases.
- The applicant has the capability to design, develop and qualify software and hardware for electrical power distribution units for aerospace.

Capabilities

- The applicant shall have proven knwoledge and experience with design, development and realization of communication systems, power electronics and embedded systems for aerospace.
- The applicant should have work-shop facilities in line with the proposed deliverables and associated activities. Examples of typical facilities are:
  - CAD software like CATIA
  - Development of Complex Systems to ARP4754 or equivalent
  - Software development to DAL A (DO178 or equivalent)
  - Hardware development and manufacturing to DAL A (DO254 or equivalent)
  - Test equipment for function and performance tests both hardware and software

5. Abbreviations

BCU	Bus Controller Unit
MFFD	MultFunctional Fuselage Demonstrator
LRU	Line Replaceable Unit
CPD	Circuit Protection Devices
PLC	Power Line Communication
LPA	Large Passenger Aircraft
SSBTC	Solid State Bus Tie Contactors
SW	Switch

XVII. JTI-CS2-2018-CfP08-LPA-03-15: Validation of Pilot State Monitoring technology benefits

Type of action (RIA/IA/CSA)	IA		
Programme Area	LPA		
(CS2 JTP 2015) WP Ref.	WP 3.1.4.9		
Indicative Funding Topic Value (in k€)	700		
Topic Leader	Honeywell International	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	24	**Indicative Start Date (at the earliest)33**	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-LPA-03-15	**Validation of Pilot State Monitoring technology benefits**
Short description	
This project will help ensuring that the Pilot State Monitoring technologies developed by the Topic Manager have a tangible path towards exploitation in commercial aircraft operations, especially in the light of its societal acceptance by its users and its adequation to their real needs. This will be achieved through active participation of the partner to the Topic Leader's activities.	

Links to the Clean Sky 2 Programme High-level Objectives34				
This topic is located in the demonstration area:	Cockpit & Avionics			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Long-range, Advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☐	☐	☐	☒	☒

33 The start date corresponds to actual start date with all legal documents in place.

34 For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

From the regulatory point of view, pilots follow rules established by the medical staff, the authorities as well the airlines to manage medical fitness. However, some psychophysiological state degradation of pilots may occur during flight while not being detected by current means & processes, thus potentially impacting flight safety.

The detection of incapacitations (e.g. fatigue) is very complex and not systematic. In this context, implementation of a "Pilot State Monitoring" system in the cockpit could provide information to pilots about their psychophysiological state in order to improve the awareness of their performance, find management strategies for their activity and to make decisions faster thus improving the level of flight safety.

The challenges such a system will face, particularly with respect to its sensitivity in an operational environment and its social acceptance, should be weighed against its benefits for any category of commercial aircraft (large aircraft or business jet) and justify the need to invest in research on this topic.

The success of such a system depends on the ability to provide benefits to each stakeholder while mitigating concerns related to its introduction in the cockpit. In the frame of Clean Sky 2, the technology is being developed and it is crucial to collect early feedback from aircraft operators and pilots to steer future efforts in the right direction.

The key objectives of the topic shall be:

- To install a Pilot State Monitoring system onboard a commercial aircraft (either a large commercial aircraft -ATR type - and/or a Business Jet).
- To gather feedback from the installation in order to adjust the system and the certification requirements.
- To use the system in standard commercial environment of either an airline or a business jet operator and preferably with a mixture of short and long haul flights.
- To collect pilot's feedback and various operational data in a real operational environment.

Collected data and additional information will address both the performance of the system and its acceptance, especially:

- Provide feedback on the performance of Pilot Monitoring technologies/sensors and their integration into a cockpit
- Contribute to the benefit study of Pilot Monitoring in operational environment
- Collect feedback from regular operations
- Identify risks and opportunities linked to usage of Pilot Monitoring
- Contribute to revision of markers used to assess the state of the pilot (in cooperation with Topic Leader)
- Contribute to development of mitigation strategies when pilot's state is identified as undesired

To be representative, the data shall be rather collected from the commercial pilot population than from test pilots who may provide biased data because of they are used to testing new technologies. Whatever category of aircraft (ATR or Business Jet) the data is collected from, the experience and usage will also benefit other categories hence the applicant will be fully compliant to the topic's objectives when offering only one type of platform for the purpose of topic execution.

The innovation potential of this call lies in:

- The definition of performance requirements (e.g. accuracy, robustness, integrity, intrusiveness) for a

Pilot State Monitoring system to be certifiable in a future cockpit

- The validation of the Concept of Operations in light of social acceptance. Development of methods for real operation data collection and re-application of data for improvement of the Pilot Monitoring system.
- The identification of root causes for prejudice and social acceptance challenges

2. Scope of work

The Pilot State Monitoring system referred to in this Topic description consists of a set of non-intrusive sensors collecting psychophysiological data from the pilot. The system will be provided to the succesful applicant by the Topic manager.
The major and mandatory set of sensors will be installed either on the pilot's seat or as wearable electronics directly on the pilot. Optionally, but strongly preferrable, a set of cameras shall be installed in the cockpit to collect additional information. The system will be installed as standalone, hence not interacting with aircraft systems, and will not require any data connection to onboard systems. Optionally the PSM system may use available power supply.

The applicant shall explain the limitations for operation of the system without compromising the safety in normal commercial operations. The applicant is responsible for the definition of the installation, particularly regarding the above-mentionned set of cameras, and potentially the identification of certification requirements ahead of the deployment in real operations. The applicant is expected to install the system into the cockpits of a small fleet of aircraft with the support of the Topic Manager. The Topic Manager expects the PSM system to be installed into 2 to 5 cockpits depending on the applicant proposal and the availability of the PSM systems for testing.

The technology will then be deployed into two waves during which pilots will have the opportunity to use the system:

- Phase 1 shall collect information data and feedback using the Pilot Monitoring technologies available at the start of the topic execution (i.e. technologies developed by the Topic Leader)
- Phase 2 shall be based on technologies updated according to feedback collected in 1st phase.

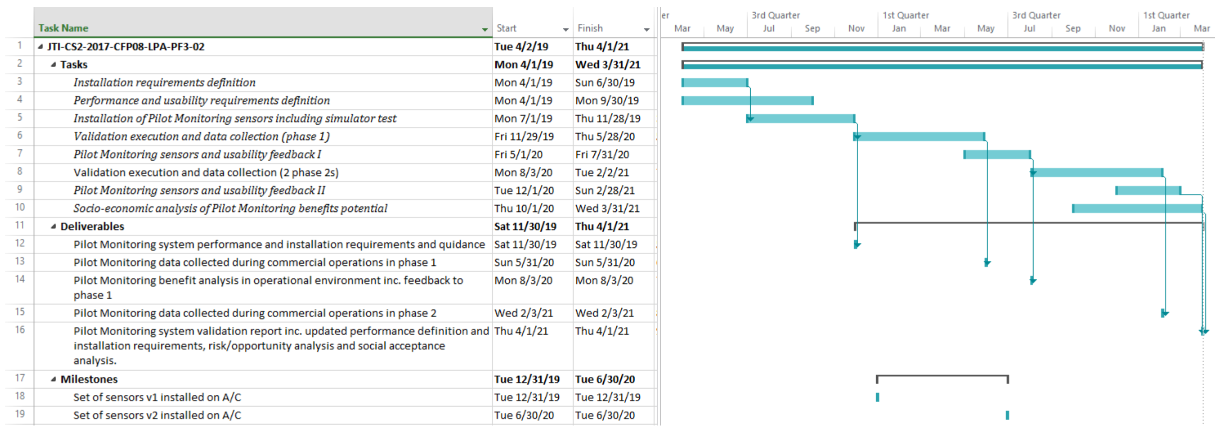
Ahead of its deployment in aircraft, the applicant shall validate the system installation in a full motion flight simulator in order to identify potential operational limitations and certification issues. This proof of concept is a required step before it gets installed into the A/C cockpit. With this, the applicant will ensure that the data will not be distorted by the unstable environment (e.g. turbolence, vibrations, etc.)

The successful bidder shall contribute to the project by:

- collecting data based on Pilot State Monitoring technologies developed within Clean Sky 2 by the Topic Leader
- providing inputs to the integration of the system into the aircraft
- installing the set of sensors into the simulator and the target aircraft platform jointly with the Topic Leader
- actively participating to the validation of the results
- contributing to the technology maturation by the Topic Leader (e.g. identification of markers)
- thoroughly assessing the social acceptance of its pilot for Pilot Monitoring
- collecting data during commercial flights
- identifying irrelevant data caused by the unstable environment, pilot's tasks, human behavior, etc…

- sharing its experience and data already acquired regarding various pilot states (nice-to-have)

Tasks		
Ref. No.	Title – Description	Due Date
Task 1	Installation requirements definition	T0 + 3m
Task 2	Performance and usability requirements definition	T0 + 6m
Task 3	Installation of Pilot Monitoring sensors including simulator test	T0 + 9m
Task 4	Validation execution and data collection (phase 1)	T0 + 15m
Task 5	Pilot Monitoring sensors and usability feedback I	T0 + 16m
Task 6	Validation execution and data collection (phase 2)	T0 + 22m
Task 7	Pilot Monitoring sensors and usability feedback II	T0 + 23m
Task 8	Socio-economic analysis of Pilot Monitoring benefits potential	T0 + 24m



	Task Name	Start	Finish
1	JTI-CS2-2017-CFP08-LPA-PF3-02	Tue 4/2/19	Thu 4/1/21
2	Tasks	Mon 4/1/19	Wed 3/31/21
3	*Installation requirements definition*	Mon 4/1/19	Sun 6/30/19
4	*Performance and usability requirements definition*	Mon 4/1/19	Mon 9/30/19
5	*Installation of Pilot Monitoring sensors including simulator test*	Mon 7/1/19	Thu 11/28/19
6	*Validation execution and data collection (phase 1)*	Fri 11/29/19	Thu 5/28/20
7	*Pilot Monitoring sensors and usability feedback I*	Fri 5/1/20	Fri 7/31/20
8	Validation execution and data collection (2 phase 2s)	Mon 8/3/20	Tue 2/2/21
9	*Pilot Monitoring sensors and usability feedback II*	Tue 12/1/20	Sun 2/28/21
10	*Socio-economic analysis of Pilot Monitoring benefits potential*	Thu 10/1/20	Wed 3/31/21
11	Deliverables	Sat 11/30/19	Thu 4/1/21
12	Pilot Monitoring system performance and installation requirements and quidance	Sat 11/30/19	Sat 11/30/19
13	Pilot Monitoring data collected during commercial operations in phase 1	Sun 5/31/20	Sun 5/31/20
14	Pilot Monitoring benefit analysis in operational environment inc. feedback to phase 1	Mon 8/3/20	Mon 8/3/20
15	Pilot Monitoring data collected during commercial operations in phase 2	Wed 2/3/21	Wed 2/3/21
16	Pilot Monitoring system validation report inc. updated performance definition and installation requirements, risk/opportunity analysis and social acceptance analysis.	Thu 4/1/21	Thu 4/1/21
17	Milestones	Tue 12/31/19	Tue 6/30/20
18	Set of sensors v1 installed on A/C	Tue 12/31/19	Tue 12/31/19
19	Set of sensors v2 installed on A/C	Tue 6/30/20	Tue 6/30/20

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

The project shall deliver reports addressing the analysis of benefits of Pilot Monitoring in operational environment, contribute to the definition of performance and installation requirements for Pilot Monitoring and provide risk/opportunity analysis.
Data collected during the flight campaigns shall be shared among the members based on the Implementation Plan.

Deliverables			
Ref. No.	Title - Description	Type*	Due Date
D1	Pilot Monitoring system performance and installation requirements and quidance	R	T0 + 9m
D2	Pilot Monitoring data collected during commercial operations in phase 1	D	T0 + 15m
D3	Pilot Monitoring benefit analysis in operational environment inc. feedback to phase 1	R	T0 + 16m
D4	Pilot Monitoring data collected during commercial operations in phase 2	D	T0 + 22m

Deliverables			
Ref. No.	Title - Description	Type*	Due Date
D5	Pilot Monitoring system validation report inc. updated performance definition and installation requirements, risk/opportunity analysis and social acceptance analysis.	D	T0 + 24m

Milestones (when appropriate)			
Ref. No.	Title – Description	Type*	Due Date
M1	Set of sensors v1 installed on A/C	HW	T0 + 9m
M2	Set of sensors v2 installed on A/C	HW	T0 + 15m

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Airline operating a mix of short-haul and long-haul aircraft
- Ability to categorize its pilot population according to diversity criterias (e.g. gender, origin, etc…)
- Abiility to collect root causes for prejudice and social acceptance
- Ability to collect data in a full motion simulator
- Possibility to involve people with operational experience

5. Abbreviations

A/C	Aircraft
CS 2	Clean Sky 2
PSM	Pilot State Monitoring

5. Clean Sky 2 – Regional Aircraft IADP

I. JTI-CS2-2018-CfP08-REG-01-16: Innovative recirculation / air treatment system

Type of action (RIA/IA/CSA)	IA		
Programme Area	REG		
(CS2 JTP 2015) WP Ref.	WP 2.3.3		
Indicative Funding Topic Value (in k€)	1400		
Topic Leader	Leonardo Aircraft	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	24	**Indicative Start Date (at the earliest)**[35]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-REG-01-16	**Innovative recirculation/air treatment system**
Short description	
Scope of this topic is the maturation of technologies, design, manufacturing and testing, both in lab test environment and in a full scale regional a/c fuselage thermal cabin demonstrator (not part of CfP), of an innovative recirculation and air distribution system which incorporates an air treatment subsystem to improve the recirculated air quality and reduce the fresh flow, along with its control logic and sensors, in order to support ELOS (Equivalent Level of Safety) demonstration for certain flight phases where meeting the ventilation certification requirement is not practical or economical. The envisaged innovative recirculation /air treatment system is independent from the ECS pack itself.	

Links to the Clean Sky 2 Programme High-level Objectives[36]				
This topic is located in the demonstration area:	Environmental Control System			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	▪ Advanced Turboprop, 90 pax ▪ Innovative Turboprop, 130 pax			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☒	☐	☒	☐

[35] The start date corresponds to actual start date with all legal documents in place.
[36] For further info see Chapter 1 “Introduction to the Programme Scene Setter / Objectives” with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

Environmental Control Systems (ECS) are one of the main power consumers in large passenger transport category airplanes.

The main function of an Environmental Control System is to maintain a comfortable environment in pressurized compartments assuring:

- compressed air supply for cabin pressurization;
- compartment temperature control to safe and comfortable levels for aircraft occupants;
- electrical/electronic bays equipment cooling;
- compartment ventilation for noxious gases removal.

The ECS cooling capacity is clearly driven by the compartments temperature control requirement and it is therefore intimately linked to the thermal characteristics of the airplane.

Such cooling capacity is directly proportional to the air mass flow rate delivered and its enthalpy with respect to the entalphy of the volume to be conditioned. Specifically, in cooling cases, the conditioned air flow temperature depends primarily of the ECS technology and on recirculation air ratio. In fact, whereas it is normally recommended to keep the temperature of the air flow entering an occupied volume at values not lower than 2°C, in practice conventional Air Cycle Machines (ACMs) based on single expansion turbine are normally forbidden to deliver conditioned air at temperatures much lower than 0°C to avoid ice formation on humidity separation sub-systems (for example re-heater/condensers). Therefore it can be assumed that ECS cooling capacity is primarily dependant on fresh flow rate delivered by the ECS packs.

This fresh flow rate is either bled from the engines (in case of conventional pneumatic systems) or must be supplied by the E-ECS in case of bleed-less systems. In conventional pneumatic systems the fresh flow rate has a negative impact on the engine perfomance, since the off-take from total compressor airflow penalizes the amount of power available to the power turbine, thus yielding lower thrust and higher specific fuel consumption. Furthermore compressor bleed tends to adversely affect engine life by increasing engine operating temperature. In bleed-less systems the fresh flow rate will impact the sizing of the cabin air compressor and the power off-take from the engine thus, once again, reducing available thrust and increasing the specific fuel consumption.

Thermal optimization of the airplane (for example reduction of airplane conductance) will yield lower required fresh flow (i.e. conditioned air flow rate delivered from the engine for conventional systems or delivered from the ECS pack in case of bleed-less systems) to meet cabin and cockpit thermal requirements. Nevertheless thermal requirements are not the only ones affecting fresh flow consumption. In particular ventilation fresh flow required by Certification Authorities can become prominent with respect to fresh flow required by the ECS to meet airplane thermal requirements.

The augmentation and filtration of recirculated air flow is one technique that is required to support an Equivalent Level Of Safety (ELOS) demonstration for certain flight phases where meeting the ventilation certification requirement is not practical or economical (for example flight operations at altitudes where the certification requirement exceeds the fresh flow required to meet cockpit and cabin thermal requirements).

The intent of this call is to select a Partner for the development of technologies, design and testing of an innovative recirculation system which incorporates an air treatment subsystem to improve the recirculated air quality and reduce the fresh flow, along with its control logic and sensors, in order to support ELOS demonstration for certain flight phases were meeting the ventilation certification requirement is not practical or economical.

The envisaged innovative recirculation /air treatment system is independent from the ECS pack itself.

The target TRL level for the envisaged system at the end of the project is 6.

Hereinafter the “List of Preliminary Specification Requirements for the Recirculation/Air Treatment System” is presented.

2. Scope of Work

The main tasks of the work to be performed by the Partner are:

Task 1: Architectural definition of the innovative ECS recirculation/air treatment system

This task shall aim at the architectural definition of the recirculation/air treatment system that regulates air treatment and optimizes the mix of outside and treated recirculated air, based upon airframer requirements, as well as the architectural definition of its control logic and sensors.

The task shall start with a study on State of the Art of air treatment and filtering for Commercial Aviation and will have, as main input, the Innovative recirculation/air treatment system Specification, which will specify the airframer requirements for the system.

This task will be based on trade-off studies addressing both existing technologies and new development technologies for advanced air treatment (for hydrocarbons and odour removal, CO2 removal and O2 generation) and advanced sensing (CO2, hydrocarbons and particulate), provided that the target TRL level for the system at the end of the project is 6.

The task shall produce as main outputs, the architecture of the system, its performances, its System Safety Analysis (SSA), its layout, shall define the system interfaces (mechanical, electrical, pneumatic), the system layout with components dimensions and weights and the system power consumption.

The task will be finalized upon successful conclusion of system Preliminary Design Review (PDR).

Task 2: Development of technologies and Manufacturing of innovative ECS recirculation/air treatment system control logic and sensors

Starting from successful conclusion of system PDR, this task shall aim at the detailed design and development of the system control logic and sensors.

It shall include the integration/adaptation of existing CO2, hydrocarbons and particulate sensors, and the development of advanced sensing technologies.

This task shall concurr to the definition of the Innovative recirculation/air treatment system Demonstration Program and Plan, which shall cover demonstration requirements, procedures and criteria for both lab test demonstration (to be conducted at applicant’s facilities) and thermal test bench demonstration (Cabin Demonstrator).

The task will support the system Critical Design Review (CDR). Upon successful conclusion of the system CDR, the task shall be responsible of innovative recirculation/air treatment system control logic and sensors manufacturing activities.

The task will be finalized upon successful conclusion of manufacturing completion review.

Task 3: Development of technologies and Manufacturing of recirculation and air treatment sub-system

Starting from successful conclusion of system PDR, this task shall aim at the detailed design and development of the recirculation and air treatment sub-system of technologies and its components.

This shall be based on trade studies, and include the integration/adaptation of existing and development of advanced air treatment technologies for hydrocarbons and odour removal, CO2 removal and O2 generation.

This task shall concurr to the definition of the Innovative recirculation/air treatment system Demonstration Program and Plan, which shall cover demonstration requirements, procedures and criteria for both lab test demonstration (to be conducted at applicant’s facilities) and thermal test bench

demonstration (Cabin Demonstrator).
The task will support the system Critical Design Review (CDR). Upon successful conclusion of the system CDR, the task shall be responsible of innovative recirculation and air treatment subsystem manufacturing activities.
The task will be finalized upon successful conclusion of manufacturing completion review.

Task 4: System Demonstration
This task shall be responsible of system integration and demonstration activities.
System demonstration will be done first on existing applicant's facilities (Lab).
Aircraft level demonstration shall be performed on thermal test bench (Cabin Demonstrator).
The preliminary objectives of the validation activities related to the innovative recirculation/air treatment system can be organized into two main areas:

- Recirculation/air treatment architectures (including control logic and sensors) and performances:
  - system behavior and performances (hydrocarbons, particulate, CO2 removal);
  - system control strategy and control logics.
- Recirculation/air treatment architectures integration installation in a regional a/c:
  - Filtration efficiency;
  - general control philosophy and stability (dynamic behavior);
  - electrical power interfaces;

More detailed definition of tests to be performed will be provided in the Innovative recirculation/air treatment system specification.
The task shall be finalized upon sucessful conclusion of Lab Demo and Thermal Test Bench Demo Review Meetings.
Applicant support to integration of System in the thermal test bench shall be required.

<u>Limits of Current Technology</u>
There are no known application of integration within commercial aircraft Environmental Control System air treatment systems aimed at filtering recirculated cabin air.

<u>Innovation</u>
There are no known application of integration within commercial aircraft Environmental Control System air treatment systems aimed at filtering recirculated cabin air. The innovative recirculation system which incorporates an air treatment subsystem to improve the recirculated air quality and reduce the fresh flow, which is scope of work specified in this CfP, contributes to aircraft level fuel savings.

Input Data			
Ref. No.	***Title – Description***	***Type***	***Due Date***
I-1	Innovative recirculation/air treatment system Specification	Report	T0+1M

List of Preliminary Specification Requirements for the Recirculation/Air Treatment System

In order to enable Appplicants to submit their Proposal, a list of Preliminary Specification Requirements for the Recirculation/Air Treatment System is anticipated hereafter:

Functional Architecture Requirements

FuAR1. The Recirculation/Air Treatment System shall recirculate air from airplane cabin underfloor volume.

FuAR2. The Recirculation/Air Treatment System shall filter recirculated air to reduce CO2, CO, Volatile Organic Compunds.

FuAR3. The Recirculation/Air Treatment System shall remove excess water from recirculated air flow if needed to maintain cabin/cockpit humidity levels between 20% and 60%.

FuAR4. The Recirculation/Air Treatment System shall inject recirculated filtered air in the mixing units where the recirculated air is mixed with temperature controlled fresh flow (from ECS packs).

FuAR5. The Recirculation/Air Treatment System shall be independent from the ECS pack itself.

FuAR6. The Recirculation/Air Treatment System shall perform a monitoring of recirculation ratio and filtration efficiency.

FuAR7. The Recirculation/Air Treatment System shall adjust the recirculation ratio and the filtration efficiency to the fresh flow delivered by the ECS in order to avoid over-recirculation and un-needed filtration in those flight phases where fresh flow delivered by the ECS pack is higher than ventilation certification requirement.

Performance Requirements

PR1. The Recirculation/Air Treatment System recirculation ratio and filtration efficiency shall maintain the current air quality standards in those flight phases where fresh flow delivered by ECS pack is as low as 0.30 lb/min.

PR2. Fresh air water content shall be compatible with cabin / cockpit humidity levels between 20% and 60%.

PR3. Carryover of water condensate shall be minimized.

Further performance requirements will be specified at a later stage.

Air Quality Requirements

AQR1. Concerning air quality requirements, FAR/CS 25.831 shall be taken into account.

- CO concentration: not to exceed 1 part in 20.000 parts of air
- CO2 concentration: not to exceed 0.5 percent by volume (sea level equivalent)

AQR2. Recirculated air shall be suitably filtered by approved HEPA filters.

AQR3. Any device or possible solution shall be adopted in designing and locating the Recirculation/Air Treatment System air inlets in order to avoid external contaminates like hydraulic fluids, de-icing fluids, cleaning agents, ground cart exhaust gasses or other contaminates present into the ambient air near the ground level.

AQR4. No humidifier is required.

Environmental Requirements

EnvR1. Applicable environmental requirements will be defined at a later stage.

Integration Requirements

Electrical interfaces

Reference and Hybrid ECS architecture:

EIR1. In case of reference and hybrid ECS architecture, the primary power to supply the ECS load will be provided at 115 VAC Wild Frequency (WF).

EIR2. Alternative level of voltage will be also available at 28 VDC to supply other ancillary components, according to MIL-STD-704F power quality standard document under normal and abnormal system operation conditions.

Interface with the Enhanced Electrical Energy Management for Bleed-less Architecture

N/A

Mechanical Interfaces

MIR1. Mechanical interface requirements will be defined at a later stage.

Reliability/ Dispatchability/ Maintainability and Testability Requirements

Here below the reliability and dispatchability requirements are reported.

Reliability

RelR1. The Operational Reliability of the System shall be at least 99%.

RelR2. The System shall be designed in order to have a value of MTBF as high as possible.

Dispatchability

DisR1. Applicable dispatchability requirements will be defined at a later stage

Maintainability

MainR1. The System shall be designed in order for the scheduled maintenance to be minimized.

MainR2. When unscheduled maintenance is foreseen, the System shall be designed in order to have a value of MTTR as low as possible.

MainR3. When specific checks or inspection are necessary to comply with safety requirements, they shall be compatible with the aircraft scheduled inspection program.

Testability

TestR1. The System shall monitor and record system performance during flight and ground operation and shall provide data for ground fault isolation, component life tracking and scheduled maintenance actions.

TestR2. The Fault Isolation System shall allow identification of the faulty component in 10 minutes with 95% accuracy, using little or no ground support unit for test.

TestR3. As much as possible, the system shall provide fault isolation without engine running.

TestR4. The Fault Isolation System and the LRU remove/replace design shall enable identification and replacement of aircraft dispatch critical components in less than 30 minutes.

Data Requirements

The initial set of data that will be provided is reported below:

DataR1. RC
DataR2. DMC
DataR3. Weight
DataR4. Size
DataR5. Power consumption
DataR6. Performances for all ground and flight operative conditions
DataR7. Mechanical and electrical interfaces
DataR8. Development roadmap

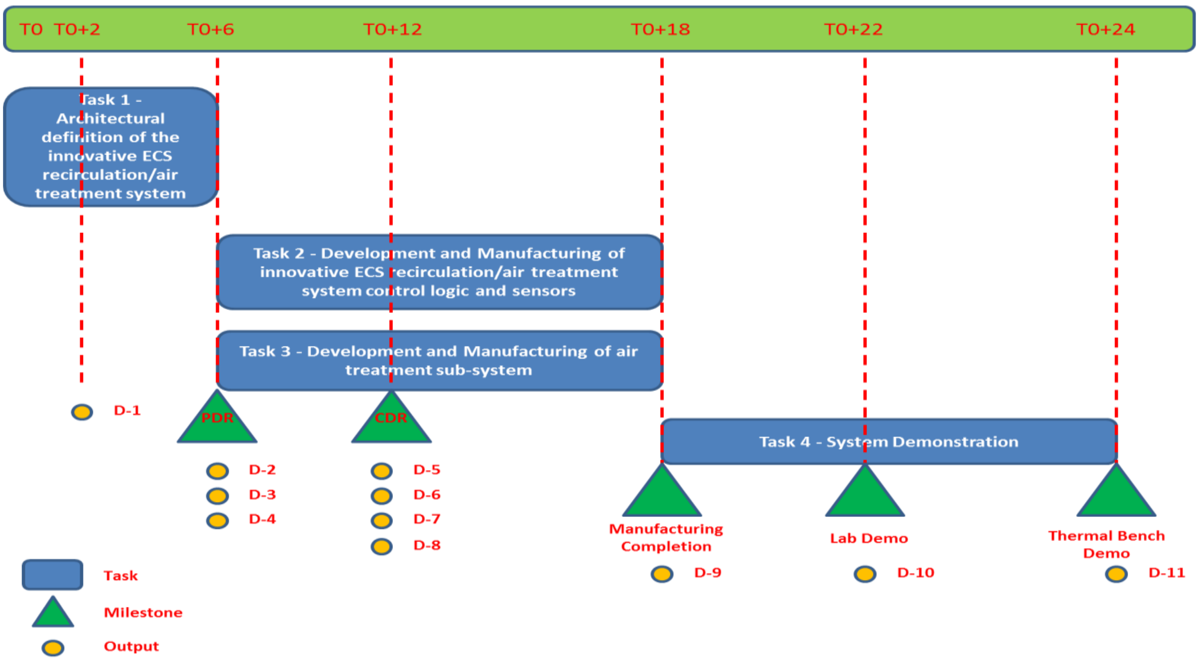
3. Major deliverables/ Milestones and schedule (estimate)

The applicant is requested to provide deliverables for the proposed activities. Applicant activity start time is corresponding to T0 (approximately at beginning of Q1 2019). Relevant CfP involvement is requested up to end of Q4 2022 (T0+48M). Following table contains a preliminary list of all the major deliverable.

Deliverables			
Ref. No.	***Title – Description***	***Type***	***Due Date***
D-1	State of the Art of air treatment and filtering for Commercial Aviation	Report	T0+2
D-2	Preliminary Innovative recirculation/air treatment system architecture and performances report	Report	For PDR (T0+6)
D-3	Preliminary Innovative recirculation/air treatment system SSA (System Safety Analysis)	Report	For PDR (T0+6)
D-4	Preliminary Innovative recirculation/air treatment system layout, ICD, weight and power consumption report	Report	For PDR (T0+6)
D-5	Innovative recirculation/air treatment system architecture	Report	For CDR (T0+12)
D-6	Innovative recirculation/air treatment system SSA (System Safety Analysis)	Report	For CDR (T0+12)
D-7	Innovative recirculation/air treatment system layout, ICD, weight and power consumption report	Report	For CDR (T0+12)
D-8	Innovative recirculation/air treatment system Demonstration Program and Plan (Lab and Cabin Demonstrator)	Report	For CDR (T0+12)
D-9	Innovative recirculation/air treatment system manufacturing	Report	For manufacturing completion review (T0+18)
D-10	Innovative recirculation/air treatment system (Lab) Demonstration test report	Report	For Lab Demo Review Meeting (T0+22)
D-11	Innovative recirculation/air treatment system (Cabin Demonstrator) Demonstration test report	Report	For Thermal Test Bench Demo Review Meeting (T0+24)

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type***	***Due Date***
M-1	Innovative recirculation/air treatment system PDR	Review Meeting	T0+6
M-2	Innovative recirculation/air treatment system CDR	Review Meeting	T0+12
M-3	Innovative recirculation/air treatment system manufacturing completion	Review Meeting	T0+18
M-4	Innovative recirculation/air treatment system Demonstration in Applicant Facilities	Review Meeting	T0+22
M-5	Innovative recirculation/air treatment system Demonstration in Cabin Demonstrator	Review Meeting	T0+24

Proposed Work plan



4. Special skills, Capabilities, Certification expected from the Applicant(s)

The applicant shall have the following competences at the beginning of the project:

- ECS hardware development, manufacturing and integration
- Air treatment and ECS modelling and simulation capability
- State-of-the-art air quality sensor technology development and specialists (inorganic and organic compounds)
- Recognized contribution to international air quality standardization committees
- Manufacturing capabilities and serial applications of air quality sensors (at TRL 9 if aerospace application) in the domain of air conditioning, biohazard detection or similar.
- State-of-the-art air treatment technology development capabilities for removal of organic and inorganic contaminants
- Manufacturing capabilities and serial applications for treatment of organic and inorganic air contaminants (at TRL 9 if aerospace application) in the domain of air conditioning, environment protection or similar
- Air quality analytical capabilities for organic and inorganic compounds
- Aviation reliability and airworthiness certification expertise
- Air quality regulation/standardization expertise
- Advanced controller development and prototyping capabilities

Facilities:

- Air systems prototyping and integration facilities;
- Test facilities in order to test Innovative recirculation/air treatment system in representative environment (pressure and temperature controlled chamber);
- Measurement instrumentation and data acquisition lab.

II. JTI-CS2-2018-CfP08-REG-01-17: Full scale Innovative pressure bulkheads for Regional Aircraft Fuselage barrel on-ground demonstrators

Type of action (RIA/IA/CSA)	IA		
Programme Area	REG		
(CS2 JTP 2015) WP Ref.	WP 3.2		
Indicative Funding Topic Value (in k€)	1000		
Topic Leader	Leonardo Aircraft	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	17	**Indicative Start Date (at the earliest)37**	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-REG-01-17	**Full scale Innovative pressure bulkheads for Regional Aircraft Fuselage barrel on-ground demonstrators**
Short description	
Validation at full size level of Innovative pressure bulkheads manufacturing process (out of autoclave liquid resin infusion and prepreg with automated lamination) and fabrication of 2 shipsets for Regional Aircraft Fuselage barrel on-ground demonstrators. Moreover an industrial and cost evaluation based on a pre-defined production business case is requested.	

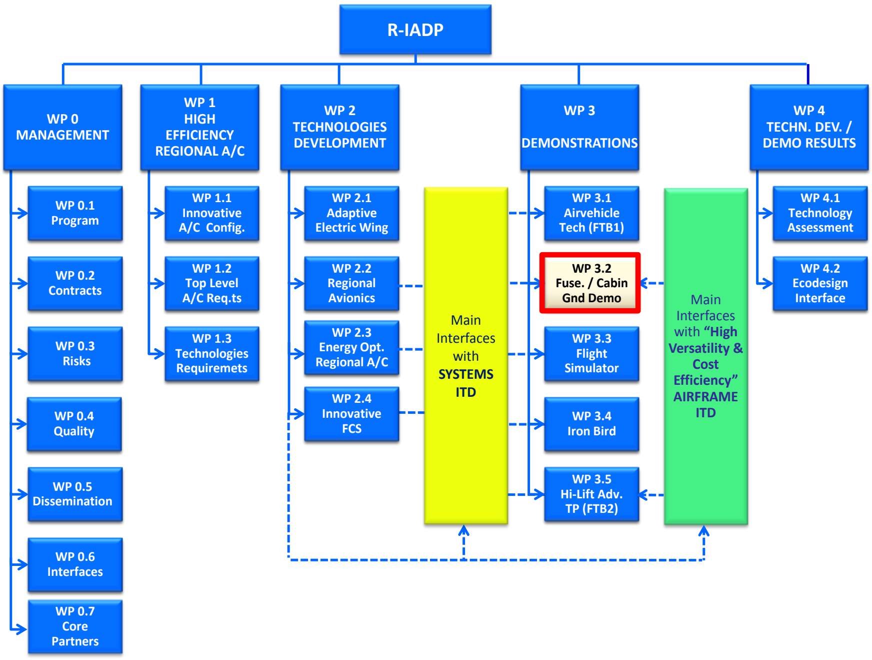
Links to the Clean Sky 2 Programme High-level Objectives38				
This topic is located in the demonstration area:	Cabin & Fuselage			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Innovative Turboprop, 130 pax Advanced Turboprop, 90 pax			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☒	☐	☒	☐

37 The start date corresponds to actual start date with all legal documents in place.

38 For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

Activities to be performed according to the present Topic description are included in a wider context of work in the framework of the Regional Aircraft IADP of Clean Sky 2. In particular, the Work Package 3.2 "Fuselage/Cabin Integrated Ground Demonstrator" represents the field where activities requested to the Applicant shall be performed. The relevant Work Breakdown Structure is shown below putting in evidence the WP 3.2:



More in detail, the activities will cover the definition, design, manufacturing, assembling and on-ground testing phases for full-scale structural Fuselage and passenger Cabin demonstrators representative of a Regional Aircraft.

Innovative low cost and low weight technologies shall be integrated into the Fuselage structural demonstrator with the objective to obtain: structural weight reduction, manufacturing recurring cost reduction, maintenance improvement and implementation of new eco-compatible materials and processes.

Innovation based on an human-centered-design approach and on board systems shall be integrated into the passenger Cabin demonstrator with the objective to obtain: improvement of cabin comfort and wellbeing, cabin interiors weight reduction, cabin interiors manufacturing recurring cost reduction, implementation of new eco-compatible materials and processes.

2. Scope of work

The scope of the present topic is the development and validation of two advanced fabrication processes of composite pressure bulkheads for regional aircraft composite fuselage manufacturing which allow a significant reduction of the overall production costs and flows. Besides a final trade-off analysis is requested to compare at industrial level, within the overall cost balance, the two fabrication processes, for a new regional aircraft.

The activities to be performed are divided in the tasks listed in the following table:

Tasks		
Ref. No.	Title - Description	Due Date
1	Process set up and validation at full size level	M0+6
2	Parts fabrication for on-ground fuselage demonstrators	M0+13
3	Trade-off and Industrial cost evaluation	M0+17

Task 1: Process set up and validation at full size level

In the present task the selected Applicant, on the basis of materials and technologies identified by Topic Manager (TM) to be detailed/confirmed at Kick-Off Meeting (KOM), is requested to develop the best choices regarding process details, driven by manufacturing costs reduction and high volume industrial applicability.

The Applicant will then fabricate two full scale parts, each one for the selected material/process, verifying the compliance with drawing requirements through destructive and non-destructive characterization, in order to validate and freeze process steps and parameters for final demonstrators.

The following fabrication processes and materials shall be preliminarily considered:

- Out of autoclave (OOA) liquid resin infusion with non-crimp fabric (NCF) dry preforms with toughened epoxy resin system for fwd bulkhead;
- IMS 977-2 prepreg material with Automated Fiber Placement (AFP) for aft bulkhead.

For both solutions prepreg omega shape stringers (according to preliminary design) will be integrated on cured skin with cobonding, secondary bonding or mechanically.

The final pressure bulkhead manufacturing technology details (material and process) will be communicated by TM during the KOM.

The Applicant, for each technology, shall be responsible for:

- Identification of the lowest-cost solutions.
- Purchase of all materials needed for part fabrication (deliverable and auxiliary).
- Tool design and fabrication.
- Selection and supply of the needed equipments.
- Process development and set-up.
- Fabrication and non-destructive inspections (visual analysis, dimensional check and ultrasonic inspection) of the first full scale item.
- Quality plan issue to be agreed with TM.
- Destructive characterization (micrographic and chemical-physical analysis) of first full scale manufacturing trial to check/quantify possible internal defects, such as porosity, delamination, inclusion, wrinkles, resin richness, etc.
- Producibility evaluation report to verify parts producibility in accordance with drawing requirements using the selected innovative processes.
- Manufacturing process control document (MPCD) preparation, describing all process parameters and manufacturing steps to be used for final demonstrators.
-

Task 2: Parts fabrication for on-ground fuselage demonstrators

Composite pressure bulkheads will be fabricated for two regional aircraft fuselage barrel on-ground demonstrators (structural and cabin). N.2 pressure bulkheads will be fabricated for each barrel demonstrator (N.4 pressure bulkheads in total) and shipped to the TM's facility together with the parts needed for assembly. Fig.1 shows the preliminary pressure bulkhead configuration valid for both processes (with 8 radially equidistant omega stringers) and main dimensions.

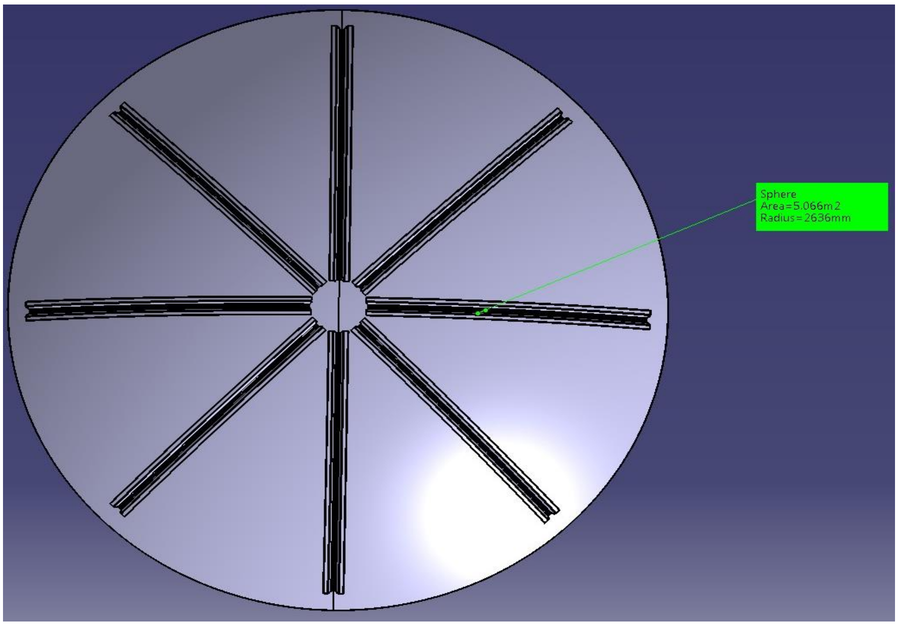


Fig.1. Pressure bulkhead

The preliminary condition of supply of the pressure bulkheads foresees:

- for both demonstrators (fwd and aft bulkheads) the execution of a certain number of coordination holes (see fig.2). Precise location and number of holes will be defined in part drawings together with related tolerances;
- for both demonstrators (fwd and aft bulkheads) the execution of 3 bonded hoisting points (see fig.3) for bulkhead handling. Configuration and precise location of these points will be defined in part drawing;
- pressure bulkheads and parts trimming according to part drawing;
- surface finishing and sealing to be defined in part drawing;
- the supply of the following angles and miscellaneous parts for bulkhead assembly to fuselage barrel (final configuration and number of these components will be defined in part drawing):
    - 24 metallic bulkhead fittings (see fig.4).
    - 24 metallic fitting splices.
    - T-shape metallic shear ties (see fig.4).
    - Metallic end stringers.

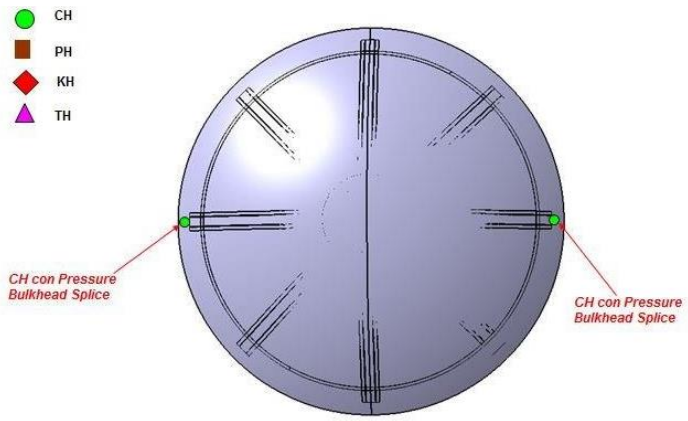


Fig.2. Coordination holes (CH) for pressure bulkhead

Final part drawings and specific supply conditions will be provided by the TM during the KOM.

A dedicated shipment of two pressure bulkheads and related miscellaneous parts for each demonstrator is requested to the Applicant for a total number of N.2 shipments (see milestones 2.1 and 2.2 in the table below). A detailed list of the parts for each shipment will be provided by the TM during the KOM.

The Applicant shall be responsible for:

- Purchase of all materials needed for parts fabrication (deliverable and auxiliary).
- Supply of all miscellaneous metallic parts.
- Tool chain design and fabrication.
- Fabrication and non-destructive inspection of all items for the barrel demonstrators.
- Quality plan issue to be agreed with TM.
- Quality report of all items including dimensional checks and weight measurements.
- Shipment of all items to the TM's facility (Pomigliano d'Arco, Naples).

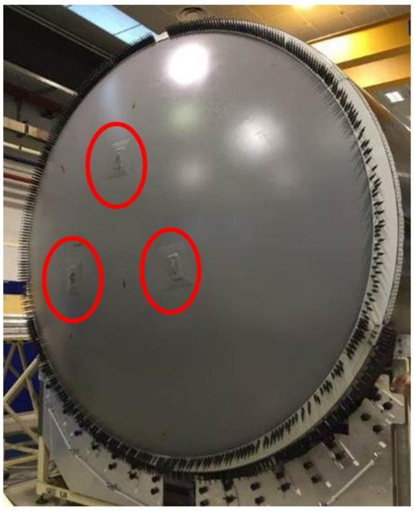


Fig.3. Pressure bulkhead with hoisting points (only for reference)

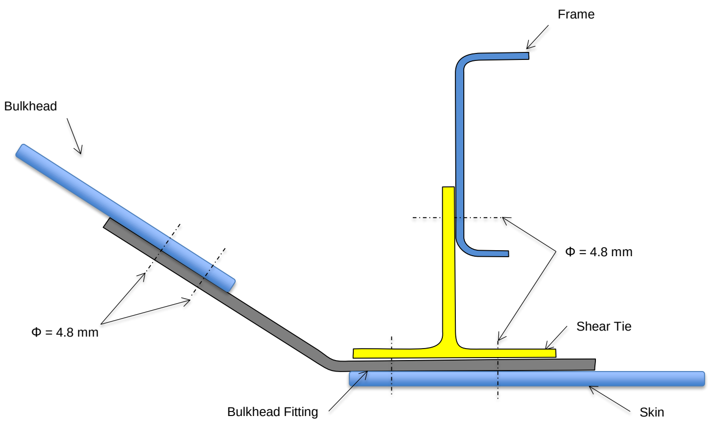


Fig.4. Pressure bulkhead joint (only for reference)

Task 3: Industrial cost evaluation

Industrial business case conditions will be provided by the TM during the KOM.

The Applicant shall be responsible for:

- Evaluation of industrial recurring and not recurring costs for both technologies based on the above business case. Particular attention shall be given to innovative automated solutions for high volume production.
- Detailed descriptive report containing:
  - quantity and associated costs of deliverable/auxiliary and metallic parts;
  - fabrication phases with relevant cost of labor;
  - types and main characteristics of needed equipments and facilities;
  - list of tools/jigs and related costs.

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	Title - Description	Type*	Due Date
D1.1	Detailed schedule	R	M0+1
D1.2	Process details assessment	R	M0+2
D1.3	Tool design and fabrication	D/HW	M0+5
D1.4	Full scale manufacturing trial fabrication and characterization	HW/R	M0+6
D1.5	Manufacturing process description	R	M0+6
D2.1	Manufacturing and quality plans preparation	R	M0+6
D2.2	Items fabrication for 1st demonstrator	HW	M0+7
D2.3	Items fabrication for 2nd demonstrator	HW	M0+13
D3.1	Industrial cost evaluation	R	M0+17

Milestones (when appropriate)			
Ref. No.	Title - Description	Type*	Due Date
M1.1	Tool chain availability for parts manufacturing	HW	M0+5
M1.2	Full scale manufacturing trial fabrication and characterization report	R	M0+7
M2.1	1st shipment for 1st demonstrator delivery	HW	M0+7
M2.2	2nd shipment for 2nd demonstrator delivery	HW	M0+13

Milestones (when appropriate)			
Ref. No.	Title - Description	Type*	Due Date
M3	Industrial cost evaluation report	R	M0+17

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Proven competence in management of complex research projects and manufacturing technologies, including quality and risk assessment capabilities demonstrated in international research projects and/or industrial environment.
- Proven competence in tool design for aeronautical composite part fabrication by a documented experience in participating in actual programs.
- Proven experience in fabrication of aeronautical composite based substructures, for actual programs. This competence shall include a strong knowledge of materials and processes, quality, tooling, part programs for CN machines.
- Proven experience in non-destructive inspections. Evidence of ultrasonic NDI qualification shall be provided.
- Proven experience in experimental testing (micrographic and chemical-physical analysis) at coupon levels. Evidence of laboratories qualification shall be provided.
- Proven experience in cost estimation at industrial level for aeronautical composite components.

5. Abbreviations

CFRP	Carbon Fiber Reinforced Polymer
LRI	Liquid Resin Infusion
RTM	Resin Transfer Molding
NDI	Non-Destructive-Inspection
CH	Coordination Hole
TM	Topic Manager
KOM	Kick-Off Meeting
MPCD	Manufacturing Process Control Document

III. JTI-CS2-2018-CfP08-REG-02-05: High fidelity power effects aerodynamics at High Reynolds conditions in Regional turboprop configuration

Type of Agreement (RIA/IA/CSA)	RIA		
Programme Area	REG		
(CS2 JTP 2015) WP Ref.	WP 3.5		
Indicative Funding Topic Value (in k€)	1000		
Topic Leader	Airbus Defense & Space	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	18	**Indicative Start Date (at the earliest)39**	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-REG-02-05	**High fidelity power effects aerodynamics at High Reynolds conditions in Regional turboprop configuration**
Short description	
The topic targets the aerodynamic characterization from wind tunnel scaled model to full scale flight Reynolds conditions of the wing for a future regional turboprop aircraft using numerical and experimental techniques (CFD + WTT). In particular the objective is to be able to predict with the highest possible fidelity the evolution with Reynolds number of the power influence on the aerodynamics including both the propeller direct (thrust, torque, 1P forces, 1P moments) and indirect (slipstream) effects on the wing, nacelles, flaps, tails and control devices. A funding split between numerical analysis (CFD) and experimental data gathering (WTT) of respectively 25%-75% is envisaged.	

Links to the Clean Sky 2 Programme High-level Objectives40				
This topic is located in the demonstration area:	Regional Aircraft Wing Optimization			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Regional Multimission TP, 70 pax			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☒	☐	☒	☐

[39] The start date corresponds to actual start date with all legal documents in place.
[40] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

Objective:

The activities under this CfP will support the development and assessment of new aerodynamic devices and concepts and loads control technologies for innovative Regional Turboprop A/C concepts targeting the Horizon 2020 objectives as described in the JTP document of Clean Sky 2 (CS2).

The topic targets the aerodynamic characterization from wind tunnel scaled model to full scale flight Reynolds conditions of the wing for a future regional turboprop aircraft using numerical and experimental techniques (CFD + WTT). In particular the objective is to be able to predict with the highest possible fidelity the evolution with Reynolds number of the power influence on the_aerodynamics including both the propeller direct (thrust, torque, 1P forces, 1P moments) and indirect (slipstream) effects on the wing, nacelles, flaps and control devices. A funding split between numerical analysis and experimental data gathering (WTT) of respectively 25%-75% is estimated.

Background:

This innovative actively adapted wing A/C concept is based on a set of new technologies that will be investigated and developed in CS2 (Clean Sky 2 program), many of which will be selected for their implementation and integration in the FTB2 Demonstrator according to the maturity level as described in the WP3.5 of the REG Platform of CS2 and, finally, tested in flight to show a TRL6.

The FTB2 Demonstrator is based on a C295W aircraft equipped with a set of new control surfaces and an affordable FCS concept developed also in CS2 project for the wing (namely actively adapting wing concept), targeting enhanced A/C performances and aerodynamic efficiency at each flight phase, as well as loads control (Manoeuvre and Gust Loads Alleviation, MLA & GLA).

The Figure 1 below depicts the FTB2 Demonstrator and the different new concepts to be developed and tested in CS2, that include new technologies focused in the improvement of the aerodynamics performances, like the "Multi-Functional Flaps" or the "Adaptive Winglets" and other technologies whose aim is reducing the A/C weight, by means of different concepts and functionalities for loads control like the new spoilers and aileron.

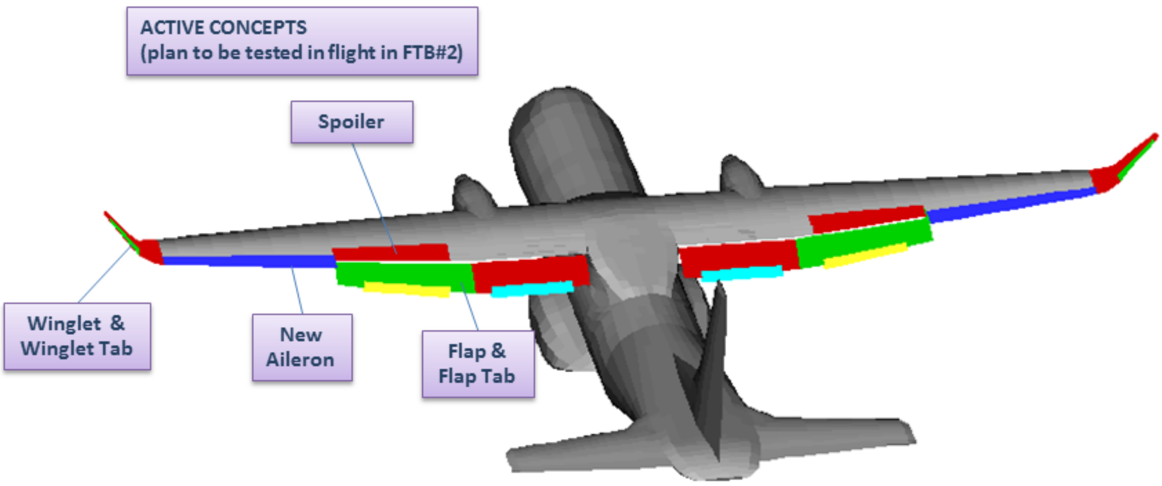


Figure 1: CS2 FTB2 actively adapting wing concept.

2. Scope of work

The work to be performed by the selected applicant to the CfP will be organized around two main topics. One is the high fidelity characterization at different Reynolds number, from scaled model to full scale, of the direct effects of the installed propeller (thrust, torque, 1P forces, 1P moments) at blade pitch angles and rotational speeds covering conditions from flight idle to maximum take-off and reversal. The other is the investigation of the indirect power effects (slipstream) on the wing, flaps and control surfaces aerodynamics again at different Reynolds numbers. The final aim is to develop a CFD methodology that allows for a reliable determination of these effects at full Reynolds either by means of extrapolation of scaled model wind tunnel test results (ideally from an atmospheric wind tunnel for reasons of cost) and/or direct numerical calculations at flight Reynolds.

To this end the selected applicant will have to investigate the most appropriate type of CFD model (propeller representation, turbulence-model, etc.) and perform the necessary CFD calculations of the aircraft at different Reynolds number. Introduction of aeroelastic effects on the propeller (particularly corresponding to the wind tunnel model) is required to assess its influence on the experimental data.

The use by the applicant of some of the following standard industrial codes (ANSYS CFX, ANSYS Fluent, TAU, PowerFlow) will be considered as a plus, as it will allow direct implementation in the design and clearance process of the FTB2 demonstrator. The applicant is thus requested to declare the CFD code that is planned to be used for the investigation. The applicant should indicate which parts of the standard code being proposed to be used need further development specifically for this application.

The resulting methodology will be validated by the applicant by means of comparisons with wind tunnel data at different Reynolds number. The generated CFD data will be delivered to the topic manager organization (see deliverable list) in order to perform further validation, based either on additional WTT information or on flight tests results of FTB2.

The wind tunnel model to be used is that currently being developed by the POLITE CfP of CS2, which is designed to be tested both at atmospheric and pressurized tunnel conditions at Mach numbers up to Mach 0.23 and Reynolds numbers (based on MAC=0.3m) between 1.5 and 6 million.

This model is an 8.6 scaled representation of the CS2 FTB2 aircraft with all associated components. It includes all the required hardware for the powered tests: variable pitch instrumented propellers (remotely controlled), 6 component rotary shaft balances on both propellers, telemetry, etc. The applicant thus only needs to negotiate with the wind tunnel the provision of the air engines and the balance crossing system. The purpose of the model is Stability & Control data, so it is not equipped with pressure taps.-

This model will be provided free of charge to be used for the tests. The applicant needs only to cover the tests costs by establishing a regular wind tunnel test contract with a wind tunnel provider, ensuring that the model will be tested up to Re = 6 million (based on MAC=0.3m). The test contract will include the acquisition of main balance data, rotary shaft balance data, propeller blades strain-gauges data, and propeller blades deformation data besides the standard main balance data. It is estimated that 2 weeks testing are needed to test all the relevant conditions. Table 1 shows a tentative example of the required test program. The topic manager organization will provide support to the applicant in preparing, managing and conducting the test campaign free of charge if required.

Figures 2 and 3 show pictures of the wind tunnel model of the FTB2, in this case without propellers.

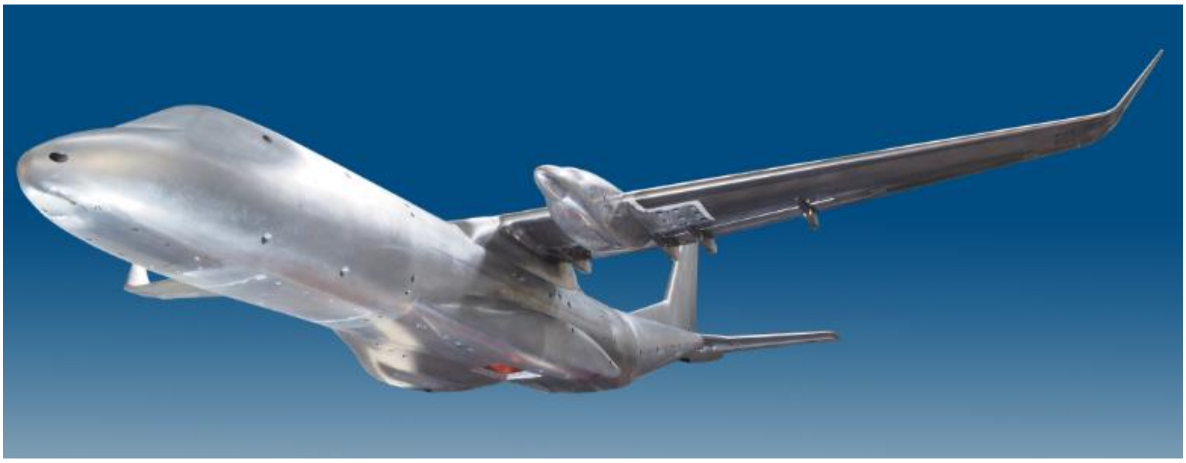


Figure 2: FTB2 WTT model

Figure 3: FTB2 WTT model

Following table depicts an example of a possible wind tunnel test matrix.

WING-BODY

BLOCK	Remote Control	PRESSURE	Mach	Alpha	Beta	CT stbd	CT port
FLAP 0 WB POWER OFF (Reference to RUAG)	No	1 atm	0.2	0°	[-30°,30°]	---	---
	No	1 atm	0.2	9°	[-30°,30°]	---	---
	No	1 atm	0.2	[-5°,20°]	0°	---	---
	No	1 atm	0.2	[-5°,20°]	5°	---	---
FLAP 0 WB POWER OFF	No	1 atm, 2 atm, 3.85 atm	0.23	0°	[-30°,30°]	---	---
	No	1 atm, 2 atm, 3.85 atm	0.23	9°	[-30°,30°]	---	---
	No	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	0°	---	---
	No	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	5°	---	---
FLAP 0 WB 1 ENGINE (Reference to RUAG)	No	1 atm	0.2	[-5°,20°]	0°	CT2	---
	No	1 atm	0.2	0°	[-30°,30°]	CT2	---
	No	1 atm	0.2	[-5°,20°]	5°	CT2	---
	No	1 atm	0.2	9°	[-30°,30°]	CT2	---
FLAP 0 WB 1 ENGINE	No	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	0°	CT2	---
	No	1 atm, 2 atm, 3.85 atm	0.23	0°	[-30°,30°]	CT2	---
	No	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	5°	CT2	---
	No	1 atm, 2 atm, 3.85 atm	0.23	9°	[-30°,30°]	CT2	---
FLAP 0 WB 1 ENGINE	Propeller Pitch	1 atm, 3.85 atm	0.23	[-5°,20°]	0°	CT2	---
	Propeller Pitch	1 atm, 3.85 atm	0.23	0°	[-30°,30°]	CT2	---
	Propeller Pitch	1 atm, 3.85 atm	0.23	[-5°,20°]	5°	CT2	---
	Propeller Pitch	1 atm, 3.85 atm	0.23	9°	[-30°,30°]	CT2	---
FLAP 0 WB 2 ENGINES	TBD	1 atm, 2 atm, 3.85 atm	0.23	0°	[-30°,30°]	CT1	CT1
	TBD	1 atm, 2 atm, 3.85 atm	0.23	9°	[-30°,30°]	CT1	CT1
	TBD	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	0°	CT1	CT1
	TBD	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	5°	CT1	CT1
FLAP 30 WB POWER OFF (Reference to RUAG)	No	1 atm	0.2	[-5°,20°]	0°	---	---
	No	1 atm	0.2	[-5°,20°]	5°	---	---
	No	1 atm	0.2	0°	[-30°,30°]	---	---
	No	1 atm	0.2	9°	[-30°,30°]	---	---
FLAP 30 WB POWER OFF	No	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	0°	---	---
	No	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	5°	---	---
	No	1 atm, 2 atm, 3.85 atm	0.23	0°	[-30°,30°]	---	---
	No	1 atm, 2 atm, 3.85 atm	0.23	9°	[-30°,30°]	---	---
FLAP 30 WB POWER OFF	Flap	1 atm, 3.85 atm	0.23	[-5°,20°]	0°	---	---
	Flap	1 atm, 3.85 atm	0.23	[-5°,20°]	5°	---	---
	Flap	1 atm, 3.85 atm	0.23	0°	[-30°,30°]	---	---
	Flap	1 atm, 3.85 atm	0.23	9°	[-30°,30°]	---	---
FLAP 30 WB 1 ENGINE (Reference to RUAG)	No	1 atm	0.2	[-5°,20°]	0°	CTmax	---
	No	1 atm	0.2	[-5°,20°]	5°	CTmax	---
	No	1 atm	0.2	0°	[-30°,30°]	CTmax	---
	No	1 atm	0.2	9°	[-30°,30°]	CTmax	---
FLAP 30 WB 1 ENGINE	No	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	0°	CTmax	---
	No	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	5°	CTmax	---
	No	1 atm, 2 atm, 3.85 atm	0.23	0°	[-30°,30°]	CTmax	---
	No	1 atm, 2 atm, 3.85 atm	0.23	9°	[-30°,30°]	CTmax	---
FLAP 30 WB 1 ENGINE	Flap + Propeller	2 atm, 3.85 atm	0.23	[-5°,20°]	0°	CTmax	---
	Flap + Propeller	2 atm, 3.85 atm	0.23	[-5°,20°]	5°	CTmax	---
	Flap + Propeller	2 atm, 3.85 atm	0.23	0°	[-30°,30°]	CTmax	---
	Flap + Propeller	2 atm, 3.85 atm	0.23	9°	[-30°,30°]	CTmax	---
FLAP 30 WB 2 ENGINES (Reference to RUAG)	No	1 atm	0.2	[-5°,20°]	0°	CT3	CT3
	No	1 atm	0.2	[-5°,20°]	5°	CT3	CT3
	No	1 atm	0.2	0°	[-30°,30°]	CT3	CT3
	No	1 atm	0.2	9°	[-30°,30°]	CT3	CT3
FLAP 30 WB 2 ENGINES	No	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	0°	CT3	CT3
	No	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	5°	CT3	CT3
	No	1 atm, 2 atm, 3.85 atm	0.23	0°	[-30°,30°]	CT3	CT3
	No	1 atm, 2 atm, 3.85 atm	0.23	9°	[-30°,30°]	CT3	CT3
FLAP 30 WB 2 ENGINES	Flap + Propeller	3.85 atm	0.23	[-5°,20°]	0°	CT3	CT3
	Flap + Propeller	3.85 atm	0.23	[-5°,20°]	5°	CT3	CT3
	Flap + Propeller	3.85 atm	0.23	0°	[-30°,30°]	CT3	CT3
	Flap + Propeller	3.85 atm	0.23	9°	[-30°,30°]	CT3	CT3
FLAP 8 WB POWER OFF (Reference to RUAG)	TBD	1 atm	0.2	[-5°,20°]	0°	---	---
	TBD	1 atm	0.2	[-5°,20°]	5°	---	---
	TBD	1 atm	0.2	0°	[-30°,30°]	---	---
	TBD	1 atm	0.2	9°	[-30°,30°]	---	---
FLAP 8 WB POWER OFF	TBD	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	0°	---	---
	TBD	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	5°	---	---
	TBD	1 atm, 2 atm, 3.85 atm	0.23	0°	[-30°,30°]	---	---
	TBD	1 atm, 2 atm, 3.85 atm	0.23	9°	[-30°,30°]	---	---
FLAP 8 WB 1 ENGINE	TBD	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	0°	CT4	---
	TBD	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	5°	CT4	---
	TBD	1 atm, 2 atm, 3.85 atm	0.23	0°	[-30°,30°]	CT4	---
	TBD	1 atm, 2 atm, 3.85 atm	0.23	9°	[-30°,30°]	CT4	---
FLAP 8 WB 2 ENGINES	TBD	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	0°	CT3	CT3
	TBD	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	5°	CT3	CT3
	TBD	1 atm, 2 atm, 3.85 atm	0.23	0°	[-30°,30°]	CT3	CT3
	TBD	1 atm, 2 atm, 3.85 atm	0.23	9°	[-30°,30°]	CT3	CT3
FLAP 20 WB POWER OFF (Reference to RUAG)	TBD	1 atm	0.2	[-5°,20°]	0°	---	---
	TBD	1 atm	0.2	[-5°,20°]	5°	---	---
	TBD	1 atm	0.2	0°	[-30°,30°]	---	---
	TBD	1 atm	0.2	9°	[-30°,30°]	---	---
FLAP 20 WB POWER OFF	TBD	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	0°	---	---
	TBD	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	5°	---	---
	TBD	1 atm, 2 atm, 3.85 atm	0.23	0°	[-30°,30°]	---	---
	TBD	1 atm, 2 atm, 3.85 atm	0.23	9°	[-30°,30°]	---	---
FLAP 20 WB 1 ENGINE	TBD	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	0°	CT4	---
	TBD	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	5°	CT4	---
	TBD	1 atm, 2 atm, 3.85 atm	0.23	0°	[-30°,30°]	CT4	---
	TBD	1 atm, 2 atm, 3.85 atm	0.23	9°	[-30°,30°]	CT4	---
FLAP 20 WB 2 ENGINES	TBD	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	0°	CT3	CT3
	TBD	1 atm, 2 atm, 3.85 atm	0.23	[-5°,20°]	5°	CT3	CT3
	TBD	1 atm, 2 atm, 3.85 atm	0.23	0°	[-30°,30°]	CT3	CT3
	TBD	1 atm, 2 atm, 3.85 atm	0.23	9°	[-30°,30°]	CT3	CT3

WING-BODY-TAILS							
BLOCK	**Remote Control**	**PRESSURE**	**Mach**	**Alpha**	**Beta**	**CT stbd**	**CT port**
FLAP 0 WBVH POWER OFF (Reference to RUAG)	TBD	1 atm	0.2	0°	[-30°,30°]	---	---
	TBD	1 atm	0.2	9°	[-30°,30°]	---	---
	TBD	1 atm	0.2	[-5°,20°]	0°	---	---
	TBD	1 atm	0.2	[-5°,20°]	5°	---	---
FLAP 0 WBVH POWER OFF	TBD	1 atm, 3.85 atm	0.23	0°	[-30°,30°]	---	---
	TBD	1 atm, 3.85 atm	0.23	9°	[-30°,30°]	---	---
	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	0°	---	---
	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	5°	---	---
FLAP 0 WBVH 1 ENGINE	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	0°	CT2	---
	TBD	1 atm, 3.85 atm	0.23	0°	[-30°,30°]	CT2	---
	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	5°	CT2	---
	TBD	1 atm, 3.85 atm	0.23	9°	[-30°,30°]	CT2	---
FLAP 0 WBVH 1 ENGINE	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	0°	CT1	---
	TBD	1 atm, 3.85 atm	0.23	0°	[-30°,30°]	CT1	---
	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	5°	CT1	---
	TBD	1 atm, 3.85 atm	0.23	9°	[-30°,30°]	CT1	---
FLAP 8 WBVH POWER OFF (Reference to RUAG)	TBD	1 atm	0.2	[-5°,20°]	0°	---	---
	TBD	1 atm	0.2	[-5°,20°]	5°	---	---
	TBD	1 atm	0.2	0°	[-30°,30°]	---	---
	TBD	1 atm	0.2	9°	[-30°,30°]	---	---
FLAP 8 WBVH POWER OFF	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	0°	---	---
	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	5°	---	---
	TBD	1 atm, 3.85 atm	0.23	0°	[-30°,30°]	---	---
	TBD	1 atm, 3.85 atm	0.23	9°	[-30°,30°]	---	---
FLAP 8 WBVH 1 ENGINE	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	0°	CT4	---
	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	5°	CT4	---
	TBD	1 atm, 3.85 atm	0.23	0°	[-30°,30°]	CT4	---
	TBD	1 atm, 3.85 atm	0.23	9°	[-30°,30°]	CT4	---
FLAP 8 WBVH 2 ENGINES	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	0°	CT3	CT3
	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	5°	CT3	CT3
	TBD	1 atm, 3.85 atm	0.23	0°	[-30°,30°]	CT3	CT3
	TBD	1 atm, 3.85 atm	0.23	9°	[-30°,30°]	CT3	CT3
FLAP 20 WBVH POWER OFF (Reference to RUAG)	TBD	1 atm	0.2	[-5°,20°]	0°	---	---
	TBD	1 atm	0.2	[-5°,20°]	5°	---	---
	TBD	1 atm	0.2	0°	[-30°,30°]	---	---
	TBD	1 atm	0.2	9°	[-30°,30°]	---	---
FLAP 20 WBVH POWER OFF	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	0°	---	---
	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	5°	---	---
	TBD	1 atm, 3.85 atm	0.23	0°	[-30°,30°]	---	---
	TBD	1 atm, 3.85 atm	0.23	9°	[-30°,30°]	---	---
FLAP 20 WBVH 1 ENGINE	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	0°	CT4	---
	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	5°	CT4	---
	TBD	1 atm, 3.85 atm	0.23	0°	[-30°,30°]	CT4	---
	TBD	1 atm, 3.85 atm	0.23	9°	[-30°,30°]	CT4	---
FLAP 20 WBVH 2 ENGINES	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	0°	CT3	CT3
	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	5°	CT3	CT3
	TBD	1 atm, 3.85 atm	0.23	0°	[-30°,30°]	CT3	CT3
	TBD	1 atm, 3.85 atm	0.23	9°	[-30°,30°]	CT3	CT3
FLAP 30 WBVH POWER OFF (Reference to RUAG)	TBD	1 atm	0.2	[-5°,20°]	0°	---	---
	TBD	1 atm	0.2	[-5°,20°]	5°	---	---
	TBD	1 atm	0.2	0°	[-30°,30°]	---	---
	TBD	1 atm	0.2	9°	[-30°,30°]	---	---
FLAP 30 WBVH POWER OFF	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	0°	---	---
	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	5°	---	---
	TBD	1 atm, 3.85 atm	0.23	0°	[-30°,30°]	---	---
	TBD	1 atm, 3.85 atm	0.23	9°	[-30°,30°]	---	---
FLAP 30 WBVH 1 ENGINE	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	0°	CTmax	---
	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	5°	CTmax	---
	TBD	1 atm, 3.85 atm	0.23	0°	[-30°,30°]	CTmax	---
	TBD	1 atm, 3.85 atm	0.23	9°	[-30°,30°]	CTmax	---
FLAP 30 WBVH 2 ENGINES	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	0°	CT3	CT3
	TBD	1 atm, 3.85 atm	0.23	[-5°,20°]	5°	CT3	CT3
	TBD	1 atm, 3.85 atm	0.23	0°	[-30°,30°]	CT3	CT3
	TBD	1 atm, 3.85 atm	0.23	9°	[-30°,30°]	CT3	CT3

Table 1. Example of Test Program

The selected applicant will have to provide to the topic manager organization all the wind tunnel test data (see deliverable list) to support in the design and flight clearance of the FTB2 demonstrator.

Technological challenges:

The detailed characterization of the propeller direct (1P forces and moments) and indirect power effects on a turboprop aircraft is a very demanding technological challenge with an important impact on the design given its influence on the handling qualities, the loads and performance of the aircraft

1P forces and moments of an installed propeller are currently poorly estimated with CFD. Similarly, indirect propeller effects on the wing are not optimally captured. Wind tunnel tests are limited to Reynolds numbers well below that of flight with corresponding uncertainties in terms of extrapolation to full scale conditions and blade aero-elastic effects. Therefore the challenge presented in this CfP will give a new insight on the quality of the data that can be reached in the wind tunnel and out of CFD calculations.

The results of the investigation will allow to better tune the current aerodynamic CFD calculation capabilities, thus positively impacting the quality and the accuracy of the CFD data to be generated in future turboprop developments with the corresponding impact in terms of aircraft weight, efficiency and safety. Furthermore it will have a direct immediate de-risking impact in the CS2 FTB2 flight clearances.

A potential refinement of the FTB2 structural design will also be made possible with the results obtained.

3. Major Deliverables/ Milestones and schedule

All the activities under this CfP are included in the WP3.5 of the CS2 REG Platform, specifically in the WP3.5.1 "FTB2 Wing".

The proposed activities are described in the Table 2 below which shows also the deadline for each task. The estimated reference T0 is January 1st, 2019

A total of 4 work packages (WP) are considered.

The WP1 is dedicated to overall management, and its task will be staging the entire project between the participants.

The WP2 is oriented to the CFD characterization of the CS2 FTB2 power effects at different Reynolds conditions covering both wind tunnel scale and full scale, including aeroelastic effects on the WTT model blades. Aeroelastic wing deformation of WTT model is considered negligible.

The WP 3 is entirely devoted to wind tunnel testing.

The WP4 will address the comparison of experimental vs numerical data, coming to the targeted outcomes on the phenomena addressed.

The due dates depicted in the following table are tentative, and depend on tunnel availability. Ideally the tests should take place as soon as possible for an early availability of the wind tunnel data.

Tasks (each sub-task is a deliverable [D] or milestone [M])		
Ref. No.	Title – Description	Due Date
Task 1.1	Exchange of the initial geometric & aerodynamic information of CS2 FTB2 [M] Familiarization with WTT model. [M]	T0+1M
Task 1.2	Managing wind tunnel contract. [M]	T0+3M
Task 1.3	Project monitoring & reporting. [M]	T0+18M
Task 2.1	Preliminary CFD characterization of the model in WTT conditions [D]	T0+5M

Tasks (each sub-task is a deliverable [D] or milestone [M])		
Ref. No.	Title – Description	Due Date
Task 2.2	Final CFD characterization of the model in WTT conditions & data delivery to topic manager organization. [D]	T0+10M
Task 2.3	Preliminary CFD characterization of the model in flight conditions [D]	T0+12M
Task 2.4	Final CFD characterization of the model in flight conditions & data delivery to topic manager organization for comparison with flight test data [D]	T0+16M
Task 3.1	WTT campaign documentation, (test matrix, data reduction, wind tunnel corrections, etc.). [D]	T0+5M
Task 3.2	Wind tunnel campaign [M]	T0+7M (depending on WTT availability)
Task 3.3	Delivery of WTT data [D]	T0+8M (depending on WTT availability)
Task 4.1	Comparison of wind tunnel results vs CFD characterization of the model in WTT conditions. [D]	T0+11M
Task 4.2	Final assessment of the lessons learned. [D] Documentation of methods, tools and processes used for the work. [D]	T0+18M

Table 2: List of milestones & deliverables

Referring to the effort to be dedicated by the selected applicant, it is estimated, that 25% of the overall budget (estimated at roughly 1 Mio€) should be dedicated to WP 1, 2 and 4. The remaining 75% would then be dedicated to the WP3.

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- High fidelity CFD analysis know-how & capabilities, particularly in the area of installed propeller simulation
- Experience in specification, managing, conduction and analysis of powered model wind tunnel tests is desirable. If requested the topic manager organization will provide support free of charge.

5. Abbreviations

CFD	Computational Fluid Dynamics
WP	Work Package
WTT	Wind Tunnel Test

IV. JTI-CS2-2018-CFP08-REG-03-01 - Laminar Flow robustness and Load control effectiveness evaluation for a Regional Turboprop wing

Type of action (RIA or IA)	RIA		
Programme Area	REG		
Joint Technical Programme (JTP) Ref.	WP 2.1		
Indicative Funding Topic Value (in k€)	1300		
Topic Leader	CIRA	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	24	**Indicative Start Date (at the earliest)41**	Q1 2019

Identification	**Title**
JTI-CS2-2018-CFP08-REG-03-01	**Laminar Flow robustness and Load control effectiveness evaluation for a Regional Turboprop wing**
Short description (3 lines)	
Within this project an experimental and theoretical assessment of laminar flow robustness, aerodynamic performances and load control effectiveness for a turboprop A/C wing has to be performed at high/medium speeds (Mach up to 0.67 and wind tunnel Reynolds number 10-11 million) including theoretical evaluation of propeller wake aerodynamic interference. Wind tunnel wing model (5 meters span) has not to be manufactured since already available from another Project under Call for Proposals. An indicative expected ROM funding distribution is: approx. 75% for WTT and approx. 25% for all other WPs.	

Links to the Clean Sky 2 Programme High-level Objectives42				
This topic is located in the demonstration area:	Regional Aircraft Wing Optimization			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Turboprop, 90 pax			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☒	☐	☒	☐

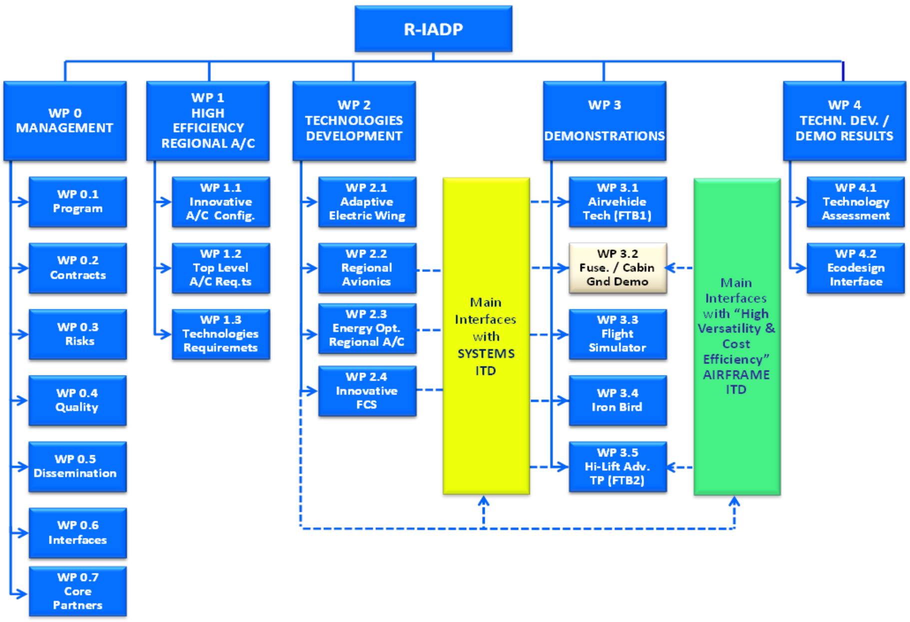
[41] The start date corresponds to actual start date with all legal documents in place.
[42] For further info see Chapter 1 “Introduction to the Programme Scene Setter / Objectives” with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

The purpose of the Regional Aircraft IADP is to bring the integration of technologies for regional aircraft to a further level of complexity and maturity than the one pursued in the Clean Sky – GRA ITD. The global strategy is to integrate and validate, at aircraft level, advanced technologies for regional aircraft so as to drastically de-risk their integration on future products. Within the R-IADP the following large-scale demonstrators are foreseen:

- Two Flying Test Beds (FTB), using modified existing regional turbo-prop aircraft with under-wing mounted engines, for demonstration campaigns; FTB#1 (Leonardo) will mainly focus on the demonstration of technologies improving the cruise and climb performance, while FTB#2 (Airbus DS) will be oriented to test technologies for Regional A/C optimized for short point-to- point flights, connecting airports with short runways and, in general, towards more advanced high-lift performances and more efficient configuration for climb and descending phases.
- Three large integrated Ground Demonstrators: full-scale fuselage and cabin (IADP), flight simulator and iron bird (IADP).

The Regional Aircraft IADP WBS is below reported.



Focusing the attention on activities planned in WP2.1, innovative active high lift and load alleviation technologies are integrated with Natural Laminar Flow wing concept:

- The aerodynamic design of a wing characterized by a partial laminar flow: turbulent for inner region and NLF for outer region, for the TP airplane at cruise. This task is performed starting from a preliminary shape taking into account the specifications in terms of flight conditions and aerodynamic performance desired. As final step of the NLF design, manufacturing requirements are defined for the regions with laminar flow, to avoid early transition due to geometrical defects. Different types of surface defaults are considered, such as surface roughness, steps, gaps or waviness.
- Taking advantage of the previous experience gained in the frame of Clean Sky – GRA ITD project by many of the involved partners, advanced Load Control & Alleviation technologies capable to improve the aircraft efficiency along the flight envelope and to mitigate the peak structural responses due to

manoeuvre loads and gusts will be implanted in the NLF TP outer wing.

- Finally, the development of adaptive Winglet, morphing TE Flap and Droop nose will be managed from the conceptual design to experimental validation of full-scale models. Structural mechanics and material aspects will be investigated along with actuation systems, electronics and safety/reliability issues.

As part of the development plan, different technologies will be validated through large-scale wind tunnel experimental validation of a natural laminar flow flexible wing model integrating innovative morphing active devices (droop nose, morphing trailing edge, morphing winglet).
Approaches and solutions finally developed will be scaled up to be further validated and finally implemented to the selected CS2 FTB#1 configuration.

2. Scope of Work

Within this project an experimental and theoretical assessment of laminar flow robustness, aerodynamic performances and load control effectiveness for a turboprop wing has to be performed. The wind tunnel model has not to be manufactured since it is already available from a different Call for Proposal.

Experimental verification has to be performed by large-scale wind tunnel test of an already available flexible wing half-model (scale 1:3, model size about 5 meters) equipped with innovative morphing active devices (droop nose, trailing edge flap with integrated morphing trailing edge, morphing winglet and wingtip). The model will include morphing movable droop nose, morphing movable trailing edge high lift and control devices and an adaptive winglet and wingtip. The model does not include the propeller, but a dummy nacelle is included.

WT Tests are planned in low speed and in "cruise conditions" to validate the relevant aerodynamic performances including laminar flow extension measurements and wing span load distribution. Therefore a large scale and very good flow quality wind tunnel has to be selected. (e.g. in cruise flight conditions (Mach 0.58) a Reynolds number, based on the existing model mean aerodynamic chord of 0.85 meters, of at least 11-12 million is expected).

Theoretical/numerical analysis will have the objective to extend to actual flight conditions wind tunnel test results. Therefore, the following activities are planned:

1) Extrapolation of wind tunnel data (including laminar extension) to flight Reynolds number condition for the most relevant test conditions;
2) Evaluate robustness and extension of laminar flow in presence of actual aircraft structure (e.g. sensitivity studies to disturbance caused by wall roughness, waviness, gaps and steps, droop nose installation and wing flexible deformation; sensitivity studies to individuate the leading edge regions from which the most critical disturbances come (ray theory));
3) Perform a study to evaluate robustness of laminar flow due to interaction of propeller wake with wing laminar flow and evaluation of actual spanwise and chorwise laminar flow extension in different flight conditions and propeller thrust level;
4) Evaluate flexibility effects of morphing Droop Nose;
5) Evaluate effectiveness of load control devices.

To perform these theoretical activities a preparation phase for methods and tools improvement and assessment could be required. In the following table, the different project tasks are reported:

Ref. No.	Title – Description
WP1	Management
WP 2	Test matrix definition
WP 3	Wind tunnel test monitoring
WP 4	Tools preparation phase
WP 5	Reynolds number effect
WP 6	Propeller wake impact
WP 7	Actual gap/step and wing deformation impact

WP 1: Management

This task is responsible for the management of the project in order to ensure that all obligations are fully respected from contractual and financial points of view. Taking into account the strong interaction between activities performed by REG IADP Core Partners and the present project, the present task will assure suitable communication between Consortium, Topic Manager (REG IADP Leader) and JU.

WP 2: Test matrix definition

The model will be manufactured in the frame of another Project under Call for Proposals and, hence, it is not part of the present Call Applicant's activities. The model represents the R-IADP TP90 A/C with a NLF wing and morphing devices for high lift and load control; its main characteristics are:

- Wing demi model of about five meters size;
- A flexible wing with Natural Laminar Flow (NLF) in the outer region at cruise. The wing shape is modified due to the aerodynamic loads acting on it, these loads depending on the flight condition considered;
- One droop nose (DN) at the leading edge (LE). The DN can be deployed and one deployment level corresponds to one DN shape (1 parameter for both deployment and shape);
- One multi-functional morphing trailing edge flap (TE). A standard trailing edge flap equipped with a morphing trailing edge tab (TE TAB) that can be used for load control;
- One morphing winglet (WL) and one movable wingtip (Wtip). The WL is a winglet equipped with a movable tab at its trailing edge (1 parameter for tab setting). The Wtip has a frozen shape but its setting on the wing can be modified through a rotation along a streamwise axis at the extremity of the wing (1 parameter for Wtip setting). These two devices can only be tested alternatively, one being dismantled to install the other on the model;
- An engine nacelle without propeller;
- No fuselage.
- All movable devices (flap excepted) are motorized.

The model size is:

	Real airplane	WT model at scale 1:3 (to be confirmed)
Wing span (without winglet)	14.827 m	4.942 m
Mean aerodynamic chord	2564.5 mm	854.8 mm
Root chord	2922.0 mm	974.0 mm
Tip chord	1480.0 mm	493.3 mm
Sweep angle (Leading edge, Trailing edge)	2.62° / -6.26°	2.62° / -6.26°

The following measurements/instrumentation is expected:

- Total forces and moments on the model measured by a wall balance (Lift, Drag, Torque and bending moment);
- 200 steady pressure taps, 15-20 unsteady pressure sensors (already included in the model);
- Few accelerometers (already included in the model);
- Strain gauges (already included in the model);
- Visualization of NLF extent with paint on the model and Infra-Red cameras;
- Detailed measurement of model surface deformation (model surface measurement with and without wind tunnel aerodynamic loads);
- Aerodynamic loads distributions (with steady pressure taps and strain gauges immersed into the wing structure);
- LC&A movable surfaces hinge moments measurements (TbC).

The wind tunnel testing section has to be such as to allow for the installation of the already available five-meter semispan model without wall interference and blockage. The wind tunnel must allow for tests at both low speed (Mach 0.148) and high speed (at least Mach 0.67) and has to have proven capability and expertise to reproduce laminar flow on a large model at high Reynolds number (at least 11 million). The proposal must include the identification of the selected wind tunnel and must provide technical information on the tunnel including flow quality and turbulence level. Low turbulence level and ability to install and test the 5-meter model at the required speed is a key requirement of the Call.

The list of tests to be performed is reported in the following table; the final test matrix could be slightly updated during the project with the agreement of the topic leader:

Mach	Objective	Angle of attack	Movables
0.45	Laminar extension, Aerodynamic performances Load measurement	At least seven CL from 0.2 to 1.1	DN, TE not actuated TE TAB 4 positions Winglet TAB 4 positions (Total 8 configurations including reference flight configuration) A selected number of tests have to be performed both with free transition and fixed transition
0.52	Laminar extension, Aerodynamic performances Load measurement	At least seven CL from 0.2 to 1.1	DN, TE not actuated TE TAB 4 positions Winglet TAB 4 positions (Total 8 configurations including reference flight configuration) A selected number of tests have to be performed both with free transition and fixed transition
0.58	Laminar extension, aerodynamic performances	At least seven CL from 0.2 to 1.1	DN, TE not actuated TE TAB 4 positions Winglet TAB 4 positions

Mach	Objective	Angle of attack	Movables
			(Total 8 configurations including reference flight configuration) A selected number of tests have to be performed both with free transition and fixed transition
0.45	Laminar extension, Aerodynamic performances, Load measurement	At least seven CL from 0.2 to 1.1	DN, TE not actuated TE TAB 4 positions Wing tip TAB 4 positions (Total 8 configurations including reference flight configuration)
0.52	Laminar extension, Aerodynamic performances Load measurement	At least seven CL from 0.2 to 1.1	DN, TE not actuated TE TAB 4 positions Wing tip TAB 4 positions (Total 8 configurations including reference flight configuration)
0.58	Laminar extension, Aerodynamic performances Load measurement	At least seven CL from 0.2 to 1.1	DN, TE not actuated TE TAB 4 positions Wing tip TAB 4 positions (Total 8 configurations including reference flight configuration)
0.62	Aerodynamic performances	At least two CL from 0.1 to 0.5	All controls zero Fixed transition only
0.67	Aerodynamic performances	At least two CL from 0.1 to 0.3	All controls zero Fixed transition only
0.148	High lift performances	Continuous variation of angle of attack for CL varying from 0.0 to CLmax (expected 1.2 clean, 1.85 flapped)	TE TAB not actuated Winglet TAB not actuated Flap/Droop nose extended (Total 3 configurations including closed flap/droop nose configuration)
0.148	High lift performances	Continuous variation of angle of attack for CL varying from 0.0 to CLmax (expected 1.2 clean, 1.85 flapped)	Wing tip TAB not actuated Flap/Droop nose extended (Total 3 configurations including closed flap/droop nose configuration)
0.3 TbC	Climb performances, laminar extension in climb, load control effectiveness	At least seven CL from 0.2 to 1.1	DN, TE not actuated TE TAB 4 positions Winglet TAB 4 positions (Total 8 configurations including reference flight configuration)
0.3 TbC	Climb performances, laminar extension in climb, load	At least seven CL from 0.2 to 1.1	DN, TE not actuated TE TAB 4 positions WingTip TAB 4 positions (Total 8 configuration including reference

Mach	Objective	Angle of attack	Movables
	control effectiveness		flight configuration)

WP 3: Wind tunnel test monitoring

It is expected that the applicant will participate in the wind tunnel test campaign and will contribute to the data analysis for tests monitoring.

WP 4: Tools preparation phase

Flight condition extrapolation, evaluation of robustness of laminar flow due to waviness, wing deformation and of propeller wake impact have to be performed. Since this is quite a challenging activity a preparation phase has to be performed. This phase has to be illustrated in the proposal and will consist of:

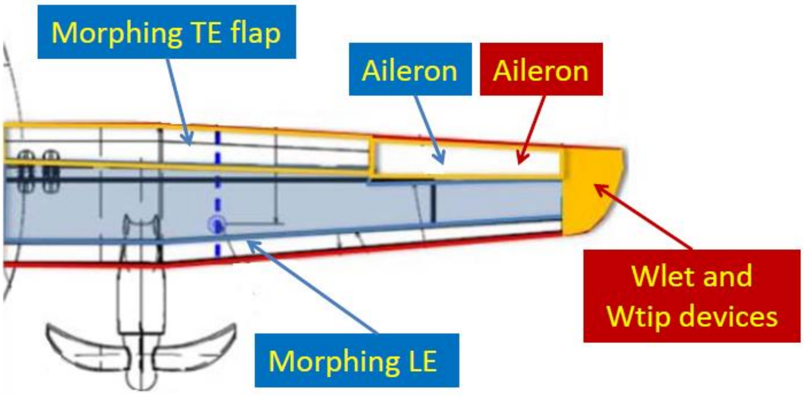
a. A review of tools, methods and previous available experimental information related to laminar flow robustness;
b. Development and/or numerical tool modification (based for example on receptivity concepts) to evaluate laminar flow robustness in actual flight conditions;
c. Description of the procedure that will be used for wing load evaluation on the deformed model and on the full-scale wing.

WP 5: Reynolds number effect

Even if wind tunnel test will be performed at high Reynolds number, the test Reynolds number will be anyway different from the flight Reynolds number. Therefore, numerical evaluation has to be performed to extrapolate test conditions to the actual flight conditions. Both aerodynamic coefficients, laminar extension and wing load distribution in flight conditions have to be calculated for a selected number of conditions.

WP 6: Propeller wake impact

It is known that propeller wake can have a detrimental impact on laminar flow, and therefore not so many laminar turboprop aircraft are known. In REG-IADP aircraft, a twin turboprop wing mounted configuration has been designed. It is expected that laminar flow will be only possible over the external part of the wing. The objective of this WP will be to evaluate which is the actual spanwise and chordwise extension of the laminar flow in the most relevant flight conditions (climb and cruise). At this end a procedure to take account of propeller wake - laminar boundary layer interaction has to be set-up and used. The planned approach for this activity should be described in the proposal text.



An additional activity will be the theoretical evaluation in a selected number of points of the effectiveness of load control devices in presence of the propeller wake (aerodynamic performances and wing load distribution calculation with and without propeller).

WP 7: Actual waviness/gap/step and wing deformation impact

The available wind tunnel model is a flexible model. Nevertheless taking into account the differences in aerodynamic load between the wind tunnel test and flight conditions the wind tunnel model deformation could be different from that corresponding to actual flight conditions.

The objective of this task is, by using both the planned wind tunnel test data and already available literature data and new state-of-art numerical tools (e.g. receptivity based methods), to perform an evaluation of actual laminar extension on the aircraft in flight conditions taking into account the wing deformation and eventual surface imperfections caused by the presence of the droop nose. Of course mainly cruise and climb conditions will have to be analysed.

The applicant will also perform an evaluation of load control effectiveness on the deformed wing by performing numerical aerodynamic analysis taking into account the wing deformation for both the model and actual flight scale wing geometry. For the wing tunnel model deformation both actual measured deformation and calculated deformation can be used, for the actual flight scale aircraft the actual deformation has to be calculated, either by using a FEM analysis or by using a simplified stick-beam approach. The analysis will be performed in a limited number of points, the proposed approach should be described in the call text.

3. Major deliverables/ Milestones and schedule (estimate)

**H=hardware; R=report; D=data,drawing*

Deliverables			
Ref. No.	Title - Description	Type(*)	Due Date
Del 1.1	Progress report (technical and management report)	R	T0+6
Del 1.2	Progress report (technical and management report)	R	T0+12
Del 1.3	Progress report (technical and management report)	R	T0+18
Del 1.4	Final technical report	R	T0+24

Deliverables			
Ref. No.	Title - Description	Type(*)	Due Date
Del 2.1	Consolidated test matrix and wind tunnel test specifications	R	T0+6
Del 3.1	Preliminary Test report (raw data)	R, D	T0+11
Del 3.2	Final Test report (corrected data)	R, D	T0+12
Del 4.1	Review of methods for Reynolds correction, laminar flow robustness. Identification and assessment of methods to be used for laminar flow robustness assessment	R	T0+9
Del 5.1	Assessment of Reynolds number on laminar flow extension and aerodynamic performances	R	T0+24
Del 6.1	Evaluation of propeller impact on laminar flow extension	R	T0+24
Del 7.1	Evaluation of gap/step wing deformation and waviness impact on laminar flow extension	R	T0+24
Del 7.2	Load control effectiveness on deformed wing	R	T0+24

Milestones (when appropriate)			
Ref. No.	Title – Description	Type	Due Date
M1 (WP2)	Provision of consolidated test matrix DEL 2.1	R	T0+6
M2 (WP3)	Performance of wind tunnel tests	D	T0+9
M4 (WP3)	Provision of final test report (DEL 3.2)	R	T0+12
M4 (WP5,6,7)	Evaluation of laminar flow robustness (deliverables DEL 5,.1 DEL 6.1 and DEL 7.1)	R	T0+23

Project kick-off is expected in March/April 2019 and tests are expected to be performed between December 2019 and December 2020.

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- ✓ Managing capabilities for large european research projects.
- ✓ Use of advanced computational tools for 3D aerodynamic (CFD) and aero-elastic/structural analyses (CFD/CSM coupling).
- ✓ Expertise in laminar/turbulent transition analysis and modelling.
- ✓ Consolidated experience in wind tunnel test technical management.
- ✓ Consolidated experience in large-scale wind tunnel test.
- ✓ Natural laminar flow measurement and test on large wind tunnel test at high Reynolds.
- ✓ Experience in Wind tunnel test activities, data analysis and reporting.
- ✓ The wind tunnel must be able to host a semimodel of 5-meter span and 0.8 mean aerodynamic chord with flap extended up to stall conditions without significative blockage effect and in clean configuration up to Mach 0.7. (The wind tunnel model is available from another call and will be provided by the topic leader). The wind tunnel must be able to demonstrate good flow quality and capability to obtain laminar flow conditions at Mach 0.6 and Reynods at least 11 million. Low turbulence level quality of the wind tunnel has to be demonstrated.

5. Abbreviations

A/C Aircraft

CFD	Computational Fluid Dynamics
CL	Lift Coefficient
CLmax	Maximum lift coefficient
CSM	Computational Structural Mechanics
DN	Droop Nose
LC&A	Load Control and Alleviation
LE	Lading edge
MDM	Measurement of model deformation
NLF	Natural Laminar Flow
TE	Trailing edge
TE TAB	Trailing edge tab
TP	Turboprop
WL	Winglet
WL TAB	Winglet Tab
WT	Wind Tunnel
Wtip	Wint tip
Wtip TAB	Wing tip tab

6. Clean Sky 2 – Fast Rotorcraft IADP

I. JTI-CS2-2018-CFP08-FRC-01-18: Adoption of a "Digital Transformation" approach to improve NGCTR design and simulation

Type of action (RIA/IA/CSA)	RIA		
Programme Area	FRC		
(CS2 JTP 2015) WP Ref.	WP 1.1		
Indicative Funding Topic Value (in k€)	1750		
Topic Leader	Leonardo Helicopters	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	60	**Indicative Start Date (at the earliest)**[43]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CFP08-FRC-01-18	**Adoption of a "Digital Transformation" approach to improve NGCTR design and simulation**
Short description	
The Topic is aimed to adopt an innovative approach in the development of the NGCTR-TD, implementing methods capable to earn the maximum value from new technologies associated to the Digital Transformation concepts. This Topic includes supporting the optimization of flight campaigns and improving design choices, thanks to new insights coming from the massive data analysis and finding innovative algorithms and correlations.	

Links to the Clean Sky 2 Programme High-level Objectives[44]				
This topic is located in the demonstration area:	Next-Generation Civil Tiltrotor			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Next-Generation Tiltrotor			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☐	☐	☐	☒	☒

[43] The start date corresponds to actual start date with all legal documents in place.

[44] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

The Flight Data analysis in a design of new innovative aircrafts is a crucial step for development and certification of the Technical Demonstrator.
In fact, in order to diagnose the causes of detected phenomena (malfunctions / abnormalities) or unexpected behaviours of the aircraft, we need to perform a massive analysis campaign in a timely manner, aimed at identifying unforeseen relationships between the different parameters and defining the necessary corrective actions.
In order to make coherent correlations between virtual models and the outcome of experimental tests, access must be guaranteed not only to the archive of time histories acquired during flights but also to all the auxiliary information (Aircraft configuration, daily reports, weather, ...) required to contextualize tests, as well as to Virtual Flight data coming from a dedicated Flight Mechanics Simulator.
A Proof of Concept on big data technologies has already verified the potential of the Hadoop platform, assessing the ability to simultaneously process large amounts of information, even unstructured, and the ability to launch complex queries.
The big data platform based on Hadoop Distributed File System has been identified as the most suitable to support the evolution of the flight data analysis process.
Further, a big data infrastructure is the prerequisite to grant computational power both to current methods and to new algorithms capable to make predictions or calculated suggestions based on large amounts of data.
The implementation of new algorithms capable to build predictive models learning from data (Machine Learning algos) offers a great potential in finding new insights and detecting unexpected relationships among parameters.

2. Scope of work

The Topic is aimed to adopt an innovative approach in the development of the NGCTR-TD, implementing methods capable to earn the maximum value from new technologies associated to the Digital Transformation concepts (Big Data; IoT; AI; AR/VR).

Moreover, it has been also addressed to support the optimization of flight test campaigns and to improve the design choices, thanks to new insights coming from the massive data analysis and finding innovative algorithms and correlations.

Scope of this request will be the adoption of the Digital Transformation technologies inside the development of the Technical Demonstrator.

The Applicant shall structure its Proposal into five main Work Packages (WP), as hereafter described:

- WP0: Project Management : Management and coordination
- WP1: Right time Analysis : Big Data platform on actual Flight Data analysis
- WP2: Extended Analysis & Machine Learning : Developing innovative algorithms and AI
- WP3 : Data Analysis and algorithms applied to NGCTR-TD
- WP4: Learning the “Digital Transformation” approach : Training & Culture Dissemination

WP0 : Project Management - Management and coordination

Management of: scope, resources and timeline of the whole project.

Adoption of international PM methodologies will be preferential.

Input from Topic Leader

- Scope
- Stakeholders
- Steering Committee

<u>Output from the Applicant</u>

- Project Management

WP1 : Right time Analysis - BigData platform to support actual Flight Data analysis methodologies
This Work package refers to the implementation of the Flight Data Analysis appliance, according to the following scheme (**Error! Reference source not found.**):

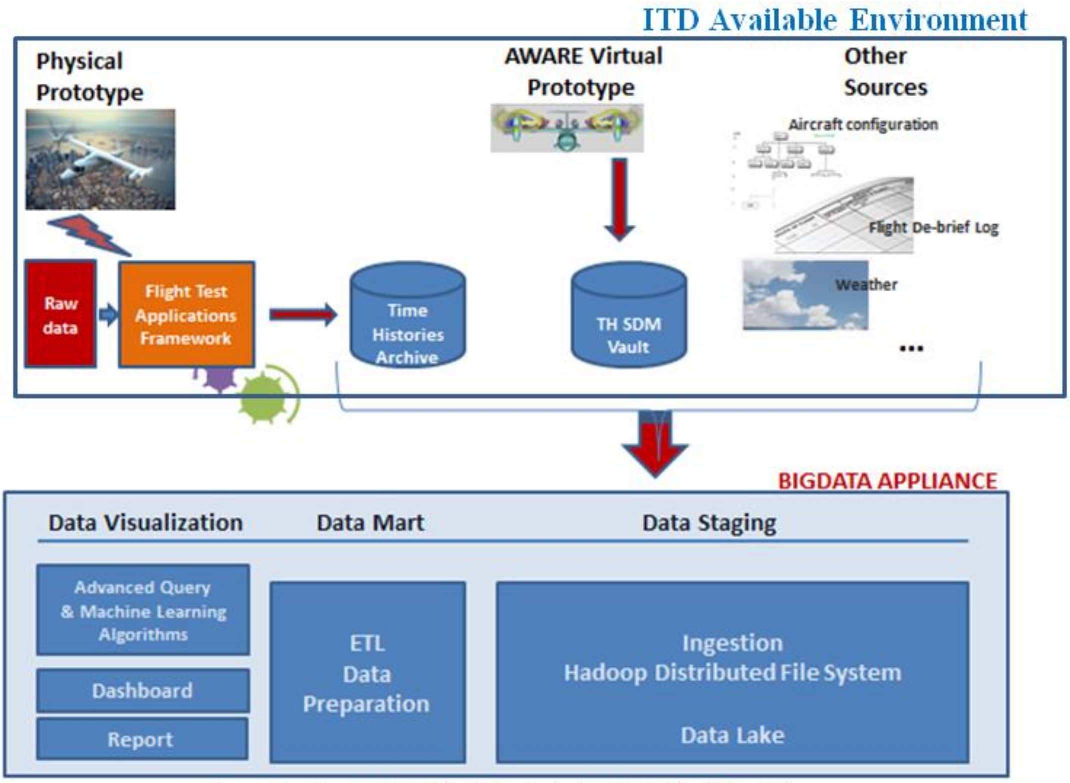


Figure 1 - From Flight Test Analysis to Flight Test Analytics

<u>Main steps envisaged are:</u>
Implementation of a laboratory environment within the Applicant site to perform the following steps:

- Infrastructural setup;
- Ingestion of Leonardo helicopters time series, and other relevant sources using data masking techniques;
- Development of the queries catalog for typical analysis.

Existing flight test data base could be a meaningful template to provide the Applicant with a right understanding of the sizing behind this objective.

For this reason, hereafter main relevant dimensions of a typical flight test data are listed:

- 3 Flying aircraft prototypes
- An average of 10.000 and a maximum of 30.000 parameters, for each flight condition.
- 600.000 of total flight conditions
- At today about 4.000 flights

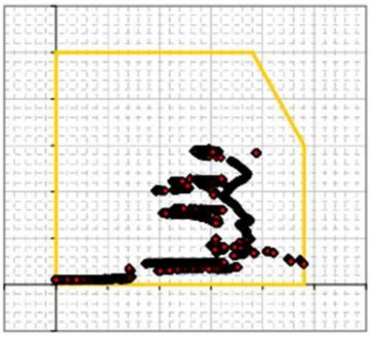
- With an average sampling rate between 50Hz-60Hz-512Hz

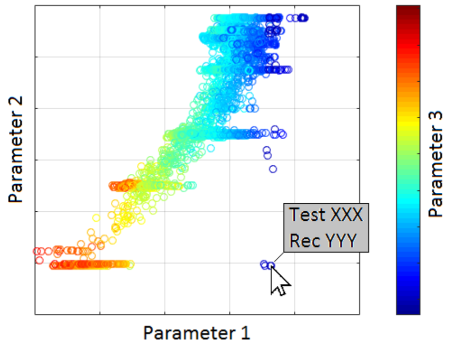
With respect to the expected analysis capabilities provided by the queries catalog, the following set of data has to be considered:

- Time histories archive data: binary data in legacy format recorded by test sensors and transducer, derived data
- Acceptance Testing Procedure, Maintenance and inspections data: flight hours, part number of component on board, software version
- Operational data: Helicopters configuration, crew members, date, site, top, crew comments
- Weather Conditions: wind level, gust level, turbulence level, temperature, humidity.

This would imply an expansion of the appliance, including additional information in order to grant a proper interpretation of engineering data.

Here below some examples of features to be implemented in WP1:

ID	FEATURE DESCRIPTION	TYPE
F.1	Capability to filter the flight data applying user-specified conditional tests on parameter time histories. This conditional tests must be applicable also to derived time histories.	**FILTERING**
F.2	Capability to filter the flight data against generalized accessory information, like the aircraft configuration, the weather conditions, the pilots on-board, the installed Flight Control System software version, etc...	
F.3	Capability to filter the flight data identifying all the conditions when the aircraft performed a standard manoeuver	
DP.1	Capability to produce derived parameters from time histories using basic mathematical functions. E.g. sum (subtract, multiply etc.) two or more time histories (that are possibly sampled at different sample rates)	**DATA PROCESSING**
DP.2	Capability to retrieve the values of given parameters at the instants of maximum/minimum value of another parameter (recorded or derived)	
DP.3	Capability to filter signals using a standard filter library (Butterworth, Chebyshev ...).	
DP.4	Capability to perform basic vector/matrix operations.	
DP.5	Implementation of logical indexing (find vector/matrix locations satisfying a conditional rule).	
DP.6	Capability to check on the whole database, a predetermined set of parameters against their limitations and collect the exceedances. 	
PP.1	Implementation of basic plotting capabilities.	**POST PROCESSING**

ID	FEATURE DESCRIPTION	TYPE
PP.2	Possibility to build interactive population plots, with advanced scoping capabilities that allow retrieving accessory information of the plotted data. 	
PP.3	Custom dashboard creation.	

Input from Topic Leader (including data coming from the Available Environment represented in **Error! eference source not found.**);

- Application field main characteristics to properly size the Big data appliance (i.e. number of parameters recorded in flight, number of conditions, average duration of flight, signal sampling rate)
- Guidelines for setting the big data appliance (i.e. preferred Hadoop distribution and applications, estimated number of nodes, RAM, disk space, …)
- List of sources whose masked data must be ingested into the data lake;
- Description of Data format and size;
- Detailed list of relevant analysis to be performed;

Output from the Applicant

- Infrastructural lab setup within the applicant site (BIGDATA APPLIANCE in **Error! Reference source ot found.**);
- Catalog of the most popular queries delivered;
- Documentation & Training.

WP2 : Extended Analysis & Machine Learning: developing innovative algorithms

This Work Package envisages the development of innovative algorithms to be applied to a Tiltrotor data. In order to build a shared team, a relocation of the laboratory within the Topic Leader site is mandatory.

Main steps envisaged are:

- Move of the lab within the Topic Leader site of Cascina Costa (IT);
- Ingestion of available data base;
- Implementation of statistical algorithms for automatic data anomalies detection (Outliers), and clustering;
- Implementation of AI algorithms aimed to synthetizing models from flight data;
- Implementation of content detection solutions.

In the following table are described the basic details of the machine learning/statistical algorithm affordable within this Work Package:

ID	FEATURE DESCRIPTION	TYPE
ADP.1	Implementation of rotorcraft-specific time histories fitting tools, such as harmonic fitting methods.	**ADVANCED DATA PROCESSING**
ADP.2	Capability to identify and fix bad-quality data (e.g. spike-removal or reconstruction of corrupted data)	
AI.1	Automatic recognition of standard maneuvers.	**AI ALGORITHM**
AI.2	Automatic event recognitions, like: gust encounters; changes in Flight Control System operational modes; anomalies in the performance of a particular subsystem.	
AI.3	Implementation of deep-learning and machine learning algorithms, aimed at "learning from data".	
AI.4	AI model development to predict aircraft behavior. These models will then be used in telemetry real time monitoring, in order to increase the safety of flight operations.	

Input from Topic Leader

- Site resources to host the lab environment;
- Full set of available time histories;
- Samples of the unstructured data to be parsed and list of field to be extracted;
- List of failures to be identified;
- Technical support from Subject Matter Experts;
- Description of Data format.

Output from the Applicant

- Deployment of the LAB to Topic Leader site;
- Available Data ingestion;
- Content detection algorithms developed;
- Machine Learning predictive models developed;
- Documentation & Training.

Starting from WP2 onwards, due to the confidentiality of data and with the aim to build an integrated team, two FTE from the Applicant are required to be working on site within the laboratory environment in Cascina Costa plant of Leonardo Helicopters;
Travel and living expenses will be on charge of the Applicant.

WP3 : Data Analysis and algoritms applied to NGCTR-TD

This WP delivers all the capabilities realized in the previous work packages, to support NGCTR-TD needs.

Main steps envisaged are:

- Ingestion of NGCTR-TD data;
- Tailoring of the above developed queries catalog;
- Application and tuning of statistical algorithms and ML;
- Development of machine learning algorithms to optimize NGCTR-TD flight campaign.

Input from Topic Leader

- Full set of NGCTR-TD time histories;
- Relevant analysis to be performed;
- List of failures to be identified;
- Technical support from Subject Matter Experts;
- Description of Data format.

Output from the Applicant

- Data ingestion of NGCTR-TD time history;

- Real time upload/update of new NGCTR-TD flights;
- Catalog of the most popular queries delivered;
- Content detection algorithms developed;
- Machine Learning predictive models developed;
- Documentation & Training.

WP4 : Learning the "Digital Transformation" approach - Training & Culture Dissemination
In order to achieve full benefits from the new approach, development of internal skills is a crucial point. Specific training paths aimed at the upgrade of existing professional skills towards data scientist, and IT people, to achieve the required competencies, have to be developed.
Main steps envisaged are:

- Preparation of a set of documentation concerning the following topics :
  - ✓ Description of the appliance IT technologies (big data ecosystem) in terms of capabilities, adopted configuration, process flows;
  - ✓ Theoretical & User manual of implemented algorithms and queries;
- Dissemination workshops;
- Dedicated training sessions.

Input from Topic Leader

- Documentation templates and guidelines
- Contents and main requirements for courses & workshops;
- Description of the attendees' profile (school background, seniority, professional role).

Output from the Applicant

- Full set of documentation delivered;
- E-learning (Moodle based) documentation delivered;
- Workshops performed on Topic Leader premises;
- Training courses performed on Topic Leader premises (North Italy location, Cascina Costa).

Project Time scheduling
The following table lists the deadline for each task completion:

Work packages		
Ref. No.	***Title – Description***	***Due Date***
0	**Project Management** : Management and coordination	T0 + 60
1	**Right time Analysis step** : Introducing a big data appliance	T0 + 6
2	**Extended Analysis & Machine Learning** : Algorithms dev.	T0 + 53
3	**Analytics applied to NGCTR-TD** : Analysis on all the flight data.	T0 + 60
4	**Learning the "data-driven" approach** : Training & Dissemination	T0 + 60

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title – Description***	***Type****	***Due Date***
D – 0A	Project Management	R ; D	Quarterly based
D – 1A	Infrastructural lab setup within the applicant site	HW	T0 + 3
D – 1B	Catalog of the most popular queries delivered upon masked data of Leonardo Helicopters	D	From T0 + 4 on monthly basis

Deliverables			
Ref. No.	***Title – Description***	***Type****	***Due Date***
D – 1C	Documentation & Training	R ; D	T0 + 6
D – 2A	Deployment of the LAB to Topic Leader site	HW	T0 + 6
D – 2B	Data ingestion	D	T0 + 7
D – 2C	Content detection algorithms developed	D	From T0 + 8 on monthly basis
D – 2D	Machine Learning predictive models developed	D	From T0 + 10 on monthly basis
D – 2E	Documentation & Training	R ; D	T0 + 53
D – 3A	Data ingestion of NGCTR-TD time hystories	D	T0 + 54
D – 3B	Real time upload/update of new NGCTR-TD flights	D	T0 + 55
D – 3C	Catalog of the most popular queries delivered	D	T0 + 55 on monthly basis
D – 3D	Content detection algorithms developed	D	T0 + 56 on monthly basis
D – 3E	Machine Learning predictive models developed	D	T0 + 56 on monthly basis
D – 3F	Documentation & Training	R ; D	T0 + 58
D – 4A	Full set of documentation reviewed and delivered	R ; D	From T0 + 6 on WP basis
D – 4B	E-learning (Moodle based) documentation delivered	R ; D	From T0 + 6 on WP basis
D – 4C	Workshops performed on Topic Leader premises	R ; D	From T0 + 6 on WP basis
D – 4D	Training courses on Topic Leader premises performed	R ; D	From T0 + 6 on WP basis

Milestones (when appropriate)			
Ref. No.	***Title – Description***	***Type****	***Due Date***
M1	WP1 LAB setup to Applicant site	HW	T0 + 3
M2	WP1 Right Time Analysis	R ; D	T0 + 6
M3	WP2 LAB move to Topic Leader	HW	T0 + 6
M4	WP1 Acceptance test	R ; D	T0 + 7
M5	WP2 Extended Analysis & Machine Learning	R ; D	T0 + 54
M6	WP2 Acceptance test	R ; D	T0 + 12 on half year basis
M7	WP3 Analytics applied to NGCTR-TD	R ; D	T0 + 60
M8	WP3 Acceptance test of development	R ; D	T0 + 58
M6	WP4 Learning the “data-driven” approach	R ; D	T0 + 60

4. Special skills, Capabilities, Certification expected from the Applicant(s)

The Applicant shall have proven capabilities and skills as per the following list:

- Technology in the big data ecosystem (Hadoop, spark, R language)
- Machine Learning, Data Mining, Advanced Analytics
- AI algorithms (Neural network, Decisional tree, ….)
- Signal processing (FFT, wavelet, …)
- Math & Statistics

5. Abbreviations

NGCTR	Next Generation Civil Tilt Rotor
NGCTR TD	Next Generation Civil Tilt Rotor Technology Demonstrator
IoT	Internet of Things
AI	Artificial Intelligence
AR/VR	Augmented Reality/Virtual Reality
TH	Time Histories
SDM	Simulation Data Management
ETL	Extract, Transform, Load
ML	Machine Learning
FTE	Full Time Equivalent

II. JTI-CS2-2018-CFP08-FRC-01-19: Certification by Simulation for Rotorcraft Flight Aspects

Type of action (RIA/IA/CSA)	IA		
Program Area	FRC		
(CS2 JTP 2015) WP Ref.	WP 1.1		
Indicative Funding Topic Value (in k€)	3000		
Topic Leader	Leonardo Helicopters	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	36	**Indicative Start Date (at the earliest)** [1]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CFP08-FRC-01-19	**Certification by Simulation for Rotorcraft Flight Aspects (CSRFA)**
Short description	
The aim of this topic is to bring together, the rotorcraft industry (represented by LH), the certification authority (represented by EASA) and simulation excellences (simulation industries/research centres/academia) to define a virtual certification process for rotorcraft flight aspects that improves and standardizes the current case-by-case approach and brings it to a quality level acceptable to the certification authority, thus facilitating the certification of future rotorcraft while improving safety, gaining insight into design and reducing program costs and environmental impacts.	

Links to the Clean Sky 2 Programme High-level Objectives[45]				
This topic is located in the demonstration area:	Enabling Technologies			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Next-Generation Tiltrotor			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☐	☐	☐	☒	☒

[1] The start date corresponds to actual start date with all legal documents in place.

45 For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

The advantage of simulation can be in general seen from three points of view:

- safety;
- economy;
- effectiveness.

During the development of a new rotorcraft, the execution of every manoeuvre has in principle a risk; while this is extremely small and acceptable for operative conditions, it can increase considerably in case of emergency conditions testing. With this respect, simulation can definitely guarantee much more safety, directly by providing an alternative to the specific critical test point and, indirectly, by reducing the number of flight hours. The reduction of flight hours has the additional benefit of reducing program costs and pollutants emission. Additionally, simulation can be in general more effective than real flight testing: in fact, the possible number of repetitions, interruptions, variations of a case of interest increases the insight into the phenomena.
These advantages can only be obtained at the cost of the availability of a validated simulation model, and an adequate simulation facility.
To capture the real rotorcraft behaviour as function of the flight conditions, the model will have to heavily rely on an accurate representation of the physical phenomena (physics based modelling), respecting on the other hand the complexity limits imposed by the real-time requirements.
The facility has also important requirements: in particular for complex manoeuvres with pilot in the loop, the level of the cues provided is very important and should be the best compromise between effectiveness and cost. So in most cases a fixed base simulator can provide sufficient cues avoiding the cost and the complexity of a motion base; audio cues provide important awareness to the pilot; attention must be posed to the mechanical characteristics of the inceptors, combining, in case of re-configurable simulators, accuracy with flexibility; the instrumentation plays also an important role and is relatively easy to be implemented using commercial hardware and software.
Simulation is going to be used more and more for design and certification. LH has been recently involved in some specific cases of certification by simulation (ref. -, -, - and Figure 7):

- power-off landing simulation;
- tail rotor loss of effectiveness simulation.

EASA is keen to explore this thematic area (ref. -) and simulation industries, research centres and academia are constantly working to reduce the gap between simulation and flight by improving simulation models and simulator cueing systems (ref. -, -, -, -, -, -, -, -).

The aim of this topic is to bring together, the rotorcraft industry (represented by LH), the certification authority (represented by EASA) and simulation excellences (simulation industries/research centres/academia) to define a virtual certification process that standardizes the current case-by-case approach and brings it to a quality level acceptable to the certification authority, thus facilitating the certification of future rotorcraft while improving safety, gaining insight into design and reducing program costs and environmental impacts.
In more detail, the research activity shall:

- identify, together with the certification authority, the areas of the certification process of rotorcraft flight aspects that can be substituted/complemented/supported by simulation;
- define guidelines, approved by the certification authority, for acceptable CSRFA simulation models fidelity;

- define guidelines, approved by the certification authority, for acceptable CSRFA simulator cueing systems fidelity.

The research shall address helicopters and tilt-rotors as well and apply the CSRFA guidelines to the Next Generation Civil Tilt Rotor Technology Demonstrator (NGCTR-TD) and the NGCTR New Tilt Rotor Concept (NGCTR-NTC), considered significant test benches due to their innovative configuration and the complexity of the flight aspects involved.
The project shall use the simulation models and the simulation facility of LH (improved/upgraded in order to support the research activity) and as much as possible low cost COTS hardware and software to define a CSRFA guideline that is shared between the rotorcraft industry and the certification authority and that is competitive with the standard flight-based approach to maximise benefits for rotorcraft industries, especially smaller ones.
The guidelines shall also address the features a simulation model should have to be used to generate interim data for training flight simulators (ref. -).

Figure 7 – The simulation facility used for the referenced certification activities

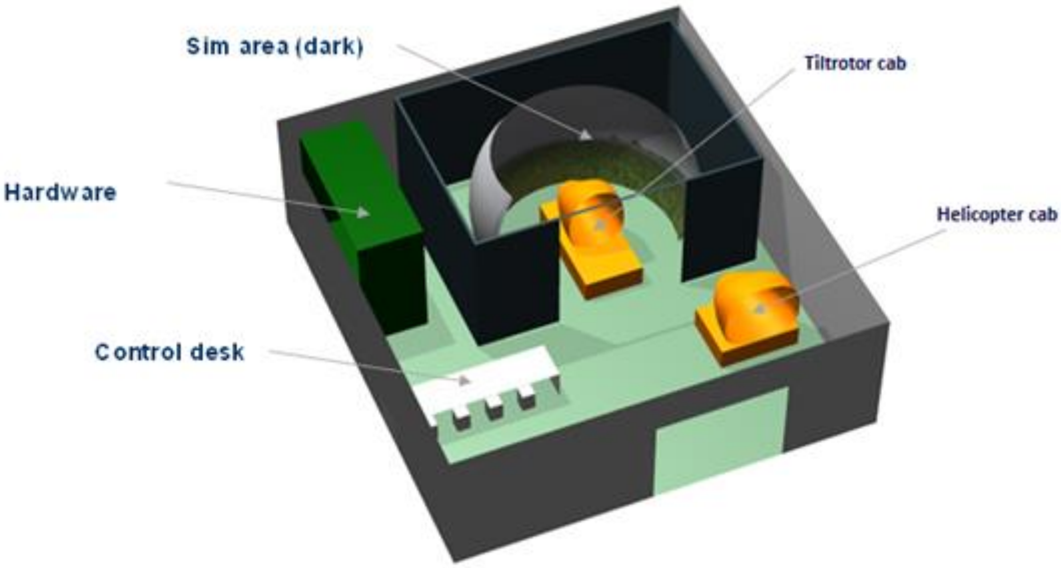


Figure 8 – Example of a possible layout of the upgraded simulation facility supporting the project

2. Scope of work

The Applicant shall structure its proposal into five main tasks as hereafter described:

- Task 0: Management and project coordination.
- Task 1: Identification of the CSRFA topics.
- Task 2: Definition of guidelines for simulation models fidelity.
- Task 3: Definition of guidelines for simulator cueing systems fidelity.
- Task 4: Discussion and synthesis of the guidelines.

Task 0: Management and project coordination

The Applicant shall manage and coordinate the project and shall involve the rotorctaft industry and the certification autority in its research activity in order to produce a shared guideline for CSRFA.

Inputs from Topic Leader:

- None.

Outputs from the Applicant:

- Project coordination. – T0 + 36

Task 1: Identification of the 'Certification by simulation' topics

The aim of this task is to identify the areas of the certification process that can be substituted/complemented/supported by simulation. The result shall be agreed upon by the rotorcraft industry and the certification authority.

The rotorcraft industry is particularly interested in:

- flight conditions at the boundary of the flight envelope (lateral flight, autorotation, vortex ring, high speed flight up to VD);
- failures (one engine failure, power-off landing, tail rotor loss);
- fast methods to simulate in real time complex aerodynamics environments like ship/obstacles/mountains airwakes and aerodynamic interference phenomena between rotors, airframe and wing.

Inputs from Topic Leader:

- List of the topics of the certification/qualification basis that the rotorcraft industry proposes to substitute/complement/support with simulation. – T0 + 1

Outputs from the Applicant:

- Finalized list of the topics of the certification/qualification basis that the rotorcraft industry and the certification authority agree can be complemented/substituted/supported by simulation. – T0 + 6

Task 2: Definition of guidelines for simulation models fidelity

The purpose of the simulation model is to reproduce in the most realistic possible way the behaviour of a real rotorcraft including the response to pilot inputs and atmospheric disturbances. This is done in general through physics based models, which should be as accurate as possible in reproducing the phenomena, the forces and ultimately the flight mechanics behaviour of the rotorcraft.

The aim of this task is to investigate the current status of simulation models fidelity and propose improvements to bring the models to the validation level required by the certification topics selected in Task 1.

The task shall focus on quantitative off-line validation of simulation models against flight data.

A set of metrics, agreed between the rotorcraft industry, the certification authority and the Applicant, shall be defined to measure the improvements of simulation models against flight test data. The metrics shall cover both time and frequency domain. The proposed improvements to the simulation models

shall be physics based and applicable to off-line as well as real-time simulations.
The task shall use as much as possible low cost COTS solutions for both hardware and software to give a competitive alternative to actual flight testing that maximises benefits for rotorcraft industries, especially smaller ones.
The modelling improvements shall be easily implementable in LH simulation tools through the activation of modelling options already available or the addition of appropriate components/modules without whole change of the current simulation software or simulation set-up. The inclusion of the modelling improvements in LH simulation tools shall follow LH guidelines.
The modelling improvements shall be implemented and tested in the LH simulation facility.
It is envisaged the need of the presence of the Applicant at LH facilities in Cascina Costa to use the current models and implement and test the improvements. This part of the activity will be helped by LH personnel.
The hardware and a time-unlimited license of the software bought/developed to meet the aim of this task shall remain property of LH.
A set of flight data (for both helicopter and tilt-rotors) will be provided by LH to test and measure (through the appropriate metrics) the modelling improvements.
Inputs from Topic Leader:

- Description of simulation model fidelity metrics currently used by LH. – T0
- Requirements for implementation in LH simulation tools. – T0
- Data set for simulation model fidelity improvement (for helicopters and tilt-rotors). – T0 + 3

Outputs from the Applicant:

- Preliminary set of metrics, agreed between the rotorcraft industry, the certification authority and the Applicant, for the evaluation of simulation modelling improvements. – T0 + 6
- Software and guidelines for physics based modelling improvements for CSRFA by simulation. – T0 + 24
- Final set of metrics, agreed between the rotorcraft industry, the certification authority and the Applicant, for the evaluation of the modelling improvements. – T0 + 24

Task 3: Definition of guidelines for simulator cueing systems fidelity
While for off-line simulations the quality of the simulation is function only of the simulation model fidelity, for real-time pilot-in-the-loop ones it is strongly influenced by the simulator cueing system: visual, aural, tactile and motion cues.
The senses the pilot uses to pilot a rotorcraft are:

- sight;
- hearing;
- touch / equilibrium.

The simulation tools used to provide the pilot with the correct sensations he feels when flying a rotorcraft are:

- visual system to simulate the out of the windows view (it can be made up for example by screen, projectors, image generator and related PCs);
- audio system to simulate the environmental noise generated by rotors, transmissions and engine and the aural warnings generated by the instrumentation (it can be made up for example by sound generator hardware and related PCs);
- motion system to simulate the accelerations and/or the vibrations experienced by the rotorcraft (it can be made up for example by a motion platform or a g-seat, a vibration platform and related PCs);
- inceptors to simulate the piloting tactile feeling and/or the force on the controls (it can be made up

by programmable control loading or force-feed-backed sticks).

The aim of this task is to investigate the current status of simulator cueing systems fidelity and propose improvements to bring it to the quality level required by the CSRFA topics selected in Task 1.

The task shall focus on qualitative pilot-in-the-loop validation of simulator cueing systems.

A set of metrics, agreed between the rotorcraft industry, the certification authority and the Applicant, shall be defined to measure the improvements of each element of the simulator cueing system.

The task shall use as much as possible low cost COTS solutions for both hardware and software to define a competitive alternative to actual flight testing to maximise benefits for rotorcraft industries, especially smaller ones.

The simulation facility at LH facilities in Cascina Costa shall be upgraded and used to perform this research activity on simulator cueing systems (visual, sound, motion and tactile cues); improvements shall also be applied and evaluated in the same simulation facility. The improvements to the LH simulation facility shall be approved by LH.

It is envisaged the need of the presence of the Applicant at LH facilities in Cascina Costa to use the current simulator set-up and implement and test the improvements. The activity will be helped by LH personnel.

LH will provide availability of test pilots to evaluate the improvements.

Since cockpit geometry and shape impacts the following piloting tasks:

- flight in general (affected by pilot control geometry and ergonomics);
- vertical take-off and landing manoeuvres (affected by outside visibility);
- instrument flight (affected by cockpit layout and panels)

It is envisaged the need of one cockpit for helicopters and one cockpit for tilt-rotors to be used interchangeably in the same simulation theatre.

The improvements to the simulation facility shall be done in two steps:

- initial:
  - upgrade of visual hardware (new screen, pcs and additional projectors) to improve visual cues;
  - refurbishment of current helicopter cabin to: enhance fidelity of controls (by improving the kinematic links between control loadings and pilot controls); remove the interference with visual; add wheels and appropriate cable connectors to allow interchangeability of cabins;
- final: implementing the tilt-rotor cabin and the improvements to the simulator cueing systems resulting from the research activity.

The hardware and a time-unlimited license of the software bought/developed to meet the aim of this task shall remain property of LH.

<u>Inputs from Topic Leader:</u>

- Description of simulator and cueing systems currently used in LH simulator (software and hardware). – T0

<u>Outputs from the Applicant:</u>

- Initial simulator upgrade necessary for the execution of the project. – T0+6
- Simulator hardware and improvements to define guidelines for simulator cueing systems fidelity. – T0 + 30
- Guidelines for simulator cueing systems for CSRFA. – T0 + 30

<u>Task 4: Discussion and synthesis of the Guidelines</u>

The effectiveness of simulation as substitute of flight testing for specific topics will be evaluated in Tasks 2 and 3 by taking already flying helicopters and tilt-rotors as test benches.

The CSRFA guidelines thus defined shall be applied in this task to the NGCTR-TD and the NGCTR-NTC.

The result of the task shall be a guideline for CSRFA agreed and shared between the rotorcraft industry and the certification authority. The guidelines shall also address the features a simulation model should have to be used to generate interim data for training flight simulators (ref. -).

Inputs from Topic Leader:

- None.

Outputs from the Applicant:

- Simulation results when applied to certification tasks suitable for the CSRFA approach. – T0 + 36
- Guidelines for CSRFA for the rotorcraft industry and the certification authority. – T0 + 36
- Results of the application of CSRFA guidelines to the NGCTR-TD and the NGCTR-NTC. – T0 +36

Tasks		
Ref. No.	Title - Description	Due Date
0	Management and project coordination	T0 + 36
1	Certification by simulation topics	T0 + 6
2	Definition of guidelines for simulation models fidelity	T0 + 24
3	Definition of guidelines for simulator cueing systems fidelity	T0 + 30
4	Definition of guidelines for CSRFA for the rotorcraft industry and certification authorities	T0 + 36

References

- Bianco Mengotti, Ragazzi, Del Grande, Cito, Brusa Zappellini - *AW189 Engine-Off-Landing Certification by Simulation*, 2016 American Helicopter Society Forum.
- Bianco Mengotti - *The Advantages of Virtual Engineering in the Rotorcraft Flight Mechanics Design Process*, 2016 Liverpool Rotorcraft Virtual Engineering Conference.
- Ragazzi, Bianco Mengotti, Sabato, Afruni, Hyder - *AW169 Loss of Tail Rotor Effectiveness Simulation*, 2017 European Rotorcraft Forum.
- *M.O.C. EASA-CS2JU*, November 2016.
- Jones, White, Fell, Barnett - *Analysis of Motion Parameter Variations for Rotorcraft Flight Simulators, 2017* American Helicopter Society Forum.
- He, Syal, Tischler, Juhasz - *State-Space Inflow Model Identification from Viscous Vortex Particle Method for Advanced Rotorcraft Configurations, 2017* American Helicopter Society Forum.
- Dalmeijer, Miletović, Stroosma, Pavel - *Extending the Objective Motion Cueing Test to Measure Rotorcraft Simulator Motion Characteristics, 2017* American Helicopter Society Forum.
- Crozon, Steijl, Barakos - *Helicopter CFD Coupled with Flight Mechanics - Current Status and Future Perspectives,* 2016 Liverpool Virtual Engineering Conference.
- Smith, Jacobson, Afman - *Certification of Computational Fluid Dynamics as Numerical Experiments,* 2016 Liverpool Virtual Engineering Conference.
- Du Val, He – *FLIGHTLAB: A Suite of Rotorcraft Virtual Engineering Tools,* 2016 Liverpool Virtual Engineering Conference.
- Masarati, Zanoni, Quaranta - *Piloted Flight Simulation Using General-Purpose Multibody Dynamics,* 2016 Liverpool Virtual Engineering Conference.
- STO-TR-AVT-296 - *Rotorcraft Flight Simulation Model Fidelity and Improvement – NATO Research group draft report*
- CS-SIMD, Certification Specifications and Guidance Material for Simulator Data, 2014

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, SW = Software, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D - 1	CSRFA list of topics.	R	T0 + 6
D - 2	Simulator initial upgrades for CSRFA research installed at LH facilities.	HW	T0 + 6
D - 3	Simulation modelling software improvements implemented/activated in LH simulation tools.	SW	T0 + 24
D - 4	Guidelines for CSRFA modelling.	R	T0 + 24
D - 5	Simulator for CSRFA research installed at LH facilities.	HW	T0 + 30
D - 6	Guideline for CSRFA simulator cueing systems.	R	T0 + 30
D - 7	CSRFA guidelines applied to the NGCTR-TD and the NGCTR-NTC.	R	T0 + 36
D - 8	Guidelines document for CSRFA.	R	T0 + 36

Milestones (when appropriate)			
Ref. No.	***Title – Description***	***Type****	***Due Date***
M1	Proposal for LH simulator initial upgrades for CSRFA research accepted by LH.	R	T0 + 2
M2	CSRFA list of topics defined.	R	T0 + 6
M3	Simulator initial upgrades for CSRFA research installed at LH facilities.	HW	T0 + 6
M4	Proposal for simulation modelling software improvements implemented/activated in LH simulation tools.	R	T + 20
M5	Simulation modelling software improvements implemented/activated in LH simulation tools.	SW	T0 + 24
M6	Proposal for simulator upgrades for CSRFA research accepted by LH.	R	T + 26
M7	Simulator for CSRFA research installed at LH facilities.	HW	T0 + 30
M8	Guidelines for CSRFA defined.	R	T0 + 36

4. Special skills, Capabilities, Certification expected from the Applicant(s)

The Applicant shall have capabilities and skills in each of the specific areas of this Topic, in particular:

- Rotorcraft Certification.
- Rotorcraft physics-based modelling.
- Rotorcraft off-line and pilot-in-the loop simulation.
- Flight simulation technologies.
- Flight simulator software and hardware design, integration and installation.
- Management of projects at international level.

The Applicant shall involve the rotorcraft industry (represented by LH, topic leader) and the certification autority (represented by EASA) in the research activity in order to produce a shared guideline for CSRFA. Flight data shall be restricted and the Appicant shall sign a data non-disclosure agreement for their usage.

5. Abbreviations

COTS	Commercial Off-The-Shelf
CSRFA	Certification by Simulation for Rotorcraft Flight Aspects
EASA	European Aviation Safety Agency
LH	Leonardo Helicopters
NGCTR	Next Generation Civil Tilt Rotor
NGCTR TD	Next Generation Civil Tilt Rotor - Technology Demonstrator
NGCTR NTC	Next Generation Civil Tilt Rotor – New Tilt Rotor Concept
NVG	Night Vision Goggles
PCS	Personal Computers
VD	Design Speed

III. JTI-CS2-2018-CFP08-FRC-01-20: Design, development and flight qualification of a supercritical composite shaft drive line for tiltrotor main drive system

Type of action (RIA/IA/CSA)	IA		
Programme Area	FRC		
(CS2 JTP 2015) WP Ref.	WP1.3		
Indicative Funding Topic Value (in k€)	400		
Topic Leader	Leonardo Helicopters	Type of Agreement	Implementation Agreement
Duration of the action (in Months)	42	Indicative Start Date (at the earliest)[46]	Q1 2019

Topic Identification Code	Title
JTI-CS2-2018-CFP08-FRC-01-20	Design, development and flight qualification of a supercritical composite shaft drive line for tiltrotor main drive system
Short description (3 lines)	
The objective is to design a supercritical composite drive shaft line for a tilt rotor drive system, including the design, development, manufacturing, testing and flight qualification activities of its components. The drive shaft line architecture should conceive suitable supports (i.e bearings), should be able to guarantee a proper damping behaviour into the operating range (i.e. damper elements) and should cope with angular deflections, mainly due to wing bending (i.e. flexible couplings). The system should be equipped with dedicated innovative monitoring and diagnostic system able to properly and timely detect possible damages of the whole drive line.	

Links to the Clean Sky 2 Programme High-level Objectives[47]				
This topic is located in the demonstration area:	Enabling Technologies			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Next-Generation Tiltrotor			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☐	☐	☐	☒	☒

46 The start date corresponds to actual start date with all legal documents in place.
47 For further info see Chapter 1 “Introduction to the Programme Scene Setter / Objectives” with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

Within the scope of Clean Sky 2 Fast Rotorcraft (FRC) Innovative Aircraft Demonstrator Platform (IADP) framework, the Next Generation Civil Tiltrotor project (NextGenCTR) is aimed at designing, building and flying a technology demonstrator to validate an innovative tiltrotor concept, the configuration of which will go beyond current architectures of this type of aircraft. In summary, this concept will involve tilting prop-rotors mounted in fixed nacelles at the tips of relatively short wings, consisting of a fixed inboard and a tilting outboard portion next to the nacelle. The tilting portion will move in coordination with the prop-rotors, to minimize rotor downwash impingement in hover and increase efficiency. The demonstration activities of the NextGenCTR IADP aim at validating the proposed architecture, technologies, systems and operational concepts to prove significant improvements with respect to the current state-of-the-art for tiltrotor concepts. The project will also allow developing substantial R&T activities to increase the know-how about tiltrotors and to generate steady, high volume research and innovation activities comparable to that of well proven helicopter platforms.

In addition to the IADP for complex vehicle configurations, the Clean Sky 2 project defines also the so-called Integrated Technology Demonstrators (ITDs) that will accommodate the main relevant technology streams for all air vehicle applications. They allow the maturing of verified and validated technologies from their basic levels to the integration of entire functional systems. Thus the ITDs can cover quite a wide range of technology readiness levels.

The Call proposal from applicants for the role of Partner, desribed in the present document, is part of the NextGenCTR FRC IADP and in particular is managed within the Workpackage 1. 3 *"*Highly Reliable, Safe & Environmentally Friendly Drive System". Aim of this WP is the design, manufacturing and testing at component level of an innovative drive system for the NextGenCTR. The research targets safe and reliable design, low environmental impact, low production and operational costs. In particular, the object of the Call is the design of a supercritical composite shaft drive line architecture.

As known, the main purpose of a drive system is to supply the power generated by the engines to both rotors and additional power take-off, such as accessories (i.e generators hydraulic and lubrication pumps, etc.). The drive system also provides synchronization of the proprotors and fulfils the need of single engine operation of the whole proprotor system by means of a dedicated interconnecting driveshaft line which basically connects mechanically the two nacelles, where both fixed and tilting gearboxes are installed. In fact in case of one engine failure the interconnecting driveshaft system transmits power to the side of the failed engine for continuing flight and guaranteeing in the meantime the synchronization of the two rotors.

The present document describes the main activities to be performed, the general time scheduling, the expected results and deliverable as well as the general requirements that JU shall consider for the selection of the appropriate Partner(s).

2. Scope of work

The activity, object of this Call is aimed to design, manufacture and test a flight cleared supercritical composite drive shaft line architecture that shall include novel sensors able to properly monitor the system during its life cycle.

Current state-of-the-art rotorcraft drivelines are made up of relatively rigid segmented metal (i.e. titanium and/or aluminium) shafting, linked by flexible couplings and hanger bearings. This design

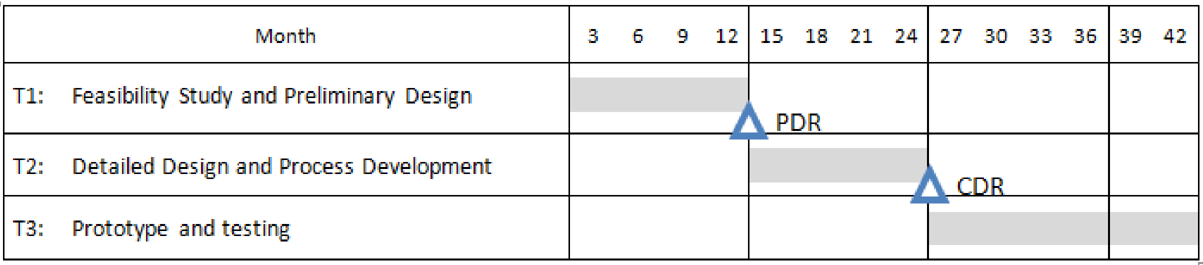
transmits the power along the driveline while accommodating the misalignment caused by the rotorcrafts structural deflections. While this type of design can transmit power and torque effectively, the use of mechanical components, such as flexible couplings and bearings, significantly affects the weight of the driveline, the system reliability, and both manufacturing and maintenance costs. As known, the driveline can be designed to be subcritical or supercritical by changing the number of shaft segments; larger number of segments in general means higher driveline natural frequencies. With sufficient number of shaft segments, the lowest natural frequency can be designed higher than the operating speeds. This subcritical design avoids spinning-up through resonant frequencies and has lower dynamic loads on the mechanical components. Although a subcritical shaft design has its advantages, it employs larger number of mechanical components than a supercritical driveline. Due to these reasons the supercritical shafting can increase reliability and reduce weight significantly. Nevertheless during the starting and stopping of the rotorcraft, supercritical drivelines go through resonant frequencies. This causes the loads on the mechanical components to be very large. To reduce the effects of this problem the current supercritical designs include vibration dampers. Generally speaking the disadvantage of the dampers is that their performance is limited to the neighborhood of resonant frequencies. Since the operating speed is designed to be as far from resonances as possible, the excitations caused from imbalance in the operating speed is damped poorly with the passive system. In the supercritical design, the resonant deflections and loads are very sensitive to the imbalance of the driveline. The manufacturing cost of these shafts is increased significantly by the tolerance requirements, which keeps the imbalance in control.
The use of composite material technology can allow to realize non–isotropic shaft, tailoring the shaft design such that it can withstand the torque load while having proper flexible bending properties: the ply orientations in the composite can make the shaft stiffer in torsion than in bending; thus, coupling these properties with use of suitable active bearings to control the stability and vibration of the highly flexible driveline, the current state-of-the-art concept of traditional drive shaft designs can be improved, overcoming the highlighted drawbacks.

The main topics to be investigated during the design phase are:

- Capability of properly transmitting design torque not operating continuously at a critical whirling speed;
- Capability of accommodating flexural curvature to allow for the effects of wing deflection and possible misalignment of the support bearings;
- Light and compact design (driveline architecture minimizing the total weight as a function of operating speed of the system);
- Usage and health monitoring system performances
- Maximization of the safety and reliability of the system;
- Maintainability and inspectability of the components;
- Environmental friendly and sustainable life and production cycle, in accordance with the general rules of Clean Sky 2 programme.

Tasks		
Ref. No.	***Title – Description***	***Due Date*** [T0 + mm]
T1	**Feasibility Study and Preliminary Design** System architecture concept definition and conception of the monitoring system preliminary design. Analytical and/or experimental critical function characteristic proof of concept. Interface drawing and detailed study execution. Basic manufacturing implications identification	T0+12
T2	**Detailed Design and Process Development** Technical drawings and production cycles execution for each components. Definition of the optimized manufacturing processes, quality and inspection procedures to guarantee the fit, form and functional requirements fulfillment. Manufacturing proof of concept development.	T0+27
T3	**Prototype and testing** Supply chain and quality assurance assessment for prototype production in a pilot line environment. Manufacturing of an appropriate number of specimens and parts. Test at component and/or assembly level to guarantee the design requirements fulfillment and support to the full-scale test phase aimed to achieve the flight clearance of the NextGenCTR demonstrator. Engineering cost and industrial capability assessment to enable the production phase start-up.	T0+42

Task Breakdown and Planning



3. Major deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	***Title - Description***	***Type***	***Due Date***
T1.D1	Detailed Study of the system	Document	T0+12
T1.D2	System Requirement Review meeting MoM	Document	T0+3
T1.D3	3D CATIA Model of the items and digital 3D Mock-up	Document	T0+12
T1.D4	Interface drawings	Document	T0+12
T1.D5	Preliminary Design Review meeting MoM	Document	T0+12
T2.D1	Technical drawings (component and assembly level)	Document	T0+23
T2.D2	Production cycles (component and assembly level)	Document	T0+23
T2.D3	Structural substantiation of the new design proposals	Document	T0+21
T2.D4	Acceptance and inspection criteria	Document	T0+21

Deliverables			
Ref. No.	***Title - Description***	***Type***	***Due Date***
T2.D5	Preliminary test phase review meeting MoM	Document	T0+18
T2.D6	Critical Design Review meeting MoM	Document	T0+24
T3.D1	Prototypes	Production	T0+30
T3.D2	Test Plan Proposal	Document	T0+24
T3.D3	Test Phase Review meeting MoM	Document	T0+28
T3.D4	Tests Readiness Review meeting MoM	Document	T0+30
T3.D5	Test Report	Document	T0+42
T3.D6	Drive line Production Set	Production	T0+42
T4.D7	Flight Clearance Document	Document	T0+42

Milestones			
Ref. No.	***Title - Description***	***Type***	***Due Date***
T1.M1	Detail study of the system availability	Documents	T0+9
T1.M2	System Requirement Review meeting	Meeting	T0+3
T1.M3	Preliminary Design Review meeting	Meeting	T0+12
T2.M1	Technical drawings availability	Documents	T0+23
T2.M2	Production cycles availability	Documents	T0+23
T2.M3	Preliminary Test Phase Review meeting	Meeting	T0+18
T2.M4	Critical Design Review meeting	Meeting	T0+24
T3.M1	Prototypes availability	Production	T0+30
T3.M2	Test Phase Review meeting	Meeting	T0+28
T3.M3	Tests Readiness Review meeting	Meeting	T0+30
T3.M4	Structural / Functional Tests execution	Test	T0+40
T3.M5	Components availability for NextGenCTR test phase	Production	T0+42
T3.M6	Flight clearance	Documents	T0+42

4. Special skills, Capabilities, Certification expected from the Applicant(s)

The Applicant(s) (company or consortium) shall describe its experience/capacities in the following subjects:

- Experience in design, sizing and manufacturing composite shaft
- Experience in design and testing of usage and health monitoring systems
- Tools for design and stress analysis. Experience in the aeronautical business sector is preferred (i.e. CATIA v5, NASTRAN or equivalent)
- Proven capability and experience in manufacturing and testing of mechanical components such as rotating drive shaft, bearing, flexible coupling and sensors. Experience in aeronautical business sector is preferred
- Experience with TRL Reviews in research and manufacturing projects. Experience in aeronautical business sector is preferred
- Experience in integration multidisciplinary teams in concurrent engineering. Experience in aeronautical business sector is preferred
- Experience in technological research and development for innovative processes
- Participation in international R&T projects cooperating with industrial partners, institutions, technology centres and universities.

- Proven experience in collaborating with reference aeronautical companies Research and Technology programs
- Capability of evaluating the experimental results versus the technical proposals
- Capability of evaluating results in accordance to Horizon 2020 environmental and productivity goals following Clean Sky 2 Technology Evaluator rules and procedures.

Manufacturing capability and equipment:

Following list gives an overview of possible and well known manufacturing equipment but can be appended by Partner(s) approved technologies:

- Facilities and machines for part roughing and grinding, heat treatment and hard coating, if any;
- Non destructive inspection capabilities and required equipment (i.e. eddy current, ultrasonic, X-ray, Tomography, magnetic, nital etch, dimensional inspection systems);
- Testing laboratory (availability of dedicated bench test rigs for functional and structural tests)

Certification (preferred):

- Design Organization Approval (DOA).
- Product Organization Approvals (POA).
- Quality System international standards (i.e. EN 9100:2009/ ISO 9001:2008/ ISO 14001:2004)
- Qualification as strategic supplier of structural test on aeronautical elements.

CAD Data management:

CATIA V5 R22 will be used for drawing, 3D model and data management.

Note:

Detailed Quality Assurance Requirements for Supplier as well as Intellectual Property management will be provided and detailed to the selected Partner(s), following the signature of dedicated NDA (or equivalent commitment), during the partner agreement phase.

5. Abbreviations

CDR	Critical Design Review
CS2	Clean Sky 2
DAL	Design Assurance Level
DDP	Declaration of Design and Performance
DOA	Design Organization Approval
FRC	Fast RotorCraft
IADP	Innovative Aircraft Demonstrator Platform
ITD	Integrated Technology Demonstrator
JU	Joint Undertaking
MoM	Minute of Meeting
NDA	Non Disclosure Agreement
NGCTR	Next Generation Civil TiltRotor
PDR	Preliminary Design Review
PR	Problem Report
SOF	Safety of Flight
SRR	System Requirement Review
TBC	To Be Confirmed
TBD	To Be Defined
TRL	Technical Readiness Level
TRR	Test Readiness Review
TTL	Technical Task Leader
WAL	Work Area Leader

IV. JTI-CS2-2018-CFP08-FRC-01-21: Development of integrated engine air intake and protection systems for Tilt Rotor

Type of action (RIA/IA/CSA)	IA		
Programme Area	FRC		
(CS2 JTP 2015) WP Ref. 1.5	WP 1.5		
Indicative Funding Topic Value (in k€)	2500		
Topic Leader	Leonardo Helicopters	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	60	**Indicative Start Date (at the earliest)**[48]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CFP08-FRC-01-21	**Development of integrated engine air intake and protection systems for Tilt Rotor**
Short description	
The activity involves the design, manufacturing, testing and flight qualification of a complex air intake, integrating a removable anti-ice system, integrated barrier filter, and a compressor washing system, inclusive of intake performance validation and associated impact on NGCTR Technology Demonstrator.	

Links to the Clean Sky 2 Programme High-level Objectives[49]				
This topic is located in the demonstration area:	Next-Generation Civil Tiltrotor			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Next-Generation Tiltrotor			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☐	☐	☐	☒	☒

[48] The start date corresponds to actual start date with all legal documents in place.

[49] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

In the framework of Clean Sky 2 FRC IADP, the present Call requires Partner(s) (company or consortium) to design, develop, manufacture, test and qualify air intake protection systems for the two engines of Next Generation Civil Tilt Rotor.

2. Scope of Work

The NGCTR engine air intake protection system shall be designed in such a way that the main intake functionalities and performances are guaranteed throughout the anticipated flight envelope, whilst ensuring adequate safety levels and environment protection for the engines.

The detailed requirements for system interfaces with the aircraft and system performance (e.g. pressure loss limit, engine intake geometry, filter space claim, flow distorsion limits, weight, roughness) shall be part of dedicated discussion with selected Partner(s), following the signature of dedicated NDA or equivalent commitment.

The air intake shall include protection systems for complete engine inlet protection. A de-ice or anti-ice system, shall be designed to remove/prevent ice formation in the engine inlet areas. In addition, the air intake shall integrate a barrier filter, in order to reduce erosion of engine components, prevent damage and extend engine life when installed on tiltrotor.

The intake de-ice/anti-ice system shall be designed in order to comply with intentional flights in icing conditions requirements, while actual development and manufacturing can be downscaled to the level of icing condition as per NGCTR TD flying activities requirements, to be detailed as part of the System Definition phase.

The integrated barrier filter shall guarantee high particle separation efficiency (ideally more than 99% capture efficiency), low pressure drop and an ample filtration area. The filter shall be capable of filtering particles and moisture considering the effects of harsh environmental conditions such as the salty desert, and be compatible with the other intake integrated systems (de-ice/anti-ice and engine compressor washing).

The typical filter maintenance/cleaning burden, imposed by the moisture accumulation (i.e.: pressure drop) throughout its operating life, shall be avoided/limited. The Partner shall perform an assessment, as part of the Trade Off phase, about the state-of-the-art barrier filters. In particular, a barrier filter with self-cleaning capability (fit and forgets approach) and/or on-wing fast cleaning systems (no filter removal required) shall be investigated. This is expected to guarantee stable filter characteristics during aircraft operations with a reduction of the associated maintenance requirements. The filter shall be designed to withstand a combination of light cleaning cycles (either self or on-wing cleaning) and thorough cleaning cycles, according to filter on-condition characteristics based on pressure drop readings and consumed life.

The pressure drop across the filter shall be monitored during the flight. A bypass mechanism shall be activated to provide an adequate flow to the engine, if the pressure differential across the filter exceeds a predetermined value, or if filtering means are not deemed necessary in predetermined flight conditions (high altitude level flights).

The de-ice/anti-ice and filtering protection systems and associated mechanisms shall be removable.

An integrated engine compressor washing shall also be included, according to the flowing and pressure requirements that will be defined during the System Definition phase, taking into account the other intake protection systems location and requirements.

Easy accessibility for inspection/maintenance shall be considered.

A dedicated study shall be conducted during the Trade Off phase in order to define an intake concept able to maximize the integration of the intake sub-systems, and the compliance with aircraft operational requirements.

Following system concept definition according to above Trade Off results, design consolidation and actual manufacturing for intake development and flight clearance qualification is requested.

As a reference, the following main characteristics shall be considered:

- engine mass flow rate in the range of 3.27÷6.91 kg/s;
- Operate altitude range of -2000ft/25000ft;
- high operating speed, ~300kt;
- Operating temperature range of -55 °C/+55°C;
- Soak (non-operating/storage) temperature range of -60°C/+85°C.

A computational fluid dynamic analysis of the entire air intake system (protections included) shall be carried out, to investigate, develop and optimize the best air particle separation solution and anti-ice system, during both airplane and helicopter mode. The simulations shall be used to ensure that an adequate stable flow of clean air is provided to the engine. Moreover, the Partner shall verify that the engine flow distortions caused by air intake with integrated barrier filter and anti-ice system are acceptable. The operating and boundary conditions to be included in the CFD analysis shall be defined by Leonardo Helicopters, such as but not limited to hovering/level flight, velocity, proprotor flux, ground effect.

In addition, system modelling shall be developed in order to predict the performance in terms of pressure drop and particle separation over time, at different speed and conditions.

The air intake system (protections included) shall be tested, as a minimum, against bird strike damage and vibrations as per DO-160, and inadvertent icing conditions as per CS 29.1093 b1) i & 29.1093 b2).

The complete list of validation tests (e.g. environmental tests, endurance cycle, bypass) shall be discussed with Leonardo Helicopters, as well testing conditions and requirements.

At the end of the design and development phase, all the evidences necessary to achieve system flightworthiness qualification shall be provided to Leonardo Helicopters, together with 2 production shipsets (LH + RH intakes) and spare parts for flight test activity on NGCTR Technology Demonstrator.

The design, the development and the qualification of the system shall follow the standard procedures for aeronautic equipment, aiming to obtaining Experimental Flight Approval (EFA) for the installed item.

In-service life requirement (TBO) will be discussed during the negotiation phase.

The Partner shall guarantee consumable availability and technical support for the entire NGCTR TD flight test activity after the first flight qualification milestone completion.

Tasks		
Ref. No.	***Title - Description***	***Due Date*** [T0 + mm]
T01	System Definition(1)	T0
T02	Trade-off study results	T0 + 06
T03	Design Architecture Definition	T0 + 14
T04	Delivery of Design Documentation	T0 + 24
T05	Test Activity	T0 + 40
T06	System flight qualification	T0 + 60

(1): High-level System Requirements will be provided to the selected Partner(s), following the signature of dedicated NDA or equivalent commitment, as part of the technical discussions between the Partner(s) and Leonardo Helicopters that will take place after the selection phase (T0).

3. Major deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	***Title – Description***	***Type***	***Due Date*** [T0 + mm]
D01	Trade Studies Results Report	REPORT	T0 + 06
D02	Filter specifications	REPORT	T0 + 06
D02	Anti-Ice specifications	REPORT	T0 + 06
D03	Preliminary 3D models and layout drawing	CATIA FILES	T0 +14
D04	Development test plan (DP)	REPORT	T0 + 14
D05	Preliminary qualification program plan (QPP)	REPORT	T0 + 14
D06	Preliminary performance, safety/reliability and stress analysis	REPORT	T0 + 14
D07	Reliability and Failure Modes & Effects Analysis (FMEA)	REPORT	T0 + 24
D08	Failure Modes, Effect and Criticality Analysis (FMECA)	REPORT	T0 + 24
D09	Safety/Hazard Analysis	REPORT	T0 + 24
D10	EMC Analysis	REPORT	T0 + 24
D11	Stress Analysis	REPORT	T0 + 24
D12	Final 3D models and layout drawing	CATIA FILES	T0 + 24
D13	Final QPP	REPORT	T0 + 24
D14	Acceptance Test Procedures (ATP)	REPORT	T0 + 24
D15	Qualification Test Procedures (QTP)	REPORT	T0 + 24
D16	Qualification by Similarity and Analysis (QSAR)	REPORT	T0 + 40

Deliverables			
Ref. No.	***Title – Description***	***Type***	***Due Date*** [T0 + mm]
D17	Production and Spare Unit, and relevant Data Conformity Documentation	HARDWARE, REPORT	T0 +40
D18	Wind/Icing Tunnel, Bird Strike and Vibration Test Report	REPORT	T0 +40
D19	Acceptance and Qualification Test Reports	REPORT	T0 + 60
D20	Instruction for Continued Airworthiness	MANUAL	T0 + 60

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type***	***Due Date*** [T0 + mm]
M01	Kick-off meeting	DESIGN REVIEW	T0
M02	System Concept Review	DESIGN REVIEW	T0 + 06
M03	Preliminary Design Review	DESIGN REVIEW	T0 + 14
M04	Development unit ready to development tests	HARWARE AVAILABILITY	T0 + 24
M05	Critical Design Review	DESIGN REVIEW	T0 + 24
M06	First Article Inspection	DOCUMENT	T0 + 30
M07	Test Readiness Review	DESIGN REVIEW	T0 + 30
M08	Production units delivered to Leonardo Helicopters for flight tests	HARWARE AVAILABILITY	T0 + 40
M09	Flight Qualification Closure	DOCUMENT & DESIGN REVIEW	T0 + 60

4. Special skills, Capabilities, Certification expected from the Applicant(s)

The Applicant(s) shall own the following pedigree and special skills:

- Compliance to SAE AS9100.
- Experience of aeronautic rules, certification processes and quality requirements.
- Experience in design, validation, manufacturing and environmental/functional qualification of airborne equipment according to RTCA-DO-160
- Experience in research, development and manufacturing in the following technology fields:
- Conventional air intake system development for aircrafts
- Experience in the field of barrier filter production for aircrafts
- Well proven engineering and quality procedures capable to produce the necessary documentation and means of compliance to achieve the “Safety of Flight” with the applicable Airworthiness Authorities (FAA, EASA, etc.).
- Design Organization Approval (DOA) desirable.
- Shape, component design and structural analysis using CATIA v5 r22, NASTRAN, Matlab or equivalent softwares.
- Capacity to repair “in-shop” equipment due to manufacturing deviations.

Detailed Quality Assurance Requirements for Supplier will be provided to the selected Partner(s) following the signature of dedicated NDA or equivalent commitment.

5. Abbreviations

CFD	Computational Fluid Dynamics
EMC	Electromagnetic Compatibility
LH	Left Hand
NDA	Non-Disclosure agreement
NGCTR	Next Generation Civil Tiltrotor
RH	Right Hand
TBO	Time Between Overhaul

V. JTI-CS2-2018-CFP08-FRC-01-22: Engine exhaust wake flow regulator for Tilt Rotor

Type of action (RIA/IA/CSA)	IA		
Programme Area	FRC		
(CS2 JTP 2015) WP Ref. 1.5	WP 1.5		
Indicative Funding Topic Value (in k€)	1600		
Topic Leader	Leonardo Helicopters	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	60	**Indicative Start Date (at the earliest)**[50]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CFP08-FRC-01-22	**Engine exhaust wake flow regulator for Tilt Rotor**
Short description	
The activity involves the design, manufacturing, testing and flight qualification of an engine exhaust, integrating a variable geometry system for gas residual energy recovery and active engine bay cooling system, inclusive of exhaust performance validation and associated impact on NGCTR Technology Demonstrator.	

Links to the Clean Sky 2 Programme High-level Objectives[51]				
This topic is located in the demonstration area:	Enabling Technologies			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Next-Generation Tiltrotor			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☐	☐	☐	☒	☒

50 The start date corresponds to actual start date with all legal documents in place.

51 For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

In the framework of Clean Sky 2 FRC IADP, the present Call requires Partner(s) (company or consortium) to develop a variable geometry exhaust system for the two engines of tiltrotor.

2. Scope of work

The engine exhaust system shall have the unique ability to maximize the tiltrotor performance during both hovering and level flight conditions. To achieve this objective the Partner shall design an exhaust system with a variable geometry, able to manage residual gas energy conversion into thrust.

The exhaust system shall be designed in such a way that the main system functionalities and performances are guaranteed throughout the whole flight envelope, whilst ensuring adequate safety levels and environment protection.

The exhaust system shall integrate a two-position primary nozzle, capable of changing its throat area, during airplane mode flight. In particular:

- During helicopter-mode flight, the exhaust gasses must have minimal influence on proprotor air flux. Throughout this phase the nozzle shall have a configuration, such that exhaust gas residual energy is minimized.
- During airplane mode the exhaust gas residual energy shall be maximized and used to provide an additional thrust. This action is expected to yield a significant performance improvement.

The design of the exhaust system shall consider its effect on the associate tiltrotor interfaces, such as but not limited to:

- The exhaust gasses must not affect the fluid dynamics of the tail.
- The interference between exhaust gasses and proprotor flux shall be studied in order to limit noise emission.
- The effect of exhaust nozzle shape on engine bay ventilation, during all flight modes, including emergency conditions shall be investigated.

In particular, an innovative system for engine bay cooling shall be developed. The Partner shall investigate strategies to direct a secondary pressurized flow to the exhaust, in order to prevent the vortex formation due to primary-secondary flow mixing and increase the mass flow of cold air. This action is expected to increase engine power performance and reduce exhaust gas temperature. The balance between the benefits (gas cooling and vortex minimization) and the amount of compressed air required shall be analysed to guarantee an overall increase of engine power performance.

Considerations on material selection, geometry, operational characteristics shall be taken into account in the system design, according to aircraft performance optimization, as well safety-related implications (i.e. engine fire, flame containment, flammable fluel fire protection aspects).

The detailed system requirements shall be part of dedicated discussion with selected Partner(s), following the signature of dedicated NDA or equivalent commitment.

The two variable geometry exhaust systems of the engines shall be completely synchronous, to avoid any aircraft destabilization. A fail safe design shall be included, in order to achieve safe conditions without impact on aircraft stability.
A computational fluid dynamics analysis shall be carried out to support the entire design phase of the project and to investigate all of the aspects described above. Moreover, the impingement of exhaust hot gasses shall be studied.
Considering the high temperatures of exhaust gasses, a structural analysis to ensure functionality and stability of system structure and actuators shall be carried out. In particular, robust analysis/validation of exhaust system in conjunction with actual operating environment shall be performed.
The design phase shall include strategies to minimize weight.
The system and associated mechanism shall be removable to leverage flexibility of the NGCTR TD during experimental flight phase.
Easy accessibility for inspection/maintenance shall be considered.
Following system concept definition according to above requirements, design consolidation and actual manufacturing for exhaust development and flight qualification is requested.
A complete list of validation tests required (e.g. environmental tests, endurance) shall be discussed with Leonardo Helicopters, as well testing conditions and requirements, on the basis of proposed technology.
For some components (i.e. actuators) already developed technologies, specifically adapted to this system, could be used.
At the end of the design and development phase, all the evidences necessary to achieve system flightworthiness qualification shall be provided to Leonardo Helicopters, together with a production 2 shipsets (LH + RH) and spare parts for flight test activity on NGCTR Technology Demonstrator.
The design, the development and the qualification of the system shall follow the standard procedures for aeronautic equipment, aimed of obtaining Experimental Flight Approval (EFA) for the installed item.
Target TBO shall be part of a discussion with selected Partner.
The Partner shall guarantee consumable availability and technical support for the entire NGCTR flight test activity following the flight qualification milestone completion.

Tasks		
Ref. No.	***Title - Description***	***Due Date*** [T0 + mm]
T01	System Definition(1)	T0
T02	Trade-off study results	T0 + 06
T03	Design Architecture Definition	T0 + 12
T04	Delivery of Design Documentation	T0 + 24
T05	Test Activity	T0 + 40
T06	System flight qualification	T0 + 60

(1): High-level System Requirements will be provided to the selected Partner(s), following the signature of dedicated NDA or equivalent commitment, as part of the technical discussions between the Partner(s) and Leonardo Helicopters that will take place after the selection phase (T0).

3. Major deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	***Title – Description***	***Type***	***Due Date*** [T0 + mm]
D01	Trade Studies Results Report	REPORT	T0 + 06
D02	Preliminary 3D models and layout drawing	CATIA FILES	T0 + 12
D03	Development test plan (DP)	REPORT	T0 + 12
D04	Qualification program plan (QPP)	REPORT	T0 + 12
D05	Preliminary performance, safety-reliability, stress analysis.	REPORT	T0 + 12
D06	Reliability and Failure Modes & Effects Analysis (FMEA)	REPORT	T0 + 24
D07	Failure Modes, Effect and Criticality Analysis (FMECA)	REPORT	T0 + 24
D08	Safety/Hazard Analysis	REPORT	T0 + 24
D09	Stress Analysis	REPORT	T0 + 24
D10	Final 3D models and layout drawing	CATIA FILES	T0 + 24
D11	Acceptance Test Procedures (ATP)	REPORT	T0 + 24
D12	Qualification Test Procedures (QTP)	REPORT	T0 + 24
D13	Qualification by Similarity and Analysis (QSAR)	REPORT	T0 + 40
D14	Production and Spare Unit, and relevant Data Conformity Documentation	HARDWARE and REPORT	T0 +40
D15	Final Performance Analysis	REPORT	T0 +40
D16	Acceptance and Qualification Test Reports	REPORT	T0 + 60
D17	Instruction for Continued Airworthiness	MANUAL	T0 + 60

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type***	***Due Date*** [T0 + mm]
M01	Kick-off meeting	DESIGN REVIEW	T0
M02	System Concept Review	DESIGN REVIEW	T0 + 06
M03	Preliminary Design Review	DESIGN REVIEW	T0 + 12
M04	Development unit ready to development tests	HARWARE AVAILABILITY	T0 + 24
M05	Critical Design Review	DESIGN REVIEW	T0 + 24
M06	First Article Inspection	DOCUMENT	T0 + 30
M07	Test Readiness Review	DESIGN REVIEW	T0 + 30
M08	Production units delivered to Leonardo Helicopters for flight tests	HARWARE AVAILABILITY	T0 + 40
M09	Flight Qualification Closure	DOCUMENT & DESIGN REVIEW	T0 + 60

4. Special skills, Capabilities, Certification expected from the Applicant(s)

The Applicant(s) shall own the following pedigree and special skills:

- Compliance to SAE AS9100.
- Experience of aeronautic rules, certification processes and quality requirements.
- Experience in design, validation, manufacturing and environmental/functional qualification of airborne equipments, according to RTCA-DO-160
- Experience in research, development and manufacturing in the following technology fields:
  - Conventional exhaust system development for aircraft, helicopter or tiltrotors
  - Actuation systems
- Capability to perform bench testing of exhaust concept using engine cell or hot gas wind tunnel.
- Experience and capability to perform CFD simulations using integrated internal/external flow models to assess aircraft performance effects like: drag; exhaust gas impingement; engine bay pumping; and tail shake.
- Well proven engineering and quality procedures capable to produce the necessary documentation and means of compliance to achieve the "Safety of Flight" with the applicable Airworthiness Authorities (FAA, EASA, etc.).
- Design Organization Approval (DOA) desirable.
- Shape, component design and structural analysis using CATIA v5 r22, NASTRAN, Matlab or equivalent softwares.
- Capacity to optimize the HW and SW design and to analyze both simulation and experimental results to ensure that the various required performance goals are met.
- Capacity to repair "in-shop" equipment due to manufacturing deviations.

Detailed Quality Assurance Requirements for Supplier will be provided to the selected Partner(s) following the signature of dedicated NDA or equivalent commitment.

5. Abbreviations

CFD	Computational Fluid Dynamics
LH	Left Hand
NDA	Non-Disclosure agreement
NGCTR	Next Generation Civil Tiltrotor
RH	Right Hand
TBO	Time Between Overhaul

VI. JTI-CS2-2018-CFP08-FRC-01-23: Experimental characterization and optimization of the RH and LH Engine intakes configuration of the next generation Tilt Rotor

Type of action (RIA/IA/CSA)	RIA		
Programme Area	FRC		
(CS2 JTP 2015) WP Ref. 1.5	WP 1.5		
Indicative Funding Topic Value (in k€)	3500		
Topic Leader	Leonardo Helicopter	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	36	**Indicative Start Date (at the earliest)**[52]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CFP08-FRC-01-23	**Experimental characterization and optimization of the RH and LH Engine intakes configuration of the next generation Tilt Rotor**
Short description	
The Applicant shall characterize in wind tunnel the key design choices of the basic engine intake configuration, as defined by LH. The Applicant will also propose optimized geometries (by CFD) to be evaluated in the same testing campaign. Moreover, it will characterize (by CFD only) the interactional effects due to rotor wake and its impact on the intake performance. Then, due to the peculiarity of the proposed intakes, an analytical assessment on the ice and snow effects shall be addressed. The novel intake geometry features will be installed on the Technology Demonstrator.	

Links to the Clean Sky 2 Programme High-level Objectives[53]				
This topic is located in the demonstration area:	Next-Generation Civil Tiltrotor			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Next-Generation Tiltrotor			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☐	☐	☐	☒	☒

52

53 For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

The novel tilt rotor configuration will host a peculiar engine/nacelle/hub design suitable to guarantee the requested operability in hover, transition and cruise conditions.

This concept will be firstly installed on the TD (Technology Demonstrator) and, after that, it will constitute one of the main features of the future new civil tilt rotor (NGCTR).

The basic configuration, as supplied by ITD, will be then assessed and fully characterized for TD, while the optimized one will be the baseline to be integrated into the NGCTR exploiting all the benefits of the proposed new concept.

The objective of this Topic is twofold:

- To assess, by dedicated experiments and advanced CFD analysis, the key driving aerodynamic choices of the configuration in order to support the CDR (Critical Design Review) phase of the NGCTR TD (Next Generation Civil Tilt Rotor TD).
- Moreover, even not required for the TD itself, to investigate since the beginning the icing and snow effects on this subsystem definition by capturing all the possible criticalities impacting the NGCTR (i.e. certification)

The following key design pillars are the main drivers of this Topic:

- Engine TD air intake assessment in hover and cruise conditions:
  The basic ITD configurations will be analyzed by CFD with rotor effects to detect total pressure losses, flow field distribution into the ducts and at the Aerodynamic Interface Plane (AIP)
- Engine TD air intake optimization in XTOL (eXtended Take Off and Landing), hover and cruise conditions:
  - Reduction of total pressure losses
  - More uniform flow field at the engine Aerodynamic Interface Plane (AIP)
  - Increase efficiency of the internal ducts (by-pass, etc.)
  - Elimination of any instability whilst ensuring adequate airflow to the engines during transition phase
- Confirmation of the nacelle integration performance by means of wind tunnel tests:
  - Manufacturing of a modular scaled nacelle wind tunnel test rig
  - Test on a wind tunnel facility of the basic ITD air intake configuration
  - Test on a wind tunnel facility of the optimized air intake configuration
- Nacelle characterisation in icing and snow conditions

2. Scope of work

The engine installation problems are peculiar of the proposed nacelle configuration (fixed engine and tilting rotor hub) which is in turn specifically related to the wide range of operations between hover and cruise condition.

The ITD design of the engine intake is characterized by a configuration that exploits the basic rotor hub settings in cruise and in helicopter mode. The basic configuration, to be supplied by the ITD to the Applicant at the beginning of the activity, is then based on two components that, at this stage of design, could be different between the Left and Right nacelle. The differences are mainly due to a possible non mirroring effects according to the particular internal drive scheme and accessory boxes. So, it is likely that the Applicant will have to manage 4 components of the internal duct (2 for LH side and 2 for the RH).

The basic TD components of the internal nacelle ducts will be aerodynamically characterised for efficiency and optimized. Wind tunnel tests are then required to assess and confirm the predtcted flow field behaviour (both on basic and optimized configurations). In parallel to the previous tasks, an assessment of the environment impact on the engine nacelle is also required (icing and snow characterization).

The Applicant shall structure its Proposal into seven main tasks as hereafter described:

- **Task 0**: Management and project coordination
- **Task 1**: Numerical assessment of the basic configurations
- **Task 2**: Numerical optimization of the internal ducts
- **Task 3**: Design and manufacturing of the nacelle models (basic and optimized)
- **Task 4**: Wind tunnel test of the nacelle configurations
- **Task 5**: Wind tunnel data analysis and post-processing
- **Task 6**: Icing and snow analysis

Task 0: Management and project coordination

This task includes the Applicant management and coordination work.
Being the required Topic efforts linked to the amount of internal ducts to be investigated (as described in the next Task descriptions), the Applicant is then required to make and to show an appropriate cost breakdown.

Task 1: Numerical assessment of the basic configurations

This task includes the CFD activity to assess the basic geometries at full scale as supplied by the ITD.
CFD assessment:

- To setup of a CFD model able to verify the engine installation efficiency by analysing the inlet and the by-pass ducts of the original nacelle configuration in a complex external aerodynamic field in a set of operating conditions provided by ITD. The rotor effects shall be included by means of a modellisation of the blade motion (pitch, lag and flapping).
- To aerodynamically analyse the configuration, mainly in terms of pressure losses, flow distortion, separations. The Applicant is encouraged to propose and to apply advanced methods to improve the accuracy in the prediction of the inlet flowfield behaviour with particular attention to the distorsion phenomena, and do not limit the investigation to the conventional URANS (Unsteady Reynolds Averaged Navier Stokes) solvers.
- The Applicant will give indications about the surface finishing characteristics effects on the basic component performances, in order to provide guidelines for full scale NGCTR TD manufacturing. A sensitivity study at the end of the CFD analysis meets this request.
- The Applicant must be ready to characterize 4 components (2 for each nacelle) at maximum.
- Two selected flight conditions will be identified by the ITD for the analysis: airplane mode and helicopter (hover) mode. The analysis will be done at 6 different engine mass flow rates in airplane mode and 3 different engine mass flow rates in helicopter mode. A reduced analysis shall also be performed on the other operating conditions defined by ITD (extended take off & landing, conversion transition phase, etc…) to confirm no adverse effect is envisaged.

Inputs from ITD Consortium:

- CAD model in CATIA V5 format of the ITD provide nacelle configuration – T0
- Operative conditions to be considered – T0
- Rotor data to support the rotor simulation – T0
- Engine data to support numerical engine model – T0

Outputs from the Applicant:

- Report of the CFD assessment of the basic geometries – T0 + 12M

Task 2: Numerical optimization of the internal ducts

This task includes the following CFD activities (at full scale):

- The setup of a coupled CFD-optimizer chain able to modify the basic geometries as for Task 1 in order to improve the engine performance in a set of operating conditions. The main parameters to handle are the pressure losses, flow distortion, separations. A multi-objective optimization is required.
- The Applicant will give indications about the surface finishing characteristics effects on the optimized component performances, in order to provide guidelines for full scale manufacturing. A sensitivity study outside the pure numerical optimization meets this request.
- The inlet and by-pass are the object of the optimization, but the external nacelle shape and the nacelle-wing junction shall be included in the CFD analysis
- The optimization activity shall include the rotor effects but without any explicit blades rotating modelling simulation into the optimization scheme: the Applicant shall propose and apply a method to include rotor inflow and swirl into the CFD optimization scheme.
- Three selected flight conditions will be identified by the ITD for the optimization: XTOL, airplane mode and helicopter (hover) mode.
- The Applicant must be ready to characterize 4 components (2 for each nacelle) at maximum. The analysis will be done at 6 different engine mass flow rates in airplane mode, 3 different engine mass flow rates in helicopter mode and 3 different mass flow rates in XTOL.
- The optimizer tool development is not part of this call: the applicant has to apply an already existing optimizer.

Inputs from ITD Consortium:

- Operative conditions to be considered (the same as Task 1) – T0
- Architectural and structural constraints on the nacelle – T0

Outputs from the Applicant:

- Report of the numerical optimization activity and final assessment – T0 + 20M
- CAD model in CATIA V5 format of the optimized nacelle inlet ducts geometries – T0 + 20M

Task 3: Design and manufacturing of the nacelle models (basic and optimized)

This task includes the necessary activities for wind-tunnel model design, manufacturing and instrumentation.

Wind Tunnel Model

A dedicated wind tunnel model is required by the applicant. The models must be designed and manufactured considering the following:

- External nacelle surface and wing fairing able to host the internal ducts components. It's envisaged a single test rig able to accommodate all the required internal ducts.
- Internal nacelle components for testing both basic and optimized geometries (The Applicant must be ready to experimentally characterize 8 components (4 for each nacelle) at maximum).
- Internal duct simulation with the proper mass-flow rates for the given conditions
- Rotating parts such as hub, inner blade specimens and full blades are not required

The wind tunnel model will be geometrically scaled by the Applicant considering the following full scale TD main reference dimensions:

- Nacelle length (from spinner vertex up to exhaust): 3.6 m
- Nacelle height (in airplane mode): 1.5 m

- Nacelle width: 1.0 m
- In helicopter mode the tilting forward part has a length of: 1.8 m

In order to estimate the appropriate scale factors for wind tunnel tests the TD mass flow rates, at full scale and at the engine AIP, have the following range: from 3.27 kg/s up to 6.91 kg/s.

Instrumentation

The applicant must be able to provide the instrumentation required for the following measurements:

- General wind tunnel parameters: pressure, temperature, humidity, wind speed, etc.
- Wall pressures on internal ducts with suitable refinements to capture relevant phenomena
- Local Flow field measurement (Velocity vectors, Pressures) at the engine AIP location
- Any additional devices/transducers the Applicant proposes to be added in order to better support the assessment

Outputs from the Applicant:

- Wind tunnel nacelle basic models PDR – T0 + 6M
- Wind tunnel nacelle basic model final design review – T0 + 9M
- Wind tunnel nacelle basic model manufactured – T0 + 16 M
- Wind tunnel optimized model components manufactured– T0 + 26 M

Task 4: Wind tunnel test of the nacelle configurations

This task includes the activity of wind-tunnel tests preparation and execution for both basic and optimized configurations for both LH and RH inlet duct geometries at maximum.

The test conditions will cover the convenient speeds (according to the scale factors chosen by the Applicant) and the tilting part attitude angles.

The detailed test matrix definition is part of the activity: at this stage, and for budgeting purposes, the Applicant should consider 100 test points at maximum for the each test campaign (basic and optimized).

The test campaign shall be splitted into two entries: the first one to assess the basic configuration in order to support the TD CDR, a second entry to check and explore the optimized ducts with the aim to supply advice and guidelines for the NGCTR engine installation integration.

Inputs from Topic Leader:

- Full scale conditions to be tested – T0

Outputs from the Applicant:

- Wind tunnel test plan – T0 + 14M
- Wind Tunnel Test (basic models) completion – T0 + 18M
- Wind-tunnel tests measurements (basic models) preliminary report – T0 + 22M
- Wind Tunnel Test (optimized components) completion – T0 + 28M

Task 5: Wind tunnel data analysis and post-processing

This task includes:

- Post processing of the acquired data
- Analysis and comparison of the performance of the ITD provided and optimized nacelle configuration.

Outputs from the Applicant:

- Report describing the results including the measured test points and conditions, acquired data, accuracy, corrections applied and comparison between configurations.
- Delivery of final wind tunnel tests analysis Report (basic configurations) – T0 + 24 M
- Delivery of final wind tunnel tests analysis Report (optimized configurations) – T0 + 32 M
- Final aerodynamic report characterizing the investigated configurations: being the wind tunnel tests

conducted without any rotating components, the Applicants shall assess the nacelle ducts not only on the basis of the experimental campaign but with the important support of the information gathered during the CFD tasks. This activity, summarizing the overall aerodynamic assessment, can be managed by the Applicant in an additional separated task at its convenience and not necessarily included in this Task 5 – T0+36M

Task 6: Icing and snow analysis

This task is oriented to analyse the icing and snow impacts on the peculiar engine nacelle configuration since the beginning of its development. As previously mentioned, the activity is not focused to clear or support the NGCTR TD preliminary flights, but to identify possible criticalities on the NGCTR aircraft nacelle design in terms of certification and/or operation envelopes caused by icing and snow and addressing some mitigation actions to be implemented in the next phase design of NGCTR. In fact, the concept of the NGCTR TD nacelle subsystem is the same to be applied to the NGCTR.

This task includes:

- Identification of the icing and snow conditions, according to the certification rules, operations and aircraft flight envelopes that the engine/nacelle has to sustain.
- Application of existing methodologies to predict the icing accretion on and within the inlet ducts.
- Identification and application of criteria to evaluate the snow effects on the nacelle inlets and ducts.

At this stage is not required to design or to propose neither an anti-icing nor a de-icing system; the task shall be focused to the characterisation of the effects on the components managed as "cold and rigid surfaces". No icing wind tunnel tests are required.

Inputs from Topic Leader:

- NGCTR flight envelopes – T0

Outputs from the Applicant:

- Analysis conditions for both icing and snow – T0 + 12M
- Icing prediction on the nacelle components (basic configuration only) – T0 + 24M
- Snow effects on the nacelle components (basic configuration only) – T0 + 30M
- Final summary on icing and snow effects on the nacelle concept – T0 + 36M

Note: the study has been requested for the basic configurations, being these geometries available at the beginning of the project. The Task can then benefit of the knowledge and background acquired during the CFD characterization in Task 1.

However, in order not to limit the activity at a pure prediction on a given geometry, the Applicant is required to issue the final report (Final summary) with a complete assessment of the icing and snow effects on the proposed nacelle concept, by addressing, for example, a sensitivity study with the geometrical variation of some components.

Project Time scheduling

The following table will list the deadline for each task completion.

Tasks		
Ref. No.	***Title - Description***	***Due Date***
Task 0	Management and project coordination	T0+36 m
Task 1	Numerical assessment of the basic configurations	T0+12 m
Task 2	Numerical optimization of the internal ducts	T0+20 m
Task 3	Design and manufacturing of the nacelle models (basic and optimized)	T0+26 m
Task 4	Wind tunnel test of the nacelle configurations	T0+28 m

Tasks		
Ref. No.	***Title - Description***	***Due Date***
Task 5	Wind tunnel data analysis and post-processing	T0+36 m
Task 6	Icing and snow analysis	T0+36 m

3. Major deliverables/ Milestones and schedule (estimate)

**Type: R: Report - RM: Review Meeting - D: Delivery of hardware/software*

Deliverables			
Ref. No.	***Title - Description***	***Type***	***Due Date***
Task 1	Numerical assessment of the basic configurations	R	T0+12 m
Task 2	Numerical optimization of the internal ducts	R	T0+20 m
Task 3	Design and manufacturing of the nacelle models (basic)	D	T0+16 m
Task 3	Design and manufacturing of the nacelle models (optimized components)	D	T0+26 m
Task 4	Wind tunnel test of the nacelle configurations (basic) accomplished	RM	T0+18 m
Task 4	Wind tunnel test of the nacelle configurations (optimized components) accomplished	RM	T0+28 m
Task 5	Wind tunnel data analysis and post-processing (basic)	R	T0+24 m
Task 5	Wind tunnel data analysis and post-processing (optimized)	R	T0+32 m
Task 5	Aerodynamic assessment of the studied configurations	R	T0+36 m
Task 6	Icing and snow analysis on the nacelle concept	R	T0+36 m

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type***	***Due Date***
M1	Final design review model design (basic) – Go ahead with basic model manufacturing	R	T0+9 m
M2	Wind tunnel entry of the basic configuration	RM	T0+17 m
M3	Wind tunnel entry of the optimized components	RM	T0+27 m
M4	Icing and snow characterisation	R	T0+36 m

4. Special skills, Capabilities, Certification expected from the Applicant(s)

The Applicant must have qualified and demonstrated skills in both numerical multi-objective optimization and simulation (CFD) for fixed and rotating (blade/propeller) components, wind tunnel testing and icing prediction. It would even be preferred if he has already conducted activities on similar subjects.

Detailed requirements and specifications for the applicant capabilities are listed below:

- Computational resources (hardware and software) suitable for the scopes of the activities in the specified timescale
- Proven capability and skill in internal duct analysis and optimization
- Wind tunnel tests management, test conduction and experimental data analysis
- Proven capability to manage projects by gathering several and different specialistic skills (numerics, model design and manufacturing, wind tunnel tests) and demostrated capability to guarantee the project scheduling and milestones, due to the strong link this project has to the ITD design process.

VII. JTI-CS2-2018-CFP08-FRC-01-24: High efficiency full electrical low pressure Compartment Pressure Control System for tilt-rotor applications

Type of action (RIA/IA/CSA)	IA		
Programme Area	FRC		
(CS2 JTP 2015) WP Ref. 1.5	WP 1.6		
Indicative Funding Topic Value (in k€)	1200		
Topic Leader	Leonardo Helicopters	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	48	**Indicative Start Date (at the earliest)**[54]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CFP08-FRC-01-24	**High efficiency full electrical low pressure Compartment Pressure Control System for tilt-rotor applications**
Short description	
The purpose activity requires the development, testing and qualification of a full electrical modular-based Low Pressure Compartment Pressure Control System, including analysis to determine the best architecture taking into account the special flight characteristics of a Tilt Rotor and an occupants range from 9 to 30.	

Links to the Clean Sky 2 Programme High-level Objectives[55]				
This topic is located in the demonstration area:	Enabling Technologies			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Next-Generation Tiltrotor			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☐	☐	☐	☒	☒

54 The start date corresponds to actual start date with all legal documents in place.

55 For further info see Chapter 1 “Introduction to the Programme Scene Setter / Objectives” with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

In the framework of Clean Sky 2 FRC IADP, the present Call requires Partner(s) (company or consortium) to develop an electrical air compressor(s) system to provide pressurized air at the inhabitant compartments.

Design & development & testing are aimed to mature and validate the scalability of the system through a mathematical system model to enable the design of NGCTR of different class/architecture.

2. Scope of work

The main objective of this Call is the determination of the best architecture and hardware development for a bleedless pressurized system for a medium class tilt-rotor.

The compressor(s) shall:

- be fully electric based on 28VDC power supply
- be designed for low noise and vibration levels
- be a high reliability system
- be inclusive of stand-alone digital controller able, but not limited to:
- determine, through airframe provided data, the best efficient control law schedule for the envisaged mission profile and inhabitants requirements
- prevent compressor(s) failure identifying the wearing of key components parts and alerting for preventive maintenance actions (including compressor(s) overall replacement),
- be inclusive of dedicated air filtering system to increase compressor(s) reliability (salt laden environment is envisaged),
- provide clean/pure air to the inhabitant compartments (e.g. no oil sprayed in the air / no sprayed contents). The electric compressor shall be oil-less.

The design shall consider a possible transition to 270VDC with a minimal impact.

It is positively evaluated a proposal including an integrated system composed by:

- the electrical air compressor(s),
- cabin pressurization system components (e.g. outflow valves),
- cabin pressurization system management

A trade-off study for electrical compressor weight_vs_cooling requirements shall be carried out.

The use of the electrical compressor to supply multiple aircraft utilities shall be investigated.

As first step of the design the Partner(s) shall study different architectures and technical solutions; as minimum the following options shall be considered:

- provide constant pressure or variable pressure to the cabin,
- adopt a single (multiple electrical motors) or multiple compressors solution (reliability purposes), and
- adopt a single or multiple stage compressor
- adopt variable geometry and/or speed compressor
- adopt innovative bearing design to improve system efficiency and minimize noise/vibration/deterioration
- adopt vibration and noise reduction HW solutions, with associated weight impact trade off

The architecture shall be scalable and/or modular.

The use of environmental friendly materials, lubricants and manufacturing processes shall be considered.

In general, the system operating conditions to be considered during the design phase are:

- Altitude envelope of -2000ft / 25000ft;

- Storage and/or non-operating temperature of -55°C / +85°C;
- Operating temperature of -55°C / +120°C;

The most critical components shall be tested for, at least, basic environmental validation.
At the end of the design activity, representative unit (critical systems and key technologies) shall be produced for EFA testing, followed by prototype hardware for flight testing on NGCTR Technology Demonstrator and for conclusion of flight qualification testing phase.
The Partner shall guarantee at list one spare system; consumable availability and technical support even following the qualification milestone completion.
The design, the development and the qualification of the system shall follow the standard procedures for aeronautic equipment.
Support to LH shall be ensured throughout the duration of the NGCTR TD flight phase.

Tasks		
Ref. No.	***Title – Description***	***Due Date*** [T0 + mm]
T01	System Definition(1)	T0
T02	Feasibility study of the system weight assessment versus weight penalizing requirements (cooling, noise)	T0 + 06
T03	Impacts evaluation of using the compressor(s) to feed multiple aircraft utilities (e.g. adding a second/third stage)	T0 + 06
T04	Trade-off between various possible modular architectures.	T0 + 06
T05	Initial compressor(s) mathematical model creation (Simulink or equivalent) for the preliminary design preparation	T0 + 12
T06	Compressor(s) mechanical, electrical and pneumatic design	T0 + 12
T07	Compressor(s) advanced diagnostic system creation	T0 + 30
T08	Best control laws to minimize fuel penalty, noise, etc… while maximizing efficiency	T0 + 30
T09	Development compressor(s) testing and design refinement	T0 + 30
T10	Compressor(s) flight qualification (critical components)	T0 + 48
T11	Validation of compressor(s) mathematical model (Simulink or equivalent) for the definition of top level architecture design for different tiltrotor class	T0 + 48

(1): High-level System Requirements will be provided to the selected Partner(s), following the signature of dedicated NDA or equivalent commitment, as part of the technical discussions between the Partner(s) and LH that will take place after the selection phase (T0).

3. Major Deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	***Title – Description***	***Type***	***Due Date*** [T0 + mm]
D01	Trade off study cooling/noise vs weight	REPORT	T0 + 06
D02	Technical impacts of using the compressor(s) to feed multiple aircraft utilities	REPORT	T0 + 06

Deliverables			
Ref. No.	***Title – Description***	***Type***	***Due Date*** [T0 + mm]
D03	Trade-off study between different various possible architectures (including at least: weight, cost, overall dimensions, reliability, performance)	REPORT	T0 + 06
D04	Initial mathematical model for preliminary design	SIMULINK or equivalent	T0 + 12
D05	3D model(s)	CATIA FILE(S)	T0 + 12
D06	Qualification program plan (QPP)	DOCUMENT	T0 + 12
D07	Performance analysis	DOCUMENT	T0 + 12
D08	Preliminary Reliability and FMEA (Failure Modes and Effect Analysis)	DOCUMENT	T0 + 12
D09	Preliminary Interface control drawings	2D DRAWINGS	T0 + 12
D10	Acceptance Test Plan	DOCUMENT	T0 + 12
D11	Preliminary Compressor(s) status monitoring and failure detection approach	DOCUMENT	T0 + 12
D12	Failure Modes, Effect and Criticality Analysis (FMECA)	DOCUMENT	T0 + 12
D13	Safety/Hazard Analysis	DOCUMENT	T0 + 12
D14	Experimental unit for EFA test	HARDWARE	T0 + 24
D15	Compressor(s) status monitoring and failure detection approach	DOCUMENT	T0 + 30
D16	Interface control drawings	2D DRAWINGS	T0 + 30
D17	Qualification by Similarity and Analysis (QSAR)	DOCUMENT	T0 + 30
D18	Qualification Test Procedure (QTP)	DOCUMENT	T0 + 30
D19	Acceptance test Procedure	DOCUMENT	T0 + 30
D20	Reliability and Reliability and Failure Modes & Effects Analysis (FMEA)	DOCUMENT	T0 + 30
D21	SW development and quality plan	DOCUMENT	T0 + 30
D22	Control laws	SIMULINK or equivalent file(s) and REPORT	T0 + 30
D23	EMC Control Plan	DOCUMENT	T0 + 30
D24	EMC Test Plan	DOCUMENT	T0 + 30
D25	Prototype unit and spare parts for installation on TD and flight testing	HARDWARE	T0 + 40
D26	EMC Test Reports	DOCUMENT	T0 + 48
D27	Flight Qualification Test Reports and related quality documents	DOCUMENT	T0 + 48
D28	Final mathematical model for the definition of top level architecture design for different tiltrotor class	SIMULINK or equivalent file(s)	T0 + 48

Milestones (when appropriate)			
Ref. No.	***Title – Description***	***Type***	***Due Date*** [T0 + mm]
M01	Kick-off meeting	Design review	T0
M02	System Concept Review	Design review	T0 + 06
M03	Preliminary Design Review	Design review	T0 + 12
M04	Development unit ready to development tests	Hardware availability	T0 + 24
M05	Critical Design Review	Design review	T0 + 30
M06	Qualification unit(s) ready to be tested	Hardware availability	T0 + 36
M07	First Article Inspection	Document	T0 + 37
M08	Test Readiness Review	Design review	T0 + 38
M09	Unit in product configuration delivered to LH for flight tests	Hardware availability	T0 + 40
M10	Qualification closure (critical components)	Document & Design review	T0 + 48

4. <u>Special skills, Capabilities, Certification expected from the Applicant(s)</u>

The Applicant(s) shall own the following pedigree and special skills:

- Compliance to SAE AS9100.
- Familiarity with, or at least knowledge, of aeronautic rules, certification processes and quality requirements.
- Capability to design, validate, manufacture and qualify (environmental/functional) airborne equipment, according to RTCA-DO-160, RTCA-DO-178 and RTCA-DO-254 (or other civil or military equivalent standards) for safety critical equipment.
- Familiarity with EMI compatibility issues: capacity to design complex electronic HW in compliance with EMC guidelines, and experience in performing EMC justification analyses and experimental assessments according to RTCA-D0-160, EUROCAE ED-107/ARP-5583, ED-81/ARP-5413 and ED-84/ARP-5412 or equivalent civil or military standards (TBC).
- Experience in research, development and manufacturing in the following technology fields:
  - Air compressor
  - Aircraft pressurization system (nice to have)
- Design Organization Approval (DOA) (nice to have)
- Capability in Safety assessment process according to SAE-ARP-4754 and SAE-ARP-4761 standards, willingness to interact closely with WAL safety specialists in order to produce the necessary outputs (safety and reliability reports and fault trees/analyses).
- in-house testing capabilities for ECU+ecompressor system rig (efficiency test)
- Shape, component design and structural analysis using CATIA v5 and NASTRAN. Capability to optimize the HW and SW design, to model mathematically/numerically complex mechatronic systems with suitable simulation tools (Matlab/Simulink) and to analyze both simulation and experimental results to ensure that the various required performance goals are met.
- Capability to repair "in-shop" equipment due to manufacturing deviations.

Detailed Quality Assurance Requirements for Supplier will be provided to the selected Partner(s) following the signature of dedicated NDA or equivalent commitment.

5. Abbreviations

DOA	Design Organization Approval
EFA	Experimental Flight Approval
EMI	ElectroMagnetic Interference
EMC	ElectroMagnetic compatibility
HW	Hardware
LH	Leonardo Helicopters
NDA	Non disclosure agreement
NGCTR	Next Generation Civil Tilt Rotor
SW	Software
PPT	Power Point Presentation
TD	Technology Demonstrator
WAL	Work Area Leader
DOCUMENT:	Document issued
REPORT:	Document or ppt presentation

7. Clean Sky 2 – Airframe ITD

I. JTI-CS2-2018-CFP08-AIR-01-37: Composite mould tool based on 3D printing

Type of action (RIA/IA/CSA)	RIA		
Programme Area	AIR		
(CS2 JTP 2015) WP Ref.	WP A-3.1		
Indicative Funding Topic Value (in k€)	800		
Topic Leader	Saab	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	24	**Indicative Start Date (at the earliest)**[56]	Q1 2019

Topic Identification Code	Title
JTI-CS2-2018-CFP08-AIR-01-37	**Composite mould tool based on 3D printing**
Short description	
The objective of the present topic is to develop a composite mould tool based on an innovative large additive manufactured structure. The tool surface shall be able to withstand a high production rate, similar to today's metallic tools. The tool is intended to be used for producing a composite demonstrator with a size of approximately 1.5x3 sqm.	

Links to the Clean Sky 2 Programme High-level Objectives[57]				
This topic is located in the demonstration area:	Advanced Manufacturing			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	▪ Advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☒	☐

[56] The start date corresponds to actual start date with all legal documents in place.
[57] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

The present topic is part of Airframe High Performance and Energy Efficiency (Activity Line A). It is one of the key research activities which will ultimately result in the demonstration of an innovative composite wing structure. This topic is part of Work Package A-3.1: Multidisciplinary wing for high and low speed. Control surface structures are an essential part of a wing. One control surface which will be an area for research/development in AIR ITD is a composite Flaperon for a large passenger aircraft, see Figure 9.

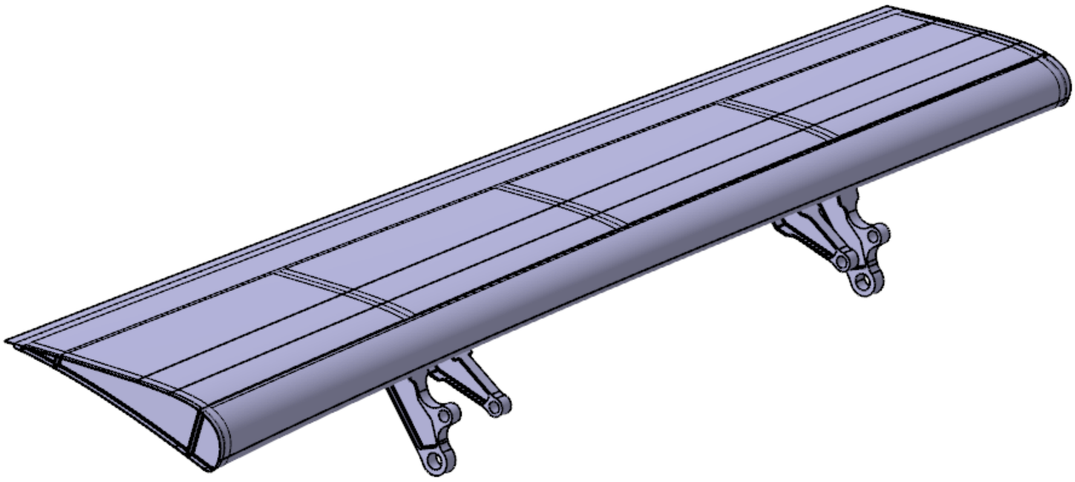


Figure 9: Illustration of Flaperon device. Note that fittings are not included in the work package

Composite structures for the aerospace industry are often made of prepreg (pre-impregnated carbon fiber) cured at high temperature (120°C – 180°C) and under pressure in an autoclave. Depending on the product and the production rates, several parts are cured in one autoclave cycle. In order to achieve this each specific autoclave cycle needs to be qualified. All of the above makes it difficult to produce parts in a lean system, i.e. single-unit manufacturing and reduces the level of flexibility. Composite curing processes are often performed with steel or invar tools in the autoclave. These tools are often heavy and complex and require significant lead times before they can be introduced in production. In addition, steel and invar tools consumes an extensive time to reach a steady state temperature in the curing process, making the curing process lengthy and thus a challenge in high rate production.
Time to market is becoming increasingly important in today's aerospace businesses and it continues to be a challenge to design and produce these tools with a short lead time. To meet market demand a major contribution would therefore be to shorten the tooling lead time via alternative manufacturing technologies.
Additive manufacture technology is developing quickly and has already been tried in the composite manufacturing process on small scales. However, their functionality for composite serial, high rate, production is unproven and there are opportunities to be investigated. Furthermore, the large size of the parts to be produced has a limitation when it comes to additive manufacturing.
Taking these points into consideration, the objective of the proposed topic is therefore to design and manufacture a tool based on additive manufacturing technique. The tool shall be able to withstand the above mentioned challenges and could be either plastic or metallic. The tool size shall be approximately 1.5x3 sqm.

2. Scope of work

It is proposed to structure the technical activities in the following work-packages:

Work Packages		
Ref. No.	***Title - Description***	***Due Date***
WP 1	Tool concept	T0 +6
WP 2	Testing and manufacturing	T0 +24
WP 3	Robustness	T0 +24

WP 1. Tool concept

This work package corresponds to the development work and the phase ends once the conceptual design is finalized. It is important that the chosen concept and material are suitable for high rate production tooling which requires a short lead time, i.e. the concept selected shall decrease the current lead time for metallic mould tools for composite production. It is important to consider different methods of heating/curing the composite parts with the aim of achieving a shorter cure time, this shall be done in close cooperation with the Topic Manager as the production method for the demonstrator is to be decided at project start and could include both in and out of autoclave production. Laminate contamination shall also be considered when choosing AM material.

Design for automation shall be a key aspect of the chosen tooling concept in order to assure a cost effective production and production rates up to 200 parts per month in a production that will last approximatively 10 years. The selected concept may have a lower life span compared to production, i.e. the tool need to be replaced or restored to its original shape. This shall be possible as long as it does not have a significant impact on recurring cost or production rate. This can be validated via analysis, if possible.

WP 2. Testing and manufacturing

In this work package, test samples to be used for coupon tests shall be produced in a smaller tool using the technique developed in the concept phase. This is also the phase where the design is verified on a small scale and test tools are manufactured. The nature of the tests and the detail of the tooling shall be agreed with the topic manager but the tests shall aim at verifying that the selected concept is able to produce parts that are defect free and that meet the laminate quality and geometric requirements equal to today's prepreg quality.

The phase ends with the production of the final tool. This tool shall be used in the production of the test demonstrator within WP A-3.1. Size of the tooling will be approximatively 1.5x3 sqm and it shall be able to handle metallic inserts (i.e. fasteners, hinge brackets, etc.) if such are included in the design of the demonstrator.

WP 3. Robustness

In this work package the robustness shall be proven. The tool geometry shall not be effected by the number of curing cycles that it will be subjected to during its expected life time (to be agreed with the Topic Manager). If the geometry of the tooling is altered unexpectedly prior to the expected tooling life time, then it shall be cost effective to modify the tool back to its original geometry. This can be validated via analysis, if possible.

A final report covering all the performed activities is expected at the end of the project.

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D 1.1	Tool concept	R	T0 +6
D 2.1	Test tool manufactured	HW	T0 +9
D 2.2	Test sample produced	HW	T0 +11
D 2.3	PDR	R	T0 +14
D 2.4	CDR	R	T0 +16
D 2.5	Final tool	HW	T0 +20
D 2.6	Verification report	R	T0 +22
D 3.1	Analysis and verification of robustness	R	T0 +22

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M 1.1	Tool concept approved	R	T0 +6
M 2.1	PDR	R	T0 +14
M 2.2	CDR	R	T0 +16
M 2.3	Final tool demonstration	HW	T0 +20
M 3.1	Robustness demonstration	R	T0 +22

4. Special skills, Capabilities, Certification expected from the Applicant(s)

Special expected skills are:

- Proven experience in additive manufacturing
- Proven experience in tool design and working with airframe designers, tooling design and joint design.
- Proven experience in tool manufacturing
- Proven experience of automation in a production environment.
- Solid knowledge in design of automated handling systems.
- Knowledge in composite manufacturing for the aerospace industry
- Knowledge in material selection for composites.
- Knowledge in the FPQ process
- Experience in technological research and development for innovative products and processes
- Experience of working with suppliers of composite material.
- Proven experience in collaborating with aeronautical companies Research and Technology programs.

The applicant(s) are required to have access to the following capabilities:

- CAD software, which is compatible with Catia V5 R24 or later, for design compatibility with topic manager
- 3d printing simulation software
- Suitable manufacture and machining facilities for tool production
- Suitable prototype workshop
- Composite curing facilities
- Laboratory facilities for mechanical testing, residual stress measurements and NDI

5. Abbreviations

AM	Additive Manufacture
CFRP	Carbon Fibre Reinforced Plastic
FPQ	First Part Qualification
NDI	Non Destructive Inspection

II. JTI-CS2-2018-CFP08-AIR-01-38: Innovative test rig for the investigation of gust loads in transonic flow conditions

Type of action (RIA/IA/CSA)	RIA		
Programme Area	AIR		
(CS2 JTP 2015) WP Ref.	WP A 4.2		
Indicative Funding Topic Value (in k€)	1000		
Topic Leader	ONERA	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	24	**Indicative Start Date (at the earliest)**[58]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CFP08-AIR-01-38	**Innovative test rig for the investigation of gust loads in transonic flow conditions**
Short description	
Benefiting from Clean Sky SFWA-ITD achievements, the main objective of this call is to contribute to the improvement of gust loads prediction and control in transonic flow conditions. The Applicant(s) will have to design and manufacture model parts composed of an innovative gust generator and a wall-mounted half-wing model to be tested in a selected ONERA transonic facility. In particular, in order to investigate non linearities induced by gust, the novel gust generator will have to produce larger aerodynamic deflections than those obtained from an already existing test mean. Innovative flow control concepts based on unsteady blowing can be considered for achieving the goals in addition to dynamic mechanical devices.	

Links to the Clean Sky 2 Programme High-level Objectives[59]				
This topic is located in the demonstration area:		Innovative Solutions for Business Jets		
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter		Low Sweep Business Jet		
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☒	☐

[58] The start date corresponds to actual start date with all legal documents in place.

[59] For further info see Chapter 1 “Introduction to the Programme Scene Setter / Objectives” with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

The mission of Joint Technology Initiative Clean Sky 2 European research program is to develop breakthrough technologies to significantly increase the environmental performances of airplanes and air transport according to the ACARE 2020 goals and Flightpath 2050. Within the framework of AIRFRAME-ITD, one of the main improvement axes is the aircraft weight reduction in order to contribute to a step change in fuel consumption levels. The key objective of the technology stream A-4 “Novel Control” is to reduce the global aircraft weight through novel load control technologies, either by investigation of smart mobile control surfaces (within WP A-4.1) or active load control (within WP A-4.2).

One task associated to the demonstration plan strategy of WP A-4.2 is dedicated to the analysis of wind tunnel gust load case, which is one of the most critical for strength design and fatigue loading source for transport type aircraft. Within Clean Sky SFWA-ITD, Wind Tunnel test campaigns provided first database and results in transonic flow conditions, dealing not only with gust load investigation but also control. The main objective in CS2 AIRFRAME ITD WP A-4.2 is to go further, to gain knowledge on gust effects (especially in the non-linear domain when encountering a gust) and to increase the maturity of load control approach. The acquisition of a relevant database will allow to assess the numerical capabilities for the prediction of loads. The main outcomes will improve the design process of the next aircraft generation. So far, the load prediction methodologies are usually based on conservative approaches resulting in aircraft structures with unnecessary weight. Any improvement in this field will have a strong impact on the margin sizing and will lead to the design of lighter aircrafts. In addition, the development of the innovative set-up will allow to assess and to de-risk the potential of advanced active load alleviation strategies in a research environment. Robust control methods will be first deployed on a model test-bed, ensuring effectiveness over a wide range of model variations or aerodynamic conditions.

2. Scope of work

To reach this goal, the Applicant(s) will provide an innovative experimental set-up for the investigation of gust load to be installed in a transonic facility. The tasks consist not only of the design and manufacturing, but also the functional verification of the different test set-up components. The first component, called gust generator (GG), will consist in a specific device allowing the generation of unsteady aerodynamic flow deflection in the wind tunnel test section. The second component, the test model will be composed of a wall-mounted half wing model (i.e. 3D swept wing) to investigate the gust effects on the aerodynamic and aeroelastic model behaviour and to perform real time demonstration of active gust load alleviation functions.

In the framework of AIRFRAME-ITD WP A-4.2, the complete innovative test set-up for gust load investigation has to be implemented and tested in the research ONERA S3Ch Wind Tunnel facility. This closed return wind tunnel is a transonic continuous run facility with a 0.8 x 0.8 m² test section for a 2.2m length. It ranges from Mach number 0.3 to 1.2 and operates at atmospheric stagnation pressure and stagnation temperature.

The achievement of the WT tests campaign is not a part of the call.

The Applicant(s) will achieve the following tasks:

Tasks		
Ref. No.	***Title – Description***	***Due Date***
Task 1	Project Management	T0+24
Task 2	Design activities	
Task 2.1	Design of the 3D half-wing model	T0+8
Task 2.2	Design of the Innovative Gust Generator	T0+10
Task 3	Manufacturing and instrumentation activities	
Task 3.1	Manufacturing and instrumentation of the 3D half-wing model	T0+14
Task 3.2	Manufacturing and instrumentation of the Innovative GG	T0+16
Task 4	Settings, Functional verification and control	T0+18
Task 5	Support during final Lab/WT Tests	T0+21

Task 1: Management

This task is devoted to the management of the project in order to ensure that all obligations are fully respected, from contractual, financial and technical progress point of views. Taking into account the strong interactions between activities performed by the Topic Manager and the Applicant(s), the present task will assure communication and reporting between the Applicant(s), the Topic Manager and JU.

Task 2: Design activities

For the design activities, the Applicant(s) will be supported by the Topic Manager providing detailed WT information (geometry, CAD files of interfaces, and general rules of model sizing) and the aerodynamic conditions of the planned WT tests.
An overview of the experimental test setup installed in the WT facility is shown in figure 1.

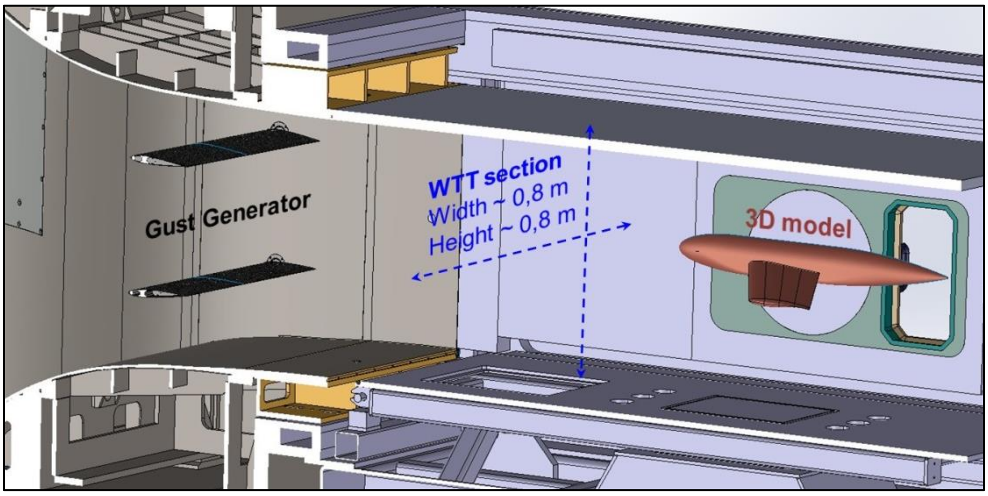


Figure 1 – Overview of the experimental test setup

Task 2.1: Design of the innovative Gust Generator

Within the framework of Clean Sky SFWA-ITD, a Gust Generator had been designed, manufactured and tested during Wind Tunnel tests campaigns. This first version of Gust Generator concept consisted in

two identical airfoils installed upstream of the wind tunnel test section. The dynamic pitch oscillations allowed to produce air flow deflections leading to the generation of a cylindrical gust field downstream. The exploitation of this first device fulfilled the initial requirements and specifications: the gust generation process had been controlled and efficient enough to generate unsteady fluctuations of vertical velocity and to induce aerodynamic and aeroelastic effects on a model.
One of the main innovation challenges of this Topic is the design of a novel Gust Generator with improved performances: the ability to generate larger gust amplitude usually defined by the ratio between vertical to horizontal velocities.
Preliminary investigations performed by the Topic Manager indicated that innovative flow control concepts can be considered for achieving the goals through the analysis of the effects of fluidic and/or mechanical devices. The combination of dynamic pitch oscillation and unsteady blowing slot demonstrated, through numerical simulations, the ability to generate larger aerodynamic deflection downwards the gust generator.
Alternative innovative concepts for gust generation proposed by the Applicant(s) will be welcomed. In this case, the Applicant(s) will have to conduct high fidelity numerical simulations to demonstrate the ability to generate unsteady aerodynamic deflections downstream of the GG device. The proposed solution will be designed to generate gust waves with requested amplitude (gust angle of +/-1° in the model area i.e. an improvement by a factor of 2 with respect to the existing GG performances) and frequency bandwidth (up to 100 Hz) during the planned Wind Tunnel tests in transonic flow conditions (Mach number ~ 0.82).
The following technical constraints and requirements needs to be met:

- Full and compact integration of the device in the WT facility,
- Generation of cylindrical gust (e.g. 2D behaviour) with vertical homogeneity and low variation in the longitudinal axis (e.g. wind axis) in the vicinity of the 3D wing-model,
- Modification of the gust characteristics such as amplitude, frequency components and shape (sinusoidal, discrete or broad band noise),
- Functioning for aerodynamic conditions up to transonic flow,
- Remote control functions for generation or stop emergency.

The solution selection will be validated by the Topic Manager to ensure that the proposed concept will allow to achieve the ambitious objectives in terms of gust generation. If not, an agreement between the Applicant(s) and the Topic Manager shall be reached during the Preliminary Design Review (PDR) to identify an improvement axis of the performances of the proposed GG or an alternative concept (Risk and mitigation analysis continuously conducted in task 1 should anticipate such issues).

Task 2.2: Design of the half wing-model
The Applicant(s) will design entirely a half model composed of a 3D swept wing and potentially a fuselage which will be wall mounted. The aerodynamic shape of the model will be provided by the Topic Manager. The mounting part (interface with the WT facility) shall allow the investigation of several configurations:

- Rigid configuration : the model attachment is completely rigid and allows the setting of the angle of attack
- Flexible configuration: the model attachment includes flexibility in pitch and will allow to study free response of this "rigid-body" mode.
- Forced motion configuration : a dynamic actuating device located at the wing root will allow to move dynamically the model in pitch (with adjustable frequency and amplitude parameters)

The design and sizing of the 3D model will be performed using advanced numerical simulations based on a Finite Element Model. No major specification is required concerning scaling and similitude aspects but

it is expected to have the “pitch rigid-body” mode and (at least) 3 elastic modes in the frequency bandwidth of interest (typically [0-100] Hz).
In order to perform the real time demonstration of active load alleviation functions, the wing will be equipped with a movable control surface, such as an aileron. Regarding the small dimensions of the wing, the design of an innovative actuating device is a challenging topic. The Applicant(s) will propose a high speed / high torque device satisfying mechanical strengths to aerodynamic loads and allowing static and dynamic deflections. Indicative performance specifications are an amplitude deflection of +/- 1°, a bandwidth of [0-100] Hz for a precision measurement lower than or equal to 0.05°.
The design tasks will consider the integration of sensors and associated wires and tubes paths through the model.

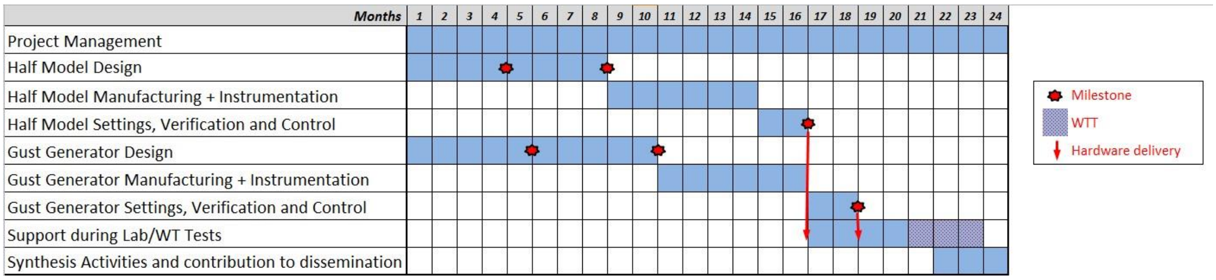
Task 3: Manufacturing and instrumentation activities
The Applicant will manufacture entirely the different parts of experimental test set-up including the aerodynamic parts (i.e. located in the flow) and the mounting parts for the integration to the Wind Tunnel facility. For the assembled test set-up, the geometrical deviations and tolerances will be provided by the Topic Manager.
For all parts of the experimental set-up, purchasing sensors and actuators components (including electronic devices) is a part of the call.
Regarding the instrumentation, the Applicant(s) will equip the GG with a reduced set of instrumentation sufficient to characterise its main functionalities (depending on the selected concept) such as motions sensors to capture dynamic motions, pressure and temperature sensors to monitor fluidic devices functioning, etc. In order to characterise the aeroelastic effects of impacting gust, the Applicant(s) will equip the model with a set of instrumentation: accelerometers (at least 10), steady (at least 30) & unsteady (at least 30) pressure sensors and strain gages (at least 10).

Task 4: Settings, Functional verification and Control
The Applicant(s) will perform metrological control of each part of the test set-up (especially the aerodynamic shapes) with a high precision measurement system and check for conformity with the CAD requirements (regarding with geometrical tolerances).
All sensors embedded in the test set-up will be calibrated and verified.
As the set-up will integrate several active devices (e.g. mechanical, fluidic …) the Applicant(s) will set the parameters ensuring their good functioning. For example, for the case of a movable aileron, the Applicant(s) will tune the control law parameters ensuring the position feedback. A demonstration plan will be elaborated from a set of functional laboratory tests showing that the main operating functionalities of active elements can be achieved in a non-representative environment (i.e. no WT environment): characterization of the frequency bandwidth or amplitude of the movable parts, flow rate estimation of fluidic devices, etc.

Task 5: Support during Laboratory and Wind Tunnel Tests
After the delivery of the different parts of the experimental set-up, the Applicant(s) will support its full Validation and Verification process that will be performed through laboratory and wind tunnel tests by the Topic Manager. A technical support of the Applicant(s) is requested by the Topic Manager during installation and in case of dysfunction (in particular for active devices) or failure.

3. Major Deliverables/ Milestones and schedule (estimate)

The proposed timetable is illustrated in the following simplified Gantt chart:



Major Deliverables and Milestones are summarized in the following tables:

Deliverables			
Ref. No.	***Title – Description***	***Type****	***Due Date***
D1	Design of the 3D half Wing-Model	Report + CAD files + FEM	T0+8
D2	Delivery of the 3D half Wing-Model	Hardware	T0+16
D3	Functional tests and control of the half Wing-Model	Report	T0+16
D4	Design of the GG	Report + CAD files	T0+10
D5	Functional tests and control of the GG	Report	T0+18
D6	Delivery of the GG	Hardware	T0+18

**Type: R=Report, D=Data, HW=Hardware*

Milestones (when appropriate)			
Ref. No.	***Title – Description***	***Type****	***Due Date***
M1	Launch Review Meeting	Review meeting	T0
M2	3D half Wing-Model PDR	Review meeting	T0+4
M3	3D half Wing-Model CDR	Review meeting	T0+8
M4	3D half Wing-Model verification results	Review meeting	T0+16
M5	GG PDR	Review meeting	T0+5
M6	GG CDR	Review meeting	T0+10
M7	GG verification results	Review meeting	T0+18
M8	Closure Meeting	Review meeting	T0+24

**Type: R=Report, D=Data, HW=Hardware*

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- The Applicant(s) will have a background in the design/sizing and the manufacturing of WT models for transonic flow conditions (high quality of aerodynamic surfaces).
- The Applicant(s) will dispose of the CAD software CATIA V5® (or a compatible software) and FEM software NASTRAN (or a compatible software) to ensure the exchanges with the Topic Manager (inputs and deliverables)

5. Abbreviations

ACARE	Advisory Council for Aerospace Research in Europe
CAD	Computer Aided Design
CDR	Critical Design Review
FEM	Finite Element Model
GG	Gust Generator
PDR	Preliminary Design Review
WP	Work Package
WT	Wind Tunnel

III. JTI-CS2-2018-CFP08-AIR-01-39: In-Seat Ventilation & Supply for Personalized Comfort Control on Board an Aircraft

Type of action (RIA/IA/CSA)	IA		
Programme Area	AIR		
(CS2 JTP 2015) WP Ref.	WP A-5.1.1		
Indicative Funding Topic Value (in k€)	450		
Topic Leader	Airbus	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	18	**Indicative Start Date (at the earliest)**[60]	Q1 2019

Identification	**Title**
JTI-CS2-2018-CFP08-AIR-01-39	**In-Seat Ventilation & Supply for Personalized Comfort Control on Board an Aircraft**
Short description (3 lines)	
The project aims to provide and demonstrate a concept of integrated seat climatization, ventilation and air supply as technology bricks for personalized comfort controlled environment for passengers in an aircraft.	

Links to the Clean Sky 2 Programme High-level Objectives[61]				
This topic is located in the demonstration area:	▪ Cabin & Fuselage			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	▪ Advanced Short/Medium-range ▪ Advanced Long-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☐	☐	☐	☒	☐

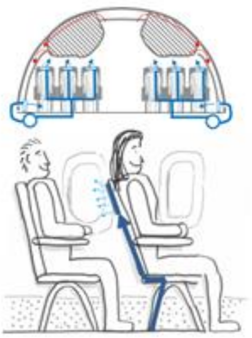
[61] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

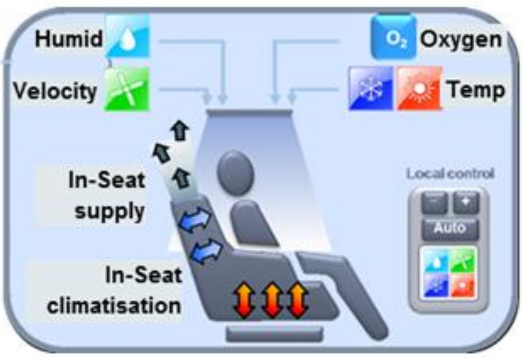
1. Background

Aircraft air conditioning systems are designed to provide an overall global comfort with constant parameters for all occupants (same cabin zone temperature, humidity, air velocities). However, the perception of the quality and comfort of the environment is highly individual and depends on each person and factors like clothing, gender, age and culture among many others.

On the other hand, automotive industry is setting the standards for individualized comfort in cars with separated temperature zones per seat, seat heating and seat ventilation. All features can be controlled by personal preferences for each seat. Even low budget cars provide seat heating and front/rear air conditioning zones. All these features will lead to increased expectations to comfort when using other transport vehicles. Seamless travel should provide the same experience from automotive to urban air mobility and short/long haul aircraft.

The innovation of this project is that it will provide means to control individual, personal parameters directly influencing the perception of the comfort. Thus, passenger experience will increase and an acceptable level of comfort will be kept or even improved, which is not possible with current means of global air conditioning only. In a later future, with a more connected and smarter aircraft environment, it could be possible for an occupant to travel with his own virtual environmental bubble from one vehicle (auto, urban air mobility, aircraft) to the other. Smart monitoring and control features would recognize and adapt the local seat to the individual preferences.





2. Scope of work

This project aims for implementation of seat climatization and ventilation into economy seats. The features designed to provide seat ventilation shall be customized, starting with simple seat heating adding further ventilation blowing or sucking means in the back of the seat ending up with complete individualized air climatization with cooling, heating means, and flow nozzles separately adjustable.

The main objectives of the topic are as follow:

- Elaborate todays individual climatization devices to control the personal space
- Design an architecture of in-seat ventilation & air supply including related controls
- Collect the best individual means of in-seat climatization and produce an E/C demonstrator and verify the optimum personalized climate for Airbus aircraft passengers.

In order to structure the activities to be performed, the following work breakdown structure is proposed:

WP1 Concept elaboration
A market review of all close-to-passenger air conditioning, sensor and controlling means shall lead to a selection of promising individual climatization elements for the E/C aircraft seat. Functionality proof of concept tests of nozzles, seat cushions, heating elements, Peltier devices, etc. from other industrial sectors will find feasible bricks to fit into an a/c seat architecture and comfort.

WP2 In-seat ventilation & air supply demonstrator for E/C seats
After all requirements to integrate an in-seat climatization have been collected and assessed a potential local climatization system for an E/C seat row shall be designed in 3D CATIA and in case 3-dimensional printed to visualize the integration aspect. A prototype seat row shall be built with original a/c materials and seat structure integrating the additional climatization function. Tests shall optimize the settings for each mean and additionally ideas how to control the individual flows/temperatures per seat shall be transformed into real prototype applications. A final test campaign at the Airbus Cabin Ventilation Mock-ups (CAV) in Hamburg will verify the selected architecture and will give recommendations for a final control architecture. The test demonstrator will be used in the Airbus CS2 LPA cabin demonstrator.

Tasks		
Ref. No.	***Title - Description***	***Due Date***
T0	Project Start - KoM	T0+1
T1	Concept Evaluation: Market review/ Proof of Concept / Sensoring • Market review of existing technologies and trends for close-to passenger ventilation means • PoC testing of individual flow elements; First Architecture of close-to-pax vent elements; assessment of local thermal comfort • Evaluate todays available thermal and emotion-sensing sensors/s/w best suited for automated comfort control • Collect all a/c seat & ventilation requirements	T0+4

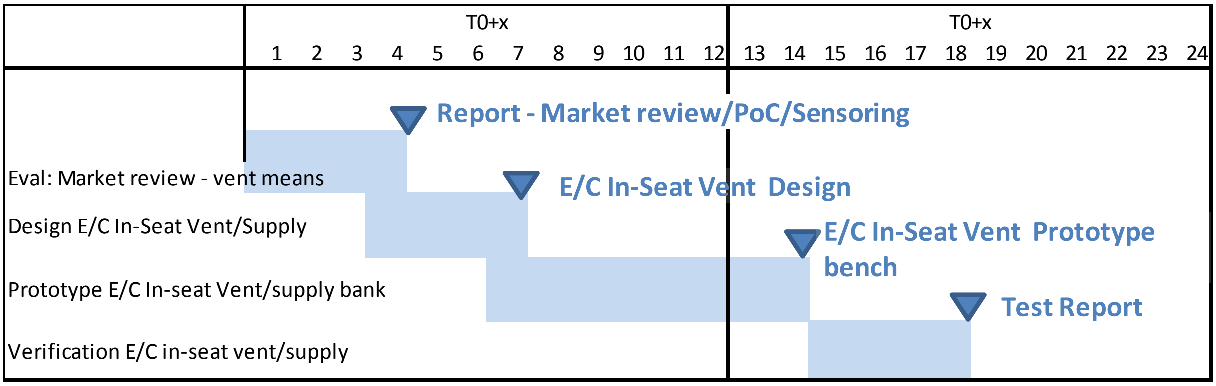
Tasks		
Ref. No.	***Title - Description***	***Due Date***
T2	<u>Design E/C In-Seat Ventilation/Air Supply</u> Design the ventilation & air supply means for a standard E/C seat row (3D virtual/printing)	T0+7
T3	<u>Prototype E/C In-seat Vent/supply bench</u> Build prototype seat row and optimise the flow pattern, air distribution, fan equipment, First idea of personal control unit	T0+14
T4	<u>Verification E/C in-seat vent/supply</u> Verification proof-of-concept test with test subjects and thermal comfort dummy in cabin ventilation mock up (A320 or A330 CAV at Airbus Hamburg)	T0+18

3. <u>Major deliverables and schedule (estimate)</u>

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1	<u>Market Review/Proof of Concept Test Report</u> • Report with consolidated results of market analysis with guideline for future projects and today's available thermal and emotion-sensing sensors • Test report Individual Ventilation Elements • Report with all requirements	R	T0+4
D2	<u>E/C In-seat climatization Design</u> Design description & 3D Model	R/D	T0+7
D3	<u>E/C In-seat climatization: Prototype bench</u> Demonstrator E/C in-seat ventilation/air supply bench	HW	T0+14
D4	<u>E/C In-seat climatization: Verification</u> Verification Test report	R	T0+18

The following picture describes the basic schedule of the project showing the tasks and milestones. Some of the tasks can be done in parallel, which is indicated by the coloured, overlapping time bar. The overall time duration is scheduled to 18 months after KoM.



4. Special skills, Capabilities, Certification expected from the Applicant

- The applicant shall have deep knowledge of aircraft cabin operations and related regulations.
- The applicant shall have knowledge of aircraft certification requirements.
- The applicant shall have deep knowledge of thermal comfort assessment and cabin local and overall ventilation.
- The applicant shall have knowledge to integrate ventilation & climatization parts into seats.
- The applicant shall demonstrate industrial capability for manufacturing physical mock-ups and measurement of comfort /ventilation parameters.

5. Abbreviations

PoC	Proof of Concept
CAV	Cabin Air Ventilation
E/C	Economy Class
AIR	Short term for ITD Airframe

IV. JTI-CS2-2018-CFP08-AIR-02-60: Full Scale Innovative Integrated Tooling for Composite Material Wing Box [SAT]

Type of action (RIA/IA/CSA)	IA		
Programme Area	AIR [SAT]		
(CS2 JTP 2015) WP Ref.	WP B-2.1		
Indicative Funding Topic Value (in k€)	950		
Topic Leader	Israel Aircraft Industries	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	20	**Indicative Start Date (at the earliest)**[62]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CFP08-AIR-02-60	**Full Scale Innovative Integrated Tooling for Composite Material Wing Box**
Short description	
The activities in this topic will be to design, develop and manufacture innovative and integrated tooling for a "one shot" process which includes an integral composite material structure comprised of 3 spars and a skin. Novel tooling concepts will ensure efficient manufacture of this ambitious integral structure.	

Links to the Clean Sky 2 Programme High-level Objectives[63]				
This topic is located in the demonstration area:	Advanced Manufacturing			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	19-pax Commuter			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☒	☐

62 The start date corresponds to actual start date with all legal documents in place.
63 For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

OPTICOMS is an AIRFRAME ITD core partner project under the Clean Sky 2 programme devoted to the research and development of technologies for more affordable composite aero structures. The consortium consists of a small aircraft OEM and three leading European aerospace automation companies, all striving towards low cost composite material automation for low volume aircraft manufacture.

OPTICOMS is advancing a wide range of technologies with an emphasis on improvement of low cost and efficient production capabilities. Reducing manufacturing costs can be achieved by developing and implementing automated manufacturing processes together with designing integral structure. The cost effectiveness parameters shall be based on low volume production of small aircraft. The project will design, manufacture and test a full scale composite wing structure.

The goals of the OPTICOMS project are consistent with WP B-1.2 of the AIRFRAME ITD (see figure 1 below) as described in the Clean Sky Joint Technical Program. Among the objectives of WP B-1.2, it is also emphasized the need for a more integral structure.

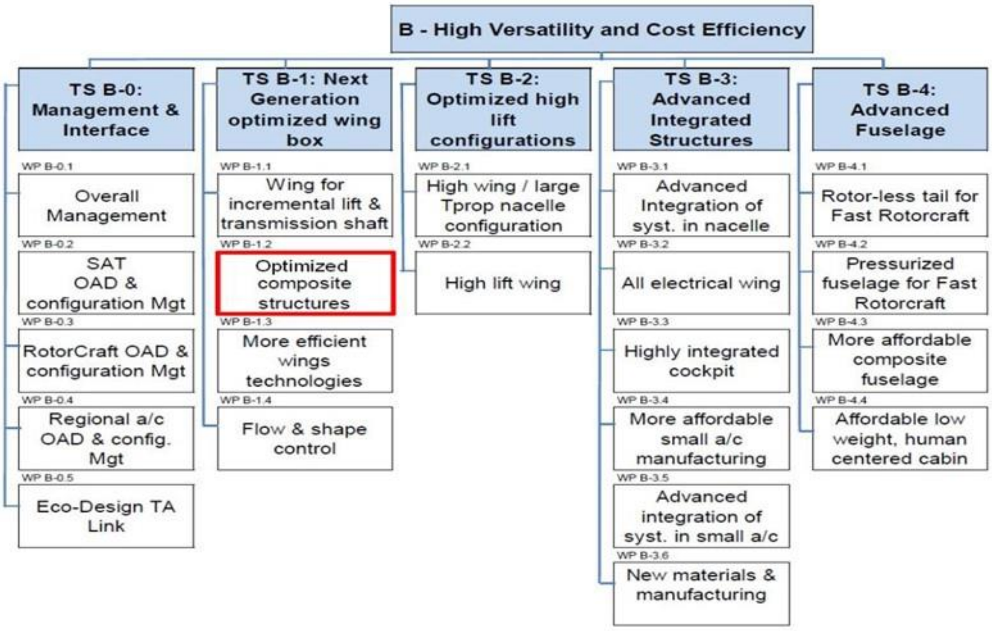


Figure 1: WP B-1.2 collocation under AIRFRAME ITD

OPTICOMS included a large wing conceptual design down-selection phase which concluded with the wing design presented in Figure 2. Note that the 3 spars and the upper skin will be produced as an integral part. The idea of all the spars and skin being manufactured in a "one shot" integral process will obviously significantly reduce manufacturing and assembly recurring costs. The tooling for such an ambitious structure is far from trivial, and the success of this challenge depends on an innovative, large integrated tooling approach. Pioneering and efficient tooling concepts for manufacturing of multiple structures simultaneously accompanied by possible novel beyond state of the art ideas such as self-heating tooling and/or built in sensor monitoring can ensure a cost effective and successful structure.

The scope of the topic is to look for robust and novel tooling concepts as well as design and tooling manufacturing for the integral structure presented (not including the bottom skin and ribs).

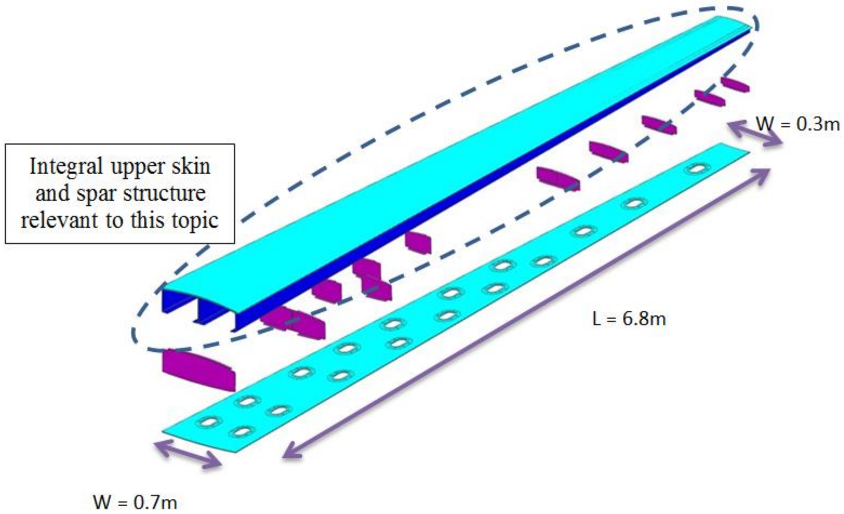


Figure 2: Down-selected Integral Composite Wing Design Concept

Expected Innovation aspects:

We expect in this topic not only straight-forward, more of the same, tool design and manufacture, but in addition some technological challenge which will benefit the selected partner, the OPTICOMS project and the AIRFRAME ITD with new ideas regarding innovative tooling:

- Tools suitable for multi-structure "one shot manufacture"
- Relatively low cost tooling approach essential for low volume production
- Tooling which are suitable for both pre-preg and LRI (Liquid Resin Infusion) with minimal adjustments
- Tooling which are suitable for automated lay up
- When feasible same tooling for lay-up and consolidation, for further cost savings
- Energy environmental efficient heating
- Tool which will provide a final part which is suitable for large scale structural bonding
- Optional sensor feedback

2. Scope of work

In order to reach the goals of the OPTICOMS project, a full scale wing structure as shown above in Figure 2 must be manufactured, assembled and tested. As mentioned above, it is essential to try to lower the manufacturing and assembly costs of this structure for low volume production. These constraints led to the automated, "one-shot", out of autoclave manufacturing concept. This topic is requesting the tooling design and manufacture for the integral spars and upper skins. The main tasks to be performed are as follows:

1 – At first a tooling conceptual design shall be proposed which will allow the manufacturing of the spars and skin in a "one shot", out of autoclave process. The applicant shall always keep in mind a low cost, efficient and robust manufacturing method. The Topic Manager has already started developing ideas for the innovative tooling approach. The selected partner will improve on these ideas and bring further innovation to the novel tooling design which shall have an impact on the efficiency and the cost of the manufacturing process. Although the assumption here is that the manufacturing process will be LRI (Liquid resin infusion), it is expected that the same tooling may be suitable for prepreg co-bonding

manufacture with minimal adjustments. A CDR is expected at the end of this task.

2 – The detailed design stage includes mechanical design, thermal and stress analyses. CAE methods will be employed to deliver a novel, robust and efficient design. In order to avoid any misinterpretation, this task includes both lay-up and consolidation tooling (which may be the same). The use of separate tool details for lay-up and consolidation phases should be avoided where sensible. As stated above, the applicant shall always keep in mind low cost, efficient and robust manufacturing.
The tooling shall comply with the following restrictions and constraints

- General Surface Tolerance ± 0.5 mm. Surface finish 32 rms.
- 190 ^{0}C Maximum Temperature capability together with 1 bar pressure applied by a vacuum bag with a vacuum of >28"Hg. (5mbar)
- Maximum vacuum leakage 0.5"Hg drop over a 5 minute period (2mbar per minute)
- Heating rates in the range 1-5 ^{0}C/minute. Maximum temperature variation between any two points on tools 20^{0}C.
- Spar tools shall be 'floating' under the vacuum bag. Fixtures with indexing attachments for locating the 3 spars accurately will be required. These fixtures will be removed before vacuum bagging.
- Any fixtures that remain inside the vacuum bag during the infusion/consolidation process shall withstand the loads and moments applied during the process.
- Drilling fixtures will be required for bushings and assembly location points.
- Demoulding aids incorporated into the tooling is desirable.
- Hard points shall be incorporated for fixtures, locators and tool assembly details.
- Best efforts shall be made to keep the weight of tooling to a minimum to assist handling and heat-up. This shall not compromise the robustness of the tools and the rigidity of the long slender spar tools in particular.
- The cost of tooling shall be minimised where possible. This is a demonstrator tool, so features necessary for serial production tooling are not required
- Handling of the anticipated long and narrow tool assembly is not expected to be straightforward. Consideration shall be given to the necessity or otherwise of support bolsters to assist tool transport to and from manufacturing stations. Any individual tool detail that weighs more than 25 kg shall have hoist points and/or fork lift provisions incorporated. Spar tooling may require distributed hoist points to avoid deflection during lifting. These hoist points will require blanking features/inserts to prevent resin ingress.
- Design tool for low cost integral structure wing production concept will take into account
    - Lay-up capabilities and limitation given by preform manufacturer
    - Topic Manager part design criteria
    - Liquid resin infusion and prepreg process requirements given by the Topic Manager
- Optional: Consideration of the use of self-heated tooling for out of autoclave/oven applications.

3 – Tool Manufacturing for the integral spars and upper skin.

The Topic Manager shall be present at the manufacturing facility during tooling build and before shipment for verification and validation of the tooling. Tooling shall be supplied together with the reports from the inspection department of the manufacturer detailing deviations, if any, from the technical requirements. The reports shall be according to international standards to enable tool acceptance and use at Topic Manager premises.

The following table presents the expected schedule of the activities:

Tasks		
Ref. No.	***Title - Description***	***Due Date***
Task 1	**Novel Tooling Concept** – Innovative conceptual design for efficient integrated tooling, focussing on minimum energy and cost for the composite automated manufacturing. Please note that due to project time constraints, the Topic Manager will already have prepared some tooling conceptual design to assist the partner.	T0+5
Task 2	**Novel Tool design** – Detailed tool design for the integral 3 spars and upper skin in a one shot process – ensuring practicality of the automated composite manufacturing technology.	T0+12
Task 3	**Tooling manufacture** for the integral 3 spars and upper skin, ensuring maintenance of all technical requirements. The Topic Manager will be present for the tooling validation and verification.	T0+20

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1	Tooling concept and preliminary sizing and cost	R	T0+5
D2	Final Tooling Drawings	R	T0 + 12
D3	Tooling Manufacture	HW	T0 + 20
Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M1	PDR	D	T0 + 5
M2	CDR	D	T0 + 12
M3	Final Tool Manufacture	HW	T0 + 20

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Workshop with equipment of the accuracy necessary for carrying out the task. Regular inspection and certified calibration of the equipment.
- Staff with training and certification necessary for equipment operation.
- Aerospace experienced tooling manufacturer

5. Abbreviations

CDR	Critical Design Review
CfP	Call for Proposal
ITD	Integrated Technology Demonstrator
LRI	Liquid Resin Infusion
OEM	Original Equipment Manufacturer
PDR	Preliminary Design Review

V. JTI-CS2-2018-CFP08-AIR-02-61: Development and Optimization of Bonding Assembly Technology for a Composite Material Wingbox [SAT]

Type of action (RIA/IA/CSA)	IA		
Programme Area	AIR [SAT]		
(CS2 JTP 2015) WP Ref.	WP B-2.1		
Indicative Funding Topic Value (in k€)	900		
Topic Leader	Israel Aircraft Industries	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	22	**Indicative Start Date (at the earliest)**[64]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CFP08-AIR-02-61	**Development and Optimization of Bonding Assembly Technology for a Composite Material Wingbox**
Short description	
The scope of this topic is to develop, design and manufacture the required full scale innovative bonding assembly tooling, in order to obtain a high quality airworthy structural bond between a lower wing cover to the already assembled wing substructure. Novel tooling concepts are necessary to apply the required pressure uniformly to ensure bonding integrity and dimensional tolerances.	

Links to the Clean Sky 2 Programme High-level Objectives[65]				
This topic is located in the demonstration area:	Advanced Manufacturing			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	19-pax commuter			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☒	☐

[64] The start date corresponds to actual start date with all legal documents in place.

[65] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

OPTICOMS is a Clean Sky project devoted to the research and development of technologies for more affordable composite aero structures. The consortium consists of a small aircraft OEM and three leading European aerospace automation companies, all striving towards low cost composite material automation for low volume aircraft manufacture.
OPTICOMS is further developing a wide range of technologies with an emphasis on the improvement of low cost and efficient production and assembly capabilities. Reducing manufacturing and assembly costs can be achieved in a variety of ways. In this project the costs will be reduced by developing and implementing automated manufacturing processes together with designing integral structure and including bonding of large scale structural parts.
Regarding the assembly phase, large scale bonded assemblies have the potential to reduce airframe assembly time as well as costs and weights, by eliminating the riveting and the corresponding stress concentrations. A pioneering development approach is needed for bonding integrity including the optimization of bondline thickness, temperature and uniformity of pressure applied. The cost effectiveness measures shall be based on low volume aircraft production. The project will design, manufacture and test a full scale composite wing structure.

The goals of the OPTICOMS project are consistent with WP B-1.2 of the AIRFRAME ITD (See Figure 1 below) under CleanSky 2 programme.

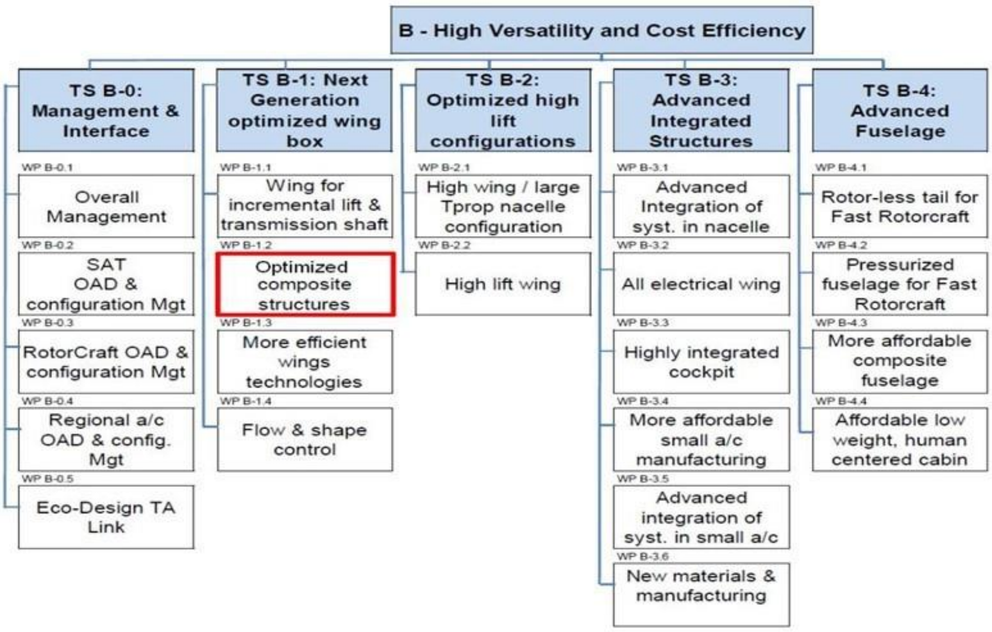


Figure 1: WP B-1.2 collocation under AIRFRAME ITD

OPTICOMS included a large wing conceptual design down selection phase which concluded with the wing design presented in Figure 2. The 3 spars and the upper skin will be produced as an integral part. The idea of all the spars and skin being manufactured in a "one shot" integral process will obviously significantly reduce manufacturing and assembly recurring costs. In addition, OPTICOMS plans to bond the lower skin to the wing box substructure in order to further reduce time, cost and weight.
This topic is striving for robust and novel tooling concepts as well as design and tooling

manufacturing for the bonded assembly of the lower wing cover to the already assembled wing box sub-structure.

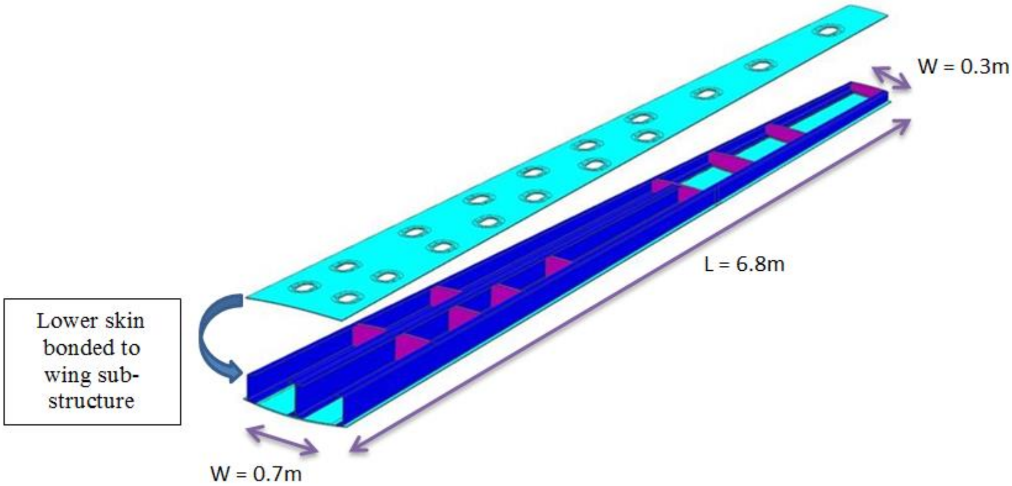


Figure 2: OPTICOMS Full Scale Wing Box

Expected Innovation aspects:

We expect in this topic not only straight-forward, more of the same, standard tool design and manufacture, but in addition some technological advances which will benefit the selected partner, the OPTICOMS project and the AIRFRAME ITD:

- Assembly bonding tooling which will ensure reasonably consistent bonding pressures and temperatures.
- Assembly bonding tooling which will help ensure reasonably consistent bondline thickness
- Incorporation of optical fiber Structural Health Monitoring (SHM) to verify bond line integrity (the SHM algorithm, technology and embedding will be the responsibility of the Topic Manager)
- Relatively low cost tooling approach essential for low volume production
- It would be desirable to have a tool which includes the possibility to apply pressure differentially to compensate for integral wing box manufacturing dimensional deviations.
- Optional sensor feedback

2. Scope of work

In order to reach the goals of the OPTICOMS project, a full scale wing structure as shown above in Figure 2 will be manufactured, assembled and tested. As mentioned above, it is essential to try to lower the manufacturing and assembly costs and weight of this structure for low volume production. These goals led to the concept of attempting to implement large scale structural bonding in order to decrease time, weight and costs. This topic is requesting the development, design and manufacturing of the tooling which will bond the lower cover to the wing box sub-structure.

The Topic Manager will invest significant time and effort in understanding the optimum parameters to ensure bonding integrity including superior adhesives, innovative surface treatments, the necessary dimensional tolerances, pressures, temperatures etc. It will be the responsibility of the selected partner to take these parameters into account in the tooling design and manufacture.

One of the big challenges in structural bonding is to avoid the “kissing bond” – i.e., the two parts are touching, but there is no guarantee of bonding quality. NDT will not be able to detect such a problem. Thus, the bonding integrity must be guaranteed by a combination of possible approaches. Correct surface treatments, optimal bonding temperature and pressures, bond line structural monitoring with possible design features will help safeguard bonding quality. In this project, the Topic Manager will provide the technologies and together with the selected partner they will attempt to implement in a novel conceptual tooling approach. The main tasks to be performed are as follows:

1- Novel Bonding Conceptual Assembly Tool Design

The selected partner must provide the tooling conceptual design which will allow the efficient bonding of the lower wing skin to the wingbox sub-structure. The partner shall always keep in mind a low cost, efficient and robust manufacturing method for low volume manufacture. The tooling conceptual design should address the innovative aspects aspired to in this project, first and foremost the application of correct pressures along the bondline. Similarly the implementation of structural health monitoring for the bondline must be considered in the design. Temperature and dimensional tolerances must also be addressed. This stage will finish with a Preliminary Design Review (PDR)

2 – Novel Bonding Assembly Tooling Detailed Design

The detailed design stage includes mechanical design and stress analyses. This shall include thermal analysis for verification of temperature uniformity and compensation for thermal expansion between the tooling and composite wingbox details. Consideration shall be given to the practicality of incorporating positional correction features to compensate for dimensional discrepancies in the integral upper cover/spar integrated assembly. CAE methods will be employed to deliver a novel, robust and efficient design. Fully detailed manufacturing drawings shall be presented at the CDR. As stated above, the selected partner shall always keep in mind low cost, efficient and robust manufacturing. This stage will include a CDR (Critical Design Review) at which the design shall be presented, assessed and approved.

The tooling is expected to comply with the following requirements and constraints:

- General Surface Tolerance $\pm$ 0.5 mm (Provisional). Surface finish 32 rms on contact surfaces.
- 130 ^{0}C Maximum temperature capability together with 1 bar pressure.
- Heating rates in the range 1-5 ^{0}C/minute. Maximum temperature variation between any two points on tools 20^{0}C.
- Composite wingbox components will be manufactured incorporating location/assembly points. The bonding tooling shall utilise these points to locate correctly the components for the bonding process.
- Consideration shall be given to the practicality or otherwise of incorporating positional correction features to compensate for dimensional discrepancies in the integral upper cover/spar integrated assembly.
- Drilling fixtures may be required for bushings and downstream assembly location points.
- Tooling shall be designed such that adhesive flash produced during the bonding process shall not interfere with the process of removing the bonded wingbox from the bonding tool. Tool details for post bonding operations, such as drilling fixtures, shall be designed such that they are protected from adhesive flash ingress.
- Hard points shall be incorporated for fixtures, locators and tool assembly details.
- Best efforts shall be made to keep the weight of tooling to a minimum to assist handling and heat-up. This shall not compromise the robustness of the tools and the rigidity necessary for proper handling of the long, slender wingbox.
- The cost of tooling shall be minimised where possible. This is a demonstrator tool, so features necessary for serial production tooling are not required, but should be considered in the design as suitable for low rate serial production.

- Handling of the anticipated long and narrow tool assembly is not expected to be straightforward. Consideration should be given to the necessity or otherwise of support features to assist tool transport to and from manufacturing stations. Any individual tool detail that weighs more than 25 kg shall have hoist points and/or fork lift provisions incorporated.
- Design tool for low cost low rate production concept taking into account
  - Geometrical limitations and deviations from nominal of the various composite details to be bonded.
  - Topic Manager part design criteria
  - Bonding process requirements given by the Topic Manager
- Optional - Consideration of the use of self heated tooling for out of oven applications.

3 – <u>Novel Tooling Manufacture</u>
The tooling will be manufactured as per design and will meet the requirements stated above.

The Topic Manager shall be present at the manufacturing facility during tooling build and before shipment for verification and validation of the tooling. Tooling shall be supplied to the Topic Manager's facility together with the reports from the inspection department of the manufacturer detailing deviations, if any, from the technical requirements. The reports shall be according to international standards to enable tool acceptance and use at Topic Manager premises.

The following table presents the expected schedule of the activities:

Tasks		
Ref. No.	***Title - Description***	***Due Date***
Task 1	**<u>Novel Bonding Conceptual Assembly Tool design</u>** – Conceptual design of innovative assembly tooling for the assembly of the lower skin to the wing substructure. The concept should attempt to address the innovation challenges defined above, with a special emphasis on the proper application of pressure along the bond-line. Dimensional tolerances, temperature, cost shall also be taken into account. Implementation of bond-line SHM must also be considered.	T0+6
Task 2	**<u>Novel Bonding Assembly tool detailed design</u>** – Detail tool design will be performed for the successful, accurate and low cost novel structural bonding assembly tooling of the lower wing cover to the already assembled wing substructure	T0+14
Task 3	**<u>Assembly Tooling manufacture</u>** ensuring maintenance of all aforementioned technical requirements. Tooling shall be inspected and supplied together with all necessary inspection and statutory documentation.	T0+22

3. <u>Major Deliverables/ Milestones and schedule (estimate)</u>

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1	Tooling concept and preliminary sizing and cost	R	T0+6
D2	Tooling Drawings	R	T0+14
D3	Tooling Manufacture and delivery	HW	T0+22

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M1	PDR	D	T0+6
M2	CDR	D	T0+14
M3	Final Tool Manufacture	HW	T0+22

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Workshop with equipment of the accuracy necessary for carrying out the task. Regular inspection and certified calibration of the equipment.
- Staff with training and certification necessary for equipment operation.
- Aerospace experienced tooling manufacturer

5. Abbreviations

CDR	Critical Design Review
CfP	Call for Proposal
ITD	Integrated Technology Demonstator
NDT	Non-destructive testing
OEM	Original Equipment Manufacturer
PDR	Preliminary Design Review
SHM	Structural Health Monitoring

VI. JTI-CS2-2018-CFP08-AIR-02-62: Virtual-Hybrid-Real On Ground demonstration for HVDC & EMA Integration

Type of action (RIA/IA/CSA)	IA		
Programme Area	AIR		
(CS2 JTP 2015) WP Ref.	WP B-3.2		
Indicative Funding Topic Value (in k€)	400		
Topic Leader	Airbus Defence & Space	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	24	**Indicative Start Date (at the earliest)**[66]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CFP08-AIR-02-62	**Virtual-Hybrid-Real On Ground demonstration for HVDC & EMA Integration**
Short description	
The topic deals with design, development and installation of a configurable virtual/hybrid/real ground test environment, aircraft and airframe representative, according to VISTAS EUROCAE standard for on-ground tested validation (up to TRL5 of technology integration of airframe) of flight control surfaces driven by electromechanical actuators powered by high voltage DC electrical generation (HVDC).	

Links to the Clean Sky 2 Programme High-level Objectives[67]				
This topic is located in the demonstration area:	Enabling Technologies			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Regional Multimission TP, 70 pax			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☒	☐

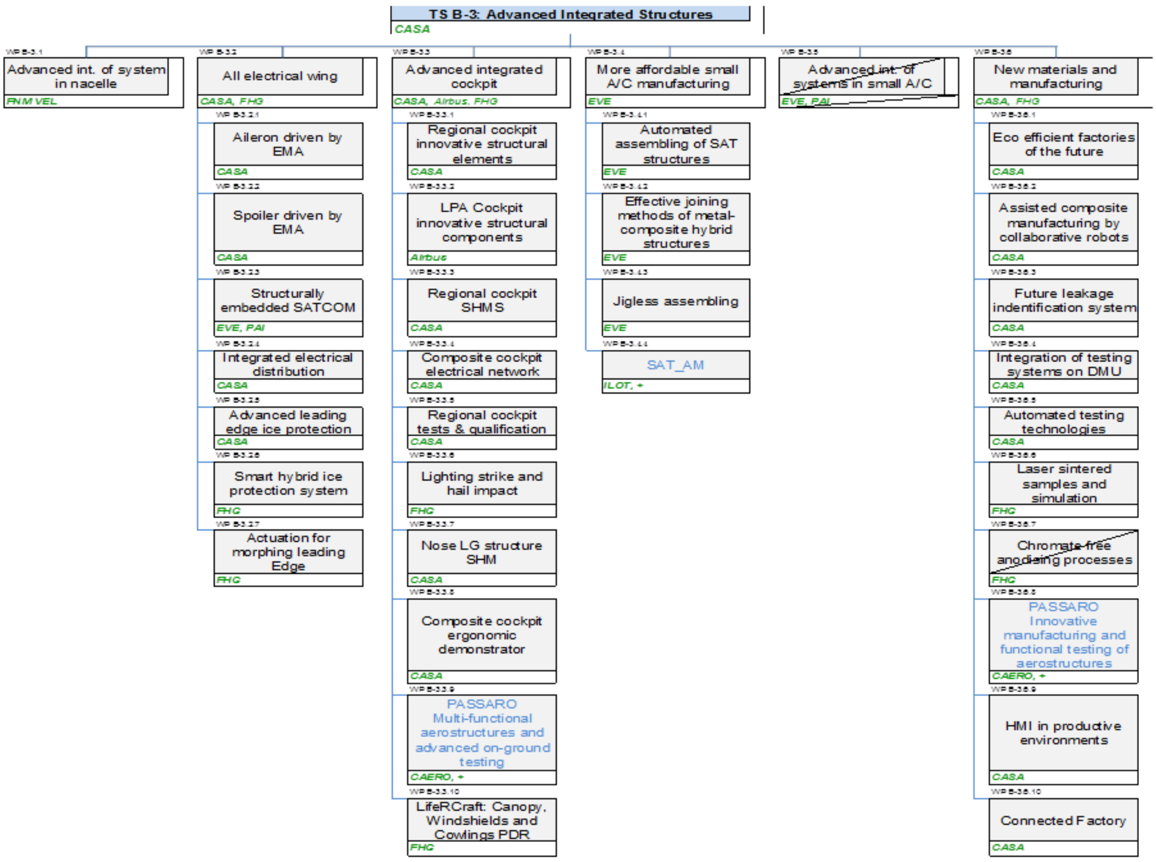
[66] The start date corresponds to actual start date with all legal documents in place.

[67] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

This topic deals with the technologies developed for on ground tests facilities dedicated to High Voltage Direct Current (HVDC) integration on the structure devoted to regional aircraft as reference platform. The facilities and equipment proposed will be used to test on ground actuation systems of electromechanical actuated surfaces such as ailerons, flaps, spoiler and winglet proposed by the Topic Manager in the context of Clean Sky 2 Regional FTB2 demonstrator, following the technology validation process before the aircraft integration.

The framework of this topic is AIRFRAME ITD *Work Package B-3.2 All Electrical Wing* where the main technology objective is to explore innovative technologies for a more electrical integration on airframe structures, particularly in the wing. In this WP it is intended that primary aircraft control surfaces be actuated by electro-mechanical actuators (EMAs) developed in SYSTEMS ITD. An on-ground test rig is required for a TRL5 validation of these airframe integration technologies. This topic will contribute to the ON GROUND ACTUATION RIG FTB#2 WING demonstrator: from design to final integration perspective.



The ON GROUND ACTUATION RIG FTB#2 WING demonstrator is an AIRFRAME ITD major demonstrator devoted to prepare the evidences required to ensure the Aircraft integration on FTB#2 demonstrator where the EMAs actuated technologies are intended to be demonstrated in flight up to TRL6.

The FTB2 demonstrator is based on the Topic Manager turboprop transport aircraft with high wing configuration thrusted by two turboprops. So far several efforts have been made in order to enhance the aircraft performances with new wing control surfaces (aileron, flap, spoiler and winglet). This effort in order to achieve a better A/C is aligned with the CS2 objectives of getting more efficient and green transport. Figure 10 depicts the FTB2 Demonstrator and the innovative control surfaces actuated by EMAs.

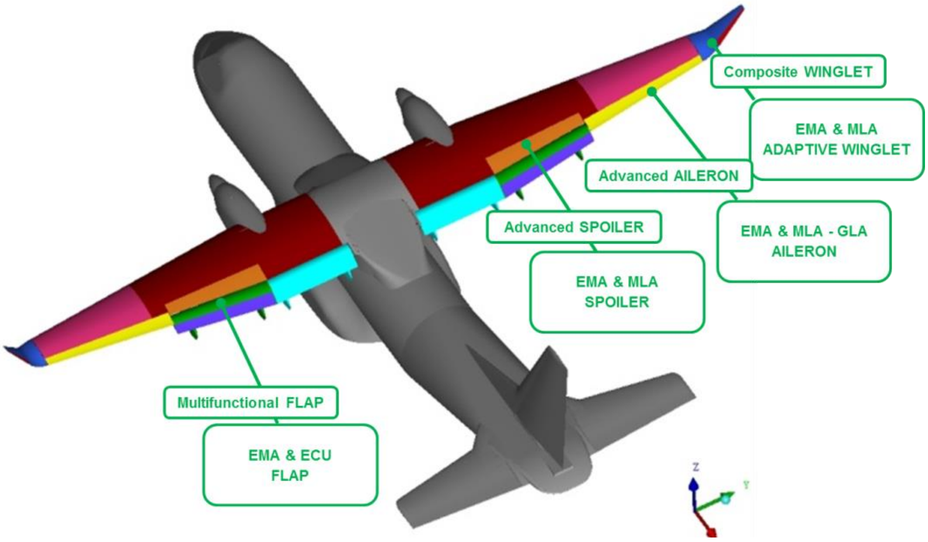


Figure 10: Regional FTB2 A/C innovative control surfaces

2. <u>Scope of work</u>

Virtual testing approach is the future and innovative solution to avoid the difficulties related to physical test benches used in aircraft development process, which are complex platforms with high initial and recurring costs. They are usually on the critical path on the development and cannot be easily multiplied to increase the validation capacity. This solution has been proved in other industries like Cell phone but in the avionics industries it is not yet implemented as there are some specific challenges as systems are complex, hardware heterogeneous and coming from multiple suppliers with different infrastructures.

The VISTAS standard was released on Nov-2017, by EUROCAE Working Group 97 titled "Interoperability of virtual avionic components" and was approved by the Council of EUROCAE on 10 November 2017. It provides the Virtual Component definition in terms of modelling and the Standardization of the interfaces (virtualization rules for the different A/C signals and buses, commands, etc.).

In the following picture, the virtual bench concept and the real test bench concept are represented through VISTAS approach. It can be noted that following this scheme the switching between real and virtual environments is immediate and in the cases of benches a huge cost avoidance can be obtained in terms of benches simplicity and wiring. Concepts like patch panels and fault insertion systems based on HW are virtualized.

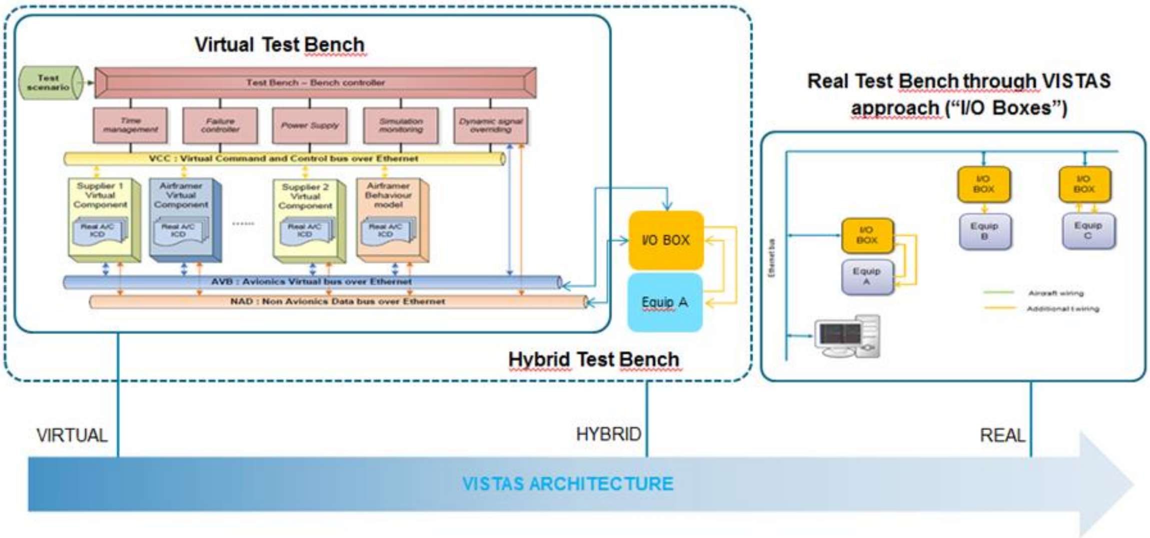


Figure 11: VISTAS approach in terms of bench architecture

The framework of the activities will be the ON GROUND ACTUATION RIG FTB#2 WING demonstrator that integrates the aircraft control systems, the electrical systems and the hydraulic.

The objectives of this topic are twofold:

- To develop an A/C representative electrical test installation composed by the HVDC part of the A/C electrical generation and distribution system. This is added to the existing electrical rig as a part of ON GROUND ACTUATION RIG FTB#2 WING demonstrator.
- To develop the I/O box concept, in accordance with VISTAS protocol, in order to provide the necessary interconnection between real and virtual test environments, and providing the necessary infrastructure for virtualization at FTB#2 actuation on-ground rig.

The HVDC electrical installation, core of the topic, shall be fully representative of A/C environment, containing real A/C equipment related to electrical conversion and distribution stages, and the corresponding real consumers (EMAs). The performance of each component will be evaluated by using the switching capability provided by the application of VISTAS protocol principles:

- In virtual mode the HVDC electrical system functionality is validated in a model based approach.
- In hybrid mode the HVDC electrical system functionality is validated mixing real A/C equipment and simulated equipment. In order to achieve this mode, real A/C equipment is connected to simulated environment via VISTAS I/O boxes.
- In real mode, the HVDC electrical system is validated always with real A/C equipment.

When testing in hybrid or real mode, the electrical test rig can be configured with different levels of integration:

- In stand-alone conditions, the HVDC electrical system is tested separately from the integrated rig, for this purpose dedicated power supplies and/or load benches may be requested for it by the partner.
- In integrated conditions, the HVDC electrical system is integrated with FTB#2 actuation on-ground rig.

The technology challenges of the topic are summarized in the following table.

Table 1: Technology challenges in the Flexible Test Rig for different A/C surfaces powered by EMAS

COMPONENT	TECHNOLOGY CHALLENGES	TECHNOLOGY DEMONSTRATORS
HVDC 270VDC network test bench	To investigate the performances of HVDC 270VDC network considering the integration of the CONVERTERS and DISTRIBUTION BOX, considering functional, protections and power quality tests in stand-alone and integrated mode.	On – ground HVDC 270VDC network test bench.
Innovative VISTAS I/O Box	To provide a low-cost device reusing existing approaches capable of virtualizing the most common avionic signals and buses: analog, discrete, RVDT, CAN, A429. RS-232/422/485	On – ground HVDC 270VDC network test bench, integrating VISTAS I/O Boxes connecting real A/C equipment to virtual avionics network
Innovative Virtual/Hybrid/Real integration of HVDC 270VDC network	To set up the corresponding virtual/hybrid and real environments by using a virtual avionics network	On – ground HVDC 270VDC network test bench, integrating VISTAS I/O Boxes connecting real A/C equipment to virtual avionics network

Work Packages and Tasks description

It is proposed to organize the main activities in two technical Work Packages (WPs) devoted to on - ground HVDC 270VDC network test bench:

- WP1: Design and manufacturing of VISTAS I/O Boxes and virtualization infrastructure implementation at ON GROUND ACTUATION RIG FTB#2 WING demonstrator
- WP2: Design and manufacturing if On – ground HVDC 270VDC network test bench

These WPs shall be under the Applicant accountability; however the Topic Manager will contribute to the conceptual design, as well as the system specification in order to define all the interface requirements between the test bench and the connected equipment (A/C and/or industrial).
In the following, technical tasks description and expected schedule are provided:

Tasks		
Ref. No.	***Title - Description***	***Due Date***
Task 1.1	Trade-off for selection of the industrial elements to be considered in the design	T0 + 3
Task 1.2	PDR: preliminary design review	T0 + 4
Task 1.3	CDR: critical design review	T0 + 5
Task 1.4	VISTAS I/O boxes manufacturing and assembly	T0 + 8
Task 1.5	Acceptance Test Procedure Execution, Delivery and Installation for VISTAS I/O boxes	T0 +9

Tasks		
Task 1.6	Acceptance Test Procedure for SW development (Final Version)	T0 + 14
Task 1.7	Support of Rigs Integration	T0 + 24*
Task 2.1	Trade-off for selection of the industrial elements to be included in the bench	T0 + 2
Task 2.2	PDR: preliminary design review	T0 + 2
Task 2.3	CDR: critical design review	T0 + 3
Task 2.4	SW specific development for Control / Acquisition System	T0 + 4
Task 2.5	Acceptance Test Procedure Definition	T0 + 5
Task 2.6	Bench installation at Topic Manager site	T0 + 8
Task 2.7	POWER ON: power on of the test bench	T0 + 10

**Task 1.7: support is required until FTB#2 Step 2 TRR (estimation 12 months after technical activities finalization)*

Additional relevant Requirements

Bench switching capabilities between different ON GROUND ACTUATION RIG FTB#2 WING demonstrator configurations shall be maintained.

The on-ground HVDC electrical test bench integrates electrically the following A/C equipment:

1. 115VAC / 270VDC Converter (x2). At rig facilities, this component will be integrated in the current Electrical Rig.
2. 270VDC Distribution Box (x1). At rig facilities, this component will be integrated in the current Electrical Rig.

Mechanical modifications shall take into account:

- Volume, weight and relative position between equipment in order to assure wire lengths representatively.
- Cooling requirements of real equipment.
- Proper AC power, DC power and signal grounding segregation of LH and RH of the aircraft with no undesired ground loops.
- Cockpit modifications –panels and/or screens- mechanical and functional representative of the real A/C equipment.

Electrical modifications shall provide:

- Fully representative of A/C power systems in terms of: type of cables, wire lengths, electrical interfaces and grounding segregation.
- All power and signal harnesses –via VISTAS- needed in order to interconnect real/model equipment to the network. Signal harnesses in a traditional way will be considered and provided as a backup solution to the I/O boxes in order to deal with potential delays that may appear to the innovative virtualization concept implementation via VISTAS I/O boxes.
- The necessary A/C connectors in order to interface A/C equipment.
- Innovative panels, screens, etc., at cockpit keeping the physical representability in terms of ergonomics and human factors aspects, and connected to the test environment via VISTAS protocol

Instrumentation (Current, Voltage; Temp, Airflow) to monitor system behavior and the corresponding extension of Acquisition System with a suitable spare capacity

The test bench shall consider an acquisition software development with National Instruments LabVIEW. The SW code shall comply with the corresponding specifications and also shall be provided in open code in order to allow further modifications if required in the future.

At signal lines, properly virtualized via VISTAS I/O boxes, patch panels and failure insertion capability shall be provided in a virtual way.

In order to provide the electrical loads to the Electrical System under test, dynamic load benches shall be considered, and integrated within the control system of the laboratory –National Instruments HW and SW based-.

Real FTI installation shall be A/C representative, and sensors shall be installed and acquired including FTI acquisition system DEWESOFT or similar technology based and defined by the Topic Manager.

The VISTAS I/O boxes shall consider the following:

- The smallest form factor achievable reusing existing technologies and previous and tested designs avoiding an specific design work for it
- Simple and low cost solution.
- Customizable at a certain margin in order to accommodate to the I/O diversity present in the A/C equipment to be virtualized.
- It shall be able to virtualize the following signals type: analog, discrete, RVDT, CAN BUS, A429 in bidirectional I/O mode in the way described at EUROCAE VISTAS protocol.
- Recording capacity at VISTAS I/O box level shall be valued positively.
- A set of several VISTAS I/O boxes (around ten units) shall be provided in order to achieve the virtualization objectives presented above at HVDC electrical laboratory.

It is also required to virtualize the existing parts of the bench (electrical, hydraulic, cockpit, surfaces benches, etc.) that are not going to be connected to VISTAS I/O boxes, as the benches have been developed in a traditional way up to now. For this purpose the corresponding SW development is included as a task within this proposal. Labview programming shall be considered at FPGA/RT targets which will be operating at PXI and cRIO instrumentation platforms from NI (National Instruments). The developed SW shall be reusable and open code, maintaining the current functionalities of the test bench.

Effort and costs

An estimation of the effort between the activities is suggested below. Furthermore, details about budget distribution are welcome.

Table 2: Indicative effort required for each main component/activity within the project

COMPONENT/ACTIVITY	Effort estimated
WP1: Design and manufacturing of VISTAS I/O Boxes and virtualization infrastructure implementation at ON GROUND ACTUATION RIG FTB#2 WING demonstrator	60%
WP2: Design and manufacturing if On – ground HVDC 270VDC network test bench	40%

Inputs and Outputs

Topic Manager will provide the following information to the Beneficiary:

- Equipment under test functional specifications (mechanical and electrical interfaces (ICDs)).
- Support in the activities defined in the Topic to ensure full-compatibility of the rigs
- VISTAS protocol
- Current specific SW developed versions at ON GROUND ACTUATION RIG FTB#2 WING demonstrator test systems

The outputs requested from the Applicant are the following ones:

- Technical Documentation required (electrical drawings in AUTOCAD electrical 2012 or above, mechanical design in CATIA V5.21 or lower, acquisition SW user manual functionality, SW open code in LabVIEW V15 or above, list of industrial parts and provider contacts, results of ATP passed to the bench)
- Delivery of the required set of VISTAS I/O Boxes and virtualization infrastructure implementation at ON GROUND ACTUATION RIG FTB#2 WING demonstrator
- Delivery of the On – ground HVDC 270VDC network test bench with capacities described

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

The deliverables and milestones due dates are in accordance with the general work plan of the AIRFRAME Work Package B-3.2 and linked with Regional Aircraft FTB2.

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1.1	PDR: preliminary design review	R	T0 + 4
D1.2	CDR: critical design review	R	T0 + 5
D1.3	VISTAS I/O Boxes HW delivery and Documentation (electrical & mechanical designs, manuals, SW open code, list of industrial parts and provider contacts, results of ATP passed to the bench)	R + D + HW	T0 + 9
D1.4	Acceptance Test Procedure for SW development (Final Version)	R	T0 + 14
D1.5	Supporting Activity Report (Incidences appeared, spares used, redesign activity if any, proposals for future activities etc.)	R	T0 + 24
D2.1	PDR: preliminary design review	R	T0 + 2
D2.2	CDR: critical design review	R	T0 + 3
D2.3	Bench documentation (electrical drawings, mechanical design, acquisition SW user manual functionality, SW open code, list of industrial parts and provider contacts, results of ATP passed to the bench)	R + D	T0 + 10

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M0	VISTAS I/O Box & SW development KOM	R	T0+1
M1	VISTAS I/O Box & SW development PDR	R	T0+4
M2	VISTAS I/O Box & SW development CDR	R	T0+5
M3	VISTAS I/O Box HW delivery	HW	T0+9

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M4	VISTAS I/O Box & SW development Closure	R	TO + 24
M5	HVDC Test Bench KOM	R	T0+1
M6	HVDC Test Bench PDR	R	T0+2
M7	HVDC Test Bench CDR	R	T0+3
M8	HVDC Test Bench POWER ON	HW	T0+10

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Solid knowledge and capabilities for designing and manufacturing mechanical and electronic test benches.
- Solid knowledge and experience in the following avionic signals and buses: RVDT, A429, CANBUS, RS-232/422/485
- Solid knowledge and capabilities for designing and manufacturing electronic test devices.
- Solid knowledge of CATIA model design
- Solid knowledge of control and acquisition systems based on National Instruments HW&SW, included SW development related.
- Proven experience in collaborating with reference aeronautical and aerospace companies in R&T programs
- Participation in international R&T projects cooperating with industrial partners
- Engineering software and licenses for Computer Aided Design (CAD), and appropriate high performance computing facilities
- Engineering software and licenses for Labview, and appropriate high performance computing facilities
- Experience in integration of multidisciplinary teams in concurring engineering within reference aeronautical companies
- Capability of specifying, performing and managing, in collaboration with the Topic Manager, the following
    - Analysis of the mechanical, electrical and control/acquisition requirements
    - Control system definition
    - Trade-off for selection of the industrial elements to be included in the bench
    - Mechanical CATIA design for bench manufacturing
    - SW specification for Control System
    - Acceptance Test Procedure Definition
- Deep knowledge and experience in the following standards: DO-178C, DO-160G, ARINC 791, ARINC 429, MIL 1553, ARINC 600
- Quality System international standards (i.e. EN 9100:2009/ ISO 9001:2008/ ISO 14001:2004)

5. Abbreviations

A/C	Aircraft
AC	Alternate current
CAD	Computer Aided Design
CB	Circuit Breaker
CDR	Critical Design Review

CfP	Call for Proposal
CISS	Customer Inspection at Suppliers Site
CS2	Clean Sky 2
CU	Control Unit
DC	Direct current
EMA	Electro Mechanical Actuator
FTI	Flight Test Instrumentation
ICD	Interface Control Document
I/O	Input/Output
JTP	Joint Technical Proposal
KOM	Kick off meeting
LH	Left Hand
PDR	Preliminary Design Review
PDU	Power Distribution Unit
RCCB	Remote Controlled Circuit Breaker
RH	Right Hand
R&T	Research and Technology
SW	Software
TBC	To be confirmed
TRU	Transformer Rectifier Unit
WP	Work Package
VISTAS	Virtual Interoperable Simulation for Tests of Avionics Systems
RVDT	Rotary Variable Differential Transformer
FPGA	Field Programmable Gate Array
RT	Real Time
PXI	PCI Extension for Instrumentation

VII. JTI-CS2-2018-CFP08-AIR-02-63: Enhanced Low Cost Complex Composite Structures

Type of action (RIA/IA/CSA)	IA		
Programme Area	AIR		
(CS2 JTP 2015) WP Ref.	WP B-2.2		
Indicative Funding Topic Value (in k€)	750		
Topic Leader	Airbus Defense & Space	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	18	**Indicative Start Date (at the earliest)**[68]	Q1 2019

Identification	**Title**
JTI-CS2-2018-CFP08-AIR-02-63	**Enhanced Low Cost Complex Composite Structures**
Short description (3 lines)	
The aim of this topic is to research and to develop design and manufacturing methodologies for A/C complex composite components applying Infusion (LRI) technologies in order to achieve improved primary structures in terms of weight and cost, and to enable immediate Design Office decisions for next future aircraft designs.	

Links to the Clean Sky 2 Programme High-level Objectives[69]				
This topic is located in the demonstration area:	Advanced Manufacturing			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Regional Multimission TP, 70 pax			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☒	☐

[68] The start date corresponds to actual start date with all legal documents in place.
[69] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

Actually, qualified low cost manufacturing processes are sought as one of the main ways to build aircraft affordable structures. Composite manufacturing processes for small and medium size aerostructures are featured by substantial labour effort and small automation level. This has a clear negative impact on intensive use of labour and on costs due to the use of complex tooling. In addition, the need of extremely expensive tooling and dedicated equipment make difficult to have a return on investment, which is detrimental for small-medium aircraft business case.
It is then crucial for transport aircraft OEM to reduce acquisition and ownership costs of composite structures, as it is little opportunity to do this with existing technologies. Innovative new concepts are therefore necessary to enhance current composite design and manufacturing processes. Cost and weight parts reduction can be achieved through the implementation of novel, innovative, composite design technologies, materials, and manufacturing processes.
Infusion (LRI) technologies are promising in terms of overcoming above-mentioned drawbacks and achieving the desired objectives. To develop an innovative and low cost manufacturing process for infusion components to be installed in the A/C is the aim of this topic.

2. Scope of work

Project goals will be achieved through the proposal, justification and selection of a technology demonstrator focused on targets compliance. It is expected to obtain up to 40% cost reduction through tooling selection and up to 20% from the innovation out of other manufacturing process. Key aspects are full integration (structure & systems) and efficient ways to solve the sealing issues.
The present topic's activities aim to close the gap between cost effectiveness in design and available technologies with regards to complex composite structures, mainly focused on transport aircraft manufacturers.
High integration, reducing and simplifying the design concept by mainly avoiding fastening solutions, is one of the key aspects to bear in mind as a main path to establish the correct strategy to achieve the required earnings in weight and costs. One-shot concepts are also key.
In addition, it is important by this project to support and reinforce the maturity of infusion technology launched in Airframe ITD WP B-2.2., and it is an opportunity to de-risk the current developments via benchmarking activities.
A ground demonstrator is expected to be manufactured. The work to be performed is applicable to research streams described within WP B2-2, B3-3 and B2.1 to complement other composite technologies being explored for wing or fuselage demonstrators manufacturing, based on composite liquid technologies.
The following main areas shall be investigated:

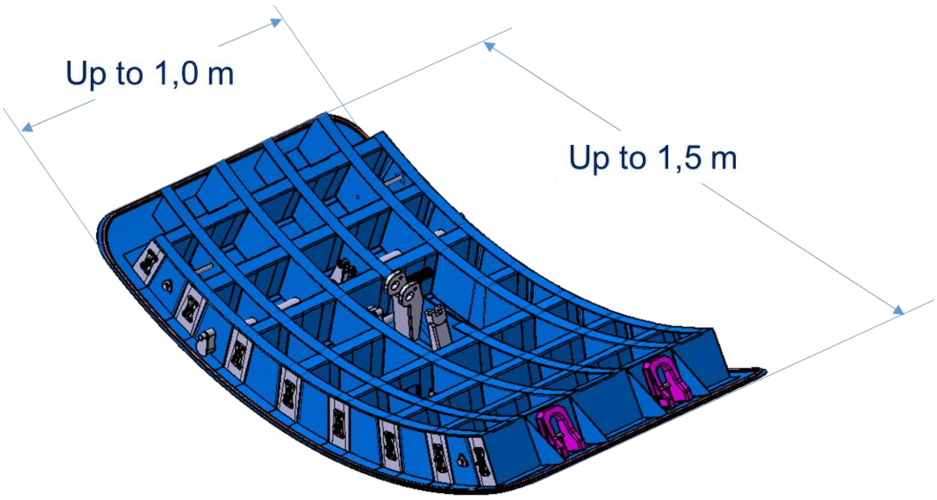
- Design and analysis methods (i. e., out of plane stresses approach).
- Materials and manufacturing processes, focused on cost savings.
- Tooling new concepts.
- Verification and Validation.

The development of tooling shall be innovative in order to meet the project targets by implementing the best performances in the following fields:

- Low Cost / Easy Manufacturing Materials, i.e. applying Additive Manufacturing Techniques,
- Eco-design, i.e. encouraging reusability and recyclability,
- Energy savings,
- Self-heating moulds (resistant, mineral oil, etc.) including a self-regulating temperature system with

embedded and advanced sensors for process monitoring.
- Reduction over the overall energy consumption by optimizing the cycle and the heating strategy.
- Surface Quality according to the standards of the Aeronautic Industry.
- CTE strategy for dissimilar materials application.

The demonstrator shall comply with project targets in terms of structural complexity as described across this document. For budgeting purposes, a medium/small structure is to be considered.
The demonstrator proposed by the Topic Manager will be an aircraft door in order to maintain compliance with the above drivers. Main characteristics for the demonstrator shall be as follows; a picture is attached as illustrative example:
- Main dimension up to 1500 mm.
- Complex structural concept including: skin (wet surface), reinforcement external frame, longitudinal stringers and circumferential frames, with a high integration degree.
- Able to carry fuselage shear loads and to withstand cabin pressure.
- Damage tolerant.
- Ability for systems high integration.
- Final deformed geometry monitoring and control.



Demonstrator Concept

2.1 Technological streams

The main technological challenges are as follow:
- Design-To-Cost basic approach.
- Design focused on maximum structural and systems integration.
- Revised Stress Analysis Methods for the materials to be used.
- Cost Efficiency in Tooling.
- Traditional issues fixing: spring-back effects for the final composite structure, NDT methods.

In addition, the main technological streams to be investigated are as follows:
AREA 1. DESIGN & ANALYSIS:
- Design Methods “Low cost manufacturing oriented”
- Standardized analysis tools that can handle complex three-dimensional geometry and monitoring & control the inter-laminar stresses (peeling, unfolding, etc.).
- Optimised design processes supporting high integration (structure - systems) facilitating manufacturing, and low cost production.

- Robust design concept avoiding traditional composite manufacturing issues (delamination, spring-back).
- Life cycle cost model.

AREA 2. MATERIALS AND PROCESS:

- Cost-Oriented Tooling design solutions.
- Efficient processes (pre-forming and cycle injection-curing).
- Liquid Resin Infusion (LRI).
- NDI Efficient methods.

2.2 Targets

Following expectations shall be targeted:

- Requirements and needed features shall be met by an appropriate test pyramid strategy, achieving TRL 5 at the end by a full scale ground demonstrator test.
- Reduction of composite design and certification costs (including testing) of about 30% for the primary structure by means of standardization and KBE concepts.
- Reduction of structural weight of about 20% w.r.t. metallic reference fuselage door weight by means of:
    - One Shot Concepts.
    - Reduction of about 95% of fasteners.
- Reduction of composite production costs of about 20% for the primary structure by means of:
    - OoA process.
    - Reduction of labour effort and errors.
    - Reduction of energy consumption during production.
    - Reduction of required raw material reducing the waste.
    - Reduction of about 95% of fasteners.
- Reduction of NRC costs of about 20% by means of:
    - Using innovative low cost tooling techniques (up to 40% of reduction in the tooling cost).

  Ground demonstrator structural stiffness and lessons learnt as outcome of this topic will permit flight clearance for operational tests with its systems at a flying prototype aircraft level for TRL 6 achievement, although this test is out of the scope of the topic.

2.3 Tasks

The activities to be performed are structured in the tasks listed in the following table:

Tasks		
Ref. No.	***Title - Description***	***Due Date***
T1	Demonstrator Design Requirement focused to final demonstrator selection to show the evidences which justify the choice for all requirements compliance.	T0+2
T2	Demonstrator Design and Analysis, centred into the high integration goal and design-to cost concept.	T0+8
T3	Feasibility Design Review.	T0+2
T4	Preliminary Design Review.	T0+4
T5	Critical Design Review.	T0+6
T6	Manufacturing Process and Tooling Design through expected innovative concepts and technologies focused on cost reduction, maintaining aerospace class structural performance.	T0+6

Tasks		
Ref. No.	***Title - Description***	***Due Date***
T7	Test Plan through a pyramid test strategy to validate the proposed design concepts and technologies approach.	T0+6
T8	Tooling Manufacturing & Try-Out, according to the design guidelines and materials & processes selected.	T0+12
T9	Ground demonstrator manufacturing according to acceptability criteria showing evidence of different technology targets.	T0+16
T10	Full scale Ground Test Execution, according to Test Plan to show substantiation with critical stress analysis allowables.	T0+17
T11	Industrialisation Assessment to feed research carried out based on main goals in comparison with equivalent manufacturing on thermoset material and correspondent process (benchmarking with running AIR ITD comparative projects in collaboration with Topic Manager).	T0+18

3. Major deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1	Demonstrator Selection	R	T0+02
D2	Conceptual and Detailed Design and Analysis	R & D (CATIA Mod., FEM & Doc.)	T0+04
D3	Manufacturing Process Approach	HW & R	T0+08
D4	Tooling Design & Manufacturing	HW & R	T0+10
D5	Demonstrator Manufacturing	HW & R	T0+16
D6	Structure Verification	R	T0+18
D7	Industrialisation Analysis	R	T0+18

**Type: R=Report, D=Data, HW=Hardware*

4. Special skills, Capabilities, Certification expected from the Applicant(s)

R&T Management:

- Competence in management of complex projects of research and manufacturing technologies.
- Proven experience in international R&T projects cooperating with industrial partners, institutions, technology centres, universities.
- Proven experience in collaborating with aeronautical companies with industrial air vehicle developments.
- Experience and skills learnt from projects focused on similar tasks.
- Quality and risk management capabilities demonstrated through applications on international R&T projects and/or industrial environment.
- Experience with TRL reviews or equivalent technology readiness assessment techniques in research and manufacturing projects for aeronautical industry.

Field of Expertise:

- International proven experience leading aircraft development projects combined with wide expertise in management of research work packages.
- Proven competence in leading aircraft project drawings, structural analysis and composite materials

damage tolerance.

- Strong capabilities in numerical optimization.
- Proven aircrafts manufacturing experience in substructures.
- Proven experience in non-destructive inspections.
- Proven experience in experimental testing: in particular impact threat, residual strength and fatigue testing from subcomponents to full scale test article.
- Quality Management: Setting up inspection schemes.
- Proven experience in: RTM, processing liquid resin infusion, vacuum assisted or similar process.
- Proven experience in design and manufacturing of manufacturing tooling for structures in different materials. Capacity to repair or modify "in-shop" the prototype manufacturing tooling for components due to manufacturing deviations. Experience and know-how with tooling for OoA technologies.
- Proven experience in the use of design, analysis and configuration management tools of the aeronautical industry (i.e. CATIA v5, MSC NASTRAN, etc.).

Manufacturing, Testing & Tooling including facilities:

- Capacity to repair "in-shop" components due to manufacturing deviations.
- Technologies for composite manufacturing with OoA processes.
- Tooling design and manufacturing for composite components.
- Suitable machines for hot-forming, injection and curing for the representative demonstrator.
- Qualified NDI.

Track record:

- Approved supplier for composite structures for aeronautical industry.

Approvals:

- Quality System international standards (i.e. EN 9100 / ISO 9001).
- Special Processes Qualification (NADCAP).

5. Abbreviations

ADS	Airbus Defense & Space
A/C	Aircraft
CTE	Coefficient of Thermal Expansion
FEM	Finite Element Model
ITD	Integrated Technological Demonstrator
KBE	Knowledge Based Engineering
LRI	Liquid Resin Infusion
NDI	No Destructive Inspection
NDT	No Destructive Test
NRC	Non-Recurring Cost
OEM	Original Equipment Manufacturer
OoA	Out of Autoclave
RTM	Resin Transfer Molding
R&T	Research & Technology
TRL	Technology Readiness Level
WP	Work Package

VIII. JTI-CS2-2018-CFP08-AIR-02-64: Cold Spray of metallic coatings on polymer and composite materials [SAT]

Type of action (RIA/IA/CSA)	IA		
Programme Area	AIR [SAT]		
(CS2 JTP 2015) WP Ref.	WP B-3.4.4		
Indicative Funding Topic Value (in k€)	700		
Topic Leader	Polskie Zakłady Lotnicze	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	24	**Indicative Start Date (at the earliest)**[70]	Q1 2019

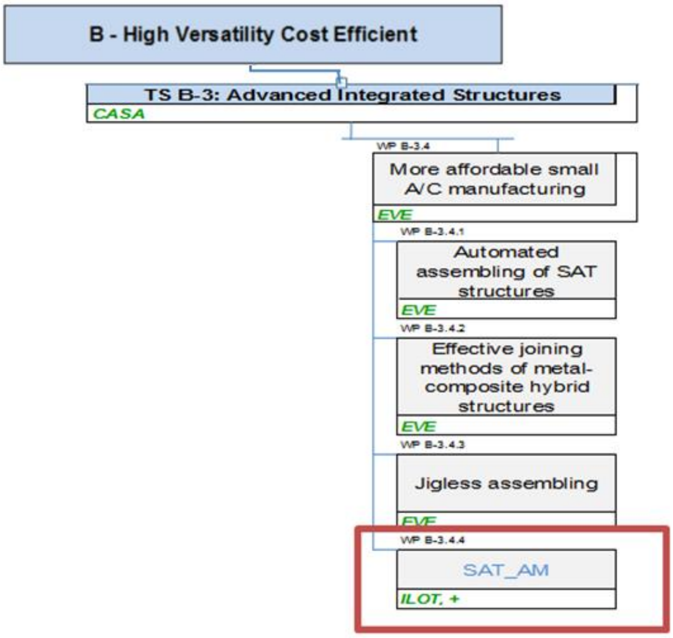
Topic Identification Code	**Title**
JTI-CS2-2018-CFP08-AIR-02-64	Cold Spray of metallic coatings on polymer and composite materials
Short description	
Improving of thermal and lightning strike resistant properties of the aircraft polymer components and composite materials requires innovative approach for top surface deposition. Conventional spraying technologies although highly efficient do not work properly with temperature sensitive powder and substrate materials. Development of Cold Spray, as alternative technique, could guarantee no porous, no oxdised, and no chemically and phase changed fully functional metallic coatings that meet suitable requirements.	

Links to the Clean Sky 2 Programme High-level Objectives[71]				
This topic is located in the demonstration area:	Advanced MRO			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	19-pax Commuter			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☐	☐	☐	☒	☐

[70] The start date corresponds to actual start date with all legal documents in place.
[71] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

The proposed topic is collocated in Airframe ITD framework under Work-Package B3.4 "More affordable a/c manufacturing". The relevant Work Breakdown Structure is shown below:



Manufacturing by conventional processes becomes increasingly cost-intensive. Therefore, a flexible and fast manufacturing process that is able to produce components of a high geometric complexity is necessary. Airplane fuselage and its components are constantly being redesigned to offer weight reduction without overloading its structural integrity. While historically made of aluminum alloys, the aircraft's skin is being redesigned now by using new tools and techniques especially Additive Manufacturing & Composite Technology that have been developed also by the Topic Manager. The Technologies allow incorporating in the aircraft design and production a larger proportion of various unreinforced and reinforced thermoplastics and composites; more specifically flame retardant polyamides, Polyacryletherereketone (PEEK), polymer matrix composites (CFRP) and carbon fiber composites (CFC). The strength-to-weight ratio and the mechanical properties of the aircraft component are improved when using this type of new materials. The primary advantages of composite materials are their high strength, relatively low weight, and corrosion resistance. However, one important limitation of using a non-metallic airframe / fuselage is its lack of electrical conductivity.
Current protective solutions improving the electrical conductivity of non-metallic structures consist of riveting aluminum based conductive plates to critical areas and/or to insert a thin conductive metallic mesh placed on the outer surface of the composite structure. The metallic wire mesh acts as a continuously-conductive path for direct or indirect electromagnetic interference effects and lightning strike energy. However, industry is seeking alternative solutions due to labour intensive and costly procedure of current technologies.
Cold spray process is considered to be one of the potential processes to overcome such problem. This technique can be also used to repair a damaged component. To promote electrical conductivity, one could use coating processes, such as Thermal Spray (TS) processes to deposit thin conductive layers over the polymer substrates. TS processes such Flame Spray and Plasma Spray are already used as local repair methods for non-metallic airplane skins. Unfortunately, the sprayed particles from the conventional TS

processes have shown to have in-flight oxidation of the molten particles which results in changing the powder material properties in the metallic coatings. Oxidation increases the coating electrical resistivity. The impingement of molten particles on non-metallic substrate may result in degradation due to erosion and thermal effects. Cold gas dynamic spray (CS) process, have the potential to solve the extreme temperature issue given that the sprayed particles remain in the solid state. CS process does not rely on thermal energy for the formation of coatings, but rather on kinetic energy: particles are accelerated above a critical velocity and plastically deform upon impact on the substrate to adhere and form a coating. Coatings produced from the CS can be characterized as oxide free due to the inert nature of the carrier gas (N2 or He) and the relatively low process gas temperatures. The numerous differences of the CS with respect to other TS processes make it a potential process to possibly lay down conductive metallic coatings over non-metallic substrate. Regrettably, it is been reported that erosion/degradation of polymer-based materials caused by the large particle impact velocity is a quite common phenomena. Thus, undertaking the further activity in improvement of operational and technological condition of the spraying process is necessary.
The outcome of the present topic related to improvement of spraying technology will be demonstrated on a front landing gear fairing made by polymer or carbon fibre composite. Example of this component is presented below on figure 1.

Fig.1 Front landing gear fairing integrated into M28 05 aircraft

2. Scope of work

Technical activities to be performed and proposed work breakdown structure with expected timing are presented below:

Tasks		
Ref. No.	***Title - Description***	***Due Date****
WP1	Spraying Feasibility: Deposition efficiency and microstructure analysis	T0 + 10
WP2	Optimization the process parameters for metallization of polymer and carbon fiber composite substrates	M10 + 9
WP3	Comparative tests with conventional technologies	M13 + 6
WP4	Manufacture the demonstrator – Metallization of Front landing gear fairing	M19 + 6

**Mx is intended as first day of month x.*

WP1 Spraying Feasibility: Deposition efficiency and microstructure analysis

- Evaluation of the current knowledge with respect to thermal spray metallization of non-metallic substrates (polymers, composites)
- Pre-selection and characterization of coating materials suitable for the experimental stage
- Development of the experimental method and basic test protocol for setting up the manufacturing parameters and measuring qualities in relation to variable operational conditions.
- Test Coupons manufacturing **-** Preliminary spraying trials and specimen investigation for determining impact behaviour and bonding mechanisms of coating - substrate system
- Down selection of the most promising systems verified for optimization stage.

WP2 Optimization of process parameters for metallization of polymer and carbon fiber composite substrates

- Characterization of feedstock, substrates and surface preparation
- Development of the optimal processing conditions and its effect of on coating characteristics:
    - Microstructure and thickness uniformity, porosity, hardness, surface morphology
    - Adhesive and cohesive bond strength of deposits
    - Thermal and electrical conductivity
- Process - Structure optimization: Coating material, process and post-process condition effect on mechanical properties (Tensile Strength, Fatigue)
- Building a test component – near net shape of the demonstrator and conduct the functionality tests

WP3 - Comparative tests with conventional technologies

- Design method and specimens for comparative tests
- Manufacture the reference and experimental specimens
- Demonstrate the feasibility of cold spray as alternative process for conductive coatings, with other properties superior to conventional technology.
- Approving and defining other areas of aircraft applications of cold spray non-metallic materials metallization

WP4 - Manufacture the demonstrator – Metallization Front landing gear fairing

- Design and manufacture fixture and other clamping system required for final metallization process
- Development of 3D demonstrator models and technology based on offline robot programming
- Manufacture the technology demonstrator
- Qualification of the spraying process for metallization of the selected polymers or composites
- Development of technology guidelines for CS non-metallic substrate metallization process

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1	Report containing results of experimental process feasibility and investigations on various coating- substrate system	R	T0 + 10
D2	Report containing test results from optimization process and the laboratory validation	R	T0 + 18
D3	Technology guideline for Cold Spray metallization technique of non-metallic aircraft structures – demonstrator	R + HW	T0 + 24

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M1	Development of preliminary cold spraying process parameters for metallization of non-metallic substrates	R	T0 + 6
M2	Conception of optimized cold spraying process and configuration materials	R	T0 + 12
M3	Technology demonstration in relevant environment	R, D	T0 + 21

A schedule synthesis is presented in the following table:

	2019									2020												2021		
	04	05	06	07	08	09	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
WP1	■	■	■	■	■	■	■	■	■	■														
WP2										■	■	■	■	■	■	■	■	■						
WP3													■	■	■	■	■	■						
WP4																			■	■	■	■	■	■
M						M1						M2									M3			
D										D1								D2						D3

4. Special skills, Capabilities, Certification expected from the Applicant(s)

Special expected skills are:

- Proven experience in CS process,
- Deep knowledge in robot path programming
- Proven experience in manufacturing of cold spraying aluminium deposition for the aerospace industry
- Experience in R&D Technology Projects
- Experience in using statistical techniques in process parameters optimization
- Experience of working related to the analysis of microstructure and the properties of the cold gas sprayed coatings
- Proven experience in collaborating with aeronautical companies within Research and Development programs

In addition, the applicant(s) are required to have access to the following capabilities:

- CATIA CAD software, V5 R21 or later
- Suitable manufacturing and robotized laboratory for Cold Spraying Process
- Laboratory facility for metallographic specimen preparation, mechanical testing, residual stress measurements, SEM metallurgical examinations, nano-indentation coating tests, corrosion and wear resistance testing, thermal and electrical conductivity, heat treatment
- Non-destructive testing equipment (radiographic, ultrasonic and penetrant testing)

5. Abbreviations

CS	Cold Spray
TS	Thermal Spray
AM	Additive Manufacturing
PEEK	Polyacrylethereketone
CFRP	Carbon Fiber reinforced polymer
SEM	Scanning Electron Microscope

IX. JTI-CS2-2018-CFP08-AIR-02-65: Design of special welding head for FSW process with automatic adjustable pin and welding force control system [SAT]

Type of action (RIA/IA/CSA)	IA		
Programme Area	AIR [SAT]		
(CS2 JTP 2015) WP Ref.	WP B-3.4.4		
Indicative Funding Topic Value (in k€)	700		
Topic Leader	Polskie Zakłady Lotnicze	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	24	**Indicative Start Date (at the earliest)**[72]	Q1 2019

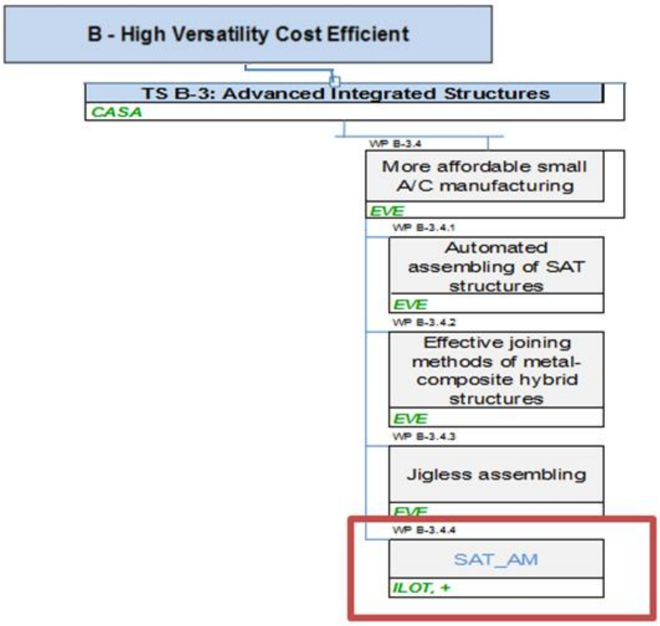
Topic Identification Code	**Title**
JTI-CS2-2018-CFP08-AIR-02-65	**Design of special welding head for FSW process with automatic adjustable pin and welding force control system**
Short description	
The aim of the project is to develop a universal head for butt and lap joining of 0.4 – 3.0 mm thicknesses sheet metal plate using linear friction stir welding (FSW) for aluminum alloys 2xxx and 7xxx series. Developed head shall allow welding of flat and concave-convex geometries (R > 200 mm) and shall provide integration with most commercially available CNC machines (independently from machine control system).	

Links to the Clean Sky 2 Programme High-level Objectives[73]				
This topic is located in the demonstration area:	Advanced Manufacturing			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	19-pax Commuter			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☒	☐

[72] The start date corresponds to actual start date with all legal documents in place.
[73] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

According to the activities of the SAT-AM project implemented under AIR ITD, the implementation of Friction Stir Welding (FSW) process for aero-structures appears to be especially suitable for welding fuselage aero-structures of high-strength aluminium alloys that can maintain the excellent properties in the weld seams. This has an impact on potential weight savings compared to the conventional riveting techniques for fuselage assembly.
The aim of the project is to develop an universal head for linear friction stir welding (FSW) of aluminum alloys in particular series 2xxx and 7xxx.The proposed solution should have the possibility of butt and lap joining of sheet metal plate having a thicknesses of 0.4 - 3.0 mm. The relevant Work Breakdown Structure under AIR ITD is shown below:



The head shall be able to automatically adjust the retraction of the pin in and out of the tool shoulder to the extension that is necessary to join the sheets within the mentioned range of thicknesses.
The design of the solution shall also allow for a complete retraction of the pin, which will allow partial or complete elimination of the exit hole.
During the joining process, the pin shall be kept at a constant depth in joined sheet metal plates.
In addition, the solution shall provide the possibility of constant force control (Z axis) during the FSW process and the possibility of its on-line correction to the set value. The developed head shall allow welding of flat and concave-convex geometries (R > 200 mm) and shall provide integration with most commercially available CNC machines (independently from machine control system).
The correctness effect of the developed solution shall be confirmed by carrying out the test of the butt and overlap joints of selected sheets made of 2xxx and 7xxx aluminum alloys in at least 3 different sheet thickness configurations. Samples prepared in this way shall be subjected to basic qualitative tests (microstructural tests confirming that the microstructure is free from defects, tensile strength test).
The demonstrator of this technology will be a special welding head for FSW process with automatic adjustable pin and welding force control system.

2. Scope of work

Technical activities to be performed and proposed work breakdown structure with expected timing are presented below:

Tasks		
Ref. No.	***Title - Description***	***Due Date****
WP1	Analysis of current solutions for FSW process - tools and CNC machines	T0 + 3
WP2	Design of special welding head for FSW process	M4 + 9
WP3	Manufacture of special welding head for FSW process	M10 + 6
WP4	Performance tests of automatic adjustable pin	M16 + 3
WP5	Performance tests of welding force control system	M16 + 3
WP6	Optimization of FSW process parameters	M19 + 3
WP7	Final tests of special welding head for FSW	M22 + 3

**Mx is intended as first day of month x.*

A synthesis of the requested activities in the different WPs is provided as follows:

WP1 – Analysis of current solutions for FSW process – tools and CNC machines

- Analysis of tools and machines currently available on the market and intended for friction stir welding (FSW) process
- Analysis of the use of conventional numeric machine tools to conduct FSW process
- Selection of the machine on which the tests will be carried out, with identification of possible needed adaptation (e.g. additional stiffening)
- Documentation with results and analysis

WP2 – Design of special welding head for FSW process

- Preparation of design documentation for the head providing automatic adjustment of the pin and correction of welding force
- Design of FSW welding head
- Documentation with results and analysis

WP3 – Manufacture of special welding head for FSW process

- Manufacture of FSW welding head
- Preliminary workings tests
- Documentation with results and analysis

WP4 – Performance tests of automatic adjustable pin

- Preparation of tests to verify the correct working of automatic adjustable pin
- Carry out tests of automatic adjustable pin working
- Documentation with results and analysis

WP5 – Performance tests of welding force control system

- Preparation of tests to verify the correct working of force control system
- Carry out tests of force control system
- Documentation with results and analysis

WP6 – Optimization of FSW process parameters

- Develop optimal process parameters for joining of aluminium 2024 and 7075 using designed welding head
- Conduct quality assessments of FSW joints
- Documentation with results and analysis

WP7 – Final tests of special welding head for FSW

- Manufacture of butt and lap joints for 3 different thickness configurations of 2024 and 7075 aluminium sheet metal
- Performing of microstructural tests

- Performing of strength tests (static stretch tests)
- Documentation with results and analysis

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1	Report containing information about tools and machines solutions for FSW process	R	T0 + 3
D2	Report containing design guidelines for welding head	R	T0 + 12
D3	Report from manufacture process and demonstrator of FSW welding head	R + HW	T0 + 15
D4	Report containing results from automatic adjustable pin and force control system tests	R	T0 + 18
D5	Report from optimization of FSW process parameters	R	T0 + 21
D6	Report from final tests with best process parameters and optimized FSW welding head	R + HW	T0 + 24

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M1	Special FSW welding head design and documentation ready	D	T0 + 12
M2	Manufacture of special FSW welding head	HW	T0 + 15
M3	Full tests of special FSW welding head	D	T0 + 24

A schedule synthesis is presented in the following table:

	2019									2020												2021		
	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
WP1			D1																					
WP2												M1, D2												
WP3															M2, D3									
WP4																		D4						
WP5																		D4						
WP6																					D5			
WP7																								M3, D6

4. Special skills, Capabilities, Certification expected from the Applicant(s)

Special expected skills are:

- Proven experience in FSW process (preferably <2 mm aluminium)
- Solid knowledge in design of joined aluminium structures consisting of sheet
- Proven experience in structural analysis of weld joints and complete component
- Proven experience in manufacturing of aluminium structures for the aerospace industry
- Knowledge in material selection and welding metallurgy for aluminium alloys
- Experience in technological research and development for innovative products and processes
- Experience in optimization of production processes

- Experience in deformation and damage mechanisms of metallic materials

In addition, the applicant(s) is required to have access to the following capabilities (own or in cooperation with others):

- Suitable manufacturing and machining laboratories for FSW
- Suitable prototype workshop
- Laboratory facility for mechanical testing, residual stress measurements, metallurgical examinations
- Laboratory facility for strength testing of welds and welded joints

5. Abbreviations

AIR	Airframe ITD
CNC	Computer Numerical Control
FSW	Friction Stir Welding
SAT-AM	More Affordable Small Aircraft Manufacturing (Core Parter project)

X. JTI-CS2-2018-CFP08-AIR-02-66: Evaluation and modelling of comfort driving parameters in a Cabin Demonstrator

Type of action (RIA/IA/CSA)	RIA		
Programme Area	AIR		
(CS2 JTP 2015) WP Ref.	WP B-4.4		
Indicative Funding Topic Value (in k€)	1100		
Topic Leader	Fraunhofer	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	36	**Indicative Start Date (at the earliest)**[74]	Q1 2019

Identification	**Title**
JTI-CS2-2018-CFP08-AIR-02-66	**Evaluation and modelling of comfort driving parameters in a Cabin Demonstrator**
Short description	
A vibro-acoustic actuation system for cabin comfort studies shall be developed and a comfort study on the thermal, vibro-acoustical, visual, spacial and ergonomic environment for passengers shall be performed within a Cabin Demonstrator. A suited measurement system to holistically assess the cabin environment shall be provided. A human comfort model shall be developed and validated for passenger physiological well-being and environmental comfort assessment, targeting different groups of passengers.	

Links to the Clean Sky 2 Programme High-level Objectives[75]				
This topic is located in the demonstration area:	Cabin & Fuselage			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Turboprop, 90 pax			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☐	☐	☐	☒	☐

[74] The start date corresponds to actual start date with all legal documents in place.
[75] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

This topic addresses the Airframe ITD activities under WP B-4.4: "Affordable low weight, human centred cabin". For this aim, passenger comfort studies will be performed on the Cabin Demonstrator provided within the Regional ITD. This demonstrator consists of a barrel of roughly 3.5 m diameter and 7.2 m length and hosts approx. 25 passengers. It is equipped with innovative interiors and shall host passengers, galley equipment, ECS components as well as power electronics. The integration of the Cabin Demonstrator as a ground demonstrator test bench will be performed in Holzkirchen, Germany (close to the city of Munich).

Current research focusses more efficient cabin interiors and ECS operation but at the same time providing increased passenger satisfaction. Passenger comfort is to a large extent determined by environmental parameters such as temperature, draft, odours, vibro-acoustics, visual appearance, etc. as well as space perception and ergonomics of the cabin and psychological state of the cabin occupant.

The Cabin Demonstrator will be equipped and prepared in order to evaluate these cabin interiors conditions in a comprehensive way using an innovative cabin outfit, advanced thermal environment and air distribution as well as the ability to perform subject studies. This environment shall be expanded by the applicant for the vibro-acoustical actuation: a system emulating the actual flight vibrations and noise shall be developed and implemented.

In order to objectively assess the cabin environmental quality, a measurement system to objectively measure the holistic psychophysical cabin environment (acoustical, thermal, visual) shall be developed. These measurements shall then be correlated with the subjective assessment of the cabin environment though subject testing of relevant cabin occupants and variations of the psychophysical environment.

In order to implement the correlations between subjective assessments and the objective measurement, methodology simulation means shall be developed based on virtual manikin approaches. So far mainly simulation models for thermal comfort are available, however their applicability to the aircraft cabin comfort prediction need to be verified. For this, a human thermal model shall be developed that is representative of the human thermoregulatory system. It shall predict the body core temperature in a normal cabin environment and during hazardous conditions. The influence of other comfort driving factors such as vibro-acoustical, visual and air quality shall be parametrically integrated in the model or provided as separate models which finally lead to the possibility to assess the cabin interior at different locations with a virtual manikin approach. These evaluations shall be performed in interaction with Indoor Environment Simulation Suite (IESS), a Modelica-based simulation environment developed by the Topic Manager within CleanSky1. The IESS computes the thermal (air temperature, velocity and radiation) and air quality parameters on a zonal approach (e.g. subdivision of body into 3 zones). These data can be made accessible to the simulation methodology. The developed simulation methodology shall provide reliable results and the methodological approach shall be validated in a ethically and technically acceptable way involving evaluation through test persons and a test campaign in the Cabin Demonstrator. Thus for comfort, cabin interiors and model validation, subject panel testing shall be foreseen, conducted and analysed on the Cabin Demonstrator. Among the different aspects of comfort and well-being, subject tests shall evaluate thermal, acoustic, spacial, air quality, ergonomics and visual appearance comfort in the Cabin Demonstrator. The study shall highlight the needs and perceptions of different target groups such as common travellers, susceptible passengers or passengers with reduced mobility.

2. Scope of work

Tasks		
Ref. No.	***Title – Description***	***Due Date***
Task 1	Requirements specification	T0+6
Task 2	Identification of passenger target groups and comfort study test design	T0+12
Task 3	Human environmental comfort model development	T0+36
Task 4	Preparation of subject test campaign	T0+30
Task 5	Conduction of subject test campaign, evaluation and elaboration of recommendations	T0+36

- Task 1: Together with Topic Manager, the requirements for subject test campaign and for the human environmental comfort model shall be established. Results are documented in a requirements specification.
- Task 2: Most relevant passenger target groups (e.g. “normal” travellers, susceptible groups, persons with reduced mobility) will be identified and a test design will be derived to assess specific needs in terms of thermal, vibro-acoustical, spacial, visual, etc., comfort. Measurement systems and methods to objectively capture the thermal, vibro-acoustical and visual comfort shall be investigated and developed.
- Task 3: Literature study on human environmental comfort models shall be conducted, as well as the implementation of a human thermal model and models for other comfort drivers, such as vibro-acoustical, visual and air quality, including evaluation of these comfort aspects adapted to aircraft cabin environments. In case of thermal comfort models, they shall be capable of evaluation for normal ECS operation as well as failure cases down to a body core temperature of 35 °C. Adaption of models to different passenger target groups needs to be performed. Derivation of an ethically acceptable model validation method and derivation of technically feasible test validation scenarios for the subject testing shall be done. A first issue of the model will be released (V1.0). After the testing campaign, the human environmental comfort model shall be validated. A new version of the model (V1.1) will be issued to the topic manager and a description of model use, assumptions and validation results will be delivered.
- Task 4: Based on results of tasks 2&3, a final setup and test design of a subject study to investigate the thermal, air quality, vibro-acoustic, visual and spacial comfort and well-being for target groups in the Cabin Demonstrator shall be developed and implemented. In addition, means to validate the human environmental comfort models needs to be implemented. A final selection of measurement system for the holistic cabin environment assessment will be elaborated and implemented in the Cabin Demonstrator. The applicant will achieve necessary ethics commissions’ permission for the subject test campaign. A subject panel will be defined and recruited. Questionnaires and psychophysical measurements will be developed. The task is closed with a test readiness review.
- Task 5: Subject tests will be performed on the Cabin Demonstrator. During the tests, subjects will be supervised by the applicant. Test results shall be documented in test reports. The task is closed with a project summary report stating specific comfort requirements and recommendations for targeted passenger groups and the correlation between model prediction and subject vote.

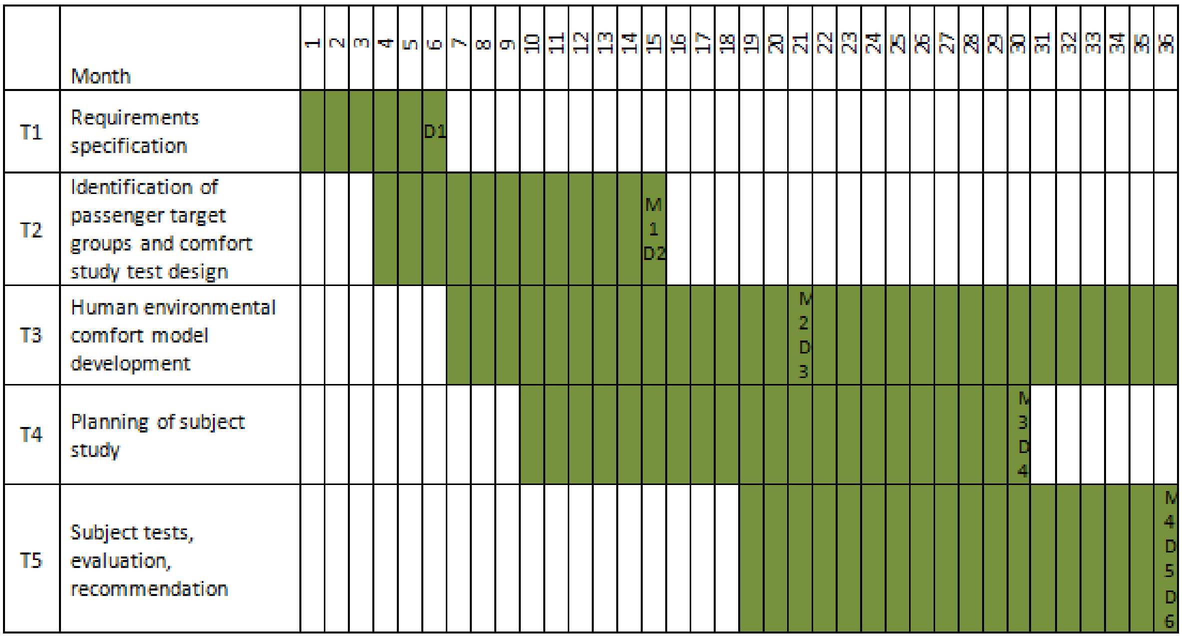
3. Major deliverables/ Milestones and schedule

**Type: R=Report, D=Data, HW=Hardware, SW=Software*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1	Requirements specification	R	T0+6
D2	Preliminary Test Design	R	T0+15
D3	Human environmental comfort model V1.0	SW	T0+21
D4	Test readiness review including ethic's commission permission	R	T0+30
D5	Project summary report	R	T0+36
D6	Validated Human environmental comfort model V1.1	SW	T0+36

Milestones (when appropriate)			
Ref. No.	***Title – Description***	***Type****	***Due Date***
M1	Preliminary comfort test design	R	T0+15
M2	V1.0 of human comfort model available	SW	T0+21
M3	Test readiness review	R	T0+30
M4	Finalization of test campaign and validation	R	T0+36

Gantt Chart for deliverables and Milestones



4. Special skills, Capabilities, Certification expected from the Applicant(s)

- The applicant shall have large experience in assessing indoor environments and the development and implementation of psychophysical measurement systems and methods as well as the set-up of vibro-acoustical actuation systems.
- The applicant shall present a convincing track record in the development of subject test campaigns specifically for thermal, visual, air quality and vibro-acoustical, spacial and ergonomics comfort.
- Particularly the applicant shall have a track record in developing and performing the associated test protocols and methods for subjective assessment methods. The application of local laws for personal data storage and the ability to obtain required ethics permission are mandatorily required.
- The applicant shall have experience in modelling human physiology and comfort perception. The preferred modelling platform is Modelica.

5. Abbreviations

ECS Environmental Control Systems

IESS Indoor Environment Simulation Suite

XI. JTI-CS2-2018-CFP08-AIR-02-67: Model based development of an innovative ECS air distribution system for ground testing with a Cabin Demonstrator

Type of action (RIA/IA/CSA)	RIA		
Programme Area	AIR		
(CS2 JTP 2015) WP Ref.	WP B-4.4		
Indicative Funding Topic Value (in k€)	1300		
Topic Leader	Fraunhofer	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	36	**Indicative Start Date (at the earliest)**[76]	Q1 2019

Identification	**Title**
JTI-CS2-2018-CFP08-AIR-02-67	**Model based development of an innovative ECS air distribution system for ground testing with a Cabin Demonstrator**
Short description	
An innovative air distribution system based on innovative materials with e.g. better acoustical damping, higher level of functional integration, etc. shall be developed using a model based design approach. This development shall be integrated in a Cabin Demonstrator and allow for mock-up ventilation with fresh and recirculated air. Furthermore, the developed system shall be flexible to integrate various subcomponents of the ECS, thereby realistically emulating the function of the whole ECS system.	

Links to the Clean Sky 2 Programme High-level Objectives[77]				
This topic is located in the demonstration area:	Cabin & Fuselage			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Turboprop, 90 pax			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☐	☐	☐	☒	☐

[76] The start date corresponds to actual start date with all legal documents in place.
[77] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

The topic addresses the Airframe ITD activities under WP B-4.4: “Affordable low weight, human centred cabin”. The outcomes of this topic will be demonstrated on the Cabin Demonstrator that is provided within the Regional ITD. This demonstrator consists of a barrel of roughly 3.5 m diameter and 7.2 m length. It is equipped with innovative interiors and shall host passengers, galley equipment, ECS components as well as power electronics. The integration of the Cabin Demonstrator as a ground demonstrator test bench will be performed in Holzkirchen, Germany (close to the city of Munich). A basic infrastructure to generate airflows at appropriate mass flow, pressure, temperature and humidity will be available at the test bench.

For the air distribution within the aircraft current activities focus on new materials such as foams or vacuum insulation panels with improved acoustical and (hygro-) thermal properties and on innovative subsystems with multifunctional use. One example could be the integration of the function of insulation, acoustic dampening and ducting in one component. The scope of the present topic is to develop and test such innovative approaches for air distribution systems. In addition, the integration of the required test system to support these elements shall be developed by the applicant. The whole process shall be supported by model based design and it shall contribute to the Topic Manager’s effort for model based test design of test systems and aircraft interiors. Model based design results shall be interfaced to an indoor environment model (based on Modelica and the IESS toolchain) of the Cabin Demonstrator which will be generated by the Topic Manager.

The air distribution system covers the low-pressure air distribution of the aircraft mock-up. Thus, necessary actuation systems, ducting to, from and within the Cabin Demonstrator, the mixing chamber and the air outlets, need to be designed and manufactured with innovative and model based approaches. Control algorithms for the proper operation of these systems shall be developed. The moisture drainage potential and airflow characteristics within the system, especially in the mixing chamber, shall be assessed. An accurate airflow rate measurement for each airflow path in the low pressure air distribution system (e.g. fresh air supply, recirculation, cabin supply, galley supply, etc.) needs to be integrated. To be compatible with the test laboratory environment, any measurements or actuation elements shall be controlled using Beckhoff components and TwinCat PLC software, model based approaches shall be compatible with the FMI/FMU standard and ideally based on Modelica language where applicable.

2. Scope of work

Tasks		
Ref. No.	***Title – Description***	***Due Date***
Task 1	Definition of Interfaces, Requirements and Boundary Conditions	T0+6
Task 2	Scouting for innovative materials, technologies and suitable modelling tools	T0+9
Task 3	Selection of technologies to be implemented on the Cabin Demonstrator	T0+15
Task 4	Model-based development of Cabin Demonstrator and ECS test specimen integration in laboratory environment	T0+21
Task 5	Fabrication and delivery of specimens and integration into laboratory environment	T0+30
Task 6	Performance assessment of innovative parts	T0+36

- Task 1: Together with Topic Manager, the interfaces of the laboratory installations and ECS components prototypes and the innovative air distribution system shall be defined. Requirements for the innovative systems shall be defined and documented. Boundary conditions for the integration and operation of the innovative air distribution system and mixing chamber shall be elaborated. Modelling interfaces to the Topic Manager's model of the Cabin Demonstrator will be defined.

- Task 2: A comprehensive list of innovative materials with improved acoustical and (hygro-) thermal properties shall be elaborated. Technologies for the functional integration of insulation, sound dampening and ducting shall be elaborated as well as materials and technologies application for the mixing chamber. In addition, suitable tools for the model based design respecting interfaces to the Topic Manager's models shall be elaborated too. The task is closed with the provision of a technology scouting summary.
- Task 3: Technologies elaborated in Task 2 shall be assessed. The result will be an explanatory list of pros and cons for each technology brick, an assessment matrix and a selection of the optimal technology to be implemented for the air distribution system and the mixing chamber and a modelling strategy for further development.
- Task 4: The integration of test specimen into the laboratory infrastructure, the Cabin Demonstrator and ECS environment will be planned by model based design. A list of required parts, actuators (e.g. flaps, fans, etc.), measurements and interfaces (electric, pneumatic, airflow, etc.) will be elaborated. A controller design for the orchestration of these systems shall be derived. The task is closed with a critical design review. The model shall be provided to the topic manager.
- Task 5: Fabrication means will be developed for the selected technology bricks and test specimens for the Cabin Demonstrator validation platform shall be produced. These shall be transferred to the Topic Manager's test site and installed in the Cabin Demonstrator. The integration of these specimens in the laboratory environment shall be performed and measurement/control systems will be installed and commissioned. The process shall be supported by results of the model based design.
- Task 6: Component-wise tests shall be performed to characterize test specimens. The performance of the entire innovative air distribution system in terms of (hygro-) thermal and acoustical aspect will be evaluated on the Cabin Demonstrator validation platform. Tests shall be documented in test reports and a summary of results including an outline of possible further improvements will be provided in the test summary report. Where necessary, models will be refined using the test results. Updated models shall be delivered to the Topic Manager.

3. Major deliverables/ Milestones and schedule

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title – Description***	***Type****	***Due Date***
D1	Requirements specification	R	T0+6
D2	Innovative technologies for the air distribution system and model based design	R	T0+9
D3	Technologies down-selection	R	T0+15
D4	Critical Design Review including modelling results of specimen integration in laboratory environment	R	T0+21
D5	Final specimen and laboratory integration infrastructure delivery	HW	T0+30
D6	Test & modelling summary report	R	T0+36

Milestones (when appropriate)			
Ref. No.	***Title – Description***	***Type****	***Due Date***
M1	List of innovative materials	R	T0+9
M2	Technology selection	R	T0+15
M3	Critical Design Review of model, specimen and laboratory integration	R	T0+21
M4	Final hardware provision	HW	T0+30
M5	Test completion	R	T0+36

Gantt Chart for Deliverables and Milestones

	Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
T1	Requirements specification						D1																														
T2	Innovative technologies for the air distribution system									M 1 D2																											
T3	Technologies down-selection															M 2 D3																					
T4	Development of laboratory integration																					M 3 D 4															
T5	Specimen fabrication and integration																														M 4 D 5						
T6	Test performance																																				M 5 D 6

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- The applicant shall have a good track record in the development and fabrication of aircraft ventilation systems.
- The applicant shall have a profound understanding of energy, enthalpy and mass flows in ventilation systems.
- The applicant shall present a track record in the design and control of ventilation systems.
- The applicant shall present a track record in Modelica Modelling or similar. A necessary requirement is to generate FMI/FMUs for interfacing with Topic Manager's models.
- The applicant shall be able to precisely and understandably synthesize the performed work into documentation.
- The applicant shall prove the ability to perform model based design and to set up the control system in a Beckhoff/TwinCat based environment.
- If electrical, overpressure or similar regulated installations are required, the applicant must provide certified staff for compliance with local regulations concerning setup and use of such systems (e.g. according to EN 50110-1, EN 50110-2, BGV A3)

5. Abbreviations

ECS	Environmental Control Systems
FMI/FMU	Functional Mock-Up Interface / Unit. Standard through which components models are made avialable without disclosing the component's model source code (http://fmi-standard.org/)
IESS	Indoor Environment Simulation Suite, Toolchain to generate models of the indoor environment in enclosed spaces

XII. JTI-CS2-2018-CFP08-AIR-03-01: Bio contamination survey

Type of action (RIA/IA/CSA)	RIA		
Programme Area	AIR		
(CS2 JTP 2015) WP Ref.	WP C-2.1 (former WP A-3.4.1)		
Indicative Funding Topic Value (in k€)	500		
Topic Leader	Dassault Aviation	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	36	**Indicative Start Date (at the earliest)**[78]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CFP08-AIR-03-01	**Bio contamination survey**
Short description	
The objective of the project is to develop exposure protocols to qualify coatings, materials and components of fuel systems. The main activities will consist in collecting samples of bio contaminated fuels and comparison with laboratory grown sources, as well as the development of an exposure protocols to qualify tank coatings, materials and components of fuel systems to bio contamination. Finally, application to a short list of selected materials, passive or functionalized (e.g. with biocide properties) will be performed.	

Links to the Clean Sky 2 Programme High-level Objectives[79]				
This topic is located in the demonstration area:	Eco-Design			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Low Sweep Business Jet			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☐	☐	☐	☒	☐

[78] The start date corresponds to actual start date with all legal documents in place.

[79] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

Bio-contamination of aircraft fuel tanks may damage coatings, initiate or accelerate corrosion, bias gauging, clog filters and contaminate supply chain. Though other industries may already have developed active bio protection schemes (ecosystems able to self-protect against alien organisms), bio contamination of aircraft fuel systems is never desired. It is prevented by a mix of passive and active maintenance operations. Generally, passive operations are routine, whereas active are unscheduled, launched when bio-contamination has developed beyond alarming levels.

Passive protection begins with regular purging of free water at bottom of tanks. It also includes routine biocide treatments of fuel, and biochemical tests of contamination level. Passive protection, if applied carefully, should prevent uncontrolled development of micro-organisms. Yet, it happens, particularly with business jets operated worldwide, that routine maintenance is skipped, either due to poor local infrastructures and service to aircraft, or to available time. Also, in some circumstances, micro-organisms develop very fast.
Active (unscheduled) maintenance operations are meant to bring bio contamination levels back to standard conditions. It can be mechanical cleaning of tanks, fuel filtering (dialysis), or higher dose biocide treatments.

In most situations, there is a time delay between diagnosis of severe bio-contamination, decision to treat, and actual treatment. Aircraft has to sustain this adverse situation for weeks, or even months, be it operated or not. If it is not, bio-contamination is in a favourable situation to develop even more, as ground temperatures and moisture offer better environmental conditions than upper troposphere to micro-organisms.

Over the long operational life of an aircraft, there is then a quite high probability that bio-contamination will develop inside fuel systems, and remain there for long. This is one of the adverse situation aircraft design must anticipate. Coatings, materials in general, need to be robust to severe bio-contamination. Manufacturers and suppliers developed in house procedure tests. Yet, the certification of an aircraft does not explicitly require to perform a test according to a defined norm (like e.g. JAR 25 for icing).

Manufacturers/suppliers usually test robustness with respect to:

- Hormoconis Resinae (fungus)
- Aspargilus Niger (fungus)
- Pseudomoas Aeruginosa (bacteria)

Those micro-organisms are frequently found in fuel surveys, and are considered particularly aggressive for coatings. Hormoconis Resinae has a proven capacity to deprecate polysulphure based sealants, that are key elements of tank protection (they prevent both fuel leaks and galvanic couplings prone to initiate corrosion). It can be grown in laboratories.
Dry spores of hormoconis resinae can be easily purchased to companies specialized in living micro-organisms (in France, e.g. Pasteur Institute, Museum d'Histoire Naturelle, or Micalis/INRA can contaminate on demand a fuel sample).

Yet, many basic questions did not receive, to our knowledge, clear answers.

- Can laboratory grown micro-organisms make valuable biofilms, or should we store contaminated fuel and make reserve of it? The core or the debate is the difference between natural contamination, implying thousands of different species, versus more homogenous contamination, implying few species. Notoriously, natural contamination is more resistant to biocide treatment. As for the potential deprecation of a coating, advantages of natural contamination are less obvious but it worthy comparing both.

- What is the ideal exposure test, depending on the type of material, and possibly the zone of aircraft fuel tank (more or less oxygenated, with stagnant or turbulent fuel, etc.)? Parameters of test, like temperature, free water level, nutriments else than fuel (dead biofilms?) could be specified.
- What should be the duration of a test?
- How should be evaluated functionalized coatings, say, with hydrophobic or biocide property?

Norms like *EN 4159 Aerospace series - Paints and varnishes - Determination of resistance to microbial growth* only partially address the last two points.

- Can we define, and control, the contamination level, all along the test? Biofilm thickness and mass are certainly key parameters, but which tracers could tell that biofilm is active, feeds on the substrate more than on fuel, etc.
- Can we overall define a testing protocol of robustness to bio-contamination, that would be a compromise between representability of a worst case, and realism (test must be feasible with acceptable duration and cost).
- Eventually, who in Europe could perform it? SMEs? Large institutes? There is a need for a network of partners, skilled in microbiology and aware of the testing issues; to which a supplier of any new coating or material could turn to.

2. Scope of work

The topic has two high level scopes:

1. Update qualification protocols of materials and equipment, with respect to bio-contamination
2. Apply it to a short list of candidate coatings, some with biocide / anti adhesive / hydrophobic functions

It is proposed to structure the activities into three main Work Packages:

WP 1: Collect and grow bio-contamination
Project will necessarily involve a Partner skilled in microbiology, who will collect samples, or receive them from other partners. This Partner will also grow on demand bio contamination and perform endurance tests on selected materials, proposed by other partners. Partners having access to bio-contaminated fuel will collect samples.

WP 2: Exposure protocols
The Partner will review existing norms, and provide a feedback.
Then, the Partner will suggest and perform innovative tests, enabling to:

- Qualify the degradation of the material under test
- Assess the contamination level all along the test
- characterize the performance of a functionalized coating (hydrophobic/ biocide)

The innovation may consist in:

- The type of bio-contamination (natural versus seeds commercially available, specific micro-organisms mixtures)
- The methods used to control bio-contamination levels and activity (imaging techniques, frequent sampling and filtration, etc.)

- The methods used to assess degradation of a material (coating, polymer, substrate)
  - Mechanical tests
  - Imaging
  - 3D inspection (thermography, radioelectric measurements, sonic waves, etc.)
- The methods used to assess performance of specific coating functions.
  - Hydrophobic
  - Antiadhesive
  - Biocide
- The main outcomes of the WP are:
  - A new testing protocol.
  - A list of the necessary competences and equipment a Partner should have to perform this protocol on a candidate material.
  - A list of companies matching requirements, in Europe.

WP 3: Endurance tests of selected materials
The protocol will be applied to a short list of materials, provided by aircraft manufacturers. Ideally, the tests should be performed by an end user of the protocol.
A final review will conclude on the added value of the suggested protocol, with respect to existing norms and in house Topic Manager tests. It is expected to present it at international committees like IATA fuel task force and IASH.

The following table presents the expected schedule of the activities:

Tasks		
Ref. No.	***Title – Description***	***Due Date***
WP1	Collect and grow bio contamination	T0+12
WP2	Exposure protocols • Review • Development of a new protocol	T0+24
WP3	Endurance tests on selected materials • Preparation (state of art and innovative materials) • Tests according to retained protocol. Conclusion. • Final report	T0+36

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1	Collect and grow bio contamination Survey Report	HW,R	T0+12
D2	Exposure protocol: Review and proposal	R	T0+24
D3.1	Samples of materials and coatings Selection Report	HW,R	T0+24
D3.2	Endurance tests according to selected materials	R	T0+36

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M1	Bio contamination samples available	HW	T0+12
M2	Exposure protocol ready (defined, and operational)	HW	T0+24
M3	Endurance tests performed and candidate coatings qualified	R	T0+36

4. Special skills, Capabilities, Certification expected from the Applicant(s)

Demonstrated experience in:

- Microbiology
- Imaging techniques and sensing techniques in general
- Aviation fuel and aviation fuel contamination
- Surface treatment and preparation. Material properties and enhancement (ex: Hydrophobic coatings)

5. Abbreviations

CS2	Clean Sky 2
IATA	International Air Transport Association
IASH	International Association for Stability, Handling and Use of Liquid Fuels
JAR	Joint Aviation Requirements
JTP	Joint Technology Programme
RIA	Research and Innovation Action
SME	Small and Medium Enterprise
WP	Work Package

XIII. JTI-CS2-2018-CFP08-AIR-03-02: Non-destructive testing (NDT) of bonded assemblies

Type of action (RIA/IA/CSA)	IA		
Programme Area	AIR		
(CS2 JTP 2015) WP Ref.	WP C-2.1 (former A-3.4.1)		
Indicative Funding Topic Value (in k€)	600		
Topic Leader	Dassault Aviation	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	36	**Indicative Start Date (at the earliest)**[80]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CFP08-AIR-03-02	**Non-destructive testing (NDT) of bonded assemblies**
Short description	
The aim of the topic is to study non-destructive testing technologies and models able to inform on the quality of a bonding, with a focus on kiss bonding. Models will be correlated with mechanical testings of coupons realized with state of the art and innovative bonding technologies. A demonstrator will be developed and applied to coupons and representative use cases of structures.	

Links to the Clean Sky 2 Programme High-level Objectives[81]				
This topic is located in the demonstration area:	Advanced MRO			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Low Sweep Business Jet			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☐	☐	☐	☒	☐

[80] The start date corresponds to actual start date with all legal documents in place.
[81] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

More and more bonded assemblies are used on structural parts of aerospace vehicles (aircraft/helicopters/aerospace vehicles). Components whose failure may lead to loss of aircraft are already bonded. To maintain the same level of safety as with mechanical assemblies, certification requires much more mechanical and fatigue testings, on full scale structures, with an obvious impact on overall development costs. The large set of samples required for mechanical tests are due to the variability of bonding conditions at manufacture stages.

Manufacturers need to prove that bondings will match mechanical stresses and fatigue that structure will face during operational life, provided that the defined bonding process is applied. Bonding processes attempt to strictly control key conditions :

- Bonded surface aspects
- Hazardous defects (possibility of human errors)
- Properties of the adhesive
- Environmental conditions
- Substrate chemical properties
- Process parameters (curing cycle/polymerization)
- Quality control
- Other specific conditions

Yet, mastering all those conditions is a challenge which explains why bondings are developing rather slowly in aerospace industry, despite all their known advantages. Bonding assemblies will become a standard if we can: 1) reduce certification costs 2) increase the confidence in the quality of a bonding, at manufacturing and operational maintenance phases.

In addition, there are not many non destructive methods enabling to assess the quality of a bonding, and fewer enabling to detect kissing bonds (contact without adherence). Quality of a bonding is by itself a difficult question if we cannot refer to mechanical testings.

For end users, a bonding is satisfying if it sustains cycled constraints representative of operational conditions. Usually, large sets of samples bonded in similar conditions are subjected to cycled constraints, yet non destructive testing of the real component of aircraft remains still prospective.

2. Scope of work

The main tasks to be performed are as follows:

- Review micro/macro scale models of adherence and cohesion for use cases covering main types of bonded assemblies:
  - primary sealant (polysulphur)/metal*
  - Thermoplastic/metal*
  - composite/metal*
  - metal/metal*
  - carbon/carbon
  - elastomer/carbon
  - elastomer/metal*
  - epoxy/metal*

  metal* =metal coated with epoxy based coat
- Provide use cases composed of representative set of coupons and few assembled parts.
  Below two simple use cases are considered, yet other examples may be sumitted:

	
Use cas 1: Composite panel with bonded stiffeners. NDT targets to assess bonding quality with respect to mechanical constraints	Use case 2: Sealant for tank water tightness. Bonding quality is related to adherence properties and sealant degradation. Mechanical constraints are low. NDT assess adherence and sealant integrity.

- Review non destructive testings of bonding quality, at main stages
  - Surface preparation
  - Process
  - Control after process, with a special interest for kissing bonds
  - Routine control over operational life (aging, degradation, etc..)
- Propose innovative surface preparation and control
- Propose criteria to assess the quality of a bonding, from an end user perspective.

  As a matter of fact, the quality of a bonding is not only assessed by the level of compliance of the manufacturing process with respect to a norm, nor of micro scale properties of the adhesive with respect to a reference nominal case, though both provide good insights. Eventually for the end user, a bonding is good if assembled parts sustain the mechanical constraints that operational conditions are supposed to submit them to. As for fatigue in general, a distinction between moderate cycles of constraints expected within flight domain, and instantaneous peaks coming from hazardous events.

- Model constraints they will be exposed to, according to the component of aircraft they belong to.
- Develop a TRL6 demonstrator of NDT.
  - Ultrasonic waves (guided or volumic)
  - Shearography
  - Laser shock
  - Bondmaster (resonance)
  - Inline process inspection (camera, stick positioning).
- Apply NDT demonstrator to representative cases of bondings
  - Set up mechanical tests
  - Manufacture samples (coupons) of state of the art cases of bonding, including innovatives ones (under development, e.g. adherence promotors).
  - Manufacture some complex assemblies.
    - Stiffened panel
    - Fixing devices on panels
    - Heating blankets
    - Foam blocks
    - Sandwiched structures with foam blocks
    - Tank protecting sealant
    - Absorbing coatings
    - Others, to be defined in case with Topic Manager.

NDT demonstrator shall enable inference on the behaviour of coupons and complex structures, with respect to the expected mechanical constraints (where those coupons and structures integrated to a real air vehicle). Mechanical tests will then be applied to those coupons and complex structures, as a final assessment of the reliability of the NDT demonstrator and its predictions.

It is proposed to structure those tasks through the following Work-Packages:

Tasks		
Ref. No.	***Title – Description***	***Due Date***
WP1	Review of adherence models and NDT methods ○ Selection of bonding cases ○ Evaluation of mechanical constraints (during operational life) ○ Parameters influencing bonding quality ○ Micro/macro scale adherence models ○ Review of NDT methods	T0+12
WP2	Use cases ○ Manufacturing samples and assemblies (standard and innovative) ○ Integration of defects (focus on kissing bonds) ○ Innovative surface preparation	T0+24
WP3	Evaluation of NDT methods ○ Selection and evaluation of NDT methods in the context of samples and structures to be tested. ○ Development of specific methods based on guided waves	T0+30

Tasks		
Ref. No.	***Title – Description***	***Due Date***
WP4	Mechanical testings ○ Procedures ○ Set up ○ Evaluation of innovative set up based on thermal stress analysis ○ Acceptance criteria (e.g. number of mechanical cycles a sound bonded structure should sustain)	T0+24
WP5	TRL6 demonstrator of NDT methods ○ Development and integration ○ Demonstration (including mechanical testings) ○ Conclusion and final report	T0+36

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.1	***Title - Description***	***Type****	***Due Date***
D1.1	Review of adherence models and NDT methods	R	T0+12
D1.2	Evaluation of mechanical constraints	R	T0+12
D2.1	Set of samples and structures to be tested	Items	T0+18
D2.2	Innovative preparation surface	R	T0+24
D3.1	Evaluation of NDT methods	R	T0+30
D3.2	Guided waves demonstrator	HW	T0+30
D4.1	Mechanical testings demonstrator	HW	T0+24
D4.2	Mechanical testings process and criteria	R	T0+24
D5.1	TRL6 (validated) demonstrator of NDT methods	HW	T0+36
D5.2	Final report	R	T0+36

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M1	Evaluation of mechanical constraints	D	T0+18
M2	Samples availability	HW	T0+18
M3	Mechanical testings set up availability	HW	T0+24
M4	NDT Demonstrator availability	HW	T0+30

4. Special skills, Capabilities, Certification expected from the Applicant(s)

Proven experience in:

- Material sciences.
- Expertize in bondings
- Expertize in NDT methods and/or mechanical tests

5. Abbreviations

IA	Innovation Action
NDT	Non Destructive Testing
TRL	Technology Readiness Level
WP	Work Package

XIV. JTI-CS2-2018-CFP08-AIR-03-03: Sizing for recycled carbon fibres to optimise adhesion in organic/inorganic composite materials

Type of action (RIA/IA/CSA)	RIA		
Programme Area	AIR		
(CS2 JTP 2015) WP Ref.	WP C-2.1.4 (former A-3.4.1.4)		
Indicative Funding Topic Value (in k€)	500		
Topic Leader	Fraunhofer	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	30	**Indicative Start Date (at the earliest)**[82]	Q1 2019

Identification	**Title**
JTI-CS2-2018-CFP08-AIR-03-03	**Sizing for recycled carbon fibres to optimise adhesion in organic / inorganic composite materials**
Short description (3 lines)	
In the present topic, carbon fibres' sizing shall be manufactured and modified in order to optimise the interlinkage between recycled carbon fibres and a polymeric or a cementitious matrix with the goal to produce improved carbon fibre composite materials with increased mechanical properties.	

Links to the Clean Sky 2 Programme High-level Objectives[83]				
This topic is located in the demonstration area:	Eco-Design			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Potentially applicable to any commercial aircraft			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☒	☐

[82] The start date corresponds to actual start date with all legal documents in place.
[83] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

Carbon fibers have gained a large interest during the last years because of their high mechanical properties. Carbon fibers are commonly used for reinforcement of composite materials or for high temperature applications. Nowadays some planes are built of over 50% of carbon fiber reinforced polymers. Sustainable recycling concepts should focus not only on the recovery but as well on a later application of recovered materials. State of the art recycling technologies for CFRP (e.g. pyrolysis) damage the sizing. This is the limiting factor for the usage of recycled carbon fibers in polymers or in building materials to increase the mechanical properties in composite materials. This interlinkage is strongly and directly affected by the sizing of the fibers.
Therefore, this topic is strongly linked to the End of Life of aircraft parts and is an enabler for the economic feasible application of recycled carbon fibers in aviation and alternative sectoral applications (e.g. automotive or construction industry). Thanks to the improved adhesion of the fibers in the matrix:

- Material properties will increase,
- The re-use and recycling quote (RRQ) of the aviation industry will increase,
- Consumption of primary raw materials will decrease,
- Reduced environmental impact, through fiber recycling instead of incineration or landfilling.

2. Scope of work

This topic addresses the manufacturing and modification of sizing for recycled carbon fibers to optimize the interlinkage between carbon fibers and the polymeric or cementitious matrix. This development aims at producing improved sizing for recycled carbon fibers to produce composite materials with increased mechanical properties.

Tasks		
Ref. No.	***Title – Description***	***Due Date***
Task 1	Review of state of the art sizing materials	T0+6
Task 2	Identification of interlinkage mechanisms between recycled carbon fibres and matrix materials	T0+6
Task 3	Development of suitable sizing for recycled carbon fibres for their application in cementitious and polymeric matrix systems	T0+18
Task 4	Definition and demonstration of the sizing application on the recycled carbon fibres	T0+22
Task 5	Assessment and characterization of the recycled fibres with the new sizing	T0+24
Task 6	Application and evaluation of the carbon fibres in cementitious and polymeric matrix materials	T0+26
Task 7	Data collection for Life Cycle Assessment	T0+30
Task 8	Project Management	T0+30

- **Task 1: Review of state of the art sizing materials:** Existing sizing materials shall be reviewed and most suitable materials shall be identified for their usage on recycled carbon fibres aiming at an application in cementitious and polymeric materials.
- **Task 2: Identification of interlinkage mechanisms between recycled carbon fibres and matrix materials:** Explanation of the interlinkage mechanisms of sizing materials with the cementitious (e.g. concrete) or polymeric matrix material must be defined in order to create a tailor-made sizing

material

- **Task 3: Development of suitable sizing for recycled carbon fibres for their application in cementitious and polymeric matrix systems:** Sizing material has to be developed for the application of recycled carbon fibres in cementitious and polymeric (thermoplastic and thermoset e.g. PEEK; Epoxy) matrix systems following the results from Task 1 and Task 2. The sizing shall be individual for each matrix system. A universal solution can only be applied in case of similar results concerning the interlinkage between the matrix and the fibre.
- **Task 4: Definition and demonstration of the sizing application on the recycled carbon fibres:** Identification and definition of the sizing technology and lab scale demonstration of the sizing developed in Task 3 using recycled carbon fibres. How many fibres can be treated and which thickness does the sizing have need to be addressed.
- **Task 5: Assessment and characterization of the recycled fibres with the new sizing:** The resulting fibers have to be analysed according to its mechanical properties.
- **Task 6: Application and evaluation of the carbon fibres in cementitious and polymeric matrix materials:** Application of the new fibers in building materials (e.g. concrete) and high performance polymers will be carried on. Analyses concerning mechanical properties and the durability of the samples must be performed. The interlinkages of fibers to the matrix material have to be characterised.
- **Task 7: Data collection for Life Cycle Assessment:** An Life Cycle Inventory has to be created (Bill of Materials and Bill of Processes) for the matrix systems containing recycled carbon fibres with new sizing. Recyclability of the developed composite systems has to be taken into account. The Life Cycle Inventory has to be provided to the Topic Manager and Eco-TA for Life Cycle Assessment. The selected applicant will receive back a simplified Eco-Statement (LCA result).
- **Task 8: Project Management:** A complete documentation of all the investigations performed in the tasks above in a final report has to be done.

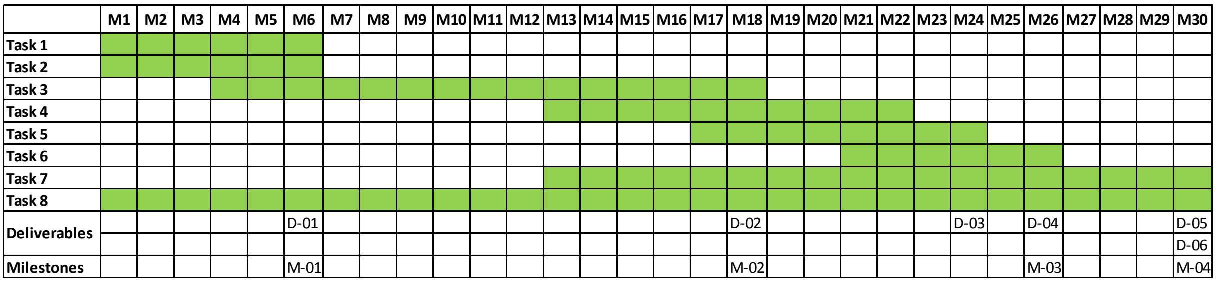
IPR issues, especially for the exchange of LCI data, will be part of the Implementation Agreement.

3. Major deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	***Title – Description***	***Type***	***Due Date***
D01	Review of the state of the art sizing materials and description of interlinkage mechanisms between fibres and matrix		T0+6
D02	Report on the development of sizing for the application of recycled carbon fibres in cementitious and polymeric matrix systems		T0+18
D03	Report on the application, assessment and characterization of the new sizing		T0+24
D04	Report on the application and evaluation of the recycled carbon fibres in cementitious and polymeric matrix systems		T0+26
D05	LCI Report		T0+30
D06	Final Report		T0+30

Milestones (when appropriate)			
Ref. No.	***Title – Description***	***Type***	***Due Date***
M01	State of the art and interlinkage mechanisms are reported		T0+6
M02	Sizing developed		T0+18
M03	New sizing demonstrated		T0+26
M04	LCI has been provided		T0+30

Gantt Chart for Deliverables and Milestones



4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Track record in chemical engineering and development of sizing
- Process technology to produce fibre reinforced composites for cementitious and polymeric matrix systems
- Equipment for fibre and composite assessment and characterization (e.g. for stiffness, single fibre tensile tests, surface assessment, fibre-matrix linkage) needs to be available.
- Proven access to recycled carbon fibres from aviation industry
- Experience in data collection for Life Cycle Assessment (otherwise a sufficient training will be given with the start of the project)

5. Abbreviations

AIR	Airframe ITD
CFRP	Carbon Fibre Reinforced Polymer
Eco-TA	Eco Design Transverse Action
ITD	Integrated Technology Demonstrator
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
PEEK	Polyether-ether-ketone
RIA	Research Innovation Action
RRQ	Re-use and Recycling Quote

XV. JTI-CS2-2018-CFP08-AIR-03-04: Development of an anaerobic digester prototype for aircraft use

Type of action (RIA/IA/CSA)	RIA		
Programme Area	AIR		
(CS2 JTP 2015) WP Ref.	WP C-2.1.4 (former A-3.4.1.4)		
Indicative Funding Topic Value (in k€)	400		
Topic Leader	Fraunhofer	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	24	**Indicative Start Date (at the earliest)**[84]	Q1 2019

Identification	**Title**
JTI-CS2-2018-CFP08-AIR-03-04	**Development of an anaerobic digester prototype for aircraft use**
Short description (3 lines)	
A technical prototype of an anaerobic digestion unit for use on board aircraft as testing device in flight environment shall be developed. The prototype unit shall be developed with regard to technical, hygienic and safety conditions and needs on board aircraft in a way that ensures also light weight and durability.	

Links to the Clean Sky 2 Programme High-level Objectives[85]				
This topic is located in the demonstration area:	Eco-Design			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Large, regional and business jet aircraft.			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☐	☐	☐	☒	☐

[84] The start date corresponds to actual start date with all legal documents in place.

[85] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

In a modern aircraft, great emphasis is put on passenger comfort e. g. with regard to cabin climate or passenger catering. There is also a great demand in reducing waste and energy consumption, and to minimise the ecological footprint. To achieve both goals towards a more eco- and human centred design, new concepts such as new bio-thermal architecture should be considered.

Today waste which was in contact with any kind of food from animal sources in international traffic is an item of high concern and cost. Due to laws for the prevention of spreading diseases anything that was in contact with animal-derived products is classified as Cat 1 ICW and needs to undergo certain sterilization procedures, depending on the local laws at the airports. On board of airplanes these wastes and contaminated items are to be handled very restrictive. They need to be stored away safely and marked.

Sewage and other organic waste may be a source for producing methane in a biogas plant. On an airplane a biogas plant could offer a secure hermetical enclosure for sewage and waste. The methane produced may be used as additional on board resource for energy and the substrate collected may be disposed in a more cost-effective way.

Anaerobic digestion on board of an aircraft will result in a new bio-thermal architecture concept by using on board waste as a source for additional on board heat and energy production. On-board energy conversion may also be further fuelled by the implementation of bio-degradable catering-service-ware made e. g. of PLA (poly lactic acid) or lignin which could be fed into anaerobic digestion, therefore different wastes/substrates combinations have to be considered. Waste heat from the anaerobic digestion process could additionally be utilised for better temperature management on board, for cold fuel temperature revival and perhaps even hold warmth potential for cold soak starts. Collection of condensation liquid from the fuselage insulation into a digester would also help to control fouling and thus minimize maintenance and running costs. Overall alternative energy and design concepts could aid in improving the waste balance of an airplane, reduce fuel demand and thus minimize the CO_2 footprint of commercial flights.

As a central component of new bio-thermal architecture an anaerobic digestion unit for on-board aircraft use as testing device in a flight test environment shall be developed.

2. Scope of work

A new bio-thermal architecture concept for aircraft would mean a profound new design of cabin and also result in a more flexible sanitary/galley architecture. Core of the concept is an alternative energy conversion and distribution/use.

As central unit a technical prototype of an anaerobic digestion unit for use on-board aircraft as a testing device in a flight test environment shall be developed in close cooperation with the Topic Manager.

Anaerobic digestion on board aircraft may be influenced by factors such as pressure, humidity, temperature, but may also influence factors like air quality (contaminants, odours, particulates) and passenger comfort.

Theoretical considerations, assumptions and empirical correlations derived from previous and current work on the topic shall be considered and implemented by the applicant. Techniques for source collection (galley waste, manure and seepage from lavatories, biodegradable disposables, fuselage condensate), substrate preparation for anaerobic digestion (homogenisation, addition of liquid and extra nutrients if necessary, addition of inoculate if necessary, hygienization if necessary) and security needs on board of an aircraft shall be considered. Furthermore alternative materials and concepts for catering-service-ware and other disposables shall be considered too. This will result in higher energy yield and increased passenger comfort. The anaerobic digestion unit shall provide at least interfaces for on board sewage, fuselage condensate and galley waste. For the galley waste as well as for sewage a

mechanical device for milling should be implemented. The process of anaerobic digestion should be a two stage digestion with an acidification vessel/stage as first step and a methanogenesis vessel/stage as second step. With regard to sanitation it is suggested that methanogenesis should be driven as a thermophilic process. A thermophilic process is not only much more effective for biogas production, but yields in additional heat which may be utilized for cold fuel temperature revival or for heat transfer for use in cabin climate stabilisation. The prototype anaerobic digestion unit shall be developed with regard to technical, hygienic and safety conditions and needs on-board aircraft in a way that ensures also light weight and durability. Finally a method/process for methane storage and conversion to energy shall be implemented.
A successful achievement of a new bio-thermal architecture concept for aircraft has a great potential for transfer to other human environments such as big passenger liners or buildings with high demand on peoples care (hotels, hospitals, etc.). Implementation of bio-thermal design in aircraft will reduce carbon footprint and enhance comfort and wellbeing on-board.

Tasks		
Ref. No.	***Title - Description***	***Due Date***
Task 1	Review of technical requirements; evaluation of two-stage thermophilic process	T0 + 4
Task 2	Development of a technical concept	T0 + 6
Task 3	Technical realisation of important components (collecting apparatus, mill, anaerobic digester, energy conversion) ready for assembly	T0 + 21
Task 4	Implementation of a prototype of an anaerobic digester for aircraft use and documentation	T0 + 24
Task 5	Recommendations	T0 + 24

Task 1: Review of technical requirements; evaluation of two-stage thermophilic process
The applicant shall work out a detailed plan of the realization and testing phase with regard to content and time schedule. Especially technical requirements and solutions and an evaluation of the two stage process of conversion of organic matter to biogas shall be reviewed, in case the solution for one component fails, technical alternatives shall be presented. The Topic Manager will assist in this task.
Task 2: Development of a technical concept
The main objective of the detailing phase is the final definition of the detailed technical concept. The applicant shall provide design solutions for the diverse components and their performance including potential manufacturing limits. After evaluation the final optimization iteration of the technical concept will be performed in cooperation with the Topic Manager.
Task 3: Technical realisation of important components (collecting apparatus, mill, anaerobic digester, energy conversion) ready for assembly
As a very important step, the components of the core unit for energy production shall be produced and tested, as well as liquid and waste collection devices connected to the core unit. Furthermore a substrate preparation apparatus (containing e.g. a mill and a conditioning unit; means necessary for the production of a fine, homogenous and preconditioned substrate - e.g. pH , temperature, hygiene - for the core unit), heat exchanging structures, control devices and an energy converter (e.g. gas turbine) have to be developed. For completion of the system additional components may be necessary (e.g. gas sensors, etc.) – this shall be decided in close cooperation with the Topic Manager. In the end of this task all parts shall be ready for assembly.
The applicant hast to provide data for a Life Cycle Inventory (Bill of Materials and Bill of Processes) for the digester system, considering the environmental footprint of the materials and processes used as

well as taking into account the recyclability of the system. Life Cycle Assessment LCA will be performed by the Topic Manager and the applicant will receive back a simplified EcoStatement as LCA result.

Task 4: Implementation of a prototype of an anaerobic digester for aircraft use and documentation

Finally the whole prototype unit has to be assembled and tested. At least one complete and functional prototype has to be delivered. All prototype(s) have to be tested and the experimental results are to be evaluated and documented. A detailed documentation manual of the unit is an additional outcome.

Task 5: Recommendations

The project is to be finalized by preparing an overall recommendation report and organising a final meeting with all participants. The report should include the potential of the developed bio-thermal structure regarding optimisation and technical realisation in aircraft design.

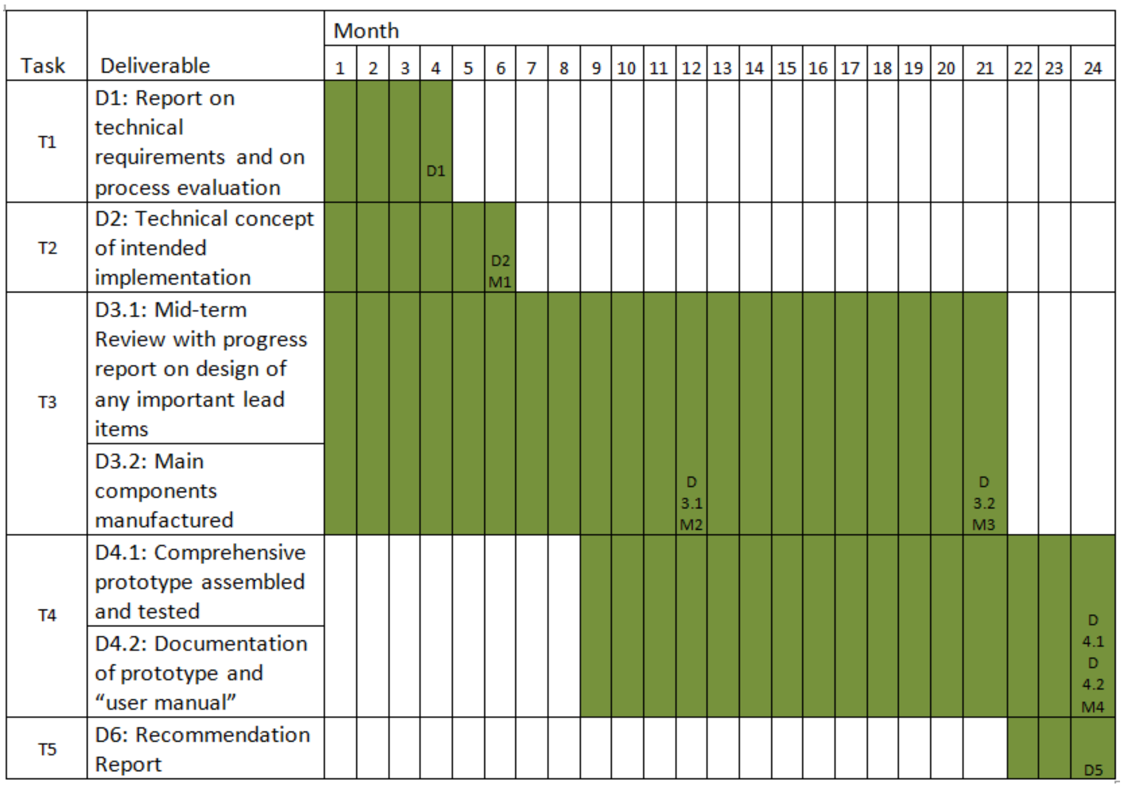
3. Major deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1	Report on technical requirements and on process evaluation	R	T0 + 4
D2	Technical concept of intended implementation	R	T0 + 6
D3.1	Mid-term Review with progress report on design of any important lead items	R	T0 + 12
D3.2	Main components manufactured	HW	T0 + 21
D4.1	Comprehensive prototype arranged and tested	HW	T0 + 24
D4.2	Documentation of prototype and provision of a “user manual”	R	T0 + 24
D5	Recommendation Report	R	T0 + 24

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M1	Sketch of technical concept + description	R	T0 + 6
M2	Mid-term report	R	T0 + 12
M3	Main components realised	HW	T0 + 21
M4	Prototype implemented	HW	T0 + 24

Gantt Chart for tasks, deliverables and Milestones



4. Special skills, Capabilities, Certification expected from the Applicant(s)

- The applicant shall present a convincing track record in the design and application of fermentation units, especially in the field of anaerobic fermentation and biogas production.
- The applicant shall prove that he/she has the means to convert a biogas production unit into the environment of an aircraft and to implement the most suited prototype into a user-defined function.
- Applicants shall be able to precisely and understandably document the work performed to enable future methodological access.
- Applicants shall demonstrate their skill to keep their knowledge on the latest state of the art and may want to inform themselves on issues such as eco-design, ISO 140 40 and comparative literature on aircraft systems.

5. Abbreviations

CfP	call for proposal
CO_2	carbon dioxide
ICW	international catering waste
LCA	live cycle assessment
PLA	poly lactic acid

XVI. JTI-CS2-2018-CFP08-AIR-03-05: Development and evaluation of a manufacturing process for a lightweight aircraft wheel made of CFRP

Type of action (RIA or IA)	IA		
Programme Area	AIR		
(CS2 JTP 2015) WP Ref.	WP C-2.3.1 (former A-3.4.3.1)		
Indicative Funding Topic Value (in k€)	450		
Topic Leader	Fraunhofer	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	24	**Indicative Start Date (at the earliest)**[86]	Q1 2019

Identification	**Title**
JTI-CS2-2018-CFP08-AIR-03-05	**Development and evaluation of a manufacturing process for a lightweight aircraft wheel made of CFRP**
Short description (3 lines)	
Based on an innovative design of an aircraft nose wheel made of CFRP, the objective of this project is the development and evaluation of a manufacturing process for the composite wheel via low-pressure RTM (LP-RTM). The project involves tasks such as manufacturing related advice during the design process of the wheel, development of a manufacturing process, collection of life cycle inventory data of the process, evaluation of fibre lay-up and manufacturing and testing of wheel prototypes.	

Links to the Clean Sky 2 Programme High-level Objectives[87]				
This topic is located in the demonstration area:	Advanced Manufacturing			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☒	☐

[86] The start date corresponds to actual start date with all legal documents in place.

[87] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

Aircraft wheels are highly stressed components which have to endure static and dynamic loads that occur during taxi operations, take-off, and landing, as well as thermal and environmental loads. Conventional aircraft wheels are made of aluminium alloy and can weigh up to 100kg depending on the type of wheel and aircraft. Due to their high specific strength and stiffness, carbon fibre reinforced plastics (CFRP) offer a high lightweight potential. In previous projects it has been shown that via substitution of automotive metal wheels by CFRP wheels, 40% of weight reduction is possible while still achieving the required fatigue life. Within AIR ITD WP C 2.3.1 (former A-3.4.3.1), a composite aircraft nose wheel is to be developed in order to demonstrate similar potential of mass reduction in the field of aircraft. This would lead to a reduction of fuel consumption during the use-phase of the aircraft. The gained competence in this project also generates secondary benefits. For example, the general benefits of an efficient LP-RTM process can be exploited in other fields such as automotive. Also the evaluation of the fibre orientation during preforming benefits in the reduction of unnecessary margins of safety during the structural analysis of FRP components which results in further lightweight potential.
In **Error! Reference source not found.**, the typical two-piece design of a conventional aircraft wheel is llustrated, as it has in principle been used for large passenger airplanes since the 1980s. This design principle applies to nose wheels as well as main landing gear wheels. In order to mount the tire, a multiple component design is required, for example in form of a detachable flange wheel or a split hub wheel, as shown in **Error! Reference source not found.**. In the split hub wheel design, the two wheel alves are joined by bolts and sealed by an O-Ring. The wheel is seated on the axle via a taper roller bearing.

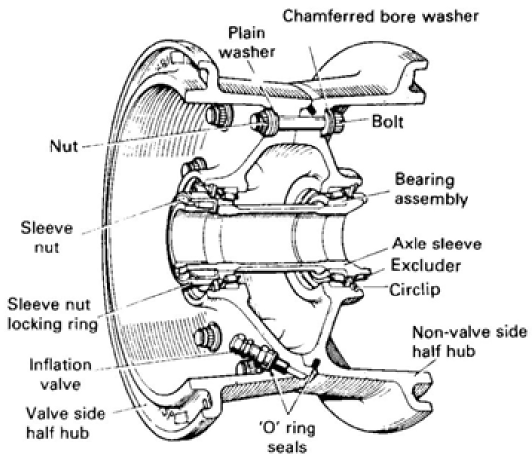


Figure 1: Basic design of an aircraft wheel [M. C. Niu, „Landing Gears," in Airframe Structural Design, Conmilit Press Ltd, 1988]

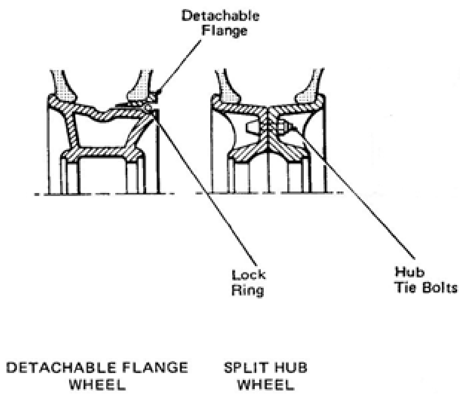


Figure 2: Multiple component designs of aircraft wheels [M. C. Niu, „Landing Gears," in Airframe Structural Design, Conmilit Press Ltd, 1988]

The nose landing wheel of an A320 like aircraft will be used as benchmark for the substitution of the metal aircraft wheel by a composite wheel. For this, innovative solutions for wheel assembly, bearing seat, manufacturing process as well as damage evaluation must be taken into consideration. The design of the composite nose wheel could be transferred to the larger scaled main landing gear in further projects.
Excluding tire and mechanical elements such as bearings, bolts, valves, etc. the nose wheel has a mass of approximately 15kg. For the tasks outlined in this document following approximate dimensions must be considered:

Outer flange diameter:	439 mm
Rim width:	224 mm
Outer tire diameter:	770 mm
Tire width:	226 mm

The development process of the composite aircraft wheel in under AIR ITD consists of six phases. Phases (1) to (3) will be processed by the Topic Manager before the start date of the selected applicant (hereafter referred as the partner). The partner is expected to provide support during the detailing phase (4), to take over the realization phase (5) and the testing phase (6).

Development phases	Milestone	Due Date	Main processor
1) Definition phase	Review of requirements	12/2017	Topic Manager
2) Concept phase	Concept review	03/2018	Topic Manager
3) Preliminary design phase	Preliminary design review	12/2018	Topic Manager
⇨ ***Expected Start Date CFP***		***04/2019***	
4) Detailing phase	Critical design review	08/2019	Topic Manager (+partner)
5) Realization phase	Manufactured prototypes	08/2020	Partner
6) Testing phase	Validation of process	02/2021	Partner

In the definition phase, all necessary information is gathered and a requirement list will be defined. In the concept phase creative methods and morphological analyses are used to create a variety of concepts which might be more suitable for a composite design than the conventional two-half design. The best concepts will be elaborated into a preliminary design stage. After a preliminary design review (PDR), the best preliminary design will be chosen and extensively analysed and finalized in the detailing phase. The partner activity will start during the detailing phase. After completion of the critical design review (CDR) at the end of phase 5 a manufacturing process for the composite wheel will be developed. A number of prototypes are to be evaluated in the testing phase.
Sustainability issues shall be addressed by simplified life cycle impact analysis. Confidential processing of supplied data will be regulated by the Implementation Agreement between the partner and the Topic Manager.

2. Scope of work

The tasks foreseen in this call for proposal are the following:

Tasks		
Ref. No.	***Title – Description***	***Due Date***
T0	Kick-off and coordination	T0+1
T1	Manufacturing related support during detailing of wheel design	T0+ 5
T2 T2.1 T2.2 T2.3 T2.4	Development of a manufacturing process: Mould manufacturing and procurement of materials Preforming and prototype manufacturing Evaluation of the fibre lay-up Collection of life cycle inventory data	T0+17
T3 T3.1 T3.2	Testing of wheel prototypes: Test preparation Testing and evaluation	T0+23
T4	Finalization and closure of project	T0+ 24

T0: Kick-off and coordination

The Topic Manager will organize a kick-off meeting with all participants and present the preliminary design of the composite wheel and status of the detailed design phase. The partner is expected to work out a detailed plan of the realization and testing phase with regard to content, time schedule and communication. The Topic Manager will assist in this task.

T1: Manufacturing related support during detailing of wheel design

The main objective of the detailing phase is the final definition of the CAD design and fibre lay-up, and the derivation of manufacturing documents. The main responsibility of the Topic Manager lies in the design and structural analysis of the composite wheel and the determination of the fibre lay-up in order to achieve the required fatigue life. The partner is expected to support the determination of manufacturing limits of the planned fibre lay-up and to critically evaluate the planned design considering the selected manufacturing process. After the evaluation the Topic Manager will run a final optimization iteration of the wheel design. The Critical Design Review will close this task and the final design of the wheel will be frozen for next steps.

In order to realize a simplified life cycle impact analysis of the planed manufacturing process (T2.4), the in- and output parameters (relative mass, energy, and material flow) for evaluation of the process are to be in defined in this task. Confidential processing of supplied data will be regulated by the Implementation Agreement between the partner and the Topic Manager.

T2: Development of a manufacturing process

The manufacturing process of the composite wheel will be based on a Low Pressure Resin Transfer Moulding (LP-RTM) technology using non-crimp fabrics. The activities under this task are the manufacturing of approximately 10 prototypes of the composite wheel and the evaluation of their fibre layup. Approximate 6 of the prototypes are necessary for the testing phase and 4 prototypes will be used as demonstrators. The manufacturing process shall have the potential to be automated in further projects. All the following tasks are to be processed by the partner.

T2.1: Mould manufacturing and procurement of materials

The manufacturing process requires moulds for the pressing process and also for the preforming process. These moulds must be designed and manufactured by the partner. For the composite part, fibre fabrics (carbon) and resin (thermosetting) are to be procured by the partner. The composite material must be fully certified for structural applications on aircraft. It is also possible that the wheel design will include other inserted components made of metal or core material which also need to be procured and manufactured by the partner.

T2.2: Preforming and prototype manufacturing

During mould manufacturing and procurement of material, a preforming concept must be developed in order to realize the planned fibre lay-up according to the CDR and expected structural performances. Patterns need to be cut and the preforming process is to be optimized. Possibly, mould reworking will be necessary. Manufacturing of approximately 10 prototypes is expected, considering LP-RTM manufacturing processes. Finally, the wheel prototypes are to be finished, assembled and a quality check (dimensional check, etc.) has to be performed.

T2.3: Evaluation of the fibre lay-up

The Topic Manager plans to evaluate the structural analysis of the detailed design phase based on the test results of the wheel prototypes. Therefore, information about the fibre lay-up realized by the manufacturing process is important. The partner is expected to evaluate and document the fibre lay-up ("as manufactured" fibre-orientations etc.) during the manufacturing process. Any suitable methods such as photography, computed tomography (CT), eddy current, ultrasonic inspection or thermal imaging etc. can be used. The fibre orientation shall be documented in a way that it can be compared with the lay-up in the structural analysis. The Topic Manager will assist in this task.

T2.4: Collection of life cycle inventory data
In order to evaluate the manufacturing process regarding economic efficiency, the applicant is expected to collect life cycle inventory data (bill of material and bill of process). Therefore, the input and output data of mass and energy as well as the amount of auxiliaries used in the manufacturing process need to be determined in a simplified way. The life cycle analysis data is to be supplied in eco-design data exchange format. If necessary the Topic Manager will support in this task. Confidential processing of supplied data will be regulated by the Implementation Agreement between the applicant and the topic leader. The partner will then be provided with a simplified life cycle analysis regarding the manufacturing process.

T3: Testing of wheel prototypes
Approximate 6 wheel prototypes have to be tested and the experimental results are to be evaluated by the partner. Radial load test (static), combined radial and side load test (static) and/or wheel roll test (dynamic) are mandatory for the experimental validation of the composite wheel prototypes. An overpressure test is optional. The test methods are used in the certification process for metal aircraft wheels and are described in ETSO-C135a. For all tests the wheels must be fitted with a suitable tire. The loads must be applied through the tire. The bearing situation of the wheel on the axle should be similar as when mounted on an airplane.

T3.1: Test preparation
Before testing the prototype wheels must be fully assembled (bearings, valves, tire, etc.) and balanced. In order to evaluate local strains, the wheels have to be equipped with several strain gauges. Depending on the design of the existing test benches, adaptations of the test bench components might be necessary by the partner.

T3.2: Testing and evaluation of results
For the radial as well as for the combined load test the wheel is to be tested for yield and ultimate load. It is to be shown whether the composite wheel can absorb the yield load and the ultimate load without major failure like cracking. Possible damages could also be: loosening of bearing cups, gas leakage through the wheel or past the wheel seal. During the wheel roll test the load must be applied by covering a distance of 3220km.

Following specific load values have been calculated by the Topic Manager and must be taken into consideration during test activities:

Specification of test loads calculated according to ETSO-C135a				
Test method	Yield load (+ side load)	Ultimate load (+ side load)	Max. static load rating	Tire Pressure
Radial load test on wheel-tire-combination	124.097 N	215.820 N	-	12,3 bar
Combined radial and side load test on wheel-tire-combination	112.815 N (+ 28.203 N)	196.200 N (+ 49.050 N)	-	12,3 bar
Wheel roll test on wheel-tire-combination	-	-	Load TBD 3220 km	14,02 bar
Overpressure test on wheel-tire-combination (optional)	-	-	-	49,2 bar

All tests are to be documented and evaluated. Measurement data of loads, displacements or strains are to be recorded. Possible damages of the wheel prototypes, bearings, etc. are to be inspected and evaluated by using for example dye penetrant inspection, eddy current test, and/or suitable NDT techniques.

T4: Finalization and closure of project
The project is to be finalized in a final meeting with all participants and by preparing an overall report. The report should include the potential of the developed manufacturing process regarding serial production of the composite aircraft wheel.

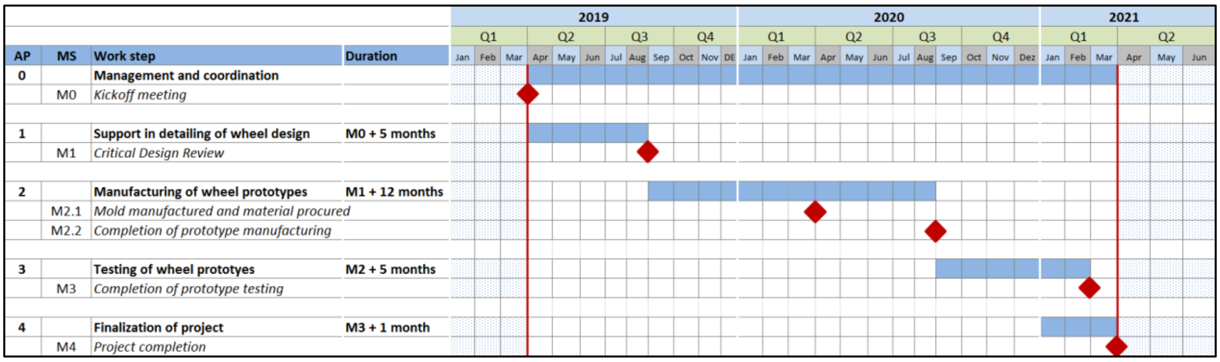
3. Major deliverables/ Milestones and schedule

**Types: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title – Description***	***Type****	***Due Date***
D0	Report with project management plan: detailed schedule, description of team structure and communication plan	R	T0+1
D1.1	Report on necessary design adjustments of the composite wheel regarding manufacturing process and material selection	R	T0+5
D1.2	Report on in- and output parameters for simplified life cycle analysis of the planned manufacturing process.	R	T0+5
D2.1	Delivery of min. 3 prototypes for demonstrator use (Additional 1 demonstrator planned for applicant)	HW	T0+17
D2.2	Report on manufacturing phase: Description of preforming process, description of injection/curing process, quality control of prototypes)	R	T0+17
D2.3	Report on evaluation of fibre lay-up (“as manufactured” fibre-orientations)	R, (D)	T0+17
D2.4	Report on life cycle inventory data (supplied in eco-design data exchange plan format)	R	T0+17
D3.1	Data from testing phase of composite wheels: load and displacement measurement, strain gauges measurement	D	T0+23
D3.3	Delivery of tested prototypes of composite wheel	HW	T0+23
D3.2	Report on testing phase: Evaluation of results from radial load test, combined load test, wheel roll test; evaluation of damage	R	T0+23
D4	Final report of project and outlook on serial production capability (production rate, costs, weight)	R	T0+24

Milestones		
Ref. No.	***Title - Description***	***Due Date***
M0	Kick off meeting with all participants	T0+1
M1	Critical Design Review	T0+5
M2.1	Completion of mould manufacturing and material procurement	T0+11
M2.2	Completion of prototype manufacturing	T0+17
M3	Completion of prototype testing	T0+23
M4	Final Meeting / Completion of project	T0+24

Gant Chart attempt for deliverables and Milestones



4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Certified Quality Management System: ISO 9001:2008 and EN 9100:2009 (mandatory)
- Capabilities and proven experience for manufacturing in LP-RTM (mandatory)
- Capabilities and experience in wheel testing in radial load, combined load and wheel roll test (mandatory)
- Procurement of composite material fully certified for structural applications on aircraft possible (mandatory)
- Experience in FRP-Wheel design, manufacturing and testing (preferable)
- Experience in draping simulation (preferable)
- Experience in damage evaluation of FRP components (preferable)
- Nadcap accreditation (preferable)
- Project language: English (mandatory)
- Software interfaces: CATIA, Ansys (preferable)
- Consultation of ISO 14000 is recommended in order to reflect on life cycle impact (preferable)

8. Clean Sky 2 – Engines ITD

I. JTI-CS2-2018-CfP08-ENG-01-32: Optimized UHPE flow path cooling design and testing using advanced manufacturing techniques

Type of action (RIA/IA/CSA)	IA		
Programme Area	ENG		
(CS2 JTP 2015) WP Ref.	WP 2		
Indicative Funding Topic Value (in k€)	1000		
Topic Leader	GE Deutschland	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	36	**Indicative Start Date (at the earliest)**[88]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-ENG-01-32	**Optimized UHPE flow path cooling design and testing using advanced manufacturing techniques**
Short description	
The call is meant to support the technology maturation process through (1) the development of a multi-disciplinary optimization process to enhance thermal management while minimizing flow losses and component weight, (2) the design and detailed thermal and flow testing (up to TRL 4) of components optimized for additive manufacturing, (3) the assessment and the optimization of the additive process through manufacturing trials to locally control and improve HW quality for key design features.	

Links to the Clean Sky 2 Programme High-level Objectives[89]				
This topic is located in the demonstration area:	Ultra-high Bypass and High Propulsive Efficiency Geared Turbofans			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Short/Medium-range, Ultra-advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

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[88] The start date corresponds to actual start date with all legal documents in place.

[89] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

Through Clean Sky 2, GE Deutschland GmbH (GEDE) deals with technology maturation programmes targeting the turbine vane frame (TVF) and HP core (HPC, combustion, thermal management) for the Ultra High Propulsive Efficiency (UHPE) commercial aircraft engine architecture.

Within the timescales of the Clean Sky 2 program, the UHPE engine will provide significant steps towards the reductions in fuel burn, emissions, and perceived noise targeted by the ACARE 2035 environmental goals for the aviation sector (75% reduction in CO_2 emissions, a 90% reduction in NO_X emissions and a 65% reduction of the perceived noise compared to a reference of the year 2000). The Ultra High Propulsive Efficiency (UHPE) engine concept requires the development of new technologies for geared aero engines planned to be introduced into the market around 2025.

One of the key challenges of the UHPE is the increase thermal power density to be extracted from the smaller core (due to the higher OPR). Failing to solve this engineering problem could lead to both operational issues (e.g. increased turnaround times) and lower engine life (thermal low cycle fatigue).

Leveraging advance manufacturing (AM) technology for design of aerospace engine components is key to enable optimized design with respect to performance, weight and cost. This, in turn, is a prime requirement of UHPE architecture featuring high OPR and BPR. The consideration of advanced manufacturing capabilities into the design phase eliminates conventional manufacturing constraints and enables the integration of multiple engine parts and functionalities into a single part. To leverage the full potential of additive manufacturing (AM) technology there is need to develop new design optimization tools and processes that allow engineers to take account for additive manufacturing requirements early in the design optimization loop.

In the UHPE program, GEDE aims to assess and mature the potential of the additive design as enabler for improved engine thermal management technologies. Activities and deliverables described in this call will support the maturation of several aerothermal technologies currently studied by GEDE. The successful applicant/consortium will benefit from the internal work done until the program start in terms of design and manufacturing feasibility studies.

The successful applicant/consortium is expected to support the process through innovative concepts enabling an enhanced thermal management at component and/or engine level. The applicant is also expected to leverage the capabilities of advanced manufacturing techniques (i.e. additive manufacturing) to unleash the design space and therefore enable lighter, more durable and efficient concepts.

Validating the innovative design through additive manufacturing trials will be critical part of the proposed activities. This will include assessing the feasibility of the process and evaluating the quality of the manufactured hardware against the agreed design specifications (e.g., dimensional tolerances, surface finishing, micro-structure analysis, etc.). This part of the program is expected to be an iterative procedure, where the learning from the first trials will be used to further optimize the process.

Capabilities in terms of multi-physics and multi-domain modelling as well as related processes and tools for hardware design, analysis and optimization are needed to execute the program. In addition, the applicant/consortium shall have experience in additive manufacturing, including post-processing of the part and inspections capabilities to achieve aeronautical quality standards. The successful applicant/consortium should also own or have access to a facility to test the manufactured component for flow loss (pressure drop and mass flow), heat transfer measurement (including advanced techniques, e.g. infrared camera, thermal wakes etc.), and material structural characteristics (LCF, HCF, creep, life) under conditions relevant for engine parts.

2. Scope of work

As topic leader, we envisage a project structure as depicted in

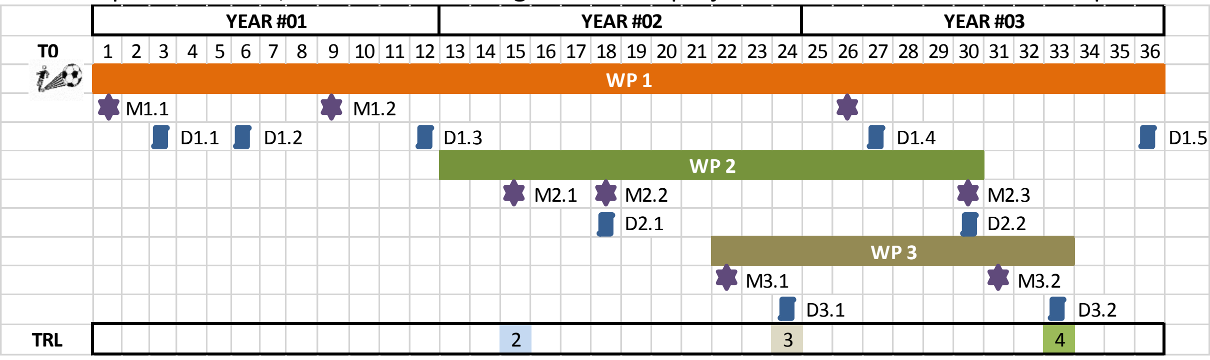


Table 2. The Work Breakdown Structure (WBS) should be aligned to the needs of the project while ensuring good tracking of the different activities and good interfaces between the WPs. Figure 12 shows a graphical representation of the different project phases along with the related MLs and DLs.

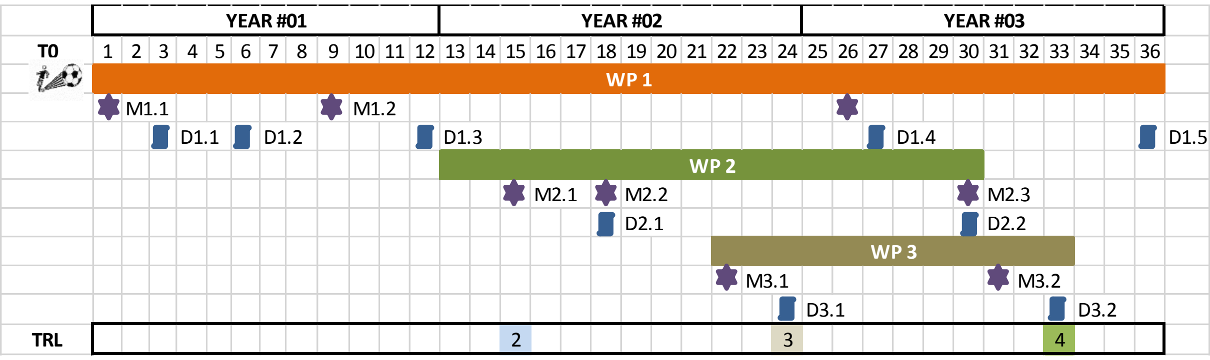


Figure 12: Work Plan Including Deliverables and Milestones

Table 2: Work Breakdown Structure

Tasks		
Ref. No.	***Title - Description***	***Due Date***
WP1	Component analysis, design and optimization	T0 + 36 months
WP2	Additive manufacturing optimization and validation	T0 + 30 months
WP3	Component design experimental investigation	T0 + 33 months

WP1 - Component analysis, design and optimization

In the first work package (WP), the component defined by the topic leader (component like but not limited to heat exchanger, internally cooled flow path components etc.) will be designed and optimized against the objectives and constraints, which will be agreed between the topic leader and WP leader. As mentioned in the introduction, the activities within this project support and integrate several aerothermal technologies currently studied by GEDE, thus the actual component(s) to be focused on will be agreed at the project start according to the internal progress on the different technologies. It can be anticipated that the work will focus on a major hot-flow component and that the new design will include the optimization of the geometry for effective cooling, minimum pressure losses, lower weight, higher life and durability.

A design approach close to the standard of GE Aviation design process will be adopted to ensure that the company requirements and legacy experience will be embedded into the final design. As part of such a process, frequent design iteration loops across the different disciplines (aero, mechanical, thermal) will be carried out prior to the final down selection of the optimized design to the tested. The following activities are expected within this WP:

- Implementation of the design requirements (boundary conditions, loads, component life etc.).
- Definition and implementation of a design optimization process including additive manufacturing considerations and related constraints.
- Development of tools and processes for automated design optimization.
- Implementation of assessment criteria to rank the optimized design based on manufacturing feasibility.

The WP will strongly interact with the WP2 to include feasibility constraints as well learning from the additive manufacturing trials into the design optimization process. The WP is also expected to support the testing phase in WP3 and carry out post-test data assessment to drive further design optimization and design recommendations. The goal of the WP is the delivery of a complete design optimization and manufacturing process for the particular component including additive capabilities and constraints.

WP2 - Additive manufacturing optimization and validation

In this WP the full potential of the AM is expected to be investigated, working closely with the WP1 within the design optimization loop and also providing manufacturing constraints for the same. There will be additive trials (4/5 trials to set manufacturing process, meeting HW quality requirements, supporting HW for test defined in WP3) based on the intermediate and on a final design iteration, including required post processing of HW. Following tasks are envisaged to be executed

- Implement Geometry CAD preparation with support structure to ensure manufacturability.
- Manufacture process setup and machine input parameters with focus to cost and targeted quality requirements.
- Deliver of additive manufactured parts, including thermal post treatment and additional postprocessing as needed.
- Deliver inspection data as agreed with the Topic Leader.
- Provide recommendations on the manufacturing process to WP1 for next design optimization loop.

Through an adequate number of trials produced in the project, the WP is expected to mature the full manufacturing process, including the requirements for the post-AM treatments and final quality assessment.

WP3 - Component design experimental investigation

The successful applicant/consortium is expected to deliver a full aerothermal and mechanical characterization of the down selected trials from WP2 under conditions and scales relevant to engine application. In the current WP expecting minimum 2 component test, which include flow check, temperature/pressure/HTC measurement and mechanical test of hardware demonstrating creep, HCF, LCF, life behaviour. As part of the WP following activities are expected

- Setup test facility and preparation for component test.
- Setup test matrix and pre-test analytical assessment.
- High quality Instrumentation to measure mass flow, temperature, pressure, stress/strain, infra red camera to measure thermal wakes, HTC (range define in Section 4)
- Aerothermal and mechanical test data collection, including advanced techniques to validate the design tools.
- Assess the design against the targets and deliver the detailed report of the component performance.

The test data should comprise (but not limited to) component flow checks, HTC, structural stress/strain data. The data will be delivered to WP1 and compared against the design intent.
For the experimental test of component, the applicant is expected to have expertise in engine component test (up to TRL4) and data acquisition/reduction to enable a detailed evaluation of the design features against the technical requirements.

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1.1	Finalization of baseline component, specifications and requirements	R	T0 + 3 months
D1.2	Design optimization framework definition and substantiation of tool capabilities	R	T0 + 6 months
D1.3	Optimized design with analytical verification (first full design loop)	R	T0 + 12 months
D1.4	Optimized design with analytical verification (final full design loop)	R	T0 + 27 months
D1.5	Final report on technology maturation achievements	R	T0 + 36 months
D2.1	Manufacturing feasibly report with results of inspections of first trials	R, HW	T0 + 18 months
D2.2	Manufacturing feasibly report with results of inspections of final trials	R, HW	T0 + 30 months
D3.1	Test campaign results (first trial) with consolidation of lessons learnt and recommendations for further optimization	R	T0 + 24 months
D3.2	Test campaign results (last trial) with consolidation of lessons learnt and recommendations for further optimization	R	T0 + 33 months

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M1.1	Kick-off meeting and WBS finalization	Review	T0 + 1 months
M1.2	Interim Design Review (first optimization loop)	Review	T0 + 9 months
M1.3	Interim Design Review (final optimization loop)	Review	T0 + 26 months
M2.1	Completion of first additive manufactured part	HW	T0 + 15 months
M2.2	First additive part ready to be tested	HW	T0 + 18 months
M2.3	Final additive part ready to be tested	HW	T0 + 30 months
M3.1	Test campaign started (first optimization loop)	Review	T0 + 21 months
M3.2	Test campaign started (final optimization loop)	Review	T0 + 31 months

4. Special skills, Capabilities, Certification expected from the Applicant(s)

Specific engineering skills, capabilities, additive manufacturing expertise and HW test facility are required to fulfil the above-mentioned tasks. Thus, the applicant/consortium is expected to provide:

- Proven track record of understanding and solving engineering problems in the aerospace industry. Capabilities in aerothermal, mechanical and system modelling and analysis of component and module are required.
- Extensive knowledge of design optimization processes and methods, including multi-physics, topology optimization, uncertainty quantification and robust design.
- Capabilities to leverage additive manufacturing technology in the design phase.
- Expertise in additive manufacturing of large size component (> 400x400 mm) with high accuracy to retain complex design features. Ability to optimize manufacturing process to target time and cost.
- Ability to perform post-AM HW treatment (HIP, sand blast, surface roughness etc.).

- Full component HW inspection and pre-test characterization capabilities, e.g. dimensions, tolerances, x-ray scan, flow check.
- Proven experience of performing component test in engine like environment (relevant Ma, Re, Bi, Pr etc.), capability to operate large scale cascade/blowdown rigs. Capability to operate the rig at stable and repeatable operating conditions.
- Test facility expected to have air flow supply with minimum 10 bar inlet pressure, 3 kg/s mass flow rate, ~600 K inlet air temperature.
- Extended capabilities to acquire detail measurements of mass flow, temperature, pressure, HTC, thermal wakes and boundary layer through advance instrumentation (e.g. infrared cameras) and data reduction process to evaluate component test performance. Experience in R&T collaborative projects, with demonstrated portfolio of successfully executed component/module design, manufacturing and test programmes.
- Proven track record with the setup of data acquisition systems and the execution of industry-standard data reduction methods.
- Experience in delivering technical and programme planning documentation, risk analyses, post-processed test results and test reports to an industry partner.

5. Abbreviations

ACARE	Advisory Council for Research and Innovation in Europe
AM	Additive Manufacturing
BPR	By-pass Pressure Ratio
Bi	Biot number
CAD	Computer Aided Design
CO_2	Carbon Dioxide
DOE	Design of Experiments
GEDE	GE Germany
HCF	High Cycle Fatigue
HIP	Hot Isostatic Pressing
HP	High Pressure
HTC	Heat Transfer Coefficient
HW	Hardware
LCF	Low Cycle Fatigue
Ma	Mach Number
NDT	Non-Destructive Technique
NO_X	Nitrous Oxides
NPI	New Product Introduction
OPR	Overall Pressure Ratio
Pr	Prandlt Number
QA	Quality Assurance
R&T	Research & Technology
Re	Reynold Number
TCF	Turbine Centre Frame
TRL	Technology Reediness Level
TVF	Turbine Vane Frame
UHPE	Ultra-High Propulsive Efficiency
WP	Work Package

II. JTI-CS2-2018-CfP08-ENG-01-33: Prediction of High Frequency Vibrations in Aircraft Engines

Type of action (RIA/IA/CSA)	RIA		
Programme Area	ENG		
(CS2 JTP 2015) WP Ref.	WP 2		
Indicative Funding Topic Value (in k€)	850		
Topic Leader	Safran	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	36	**Indicative Start Date (at the earliest)**[90]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-ENG-01-33	**Prediction of High Frequency Vibrations in Aircraft Engines**
Short description	
Definition of high-frequency modelling practices for a complex engine structure. Determine vibration levels at high frequencies, vibration transmission paths and loss factors for an engine frame structure.	

Links to the Clean Sky 2 Programme High-level Objectives[91]	
This topic is located in the demonstration area:	Ultra-high Bypass and High Propulsive Efficiency Geared Turbofans
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Short/Medium-range, Ultra-advanced Short/Medium-range
With expected impacts related to the Programme high-level objectives:	

Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

[90] The start date corresponds to actual start date with all legal documents in place.
[91] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

The UHPE Demonstration Project aims at designing, manufacturing & testing an Ultra High Propulsion Efficiency Engine Demonstrator.

The design of more fuel efficient engines requires minimization of the vibration sources in the engine, which can induce, if not well under control, high clearance closures (and as a consequence, a decrease in the engine efficiency), and oversizing of the equipment which are mounted onto the engine.
If the low frequency vibration sources are mainly due to the unbalance of rotating parts (and are considered in state-of the-art practices by engine manufacturers), high frequency sources can be various: aerodynamic excitation, power gear boxes, roller or ball bearings flaws, instabilities…
As these excitations generate vibrations at high frequencies, the prediction of these vibration levels encounters the following problems:

- Limitation of the Finite Element Modelling (FEM): for high frequency prediction via FEM, very refined meshing are needed (as complex systems can have a large number of eigen frequencies in high frequency range of interest)
- Uncertainties of input data (e.g. boundary conditions) or excitations (multiples sources, multiples points of excitations, unknown level of excitation)
- Variations in the fabrication process (e.g. two engines of the same type are not exactly the same, and then high variations of vibrations can be measured at high frequencies)

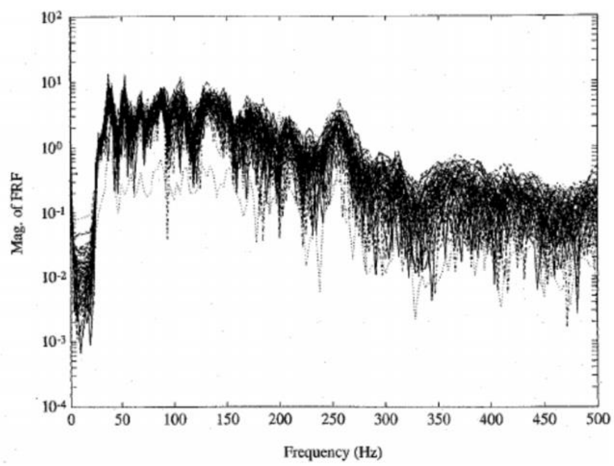


Figure 13 : Amplitude of frequency responses recorded for 99 nominally identical Isuzu pickup trucks (source: Kompella & Bernhard)

In order to optimize the overall system performance and sizing, the high frequency vibration paths have to be well predicted so the engine weight has to be minimized. A macroscopic representation of these frequency paths can be made via energetic methods such as Statistical Energy Analysis, which are already commonly used in the car and the building industry.
SEA is one of the methods for the prediction of the transmissibility of vibrations (and sounds) through complex structures. This method is particularly adapted for the estimation of vibration levels and high frequencies responses. In SEA, a complex system such as an aircraft engine can be represented by several subsystems with coupling relations between them, and a linear system of equations based on the input powers, the transmitted powers and the dissipated energies at the level of each subsystem.

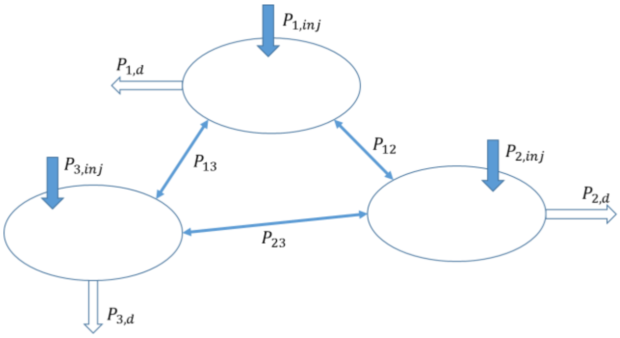


Figure 14 : Example of repartition of powers in a SEA system

The parameters of these equations in SEA are obtained by having several hypothesis on the dynamic properties of each sub-structure, which simplifies significantly the analysis which would be difficult to achieve via other methods like FEM. The knowledge of the injected powers and the SEA characteristics enables to estimate vibration energies, and so the vibration transmissions paths through the subsystems.

The two main difficulties met to apply the SEA method are the following:

- Check of the several hypothesis of the SEA model: many hypothesis are made to represent a system with a SEA model (such a sufficient number of modes by frequency-band, low coupling between each subsystem…). It is necessary to know well the hypothesis of the SEA system and subsystem (modal densities, dampings…), in order to ensure that the considered system and the sub-structuration chosen to create the model enables to check them
- Estimation of the global parameters of the model, especially the coupling loss factors and the damping loss factors which enable to describe the energy paths through the subsystems.

Another way to have a high frequencies representative modelling is to use Frequency Response Functions (FRF). These functions are used in experimental modal analysis, to identify the damping, the resonant frequencies and the mode shapes of a physical structure. They represent the frequency domain relationship between an input (x) (generally a force for a structural system) and output (y) (generally an acceleration, a velocity or a displacement) of a linear, time-invariant system.

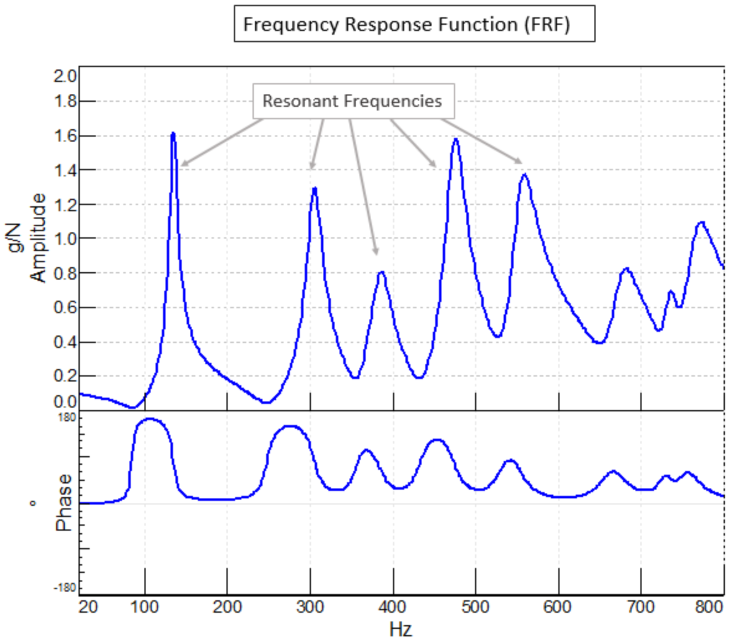


Figure 15 : Bode Plot of Amplitude and Phase of a FRF function. Amplitude has peaks corresponding to natural frequencies/resonances of test object. Phase has shift at resonant frequency.

This list of analytic methods to calculate high-frequencies levels if of course not exhaustive, and other methods can be proposed by the partner if relevant. **Multi-bodies approaches and FEM with very refined meshing shall be considered <u>out of the scope</u> of this WP, though.**

The main goal of this WP is to propose high-frequency modelling practices based on an engine complex structural frame (such as Fan Frame), to define a test matrix and a test vehicle and to validate these practices via vibration tests and vibration measurement at high frequencies.

2. Scope of work

Tasks		
Ref. No.	***Title – Description***	***Due Date***
Task 0	Theoretical description of the High Frequency methods proposed	T0 + 1 month
Task 1	Definition of the test matrix and needed instrumentation	T0 + 5 months
Task 2	Definition of the test vehicle and associated test bench systems	T0 + 9 months
Task 3	Design / manufacturing of test vehicle and test bench systems	T0 + 20 months
Task 4	High-frequency models of an engine case	T0 + 20 months
Task 5	Test campaign	T0 + 26 months
Task 6	Analysis of test data and high-frequency models tuning	T0 + 34 months
Task 7	Documentation and training of the topic leader	T0 + 36 months

<u>Task 0</u>

A report about the state-of-the-art methods to predict high-frequency vibrations and vibration transmission paths will be done.

At the end of this task, 2 or 3 modelling methods will be proposed, and clearly described before being used for the creations of models in Task 4. These methods will be benchmarked in Task 4 and Task 6. Criteria about the choice of the methods shall be the quality of correlation vs tests results, but also the capacity to use it in an industrial context (time for the creation of the models, calculations and analysis of the results, skills needed to use the methods, user-friendliness…).

Task 1

Task 1 and Task 4 will be done in parallel.

The engine substructure (engine fan frame with or without adjacent bearing supports – the presence of adjacent supports will be decided in Task 4, if the modelling shows sensitivity to these supports) will be divided in several virtual areas (such as the arms, the inner and the outer parts, which can also divided in several azimuthal areas)

A test matrix will be built to define a test which consists in applying successive dynamic excitations (~100 points of application) on the same area of a complex existing engine substructure between 400 and 10 000 Hz.

High frequency vibrations will be measured in several points on the other virtual areas of the engine frame.

The test will be done again while changing the area of excitation of the engine frame, until all the areas of the engine frame have been covered.

The key parameters to be scanned are:

- Modal densities / Modes-in-band / Modal recovery
- Vibration levels (and energies)
- Resonant frequencies and damping
- Vibration transmission paths
- Injected / Dissipated / Transmitted Powers
- Shape of modes
- Damping Loss factors
- Coupling Loss factors

Appropriate instrumentation to measure high frequency levels on this substructure will be defined, and be consistent with the needs for model matching (model from Task 4) and understandings of the vibration transmission paths.

The level of the solicitation will be high enough to have a representative percentage of the vibration levels which can be measured in an engine.

An example is given below:

- 10 g at 400 Hz
- 50 g between 800 Hz and 3,000 Hz
- 250 g between 5,000 and 10,000 Hz

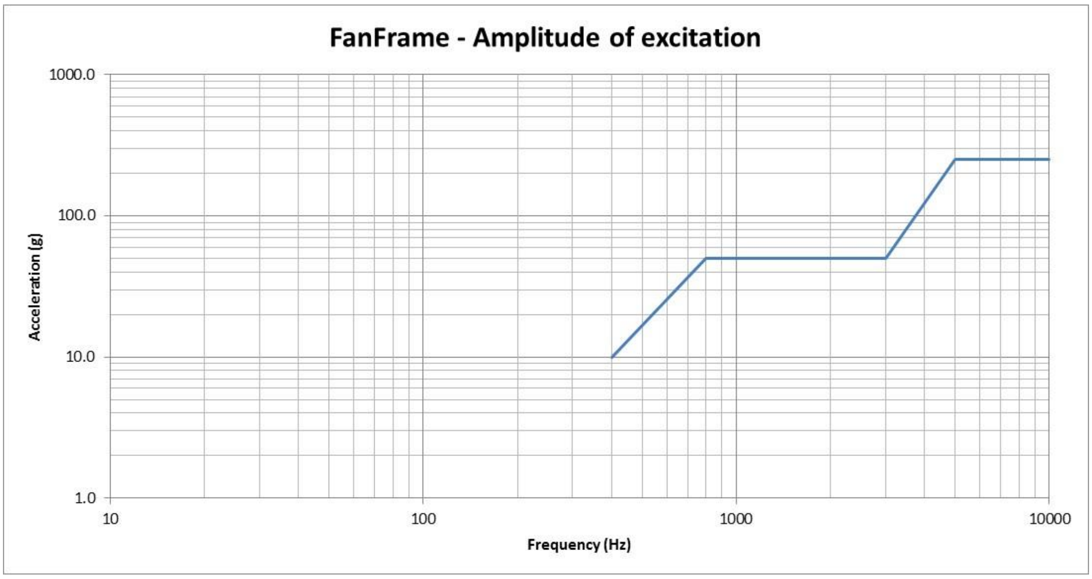


Figure 16 : Example of amplitude of dynamic excitation

Task 2

This Task aims at defining the rig test of the Engine Frame structure and its associated systems (e.g. actuators) compliant with the specifications defined in Task 1. The studied frame will be of a real aircraft engine frame structure. The engine frame will be supplied by the topic leader. The test vehicle and the associated test rig systems will be of the partner's responsibility.

During this task, the following interfaces and schemes will be defined:

- Mechanical
- Functional (such as the analysis of the control systems of the actuators).
- Interfaces to the actuators, the bench, the control systems

Task 3

Based on the agreed definition of the test rig and its associated systems, this Task includes the design and manufacturing work of the test vehicle and the associated systems (actuators, hardware to support the engine structure, table to support the assembly, instrumentation, hydraulic and control systems…). This work will be done by the partner.

The design will enable the integration of an existing engine frame structure in a test rig assembly including the systems capable to conduct the variation of the test parameters defined in the test matrix from Task 1.

The presence or not of bearing supports casings linked to the engine frame will be determined by a sensitivity study carried out in Task 4.

The instrumentation will be integrated in order to be consistent with the modelling activity (task 4) and enabling the understanding of vibration transmission paths in the engine structure. Therefore, the location of the sensors (mainly accelerometers) will be based on key zones from modelling results (from Task 4). The type and precision of the sensors will be finalized, and the sensors integrated in the test vehicle.

The parts will be defined, manufactured, instrumented and assembled to the complete test vehicle by

the partner. The vehicle will be installed in the test bench and connected to the electrical systems and data acquisition and control system.
At the end of this work package, the complete test assembly will be commissioned and instrumentation sensors calibrated.

Task 4
In this Task, the engine frame will be represented by models first while isolated, then in its environment in the test rig by the partner. The modelling methods will be those proposed and agreed in Task 0.
These models will permit to estimate the vibration levels on several bands at high frequencies, the main dynamic characteristics (e.g. modal density), and the vibration paths in the sub-components of this engine structure.
Sensitivity studies will be carried out to identify the key influent parameters, for each model.
A sensitivity study will also be made, for each model, to see whether the bearing supports are influent on the results or not, to determine if they should be considered in the assembly in Task 2 and Task 3.
A prediction of the vibration levels and the vibration transmission paths with both models on the rig test will be done, in order to compare the results between each model and correlate them to test results in Task 6.
Durations to create each model, to make calculations and to analyze results will also be compared between each model.
Multi-bodies approaches and Finite Element Methods with very refined meshing are out of the scope of this WP.

Task 5
In this Task, the agreed test matrix will be run and the data acquired by the partner.
A test report (with the preparation of the test, the presentation of the test matrix, the test parameters, the type and precision of instrumentation, the bench interface and system schemes, the description of the test vehicle and the tests conditions, analysis of the test data…) will be provided to the topic leader.
All the raw test data, post-treated data and codes enabling the treatment of the data will also be provided to the topic leader.

Task 6
In this Task, the data of Task 5 will be analyzed and compared to the prediction of Task 4 in order to achieve a complete understanding of the physical vibration paths through the engine structure. The differences will be analyzed and new methods set up in order to acquire a methodology able to predict the vibration paths and the damping and coupling loss factors in an engine complex structure.
The main deliverable is a methodology to calculate vibration transmission paths and vibration levels at high frequencies for different zones in the engine frame depending on the key parameters.
All the models created in Task 4, and the correlated models in Task 6 will be provided to the topic leader.
All the calculations jobs and the results (from the models and from the tests) will be provided to the topic leader, in an exchange format agreed between the partner and the topic leader.

Task 7
In this Task, the partner will carry out a training session for the topic leader to use the chosen methodology in Task 6, and to the tools that were developed) in Task 4 and Task 6.
Following documents shall be provided to the topic leader:

- A detailed report about the benchmark between all the models and all the methodologies tested, the correlation with test data (correlation before and after tuning of the model and/or adaptation of the methodology) and the comparison between the methodology in terms of correlation vs test data but also an analysis about the capacity to use it in an industrial context (such as calculation time and time for creation of each model, user-friendliness…)
- A modelling practice report, explaining the methodology (hypothesis, how to use it, limitations of the methodologies…)
- A modelling manual, explaining in detail :
    - How to use the tools and the code involved in the methodology
    - The input data and the validations results of the tools and the methodology
- For every tool developed or programmed :
    - A user guide
    - A programming note explaining the code
    - Tools developed, programmed or used in this WP will be provided to the topic leader
- A training support to use the methodology
- A synthesis report of the work done during the WP

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R: Report, RM: Review Meeting, D: Delivery of hardware/software*

Deliverables			
Ref. No.	**Title – Description**	**Type (*)**	**Due Date**
D0	Modelling method definition Choice of the 2 or 3 methodologies to create the high-frequency models	RM	T0 + 1 month
D1	Test definition Test matrix, test parameters, type and precision of instrumentation	RM	T0 + 5 months
D2	Concept description Concept of test vehicle Interface and system schemes	RM	T0 + 9 months
D3	Detailed description Detailed description of test vehicle, test bench and systems	R	T0 + 15 months
D4	Test commissioning Report of commissioning of the test rig and data acquisition system	R	T0 + 20 months
D5	Model and test prediction Description of the models and the used formulas and delivery of the models	R and D	T0 + 20 months
D6	Test report Description of test conditions and delivery of associated test data	R and D	T0 + 24 months
D7	Analysis of test data and adapted methodology Detailed analysis of the test data, comparison with prediction by the model. Analysis of the differences. Adaptation and delivery of the modelling and methodology to predict high level frequencies	R and D	T0 + 34 months

Deliverables			
Ref. No.	**Title – Description**	**Type (*)**	**Due Date**
D8	Documentation and training Training review with the topic leader in order to use the methodology (and training manual associated) Tools developed to use the methodology User guide and programming note associated to the tools and the code involved in the methodology Modelling practices report Modelling manual report	R, D and RM	T0 + 36 months

Milestones (when appropriate)			
Ref. No.	**Title – Description**	**Type**	**Due Date**
MS 0	Choice of the modelling methods		T0 + 1 month
MS 1	End of Test definition Phase		T0 + 5 months
MS 2	End of Concept Phase		T0 + 9 months
MS 3	End of Detailed Phase		T0+15 months
MS 4	Test bench commissioning		T0 + 20 months
MS 5	Delivery of prediction results		T0 + 20 months
MS 6	Delivery of the modelling and the adapted methodology		T0 + 34 months
MS 7	Delivery of the documentation		T0 + 36 months

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Proven competence in design, manufacturing, instrumentation of complex component rig tests and the associated systems
- Proven competence in high-frequency analysis, transmissibility and energetic approaches
- Design and analysis tools of the aeronautical industry: for programming, Matlab is preferred
- Availability of test benches to support test campaign
- Proven competence in test analysis

III. JTI-CS2-2018-CfP08-ENG-01-34: Airflow characterization through rotating labyrinth seal

Type of action (RIA/IA/CSA)	RIA		
Programme Area	ENG		
(CS2 JTP 2015) WP Ref.	WP2		
Indicative Funding Topic Value (in k€)	600		
Topic Leader	Safran	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	24	**Indicative Start Date (at the earliest)**[92]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-ENG-01-34	**Airflow characterization through rotating labyrinth seal**
Short description	
The aim of this project is to test different configurations of labyrinth seals to determine the pressure loss characteristics for different rotor speeds and different radial clearances. The test rig shall be able to test only a seal configuration in a simplified environment (see figure 4). Safran Aircraft Engines will design the seals and the partner will manufacture the seals, design and assembly the test vehicle, conduct the test campaign and analyse the results. This results shall be compared with the present numerical model predictions in order to perform a gap analysis. If the calculations do not match with the test results then we expect the partner to propose improvements to our existing model.	

Links to the Clean Sky 2 Programme High-level Objectives[93]				
This topic is located in the demonstration area:	Ultra-high Bypass and High Propulsive Efficiency Geared Turbofans			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Short/Medium-range, Ultra-advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

[92] The start date corresponds to actual start date with all legal documents in place.
[93] For further info see Chapter 1 “Introduction to the Programme Scene Setter / Objectives” with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

Optimizing LPT efficiency requires to minimize airflow leakages between the static parts and the rotating parts. Firstly, bypass airflow are not working in the LPT which decreases LPT performance. Secondly, reintroductions of airflow into the flowpath make local pressure losses which decreases LPT performance. Integration issues, high operating temperature conditions and robustness requirements lead to design labyrinth seal at the top of the blades and under the distributors.

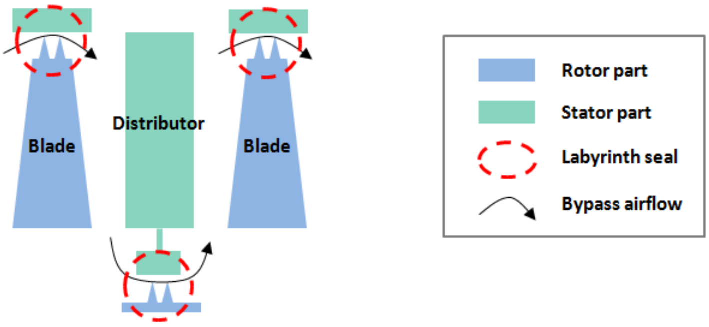
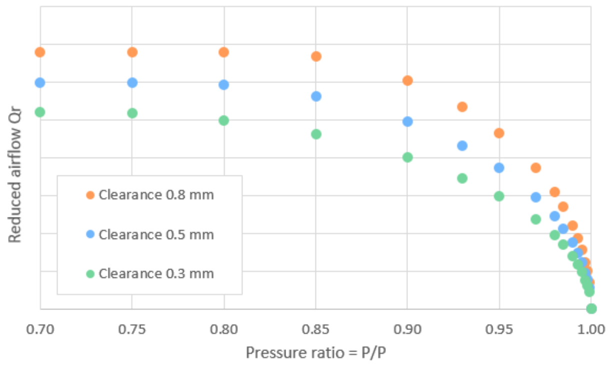


Figure 1: schematic view of bypass airflows in a LPT

Labyrinth seal design and optimization is based on pressure loss characteristics (reduced flow depending on pressure ratio) which take into account the seal geometry and the rotor speed.
Safran Aircraft Engines has developed a numerical model to calculate the pressure loss characteristics (see figure 3) of the labyrinth seals and this model has been validated with partial test for a wide range of configurations.

The aim of this project is to test different configurations of labyrinth seals to determine the pressure loss characteristics **for different rotor speeds and different radial clearances**. The test rig shall be able to test only a seal configuration in a simplified environment (see figure 4). *Safran Aircraft Engines* will design the seals and the partner will manufacture the seals, design the test vehicle, conduct the test campaign and analyze the results. This results shall be compared with the present numerical model predictions in order to perform a gap analysis. If the calculations don't match with the test results then we expect the partner to propose improvements to our existing model.



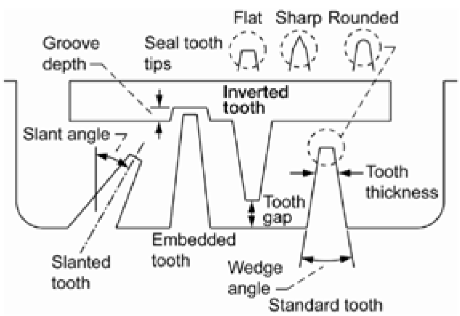


Figure 2: example of pressure loss characteristics (left)
Figure 3: generalized schematics of labyrinth seal throttle configurations (right)

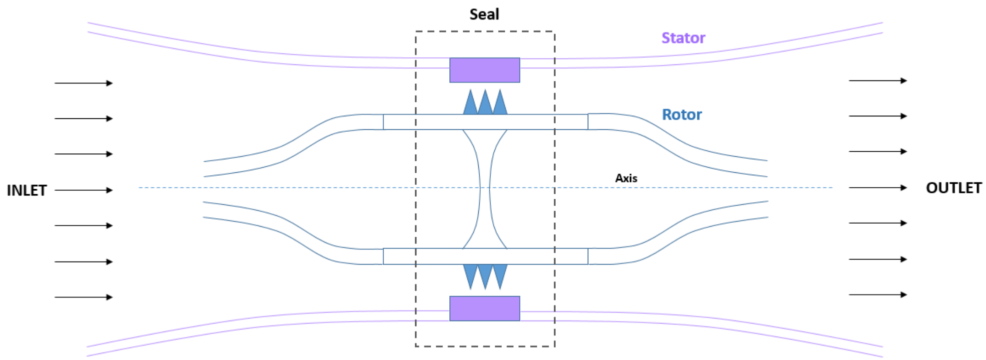


Figure 4: example of a simplified test rig to test a seal configuration

This study is related to the Work Package WP2.4.2 :

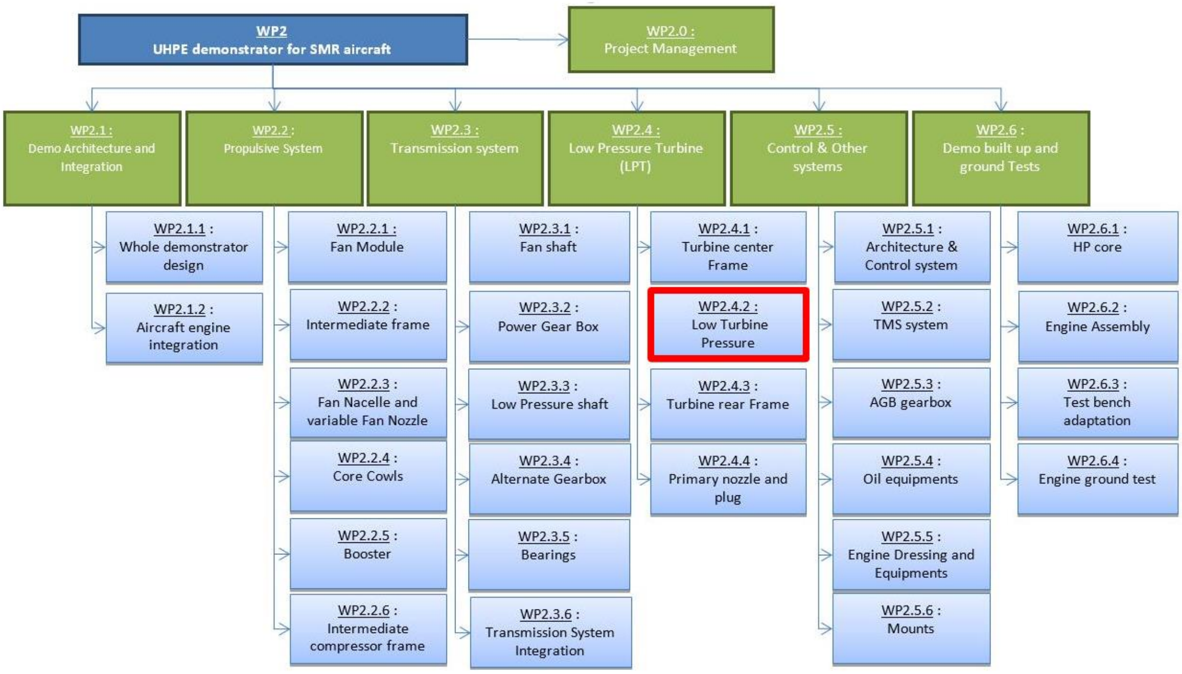


Figure 5: workpackages

2. Scope of work

Test Vehicle Description

This paragraph describes the input parameters and the number of configurations to be tested during the test campaign.

The final geometry of the seals, final air pressures, final air temperatures, final radial clearances and final rotor speed are not frozen yet but the range is defined in this document. The number of configurations shall be considered as a frozen target unless if it is not compliant with financial or schedule aspect. In this case, the partner is encouraged to detail its constraints in order to determine if a trade-off is possible.

Seal configurations

A seal configuration means :

- a given seal geometry
- a given axial position between rotor part and stator part

Each seal configuration will be tested with :

- 10 pressures ratio (pressure ratio = dowstream pressure divided by upstream pressure)
- 2 air temperatures
- 3 radial clearances

The test campaign is divided into 2 test campaigns called test campaign #1 and test campaign #2.
Here is the number of seal configurations to be tested :

- 20 seal configurations (= 15 geometries + 5 axial positions) in the test campaign #1
- 20 seal configurations (= 15 geometries + 5 axial positions) in the test campaign #2

The seal configurations designed and tested in the test campaign #2 will depend on the results of the test campaign #1. This is the reason why the task 12 (*Seals designing #2)*.
For instance, if the test campaign#1 shows that rotor speed has no impact on the influence of teeth length then we will not test different teeth length during the test campaign #2.

<u>Radial clearance</u>
Here is the range of the radial clearances to be tested :

  - Min clearance = 0.1 mm
  - Max clearance = 1.00 mm

Each seal configuration will be tested for 3 radial clearances.
The test bench shall be able to measure the radial clearance with an accuracy of +/-0.01 mm on the mounted seal for at least 8 circumferential position.
The task 3 shall lead to the best solution between a clearance control system and a specific manufacturing for each radial clearance to be tested.

<u>Axial position</u>
Each seal configuration will be defined with a specific axial position between rotor part and stator part.
The test bench shall be able to control the axial position inside this indicative range :

  - Min axial position = 0.00 mm (reference)
  - Max axial position = 5.00 mm

Each seal configuration will be tested for 1 axial position.
Axial position shall be measured with an accuracy of +/-0.05 mm on the mounted seal.

<u>Rotor speed</u>
As explained in the paragraph §1, the objective of this study is to test different configurations of labyrinth seals to determine the pressure loss characteristics for different rotor speeds. Here is an indicative range of the rotor speed to be tested :

  - Min rotor speed = 0 rpm
  - Max rotor speed = 15000 rpm

Each seal configuration will be tested for 4 rotor speeds (including the static case)

<u>Air pressure</u>
Here is the range of the upstream air pressure to be tested :

- Min upstream pressure = ambiant pressure = 1.00 bar
- Max upstream pressure = 9.00 bar

Here is the range of the downstream air pressure to be tested :

- Min downstream pressure = ambiant pressure = 1.00 bar
- Max downstream pressure = 3.00 bar

Each seal configuration will be tested for 10 pressure ratios (pressure ratio = downstream pressure divided by upstream pressure).

Air temperature

Here is the range of the air upstream air temperature to be tested :

- Min temperature = Tamb = 20°C
- Max temperature = 150°C

Each seal configuration will be tested for 2 air temperatures.

The maximum temperature shall not be reached for any airflow. The maximum airflow related to the maximum temperature will be discussed and frozen during the task 2.

Seal diameter

A unique seal diameter will be frozen during the task 2 (between 200mm and 300mm).

Instrumentation

The test vehicle shall be able to measure the following parameters :

- Static pressure : stabilized data only with an accuracy of +/- 0.01 bar
- Total pressure : stabilized data only with an accuracy of +/- 0.01 bar
- Total temperature : stabilized data only with an accuracy of +/- 5°C
- Airflow : stabilized data only with an accuracy of +/- 2%
- Radial clearance : static measure on 8 circumferential positions with an accuracy of +/- 0.01 mm
- Axial position : static measure with accuracy +/- 0.1 mm
- Rotor speed : transient data 1Hz with accuracy +/- 1%

Tasks

Tasks		
Ref. No.	**Title – Description**	**Due Date**
Task 0	Airflow characterization through rotation labyrinth seals – Management and reporting **Progress Reporting & Reviews:** • Quarterly progress written reports shall be provided by the partner, referring to all agreed workpackages and including technical achievement, updated workplan, inputs and outputs status, financial status, update of the risk analysis and mitigation plan. This report shall be presented during a face to face meeting which will take place alternatively in the partner offices and in Safran Aircraft Engines offices. • Monthly coordination meetings shall be conducted via telecom. • The partner shall support reporting and agreed review meetings with reasonable visibility on its activities and an adequate level of information. • The partner shall warn Safran Aircraft Engines if any event has a significant impact on the work plan.	All along the project

Tasks		
Ref. No.	**Title – Description**	**Due Date**
Task 1	Project launch The partner and Safran Aircraft Engines shall perform a face to face meeting in Safran Aircraft Engines offices. The partner shall present the risk analysis and the mitigation plan based on the learning of this present document. The partner shall also present the technical means and the relevant projects it has achieved. Safran Aircraft Engines shall present the background of the project, the deliverables and the work plan target. This meeting shall allow to meet the team project on both sides, to define the key roles, to plan the quarterly report meetings and the monthly coordination meetings.	T0 + 1 month
Task 2	Final requirement A common agreement between the partner and Safran Aircraft Engines shall freeze the final technical requirements: size, rotor speed, list of measured parameters and accuracy, air pressure, air temperature, radial clearance and accuracy. Each parameter will respect the range defined in this document.	T0 + 3 months
Task 3	Test vehicle interface definition The partner shall provide the final test vehicle interface definition between the seal and the test vehicle.	T0 + 5 months
Task 4	Test vehicle specifications The partner shall provide the final test vehicle definition, the assembly plan and the compliance matrix to show the test vehicle respects all the requirements previously frozen.	T0 + 5 months
Task 5	Test vehicle assembling The partner shall assembly the test vehicle and update the compliance matrix. The partner shall stand a face to face meeting to present the test vehicle.	T0 + 10 months
Task 6	Seal prototyping The partner shall manufacture a seal with the final manufacturing process. A dimensional inspection report shall be written.	T0 + 7 months
Task 7	Test vehicle commissioning The partner shall conduct a first run with the seal prototype in order to debug and check the test vehicle. Data post processing shall also be frozen after this task.	T0 + 11 months
Task 8	Seals designing #1 Safran Aircraft Engines shall provide the blueprints of the seals designed for the test campaign #1 and the design of the seals. The test matrix #1 shall be defined by Safran Aircraft Engines but there will be no change in the number of configurations, the number of clearances, the number of pressures or the number of temperature tested in comparison with this document.	T0 + 7 months
Task 9	Seals manufacturing #1 The partner shall manufacture and provide the seals designed by Safran	T0 + 11

Tasks		
Ref. No.	**Title – Description**	**Due Date**
	Aircraft Engines for the test campaign #1. A dimensional inspection report shall be written.	months
Task 10	Test campaign #1 The partner shall conduct the test campaign #1 and write a weekly report to summarize the key events.	T0 + 13 months
Task 11	Results report #1 The partner shall provide the full set of data for the test campaign #1 after post processing. The results shall be presented in an interactive way to be able to compare several configurations with or without post-processing on the same graph. A statistic approach shall be used to analyse the differences between the configurations tested.	T0 + 14 months
Task 12	Seals designing #2 Safran Aircraft Engines shall provide the blueprints of the seals designed for the test campaign #2 and the design of the seals. The test matrix #2 shall be defined by Safran Aircraft Engines but there will be no change in the number of configurations, the number of clearances, the number of pressures or the number of temperature tested in comparison with this document.	T0 + 16 months
Task 13	Seals manufacturing #2 The partner shall manufacture and provide the seals designed by Safran Aircraft Engines for the test campaign #2. A dimensional inspection report shall be written.	T0 + 19 months
Task 14	Test campaign #2 The partner shall conduct the test campaign #2 and write a weekly report to give the key events.	T0 + 21 months
Task 15	Results report #2 The partner shall provide the full set of data for the test campaign #2 after post processing. The results shall be presented in an interactive way to be able to compare several configurations with or without post-processing on the same graph. A statistic approach shall be used to analyse the differences between the configurations tested.	T0 + 22 months
Task 16	Global analysis The partner shall perform and present the global analysis of the both test campaigns. The results shall be post processed in order to do the comparison with the Safran Aircraft Engines numerical model. A gap analysis shall be performed to update and improve the numerical model.	T0 + 23 months
Task 17	Final report The partner shall write the final report and present a sum up during a face to face meeting in Safran Aircraft Engines offices. This report shall include the technical work but also a feedback on the project (evolution and efficiency of the risk analysis, evolutions of the work plan, feedback on the organization).	T0 + 24 months

3. Major Deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	***Title – Description***	***Type****	***Due Date***
D1	Scoping report (see task 1)	R	T0 + 1 month
D2	Test vehicle interface definition (see task 3)	R	T0 + 5 months
D3	Test vehicle specifications (see task 4)	R	T0 + 5 months
D4	Test vehicle assembling (see task 5)	R	T0 + 10 months
D5	Seal prototyping (see task 6)	R	T0 + 7 months
D6	Seals manufacturing (see task 9)	R	T0 + 11 months
D7	Results report #1 (see task 11)	D + R	T0 + 14 months
D8	Seals manufacturing #2 (see task 13)	R	T0 + 19 months
D9	Results report #2 (see task 15)	D + R	T0 + 22 months
D10	Global Analysis (see task 16)	R	T0 + 23 months
D11	Final report (see task 17)	R	T0 + 24 months
**Types: R=Report, D-Data, HW=Hardware*			

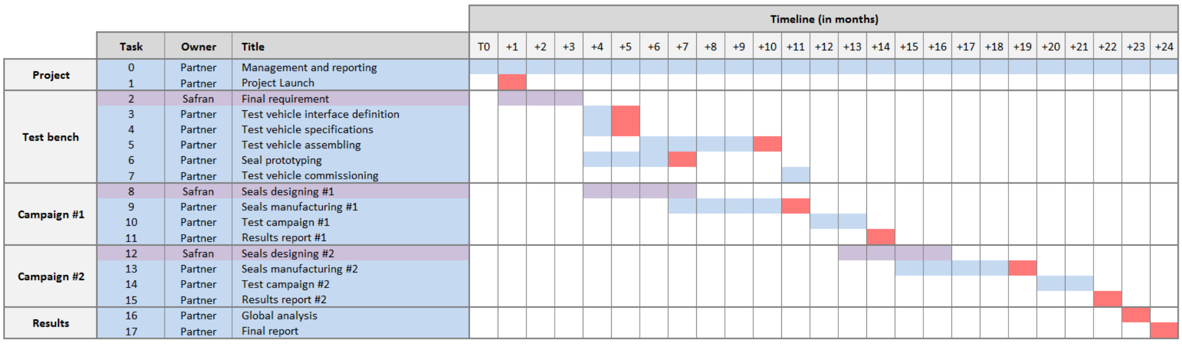


Figure 6: tasks planification

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Proven experience in pressure loss characteristics measurement.
- Proven capacity in complex test vehicle assembling.
- Proven capacity in rotational parts manufacturing and dimensional inspection.
- Proven capacity of result analysis with physical and statistic approach.
- Proven capacity of the following measurement :
    - Total and static air pressure
    - Total air temperature
    - Airflow
    - Radial clearance
    - Axial position
    - Rotor speed
- English language is mandatory.

5. Abbreviations

LPT	Low Pressure Turbine
rpm	Rotation per minute
P/P	Pressure ratio = $P_{Downstream}$ / $P_{Upstream}$
$P_{Upstream}$	Upstream pressure
$P_{Downstream}$	Downstream pressure
$T_{Upstream}$	Upstream temperature
Q	Airflow
Qr	Reduced airflow = $\frac{Q}{P_{Upstream}}\sqrt{T_{Upstream}}$

IV. JTI-CS2-2018-CfP08-ENG-01-35: Oil flow 4 channels regulation valves

Type of action (RIA/IA/CSA)	IA		
Programme Area	ENG		
(CS2 JTP 2015) WP Ref.	WP 2		
Indicative Funding Topic Value (in k€)	1400		
Topic Leader	Safran	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	26	**Indicative Start Date (at the earliest)**[94]	Q1 2019

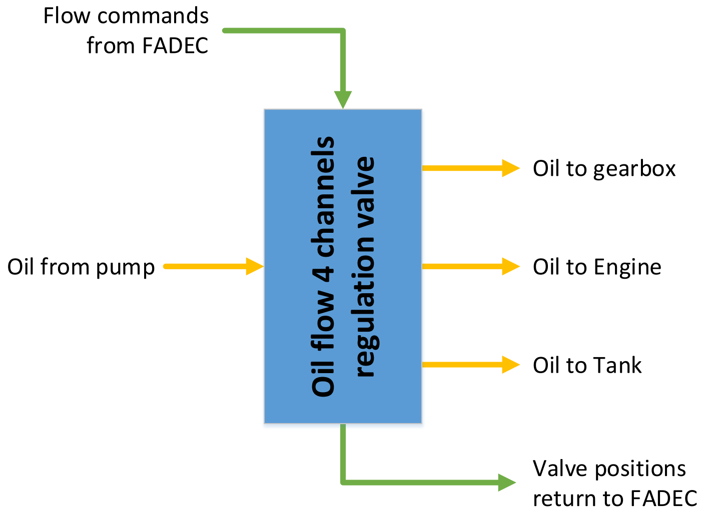
Topic Identification Code	Title
JTI-CS2-2018-CfP08-ENG-01-35	**Oil flow 4 channels regulation valves**
Short description	
The UHBR new architecture introduces a gearbox with a dedicated and complex oil cooling system. The solution foreseen in the oil circuit introduces an oil recirculation in order to control, through a three valve outputs, the oil flow provided to the engine and the gearbox. The gearbox system is very sensitive to the oil flow precision and these kinds of valve are not part of SAFRAN legacy, thus a demonstration of capability in terms of flow precision through the all range of oil flow, temperatures and pressures shall be done in order to improve the oil circuit architecture. The objective is to reach TRL 5 by manufacturing 2 prototypes and performing associated demonstration/qualification tests.	

Links to the Clean Sky 2 Programme High-level Objectives[95]				
This topic is located in the demonstration area:	Ultra-high Bypass and High Propulsive Efficiency Geared Turbofans			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Short/Medium-range, Ultra-advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

[94] The start date corresponds to actual start date with all legal documents in place.
[95] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background.

The 4 channels Oil flow regulation valve function is to split an incoming oil flow into three secondary flows going to the gearbox, the engine and the oil tank in accordance with FADEC command. The valve shall be oil driven and a position return shall be return to the FADEC to close the command loop. The valve functionnal interfaces are described on the following figure :



The oil flow split shall occurre with an high accurancy : output flows shall be achieved with a precision of less than 5% of command flow. In addition the oil pressures of the three outputs are not correlated together and the accuracy of oil split shall not be impacted by an output pressure variation. Finally, the valve shall afford a failsafe position in case of command loss to ensure a safe engine shutdown.

The objectives of the workpackage are :

1. To propose a design of the valves to achieve the required accuracy
2. To manufacture 2 valves for equipments and system test
3. To perform qualification test on the valve to reach a TRL5

2. Scope of work

Tasks		
Ref. No.	***Title - Description***	***Due Date***
T1	Preliminary Design	T0 + 4 months
T2	Critical Design	T0 + 8 months
T3	Detailed Design	T0 + 12 months
T4	Assembly of the equipment	T0 + 18 months
T5	Qualification tests	T0 + 24 months

Preliminary Design

During the Preliminary Design, the supplier shall analyse Safran Aircraft Engines requirements for the 4 channels regulation valve and propose an architecture for the equipment that respects the functionnal and the physical requirements.

After this task, the supplier shall provide to Safran Aircraft Engines a compliance matrix, a preliminary physical model, a preliminary performance model of the equipement and a validation & verification plan to ensure that a TRL5 will be reached at the end of the project.
The physical model shall include a 3D model with the positions of all interfaces of the equipment. In addition an estimation of weight and center of gravity shall be given to Safran Aircraft Engines.
The performance model shall return the position and the valves and the oil caracteristics (flow, pressure, temperature) for all outputs considering varing inputs : oil characteristics (flow, pressure temperature) and FADEC inputs.
This task will end with an official meeting performed with Safran Aircraft Engines technical reviewer. A TRL3 review shall also be validated at the end of this task.

Critical Design

During the Critical Design, the supplier shall size the complete equipement in accordance with the architecture validated in the previous task. With this final design the suppier shall confirm the compliance matrix and begin to detail the test procedures that will be applied during the test.
After this task the supplier shall provide to Safran Aircraft Engines an updated compliance matrix, a FMEA, a final physical model, a final performance model of the equipement and a test procedure in accordance with validation and verification plan.
This task will end with an official meeting performed with Safran Aircraft Engines technical reviewer.

Detailed Design

During the Detailed Design, the supplier shall prepared the assembly tasks with detailed equipement drawing and assembly process.
After this task, the supplier shall provide to Safran Aircraft Engines detailed internal drawing of the equipment and assembly process documentation.
This task will end with an official meeting performed with Safran Aircraft Engines technical reviewer.

Assembly of the equipment

During this task, the supplier shall assemble two equipements in order to perform internally the TRL5 validation test.
After the qualififcation test, the assembled equipments shall also be provided to Safran Aircraft Engines for system integration and TRL6 validation.

Qualification tests

During this task the supplier shall performed the required test for TRL5 validation. A preliminary list of test could be :

- Functionnal performance test (nominal behaviour, accuracy, transient…) for hot and cold oil
- Hydraulic tests (proof pressure, high and cold temperature, contamination, …)
- Environmental test (vibration, thermal…)

3. Major Deliverables/ Milestones and schedule (estimate)

T0 : Start of project with Technical needs delivered by Safran Aircraft Engines

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1	Preliminary performances of the equipment	D	T0 + 4 months
D2	Preliminary physical model	D	T0 + 4 months
D3	PDR Presentation	R	T0 + 4 months
D4	Final performances of the equipment	D	T0 + 8 months
D5	Final physical model	D	T0 + 8 months
D6	CDR Presentation	R	T0 + 8 months
D7	FMEA	R	T0 + 8 months
D8	DDR Presentation	R	T0 + 12 months
D9	Qualification report	R	T0 + 25 months
D10	Qualified Hardware for TRL 6 Test	H	T0 + 25 months
D11	TRL 5 Presentation	R	T0 + 26 months

**Type: R=Report, D=Data, HW=Hardware*

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M1	Preliminary Design Review	R	T0 + 4 months
M2	Critical Design Review	R	T0 + 8 months
M3	Detailed Design Review	R	T0 + 12 months
M4	Start of Qualification Test	R	T0 + 18 months
M5	End of Qualification Test	R	T0 + 24 months
M6	TRL5 Review	R	T0 + 26 months

**Type: R=Report, D=Data, HW=Hardware*

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Hydraulics Sizing
- Hydraulic equipement assembly
- Aeronautics equipement qualification

5. Abbreviations

CDR Critical Design Review
DDR Detailed Design Review
FMEA Failure Mode and Effects Analysis
PDR Preliminary Design Review
UHBR Ultra High Bypass Ration
TRL Technology Readiness Level

V. JTI-CS2-2018-CfP08-ENG-01-36: Optimizing impingement cooling

Type of action (RIA/IA/CSA)	RIA		
Programme Area	ENG		
(CS2 JTP 2015) WP Ref.	WP2		
Indicative Funding Topic Value (in k€)	600		
Topic Leader	SAFRAN	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	24	**Indicative Start Date (at the earliest)**[96]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-ENG-01-36	**Optimizing impingement cooling**
Short description	
The aim of this project is to test different configurations of LPTACC pipes with a variation of the drilling pattern, the pipe geometry, the impingement distance, the airflow, the air temperature in order to develop numerical methods to predict heat transfer coefficient. *Safran Aircraft engines* will design the pipes and the partner will manufacture the pipes, design and assembly the test vehicle, conduct the test campaign, analyse the test result and develop the numerical method to predict the heat transfer coefficient.	

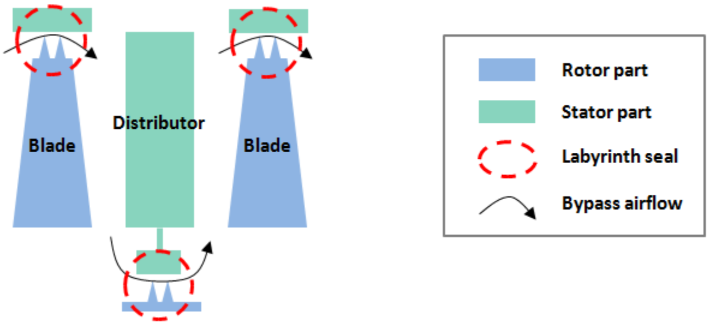
Links to the Clean Sky 2 Programme High-level Objectives[97]				
This topic is located in the demonstration area:	Ultra-high Bypass and High Propulsive Efficiency Geared Turbofans			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Short/Medium-range, Ultra-advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

[96] The start date corresponds to actual start date with all legal documents in place.

[97] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

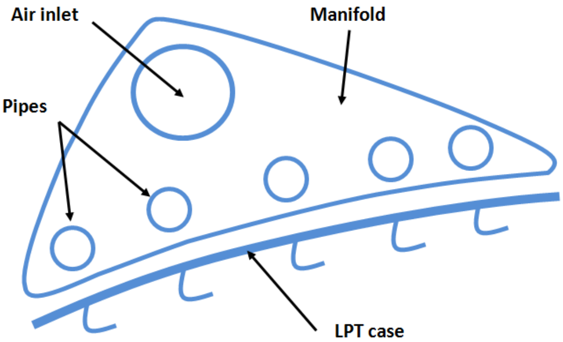
1. Background

Optimizing LPT efficiency requires to minimize airflow leakages between the static parts and the rotating parts. Firstly, bypass airflow are not working in the LPT which decreases LPT performance. Secondly, reintroductions of airflow into the flowpath make local pressure losses which decreases LPT performance. Integration issues, high operating temperature conditions and robustness requirements lead to design labyrinth seal at the top of the blades and under the distributors.



Schematic view of bypass airflows

For given pressure conditions, the bypass airflow through a labyrinth seal is strongly dependant on the radial clearance between the rotor part and the stator part. This the reason why *Safran Aircraft Engines* has developed LPTACC system to control the radial clearance in operation. This system control the LPT case temperature with an impingement cooling.



2D schematic view of the LPTACC system around the LPT case (left)
Picture of an impingement cooling pipe (right)

The aim of this project is to test different configurations of LPTACC pipes with a variation of the drilling pattern, the pipe geometry, the impingement distance, the airflow, the air temperature in order to develop numerical methods to predict the heat transfer coefficient.

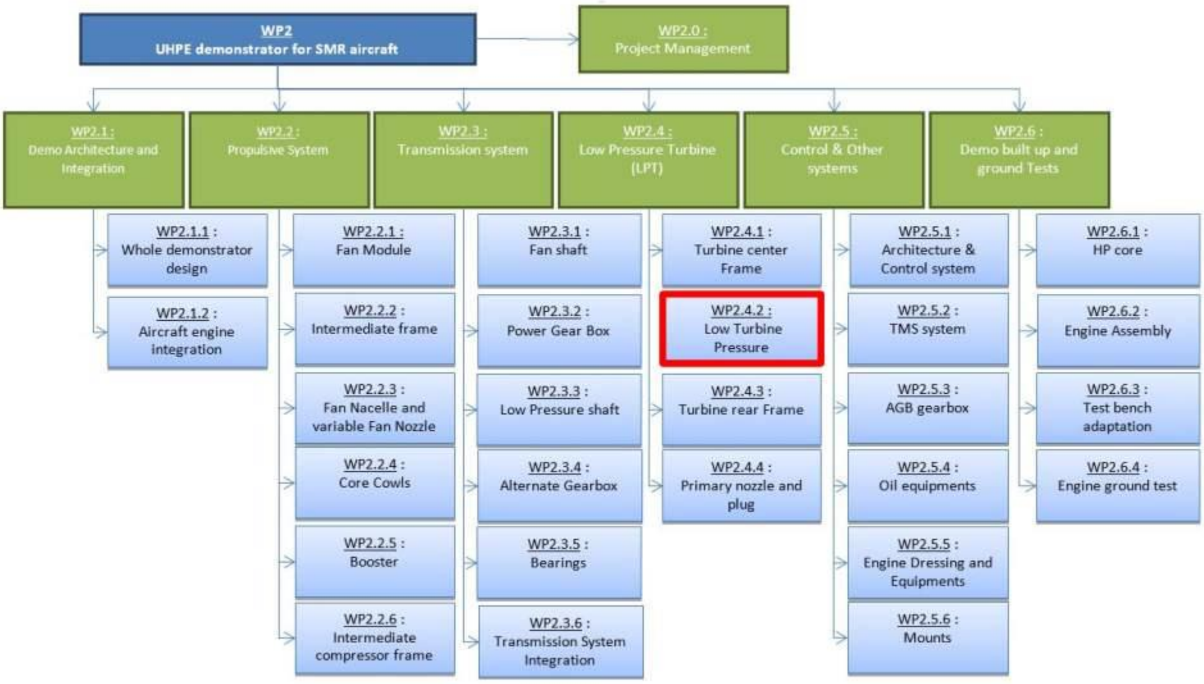
The expected numerical method has 2 modeling levels :

- 0D correlation to be implemented in a thermal model to calculate the heat transfer coefficient based on the relevant parameters (geometry, air conditions, etc…). The partner shall determine the validity domain of the 0D correlation.
- CFD method based on Fluent code or elsA code validated with the relevant test bench

configurations. This CFD method shall be predictive for new LPTACC configurations as tested. The partner shall determine the validity domain of the CFD method.

Impingement cooling on a real engine is made by a circular pipe around a circular LPT case. It is assumed for the test bench that the impingement cooling will be made by a straight pipe above a flat plate.

This study is related to the Workpackage W2.4.2 :



2. Scope of work

Test Vehicle Description

This paragraph describes the input parameters and the number of configurations to be tested during the test campaign.

The final geometry of the LPTACC pipes and flat plates, final air pressures, final air temperatures and final distance impact are not frozen yet but the range is defined in this document. The number of configurations shall be considered as a frozen target unless if it is not compliant with financial or schedule aspect. In this case, the partner is encouraged to detail its constraints in order to determine if a trade-off is possible.

LPTACC pipes and flat plates configurations

The test vehicle is assumed to be composed by a straight pipe above a flat plate.

A configuration means :

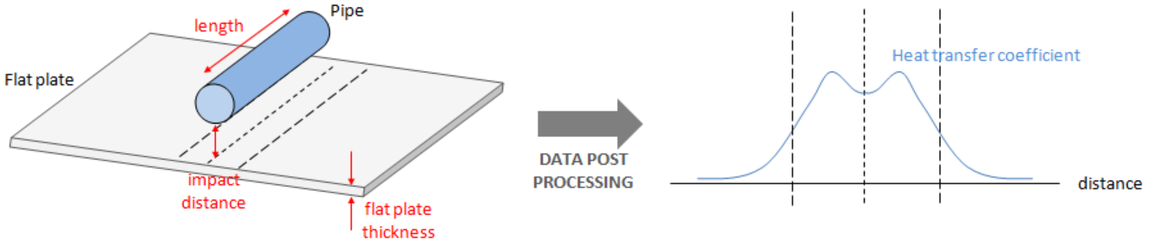
- a given LPTACC pipe
- a given flat plate

Each configuration will be tested with :

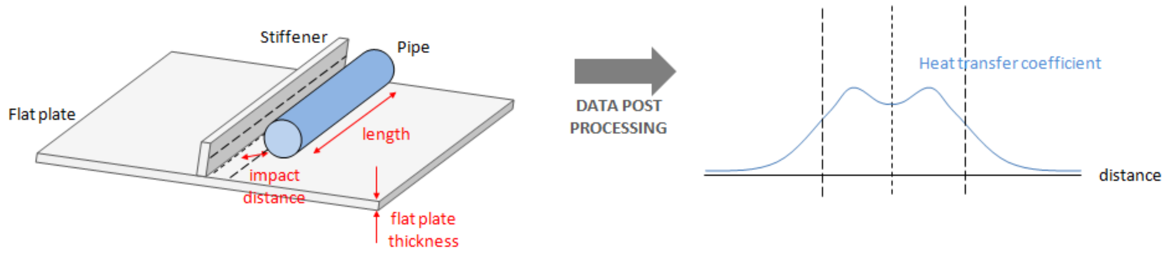
- 10 upstream pressures
- 2 air temperatures

- 4 impact distances

The test campaign is divided into 2 test campaigns called test campaign #1 and test campaign #2. For the test campaign #1, several configurations of pipes will be tested with a unique flat plate.



For the test campaign #2, several configurations of pipes will be tested with 2 different flat plates (variation of the stiffener geometry).



Schematic view of the test vehicle for the test campaign #2

Here is the number of configurations to be tested :

- 8 configurations (including 8 pipes and 1 unique flat plate) in the test campaign #1
- 8 configurations (including 4 new pipes and 2 new flat plates) in the test campaign #2

<u>Impact distance</u>

Here is the range of the impact distance to be tested :

- Min impact distance = 1 mm
- Max impact distance = 10 mm

Each configuration will be tested with 4 impact distances.

<u>Air temperature</u>

Here is the range of the air temperature to be tested :

- Min air temperature = Tamb = 20°C
- Max air temperature = 200°C

Each configuration will be tested with 2 air temperatures.

<u>Air pressure</u>

Here is the range of the upstream air pressure to be tested :

- Min upstream air pressure = Pamb = 1.00 bar
- Max upstream air pressure = 5.00 bar

The downstream air pressure is assumed to be the ambiant pressure Pamb = 1.00 bar

Each configuration will be tested for 10 upstream air pressures.

Pipe length
Here is the range of the pipe length to be tested :
- Min pipe length = 80 cm
- Max pipe length = 150 cm

The unique final pipe length will be frozen during task 2.

Pipe diameter
Here is the range of the pipe diameter to be tested :
- Min pipe diameter = 15 mm
- Max pipe diameter = 30 mm

Instrumentation
The test vehicle shall be able to measure the following parameters :
- Static air pressure : transient data (1 Hz) with an accuracy of +/- 0.01 bar
- Total air pressure : transient data (1 Hz) with an accuracy of +/- 0.01 bar
- Total air temperature : transient data (1 Hz) with an accuracy of +/- 2°C
- Metal temperature : transient data (1 Hz) with an accuracy of +/- 2°C

  Instrumentation shall be able to determine a transient thermal mapping of the flat plate.
- Airflow : transient data (1 Hz) with an accuracy of +/- 2%
- Impact distance : static measure with accuracy +/- 0.1 mm

TASKS

Tasks		
Ref. No.	***Title – Description***	***Due Date***
Task 0	*Optimizing impingement cooling – Management and reporting* • Quarterly progress written reports shall be provided by the partner, referring to all agreed workpackages and including technical achievement, updated work plan, inputs and outputs status, financial status, update of the risk analysis and mitigation plan. This report shall be presented during a face to face meeting which will take place alternatively in the partner offices and in *Safran Aircraft Engines* offices. • Monthly coordination meetings shall be conducted via telecom. • The partner shall support reporting and agreed review meetings with reasonable visibility on its activities and an adequate level of information. • The partner shall warn *Safran Aircraft Engines* if any event has a significant impact on the work plan.	All along the project

Tasks		
Ref. No.	***Title – Description***	***Due Date***
Task 1	Project launch The partner and *Safran Aircraft Engines* shall perform a face to face meeting in *Safran Aircraft Engines* offices. The partner shall present the risk analysis and the mitigation plan based on the learning of this present document. The partner shall also present the technical means and the relevant projects it has achieved. *Safran Aircraft Engines* shall present the background of the project, the deliverables and the work plan target. This meeting shall allow to meet the team project on both sides, to define the key roles, to plan the quarterly report meetings and the monthly coordination meetings.	T0 +1 month
Task 2	Final requirements A common agreement between the partner and *Safran Aircraft Engines* shall freeze the final technical requirements : LPTACC pipes size, number of pipes, list of measured parameters and accuracy, air pressure, air temperature, airflow, impact distance, flat plate geometry.	T0 + 3 months
Task 3	Numerical method and validation plan The partner shall present the state of the art of the relevant CFD methods developed to model impingement cooling. The aim is to to freeze the numerical method and the validation plan. A special attention will be paid to the validity domain.	T0 + 4 months
Task 4	Test vehicle interface definition The partner shall provide the final test vehicle interface definition between the LPTACC pipe designed by *Safran Aircraft Engines* and the test vehicle designed by the partner.	T0 + 6 months
Task 5	Test vehicle specifications The partner shall provide the final test vehicle specifications, the assembly plan and the compliance matrix to show the test vehicle respects all the requirements previously frozen.	T0 + 6 months
Task 6	Test vehicle assembling The partner shall assembly the test vehicle and update the compliance matrix. The partner shall stand a face to face meeting to present the test vehicle.	T0 + 10 months
Task 7	Pipe and flat plate prototyping *Safran Aircraft Engines* shall design a LPTACC pipe and a flat plate and the partner shall manufacture it. A dimensional inspection report shall be written.	T0 + 8 months
Task 8	Test vehicle commissioning The partner shall conduct a first run with the LPTACC pipe prototype in order to debug and check the test vehicle. Data post processing shall also be frozen after this task.	T0 + 11 months

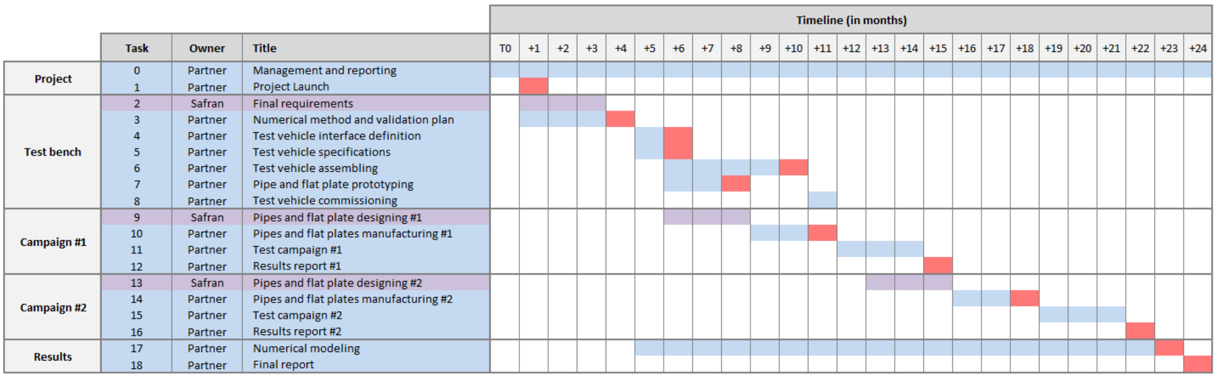
Tasks		
Ref. No.	***Title – Description***	***Due Date***
Task 9	Pipes and flat plates designing #1 *Safran Aircraft Engines* shall provide the blueprints of the LPTACC pipes and the flat plates designed for the test campaign #1. There will be no change in the number of configurations, the number of impact distance, the number of pressures, the number of temperature tested and the number of flat plate tested in comparison with this document.	T0 + 8 months
Task 10	Pipes and flat plates manufacturing #1 The partner shall manufacture the LPTACC pipes and the flat plates designed for the test campaign #1. A dimensional inspection report shall be written.	T0 + 11 months
Task 11	Test campaign #1 The partner shall conduct the test campaign #1 with the first set #1 of LPTACC pipes and flat plate previously manufactured. The partner shall write a weekly report to give the key events.	T0 + 14 months
Task 12	Results report #1 The partner shall provide the full set of data for the test campaign #1 after post processing.	T0 + 15 months
Task 13	Pipes and flat plates designing #2 *Safran Aircraft Engines* shall provide the blueprints of the LPTACC pipes and the flat plates designed for the test campaign #2. There will be no change in the number of configurations, the number of impact distance, the number of pressures, the number of temperature tested and the number of flat plate tested in comparison with this document.	T0 + 15 months
Task 14	Pipes and flat plates manufacturing #2 The partner shall manufacture the LPTACC pipes and the flat plates designed for the test campaign #2. A dimensional inspection report shall be written.	T0 + 18 months
Task 15	Test campaign #2 The partner shall conduct the test campaign #2 with the second set #2 of LPTACC pipes and flat plate previously manufactured. The partner shall write a weekly report to give the key events.	T0 + 21 months
Task 16	Results report #2 The partner shall provide the full set of data for the test campaign #2 after post processing.	T0 + 22 months
Task 17	Numerical modeling The partner shall develop the numerical model to predict the heat transfer coefficient : • 0D correlation • CFD method A face to face meeting shall be stood in *Safran Aircraft Engines* offices in order to present the results to the method and thermal experts.	T0 + 23 months

Tasks		
Ref. No.	***Title – Description***	***Due Date***
Task 18	<u>Final report</u> The partner shall write the final report and present a sum up during a face to face meeting in *Safran Aircraft Engines* offices with all the team project. This report shall include the technical work but also a feedback on the project (evolution and efficiency of the risk analysis, evolutions of the work plan, feedback on the organization).	T0 + 24 months

3. Major Deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	***Title – Description***	***Type****	***Due Date***
D1	Scoping report (see task 1)	R	T0 + 1 month
D2	Numerical method and validation plan (see task 3)	R	T0 + 4 months
D3	Test vehicle interface definition (see task 4)	R	T0 + 6 months
D4	Test vehicle specifications (see task 5)	R	T0 + 6 months
D5	Test vehicle assembling (see task 6)	R	T0 + 10 months
D6	Pipes and flat plate prototyping (see task 7)	R	T0 + 8 months
D7	Pipes and flat plate manufacturing #1 (see task 10)	R	T0 + 11 months
D8	Results report #1 (see task 12)	D + R	T0 + 15 months
D9	Pipes and flat plate manufacturing #2 (see task 14)	R	T0 + 18 months
D10	Results report #2 (see task 16)	D + R	T0 + 22 months
D11	Numerical modeling (see task 17)	D + R	T0 + 23 months
D12	Final report (see task 18)	R	T0 + 24 months

**Types: R=Report, D-Data, HW=Hardware*



4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Proven experience in heat transfer coefficient measurement.
- Proven experience in CFD with thermal coupling.
- Proven capacity in test vehicle assembling.
- Proven capacity of result analysis with physical and statistic approach.
- Proven capacity of the following measurement :
  - Total and static air pressure
  - Total air temperature
  - Metal temperature
  - Airflow
- English language is mandatory.

5. Abbreviations

LPT	Low Pressure Turbine
LPTACC	Low Pressure Turbine Active Clearance Control
CFD	Computation Fluid Dynamic
LPT	Low Pressure Turbine

VI. JTI-CS2-2018-CfP08-ENG-01-37: Aerodynamic upgrade of Surface Air Cooled Oil Cooler (SACOC)

Type of action (RIA/IA/CSA)	RIA		
Programme Area	ENG		
(CS2 JTP 2015) WP Ref.	WP2		
Indicative Funding Topic Value (in k€)	650		
Topic Leader	Safran	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	24	**Indicative Start Date (at the earliest)**[98]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-ENG-01-37	**Aerodynamic upgrade of Surface Air Cooled Oil Cooler (SACOC)**
Short description	
The next generation of Geared Turbofan, like the UHBR concept, requires larger heat exchangers to dissipate the heat generated in operation. The main aims of this project are: • to develop a predictive numerical methodology to assess the performance of any new air heat exchanger concept. The methodology will be validated against an experimental database to be acquired in this project. • to evaluate numerically but also experimentally new concepts like SACOC without fins to improve the current SACOC technology, resulting from the better understanding of physical phenomena.	

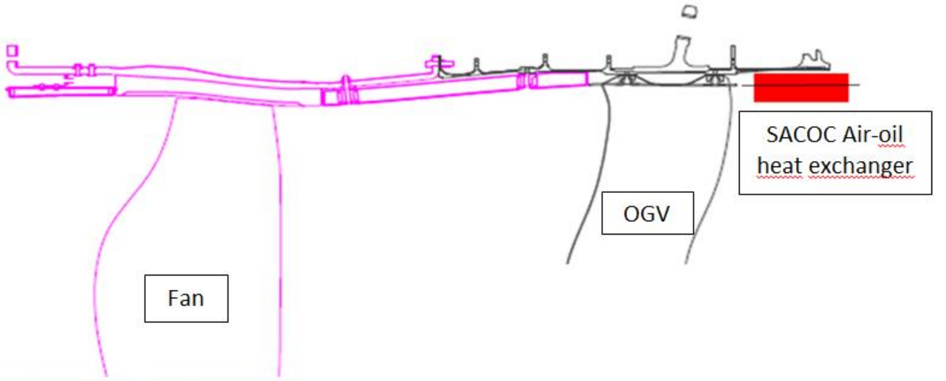
Links to the Clean Sky 2 Programme High-level Objectives[99]				
This topic is located in the demonstration area:	Ultra-high Bypass and High Propulsive Efficiency Geared Turbofans			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Short/Medium-range, Ultra-advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

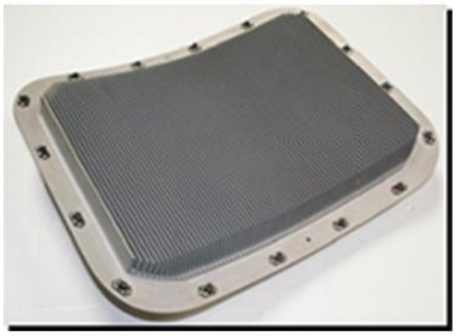
[98] The start date corresponds to actual start date with all legal documents in place.

[99] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

The next generation of Geared Turbofan, like the UHBR concept, requires larger heat exchangers to dissipate the heat generated in operation. The installation of the exchanger in the fan negatively affect the performance, volume and mass of the engine and actions should be taken to reduce their impact on the fuel burn.



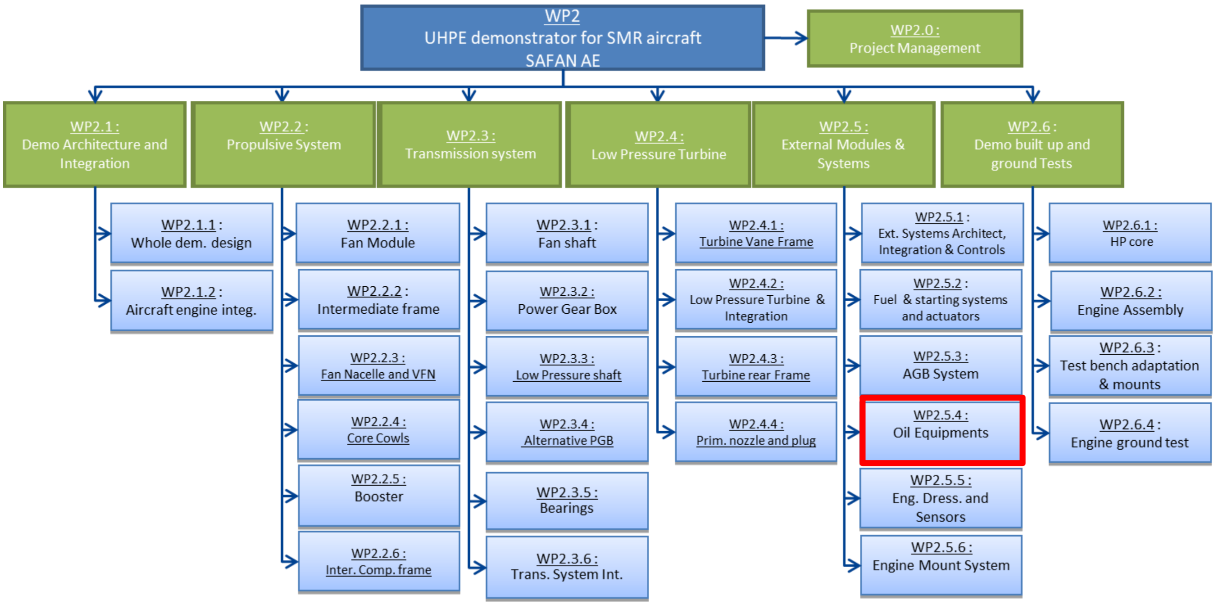


Typical SACOC heat exchanger with fins

Our proposal is:

- to develop a predictive methodology on the SACOC (Surface Air Cooled Oil Cooler) air heat exchanger and its impact on the aerodynamics (including acoustics) of the secondary flow. An experimental database will be acquired to validate the methodology.
- to evaluate new concepts without fins, such as the Vortex Generator to improve the current SACOC technology, resulting from the better understanding of physical phenomena. This evaluation will be carried out by calculation according to the previously validated methodology but also partially by testing. Special attention will be paid to the trade-off between thermal benefits and head losses in the secondary flow introduced by the new concepts.

This study is related to the Work Package WP2.5.4 :



2. Scope of work

Tasks		
Ref. No.	***Title – Description***	***Due Date***
Task 0	Aerodynamic SACOC upgrade – *Management and reporting* • Quarterly progress written reports shall be provided by the partner, referring to all agreed workpackages and including technical achievements, updated workplan, inputs and outputs status, financial status, update of the risk analysis and mitigation plan. This report shall be presented during a face to face meeting which will take place alternatively in the partner offices and in *Safran Aircraft Engines* offices. • Monthly coordination meetings shall be conducted via telecom. • The partner shall support reporting and agreed review meetings with reasonable visibility on its activities and an adequate level of information. The partner shall warn *Safran Aircraft Engines* if any event has a significant impact on the workplan.	All along the project

Tasks		
Ref. No.	***Title – Description***	***Due Date***
Task 1	Project launch The partner and *Safran Aircraft Engines* shall perform a face to face meeting in *Safran Aircraft Engines* offices. The partner shall present the risk analysis and the mitigation plan based on the learning of this present document. The partner shall also present the technical means and the relevant projects it has achieved. *Safran Aircraft Engines* shall present the background of the project, the deliverables and the workplan target. This meeting shall allow to meet the team project on both sides, to define the key roles, to plan the quarterly report meetings and the monthly coordination meetings.	T0 +1 month
Task 2	Project requirement *Safran Aircraft Engines* shall present the project's requirements for both numerical methods and test.	T0 + 2 months
Task 3	Numerical method and validation plan The partner shall present the state of the art of the relevant CFD methods developed to model air heat exchange pressure losses, and acoustics in the secondary flow. The oil won't be modeled. The aim is to freeze the numerical method and the validation plan. A special attention will be paid to the validity domain.	T0 + 3 months
Task 4	Strategy to test key parameters and to model by numerical approach The partner shall present the strategy of testing in accordance with his strategy for numerical method. Four concepts or devices to improve the heat exchanger efficiency shall be proposed for testing. The choices should be approved by SAE and should include a classical fins based exchanger and new technologies like Vortex Generator implantation or jet flow in the flow path instead of fins or to improve fins efficiency. Based on calculation, the most promising solution will be chosen for the test. A specific configuration compliant with current acoustic requirements will be studied and instrumented	T0 + 4 months
Task 5	Test vehicle specifications and instrumentation The partner shall provide the final test vehicle specifications, the assembly plan and the compliance matrix to show the test vehicle respects all the requirements previously frozen. Instrumentation will be specific for thermal and aerodynamical test. The instrumentation will be capable of fine local and average measurement on pressure loss and heat flux. Specific tests allowing a detailed qualification and/or quantification of velocity fields (average values and turbulent values) to be compared to numerical results shall be proposed in addition to conventional tests (ex : PIV, LDA, other…) and will be considered as differentiating in the final technical proposal.	T0 + 5 months

Tasks		
Ref. No.	***Title – Description***	***Due Date***
Task 6	Test vehicle assembling The partner shall assemble the test vehicle and update the compliance matrix. The partner shall stand a face to face meeting to present the test vehicle.	T0 + 10 months
Task 7	Test vehicle commissioning The partner shall conduct a first run with the reference heat exchanger prototype in order to debug and check the test vehicle. Data post processing shall also be frozen after this task.	T0 + 11 months
Task 8	Test campaign #1 The partner shall conduct the test campaign #1 with the reference heat exchanger. The partner shall write a weekly report to give the key events. Each test campaign will include some variations of boundary conditions like massflow, pressure, heat flux, and other characteristics specific to each configuration tested. These variations will be discussed at task 5. Test will be steady sate and not transient. Each test will have sufficient number of test points to verify repeatability of test and to later analyse the test results and compare with numerical results	T0 + 14 months
Task 9	Results report #1 The partner shall provide the full set of data for the test campaign #1 after post processing. Test results will be analyzed and compared with numerical results, bibliography and previous test .	T0 + 15 months
Task 10	Test campaign #2 The partner shall conduct the test campaign #2 with the new concept of heat exchanger. The partner shall write a weekly report to give the key events. Each test campaign will include some variations of boundary conditions like massflow, pressure, heat flux, and other characteristics specific to each configuration tested. This variations will be discussed at task 5 . Test will be steady sate and not transient. Each test will have sufficient number of test points to verify repeatability of test and to later analyse the test results and compare with numerical results	T0 + 16 months
Task 11	Results report #2 The partner shall provide the full set of data for the test campaign #2 after post processing and compare with numerical results. Test results will be analyzed and compared with numerical results, bibliography and previous test.	T0 + 17 months
Task 12	Test campaign #3 The partner shall conduct the test campaign #3 with a second concept of heat exchanger. The partner shall write a weekly report to give the key events. Each test campaign will include some variations of boundary conditions like massflow, pressure, heat flux, and other characteristics specific to each configuration tested. This variations will be discussed at task 5. Test will be steady sate and not transient. Each test will have sufficient number of test points to verify repeatability of test and to later analyse the test results and compare with numerical results	T0 + 18 months

Tasks		
Ref. No.	***Title – Description***	***Due Date***
Task 13	Results report #3 The partner shall provide the full set of data for the test campaign #3 after post processing and compare with numerical results. Test results will be analyzed and compared with numerical results, bibliography and previous tests.	T0 + 19 months
Task 14	Test campaign #4 The partner shall conduct the test campaign #3 with the third concept of heat exchanger. The partner shall write a weekly report to give the key events. Each test campaign will include some variations of boundary conditions like massflow, pressure, heat flux, and other characteristics specific to each configuration tested. This variations will be discussed at task 5 . Test will be steady sate and not transient. Each test will have sufficient number of test points to verify repeatability of test and to later analyse the test results and compare with numerical results.	T0 + 20 months
Task 15	Results report #4 The partner shall provide the full set of data for the test campaign #4 after post processing and compare with numerical results. Test results will be analyzed and compared with numerical results, bibliography and previous test.	T0 + 21 months
Task 16	Final report The partner shall write the final report and present a sum up during a face to face meeting in *Safran Aircraft Engines* offices with all the team project. This report shall include the technical work but also a feedback on the project (evolution and efficiency of the risk analysis, evolutions of the workplan, feedback on the organization). Test results will be analyzed and compared with numerical results, bibliography and previous test.	T0 + 24 months

3. Major Deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1	Scoping report (see task 1)	R	T0 + 1 month
D2	Numerical method and validation plan (see task 3)	R	T0 + 3 months
D3	Strategy of influences to test and to model by numerical method (see task 4)	R	T0 + 4 months
D4	Test vehicle specifications (see task 5)	R	T0 + 5 months
D5	Test vehicle assembling (see task 6) drawings, CAD, instrumentation plan, design documents	R	T0 + 10 months
D6	Test vehicle commissioning (see task 7) parts characteristics measured, all recorded data	D+R	T0 + 11 months
D7	Results report #1 (see task 9) analysis and all recorded data	D + R	T0 + 15 months
D8	Results report #2 (see task 11) all recorded data	D + R	T0 + 17 months
D9	Results report #3 (see task 13) all recorded data	D + R	T0 + 19 months

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D10	Results report #4 (see task 15) all recorded data	D + R	T0 + 21 months
D11	Final report (cf task 16)	D + R	T0 + 24 months

**Types: R=Report, D-Data, HW=Hardware*

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- A test bench with airflow at low pressure (2 bar maxi), ambient temperature and massflow of 10 to 50 kg/s (to be confirmed after discussion between partner and Safran Aircraft Engines) and capacity to have thermal heating of 150°C maximum
- Ability to propose adequate thermal, aerodynamical and acoustic instrumentations for the requested tests, and implement them in dedicated experimental means
- Ability to propose and apprehend a multiphysic activities package that demonstrates a technical expertise considering CFD aspects and expertise (conventional Navier Stockes CFD steady & unsteady or advanced methodologies such as LBM CFD)
- Ability to lead and perform the necessary requested tests to qualify such complex flows(including advanced techniques or instrumentation such as PIV or LDA) considering thermal, aerodynamics ans acoustics domains. An effective partnership with other companies and/or laboratories can be proposed to achieve this capability

	Task	Owner	Title	Timeline (T0, +1 … +24)
Project	0	Partner	Management and reporting	
	1	Partner/Safran	Project launch	
	2	Safran	Project requirements	
	3	Partner	Numerical method and validation plan	
	4	Partner/Safran	Strategy to test key parameters and to model by numerical approach	
Test bench	5	Partner	Test vehicle specifications	
	6	Partner	Test vehicle assembling	
	7	Partner	Test vehicle commissioning	
Campaign #1	8	Partner	Test campaign #1	
	9	Partner	Validation od numerical methodology & results	
Campaign #2	10	Partner	Test campaign #2. Concept 1	
	11	Partner	Numerical assessment & results	
Campaign #3	12	Partner	Test campaign #3. Concept 2	
	13	Partner	Numerical assessment & results	
Campaign #4	14	Partner	Test campaign #4. Concept 3	
	15	Partner	Numerical assessment & results	
Final report	16	Partner	Final report	

5. Abbreviations

SACOC	Surface Air Cooled Oil Cooler
SAE	Safran Aircraft Engines
UHBR	Ultra High Bypass Ratio turbofan
CFD	Computation Fluid Dynamic

VII. JTI-CS2-2018-CfP08-ENG-01-38: Low NOx / Low soot injection system design for spinning combustion technology

Type of action (RIA/IA/CSA)	RIA		
Programme Area	ENG		
(CS2 JTP 2015) WP Ref.	WP 3		
Indicative Funding Topic Value (in k€)	600		
Topic Leader	Safran	**Type of Agreement**	IA
Duration of the action (in Months)	36	**Indicative Start Date (at the earliest)**[100]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-ENG-01-38	**Low NOx / Low soot injection system design for spinning combustion technology**
Short description	
Safran Helicopter Engines has recently developed and patented a new spinning combustion technology (SCT). This technology improves ignition and blow-off capabilities and enables combustor weight reduction, without compromising turbine nor combustor lifetime. This project is dedicated to further improvement of SCT. The partner will design, manufacture and test a more advanced low NOx and low soot/particles injection systems, which will aim at improving next generation of gas turbine engines.	

Links to the Clean Sky 2 Programme High-level Objectives[101]				
This topic is located in the demonstration area:	Small Aircraft, Regional and Business Aviation Turboprop			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	19-pax Commuter			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☐	☒	☐	☐	☒

[100] The start date corresponds to actual start date with all legal documents in place.
[101] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

WP3 targets the acquisition of technologies for the high performance short range gas turbine engines market (WP3 of Engine ITD). One key technology enabler on the core engine is light-weight and low emissions combustion system. Safran Helicopter Engines has recently developed and patented a spinning combustion technology (SCT) for its next generation engines. Such a technology has already been embedded in the Arrano engine, which exhibits CO2 reduction about 15% compared to the previous engine generation. Spinning combustion allows improved ignition and blow-off capabilities as well as combustor weight reduction, without compromising turbine and combustor lifetime. Today pollutant emissions however remain in the same range as previous Safran technologies, notably because development efforts were not focused on that topic in the preceding development projects. The proposed project therefore focuses on the development of low NOx and low soot/particles spinning combustion injection systems to be exploited on future turboshaft/turbo-propeller engines for greener aero-propulsion.

The tasks of the partners will be to propose and test development paths for low-emission injection systems dedicated to spinning combustion. The corresponding TLR target is 4. The tests will cover a large range of operating conditions, from idling to take-off power. The project will also quantify the impact of the proposed injection systems on several performance of the combustor, namely the outlet temperature profile, liner temperature field and lean blow-off limits. All the results should be transferred in CFD tools to be provided to Safran at the end of the project. Regarding CFD a LES framework will be preferred since this technique is the one deployed in the Safran Helicopter Engines combustor design office. This transfer will allow Safran to further improve and upscale or downscale the low-emission injection system developed within the project and finally to extend the low-emission spinning combustion technology to a wide range of Safran engines.

Figure 2 shows the work breakdown structure of WP3 demonstration platform.

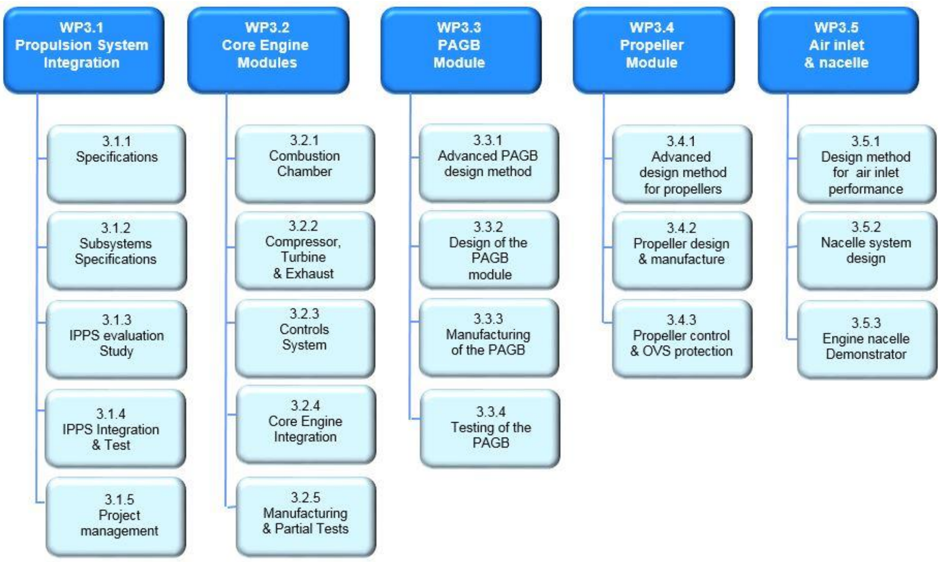


Figure 17: WP3 Work breakdown structure

2. Scope of work

The purpose of the study is threefold :

1. to propose development paths for low-emissions (NOx and soots) spinning combustion injection systems,
2. to characterize experimentaly at least two SCT injector configurations,
3. to transfer the acquired knowledge in CFD tools (LES) to be delivered to Safran at the end of the project for in-house further development of the spinning combustion technology.

Five activity streams are identified, which are listed hereafter and schematically presented in Figure 2.

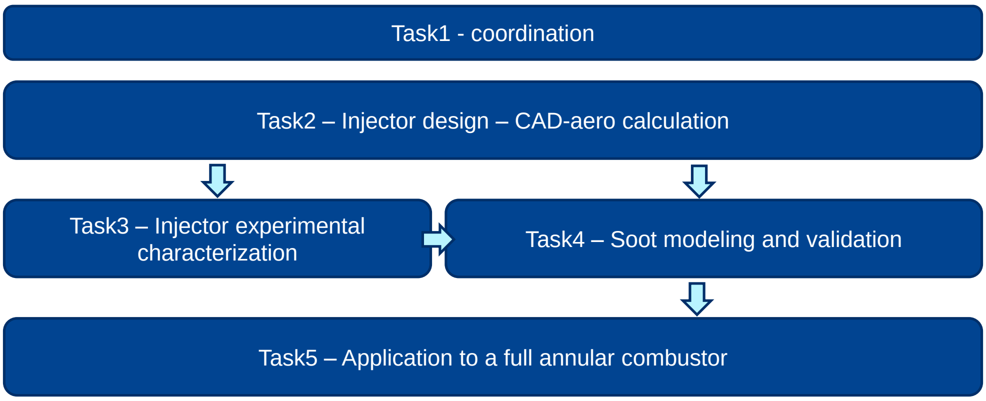


Figure 2: Project breakdown structure

Task 1: Management and coordination

Organization:

- The partners shall nominate a team dedicated to the project and should inform the consortium program manager about the name (s) of this key staff

Time schedule and work-package description:

- The partners will work to the agreed time-schedule and work-package description
- Both the time-schedule and the work-package description laid out in this call shall be further detailed and agreed at the beginning of the project

Progress reporting and reviews:

- Progress reports (i.e. deliverables) will be written over the duration of the program
- The full experimental database will be made available to the topic manager before the end of the program
- For all work packages, technical achievements, timescales, potential risks and proposal for risk mitigation will be summarized
- Regular coordination meetings shall be conducted via teleconference or webex where appropriate
- The partners shall support reporting and review meetings with reasonable visibility on the activities and an adequate level of information
- The partners shall support, as appropriate, face-to-face review meetings to discuss the progress

Task 2 : Injector design, CAD and manufacturing

This task will be dedicated to low-NOx, low-Smoke injector design and manufacturing for spinning combustion. Design activities will concern CAD, meshing and non-reactive flow simulations to respect swirl and effective cross section targets from Safran Helicopter Engines. The fuel path integration within injectors should also be taken intake account in the design process. At least two variants of the injector, agreed by Safran Helicopter Engines, should finally be proposed for tests in Task 3. These variants should be manufactured and provided for experimental characterization. CAD, mesh and simulation results should be provided to Safran Helicopter Engines in standard formats readable at Safran (typically .iges, .msh, .h5). A detailed presentation of the spinning-combustion concept and injector design and integration constraints will be performed by Safran Helicopter Engines at the kick-off meeting. At this stage, 3-dimensional combustion calculations based on a validated simulation framework (with references including world-class peer-reviewed publications - PRP) will be conducted to assess the stable operation of the injectors priori to their installation on the test bed (Task3).

Task 3 : Experimental investigation of SCT injectors with combustion

This task will be dedicated to the experimental investigation of low-NOx and smoke injectors at relevant operating conditions using kerosene. In this task, it will be possible to characterize only isolated injectors instead of a full annular configuration, with the aim to analyse in details their operation. The detailed test campaign will be discussed with Safran Helicopter Engine at the kick-off meeting, however it should contain at least 4 operating conditions in terms of pressure, temperature and air-mass flow rate, covering the whole operating range of the combustor (see table 1 for typical conditions to be explored). For each condition, a variation of fuel-mass flow rate should be performed and recorded from stable operation to lean-blow-off to extract the injector stability map. In order to cover a relevant operating domain, the general capabilities of the test bed should respect criteria given in Table 2.

Advanced diagnostics are expected at these different operating conditions for detailed analysis of combustion dynamics and pollutant formation processes, including:

- In-situ non intrusive measurement using optical diagnostics
    - PIV (Particle Image Velocimetry)
    - PLIF-kerosene (Planar Laser Induced Fluoresence, notably for aromatics considered as soot precursors), quantitative data are expected
    - PLIF-OH (for OH radical detection to track reactive zones)
    - PLIF-NO (for quantitative NO concentration measurements)
    - LII for soot (Laser Induced Incandescence)
    - PDPA characterization of the spray will be appreciated (Phase Doppler Particle Analysis)
    - Combined PLIF-OH and PLIF-Kerosene will also be appreciated to understand the correlation between fuel presence and reactivity
- Global measurements at the combustor exit
    - Gazeous concentration indices (mg/g kerosene) of CO and NO
    - Soot (smoke number or smoke index)
    - Particulate Matter distribution measurements would also be appreciated

This experimental campaign should bring the proposed injector design to TRL=4. The generated data will also be exploited for CFD code validation (Task 4). All generated data (raw and post-processed) will be furnished at Safran Helicopter Engines, in a format to be defined during the kick-off meeting.

Condition 1	Condition 2	Condition 3	Condition 4
Pressure 4 bars	Pressure 8 bars	Pressure 14 bars	Pressure 18 bars
Temperature 550K	Temperature 600K	Temperature 650K	Temperature 700K
Air mass flow rate 50g/s	Air mass flow rate 100g/s	Air mass flow rate 150g/s	Air mass flow rate 175g/s

Table 1 – Typical operating conditions to be tested

Pressure	Temperature	Air mass flow rate	Fuel mass flow rate
1-20 bars	300-900K	0-175g/s	0-10g/s

Table 2 – Required capabilities of the test bed

Task 4 : Numerical tool development and validation

The partner will first propose a numerical model for NOx and soot formation and oxidation to be implemented in the Safran Helicopter Engines CFD code. Due to strong unsteadiness and intermittency of turbulent combustion processes in helicopter combustors, the proposed model will have to be developed within a Large Eddy Simulation framework and compatible with the Thickened Flame Model (TF-LES) exploited in Safran design offices.

The model will then be validated and calibrated against experimental data acquired in Task 3. The different operating conditions will have to be simulated with a unique set of model parameters. This simulation work includes : (i) mesh generation, (ii) simulation set-up, (iii) LES reactive flow simulations, (iv) post-processing and analysis. Post-processing will concern comparison to in-situ experimental fields of velocity, species concentrations (Fuel, OH, NO, soot) and spray characteristics, but also global pollutant concentrations (soot, NOx, CO) at the burner exit.

Simulation set-up, results and tools (soot and NOx model subroutines, pre and post-processing) will have to be furnished to Safran and support will be provided to the Safran Helciopter Engines CFD team within the projet for integration of the routines in Safran CFD Large Eddy Simulation code. The objective of this subtask will be to transfer simulation skills and tools to the Safran design office for further development of SCT combustors. CAD, mesh and simulation results should be provided to Safran Helicopter Engines in standard formats readable at Safran (typically .iges, .msh, .h5).

Task 5 : Demonstration of CFD tools capabilities and new injector performances on a full-scale combustor

In this task, the knowledge acquired in tasks 2 to 4 will finally be exploited on a full Safran spinning combustion configuration. This configuration is an annular combustor, in which the low-emission injectors designed in the project will be integrated. For this purpose, the best candidate of Task 3 will be selected. Modification of the combustor drilling map may be proposed by the partner, in agreement with the Safran design office, to respect the combustor pressure drop target and air-flow distribution in the combustor, as well as correct combustor exit temperature profiles.

All technical details will have to be accounted for in the LES CFD simulations (effusion cooling, axial diffusor of the compressor, bleeding, primary and dilution holes) for a relevant description of combustion processes including pollutant formation in the primary zone and oxidation up to the combustor exit. Specifically, for effusion cooling, an approach accounting for the detailed drilling map of the combustor will be used to carefully describe near wall interactions between the flame and air-cooling films. References on the CFD effusion cooling topic should be given in the proposal.

Several types of simulations will be conducted to assess the performances of the new injector, in comparison with a reference configuration available at Safran Helicopter Engines and equipped with standard spinning combustion injectors (not optimized for NOx and soot). At least these two configurations will have to be computed including :

- Several steady-state conditions describing the combustor operating range from idling to take-off power. A focus on NOx and soot will be performed, exploiting the numerical models developed and validated in Task 4.
- Lean-blow-off simulations will also be performed to assess operability capabilities
- Heat transfer and thermal state of the combustor walls will also be investigated to verify that

Safran criteria for assessing the combustor life-time are still respected

- Analysis of the radial and overall temperature profile will also be performed to ensure that the turbine life-time target will be respected

This task will allow to prove, from a numerical point of view, a TRL=5 for the injector technology integrated in a full annular combustor, opening the way for full annular tests at Safran Helicopter Engines after the project. CAD, mesh and simulation results should be provided to Safran Helicopter Engines in standard formats readable at Safran (typically .iges, .msh, .h5).

Tasks		
Ref. No.	***Title - Description***	***Due Date***
Task 1	**Management** • Quarterly progress reports in writing shall be provided by the partner, referring to all agreed work packages, technical achievement, time schedule, potential risks and proposal for risk mitigation. • Monthly coordination meetings shall be conducted via teleconference. • The partner shall support reporting and agreed review meetings with reasonable visibility on its activities and an adequate level of information. • The review meetings shall be held at the topic manager's premises.	T0 + 36 months
Task 2	**Task 2 : Injector design, CAD and manufacturing** • Injectors design (CAD) and characterization with CFD • Injectors manufacturing	T0 + 12 months
Task 3	**Experimental investigation of SCT injectors with combustion** • Injectors detailed experimental characterization (in-situ optical diagnostics and combustor exit measurements) • Best injector candidate selection (Low NOx and soot)	T0 + 24 months
Task 4	**Numerical tool development and validation** • LES Numerical models for soot and NOx validated on the experimental data from Task 3 • Support to implementation in Safran CFD code (model, pre-post-processing tools)	T0 + 30 months
Task 5	**Demonstration of CFD tools capabilities and new injector performances on a full-scale combustor** • Simulations of full annular configurations (reference and optimized for NOx and soot)	T0 + 36 months

3. Major Deliverables/ Milestones and schedule (estimate)

** Type: R: Report, RM: Review Meeting, D: Delivery of hardware/software*

Deliverables			
Ref. No.	***Title - Description***	***Type (*)***	***Due Date***
D1	Injector design (CAD), simulation data (files)	D	T0 + 12 month
D2	Manufactured SCT injectors	D	T0 + 10 month
D3	Report on injector design and simulation	R	T0 + 12 months

Deliverables			
Ref. No.	***Title - Description***	***Type (*)***	***Due Date***
D4	Experimental database (raw and post-processed files)	D	T0 + 24 months
D5	Technical report on experiments (techniques, results, analysis)	R	T0 + 24 months
D6	Model subroutines for NOx and Soot formation (LES), pre and post-processing tools	D	T0 + 30 months
D7	Simulation files (inputs, outputs, videos)	D	T0 + 30 months
D8	Report on the CFD simulations for isolated injectors, including parameterization	R	T0 + 30 months
D9	Simulation files (inputs, outputs, videos)	D	T0 + 36 months
D10	Report on the CFD simulations for full annular configuration	R	T0 + 36 months

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type (*)***	***Due Date***
MS 0	Kick-off meeting : validation of CAD and simulation formats, definition of swirl and effective area targets, fuel path integration constraints, injector integration constraints on the test bed	RM	T0
MS 1	1st Progress Review: validation of designs to be computed	RM	T0 + 3 months
MS 2	2nd Progress Review: validation of simulation results and analysis	RM	T0 + 6 months
MS 3	3rd Progress Review: experimental campaign content	RM	T0 + 9 months
MS 4	4th Progress Review : validation of the manufactured injectors before tests	RM	T0 + 10 months
MS 5	5th Progress Review : Numerical strategy review – choice of the modelling approach	RM	T0 + 12 months
MS 6	6th Progress Review: injectors stability map characterization	RM	T0 + 14 months
MS 7	7th Progress Review: experimental results analysis	RM	T0 + 24 months
MS 8	8th Progress Review : CAD modification of the full annular combustor for integration of the best injector candidate (drilling map modification)	RM	T0 + 26 months
MS 9	9th Progress Review : model validation against experiments	RM	T0 + 30 months
MS 10	10th Progress Review : review of simulation results on the reference and optimized annular configuration	RM	T0 + 36 months

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- From a general point of view, the applicant should be specialized in advanced optical diagnostics development and exploitation in relevant conditions. An expertise in CFD code development and exploitation and in particular Large Eddy Simulation models will also be required.
- A strong experimental expertise in combustion for aero-engines and optical diagnostics is

mandatory. The applicant should in particular be familiar with high time resolution measurements, high speed video recording, and proven capabilities (publications…) for quantitative laser measurements including PIV, Planar LIF for kerosene, OH, NO.

- It is mandatory to have an existing and validated test bed over the following operating range
    - 1-20 bars,
    - 300-900K,
    - 0-10 g/s fuel mass flow rate
    - 0-175 g/s air mass flow rate
- Strong expertise in CFD code and physical model (including NOx and soot) development for Large Eddy Simulation is mandatory. High-level publications in this field is required to guaranty the quality of CFD studies. High Performance Computing skills will be appreciated to assess the numerical efficiency of the proposed models to be transferred to Safran. Previous cooperation with the aerospace industry on Large Eddy Simulation of real combustors will be required as a guaranty of knowledge of model integration constraints (compatibility with two-phase flows and inlet/outlet/wall/effusion cooling boundary conditions). Publication in this field in collaboration with industrials will be appreciated. Strong knowledge of the AVBP code, exploited at Safran design office, will be highly appreciated, simplifying a lot the model transfer within the project.
- Experience in complex geometries design (CAD) for the aerospace industry will be appreciated.
- Capability to perform simulations on several HPC platforms for guarantying CPU availability within the project is required.
- Capability to repair in a short timeframe any damage occurring to the test equipment during the test campaign.
- Capability to machine or sub-contract the manufacturing of the injectors.
- If several partners are implicated, previous collaboration within the consortium will be appreciated.

5. Abbreviations

ITD	Integrated Technology Demonstrator
LES	Large Eddy Simulation
CFD	Computational Fluid Dynamics
PIV	Particle Image Velocimetry
LIF	Laser Induced Fluorescence
PRP	Peer-reviewed Publication (Proceedings of the combustion institute, Combustion and Flame, Flow Turbulence and Combustion)

VIII. JTI-CS2-2018-CfP08-ENG-02-09: Development and verification of microstructure, residual stress and deformation simulation capability for additive free-form direct deposition using multiple superalloys

Type of action (RIA/IA/CSA)	RIA		
Programme Area	ENG		
(CS2 JTP 2015) WP Ref.	WP 4		
Indicative Funding Topic Value (in k€)	800		
Topic Leader	GKN Aerospace	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	30	**Indicative Start Date (at the earliest)**[102]	Q1 2019

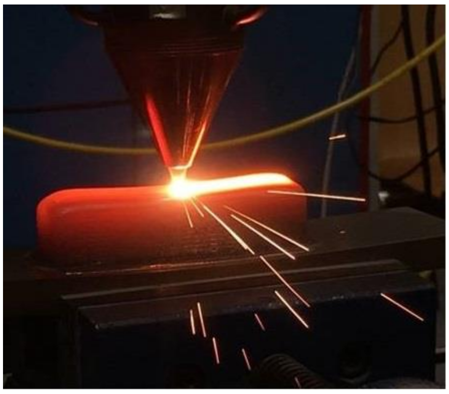
Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-ENG-02-09	**Development and verification of microstructure, residual stress and deformation simulation capability for additive free-form direct deposition using multiple superalloys**
Short description	
Development and verification of microstructure, residual stress and deformation simulation capability for additive free-form powder deposition using multiple superalloys. The methods should be capable of handling typical design features for engine structures with a turn-around time for simulation set-up, execution and evaluation within a working week. Validation experiments using the laser blown powder process are to be performed by the CfP consortium on design features.	

Links to the Clean Sky 2 Programme High-level Objectives[103]	
This topic is located in the demonstration area:	Ultra-high Bypass and High Propulsive Efficiency Geared Turbofans
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Short/Medium-range, Ultra-advanced Short/Medium-range
With expected impacts related to the Programme high-level objectives:	

Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

[102] The start date corresponds to actual start date with all legal documents in place.
[103] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

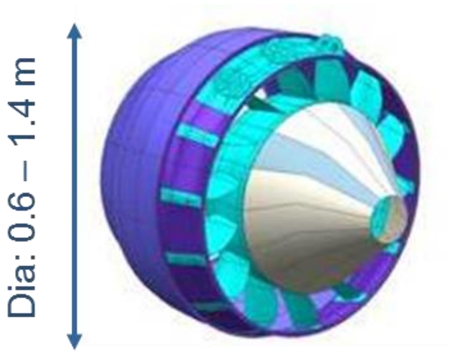
1. Background



Commercial aircraft engines are increasingly becoming more efficient by the development of lower specific thrust fans and core engines with higher specific power. As a consequence, engine pressures and turbine temperatures increase making the design and manufacture of engine hot section components more difficult. Also, some new super alloys are only processable in powder form as they can not be cast or forged to aerospace quality. Typically, more expensive materials that are hard to process will need to be used with a higher cost as a likely result. To mitigate the risk for higher costs and to enable the use of highly capable powder alloys where it is needed the Laser Blown Powder direct Deposition (LBPD) process is being developed by the Topic Manager, see photo to the right. The process will enable build up of bi-alloy components to enable local use of the capable on components that are in conventional cast, forged or sheet material forms.

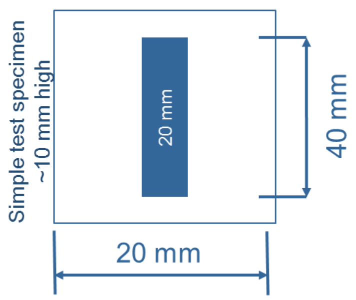
A number of requirements needs to be fullfilled to enable a generic applicability of the process to typical engine components:

1. Shape distortions to the component
2. Residual stresses and their potential effect on component function and life
3. Microstructure limits (Primarily grain size and anisotropy – phase transitions as post processing)
4. Defect control



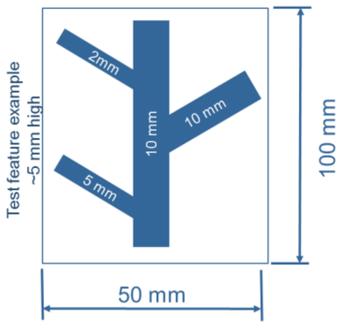
A suite of simulation methods are being developed to support LBPD process development and the design of components using LBPD and this topic adresses primarily development and validation models for bullets 2 and 3 above which subsequently can be used to predict 1 and 4. An additional requirement for the simulation approach is that the methods should be capable of handling LBPD features on complex engine structures (illustration to the right), with a turn-around time for simulation set-up, execution and evaluation within a working week. Typical features may include circumferential flanges, attachment bosses, built up weld interfaces, fastening features or local reinforcement. LBPD feature dimensions are typically in the centimeter range in - at least in two dimensions - and the thickness of a deposited layer is typically a fraction of a millimeter. Considering that the microstructures most often is characterized in micrometers we conclude that the problem stretches over four orders of magnitude in geometry scale and that the modelling approach must be at a level that enables reaching the turn-around target.

The simulation approach should be possible to adapt to a range of alloys however, this project will specifically look at validating Alloy 718 (which is the most common alloy for these parts today) and one additional high temperature alloy that will be defined by the Topic Manager at the start of the project.



The project is proposed to consist of 4 technical tasks. The first is a model definition, development and validation task that stretches throughout the project. The second task is experimental and focuses on building and examining simple geometry test specimens (example to the right) with a design of experiments approach to process parameters that will give a wide range of microstructure examples for two superalloys. The total number of specimen expected in this is 100. The results from cut-ups revealing the microstructure and deformed shape measurements with for instance GOM will be needed on the complete set of manufactured specimen. It is further anticipated that some specimen will be studied more closely and be instrumented for temperature and strain over time. Residual stress measurements X-ray investigations will be required for some of the specimen to complement the mechanical data and to understand the occurrence of cracks or defects in the material.

The third task will experimentally investigate effects of gradually changing process conditions due to geometry irregularities that give variations to the heat sink capability or temperature as the deposition head passes. Also, these specimens will be used for assessing component deformation on a more complex level than the simple specimen can do. A typical geometry for this feature is shown to the right. The number of features to be manufactured is estimated to 25. The feature shape distortion and residual stresses should be measured and cut-ups to investigate key locations in the article should be included in the test campaign. In a similar fashion to the test above some of the specimen will be subjected to more extensive examinations.



The fourth task will be the validation task where the created modelling capability is proven towards a specifically devised test article where several typical engine features are built on a non flat substrate with LBPD. The test geometry will be agreed with the topic manager and typically be 300x300mm in size with 4 – 5 features (using two alloys for deposition) protruding a maximum of 40 mm from the surface. The geometry will be discussed and agreed by the topic manager. Simulation prior to test will be used to guide the geometrical design built.

The models developed in the project are intended to be implemented in target software used in industry for thermomechanical simulation. The modelling requirements can be summarized as follows:

- Based on physics, calibrated to match test sample
- Microstructure evolution resulting from simulation as post-process during simulation
    - o Grain size and directional growth
    - o Phase Composition
    - o Defect probability (Pores, Lack of fusion)
- Mechanical properties, used during simulation affecting simulation result
    - o Stress-strain relations depending on temperature history based on microstructure evolution capturing the cyclic nature of weld passes

The research focus lies on modelling and validating microstructure and residual stress levels in a Finite Element software where the models to predict structural behaviour and temperature condition already are present. -Defect modelling and the ability to predict the transitional microstructure between the alloys in a bimetallic design feature is not seen as mandatory as an outcome, at the same time as it would add value if it is incorporated in the project without compromising the other results.

2. Scope of work

For all specimens and test articles the complete test includes materials acquisition, instrumentation building the test article with following heat treatment, recording, assembling and analyzing test data. The research consortium will perform the complete task, with support and guidance on parameter and geometry details from the topic manager. Powder materials and substrates used shall satisfy standards and specifications applicable to aerospace components as set forth by the Topic Manager.

Tasks		
Ref. No.	***Title - Description***	***Due Date***
1	**Management:** – The partner shall nominate a team dedicated to the project and should inform the Topic manager about the name/names of key staff.	M30

Tasks		
Ref. No.	***Title - Description***	***Due Date***
	– The time-schedule and the work package description laid out in this topic shall be further detailed as required and agreed during negotiation based on the Partner's proposal. – Monthly one-pager and quarterly progress reports in writing shall be provided by the partner, referring to all agreed work packages, technical achievement, time schedule, potential risks and proposal for risk mitigation. – Regular coordination meetings shall be installed (preferred as telecom). More comprehensive review meetings shall typically be held quarterly by WEBEX, at Topic Manager's premises or at the partner's premises.	
2	**Model development:** Based on the developers' experience and prior knowledge paired with a literature review, a model is laid out. The parameter space to be considered for test 1 is derived from this knowledge such that the DOEs are made suitable to the modelling task. Development of the models into suitable form for integration with software and formal description of the model is to be conducted. Subsequently, calibration of the model is done by using test 1 and later test 2 data to render a good representation of first tests The result is a model described in mathematical form as well as in a suitable program code (Fortran or language to be agreed with the Topic Manager) that is delivered to the topic manager along with the validation results.	M26
3	**Test 1: Single wall build** Two sub-DOEs are considered for material properties modelling and calibration where the first covers a wide parameter variation in order to explore the parameter range. This is guided by the microstructure model developed in task 2 and process understanding anticipating an outcome in different regimes of microstructure. The second variation set is focused on a more limited variation increasing the fidelity in the range of desirable microstructure, using the learnings of the first exploratory set. A total count in the order of 100 specimen is expected investigated with microscopy in relevant crossections. The DOE variations are to be defined in detail and agreed with the topic manager. The incoming material for substrates needs to be marked for traceability. The substrates' stress state need to be characterized before (for some) and after deposition. During the build, deformation needs to be measured using an in-situ measurement in at least 3 points. Some of the samples will be subject to further investigation using more detailed and in depth measurements. This will include measurements during build, as well as post build X-ray measurements. Heat treatment is to be done on a subset of the specimen after non-destructive testing has been performed in built state.	M16
4	**Test 2: Junction topology build** Using results from Test 1 and simulation results, a DOE is defined and agreed by the Topic Manager on a crossing junction pattern. A variation of conditions is sought that challenges the microstructure model at the	M24

Tasks		
Ref. No.	***Title - Description***	***Due Date***
	junction by causing local condition that differ from other regions and can affect microstructural quality, occurence of defects and cracks Results are fed back to the modeling task for possible adjustments of the models. The target geometry is fixed and will consist of a central straight wall joined with walls built at angles from the straight wall.	
5	**Validation shape build** The final task will demonstrate that a controlled material quality based on simulation using the developed model can be achieved. The model is frozen prior to the test based on tasks 2 – 4. Possible improvements are to be included in a revision to the code and transferred to the topic manager at the end of the project. Task activities include: A specifically devised test article is to be proposed and agreed where several typical engine features are built on a non-flat substrate with LBPD. Pre-test simulation to ensure that the test article is suitably designed A test set of 5 validation articles will be manufactured and characterized. Post test simulation as validation of the developed code. Compare, analyse and conclude on the validity of the developed software and possible ways to improve.	M30

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1	Detailed project plan	D	M 2
D2	Test 1 summary report. Describing geometries, tests and data content stored in formats agreed with topic manager. Specimens built will be delivered to the topic manager. Report summarizing the first computations made of specimen builds using the relevant measured data for comparison.	R, D, HW	M 15
D3	Model description and validation Report with mathematical description and physical reasoning. Model calibration logic including how measured data was used. The report includes references from literature review.	R, D	M 24
D4	Test 2 summary report. Describing junction wall geometries, tests and data content stored in formats agreed with topic manager. Specimens built will be delivered to the topic manager	R, D	M 24
D5	Test validation report. Describing geometries, tests and data content stored in formats agreed with topic manager. Simulation results on validation HW. Hardwares built to be delivered to the topic manager. Code transferring to the topic manager.	R, D, HW	M 30

Milestones (when appropriate)			
Ref. No.	***Title – Description***	***Type****	***Due Date***
M1	Test 1 readiness review – single wall build DOE 1	R	M 4
M2	Post test review – single wall build	R	M12
M3	Test 2 readiness review - complex junction	R	M 15
M4	Post test review – complex junction	R	M21
M5	Microstructure model completed		M24
M6	Test readiness review – task 3 complex shape	R	M24
M7	Post test review – task 3 complex shape	R	M27

A project outline is shown below:

Month	3	6	9	12	15	18	21	24	27	30
Project management										
Modelling micro structure and defects										
DOE Parameter space determined										
Models defined, using prior knowledge an literature review										
Models demonstrated										
Model development and calibration										
Reporting										
Test 1 wall build for material properties modelling										
DOE 1, wide parameter range build										
Reporting & Compilation of data										
DOE 2, refined parameter range build										
Reporting & Compilation of data										
Test 2 Junction topology build for validation of models										
DOE 3 Process parameters set										
Build & measure										
Reporting & Compilation of data										
Test 3 Engine relevant shape build										
Process parameters & detailed geometry set										
Pre-test simulation and design of test specimen										
Build & Measure										
Post test analysis										
Reporting & Compilation of data										

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Representative facility for the manufacture of test items. The system should be of industrial type. The laser power must be above 4.5 kW, with accurate indication of material flow, positioning and direction of laser and powder nozzles during the entire manufacture.
- Equipment and proven ability to perform high quality blown powder manufacture for multiple super alloy powders such as Alloy718.
- Documented experience in model development for microstructures, with sufficient competence in numerics. Models useful in a thermomechanical simulation environment that can be adapted to superalloys should be proposed in the application.
- Capability for advanced measurements for example optical distortion measurements, metallographic (microscopy, cut-ups, etching) identification of microstructure and defects, residual stress measurements, X-ray identification
- Optional, but not mandatory is to perform in-situ measurement system ICP-MS and computed tomography.

5. Abbreviations

AM	Additive manufacturing
DOE	Design of Experiments (systematic selection of tests)
GOM	Device for optical displacement measurements
HW	Hardware
ICP-MS	Inductively Coupled Plasma Mass Spectroscopy
LBPD	Laser Blown Powder direct Deposition

IX. JTI-CS2-2018-CfP08-ENG-03-23: Probabilistic simulation of defect probability in LWD – Wire fusion processes

Type of action (RIA/IA/CSA)	RIA		
Programme Area	ENG		
(CS2 JTP 2015) WP Ref.	WP 5		
Indicative Funding Topic Value (in k€)	600		
Topic Leader*	GKN Aerospace	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	30	**Indicative Start Date (at the earliest)**[104]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-ENG-03-23	**Probabilistic simulation of defect probability in LWD – Wire fusion processes**
Short description	
Create a simulation chain that probabilistically can predict the likelihood of defect appearance for direct deposition AM processes. The focus is to capture the variation in relative positioning of end-effector and component starting with a robot program and a component geometry and taking into account real path to programmed path variations. Models of physical defect generation is not in focus. Key aspects of the project will be simulation of robot movement (Off-line CAM), simulation of component deformation and heat pick-up (FE) and the integration of these in a Monte-Carlo simulation framework.	

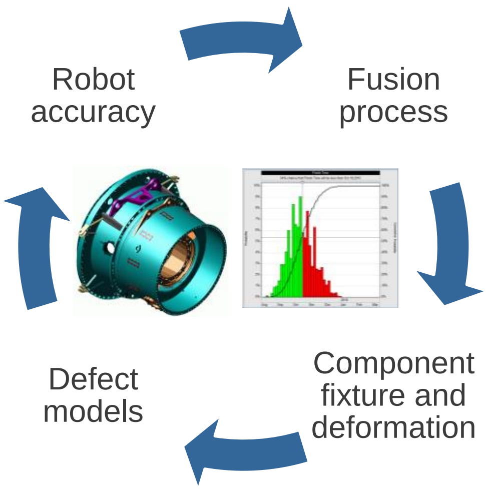
Links to the Clean Sky 2 Programme High-level Objectives[105]				
This topic is located in the demonstration area:		Ultra-high Bypass and High Propulsive Efficiency Geared Turbofans		
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter		Advanced Short/Medium-range, Ultra-advanced Short/Medium-range		
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

[104] The start date corresponds to actual start date with all legal documents in place.
[105] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

The drive for environmental improvements in air transport in combination with increasing global competition on all supplier levels in the aero engine business gives a need for innovation in engine performance and architecture, in component design and in the processes and materials that are used to manufacture parts.

The topic manager is developing innovative compressor structure technology for a new Very High Bypass Ratio (VHBR) engine architecture. The technologies will be matured and eventually demonstrated in full scale engine demonstrator tests. The structures will be designed with a geometrically complex shape to incorporate all necessary functionality at the same time as they will be optimized for lowest weight, cost and compressor efficiency. An example of a similar structure from an existing engine can be seen in above. The component will be made in titanium using a fabrication approach where several subcomponents in sheet, forgings, castings and direct depostion additive manufacturing features are welded together to form the final component geometry.



The direct deposition addditive manufacturing processes considered here are primarily robotized Laser Wire Deposition (LWD) and secondarily Laser Blown Powder Deposition (LBPD). These fusion processes rely on precise control of process parameters to ensure that the final result will be flight worthy. The final quality with respect to defects will depend on the overall process' capability to maintain conditions within defined limits of relative positioning of the end-effector and the component as well as keeping the physical parameters (temp, heat input and output, material feed and quality) under control.

This CfP topic is initiated to enable development of supporting methods that can assess the accuracy and robustness of the process chain and finally indicate the likelihood of defect appearance in the fused material. The methods will be used for Design for Manufacturing in the early design phase of engine components, in setting requirements for the development of manufactuirng processes and finally in adapting workshop resources to the manufactuing of a volume of specific components. Simulation turn-around time is key in early industrial implementation. A target simulation turn around time is therefore 48 hours with a stretch target of 12 hours (over night) using typical computing power industrially available at the projected time for closing of this project.

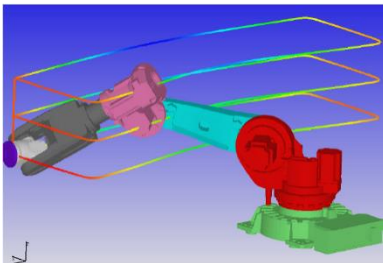
The applying consortium should create a simulation chain that probabilistically can predict the likelihood of defect appearance for the processes in scope. The focus should be to capture and simulate the variation in relative positioning of end-effector and component, starting with a robot program and a

component geometry and taking into account real path to programmed path variations. This starting point will then be compared to component position deflections depending on heat input and fixture constraints. Models of actual defect generation (appearance of lack of fusion or pores and their dependance on temperature, strain, material composition variation) will be used but is to be found in literature or to be provided by the Topic manager.
Key aspects of the project will be to simulate variation along a robot path, automatic generation and simulation of robot movement (Off-line CAM), simulation of component deformation and heat pick-up (FE) and the integration of these in a Monte-Carlo simulation framework. Experimental validation in a relevant process/component set-up is expected to be included in the project proving relative positioning accuracy under a variety of conditions. Proving the actual defect probability in experiments is not part of the project scope while the assessment of simulation turn-around time is.
The research will be performed interactively with the Topic manager where he will define typical component geometries and process requirements and foreseen equipment. The project result will enable a highly robust manufacturing process for complex, high performance and low weight engine components thus maintaining a competitive European supply chain.
The work will go through the following steps:

- Literature review of available methods, synthesis and decide on integrated modelling approach includig definition of final experimental test case.
- Modelling and statistical verification of submodels
- Development of model integration capability and pre-test analysis
- Set up verification test and characterize robustness of each contribibuting factor.
- Final experimental test campaign to determine how variability factors are accumulated in the simulation chain
- Final assessment and release of model framework

2. Scope of work

Tasks		
Ref. No.	***Title - Description***	***Due Date***
1	**Management:** – The partner shall nominate a team dedicated to the project and should inform the Topic manager about the name/names of key staff. – The time-schedule and the work package description laid out in this topic shall be further detailed as required and agreed during negotiation based on the Partner's proposal. – Monthly one-pager and quarterly progress reports in writing shall be provided by the partner, referring to all agreed work packages, technical achievement, time schedule, potential risks and proposal for risk mitigation. – Regular coordination meetings shall be installed (preferred as telecom). More comprehensive review meetings shall typically be held quarterly by WEBEX, at Topic Manager's premises or at the partner's premises.	M30
2	**Literature review and definition of test case** Literature review of available methods, synthesis and decide on integrated modelling approach including definition of final experimental test case. This task will start with the definition of the test case related to the key	M6

Tasks		
Ref. No.	***Title - Description***	***Due Date***
	aspects defined above and will be discussed and formalized together with the topic manager. This includes the definition of the component geometry, material properties, weld parameters, fixturing strategies, robot and welding equipment, development needs, simulation capabilities, available data with distibutions and definition of the desired final state. The definition above will serve as input to the literature study on earlier work within the scope of research and identification of gaps as input to further development. Areas that need to be investigated are described below. Thus further areas can be considered depending on the definition of the test case. • How to capture and simulate the variation in relative positioning of end-effector and component starting with a robot program and a component geometry and taking into account real path to programmed path variations  • Automatic generation and simulation of robot path. • Simulation of component deformation during deposition including effects for heat (FE-calculations) • Adaptive control of robot path consider 3d effects • Models of actual defect generation (appearance of lack of fusion or pores and their dependence on temperature, strain, material composition variation)	
3	**Modelling and statistical verification of sub-models** Within task 3 the aim is to identify and mature the simulation capabilities identified task two. The simulation capabilities should be applied on the test case defined in order to demonstrate the ability to • Simulate variation in relative positioning of end effector along a defined path building the geometry defined in the test case. • Automatically generate and simulate the nominal build sequence of the LWD not considering effects of heat. • Simulate deformation due to heat effects during deposition. • Addaptive control of robot path due to deformations during build-up. Within this task the main focus is to virtually demonstrate the capabilities thus some simple physical experiments can be performed in order to identify the main sources of variation and investigate critical build sequences that contribute to defects in the material.	M18
4	**Development of model integration capability and pre-test analysis** Main focus in this task is to connect the disciplines defined in task 3 and demonstrate a simulation chain.	M24
5	**Set up verification test and characterize robustness of each contributing**	M20

Tasks		
Ref. No.	***Title - Description***	***Due Date***
	factor. Early testing based on the studies in task 2 and 3 in order to collect virtual and physical data to identify and quantify sources of variation to defects and deformation. Physical test run on the defined test-case geometry. Collect data on critical key process variables and identify uncertainties. How can process variables be adjusted to control deformation.	
6	**Final experimental test campaign to determine how variability factors are accumulated in the simulation chain** Based on the findings in earlier tasks run a simple DoE to further investigate the process and find suitable actions for improved robustness and define proposal for further development. Experiments that challenges the effects of variability. Test cases could be thin walled cone with wall-stiffeners and bosses. The experiments need to challenge deformation and speed. Thus the test-cases will be discussed and agreed together with the topic manager. Correlate the virtual simulation chain with physical outcome.	M28
7	**Final assessment and release of model framework** The report highlights the project findings and references all issued reports. A final presentation shall also be delivered and presented to a consortium selected by the topic manager. Finally, relevant methods and scripts are transferred to the topic manager	M30

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1	Detailed project plan related to Task 1.	R	M1
D2	Literature survey as defined in Task 2.	R	M4
D3	Report on the capabilities defined in Task 3 and deliver developed code to the topic manager	R	M18
D4	Report on the demonstration of simulation chain related to Task 4 and deliver developed code to the topic manager.	R	M24
D5	Final report that summarize the project and deliver the model framework to the topic manager	R, D	M30

Milestones			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M1	Define suitable test case as defined in Task 2.	D	M6
M2	Report on the demonstration on the capabilities developed in task 3.	R+D	M18

Milestones			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M3	Report on the verification test defined in task 5- Hardwares built to be delivered to the topic manager	R+D	M20
M4	Report on the final experiments defined in task 6. Hardwares built to be delivered to the topic manager	R+D	M28
M5	Final project presentation	R	M30

A project outline is shown below:

Month	3	6	9	12	15	18	21	24	27	30
1: Project managemenent	■	■	■	■	■	■	■	■	■	■
Detailed project plan	■									
2: Literature review and definition of test case	■	■	■	■	■	■	■			
Definition of test case	■									
Literature review	■	■								
3: Modelling and statistical verification of sub-models	■	■	■	■	■	■				
Simulate variation in relative positioning of end effector		■	■	■						
Automatically generate and simulate the nominal build sequence			■	■	■					
Simulate deformation due to heat effects during deposition			■	■	■	■				
4: Development of model integration capability				■	■	■	■	■		
Define and create the simulation chain				■	■	■				
Demonstration of the simulation chain						■	■	■		
5: Set up verification test and characterize robustness			■	■	■	■	■			
Simplified test to identify sources of variation			■	■						
Physical demonstration of the test case					■	■	■			
6: Final experimental test campaign					■	■	■	■	■	
Initiate DoE					■					
Physical testing						■	■	■	■	
7: Final assessment and release of model framework			■	■	■	■	■	■	■	■

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- The CfP partner/consortium should have equipment for robotised Laser Wire Deposition to enable experiments in an industrial relevant environment.
- The CfP partner/consortium should have ability and documented experience in geometrical variation simulation.
- The CfP partner/consortium should have ability and experience in manufacturing process simulation (Mainly automatically generation and simulation of robot path and simulation of fusion processes and its effect on component distortion)
- Experience in performing applied collaborative industrial research in international environment is considered as essential.

5. Abbreviations

CAM	Computer Aided Manufacturing
DoE	Design of Experiments
FE	Finite Element
LBPD	Laser Blown Powder Deposition
LWD	Laser Wire Deposition

X. JTI-CS2-2018-CfP08-ENG-03-24: VHCF material model for case hardened gear steels for application in an epicyclic power gearbox

Type of action (RIA/IA/CSA)	RIA		
Programme Area	ENG		
(CS2 JTP 2015) WP Ref.	WP5		
Indicative Funding Topic Value (in k€)	2400		
Topic Leader	Rolls-Royce	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	48	**Indicative Start Date (at the earliest)**[106]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-ENG-03-24	**VHCF material model for case hardened gear steels for application in an epicyclic power gearbox**
Short description	
The projects aim to develop a material model for future case hardened gear steels considering representative conditions of an epicyclic gearbox such as material volume, stress ratio (R = -1 fully reversed), load cycle waveform and dynamic effects for the relevant Very High Cycle Fatigue regime (VHCF) ≥ 10^8 cycles. A fast rotating recirculating gear sub-element test rig shall be developed and utilised to generate necessary bending fatigue datasets.	

Links to the Clean Sky 2 Programme High-level Objectives[107]				
This topic is located in the demonstration area:	Ultra-high Bypass and High Propulsive Efficiency Geared Turbofans			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Long-range, Ultra-advanced Long-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

[106] The start date corresponds to actual start date with all legal documents in place.
[107] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

Through Clean Sky 2, Rolls-Royce is developing and demonstrating the complete range of technologies required for Very High Bypass Ratio (VHBR) engines.

Within the timescales of Clean Sky 2, VHBR engines will realise significant environmental benefits:

- Up to 25% fuel burn and CO_2 emission reduction relative to year 2000 baseline (consistent with 10% reduction relative to year 2014 baseline)
- Noise levels making a significant step towards ACARE 2035 targets (- 11 EPN dB per operation relative to 2000 situation: including engine, nacelle, aircraft technologies - airframe noise reduction, novel aircraft configurations – and ATM benefits)
- Contribute to delivery of NO_X emission reductions through reduced fuel burn. Specific objectives will not be defined owing to the strong dependency on overall core engine cycle decisions.

Development of VHBR technology will also maintain European competitiveness in the development and integration of engines for Middle of Market short range commercial aircraft, to ensure capability across the full range of technologies required by geared engines, and develop a world-leading European capability for VHBR engines for the large aircraft market, establishing a lead in this emerging market.

Geared turbofans provide a significant improvement in aero-engine efficiency by allowing the fan and turbine to rotate at their optimum speeds. This allows for a higher by-pass ratio (larger fan at a lower speed than traditional turbofans) and a lighter, fast rotating and more efficient turbine. With the turbine and fan rotating at different speeds a gearbox is required to transfer a high level of torque within a restricted space envelope to minimise the size of the engine core. Epicyclic gearboxes provide a space efficient solution but require very high load transfer through the gears.

In order to develop a compact and lightweight gearbox and to guarantee the high level of reliability required for aerospace applications it is necessary to carry out material tests under representative conditions for a fast rotating epicyclic gearbox.

Current test standards utilise pulsator machines (modified High Cycle Fatigue (HCF) machines) to determine the materials tooth root bending performance on a sub-element test gear. Using pulsator testing it is only possible to test positive stress ratios $R > 0$ (unidirectional). Furthermore it does not account for friction, dynamic and environmental effects and constitutes a significant level of abstraction of the load cycle waveform as shown in Figure 18.

Literature (FVA research project 196) has shown that the pulsator testing leads to an overestimation of the tooth root bending material performance for standard automotive applications of about 10%.

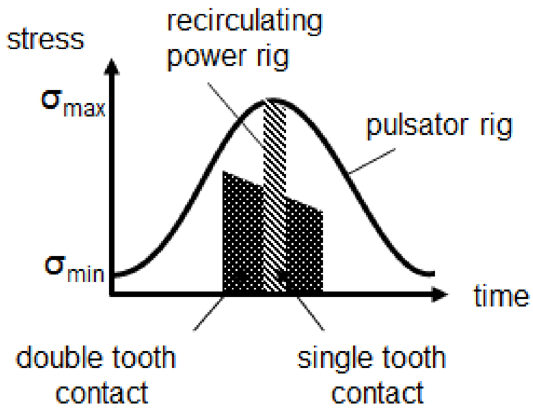


Figure 18 stress cycle waveform for tooth root bending during pulsator testing and spur gear contact

The high rotational speed of power gearboxes in future VHBR aero-engines leads to an accumulation of very high cycles (VHCF N ≥ 10^8 cycles) at maximum take-off (MTO). The VHCF material behaviour is outside current industry experience and testing standards ($N_L = 3{\cdot}10^6$ run-out cycles for tooth root bending to ISO6336-5 / AGMA 2001-D04).

A material model for the VHCF regime is seen as an enabler for future gear steel material developments. This understanding can also be leveraged across to the automotive industry which faces a similar challenge for the transition to electric mobility. Compact and lightweight gearboxes are needed to reduce the rotational speed of electric motors running up to 20,000 rpm. The material utilised in these gearboxes will quickly accumulate load cycles in the VHCF regime.

The work to be covered by the partner selected shall be on the one hand to design, build and operate a recirculating rig capable to test tooth root bending for the different R ratios of R = 0 and R = -1. The required torque and rotational speed, to accumulate the required cycles of N ≥ 10^8 cycles in an economically reasonable time, will be outside current industrial standards.

On the other hand the partner shall develop a VHCF material model for case hardened gear steels to predict the material life for the application in a fast rotating epicyclic gearbox. The model shall utilise state of the art knowledge about microstructural failure mechanisms and shall be validated using the rig test data generated within this project.

The successful Partner shall demonstrate both the capability to deliver the rig technology based on established track records of innovation and test facility capability, as well as proven knowledge in the field of material science, material characterisation, very high cycle fatigue (VHCF) and failure mechanisms simulation. This implies demonstration of evidence of existing development and research facilities. Experience with quality systems such as ISO 9001 or ISO 17025 will be advantageous.

2. Scope of work

The objective of this project is to deliver a VHCF material model for case hardened gear steels and a recirculating rig test programme to describe and validate the tooth root bending material behaviour in

the VHCF regime under representative conditions of an epicyclic gearbox for future large civil geared turbofan aero-engine application.
The recirculating rig test programme shall include testing in unidirectional (R = 0) and fully reversed (R = -1) mode. Rolls-Royce will provide the sets of test articles made from two different high strength case hardened gear steels.

Tasks		
Ref. No.	***Title - Description***	***Due Date***
WP1	**Develop and Design Advanced Recirculating Rig**	year 0 - 0.5
WP2	**Build and Commissioning Advanced Recirculating Rig**	year 0.5 - 2
WP3	**Material 1 Data Generation for VHCF 1 to $5{\cdot}10^8$ cycles**	year 2 - 3
WP3.1	Testing completed	
WP3.2	Test Data analysed	
WP3.3	Material / Failure Characterisation completed	
WP4	**Material 2 Data Generation for VHCF 1 to $5{\cdot}10^8$ cycles**	year 3 - 4
WP4.1	Testing completed	
WP4.2	Test Data analysed	
WP4.3	Material / Failure Characterisation completed	
WP5	**Develop VHCF Material Model**	year 2 - 4
WP5.1	Conduct Literature Study	3 months
WP5.2	Define Requirements	3 months
WP5.3	Develop VHCF Material Model	12 months
WP5.4	Validate VHCF Material Model	6 months

To enable the delivery of a successful programme five distinct work packages (WP) have been identified. WP1 and WP2 consist of the development, design, built and commissioning of the advanced recirculating test rig. WP3 and WP4 describe the delivery of the rig test programme, test data and material analysis for two materials. WP5 represents the development of the VHCF material model for case hardened gear steels.
The VHCF material model and rig test results will provide evidence required for demonstrating the maturity level TRL4.

WP1 - Develop and Design Advanced Recirculating Rig
This work package covers all aspects of the development and design of the advanced recirculating rig including instrumentation technologies. In order to carry out the recirculating rig test programme for high strength gear steels in the VHCF regime the minimum rig requirements are summarised as follows:

- 2/3-axis mode including variable centre distance of 200 to 250 mm
- rotational speed ≥ 12,000 rpm
- torque 5,000 Nm
- oil inlet temperature of 90 to 140° C
- capable of accommodating single helical or spur gear test articles

The high rotational speed is needed to accumulate cycles in the VHCF regime in an economically reasonable time. To ensure that the test article will fail in the tooth root it is necessary to increase the safety factor for contact fatigue failure. In order to have sufficient margin for future gear steel developments the high level of torque is required.

WP2 - Build and Commissioning Advanced Recirculating Rig
This work package covers all aspects of the build and commissioning of the advanced recirculating rig incorporating cooling and all instrumentation required. All instrumentation shall be calibrated and traceable to a national standard.

WP3 / WP4 – Material Data Generation for the VHCF regime
This work package covers all aspects of the operation of the advanced recirculating rig to deliver the VHCF material test programme as well as the analysis of the test data. The methods utilised to analyse the rig test data shall include Finite Element (FE) analysis and analysis to ISO 6336 standard.
Furthermore a detailed material and failure characterisation is required to establish a relationship between the mechanical test results and microstructural features of the material. The characterisations shall include metallography and residual stress measurements.
All test articles will be provided by Rolls-Royce. The test requirements and the scope of test programmes will be agreed between the partner and Rolls-Royce.

WP5 - Develop VHCF Material Model
This work package covers all aspects of the development and validation of a VHCF material model. It shall utilise state of the art knowledge about the material behaviour under cyclic loading in the VHCF regime which includes the effect of non-metallic inclusions and shall be capable of predicting VCHF material behaviour across multiple R-Ratios (between R = 0 and R = -1).
The VHCF material model shall account for the local material properties of a case hardened gear steel and the complex stress situation in the tooth root as shown by Figure 19.
The model shall be capable of being applied to real life gear applications and shall be validated by the recirculating rig testing as agreed between the partner and Rolls-Royce.
Fundamental material properties which are not generated under WP3 and WP4 and are required for the development of the material model will be provided by Rolls-Royce.

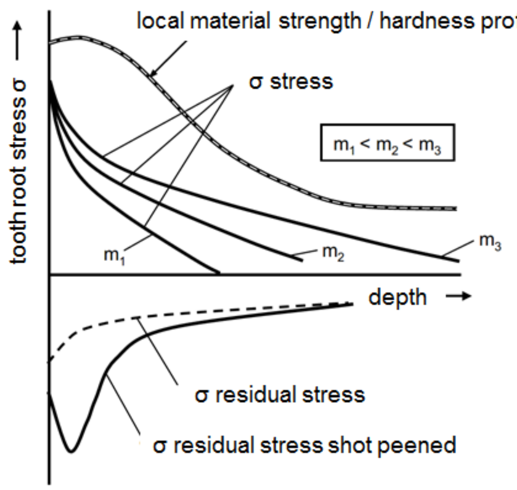


Figure 19 schematic representation of the main effects determining the fatigue life in the tooth root

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1	Advanced Recirculating Rig	HW	year 2
D2	Material 1 VHCF Testing complete	R / D	year 3
D2.1	Material 1 Bending Fatigue Data analysed	R /D	year 3
D3	Material 2 VHCF Testing complete	R / D	year 4
D3.1	Material 2 Bending Fatigue Data analysed	R /D	year 4
D4	VHCF Material Model validated	R / D	year 4

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
MS1.1	Define Rig and Instrumentation Requirements	R	month 1
MS1.2	Rig Preliminary Rig Design Review	R	year 0.25
MS1.3	Rig Critical Design Review	R	year 0.5
MS2	Test Readiness Review (rig commissioned)	HW	year 2
MS3.1	Material 1 VHCF Testing complete	R / D	year 3
MS3.2	Material 1 Test Data analysed	R / D	year 3
MS3.3	Material 1 Material / Failure Characterisation complete	R / D	year 3
MS4.1	Material 2 VHCF Testing Material 2 complete	R / D	year 4
MS4.2	Material 2 Test Data analysed	R / D	year 4
MS4.3	Material 2 Material / Failure Characterisation complete	R / D	year 4
MS5	VHCF Material Model validated	R / D	year 4

4. Special skills, Capabilities, Certification expected from the Applicant(s)

It is expected that a specific set of skills and facilities are required by the candidate and it is therefore expected that the response will address the following areas of expertise as a minimum

- **Skill 1:** Experience of recirculating test rig development, manufacture and instrumentation.
- **Skill 2:** Quality controlled management of facilities and processes for the recirculating rig testing.
- **Skill 3:** Gear test data processing methods shall include all aspects of test gear design, instrumentation measurements, measurement uncertainties and limitations. The methods shall utilise FE analysis and analysis to ISO 6336 standard.
- **Skill 4:** Capability to characterise the material and failure mechanisms by analytical methods such as, but not limited to, residual stress measurement by X-ray diffraction and metallography.
- **Skill 5:** Capability to describe material failure mechanism phenomena in the VHCF regime through theoretical models.

5. Abbreviations

VHBR	Very High By-pass Ratio
VHCF	Very High Cycle Fatigue, $N \geq 10^8$ cycles

FE	Finite Elements
FVA	Forschungsvereinigung Antriebstechnik e.V. (Research Association for Drive Technology)
HCF	High Cycle Fatigue, $N < 10^8$ cycles (the usual run-out for steels is $N_L = 10^7$)
N_L	Number of cycles for run-out
R	Stress ratio (lower stress level / upper stress level)

XI. JTI-CS2-2018-CfP08-ENG-03-25: **Development of design methodologies for thermal management and scavenge / sealing interactions in future vent-less UltraFan® bearing chambers**

Type of action (RIA/IA/CSA)	RIA		
Programme Area	ENG		
(CS2 JTP 2015) WP Ref.	WP 5		
Indicative Funding Topic Value (in k€)	1700		
Topic Leader	Rolls-Royce	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	36	**Indicative Start Date (at the earliest)**[108]	Q1 2019

Topic Identification Code	**Title**
JTI-CS2-2018-CfP08-ENG-03-25	**Development of design methodologies for thermal management and scavenge / sealing interactions in future vent-less UltraFan® bearing chambers**
Short description	
This proposal is aimed at understanding design rules and methodologies required to facilitate the use of low pressure and temperature bearing chamber environments and sealing systems. The proposal will determine the most appropriate method(s) to manage local bearing chamber temperatures and to understand scavenge and sealing system interactions in bearing chambers that are not vented. Design criterion and methodologies will be developed that will enable the realisation of robust thermal management and bearing chamber sealing in future vent-less UltraFan® bearing chambers.	

Links to the Clean Sky 2 Programme High-level Objectives[109]				
This topic is located in the demonstration area:	Ultra-high Bypass and High Propulsive Efficiency Geared Turbofans			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Long-range, Ultra-advanced Long-range			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
☒	☐	☐	☐	☐

[108] The start date corresponds to actual start date with all legal documents in place.
[109] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

As a part of engine projects in Clean Sky 2, the Topic Manager will lead the design and development of VHBR technologies for the UltraFan® engine demonstrator (WP6 of Engine ITD) for the large engine market. One of the key technologies required to meet the goals of WP6 is an efficient, mass optimised oil lubrication and heat management system.

In the current state of the art a typical Civil Large Engine (CLE) uses an oil heat management system to lubricate and cool transmissions components. Oil is supplied to bearing chambers and gearboxes where it is used to absorb heat from transmission components in order to lubricate and thermally manage them. The oil is retained within these chambers using an air pressurising and venting system that utilises high pressure air drawn from the engine compressors. The use of and venting of this high pressure air represents an efficiency loss to the gas turbine and also results in environmental emissions to atmosphere.

The current understanding held by the topic manager is built around current CLE best practice and has the following shortcomings with regard to future UltraFan® products:

1) Increasing heat loads are satisfied by increasing oil flows with limited understanding of any benefits of revised oil delivery or distribution leading to larger system oil volumes.
2) The heat generation of different bearing types is not well understood.
3) High pressure and high temperature air is used to pressurise bearing chambers leading to high additional heat generation and consequential demand for increased oil flows.
4) A venting system is required to control bearing chamber pressure by venting the high pressure sealing air to an atmospheric sink, leading to a cycle efficiency debit and environmental emissions

Future UltraFan® engines represent a significant challenge for oil heat management System designs due to significantly increased heat loads associated with the power gearbox, the attendant increase in system oil volumes that come with these heat loads and will be required to minimise environmental emissions in order to satisfy future regulatory requirements.

The current proposal is expected to deliver improved design rules and methodologies required to realise more efficient thermal management systems by reducing oil volumes required for cooling, utilise improved oil distribution and to minimise the amount of high pressure air used for chamber sealing. This will enable the benefits of the UltraFan® architecture to be fully realised in future products.

The objectives of the current proposal are to:

I. Create a simplified bearing chamber test rig and explore the relationship between oil flow and cooling performance, isolating key dependencies that would need to be reflected in any kind of modelling method.
II. Explore how bearing designs and oil distribution systems can be used to maximise oil cooling performance including under soakback conditions.
III. Use the same rig to explore the relationship between sealing air flow, scavenge system performance and bearing chamber sealing.
IV. Develop design rules and methodologies required to design efficient oil cooling and bearing chamber sealing systems.

2. Scope of work

In the current proposal it is envisaged that a simplified bearing chamber test rig will be created and used to support the formulation of design rules and methodologies by studying the parameters relevant to both chamber cooling and sealing. This proposal does not seek to replicate precise CLE gas turbine bearing chamber conditions because it is recognised this would yield a highy complex and costly rig configuration. The aim of this proposal is to create a simplified rig capable of providing parametric data that can be used to develop the required design methodologies.

An outline of the tasks is given in the following table.

Tasks		
Ref. No.	***Title - Description***	***Due Date***
T1	Management	T0+36 months
T2	Theoretical assessment of potential improvements	T0+12 months
T3	Design bearing chamber test rig	T0+12 months
T4	Build bearing chamber test rig	T0+24 months
T5	Investigate oil cooling performance	T0+36 months
T6	Investigate sealing performance	T0+36 months
T7	Develop design Methodologies	T0+36 months

A brief description of the tasks is given below.

Task1: Management

Organisation: The partners shall nominate a team dedicated to the project and should inform the consortium programme manager about the name (s) of this key staff

Time schedule and work-package description:

- The partners will work to the agreed time-schedule and work-package description
- Both the time-schedule and the work-package description laid out in this call shall be further detailed and agreed at the beginning of the project.

Progress reporting and reviews:

- Five progress reports (i.e. deliverables) will be written over the duration of the programme
- For all work packages, technical achievements, timescales, potential risks and proposal for risk mitigation will be summarised
- Regular coordination meetings shall be conducted via telecom or WebEx where appropriate
- The partners shall support reporting and review meetings with reasonable visibility on the activities and an adequate level of information
- The partners shall support quarterly face-to-face review meetings to discuss the progress

Task 2: Theorectical assessment of potential improvements

Drawing on the considerable body of scientific literature available on this topic, this task will determine the most appropriate methods to manage local bearing chamber temperatures including the impact of soakback heating. Consideration should be given to different methods of oil distribution and oil transfer within the bearing as well as different bearing mounting arrangements that may improve oil flows and thermal management. The effect of different bearing types (including hybrid bearings) should be considered and if appropriate alternative test geometries or configurations identified for use in Task 5.

It is expected that the number of different bearing types tested will need to be limited to ensure sufficient test time is available to explore and characterise the integration aspects (oil distribution, oil transfer, mounting configuration and geometry etc) as these are not well understood. A strategy for achieving this could be a limited test matrix to characterise heat generation differences between a few bearing types with a single type downselected for integration testing. The partners shall agree with the Topic Manager the test configurations downselected in order to ensure the complete test matix is achievable within the indicative funding value.

Task3: Design Bearing chamber test rig

It is envisaged that a single shaft test rig will be required to complete Tasks 5 and 6. The rig is not intended to exactly simulate the geometry or operating conditions of a CLE bearing chamber, but it must be representative enough to enable the controlling parameters to be explored.

In order to define a test rig compatible with the indicative funding value for this Call for Proposal (CfP), guidance is given here to illustrate the scale and scope of the rig. This guidance does not constitute a definitive requirement set for the rig, but does provide a set of dimensional data that the Topic Manager believes is consistent with previous test rigs created within the industry for bearing chamber research.

General rig type and features:

A single shaft with a slave bearing chamber housing that can be heated to generate thermal loading. The shaft to housing sealing interface may be single or double as long as sufficient pressurising air can be passed into chamber. The amout of air entering the chamber is required to be variable. The rig is expected to use a single thrust bearing that can be loaded and then be fed with oil that can be heated. A scavenge pump will be required to draw both air and oil from the chamber. In order to ensure sufficient heat is generated and soakback conditions may be replicated, it is suggested that consideraton be given to heating some parts of the rig shaft to provide a further heating flux to the system.

Different types of bearing, bearing locating features, oil feed and oil distribution geometries are required to be tested, therefore the rig has to accommodate these changes.

Recommended key rig parameters:

Bearing diameter,	150 – 200mm
Rotational speed,	~10,000rpm
Bearing load end load,	45kN – 68kN
Sealing air flow,	0.0001 – 0.01 kg/s
Internal pressure,	101.32kPa – 0.6895kPa
Max oil feed temp,	100deg C
Max temp for casing,	200deg C

Task 4: Build bearing chamber test rig

With the guidance provided in Task 3 a simplified test rig is required to be built. The build and subsequent testing of the rig shall comply to all relevant safety and environmental regulations and guidelines.

The rig is likely to require modification to enable different internal geometries, configurations, as well as different sealing flows.

The rig should have sufficient instrumentation to enable data collection for use in Task 7 where design rules and methodologies will be established.

It would be advantageous to allow internal viewing of the chamber (eg if thermal imaging is selected as an instrumentation means), however if embodiment would limit the scope of the test exploration

acheivable, then suitable alternative instrumentation may be considered.
In order to support Task 6 it is expected that a means to meter air into the bearing chamber as well as the shaft sealing interface will be required.

Task 5: Investigate oil cooling performance
In the current state of the art a typical thrust bearing is cooled by oil fed via an under bearing race feed and then distributed into the rolling elements where it lubricates and extracts heat and is subsequently ejected from the elements. Increased bearing loads and heating are managed by increasing oil flows which also increases churning losses within the bearing and also total oil system volume and mass.
Using the test rig established in task 4 and the downselected configurations agreed in task 2, an exploration of the relationship between oil flow and flow distribution on bearing and bearing chamber temperatures is required. Consideration should be given to splitting total oil flow into lubricating and cooling streams, as well as the use of multiple cooling streams.
An exploration should also be performed of the impact of different bearing geometries and bearing types (including hybrid bearings) on both oil cooling performance and bearing heat generation.
An extension of this task shall consider thermal soakback conditions where oil flows have ceased but the thermal load remains for sometime (heat soak from hot casing or shaft). In this scenario use of the scavenge system or internal chamber geometries or thermal breaks may be considered.

Task 6 Investigate chamber sealing performance
For a future UltraFan® product a reduction in the magnitude of high pressure sealing air used to pressurise a bearing chamber is required to minimise SFC impact and maximise the architecture benefits. This may be achieved by using lower pressure air to buffer a bearing chamber in conjunction with low leakage seals and a ventless chamber configuration to minimise environmental impact.
This Task will explore the interaction between sealing airflows, bearing chamber pressure and scavenge system performance in order to characterise sealing performance.

Task 7: Develop design methodologies
This Task will use the data generated in Tasks 5 and 6 to produce a design toolkit that may include (but not be limited to) design guidance, methodologies, design curves, parametric lookups etc that may be used to inform the design of bearing chamber thermal management schemes and scavenge only bearing chamber sealing systems.

3. Major Deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1	Management report: summarise the project management of the programme, including deliverables, level of spend and dissemination	R	T0+36 months
D2	Theoretical assessment report: Report summarising the theoretical assessment results and configurations that will be tested.	R	T0+12 months
D3	Rig design report: Report providing design rationale and rig configuration.	R	T0+12 months
D4	Test Rig: Commissioned test rig.	HW	T0+24 months

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D5	Test results: All data & measurements captured from rig testing.	D	T0+36 months
D6	Final report: Report summarising the testing performed, data captured and the insight gained along with set of design rules & methodologies.	R	T0+36 months

Type: R=Report, D=Data, HW=Hardware

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M1	Management report: summarise the project management of the programme, including deliverables, level of spend and dissemination	R	T0+36 months
M2	Rig design report: Report providing design rationale and rig configuration and testing to be performed	R	T0+12 months
M3	Design methodologies: Report summarising the testing performed, data captured and the insight gained along with set of design rules & methodologies.	R	T0+36 months

Type: R=Report, D=Data, HW=Hardware

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Experience in the following topic areas or ability to partner with a suitable organisation that has the relevant experience;
- Bearing chamber and bearing design
- Bearing chamber sealing systems
- Oil scavenge systems
- Facility able to accommodate the test rig described in this proposal

5. Abbreviations

VHBR	Very High Bypass Ratio
CLE	Civil Large Engine
Brg	Bearing

9. Clean Sky 2 – Systems ITD

I. JTI-CS2-2018-CFP08-SYS-02-46: Modeling of friction effects caused by surface contact with high pressure and rapid movement

Type of action (RIA/IA/CSA)	RIA		
Programme Area	SYS		
(CS2 JTP 2015) WP Ref.	WP 3.2.2		
Indicative Funding Topic Value (in k€)	700		
Topic Leader	Liebherr-Aerospace Lindenberg	Type of Agreement	Implementation Agreement
Duration of the action (in Months)	33	Indicative Start Date (at the earliest)110	Q1 2019

Topic Identification Code	Title
JTI-CS2-2018-CFP08-SYS-02-46	Modeling of friction effects caused by surface contact with high pressure and rapid movement
Short description	
The goal of this work package is to investigate the in-situ surface processes at a bearing contact of a landing gear shock strut during operation and to develop an enhanced model for simulation of stress / fatigue levels depending on the operational conditions.	

Links to the Clean Sky 2 Programme High-level Objectives111				
This topic is located in the demonstration area:		Landing Systems, Enabling Technologies		
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter		Advanced Long-range		
With expected impacts related to the Programme high-level objectives:				
Reducing CO2 emissions	Reducing NOx emissions	Reducing Noise emissions	Improving EU Competitiveness	Improving Mobility
☐	☐	☐	☒	☒

[110] The start date corresponds to actual start date with all legal documents in place.
[111] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

The issue of burn marks appearing on landing gear shock struts under harsh operational conditions is well known and described in SAE AIR 5913. Despite not being uncommon on in-service aircraft, reproducibility of this phenomenon on test rigs is rather limited. Today there is no simulation environment available, that allows to simulate the different operating conditions and predict the extent of damage caused by this phenomenon.

A simulation environment would lead to improved design rules of landing gears and improves the environmental impact of the life cycle of landing gear shock stuts due to less in-service replacements or repairs of damaged sliding tubes.

Moreover the simulation environment would enable an accelerated development and validation of landing gear design solutions with state-of the art coating technologies as well as future coating solutions introduced for environmental reasons.

The goal of this work is to investigate the contact area of the relevant structures taking into account the relevant physics (e.g. mechanics, heat conduction, fluid dynamics) on multiple scales down to microscopic surface processes and to develop a model for the simulation surface impacts depending on the operational conditions (e.g. forces, speed, movement) and correspondingly predict stress / fatigue levels.

2. Scope of work

Goal of this topic is to develop, and validate a simulation environment, which can reproduce 'Burn Mark' effects based on the critical parameters of aircraft landing scenarios. The innovation aspect lays in the capacity to simulate and predict - in a unique co-simulation environment - the combined effect of mechanics, lubrication, thermal phenomena affecting the performance of the contact surface under the different operating conditions, which lead to critical stress scenarios and fatigue accretion up to severe decay in landing gear performances.

The co-simulation environment should ideally combine and integrate in 1-D and 3-D modeling wiht a view to instantiate it to the specificity of the „burn mark" phenomenon.

The simulation environment should support:

- Simulation of the relevant scales of surface contact (reflecting area of impact for stress, but also energy transport.
- Evaluation of effects caused by the contact, reflecting forces, movement, lubrication, heat build-up and heat conduction as well as tolerances respctively possible deviations of the structural elements in shape and dimensions. The combination of these effects and the investigation of the contribution of each effect represents the innovative step
- Simulation should enable a prediction of structure change, dynamic distribution of heat caused by friction, evaluation of critical local thermal conditions and resulting effects.

Input parameters for the simulation should be a time signal, describing the applied forces and start temperature of the involved components, and a description of the near-surface condition of the simulated structures resulting from their tribological history.

Tasks		
Ref. No.	Title – Description	Due Date
T1	Investigation of material samples to retrieve the relevant material parameters (lab) in order to validate the depth of field of the model	Q3/2018
T2	Modelling of physical contact materials (including surface layers) to a relevant depth including energy flow	Q3/2019
T3	Simulation of physical contact accounting for relevant surface parameters like: - pressure, temperature, contact area, contact angle and effects like: - deformation - adhesion - temperature (energy flow) - lubrication	Q2/2020
T4	Translation of large scale movement of Landing Gear into microscopic contact with all relevant parameters like: - plastic deformation in adhesive contacts - lubrication film build-up - formation and decay of tribochemical boundary layers	Q3/2020
T5	Comparison of simulation results with test and field data	Q4/2020

3. Major Deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	Title - Description	Type*	Due Date
D1	Detailed report about physical behaviour of / effects on contact materials, in particular depending on pressure, angle, temperature, relative movement	R	Q3/2018
D2	Simulation model / detailed description of model and parameters (including simulation environment)	R / M	Q3/2019
D3	Description / presentation of simulation results	R / D	Q2/2020
D4	Description / model of transfer function(from runway model to physical surface model)	R / M	Q3/2020
D5	Detailed Report (comparison with real data)	R	Q4/2020

*Type: R=Report, D=Data, HW=Hardware, M=Simulation Model

Schedule

		Q2 2018	Q3 2018	Q4 2018	Q1 2019	Q2 2019	Q3 2019	Q4 2019	Q1 2020	Q2 2020	Q3 2020	Q4 2020
Phase 1	Investigate material samples											
Phase 2	Modeling of physical contacts											
Phase 3	Simulation of physical contact											
Phase 4	Translation of movement											
Phase 5	Comparison simulation - test											

Milestones (when appropriate)			
Ref. No.	Title - Description	Type*	Due Date
M1	Physical Analysis succeeded	R	Q3/2018
M2	Model complete	R / M	Q3/2019
M3	Simulation complete	R / D	Q2/2020
M4	Documentation complete	R	Q4/2020

*Type: R=Report, D=Data, HW=Hardware, M=Simulation Model

4. Special skills, Capabilities, Certification expected from the Applicant(s)

Detailed experience in tribology, surface physics, multi-physics and multi-scale simulation
Experience in thermodynamics and fluid mechanic
Experience in modelling and simulation of surface contact reactions/behavior

II. JTI-CS2-2018-CFP08-SYS-02-47: New grip generation for active inceptor

Type of action (RIA/IA/CSA)	IA		
Programme Area	SYS		
(CS2 JTP 2015) WP Ref.	WP3.2.5		
Indicative Funding Topic Value (in k€)	500		
Topic Leader	Safran	Type of Agreement	Implementation Agreement
Duration of the action (in Months)	24	Indicative Start Date (at the earliest)112	Q1 2019

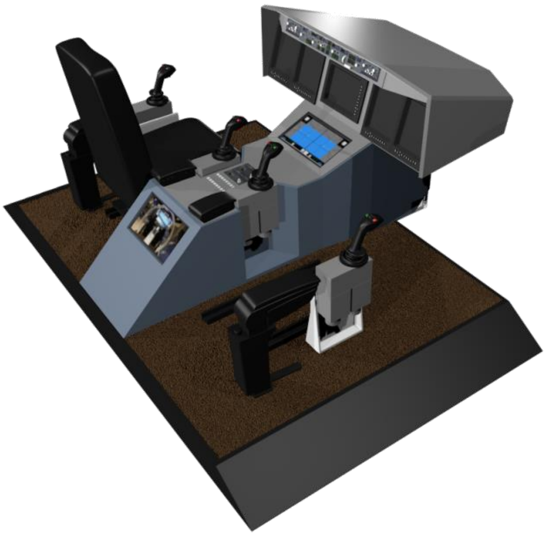
Topic Identification Code	Title
JTI-CS2-2018-CFP08-SYS-02-47	New grip generation for active inceptor
Short description	
New generation of active Inceptor will give the opportunity to provide to pilots more and more functionalities, especially fitted directly on the grip. The aim of this topic is to investigate new grip generation including new sensing devices, and the associated connections constraints, while keeping high integrity level, compliant with aeronautic requirements.	

Links to the Clean Sky 2 Programme High-level Objectives113				
This topic is located in the demonstration area:	Cockpit & Avionics			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Compound helicopter Next-Generation Tiltrotor Advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing CO2 emissions	Reducing NOx emissions	Reducing Noise emissions	Improving EU Competitiveness	Improving Mobility
☐	☐	☐	☒	☐

[112] The start date corresponds to actual start date with all legal documents in place.
[113] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

The activity of WP 3.2.5 Smart Active Inceptors for Tilt Rotor demonstration is a part of the SYS WP 3 Innovative Electric Wing.
Flight Controls for Tilt Rotor have a high level of complexity due to aircraft architecture (midway between A/C and H/C). Active inceptor and especially grip (which is part of inceptor) are means to improve flight information shared between pilots and FCCs, and by this way improve safety during flight.
The Objective of the WP is to develop an innovative Cockpit control system with the integration of Smart & Active Inceptors.



Innovative cockpit example

With the progressive disappearance of mechanical links between aerodynamic control surfaces and piloting inceptor devices and the wide use of FlyByWire, the image of the aircraft behavior is no longer provided to pilots by passive inceptor devices only. The development of active inceptor allows giving pilots a direct feeling of the aircraft behavior, in particular flight limitations or control surface positions.
In the opposite way, new generation of inceptors is an opportunity to capture more information coming from pilot actions and/or behaviors, especially fitted directly on the grip, eg detection sensors for Hands On/Hands Off management, new buttons, new devices (eg screens), ...
Beyond the interest of new sensors to catch or manage A/C conditions and behavior, these additional devices need to be connected to dedicated computers, and consequently will increase number and type of wires between grip and inceptor base. The reduction of connection points and wire size will become a challenge (eg multiplexing up to 40 discrete & 10 analogic signals in a volume < 10cm3, complying with high integrity requirements).

The aim of the topic is to focus on all new functionalities to be fitted on grip, including sensor or specific device (e.g. screens, visual indicators, etc.) and the way to connect all these devices on the inceptor taking into account reduced volume, safety constraints and integrity requirements.

Smart Active Inceptor

2. Scope of Work

This topic encompasses following studies.

a) New functionalities and associated sensors/devices

- Functionality analysis
    - Context and constraint analysis
    - New functions definition
        - Hands On/Hands Off
        - Remote Switches Concentrator
        - Embedded safety
        - …
    - Safety analysis
    - Technological analysis and components design
- Physical integration and interfaces between grip and inceptor
    - Integration of new functions/components on grip
    - Interfaces constraints with inceptor (mechanical & electrical)
- Expected performances
    - Integrity level (mix of high integrity and low integrity level according to signal type and criticity):

      Some functions are considered as critical, for example: AP disconnect, Hands On detection

      ➔ DAL-A / Monitoring

      Other fuctions are considered as not critical, for example: Push to talk

      ➔ Dal-C simplex

      Partition between critical functions and other fuctions will be frozen during preliminary design phase.
    - Sizing: up to 40 discrete & 10 analogical signals in a volume < 10cm3
    - Max weight: 600 g (including all components and functions)

b) Mock-up for test bench

- Prototype manufacturing
- Integration on inceptor
- Evaluation
    - functional and performance tests
    - Ergonomics (based on TM and pilot evaluations

c) Development of flight equipment (according to evaluation conclusions)

- Definition file
- Manufacturing
- Test

- Test plan and procedures
- Qualification tests

Tasks		
Ref. No.	Title - Description	Due Date
T1	Design phase	T0+6 months
T2	Evaluation (based on prototype)	T0+12 months
T3	Equipment Detailed Design for flight test	T0+16 months
T4	Manufacturing	T0+20 months
T5	Qualification	T0+24 months

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	Title - Description	Type*	Due Date
D1	Preliminary Design Report ➔ Functional analysis, trade-off synthesis, choice recommendations	R	T0+6 months
D2	Evaluation Report ➔Choice justification	R	T0+12 months
D3	Product Requirement Specification (PRS) Including Interface Control Documents	R	T0+16 months
D4	Product Qualification Test Report (QTR)	R	T0+24 months
D5	2 shipsets (shipset = grip Left + Right)	HW	T0+24 months

Milestones (when appropriate)			
Ref. No.	Title - Description	Type*	Due Date
M1	Preliminary Design Review The main objective of M1 is to validate the recommendations of JDP phase.	D	T0+6months
M2	Evaluation Review The main objective of M2 is to validate the technological choices and definition to be developed.	D	T0+12 months
M3	Qualification Plan Review The main objective of M3 is to validate the qualification test plan.	D	T0+18 months
M4	Delivery & Final Acceptance Review The main objective of M4 is to assess final results.	R	T0+24months

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- knowledge on Flight Control System environments
- Konwledge on Ergonomics

5. Abbreviations

JDP	Joint Development Phase
QTR	Qualification Test Report

III. JTI-CS2-2018-CFP08-SYS-02-48: Design and development of a long stroke Piezo Electric Actuator

Type of action (RIA/IA/CSA)	IA		
Programme Area	SYS		
(CS2 JTP 2015) WP Ref.	WP 4.1		
Indicative Funding Topic Value (in k€)	800		
Topic Leader	SAFRAN	Type of Agreement	Implementation Agreement
Duration of the action (in Months)	36	Indicative Start Date (at the earliest)114	Q1 2019

Topic Identification Code	Title
JTI-CS2-2018-CFP08-SYS-02-48	Design and development of a long stroke Piezo Electric Actuator
Short description	
The purpose of this topic is to design and develop a prototype of a long stroke piezo electric actuator with increased stroke and load capabilities. The actuator functionalities and performances will be assessed on a prototype laboratory in order to achieve a TRL4.	

Links to the Clean Sky 2 Programme High-level Objectives115				
This topic is located in the demonstration area:	Electrical Systems			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Long-range			
With expected impacts related to the Programme high-level objectives:				
Reducing CO2 emissions	Reducing NOx emissions	Reducing Noise emissions	Improving EU Competitiveness	Improving Mobility
☒	☒	☐	☒	☒

[114] The start date corresponds to actual start date with all legal documents in place.
[115] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

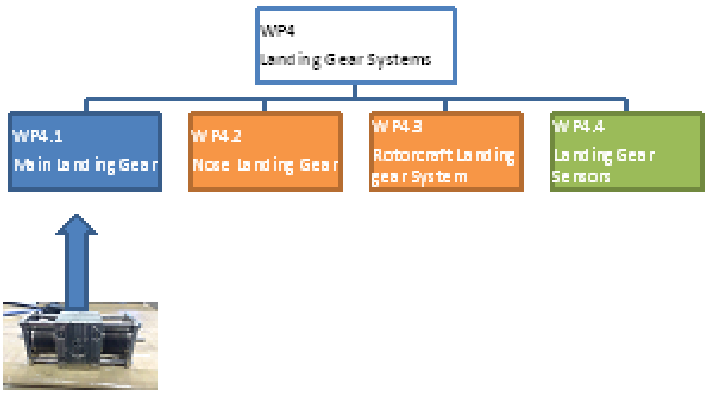
Modern aircraft make use of hydraulic systems that supports many on-board services including flight controls, landing gear and braking systems. Although quite complex, aircraft hydraulic systems have been utilised on aircraft for many years and thus have been highly optimised, which leaves limited potential for performance benefits.

Electric actuation is a research topic that is currently being explored as a possible way to obtain further efficiency gains. A variety of technologies has been considered to support electric actuation, many leading to expensive, heavy or complex solutions. Recent investigations showed that piezo electric actuation technology may be advantageous for Landing Gear (LG) locking actuators, both in terms of performance requirements and weight targets.

Piezoelectric actuators have traditionally been used in applications requiring high positional accuracy and reliability but relatively short strokes e.g. optics, sensors, instrumentation drives etc. Piezoelectric actuators have no sliding parts and do not require lubrication which would have the advantage to reduce the maintenance operations.

The purpose of the proposed research topic is to develop a long stroke actuator based on piezo technology for future A/C locking actuation applications.
Targeted platform is typically the next generation of Single Aisle aircrafts developped in the next decade that are likely to place a far greater emphasis on electrical actuation.

This work will contribute to **WP 4 Landing Gear Systems**, and in particular to WP4.1.1.



The traditional limitations of classical piezoelectric actuator is the limited stroke, which prevents to use this technology in locking/unlocking applications requiring stroke higher than 1mm (e.g. landing gears and their associated doors, cargo doors, cargo handling systems). Today, strokes operations in the range of order of 10 to 100mm are covered by either:

a) A conventional hydraulic actuator supplied by a centralised hydraulic system, which is expensive, complex from an installation and assembly process point of view, and at odds with the current trend to remove hydraulics.
b) Electro-mechanical actuators are expensive and tend to be complex, - with multiple gearing stages - and prone to environmental failures/contamination as they operate in a harsh environment during flight.

When overcoming the current stroke and load capabilities of piezo technology, it will be a suitable alternative to the above "classical solutions".

From a qualitative standpoint, this project will contribute to:
- reduce the number of components within the actuator
- increase the system reliability
- decrease manufacturing costs.

The proposed activity is aligned with the following Systems ITD Strategic Objectives:

Objective	Description	CFP07
Reduction of environmental Impact	Fuel burn reduction thanks to weight saving at system level up to 10%	✓
	Less hydraulic fluid – Reduction of leakage	✓
	Maintenance costs	✓
Enabler for More Electric Aircraft (MEA)	Reduced hydraulic aircraft configuration	✓

2. Scope of work

The project aims at enhancing piezo electric actuation technology in order to achieve the performances needed for future A/C landing gear uplock and downlock systems.

In order to understand the pros, and cons of existing piezo technologies and the related challenges of the application, typical performances of long stroke piezo actuators have been compared in the following spreadsheet :

	Piezo Mechanic Actuators	Piezo Hydraulic Actuators	Unlocking requirements (*)
Max Stroke	0,5mm-2mm	20mm	20mm-40mm
Max Force (blocked)	60N-600N	150N	150N-2000N
Max Speed (blocked free)	0,5-2 m/s	1mm/s	10mm/s-50mm/s
Max Weight	130g-200g	250g-300g approx.	1000g
Pictures			

(*) Due to the fact that unlocking applications cover different ranges of actuation performances, the targets are defined accordingly in the above spreadsheet.

As it can be seen in the above spread sheet, purely mechanical piezo actuators achieve small strokes, at high speed, in small volume. On the contrary, piezo hybrid actuators can achieve long stroke at low speed in higher volumes.

Therefore, the purpose of this research project will be to ensure the scalability of the existing technologies to the application requirements.

Key research areas for potential innovation and performance increase are:

- Investigate alternative power input configurations
- Use of different materials for the basic stack
- Highly dynamic energy storage devices
- Identify new thermal management methods

The technology(ies) and prototype(s) developed within this programme will be required to be compatible with existing landing gear designs both in terms of functionality and space envelopes and with regard to the harsh operating environment within a landing gear bay.

A close co-operation with the selected applicant from the early phase of the project will ensure to identify potential technologies whilst at the same time determining which aspects of the aircraft environment are most critical in the development of these technologies.

The production target platform for this programme shall be the next generation of Single Aisle aircraft being developed in the next decade; these are likely to place a far greater emphasis on electrical actuation than is currently employed by aircraft of this type with the aim of reducing overall fuel consumption and operating costs.

Main Activities

Tasks		
Ref. No.	Title - Description	Due Date
T1	Preliminary studies and concept validation	M1 – M09
T2	Laboratory Prototype Design	M10 – M22
T3	Manufacture of Laboratory prototype	M23 – M29
T4	Testing the Laboratory prototype	M30 – M36

3. Major Deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	Title - Description	Type*	Due Date
D1	Preliminary studies and concept validation report	R	M09
D2	Laboratory prototype specification	R	M22
D3	Laboratory Prototype	HW	M29
D4	Test report	R	M36

**Type: R=Report, D=Data, HW=Hardware*

Milestones (when appropriate)			
Ref. No.	Title - Description	Type*	Due Date
M1	Conceptual Review validated	R	M09
M2	Design Review passed	R	M22
M3	Technology Maturity Review (TRL4) achieved	R	M36

*Type: R=Report, D=Data, HW=Hardware

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Proven experience in the use of Piezo-electric technology in industrial sector such as Aerospace or Automotive.
- Relevant experience in aircraft system integration and installation.
- Experience in collaborative research.
- Relevant experience in multi-disciplinary integration.
- Knowledge of aerospace development, quality standards and certification processes.
- Demonstrated experience in project and quality management in the context of aerospace development.
- Access to a supply chain for all the necessary components and material.

5. Abbreviations

CDR	Critical Design Review
EHA	Electro-Hydraulic Actuator
EMA	Electro-Mechanical Actuator
PDR	Preliminary Design Review
TRL	Technology Readiness Level

IV. JTI-CS2-2018-CFP08-SYS-02-49: Health Monitoring for Electro-Hydraulic Actuator fluid

Type of action (RIA/IA/CSA)	IA		
Programme Area	SYS		
(CS2 JTP 2015) WP Ref.	WP 4.1		
Indicative Funding Topic Value (in k€)	500		
Topic Leader	SAFRAN	Type of Agreement	Implementation Agreement
Duration of the action (in Months)	24	Indicative Start Date (at the earliest)116	01 2019

Topic Identification Code	Title
JTI-CS2-2018-CFP08-SYS-02-49	Health Monitoring for Electro-Hydraulic Actuator fluid
Short description	
The purpose of this research topic is to develop and validate a system to monitor the level of contamination of the aviation hydraulic fluids (e.g. number and size of the particles, the percentage of water, etc.) within a representative aircraft environment. Early detection of unacceptable level of fluid contamination will allow preventing detrimental effects on the equipment lifetime as well as improving efficiency and reducing the costs of maintenance operations. This research targets TRL6 validation	

Links to the Clean Sky 2 Programme High-level Objectives117				
This topic is located in the demonstration area:		Advanced MRO		
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter		Advanced Long-range		
With expected impacts related to the Programme high-level objectives:				
Reducing CO2 emissions	Reducing NOx emissions	Reducing Noise emissions	Improving EU Competitiveness	Improving Mobility
☐	☐	☐	☒	☒

116 The start date corresponds to actual start date with all legal documents in place.
117 For further info see Chapter 1 “Introduction to the Programme Scene Setter / Objectives” with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

In commercial aircrafts, flats, slats, tail plane fins and landing gears, i.e. all kinds of safety-critical mechanical subsystems, are powered by hydraulic actuators. For safety reason the hydraulic fluids used in these subsystems need to be fire resistant. Phosphate-esters fluids, which are widely used for this purpose, are hygroscopic in nature and, moreover, their chemical properties are highly dependent on operation conditions. As a result, their lifetime is highly unpredictable. The performance of the entire aircraft hydraulic system is affected by the condition of the hydraulic fluid and if chemical degradation goes undetected, it may cause downstream mechanical damage to the hydraulic system itself and to its consumers such as flight controls, the landing gear, and the braking system (fluid ageing can lead, amongst other things, to considerably-reduced filter service life, but also to blocking of nozzles and lubrication channels).

Assessing the condition of the hydraulic fluid in an aircraft is laborious, time-consuming, and expensive. The current state of the art in aircraft maintenance is that hydraulic fluid testing is carried out off-line, which means that fluid samples are taken through a dedicated valve, and sent to dedicated laboratories for off-site analysis. Time to get analysis results is typically a few days. For this reason, the fluid is typically tested less than once a year with the risk of unscheduled maintenance if the fluid has exceeded its limits of usage.

These off-line tests mainly consist in checking the fluid cleanliness class according to NAS1638 standard (the hydraulic equipment are usually qualified to operate with a fluid cleanliness class no higher than 9), and the percentage of water in the fluid.

With the development of Electro-Hydraulic Actuators the number of independent hydraulic circuits within the aircraft will be increased, and the problem of detection of the hydraulic fluids contamination and the impact on the maintenance activities will be amplified.

This situation can be improved through the use of on-line measurement means (i.e. use of sensors integrated to the EHA or in-line in the hydraulic circuits) providing results immediately. Periodic measurements on a daily or weekly basis can be used to establish a degradation trend from which innovative aircraft maintenance schemes can be implemented with a large cost savings potential.

Some studies have already been done is the past to monitor two important chemical contamination properties (water and acid) in phosphate-ester hydraulic fluid by non-dispersive infrared (NDIR) optical absorption. However, this requires the construction of a mechanical manifold with sapphire optical windows that is sufficiently strong to sustain the pressures (200–400 bar) inside an aviation hydraulic system.

More integrated solutions to measure fluid characteristics can already be found across a wide range of worldwide industries, including oil and gas production, liquid and gaseous fuels, chemical production, wind and conventional electric power generation, food and beverage, as well as inks used in advanced printing technologies. However these sensors have not been tested with phosphate-ester hydraulic fluids, and are not qualified to work in the harsh aircraft environment.

From a qualitative standpoint, this project will contribute to:

- increase the system reliability
- decrease maintenance costs

The proposed activity is aligned with the following Systems ITD Strategic Objectives:

Objective	Description	CFP08
Improvement of competitiveness: Cost of ownership	Maintenance costs	✓

While such sensors could be used to monitor any type of hydraulic equipment, their usage will be particularly beneficial for EHA, which are not connected to the aircraft hydraulic circuit. Such EHA are often designed as integrated equipment with their own reservoir, so that their fluid will not be controlled through the normal maintenance operation on the aircraft hydraulic circuit. Controlling the fluid in the reservoir will likely only be possible in maintenance shop after removal of the EHA. As a consequence, while the fluid monitoring sensor will allow increasing the reliability of the equipment by detecting any aging of the fluid that may have detrimental effects, they will induce high savings by preventing the removal of the EHA equipment to control the fluid quality.

2. Scope of work

The aim of the project is to monitor the ageing and contamination of aircraft hydraulic fluid (in particular in case of use of EHA) with the objective to anticipate any detrimental effect to the hydraulic system and its components, and to schedule a preventive maintenance operation.

The first part of the project will consist in the identification and evaluation of relevant sensor technologies for the measurement of the properties of the hydraulic fluids (among which the viscosity, the density, the dielectric constant, the relative humidity and the temperature).

The evolution of these properties will then have to be correlated with the various contamination sources of phosphate-esters fluid used on aircraft, including:

- water content (due to the hygroscopic nature of phosphate-esters fluid)
- acidity (as a result of the hydrolysis reaction between phosphate-ester-based fluids and water)
- dissolved air (pressure drops can lead to bubble generation and cause cavitation within the circuit; air in the system will then also result in oxidation of the fluid)
- chlorine (chlorinated solvents may be inadvertently introduced during cleaning procedures; the chlorinated aqueous solutions are highly corrosive)
- particulate matter contamination (following chemical degradation the fluid becomes corrosive and may attack all kinds of metallic parts inside the hydraulic system, which generates particle contamination in the fluid)

This correlation will be performed in 2 steps:

- experimental design tests on controlled samples of fluid (mixed with foreign fluids and different types of contaminant)
- tests on a test bench representative of the aircraft environment

As data are collected from the tests, the algorithms to determine the quality of the fluid and the need for maintenance operation will be developed and tested.

These innovative diagnostic schemes will have to be able to detect changes in the fluid properties:

- that could have detrimental impact on the performances or life of equipment on the circuit (increased erosion, corrosion, damaged due to increased cavitation, …)
- that are the sign of an unpredictable damage on an equipment (excessive wear generating metallic particles in the system for example)

The performance of the system will be measured through correlation of the results against the typical criteria applied to check fluid contamination on aircraft : fluid cleanliness class (number and size of particles as per NAS1638 standard) and percentage of water in the fluid. A level of correlation higher than 90% is targeted.

In parallel, tests will have to be conducted to demonstrate that the selected sensor is capable:

- to withstand the various environmental requirements applicable to aircraft equipment
- to meet the reliability requirements
- to ensure robust data transmission

Main Activities:

Tasks		
Ref. No.	Title - Description	Due Date
T1	Preliminary studies and concept validation	M01 – M03
T2	Experimental Design testing in laboratory	M04 – M09
T3	Tests with representative Aircraft environment (TRL4)	M10 – M15
T4	TRL5/6 demonstration	M16 – M24

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

Deliverables			
Ref. No.	Title - Description	Type*	Due Date
D1	Preliminary studies and concept validation report	R	M05
D2	Experimental testing summary	R	M12
D3	TRL assessment report	R	M24

Milestones (when appropriate)			
Ref. No.	Title - Description	Type*	Due Date
M1	Conceptual Review validated	R	M09
M2	Technology Maturity Review (TRL4)	R	M15
M3	Technology Maturity Review (TRL5)	R	M21
M4	Technology Maturity Review (TRL6)	R	M24

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Experience in sensor technologies for measurement of fluid properties in industrial sectors not limited to Aerospace.
- Experience in collaborative research.
- Relevant experience in multi-disciplinary integration.
- Knowledge of aerospace development, quality standards and certification processes.
- Capabilities to work with aircraft fluids (including phosphate-esters)
- Access to a supply chain for all the necessary components and material.

5. Abbreviations

A/C	Aircraft
EHA	Electro-Hydraulic Actuator
NDIR	Non-Dispersive InfraRed
TRL	Technology Readiness Level

V. JTI-CS2-2018-CFP08-SYS-02-50: Innovative RTM tooling for CFRP primary structural parts

Type of action (RIA/IA/CSA)	IA		
Programme Area	SYS		
(CS2 JTP 2015) WP Ref.	WP 4.2.2		
Indicative Funding Topic Value (in k€)	750		
Topic Leader	Fokker Landing Gear	Type of Agreement	Implementation Agreement
Duration of the action (in Months)	18	Indicative Start Date (at the earliest)[118]	Q1 2019

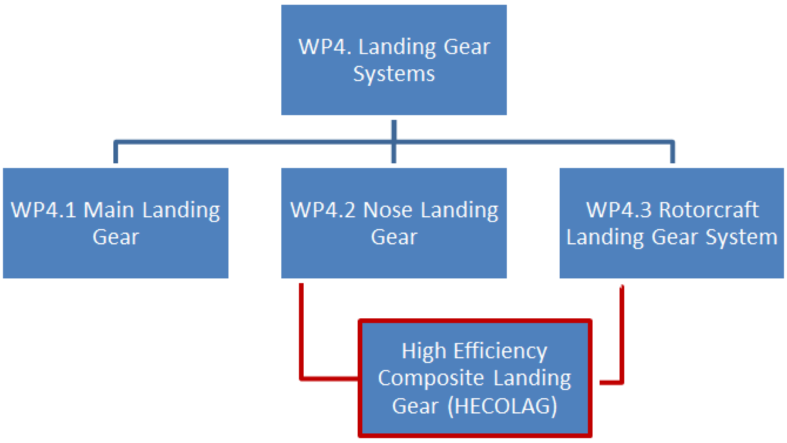
Topic Identification Code	Title
JTI-CS2-2018-CFP08-SYS-02-50	Innovative RTM tooling for CFRP primary structural parts
Short description	
For complex shaped and high performance CFRP structures the metal moulding tools currently in use are complex, heavy and expensive. The topic aims to develop robust, wear resistant, lightweight, low cost tooling with integrated dynamic controlled electrical heating system, that is suitable for high-pressure resin injection processes and complex shaped products.	

Links to the Clean Sky 2 Programme High-level Objectives[119]				
This topic is located in the demonstration area:	Landing Systems, Enabling Technologies, Advanced Manufacturing			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Long-range Compound helicopter Next-Generation Tiltrotor			
With expected impacts related to the Programme high-level objectives:				
Reducing CO2 emissions	Reducing NOx emissions	Reducing Noise emissions	Improving EU Competitiveness	Improving Mobility
☒	☒	☐	☒	☐

[118] The start date corresponds to actual start date with all legal documents in place.
[119] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

Over the years, aircraft have become more light weight, thereby saving fuel and costs and increasing performance, range and capacity. The application of composites has been a great contributor to these more light weight structures. Landing Gear Parts however, being a load carrying and flight critical system conventionally are made from metal, such as aluminium, titanium and/or ultra-high strength steel. Within the WP4.2 and WP4.3 work packages of the Systems ITD, the HECOLAG project (High Efficiency Composite Landing Gear) will develop highly efficient composite landing gear parts, both for large aircraft nose landing gear and helicopter landing gears. Primary goals are the development and demonstration of advanced structural concepts, highly automated production technologies to reduce weight and cost, and a certification strategy that is suited to the use of composite materials in landing gear structures.



The technical feasibility of composite materials in critical landing gear structures has been proven during the last decade, the next challenge is currently to achieve to not only higher weight and cost efficiency, but also larger sizes. Since the use of high-pressure resin injection manufacturing technologies or resin transfer moulding (RTM) is key to achieving the required quality and affordability, larger component sizes also result in larger and heavier tools. But large tools then become bottlenecks in the manufacturing chain, due to their high weight which results in handling and cleaning difficulties, high energy consumption (for both heating and cooling) and expensive equipment setups. In the automotive industry, the use of these types of large tools and manufacturing methods is becoming more common for the next generation of "light weighted" cars. However, the relatively low manufacturing rates and the higher safety requirements of aerospace products make the investment in equipment less affordable. Therefore, RTM tooling for large products requires investigation in other technologies.

Injection tools are traditionally machined from metal blocks (steel, invar, etc), forming an upper and a lower mould, with a product cavity in between that is sealed at the joint. The product dry fibre preform is placed in these tools and after closing (using bolts, press or other means) is heated and injected with resin. The resin then cures in the mould at high temperature and is released for further processing after cool-down. In case of more complex (hollow) products, internal cavities are present and inner tools (or mandrels) are needed that can be fixed accurately in the required position and released from the product after injection and cure. With increasing size of CFRP products, the size and weight of metal tools make them costly, cumbersome to handle, inefficient to heat and cool, noting that thermal expansion differences with CFRP parts become an issue. Therefore, more innovative tooling methods are to be investigated that use tooling materials such as CFRP, polymer/elastomer (or hybrid). These should possibly incorporate heating and/or cooling elements that can be controlled dynamically (for instance electrically). Such tools should enable lower cost of manufacturing processes by using less energy, shorter processing cycles, minimize negative effects of differences in thermal expansion, and allow more flexible production processes.

2. Scope of work

In close collaboration with the HECOLAG partners, the applicant shall develop new or improved tooling concepts (including materials and processes) for large (up to 2x0.75m) RTM products containing internal cavities. The innovative tooling shall be able to withstand high injection pressures (up to 20 bars), operate in industrial manufacturing environments with manufacturing rates of up to 500 parts/year. The innovative tooling shall allow achieving significant reduction of energy consumption, improved handling (e.g. limiting the need for expensive equipment), modularity, flexibility of re-use (e.g. to manufacture product variants with the same set of tools). Target applications are large CFRP components (with associated low CTE).

The proposed innovative tooling concept shall be demonstrated on a composite landing gear component developed within the HECOLAG project. This will be a complex shape, hollow CFRP part with an approximate size of 1900x500x200mm (full specifications will be provided after partner selection). The benefits and performance of the new tooling concept will be compared to the baseline tool developed within the HECOLAG project.

Tasks		
Ref. No.	Title - Description	Due Date
T1	RTM tool concept design and selection	T0+3M
T2	RTM tool design	T0+8M
T3	RTM tool manufacturing	T0+13M
T4	RTM tool test and verification	T0+15M
T5	RTM tool demonstration	T0+18M

Improved tooling concepts and tooling materials shall be identified and described, based on geometric and process requirements defined by the Topic Manager. The aim of the improved concepts and materials is to reduce product manufacturing cost, by reduced tool weight, heating/cooling energy consumption, product flexibility. At the same time, the concept and materials must be cost-efficient and suitable for aerospace production environments.

Successively a detailed design of the selected concept shall be worked out. This will encompass material testing (to verify material suitability to process parameters) and execution of the relevant analyses, such as thermal aspects and deformation. The Topic Manager will contribute to the design phase and provide requirements and key design parameters for the development (e.g. product shape and geometry, process boundaries and product material types).

The participant shall manufacture the RTM tool and perform all relevant tool testing and tool verifications (geometry checks, thermal surveys, pressure/vacuum checks).

Finally, the RTM tool shall be used to manufacture one (or more) demonstration products with a view to validate the performance of the RTM tool. The Topic manager will provide the dry fibre preform to be used as well as the process specifications.

The applicant shall elaborate on the results of the checks and demonstration of the RTM tool will, as well as on the comparison with the baseline tool.

3. Major Deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	Title - Description	Type*	Due Date
D1	Improved RTM tool concept description	R	T0+3M
D2	RTM tool technical data package containing design description, mechanical and thermal analysis results, materials description	R	T0+8M
D3	RTM tool test and verification report	R	T0+18M

**Type: R=Report, D=Data, HW=Hardware*

Milestones (when appropriate)			
Ref. No.	Title - Description	Type*	Due Date
M1	Tool design completed		T0+8M
M2	Tool manufacturing completed		T0+13M
M3	Final reporting completed		T0+18M

**Type: R=Report, D=Data, HW=Hardware*

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Proven experience in tools and tool materials for RTM processing suitable for series production, aerospace experience will be benificial
- Knowledge of aerospace products, development, quality requirements.
- Experience in the development of RTM tools, including the use of composite tool materials (such as elastomers or shape memory polymers), experience with integrated heating/cooling methods will be beneficial.

5. Abbreviations

CFRP	Carbon Fibre Reinforced Plastic
CS25	Certification Specification of large aeroplanes (EASA)
CSJU	Clean Sky Joint Undertaking
CTE	Coefficient of Thermal Expansion
HECOLAG	High Efficiency Composite Landing Gear
ITD	Integrated Technology Demonstrators
RTM	Resin Transfer Molding
WP	Work Package

VI. JTI-CS2-2017-CFP08-SYS-02-51: Innovative quality inspection methods for CFRP primary structural parts

Type of action (RIA/IA/CSA)	IA		
Programme Area	SYS		
(CS2 JTP 2015) WP Ref.	WP 4.2		
Indicative Funding Topic Value (in k€)	750		
Topic Leader	FLG	Type of Agreement	Implementation Agreement
Duration of the action (in Months)	24	Indicative Start Date (at the earliest)[120]	Q1 2019

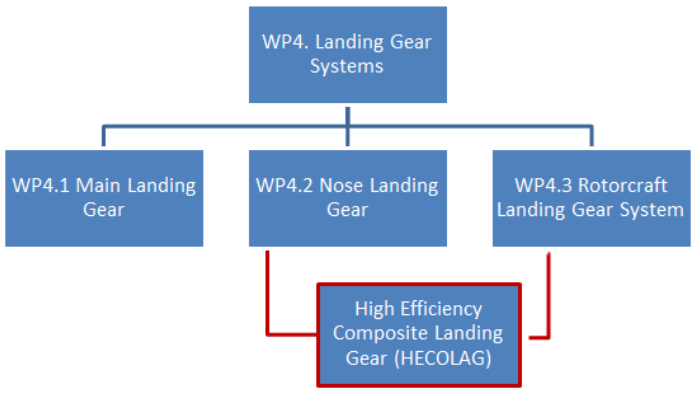
Topic Identification Code	Title
JTI-CS2-2017-CFP08-SYS-02-51	Innovative quality inspection methods for CFRP primary structural parts
Short description	
Development of new NDI methods and/or techniques capable of inspecting the more complex features associated with the development of highly efficient composite landing gear parts. The objective is to reliably detect anomalies in complex structures and demonstrate qualification, in a cost-efficient way, suitable for a production environment.	

Links to the Clean Sky 2 Programme High-level Objectives[121]				
This topic is located in the demonstration area:	Landing Systems, Enabling Technologies, Advanced Manufacturing			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Compound helicopter Next-Generation Tiltrotor Advanced Long-range			
With expected impacts related to the Programme high-level objectives:				
Reducing CO2 emissions	Reducing NOx emissions	Reducing Noise emissions	Improving EU Competitiveness	Improving Mobility
☒	☒	☐	☒	☐

[120] The start date corresponds to actual start date with all legal documents in place.
[121] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

Over the years, aircraft have become more lightweight, thereby saving fuel and costs and increasing performance, range and capacity. The use of composite materials has been a great enabler for these more lightweight structures. However, load carrying and flight critical system such as Landing Gear Parts are traditionally made of metal such as aluminium, titanium and/or ultra-high strength steel. Within the WP4.2 and WP4.3 work packages of the Systems ITD, the HECOLAG project (High Efficiency Composite Landing Gear) will develop highly efficient composite landing gear parts, both for large aircraft nose landing gear and helicopter landing gears. Primary goals are the development and the demonstration of advanced structural concepts, highly automated production technologies to reduce weight and cost, and a certification strategy that is suited to the use of composite materials in landing gear structures.



An important aspect in the certification and manufacturing of highly efficient composite landing gear parts is the use of Non Destructive Inspections (NDI). The application of NDI ensures that the manufactured composite parts conform to the intended and certified design. However, the current requirement for detailed NDI on all manufactured components is also a significant cost driver. To qualify the NDI technique, i.e. to ensure that the NDI technique being used is reliable and capable of finding deviations from the intended design, empirical trials are performed, covering equipment, operators, and a range of defects, damages and deviations. The inability to reliably detect anomalies, i.e. lack of confidence in design compliance, results in additional material, and consequently weight, in order to mitigate the risk of deviations. Currently the most established NDI technique for CFRP components (after manufacturing) is ultrasonic C-scan inspection, which has proven to be reliable in detecting characteristic defects for traditional composites (such as delamination). However, the complex shapes and large thicknesses of the landing gear components developed within HECOLAG require more advanced scanning and defect detection methods than currently available, for instance using phased array techniques and more advanced data processing. The availability of such methods would enable detection and sizing of defects in complex geometries at higher reliability, leading to lower component weight and paving the way to higher automation (for instance using robots). This may help reducing the recurring cost associated to scanning of complex shapes using traditional methods, thus generating a significant effect on the serial cost of these innovative products.

2. Scope of work

Goal of this topic is for the applicant to develop (in close collaboration with the HECOLAG partners) new or improved NDI methods and/or techniques, capable of performing reliable inspections on complex features (associated with composite landing gear parts) with a high degree of automation (both in scanning and data analysis / evaluation). The partner shall also validate the new or improved NDI methods and/or techniques against the requirements that are applicable in civil aerospace structures (such as CS25). The new methods and/or techniques must be cost efficient (through e.g. automation of scanning and data analysis) and suitable for application within a production environment.

The applicant shall initially validate the improved NDI method on characteristic test samples through a comparison with reference tests. If successful the application shall demonstrate the NDI method on composite landing gear components developed in WP4.2 (by the HECOLAG partners), such that the results can be used in improved designs for the WP4.3 demonstrator components.

Tasks		
Ref. No.	Title - Description	Due Date
T1	Development of improved NDE methods (compared to state of the art)	T0+6M
T2	Inspection plan definition	T0+9M
T3	Inspection demonstration	T0+21M
T4	Inspection validation and reporting	T0+24M

The applicant shall identify and describe the improved NDI methods and/or techniques, based on requirements defined by the TM. The requirements will focus on the ability to reliable inspect more complex features associated with highly efficient composite landing gear parts, such as large laminate thickness (up to 50mm), high local curvatures combined with non-parallel surfaces (up to 10°), integrated T-joints, one-sided access (due to internal cavities). In addition, the method shall also be cost-efficient and suitable for a production environment. Examples of improved methods are more advanced use of phased array transducers (supported by simulation of beam propagation in complex laminates), automated data processing/defect detection and more extensive use of robots.

In order to test and validate the improved methods, the applicant shall document inspection plans describing the NDI methods and techniques required/applied, the test samples, the equipment to be used and the equipment settings, anomaly standards, test conditions, etc. The aim of the inspection plans is to determine to what extent the manufacturing defects types at certain sizes (for instance delamination, porosity, fibre waviness for a range of characteristic geometrical configurations) and in-service damages (for instance impact) are detectable using the improved methods. The Topic Manager will provide the materials, the definition of geometric features and the defect type (and size) for the applicant to develop the appropriate inspection plans.

The defined inspection plan shall be executed on characteristic samples of composite landing gear parts provided by the Topic Manager, to validate the performance of the improved inspection methods. The improved inspection method shall also be applied on full-scale demonstrator components developed and manufactured by the HECOLAG partners in WP4.2, to validate the methods on realistic full-scale hardware and to check automation potential.

For validation purposes, the test resulting from the application of the improved NDI method will be compared with reference tests (for instance radiographic CT scan) and duly reported.

3. Major Deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	Title - Description	Type*	Due Date
D1	Improved NDE description	R	D1
D2	Inspection plans	R	D2
D3	Inspection test report	R	D3
D4	Inspection demonstration and validation report	R	D4

**Type: R=Report, D=Data, HW=Hardware*

Milestones (when appropriate)			
Ref. No.	Title - Description	Type*	Due Date
M1	Improved NDI and inspection plans complete		T0+9M
M2	Inspection tests complete		T0+21M
M3	Validation complete		T0+24M

**Type: R=Report, D=Data, HW=Hardware*

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Good knowledge in defect characterisation, detection and inspection technologies, including advanced data analysis techniques to detect material anomalies in composite materials (such as fiber waviness and undulation, porosities, etc), experience in the aerospace sector will be benificial
- Knowledge of aerospace development, inspection standards and inspection qualification processes.
- Proven experience in qualification and verification strategies for inspecting complex composite structures such as civil aircraft structures (CS25/FAR25).
- Experience in the development of innovative NDI methods and techniques, experience in inspection simulation and industrial application will be beneficial.

5. Abbreviations

CFRP	Carbon Fibre Reinforced Plastic
CS25	Certification Specification of large aeroplanes (EASA)
CSJU	Clean Sky Joint Undertaking
HECOLAG	High Efficiency Composite Landing Gear
ITD	Integrated Technology Demonstrators
NDI	Non Destructive Examination
WP	Work Package

VII. JTI-CS2-2018-CFP08-SYS-02-52: Innovative Composite Material Qualification Methodologies

Type of action (RIA/IA/CSA)	IA		
Programme Area	SYS		
(CS2 JTP 2015) WP Ref.	WP 4.2		
Indicative Funding Topic Value (in k€)	1000		
Topic Leader	FLG	Type of Agreement	Implementation Agreement
Duration of the action (in Months)	24	Indicative Start Date (at the earliest)[122]	Q1 2019

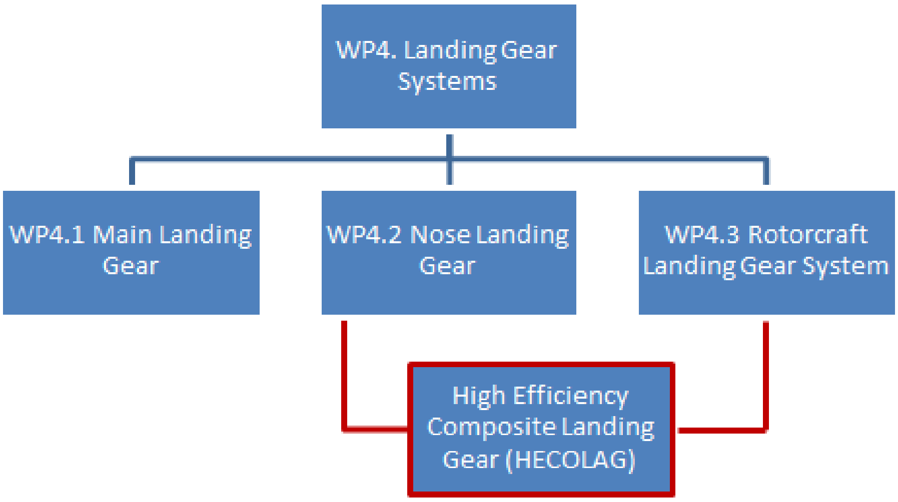
Topic Identification Code	Title
JTI-CS2-2018-CFP08-SYS-02-52	Innovative Composite Material Qualification Methodologies
Short description	
Development and validation (testing) of a new material qualification and test methods of new composite materials in safety critical single load path aircraft structures. The aim is to reduce the number of material tests required, without compromising confidence level, robustness and reliability of the material allowables.	

Links to the Clean Sky 2 Programme High-level Objectives[123]				
This topic is located in the demonstration area:	Landing Systems			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Compound helicopter Next-Generation Tiltrotor Advanced Long-range			
With expected impacts related to the Programme high-level objectives:				
Reducing CO2 emissions	Reducing NOx emissions	Reducing Noise emissions	Improving EU Competitiveness	Improving Mobility
☒	☒	☐	☒	☐

[122] The start date corresponds to actual start date with all legal documents in place.
[123] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

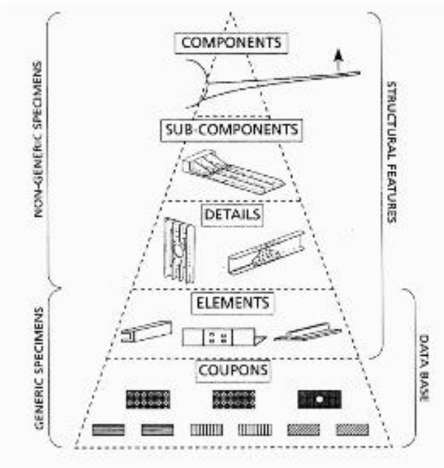
1. Background

Over the years, aircraft have become more light weight, thereby saving fuel and costs and increasing performance, range and capacity. The application of composites has been a great contributor to these more light weight structures. Landing Gear parts however, being a load carrying and flight critical system, conventionally are made from metal such as aluminium, titanium and/or ultra-high strength steel. Within the WP4.2 and WP4.3 work packages of the Systems ITD, the HECOLAG project (High Efficiency Composite Landing Gear) will develop highly efficient composite landing gear parts, both for large aircraft nose landing gear and helicopter landing gears. Primary goals are the development and demonstration of advanced structural concepts, highly automated production technologies to reduce weight and cost, and a certification strategy that is suited to the use of composite materials in landing gear structures.



One of the issues preventing the introduction of lightweight and cost effective composite primary structural parts is the need to perform a large number of material tests supporting the design. These are currently required to reliably determine material allowables with high confidence levels associated to the use in single load path safety critical structures. These allowables need to be determined for a large range of material parameters, much more than would be the case for traditional metals. The reason for this is that composite materials have many additional material parameters that are not applicable to metals, such as fibre stacking orientation, stacking sequence, fibre and resin type, fibre volume fraction, effects of temperature, moisture and impacts.

Traditionally these properties are determined following a so-called Building Block Approach (see figure, ref CMH17), where testing is performed at multiple levels with the aim to ensure high robustness of design parameters (resulting in a high safety level). Using this method, only a few tests are performed on large integrated (and thus costly) structures such as wing, fuselage and empennage. More tests are performed on sub-assemblies of those structures (e.g. complex joints). This goes up in the range of hundreds of tests on simplified but typical elements (ply drops or simple joints) and thousands of tests at laminate (material) level to characterize the basic properties and their variability. The lower level tests are required because demonstrating the required reliability (so called A-basis or B-basis) at higher building block level would require many complex tests and high cost, while risks would remain high until the structure is fully tested with the required number of replicates. For each material used, lower level building block test data must be generated for all relevant properties, at all relevant environments, in all relevant combinations and in sufficient numbers (replicates) to demonstrate the required reliability.



For single load path structures (such as landing gears) where no load redistribution is possible after failure of one element, the required reliability is higher (A-basis, showing 99% probability with 95% confidence interval) than for most other aircraft structures such as wing, fuselage or empennage (B-basis, showing 90% probability with 95% confidence interval). This creates the necessity to test very large test matrices, with many replicates and batches for coupons and elements in all potential combinations of material, layup, environment, load type, impact or damage presence, etc. This requirement is a large hurdle in the development of innovative composite landing gear structures, since any change of material, or improvement of design (to reduce weight or cost), will create the need to test a large number of additional samples.

Therefore, there is a strong need to develop an improved qualification approach, i.e. a combination of analysis and test, where material and element properties are determined in such a way that variations in the design or material can be qualified with limited additional testing. The approach of combining advanced analysis and simulation methods, statistical methods and correlation techniques can be used to explore more efficiently the design space, correlate it with test results and validate the models using different test data sets. Such an approach would create the ability to allow for larger variation in design and layup of composite structures, quicker introduction of new and improved materials/design concepts and wider application of such structures.

Improved material qualification methods have already been investigated for traditional composite aerospace structures, but currently do not exist for single load path structures such as landing gears. Application of existing methods is not straightforward, due to the more stringent requirements in terms of reliability levels, product complexity (geometric constraints and high load levels), wall thicknesses and thickness variations, and environmental conditions (such as impact).

2. Scope of work

Aim of the improved single load path material qualification method is to reduce the lead-time and cost associated to material qualification for single load path structures and allow for more design flexibility.

In close collaboration with the HECOLAG partners, the applicant shall develop improved methods for material qualification that perform better than the traditional building block method (identified as current baseline) without reducing reliability. The method shall be test validated to ensure applicability and to show equivalence to the baseline method (traditional building block approach). The method shall allow a reduction in the required number of tests without compromising material characterization, robustness and reliability of the material allowables. The improved material qualification method must be suitable to be used in the next generation of primary single load path composite aircraft structures and systems (as developed in WP4.2 and WP4.3), using the material system (CFRP using textile preforms and RTM) and design features used by the Topic Manager.

Tasks		
Ref. No.	Title – Description	Due Date
T1	Improved qualification method definition and description (with comparison to state of the art)	T0+5M
T2	Material test plan describing the type, number and method of tests at coupon and element level, also identifying samples for correlation and samples for validation	T0+8M
T3	Material test and reporting	T0+20M
T4	Correlation of method with test data	T0+21M
T5	Validation of method with validation data	T0+23M

The innovative method should reduce the number of tests required for qualification, taking into account all relevant material parameters for complex composite laminates. Applicants will define and describe the new material qualification method, based on both current state-of-the-art and requirements as specified by the Topic Manager. To show the benefits of the new method, a comparison to the baseline building block and current state-of-the-art methods must be carried out, as well as a description of the proposed analytical, statistical and test methods to be used.

The validity of the improved method shall be demonstrated through a number of tests and against the performances of the baseline methods . Applicants shall define a Material Test Plan describing all tests and analysis methods required for correlation and validation. The description shall include test methods, test article configurations, number of replicates per test, test conditions, etc. The test plan shall include a sufficient number of physical tests to be able to demonstrate the validity of the improved method. The Topic Manager will provide the material definition and the relevant material parameters to be used with a view to ensure applicability of the method to the structures developed within WP4.2 and WP4.3.
Applicants are also encouraged to propose and develop alternative and innovative approaches that will be evaluated and may be adopted by the HECOLAG partners. For instance, methods to automate test activities (for instance, sample size checks using optical methods), or advanced material analysis methods may be of interest.

In order to enable valid comparison with existing methods and data currently used (building block method with associated test data), the relevant material test samples must be manufactured using materials and processes specified by the Topic Manager (CFRP using textile preforms and RTM), at a quality level that is in line with aerospace quality standards.

Correlation analyses for relevant test samples will be performed in close cooperation with the Topic

Manager, to ensure that the methods fit the objectives of the relevant WP (Calibration). Applicants will report the correlation results with and without calibration. The applicant and Topic Manager will cooperatively establish a plan to perform additional characterization tests or modification of the analysis methods, should the calibration fail to meet a pre-defined tolerance target.

Finally, applicants will validate the new approach against criteria such as performance and suitability to the targeted application. Validation will compare the new models with test results using the calibration factors previously identified, so that the new material qualification method is validated.

3. Major Deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	Title - Description	Type*	Due Date
D1	Improved method description	R	T0+5M
D2	Material test plan (including test matrix, test methods, analysis algorithms, correlation methods, validation methods, etc)	R	T0+8M
D3	Material test report	R	T0+20M
D4	Correlation and validation report	R	T0+24M

*Type: R=Report, D=Data, HW=Hardware

Milestones (when appropriate)			
Ref. No.	Title - Description	Type*	Due Date
M1	Methods and plans complete		T0+8M
M2	Testing complete		T0+20M
M3	Validation complete		T0+24M

*Type: R=Report, D=Data, HW=Hardware

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Proven experience in composite material characterisation and test technologies, such as described in CMH-17, aerospace experience is beneficial.
- Knowledge of aerospace development, quality standards and certification processes.
- Extensive knowledge of and preferably proven experience in certification and validation strategies for composite civil aircraft structures (CS25/FAR25), including the application of statistical methods and other methods relevant for certification and validation.
- Experience in the development of methods, such as material analysis methods, statistical methods, etc.

5. Abbreviations

CFRP	Carbon Fibre Reinforced Plastic
CMH17	Composite Materials Handbook
CS25	Certification Specification of large aeroplanes (EASA)
CSJU	Clean Sky Joint Undertaking
FAR25	Federal Aviation Regulations for transport category airplanes
HECOLAG	High Efficiency Composite Landing Gear
ITD	Integrated Technology Demonstrators
RTM	Resin Transfer Molding
WP	Work Package

VIII. JTI-CS2-2018-CFP08-SYS-02-53: Development of an optimized DC-DC converter for a smart electrical system

Type of action (RIA/IA/CSA)	IA		
Programme Area	SYS		
(CS2 JTP 2015) WP Ref.	WP 5.2		
Indicative Funding Topic Value (in k€)	700		
Topic Leader	Safran	Type of Agreement	Implementation Agreement
Duration of the action (in Months)	18	Indicative Start Date (at the earliest)[124]	Q1 2019

Topic Identification Code	Title
JTI-CS2-2018-CFP08-SYS-02-53	Development of an optimized DC-DC converter for a smart electrical system
Short description	
In the context of the More Electrical Aircraft, the purpose of this topic is to develop an optimized and compact bidirectional modular DC/DC converter to be used in a smart electrical system.	

Links to the Clean Sky 2 Programme High-level Objectives[125]				
This topic is located in the demonstration area:		Electrical Systems		
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter		Advanced Long-range Ultra-advanced Long-range		
With expected impacts related to the Programme high-level objectives:				
Reducing CO2 emissions	Reducing NOx emissions	Reducing Noise emissions	Improving EU Competitiveness	Improving Mobility
☒	☒	☐	☒	☒

[124] The start date corresponds to actual start date with all legal documents in place.

[125] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

The growing demand for electrical energy on board, calls for exploring the optimization potential of aircraft electrical systems. Traditionnally electrical systems have been re-used from past programs with little attention to the progress made on the integration of power electronics with mechanical systems (mechatronics). The combination of the two research branches may deploy large optimization potential and generate opportunities for remarkable improvement of system performances. This multidisciplinary approach paves the way to innovative system architectures and optimized configurations that lead to remarkable prerfomance improvements.

One example of how such an multidisciplinary appraoch can provide valuable benefits in terms of mass and volume footprint reduction is the following:

- an electrical system composed of a primary source (mechanical, such as an electric generator driven by a mechanical primary mover) and
- a secondary source placed either in series or in parallel with the primary source and consisting of an electrical storage system and a conversion system.

The overall system weight will be lower thanks to the decreased complexity surrounding the installation and the integration of large electrical generators (either on engine gearboxes or for the Ram Air Turbine).

The secondary may supports to the primary during corner conditions or peak transients allowing the primary source to be fine-tuned in size, thus creating significant mass and volume reduction at aircraft level.

The secondary may use current or alternative storage technologies, in which case, it will use a converter (the object of this program) to link storage (usually low voltage) to the aircraft distribution system (usually a higher voltage).

In order for this architecture to be attractive, power density and modularity of the power electronics (especially DC/DC converters) need enancements beyond the current State of the Art.

Many topologies exist for DC/DC converters however, none currently meets the power densities required to make these new architectures competitive. The target of this study is to design a modular DC/DC bidirectional converter (LVDC to HVDC, 4-30kW) that is highly efficient (>96% efficiency to mitigate thermal issues) and achieves non-packaged power densities of over 5kW/kg.

This converter could also be used to improve network power quality using hybridation with supercapacitors or batteries, to deliver or absorbe load transients (flight control actuators for exemple). To be able to meet those challenging requirements, the voltage variation range has to be increased and the dynamics must be fast enough.

It is therefore a requirement for this topology to use wide bandgap semiconductors (GaN for LVDC and SiC for HVDC) and/or soft switching in order to increase switching frequency and reduce the size and mass of all passive components (Capacitors, inductors, transformers).

Finaly, this topology must be robust to single failures and allow reconfiguration by using the modularity of the elementary converters.

The proposed innovative topology will contribue to :

- Reduce losses (soft switching and wide bandgap semiconductors)
- Reduce weight (passive component and thermal management)
- Increase availability
- Improve network power quality and easy network reconfiguration

State of the Art (ref. [126],[127]) use Si MOSFET technology on LVDC side with a 100 kHz switching frequency. GaN technology will allow switching at higher frequencies, reducing passive components, increasing control bandwith and reducing response time on transients. These new technology, associated with soft switching, will contribue to increase efficiency and power density (actually 3.6 kW/kg at peak power with the heatsink).

A list of requirements is provided :

- environmental and climatic conditions –reference is RTCA DO-160G procedure
- EMI constraints (RTCA DO-160G procedure) are an essential part of this study
- The converter shall respect REACH and RoHS environnemental requirements
- DC voltage Power quality compliant with MIL-STD-704F standard
- Voltage control accurency +/- 1%
- Current control accurency +/- 3%
- Load transient: Voltage variation < 10%
- Load transient: response time < 10ms
- Converter compatible for permanent or pulsed operation with thermal management adaptation
- Electrical insulation between HVDC and LVDC (2500 Vrms dielectric strengh)
- Safety: HVDC/LVDC insulation Fault < 10-9
- Safety: Loss off total fonction < 10-5
- Power density > 5 kW/kg without packaging and thermal management
- Efficiency > 96 % (from half to full power)

The TM will provide more detailled technical specifications for the converter development during the project.

The final prototype shall withstand aeronautical constraints for qualification, be representative of the final product's mass and volume and be able to deliver its performance within its operational environmental enveloppe. The prototype development shall consider requirements for future industrialization.

2. Scope of work

[126] Development of a 12 kW isolated and bidirectional DC-DC Converter dedicated to the More Electrical Aircraft: The Buck Boost Converter Unit (BBCU)" PCIM 2016

[127] Optimisation d'une structure de conversion DC-DC réversible pour application aéronautique" HAL Id: hal-01361595)

Tasks		
Ref. No.	Title - Description	Due Date
T1	Specification analysis Perform common analysis of technical specification: clarification, compliance matrix and update proposal.	T0 + 2 months
T2	Architecture proposal Evaluate the compliance of current technologies and existing OTS components (aerospace or other domains) with the technical specification (several architecture acceptable)	T1 + 2 months
T3	Preliminary Design Review Specification of components (especially magnetics) Preliminary major analyses (as determined by the applicant) 3D Digital Mock Up	T1 + 3 months
T4	Detailed design phase Component choices, layout and 3D model Relevant analyses to ensure performance Equipment detailed description	T3 + 6 months
T5	Prototype Manufacturing Delivery of a functional prototypes and associated test data validating the performance metrics.	T4 + 5 months

3. <u>Major Deliverables/ Milestones and schedule (estimate)</u>

Deliverables			
Ref. No.	Title - Description	Type*	Due Date
D1	Compliance matrix and non-compliance justification	R	T1
D2	Architecture overview	R	T2
D3	3D Model	R/D	T3
D4	Performance simulation report	R/D	T3
D5	Detailed analyses report	R	T4
D6	Prototypes	HW	T5

**Type: R=Report, D=Data, HW=Hardware*

Milestones (when appropriate)			
Ref. No.	Title - Description	Type*	Due Date
M1	Technical Specification Review	R	T1 + 1 month
M2	Architecture presentation	R	T3 + 1 month
M3	Detailed design presentation	R	T4 + 1 month
M4	Prototype Inspection Review	HW	T5 + 1 month
M5	Project ending meeting	R	T5 + 2 month

**Type: R=Report, D=Data, HW=Hardware*

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Good knowledge in Power Electronics design and manufacturing, in particular for high current and high frequency converters and transformers
- Knowledge on Mechatronics AND thermal integration; automatism and control;
- Knowledge of aeronautics requirements (DO160)
- Expertise on EMI
- Capability to realize prototypes and perform functional and normalized tests according to DO160 with power supply up to 600A

5. Abbreviations

ADC	Ampere Direct Current
EN	European Standard
FMEA	Failure Modes and Effects Analysis
FTA	Fault Tree Analysis
GaN	Gallium Nitride
HVDC	High Voltage Direct Current
LVDC	Low Voltage Direct Current
ISO	International Organization for Standardization
OTS	Off-the-Shelf
REACH	Registration, Evaluation and Authorisation of Chemicals
ROHS	Restriction Of Hazardous Substances
RTCA	Radio Technical Commission for Aeronautics
SiC	Silicon Carbide

IX. JTI-CS2-2018-CFP08-SYS-02-54: Development of a HVDC current limiter

Type of action (RIA/IA/CSA)	IA		
Programme Area	SYS		
(CS2 JTP 2015) WP Ref.	WP 5.3.1		
Indicative Funding Topic Value (in k€)	650		
Topic Leader	Zodiac Aero Electric	Type of Agreement	Implementation Agreement
Duration of the action (in Months)	24	Indicative Start Date (at the earliest)[128]	Q1 2019

Topic Identification Code	Title
JTI-CS2-2018-CFP08-SYS-02-54	Development of a HVDC current limiter
Short description	
The purpose of this research work is to design and develop a HVDC current limiter prototype. The work encompasses design, performance simulation and prototype testing of an HVDC current limiter. The targeted application is Large Aircraft HVDC Power management centre. The prototype shall be validated up to TRL6.	

Links to the Clean Sky 2 Programme High-level Objectives[129]				
This topic is located in the demonstration area:		Electrical Systems		
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter		Advanced Long-range Ultra-advanced Long-range		
With expected impacts related to the Programme high-level objectives:				
Reducing CO2 emissions	Reducing NOx emissions	Reducing Noise emissions	Improving EU Competitiveness	Improving Mobility
☒	☒	☐	☒	☐

[128] The start date corresponds to actual start date with all legal documents in place.
[129] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

A constant and gradual increase of the electrification of aircrafts has been seen since last decade. The More Electric Aircraft (MEA) could be a great source of improvements, bringing reduced environmental impact, rationalisation of maintenance costs and better energy management. New architectures of aircraft electrical network, such as the electrical distribution of a High Voltage DC network, show high innovation potential. However, their actual adoption poses some significant challenge such as e.g. the development of protection systems, which needs to be adequately addressed.

A typical aircraft electrical distribution architecture is composed of a main power source (motors, auxiliary power unit, ram air turbine, batteries and park power plant) followed by distribution/protection components that are usually active switching components driven by electronics (RCCBS or SSPC for instance) or electromechanical components. Distribution/protection components supply and protect different types of loads that can be either motors, actuators, bleed systems, resistive systems, power electronics...

Each load has its own characteristics. In case of a load having a capacitance behaviour and after the associated distribution/protection components is being closed, a high current is propagated through the distribution/protection component to the load. In case of short-circuit occurring on a load while the distribution component is in close state, an even higher current is propagated from the source to the load, through the distribution/protection device. These are two examples of constraints that are key design drivers for the all electrical power chain, as each one of the components between the source and the load have to withstand the constraints. It follows that the use of a component with the ability to limit the current can be of great interest for the optimisation of the power chain, reducing the weight and the power dissipation of all components. Fault-current limiter already exists within industrial sector, for medium and high voltages electrical distribution. The voltage levels are generally beyond 6,6kV and the level of distributed power is much more important than the one that can be found within current and MOE architectures. Some current limiting products are available for aircraft HVDC applications but they behave like fuses with much longer blowing time. There is an emerging need to develop a scalable current limiter with a performance profile showing very small impedance at nominal operating conditions (contrary to the fuse, which can dissipate a lot of heat) and a fast increase of impedance during fault conditions.

The objective of this topic is to develop an optimized current limiter to be integrated in an HVDC aircraft power distribution center. The current limiter environment will be very hot (ambient temperature above 100°C for normal operating conditions) and with a small amount of available volume for cooling, the current limiter will have to provide low losses (only few tens of watts). The need for a passive and configurable solution will have to be thoroughly studied (current sensing, short-circuit detection, power components driving, saturable components etc.) The challenges will consist in providing a simple, effective, low volume and low losses solution.

2. Scope of work

The objective of this task is to develop, simulate, test and deliver a current limiter component for an HVDC bus. This current limiter will have the following characteristics:

- HVDC network capability
- Low level of losses
- Passive solution, the current limitation value being set during design
- High level of integration (volume and weight)

- Capability to withstand electrical power center environment
- Scalable definition to be adapted for low level of currents (from 100A) as for high level of current (up to 300A)

The current limiter will be tested within an equipment for a TRL6 demonstration. The applicant shall demonstrate the technological gaps required to cover the complete range of current if a single technology cannot cover the complete range.

Tasks		
Ref. No.	Title - Description	Due Date
T1	Current limiter prototype definition	T0+6 Months
T2	Manufacturing and stand-alone prototypes testing according to current limiter specification	T0+12 Months
T3	Update of current limiter definition. Detailed design	T0+16 Months
T4	Manufacturing and final version testing according to Current limiter specification	T0+22 Months

3. Major Deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	Title - Description	Type*	Due Date
D1	Current limiter prototypes definition and specifications	R	T0+6
D2	Technical synthesis and prototypes validation test report	R	T0+13
D3	Prototypes delivery	HW	T0+13
D4	Detailed design refinement	R	T0+16
D5	Report on the current limiter validation test and TRL6 demonstration	R	T0+24
D6	Delivery of the current limiter	HW	T0+24

*Type: R=Report, D=Data, HW=Hardware

Milestones (when appropriate)			
Ref. No.	Title - Description	Type*	Due Date
M1	Current limiter prototypes Preliminary Design Review	Review	T0+3
M2	Current limiter prototypes Detailed Design Review	Review	T0+6
M3	Current limiter prototypes Validation Review (after stand-alone tests)	Review	T0+10
M4	Current limiter final version Detailed Design Review	Review	T0+16
M5	Current limiter final version Validation Review (after stand-alone tests)	Review	T0+24

*Type: R=Report, D=Data, HW=Hardware

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Design capabilities in overload, short-circuit, over voltages and lightning protections devices for power applications
- Design and manufacturing capabilities for custom power semi-conductors or products for high-voltage and high temperature environment
- Electro-thermal, mechanical and thermal simulation capabilities
- Access to testing facilities for semi-conductors
- Access to testing facilities representative of aircraft electrical networks in terms of sources (constant or variable frequancies), loads, etc.

5. Abbreviations

HVDC	High Voltage Direct Current

X. JTI-CS2-2017-CFP08-SYS-02-55: Air Treatment System for Airborne Microbe Removal from Air Circulation or Chambers

Type of action (RIA/IA/CSA)	RIA		
Programme Area	SYS		
(CS2 JTP 2015) WP Ref.	WP 6.0.2		
Indicative Funding Topic Value (in k€)	650		
Topic Leader	United Technologies Research Centre	Type of Agreement	Implementation Agreement
Duration of the action (in Months)	24	Indicative Start Date (at the earliest)130	Q1 2019

Identification	Title
JTI-CS2-2017-CFP08-SYS-02-55	Air treatment system for airborne microbe removal from air circulation or chambers
Short description (3 lines)	
This topic will develop a prototype system designed to improve the biological quality of the air in aircraft cabins by using novel high performing technologies that do not rely on mechanical filtration. The developed system should feature rapid, efficient and durable broad range virus and bacteria deactivation potential, small footprint and low power consumption for integration into current/future aircraft ECS architecture.	

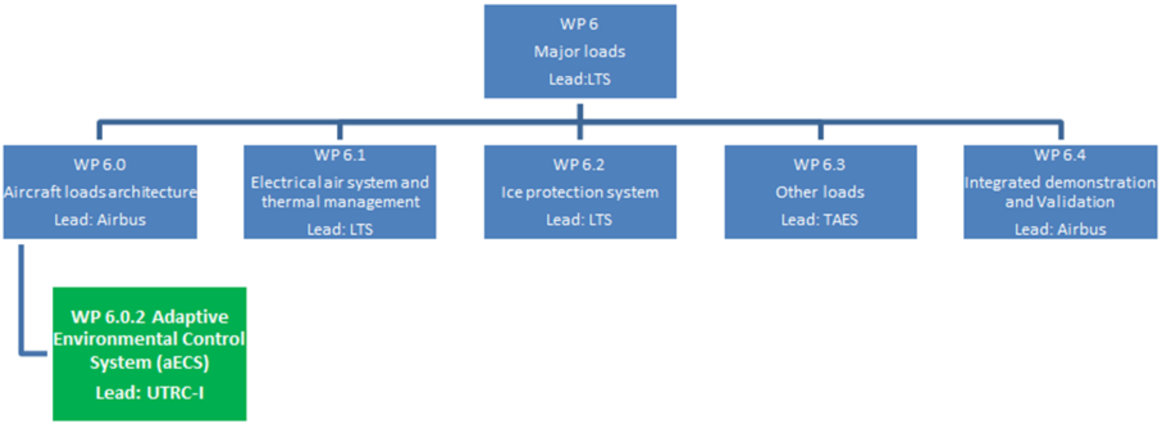
Links to the Clean Sky 2 Programme High-level Objectives131				
This topic is located in the demonstration area:	Environment Control System			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Long-range Ultra-advanced Long-range			
With expected impacts related to the Programme high-level objectives:				
Reducing CO2 emissions	Reducing NOx emissions	Reducing Noise emissions	Improving EU Competitiveness	Improving Mobility
☒	☒	☒	☒	☐

[130] The start date corresponds to actual start date with all legal documents in place.
[131] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

WBS: 6.0.2 Adaptive Environmental Control System

The provision of an environment for human habitation at modern jet aircraft cruising altitudes comes at a cost: the environmental control system (ECS) is one of the largest non-propulsive energy consumers on board a passenger aircraft. In order to reduce the Specific Fuel Consumption (SFC) impact of the ECS, an adaptive Environmental Control System (aECS) is being developed in the Clean Sky 2 Systems ITD WP 6.0.2. This system is enabled by an air quality control system that uses an increased level of cabin air re-circulation so that less air is brought into the cabin from the outside. A key target of WP 6.0.2 is to maintain 'traditional' cabin air quality with decreased outside air flowrate while maintaining existing air quality standards and realising annual fuel savings in excess of 2%.



Increasing the level of recirculated air in aircraft can result in an increased level of airborne microorganisms. While high-efficiency particulate air (HEPA) filters are designed to remove the majority of airborne particulates including bacteria and fungi, certain microorganisms smaller than 0.3 m are able to pass through the HEPA filtration system and therefore impact the quality of the cabin air. The application of various technical solutions (for example UVC LED, plasma, electro-static precipitation technologies) for disinfection purposes is well established in domains such as buildings. The aim of this project is to develop a suitable technology and prototype (for example, UVC LED) that can be validated at TRL 3-4 through laboratory integration with the aircraft aECS being developed in WP 6.0.2, to serve as an additional air purification step in the aECS. Furthermore, the system will serve as a means to preserve the HEPA filters as it will reduce the microbial load of air which is directed to the filters.

2. Scope of work

Beyond current state-of-the-art of development of biocidal/microbial technology, the objective of this activity is to develop and validate at TRL 3-4 a prototype that is capable of improving the biological quality of the air that is recirculated in a commercial aircraft cabin. This shall be designed such that it is easily integrated into the current/future ECS architecture. It should not have any negative impacts on any other aircraft system and should not increase ozone levels in the aircraft. The developed technology will be compact, lightweight, robust, with low voltage capability and low power requirements. It will target operation in environmental conditions found in aircraft cabins/cargo bays without posing any safety concerns for the aircraft. It should also be capable of reducing the viability of a number of microorganisms including pathogens in the airflow.

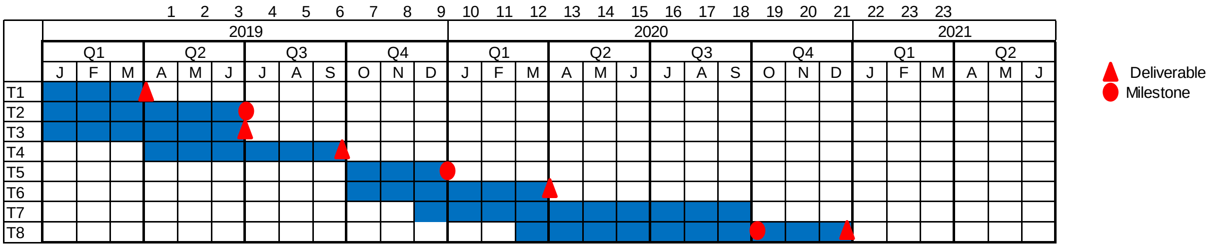
Specifically, proposals should consider the following -

- The applicant shall develop a concept of operations for the anti-microbial system, including trade-off of various concepts / architectures.
- The applicant shall develop a detailed system specification document addressing all requirements and KPIs as determined by the topic manager.
- The applicant shall conduct simulations to ensure optimal and uniform energy distribution within the air flow path to ensure the highest performance at the lowest pressure drop. Mechanical and electrical design requirements shall be met.
- The applicant shall conduct studies to determine the optimal performance parameters to remove relevant pathogens to improve the biological quality of recirculated air.
- The applicant shall test the device efficacy at relevant operating conditions for aircraft cabin, in particular at lower ambient pressure.
- A prototype of the system at TRL 3-4 shall be built and the functionalities tested to verify performance against the operational KPIs. The prototype system will be tested in a test chamber that is capable of replicating the airflow of an aircraft ventilation system. Microbial tests should also be performed to verify the improvement in the biological quality of the air.
- The system shall be integrated into the test bench at the aECS partner facility and tested.

Tasks		
Ref. No.	Title - Description	Due Date
T1	Define system requirements	T0 + 3M
T2	Define and develop methodology to examine functionality and operational efficacy of the device	T0 + 6M
T3	System physical models developed	T0 + 6M
T4	Determine optimum operational parameters to demonstrate a minimum 2 log reduction (preferred 4 log) of pathogens commonly found in commercial aircraft cabin air	T0 + 9M
T5	Prototype design	T0 + 12M
T6	Prototype development	T0 + 15M
T7	Functional and microbial studies to demonstrate operational efficacy of the device (from methodology developed in T2)	T0 + 21M
T8	Integration and testing of the air purification system in the ECS test rig at the aECS partner facility	T0 + 24M

3. Major Deliverables/ Milestones and schedule (estimate)

Proposed Gantt chart



Deliverables			
Ref. No.	Title - Description	Type*	Due Date
D1	System requirements document	D	T0 + 3M
D2	Simulation report defining physical integration with the aECS	R	T0 + 6M
D3	Microbial reduction test report based on simulation studies and experiment	R	T0 + 9M
D4	Prototype system optimised for air purification applications (delivery to aECS partner test bench)	HW	T0 + 15M
D5	Prototype demonstration at test facility	Demo	T0 + 22M

**Types: R=Report, D-, HW=Hardware*

Milestones (when appropriate)			
Ref. No.	Title - Description	Type*	Due Date
M1	Detailed test plan and methodology definition established	R	T0 + 6M
M2	Critical design review	M	T0 + 12M
M3	Integration of device at test bench	R	T0 + 21M

**Types: R=Report, D-Data, HW=Hardware, M-meeting*

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- The applicant shall demonstrate expertise in the design and development of biocidal technologies, including, where appropriate, optical, electrical, mechanical engineering and microbiological testing.
- The applicant shall have access to the appropriate facilities to perform airflow simulations to mimic conditions found in an aircraft ventilation system and to perform biological testing.

5. Abbreviations

aECS	Adaptive Environmental Control System
ECS	Environmental Control System
HEPA	High-Efficiency Particulate Air
KPIs	Key Performance Indicators
SFC	Specific Fuel Consumption

XI. JTI-CS2-2018-CFP08-SYS-02-56: Winglet tab EMA development and validation for flight control systems in new electrical wing

Type of action (RIA/IA/CSA)	IA		
Programme Area	SYS		
(CS2 JTP 2015) WP Ref.	WP 3.2		
Indicative Funding Topic Value (in k€)	900		
Topic Leader	CESA	Type of Agreement	Implementation Agreement
Duration of the action (in Months)	36	Indicative Start Date (at the earliest)132	Q1 2019

Topic Identification Code	Title
JTI-CS2-2018-CFP08-SYS-02-56	Winglet tab EMA development and validation for flight control systems in new electrical wing
Short description	
This call will cover the development and validation of EMA & ECU for winglet tab actuation to be used on the Regional aircraft FTB2 platform. The validation activities will be carried out with the final purpose of obtaining a permit to fly. This will also include extended tests for aileron, spoiler and flap tab actuation systems to evaluate the overall performance of the complete flight controls implemented in the new electrical wing.	

Links to the Clean Sky 2 Programme High-level Objectives133				
This topic is located in the demonstration area:	Regional Aircraft Wing Optimization			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing CO2 emissions	Reducing NOx emissions	Reducing Noise emissions	Improving EU Competitiveness	Improving Mobility
☐	☐	☐	☒	☐

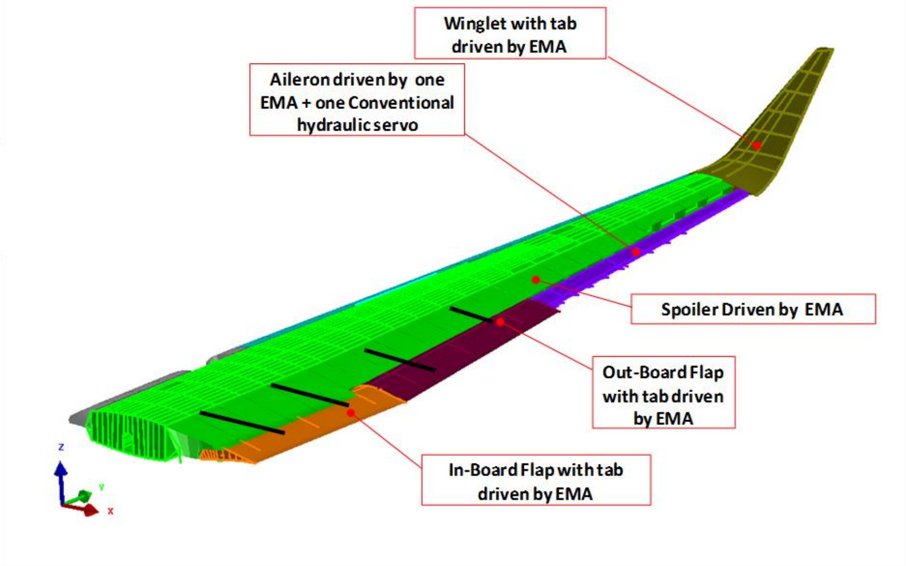
[132] The start date corresponds to actual start date with all legal documents in place.
[133] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

In previous activities being carried out within systems ITD, several EMAs are being developed for Aileron, Spoiler and Flap tab which will be used as a load alleviation system (MLA and GLA).

In the framework of Clean Sky 2 Systems ITD, the Call requires partners to provide to the Topic Manager concurrent engineering to the area of complex Flight Control systems integration in innovative airframe structures. The technological lines will extend from design phases to delivery of highly integrated system. The TRLs required will ultimately allow the Clean Sky 2 Regional Aircraft FTB2 demonstrator a flight test campaign in the Regional Aircraft IADP.

The electromechanical actuators for aircraft control systems (EMAs) is an essential system for the load alleviation systems (MLA and GLA) which allow structural optimization of the whole wing by means of this active system. An example of the current state of the art of this technology is a EMA rudder actuator of the GRA in active-standby configuration with other redundant actuator. The step forward is the use of EMA on wing flight control surfaces with more severe high level requirement level such as high duty cycles, system criticality etc



This call will cover the development and validation of EMA & ECU for winglet tab actuation to be used on the Regional aircraft FTB2 platform. The validation activities will be carried out with the final purpose of obtaining a permit to fly . This will also include extended tests for aileron, spoiler and flap tab actuation systems to evaluate the overall performance of the complete flight controls implemented in the new electrical wing.

2. Scope of work

This call will cover the develoment and validation of electromechanical actuation for winglet tab. The winglet tab actuation includes the EMA and its dedicated Electronic Control Unit. Different configurations will be studied and evaluated to determine the optimum system architecture from a technical point of view. Volume, mass, electrical consumption, power to mass ratio, reliability, durability and safety are concepts that will drive the development.

The main challenges of this development can be summarized as follows:

- Achieve TRL 6 (flight test in Regional IADP)
- Single ECU with capability to handle different types of EMA (linear or rotary) and Built-in Test features
- Actuator dynamic response to meet requirements from Load Alleviation System
- Integration with other Flight Control Systems embeded in the new electrical wing

A preliminary set of requirements is provided here below. Final requirements will be issued by Topic Manager during early stages of the development.

Performance & Architecture requirements

- The EMA shall be of the rotary type
- The EMA shall integrate the following components:
  - Motor assembly: DC brushless motor (and gearbox if necessary).
  - Resolver for rotor position feedback.
  - Normally closed brake
  - Two RVDTs for output position feedback.
- EMA nominal operating voltage: 28 VDC
- Maximum space envelope: 170 mm x 80 mm x 50 mm
- Maximum weight: 2000 g

The following operational points are defined for the Winglet Tab EMA:

- Nominal operation: 100 Nm @ 10 rpm
- Stall torque: 104 Nm as a minimum
- The actuator shall consider that during normal flight, the actuator is suffering a nominal load due to dynamic pressure within a range of [0-75] Nm with peaks of 100Nm.

Validation requirements for Winglet Tab Actuation System

The minimum validation requested will be the necessary to ensure the safety of flight condition and will be agreed with the Topic Manager. As a reference, this is a list of general requiremnts that are likely to be demanded:

- Endurance and Duty Cycle
- Fatigue
- Vibration
- Explosion proofness
- Waterproofness
- Fluids Susceptibility
- Sand and Dust
- Fungus Resistance
- Salt Spray
- Icing
- Constant acceleration
- Aircraft Attitude
- Magnetic Effects
- Audio frequency conducted susceptibility- Power Inputs
- Induced signal susceptibility

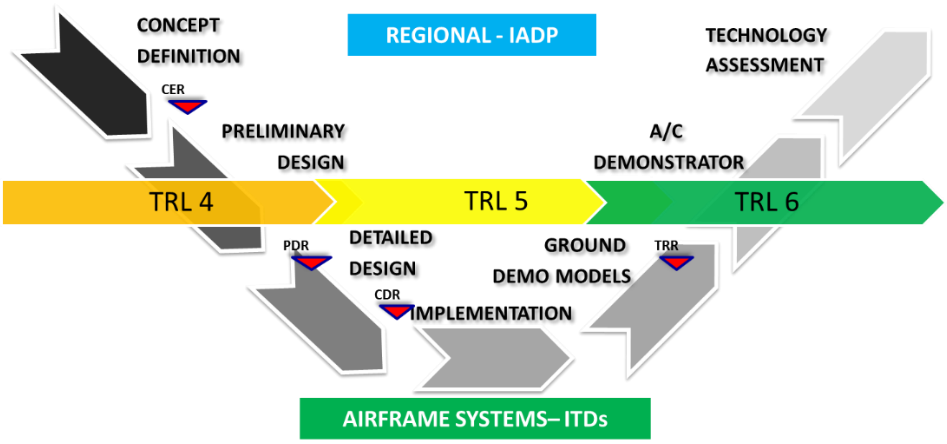
- Radio Frequency Susceptibility (conducted)
- Radio Frequency Susceptibility (radiated)
- Emission of radio frequency energy
- Lightning Induced Transient Susceptibility
- Electrostatic Discharge
- Voltage Spikes
- Power Input

Environmental, electrical and vibration requirements will be specified according to RTCA DO-160, MIL-STD-704 and MIL-STD-810. Detail categories will be provided during early stages of the development. Specific test profiles will be also provided for endurance and fatigue tests (limited number of cycles will be requestes to achieve Safety of Flight).

Validation to achieve overall integration and safety of flight of complete Flight Control Systems in the new electrical wing

Additional test requirements to validate integration and obtain flight clearance for Aileron, Spoiler, Flap Tab and Winglet Tab actuation Systems. Development of Aileron, Spoiler and Flap Tab actuation systems has been performed in previous calls. Details of these systems will be provided by the Topic Manager. This tests may include some of those listed above for Winglet Tab Actuation System validation.

Before achieving TRL 6 in Regional IADP flight tests, TRL 5 will be accomplished through tests at Actuation System Integration rig. Support to these tests will be required. Level of validation may change in line with the results of the integration tests.



Hardware Deliverables

The estimated number of sets to be manufactured for are indicated in the following table:

HARDWARE DELIVERABLES	Validation test	Ground rig	Flight tests
WINGLET TAB ACTUATION	3	3	3

Additionally, new electrical wing challenging requirements for flap tab EMA has led to modification of the total surface area on which the selected Flap tab will actuate. Division of the surface area will

require additional EMAs & ECUs to be validated and integrated. Also, more prototypes for aileron and spoiler may be required to achieve the overall integration and safety of flight validation tests .
The selected partner will deliver EMA and ECU hardware including the COTS needed for final assembly. Topic manager will provide sufficient details of both EMAs and ECUs components in order to manufacture and assembly the units to be used for those additional tests.

Tasks		
Ref. No.	Title - Description	Due Date
1	WINGLET TAB ACTUATION SYSTEM DESIGN	M5
2	MANUFACTURING AND ASSEMBLY (EMAs &ECUs)	M12
3	QUALIFICATION PLANS	M12
4	WINGLET TAB VALIDATION	M24
5	FLIGHT CONTROL ACTUATION SAFETY OF FLIGHT VALIDATION (EMAs and ECUs)	M36

3. Major Deliverables/ Milestones and schedule (estimate)

**Type: R=Report, D=Data, HW=Hardware*

As a minimum, the following deliverables shall be provided. Final set of document required will be agreed between the partner and the Topic Manager

Deliverables			
Ref. No.	Title - Description	Type*	Due Date
D1	WINGLET TAB ACTUATION SYSTEM DESIGN	Doc	M5
D2	QUALIFICATION PLANS	Doc	M12
D3	EMAS AND ECUS VALIDATION HARDWARE	Prototypes	M12
D4	WINGLET TAB VALIDATION	Doc	M24
D5	FLIGHT CONTROL ACTUATION SAFETY OF FLIGHT VALIDATION (EMAs and ECUs)	Doc	M36

Milestones (when appropriate)			
Ref. No.	Title - Description	Type*	Due Date
M1	WINGLET TAB ACTUATION SYSTEM DESIGN	R	M5
M2	EMAS AND ECUS VALIDATION HARDWARE	HW	M12
M3	FLIGHT CONTROL ACTUATION SAFETY OF FLIGHT VALIDATION (EMAs and ECUs)	R	M36

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- Experience in development and verification of airborne complex electronic hardware according to RTCA-DO-254 for critical equipment or other civil or military equivalent standards.
- Experience in development and verification of airborne electronic software according to RTCA-DO-178 for critical equipment or other civil or military equivalent standards.
- Competence in management of complex projects of research and manufacturing technologies.
- Experience in integration multidisciplinary teams in concurring engineering within reference

aeronautical companies.

- Proven experience in collaborating with reference aeronautical companies, industrial partners, technology centers within last decades in: Research and Technology programs (TRL Reviews)
- Industrial air vehicle with "in – flight" components experience.
- Capacity to repair "in-shop" equipment due to manufacturing deviations.
- Capacity to assembly and testing complex aeronautical equipment.
- Capacity to support documentation and means of compliance to achieve prototype "Permit to Fly" with Airworthiness Authorities (FAA, EASA…).
- Design and analysis tools of the aeronautical industry.
- Competence in management of complex projects of research and manufacturing technologies.
- Experience in integration multidisciplinary teams in concurring engineering within reference aeronautical companies.
- Proven experience in collaborating with reference aeronautical companies, industrial partners, technology centers within last decades in: Research and Technology programs (TRL Reviews)
- Industrial air vehicle with "in – flight" components experience.
- Capacity to support to Air vehicle Configuration Control
- Quality System international standards
- Capacity of performing Life Cycle Analysis (LCA) and Life Cycle Cost Analysis (LCCA) of materials and structures, and systems.
- Capacity of evaluating results in accordance to Horizon 2020 environmental and productivity goals following Clean Sky 2 Technology Evaluator rules and procedures.

XII. JTI-CS2-2018-CFP08-SYS-03-17: Improved Thermal Properties of Computing Platforms for Next-Generation Avionics [SAT]

Type of action (RIA/IA/CSA)	RIA		
Programme Area	SYS [SAT]		
(CS2 JTP 2015) WP Ref.	WP 7.4		
Indicative Funding Topic Value (in k€)	800		
Topic Leader	Honeywell International	Type of Agreement	Implementation Agreement
Duration of the action (in Months)	30	Indicative Start Date (at the earliest)134	Q1 2019

Topic Identification Code	Title
JTI-CS2-2018-CFP08-SYS-03-17	Improved Thermal Properties of Computing Platforms for Next-Generation Avionics
Short description	
The proposed activity shall investigate, develop, and validate emerging thermal-aware SW-based techniques that will reduce operational temperature of electronic circuits. The expected impact of the improved thermal performance will both improve computing performance and will reduce size and weight of electronics due to relaxed dissipation requirements.	

Links to the Clean Sky 2 Programme High-level Objectives135				
This topic is located in the demonstration area:	Cockpit & Avionics, Enabling Technologies			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Short/Medium-range 19-pax Commuter			
With expected impacts related to the Programme high-level objectives:				
Reducing CO2 emissions	Reducing NOx emissions	Reducing Noise emissions	Improving EU Competitiveness	Improving Mobility
☒	☒	☒	☒	☒

[134] The start date corresponds to actual start date with all legal documents in place.

[135] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

COAST project

The activity is expected to contribute to the Clean Sky 2 objectives by more resource-efficient platforms which will have reduces SWaP and thus enable more functional content thanks to increased affordability.

The proposed research topic is linked with the Systems ITD work package 7.4 COAST – Cost-Effective Avionic Systems as part of a Small Aircraft Transport (SAT) and in particular, to two key technology focus: Compact Computing Platform (CCP) and High-Integrity Electronics (HIE). The CCP targets the development of an affordable avionic platform for the CS23 segment providing similar capabilities and computing performance of a larger aircraft. The HIE is dedicated to optimize the design of small form-factor electronics (e.g., remote data concentrators) that are sensitive to strict cost, size, weight, and installation constraints. Both, CCP and HIE are safety-critical avionics systems.

The initial developments of the small-size electronics in the COAST activity have shown great potential of new computing hardware (HW) components (e.g., Central Processing Unit (CPU)) and have revealed heat dissipation challenges preventing optimum downsizing of the Line-Replacement Units (LRUs) in CCP and of the distributed data concentrators in HIE.

Our initial Voice of the Customer (VoC) survey among the SAT OEMs indicated that the prescribed operational temperature ranges and extensive heat dissipation (e.g., active cooling) complicate aircraft installation and integration (reduces reliability, serviceability, and availability). Both, the complicated aircraft installation and integration lead to severe schedule delays and budget slip increase for OEMs.

In the avionics domain, there is significant ongoing effort on mechanical side that is dedicated to advanced heat-conducting materials and heatsink designs. However, to the best of our knowledge there has been very limited effort in the avionics domain focused on the root cause – efficient thermal-management of the HW components in SW for the small-size electronics.

Thermal-aware resource management

HW components consume Energy to switch the logical gates and perform logical operations. The impedance of the logical gates results in a dissipated heat. The dissipated heat defines the thermal profile of a HW component. The thermal profile is measured by operational temperature.

The Energy (E) of a HW component is defined by the average Power consumption over a period T:

$$E = P_{avg} * T$$

The average Power consumption (P_{avg}) of a HW component is given by the static and dynamic Power:

$$P_{avg} = P_{static} + P_{dynamic}$$

The static Power present the leakage and it is always available. The dynamic Power is defined by:

$$P_{dynamic} = f * C * V^2,$$

where the f is the frequency, C is the capacitance of the logical gates, and V is the supplied voltage.

The listed relations suggest that the efficient **thermal-aware resource management** in SW can be introduced by lowering the dissipated heat and respectively lowering the Energy consumption. Potential alternatives to reduce the Energy consumption are by reducing the consumed Power and completing the SW execution for a shorter period. The consumed Power can be reduced by using heterogeneous computing, powering down unused part of the HW components, operate at a lower frequency than the maximum, and introduce Dynamic Voltage and Frequency Scaling (DVFS) that exploits the slack. The list of considered parameters can be further extended following the suggestion of Calore et al. [1].

Ge et al. [2] suggests that the CPU consumes more than half power in the small-size electronics. Taking this into account, we consider the list of feasible CPUs in CCP to be dual-/quad-core high-end embedded processors (e.g., ARM- and PPC-based) with potentially an on-chip GPU and in HIE to be low-/mid-range dual-core embedded processors (e.g., ARM-based). Some of the simpler solutions will be leveraged in the HIE prototypes which use simpler chips and thus some solutions are not feasible (e.g. leveraging GPU cores).

Related Work

Over the past few years, the thermal-aware resource management has been identified as an important topic. The FP7-CONTREX project [3] analyses the power and temperature profile of modern HW components. The presented results suggest that the power consumption of an SW process may significantly increase the overall system thermal profile such that the reliability and lifetime of the HW component are compromised. Volp et al. [4] demonstrate that the mishandling of the energy consumption management is as severe as timing violations in a safety-critical system. [3, 4] confirm that efficient thermal-aware resource management is indeed a challenge and needs to be addressed. The captured VoC in COAST project confirms that the efficient thermal-aware resource management needs to be addressed.

There are numerous related works devoted to efficient utilization of heterogeneous resources. The FP7-SAVE project [5] aims at addressing the challenge of exploiting computing resources of a heterogeneous system and taking advantage of their individual characteristics to optimize the performance/energy trade-off. The FP7-SAVE project provides self-adaptivity and hardware-assisted virtualization to dynamically and autonomously decide how to optimally allocate the workload to the specialized resources while optimizing a user-defined goal (e.g., performance, energy, reliability). The H2020-TANGO project [6] is another example of the same problem with the goal of self-adaption of both heterogeneous system and applications by making use of a wide range of optimization criteria.

We consider the FP7-SAVE and H2020-TANGO projects to have very similar goals as the proposed research topic. Although their self-adaptation approach might be well suited to Embedded Systems and High Performance Computing, we anticipate that the dynamic and autonomous decisions will hardly comply with the rigorous requirements for safety-critical systems in the avionics domain.

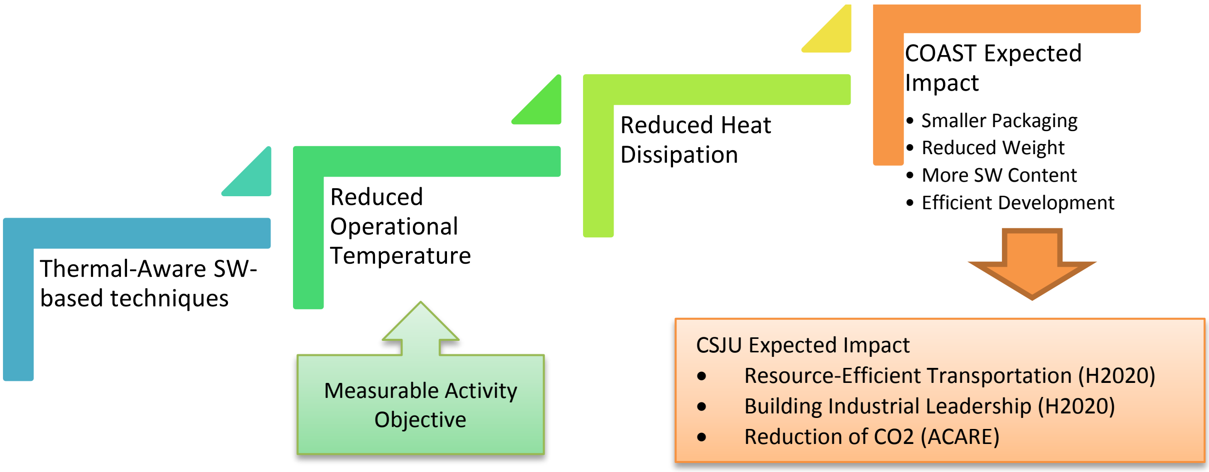
Lal et al. [7] suggested that in a heterogeneous system, the GPU is feasible power and performance alternative to the CPU. The proposed research topic aims at verifying the feasibility of the GPGPU computation for safety-critical systems in the avionics domain.

Lenz et al. [8] and Zaykov et al. [9] aim at optimizing the power and energy consumption across tiles in a multi-tile processor. Lenz et al. [8] propose a global meta-scheduler to provide optimal slack exploitation, relies on tile-based processor, assume that the messages do not collide with each other, and assume that the Network Interfaces follow a precompiled communication schedule. The proposed topic intends to relieve all their assumptions such that it would be applicable to embedded COTS processors, where: cores are employed instead of tiles, inter-core interference is present, and the cross-core communication does not follow a precompiled communication schedule. Moreover, the global slack exploitation is expected to be substituted by a distributed following [9]. Zaykov et al. [9] extend the communication protocol between the tiles with slack information. The proposed approach targets data-flow applications and relies on tile-based architecture extended with a specialized IP-core to register and compute the slack inherit from other tiles. The proposed research work intends to adopt a similar approach without the need of specialized HW, extend it from tiles to cores, and from data-flow to programing models compliant with the avionics domain. The disturbed slack management may adopt an advanced Proportional-Integral-Derivative (PID) for controlling the DVFS [10].

The proposed research work aims at exploiting the results from adjacent domain such hand-held devices [11], embedded, and High-Performance Computing [12, 13].

Project Scope

The proposed activity shall investigate and validate emerging thermal-aware SW-based techniques for thermal-aware resource management that reduce operational temperatures of HW components in small-size electronics. Some promising candidates are: power- and energy-aware scheduling algorithms, improved load balancing among processor cores in a multi-core processor, optimized usage of specialized co-processors, innovative usage of GPUs, exploitation of various clock frequencies (e.g., DVFS), engagement of advanced power-up and power-down schemes in recent small-size electronics, adoption of various thermal-aware techniques based on the operational temperature, and others. Additional focus shall be dedicated to real-time operational temperature monitoring and capturing combined with a demo model design to predict the end of life of critical components relative to operational temperature history.



The project is expected to cover the following open research challenges: How to efficiently adopt multiple SW techniques for thermal-aware resource management considering various inputs such as available slack, operational temperature, and the heterogeneous computing resources. Less or more aggressive techniques are expected to be proposed trading guaranteed performance for improvement of the thermal profile. How to decide how much slack to use? How to improve the thermal profile for zero slack? How to design a demonstration model to predict end of life of critical components? Identify when it is thermal efficient to offload computation from the CPU to the GPU.

Requirements for proposed thermal-aware SW-based techniques: shall increase the guaranteed performance; shall reduce the operational temperature; shall be applicable to COTS HW components and shall not rely on any specialized custom IP cores; sShall be compliant with the existing SW standards (e.g., native certifiable avionics RTOS API and ARINC 653); shall consider communicating SW processes spawn over multiple cores in a modern embedded multicore processor; shall be compliant with existing resource management techniques in the certifiable avionics RTOS; shall be certifiable and compliant with avionics standards such as DOI 178B/ C and CAST 32 paper; shall explore potential compiler optimization applicable for safety-critical domain [14]; shall advise the SW engineers how to write more thermal-efficient code.

Measurable Objectives

- increased guaranteed performance by 30 % for an equivalent thermal profile, and
- reduction of operational temperature by 20 % for an equivalent guaranteed performance.

Expected Impact

- Improved reliability: the reduced heat dissipation benefits are twofold: i) slow-down the aging of the hardware components as their operational temperatures are lower, ii) the absence of complex cooling systems (e.g., active cooling) reduces the probability of system failures.
- Improved availability by streamlined production cycles in LRU packaging.
- Improved serviceability: the real-time temperature monitoring with prediction models can facilitate predictive maintenance.
- Reduced SWaP as result of the more compact design and thermal-aware SW-based techniques.
- Improve the practically available performance for the same thermal profile.

The notional expected target benefits of the deployed solutions are: 20 % smaller packaging size, 10 % weight reduction, and 20 % more SW content. The expected increase in development efficiency is elimination of at least one cycle in packaging design.

2. Scope of work

Tasks		
Ref. No.	Title - Description	Due Date
T1	Research thermal-aware SW-based candidate technologies capable to reduce heat dissipation and improve guaranteed performance	T0+6m
T2	Review and prioritize the candidate technologies	T0+9m
T3	Detailed concept of the selected candidate prototypes	T0+12m
T4	Detailed design of the selected candidate prototypes	T0+15m
T5	Implementation of the selected candidate prototypes	T0+25m
T6	Prototype, validation, and updates	T0+28m
T7	Comparison and final recommendations	T0+30m

The activity shall start by T1 with research into individual thermal-aware SW-based candidate technologies which can be deemed beneficial to reduce the heat dissipation and improve guaranteed performance. The research work will consider only on those candidate technologies showing a material potential for thermal performance improvement while fi-ulfilling the topic target in terms of performance and applicability in avionics. In-depth study of literature, industrial usage, and commercial solutions are mandatory. The research results shall be summarized in D1. It is expected that there will be between 5 and 10 candidate technologies.

After identifying multiple candidate technology, they shall be compared in T2 based on common criteria agreed by the TM and shall be prioritized with the aim to select the most promising technologies for further development. The performing party will agree with the TM on 1-3 candidates based on complexity, feasibility level, and other criteria given by the TM. Should the preceding research indicate, there is a clear promising candidate, there can be a single candidate selected. In the opposite case, multiple paths shall be recommended, at maximum 3 though. The comparison and prioritization shall be documented in D1.

The selected candidate technologies shall be further conceptualized in T3 to clarify scope of the development, functional and platform assumptions, required interfaces, and all risks related with the solution development and deployment. The prototype concepts shall be summarized in D2. The reason for this activity is that the TM can assess more clearly the perimeter of the selected prototypes and give a final approval for their development. The platform of choice of benchmark and deployment will be decided by the TM. The target benchmark applications will be fixed in collaboration between TM and the applicant. The concept shall also contain performance monitoring data collection and storage mechanism for later benchmarking purposes.

T4 shall be dedicated to detailed design of the selected candidates. The design and the report shall be provided in D3. Acceptable artefacts are design models and/or drawings clarifying important aspects, such as scope delimitation, interfaces, internal architecture, triggers, functional sequencing, mode logic, performance monitoring, etc.

T5 shall be dedicated to full-scope implementation of the delivered design of the selected candidates. The report and the SW source code will be provided as D4. The SW source code shall be properly documented to facilitate functional understanding. Executables without source code as deliverable are negotiable but not preferred.

In T6, the prototypes shall be validated on the agreed platform and against agreed metrics. The developed solutions shall be compared with legacy architectures. The mandatory parameter is operational temperature (not ambient) and guaranteed computation performance. Multiple execution schemes representative of the aeronautical applications shall be used as benchmarks. The applications jointly firmed in T3 shall be used for benchmarking.

3. Major Deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	Title - Description	Type*	Due Date
D1	Report on technology candidates reducing heat production	R	T0+9m
D2	Report on detailed concept of the selected candidate prototypes	R	T0+12m
D3	Report on detailed design of the selected candidate prototypes	R, D	T0+15m
D4	Report on implemented candidate prototypes	R, D	T0+25m
D5	Final assessment of reduction of produced heat and recommendations.	R, D	T0+30m

*Type: R=Report, D=Data, HW=Hardware

4. Special skills, Capabilities, Certification expected from the Applicant(s)

Candidate applicants should have a blend of high-level interdisciplinary skills to undertake and effectively carry out a sufficiently wide research in the area of the candidate technologies:

- Experience in R&D in the aeronautical or space domain.
- Know-how in benchmarking ofavionic platforms.
- Good knowledge of thermal analysis and/or power-/energy-aware modelling of the HW components.
- Competence in R&D in embedded systems and heterogeneous computing platforms, with special focus on scheduling optimization.
- Experience in one of the following domains: GPU-based acceleration, use of co-processing cores, processor resource management, and execution-time analysis.
- Capability to build functional prototypes and components for an industrial safety-critical system.

5. Abbreviations

COAST	Cost-Affordable Avionic Systems
COTS	Commercial of The Shelf
CPU	Central Processing Unit
DAL	Design Assurance Level
GPU	Graphical Processing Unit
HW	Hardware
IP	Intellectual Property
LRU	Line Replaceable Unit
OEM	End Manufacturer
PID	Proportional-Integral-Derivative
SAT	Small Aircraft Transport
SW	Software
SWaP	Size, Weight, and Power
VoC	Voice of the Customer
TM	Topic

References

[1] Calore et al., "Evaluation of DVFS techniques on modern HPC processors and accelerators for energy-aware applications", Distributed, Parallel, and Cluster Computing, 2017.

[2] Ge et el., "PowerPack: Energy Profiling and Analysis of High-Performance Systems and Applications," in IEEE Trans. on Parallel and Distributed Systems, vol. 21, no. 5, pp. 658-671, 2010.

[3] Görgen et al., "CONTREX: Design of Embedded Mixed-Criticality CONTRol Systems under Consideration of EXtra-Functional Properties," In Proc. of The Euromicro Conference on Digital System Design (DSD), 2016, pp. 286-293.

[4] Völp et al., "Has energy surpassed timeliness? Scheduling energy-constrained mixed-criticality systems," In Proc. of the Real-Time and Embedded Technology and Applications Symposium (RTAS), 2014, pp. 275-284.

[5] Durelli et al., "SAVE: Towards Efficient Resource Management in Heterogeneous System Architectures", In Proc. of the Reconfigurable Computing: Architectures, Tools, and Applications (ARC), pp. 337-344, 2014.

[6] Djemame et al., "TANGO: Transparent heterogeneous hardware Architecture deployment for eNergy Gain in Operation", In Proc. of Program Transformation for Programmability in Heterogeneous Architectures (PROHA), pp. –, 2016.

[7] Lal et al., "GPGPU Workload Characteristics and Performance Analysis", In Proc. of the Int'l Conf. on Embedded Computer Systems: Arch., Modelling, and Simulation (SAMOS), 2014, pp. 115-124.

[8] Lenz et al., "Global Adaptation for Energy Efficiency in Multicore Architectures," In Proc. of the Euromicro Int'l Conf. on Parallel, Distributed and Network-based Processing (PDP), 2017, pp. 551-558.

[9] Zaykov et. al., "Run-Time Slack Distribution for Real-Time Data-Flow Applications on Embedded MPSoC," In Proc. of the Euromicro Conference on Digital System Design (DSD), 2013, pp. 39-47.

[10] Rodopoulos et al., "Tackling Performance Variability Due to RAS Mechanisms with PID-Controlled DVFS", IEEE Computer Architecture Letters, vol. 14, no. 2, pp. 156-159, 2015.

[11] M. Zanella "Energy-Aware Run-Time Management of Distributed Mobile Devices", MSc thesis, Politecnico Milano, Italy, 2017.

[12] W. Fornaciari et al., "Runtime Resource Management for Embedded and HPC Systems", In Proc. of the Workshop on Parallel Programming and Run-Time Management Techniques for Many-core Architectures and the Workshop on Design Tools and Architectures for Multicore Embedded Computing Platforms (PARMA-DITAM), pp. 31-36, 2016.

[13] Scionti et al., "OPERA: A Low Power Approach to the Next Generation Cloud Infrastructures," In Proc. of the Euromicro Conference on Digital System Design (DSD), 2016, pp. 326-333.

[14] Jimborean et al., "Fix the code. Don't tweak the hardware: A new compiler approach to Voltage-Frequency scaling", In Proc. of the Int'l Symposium on Code Generation and Optimization (CGO), pp. 262-272, 2014.

XIII. JTI-CS2-2018-CFP08-SYS-03-18: Development and testing of innovative Cr free anodic layers removal solution

Type of action (RIA/IA/CSA)	RIA		
Programme Area	SYS		
(CS2 JTP 2015) WP Ref.	WP 100.2		
Indicative Funding Topic Value (in k€)	500		
Topic Leader	Liebherr	Type of Agreement	Implementation Agreement
Duration of the action (in Months)	24	Indicative Start Date (at the earliest)[136]	Q1 2019

Topic Identification Code	Title
JTI-CS2-2018-CFP08-SYS-03-18	Development and testing of innovative Cr free anodic layers removal solution
Short description	
In 2024, the use of Chromium VI (Cr6+) substances will be forbidden by the REACH Regulation. Many studies have been focused on the development of alternative solutions to CAA or chemical conversion coatings (Alodine®). These studies have led to the development of new protective layers (e.g. SAA, TSA, chemical conversions coatings with CrIII) but few were dedicated to the development of processes required to remove these new oxide layers. Indeed, current processes use Cr6+-based components (e.g. phosphochromic etching) and the alternative Cr free process with NaOH can lead to substrate etching if not stopped on time. The aim of this study is thus to develop a Cr free solution to remove anodic layers obtained with new alternative treatments, without deteriorating the aluminium alloy substrate.	

Links to the Clean Sky 2 Programme High-level Objectives[137]				
This topic is located in the demonstration area:	Landing Systems, Enabling Technologies, Eco-Design			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	Advanced Long-range			
With expected impacts related to the Programme high-level objectives:				
Reducing CO2 emissions	Reducing NOx emissions	Reducing Noise emissions	Improving EU Competitiveness	Improving Mobility
☐	☐	☐	☒	☒

[136] The start date corresponds to actual start date with all legal documents in place.
[137] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

The aviation community is committed to reducing their environmental impact in light of increasing demand for extra passenger capacity. This has been formalised in 2001 by the Advisory Council for Aeronautical Research in Europe through the definition of stringent global targets for aircraft technology, to be achieved by 2020. Embracing those ambitious targets, the Clean Sky program is supporting research activities aiming at a substantial reduction of the environmental impact of manufacturing, maintenance and disposal of aircraft and related products.

Aluminium alloys are widely used in aeronautics applications for airframe, but also for on-board systems. Nowadays, 95% of aluminium parts are protected by surface treatments in order to prevent corrosion. These surface treatments use or contain the CMR compound Cr^{6+} (e.g. CAA, Alodine®) and create a protective oxide layer on top of the aluminium surface. In serial production, treatment removal could be required if the parts are not well coated. Coating removal may also be needed in the repair shops. The method of stripping the protective layers formed during these processes uses also Cr^{6+} (e.g. chromic acid and phosphoric acid). In 2024, the use of Cr^{6+} will be forbidden by the Reach Regulation. So the optimal use of materials, energy and resources involved in production, and avoidance of hazardous non-Reach compliant materials for aircraft on-board systems will help considerably reduce the environmental impact of operations.

Many studies, in particular in the frame of the Clean Sky Program, have focused on the development of alternative solutions to CAA or chemical conversion coatings (Alodine®). These studies led to the development of new processes such SAA, TSA and chemical conversions with CrIII; however, only few were dedicated to the development of Cr free processes able to remove these new oxide layers.

The most common etching method used to remove the anodic layers consists of immersing spare parts in a solution composed of phosphoric acid and chromic acid (Cr^{6+} based solution). In that case, only the oxide coating is removed, the substrate is not affected by the treatment. Other methods using Cr^{6+} solutions exist, such as sulfuric acid and chromic acid, Anachem 6-16 or mixture of chromic acid, sulfuric acid and fluorhydric acid.

A method that does not use Cr^{6+} consists in immersing spare parts in a solution of sodium hydroxide (NaOH), but such a method has several drawbacks : it requires robust monitoring since NaOH also attacks the substrate and this could generate fatigue drop down; furthermore, the etching is not uniform in complex shape parts (some areas are more etched than others).

The aim of this study is then to develop a Cr free solution to remove anodic layers obtained with the new alternative treatments selected by the TM (SAA and CrIII chemical conversion) and with current process (CAA and Alodine ®) for repair. The method should be able to manage a uniform attack without affecting the aluminium alloy substrate and its properties.

2. <u>Scope of work</u>

Tasks		
Ref. No.	Title - Description	Due Date
Task 1	Definition of the requirements, screening & evaluation of existing treatments with / without Cr	M12
Task 2	Development and evaluation of innovative Cr free method on reference alloys	M18
Task 3	Identification of the best Cr free solution & implementation on other aluminium alloys & complex parts	M24

The first step of the project will be dedicated to:

- The definition of test requirements, with determination of test samples' configurations to be retained for the project as well as the test characterisations to be performed,
- identification, characterization and evaluation of existing treatment with and without Cr

The applicant will study, develop and evaluate an innovative Cr free anodic layers removal solution.

The best solution among existing one and newly developed treatments will be identified, the down-selected method will be validated on other aluminium alloys and complex parts.

Task 1 - Definition of the requirements, screening & evaluation of existing treatments with / without Cr

At the beginning of the project, the Topic Manager will share with the applicant detailed information regarding nature and characteristics of the samples, to support the definition of the test requirements.

The following information regarding type of alloys to be studied, type of oxide layers to be removed and type of re-treatment should be taken into account, considering that a minimum of 8 configurations are expected to be characterised and evaluated at each stage.

Type of Alloys to be studied	Type of oxide layers to be removed	Type of re-treatment after oxide layer removal
•2024 machined (task 1&2) •7075 machined (task 1&2) •2618 machined (task 3) •7010 (task 3) •AS7G06 casting (task 3) •AU5NKZr casting (task 3)	•CAA (less than 5 µm thickness) •Alodine (less than 1µm thickness) •Thin SAA (less than 10µm thickness) •chemical conversion with CrIII (less than 1 µm thickness)	•Thin SAA •chemical conversion with CrIII

All samples required for the study will be provided by the TM. It should be noted that CAA and SAA layers are always sealed with respectively CrVI and CrIII sealing solutions.

The test characterisations to be performed on the samples will be defined, considering parameters such as: microstructural observations of cross section, microstructural observations of surface, surface analysis, fatigue testing, salt spray testing (when relevant),…

Before any development, the existing treatments should be identified, characterized and evaluated along the define test requirements, for both existing treatments with and without Cr.

Alternatives solutions without Cr^{6+} exists that are based on sulfuric acid and fluorure, fluorhydric acid or nitric Acid. Commercial solutions, originnaly sold for deoxidizing and desmutting wrought aluminum alloys before conversion or anodizing, are also available.

These and any other relevant solutions, stemming from the State of the Art analysis provided by applicant In their proposal, may be considered for the screening phase, as long as they ensure that the substrate is not attacked. In this respect, a preliminary verification phase may be worthwhile.Applicants are encourged to propose additional relevant solutions for the screening phase.

TThe applicant and the TM will select the most promising amongst these different solutions to be further evaluated in the project.

Task 2 - Development and evaluation of an innovative Cr free method on reference alloys

An innovative chemical etching process to remove oxide layers formed with / without Cr shall be developed.

The new method shall not contain CrVI components, to be REACH compliant, and shall ensure performances equivalent to currently use treatments, such as:

- etching of the oxide layer only and no etching of the substrate,
- uniform etching on complex shapes,
- low fatigue drop: equivalent to fatigue drop down observed with CAA or SAA
- anodizing or chemical conversion after oxide layer removal still efficient : SST 500h without pit

The developed treatment will be characterized and evaluated along the test requirements defined in Task 1.

Task 3 - Identification of the best Cr free solution & implementation on other aluminium alloys & complex parts

A comparison between existing and developed treatments will be done and a ranking based on characterizations will be proposed. The best solution will be defined according to previous characterization and their compliancy with the requirements defined in Task 1.

The best method will then be applied on a wider range of aluminium alloys and also on complex parts.

These complex parts will be provided by the TM:

- Part 1 : approximate dimensions 30*30*80 mm
- Part 2 : approximate dimensions 190*120*75 mm
- Part 3: approximate dimensions 400*300*200 mm

The aim of this task would be to check that the attack is uniform even on complex shape and that a new treatment applied on parts after stripping is still efficient. This will require control of the whole parts and SST after new treatments (SAA and chemical conversion with CrIII).

3. Major Deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	Title - Description	Type*	Due Date
D1	Definition of the test requirements	R	M2
D2	Results of screening and evaluation for existing treatments with & without Cr	R	M12
D3	Results of the evaluation for developed innovative Cr free treatment	R	M18
D4	Evaluation of the best solution on other alloys & complex parts	R	M24

Milestones (when appropriate)			
Ref. No.	Title - Description	Type*	Due Date
M1	Choice of the screening solutions	R	M7
M2	Choice of the best solution to be implemented on other alloys and parts	R	M18

**Type: R=Report, D=Data, HW=Hardware*

Special skills, Capabilities, Certification expected from the Applicant(s)

- Strong experience on surface technologies, especially on chrome free surface treatments (SAA, chemical conversion coating with CrIII)
- Strong experience and knowledge on the surface treatments of the following alloys : cast AS7G06 and AU5NKZr, 7075, 7010, AA2024 and 2618.
- Capabilities required to performed the study :
    - Laboratory or pre-industrial baths (able to treat complex parts as referred to in the topic description)
    - Optical microscope, SEM-EDX, FIB, XRD and any other surface analysis methods that will be relevant to detect remanent oxide layer
    - Metallographic preparation for microstructural analysis
    - Fatigue testing (rotative bending is prefered)
    - Salt Spray Test

4. Abbreviations

Cr6+	Chromium VI
CAA	Chromic Acid Anodizing
SAA	Sulfuric Acid Anodizing
TSA	Tartaric Sulfuric Acid Anodizing
CMR	Carcinogenic, mutagenic, reprotoxic
TM	Topic Manager
SEM-EDX	Scanning Electron Microscope with Energy Dispersive X-Ray
FIB	Focused Iom Beam System
XRD	X Ray Diffraction
SST	Salt Spray Test

PART B: Thematic Topics

1. Overview of Thematic Topics

List of Topics for Calls for Partners (CFP08) – Part B

Identification Code	Title	Type of Action	Value (Funding in M€)
JTI-CS2-2018-CFP08-TT-01	**Concept Design of a 19-seat Commuter Aircraft with Hybrid-Electric Powertrain**	RIA	0.80
JTI-CS2-2018-CFP08-TT-02	**Innovative NOx Reduction Technologies**	RIA	1.00
JTI-CS2-2018-CFP08-TT-03	**End-to-End impact scenarios for hybrid-electric propulsion concepts in short range / regional commercial air transport**	RIA	0.40
JTI-CS2-2018-CFP08-TT-04	**Cognitive Computing potential for cockpit operations**	RIA	0.80

2. Call Rules

Before submitting any proposals to the topics proposed in the Clean Sky 2 Call for Proposals, all applicants shall refer to the applicable rules as presented in the "*Rules for submission, evaluation, selection, award and review procedures of Calls for Proposals*" and the "*Work Plan 2018-2019*".

IMPORTANT:
The "additional conditions" laid down in the CS2JU Work Plan (see chapter 3.3 "*Call management rules*") are not applicable to the topics listed in this call text document.

Special conditions apply to these topics which are launched outside the complementary framework of an IADP/ITD/TA (hereinafter referred to as Thematic Topics):

- **Page limit:**

The limit for a full proposal answering a Thematic Topic is **30 pages** in total, see proposal template B.I.

- **Scoring and weighting:**

For Thematic Topics: to determine the ranking, the score for the criterion 'excellence' will be given a weight of 1.5.

- **Admissibility**

Standard admissibility conditions and related requirements as laid down in Part B of the General Annex of the Work Programme shall apply mutatis mutandis with the following additional condition(s) introduced below:

- The 16 Leaders of JU listed in Annex II to Regulation n° (EU) No 558/2014 and their affiliates[138] **may not apply** to the topics listed in this call text document.

3. Programme Scene setter/Objectives

In accordance with Article 2 of the COUNCIL REGULATION (EU) No 558/2014 of 6 May 2014 the **Clean Sky 2 high-level (environmental) objectives are**:

"*(b) to contribute to improving the environmental impact of aeronautical technologies, including those relating to small aviation, as well as to developing a strong and globally competitive aeronautical industry and supply chain in Europe.*
This can be realised through speeding up the development of cleaner air transport technologies for earliest possible deployment, and in particular the integration, demonstration and validation of technologies capable of:

> *(i) increasing aircraft fuel efficiency, thus reducing CO2 emissions by 20 to 30 % compared to 'state-of-the-art' aircraft entering into service as from 2014;*
> *(ii) reducing aircraft NOx and noise emissions by 20 to 30 % compared to 'state-of-the-art' aircraft entering into service as from 2014."*

These Programme's high-level (environmental) objectives have been translated into **targeted vehicle performance levels,** see table below. Each conceptual aircraft summarises the key enabling technologies, including engines, developed in Clean Sky 2.

Conceptual aircraft / air transport type	Reference a/c*	Window[1]	ΔCO_2	ΔNO_x	Δ Noise	Target[2] TRL @ CS2 close
Advanced Long-range (LR)	LR 2014 ref	2030	20%	20%	20%	4
Ultra advanced LR	LR 2014 ref	2035+	30%	30%	30%	3
Advanced Short/Medium-range (SMR)	SMR 2014 ref	2030	20%	20%	20%	5
Ultra-advanced SMR	SMR 2014 ref	2035+	30%	30%	30%	4
Innovative Turboprop [TP], 130 pax	2014 130 pax ref	2035+	19 to 25%	19 to 25%	20 to 30%	4
Advanced TP, 90 pax	2014 TP ref[4]	2025+	35 to 40%	> 50%	60 to 70%	5
Regional Multimission TP, 70 pax	2014 Multi-mission	2025+	20 to 30%	20 to 30%	20 to 30%	6
19-pax Commuter	2014 19 pax a/c	2025	20%	20%	20%	4-5
Low Sweep Business Jet	2014 SoA Business a/c	2035	> 30%	> 30%	> 30%	≥ 4
Compound helicopter[3]	TEM 2020 ref (CS1)	2030	20%	20%	20%	6
Next-Generation Tiltrotor	AW139	2025	50%	14%	30%	5

*The reference aircraft will be further specified and confirmed through the Technology Evaluator assessment work.
[1]All key enabling technologies at TRL 6 with a potential entry into service five years later.
[2]Key enabling technologies at major system level. The target TRL indicates the level of maturity and the level of challenge in maturing towards potential uptake into marketable innovations.
[3]Assessment v. comparable passenger journey, not a/c mission.
[4] ATR 72 airplane, latest SOA Regional A/C in-service in 2014 (technological standard of years 2000), scaled to 90 Pax.

[138] See the definition under Article 2.1 (2) of the H2020 Rules for Participation

To integrate, demonstrate and validate the most promising technologies capable of contributing to the CS2 high-level and programme specific objectives, the CS2 technology and demonstration activity is structured in **key (technology) themes,** further subdivided in a number of **demonstration areas**, as depicted below. A demonstration area may contribute to one or more objectives and also may involve more than one ITD/IADP.

Ref-Code	Theme	Demonstration area
1A	Breakthroughs in Propulsion Efficiency (incl. Propulsion-Airframe Integration)	Advanced Engine/Airframe Architectures
1B		Ultra-high Bypass and High Propulsive Efficiency Geared Turbofans
1C		Hybrid Electric Propulsion
1D		Boundary Layer Ingestion
1E		Small Aircraft, Regional and Business Aviation Turboprop
2A	Advances in Wings, Aerodynamics and Flight Dynamics	Advanced Laminar Flow Technologies
2B		Regional Aircraft Wing Optimization
3A	Innovative Structural / Functional Design - and Production System	Advanced Manufacturing
3B		Cabin & Fuselage
3C		Innovative Solutions for Business Jets
4A	Next Generation Cockpit Systems and Aircraft Operations	Cockpit & Avionics
4B		Advanced MRO
5A	Novel Aircraft Configurations and Capabilities	Next-Generation Civil Tiltrotor
5B		RACER Compound Helicopter
6A	Aircraft Non-Propulsive Energy and Control Systems	Electrical Systems
6B		Landing Systems
6C		Non-Propulsive Energy Optimization for Large Aircraft
7A	Optimal Cabin and Passenger Environment	Environmental Control System
7B		Innovative Cabin Passenger/Payload Systems
8A	Eco-Design	
9A	Enabling Technologies	
	Technology Evaluator	

The individual topic descriptions provide more detailed information about the link/contribution to the high-level objectives.

4. Clean Sky 2 – Thematic Topics

I. JTI-CS2-2018-CFP08-TT-01: Concept Design of a 19-seat Commuter Aircraft with Hybrid-Electric Powertrain

Type of action (RIA/IA/CSA)	RIA		
Programme Area	SAT		
(CS2 JTP 2015) WP Ref.	N/A		
Indicative Funding Topic Value (in k€)	800 k€*		
Topic Leader	N/A	**Type of Agreement**	N/A
Duration of the action (in Months)	36*	**Indicative Start Date**[139]	Q4 2018

*The JU considers that proposals requesting a contribution of 800k€ over a period of 36 months would allow this specific challenge to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts and/or proposing different activity durations.

Topic Identification Code	**Title**
JTI-CS2-2018-CFP08-TT-01	**Concept Design of a 19-seat Commuter Aircraft with Hybrid-Electric Powertrain**
Short description	
This thematic topic would focus on the concept design of 2 configurations of a 19-seat commuter aircraft based on a hybrid-electric power train architecture. Architectures may include (but are not limited to) concepts based on a jet-fueled (Diesel cycle) piston engine generating electric power, recharging batteries and driving electric propellers or fans (distributed or not). The expected project outcome would include aircraft configuration (aero and structural) as well as sizing and layout of system components, and quantified environmental targets for each architecture with the objective of paving the way towards a potential full-scale European demonstrator.	

Links to the Clean Sky 2 Programme High-level Objectives[140]				
This topic is located in the demonstration area:	N/A			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	N/A			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
X	**X**	**X**	**X**	**X**

139 The start date corresponds to actual start date with all legal documents in place.

140 For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Specific challenge

A number of activities are currently ongoing in the frame of the Small Air Transport (SAT) transverse activity of Clean Sky 2. These are related to the development of advanced engine demonstrators:

- reliable and efficient small gas turbines (turboprop) for short range/regional aircraft (up to 19 seats), in the power range below 1800 hp (thermal), for 2 different configurations :
  - high-speed, high altitude, pressurized a/c
  - low-speed, low altitude, unpressurized a/c
- light-weight jet-fueled (Diesel cycle) piston engines for general aviation and commuter aircraft (9 to 12 seats) in the range of 200-400 hp.
- High Power Density Engine concept (2.5kW/kg or 160kW/l) also based on light-weight jet-fueled (Diesel cycle) piston engines with target application as power generation unit in the range of 300kW to 1MW.

On the other hand, hybrid-electric propulsion and pure electric propulsion are widely seen as having the potential to bring further gains in overall aircraft energy efficiency and emissions reductions, in particular when combined with the potential for relaxing design constraints related to current aircraft designs and making use of e.g. distributed propulsion, energy carriers such as advanced batteries and fuel-cells; and advanced airframe/propulsion integration.

The limitation in specific energy storage capacity of today's battery technology however leads to favour hybrid-electric propulsion concepts instead of full-electric configurations. Depending on the size of the aircraft, the power generation unit would be an internal combustion engine (ICE), typically a piston engine for general aviation and commuter aircraft up to 19 seats or a gas turbine for larger regional aircraft.

The ambition of the present topic is to pave the way towards a potential full-scale European demonstrator at a later stage.

The concept design of the 2 configurations described below should therefore cover the relevant design phases leading to a Preliminary Design Review at the end of the project.

The proposers are therefore strongly encouraged to constitute an Advisory Board to the project, involving relevant industrial parties linked to the major aspects/components of the design.

2. Scope

The aim of this topic is to study and propose a concept of a hybrid-electric power train for a small commuter size aircraft (typically 19 pax).

Two vehicles need to be designed, for which a typical aircraft specification would be provided at the start of the project:

- a low-speed (230 KTAS)/low altitude (15000ft), unpressurized configuration
- a high-speed (290 KTAS)/high altitude (25000ft), pressurized configuration

Both designs should be compliant with FAR23 / CS23 regulation, range and payload to be optimized.

The action will depart from an analysis and literature review of the State of the Art [SoA] of research and/or developments underway in the field of future hybrid-electric propulsion architectures, in their various concepts and state of technology readiness.

On systems level, the research has to focus on efficiency and TRL of every single component of the power train, i.e. energy storage systems, powerplant, generator, power distribution and conversion, electric motor and propulsors.

Such propulsors can be a propeller, a shrouded fan, or even a distributed propulsion system. On integrated system level the power train architecture shall be optimized for efficiency and mass, and

inherent issues such as EMI, arcing and component cooling have to be systematically addressed.
Feasibility should be assessed and concepts should be proposed first using state-of-the-art components or assuming near term realistic performance targets, after which evolutionary concepts may be proposed based on reasonable assumptions regarding performance levels to be achieved in the longer term future.
Research on aircraft level will focus on the integration of the power train components in the airframe and analyze efficient new aircraft configurations taking into account the peculiarities of hybrid-electric propulsion systems.
A holistic optimization approach is required on aircraft level with respect to mass and centre of gravity, power management strategies, certification requirements, fuel consumption and related emissions, community noise, infrastructure compatibility and acquisition and operating cost.
The work needs to include an analysis of the various fault scenarios for both the electric machine(s) and the power converter(s) for the various architectures under investigation, to confirm their fulfillment of the fault-tolerance requirements of the Hybrid-electric power train concept for a small 19 seats commuter a/c.

3. Expected outcomes/impact

- A comprehensive literature review of the state-of-the-art of
    - electric or hybrid-electric aircraft configuration studies, including but not restricted to the 19-seat category
    - individual components relevant to the hybrid-electric architecture
- For each configuration, the concept design is expected to provide all information and material relevant to pass a Preliminary Design Review (PDR) in industrial terms:
    - (a) the conceptual design of the aircraft, including 3D CAD model and aerodynamic model validation, and structural concept.
    - (b) at system level, detailing the sizing and layout of all components, following a system optimization but also component optimization.
    - (b) primary performance parameters and propulsion system fault-tolerance related to the reliability/availability criteria
    - (c) quantified environmental targets for each architecture
- Demonstrate the feasibility and benefits of the hybrid piston-electric power train concept (or any other powerplant option) to the field of flight transportation for small commuter a/c.
- Identification of scientific and technical challenges for the successful deployment of such architectures, and specifically categorization and specification of gaps from the current SoA to the required performance for a viable commuter size aircraft.
- Advise on the required steps towards the progress needed in improving individual system components performance.
- Upgrade potential: indicate the potential for aircraft performance improvement (specifically reagarding range) based on technology insertion at component level [e.g. higher energy density batteries or more efficient Diesel engine cycles, fuel cells, etc.]
- Set-Up of a relevant Advisory Board to the project (or End User Group), so as to involve component providers from the early stage, in view of a potential physical demonstrator at European level.

As part of the project implementation, the JU envisages a review of the technological relevance against the objectives.

4. Topic special conditions

Special conditions apply to this topic:

- **Page limit:**

The limit for a full proposal answering a Thematic Topic is **30 pages** in total, see proposal template B.I.

- **Scoring and weighting:**

For Thematic Topics: to determine the ranking, the score for the criterion 'excellence' will be given a weight of 1.5.

- **Admissibility**

Standard admissibility conditions and related requirements as laid down in Part B of the General Annex of the Work Programme shall apply mutatis mutandis with the following additional condition(s) introduced below:

  - The 16 Leaders of JU listed in Annex II to Regulation n° (EU) No 558/2014 and their affiliates[141] **may not apply** to the topics listed in this call text document.

[141] See the definition under Article 2.1 (2) of the H2020 Rules for Participation

II. JTI-CS2-2018-CFP08-TT-02: Innovative NOx Reduction Technologies

Type of action (RIA/IA/CSA)	RIA		
Programme Area	ITD ENGINES		
(CS2 JTP 2015) WP Ref.	N/A		
Indicative Funding Topic Value (in k€)	1000 k€*		
Topic Leader	N/A	**Type of Agreement**	N/A
Duration of the action (in Months)	48*	**Indicative Start Date**[142]	Q4 2018

*The JU considers that proposals requesting a contribution of 1000k€ over a period of 48 months would allow this specific challenge to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts and/or proposing different activity durations.

Topic Identification Code	**Title**
JTI-CS2-2018-CFP08-TT-02	**Innovative NOx Reduction Technologies**
Short description	
This topic addresses the general objective of NO_x reduction in aero-engines through specific technologies or methods of controlling nitric oxides production from the combustion process of kerosene. Proposals are expected to provide solutions focusing on key technologies and tools (numerical and/or experimental), innovative concepts for advanced low emissions combustion, for the mid-term (EIS 2035) and long-term (EIS 2050) technology goals.	

Links to the Clean Sky 2 Programme High-level Objectives[143]				
This topic is located in the demonstration area:	N/A			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	N/A			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
X	**X**	**X**	**X**	

[142] The start date corresponds to actual start date with all legal documents in place.
[143] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Specific challenge

To date, good progress has been made towards the ACARE SRA goals for 2020 (see "ACARE Success Stories: benefits beyond aviation" published in March 2011 and the Clean Sky 1 Technology Evaluator Report[144] published in 2017). In the renewed ACARE SRIA, released in 2012, the goals were extended to 2050 and stretched to more ambitous levels to contribute sufficiently to the need for aviation to strongly reduce its potential environmental impact in the face of continued growth of demand.

In 2050, technologies and procedures available should allow a 75% reduction in CO_2 emissions per passenger kilometre and a 90% reduction in NO_x emissions. The perceived noise emission of flying aircraft is to be reduced by 65%. These are relative to the capabilities of typical new aircraft in 2000.

These goals have been translated into the Clean Sky 2 Joint Undertaking Regulation[145] and its high-level objectives as follows:

(i) Increasing aircraft fuel efficiency, thus reducing CO_2 emissions by 20 to 30% compared to "state-of-the-art" aircraft entering into service as from 2014

(ii) Reducing aircraft NO_x and noise emissions by 20 to 30% compared to "state-of-the-art" aircraft entering into service as from 2014.

Under ICAO CAEP/6 legislation, and now CAEP/8 (which may also be further restricted in the next revision), the NO_x requirements have become the main driver in the development of combustors for the next generation of aero-engines. In addition, future engine cycles, characterized by the requirements of lowest fuel consumption and CO_2 emissions trend towards higher BPR and higher OPR, resulting in core engines with increased combustor inlet pressures, temperatures and significantly lower air/fuel ratios. In the future, the main driver may be shifted towards nvPM requirements, especially at low power.

Although the focus of this topic is on NOx reduction, it is well understood that the combustor design space is constrained by conflicting requirements of reducing CO_2 and noise while minimizing CO, unburned HC, smoke, nvPM. The difference in LTO NOx levels between the best design for low NO_x and the best design for low CO_2 can be up to 30%, noting that the best design for Noise is yet another optimum.

The focus of this topic will be on engine technologies. Aircraft and ATM contributions to NOx reduction are to be considered out of scope. Although alternative fuels are evidently of interest, there are currently also left out of scope of the present topic.

2. Scope

The scope of this topic is twofold in terms of timeframe: progress on mid-term technology developments for EIS 2035, and breakthrough technologies for long term developments for EIS 2050.

The scope is also twofold in terms of technology concepts (although not restricted to): primary control technologies to reduce NOx in the primary combustion zone, or secondary technologies to reduce NOx already present in the combustion gas (outside of the combustion zone, in the exhaust).

Concepts and technologies may address any aero-engine market segment, i.e. turbofans, turboprops, helicopter engines.

2.1. Mid-term technology developments for EIS 2035

Over the past decades, only significant improvements of conventional but optimised rich burn combustors avoided excessive NO_x formation due to the worse cycle conditions. This approach however

[144] http://www.cleansky.eu/technology-evaluator-te

[145] Council Regulation (EC) No 71/2008 of 20 December 2007 setting up the Clean Sky Joint Undertaking

has limited potential to cope with future legislative requirements while facing further demanding cycle conditions. Therefore, a revolutionary step towards highly advanced rich or lean burn combustion techniques is mandatory to meet future certification requirements with margin.

Significant efforts have been invested in recent years in the development of Lean Burn Combustion, not only in the Clean Sky framework but also in several European and national Programmes (including H2020 and earlier FPs).

A number of challenges still remain and need to be overcome.
Further developments of key technologies/tools helping progress in low emissions combustion technology are expected in the following areas:

- Progress in fundamental understanding and modelling of low emission combustion processes, including thermoacoustics, combustion dynamics/stability, entropy noise generation and propagation, particulates research (smoke/soot), spray modelling (especially at high pressure/temp.), etc. Improve predictive models including CO, NO_x, unburned HC, (SO_2), as well as particles (growth and size distribution). Improve accuracy of quantitative chemical kinetic mechanisms modelling, in particular for high pressure combustion.
- Progress in improving numerical simulation methods of combustion processes. Increasing predictive accuracy (and computational speed), relative to current state-of-the-art combustion CFD with validated emission indices and combustor performance metrics.
- Progress in improving or development of new measurement techniques for experimental validation of the combustion flow field, in particular for the measurement of unsteady temperature. Sampling methodology development and validation. Diagnostic instrumentation capable of measuring more accurately temporally and spatially species, velocity, temperature, pressure, particle sizes and distribution, on low and high TRL rigs.
- Progress in instrumentation of combustion chambers (flame detectors, flame temperature, …) for development engines in the short term but with a view on Health Monitoring in the long term. Development of MEMS-based fuel-air injectors with high-speed micro-actuators embedded in the assembly. Fuel cocking monitoring. Active Control.
- Progress in "integrated" and optimized combustion chamber designs, including monitoring instrumentation, based on advanced manufacturing techniques (additive manufacturing).

The availability of fundamental test cases, fundamental experimental databases on emissions production on given reference combustor configurations, with open access and availability to the research community to run CFD or measurement technique validations on advanced low emissions combustors (reference test cases) is strongly encouraged. Some similar initiatives already exist (e.g. ISF).

Key technologies/tools should be specifically improved in terms of application to (but not limited to):

- Advanced Rich Burn and RQL Combustors (single or double injector, …), especially regarding soot/particles generation
- Lean Burn Combustors
    - Staged Lean Burn Combustor (with pilot injector)
    - Lean Direct Injection (LDI)

<u>2.2. Breakthrough technologies for Long-term innovative concepts for EIS 2050.</u>
Additionally, new concepts for primary zone or secondary zone technologies would be expected to be investigated or reconsidered as long term technology goals in a holistic approach at complete engine

design level or even at aircraft level.
The scientific and technical challenges preventing the successful deployment of such technologies should be identified.

Some examples of alternative NO_x reduction technologies have been identified over the years, sometimes used in other sectors (industry, automotive, etc.), sometimes evaluated only at very low TRL so far, and/or suffering issues in providing either a competitive market solution, reliability or weight issues when applied to aeronautical applications. Some of these examples however may exhibit promising potential for low emission engines in the long term future if their main drawbacks can be overcome.

- Lean Pre-mixed Pre-vapourized (LPP)
- Flameless oxidation combustion (flue gas recirculation)
- Jet-stabilized combustion
- Catalytic combustion
- Trapped Vortex Combustion
- Stagnation Point Reverse Flow (SPRF) Combustor
- Electrochemical blocking of NO_x molecules (modulated arc and/or microwave discharges)
- Plasma assisted combustion (high-frequency discharges, Nanosecond Repetitively Pulsed (NRP) discharges)
- Electromagnetic decomposition of NOx molecules
- Selective Catalytic Reduction (SCR)
- Selective Non-Catalytic Reduction (SNCR)
- Water/Steam injection
- Intercooled/Alternative engine cycles
- Variable geometry engines and/or combustors
- Pressure Gain Combustors

3. Expected outcomes/impact

Proposals may address one or more technology solutions/tools/concepts described in the previous section or new solutions responding to the need of low emission combustors, at engine level.

The expected outcome of a project should include:

- A comprehensive literature review of the state-of-the-art in relation with the solution proposed.
- Key technologies/tools/concepts helping progress in low emissions combustion technology may cover one or several of the previously described items but the proposal should clearly state the initial TRL of the study and clear objectives in terms of NO_x reduction target.
- Identification of scientific and technical challenges preventing the successful deployment of such technologies.

As part of the project implementation, the JU envisages a review of the technological relevance against the objectives.

4. Topic special conditions

Special conditions apply to this topic:

- **Page limit:**

The limit for a full proposal answering a Thematic Topic is **30 pages** in total, see proposal template B.I.

- **Scoring and weighting:**

For Thematic Topics: to determine the ranking, the score for the criterion 'excellence' will be given a weight of 1.5.

- **Admissibility**

Standard admissibility conditions and related requirements as laid down in Part B of the General Annex of the Work Programme shall apply mutatis mutandis with the following additional condition(s) introduced below:

  - The 16 Leaders of JU listed in Annex II to Regulation n° (EU) No 558/2014 and their affiliates[146] **may not apply** to the topics listed in this call text document.

[146] See the definition under Article 2.1 (2) of the H2020 Rules for Participation

III. JTI-CS2-2018-CFP08-TT-03: End-to-End impact scenarios for hybrid-electric propulsion concepts in short range / regional commercial air transport

Type of action (RIA/IA/CSA)	RIA		
Programme Area	N/A		
(CS2 JTP 2015) WP Ref.	N/A		
Indicative Funding Topic Value (in k€)	400 k€*		
Topic Leader	N/A	Type of Agreement	N/A
Duration of the action (in Months)	24*	Indicative Start Date[147]	Q4 2018

*The JU considers that proposals requesting a contribution of 400k€ over a period of 24 months would allow this specific challenge to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts and/or proposing different activity durations.

Topic Identification Code	Title
JTI-CS2-2018-CFP08-TT-02	**End-to-End impact scenarios for hybrid-electric propulsion concepts in short range / regional commercial air transport**
Short description	
The objective of this project is to assess how Hybrid Electric Propulsion could support reductions in airborne emissions of short range, regional air transport operations. The horizon for potential aircraft EIS is 2035+. Infrastructure related impacts [e.g. recharging scenarios], operational and fleet composition impacts should be assessed and shown in varying scenarios. The "end-to-end" impact scenarios should consider expected full life-cycle effects of the use of new materials, energy carriers and energy use over the complete lifecycle of the aircraft, in the design, manufacturing, support, maintenance and disposal alongside the "on ground" and in flight operations.	

Links to the Clean Sky 2 Programme High-level Objectives[148]				
This topic is located in the demonstration area:	N/A			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	N/A			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
X	X	X	X	X

[147] The start date corresponds to actual start date with all legal documents in place.

[148] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Specific challenge

To date, good progress has been made towards the ACARE[149] SRA goals for 2020. In a renewed ACARE SRIA, released in 2012, the goals were extended to 2050 and stretched to more ambitous levels to contribute sufficiently to the need for aviation to strongly reduce its potential environmental impact in the face of continued growth of demand. In 2050, technologies and procedures available should allow a 75% reduction in CO2 emissions per passenger kilometre and a 90% reduction in NOx emissions The perceived noise emission of flying aircraft is to be reduced by 65%. In addition, aircraft should be fully recyclable by 2050. These are relative to the capabilities of typical new aircraft in 2000. These goals have been translated into the Clean Sky 2 Joint Undertaking Regulation and its high-level objectives as follows:

(iii) Increasing aircraft fuel efficiency, thus reducing CO2 emissions by 20 to 30% compared to "state-of-the-art" aircraft entering into service as from 2014

(iv) Reducing aircraft NOx and noise emissions by 20 to 30% compared to "state-of-the-art" aircraft entering into service as from 2014

Current assessments indicate that the rate of aircraft emissions improvements, based on evolutionary design approaches [at fleet level roughly 1.0 to 1.5% per annum and between consecutive "generations" of aircraft roughly 15 – 20% every 15 to 20 years] is not sufficient to achieve the goals set for 2050. New propulsion concepts, and new aircraft configurations including improved systems and materials are likely to require more disruptive approaches in the timeframe from now until the potential EIS in 2035 of "clean sheet" designs. Hybrid-electric propulsion is widely seen as having the potential to bring further gains in energy efficiency and emissions reductions, in particular when combined with the potential for relaxing design constraints related to current aircraft designs and making use of e.g. distributed propulsion, embedded engines, boundary layer ingestion effects, energy carriers such as advanced batteries and fuel-cells; and advanced airframe/propulsion integration.

The study should focus on the end-to-end decarbonisation potential and life-cycle effects of a future fleet of regional / short-haul aircraft using a hybrid-electric propulsion concept, and incorporating the potential impact of alternative short range/regional aircraft architectures concerning an advanced aircraft design concept, propulsion hybridization, and significantly increased energy efficiency. The impact of components' increased power density and efficiency, and recharge/discharge rates for on board energy carriers like batteries.

2. Scope

For practical reasons the scope of the study will be limited to the air transport system's segment that can be served by aircraft with a maximum range no greater than 2000km and sized between 40 and 70 passenger seating capacity. A sensitivity analysis of the benefits of new propulsion concepts with respect to aircraft sizing is expected. A relevant reference aircraft exhibiting the 2014 "State-of-the-Art" aircraft in service and/or in production shall be selected, and comparative performance in the sense of life-cycle impact as well as airborne emissions will be shown.

The action should depart from an analysis of the State of the Art [SoA], and literature listing of research and/or development underway in the field of future hybrid-electric propulsion architectures, in their various concepts and state of technology readiness also considering other sectors. The SoA analysis and the resulting study on the potential use on aircraft should include an analysis of potential vehicle

[149] ACARE - Advisory Council for Aviation Research and Innovation in Europe; http://acare4europe.org/

designs as related to top-level requirements such as range, payload and dimensioning. Previous research into the in-flight performance potential and the technology gaps that require action, as well as the lifecycle effects potentially resulting from hybrid-electric propulsion concepts should be referenced and synthesized.

Technology options should be assessed and the potential for gains in aircraft efficiency assessed, using current state-of-the-art components / systems or near term realistic performance targets as a departing point, after which more advanced concepts should be proposed, using assumptions regarding performance levels to be achieved in the longer term future. The study should quantify the limitations in aircraft range and performance e.g. as a function of the battery / energy carrier technology level, providing suggestions for high specific energy options including their likely means of production.
Life-cycle effects should be analyzed, regarding the use of materials, energy carriers and energy use over the complete lifecycle of the aircraft, in the design, manufacturing, support, maintenance and disposal alongside the "on ground" and in flight operations. Analysis of the resource consumption and impact of the production of energy carriers [e.g. batteries] is a key aspect to be investigated, this being one of the main contributors to the life cycle impact when compared to conventional technology. The electrical recharging and storage aspects of the hybrid-electric concept, through on-ground recharging and/or via in-flight recharging, should be analyzed and various concepts compared for their potential benefits. Recycling and reuse aspects should be included as well as electricity production aspects and the sensitivity of this impact with respect to the energy source.
The possible airport infrastructure impacts are also suggested for inclusion in the analysis [depending on charging scenarios / strategies].

A synthesis report including the key technology challenges versus the SoA, and suggested solutions to address them should be provided with the aim to define a baseline to be used to direct and accelerate the research on hybrid electric propulsion for the regional aircraft market.

For this study the use of current aviation fuels in the hybrid-electric architecture should be assumed, with the overall lifecycle and *net emissions* impact of sustainable fuels to considered out of scope.

3. Expected outcomes/impact

- A comprehensive literature review of the state-of-the-art in regional aircraft life cycle assessment.
- Quantified environmental [energy and emissions reductions] potentials for novel architecture options with specific emphasis to be addressed to architectural and component improvements considering life cycle analysis effects of a regional aircraft.
- Contribution to identify the scientific and technical challenges for the successful deployment of hybrid-electric propulsion architectures, with clear indication of gaps from the current state-of-the-art to the required performance of a viable regional aircraft.

As part of the project implementation, the JU envisages a review of the technological relevance against the objectives.

4. Topic special conditions

Special conditions apply to this topic:

- **Page limit:**

The limit for a full proposal answering a Thematic Topic is **30 pages** in total, see proposal template B.I.

- **Scoring and weighting:**

For Thematic Topics: to determine the ranking, the score for the criterion 'excellence' will be given a weight of 1.5.

- **Admissibility**

Standard admissibility conditions and related requirements as laid down in Part B of the General Annex of the Work Programme shall apply mutatis mutandis with the following additional condition(s) introduced below:

  - The 16 Leaders of JU listed in Annex II to Regulation n° (EU) No 558/2014 and their affiliates[150] **may not apply** to the topics listed in this call text document.

[150] See the definition under Article 2.1 (2) of the H2020 Rules for Participation

IV. JTI-CS2-2018-CFP08-TT-04: Cognitive Computing potential for cockpit operations

Type of action (RIA/IA/CSA)	RIA		
Programme Area	N/A		
(CS2 JTP 2015) WP Ref.	N/A		
Indicative Funding Topic Value (in k€)	800 k€*		
Topic Leader	N/A	**Type of Agreement**	N/A
Duration of the action (in Months)	36*	**Indicative Start Date**[151]	Q4 2018

*The JU considers that proposals requesting a contribution of 800k€ over a period of 36 months would allow this specific challenge to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts and/or proposing different activity durations.

Topic Identification Code	**Title**
JTI-CS2-2018-CFP08-TT-04	**Cognitive Computing potential for cockpit operations**
Short description	
The objective of this research project is to assess how Cognitive Computing could efficiently support by 2035+ pilot decision making in unexpected or very complex situations.	

Links to the Clean Sky 2 Programme High-level Objectives[152]				
This topic is located in the demonstration area:	N/A			
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter	N/A			
With expected impacts related to the Programme high-level objectives:				
Reducing **CO2** emissions	Reducing **NOx** emissions	Reducing **Noise** emissions	Improving EU **Competitiveness**	Improving **Mobility**
			X	**X**

[151] The start date corresponds to actual start date with all legal documents in place.

[152] For further info see Chapter 1 “Introduction to the Programme Scene Setter / Objectives” with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Specific challenge

Designing machines which are able to interact naturally and "intelligently" with human beings has been a key aspiration of computer sciences for years. As the transport sector moves towards vehicles and transport systems which perform autonomously in social ecosystems: e.g. virtual assistants, assistive robots, autonomous transport vehicles, etc., this capability will become a requirement.

A variety of assisted solutions have been developed in recent years to benefit from embedded and intelligent systems towards more assisted and increasingly towards autonomous operations in domains such as manufacturing, health care, automotive, space, etc.

Similar benefits are expected to emerge in the next decade towards autonomous flight transport. The benefits and the potential of such technologies is still to be defined to assess how aircraft control could be better shared between the human and the machine, beyond the existing state of the art.

This topic contributes to the CS2 High Level Objectives by supporting the path towards European Aeronautical industry competitiveness in the field of more autonomous flight transport, and towards increased air transport capacity, efficiency and safety.

2. Scope

The action will depart from an analysis of the State of the Art of cognitive computing applied to sectors such as – inter alia - automotive, health care or space…to define the current usage, and existing requirements and limitations of such technologies.

A second starting point should be the review of past research on "Intelligent pilot assistance systems" based on conventional technologies. A mapping exercise and a review of these initiatives would be expected clearly depicting the targeted scope of pilot support, the achievements, the shortcomings and the level of demonstration (lab / Flight simulator / flight testing)

Cockpit operations of large commercial aircraft such as the A350, A380 or A320, or similar, should also be analyzed along 2 directions: the pilot ["man in the loop"] interaction with the systems and the nature of information delivered. The analysis should allow for identifying specific in-flight conditions, related pilot behavior, and how data is interpreted, and how and when collaborative / assisted decisions are made.

The core of the action should consist of identifying how cognitive computing could bring more efficient support to the pilot in the light of existing limitations (e.g misunderstanding of the information delivered and the risk of wrong decisions made).

The action should address how the cognitive computing could provide benefits and what kind of areas deserve specific effort of maturation to make emerging solutions by 2035+ for future cockpit and flight control concepts.

The action should address the following aspects:

- Identification of essential parameters necessart to follow he state of the aircraft and planning capabilities with respect to the mission
- Identification of pilot expectations in various context based on information available (identified before) and current pilot state

- Analysis of channel of acquisition and transmission of the information (text, voice, vision, …) from/to the pilot
- Nature and content of the information to be given to the pilot to make the right decision

The action will result in case studies deemed relevant (either simulation or specific demonstrations) to extrapolate the potential of cognitive computing and to demonstrate how they will offer a significant aid to the pilot. Those case studies will help identifying the nature of technologies to be further mature/ developed over the next decade (from TRL1 to TRL6). They will also provide the kind of data necessary to make the solutions effective and how pilots should be trained in such a context to make the solution robust and effective (machine learning approach).

3. Expected outcomes/impact

- A comprehensive literature review of the state-of-the-art in the area of research.
- Progress in improving man/machine interaction in the field of more autonomous flight transport
- Robust collaborative decision making, to satisfy aeronautical safety objectives, with significant benefits in pilot workload and effectiveness
- Identify a technology roadmap for a flight crew digital assistant function
- Identify the pathway to a digital assistant function supporting flight crews or remotely operated air vehicles
- Demonstrate the applicability of the benefits of the cognitive assistant improvements to the field of flight transportation
- Identification of scientific and technical challenges preventing the successful deployment of such technologies
- Specific emphasis should be given to assessing the predictability and certifiability of such approaches. This would require a specific approach, e.g. as it is currently under investigation in the automotive domain (deep driving, etc…)

As part of the project implementation, the JU envisages a review of the technological relevance against the objectives.

4. Topic special conditions

Special conditions apply to this topic:

- **Page limit:**

The limit for a full proposal answering a Thematic Topic is **30 pages** in total, see proposal template B.I.

- **Scoring and weighting:**

For Thematic Topics: to determine the ranking, the score for the criterion 'excellence' will be given a weight of 1.5.

- **Admissibility**

Standard admissibility conditions and related requirements as laid down in Part B of the General Annex of the Work Programme shall apply mutatis mutandis with the following additional condition(s) introduced below:

  - The 16 Leaders of JU listed in Annex II to Regulation n° (EU) No 558/2014 and their affiliates[153] **may not apply** to the topics listed in this call text document.

[153] See the definition under Article 2.1 (2) of the H2020 Rules for Participation