Annex VI:
10th Call for Proposals (CFP10) -
List and Full Description of Topics

Call Text

R1 [V2]

- 12 March 2019 -

The present preliminary version of the Call Text is released for information and addressed to any interested party prior to the official launch of the Call anticipated in May 2019. The final call text document serving as the foundation for any application to this Call and Q&A will be published via the H2020 Funding & Tender Opportunities Portal of the European Commission. 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**
R1 (V2)	12/03/2019	Preliminary draft released for information via JU website

Important notice on Q&As

Question and Answers will open as from the Call Opening date i.e. on or soon after 07 May 2019 via the H2020 Funding & Tenders Opportunities 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**: Info-Call-CFP-2019-01@cleansky.eu.

Note that questions received **up until 05/07/2019, 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: 06/06/2019, 04/07/2019 and 01/08/2019 (estimated dates).

The Q/As will made available via the H2020 Funding & Tenders Opportunities Portal of the European Commission.

CfP10 Info Days (Main and Local): May and June 2019.
More information on the Call and related events via the Clean Sky 2 website: www.cleansky.eu

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List of Topics for Calls for Proposals (CFP10) – Part A

Identification Code	Title	Type of Action	Value (Funding in M€)	Topic Leader
JTI-CS2-2019-CfP10-LPA-01-72	Development of a distributed CFD platform for collaborative design	IA	0.6	Airbus
JTI-CS2-2019-CfP10-LPA-01-73	Innovative Thrust Reverser Actuator System (ITRAS)	IA	0.9	Airbus
JTI-CS2-2019-CfP10-LPA-01-74	UHBR Engine Studies for Aircraft Operations and Economics	IA	0.5	Airbus
JTI-CS2-2019-CfP10-LPA-01-75	Advanced solutions for 2030+ UHBR Core Noise reduction	IA	2.5	Safran Aircraft Engines
JTI-CS2-2019-CfP10-LPA-01-76	Supporting implementation of 2030+ UHBR low noise fan technology solutions through enhanced modeling capabilities	IA	1.4	Safran Aircraft Engines
JTI-CS2-2019-CfP10-LPA-01-77	Advanced Pitch Control Mechanism TRL4 Demonstration	IA	3.5	Safran Aircraft Engines
JTI-CS2-2019-CfP10-LPA-01-78	Innovative turbine cavity swirl control systems through Additive Manufacturing	RIA	0.9	GE Avio
JTI-CS2-2019-CfP10-LPA-01-79	Development of multidisciplinary design tools for rapid concept design for aero engine components	IA	0.5	GKN
JTI-CS2-2019-CfP10-LPA-01-80	Rear fuselage and empennage shape optimization including anti-icing technologies	RIA	1.5	Airbus
JTI-CS2-2019-CfP10-LPA-01-81	Fiber reinforced thermoplastics manufacturing for stiffened, complex, double curved structures	IA	0.7	German Aerospace Center, DLR
JTI-CS2-2019-CfP10-LPA-01-82	Development of Thermoplastic press forming Tool for Advanced Rear End Closing Frame Prototype and Tooling 4.0 for Assembly and transportation of the Advanced Rear End Prototype.	IA	0.75	Aernnova
JTI-CS2-2019-CfP10-LPA-01-83	Development and simulation of a forming process for LE HLFC wing outer skins	IA	1.3	Aernnova
JTI-CS2-2019-CfP10-LPA-01-84	Development of a manufacturing process and a manufacturing unit for production of a laser treated titanium panel with a 3D printed substructure	IA	1.5	Fraunhofer
JTI-CS2-2019-CfP10-LPA-01-85	Design and manufacturing of multi-functional Ice Protection System power feed/monitoring lines and Shielding/High-lift electrical actuation system for a HLFC Wing demonstrator	IA	0.7	SONACA
JTI-CS2-2019-CfP10-LPA-01-86	Develop and test Power Efficient Actuation Concepts for Separation Flow Control at large aerodynamic areas requiring very low actuation energy	IA	0.9	Airbus
JTI-CS2-2019-CfP10-LPA-01-87	Loop Heat Pipe development for severe environment	IA	0.5	Liebherr

Identification Code	Title	Type of Action	Value (Funding in M€)	Topic Leader
JTI-CS2-2019-CfP10-LPA-02-30	Development of innovative welding systems for structural joints of Thermoplastic matrix based Composites	IA	0.75	Aernnova Composites Illescas
JTI-CS2-2019-CfP10-LPA-02-31	Development of short fibre reinforced thermoplastic airframe clips and brackets using factory waste	IA	0.5	Fokker
JTI-CS2-2019-CfP10-LPA-02-32	Innovative miniaturized sensing device for large wave length spectrum reception capability as a tool for quality control and aircraft maintenance	RIA	0.8	Airbus Operations
JTI-CS2-2019-CFP10-LPA: 19 topics			**20.70**	
JTI-CS2-2019-CFP10-REG-01-18	Theoretical and experimental evaluations of strain field modification induced by flaws in loaded composite structures	RIA	0.45	Leonardo SpA - Aircraft
JTI-CS2-2019-CFP10-REG-01-19	Innovative Noise Generation System for testing of Regional Cabin Interior Noise reduction	IA	0.55	Leonardo SpA - Aircraft
JTI-CS2-2019-CFP10-REG-02-06	SHMS and Dynamic fields sensors development	RIA	0.35	Airbus Defence & Space
JTI-CS2-2019-CFP10-REG: 3 topics			**1.35**	
JTI-CS2-2019-CFP10-FRC-01-28	Innovative kinematic analysis to incorporate multiple functions within a movable surface	RIA	0.50	Leonardo SpA Helicopter
JTI-CS2-2019-CFP10-FRC-01-29	Smart Active Inceptors System development for Tilt Rotor application	IA	3.50	Leonardo SpA Helicopter
JTI-CS2-2019-CFP10-FRC-01-30	Multipurpose bench for Tiltrotor equipment functional test	IA	0.80	Leonardo SpA Helicopter
JTI-CS2-2019-CFP10-FRC-01-31	Engine exhaust wake flow regulator for Tilt Rotor	IA	1.60	Leonardo SpA Helicopter
JTI-CS2-2019-CFP10-FRC: 4 topics			**6.40**	
JTI-CS2-2019-CFP10-AIR-01-41	Low speed handling quality and innovative engine integration of a new configuration aircraft	IA	0.70	Dassault Aviation
JTI-CS2-2019-CFP10-AIR-01-42	Development of a methodology (test, measurement, analysis) to characterize the behaviour of composite structures under dynamic loading	RIA	0.50	Dassault Aviation
JTI-CS2-2019-CFP10-AIR-01-43	Verification of advanced simplified HLFC concept with variable porosity	RIA	0.75	German Aerospace Center DLR
JTI-CS2-2019-CFP10-AIR-01-44	Development of a methodology to optimize a wing composite panel with respect to tyre damage certification requirement	RIA	1.40	Dassault Aviation
JTI-CS2-2019-CFP10-AIR-01-45	Coupon and element testing and manufacturing of test article for morphing technologies	IA	0.90	Fokker Aerostructures
JTI-CS2-2019-CFP10-AIR-02-77	Increasing the efficiency of pulsed jet actuators for flow separation control.	RIA	0.70	Airbus

Identification Code	Title	Type of Action	Value (Funding in M€)	Topic Leader
JTI-CS2-2019-CFP10-AIR-02-78	Application of graphene based materials in aeronautical structures for de-icing, lightning strike protection, fire barrier and water absorption prevention purposes	IA	0.50	Leonardo SpA Aircraft
JTI-CS2-2019-CFP10-AIR-02-79	Development of FEM fastener parametric/adaptable sizing tool including EMC impact, and manufacturing and EMC/LSP testing of demonstrators [SAT]	IA	0.475	Evektor
JTI-CS2-2019-CFP10-AIR-02-80	Innovative flight data measurements to support the aerodynamic analysis of a compound helicopter demonstrator	IA	1.20	Airbus Helicopters
JTI-CS2-2019-CFP10-AIR-02-81	Active Flow control on Tilt Rotor lifting surfaces	RIA	0.60	Leonardo SpA Helicopter
JTI-CS2-2019-CFP10-AIR-02-82	Innovative approaches for interior Noise Control for Next Generation Civil Tilt Rotor	RIA	0.65	Leonardo SpA Helicopter
JTI-CS2-2019-CFP10-AIR-02-83	Innovative weight measurement system for Tilt Rotor application	IA	0.80	Leonardo SpA Helicopter
JTI-CS2-2019-CFP10-AIR-02-84	Modular platform development for Tilt Rotor final assembly	IA	1.00	Leonardo SpA Helicopter
JTI-CS2-2019-CFP10-AIR-02-85	Development of a multifunctional system for complex aerostructures assembly, assisted by neural network softwares	IA	0.90	Leonardo SpA Aircraft
JTI-CS2-2019-CFP10-AIR-02-86	Development of equipment for composite recycling process of uncured material	IA	0.80	Leonardo SpA Aircraft
JTI-CS2-2019-CFP10-AIR-03-07	End of Life (EoL) for biomaterials	RIA	0.35	INVENT GmbH
JTI-CS2-2019-CFP10-AIR-03-08	Disassembly and recycling of innovative structures made of different Al-Li alloys	RIA	0.35	Aero-Magnesium
JTI-CS2-2019-CFP10-AIR-03-09	Scrapping of carbon reinforced thermoplastic materials	RIA	0.35	Netherlands Aerospace Centre
JTI-CS2-2019-CFP10-AIR: 18 topics			**12.925**	
JTI-CS2-2019-CfP10-ENG-01-43	Low NOx / Low soot injection system design for spinning combustion technology	RIA	0.6	Safran Helicopter Engines
JTI-CS2-2019-CfP10-ENG-04-08	Revalorisation of Recycled Carbon Fibers and CFRP preparation through Eco design [ECO]	IA	1.75	Fraunhofer
JTI-CS2-2019-CFP10-ENG: 2 topics			**2.35**	
JTI-CS2-2019-CfP10-SYS-01-15	Enhanced digital georeferenced data models for cockpit use	IA	1.00	Thales
JTI-CS2-2019-CfP10-SYS-01-16	Innovative processing for flight practices improvement	IA	0.60	Thales
JTI-CS2-2019-CfP10-SYS-01-17	New Efficient production methods for 94 GHz (W-band) waveguide antennas	IA	0.50	SAAB

Identification Code	Title	Type of Action	Value (Funding in M€)	Topic Leader
JTI-CS2-2019-CfP10-SYS-01-18	Low-profile/drag electronically steerable antennas for In-Flight Connectivity	IA	1.40	Thales
JTI-CS2-2019-CfP10-SYS-01-19	VOC filtration device for Inerting System	IA	0.90	Zodiac Aerospace
JTI-CS2-2019-CfP10-SYS-01-20	Innovative high flow rate constant pressure valve for inert gas discharge from pressurized vessels	IA	0.70	Diehl Aviation
JTI-CS2-2019-CfP10-SYS-01-21	Grey Water Container with Reduced Biofilm Growth	IA	0.70	Diehl Aviation
JTI-CS2-2019-CfP10-SYS-02-58	Automatic Haptic System Test Bench for Active Inceptors	IA	0.70	Safran
JTI-CS2-2019-CfP10-SYS-02-59	Innovative DC/DC converter for HVDC power sources hybridization	IA	0.80	Airbus
JTI-CS2-2019-CfP10-SYS-02-60	Toward a Digital Twin ECS and thermal management architecture models : Improvement of MODELICA libraries and usage of Deep Learning technics	IA	0.60	Liebherr
JTI-CS2-2019-CfP10-SYS-02-61	Vapor Cycle System - Heat Exchanger performance 3D modelization with different new low GWP refrigerants	RIA	1.20	Liebherr
JTI-CS2-2019-CfP10-SYS-03-23	Electro-Mechanical Landing Gear system integration for Small Aircraft [SAT]	IA	0.60	Piaggio Aero
JTI-CS2-2019-CfP10-SYS-03-24	Power Semiconductor Device module using Silicon Carbide devices for a relatively high-frequency, circa 100kW aircraft motor drive applications	IA	0.62	University of Nottingham
JTI-CS2-2019-CFP10-SYS: 13 topics			**10.32**	

List of Topics for Calls for Proposals (CFP10) – Part B

Identification Code	Title	Type of Action	Value (Funding in M€)
JTI-CS2-2019-CFP10-THT-07	Ultra-High Aspect ratio wings	RIA	2.00
JTI-CS2-2019-CFP10-THT-08	Experimental and numerical noise assessment of distributed propulsion configurations	RIA	2.00
JTI-CS2-2019-CFP10-THT-09	Disruptive Active Flow Control for aircraft engine applications	RIA	1.50
JTI-CS2-2019-CFP10-THT-10	Non-intrusive, seedless measurement system: design, development, and testing	RIA	1.50

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

SPD Area	No. of topics	Ind. topic Funding (in M€)
IADP Large Passenger Aircraft	19	20.7
IADP Regional Aircraft	3	1.35
IADP Fast Rotorcraft	4	6.4
ITD Airframe	18	12.925
ITD Engines	2	2.350
ITD Systems	13	10.32
Small Air Transport related topics*	[2]	[1.10]
ECO Design related topics*	[1]	[1.75]
TOTAL	**59**	**54.045**
**TA related topics are proposed and embedded in the following SPDs and as follows: AIR ITD: 1 SAT topic, 0.48M€ ; SYS ITD: 1 SAT topic, 0.60M€ ; ENG ITD: 1 ECO topic, 1.75M€*		

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 "*Third amended Work Plan 2018-2019*" and the "*Rules for submission, evaluation, selection, award and review procedures of Calls for Proposals*"[1].

The following additional conditions apply to the calls for proposals launched within the complementary framework of one IADP/ITD/TA:

1. In the light of the specific structure of the programme and the governance framework of the JU, the specific legal status and statutory entitlements of the "members" of the JU and in order to prevent any conflict of interest and to ensure a competitive, transparent and fair process, the following "additional conditions" in accordance with Article 9.5 of the H2020 Rules for Participation:

    - **The 16 Leaders of JU listed in Annex II to Regulation n° (EU) No 558/2014 and their affiliates[2]** may apply to Calls for Proposals **only in another IADP/ITD** where they are not involved as Members.

[1] These documents are accessible via the Participant Portal.
[2] See the definition under Article 2.1(2) of the H2020 Rules for Participation

- **The Core partners and their affiliates** may apply to calls for proposals only in another IADP/ITD where they are not involved as member.

2. Applicants may apply to calls for proposals if they:
   - officially state whether they are an affiliate[3] to a member of the JU or not;
   - Issue a declaration of absence of conflicts of interest[4].

   These elements shall determine the admissibility of the proposal.

The above criteria and the declarations will be checked by the JU which will determine the admissibility of the proposals. The CS2JU reserves its right to request any supporting document and additional information at any stage of the process.

Please note that proposals may include the commitment from the European Aviation Safety Agency (EASA) to assist or to participate in the action without EASA being eligible for funding.

Please note that the provisions under the chapters on "Special skills, Capabilities, Certification expected from the Applicant(s)" do not constitute additional conditions for participation according to Art. 9(5) H2020 Rules for Participation.

3. Programme Scene setter/Objectives

In accordance with Article 2 of the COUNCIL REGULATION (EU) No 558/2014 of 6 May 2014[5] 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 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."*

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.

[3] See the definition under Article 2.1(2) of the H2020 Rules for Participation
[4] As part of the declaration, the legally authorized representative of the applicants entities will be requested to declare whether the representative(s) of the entity participate to the IADP/ITD steering committees and whether they representative(s) of the entity was involved in the preparation, definition and approval of the topics of the calls or had any privileged access information related to that.
[5] JOL_2014_169_R_0006

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-CS2-2019-CfP10-LPA-01-72: Development of a distributed CFD platform for collaborative design

Type of action (RIA/IA/CSA):		IA	
Programme Area:		LPA	
(CS2 JTP 2015) WP Ref.:		WP 1.1	
Indicative Funding Topic Value (in k€):		600	
Topic Leader:	Airbus	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	36	**Indicative Start Date (at the earliest)[6]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-LPA-01-72	**Development of a distributed CFD platform for collaborative design**
Short description	
Development of an open-source CFD simulation platform and methodology to enable co-design between an airframe manufacturer and an engine manufacturer, while maintaining IP and IT security. This includes code-to-code coupling, communication between different simulation platforms, post processing of the simulation, and demonstration on industrial configuration.	

Links to the Clean Sky 2 Programme High-level Objectives[7]	
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 Ultra-advanced Long-range Advanced Short/Medium-range Ultra-advanced Short/Medium-range

With expected impacts related to the Programme high-level objectives:

Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☒	☐	☐

[6] The start date corresponds to actual start date with all legal documents in place.
[7] 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

It is now a common knowledge that the commercial aircraft industry is putting a lot of efforts toward the reduction of aircraft fuel burn and pollutant emissions. The research that is conducted in this regard is of particular importance to respect environmental constraints and to keep producing competitive airplanes.

As a matter of fact, the average commercial aircraft fuel efficiency has approximately doubled between 1960 and 2010. This can be explained by a number of factors, among which improved aircraft aerodynamics at transonic Mach numbers, improved materials, and better engines. Although further progress may be achieved both in terms of external aerodynamics (laminar wings / fuselage, riblets) or in terms of systems and structure (electric deicing, composite materials), large improvements will be obtained by working on the powerplant and its integration to the aircraft.

For instance, an engine with a lower Fan Pressure Ratio (FPR), and higher mass flow rate is more efficient and allows to decrease noise emissions, but that also involves larger fan diameters. This explains the current efforts to increase thebypass ratio (BPR) of civil aircraft engines, hence the « Ultra High Bypass Ratio » (UHBR)denomination for future turbofan engines. However, a larger fan diameter also results in a larger casing, which leads to increased nacelle weight and drag penalties.
To take advantage of the future generation of turbofan engines, innovative nacelle designs must thus be examined. For instance, one possibility is to consider shorter and thinner inlet lips. However, this approach leads to increased aerodynamic interactions between the air intake and the fan, which is no longer shielded from the external flow. To ensure a proper operation of both fan and air intake in the whole flight envelope of the aircraft these interactions must be mastered early in the design process of both components. On the long term, new propulsion paradigms must be envisioned to further decrease fuel burn. For instance, the Boundary Layer Ingestion (BLI) concept consists in embedding the engines and the airframe together so that the engines ingest a portion of the airframe boundary layer, which decreases wake drag penalties. In this kind of configuration, the aircraft and the engines are fully coupled, as the fans operate under distorted inflow, and as the pressure distributions on the airframe are affected by the fans. Designing such an aircraft requires a characterization of these interactions, and numerical capabilities that capture the effect of each component on the others.

From the numerical standpoint, it is possible to capture fan-airframe interactions with high fidelity CFD simulations in which both fan and airframe are represented. However, fan and airframe design involve different sets of skills, so that fan geometries are usually not available to institutions or companies designing airframes, and reciprocally airframes are not available to institutions or companies designing fans. It is thus required to develop numerical capabilities that allow producing such a simulation, while preserving intellectual property and IT security across different entities.

2. Scope of work

The objective of the work is to develop and to setup an open-source collaborative co-simulation platform that could be used by both academia and industry to simulate separate aircraft components (such as a fan and an airframe) designed by separate entities, in a unique CFD simulation, while ensuring that intellectual property is protected. This involves code-to-code coupling, communication between two private networks, and post processing of the simulation.

Tasks		
Ref. No.	***Title – Description***	***Due Date***
WP1	**Code-to-Code coupling for co-simulation in a single organization**	M0+18
WP1.1	Coupling between two instances of a CFD solver (solver A)	
WP1.2	Coupling between CFD solver A and another CFD solver (solver B)	
WP1.3	Coupling between solver A or solver B and a CFD solver used in production at Airbus different from solvers A and B	
WP2	**Aerodynamic and Aeroacoustic post processing solutions for the analysis of the result of the cosimulation**	M0+24
WP2.1	Effect of the powerplant on the airframe	
WP2.2	Effect of the airframe on the powerplant installation	
WP2.3	Extension to co-processing	
WP3	**Demonstration of the co-simulation platform on an industrial configuration in multiple organizations**	M0+36
WP 3.1	Generic preliminary works	
WP 3.2	Faisibility Demonstration	
WP 3.3	User interface	
WP 3.4	Application to industrial configuration and design trade-study	

<u>WP1 – Code-to-Code coupling for co-simulation in a single organization</u>

The objective of this workpackage is to demonstrate the code-to-code coupling approach on a configuration representative of an industrial application, but without the constraint linked to working on separate networks (IT and IP management). The coupling shall be demonstrated on a 3D nacelle + fan configuration with a mesh discretization comparing to the one used in production by Airbus. The coupling shall work in fully parallelized mode. Finally, the interfaces between engine and airframe must be completely conservative, i.e. mass flow rate, momentum and energy losses < 0.1%.

Key competences: Advanced computational fluid dynamics, numerical methods, code to code coupling.

WP1.1 : Coupling between instances of the same CFD solver (solver A)

This activity will consist in demonstrating the possibility of coupling two separate instances of a given CFD solver (used in aeronautics for research actvities). The coupling will be realized via a dedicated boundary condition that will allow an easy interfacing of those two instances.

WP1.2 : Coupling between CFD solver A and another CFD solver (solver B)

This activity will consist in extending the capability developed in WP1.1 to set-up a coupling between two different solvers. The solvers should be of different type (used for instance by different institutions) to demonstrate the genericity of the coupling platform.

WP1.3 : Coupling between solver A or solver B and a CFD solver used in production at Airbus different from solvers A and B

This second activity will focus on demonstrating the adequacy of the coupling platform by coupling either solver A or B with a solver used in production at Airbus. This is a requirement to demonstrate the viability of the solution in WP3.

<u>WP2 – Aerodynamic and Aeroacoustic post processing solutions for the analysis of the result of the cosimulation</u>

The objective of this workpackage is to develop post processing solutions adapted to the analysis of the advanced fan-airframe simulations realized thanks to the code-to-code coupling. These solutions must adress both aerodynamic and aeroacoustic requirements.

Key competences: Turbomachinery simulation, aircraft simulation, aero-acoustics, post processing

WP2.1 : Effect of the powerplant on the airframe
This activity will focus on extracting data relevant for the airframe manufacturer from the co-simulation, and in particular anything related to the effect of the powerplant installation on the airframe. This will include isentropic Mach number cuts on the air intake lips, axial cuts upstream of the fan, pressure distributions on the wings, distortion criteria, but also data dedicated to aeroacoustic such as coupling surfaces for acoustic propagation and microphone probes.
WP2.2 : Effect of the airframe on the powerplant installation
This activity will focus on extracting data relevant for the engine manufacturer from the co-simulation, and in particular anything related to the operation of the fan. This will include 0D and 1D data such fan pressure ratio, fan efficiency, fan blade unsteady loads, but also 3D detailed analysis such as time-averaged solutions in the absolute frame of reference. As above, aeroacoustic data shall also be extracted, such as the turbulent rate in the rotor wakes.
WP2.3 : Extension to co-processing
All the activities above focus on extracting data at the end of the co-simulation. Ideally, it should be possible to extract such data during the co-simulation to ensure that the simulation set-up is satisfying and physically consistent. This will require a coupling between the co-simulation solvers and the post processing tool, so that the data may be extracted between consecutive CFD solver iterations.

WP3 – Demonstration of the co-simulation platform on an industrial configuration in multiple organizations
The objective of this workpackage is to demonstrate that the code-to-code coupling and post processing building bricks developped in WP1 & WP2 are operational in a realistic environment consisting of distributed & heterogenous computational platforms communicating through a public network. A demonstration on an industrial application using an appropriate user interface and the comparison of the results obtained in WP1 will allow to validate the whole project.
Key competences:Networks, User interfaces, Turbomachinery design & simulation, aircraft design & simulation
WP3.1: Generic preliminary works
A protocol enabling communications between coupled codes running on HPC infrastructures of different companies will be defined. This protocol must be compliant with IT policies of each companies and shall deliver required bandwidth to minimize overhead communication costs. This protocol will be demonstrated operational using a generic mockup representative of targeted CFD simulation but without the constraint of effectively embarking CFD codes in a first step.
WP3.2: Feasibility Demonstration
The protocol elaborated in WP3.1 will be used in conjunction with the coupling software implemented in WP1 and the post-processing software implemented in WP2 to demonstrate the faisibility of the concept of distributed CFD simulations.
WP3.3: User interface
An adhoc user interface software will be developed to improve users experience while running such distributed simulations. The use case implemented in WP3.2 will be re-used to demonstrate how such simulation can be easily performed by end-users and contribute to collaborative design.
WP3.4 : Application to industrial configuration and design trade study
The coupling set-up realized in WP1.3 will be used to demonstrate the industrial relevance of the co-simulation platform. A first simulation will be realized with an airframe and fan geometry representative of a commercial aircraft. Then a sensitivity study will be performed by varying one or two design parameters for both fan and airframe. New simulations will be performed and the results will be analyzed together with Airbus to validate the coupling platform.

3. Major Deliverables/ Milestones and schedule (estimate)

Schedule		Year1				Year2				Year3			
	Task	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
WP1	**Code-to-Code coupling for co-simulation in a single organization**												
WP1.1	Coupling between two instances of a CFD solver (solver A)	■	■										
WP1.2	Coupling between CFD solver A and another CFD solver (solver B)			■	■								
WP1.3	Coupling between solver A or solver B and a CFD solver used in production at Airbus (different from solvers A and B)					■	■	■					
WP2	**Aerodynamic and Aeroacoustic post processing solutions for the analysis of the result of the cosimulation**												
WP2.1	Effect of the powerplant on the airframe			■	■	■	■	■					
WP2.2	Effect of the airframe on the powerplant installation			■	■	■	■	■					
WP2.3	Extension to co-processing					■	■	■	■				
WP3	**Demonstration of the co-simulation platform on an industrial configuration in multiple organizations**												
WP3.1	Generic preliminary works	■	■	■	■	■	■	■	■				
WP3.2	Feasibility Demonstration							■	■	■	■		
WP3.3	User interface									■	■	■	■
WP3.4	Application to industrial configuration and design trade-study									■	■	■	■

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1.1	Coupling Two instances of CFD solver (solver A)	Software Doc/Demo	M0+6
D1.2	Coupling Solver A with another CFD solver (solver B)	Software Doc/Demo	M0+12
D1.3	Coupling solver A or Solver B with CFD solver used in Airbus (different of solvers A and B)	Software Doc/Demo	M0+18
D2.1	Effect of the powerplant on the airframe	Software Doc/Data	M0+21
D2.2	Effect of the airframe on the powerplant inst.	Software Doc/Data	M0+21
D2.3	Extension to co-processing	Software Doc/Data	M0+24
D3.1	Generic preliminary works	Software Report	M0+24
D3.2	Feasibility Demonstration	Demo	M0+30
D3.3	User interface	Software Doc/Demo	M0+36
D3.4	Application to industrial configuration and design trade-study	Demo	M0+36

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	Review of detailed work plan for all tasks (Kick off)	Meeting	M0
M2	First Coupling activities and post-processing prototype	Demo	M0+12
M3	Coupling and post-processing demonstration	Demo Data	M0+24
M4	Final integration of the full environment Application to industrial configuration review	Meeting Demo	M0+36

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

Demonstrated capabilities in:

- Code-to-Code coupling
- Networks & IT
- Advanced high fidelity computational aerodynamic modelling for turbomachinery and aircraft simulations
- Advanced aerodynamic and aero-acoustic post processing
- Fan design and / or aircraft design
- Understanding of fan-airframe interactions

All the capabilities developed in the frame of this project should be generic enough to be readily usable by any entity and as such they should be compatible with Airbus environment, as Airbus will participate to the validation of the platform in WP 3.X

5. Abbreviations

CFD	Computational Fluid Dynamics
IP	Intellectual Property
IT	Information and Technology
HPC	High Performance Computing

II. JTI-CS2-2019-CfP10-LPA-01-73: Innovative Thrust Reverser Actuator System (ITRAS)

Type of action (RIA/IA/CSA):		IA	
Programme Area:		LPA	
(CS2 JTP 2015) WP Ref.:		WP 1.1	
Indicative Funding Topic Value (in k€):		900	
Topic Leader:	Airbus	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	24	**Indicative Start Date (at the earliest)[8]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-LPA-01-73	**Innovative Thrust Reverser Actuator System (ITRAS)**
Short description	
The integration of the new generation of large turbofan engines with short nacelles, slim aero-lineslines and wing closed coupling pylon, requires much more compact and innovative solutions for the Thrust Reverser function. For Short-Medium Range Aircraft future application at first and further scalability to Long Range A/C, the Thrust Reverser concept can be compatible with an electrical Thrust Reverser Actuator System (TRAS) which power remains below 10-20KW per Nacelle. The proposed activity will consist of defining the best candidate in terms of electrical motors and the way they can be integrated in the Nacelle environment.	

Links to the Clean Sky 2 Programme High-level Objectives[9]				
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 CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☐	☐

[8] The start date corresponds to actual start date with all legal documents in place.
[9] 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.

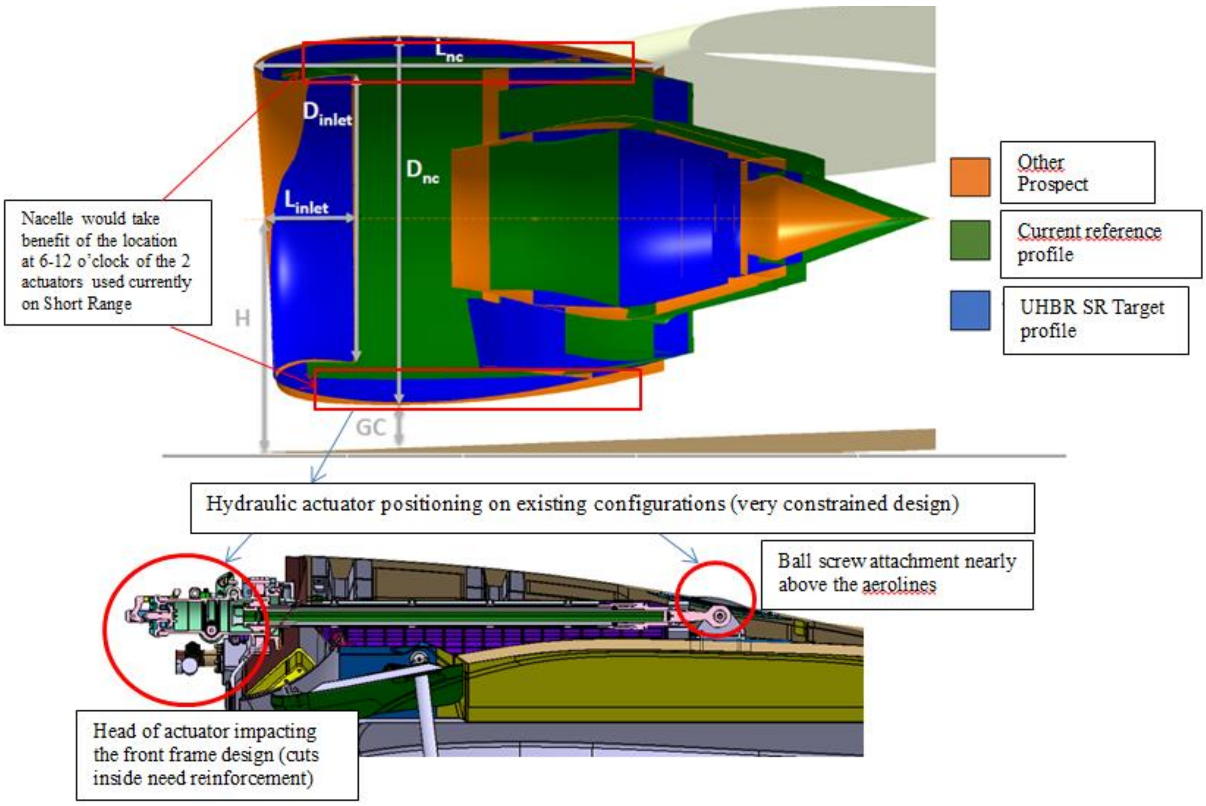
1. Background

The next generation propulsion systems will offer significant propulsive efficiency improvements through Ultra High Bypass Ratio (UHBR), low Fan Pressure Ratio fans, however at the expense of a strong increase in engine and nacelle diameters.
Engine cores work at higher temperatures & become smaller compared to the fan.

UHBR propulsion systems will only deliver attractive fuel burn benefits at aircraft level if the integration of the propulsion system and its installation onto the aircraft offset the burden of much larger and heavier engines

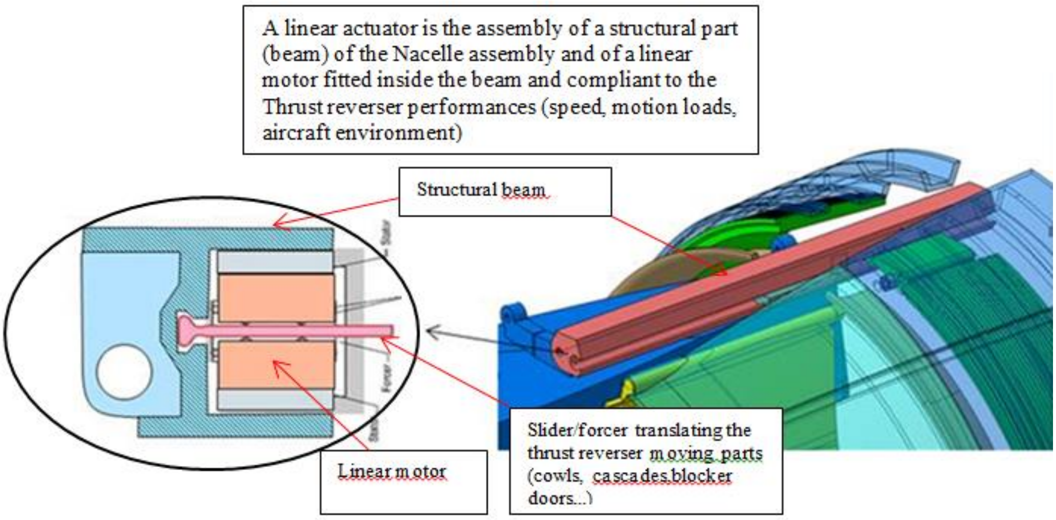
The integration of the propulsion system & its installation onto the aircraft are thus key enablers to maximize the fuel and C02 savings.
Among the various challenges directly linked to the large fan diameter and extremely wing/engine close coupling, the current Thrust Reverser function, architecture, and integration in the aft nacelle has to be approached differently in a more compact and efficient approach.

Here below is given a sketch showing the slim Nacelle target profile for UHBR SR compared to current situation.



This profile obviously put some constraints on the space allocation for the TRAS at 6 and 12 o'clock with shorter length and thinner space allocation with higher loads foreseen on actuators then bigger components
Traditional actuators (2 hydraulic actuators used on SR or electrical motors used on LR) which are not integrated inside the structure may be a final space allocation issue for other TRAS concepts than Fixed

or Translating cascades (due to higher Thrust reverser loads)
The intent of this topic is to explore linear motor technologies (e.g. linear motors) applied to a Thrust reverser module of a short middle range UHBR engines with further and deeper integration capability inside the Pylon & nacelle structure like the example presented below.



The integration of linear motor technologies in the Nacelle aerolines (Specific Fuel Burn reduction), operated with limited electrical power offered in Take-off and Landing configuration (currenly SR limitation around 15-20KW) is key for potential for future applications (economic viability of the solution).
The aim of this topic is to depart from state of the art linear motor technology typically used for Machining tools (guidance and positioning tables)and to assess the constraints of the selected motors to fit inside a given space allocation and to comply with Thrust reverser performances against the challenging Nacelle environment.
After completion of the study phase, the applicant(s) will define, develop and test the best solution of a linear motor and linear actuator inside a SR integrated Pylon/Nacelle solution.
The detailed topic description hereafter focuses on the following with the associated expected benefits:

- Performances: Even if Linear motors have a lower Force (Newton)/ weight (Kg) ratio than rotative motors , they have interesting properties which may be used within a TRAS and be promoted and developped for a linear actuator
- Integration in Structure: The natural translation motion of a linear motor (with no need of gearbox,ballscrew) is the key enabler for an easier integration in the limited area of the Nacelle
- Aircraft Economics. The incorporation of linear motors may be an economic good news for Recurring Costs and Maintainability

2. Scope of work

The Topic Manager (TM) will define the process of concurrent engineering between his own activities (Performances specification,Pylon and Nacelle structural design , structural beam design in interface with linear actuator) and the Applicant activities.
The topic manager will convene the formal gate reviews and will provide the applicant(s) with the necessary support to prepare them. He will provide the applicant(s) with contraints and requirements (Mechanical Loads, DMU catparts, simulation models,…). This will especially include the management of the loads coming from the Thruster reverser ,Nacelle ,Pylon and Engine to the linear actuator.

The Applicant will run the project, using his own procedures or methods and will implement requirements defined in agreement with the Topic Manager constraints. Progress will be timely monitored and validation of different gates will be deemed satisfactory only is succesful (from TRL 2 to 4 across the project horizon).
The Applicant will be responsible for the design , performances and validation of the linear actuator fitted inside the structural beam of the Pylon/Nacelle structure
The applicant, with support of the TM, will be in charge of studying, designing and integrating (functionnaly and physically)to the linear motor the complete linar actuator system including the following elements:

- Primary locking system (PLS) preventing from any inadvertent Thrust reverser deployment in Flight,
- Mechanical Deployment Unit (MDU) enabling manual opening of the cowls for Maintenance,
- TRCU (TR Control Unit) concentrating the power supply, control and monitoring electronic hardware of the linear actuator

Main novelties of the proposal
The innovation is mainly driven by the use of linear motor never used in Aeronautics before compared to the conventional rotative electrical motor (induction or brushless) with no need of gearboxes or ball screw in actuators but with the potential need of designing new concept of longitudinal sliders and PLS.
The innovation will come through a deeper structural/systems integration compared to what is currently visible on other flying concepts

Tasks		
Ref. No.	***Title – Description***	***Due Date***
WP1	Define range of possible architectures using linear motors versus Thrust reverser actuation systems (TRAS) performances and constraints of integration in structure Propose several solutions for linear actuators (including PLS,MDU,TRCU)	T0 + 5months
WP2	Assess the best candidate (s) configuration (s) of linear actuators with possible options through: -Performance analysis supports by modelling and simulation -Space allocation compliance (clash analysis,..) -Overall criteria evaluation (Weight, Recurring cost, Performances, Reliability, Demonstrator planning…) Provide the final detailed technical specification type SRD and interface document SIRD , DMU space allocation envelopes for all the components of the linear actuator in order to enable the detailed design and validation phase	T0 + 10months

Tasks		
Ref. No.	***Title – Description***	***Due Date***
WP3	According to the detailed specification: - Define and size the elected linear actuator for an UHBR SR Thrust reverser (TR) taking into account operational and environmental constraints (specially loads from Engine, Nacelle) -Provide periodic and final budgets of all evaluation criteria (Weight, Perfo,…) up to theTRL3 -Provide an aircraft qualification assessment of all the components of the elected linear actuator -Assess the manufacturability (within the budget evaluation forecast) of a physical demonstrator integrating the TM activities (Structural beam and Nacelle design) -Develop a physical demonstrator fully representative of the mechanical interfaces with 2 linear actuators (Applicant) + 2 structural beams and 2 sliders fitted with different cowl panels stiffness (provided by the TM) -Test and correlate with simulation model -Provide a final design and test report	T0+24months

3. Major Deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
WP1	• Linear motor technology benchmark status • Scope of possible architecture and linear actuators likely to be proposed for a TRAS SR	• Report • Report	T0 + 5months
WP2	• Comparison dossier and evaluation/presizing of linear actuators and choice of 1 solution • Release of the detailed linear actuator specifications (SRD, SIRD,DMU space alloc,…)	• Report • Report	T0 + 10months
WP3	• Design and stress analysis of the linear actuator elected solution (chosen at the end of WP2) • Status of the aircraft qualification of the linear actuator components (gap to aircraft standards) • Final evaluation of TRL3/4 criteria (Weight, Performances,…) with justification • Demonstrator co design and evaluation with TM • Demonstrator Manufacturing • Tests • Final dossier (tuning model/simulation- tests results, linear actuator final budgets,…)	• Report • Report • Report • Report • Hardware • Tests • Report	T0 + 24months

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

The Applicant(s) should have a strong background in Structure /Systems integration, Electrical motors, as well as complex systems simulation and modelling development involving various disciplines (thermodynamic, heat exchange, mechanic, electrical, systems control). A knowledge of Thrust reverser concepts and constraints will be appreciated.

5. Abbreviations

MDU	Mechanical deployment unit
DMU	Digital Mock Up
SRD	System Resuirement Document
SIRD	System Installation Requirement Dossier
PLS	Primary lock systems
SFC	Specific Fuel Consumption
TR	Thrust Reverser
TRAS	Thrust Reverser Acuation System
TRCU	Thrust reverser Control Unit
SR	SR Short Range Aircraft
LR	LR Long Range Aircraft
UHBR SR	Ultra High Bypass Ratio Short Range

III. JTI-CS2-2019-CfP10-LPA-01-74: UHBR Engine Studies for Aircraft Operations and Economics

Type of action (RIA/IA/CSA):		IA	
Programme Area:		LPA	
(CS2 JTP 2015) WP Ref.:		WP 1.1	
Indicative Funding Topic Value (in k€):		500	
Topic Leader:	Airbus	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	36	**Indicative Start Date (at the earliest)[10]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-LPA-01-74	**UHBR Engine Studies for Aircraft Operations and Economics**
Short description	
The proposed project intends to maximise the potential of future UHBR engines by studying some of the potential risks which might arise fromthese architectures with respect to aircraft operations (for example descent capability), economic competitiveness and robustness to energy source.	

Links to the Clean Sky 2 Programme High-level Objectives[11]	
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 CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☐	☐

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

[11] 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

With the more aggressive cycles (high compressor loadings, low core sizes etc.) typical of UHBR engines, low power stability challenges are anticipated. This may make it difficult to reach acceptable levels of idle thrust required for aircraft descent and manoeuvres from idle (such as go-around and ground manoeuvres for example). This problem is further compounded by the fact that improved aircraft aerodynamics will require even lower idle thrust than current-gen aircraft.
Additionnally, these engines are expected to exhibit increased core temperatures with reduced cooling flows to maximise performance. This can be achieved through the use of CMC materials in the hot sections (combustor, high-pressure turbine) which will change the tradeoff between engine performance and durability, which directly impacts airlines, and as such aircraft economic competitiveness.
Finally, once introduced into service, the UHBR (or any other future propulsion concept) will need to stay in service for a few decades. Due to the high level of pressures and temperatures in the engine, emissions are anticipated to be a challenge over the in-service time span. Given the increasing environmental pressures on aviation (ever more stringent standards on CO2, NOx, particulate matter etc.) the composition or the type of fuel used may have evolved considerably from current Jet-A standard for which it was optimised. It is therefore important to assess how the engine will respond to such changes and the impacts to its ability to perform the missions for which it was planned.

The intent of this workpackage is to further the understanding of the above issues to secure the full potential of the UHBR, or plan for mitigating options as early as possible to minimise downsides.
In the proposed project, these three aspects will be looked at from an engine perspective only.

2. Scope of work

Tasks		
Ref. No.	***Title – Description***	***Due Date***
1.1	Compressor Stability	M0 + 6
1.2	Idle Prediction	M0 + 12
2	Impacts of New Materials on Engine Time on Wing	M0 + 18
3.1	Emissions Predictions for UHBR with Conventional Fuel	M0 + 12
3.2	Impact of Alternative, Non-Drop-In Fuels	M0 + 24
3.3	Dual fuel capability (kerosene + alternative fuel)	M0 + 36

Part 1: Engine Impacts on Aircraft Operational Capabilities

State of the art
The state of the art is to design the engine for optimal performance at "high-power" conditions (until end of cruise) and then idle phases are a consequence of that design, with the risk of harming aircraft descent/deceleration capability as well as manoeuvrability in approach or on the ground.

Advancements expected from this project
This part of the project aims at understanding how the engine cycle and components design (especially HPC, since its stability relates directly to idle and accceleration capabilities) can be used to predict idle characteristics at early design stage, to tackle potential threats from the start and have a realistic view of the fuel burn gains brought by advanced engine configurations like the UHBR when taking into account all operational constraints.

Task 1.1: Compressor Stability

Applicants are expected to:

- By analysis, correlate compressor stability with trends of OPR, FPR and core size, compressor loading, if any.
- By analysis, define what parameter is best suited to monitor compressor stability.
- Define a method to estimate, as reliably and as accurately as possible, the need for compressor stability in accordance with the engine/compressor design, thermal and deterioration state, transient vs steady state operations, etc.
- Validate this method using existing examples and test / simulation data.
- Establish the link between compressor pressure ratio / blade loading and compressor stability, in order to estimate how much compressor weight / efficiency is traded for compressor stability (in all flight phases).

Task 1.2: Idle Prediction

For this task, the following is expected:

- Establish an exhaustive list of all the engine limits, differentiating "hard" (cannot be overcome) physical limits (e.g., minimum FAR, minimum compressor Surge Margin, maximum TET/EGT, minimum go-around acceleration from approach idle…) from "tradable" limits that could be overcome by changes in the engine or A/C design (e.g. min. ECS pressure)
- Define methods to quantify/predict the "hard" limits: find the best parameters to evaluate the limits, establish a process to estimate these parameters in accordance with the engine design. These parameters and processes shall be substantiated by analysis
- Validate the process with existing examples and test / simulation data

Part 2: Engine Impacts on Aircraft Use and Economic Competitiveness

State of the art

Engines represent a significant part of aircraft ownership costs. In particular, the hot section of the engine (combustor and high-pressure turbine) needs to be carefully designed to achieve an acceptable compromise between performance and durability.

Metallic materials currently used in engines have characteristics which are well understood, leading to acceptable design compromises between performance and durability. However these materials are not appropriate to sustain the higher temperatures or lower cooling flows required to achieve UHBR performance.

Advancements expected from this project

CMC materials are viewed as an important enabler for the next generation of engines.

This part of the project aims at understanding the characteristics of CMC for engine hot sections and how their introdution will change the compromises between performance and durability of engines, and as such the economic competitiveness of an aircraft fitted with such engines.

The proposed tasks for this study are as follows:

- Give an overview on existing CMC materials and manufacturing processes
- Compare CMC material properties vs. metallic (single crystal alloys)
- State of the art on cooling techniques and challenges for CMC vanes and blades
- Lifing aspects: Analyse damage mechanisms (creep, low & high cycle fatigue, oxidation) for CMCs and explain communalities and differences with metallic blades & vanes

- Investigate on component deterioration due to engine usage: Main mechanisms and differences to metallic components
- Evaluate impact of material change on maintenance costs

Part 3: Impacts of fuel characteristics on engine design and performance

Background

Once introduced on an aircraft type the UHBR (or any other future propulsion concept) will need to stay in service for a few decades. By then, given the increasing environmental pressures on aviation (climate change, air quality, etc.), the composition or the type of fuel used may have evolved considerably from current Jet-A standard for which it was optimised.

Therefore it is important to understand the implications of such moves towards new fuels or fuel mixes, in terms of compatibility with the design but also in terms of possible performance and emissions impacts (CO2, NOx, but also nvPM for which standards have emerged since 2016 and will be more and more restrictive).

Advancements expected from this project

As such, this part is dedicated to the study of how alternative fuels (different composition or different fuels altogether (e.g. hydrogen, methane, propane)) will impact engine use and performance characteristics.

The first task is to establish a baseline for comparison. For this, a UHBR engine running on kerosene will need to be assessed. A performance (including weight) model will be set up, and a method to predict emissions types and quantity will be developed.

It is then proposed to study these alternatives in two steps: first with alternative fuel only (without any kerosene), and second, as it may be more readily accepted by the market, to evaluate the feasibility of an engine that is able to run either on kerosene or on the alternative fuel.

Task 3.1: Prediction of emissions of a reference UHBR engine running on kerosene

- Develop a performance model (including weight) for a UHBR engine
- Perform a litterature review on emissions predictions models
- Propose a model and assess emissions of the reference UHBR engine

Task 3.2: Study of alternative, non drop-in fuels

- Evaluate, by analysis, the main changes to be made to engines in order to use non drop-in fuels
- Investigate whether these changes would be retrofittable
- Analyse the impact on performance, weight and emissions, compared to a conventional kerosene engine
- Propose a design for a combustor burning alternative fuels, and verify its emissions characteristics by analysis (CFD)

Task 3.3: Study of Dual-fuel engines (Kerosene + Other)

- Evaluate feasibility and impact on performance, weight, emissions
- Propose a design for a dual-fuel combustor and verify its emissions characteristics by CFD

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 establishing link between turbofan design parameters (OPR, FPR, core size etc.) and compressor stability	R	M0 + 6
D1.2	Report clarifying how to best monitor compressor stability	R	M0 + 12
D1.3	Report describing the process of establishing the need for stability margin	R	M0 + 18
D1.4	Validation report of the process	R	M0 + 24
D1.5	Report establishing the link between design blade loading and compressor stability	R	M0 + 30
D1.6	Report describing engine limits	R	M0 + 6
D1.7	Method to quantify / predict the "hard" limits	R	M0 + 12
D1.8	Idle limit establishment process validation report	R	M0 + 18
D2.1	Overview on existing CMC materials, manufacturing processes and material properties	R	M0 + 12
D2.2	Life prediction model for CMCs.	R + D	M0 + 24
D2.3	Analysis of CMC component deterioration and impact of CMC usage on DMC	R	M0 + 36
D3.1	Literature review on emissions predictions	R	M0 + 6
D3.2	Emissions predictions model and assessment for reference UHBR engine	R + D	M0 + 12
D3.3	Evaluation of the impact of alternative, non-drop-in fuels on engine performance, weight and emissions	R	M0 + 18
D3.4	Combustor design and emission characteristic evaluation for the most promising alternative fuel	R + D	M0 + 24
D3.5	Report on feasibility and challenges of dual-fuel engine	R	M0 + 30
D3.6	Combustor design and emissions characteristics for dual-fuel engine	R + D	M0 + 36

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

- Aircraft gas turbines performance modelling and simulation
- Multidisciplinary and complex systems simulations
- Mechanica and electrical systems design
- Gas turbine dynamics and transient simulations
- Engine thermal management and simulations
- Propulsor systems and subsystems modelling
- 3D fluid dynamics simulations
- Combustion and emissions modelling
- Thermo-mechanical analysis
- Failure mechanisms & life estimation

5. Abbreviations

A/C	Aircraft
ACARE	Advisory Council for Aviation Research and Innovation in Europe
CFD	Computational Fluid Dynamics
CMC	Ceramic Matrix Composite
DMC	Direct Maintenance Cost
ECS	Environmental Control System
EGT	Exhaust Gas Temperature
FAR	Fuel / Air Ratio
FPR	Fan Pressure Ratio
GDP	Gas Path Diagnostics
GPA	Gas Path Analysis
OPR	Overall Pressure Ratio
PR	Pressure Ratio
SAS	Secondary Air System
TET	Turbine Entry Temperature
UHBR	Ultra High Bypass Ratio

IV. JTI-CS2-2019-CfP10-LPA-01-75: Advanced solutions for 2030+ UHBR Core Noise reduction

Type of action (RIA/IA/CSA):		IA	
Programme Area:		LPA	
(CS2 JTP 2015) WP Ref.:		WP 1.1	
Indicative Funding Topic Value (in k€):		2500	
Topic Leader:	Safran Aircraft Engines	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	42	**Indicative Start Date (at the earliest)[12]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-LPA-01-75	**Advanced solutions for 2030+ UHBR Core Noise reduction**
Short description	
For Next Generation UHBR engines, Jet (cycle effect) and Fan (advanced liners and OGV concepts) noise will become less dominant and this will lead to further emergence of core noise sources. This topic aims at developping advanced solutions to reduce core noise of 2030+ UHBR engines. This will imply Improvements of combustor models fidelity (incl. more realistic geometric and flow fields description) and design of low noise treated Ceramic Matrix composites (CMC) exhaust concept based on new CMC manufacturing techniques. The different concepts will be validated with 2D/3D models parallel to the development of integrated combustor – turbine noise prediction techniques necessary to provide an optimum design for both low and high frequency liners implemented in a UHBR core nozzle and center body. Experimental campain will be performed benefiting from improved test set-up and signal processing for better identification of core/combustor noise. The maturation of the solutions will be focussed on 2030+ UHBR applications.	

Links to the Clean Sky 2 Programme High-level Objectives[13]				
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:		Ultra-advanced Long-range Ultra-advanced Short/Medium-range		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☐	☐	☒	☐	☐

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

[13] 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 desire for more ecologic and more economic turbofan engines in civil aviation leads to an increase in the “ByPass Ratios” (BPR) and lower “Fan Pressure Ratios” (FPR). The next generation of engines with significantly higher Bypass Ratios (UHBR) are being developed to further reduce the fuel consumption while enhancing environmental performance and satisfying regulatory requirements.

These engines have a larger fan diameter with a lower rotation speed. Advanced UHBR engine architectures should furthermore includes core with low emission combustor technology and low number of LP turbine stages. These architecture evolutions are having several consequences on the engine noise signatures. Anticipated the reduction of usually dominant noise sources, Jet (cycle effect) and Fan (advanced liners and OGV concepts), and the potential increase in magnitude of combustor noise (due to new clean combustor design and reduced BP stage), should lead to further core noise emergences risk.

Therefore core/combustor noise mitigation solutions must be addressed to ensure that advance UHBR 2030+ meet required noise limits. Advance core/combustor noise physics understanding and mitigation strategies development are in consequence foreseen through this topic.

Core noise can be split into two major contributors, ‘direct noise’ and ‘indirect noise’. The noise originated from the acceleration of flow inhomogeneities through the nozzle guide vane, or turbine blades, downstream of the combustion chamber, is called ‘indirect noise’. This is to distinguish it from the ‘direct noise’ generated by the unsteady heat released by the flame. The relative contribution of direct and indirect combustion noise requires an improvement in the understanding of combustion noise and its sources, as well as the development of accurate predictive tools.
Standard engines noise measurements are highly valuable but offer partial answer to go further regarding combustor physic understanding and high fidelity/noise tools simulation assessments. Indeed, advanced flow-field measurements in the combustor and turbine associated with dedicated signals treatments technics are required to gain knowledge and increase the simulation TRL level.

New findings and improved understanding in driver mechanisms for combustion noise are necessary, but they might not be sufficient to suppress foreseen core noise emergences. Consequently, low noise hot liners concepts may have to be integrated to further reduce core noise peaks during specific operation phases. The present topic supports the development of UHBR2030+ low noise Ceramic Matrix composites exhaust by focusing on advance acoustic concept implementation and maturation. To this end, further acoustic optimization, design studies and noise test demonstrations are required to bring on more efficient solutions that could be implemented inside new low noise CMC exhaust. Room exists to further develop and propose both low and high frequency core nozzle and center body concepts. More efficient hot liners can be developed using advanced aeroacoustics design tools and absorbing material findings in the field from previous research programmes. Innovative low noise exhaust solutions can be optimised to maximise core noise reduction, while considering new CMC process compatibility and weight reduction.
This will thus become a highly valuable technology to further improve the noise margin for 2030+ advance architectures. Therefore, low noise CMC exhaust have to be considered as part of the UHBR technologies that will help fulfill CS2 environmental and performance objectives.

The subject of this topic concerns the development of advanced solutions for 2030+ UHBR core noise reduction among which are:

- Improvement of combustor models fidelity to include more realistic geometric (3D modelisation) and flow fields description. The advanced solutions will be based on high fidelity large eddy simulation (LES), analytical and numerical computational aeroacoustics (CAA) noise tools aiming a full integrated combustor-turbine-exhaust methodological approach. A reinforcement of core/combustor noise understanding as well as an industrial applicability to new engine with low emission designs and low noise exhaust are also targeted.
- Deeper examination of experimental noise data to be acquired, considering advanced instrumentation test set-up and signal processing to better identify core/combustor noise signature. This will be usefull to better understand the physics involved in the generation and propagation of combustion noise through Turbine Rear Frame (TRF) and turbine blade rows in core aero-engines.
- Development and optimisation of advanced low noise CMC core nozzle and center body liner concepts for the reduction of both low and high frequency core noise emergences
- Fully-integrated simulation approach considering noise sources from the combustor through the turbine and exhaust nozzle, including hot stream liners effects. This will allow for further optimization of low-noise exhaust concepts and an improvement of engine/aircraft noise predictions.

The activities include acoustic (and also aerodynamic) TRL3 demonstration on large 2D liner panels to assess the performance of innovative low noise UHBR CMC exhaust concepts under representative aeroacoustics tests conditions. Advance low noise CMC exhaust full scale design will be produced contributing to the future demonstration of UHBR2030+ low noise Ceramic Matrix composites exhaust at TRL6.

This activity is part of the “Ultra-high Bypass and High Propulsive Efficiency Geared Turbofans” demonstration area and the UHBR Integration roadmap. Results will feed into the UHBR engine model for use in the Technology Evaluator to assess the noise benefit. The topic will also contribute to deliver higher TRL level regarding core/combustion noise understanding and modelisation that are highly valuable to monitor UHBR 2030+ core aero engines noise emergences risks.

2. <u>Scope of work</u>

The main concern is to develop advanced solutions for 2030+ UHBR core noise reduction.

To improve the prediction of the generation of indirect noise and the transmission and attenuation of direct combustion noise in engine cores, the maturitation of advance aeroacoustics methodologies will have to be pursued. An extension of the calculation process to include following improvements will be targeted : 3D capture of combustor noise sources using high fidelity LES, extension of aeroacoustics models to improve physical representativeness of combustor-turbine-exhaust transfer function and CFD/CAA numerical coupling to achieve a full integrated prediction of core noise including all required technological effects.

Lined core nozzle and center body provides an efficient solution to mitigate core/combustor noise. This topic support the development of UHBR2030+ low noise Ceramic Matrix composites exhaust. An optimized design, able to reduce both low and high frequency, will need to be further developped for advanced CMC solution. Three different concepts will be designed and optimized considering high grazing flow and temperature exhaust conditions. Large samples will be manufactured to be tested on **TRL3** acoustic experimental set-up. Following these outcomes, advanced low noise CMC exhaust will be designed and the acoustic performance calculated to demonstrate the benefits and further increase the technology readiness level.

In parallel, a better physical understanding of engine core/combustor noise sources generation and evolution will be developped through experimental activities and data analysis. A survey will be conducted to improve engine core noise expertise, targeting firstly a better analysis of existing experimental engine acoutic database and secondly an ability to define advance core noise test set up. An engine acoustic test campaign will have to be instrumented with dedicated sensors and analyzed using advance signal treatments technics to acquire more valuable data for core/combustor noise understanding and modelisation.

To complete, a full integrated combustor – turbine noise prediction will need to be performed to demonstrate topic methodological maturation progress and abilities to better predict core noise including advance core/combustor design drivers and low noise technological effects ; supporting maturation of UHBR2030+ core noise prediction tools and low noise design solutions toward future TRL6 demonstration.

Advanced solutions for UHBR 2030+ core noise reduction topic_work plan is spread over 3.5 years. The main tasks are developed below:

Tasks		
Ref. No.	***Title – Description***	***Due Date***
Task 1	Management and Risk reduction plan	T0+42
Task 2	Requirements	T0+24
Task 3	Improved LES prediction of turbulent combustion noise sources terms	T0+36
Task 4	Improved aeroacoustics models for prediction of combustor-turbine-exhaust nozzle transfer function and calculation of combustor noise components	T0+36
Task 5	Improved CAA prediction of combustor-turbine noise radiation through exhaust nozzle including low noise technology effects	T0+36
Task 6	CMC acoustic exhaust technology maturation support: advanced acoustic concept identification and assessment through partial tests	T0+30
Task 7	CMC acoustic exhaust technology maturation support : improved integrated acoustic design and performance calculation at full scale	T0+38
Task 8	Engine combustor noise signature analysis and advanced experimental set-up preparation	T0+36
Task 9	Advanced engine combustor noise data acquisition and measurement analysis	T0+42
Task 10	Calculations of bypass ratio and engine architecture/technological effects on combustor noise	T0+42

Task 1: Management and Risk reduction plan_
The applicant has to ensure management and reporting activities throughout the project. A management plan has to be delivered and partner's progresses regularly reported. The applicant has also to support all project monitoring and coordination tasks.

- Progress Reporting & Reviews:
  - Regular 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 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 review meetings shall be held at the topic manager's facility.

- General Requirements:
  - The partner shall work to a certified standard process.

A risk reduction plan will be also provided. The plan will include simulation, test … and associated capability demonstration for each technical task and element. The applicant has to establish and deliver the related risk reduction plan. Mitigation actions and status shall be adequately monitored.

Task 2: Requirements

This task aims at contributing to specifications written under Safran Aircraft Engines leadership. The applicant has to support in particular the advanced requirements break down into detailed technical elements to ensure full compliance assessment capacity.

Task 3: Improved LES prediction of turbulent combustion noise sources terms

High fidelity simulations will be performed to solve reacting compressible and turbulent flow field inside 2 reference combustor configurations. A LES approach will be performed using an appropriate High fidelity CFD software compatible with topic manager simulation requirements (set-up inc. numerical and frequency resolutions, boundaries…) and recommended best practices. For each of the 2 reference configurations, three power conditions will be computed, post-treated and particularly studied to cover combustor operating mode and allow accurate experimental comparisons. The configurations and associated test conditions will be proposed by the topic manager.

Several separated simulations, with dedicated sector domain will be tested to be able to identify potential reduction in the size of the computational domain while determining (after reconstitution) representative 3D noise source terms. A single-sector (one burner) and a dedicated reduced/periodic angular-sector (allowing to capture full 3D burners/geometries interaction and resonance effects on the studied frequency range) and/or full 3D 360° simulation will be at minimum simulated. Appropriate computational domains and boundaries conditions (acoustic impedance …) will be defined by the applicant to produce LES simulations that can represent accurately a realistic configuration for combustor noise studies (inc. coupling effects between the interaction of the combustor and engine components environments). For the partial sector calculations, dedicated boundaries conditions will be also included to target a full 3D reconstruction. Results from these 3D investigations will guide modeling techniques and model selection for predicting unsteady combustor simulations that represent a step forward compared to the single sector approach.

Several Probes will be included to be able to analyze different fluctuations region and characterized evolution up to combustor's exit (including DHP). Relevant flow quantities will be analyzed inside the combustion chamber and sampled at the combustor's exit in the LES simulation to be used as an input for advanced aeroacoustic model in Task 4. Correlation between signals will be analyzed and the quantities contributions to 'direct' and 'indirect' combustion noise determined. A comparison between sector and 3D flow field data (azimuthal and radial contents) will be then performed and analyzed in task3. Results will be produced and post treated by applicant to allow a comparison between topic manager and Task 4 aeroacoustics noise models.

Task 4: Improved aeroacoustics models for prediction of combustor-turbine-exhaust nozzle transfer function and calculation of combustor noise components

The results from the Task-3 simulations will be used as input to aeroacoustics models for predicting combustor noise component at turbine exit.

Flames create acoustic waves and entropy waves inside the combustion chamber which propagates through the combustor- downstream engine components. The transmitted acoustic waves are defined as direct combustion noise. Interaction of inhomogeneities outgoing the combustor exit with strong mean-flow gradients encountered in downstream nozzle and turbine stages generates acoustic pressure fluctuations, which are referred to as indirect combustion noise.

Analytical solutions based on Cumpsty and Marble actuator disk exist to estimate low-frequency engine core noise. Assuming acoustic compactness, flow fluctuations are considered to be plane both upstream and downstream of the row undergoing a discontinuous jump in strength across the row. This analytical methodology has been further extended and implemented to extract the acoustic and entropy waves at the outlet of the combustion chamber configuration and then analytically compute the transmitted noise at the outlet of the turbine stage.

- Core noise prediction of a full combustor geometry

Basically, only plane waves are evaluated in the diagnostics due to the simplification of the full geometry into a LES periodic sector. In order to better describe the pressure field (including also the first azimuthal mode, resonance,…) the development of the existing solution to ensure applicability to the full geometry approach (considered in task 3) will be performed by applicant and applied on the 2 reference configurations.

- Extension of transfer functions for improved physical fidelity

To improve the prediction of direct or indirect noise from combustion noise, the development of an advanced transfer functions calculation with a higher physical fidelity will be performed by applicant and applied on the two reference configurations. The modelisation of acoustic attenuations phenomena (on acoustic sources term and screen effects) though turbine stage will be also considered and additional 3D effects could also be included. The applicant shall apply and validate the improvements in the transfer function using the two reference configurations in Task 4.

For all improved methodologies, applicant will specifically take care to determine and introduce properly variables at the interface of LES, CAA and analytical models, considering the different steps and models targeted in tasks 3, 4 and 5. The applicant will have to explain in details the model assumptions and associated tools developments to ensure a future application in an industrial context by topic manager.
Comparisons between the different modelling approaches and available experimental measurements will be performed in task 4 to assess the methodological progress achievements.

Task 5: Improved CAA prediction of combustor-turbine noise radiation through exhaust nozzle including Low noise technological effects
Results from the Task-4 simulations will be used as input in CAA simulations to predict the noise radiated from the exhaust nozzle to the far field. A dedicated numerical interface approach will be considered by applicant to inject appropriately the combustor and turbine source terms in the CAA solutions. Full spectra core noise calculation and radiation up to far field will be predicted by applicant considering an appropriate noise propagation methodology.
Applicant will then introduced liners technological effects on core nozzle and center body exhaust. A CAA (preferentially temporal) approach covering a wide frequency resolution will be considered by applicant to simulate the core noise radiation with and without liner effects on the 2 reference configurations.
Comparisons between the different modelisations fidelities and measurements will be performed in task 5 to assess the methodological progress achievements.

Task 6: CMC acoustic exhaust technology maturation support: advanced acoustic concept identification and assessment through partial tests
The applicant has to perform a screening of the best liners concepts to reduce UHBR 2030+ core noise. Advanced solutions allowing to reduce both combustion and turbine noise signatures at low and high frequency, respectively, will be investigated. The best candidates will be then further optimised by applicant considering new CMC manufacturing processes and flightworthy integration constraints specified by topic manager.

Three advance UHBR concepts will be defined by applicants (considering frequency range and integration) and compared to 2 references design defined by topic manager.
The applicant will develop and design 2D prototypes for the 3 advanved concepts. A gradual design and validation approach has to be pursued to ensure progress toward efficient solutions: starting from 2D small prototypes up to 2D large panels. A dedicated high temperature and grazing flow modelisations will be considered (and if necessary developed) by the applicant to optimize the liners geometries. Results from partial tests will be exploited and examinated to improve modelling accuracy. Dedicated acoustic tests for hot stream liners will be performed by the applicant on small samples to characterize the acoustic performances, validate the modelisation and ensure abilities to perform appropriate scaling for the final 2D large scale tests.
Liner concepts and associated definitions will be refined during design reviews (concept review, PDR and CDR for 2D panels). At CDR, applicant has to present detailed design definitions for three 2D panels prototypes (around 150 mm by 800mm).
The applicant has to manufacture five 2D representative large plane prototypes (around 150 mm by 800mm) according to the final CDR definition. The applicant will be in charge of providing all components and materials required for 2D prototypes manufacturing.
The applicant has to test the three advanced 2D large panels and compared them with the two states of the art reference panels. High grazing flow tests bench with large test section has to be used to ensure relevant acoustic TRL3 maturation. Each of the 5 large panels will be characterized under around 10 different operating flow conditions, covering especially targeted Mach number, thermodynamic and acoustic conditions at exhaust. Adaptation of the test bench will be if necessary performed by applicant to ensure sufficient representativity of the tests. The grazing flow test campaign will include acoustics and aerodynamics measurements to fully characterize aeroacoustics flow conditions and determine potential side effects on pressure losses. A presentation of the test results & detailed analysis will be performed by the applicants.

Task 7: CMC acoustic exhaust technology maturation support: improved integrated acoustic design and performance calculation at full scale
The three advanced concepts from task6 will be extended by the applicant to fit 3D engine core nozzle and centerbody of 2 engines (a reference with a medium bypass ratio and a higher UHBR) that will be specified by topic manager. Design will be optimized for both low and high frequency liners taken advantage of recent advances in integrated combustor – turbine noise prediction techniques. Low noise concepts will be specifically adapted to fit topic manager integration requierements and considering especially ceramic materials optimization potential. Exhaust liner solutions and definitions will be precised during full scale acoustic integration design reviews (concept review, PDR and CDR).
The applicant will have to ccompute the acoustic performance of the final solutions using an advanced CAA methodology (considering task 5 results) including grazing flows and hot stream liner modeling (considering task 6 results). The acoustic performance of each five concepts will be calculated by the applicant for the two proposed engines configurations. For each of the two engine configurations, the noise attenuations will be calculated at 5 operating points and supply to topic manager to allow evaluations at aircraft level.

Task 8: Engine combustor noise signature analysis and advanced experimental set-up preparation
Experimental measurments and analysis of engine core noise configuration are required to characterize precisely the combustor signatures and better identified corresponding noise sources mechanism and generation. Results from these investigations are required to assess noise prediction tools and guide appropriately modeling techniques development.

- Literature review and survey in aero-engine core noise

A literature review/survey will be performed by the applicant to ensure an updated know how regarding

core noise analysis and identify the best way forward for experimental characterization.
Firstly, the applicant will specifically document the knowledge regarding expected/potential core noise components signatures and associated direct and indirect noise source generation/mechanism considering especially UHBR architectures. Secondly, the applicant will review experimental techniques (existing or identified as most promising solutions to further develop) to characterize core noise spectral contributions. The review will therefore address advanced source separation/eduction method with several measurements locations (inside the combustor, turbine, and nozzle, as well as outside the engine) and/or advanced signal processing tools. Coherence techniques, modal analyses, source locations,… to identify far-field noise contributions and propagation characteristics of combustion noise will be documented. Possibilities to qualify direct and indirect combustion noise generation using specific unsteady quantities measurements (pressure, temperature,…) will be included in the survey workframe. Progress regarding advance sensors and probe ensuring integration feasibility inside adverse engine exhaust environment will be also considered by applicant in order to identify best solutions for combustor noise test.

- Combustor noise analysis on engine configurations

An analysis of the core noise signature will be performed by the applicant (together with the topic manager and enlightened by the previous literature survey) using existing pressure data on several engine configurations.

- Advance combustor noise test preparation and definition

Based on the previous literature/Survey and combustor noise analysis, an advance experimental set-up will be defined by applicant to be implemented during topic manager engine test measurement. The specific set-up will be refined during instrumentation reviews (concept review, PDR and CDR).
At CDR, applicant has to present the detailed test set-up that will be have to be validated by topic manager to ensure compatibility with the engine test constraints.

Task 9: Advanced engine combustor noise data acquisition and measurement analysis
To develop a better understanding of the core/combustor-noise source an acoustic test campaign will be perform using task8 advance measurement and analysis technics. The topic manager will be responsible for implementing engine tests and the applicant will have to contribute to the acoustic measurement campaign. Applicant will be in charge to supply the dedicated instrumentation and acquisition test set-up. The applicant will also be in charge to perform the advance core noise measurements acquisitions during the dedicated test configurations. Applicant will validate, analyse and supply to topic manager the raw and post-treated data.

Task 10: Calculations of bypass ratio and engine architecture/technological effects on combustor noise
Based on the acquired knowledge and improved methods/solutions developed during this topic, the applicant will be in charge of performing a fully integrated combustor – turbine noise prediction on two engine configurations that will be specified by the topic manager (a reference with a medium bypass ratio and a higher UHBR). In these simulations, noise sources, technological effects such as low noise concepts (task7), and variations in the number of turbine stage will have to be considered to demonstrate abilities to mitigate core noise. For each of the two engine configurations, the noise attenuations/reductions will be calculated on 5 operating points and supply to topic manager to allow advance prediction / evaluations at aircraft level.

3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1.1	Management plan & Risk reduction plan	R	T0 + 6 months
D2.1	Advanced solutions for UHBR 2030+ core noise work task specifications completion	R	T0 + 15 months
D3.1	Improved LES prediction of turbulent combustion noise sources terms intermediate results and report	R & D	T0 + 12 months
D3.2	Improved LES prediction of turbulent combustion noise sources terms final results and report	R & D	T0 + 30 months
D4.1	Improved aeroacoustics models for prediction of combustor-turbine-exhaust nozzle transfer function and calculation of combustor noise components final results and report	R & D	T0 + 32 months
D5.1	Improved CAA prediction of combustor-turbine noise radiation through exhaust nozzle including Low noise technological effects final results and report	R & D	T0 + 34 months
D6.1	CMC acoustic exhaust technology maturation support: advanced acoustic concept identification and assessment through partial tests – selection, optimisation of the best liners concepts & dedicated high temperature and grazing flow tools modelisations & assesments	RM, R & SW	T0 + 18 months
D6.2	CMC acoustic exhaust technology maturation support: advanced acoustic concept identification and assessment through partial tests – 2D panels manufacture of 5 concepts	HW & R	T0 + 26 months
D6.3	CMC acoustic exhaust technology maturation support: advanced acoustic concept identification and assessment through partial tests – 2D panels tests results and analysis	R & D	T0 + 30 months
D7.1	CMC acoustic exhaust technology maturation support: Acoustic performance of the final 3D solutions using advanced CAA methodology	R & D	T0 + 38 months
D8.1	Engine combustor noise signature literature survey	R	T0 + 18 months
D8.2	Engine combustor noise signature data base analysis	R & D	T0 + 24 months
D9.1	Advanced engine combustor noise tests report, data results and analysis	R & D	T0 + 42 months
D10.1	Calculations of bypass ratio and engine architecture/technological effects on combustor noise results and final report	R & D	T0 + 42 months

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1.1	Management and risk reduction plan update review and report	RM & R	T0+20 months
M2.1	Advanced solutions for UHBR 2030+ core noise work task specifications review	RM & R	T0 + 6 months
M4.1	Improved aeroacoustics models for prediction of combustor-turbine-exhaust nozzle transfer function and calculation of combustor noise tools	RM, R & SW	T0 + 30 months
M5.1	Improved CAA prediction of combustor-turbine noise radiation through exhaust nozzle including Low noise technological effects intermediate methodologies, tools and report	RM, R & SW	T0 + 16 months
M6.1	CMC acoustic exhaust technology maturation support: advanced acoustic concept identification and assessment through partial tests – Concepts selection and optimisation / PDR	RM & R	T0 + 12 months
M6.2	CMC acoustic exhaust technology maturation support: advanced acoustic concept identification and assessment through partial tests – Concepts selection and optimisation / CDR	RM & R	T0 + 18 months
M7.1	CMC acoustic exhaust technology maturation support: advanced acoustic concept identification and assessment through partial tests – 3D concepts optimisation and full scale exhaust design / CDR	RM & R	T0 + 32 months
M8.1	Task 8: Advanced solutions for UHBR 2030+ core noise mitigation – Engine combustor noise test preparation	RM & R	T0 + 24 months
M9.1	Advanced engine combustor noise instrumentation results delivery	RM & HW & R	T0 + 36 months
M10.1	Calculations of bypass ratio and engine architecture/technological effects on combustor noise first results	RM, R	T0 + 36 months

DIAGRAMME GANT			2020				2021				2022				2023			
	REF	Label	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Activities	Task/Mil./Del.	CFP Advanced solutions for 2030+ UHBR core noise reduction																
Management & requierements	NA	Management and reporting																
	T1	Risk reduction plan																
	M1.1,D1.1	*Risk reduction plan*																
	T2	Requierements																
	D2.1 & D2.2	*Innovative Low noise stator Specifications*																
Advanced modelisation solutions	T3	Improved LES prediction of turbulent combustion noise sources terms																
	D3.1	*LES intermediate results and report*																
	D3.2	*LES final results and report*																
	T4	*Improved aeroacoustics models*																
	M4.1	*combustor-turbine-exhaust nozzle transfer function and associated noise tool*																
	D4.1	*advanced transfert function final results and report*																
	T5	Improved CAA prediction including Low noise technological effects																
	M5.1	intermediate methodologies, tools and report																
	D5.1	*final results and report*																
Advanced Low noise CMC exhaust solutions	T6	advanced acoustic concept identification and assessment through partial tests																
	D6.1	*Concepts selection and high t°C/flow modelisations assesments*																
	M6.1 & M6.2	*Advanced concepts PDR & CDR*																
	D6.2	*2D large panels manufacture of 5 concepts*																
	D6.3	*2D tests results and analysis*																
	T7	improved integrated acoustic design and performance calculation at full scale																
	M7.1	*3D Low noise CMC exhaust design*																
	D7.1	*Acoustic performance of the final 3D solutions using advanced CAA methodology*																
Advanced Experimental analysis	*T8*	Survey & data analysis and experimental set-up preparation																
	D8.1	*Engine combustor noise signature literature survey and analysis*																
	M8.1	*Engine combustor noise test preparation*																
	T9	Advanced engine combustor noise data acquisition and measurement analysis																
	M9.1	*Advanced engine combustor noise instrumentation delivery*																
	D9.1	*Advanced engine combustor noise tests report, data results and analysis*																
Full Integrated simulations	T10	Calculations of bypass ratio and engine architecture/technological effects																
	M10.1	*Integrated simulations first results*																
	D10.1	Integrated simulations results and report																
		TRL														3		

Safran Aircraft engines will provide 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)

- Experience in combustor flow simulations with LES for aeroacoustics purposes
- Experience in aeroacoustics models for combustor engine noise prediction and capacities to support advanced theoretical extensions and developments in the models
- Experience in CAA prediction of combustor-turbine noise radiation, including noise source termes and Low noise technology effects
- Experience in design, manufacturing, testing of advanced acoustic liners technologies
- Experience in advance absorbing material and associated modelisation. Capability to model the performance of acoustic materials under high speed flow and high temperature conditions
- Capacities to specify / identify / develop advanced low noise liners solutions for engine exhaust
- Proven background, knowledge and capability to manufacture advanced acoustic panel structures.
- Experience in acoustic structure integration and mechanics of aircraft engine components
- Expertise in advanced composite material, specifically CMC materials
- Experience in liner tests characterization for aircraft engines. Availability of associated test benches
- Expertise in combustor and engine core noise. Abilities to perform a state of the art review/survey and data analysis of engine and core noise measurements
- Experience in advanced experimental techniques for aeroacoustics. Ability to develop or provide specific sensors that can resist to high temperature and adverse environements
- Experience in signal acquisition and psot-processing for noise source separation and identification
- The applicant shall provide adequate information necessary for an effective and efficient project management during the course of the project
- English language is mandatory

5. Abbreviations

UHBR	Ultra High Bypass Ratio
CoR	Concept Review
PDR	Preliminary Design Review
CDR	Critical Design Reviw
TRF	Turbine Rear Frame
CFD	Computational Fluid Dynamics
CAA	Computational AeroAcoustics
LES	Large Eddy Simulation
OGV	Outlet Guide Vane
NGV	Nozzle Guide Vane
TRR	Technology Readiness Review
TRL	Technology Readines Level
TRF	Turbine Rear Frame
CMC	Ceramic Matrix Composite

V. JTI-CS2-2019-CfP10-LPA-01-76: Supporting implementation of 2030+ UHBR low noise fan technology solutions through enhanced modeling capabilities

Type of action (RIA/IA/CSA):		IA	
Programme Area:		LPA	
(CS2 JTP 2015) WP Ref.:		WP 1.1.3.4	
Indicative Funding Topic Value (in k€):		1400	
Topic Leader:	Safran Aircraft Engines	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	42	**Indicative Start Date (at the earliest)[14]:**	> Q1 2020

Topic Identification Code	Title
JTI-CS2-2019-CfP10-LPA-01-76	**Supporting implementation of 2030+ UHBR low noise fan technology solutions through enhanced modeling capabilities**
Short description	
The design of innovative low fan noise technologies for next generation UHBR engines is highly conditioned by the accuracy of aeroacoustic modelisations and related design tools. Recent advances in numerical techniques, allowing to foresee more integrated approaches associated with more realistic high fidelity aeroacoustic simulations will be considered to further guide UHBR Low fan noise design and noise reduction technologies concepts (such as fan frame liners and low noise OGV concepts). The aim of the topic is to develop new postprocessing solutions to be applied on numerical/experimental results to further identify 2030+UHBR fan noise sources components/mecanisms and improve noise status. The maturation of the modelling solutions will focus on UHBR application with a more integrated "under the wing" configuration, with results extrapolated to BLI power plant systems integration.	

Links to the Clean Sky 2 Programme High-level Objectives[15]				
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:	Ultra-advanced Long-range Ultra-advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☐	☐	☒	☐	☐

[14] The start date corresponds to actual start date with all legal documents in place.
[15] 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 engines with significantly higher Bypass Ratios (UHBR) are being developed to further reduce the fuel consumption. These engines have a larger fan diameter, a lower rotation speed and a reduced number of blades. Drag penalties induced by the increased engine diameter are typically being offset by means of shorter and thinner nacelles. These architecture evolutions are having several consequences on the engine noise signatures. Fan noise becomes even more the predominant acoustic source of the engine and its signature tends to shift towards low frequencies.
UHBR Fan/OGV module specificities (like reduced speed, reduced rotor – stator spacing and reduced OGV count) may furthermore lead to dominating fan noise sources (mecanisms/components) changes.
Advanced UHBR engines architecture should in parrallel evolves toward compact nacelle/fan-module & flowpath design. Such fan module architecture evolutions are pivotal to rich higher integrated propulsion system performance efficiency but in other hand may lead to further noise sources increasements and drawbacks due to higher fan/Inlet interaction and distorsion pattern.
Moreover desire to improve the overall performance of the aircraft in terms of fuel consumption leads to aerodynamic and acoustic challenges related to engine integration and installation solutions. This may result in new ways to install the engines on the aircraft like more integrated “under the wing” configurations or BLI architecture concepts. Such changes can also affect future aircraft noise levels by means of generating, modifying or creating new noise sources. Therefore, major integration effects need to be considered to improve noise status projection.
Enhanced modeling capabilities, able to take into account advance integration/installation effects and UHBR fan module specificities, are in consequence foreseen to guide 2030+ UHBR low noise fan design/technologies taken into account advance integration/installation effects and UHBR fan module specificities. High fidelity aeroacoustics fan noise simulations (Figure 1) are becoming more and more valuable solutions to allow a better physics understanding and progress toward a more realistic integrated configuration.

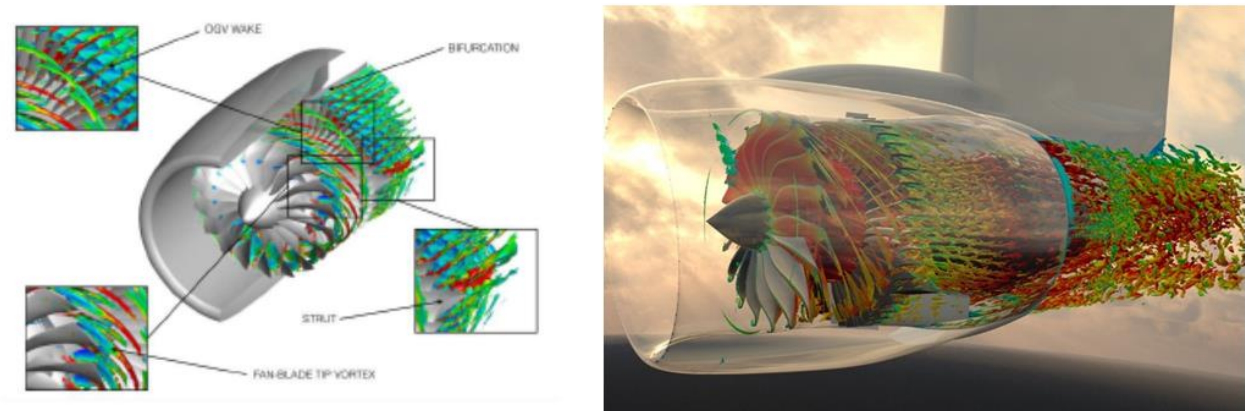


Figure 1 : Advance unstationnary (left) and high fidelity (right) aeroacoustics fan simulations

Further numerical demonstration studies are required to experience such high fidelity simulations on future 2030+ UHBR architecture configuration and installation. Room exists to further develop advance numerical set-up and functionnalities in a perpsective to include low noise fan frame technologies such as low noise soft OGV (Figure 3). A full integrated modeling will bring the opportunity to reduce more effectively noise sources and reach improved low noise concepts design.

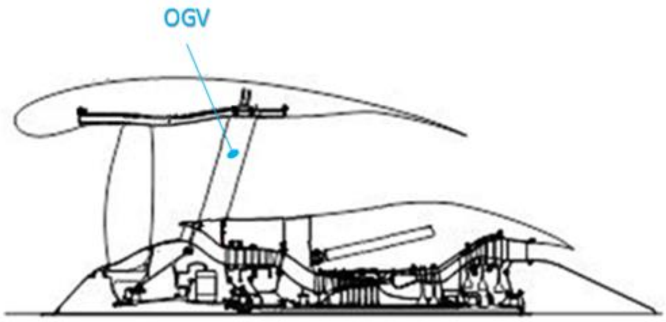


Figure 2 : Typical outlet guide vanes in UHBR engine environement

Figure 3 : Soft solutions extension along the OGV side

High fidelity simulations of UHBR TR4/5 large scale test demonstrations inside wind tunnel environment, combined with innovative post processing solutions, are also considered to be highly valuable solutions to understand how to improve experimental set-up definition and take advantage of noise data base. (And hence a more accurate in flight transposition noise status).
Therefore, advance modelling capabilities based on high fidelity solutions are key tools to integrate challenging UHBR architecture specificities and guide 2030+UHBR low noise fan design and technologies. Such advance simulation solutions, with more integrated approaches will thus contribute and enhance the possibility to fulfill CS2 environmental and performance objectives.
The subject of this topic concerns the development of advance UHBR aeroacoustics simulations in a perspective to fully take into account integration effects as well as low noise fan frame technologies. The activities include, inter alia, aeroacoustic simulations of UHBR large scale mock-up configurations and comparisons to experimental results (provided by topic manager) to verify prediction capabilities.
This activity is part of the "Ultra-high Bypass and High Propulsive Efficiency Geared Turbofans" demonstration area and the UHBR Integration roadmap. Results will feed into the UHBR engine model for use in the Technology Evaluator to assess the UHBR low noise concepts benefit.

2. Scope of work

The main concern is to set-up high fidelity fan noise computations and develop around advanced modelings and post-processing capabilities to improve prediction accuracy and support implementation of UHBR 2030+ UHBR low noise fan technology.
To further improve fan noise sources prediction, there is a need to learn from appropriate high fidelity solutions and to develop extended domain set-up to better integrate the propulsion system environments. To well understand each effects and contribution, a gradual extended simulation approach have to be performed considering:
- (1) Isolated fan module (task3)
- (2) Integrated propulsion system in static conditions (task4)
- (3) Integrated propulsion system in flight conditions (task4)

In a perspective to further guide 2030+ UHBR low noise fan design and technology solutions there is a requisite to perform not only conventional but also advance analysis and post-treatments to further correlate fan noise components signatures to corresponding noise sources mechanisms. Innovative post-treatments solutions will have to be further developed in task 6 to achieve a better physical understanding from numerical/experimental data bases.
Based on the knowledge arising from previous tasks, a high fidelity numerical simulation of an

integrated UHBR fan module large scale demonstrator inside wind tunnel environment will be performed by the applicant in task 5. Advance solutions will be developed in parallel in task 7 to better exploit/benefit numerical and experimental databases, learn from each other and improve results correlations/comparisons. Such solutions could also be highly valuable to understand how to improve experimental set-up definition and extend the exploitation rate of 2030+ UHBR fan noise data base from large scale TRL4/5 tests demonstration.
In parallel, advance high fidelity aeroacoustics simulations will be performed to support low noise fan frame concepts maturation. A CFD turbomachinery computation able to model simultaneously noise source generations and fluid/structure damping phenomena will be considered to simulate innovative low noise over the rotor and OGV technologies. TRL2 to TRL4 tests cases will be simulated and compared with experimental data bases provided by topic manager. Possibilities to optimize and further improve the low noise fan frame concepts performance with a more realistic modelling (and integrated approach) should be thus available through task 8. A final prediction of 2030+ UHBR fan module with low noise concepts will have to be performed in task 9.
Based on the topic results an improved UHBR 2030+ in flight noise status, including innovative low noise technologies benefits, could be achieved by topic manager. The new modeling capabilities will furthermore be made available in perspective to further guide 2030+ UHBR low noise fan design and technology solutions.
The topic maturation work plan is typically spread 3.5 years. The main tasks are developed below:

Tasks		
Ref. No.	***Title – Description***	***Due Date***
Task 1	Management and Risk reduction plan	T0+42
Task 2	Requirements	T0+24
Task 3	High fidelity aeroacoustics simulation of a UHBR fan module	T0+42
Task 4	High fidelity aeroacoustics simulation of an integrated UHBR propulsion system including environments and installation effects	T0+36
Task 5	High fidelity aeroacoustics simulation of a UHBR fan module large scale demonstrator inside wind tunnel environment including inflow and out of flow measurements comparison and extrapolation	T0+42
Task 6	Innovative aeroacoustics numerical and experimental signal/data base treatments for advanced noise source diagnostic	T0+30
Task 7	Innovative aeroacoustics numerical simulations for advanced antenna instrumentation signal correction and data correlation	T0+36
Task 8	Development of advance aeroacoustics simulation abilities for innovative fan frame noise reduction concepts and partial tests assessments	T0+36
Task 9	High fidelity aeroacoustics modelisation of a UHBR fan module including conventional and advance fan frame noise reduction concepts	T0+42

Task 1: Management and Risk reduction plan
The applicant has to ensure management and reporting activities throughout the project. A management plan has to be delivered and partner's progresses regularly reported. The applicant has also to support all project monitoring and coordination tasks.

- Progress Reporting & Reviews:
  - Regular 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 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 review meetings shall be held at the topic manager's facility.

- General Requirements:
  - The partner shall work to a certified standard process.

A risk reduction plan will be also provided. The plan will include demonstrations capabilities for each technical task and element. The applicant has to establish and deliver the related risk reduction plan. Mitigation actions and status shall be adequately monitored.

Task 2: Requirements
This task aims at contributing to specifications written under Safran Aircraft Engines leadership. The applicant has to support in particular the advanced requirements break down into detailed technical elements to ensure full compliance assessment capacity.

Task 3: High fidelity aeroacoustics simulation of a UHBR fan module
High fidelity simulations will be performed to calculate a UHBR large scale fan module noise signature considering both tones and broadband components. The applicant will propose High fidelity aeroacoustics CFD solutions able to capture and propagate appropriately the different fan noise sources mechanisms over a large frequency ranges (~0.5 to 3.5 KHz) as well as their evolutions along the operating line. Full 360° and unsteady approaches will be considered to catch appropriately the noise field generated by fan/OGV module.
The numerical set-up of the selected approaches will have to integrate the appropriate aeroacoustics simulations features (boundaries conditions: injection/wall/domains …); the modelisations will be defined by applicant and in agreement with topic manager to ensure a compatibility with industrial requirements and practices.
For this Task3 baseline configuration, four conditions will be computed and particularly studied to cover fan operating range. The UHBR fan module geometries as well as calculation required parameters (initializations, operating conditions,…) will be provided by topic manager.
Depending on fan noise mechanisms/components, applicant may considerate several separate simulations considering appropriate CFD and aeroacoustics models. Solutions will have also to be selected considering their potential to be applicable to the advanced/extended simulations targeted in tasks 4, 5 and 9.
Both aerodynamics and aeroacoustics data post-treatments (defined in agreements with topic manager) will be performed by applicant to assess results consistencies and allow experimental data correlations. Conventional and advanced numerical post-treatments (also in connection with task 6 activities) will be achieved to calculate aerodynamic performances and fan noise signatures, allow experimental comparison and support advanced physical understanding. An analysis of fan noise signature in connection with noise sources mechanisms/components will be in particular achieved by applicant.

Task 4: High fidelity aeroacoustics simulation of an integrated UHBR propulsion system including environments and installation effects
In task 4, the previous task 3 High fidelity simulations domains have to be extended to allow the calculation of the UHBR large scale fan module noise (tones and broadband components) within the integrated propulsion system environments. The fan noise sources will have to be computed in far fields over the same frequency range (~0.5 to 3.5 KHz) for 3 certification points.
A gradual more extended simulation approach will be followed considering first a static operating line, including secondly flying environments conditions and then installation effects. The following cases will be consecutively computed to reproduce experimental large scale tests configurations and conditions:

- Static configuration : 3 points (AP/CB/SL)
- Flight paths trajectories : 3 points (AP/CB/SL)
- Installed (wing) on flight paths trajectories : 3 points (AP/CB/SL)

The corresponding geometries as well as calculation required parameters (initializations, operating

conditions …) will be provided by topic manager.
The applicant will constitute the high fidelity simulations domains in compliance with CFD and aeroacoustics models requirements and in agreement with topic manager data expectations. Solutions will also be developed considering their partial reuse in tasks 5 and 9.
Both aerodynamics and aeroacoustics data postprocessing (defined in agreements with topic manager) will be performed by applicant to assess results consistencies and allow experimental data correlations. Conventional and advanced numerical postprocessings (also in connection with task 6 activities) will be achieved to calculate aerodynamic performances and fan noise signatures, allow experimental comparisons and support advanced physical understandings. A deep analysis of models extensions effects on fan noise signatures have to be conducted by applicant.

Task 5: High fidelity aeroacoustics simulation of an integrated UHBR fan module large scale demonstrator inside wind tunnel environment including inflow and out of flow measurements comparison and extrapolation
In task 5, high fidelity simulations of an integrated UHBR fan module large scale demonstrator inside wind tunnel environment will be conducted. These simulations will include the experimental test set up and also further numerical probes (to be defined in agreement with topic manager) aiming to bring out the best of both experimental and numerical data bases and achieved an improved results exploitability.
A total of 4 points will be at minimum simulated, considering at least two wind tunnel Mach flow conditions and for each two UHBR large scale fan module operating conditions. Geometries and calculation required parameters (initializations, operating conditions …) will be provided by topic manager. Applicant will constitute the high fidelity simulations domains in compliance with experimental set-up, CFD and aeroacoustics models requirements and in agreement with topic manager data expectations.
Both aerodynamics and aeroacoustics data post-treatments (defined in agreements with topic manager) will be performed by applicant to assess results consistencies and allow experimental data correlations. Conventional and advanced numerical post-treatments (also in connection with task 6 and task 7 activities) will be achieved to calculate aerodynamic performances and fan noise signatures, allow experimental comparisons and support advanced physical understandings. A deep analysis of results will be conducted aiming to highlight wind tunnel effects on fan noise data (by comparing with task 4 results) and to provide an extended experimental data base.
Based on these extended data base an improved UHBR 2030+ in flight noise assessments will be further conducted by topic manager.

Task 6: Innovative aeroacoustics numerical and experimental data treatments for advanced noise source diagnostic
Innovative data processing solutions are required to further correlate fan noise components signatures to corresponding noise sources mechanism. Results from these investigations to identify, classify fan noise sources and allow to correlate in-duct/near field with far field signals are expected to better understand physics and further guide 2030+ UHBR low noise fan design and technology solutions.

- Literature survey

A literature survey will be performed by applicant to ensure an updated know how regarding fan noise advance treatments analysis and identify the best way forward to achieve fan noise source mechanisms identification and emergence classification. The review will be performed in the topic context of integrated 2030+UHBR fan architecture and in order to further exploit high fidelity numerical/experimental aeroacoustics data bases.
In the first part of the survey, the applicant will specifically document the knowledge regarding state of the art methods to separate fan noise components and identify associated noise mechanisms. The review will consider source separation/detection method with several sensors location and associated

signal processing. Coherence techniques, source separations, modal analyses, source locations/beamforming … will have to addressed.
In the second part, the applicant will review innovative techniques that could allow to better identify fan noise mechanisms/generation, hierarchize noise sources, allow to correlate in-duct/near field with far field signals and make links between aerodynamic field/parameter and aeroacoustics noise field. Possibilities offered by recent deep learning/big data base solutions have to be reviewed.

- Baseline treatment methodologies and tools

The objective of this sub task is to make available an aeroacoustics treatment tools that need to be compatible with topic numerical/experimental data bases. The tools will include at minimum broadband/tones source separation, modal analysis and beamforming. The baseline functionalities will be refined during software/tools treatments reviews (concept review, PDR and CDR). To ensure an applicability to topic numerical/experimental data bases some validation tests will have to be performed using input from tasks 3, 4, 5, 8 and 9.

- Innovative treatment methodologies and tools

Innovative aeroacoustics treatment tools have to be developed and make available to performance advance analysis of topic numerical/experimental data bases. The targeted tools may include innovative functionalities from recent deep learning/big data base solutions and/or others coming from the previous review survey.
The selected functionalities will be refined during software/tools treatments reviews (concept review, PDR and CDR). To ensure an applicability to topic numerical/experimental data bases some validation tests will have to be performed using input from tasks 3, 4, 5, 8 and 9.

Task 7: Innovative aeroacoustics solution for advanced antenna instrumentation signal correction and data correlation
Innovative solutions are required to better correlate experimental with high fidelity solutions in a perspective to extend 2030+ UHBR noise data base from large scale tests. Results from these investigations to better define inflow/outflow sensors location, understand further correction to apply to experimental/numerical data are expected to improve 2030+ UHBR noise status.

- Literature survey

A literature survey will be performed by applicant to ensure an updated know how regarding correction to apply to experimental and numerical datas and identify the best way forward to achieve experimental and numerical correlation.

- Sensors integration analysis and advices

The applicant will perform a parametric study to understand how far sensors location inside wind tunnel environments (considering both experimental and numerical methodologies) can be improved.

- Innovative data correction and tools

Based on the literature review and the parametric study, applicant will define correction to apply to experimental and numerical data bases, in a perspective to better correlate results and if possible further extend noise data base. The proposed numerical and experimental corrections will be integrate in a dedicated tool.

Task 8: Development of advance aeroacoustics simulation abilities for innovative fan frame noise reduction concepts and partial tests assessments
The aim is to investigate and develop high-fidelity numerical aeroacoustics simulations to support advance low noise fan frame concepts maturation. The new CFD modelling capabilities will have to integrate abilities to simulate both fan/OGV stage noise source generations and damping phenomena due to the presence of three low noise technologies. Advance high fidelity fluid/structure damping modelisations will have to be considered to mimic conventional liners and advance soft damping

solutions (including porous/fluid/surface technological concepts) integrated in the low noise over the rotor and OGV fan frame parts.
The high fidelity aeroacoustics solutions will be evaluate with gradual turbomachinery technological demonstration and maturation tests cases (without and with low noise fan frame concepts) from TRL2 to TRL4 that will be provided by topic manager. Aerodynamic and acoustic performance effects predicted with the high fidelity numerical models will have to be compared with experimental data bases. The solutions may be also exploit to explore possibilities to further optimize and improve performance of these low noise fan frame concepts.
Solutions will also have to be developed in the perspective to achieve representative assessments on 2030+ UHBR fan module configurations with low noise concepts (to be performed in task 9).

Task 9: High fidelity aeroacoustics modelisation of a UHBR fan module including conventional and advance fan frame noise reduction concepts
High fidelity simulations will be performed to calculate a UHBR large scale fan module noise signature including conventional and advance fan frame noise reductions concepts (on tones and broadband components). Three low noise technological configurations will be considered including conventional liners, over the rotor and lined OGVs concepts.
The applicant will propose High fidelity aeroacoustics CFD solutions able to capture and propagate appropriately the different fan noise sources mechanisms including the technological noise reduction effects. The treated fan noise sources will have to be computed in far fields over the same frequency range (~0.5 to 3.5 KHz) for 3 certification points.
The numerical set-up of the selected approaches will have to integrate the appropriate aeroacoustics simulations features (boundaries conditions: injection/wall/domains/damping…); modelisations will be defined by applicant and in agreement with topic manager to ensure a compatibility with industrial requirements and practices.
For this Task9, three treated configuration, and for each three conditions will have to be computed. The UHBR fan module geometries, technological solutions as well as calculation required parameters (initializations, operating conditions,…) will be provided by topic manager.
Depending on fan noise mechanisms/components, applicant may considerate several separate simulations considering appropriate CFD and aeroacoustics models. Advanced solutions specifically developed in task 8 have to be considered.
Both aerodynamics and aeroacoustics data post-treatments (defined in agreements with topic manager) will be performed by applicant to assess results consistencies and allow experimental data correlations. Conventional and advanced numerical post-treatments (also in connection with task 6 activities) will be achieved to calculate aerodynamic performances and fan noise signatures, allow experimental comparison and support advanced physical understanding.
An analysis of treated fan noise signature in connection with noise sources mechanisms/components and low noise technologies damping effects will be achieved by applicant. Based on these new data an improved UHBR 2030+ in flight noise assessments including advance fan frame noise reduction concepts will be further conducted by topic manager.

3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1.1	Management plan & Risk reduction plan intermediate status	RM & R	T0 + 2 m
D2.1	Low noise fan modelling specification	RM & R	T0 + 4 m
D2.2	Low noise fan modelling specification completion	RM & R	T0 + 16 m
D3.1	High fidelity aeroacoustics simulation of a UHBR fan module – activities report and numerical calculation data base	RM, R & D	T0 + 14 m
D4.1	High fidelity aeroacoustics simulation of an integrated UHBR propulsion system including environments and installation effects – activities report and numerical calculation data base	RM, R & D	T0 + 34 m
D5.1	High fidelity aeroacoustics simulation of an integrated UHBR fan module large scale demonstrator inside wind tunnel environment – activities report and extended data base	RM, R & D	T0 + 40 m
D6.1	Innovative aeroacoustics numerical and experimental data treatments for advanced noise source diagnostic - survey review report & concept review meeting	RM & R	T0 + 12 m
D6.2	Innovative aeroacoustics numerical and experimental data treatments for advanced noise source diagnostic – tools and activities report	RM, R & SW	T0 + 30 m
D7.1	Innovative aeroacoustics solution for advanced antenna instrumentation signal correction and data correlation - survey review report & concept review meeting	RM & R	T0 + 12 m
D7.2	Innovative aeroacoustics solution for advanced antenna instrumentation signal correction and data correlation - tools and activities report	RM, R & SW	T0 + 30 m
D8.1	Development of advance aeroacoustics simulation abilities for innovative fan frame noise reduction concepts - advance high fidelity fluid/structure damping modelisation methodological solution review	RM, R	T0 + 12 m
D8.2	Development of advance aeroacoustics simulation abilities for innovative fan frame noise reduction concepts – tools and activities report	RM, R & SW	T0 + 30 m
D9.1	High fidelity aeroacoustics modelisation of a UHBR fan module including conventional and advance fan frame noise reduction concepts – activities report and numerical data base	RM, R & D	T0 + 42 m

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1.1	Risk reduction plan Completion review	RM & R	T0+26 m
M3.1	High fidelity aeroacoustics simulation of a UHBR fan module – Models and first high fidelity runs meeting review	RM, R & D	T0+8 m
M3.2	High fidelity aeroacoustics simulation of a UHBR fan module – Post-treatments applications and first results meeting review	RM, R & D	T0+10 m
M4.1	High fidelity aeroacoustics simulation of an integrated UHBR propulsion system including environments and installation effects – Models and first high fidelity runs meeting review	RM, R & D	T0+20 m

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M4.2	High fidelity aeroacoustics simulation of an integrated UHBR propulsion system including environments and installation effects – Post-treatments applications and first results meeting review	RM, R & D	T0+24 m
M5.1	High fidelity aeroacoustics simulation of an integrated UHBR fan module large scale demonstrator inside wind tunnel environment - Models and first results meeting review	RM, R & D	T0 + 28 m
M5.2	High fidelity aeroacoustics simulation of an integrated UHBR fan module large scale demonstrator inside wind tunnel environment - Post-treatments applications and first results meeting review	RM, R & D	T0 + 34 m
M6.1	Innovative aeroacoustics numerical and experimental data treatments for advanced noise source diagnostic - software/tools treatments PDR review	RM & R	T0 + 16 m
M6.2	Innovative aeroacoustics numerical and experimental data treatments for advanced noise source diagnostic - software/tools treatments CDR review	RM & R	T0 + 22 m
M7.1	Innovative aeroacoustics solution for advanced antenna instrumentation signal correction and data correlation - software/tools treatments PDR review	RM & R	T0 + 16 m
M7.2	Innovative aeroacoustics solution for advanced antenna instrumentation signal correction and data correlation - software/tools treatments CDR review	RM & R	T0 + 22 m
M8.1	Development of advance aeroacoustics simulation abilities for innovative fan frame noise reduction concepts - first applications and results reviews	RM, R & D	T0 + 18 m
M8.2	Development of advance aeroacoustics simulation abilities for innovative fan frame noise reduction concepts - final test cases demonstrations results and report	RM, R & D	T0 + 36 m
M9.1	High fidelity aeroacoustics modelisation of a UHBR fan module including conventional and advance fan frame noise reduction concepts - Models and first results meeting review	RM, R & D	T0 + 34 m
M9.2	High fidelity aeroacoustics modelisation of a UHBR fan module including conventional and advance fan frame noise reduction concepts - Post-treatments applications and first results meeting review	RM, R & D	T0 + 36 m

DIAGRAMME GANT		
	REF	Label
Activities	Task/Mil./Del.	CFP Advanced solutions for 2030+ UHBR core noise reduction
Management & requierements	NA	Management and reporting
	T1	Risk reduction plan
	M1.1,D1.1	*Risk reduction plan*
	T2	Requierements
	D2.1 & D2.2	*Low noise fan modelling specifications*
High fidelity aeroacoustics simulation	T3	Aeroacoustics simulation of a UHBR fan module
	M3.1 & M3.2	*Models and &Post-treatments first results meeting reviews*
	D3.1	*activities report and numerical calculation data base*
	T4	Aeroacoustics simulation of an integrated UHBR propulsion system
	M4.1 & M4.2	*Models and first high fidelity runs meeting reviews*
	D4.1	*activities report and numerical calculation data base*
	T5	UHBR fan module large scale demonstrator inside wind tunnel environment
	M5.1 & M5.2	*Models and first high fidelity runs meeting reviews*
	D5.1	*activities report and extended data base*
Innovative aeroacoustics treatments solutions	T6	data treatments for advanced noise source diagnostic
	D6.1	*survey review report & concept review meeting*
	M6.1 & M6.2	*software/tools treatments PDR and CDR reviews*
	D6.2	*tools and activities report*
	T7	advanced antenna instrumentation signal correction and data correlation
	M7.1 & M7.2	*survey review report & concept review meeting*
	M7.1	*software/tools treatments PDR and CDR reviews*
	D7.2	*tools and activities report*
High fidelity low fan noise concepts simulation	*T8*	abilities for innovative fan frame noise reduction concepts
	D8.1	*modelisation methodological solution review*
	M8.1 & M8.2	*first applications and final results reviews*
	D8.2	tools and activities report
	T9	aeroacoustics modelisation of a UHBR fan module including low noise concepts
	M9.1 & M9.2	*Models and &Post-treatments first results meeting reviews*
	D9.1	*activities report and numerical data base*

Safran Aircraft engines will provide 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)

- Experience of high fidelity flow simulations for fan noise aeroacoustics purposes
- Experience in fan noise sources mechanisms, aeroacoustics models and post-treatments for fan noise prediction
- Experience in aerodynamic calculation for fan module performance purpose
- Experience of high fidelity flow simulations for integrated propulsion systems including installation effects
- Experience of high fidelity wind tunnel flow simulations for aeroacoustics purposes
- Experiences of acoustic measurements in wind tunnel environments
- Experience in advance signal post processing to separate and identify noise components, perform modal analysis and beamforming treatments
- Experience in advance signal processing, deep learning/big data base solutions for advance CFD and physics treatments.
- Experience in measurements noise corrections for in-flow/out of flow wind tunnel measurement
- Experience in large scale fan rig tests and acoustic / aerodynamic post-treatments
- Expertise in High fidelity simulations to modelise aeroacoustics noise interaction, capacity to develop and implement advance high fidelity CFD fluid/structure damping/absorbing solutions
- Experience in design, manufacturing, testing of advance liners technologies
- The applicant shall provide adequate information necessary for an effective and efficient project management during the course of the project

5. Abbreviations

UHBR	Ultra High Bypass Ratio
CoR	Concept Review
PDR	Preliminary Design Review

CDR	Critical Design Reviw
TRR	Technology Readiness Review
GEN	Generation
OGV	Outlet Guide Vane

VI. JTI-CS2-2019-CfP10-LPA-01-77: Advanced Pitch Control Mechanism TRL4 Demonstration

Type of action (RIA/IA/CSA):		IA	
Programme Area:		LPA	
(CS2 JTP 2015) WP Ref.:		WP 1.1	
Indicative Funding Topic Value (in k€):		3500	
Topic Leader:	Safran Aircraft Engines	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	42	**Indicative Start Date (at the earliest)[16]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-LPA-01-77	**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[17]				
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 Ultra-advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☐	☐

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

[17] 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

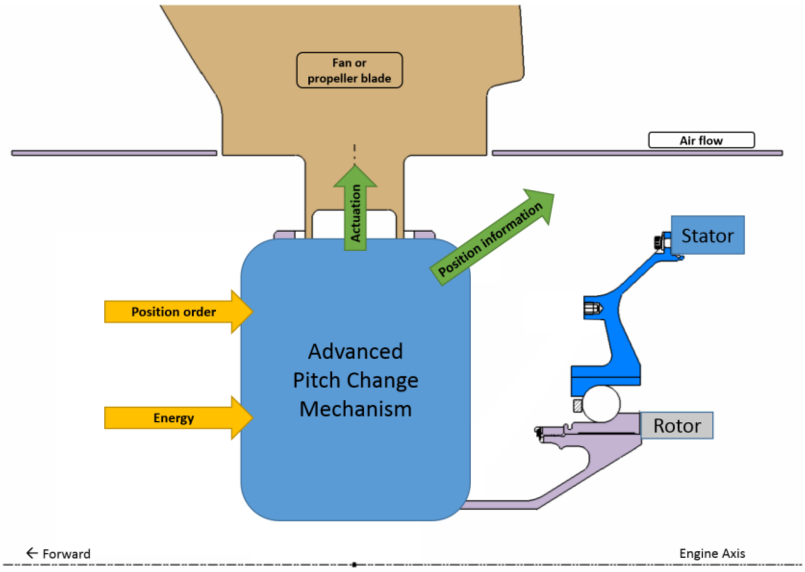


Figure 1 Advanced PCM in forward engine environment

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 was 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 PCM; one in each rotor, to enable independent control of each propeller blade stage.
SAGE2 PCM are both similar, located on a rear-end part of the engine, and based on static hydraulic actuators transferring motion and loads thanks to bearings and rods.
CleanSky 1 Open Rotor shown potential for such a solution but with several changes for a more viable concept with industrial exploitations. This topic pursues the aim to develop a PCM located at the fore-front of the engine, embedded in the rotating part.
The objectives of the current topic is to provide a new PCM technology with advanced performance pitch control mechanism featuring reduced mass; enhanced stiffness; improved maintainability; high accuracy and increased actuation capability. This will allow providing more fuel efficient; more reliable; lighter future engines featuring blade pitch control.
This PCM study shall be a major technological breakthrough for the development of all the CS2 demonstrators: UHBR (variable and geared fan), BLI (embedded and variable fan) and USF (variable open propeller).
The most important advantages of a variable pitch fan/propeller architecture are:

- Efficiency and margins improvement → **Noise and fuel burn reduction**
- The reverse thrust capability : mass gain → **Fuel burn reduction**
- Reduce excessive drag in safety modes → **Safety of high BPR architecture**

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.

TRL4 is intended as PCM validation in relevant lab environment. By representative testing conditions in a relevant lab environment we mean a rotating bench capable of testing the PCM use over its entire angular range and under normal working loads (for example torque from the blade). Some components tests can be performed at the part level in order validate, at the end, the whole PCM concept.

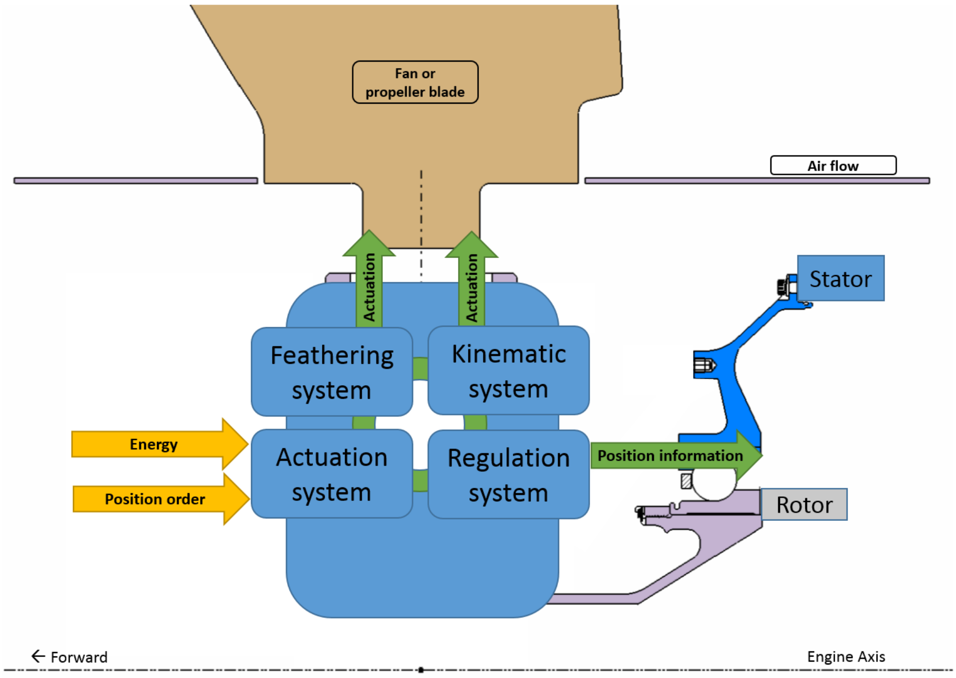


Figure 2: Advanced PCM sub systems

The Pitch Actuation sub systems are:

- Feathering system
- Actuation system
- Kinematic system
- Mesure/Regulation system

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.

Advanced PCM maturation work plan is typically spread over 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 2020
PCM_Task_02	Conceptual integrated PCM design	Q3 2020
PCM_Task_03	Preliminary integrated PCM design Preliminary test plan.	Q2 2021
PCM_Task_04	Detailed integrated PCM design: same as PDR at detailed level for final validation. Detailed test plan.	Q4 2021
PCM_Task_05	PCM manufacturing	Q3 2022
PCM_Task_06	PCM individual components testing	Q3 2022
PCM_Task_07	PCM assembly (PCM and PCM rig)	Q4 2022
PCM_Task_08	PCM rig commissioning	Q2 2023
PCM_Task_09	PCM acceptance and qualification testing	Q3 2023
PCM_Task_10	PCM investigations; lessons learned and way forward analysis	Q4 2023

Safran Aircraft Engines will be responsible for the integration of the PCM system in the engine and the applicant(s) will be in charge of the development study of the PCM module demonstrator. The applicant will closely work with the topic manager all along the project. SAFRAN will provide the requirements and will support the applicant during the different stages, with its engine designer vision and will guide the applicant through the whole project. Joint meetings are expected for major deliverable/review as well as during quarterly progress reviews. At least monthly phone calls will be established for project progress follow-up and technical interactions.
It is important to note that the CFP can be carried out by an applicant OR a consortium (leaded by the main applicant) in order to cover all the skills required to succeed in developing an advanced PCM.

<u>High level requirements for advanced PCM demonstration:</u>

- Rotor speed: from 700 to 1200RPM.
- Available volume: preliminary 2D design box: [length; radius] = [750; 280] mm.
- Actuation capability: 3000Nm 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.
- Weight : 200kg +/-50kg
- 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.

- Power supply: To be defined during the development.

Note: already available at aircraft level 115VAC/400Hz and 3000 PSI hydraulic pressure.

- Stiffness: 60Nm/rad for each 1Nm blade actuation capability.

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

- Accuracy:
    - Absolute accuracy (between request and individual blade): +/-0.5deg.
    - Relative accuracy (between one blade to one another): +/-0.1deg.

- Life:
    - Targeted engine life: 60 000hr and 36 000 cycles.
- 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 topic work based on detailed specification datasheet provided by SAFRAN.

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 2020
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 2020

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
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 2021
PCM_Del_04	Detailed Review Presentation: • Same as PDR at detailed/final stage. Detailed Design Report	R	Q4 2021
PCM_Del_05	TRL3 Review Presentation: • Design capability • Design validation status • Production capability • Handling capability • Manufacturing capability TRL3 Design Report	R	Q4 2021
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 2022
PCM_Del_07	Component Testing Review Component Testing Report	D	Q2 2022
PCM_Del_08	Component tested hardware: key component after testing (sensor; bearing; seal).	HW	Q3 2022
PCM_Del_09	Assembly Review : same as manufacturing at complete hardware stage level. Assembly Report (PCM and PCM rig)	D	Q4 2022
PCM_Del_10	N/A	N/A	N/A
PCM_Del_11	PCM test rig commissioning report	D	Q2 2023

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
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 2023
PCM_Del_13	TRL4 Review : same as TRL3 at TRL3 stage. TRL4 Design Report	R	Q2 2023
PCM_Del_14	Tested PCM hardware (min 1 complete PCM)	HW	Q3 2023
PCM_Del_14	PCM investigations; lessons learned and way forward analysis report	R	Q4 2023

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
PCM_MS_01	Specification Review	R	Q2 2020
PCM_MS_02	COR	R	Q3 2020
PCM_MS_03	PDR	R	Q2 2021
PCM_MS_04	CDR	R	Q4 2021
PCM_MS_05	TRL3 review	R	Q4 2021
PCM_MS_06	Manufacturing Review	R	Q3 2022
PCM_MS_07	Component Testing Review	R, HW	Q2 2022
PCM_MS_09	Assembly Review (PCM and PCM rig)	R	Q4 2022
PCM_MS_11	PCM Rig Commissioning Review	R	Q2 2023
PCM_MS_12	Acceptance and Qualification Test Review	R	Q3 2023
PCM_MS_13	TRL4 Review	R	Q3 2023
PCM_MS_14	Tested PCM Commissioning	R, HW	Q3 2023
PCM_MS_15	PCM investigations; lessons learned and way forward analysis review	R	Q4 2023

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

VII. JTI-CS2-2019-CfP10-LPA-01-78: Innovative turbine cavity swirl control systems through Additive Manufacturing

Type of action (RIA/IA/CSA):		RIA	
Programme Area:		LPA	
(CS2 JTP 2015) WP Ref.:		WP 1.1.3.4	
Indicative Funding Topic Value (in k€):		900	
Topic Leader:	GE Avio	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	24	**Indicative Start Date (at the earliest)[18]:**	> Q1 2020

Topic Identification Code	Title
JTI-CS2-2019-CfP10-LPA-01-78	**Innovative turbine cavity swirl control systems through Additive Manufacturing**
Short description	
Up to 15% of total losses in turbine efficiency can be related to leakages flow through the flow path seals, which therefore play a key role in determining the turbine global performance. Negative impacts of the leakages are related to the amount of by-pass flow flowing through seal, and the way this flow is re-injected in the flow path. The new manufacturing process based on Additive Manufacturing gives large opportunity by opening new design space for innovative solutions currently not implementable, improving both the sealing capability and the control of the swirl factor during re-ingestion phase. This Call for Proposal aims at developing and investigating different potential sealing/swirl control architectures, realizing prototypes of the most promising solutions for experimental validation in a simplified environment (TRL3).	

Links to the Clean Sky 2 Programme High-level Objectives[19]	
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 Advanced Short/Medium-range

With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☐

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

[19] 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 CS2 LPA technology demonstrator “Common Technology Bricks for Future Engines”, a range of technologies are developed that are key elements of more than one future engine configuration. Since the next generation (N+1) aircraft is expected to be powered by an advanced turbofan, this technology demonstrator focus on the generation after that (N+2), which is expected to enter into service in 2030 at the earliest, depending on the maturity of the new technologies being developed and their reliability. As all these technologies are maturing at sub-system level, and mandatory for a number of exploitation routes, they are also referred to as enabling as well as transversal technologies.

Many studies are ongoing to drive the developoment of new engine architectures (e.g. geared solutions) for EIS in 2030+, able to increase the thermodynamic cycle efficiency. In this context, one of the key enabler to support these solutions is the low pressure turbine that will be required to be very efficient, light and compact. High speed turbine, tipically included in this new geared engine solutions, have been estensively studied from an aerodynamic point of view, but its interaction with the secondary air system is still a source of important efficiency losses, that the new architectures may exhacerbate.

Turbine Sealing and rotating cavities flows control, main topics of this proposal, have been considered as mandatory technologies to be improved to match this goals. Up to 15% of total losses in turbine efficiency can be related to leakages flow through the flow path seals mainly for two reasons: the leakage flows do not work through the airfoil in line with thermodynamic cycle and the same flow is re-injected in the main flow path with negative impact on the aerodynamic behavior.

Tipically, flow path seals between parts, having different relative velocities and working at high temperaure, are based on labyrint geometries through straight fin and abradable material (tipically honeycomb). In order to guarantee the flow path desired geometrical shapes, seals are located as schematically reported in Figure 1, just ouside the flow path lines, in the so called “cavity seals”.

Disks and all critical parts need to be cooled with air coming from the compressor and that will be mixed with ingestion air coming from the flow path. All the flows will be re-injected in the flow path downstream the seals. The way this flow is managed through the cavities and is introduced in the flow path can play important role in defining the overall turbine efficiency.

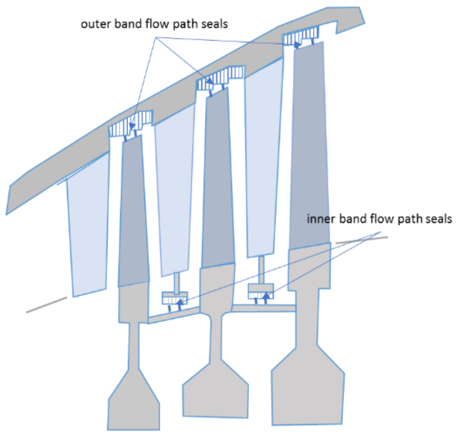


Figure 1: Typical layout of LPT with a highlight of flow path seals

Main goal of this topic is to understand the development of the flow field within specific rotating cavities and develop specific features able to control it for a better interaction with the main flow path. Additive manufacturing process could be the key technology to allow such rotating cavities architecture revision.

2. Scope of work

The applicant is asked to study the fluid behaviour of a Low-Pressure Turbine reference geometry, provided by the Topic Leader, propose and evaluate solutions to improve its impact on the performances, design and manufacture prototypes and test them in a simplified environment, up to TRL=3.
The applicant will perform these activities using a phase and gate approach. The topic leader will periodically meet the applicant in person or via teleconference to accurately track the evolution of the tasks.
Project is structured in five different tasks:

<u>T1 Concepts Definition</u>

The applicant will study the fluid-dynamic behaviour of two different rotating cavities (two Architectures simulating turbine inner band (Arch.1) and outer band cavities (Arch.2), as schematically reported in figure 2, whose geometries will be provided by the topic Leader, with focus on the sealing performances and swirling characteristics at the cavities exit.

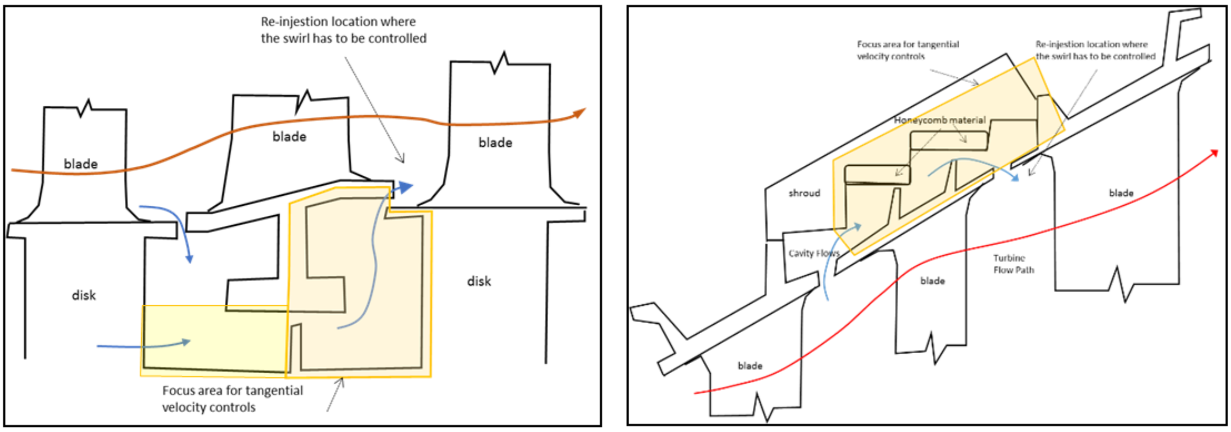


Figure 2: The two reference cavity architectures (Arch.1 – left, Arch.2 – right)

Based on these analyses some solutions to improve the flow behaviour and reduce the negative impact of the swirling inside the cavity and in the mixing region with the flow path will be proposed and benchmarked by the applicant under the technical coordination of the Topic Leader. The most promising solutions will be further assessed and optimized, until an optimum solution is selected for each cavity architecture.
Different tools are admitted for the simulations, pending validation on a representative configuration if not already public.
The applicant shall cover all the costs related to the different IT tools licences.

<u>T2 Test Articles design</u>

The applicant shall design some prototypes of the new cavities proposed solutions, able to be tested in a simplified rig, as defined in tasks T3 and T4.
The prototypes will include the flow control capabilities highlighted in the task T1, structural and manufacturability evaluation agreed with the Topic Leader. Topic Leader will support the Additive Manufacturing part design if needed.
Four prototypes for each Architecture are expected to be designed.

<u>T3 Test Articles manufacturing</u>

The applicant will manufacture and/or procure the test articles for the whole test activities planned in this proposal under its own responsibility. At least 8 prototypes, suitable for testing, will have to be made. Additional parts, coupons or simplified components could be necessary, to set up the process and to be used for validating it.
Prototypes will be adequately measured to guarantee the alignment with the requirements.

T4 Rig Set Up

In order to perform the experimental validations, a dedicated rig shall be realized. This can be a new rig or an adaptation of an existing one. The rig shall be capable to simulate rotating cavities allowing specific measurement of the flow field at inlet and exit sections.
Details of rig requirements will be agreed between the applicant and the topic Leader; high level requirements are:

- Capability to test different cavity architectures, simulating inner or outer geometries, as schematically reported in Figure 2. It is expected not to simulate the main flow path with the airfoils.
- The rig must be able to simulate the flow evolution in a rotating cavity, with specific focus in the swirl factor (ratio between flow tangential velocity and disks rotating speed). Reference engine values, to be used to propose a rig similitude are:
  - Mean cavity radius between 0,15 and 0,5 meters, cavity radial extension between 0,02 and 0,06 meters
  - Rotating speed up to 11000 rpm
  - Fed cooling air at inlet section up to 0,25 kg/s
  - Cavity Pressure Ratio (from the upstream of the seal to the flow path mixing region) up to 1,5

Rig shall be flexible enough to allow specific local features changes maintaining the same main components (disks, interfaces, etc.)
Specific instrumentation will be needed to measure the flow field in different cavity exit sections, cavity flow function and system windage losses.
Specific capability to measure flow field inside the cavities will be considered as additional preference.
Rig design, procurement and assembly will be in charge to the applicant and will be managed and agreed through specific review with topic Leader.

T5 Test Campaign

In agreement with the Topic Leader, the applicant will prepare a comprehensive test plan to collect the experimental data required to validate the solutions for the two cavities architectures identified and re-designed in T1 and T2. For each of them four different geometries are planned to be tested: a reference one and three studied for flow control.
Dedicated instrumentation will be installed on the test article to perform the tests campaigns as reported in task T3 and T4.
Each geometric condition will be tested at different mass flow (pressure ratio) and inlet swirl, for at least 15 testing points.
At least 8 rig assembly and 90 testing points are expected as complete experimental validation campaign.
Expected measurements for each of testing points are:

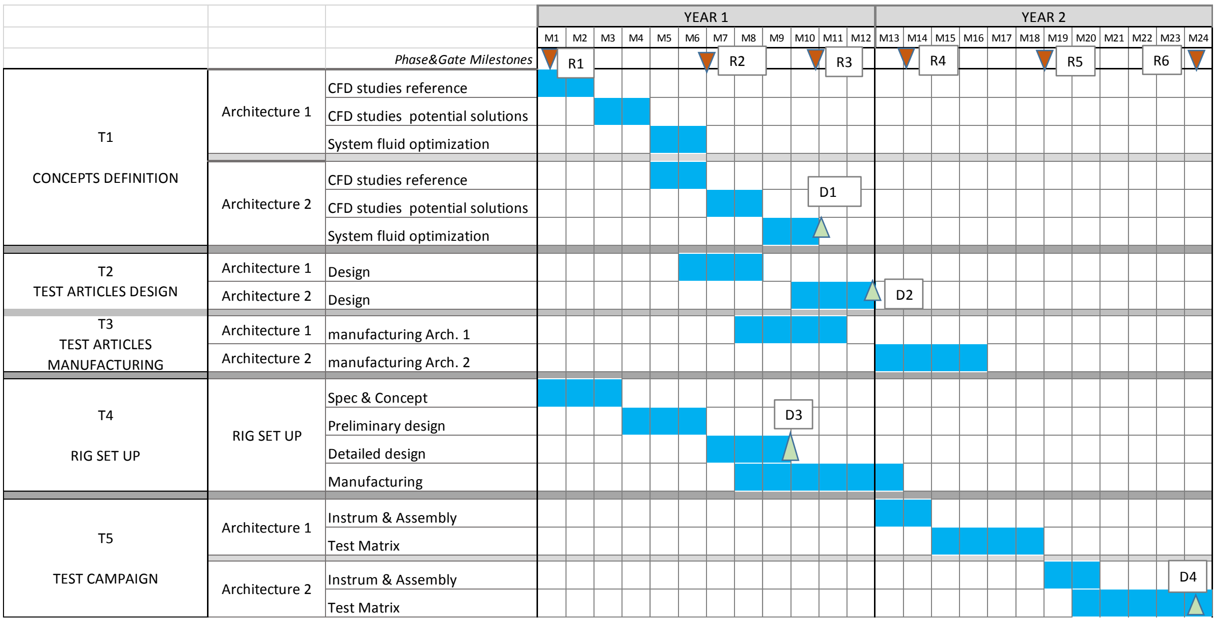
- Pressure distribution at inlet, exit and inside the cavities
- Cavity Flow Function
- Windage losses
- Flow velocity components at inlet and in at least three planes at cavity exit

- Capability to measure internal cavity flow field (velocity components) will be considered as additional preference

The applicant, under topic Leader technical supervision, will perform the whole test campaign.

Tasks		
Ref. No.	***Title – Description***	***Due Date***
T1	Concepts Definition	M10
T2	Test Articles design	M12
T3	Test Articles manufacturing	M16
T4	Rig Set Up	M12
T5	Test Campaign	M23

Schedule for Topic Project (Level 2 Gantt):



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	Concepts design - Report with activity description, solutions comparison and ranking for both Architectures 1 and 2. Numerical models used are part of the deliverable.	R, D	M10
D2	Designs release - Final design of Architectures 1 and 2, related drawings and/or CAD models suitable for manufacturing; report with final predicted performances, stress and dynamic assessment.	R, D	M12
D3	Rig Design - Report with functionality description, instrumentation, structural assessment; drawings and/or CAD models suitable for manufacturing.	R, D	M10

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D4	Test Results - Report with Architectures 1 and 2 testing campaign description and results. Organized database with all recorded data and their reduction	R,D	M24

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
R1	Kick Off - Agreement on detailed spec & Overall plan	Meeting	M1
R2	Arch. 1 proposed solutions review	R, Meeting	M6
R3	Arch. 2 proposed solutions review	R, Meeting	M10
R4	Rig set up availability	HW, Meeting	M13
R5	Arch1 Test campaign review Arch 1. Results review – comparison with numerical expectation – Technology final assessment	D, Meeting	M18
R5	Arch2 Test campaign review Arch 1. Results review – comparison with numerical expectation – Technology final assessment	D, Meeting	M24

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

The above-mentioned requirements will be fixed in more details during the partner agreement phase. This will also include the IP-process.

Special Skills

The applicant shall describe its experience/capacities in the following subjects:

- Extensive and proven experience in CFD methodologies application and validation.
- Specific skills in CFD applied to rotating cavities simulations will be considered as additional preference
- Proven experience in physical modelling definition, numerical implementation and validation.
- Proven experience in experimental testing with measurements of fluid-dynamics behaviour in rotating condition (flow fields, windage losses, flow visualization)
- The applicant needs to demonstrate to be in the position to have access to the test facilities required to meet the topic goals.
- Experience in rig design and supply chain management (for T/As procurement and relative measurements & inspections)
- Experience in aerospace R&T and R&D programs, program management.
- Applicant needs to demonstrate to have access to expertise for “design to additive” components and 3D printing.

5. Abbreviations

CAD	Computer Aided Design
CFD	Computational Fluid Dynamics
EIS	Entry Into Service
JU	Joint Undertaking
IADP	Integrated Area Development Program

LPA	Large Passenger Aircraft
LPS	Low Pressure System
TRL	Technology Readiness Level

VIII. **JTI-CS2-2019-CfP10-LPA-01-79: Development of multidisciplinary design tools for rapid concept design for aero engine components**

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€):		500	
Topic Leader:	GKN	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	24	**Indicative Start Date (at the earliest)[20]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-LPA-01-79	**Development of multidisciplinary design tools for rapid concept design for aero engine components**
Short description	
Open Rotor engine concepts are strong candidates for future aircraft propulsion. Since many engine architectures options exist, it is of critical importance to quantitatively compare and assess the value of a wide range of alternative concepts with respect to their performance and functionality as well as their impact on risk and cost of realization before down-selection. This CfP aims at developing multidisciplinary tools for structural engine components with specific focus on methods analyzing manufacturing tools' geometrical accessibility.	

Links to the Clean Sky 2 Programme High-level Objectives[21]				
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:		Advanced Long-range Ultra-advanced Long-range Advanced Short/Medium-range Ultra-advanced Short/Medium-range		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☐

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

[21] 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 Open Rotor Engine architecture with its inherent high effciency due to the high propulsive efficiency may be a game changing concept for environmentally friendly aviation. In the the previous Clean Sky project, an Open Rotor engine was developed and tested in full scale, see illustration to the right. The test succesfully proved reduced fuel consumption and low noise emission.

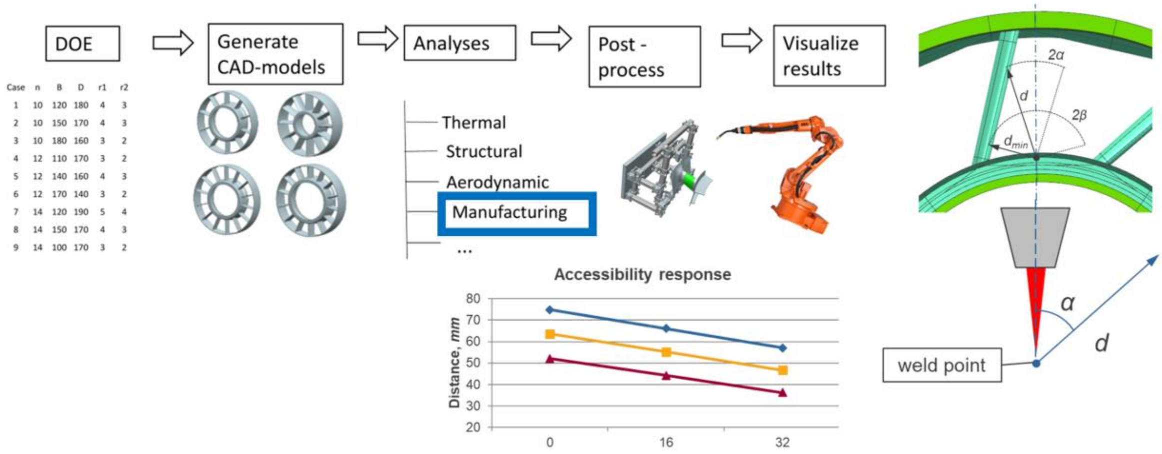
Open Rotor engine

Even though a succesful demonstration on engine level was achieved, several uncertainties in the next step exists. The first uncertainty concerns how to integrate the engine into the airframe. Under or over wing mounting or engines that are poded to the aft fuselage are all being discussed. The second uncertainty is the internal engine arcitecture. Since only a few open rotor engines have been designed (as for instance the GE UDF in the 80s), the mechanical architecture has not matured to one dominating design style. Both geared drive propulsors and direct drive turbine propulsors exist and in addition there are patents with contra-rotating puller propellers and engines that look like a hybrid betwenen turboprop engines and OR engines with on large front propeller followed by a static guide vane that closes out the swirl from the front rotor. The take-away from this discussion is that engine architecture changes are likely in the next phase of bringing the Open Rotor concept into commercial service.

The Open Rotor Propellers are connected to safety critical internal rotating structures, as can be seen in the example below where a rotating structure to the engine above is displayed. Safety requirments and complex geometry combined with a string drive to achieve the lowest weight indicates that these structures may be very costly. Therefore, the knowledge to build these structure from the best alloy in the best material forms (Forgings, Castings, Sheet, Additive Manufacturing etc) joined by the appropriate and most competitive technology.

This research topic adresses further development of multi-disciplinary design methods that are able to create and probabilistically evaluate a wide range of concepts in an uncertain design environment to generate a design regime that is resiliant to changes. The approach allows the generation of robust design solutions with quantified metrics for an impact assessment with regard to adaptability to requirement change during development, in service (as changes to the engine cycle due to de-rating or uprating engines) or ni subsequent projects where derivative engines are to be developed.

This multi-disciplinary design environment is partly established for structural engine components by the topic Leader but lacks efficient means for rapid and quantitative assessment of manufacturability, specifically with respect to accessibility for manufacturing tools and probes or devices for non destructive inspection.



A generic view of the analysis flow of the intended flow indicating need for quantitative models for assessing manufacturing tool accessibility

The representation and quantified definition of metrics and evaluation criteria that allow trade off studies and resilient design definitions are typically delimited to "traditional" mechanical behaviour such as stresss, strain, durability et.c. But, competitive business introduction of highly functional and safety critical products, such as Open Rotors (and their components), need also to be assessed versus their manufacturability and resilence against changes that are likely to occur along the development and realisation process. Risk analyses are often based on qualitative assumptions and this work will focus on developing methods and tools that enable a quantified risk assessment. This requires both a systematic process of deriving the quantified metrics, the use of advanced simulation methods and tools (such as function means modelling, path and collition detection between component, manufacturing tools) along with more established methods and tools for mechanical integrity.

The approach for development will go through the following steps:

1. Define/ensure compatible multidisciplinary framework/environment compatible with industrial need/platform and agree relevant geometry ranges for engine components and the manufacturing process tools to be analysed. Success criteria for the method development for accuracy, flexibility in applicability to geometries and tools and speed of execution of (~1000 design cases) is to be discusses and agreed with the Topic Leader,
2. Development of *autmated* simulation methods of accessibility for direct deposition additive manufacturing tools, weld tools and inspection processes.
3. Development of methods and tools for multidimensional assessment and visualisation of design space including accessibility results for manufacturing tools.
4. Demonstrate appropriateness for the developed models and efficiency in execution in a use case provided by the Topic Leader. The use case will include geometry options, functional requirement ranges, and citeria for value assessment of the wide range of multidisciplinary results. The CfP-consortium will propose digital experiments to validate the developed methods and assess the results from the methods demonstration towards the agreed success criteria.

2. <u>Scope of work</u>

Tasks

Ref. No.	*Title – Description*	*Due Date*
1	**Agree prerequisites, approach and success criteria** Define and agree with Topic Leader the appropriate design space, identification of functional requirements, constraints and what value drivers are most relevant for evaluation. Literature study is conducted to identify, select and motivate modelling methods/tools for geometrical accessibility in the context of value assessment, functional modelling, constraints representation, mechanical integrity modelling and simulation A base line component application, and associated manufacturing tools are identified as the reference. Topics that need to be addressed; - Identification of governing expectations, needs and requirements - Identification of boundaries and constraints, valid for all possible concepts to be studied - Identification of most critical impact assessment metrics, e.g. weight, manufacturing risk including tool accessibility for three processes, production process impact, mechanical integrity criterial etc. Success criteria for the methods development regarding accuracy, speed of execution and flexibility shall be defined and agreed with the Topic Leader	M4
2	**Development of methods for automated evaluation of accessibility** Develop methods for automated assessing accessibility of manufacturing process tools for welding, direct deposition additive manufacturing and non-destructive testing (Radiography and/or Ultrasonic testing). The accessibility methods are foreseen to operate from multiple models generated in a CAD software. Algorithms for quantifying accesibility will be developed to enable automated probabilistic analysis that can operate in parallel to analyses tools that autaomtically asssesses functional aspects and cost performance. Develop and verify that the methods are able to operate within an automated process using parameterized CAD models by a format/method that is neutral to CAD software or easily adaptable to alternative softwares and with an overarching visualization and assessment environment available at the Topic Manger facility. The method is to be developed with the resilient multi-disciplinary design environment as a prerequisite and boundary condition. It should be able to generically evaluate clashes, and accessibility for direct deposition additive manufacturing tools, weld tools and inspection processes (typically visual inspection, radiographic and optionally ultrasonic testing) in a complex open rotor engine structure manufactured as a weld assembly of cast/forged components with additively manufactured features added.	M18

Tasks		
Ref. No.	***Title – Description***	***Due Date***
3	**Development of methods for multidimensional assessment and visualisation of design space.** This task addresses the needs to assess all MDO parameters in a consolidated way with a probabilistic approach where sensitivities to changes in the design regime and in functional requirements can be assessed with regards to solution value and robustness (low risk). The focus here should be the additional complexity that is introduced when accessibility aspects are studied.	M18
4	**Validation of the methods appropriateness in digital experiments** A specific use case (within the limits of Task 1) will be provided by the Topic Leader, as illustrated by the analysis flow illustration. The use case will include a weld assembled engine component with high geometric complexity (typically the rotating structure shown above), typical geometry options, functional requirement ranges, specific access requirements for different methods and citeria for value assessment of the wide range of multidisciplinary results. The CfP-consortium will propose and conduct digital experiments to validate the developed methods and assess the results from the methods demonstration towards the agreed success criteria.	M24

3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1	Detailed Project Plan	R	M1
D2	Report that includes documented baseline component and manufacturing processes, evaluation criteria, methods selection motivation and success criteria for the project results	R	M4
D3	Methods/tools for automated accessibility assessment	SW/R	M18
D4	Tools for multidimensional assessment and visualisation of design space with focus manufacturing process tools accessibility	R/SW	M18
D5	Description of results of digital experiments of the use case including evaluation of success criteria	R	M24

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	Literature study as defined in Task 1	R	M4
M2	Definition of use case and success criteria as defined in task 2	R	M4
M3	Proof provided that the methods propose can operate in Topic leader environment	R	M18

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

The consortium is expected to have the following abilities or expererence:

- Experience and existing tools within multidisciplinary design optimisation and engineering automotion techniques with a focus on manufacturing assessment for conceptual level using state of art tools (Siemens NX preferred).
- Modelling and simulaton of manufacturing equiment tools and equipment, in use with product specimens.
- Value Impact Assessment modelling and simulation.
- Experience from using multidisciplinary modelling and interactive, visual analytics.
- Generative modelling and automation of engineering processes.

5. Abbreviations

CAD	Computer Aided Design
MDO	Multi-Disciplinary Optimisation

IX. JTI-CS2-2019-CfP10-LPA-01-80: Rear fuselage and empennage shape optimization including anti-icing technologies

Type of action (RIA/IA/CSA):	RIA		
Programme Area:	LPA		
(CS2 JTP 2015) WP Ref.:	WP 1.2		
Indicative Funding Topic Value (in k€):	1500		
Topic Leader: Airbus		Type of Agreement:	Implementation Agreement
Duration of the action (in Months): 36		Indicative Start Date (at the earliest)[22]:	> Q1 2020

Topic Identification Code	Title
JTI-CS2-2019-CfP10-LPA-01-80	Rear fuselage and empennage shape optimization including anti-icing technologies
Short description	
The purpose of this research proposal is to develop numerical methods for the prediction of 3D ice-accretion on empennage surfaces which will support and will be validated by the design and execution of experimental testing of passive, low cost and high durability anti-ice coatings. Additionally this project covers the development of computational methods for the aerostructural optimization of a large aircraft component, in this case an advanced rear-end taking into consideration anti-ice technologies and devices.	

Links to the Clean Sky 2 Programme High-level Objectives[23]				
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:	Advanced Long-range Ultra-advanced Long-range Advanced Short/Medium-range Ultra-advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	Reducing NO_x emissions	Reducing Noise emissions	Improving EU Competitiveness	Improving Mobility
☒	☐	☐	☐	☐

[22] The start date corresponds to actual start date with all legal documents in place.
[23] 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

Work Package 1.2 is devoted to the development of concepts, enabling technologies and capabilities for the design and manufacture of the optimum rear fuselage and empennage for the next generation of commercial aircraft.
The Advanced Rear End (ARE) concept, developed in WP1.2, aims at the integration of conceptual and aerodynamic design, structural and systems architectures, materials technologies and industrial processes to help achieve new standards in economic, environmental and manufacturing efficiency and flexibility.
A demonstrator of an Advanced Rear End will be developed and tested. This research topic will contribute to defining the optimal configurations that will allow to:

- Deliver the following performance improvements at component level with respect to the 2014 short range reference aircraft: 20% Weight reduction, 20% recurring costs reduction, 50% Lead time reduction
- Reduce the fuel burn at aircraft level by 1.5% stemming from the previous goals
- Deliver Digital Mock-Ups and Technical Definition Dossiers of an integrated Advanced Rear End

The purpose of this research proposal is to identify, investigate and quantify aerodynamic and aeroelastic enablers to allow the size reduction of the empennage of a classical configuration and/or to facilitate the consideration of alternative configurations driven by non-aerodynamic considerations (e.g., V-Tail and the family of Cross-tails). Several elementary technology bricks are proposed for study, including experimental testing, each with particular focus on the key aerodynamic design drivers of an empennage, stemming from its required functions.

2. Scope of work

In order to fulfil the objectives laid out in the previous section the following lines of work will be covered in this proposal:

- Numerical **simulation of ice accretion** processes, with and without surface protection, for three-dimensional shapes
- Evaluation and integration of **anti-ice coatings and devices** for three-dimensional shapes
- Development of **aerostructural optimisation** methods including aeroelastic and flight mechanics constraints, embodying anti-ice solutions.
- Large scale experimental validation in a ***wind tunnel*** of the ice accretion process with and without anti-ice protections

The performance improvement objectives sought in the Clean Sky 2 project call for a departure of the conventional empennage configurations and technologies that constitute the state of the art in aircraft design.

An “Advanced Rear-End” component for the next generation of ultra-efficient aircraft might consist of a very compact rear fuselage, with no cut-out for the horizontal stabiliser and a simplified V-tail or T-tail configuration. The V-Tail presents challenges for the stability and control of the aircraft, mainly arising from the aerodynamic saturation of the tail surfaces. Therefore, aerodynamic technologies and concepts which may help increase the lift capability of the V-tail, particularly in unfavourable conditions, are of interest in this project.
The T-tail is a relatively well known configuration and tends to be used only when there is no other alternative due to its lower performance when compared with the conventional arrangement arising from its larger size, in spite of its merits in terms of simplicity and better use of the unpressurised rear-fuselage. The two factors that make the T-tail less effective and therefore requiring a larger size to fulfil

its stability and control functions are its much greater aerodynamic degradation when ice is formed on the leading edge and its adverse aeroelastic effects, in particular considering the flutter behaviour.
This project seeks to explore design methods for the synthesis of a potential candidate concept of an advanced rear-end component which will become the baseline configuration of the next family of commercial aircraft.

The following sections detail the lines of work proposed in order to accomplish this goal.

a) Numerical simulation of Ice accretion in 3D shapes

The usual approach for the numerical prediction of the ice accretion is to perform a 2D simulation of the ice shape build-up and extrude this shape along the leading edge. This method cannot capture the influence on the ice accretion of a non-straight leading edge, which results in the current lack of capability to exploit innovative aerodynamic concepts.
The objective of this work is to develop numerical methods for the prediction of ice-accretion on 3D shapes, including non-straight leading edges. Additionally, the effect of anti-icing devices shall be captured as well. The topic manager will provide the applicants with all the required information regarding the devices and materials of interest.

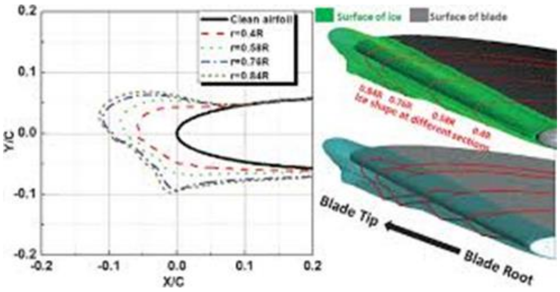


Figure 1 Current approach for the 3D simulation of ice-accretion

b) Development and testing of anti-ice coatings and devices on 3D shapes

This line of work will evaluate and integrate passive materials and coatings to prevent the ice accretion on the leading edge of tail surfaces, with particular focus on non-straight leading edge shapes. It is not intended that fundamental research will be performed to develop these materials but rather that the integration aspects of existing concepts/ coatings (already studied and developed by applicant(s) or available in the market) on a realistic structure are investigated. The performance of the integrated shape + material will be validated in a large scale wind tunnel test.

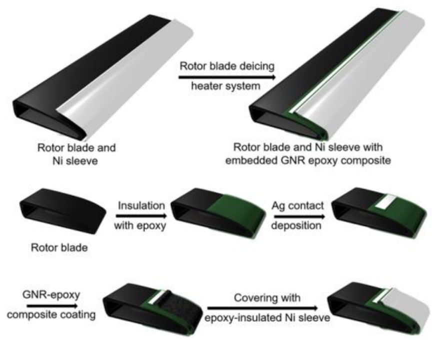


Figure 2 Example of leading edge coatings and materials to prevent ice accretion

c) Aerostructural optimisation of the rear-end

The conventional configuration of the rear-end of large commercial aircraft is well known and its design has evolved incrementally through the development of complete product families by the leading aircraft manufacturers. A departure from this configuration might result initially in a less efficient component due to the lack of prior design knowledge. The advent of high fidelity aerostructural optimisation technology may help reduce this risk and accelerate the development of an ultra-efficient concept.
Europe lags behind the US in the research and application of these technologies in aircraft design, even when sufficient knowledge is distributed across European research institutes and Universities to tackle and exploit this technology effectively. The applicants will develop and apply innovative aerostructural optimisation methods to the rear-end configurations proposed for the advanced rear-end concept, including icing considerations. The plausible configurations are a T-tail or a V-tail but the focus here is on the capability development. The application of the developed capability to both configurations is feasible and expected to enrich the results database to inform the design process.
To clarify the objective; given a configuration (a generic statement of the rear-end being “T-tail” or “V-tail”), what is sought is the “optimal” geometric shape of the rear fuselage and empennage, this shape being the outcome of the optimisation process.

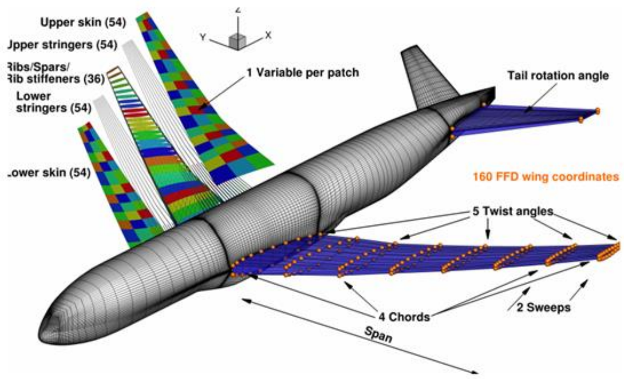


Figure 5: Optimization design variables. Structural design variable grouping (left) and geometric design variables (right).

Figure 3 - Example of aerostructural optimisation state of the art, G. Kenway, J. Martins,, University of Michigan

The research work will concentrate on the advanced geometric modelling of a rear-end parametric component using a geometry kernel suitable for shape optimization using the adjoint method. In a first phase a pure drag minimisation of the rear fuselage and empennage subject to simple geometric and handling qualities constraints will be performed, including the effects of the anti-icing technologies under study.
A second phase will incorporate structural and aeroelastic constraints –driven by the flight mechanics requirements of the aircraft- performing a complete aerostructural optimisation loop to maximise a performance metric. Both flutter and static aeroelastic constraints will be used in the process.
The structural concepts included in the aerostructural optimisation will be derived from the work performed in the Advanced Rear End project regarding structural and manufacturing technologies. The required information will be provided to the applicants by the topic manager.

d) Wind tunnel large scale testing of ice accretion processes with and without anti-ice protections on tail surfaces

The numerical predictions for ice-accretion and the performance of the anti-ice coatings and materials will be validated in a large scale wind tunnel test. It is envisaged that a representative model -or section- of a tail surface - will be tested in icing conditions incorporating various anti-icing coating and materials.

The wind tunnel model shall be of a representative size to capture the physical ice-accretion characteristics on the features of interest (the leading edge) and shall be manufactured by the applicant. If required, additional models or modular leading edge components could be supplied by the topic leader. It is acceptable that an "equivalent" airfoil –in the context of ice accretion, i.e. reduced chord and adapted airfoil shape- is used, respecting the shape and size of the leading edge. The leading edge materials should be representative of the actual materials used for the final application (a commercial aircraft tail). The different coatings of materials shall be applied on the basic structure. Guidance on these materials shall be provided by the topic leader. The wind tunnel test will be carried out at test speeds between 80m/s and 120m/s, although higher speeds would be desirable. The tests will be carried out at atmospheric pressure, i.e., no altitude icing is required. The ice-accretion process in the experiment will be compared with the numerical predictions for their validation and development.

Innovation Content

This project explores three main innovation dimensions:

- **Development of numerical methods for the prediction of 3D ice-accretion on lifting surfaces.** The modelling of ice accretion is a complex topic which has so far only tackled 2D geometries. There is intense research activity in the US, prompted by the FAA, to improve the modelling of ice formation on lifting surfaces. The full exploitation of numerical prediction of ice accretion can only be achieved considering realistic 3D shapes, including local undulations designed to modulate the accretion. This capability is currently outside of the industrial practice and this project will stimulate ground-breaking research in this direction.
- **Evaluation and testing of passive, low cost and high durability anti-ice coatings.** There is significant fundamental research being carried out on anti-ice coatings. This project will serve as a platform to integrate and test the existing options in a large demonstrator to be tested in the wind tunnel. In particular, this project will focus on the effect of passive anti-ice materials and coatings on non-straight leading edges. This is a novel topic of research which will build on the work performed within Clean Sky, where these shapes will be designed and tested in ice-free conditions. The liaison between the two projects, if necessary, will be provided by the topic manager.
- **Development of computational methods for the aerostructural optimization** of a large aircraft component, in this case an advanced rear-end. The theoretical framework and pre-industrial tools are well developed to tackle the automatic synthesis of external aerodynamic shapes including structural and aeroelastic constraints. This field is led by US research groups, in particular the University of Michigan and Stanford University. The potential of this technology cannot be understated and it will form the basis of advanced aerospace design in the next years. This project will offer a realistic framework to develop and explore high fidelity aerostructural synthesis of a large aircraft component in collaboration with industry, providing ample scope for innovation and dissemination. Industry will benefit directly by acquiring this capability which will be used for the next generation of aircraft.

3. Major Deliverables/ Milestones and schedule (estimate)

The main deliverables of this project are:

- Theoretical background on aerostructural optimisation and application proposal to an advanced rear-end concept
- Delivery of a numerical prediction method for ice-accretion on 3D shapes, including the effect of anti-ice materials and coatings
- Delivery of a usable numerical method for advanced aerostructural design, including geometric modelling and multidisciplinary optimisation

- Technology selection of solutions for practical passive anti-ice protections and integration studies
- Experimental validation of the anti-ice concepts and materials proposed in a wind tunnel
- Analysis of experimental data and correlation with numerical predictions.
- Overall conclusions and recommendations

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
ARE_C10_01	Partner contribution detailed description (content, deliverables, planning)	Report	T0 + 6
ARE_C10_02	Anti-ice materials technology scouting report	Report	T0 + 12
ARE_C10_03	Aerostructural optimisation methodology overview	Report	T0 + 12
ARE_C10_04	Numerical simulation of ice-accretion, methodology overview	Report	T0 + 12
ARE_C10_05	Intermediate reports on numerical methods; ice accretion and aerostructural optimisation	Report	T0 + 24
ARE_C10_06	Wind tunnel models	Report and specimens	T0 + 24
ARE_C10_07	Completion of Icing Wind Tunnel testing	Test report	T0 + 32
ARE_C10_08	Delivery of numerical prediction tools for ice accretion	Report and tools	T0 + 34
ARE_C10_09	Delivery of aerostructural optimization results and methodology	Report and tools	T0 + 34
ARE_C10_10	Final report, conclusions and recommendations	Data and Report	T0 + 36

4. <u>Special skills, Capabilities, Certification expected from the Applicant(s)</u>

The applicant(s) shall be able to demonstrate sound technical knowledge in the following areas:

- Advanced geometric modelling, CFD analysis, adjoint-based aerodynamic shape optimization
- Aeroelastic modelling, analysis and optimization
- Numerical modelling of ice accretion on lifting surfaces
- Aerostructural optimisation
- Wind Tunnel Testing: low speed and icing applications
  - ✓ Wind Tunnel Model design and build. In-house model manufacturing capability
  - ✓ Excellent mechanical design capability applied to aeronautical projects. Knowledge of design standards, materials and tolerancing.
- Demonstrated mechanical design capability to design WT models and mechanisms
  -

The applicant shall, as minimum requirements, use the following equipment for aerodynamic and aeroelastic design and testing:

- High Performance Computing (HPC) and state of the art CFD solvers.
- Icing wind tunnel with the following characteristics:
  - suitable for aeronautical testing,
  - minimum test speed 80 m/s,
  - surface flow visualisation
  - infra-red thermographic cameras

5. Abbreviations

VG	Vortex Generator
CDR	Critical Design Review
HPC	High Performance Computing
LE, TE	Leading Edge, Trailing Edge
VTP	Vertical Tail Plane
IWT	Icing Wind Tunnel
WTT	Wind Tunnel Testing
CFD	Computational Fluid Dynamics
FAA	Federal Aviation Administration
ARE_CfP09	*JTI-CS2-2018-CfP09-LPA-01-63 Rear End Aerodynamic and Aeroelastic Studies*

X. JTI-CS2-2019-CfP10-LPA-01-81: Fiber reinforced thermoplastics manufacturing for stiffened, complex, double curved structures

Type of action (RIA/IA/CSA):		IA	
Programme Area:		LPA	
(CS2 JTP 2015) WP Ref.:		WP 1.2	
Indicative Funding Topic Value (in k€):		700	
Topic Leader:	DLR	Type of Agreement:	Implementation Agreement
Duration of the action (in Months):	30	Indicative Start Date (at the earliest)[24]:	> Q1 2020

Topic Identification Code	Title
JTI-CS2-2019-CfP10-LPA-01-81	Fiber reinforced thermoplastics manufacturing for stiffened, complex, double curved structures
Short description	
The main objective of this call is the contributions to a mid-scale demonstration of a thermoplastic rear-end part by developing: a thermal simulation model for a Xenon heating lamp in combination with a heated tooling; process, manufacturing and demonstration of complex double curved stringers and stiffeners out of fiber reinforced thermoplastic; design and manufacturing of an innovative self- heated, double curved tooling for thermoplastic rear-end structures.	

Links to the Clean Sky 2 Programme High-level Objectives[25]				
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 Ultra-advanced Long-range Advanced Short/Medium-range Ultra-advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	Reducing NO_x emissions	Reducing Noise emissions	Improving EU Competitiveness	Improving Mobility
☒	☐	☐	☒	☐

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

[25] 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 "Advanced rear-end (ARE) aims to the integration of conceptual design, structural and systems architectures, materials technologies and industrial processes. To achieve this objective WP1.2 will develop concepts, enabling technologies and capabilities for the design and manufacture of the optimum rear fuselage and empennage for the next generation of commercial aircraft.

The WP1.2 "Advanced rear-end" is subdivided in 5 workpackages which can be seen in the WBS below.

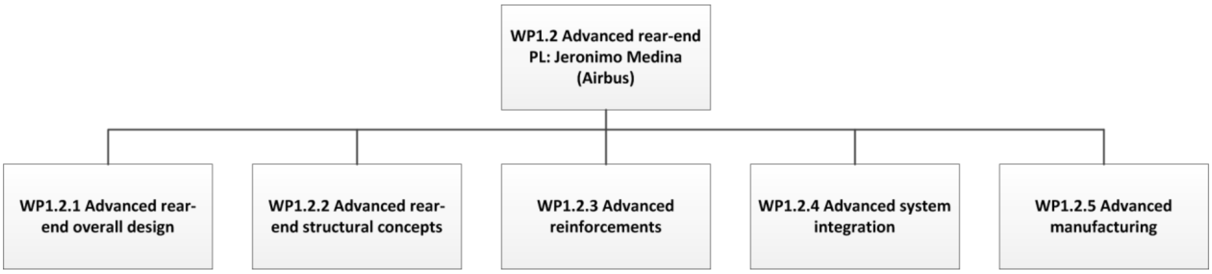


Figure 1: Work breakdown structure of WP1.2

The proposed topic is located in the sub-workpackage 1.2.5 "Advanced manufacturing" and will contribute to an evaluation of different models, methodologies and manufacturing processes investigated in WP1.2.

This evaluation and the corresponding down-selection of the manufacturing process aims at enabling thermoplastic manufacturing processes for thick and double curved laminates as an alternative to the thermoset investigations done also in WP1.2.5.

Current activities in WP1.2.5 are focused on the technology validation and assessment for a manufacturing approach of a thermoplastic rear end. For this, a section of a double curved rear end structure was chosen. The defined section with 2.1m length and 1.4m width consist of highest curvature and varying skin thicknesses, 3 Stringers, 12 Clips and 3 Frames integrated with different joining technologies.

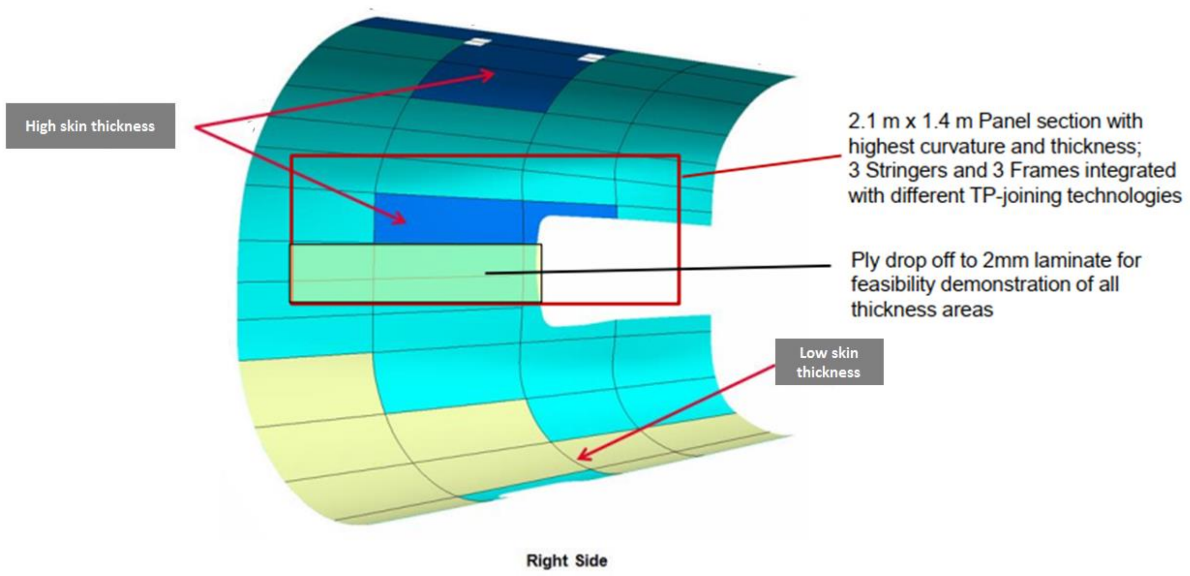


Figure 2: Defined Rear End Section with critical design features

In the field of skin layup the activities are focused on the pre-definition of processing parameters for the most common materials used for the automated manufacturing of Carbon Fiber Reinforced Plastic (CFRP) structures with Automated Fiber Placement (AFP) or Automated Tape Laying (ATL) Technologies. Therefore the topic manager defined a test matrix and carried out experimental trials to understand the fundamentals of the tape placement process for thermoplastics with a Xenon heating device. In parallel the optical and thermal characterization of the composite is carried out. The generated knowledge from these Parameter studies shall be used to simulate the tape placement process by a combined optical-thermal simulation approach which is part of this topic.
After separate manufacturing of skin laminates and stiffeners, these components have to be welded together. Therefore a co-consolidation approach with an innovative tooling is in development. The tooling concept allows the co-consolidation of skin and stiffeners in one step and create a panel with higher integration level. The topic manager is currently focusing on the development and investigation of this tooling concept on smaller scale. The generated knowledge from this work shall be used to define a baseline specification for the tooling addressed in this topic.
The mid-scale demonstration planned in WP1.2, with support of the topic, will demonstrate the feasibility of a manufacturing process of a thermoplastic advanced aircraft rear-end.

2. Scope of work

The main focus of this topic is the support of the ongoing work for a technology demonstration and validation of a manufacturing process for an integral thermoplastic rear end with critical design features e.g. double curved areas and high skin thicknesses. The planned demonstrator size is 2.1m x 1.4m. The work can be divided into 3 main tasks:

Topic. No.	Title - Description	Objectives

T1	**Optical-Thermal-Simulation model for TP-AFP with Xenon heating device**	• Simulation model for Xenon heating device layup process in combination with heated tooling • Pre-definition of layup parameters based on optical material properties, heating source design and machine properties • Power/Speed sequence generation for direct machine implementation
T2	**Process development and manufacturing of TP-Stiffeners**	• Manufacturing process for double curved CF- thermoplastic stiffener with high draping grades in aerospace quality • Manufacturing process for CF-thermoplastic clips • Part delivery for overall manufacturing process demonstration
T3	**Design and Manufacturing of a heated Tooling**	• Unique design, material combinations and thermal management to ensure the needed consolidation temperatures and pressures • Part design and process driven heating zones • Consolidates the skin, stiffeners and clips in one step • Self-heating capabilities up to 400°C and integrated sensors

T1: Optical-Thermal-Simulation model for TP-AFP with Xenon heating device

For skin manufacturing a Xenon heating device will be used. Therefore a combined optical and thermal simulation model has to be developed which allows the estimation of the amount of energy needed to heat up the placed tapes and the substrate at occurring layup speed. The model should be compatible with Ansys simulation environment. For laser applications several simulation approaches are known. Nevertheless no simulation model for the pre-definition of layup heating parameters for a broadband light source like the Xenon heating device with a Quartz light guide is known.

In a first step the optical characterization of the composite and the Xenon heating device is needed. The composite characterization will be delivered by the topic manager, the characterization of the Xenon heating device has to be done by the applicant. In a next step the optical and thermal model has to be developed. To achieve this, the geometrical properties of the tape placement machine, the heating device, the energy flow from the heated mould and high resulted temperature profiles from the tape placement process will be delivered by the topic manager. The modelling, meshing, definition of material properties and boundary con0ditions, analysis of the combined model has to be done by the applicant. As the main result the applicant has to deliver a combined optical and thermal simulation model which allows the generation of Power/Speed sequences for constant layup temperatures that can be directly implemented in the layup machine.

The experimental validation of the developed model will be done in collaboration with the topic manager on a tape placement machine at the topic manager’s production site. After validation the input from the developed and validated simulation model will be used by the topic manager to manufacture the complex skin for the mid-scale demonstrator.

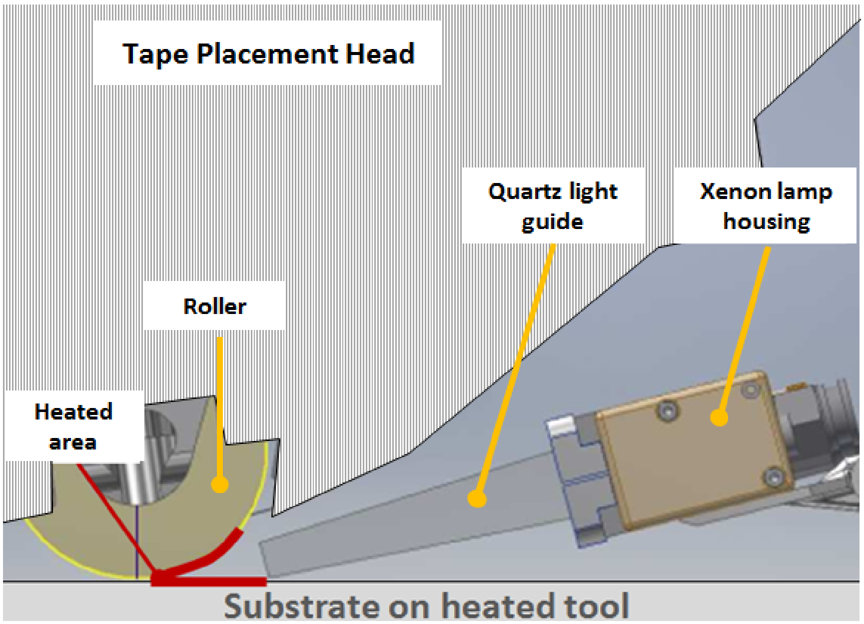


Figure 3: Tape Placement Process with Xenon heating device

T2: Process development and manufacturing of TP-Stiffeners

To support the evaluation and assessment process for the mid-scale demonstrator panel 3 Omega Stringer, 12 Clips and 3 Z-shaped Frames consisting of CF-PEKK are needed. The length of the 3 Omega shaped Stringer will not exceed 2.1m. The length of the 3 frames will not exceed 1.4m with a Frame height around 120mm, a Frame web of 30mm.

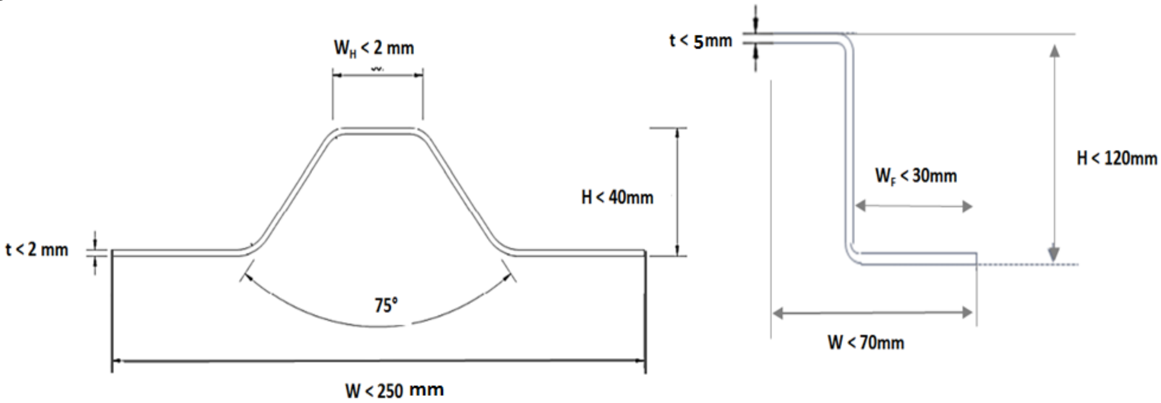


Figure 4: Stiffener cross section

For these, several manufacturing approaches are well known. The most suitable approach has to be adapted to the complex shape of the rear end stiffeners and the stiffeners have to be manufactured to support the final demonstration of the overall manufacturing concept for the rear end demonstrator.

Based on the provided information from the topic manager the applicant has to develop a robust manufacturing process for a production rate of 60 AC/ month with the flexibility of +/- 10 AC/month for each part, to deliver the process description from the material delivery to the quality control (flow chart), to manufacture the needed stiffeners and to verify that the dimensional and geometrical properties are in line with the requirements. After delivery to the production site of the task leader the stiffeners will be integrated into the demonstrator by the task leader.

T3: Design and Manufacturing of a heated Tooling

The co-consolidation of skin and stiffeners to the mid-scale demonstrator will be done in a heated

metallic tooling which fulfils the requirements for a high-rate production of thermoplastic aircraft parts. In the literature different tooling concepts for layup and consolidation of fibre reinforced thermoplastics are known. The tooling will probably not exceed the size of 3m x 2.5m x 0.5m and is divided into two main cavities, one cavity will be used for the layup of the skin and the consolidation cycle, the second cavity will only be used for the consolidation cycle. Both cavities will be assembled together for the consolidation cycle. As a differentiation to the state of the art, the tooling consists of part design and process driven heating zones that allows a fast skin layup and consolidation of the integrated part in autoclave or press.
To ensure needed consolidation pressures, different materials will be used. However, the fundamental work regarding the thermal management and thermal expansion will be done by the topic manager and delivered to the applicant as input for the design and manufacturing considerations of the mid-scale demonstrator tooling. A CAD model of the mid-scale demo part will be delivered to the applicant as well. The geometrical deviations of the machined tooling to the CAD model are limited to 0.6 mm. A surface roughness of Ra = 0.8 µm is needed for all forming areas that are in contact with the laminate. The tooling surface of the layup mould has to be designed to withstand the radiative energy from the used Xenon heating device and needs to feature heating capabilities up to 400°C and sensor capabilities to monitor the heating process.
Based on the delivered information the applicant has to design, manufacture, assemble, test and deliver the tooling including the needed heating system to the topic manager's production site. After delivery the tooling will be integrated by the topic manager in the existing infrastructure and tested together with the applicant. Afterwards the tooling will be used by the topic manager to manufacture the mid-scale demonstrator.

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

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

Deliverables - T1 Optical-Thermal-Simulation model			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1.1	Definition of work plan and schedule	R	T0+1
D1.2	Optical characterization of Xenon heating device	R	T0+7
D1.3	Modelling of optical-thermal simulation model	R	T0+11
D1.4	Experimental validation	R	T0+11
Deliverables - T2 Process development of TP-Stiffeners			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D2.1	Definition of work plan and schedule	R	T0+3
D2.2	Design of needed stiffeners	R	T0+6
D2.3	Development of manufacturing approach and manufacturing of stiffeners	R	T0+12
D2.4	3 Frames, 3 Stringer, 12 Clips consisting of CF/PEKK	HW	T0+18
Deliverables - T3: Heated tooling for TP-Rear End			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D3.1	Definition of work plan and schedule	R	T0+3
D3.2	Design of the heated tooling based on baseline document	R	T0+10
D3.3	Manufacturing and assembly of the heated tooling	R	T0+12
D3.4	Functional test and delivery of the tooling	R, HW	T0+18

Milestones - T1 Optical-Thermal-Simulation model

Ref. No.	Title - Description	Type*	Due Date
M1.1	Way forward agreed	R	T0+3
M1.2	Ray tracing simulation of Xenon heating device performed	R,D	T0+6
M1.3	Combined optical thermal simulation model ready, Power speed sequence for target temperature generated	R,D	T0+10
M1.4	Simulation approach validated	R,D	T0+12
Milestones - T2 Process development of TP-Stiffeners			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M2.1	Way forward agreed	R	T0+3
M2.2	Critical design review agreed	R	T0+8
M2.3	Manufacturing approach for each stiffener feasible	R,D	T0+12
M2.4	Stiffeners delivered by applicant	HW	T0+18
Milestones - T3: Heated tooling for TP-Rear End			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M3.1	Way forward agreed	R	T0+3
M3.2	Critical design review agreed	R	T0+6
M3.3	Assembled tooling and preliminary acceptance at applicant production site	HW,D	T0+10
M3.4	Operational tooling at task leader production site	R,D	T0+12

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

(M) - Mandatory; (A) – Appreciated

- The applicant should have a strong knowledge and experience in the development of realistic simulation of manufacturing processes of composites (M).
- The applicant should have a strong knowledge and experience in the field of optical characterization of radiative heating sources (M).
- The applicant should have a strong knowledge and experience in the field thermal simulation models (M).-
- The applicant should have a strong knowledge, experience and capabilities in the manufacturing of fibre reinforced thermoplastic profiles with processing temperatures of 340°C to 410°C (M)
- The applicant should have a strong knowledge and experience in the field of hot stamp forming and Continuous Compression Moulding (M)
- The applicant should have a strong knowledge and experience in design and manufacturing of curing and layup moulds for composites (M).The applicant must have the capability to do functionality tests with (M).

5. Abbreviations

AC	Aircraft
AFP	Automated fibre placement
ATL	Automated tape laying
CAD	Computer Aided Design
CF	Carbon Fibre
CfP	Call for Partner
CFRP	Carbon fiber reinforced plastic

PEKK	Polyetherketoneketone
TP	Thermoplastic
WP	Workpackage

XI. JTI-CS2-2019-CfP10-LPA-01-82: Development of Thermoplastic press forming Tool for Advanced Rear End Closing Frame Prototype and Tooling 4.0 for Assembly and transportation of the Advanced Rear End Prototype

Type of action (RIA/IA/CSA):		IA	
Programme Area:		LPA	
(CS2 JTP 2015) WP Ref.:		WP 1.2	
Indicative Funding Topic Value (in k€):		750	
Topic Leader:	Aernnova	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	24	**Indicative Start Date (at the earliest)[26]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-LPA-01-82	**Development of Thermoplastic press forming Tool for Advanced Rear End Closing Frame Prototype and Tooling 4.0 for Assembly and transportation of the Advanced Rear End Prototype**
Short description	
Development of innovative press-forming tool for Thermoplastic Closing Frame, including consolidation of stiffeners and press-forming of frame caps considering variable frame thickness and innovative Tooling Set (including Drilling templates, Handling devices, Assemblies and Transportation) for the Advanced Rear End Prototype Specimen, including ALM techniques and strengths/deformations sensorization.	

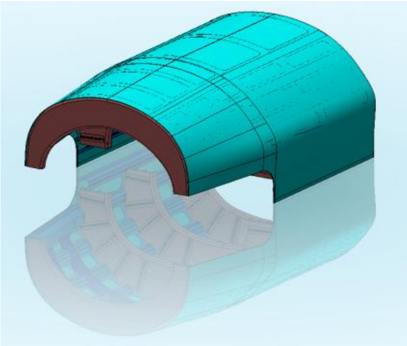
Links to the Clean Sky 2 Programme High-level Objectives[27]				
This topic is located in the demonstration area:		Advanced Rear End Technologies		
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter:		Advanced Long-range Advanced Short/Medium-range		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☐

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

27 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

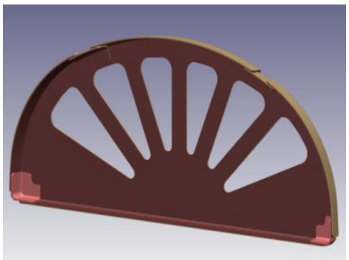
This Call for Proposal is included within the CS2 LPA WP 1.2 Advanced Rear End (ARE) Workpackage.
This WP 1.2 ARE project aims to find new innovative solutions that improve current state of the art material and manufacturing processes. In particular, in terms of high production rates and sustainability enhancement by means of automation, use of new materials and innovative solutions.
A major objective of this WP is to integrate a Rear End fuselage Demonstrator.

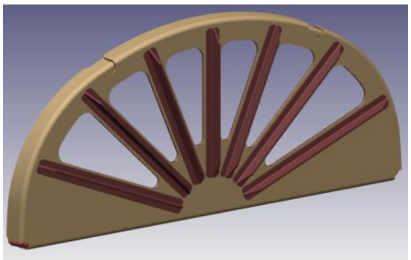


The overall dimensions of the ARE Demonstrator, will be aproximately 3 meters x 2,2 meters x 1,2 meters. The Demonstrator integrates five main parts:

- High integrated composite skin, including cocured omega stringers, cocured beams and cocured countour frames.
- Three (3) high load composite frames.
- One (1) Closing Frame

In order to achieve the appropriate TRL for some of the required components and envisioned processes some important developments have to be undertaken. The focus of this topic is the design and manufacture of innovative Tooling for the high rate production, high automation and new thermoplastic materials use.
This topic is composed of two main aspects: the Thermoplastic Frame Tooling and the Assembly Tooling.
Regarding the Thermoplastic Frame Tooling development, this topic is expected to address a highly integrated tooling structure, enabling the heating, press forming and bonding of the whole thermoplastic Closing Frame product. In particular, the tooling should perform the press forming of the flanges and the bonding of the stiffeners in a signle process.
The Closing frame is depicted below and its dimensions are 2,2 meters x 1,2 meters.





Regarding the Assembly; this topic will focus on the assembly of composite high load frames in high integrated composite skin. The tooling must include smart and innovative aspects of Industry 4.0, as light drilling templates made by ALM Techniques and digitalization of the tooling through the sensorization, in real time, of temperatures, strains and deformations and potentially process control means based on the sensor data, and use of artificial intelligence (AI) means, as digital twins (DT), machine learning (ML), algorithms and/ or big data techniques. It is expected that the Digitalization of the tooling will allow knowing the state of products and tooling along all the assembly process and thus taking corrective measures before the end of the process where correction is more expensive or even impossible.

2. Scope of work

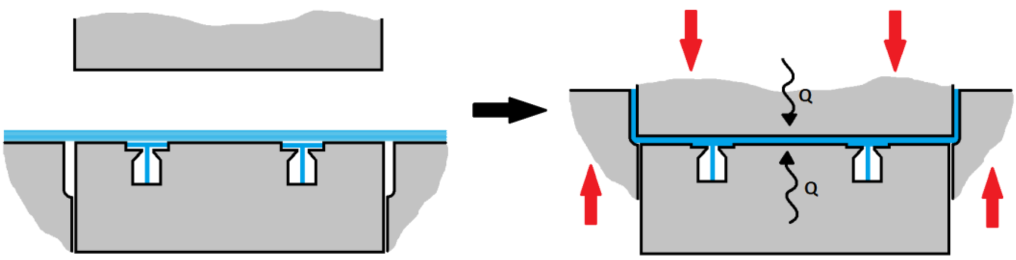
The selected partner shall develop, design, manufacture and deliver to the Topic Manager all the prototype toolings including all the "secondary toolings" as handling jigs, frames for composite placement, drilling templates, locating templates, and the "manipulation tooling", like work platforms, slings, turning devices.
The development of this tooling shall be innovative in order to implement the best performances in the following fields:

- Low Cost / Natural Materials, i.e. applying Additive Manufacturing Techniques,
- Eco-design, i.e. encouraging reusability and recyclability,
- Energy savings,
- Assembly processes simplification and time savings, i.e. implementing gauge-less coordination techniques, developing assembly processes simulations, wireless sensorization of key tooling points, etc.,
- Simplify Transportation processes,

always ensuring that the specimen assembled with the prototype tooling fit with the Aeronautical Quality Standards.
The applicant will join and participate in the concurrent engineering phase to be aligned with the design philosophy, challenges and demonstrator manufacturing support. This includes an involvement into the closing frame manufacturing process definition as the tooling has to be able to reproduce all the key parameters involved in the product definition.
All inputs required for the tooling set design will be provided by the Topic Manager (geometry, integration constraints, tolerances to be achieved, processes, quality level, etc). The detailed requirements will be made available at the beginning of the project by the Topic Manager.
All the Tooling set, including handling and transportation tools, will be delivered at the Topic Manager facility. The topic Manager will be the responsible to manufacture the parts.

a) Thermoplastic Frame Tooling

This structure will be made of thermoplastic materials and carbon fiber reinforcements. The closing frame will join with the "T" preconsolidated stiffeners. This bonding task will be developed at the same time as the one-shot press forming process of the closing frame. The manufacturing part will be performed by the Topic Manager (TM) at their facilities.



The development of this tooling shall be innovative in order to implement the best performances in the following fields:

- To achieve a fully automated performing process able to form frame flanges and consolidate already manufactured stiffeners in one-shot, not limited to current SoA press-forming systems, but also self-heated tools by not conventional means or other innovative devices.
- The system will be able to accommodate different geometries and thickness changes due to

different ply thickness (different Thermoplastics).

- The system will admit automated material loading.
- The system shall be capable to manufacture frames with different Thermoplastic matrix and reinforcement formats (tape/fabric).
- The system will enable manufacture components at rates higher than 60 a/c per month.
- Temperature homogeneity in the forming area will be ±10º. Appropriate control system must be included for forming temperatures up to 400ºC.

always ensuring that the specimen manufactured with the prototype tooling fit with the Aeronautical Quality Standards.

b) Assembly Tooling

The scope of this call is to obtain also sub-assembly, assembly, handling and transportation tooling to integrate the ARE Specimen and to allow transport it also in a safe way. The assemblies will be performed by the Topic Manager (TM) at their facilities.

Each frame will be located by means of tooling holes and datum plates. Due to the cylindrical shape of the skin, the frames will reach their tooling location sliding longitudinally, which means that retractable locators have to be used. Any kind of automated device to assist these positioning operations will be appreciated.

An innovative solution for tooling related with the sensorization of the tooling, control process means (IA, ML…) and new manufacturing technologies for highly integrated multitasking toolings as well as new manufacturing technologies for drilling templates (for instance ALM techniques) should be implemented.

The Partner shall propose the most suitable and innovative assembly process (saving time and energy) for the chosen technology of every Single Part. Each sub-assembly and the final assembly will require all the necessary tooling (jig, drill, lift, etc.) to produce a part in accordance with the drawings. The number of these “secondary tools” should be reduced by an innovative design of the prototype Assembly and Transportation tooling in order to achieve the already said targets in terms of time and energy reduction.

In addition, it will be appreciated and desirable if the defined Prototype Tooling could simplify the assembly and transportation process.

Tasks

During all the tasks listed here above, both Topic Leader and Applicant(s) will be in close interaction in order to progress efficiently and to reorient tasks if any change or issues are encountered or foreseen.

Thermoplastic Frame Tooling Tasks		
Ref. No.	***Title - Description***	***Due Date***
T1.1	Concurrence engineering and design composites development for tooling definition.	T0 + 2M
T1.2	Preliminary Tooling Set Design and definition	T0 + 4M
T1.3	Main Tool Design and validation process (CDR) with aeronautical standards	T0 + 8M
T1.4	Manufacture the Press-forming tooling.	T0 + 11M
T1.5	Delivery of the manufacturing tooling to the TM facilities and support set up	T0 + 12M
Assembly Tooling Tasks		
Ref. No.	***Title - Description***	***Due Date***

T2.1	Plateau phase-Concurrent engineering	T0 + 4M
T2.2	Preliminary Tooling Set Design and definition	T0 + 8M
T2.3	Main Tool Design and validation process (CDR) with aeronautical standards	T0 + 12M
T2.4	Detail Design Manufacture, Delivery, installation and Acceptance of the complete tooling set	T0 + 16M
T2.5	Assistance during assembly	T0 + 24M

Thermoplastic tasks

Task 1.1 – Concurrence engineering and design composites development for tooling definition.
Concurrent engineering with the Topic Manager to understand the specimen arquitecture and the available design level.
Within this task, the Applicant(s) will receive all the information regarding geometry, constrains, preliminar assembly philosophy and related key characteristics and other requirements.

Task 1.2 – Preliminary Tooling Test Design and Definition
Within this task, the Applicant(s) will receive the inputs, and be in charge of the design, the justification, the manufacturing and the quality control of the Tooling Set within the adjoining elements. Any auxiliary device or equipment shall be identified at this stage.
The deliverables of this task will include all preliminary 3D models..

Task 1.3 –Main Tool Design and validation process (CDR) with aeronautical standards
The deliverables of this task will include a matured 3D models and 2D drawings with operational assessment. Key Tolerances shall be defined at this stage.

Task 1.4 – Manufacture the Press-forming tooling.
Within this task, the Applicant(s) will finish the Detail Design of the Tool.
A Pre-Ship Acceptance process, in accordance with the Topic Manager, will be performed prior to the delivery in the Topic Manager facility. The Applicant(s) will be in charge of the installation and Set-up of every component of the Tooling Set. A Final-Acceptance process will be done at TM facilities.

Task 1.5 – Delivery of the manufacturing tooling to the TM facilities and support set up.
The Applicant(s) will provide the necessary on-site assistance for the adequate tool operation.

Assembly tasks

Task 2.1 – Plateau phase-Concurrent Engineering
Concurrent engineering with the Topic Manager to understand the specimen arquitecture and the available design level in order to outline tool options and best assembly sequence/philosophy.
Within this task, the Applicant(s) will receive all the information regarding geometry, constrains, preliminar assembly philosophy and related key characteristics, as well as tools for the handling, assemblies and transportation for the built assembly and adjoining elements integration.
During these tasks, innovative solutions for tooling related with the sensorization of the assembly tooling, the automation of parts positioning and ALM techniques will be technologically screened.

Task 2.2 – Preliminary Tooling Set Design and Definition
Concurrent engineering with the Topic Manager to reach the Preliminary Design Review (PDR) level of

the Tooling Set. Within this task, the Applicant(s) will receive the inputs, and be in charge of the design, the justification, the manufacturing and the quality control of the Tooling Set within the adjoining elements. For that, the Topic Leader will provide the Applicant with all necessary information such as geometry, integrative constrains, general tolerances and process specifications to achieve the task.
The deliverables of this task will include preliminary 3D models.

Task 2.3 –Main Tool Design and validation process (CDR) with aeronautical standards
FMEA/AMFE will be carried out to foresee and prevent any risk for the project, giving appropriate mitigation plan.
FEM analysis including the assembly loads and thermal conditions of the assembly site, ie Build-up stress and deformations measurements and new manufacturing technologies for drilling templates, should be implemented during this task, and validated in a CDR maturity gate.
The deliverables of this task will include a matured 3D models and 2D drawings with accessibility (maintenance and operational) assessment (AR/VR integration will be appreciated).

Task 2.4 – Detail Design, Manufacture, Delivery and installation of the complete tooling set
Within this task, the Applicant(s) will finish the Detail Design and the assembly plan ready for the manufacturing and actual assembly of the Tooling Set.
A Pre-Ship Acceptance process will be performed prior to the delivery in the Topic Manager facility.
The Applicant(s) will be in charge of the installation and Set-up of every component of the Tooling Set. Afterwards, a Final Acceptance process will be performed prior to the Start of Production at the Topic Manager facility.
Minimum required documents to commission the assembly tool will be agreed between Applicant(s) and TM in terms of ergonomics, safety regulation and operation (i.e. CE compliance)

Task 2.5 – Assistance during assembly
The Applicant(s) will provide the necessary on-site assistance, as requested, during the ARE specimen assembly/verification and tests. In addition to that, the Applicant(s) will be also involved in the measuring of the different elements before delivery.

Common idea behind all assembly tasks:
The assembly tooling has to be sized to withstand the loads coming from the assembly activities and to meet the required tolerance for the assembly itself. All the dedicated drilling templates and locators are part of the jig, therefore they shall be treated as a whole and sensorized if required.
As a matter of fact, the build up stresses are key for the final part geometrical compliance and with “sensitive” jigs (sensor/detectors) that could record “on line” during the assembly, warning and giving information in order to adapt the standard process to the real behaviour of the structure all the time, the reduction of potential non conformances and defectology is evident. As a consequence, smart-actuators could be used to update the process sequence or modifying the jigs on-line without the intervention of the operator. It is quite important.

3. Major Deliverables/ Milestones and schedule (estimate)

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

Thermoplastic Frame Tool Deliverables:			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D.11	Device specification	R	T0+4M
D1.2	Technical specification press-forming tooling.	R	T0+8M
D1.3	Curing tooling manufactured	HW	T0+11M
D1.4	Final report: Conclusions and lesson learned	R	T0+12M
Assembly Tool Deliverables:			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D2.1	Tooling Set PDR Documents	D, R	T0+8M
D2.2	Tooling Set CDR Documents	D, R	T0+12M
D2.3	Full Tooling Set	R, D, HW	T0+16M
D2.4	Tooling Set Assesment Report	R	T0+16M
D2.5	Final report: Conclusions and lesson learned	R	T0+24M

Thermoplastic Frame Tool Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M1.1	Device and tooling specification	R	T0+4M
M1.2	Device and press-forming tooling manufactured	R	T0+8M
M1.3	Curing tooling manufactured	R	T0+11M
M1.4	Tooling reception	R	T0+12M
Assembly Tool Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M2.1	Technology screening, materials and trade-offs	R	T0+6M
M2.2	Tooling Set PDR	R	T0+8M
M2.3	Tooling Set CDR	R	T0+12M
M2.4	Assembly tool delivery	HW	T0+16M
M2.5	Final reports, Lessons learnt and project closure	R	T0+24M

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

The consortium should have proven experience in aeronautic tools design, manufacturing and quality.
- Experience in former CleanSky European or collaborative programs (A).
- Internal management of the project (with single focal-point) (M).
- CAD-CAM software license compatible with project DMU: CatiaV5R21 (M).
- An international standard quality management system (i.e. EN 9100:2009/ ISO 9001:2008/ ISO 14001:2004). (M)
- Temperature, strains and deformations sensor knowledge, artificial intelligence (AI) means, as digital twins (DT), machine learning (ML), algorithms and/ or big data techniques (M)
- ALM technology knowledge. (A).
-Capacity to repair or modify "in-shop" the prototype manufacturing tooling for components due to manufacturing deviations. (A).
- Qualification as strategic supplier of manufacturing tooling on aeronautical elements. (A).
- 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 grant preparation phase. This will also include the IP-process.

(M) – Mandatory; (A) – Appreciated

5. Abbreviations

ALM	Additive Layer Manufacturing
ARE	Advanced Rear End
CDR	Critical Design Review
GBD	Ground Based Demonstrator
PDR	Preliminary Design Review
TLR	Top Level Requirements
TRL	Technology Readiness Level
KC	Key Characteristic
SoA	State-of-the-Art

XII. JTI-CS2-2019-CfP10-LPA-01-83: Development and simulation of a forming process for LE HLFC wing outer skins

Type of action (RIA/IA/CSA):		IA	
Programme Area:		LPA	
(CS2 JTP 2015) WP Ref.:		WP 1.4	
Indicative Funding Topic Value (in k€):		1300	
Topic Leader:	Aernnova	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	26	**Indicative Start Date (at the earliest)[28]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-LPA-01-83	**Development and simulation of a forming process for LE HLFC wing outer skins**
Short description	
Development and simulation a forming process adequate for manufacturing microperforated outer skin for leading edges of HLFC wings with double curvature and variable micro-perforation density. Stretching and hot forming will be developed and compared with small-scale demonstrators, in order to define the more adequate technology for manufacturing of final demonstrators. Preliminary studies could consider also other alternative forming technologies proposed by partners. Chosen forming method will be simulated and validated with several large-scale demonstrators up to 5 meter long.	

Links to the Clean Sky 2 Programme High-level Objectives[29]				
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 CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☐

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

[29] 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

Research done inside WP.1.4 of Cleansky2, shows that, stretch forming or hot forming could be appropriate for shaping microperforated metallic sheet metals with the objective of manufacturing Leading Edges with Hybrid Laminar Flow Controlled (HFLC) technology.

Each of these technologies presents advantages and disadvantages, p.e; Stretch forming can be only used for easy formable metals as Cres, aluminium or Titanium CP40. On the other hand, hot forming requires working on inert atmospheres to avoid metal oxidation inside microperforations.

WP1.4.4 objective is to design a complete functional HLFC wing and to prove the performance of the targeted mechanical design in a large-scale, integrated ground-based demonstrator (TRL-4).

One of the main challenges on HLFC wing design is to integrate inside the small space of the leading edge the HLFC systems (vacuum chambers, pipes…etc.), together with de-icing and high lift systems. Therefore, partners on this WP proposed to reduce HLFC complexity by using variable pitch microperforations along the outer skin in other to control suctions without necessity of internal chambering.

This variable density of microperforations introduce a new complexity factor on sheet forming process. Research done until now, considering only constant microperforation, leaded toward stretch forming as the more precise and industrial technology for forming HLFC Outer Skins. But variable microperforation could make this forming method non-viable and could force the use of hot forming.

Large microdrilled metal sheets will have a very high added value before forming, so robust process "Right first time" with “zero defects” will be required. A precise FEM simulation tool based on appropriate material characterization will avoid waste of materials on "trial-error" industrialization and will increase the competitiveness of HLFC technology.

To tackle these challenges, this topic aims at:

- Study of alternative forming technologies applicable to variable density microperforated sheet metals (Titanium Gr2 (CP40) or Titanium G5 (Ti6Al4V))
- Development of stretch forming for variable microperforated sheet of Titanium CP40 with thickness between 0,6 and 1,2 mm
- Development of a precise FEM simulation tool for stretch forming of variable microdrilled Titanium CP40.
- Adjust and correlation of FEM simulation tool by mean of small-scale demonstrators.
- Validation of process and simulation tool with large-scale demonstrators.

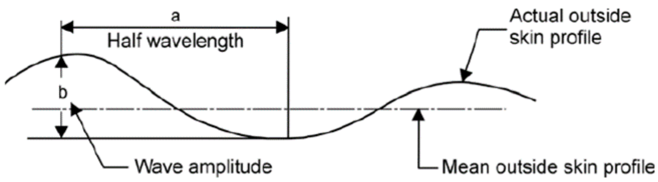
Raw material required for trials and demonstrators will be supplied by the CFP Partners but the microperforation process will be performed by the topic manager.

2. Scope of work

Tasks		
Ref. No.	***Title - Description***	***Due Date***
Task 1	Process development of technologies applicable for forming of variable microperforated sheet metals	T0+7
Task 2	Development of a precise FEM simulation tool for stretch forming of variable microdrilled Titanium CP40.	T0+11
Task 3	Adjust and Correlation of FEM simulation tool with small-scale demonstrators.	T0+14
Task 4	Design and manufacturing of forming tools for large scale demonstrators	T0+17
Task 5	Manufacturing of large-scale process demonstrators.	T0+20
Task 6	Definition of equipment and investments required for a high production rate.	T0+26

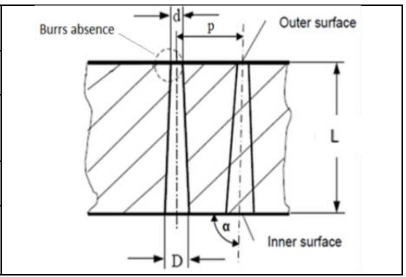
This topic relies on the outer skin geometries for small scale demonstrators and final Ground Base demonstrator (GBD) developed inside WP1.4.4. Master geometries will be supplied by Topic Manager at the project start. Small-scale demonstrators and GBD indicative geometries are defined on the next paragraphs.
The Applicant shall present in the proposal a preliminary benchmarking of alternative forming technologies able to shape variable microperforated sheet metals with double curvature. Beside baseline technologies defined on previous Paragraph (Stretching and Hot forming), the Applicant could propose other alternative forming technologies deemed suitable to meet the specifications defined in the tables below (related to tolerances, component dimensions, cost and productivity concepts). Those technologies will be assessed together with the topic manager at the beginning of the project.
Indicative Outer Skin tolerances for demonstrators:

CHARACTERISTICS: ***DIMENSIONAL***	**VALUE AND TOLERANCE**
Shape tolerance* ***Weighed application on dimensional inspections will be allowed.**	± 1 mm
Contour tolerance	± 1 mm
Waviness (Max wave amplitude)	b=2 mm
Waviness (Max mean slope [b/a])	0,005
Overall profile as per TDD	+/- 0.8mm
Outer Surfaces	Ra 3.2
Increases in Edges	≥ 15 mm
Nominal Thickness	e ≤ 5 mm --- ± 0.1 mm e ≥ 5 mm --- ± 4%
Pilot holes (PH) position	± 0,2mm.
Pilot holes (PH) tolerance	Tolerance H9



In other to be able to achieve this tolerances the applicant is expected to develop a FEM simulation tool adapted to microperforated materials that allow predicting springback and required tool geometry. Microdrilling geometry and variable distribution for demonstrators is not yet established but indicative parameters can be found on the following table:

Micro-holes	
Material Thickness:	0,6 - 1,2 mm (L)
Distance between holes – Pitch (p)	0,4 - 1,5mm, squared grid **Variable along the panel**
Entrance diameter (d)	120 ± 6 µm
Exit diameter (D)	50 ± 3 µm



Task 1: Process development of technologies applicable for forming of variable microperforated sheet metals
Starting from the specification of the outer skins for small scale and GBD demonstrators, and taking into account developments on microperforated sheet metals forming already performed in WP1.4, different forming technologies will be tested on representative variable microdrilled samples with the same material and thickness of demonstrator.
Tested forming technologies must include compulsory hot forming and stretch forming, but any other technology proposed by partners and approved by topic manager, could be also tested.
Based on previous research in WP1.4, outer skin for HLFC wing could be design on Titanium CP40 or Titanium G5 (Ti6Al4V) with thickness between 0.6 and 1.2 mm. Nevertheless, it has been decided that the outer skin of GBD will be made of Titanium CP40.
Empiric testing will lead to determine optimum process parameters (force, lubrication, temperature….) for each technology. Test campaign carried out by the applicant must be sufficient to determine the most suitable forming technologies for both materials.
Conclusion of Task 1 shall be a milestone defining optimum process parameters and conditions for demonstrators manufacturing.

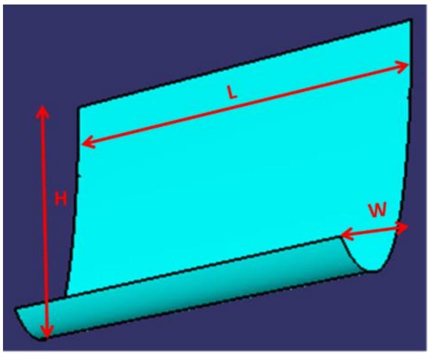
Task 2: Development of a precise FEM simulation tool for stretch forming of variable microdrilled Titanium CP40
Applicant must consider the experimental characterization of static or dynamic mechanical properties of the microdrilled materials required for FEM models parameterization. E.g.;

- Yield Strength ($R_{p0.2}$).
- Tensile Strength (R_m).
- Fracture elongation (A%).
- Young Module (E).
- Poisson Coefficient.
- Hardening Curves.
- Forming Limit Curves within forming temperature range.....

A FEM simulation tool will be developed and optimized for the selected forming technology

Task 3: Adjustment and Correlation of FEM simulation tool with small-scale demonstrators.
This task includes the manufacturing of four (4) small scale demonstrators with different representative shapes of the final leading Edge for the HLFC-Wing. Differences between simulation and real deformation will be used to adjust the FEM simulation tool.

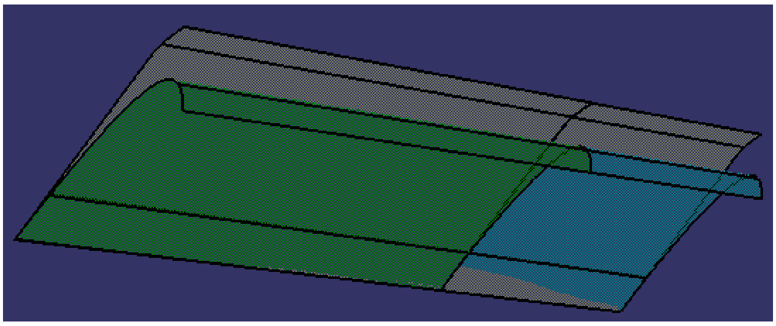
Indicative dimension of the four (4) small-scale demonstrators will be as follows:



- 900 mm (H) x 120 mm (W) x 600mm (L)
- 400 mm (H) x 60 mm (W) x 1550mm (L)
- 420 mm (H) x 70 mm (W) x 1550mm (L)
- 450 mm (H) x 80 mm (W) x 1550mm (L)

Task 4: Design and manufacturing of forming tools for large-scale demonstrators
The Applicant will design and manufacture the forming tools based on the detailed design of GBD demonstrators that will be made available by the topic manager. The GDB will be split into two different sub-components, with approximated dimensions of:

- 970 mm (H) x 145 mm (W) x 4,700 mm (L). Approximate Flat pattern 4,800 mm x 1,200 mm
- 870 mm (H) x 107 mm (W) x 2,400 mm (L). Approximate Flat pattern 2,500 mm x 1,000 mm



The Simulation tool developed in Task 2 & 3 will be used for compensation of spring back and optimization of component tolerances.
Inside of this task, research on reduction of cost of large forming tooling could be included.

Task 5: Manufacturing of large-scale process demonstrators.
Variable microdrilled sheet metals, supplied by Topic Manager, will be formed by the Applicant with process and tools defined and build in previous tasks.
Tolerances for forming process defined in the scope of work will be achieved and measured with appropriate metrology techniques.

Task 6: Definition of equipment and investments required for a high-production rate.
Activities of this task will be aimed to:

- Determination of best equipment for serial manufacturing of a HLFC wing. Automation of process and handling for high cadence programs will be analyzed.
- Economic viability assessment for high-production rate application (estimated rate 200 AC/year)

3. <u>Major Deliverables/ Milestones and schedule (estimate)</u>
**Type: R=Report, D=Data, HW=Hardware*

Deliverables (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1	Microperforated outer skin demonstrators basic specification (information from Topic Manager)	R	T0+1
D2	Selection of forming process, optimum process parameters and conditions for demonstrators manufacturing	R	T0+7
D3	FEM tool description and optimization	R	T0+11
D4	Small-scale demonstrators (this small demonstrators will be used on activities of main project WP1.4.4)	HW	T0+11
D5	Microperforated outer skin demonstrators detailed specification (information from Topic Manager)	R	T0+11
D6	Design of forming tools.	R	T0+14
D7	Forming process of outer skins for a LE HLFC wing	R	T0+20
D8	Demonstrator of formed panel for a LE HLFC wing demonstrator (GBD _ WP1.4.4)	HW	T0+20
D9	Investment and cost analysis for serial manufacturing of a HLFC wing (forming process)	R	T0+26

Milestones (when appropriate)			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M1	Forming process selection	R	T0+7
M2	Forming simulation tool available and optimized	D	T0+11
M3	Small scale demonstrators formed and available	HW	T0+11
M4	Detailed design review of forming tooling (CDR)	R	T0+14
M5	Forming tools available	HW	T0+17
M6	Outer skins for GBD demonstrator formed and available	HW	T0+20

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

The applicants should have:

- Proven technological background, technical capabilities and equipment to stretch forming and hot forming titanium components for aerospace sector (up to 5 meters).
- Previous experience and background in the metallurgical metallography and forming properties characterization. In addition, large experience in simulation of forming processes (ABAQUS, PAMSTAMP…) would be valuable.
- A demonstrated ability to protect new intellectual property and avoid conflict with existing IPR.
- A demonstrated ability to industrialize developed technology related with forming technologies.
- A demonstrated experience from collaborative R&D of manufacturing technologies within European projects.

5. Abbreviations

WTT	Wing Tunnel Testing
GBD	Ground Base Demonstrator

CDR	Critical Design Review
IPR	Information Property Rights
R&D	Rearch and Development
Cp40	(Titanium) Commercially Pure Grade 2
G2	Grade 2 (Titanium)
G5	Grade 5 (Titanium)
LE	Leading Edge
HLFC	Hybrid Laminar Flow Control
FEM	Finite Elements Modell
CfP	Call for Proposal
(H)	Height
(W)	Width
(L)	Long
AC	Aircraft

XIII. JTI-CS2-2019-CfP10-LPA-01-84: Development of a manufacturing process and a manufacturing unit for production of a laser treated titanium panel with a 3D printed substructure

Type of action (RIA/IA/CSA):	IA		
Programme Area:	LPA		
(CS2 JTP 2015) WP Ref.:	WP 1.4.1.3 (and WP 1.4.4.3)		
Indicative Funding Topic Value (in k€):	1500		
Topic Leader: Fraunhofer		**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months): 24		**Indicative Start Date (at the earliest)[30]:**	> Q1 2020

Topic Identification Code	Title
JTI-CS2-2019-CfP10-LPA-01-84	**Development of a manufacturing process and a manufacturing unit for production of a laser treated titanium panel with a 3D printed substructure**
Short description	
For the HLFC and wing demonstrators a microperforated titanium panel has to be bonded to a support sub-structure with HTP/wing geometry. Therefore it is required to develop a manufacturing cell for the laser treatment of titanium panels with an optics unit that is able to provide good bonding properties homogeneously over the whole surface, and to develop and build 3D printed support sub-structures with customized materials that fullfill aircraft requirements, to which the titanium panel is bonded to.	

Links to the Clean Sky 2 Programme High-level Objectives[31]	
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:	Ultra-advanced Long-range
With expected impacts related to the Programme high-level objectives:	

Reducing CO_2 emissions	Reducing NO_x emissions	Reducing Noise emissions	Improving EU Competitiveness	Improving Mobility
☒	☐	☐	☒	☐

[30] The start date corresponds to actual start date with all legal documents in place.
[31] 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 enormous drag-reduction potential of HLFC (Hybrid laminar Flow Control) technology is key for the aeronautical industry and calls for the development of innovative suction concepts. The design of an integrated and efficient suction system for HLFC is indeed a challenge to minimize the associated weight, along with the reduction of the required suction power. In the frame of HLFC, hybrid structures with aircraft dimensions, along with technologies to enable better bonding that dramatically increases structural properties, are therefore necessary. To bring the HLFC concept to the control surfaces of an aircraft, typically a microperforated titanium panel is attached to a support sub-structure with wing/HTP geometry. Laser treatment of the titanium surface has been found as one of the optimum solutions for joining the different materials to such a hybrid structure.
On the HLFC aerodynamical aspect, external aero-surfaces must have most of its micro-perforated surface aerodynamically clean and unobstructed, to enable suction on the largest surface possible. For this reason and to save weight, the support substructure must be kept to the minimum. Therefore, a hollow substructure such as, for example a honeycomb shaped one, is found to be a good support.

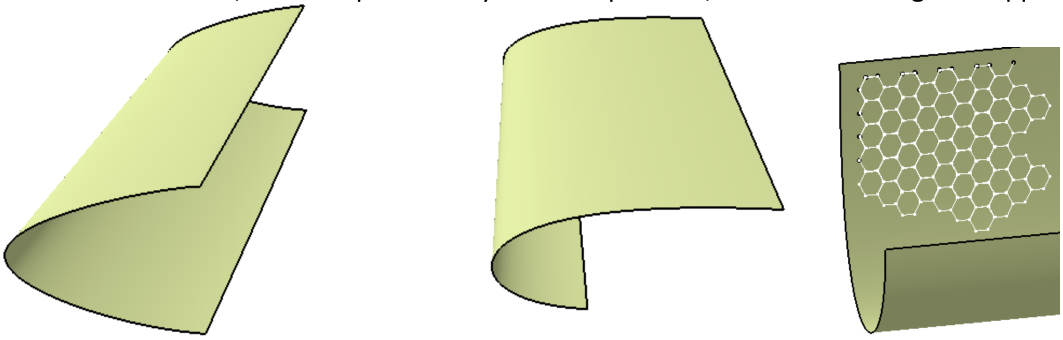


Fig.1 curved titanium panels

To achieve these goals it is expected that the applicant(s) develop a manufacturing cell for the laser treatment of titanium panels with an optic unit that is able to provide good bonding properties homogeneously over the whole surface; and to develop and build 3D printed support sub-structures with customized materials that fullfill aircraft requirements, to which the titanium panel is bonded to. Details will be outlined below.
It is assumed that the work load for the 3D printing set-up of the substructure is approx. twice that of developing the laser optics unit.
The laser treatment and the 3D print of the substructure is required for the CS2 HLFC wing demonstrator. In addition, the laser treatment only without 3D printing is required for the CS2 HLFC HTP demonstrator. For the latter demonstrator the substructure is fabricated by conventional means of composite manufacturing.

Detailed background description of Laser treatment of microdrilled sheets for HLFC:
An essential feature of the manufacturing process for the HLFC concept is to join a microperforated titanium panel (thickness between 0.5-5 mm) with the support substructre with HTP/Wing geometry. The titanium panel will act as a cover to the leading edge, and the microperforation will allow air to penetrate the Ti panel and to modify airflow over the HTP/Wing skin. Therefore, the geometry of Ti panel will resemble the leading edge geometry and be of concave shape. To ensure sufficient adhesion between titanium and the substructure, the titanium panel has to be pretreated using a laser emitting infra-red radiation. This requires to incident the laser radiation homogeneously and with high precicsion over the titanium panel. The laser treatment need to process the inner side of the concave titanium panel with sufficient process speed. The call asks for the development of laser manufacturing cell for

this task (see. Fig. 2). The scientific/engineering challenge is to design an optics system that is able to generate a homogeneous treatment of the whole surface. This requires to achieve the same flux of photons in time over the whole area to be scanned. It is up to the applicant(s) if the fullfillment of this requirement is demonstrated by simulation and/or experiments.

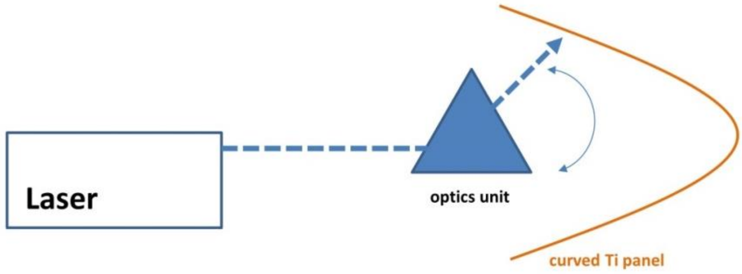


Fig. 2. Schematic view of the optical system required for homogeneous laser treatment of the Ti panel.

Detailed background description of substructure manufacturing using 3D printing:
Another essential feature of the HLFC concept is to join the wing microperforated laser treated titanium panel with a support substructure, as light as possible, strong enough to withstand aerodynamic, inertia and high energy impact loads, as well as thermal loads from an ice protection system. The titanium panel will act as a cover to the leading edge with this substructure, and the microperforation will allow air to penetrate the Ti panel, being transferred to the HLFC suction system, modifying the airflow over the wing skin (WP1.4.4).

A tailored structure following the contour of the complex Leading Edge with the laser-treated titanium surface as outer shield is needed. This structure must be designed per aero-requirements, and be easy to replace and maintain.

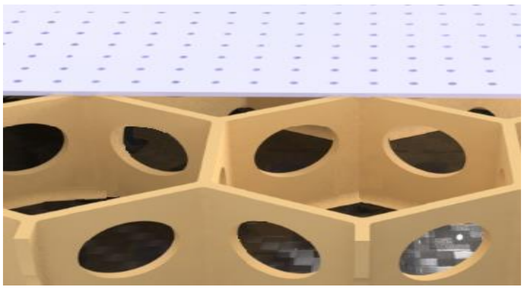


Fig. 3. Schematic view of a honeycomb printed structure underneath the microperforated skin.

A 3D printing cell is needed to be developed that is capable of printing inside a concave structure on small and large curvatures, replicating the inner primary LE structure, within precise final tolerances, and with the minimun number of printed supports. The scientific&engineering challenge is to investigate and identify the right printing material, physically and chemically compatible with normal aircraft liquids (fuel, hydraulic fluids, anti-ice liquids, sealants, resins, etc.). Coupons and critical details tests will be carried out by the applicant(s) in order to obtain the new structure' mechanical properties, the repetitivity verification of the manufacturing process and its overall quality, as well as hail strike behaviour of the printed sub-structure.

For the 3D-printing process a metallic skin support tool will be required to maintain the natural laminar aero-surface geometry of the aircraft since the boundary layer is very sensitive to surface waviness and imperfections. Therefore, the main challenge is to achieve the tight external aero-tolerances of the nominal HLFC profile. The support tool shall keep the skins in place while 3D-printing, and within tight tolerances during the process. Additional machining means should be present, to allow tight interface tolerances; also available to remove support printed structures, if present.

2. Scope of work

For clarity, the overall work to be done is divided into the two natural manufacturing steps, although both activities are expected to be worked on parallel in time. Tasks and deliverables are fully aligned with the CS2 LPA WP1.4.1 and WP1.4.4 time-schedules, in order to build the demonstrators. Unified planning is shown at the end.

Laser treatment of microdrilled sheets on HLFC:
To manufacture the ground-based demonstrators for showcasing the HLFC concept (WP1.4.1 and WP1.4.4) the applicant(s) is expected to develop a manufacturing tool (laser, laser optics unit including housing and handling system) for the laser pretreatment of a curved titanium panel.

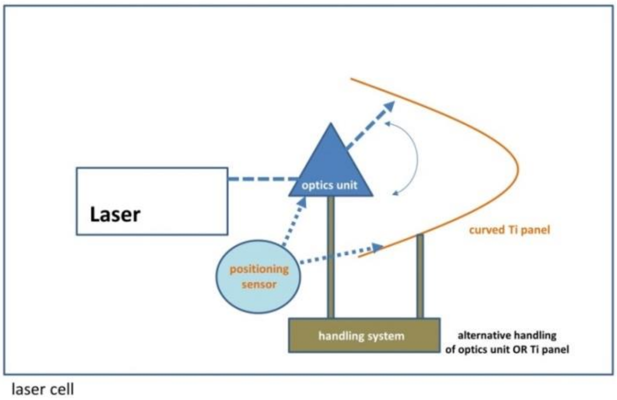


Fig. 4 Manufacturing tool for laser treatment

The overall dimensions of the curved titanium panels will be: 2100x500x310 mm (length x depth x width) and manufacturing tools have to be planned and build accordingly. Details of the structure and local requirements for the unit will be provided by the topic manager after work commencement.

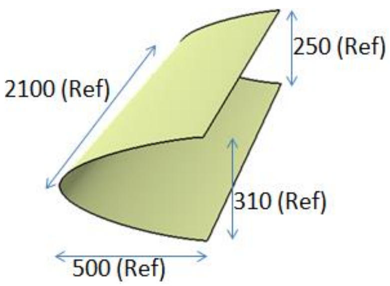


Fig. 5 curved titanium panels ref dimensions

The laser has to operate with a wavelength λ = 1000 - 1100 nm, with a pulse length t in the ns-regime (e.g. t = 10-300 ns), with an average power of up to 500 W, with a pulse repetition frequency f in the kHz regime, with f at least 10 kHz and a spot diameter enabling high scanning rates.

The main tasks related to the laser treatment of the microdrilled panels can be grouped into the following tasks:

Task 1: Basic concept for laser treatment unit and manufacturing tool
The applicant(s) is expected to design a concept for hardware installation and general setup for the laser treatment as outlined above. The applicant will be briefed on details of the laser process and local requirements by the topic manager. The system needs to be variable to allow also for a treatment of different (but less complex) geometries, like a flat panel or the interior part of a tube of the same size.

Task 2: Design of laser treatment system
The design of the laser treatment system comprises a laser, an optics unit for beam steering, additional optical elements (if required for beam shaping etc.), and a computer system with interfaces as control of the components.
It is necessary that the laser treatment achieves a homogenous surface modification effect over the whole area by the innovative design of an optics unit. It is also required that different scanning strategies can be employed to prevent heat damage to the titanium panel. To ensure a homogeneous surface treatment the area of overlap for individual laser pulses on the titanium surface should be variable and should achieve values between 10 and 95%.
Furthermore it is required that the laser beam hits the surface on the inner part of the curved panel everywhere perpendicularily. The optics tool must be fully integrated in the cell and be capable of adapt the focal length of the laser beam in a tight confined space, fully compatible with the interfaces of the leading edge. The optics unit must be capable to achieve a homogenous treatment of components differing in size and shape, up to the indicated maximum size in Task1. Specifically it is required that the optics unit is capable for the processing of concave aerospace structures.
It is expected that the system is desgined such that it achieves high scanning rates, i.e. the optics system needs to match the laser characteristics. For this task a solid state, pulsed IR laser with sufficient power and repetitition rate is required and needs to be integrated. For the beam guidance between laser to laser optics a glass fibre is mandatory.

Task 3: Design of a positioning system
The manufacturing tool (see below) should include a concept and hardware for measuring the panel position in the cell. Together with CAD analysis or geometry data provided with the component the area to be treated should be automatically determined (alternative solution with identical results provided by the applicant(s) is acceptable). Also, innovative solutions for tooling related with the sensorization of the final external tolerances should be technologically screened.
A scanner to control the distance between scan optics and surface should avoid out of focus treatments and guarantee a high surface treatment quality. The data acquired from the distance measuement should automatically control the handling system and/or the focal length adaptation.

Task 4: Design of laser cell and handling system (manufacturing tool)
The manufacturing tool comprises a laser cell that houses the positioning system (see above), laser treatment system (see above), and a handling system.
The system needs to be sufficient in size for the indicated geometry including full compliance with laser safety regulations. The cell has to be integrated with existing infrastructure at the installation site in Bremen, Germany. It is expected that the implementation of a robotic system for component handling or optics handling is required (alternative solution with identical results provided by the applicant is acceptable). In case of handling and moving the laser optics the glass fibre between laser and laser optics should have a sufficient length to enable treatment of the whole surface of the indicated geometry. Strong bending of the glass fibre during handling has to be avoided. The laser cell should include a system for visual contact of the laser process, e.g., established by a flexible camera system.

Process control via a optical emission spectroscopy (OES) and installation of a flexible OES-detector in the cell is desirable but not mandatory.

Task 5: Manufacture, Delivery, installation of the laser treatment tool set
The task should be concerned with the manufacturing and delivery of the manufacturing tool. The installation (laser treatment unit with optics unit, positioning system, and laser cell) has to be installed at a site in Bremen, Germany , where it remains after project finish.

Task 6: Assistance during assembly and functional test
The applicant supports the on-site installation and testing of the manufacturing unit at the installation site. Functional testing includes treatment of a curved as well as a flat sheet with the described geometry.

3D Printing of substructure with laser treated surface as base
To manufacture the ground-based demonstrator for showcasing the HLFC concept on the wing (WP1.4.4), the applicant(s) has to join and participate in the concurrent engineering phase, and is responsible for the detailed definition of a 3D Printed structure (honeycomb or open cellular lattice structure with different density gradients) over a previously treated microperforated titanium surface, following the exact contour of the complex Leading Edge. This structure must be engineered and tailored to suction chamber aero-requirements, mechanically tested by coupons, and must be easy to replace and maintain.

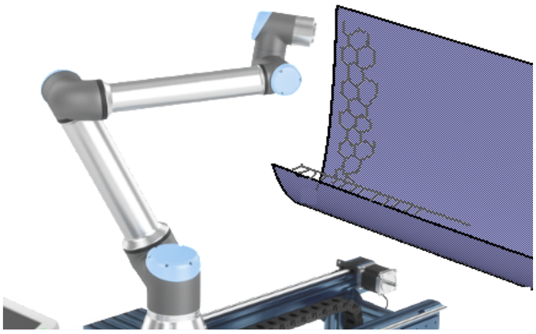


Fig. 6 3D printing unit

This manufacturing step is divided in 4 main tasks described below; The tasks and deliverables are fully aligned with the CS2 LPA WP1.4.4 time-schedule, in order to build a demonstrator, in time, with all the inputs coming from the previous activities in the WPs and in the rest of the HLFC work-packages:
During all the tasks listed here above, both Topic Leader and applicant(s) will be in close interaction in order to progress efficiently and to reorient tasks if any change or issues are encountered or foreseen.
The 3D printing process will require a second, separate manufacturing unit. It is the responsibility of the CS2 members to ship the titanium panel to the 3D printing unit.

Task 7 – Development of a 3D printing head and bed for complex surfaces
Within this task, the applicant(s) will develop a 3D printing head that is capable of reaching already laser treated complex surfaces and is compatible with the selected material, chosen in parallel task T8. The dimensions of the 3D print component are as above: 2100x500x310 mm (length x depth x width).
Specific geometry information, constraints and related key characteristics, will be provided by the topic manager after work commencement. Bed, or a tool supporting the microperforated titanium skin within tight aero tolerances will be analysed including the compensation of the deformation effects due to the laser treatment and other process stresses. Thermal stresses during printing and on-line deformation measurements should be implemented during this task. Adaptation assessment for different LE shapes or demonstrators should be performed during this task.
Matured Tool 3D models with tolerance analysis and accessibility assessment (AR/VR integration will be

appreciated) will be part of the outcome of this task. During these tasks, innovative solutions for real-time sensorization during printing, and final external tolerances prognosis will be technologically screened.
The deliverable of this part of the task will be a report of the baseline tool head, after assessment on costs, risks, manufacturing rate, Life-Cycle-Analysis, REACH, etc.

Task 8 – Infill Shape and Material characterisation and process definition (case study)
Within this task, the applicant(s) will be in charge of the material selection for the substructure, its variable density infill design (minimizing blocking area), inside the wing LE (WP1.4.4), FEM analysis, coupons definition, material characterization and high energy impact tests.
For that, the Topic Leader will provide the Applicant(s) with all necessary information such as environmental requirements, loads, design constrains or flow characteristics inside the chambers (if applicable).
The required sub-tasks are as follows for the characterisation of the infill material:
• Specimens design and manufacturing
• Out of plane loading: traction and compression test (experimental testing)
• Bending allowable (experimental testing)
• Correlate numerical model and virtual testing of new designs.
• Validation test (bigger size specimen).
The applicant must provide at least 3 types of materials (in agreement with the Topic Leader) for the analysis at coupon level. These coupons will be manufactured to testable sizes. The applicant must provide a sufficient amount of test specimen for the testing process (5 specimens per test for each type of material union technology/design)
Validation test: A bigger size validation specimen will be designed representative of the final HLFC wing product with all post-processes applied, manufactured and tested under cyclic fatigue and considering the chosen manufacturing process. The load cases will be defined in the negotiation phase and the number of cycles for the test will be defined later (typically 50000 cycles).
The applicant will provide all tooling (design and manufacturing) necessary for performing the test
Note: all tools (design and manufacturing) as well as the required materials necessary to carry out the mentioned tests: static, dynamic and fatigue test will be responsibility of the applicant.

Task 9– 3D-Printing Tool Manufacture, Delivery, installation of the complete tooling set
Within this task, the applicant(s) and the topic manager will be in charge of the review of the design, the justification plan, ready for manufacturing and assembly, including the verification and pre-test plan of the different elements and installation. For that, the topic Leader will provide the applicant(s) with all necessary information and requirements. This concerns also the specific sub-systems (control and monitoring sensors …) and their possible adaptations for the demonstrators.
Different reviews will be organized in order to keep the project on track and to validate each step before starting the next one.
Along with the delivery, CoCs must be provided before starting on-site assembly activities.

Task 10 – Assistance during assembly and functional test of the 3D-printing unit
The 3D printing unit is setup at a different location than the laser unit, in Spain. The applicant(s) will provide the necessary on-site assistance, as requested, during the components manufacturing, assembly/verification and functional test. In addition to that, the Applicant(s) will be also in charge of the pre-testing of the different elements before delivery.

The tasks are summarized in the following table.

Tasks		
Ref. No.	***Title - Description***	***Due Date***
T1	Basic concept for treatment unit	M2
T2	Design of laser treatment system	M7
T3	Design of a positioning system	M7
T4	Design of laser cell and handling system	M7
T5	Manufacture, delivery, installation of the laser treatment tool set	M10
T6	Assistance during assembly and functional test	M10
T7	Development of a 3D printing head and bed for complex surfaces	18M
T8	Infill Shape and Material characterisation and process definition (case study)	12M
T9	3D-Printing-Tool Manufacture, Delivery, installation of the complete tooling set	20M
T10	Assistance during assembly and functional test	24M

3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1	Concept for cell design (including laser system and optics)	R	M2
D2	Study of homogeneity of laser treatment on the inner side of a curved geometry (simplified geometry)	R	M6
D3	Demonstration of handling system (laser optics or sample)	R	M6
D4	Optics unit delivery	R, HW	M9
D5	Final document delivery	R	M12
D6	Full manufacturing laser cell unit delivery	HW	M12
D7	Tradeoffs report (Materials, Integration...) for 3D-Printing	R	19M
D8	LE substructure manufacture	HW,D	24M
D9	Tool Manufacturing, delivery and validation documents for 3D-Printing	HW,D	24M
D10	Final report: Conclusions and lesson learned	R	M24

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	Demonstration of homogeneous laser treatment on the inner side of a curved geometry (simplified geometry)	HW, R	M5
M2	Material selected for 3D-Printing	HW, R	M6
M3	Test campaign: Material characterisation (on coupons) and Small scale demonstrator for 3D-Printing	HW, R	M19

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

(M) – Mandatory; (A) – Appreciated

The applicant(s) should have proven experience in lasers and 3D printing. Experience in aeronautic equipment design, manufacturing and quality is helpful.
- Knowledge of laser optics and laser guidance in complex geometries (M)
- Knowledge of combination of lasers with individual optics to enable high process rates (M)

- Knowledge of optic or sample handling systems (M)
- Experience in former HLFC European or collaborative programs (A).
- CAD-CAM software license compatible with project DMU: CatiaV5R21 (M).
- An international standard quality management system (i.e. EN 9100:2009/ ISO 9001:2008/ ISO 14001:2004). (A)
- ALM technology knowledge. (M).
-Capacity to repair or modify "in-shop" the prototype manufacturing tooling for components due to manufacturing deviations. (A).
- Qualification as strategic supplier of manufacturing tooling on aeronautical elements. (A).
- 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 IPR agreements.

5. Abbreviations

ALM	Additive Layer Manufacturing
AR	Augmented Reality
CAD/CAM	Coputer Aided Design / Computer Aided Manufacturing
CATIA	Computer-aided three dimensional interactive application
CDR	Critical Design Review
CoC	Certificate of Conformity
DMU	Digital Mock-up
FEM	Finite Element Model
FMEA/AMFE	Failure Mode and Effect Analysis (Análisis Modal de Fallos y Efectos)
HLFC	Hybrid Laminar Flow Control
IP	Intelectual Property
ISO	International Organization for Standardization
LE	Leading Edge
LLI	Long Lead-time Items
NL	Natural Laminar
OES	Optical emission spectroscopy
REACH	Registration, Evaluation, Authorization and restriction of Chemicals' regulation
VR	Virtual Reality
WIPS	Wind Ice Protection System
WP	Work Package

XIV. JTI-CS2-2019-CfP10-LPA-01-85: Design and manufacturing of multi-functional Ice Protection System power feed/monitoring lines and Shielding/High-lift electrical actuation system for a HLFC Wing demonstrator

Type of action (RIA/IA/CSA):		IA	
Programme Area:		LPA	
(CS2 JTP 2015) WP Ref.:		WP 1.4	
Indicative Funding Topic Value (in k€):		700	
Topic Leader:	Sonaca SA	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	35	**Indicative Start Date (at the earliest)[32]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-LPA-01-85	**Design and manufacturing of multi-functional Ice Protection System power feed/monitoring lines and Shielding/High-lift electrical actuation system for a HLFC Wing demonstrator**
Short description	
The main purpose of this topic is to develop innovative concepts of a HLFC Wing Ice Protection System power feed lines, aiming at a high structure/system integration and multi-functional design. In order to support a physical demonstration of the selected concept, piping/wiring/secondary supports will be defined and delivered for a HLFC Ground Base Demonstrator. Similarly, the Shielding/High-lift device electrical actuation will also be designed, delivered and installed so as to support the GBD functional test.	

Links to the Clean Sky 2 Programme High-level Objectives[33]				
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 CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☐	☐

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

Having laminar wings on future aircrafts is an important challenge for the aeronautical industry. Those new laminar wings will directly reduce the fuel consumption of the aircraft during its mission and is therefore very interesting. In addition to the laminarity, a system is developped to control the boundary layer (HLFC – Hybrid laminar Flow Control) which is very sensitive to wing surface quality. Indeed, any defaults will go to a loss of laminarity in the area, such as steps, gaps, profile deviation but also insect impacts. By consequence a shielding device has to be integrated into the wing leading edges to protect the wings during take-off and landing phases. This shielding device is actuated in order to be deployed for the take-off and landing phases, and stowed for the cruise conditions. Thanks to that, the shielding panel has a secondary function such as High-lift. In addition to this device, a Wing Ice Protection System (WIPS) has to be installed on the leading edges to protect them from the ice acretion. Those two systems require energy that needs to be carried from the power electronics system supply powered by the generators to the components through small areas.

2. Scope of work

The scope of this topic is covering two Wing Leading Edge (WLE) functionnalities and corresponding sub-systems. The Wing Ice Protection System feed and monitoring lines from one hand and a Shielding/High-lift electrical Actuation System on the other hand. Those two items are proposed to be developed, reviewed for detailed design and delivered, as contribution to the Ground Base Demonstrator planned to be designed, assembled and tested in the framework of the HLFC-WIN project. As novel concepts and technologies are expected to be proposed, the activity will start with the identification, assessment and selection of the most performant and adapted solution.

2.1 Ice Protection System power feed/monitoring lines and their supports

The current commercial aircrafts Wing Ice Protection Systems are mainly based upon an air bleed concept, for which a pipework is running along the wing fixed leading edge. Their telescopic ducts feed the High-lift devices (Slats) drilled “picolo” tubes with hot air which is then blown onto the inner surface and inside the nose cavity. More electrical aircraft trend is currently supported by developments in the field of electrical ice protection technologies, for example implementing “surface” heating elements for which the required power is brought by dedicated electrical power feeding lines (bundles) and their inter-connections. Monitoring sensors are also planned to be necessary for an appropriate control of the system, with their own lines and insulations.
Once a HLFC suction system has to be added into the Leading Edge with its limited space allocation, Ice Protection System (IPS) harnesses lay-out, bundles design and associated connectors integration is important so as to contribute to the compliance with regards to safety and segregation requirements and operability objectives. The supporting secondary structures, being raceways/studs/brackets/etc. are necessary for a safe routing support under loads and possible failure cases. They may be replaced by more integrated and protective solutions, for example when one thinks to embed power and or monitoring lines onto main or secondary structural elements. The interface connectors are also included within this topic.
The voltage/power to carry trough the power feed lines are about 200V to 600v for 3 to 8kW per span meter of de-iced sections, and at minimum, 4 power feed lines and sensor lines are foreseen per WLE (to be confirmed by the Topic Leader at the beginning of the project).
If an electrical IPS is higly probable, the possible synergies of a traditional bleed air solution with the HLFC suction system may be selected if it is demonstrated as the most performant option.
As the HLFC Wing Leading Edge will present a Shielding functionnality and alternative high-lift device (movable Krueger panel), it is expected that an ice protection system capability could also be applicable

to both deployed and/or retracted configurations. If this should be the case, dedicated power feed and control lines will be implemented, as well as features allowing quick connect/disconnect.
For both elements (WLE skin and Shielding panel), the numer of elements and connectors shall be limited to its maximum and easy and quick (dis)connection shall be guaranted (ie: each HLFC/shielding panels can be removed independately, short time required for the electrical connection,…)

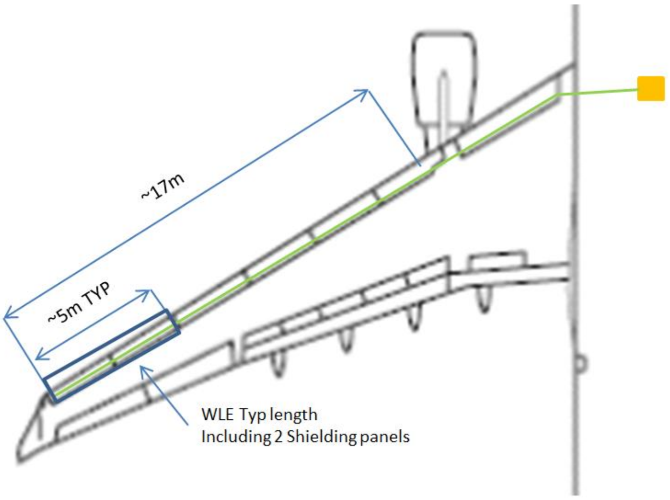


Figure 1: Wing view with electric routes overview (green for lines, orange for power electronics)

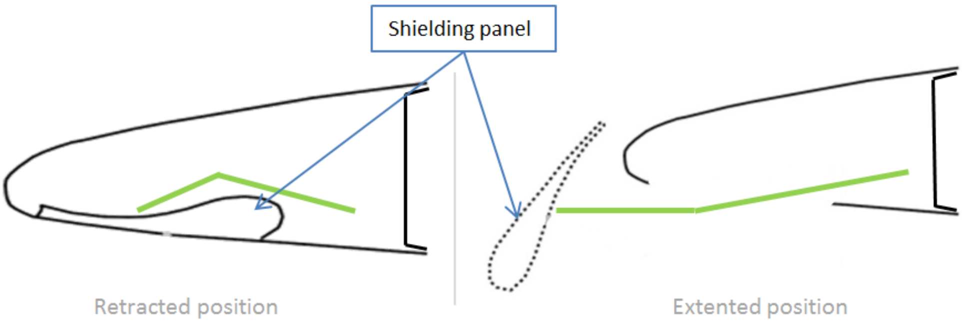


Figure 2: Illustration of High-lift panel retracted and extended, green lines are electric cables

2.2 Shielding/High-lift electrical power feed/monitoring lines, actuation and their supports

Wing Leading high-lift devices (Slats) are traditionally deployed and retracted at discrete positions by a Track + Rack + Pinion mechanical system. Geared Rotary Actuators (GRA) are implemented and activated through a continuous torque shaft running along the Wing Leading Edge. The HLFC wings will present alternative concepts for their Shielding and High-lift capabilities, such as intrados Krueger Panels. The limited space allocation implies that novel kinematics and its actuation system concepts provide a high degree of integration and alternative power feed and control architecture.
As for the IPS, the required power feed/monitoring lines are requested to be integrated within the HLFC Wing Leading Edge. By consequence, the need of integrated structure/system elements is present in this part of the topic, as well as the connectors.
The topic also covers the actuation required to deploy/retract the Shielding/High-Lift panels during the operationnal and functionnal test of the GBD (2 panels are foreseen on the GBD). Per Krueger panel, the actuation is composed by: Actuators, GRAs, Power control and monitoring devices, power/sensors bundles, secondary stuctures, instrumentation (torque meter, position switch, etc). The power level is about 1 to 4kW.
From a future HLFC A/C power supply interface, the design will start with a theoretical electrical drive

architecture, the identification of the possible technologies and a first system safety assessment. Performance of theoretical options will be evaluated.
Upon the selected concept, the Applicant will then design and manufacture a representative actuation and its control system which will be representative of the interface and space allocation of the theoretical concept. It will provide a representative deployment and retraction capability of the manufactured Ground Based Demonstrator Shielding & High-lift devices, and will interface with the kinematics designed by the Topic Leader. The drive system will probably be required to be delivered with its supporting tools and ground test facility adaptations.
The performance of the drive concept will be verified by ground tests and operability simulations, completed by a theoretical A/C level direct operating costs evaluation.

2.3 Tasks definition and planning overview

The following tasks are planned within this project with the associated proposed planning:

Tasks		
Ref. No.	***Title - Description***	***Due Date***
T1	IPS power feed/monitoring lines and their support: conceptual design and trade-off analysis	T0 + 6M
T2	Shielding power feed/monitoring lines, actuation and their supports: conceptual design and trade-off analysis	T0 + 6M
T3	IPS power feed/monitoring lines and their supports design	T0 + 23M
T4	Shielding power feed/monitoring lines, actuation and their supports design	T0 + 23M
T5	IPS power feed/monitoring lines and their support manufacturing and tests	T0 + 32M
T6	Shielding power feed/monitoring lines, actuation and their manufacturing and tests	T0 + 32M
T7	Support during final assembly and GBD tests	T0 + 35M

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
Task 1	■	■	■	■	■	■																													
Task 2	■	■	■	■	■	■																													
Task 3					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■												
Task 4					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■												
Task 5																			■	■	■	■	■	■	■	■	■	■	■	■	■	■			
Task 6																			■	■	■	■	■	■	■	■	■	■	■	■	■	■			
Task 7																															■	■	■	■	■

Figure 3: Proposed planning

During all the tasks listed here above, both Topic Leader and Applicant(s) will be in close interraction in order to progress efficiently and to reorganize the work if any change or issue is encountered. For this, a risks register and mitigations plans are to be used and kept up-to-date.

<u>Task 1 – IPS power feed/monitoring lines and their support: conceptual design and trade-off analysis</u>

Within this task, the Applicant(s) will be responsible for the conceptual design of the IPS power feed/monitoring lines in an system/structural integrated way. The approach shall also includes the different connectors required all along the selected WLE. During this phase, the Applicant(s) shall have to consider the appropriate technology and multi-functionnal options to design an innovative way to carry electricity through the wing.
At the end of the task, a trade-off analysis will be performed by both the Topic Leader and the Applicant(s) to select the best concept to continue with. The trade-off shall assess different aspects such

as (non-exhaustive list):
- Total weight and benefits generated from integrated functionnalities
- Integrability (Compliance with segregation/installation ruels, interfaces, EMH)
- Reliability and endurance
- Operability (accessibility, repairability, avaibility)
- Compatibility with loads and environmental conditions
- Costs
- TRL fit (TRL 4 is expected)

The Topic Leader will provide at the beginning of the task the required information to the Applicant(s) such as number of lines, power/voltage to consider, allocated space if any.
The deliverables of this task will be the complete assessment report and the trade-off matrix. The selected concept will be the input for task 3.

Task 2 – Shielding power feed/monitoring lines, actuation and their supports: conceptual design and trade-off analysis

Within this task, the Applicant(s) will be responsible for the conceptual design of the Shielding actuation power feed/monitoring lines in an system/structural integrated way. The approach shall also includes the different connectors required all along the selected WLE. A conceptual approach of the actuation should also be drafted during this task.
A close link between task 1 and 2 could be seen and then, some studies could be coupled if necessary.
At the end of the task, a trade-off analysis will be performed by both the Topic Leader and the Applicant(s) to select the best concept to continue with. The trade-off shall assess different aspects such as (non-exhaustive list):
- Total weight and benefits generated from integrated functionnalities
- Integrability (Compliance with segregation/installation ruels, interfaces, EMH)
- Reliability and endurance
- Operability (accessibility, repairability, avaibility)
- Compatibility with loads and environmental conditions
- Costs
- TRL fit (TRL 4 is expected)

The Topic Leader will provide at the beginning of the task the required information to the Applicant(s) such as number of lines, power/voltage to consider, allocated space if any, actuation requirements.
The deliverables of this task will be the complete assessment report and the trade-off matrix. The selected concept will be the input for task 4.

Task 3 – IPS power feed/monitoring lines and their support design

From the concept selected within task 1, the Applicant(s) will be responsible for the preliminary and detail design of the required components in order to fit with the GBD integration rules and constrains. In addition to the design phase, the Applicant(s) will be responsible for the justification of the components (structural and system justification, EMH, weight, operability,…).
If a bleed air IPS concept is selected, it is highly probable that it will share functionalities and interfaces with the HLFC suction system. In this case, the Applicant(s) will design and provide the structural justifications for its pipework and the necessary control equipment (valves, sensors, unit). A pneumatically performant and weight optimized architecture will be sought and justified. State-of-art and novel manufacturing technologies will be proposed by the Applicant, in parallel of a detailed integrated design (secondary supports) within the WLE. One may think of ALM optimization or structural parts contribution as weight reduction opportunities for bleed and suction ducts.
For the selected concept (electric or bleed air), the detailed design will be particularly developed in-line with the identified technologies and in compliance with the required quality objectives. A preliminary

manufacturing plan will detail the theoretical plant, equipment and tools.
The Applicant(s) will demonstrate the operability through accessibility/repairability and replaceability analysis and/or tests of the sub-system. A high level of reliability is expected to be assessed and guaranteed.
The deliverables of this task will be the CAD models and the justification reports.

<u>Task 4 – Shielding power feed/monitoring lines, actuation and their supports design</u>
From the concept selected within task 2, the Applicant(s) will be responsible for the preliminary and detail design of the required components in order to fit with the GBD integration rules and constrains. In addition to the design phase, the Applicant(s) will be responsible for the justification of the components (structural and system justification, EMH, weight, operability,…).
In addition to that, the software and the associated user guide for the motor use as to be developped (if require)
The deliverables of this task will be the CAD models, the justification reports and the user manual.

<u>Task 5 – IPS power feed/monitoring lines and their support manufacturing and tests</u>
Following the design tasks, the Applicant(s) will have to manufacture and tests the designed components prior to deliver it to the Topic Leader for the final assembly of the components within the GBD. The components should be tested before delivery. The tests shal integrate, at minimum, an insulation resistance, ohmic resistance per unit length, continuity of conductors/connectors, resistance to dry arc propagation, Resistance to wet arc tracking…
In the case of bleed air IPS and for the Ground Based Demonstrator, it is not foreseen to apply hot air condition or perform icing conditions to demonstrator. It is however foreseen that the pipework will be submitted to a ground-level flow test so as to identify its pneumatic characteristics and demonstrate tightness. The HLFC suction system will then be demonstrated to be functioning in the fully integrated demonstrator assembly, with possible IPS pipework and valves interactions.
The deliverables for this task will be the different components (manufactured or procured) with their ground test reports and quality inspection reports.

<u>Task 6 – Shielding power feed/monitoring lines, actuation and their manufacturing tests</u>
Following the design tasks, the Applicant(s) will have to manufacture and tests the designed components prior to deliver it to the Topic Leader for the final assembly of the components within the GBD. The test shall includes actuation test of the motor(s), logic control (if it's robust, and in line with the requirements),…
The deliverables for this task will be the different components (manufactured or procured) with their ground test reports and quality inspection reports.

<u>Task 7 – Support during final assembly and GBD tests</u>
The Applicant(s) will provide any technical assistance to the Topic Leader during the installation of the different components into the GBD, but also during the tests.
This assistance will be done on request by the Applicant(s).

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1.1	Trade-off matrix, assessment results and route to overall system qualification	R	T0 + 6M
D2.1	Trade-off matrix, assessment results and route to overall system qualification	R	T0 + 6M
D3.1	CAD models and justification reports	R/D	T0 + 23M
D4.1	CAD models and justification reports	R/D	T0 + 23M
D4.2	Electrical motor interface user manual	R	T0 + 23M
D5.1	Manufactured and procurements components with their ground test reports and quality inspection reports	R/HW	T0 + 32M
D6.1	Manufactured and procurements components with their ground test reports and quality inspection reports	R/HW	T0 + 32M

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	Kick-off meeting	RM	T0
M2	Assessment and concept selection	R/RM	T0 + 6M
M3	PDR for all elements	RM	T0 + 10M
M4	CDR for all elements	RM	T0 + 18M
M5	All components delivery	RM	T0 + 32M

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

- The Applicant(s) must have proven experience in electrical wiring design and manufacturing.
- The Applicant(s) must have proven experience in pipe work design and manufacturing.
- The Applicant(s) must have proven experience in actuation components design and manufacturing.
- The Applicant(s) must have experience in inspection and testing of electrical and mechanical systems.
- The Applicant(s) must have experience in manufacturing of electrical and mechnical systems.
- Experience in aeronautic design would be appreciated.
- Experience in former collaborative programs would be highly appreciated.
- An international standard quality management system would be appreciated.

5. Abbreviations

A/C	Aircraft
CAD	Computer Aided Design
CDR	Critical Design Review
EMH	ElectroMagnetic Hazards
GBD	Ground Based Demonstrator
GRA	Gear Rotary Actuator
HLFC	Hybrid Laminar Flow Control
IPS	Ice Protection System
PDR	Preliminary Design Review
QA	Quality Assurance
TRL	Technical Readiness Level
TYP	Typical

WIPS	Wing Ice Protection System
WLE	Wing Leading Edge

XV. JTI-CS2-2019-CfP10-LPA-01-86: Develop and test Power Efficient Actuation Concepts for Separation Flow Control at large aerodynamic areas requiring very low actuation energy

Type of action (RIA/IA/CSA):		IA	
Programme Area:		LPA	
(CS2 JTP 2015) WP Ref.:		WP 1.5.3	
Indicative Funding Topic Value (in k€):		900	
Topic Leader:	Airbus	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	36	**Indicative Start Date (at the earliest)[34]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-LPA-01-86	**Develop and test Power Efficient Actuation Concepts for Separation Flow Control at large aerodynamic areas requiring very low actuation energy**
Short description	
The objective is to develop and realize advanced actuation concepts for flow separation control which are more power efficient compared to state of the art pulsed jet actuators, reducing considerable the net mass flow (by factor 3-5). After being developed and designed the actuators shall be manufactured, tested and fully characterized in a small scale wind tunnel test, followed by a representative scale wind tunnel test. Numerical simulations of the flow shall support the design phase of the actuators and shall be applied for a comprehensive understanding of the occurring flow phenomena, paving the way for integration at representative aircraft scale.	

Links to the Clean Sky 2 Programme High-level Objectives[35]				
This topic is located in the demonstration area:		Enabling Technologies for: 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 Advanced Short/Medium-range Ultra-advanced Short/Medium-range		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☒	☐	☒	☒

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

[35] 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

Several R&T projects have demonstrated the effectivity of the active flow control technology using net mass flow to delay or suppress flow separation when applied on the wing leading or trailing edge.

The technique of active flow separation control using a net mass flow is considered today being the only method, providing the requested effectivity and maturity to delay flow separation on real aircraft applications. Other methods, like synthetic jet actuators (SJA) or plasma actuation proved to be not effective at high Re numbers corresponding to real aircraft flight conditions or not being mature and robust enough w.r.t. real aircraft environmental conditions encountered during normal operation (rain, icing, sand, very low temperatures).

The state of art of today active flow control technology using net mass flow is considered as being the technology of pulsed jet actuator (PJA). The advantage of PJA consists in the reduced mass flow by about 40% compared to the continuous blowing technology and an increased effectivity due to the formation of vortices downstream the actuator exhaust.

The application of the AFC technique with a net mass flow on aircrafts is relying on two potential sources of compressed air: bleed air off-take from the engines or stand alone compressors generating the needed pressure and mass flow for the flow control actuation. Both of the sources have a negative impact on the total aircraft performance. The bleed air off-take has a negative impact on the engine performance during take off and climb, the stand alone compressor solution needs additional electrical energy, effecting also the overall performance of an aircraft.

In case the AFC technology will be applied to control a larger aerodynamic area, the high amount of air required by the today established flow control technology would endanger the use at relevant industrial applications. The provision of the required high mass flow could annihilate the performance gain at overall aircraft level realized through the AFC technology or could make the technology even not applicable.

Therefore there is a strong request to reduce the used net mass flow as much as possible while maintaining the already known effectivity of the flow separation control technology.

Preliminary studies are indicating that more refined actuation methods result in the same effectivity of the flow separation control, but requesting a net mass flow reduced by factor of 3-5 compared to the well known pulsed jet actuation method. Considering the outcome of the above studies, there exist promising approaches for flow separation control techniques, able to be effective and at the same time more efficient w.r.t. the requested energy (e.g. net mass flow). However, until now these methods were not validated and matured yet, neither by in-depth numerical studies nor by experimental means.
The background of this topic is therefore to open the door for new, not yet highly matured actuation concepts, developing innovative solutions with a much higher aircraft net benefit than the matured and already considered solutions in LPA Platform 1.The new technology shall have at the closure of the project a maturity level of TRL 3-4.

The objective of the project is to develop, realize and test advanced actuation concepts for flow separation control which are more power efficient compared to state of the art pulsed jet actuators, thus reducing the net mass flow by a factor of 3-5 compared to the well known pattern of actuation for pulsed jets (PJ).

2. Scope of work

The studies have to include the following aspects:

- Manufacturing or adaption of existing wind tunnel models owned by the selected partner, so that a system of pulsed jet actuators (PJA) is installed into the leading edge of the WT models.
- Development, design, manufacturing and integration of a system of pulsed jet actuators, able to be operated using the baseline actuation pattern and applying more advanced pulsed jet actuation patterns.
- Consequent manufacturing and integration of a system of pulsed jet actuators at represenantive aircraft scale.
- WT testing using the baseline and more advanced PJ actuation patterns at a small and a representative scale.

There shall be investigated different methods of advanced flow separation control using net mass flow, with the objective to demonstrate a similar aerodynamic effectivity as the already known effectivity seen when operating PJ with the so called baseline actuation pattern (see Fig2), However, the requested net mass flow shall be reduced by a factor of 3-5 compared to the pulsed jets (PJ) baseline actuation pattern. Details about the baseline actuation pattern will be given later in the document.
The partner shall characterize aerodynamically a wing configuration with and without flow control (baseline actuation pattern) and subsequently work out and test advanced PJ actuation patterns to overcome the flow separation. This advanced PJ actuation patterns must be profoundly analyzed, understood and validated with numerical and experimental testing.

Task 1: Adaption of the small scale WT model, including the integration of the pulsed jets actuator (PJA) system.

The partner will build or adapt an own existing WT model like an extruded 2.5D airfoil (swept constant-chord half-model) consisting of a main element and a flap (see Fig.1). The aspect ratio of the wing model shall be at least 4.
A system of actuators shall be integrated into the leading edge of the WT model (see Fig1), covering the full wing span. The systems of actuators shall consist of a line of blowing slots, arranged side by side in spanwise direction (see Fig2) and integrated into the leading edge of the airfoil.
It is foreseen to use for each of the jets a separate actuation valve which is connected to a pressurized duct, providing the needed net mass flow for the blowing jets. It is required to facilitate the adjustment of the actuation frequency and of the actuation time of each individual jet and to allow for a variation of the actuation sequence of the jets.
The chordwise position of the blowing jets shall be defined using pre-tests without flow control, indicating the line of flow separation (see Task 2).

Task 2: Numerical studies and wind tunnel tests on the small scale WT model with and without the baseline PJ actuation pattern.

The wind tunnel model without AFC shall be characterized using numerical simulations and wind tunnel tests. The max. lift and stall behaviour of the wing shall be assessed, incl. the position of the flow separation line.
The Ma number of the wind tunnel free stream has to be adjusted between 0.1 and 0.2 and the Re number must be higher than 1 Mio, based on the Mean Aerodynamic Chord (MAC) of the model and free stream conditions.

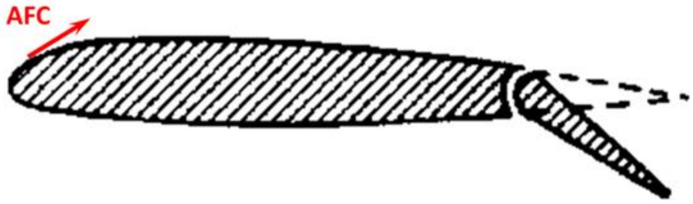


Fig1: Main wing element with installed flow control at the leading edge

The second phase of Task1 shall comprise numerical studies and wind tunnel experiments of the wing model using the PJ baseline actuation pattern.

The baseline PJ actuation pattern consists in an alternately turning on of every second jet in spanwise direction at the same time (see Fig2), leading to a duty cycle of approx. 0.5.

The baseline PJ actuation pattern test shall provide an oscillating nondimensional frequency of F^{+}=1 (approx. 1kHz).

The tests with the baseline PJ actuation pattern will be considered as bench mark w.r.t. the aerodynamic effectivity of the AFC method to delay flow separation and the needed net mass flow for the actuation.

The wind tunnel test results shall provide data of the net massflow used for the PJ actuation as a funtion of the adjusted free stream Ma number and the gain in lift. This data will be used later for a comparison with the results of the tests applying the advanced PJ actaution pattern in Task3.

The test matrix will comprise a variation of the angle of attack, of the free stream Ma number and of the velocities of the flow control jets. The Ma number of the PJA jets has to be adjustable between Ma = 0.4 and 0.9.

The topic manager will provide to the partner the needed information for designing and preparing the wind tunnel tests with the baseline PJ actuation pattern. This will include the dimensions of the blowing slots (width and height), the spacing between the blowing slots and the order of magnitude for the needed net mass flow derived from previous tests.

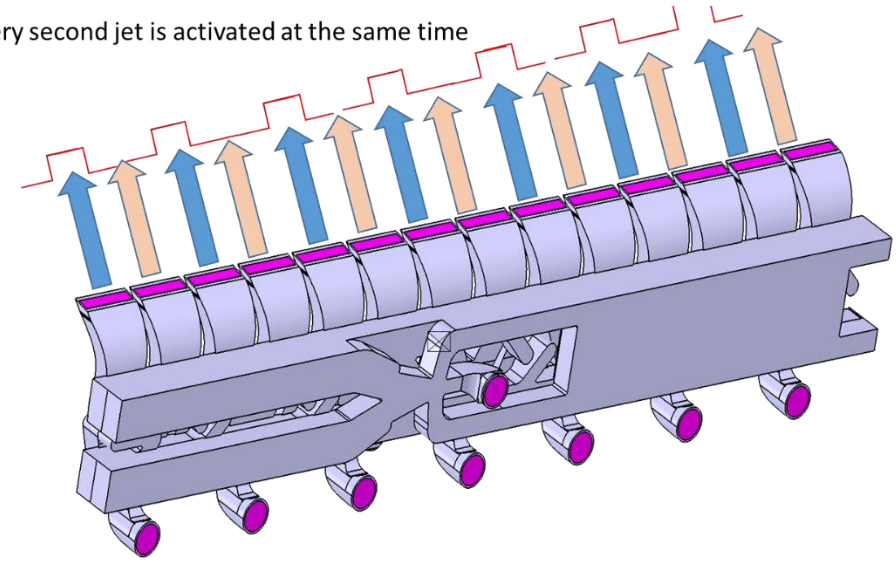


Fig2: Example of a baseline PJA switching pattern

The effectivity of the flow control method to delay flow separation and the impact on the free stream flow shall be demonstrated using multiple-hole probes and PIV measurement techniques downstream the actuator position. The experimental data will be used to validate the numerical simulations.

Flow visualization techniques (e.g. tuft visualisation) shall be applied downstream the position of the actuators.

The planned test will include measurements of the overall forces acting on the model (balance measurements), as well as pressure distributions on the wing surface. In addition the mass flow of the air supply to the flow control actuators will be measured as well as the internal pressure inside the actuators.

Task 3: Investigating the advanced PJ actuation patterns on the small scale WT model using numerical studies and wind tunnel tests.

With the already installed system of actuators there shall be done small scale wind tunnel tests with different actuation patterns of the pulsed jets.

The advanced actuation patterns shall include:

1. Variation of the jets pulsation sequence in spanwise direction. This shall comprise one or multiple traveling waves of jets in spanwise direction (see Fig3).
2. Variations of the blowing time of every single jet while actuating all or a part of the jets at the same time (e.g. reduced duty cycle).
3. Variation of the spacing between a pair of two adjacent blowing slots in spanwise direction (see Fig4). The impact of an increased spacing between a pair of two adjacent blowing slots on the aerodynamic effectivity of actuation shall be assessed.

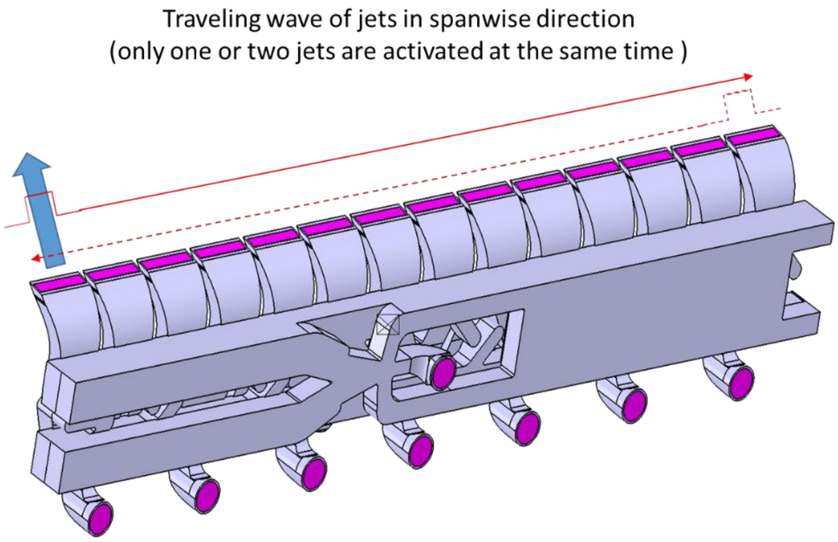


Fig3: Example of a traveling wave for actuation

During the wind tunel tests the Ma number of the free stream flow shall be varied between 0.1 and 0.2. Also the net mass flow provided to the actuators shall be varied, the jets pulsation sequence in spanwise direction and the blowing frequency and time duration (duty cycle) of every single jet, giving insight into the sensitivity of the actuation method to changing parameters.

The effectivity of the flow control methods to delay flow separation and the impact on the free stream flow shall be demonstrated using multiple-hole probes and PIV measurement techniques downstream the actuator position. The experimental data will be used to validate the numerical simulations.

Flow visualization techniques (e.g. tuft visualisation) shall be applied downstream the position of the actuators.

The planned test will include measurements of the overall forces acting on the model (balance

measurements), as well as pressure distributions on the wing surface. In addition the mass flow of the air supply for the flow control actuators will be measured and the pressure inside the settling chamber of the actuators.
The task will include also numerical simulations of the interaction between the actuator jets and the outer flow. The most efficient actuation patterns (at least three cases) for this type of flow control will be analysed in more detail, understanding the interaction between the blowing jets and the outer flow.

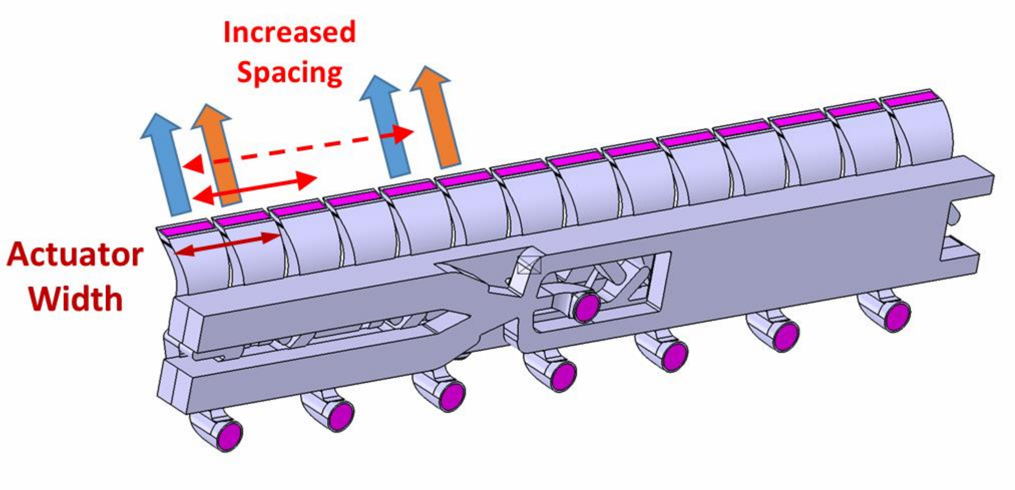


Fig4: Variation of the spacing between the single PJA in spanwise direction

Task 4: Design, manufacturing and integration of a pulsed jet actuator system at representative scale. Pre-testing in silent conditions (Ground Test).

A system of pulsed jet actuators shall be designed and manufactured, ready for integration into a into a wing geometry at representative scale.
The partner will build or adapt an own existing WT model like an extruded 2.5D airfoil (swept constant-chord half-model) consisting of a main element and a flap (see Fig.1).
Representative aircraft scale means a downscaling of the AFC system and of the airfoil to not more than 30% compared to a full aircraft scale (A320).
It will be allowed to reduce the span of the airfol to fit into a corresponding large wind tunnel section.
It is foreseen to use for each of the jets a separate actuation valve which is connected to a pressurized duct, providing the needed net mass flow for the blowing jets. It is required to facilitate the adjustment of the actuation frequency and the actuation time of each individual jet and the actuation sequence in time of the jets.
The pulsed jet actuators at representative scale shall be designed, manufactured and pre-tested in silent conditions (ground test), needed for the characterization of the AFC system. This will comprise the jet velocity profile at the exit of the actuators in a pulsed working mode, as well as the uniformity of the jets in spanwise direction.
The presusre losses inside the AFC system, the actuation frequency and the blowing time duration of the single jets shall be captured as well.

Task 5: Investigating the advanced PJ actuation patterns on an WT model at representative aircarft scale.

Applying the results from Task 3 for the most promising actuation patterns of the PJ, wind tunnel tests and numerical simulations shall be conducted with the flow control system of PJA at a representative aircraft scale.
The Ma number of the wind tunnel free stream has to be adjusted between 0.1 and 0.2 and the Re number must be higher than 5 Mio, based on the Mean Aerodynamic Chord (MAC) of the model and free stream conditions.
The net mass flow provided to the actuators shall be varied, the jets pulsation sequence in spanwise direction and the blowing frequency and time duration (duty cycle) of every single jet, giving insight into the sensitivity of the actuation method to changing parameters at increased Re numbers.
The effectivity of the flow control methods to delay flow separation and the impact on the free stream flow shall be shown using multiple-hole probes and flow visualization techniques (e.g. tuft visualisation) downstream the actuator position. The experimental data will be used to validate the numerical simulations.
The planned test will include measurements of the overall forces acting on the model (balance measurements), as well as pressure distributions on the wing surface. In addition the mass flow of the air supply for the flow control actuators will be measured and the pressure inside the settling chamber of the actuators.
The task will include also numerical simulations of the interaction between the actuator jets and the outer flow. The most efficient actuation patterns (three cases) for this type of flow control will be analysed in more detail, understanding the interaction between the blowing jets and the outer flow at increased Re numbers.

WT model	Min Re Number required during the test	Free-stream Ma number required
Small scale WT model	1 Mio	0.1-0.2
Representative scale WT model	5 Mio	0.1-0.2

Tab1: Wind Tunnel models required for the execution of the project

Task 6: Evaluation of the advanced actuation methods, recommendations and delivery of the final report.

The data of the wind tunnel test are to be analysed and results to be delivered. This analysis will include overall measurements (balance), pressure measurements on the wing surface and data about the flow control characteristics (mass flow, pressures, frequency, pulsation sequence and duty cycle).
Results from numerical simulations will be compared to the wind tunnel tests data.
A final report shall be delivered, exhibiting information about the different actuation methods, the used actuation parameters and an outlook for application in real aircraft conditions.

3. Major Deliverables/ Milestones and schedule (estimate)

Month /Task	1st year												2nd year												3rd year											
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	M25	M26	M27	M28	M29	M30	M31	M32	M33	M34	M35	M36
T1							D1																													
T2												M1	D2																							
T3																				M2	D3															
T4																										M3	D4									
T5																																		M4	D5	
T6																																				D6

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1	Small scale WT model with an integrated systsem of pulsed jet actuators.	HW Report	M7
D2	Results of numerical studies and wind tunnel tests on the small scale WT model with and without the baseline PJ actuation patter.	Report Data	M13
D3	Results of numerical studies and wind tunnel tests with advanced PJ actuation patterns on the small scale WT model.	Report Data	M21
D4	Pulsed jet actuator system integrated in the representative scale WT model. Ground test report.	HW Report	M27
D5	Results of numerical studies and wind tunnel tests with advanced PJ actuation patterns on the representative aircraft scale WT model.	Report Data	M35
D6	Final report of numerical results and wind tunnel test with the advanced actuation methods.	Report Data	M36

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	Numerical studies and wind tunnel tests on the small scale WT model with and without the baseline PJ actuation pattern finished.	M12	M1
M2	Wind tunnel tests with advanced PJ actuation patterns on the small scale WT model finished.	M20	M2
M3	Ground test with the pulsed jet actuator system at a representative scale WT model finished.	M26	M3
M4	Wind tunnel tests with advanced actuation methods on the representative scale WT model finished	M34	M4

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

The applicant will have expertise in the area of wind tunnel model modification and model instrumentation, as well as in the area of wind tunnel testing, data post processing and flow visualization (PIV, tufts).
The applicant will provide the wind tunnel model including the needed system to feed the actuators with required amount of pressurized air flow for the flow control system.
The applicant shall have a sound R&T background in testing and demonstration of flow control techniques in wind tunnel facilities suitable for models of the size mentioned above.
The applicant will have expertise in the area of PIV measurement technique applied during the wind tunnel tests.
The applicant shall have profound knowledge and experience in developing and maturing of active flow control technology with net mass flow, being familiar with the actuation method of pulsed jet actuators (PJA).
The applicant shall have sound expertise in conducting unsteady numerical flow simulations of internal and external flow.

5. Abbreviations

AFC	Active Flow Control
PJ	Pulsed Jets
PJA	Pulsed Jet Actuators
WT	Wind Tunnel

XVI. JTI-CS2-2019-CfP10-LPA-01-87: Loop Heat Pipe development for severe environment

Type of action (RIA/IA/CSA):		IA	
Programme Area:		LPA	
(CS2 JTP 2015) WP Ref.:		WP 1.5	
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)[36]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-LPA-01-87	**Loop Heat Pipe development for severe environment**

Short description

This topic is focused on a passive cooling device dedicated to the thermal management of valves located inside the A/C engine and therefore exposed to very harsh radiative and convective environment:

- Motor radiative temperature up to 800°C;
- Air through the valve up to 650°C (continuous);
- Local air surrounding the valve up to 300°C.

The objective of this topic is to develop and manufacture the prototype of such a high temperature apparatus and therefore show advantages and drawbacks of the technology in such environment. The specific environment needs an identification of the working fluid that can gather requirements for cooling and satisfy aeronautical safety issues. Thermo-physical properties of this fluid would therefore drive the design of the adapted cooling device

Links to the Clean Sky 2 Programme High-level Objectives[37]	
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 CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☐	☐

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

[37] 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

Due to UHBR new generation engines, bleed system will operate in harsher environment than in current engine generation. Bleed system integrates several pressure regulating valves located inside the engine environment. Depending on the station where a valve is integrated, it can be exposed to very critical thermal conditions. Since the accuracy of regulation and also its reliability strongly depends on temperature sensible parts of the valve, the valve must be protected from steady state and transient overheating.

Cold sources are very rare in this region of the engine, that is why the Topic Manager needs to adapt some innovative cooling means to this environment in order to bring them as close as possible to the compact valve. The present Topic is focused on a passive technology of heat management for harsh environments; two-phase capillary pumped loops which can offer a relevant option to integrate efficient cooling to the valve. The needed technology does not yet exist on the market because of temperature levels encountered in this environment:

- Motor radiative temperature up to 800°C;
- Air through the valve up to 650°C in steady state and up to 750°C during transients;
- Local air surrounding the valve up to 300°C;
- Fan air flow cold source at a maximum of 100°C.

A two-phase capillary pumped loop stands on two basic thermo-physical properties of a fluid:

- Latent heat of vaporization: evaporation of the working fluid can offer high heat flow amplitude of cooling and condensation;
- Surface tension: the management of liquid-vapor interface can offer a certain level of pressure drop, higher enough to face pressure loss inside the whole loop and therefore obtain a global flow and renew fresh fluid from the condenser to the evaporator.

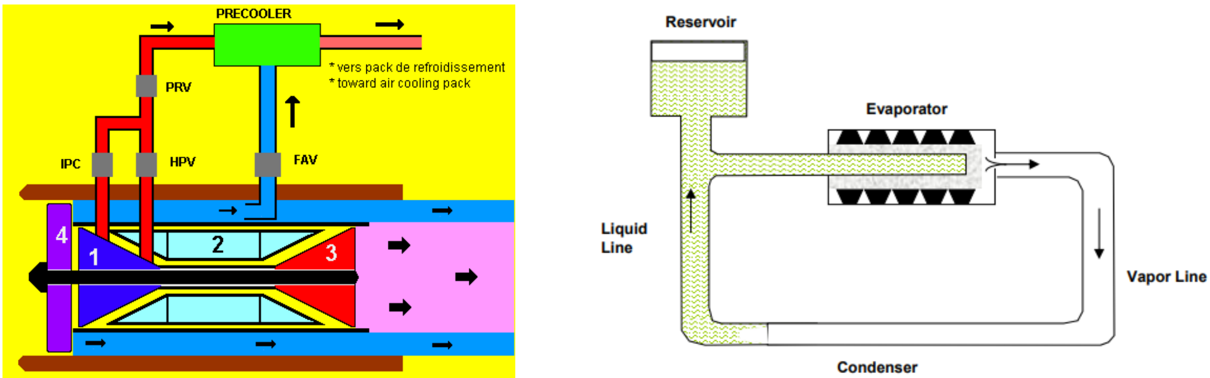


Figure 1 – Bleed valves inegration and two-phase loop description

Several developments are described in aeronautical fields from low power dedicated to avionics cooling [1] to high power for wing anti-ice purpose [2]. For a very large majority of cases, the thermal managed object is limited to a maximum of 100°C and its direct environment often lower than 50°C. In the present topic, the awaited heat load is below 100 W over a maximum distance of 30 cm with or against gravity. The present need therefore represents an ambitious objective, in which the Topic Manager wishes to control the sensible part of the valve below 200°C with a heat sink up to 100°C.

[1] Loop Heat Pipes and mini-Vapour Cycle System for Helicopter Avionics Electronic Thermal Management, Claudio ZILIO, Simone MANCIN, Romain HODOT, Claude SARNO, Vincent POMME, Bertrand TRUFFART, 16th International Refrigeration and Air Conditioning Conference at Purdue, July 11-14, 2016

[2] A review of loop heat pipes for aircraft anti-icing applications, Qian Su, Shinan Chang, Yuanyuan Zhao,

Haikun Zheng, Chaobin Dang, Applied Thermal Engineering, Volume 130, 5 February 2018, Pages 528-540

[3] Heat pipe-based cooling apparatus and method for turbine engine, Kattalaicheri Srinivasan Venkataramani, Thomas Ory Moniz, Justin P. Stephenson, William Andrew Bailey, General Electric Co, US7845159B2, 2010

[4] Aircraft turbine-engine module casing, comprising a heat pipe associated with a sealing ring surrounding a movable impeller of the module, Christophe SCHOLTES, Safran Aircraft Engines SAS, US20180209291A1, 2006

2. Scope of work

The following tasks have to be performed:

Tasks		
Ref. No.	***Title – Description***	***Due Date***
1	Selection of best working fluid candidates for two-phase loops in harsh environment	T0+3
2	Full characterization of thermo-physical properties of the selected fluids	T0+9
3	Two-phase loop demonstrator design and manufacturing	T0+21
4	Demonstrator test and validation in partially representative environment	T0+24

Task 1 - Selection of best working fluid candidates for two-phase loops in harsh environment

Capillary pumped loops have historically been developed for a range of working fluids dedicated to applications they are adapted for: ammonia in space application, water, methanol and others for ground and aeronautical industries. The focused temperature level is potentially not adapted to these working fluids anymore; a preliminary study needs to highlight this state of the art.

To conclude this study step, a trade-off evaluation is awaited to select two working fluids able to meet the requirements based on literature assumptions.

Task 2 - Full characterization of thermo-physical properties of the selected fluids

Following selection of two suitable working fluids in Task 1, Task 2 aims at fully characterizing the thermo-physical properties of these two fluids. These properties are the necessary inputs for the heat loop design in Task 3.

Task 3 - Two-phase loop demonstrator design and manufacturing

Depending on the interface types offered with the valve heat source and the cold sink, both provided by the Topic Manager, and on the thermo-physical properties of the fluids selected, a design shall be proposed.

Predicted performances have to be estimated on the whole operating envelop.

Finally, a full-scale heat loop demonstrator to be tested by the partners and a spare to be integrated by the Topic Manager for further testing, shall be manufactured.

Task 4 - Demonstrator test and validation in partially representative environment

A test bench shall be assembled to measure and characterize preliminary performance of the cooling device. The targeted environment being only achievable with a real engine demonstration, a degraded demonstration is targeted here. Therefore, the following parameters are requested for the testing environment:

- Hot source: 200°C,
- Cold sink: 100°C,
- Environment: minimum 150°C up to 300°C.

A dedicated thermal instrumentation shall be implemented to characterize:
- overheating at the evaporator,
- mean temperature of the condenser,
- and global conductance.

Validation of the heat loop device will be done on steady state cases to be defined in collaboration with the Topic Manager.

3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1	Working fluids overview and trade-off report	R	T0+3
D2	Fluid thermo-physical properties characterization report	R	T0+9
D3	Prototype design justification and definition and heat loop demonstrators	R+HW	T0+21
D4	Prototype test results report	R	T0+24

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	Selection of 2 working fluids for the given environment	D	T0+3

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

Skills
- LHP designing and manufacturing
- Thermodynamics applied to capillary pumped loops
- Experimental skills for LHP

Capabilities
- Computing facilities for two-phase loops design
- Experimental capacibilites to test LHP

5. Abbreviations

LHP	Loop Heat Pipe
UHBR	Ultra-High Bypass Ratio

XVII. JTI-CS2-2019-CfP10-LPA-02-30: Development of innovative welding systems for structural joints of Thermoplastic matrix based Composites

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€):		750	
Topic Leader:	Aernnova Composites Illescas	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	18	**Indicative Start Date (at the earliest)[38]:**	> Q1 2020

Topic Identification Code	Title
JTI-CS2-2019-CfP10-LPA-02-30	**Development of innovative welding systems for structural joints of Thermoplastic matrix based Composites**
Short description	
The objective of the topic is to achieve a structural bond of small/medium reinforcement parts to the primary structural elements to achieve highly integrated subassemblies. Reinforcement is made of Carbon fibre with thermoplastic matrix. The welding systems shall be capable of welding different types of Thermoplastics and shall be energy efficient, quick in execution, minimal tool dependant and able to be inspected with current state of the art non-destructive technologies.	

Links to the Clean Sky 2 Programme High-level Objectives[39]				
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 CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☒

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

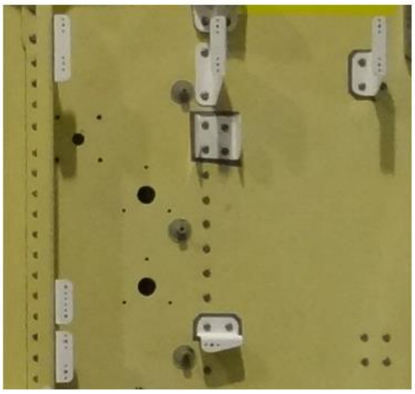
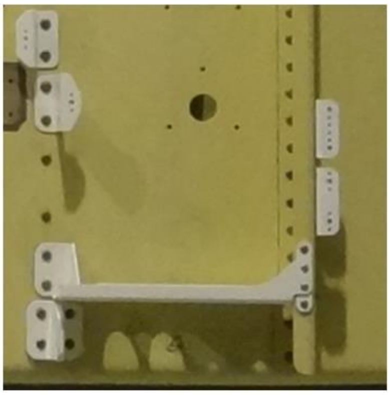
[39] For further info see Chapter 1 “Introduction to the Programme Scene Setter / Objectives” with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

This topic is part of the Next Generation Fuselage, Cabin and systems integration activity in LPA Platform 2 and is included within the CS2 LPA WP2.1.4, focusing on technology for upper shell elements, which has been conceived within the development, design and manufacturing of the multifunctional fuselage demonstrator WP2.1 (MFFD) with the following main guidelines:

- Half-barrel concept with longitudinal seams to increase accessibility during assembly
- Multifunctional structures with integrated system/cabin functions to reduce assembly efforts
- Pre-equipped modules with integrated cabin/system functions for fast assembly
- Dustless-joining of structural components to enable pre-assembly of systems
- High automation level of manufacturing and assembly processes
- Less structural joints by integral manufacturing processes and manufacturing of large components/parts to enable fast and cost-effective assembly
- Tolerant management for assembly of large components
- Significant reduction of single (small) parts to reduce assembly costs
- Cost-effective high volume composite structures by using composite architecture and design
- Design for manufacturing and assembly

Tipically, small/medium reinforcement parts (splices, cleats, gussets, wedges, fittings, doublers) are riveted to the primary structural elements (frames, skins, spars, ribs) along the aircraft.

In thermoplastic structures, the welding of these parts will eliminate the need for fasteners, reducing weight and consequently reducing fuel consumption.
Positioning and attach of these elements is not repetitive and, in some cases, are located in places where no big welding heads can access. The challenge is to develop a flexible welding system for these type of parts.
The welding of already consolidated detail parts can be achieved by different technologies including but not limited to laser, induction, ultrasonic, resistance and conduction welding.
Main challenges for welding thermoplastic parts lay on the chemical compatibility of the different plastic matrixes available.

Besides the morphological characteristics, the current state-of-the-art techniques for thermoplastic welding are also challenging varying on the application.
Resistance and Induction welds show rather medium to low welding speeds (ranging from 0.5 to 4m/min) but Laser welding can be quite fast reaching up to 25m/min demonstrated. Moreover, Ultrasonic welding is very fast in spot welding but is still under development for continuous welding

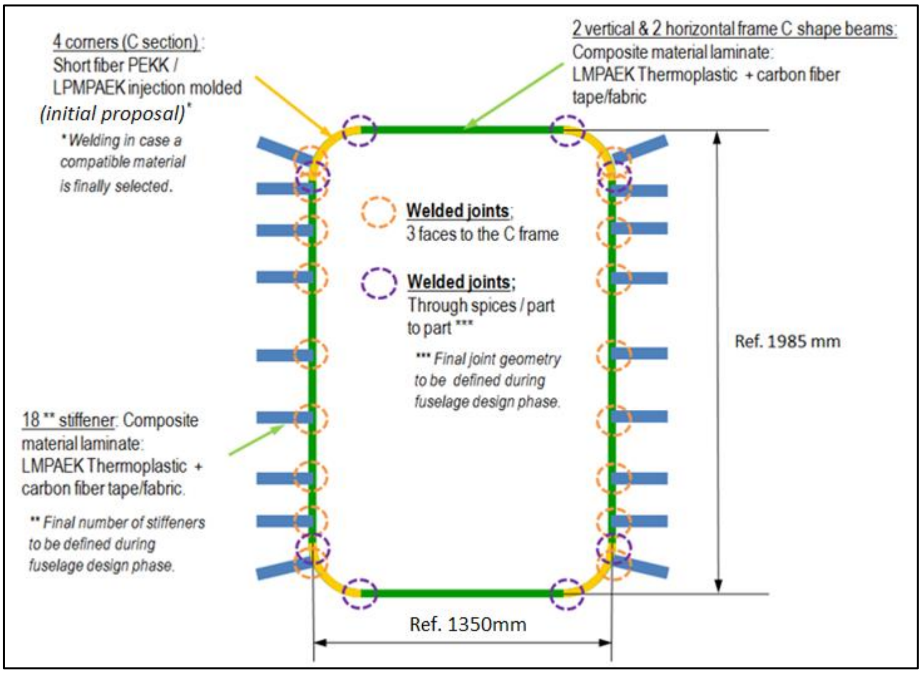
applications.
A very interesting feature of the Resistance welding is that the heat is only generated at the weld interface and it is independent of the weld length; therefore very good for long welds, reducing the welding time dramatically if the welding area is big.
On the other hand, the Laser welding is very dependant on the part thickness to be welded and can be limitations for high thicknessess. while Resistance welding has no limitations in thickness at all (but requires a resistive element bewteen the welding seam to stay after welding becoming a "flyaway" part). In this lieu, the Induction welding can be advantageous to the other techniques only if the reinforcement (or matrix additives) are conductive (i.e. not working well with aramides and glass fibres)
One of the biggest challenges for the present application is the size of the welding areas together with the accessibility. Therefore medium to big sized end-effectors will not be capable to weld all the surfaces especially because pressure between elements to be welded is required.
The outcome of the topic will help possible applications, especially for the in-service environment. Fuselage repairs, or damage tolerance design factors can benefit from the thermoplastic capability to weld or repair using small end-effectors/dedicated ones for specific areas or applications.

Today's SoA CFRP door surround structure concept would be a challenge for new thermoplastic CFRP aircraft fuselage regarding the targeted low recurring costs & high production rate. Therefore a Thermoplastic door surround structure (DSS) highly integrated and optimised for manufacturing is an option to explore due to Thermoplastic welding and integration manufacturing advantages.
Making use of thermoplastic joining technologies to contribute to high integration and weight reduction target, will enable benefits in the cabin layout due to reducing DSS affected area (1 frame pitch more for undisturbed cabin area).

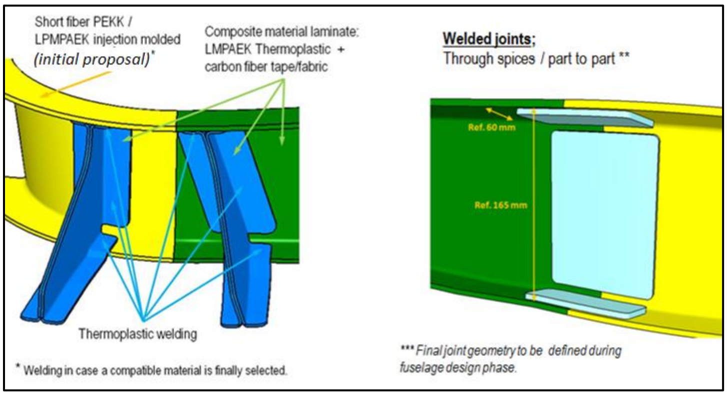
2. Scope of work

The scope of the current topic is to develop a welding system to achieve a structural bond of reinforcement parts (gussets, wedges, fittings) to structural frames to obtain a highly integrated Door Surround Structure (DSS).

The system shall be capable of welding reinforcement parts to the main frame in the most innovative and efficient way. Supporting tools and jigs should be kept to the minimum robust.



Specimen 1



Welded parts details

The system shall be flexible enough to be capable of welding different parts without substantially modifying the jigs or required supporting tools.

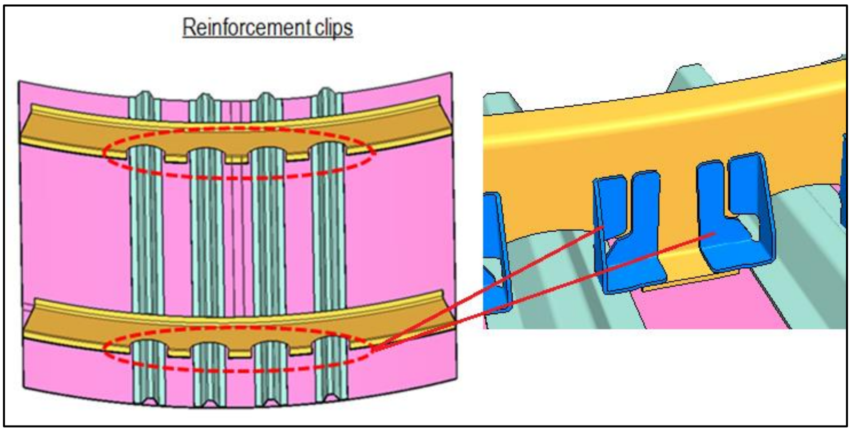
The system should also able to accommodate different geometries and thickness changes with parts that can be quickly replaced, i.e. different DSS designs for a single aircraft.
The system should also aim to automated operations for high rate scenarios, keeping low the number of steps involved in the welding process.

Temperature homogeneity in the welding area shall be achieved as well as control of heating and cooling down stages to minimize springback, residual stresses and to avoid morphological non-conformances of the thermoplastic matrix.
The device must be able to perform welding on “C” and “Z” section frames of “T” section stiffeners and fittings, ensuring compaction and tolerances required by the materials and manufacturing process. Tight corners and hardly accessible welding areas are to be foreseen during the design of the system.
The system shall be capable to work on non-controlled environment, and some parameters such as temperature, humidity and lighting may not be the typical for a composite “climate controlled area”.

This requirement enables the system to perform the welding not only in manufacturing facilities but also at maintenance in-service hangers where environment conditions are not always optimum.

It will be welcome a system flexible enough to weld other kinds of structures, especially DSS sections (directly or through splice), thermoplastic clips to fuselage frames and stringers and thermoplastic reinforcements. The system shall not affect the quality of the consolidated frame and stringers participating in the welding. Only welding interfacing areas shall be re-consolidated.

It is also part of this topic, to be able to use the developed process to weld reinforcement clips to the thermoplastic fuselage panel that will be tested; shown next.



Specimen 2

Different manufacturing trials must be performed in order to accept the welding system.

The Partner shall:

- Propose and manufacture the most suitable and innovative system design for the chosen technology to be applied for DSS, including supporting tools, automated devices, heating systems, end effectors required to weld DSS frames to DSS fittings and clamping methods to ensure welding surfaces contact.
- Provide at the beginning of the project a comparison of the state-of-the-art welding technologies (i.e. Laser, Induction, Conduction, Resistance and Ultrasonic welding -but not limited to them) with the selected solution in order to justify the most suitable for the scope of the project. Baseline resistance welding but open to other technology suitable for these applications.
- Generate process documentation in agreement with the Topic Manager specification. This documentation will include, at least, welding parameters (temperatures, speeds, pressures, tolerances…) as well as the tooling list and materials required.
- Manufacture and test coupons to validate the equipment and tooling.
- Delivery of the Prototype System and tooling set for manufacturing to the Topic Manager facilities in appropriate transportation means.
- Support set up in the Topic Manager premises.
- Follow up of the works performed by the Topic Manager until the end of the manufacture of a demonstrator compliant with typical aeronautical component specification standards.
- It would be desirable that the proposed technology allows welding areas on blind joints (only one side access).

Expected physical deliverables:

Prototype system: actual equipment to achieve coupon level welding and full size specimens welding.
Advanced Specimen 1: One full scale DSS demonstrator featuring gussets and splice welding to main frame.
Advanced Specimen 2: One full scale Stiffened Panel demonstrator featuring clips-to-frame welding.
Basic Coupons and tests: A minimum of 3 different configurations of Level2 specimens (typical welds between stringers and gussets to structural elements: T-shape to skin welding, L-shape to skin welding, gusset to both skin and frame welding) for testing (lap shear, tension …) in order to obtain welding allowable values.

Note:

- All physical demonstrators to be supplied in almost-ready-to-weld condition by Topic Leader.
- Candidate activity is limited to the welding process.
- Basic Coupons tests to be performed by candidate.

Tasks

These Topics are divided in 5 main tasks summarized in the following table and described below:

Tasks		
Ref. No.	**Title – Description**	**Due Date**
T1	Concurrence engineering and design composites development for system, tooling and test plan definition. Welding Technology section.	T0+6
T2	Manufacture the tools, jigs, end-effectors and devices.	T0+8
T3	Coupons manufacturing and test.	T0+10
T4	Validation of the system as agreed with the TM.	T0+12
T5	Delivery of the system to the TM facilities and support to set up and DSS prototypes welded assembly.	T0+18

The development of this system shall be innovative in order to implement the best performances in the following fields:

- Low Cost / Natural Materials, i.e. applying Additive Manufacturing Techniques,
- Eco-design, i.e. encouraging reusability and recyclability,
- Energy savings,
- Assembly processes simplification and time savings, i.e. implementing gauge-less coordination techniques, developing assembly processes simulations, wireless sensorization of key tooling points, etc.,

During all the tasks listed here above, both Topic Leader and Applicant(s) will be in close interaction in order to progress efficiently and to reorient tasks if any change or issues are encountered or foreseen.

Task 1 – Concurrence engineering and design composites development for system definition.
Concurrent engineering with the Topic Manager to understand the specimen arquitecture and the available design level in order to outline tool and system options.
Within this task, the Applicant(s) will receive all the information regarding geometry, constrains, preliminar assembly philosophy and related key characteristics and other requirements.

Task 2 – Manufacture the tools, jigs, end-effectors and devices.
Within this task, the Applicant(s) will receive the inputs, and be in charge of the design, the justification,

the manufacturing and the quality control of the Tooling and system Set within the adjoining elements. For that, the Topic Leader will provide the Applicant with all necessary information such as geometry, integrative constrains, general tolerances and process specifications to achieve the task.
The deliverables of this task will include all 3D models and 2D drawings. Different reviews will be organized in order to keep the project on track and to validate each step before starting the next one.
The information provided will cover both Specimen 1 and Specimen 2, but coupon testing specimens as well as any required manufacturing trial will be developed jointly between Applicant and Topic Manager in order to identify the tests that suite the individual welding requirements as per aeronautical standards.

Task 3 – Coupons manufacturing and test.
The deliverables of this task will include a prototype system with operational assessment. It will include coupon specimens manufacturing and testing (lap shear, tension …) in order to obtain welding allowable values. Some detail tests will be necessary, using small specimens, simulating welding in different parts of the components and applying loads in different directions.
Different reviews will be organized in order to keep the project on track and to validate each step before starting the next one.
The applicant will work in close collaboration with the Topic Manager to validate the outcomes of the different activities in this task.

Task 4 – Validation of the welding system as agreed with the TM.
Within this task, the Applicant(s) will demonstrate the full functionality of the system and perform trials at almost full-scale level.
A Pre-Ship Acceptance process, in accordance with the Topic Manager, will be performed prior to the delivery in the Topic Manager facility.

Task 5 – Delivery of the manufacturing tooling to the TM facilities and support set up.
The Applicant(s) will be in charge of the installation and Set-up of every component of the Tooling Set. Finally a Final Acceptance process, in accordance with the Topic Manager, will be performed prior to the Start of Production at the Topic Manager facility.
The Applicant(s) will provide the necessary on-site assistance, as requested, during the final specimen manufacturing and tests. In addition to that, the Applicant(s) will be also involved in the measuring of the resulting DSS and Stiffened Panel components.

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	Device specification	R	T0+4
D2	Equipment, tools, jigs, end-effectors and devices.	HW	T0+8
D3	Technical specification welding system.	R	T0+8
D4	Test report at test coupon level manufacturing.	R	T0+11
D5	Welding system and tooling delivered.	HW	T0+12
D6	Final report for Specimen 1 and Specimen 2: Conclusions and lesson learned	R	T0+18

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	Device specification	R	T0+4
M2	Tools, jigs and end effector concepts PDR	D	T0+6
M3	Tools, jigs and end effector CDR	D	T0+8
M4	System tests at small coupon level	HW	T0+9
M5	System tests at Specimen 1 and Specimen 2 level	HW	T0+12

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

(M) – Mandatory; (A) – Appreciated.

The consortium should have proven experience in aeronautic tools design, manufacturing and quality.

- Experience in former CleanSky European or collaborative programs (A).
- CAD-CAM software license compatible with project DMU: CatiaV5R21 (M) / Catia V6 (A)
- An international standard quality management system (i.e. EN 9100:2009/ ISO 9001:2008/ ISO 14001:2004). (A)
- Carbon/Glass Reinforced Thermoplastic processing experience.
- Temperature, strains and deformations sensor knowledge, artificial intelligence means, as digital twins, machine learning, algorithms and/or big data techniques (M)
- Capacity to repair or modify “in-shop” the prototype manufacturing tooling for components due to manufacturing deviations. (A)
- Qualification as strategic supplier of manufacturing tooling on aeronautical elements. (A)
- 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.

XVIII. JTI-CS2-2019-CfP10-LPA-02-31: Development of short fibre reinforced thermoplastic airframe clips and brackets using factory waste

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€):		500	
Topic Leader:	Fokker	Type of Agreement:	Implementation Agreement
Duration of the action (in Months):	24	Indicative Start Date (at the earliest)[40]:	> Q1 2020

Topic Identification Code	Title
JTI-CS2-2019-CfP10-LPA-02-31	Development of short fibre reinforced thermoplastic airframe clips and brackets using factory waste
Short description	
Thermoplastic composites offer great potential to recycle factory waste by reusing it in the form of short fibre compounds for products such as airframe clips and system brackets. Key aspects of this topic are the development, manufacturing and structural validation of frame clips and system brackets to be installed in a fuselage demonstrator together with an environmental, economical, and technical assessment of the technology.	

Links to the Clean Sky 2 Programme High-level Objectives[41]				
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 CO_2 emissions	Reducing NO_x emissions	Reducing Noise emissions	Improving EU Competitiveness	Improving Mobility
☒	☐	☐	☒	☒

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

[41] 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 WP2.1 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 next generation cabin. The demonstration will enable aircrafts higher production rate together with a fuselage weight and recurring cost reduction.

The driver of this approach is to attain a significant fuel burn reduction by substantially reducing the overall aircraft energy consumption, apply low weight systems and architecture integration 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 approaches such as design for manufacturing & automation, sensorization, and data analysis to demonstrate desired improvements.

Design 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 lower fuselage shell, including cabin and cargo floor structure and relevant main interior and system elements. The demonstrator has a length of around 8m, and a varying radius between 2 and 2.5m, similar to an A321 lower half fuselage.

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

Figure 1 provides a view on the lower half fuselage module concept with some characteristic features highlighted. The lower fuselage module itself is divided into two main modules: the lower fuselage stiffened shell module and the passenger floor and cargo hold module.

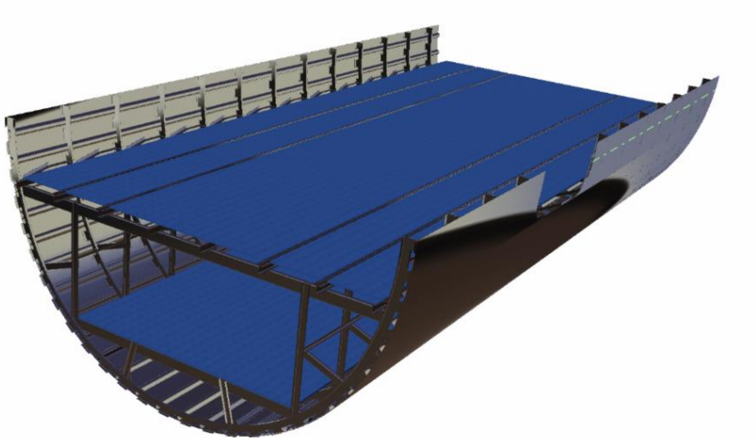
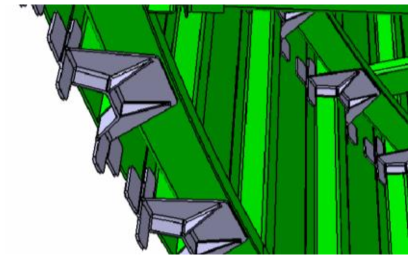


Figure 1: Overview of the MultiFunctional Fuselage demonstrator lower half and welded joints

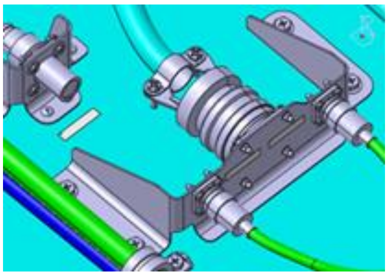
Development of short fibre reinforced thermoplastic frame clips and brackets using factory waste

This call topic aims to contribute to the benefits of thermoplastic composites for the lower half of the Multi-Functional Fuselage Demonstrator (MFFD). Replacing fasteners by welding and re-using thermoplastic factory waste into products such as frame clips and brackets allows cost reductions and will reduce the impact on environment.

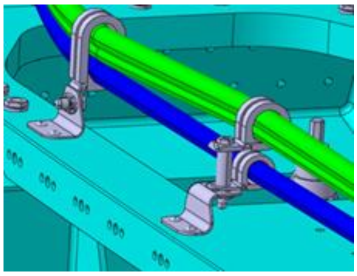
The specific aim of this topic is to develop short fibre reinforced thermoplastic frame clips and system brackets using the factory waste material of long fibre reinforced thermoplastic composites. An overview of frame clips and system brackets is given in figure 2.



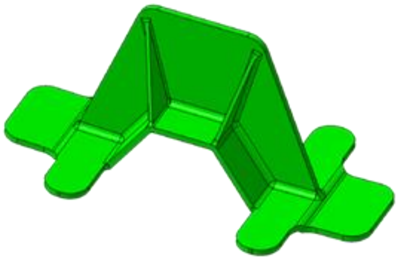
Frame clip



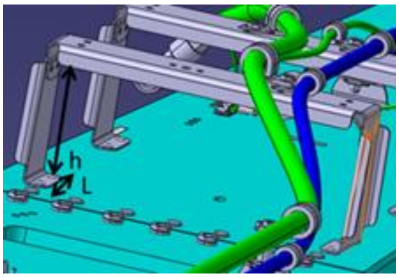
System bracket 1



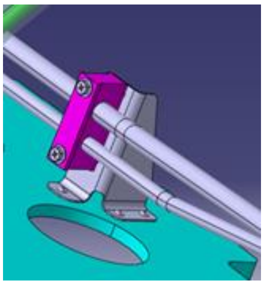
System Bracket 2



Frame clip



System bracket 3



System bracket 4

Figure 2: Examples of parts to be delivered

Frame clips are primary structural components and will see relatively high loads so to fully explore the suitability of this material, the applicant is asked to conduct some structural tests. The system brackets are secondary parts and if the manufacturing method is the same as for the frame clips no structural testing on part level is envisioned.

- The lower fuselage will have 13 frames and about 36 stringers, so about 500 frame clips including those used for testing are requested
- Baseline bracket and clip joining method to the rest of structure is welding, hence material compatibility is required, baseline material will be C/PAEK (LM)
- Approximate number of system brackets is: 20 system brackets (1), 120 system brackets (2), 50 system brackets (3), and 80 system brackets (4)
- The preferred manufacturing technologies is injection moulding but provided that the high production rate can be achieved alternatives such as 3D printing may be considered

2. <u>Scope of work</u>

The scope of work is summarized in four main tasks as stated in the table below. The first task can be regarded as a transversal task. It will adress the technology specification and validation. The following two tasks focus on specific applications and will need to be executed in parallel. The last task deals with an environmental and ecomonical validation of the technology.

Tasks

Ref. No.	*Title - Description*	*Due Date*
T1	Technical specification and validation	M18
T2	Development and manufacturing of all frame clips	M12
T3	Development and manufacturing of all system brackets	M15
T4	Environmental and economical evaluation of the technology	M22

T1 Technical specification and validation

The first activity is to deliver a baseline description report including all requirements, materials and specific design principles for the products based on the proposed manufacturing technology. The input material will be factory waste and part of the activities are to technically assess the strength of this material compared to pristine material sourced directly from supplier. Coupon static strength test should be sufficient to gain a first insight in any possible differences. As part of the technical validation a structural testing program needs to be conducted. This test program is split into two parts: strength of the parts and strength of the welded interfaces. The first part will focus on structural coupon tests of the material are requested as well as strength test of the complete part. Particular for the frame clips, flange bending tests are foreseen. The second part will focus on weld strength of the parts welded to UD C/LMPAEK structural laminates. Typical shear and pull-off tests are required.

T2 Development and manufacturing of all frame clips

Rather than forming frame clips out of long fibre reinforced plastics, short fibre reinforced plastics offer a promising alternative as recycling of factory waste becomes possible. In this task, the applicant will be asked to develop and manufacture all frame clips of the multifunctional fuselage demonstrator. The topic leader will provide the baseline design but the applicant may need to adjust this to suit the specific manufacturing technology used. Particular aspects such as compensation for material shrinkage during consolidation need to be addressed. The frame clips are regarded as the most important deliverable of this call topic as they are an essential part in the assembly of the MFFD by the topic leader. This task will be completed when all frame clips are delivered to and accepted by the topic leader.

T3 Development and manufacturing of all system brackets

Figure 2 provides an impression of the specific types of system brackets. If the same manufacturing technology is used as for frame clips no further strength assessment is required. Similar to the frame clips, the topic leader will provide initial designs for the system brackets. Depending on the proposed manufacturing technology by the applicant, the applicant may need to re-design the brackets. This task will be completed when all system brackets are delivered to and accepted by the topic leader.

T4 Environmental and economical evaluation of the technology

This technology has the potential to offer significant environmental and ecomonical benefits. The environmental benefits are the ability to re-use/recycle manufacturing waste or ‘off-cuts’ and thereby reducing waste. Furthermore this material and process offers a significant cost reduction. Both aspects need to be assessed in more detail by a thorough environmental and economical assessment thereby contributing to the viability of this technology. Examples of what should be adressed are: how can this technology be applied in an industrial setting, what material waste is available and what can be recycled and what not.

The topic leader may be able to supply some manufacturing ‘off-cuts’ that can be used to compare any possible differences in structural behaviour. However, as this supply of material ‘off-cuts’ will be limited, the applicant will need to budget for sourcing the majority of pristine UD C/PAEK from a supplier.

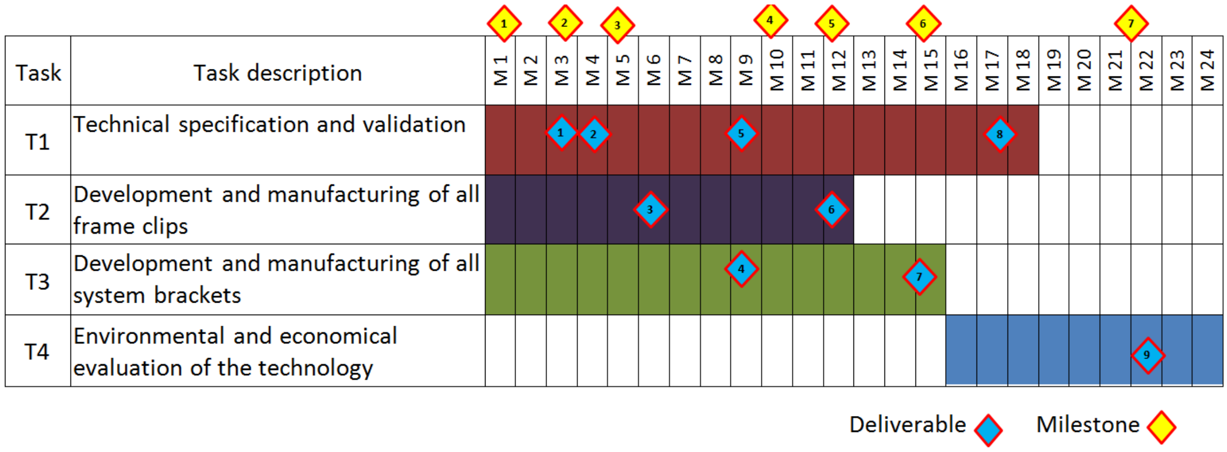
3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1	Baseline description report including requirements, materials and design principles covering all parts (e.g. clips and brackets)	R	M3
D2	Structural test plan	R	M4
D3	Frame clips: final design & tooling design	R, D	M6
D4	System brackets: final design & tooling design	R, D	M9
D5	Component structural test evaluation report	R, D	M9
D6	Delivery of all frame clips for the lower fuselage shell	HW	M12
D7	Delivery of all system brackets for the lower fuselage shell	HW	M15
D8	Interface structural test evaluation report	R, D	M18
D9	Ecological and economical impact final evaluation report	R, D	M22

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	Kick-off meeting	RM	M1
M2	Baseline review meeting	RM	M3
M3	Intermediate design review (IDR)	RM	M6
M4	Test evaluation review meeting	RM	M10
M5	Delivery of all frame clips	HW	M12
M6	Delivery of all system brackets	HW	M15
M7	Final Evaluation review meeting	RM	M22

Gannt Chart for deliverables and Milestones



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. The Topic leader will approve gates and authorize progress to subsequent phases.
- Demonstrated experience in management, coordination of development projects

Capabilities

- The applicant should have work-shop facilities in line with the proposed deliverables and associated activities or, if such equipment is not available, have exisiting relation with institutions or companies that accommodate such equipment.
- The applicant should have proven capabilities to design tooling and to re-design parts if needed. Catia releases compatible to the Topic leader are required
- The applicant should have a sound knowledge of the processing of short fibre thermoplastic composites
- The applicant should have a sound knowledge in structural testing of these structures as well as the capability to join these type of structures.

5. Abbreviations

IDR	Intermediate Design Review
LPA	Large Passenger Aircraft
MFFD	MultiFunctional Fuselage Demonstrator
LM	Low melt
UD	Unidirectional

XIX. JTI-CS2-2019-CfP10-LPA-02-32: Innovative miniaturized sensing device for large wave length spectrum reception capability as a tool for quality control and aircraft maintenance

Type of action (RIA/IA/CSA):		RIA	
Programme Area:		LPA	
(CS2 JTP 2015) WP Ref.:		WP 2.4.2	
Indicative Funding Topic Value (in k€):		800	
Topic Leader:	Airbus Operations	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	30	**Indicative Start Date (at the earliest)[42]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-LPA-02-32	**Innovative miniaturized sensing device for large wave length spectrum reception capability as a tool for quality control and aircraft maintenance**
Short description	
The project will develop an innovative miniature camera with an electronic system sensitive to all visible, infrared and X-ray waves that will be the reception element from an inspection feature dedicated to quality control and in aircraft maintenance for damage detection in small cavities of structure assemblies with a proper spatial resolution, weight and compactness.	

Links to the Clean Sky 2 Programme High-level Objectives[43]				
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 CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☒

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

[43] 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 objective of Large Passenger Aircraft (LPA) Platform 2 Multifunctional Fuselage (WP2.1) and Lower Centre Fuselage (WP2.3) Demonstrators 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 for the next generation fuselage and cabin to enable a high production rate, fuselage weight and cost reduction.

WP2.4 is focused, in this framework, to develop enablers aligned to demonstration needs for manufacturing, assembly and test solutions for reduced lead time and improved quality and maintenance. The topic contributes to the non specific cross functions work in WP2.4.2 in synergy with ITD Airframe to investigate innovative structural tests means and measurement technologies facilitating the implementation of “Online NDI/Process Monitoring” in composite manufacturing processes for an integrated and optimized damage detection.

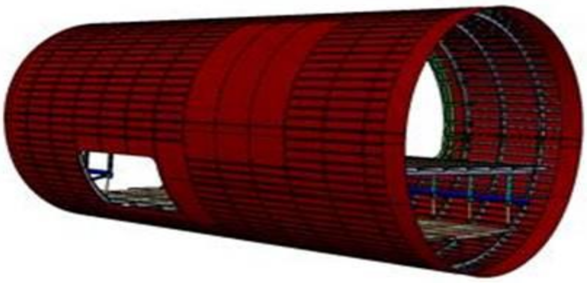


Figure 1 – Typical Multifunctional fuselage

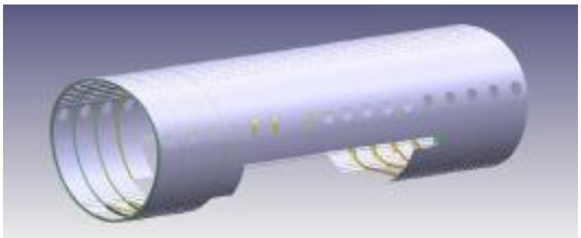


Figure 2 – Typical Lower Centre Fuselage Next generation- Shell structure

The topic will contribute to the development of sensing capabilities that will be installed from manufacturing step and assembly that will be used also for quality control and in aircraft maintenance operations contributing to structure health monitoring. Figure 3 illustrates possible localization for health monitoring of typical damages we may encounter in composite structure manufacturing and assembly operations as lack of composite fusion, group of porosities and delamination.

Figure 3 – Potential structural on board health monitoring distribution

Generally the field of inspection technologies offering the detection capability required are the assisted visual check, optical interferometry, X-ray, infrared thermography or even combination of technics depends of the inspection needs.

Therefore the innovation of the project will be to develop a unique miniature sensing camera capable to read/detect and transfer data in the fields of visual spectrum, infrared and X-ray wave length waves. It will be part of a quality control system requiring emitter and receiver devices, often used when visual or radiation technologies are needed mostly for complex stack of components made of different materials or multiple interfaces.

The advantage of a digital sensing technology is offering the possibility to integrate it into an automatic analysis device and enter into feedback loops analysis when needed. In that configuration sensing technologies needs a reading device that will transfer the image to a central analysis system by wireless in order to do not limit connectivity capabilities.

2. Scope of work

The project shall develop a miniature sensing camera capable to read/detect and transfer data in the fields of visual spectrum, infrared and X-ray wave length waves.
The use case targeted in the project is welding process control on line with the thermoplastic welding tool, offering the capability to be definitively installed on the fuselage assembly for quality control in the final assembly line and during aircraft operation sustaining predictive health monitoring.
Non conformities that could be induced by welding process applied on thermoplastic composite elements are porosity, lack of fusion between splices and overheating.
Before welding a quality control must be realized in order to identify if there is a lack of resin that could be the origin of lack of fusion.

To validate working conditions, and demonstrate compliance with aircraft design and interface requirements defined by the Topic leader, a prototype must be implemented by the partner to investigate a curved stiffened panel of 2m by 2m provided by the Topic leader. This panel will contains delamination and lack of bonding between stiffeners and skin.

The reading device must be adapted to very small available space and be as light as possible in order to be installed on board of the aircraft.
The sensor must satisfy the following requirements:

- one sensing device for all spectrum , flexible to be installed on curved surfaces,
- available gaps to install sensing technologies is very limited, therefore the sensing device must

be no more than 0,5mm thickness,
- spatial resolution must be of 0,05mm,
- the technology reading capability must be adjustable to local needs, and covering from 1x1mm to 10x10mm surfaces,
- to stay on the aircraft, therefore it must be compatible with aircraft system standards and offering wireless questioning capability,
- and total weight of the receiver and transmitter of no more than 0,01 kg.

The industrialization aspects must be oriented to low cost electronics and be eco efficient.

Tasks		
Ref. No.	***Title - Description***	***Due Date***
Task 1	Configuration definitions – Identification of all physics that will drive the sensing capabilities that will be applied in the field of typical welding defect on thermoplastics such as lack of bonding – or delamination induced in assemblies or aircfaft in operation. Targeting an optimized set up identifying integration constraints. Identify and define specific requirements from the industrial contexts (Structural and Electrical Systems) and automatic process specifications, all with topic leader inputs. The outcome of this task will be definition of the concept and of the final evaluation.	T0+3
Task 2	Define and make preliminary evaluation of the sensing technology for all spectrum detections.	T0+7
Task 3	Design and develop detector based on task 1 and 2 outcome.	T0+22
Task 4	Integration and evaluation of the prototype in laboratory environment by the project partner(s) on representative defect and damages. Test components will be deliverd by the Topic Leader.	T0+30
Task 5	Validation - Tests on demonstrator and validation of detection capabilities (delamination, de-bonded surface) and functionalities (data transfer, self testing) will be defined and realized with topic leader contribution Test panel will be delivered by Topic Leader.	T0+36

3. <u>Major Deliverables/ Milestones and schedule (estimate)</u>
**Types: R=Report, D=Data, HW=Hardware, RM=Review Meeting*

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
1.1	List of the specific requirements from the industrial context (Structural and Systems) and system specification inputs.	R	T0+3
2.1	Sensing technology evaluation.	R &HW	T0+7
3.1	Design and development of detecting feature.	HW	T0+22
4.1	Technical results in laboratory environment	R	T0+15
5.1	Evaluation of the detecting device for delamination or de-bonded stiffeners composite skin on the Topic leader demonstrator-identification of detection capability.	R	T0+34

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
1	Requirements and technology evaluation.	RM	T0+08
2	Detecting feature definiton.	RM	T0+23

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

The applicant(s) shall have:

- Demonstrated capability to invent, design and produce innovative sensing devices with integration of optoelectronics such as transceivers, bolometers and interrogating devices;
- Experience in system reliability testing standards;
- Knowledge in wireless technologies applicable to optoelectronics systems;
- Experience in interdisciplinary research and development team/consortium management.
- Experience in the field of aircraft production and assembly including all main aspects of a production processes and industrialization constraints, including quality control on composite structure
- Experiences in the different disciplines of various optical sensing technologies including specific automated measurement systems;
- Capabilities available in the fields of optical interferometry, X-ray, infrared thermography for the evaluation tests;
- Likely experience in aircraft operation aspects including inspection context conditions impacting damage detecability level and conditions of inspection applications.

5. Clean Sky 2 – Regional IADP

I. JTI-CS2-2019-CFP10-REG-01-18: Theoretical and experimental evaluations of strain field modification induced by flaws in loaded composite structures

Type of action (RIA/IA/CSA):		RIA	
Programme Area:		REG	
(CS2 JTP 2015) WP Ref.:		WP 3.1; WP 3.2	
Indicative Funding Topic Value (in k€):		450	
Topic Leader:	Leonardo Aircraft Division	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	18	**Indicative Start Date (at the earliest)[44]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-REG-01-18	**Theoretical and experimental evaluations of strain field modification induced by flaws in loaded composite structures**
Short description	
Investigation on strain field modification induced by damages and defects in loaded composite structures. Flaw mapping by virtual testing approach for SHM with passive static sensors, like strain gages or sensorized optic fiber. The virtual testing approach will consist of experimental evaluations of modification of the strain field induced by damages and/or defects with a scale-up approach coupled with FEM calculation on the reference full scale structure, in which experimentally validated defect models are inserted.	

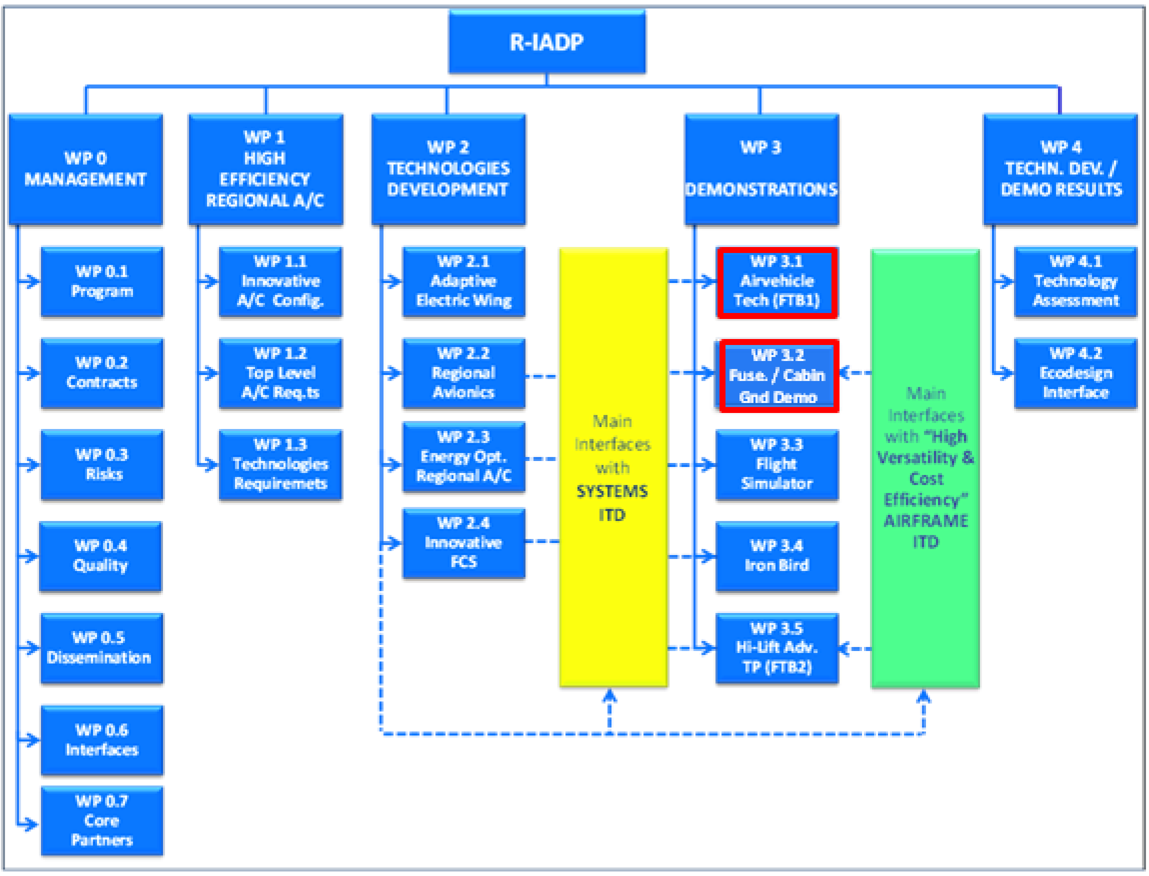
Links to the Clean Sky 2 Programme High-level Objectives[45]				
This topic is located in the demonstration area:		Regional Aircraft - Fuselage		
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter:		▪ Advanced Turboprop, 90 pax ▪ Innovative Turboprop, 130 pax		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☒	☐	☒	☐

44 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

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 Packages 3.1 “Air-vehicle technologies (FTB1)” and 3.2 “Fuselage/Cabin Integrated Ground Demonstrator” represent the field where activities requested to the Applicant shall found the applications. The relevant Work Breakdown Structure is shown below putting in evidence WP 3.1 and WP 3.2:



More in detail, the activities will cover the definition, design, manufacturing, assembling and on-ground testing phases for full-scale structural Outer Wing Box (WP 3.1) and Fuselage and Passenger Cabin demonstrators (WP 3.2) representative of a Regional Aircraft.

In WP 3.1, innovative low cost and low weight processes and SHM technologies shall be integrated into the Outer Wing Box on ground demonstrator with the objective to obtain: structural weight reduction, manufacturing and assembling recurring cost reduction, maintenance improvement and implementation of new eco-compatible materials and processes.

In WP 3.2, advanced composite, innovative low cost and low weight processes and SHM 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.

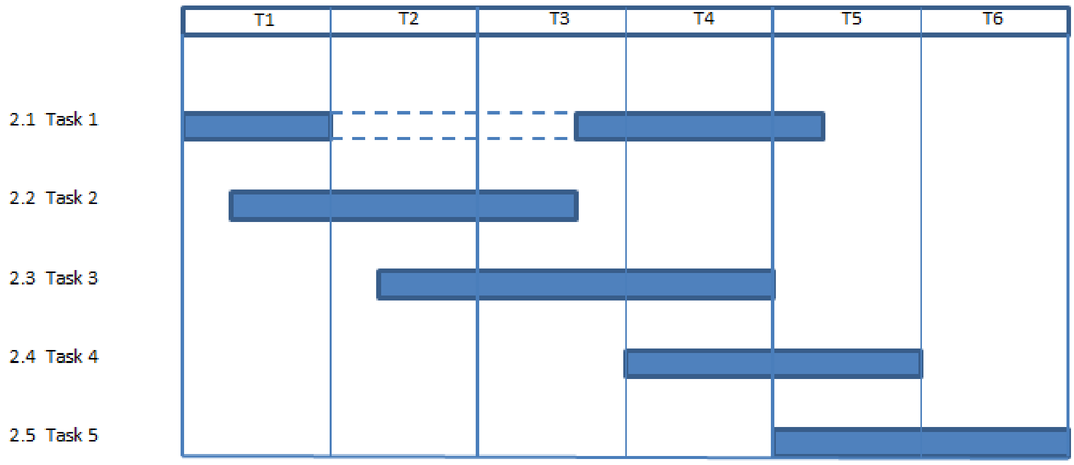
2. Scope of work

Structural Health Monitoring (SHM) is a technology aimed to monitor the soundness of the structures. It has been studied for several applications, in particular for aircraft structure monitoring, which will be considered in this proposal. The goal is to utilise the information acquired during the monitoring to save maintenance costs, to improve flight safety, to extend the service life and to improve the design, reducing the fail-safe requirements and producing lighter structures. Nowadays there are different issues investigated by SHM research. One issue is related to monitoring of the real in service loading history, and to evaluate the level of structure ageing on the basis of real loads. A similar issue is impact detection, based on recording the vibrations produced by impacts by hail, debris, birds, tool drops during maintenance, etc., using sensors that are able to measure such vibrations. But the most largely investigated issue is damage detection, i.e. developing a system that using sensors is able to detect the damages produced by structural ageing and impacts during the service life; usually these damages are monitored by periodic inspections, visual or with the utilization of non-destructive inspection (NDI) apparatuses, like ultrasounds scanning, X-ray, thermography, interferometry, eddy currents, etc. The utilization of sensors allows more frequent inspections, with the final target of a continuous in flight monitoring, with the potential cost reduction. Of course that requires that all the system chain, formed by sensors, conditioning apparatus and the software, works in a suitable and reliable way in order to allow the required certification. The damage detection can be performed with two different types of sensors; dynamic sensors (i.e. piezo) and static sensors (like strain gages or sensor optic fibres). Dynamic sensors work by the transmission of mechanical waves through structures. The waves are deviated and/or reflected by damages; the use of a suitable software allows a correlation of the wave deviation with the types and sizes of defects and damages; some concerns exist in the utilization of dynamic sensors during the flight, due to the superposition of the waves with the proper flight vibrations. A different approach is considered in this context, based on static sensors. The studies on the SHM systems based on the utilization of static sensors are based on comparison of the strain field caused on a structure by a load array in pristine and damaged condition; the presence of damages causes a change of the strain field that can be correlated with the type, location and sizes of damages. The major difficulty of this approach is given by the need to know the load level, which is always known during a lab test but not in service (obviously). Different algorithms based on this approach have been developed and patented by Leonardo aircraft, they are based on a reverse finite element method (FEM) approach and on a neural network approach. This CfP shall be finalized to further develop a software for the implementation of these SHM algorithms. Such software is already available and will be provided by the Topic Manager to the selected Applicant at the beginning this CfP Project. Namely this software is able to detect flaws existing in the structures; the activities described by this CfP will allow the improvement of the software use also to obtain information about type and size of the detected flaws. The software certification is not included in the activities requested by this CfP.

To achieve this objective, the main activities requested to the selected Applicant are divided and described in the tasks listed in the following table:

Tasks		
Ref. No.	***Title – Description***	***Due Date***

Task 1	Modelling of the strain field modification induced by the presence of flaws, with different kind of morphology and size	T0 + 13
Task 2	Experimental determination of the strain field modification induced by the presence of flaws, with different kind of morphology and size, on composite specimens	T0 + 8
Task 3	Experimental determination of the strain field modification induced by the presence of flaws, with different kind of morphology and size, on composite elements	T0 + 12
Task 4	Virtual morphology definition of diagnostic indications provided by the SHM software on damaged representative subcomponents, with different size, type and positions of the flaws	T0 + 15
Task 5	Virtual morphology definition of diagnostic indications provided by the SHM software on damaged structures, with different size, type and positions of the flaws	T0 + 18



Task 1: Modelling of the strain field modification induced by the presence of flaws, with different kind of morphology and size

The information about the reference full scale structure to model (design, material properties and loads) will be made available for the activities covered by this proposal.

In this task: it will be defined and developed FEM prototypes of typical flaws induced on the reference composite fuselage structures. These flaw models will be successively validated and/or tuned by experimental evaluation developed in different tasks (2 and 3).

The activities will be:

- Definition of the flaws to be modeled, with different kind of morphology (delamination, debonding, impact damage, etc.) and size.
- Modelling of the flaws, on the basis of known information and flaws morphology (e.g. a delamination can be modeled as a lay-up with separation between plies, a damaged area can be modeled as a zone with reduced material properties, etc.).
- Definition of specimens and elements to be tested in tasks 2 and 3, in terms of geometry, material, lay-up and testing procedure: tension, compression, bending, required stress and strain measurements etc.
- Engineering evaluation of the test results obtained in tasks 2 and 3; validation and/or tuning of the

flaw models.

Task 2: Experimental determination of the strain field modification induced by the presence of flaws, with different kind of morphology and size, on composite specimens

A plan for the fabrication of artificial defects and for impact damaging will be defined, and an activity to check the suitability of the procedure, by NDI and, if necessary, destructive verifications (e.g. cutting and microscopy) will be performed.
On the basis of the test plan defined in task 1, the specimens will be fabricated. The specimen fabrication process will include panel fabrication (including impact damaging and/or defect inclusion, when required), specimen cutting, tab fabrication and bonding (if applicable). The material and the fabrication process will be representative of the reference test article. The panels for specimen fabrication will be made available, including defects if required. The partner will perform impact damage as required by the test plan, as well as NDI of panels and specimens.
On the basis of the test plan, the specimens (e.g. tension, compression, in plane shear, bending) will be tested. A sufficient number of strain gages and/or rosettes will be used to record the strain distribution in the flaw nearby. A report including all the test procedure and results will be provided.

Task 3: Experimental determination of the strain field modification induced by the presence of flaws, with different kind of morphology and size, on composite elements

A plan for the fabrication of artificial defects and for impact damaging will be defined, and an activity to check the suitability of the procedure, by NDI and, if necessary, destructive verifications (e.g. cutting and microscopy) will be performed.
On the basis of the test plan defined in task 1, the elements (e.g. panel stiffened with a single stringer, panel joints, etc.) will be made available including defects. The element impact damaging will be in charge at this call activities, when required. The material and the fabrication process, as well as the element geometry will be representative of the reference test article.
On the basis of the test plan, the elements will be tested. A sufficient number of strain gages and/or rosettes will be used to record the strain distribution in the flaw nearby. A report including all the test procedure and results will be provided.

Task 4: Virtual morphology definition of diagnostic indications provided by the SHM software on damaged representative subcomponents, with different size, type and positions of the flaws

A CATIA model of a representative subcomponent (e.g. panel stiffened with stringers) will be provided, and a FEM model in pristine condition will be created.
Using a specific SHM software, which will be made available, the developed flaw models will be virtually tested on a subcomponent. Namely, different positions and sizes of flaws will be identified, and the developed FEM subcomponent in pristine condition will be used to develop also models with added flaws.
The SHM software will be fed with the FEM in different load conditions (to be provided) and the diagnostic outputs will be recorded, in order to establish a typical correlation (database) between flaw types and sizes and software indication.

Task 5: Virtual morphology definition of diagnostic indications provided by the SHM software on damaged structures, with different size, type and positions of the flaws

A CATIA model of a representative component (e.g. a wing box or a fuselage barrel) will be provided, and a FEM model in pristine condition will be created.
Using a specific SHM software, which will be made available, the developed flaw models will be virtually tested on a component. Namely, different positions and sizes of flaws will be identified, and the

developed FEM component in pristine condition will be used to develop also models with added flaws. The SHM software will be fed with the FEM in different load conditions (to be provided) and the diagnostic output will be recorded, in order to establish a typical correlation (database) between flaw types and sizes and software indication.

3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref. No.	**Title - Description**	**Type**	**Due Date**
D1.1	Description of flaws and concepts for flaw modelling	R	T0 + 2
D1.2	Specimen and element Test Plan	R	T0 + 3
D1.3	FEM of pristine and damaged specimens and elements	R	T0 + 10
D1.4	Comparison between virtual and experimental results for validation of defect models	R	T0 + 13
D2.1	Specimen fabrication	HW	T0 + 5
D2.2	Test Results (for Specimens)	R/D	T0 + 8
D3.1	Element fabrication	HW	T0 + 8
D3.2	Test Results (for Elements)	R/D	T0 + 12
D4.1	Description of flaws to be virtually tested on subcomponents through the using of FEM of subcomponent with flaws	R	T0 + 12
D4.2	SHM software outputs (maps) for subcomponents pristine vs flaws stressed by typical loads	R/D	T0 + 15
D5.1	Description of flaws to be virtually tested on the full scale components through the using of FEM of subcomponent with flaws	R	T0 + 15
D5.2	SHM software outputs (maps) for virtual test full scale component pristine vs flaws stressed by typical loads	R/D	T0 + 18

Milestones			
Ref. No.	**Title – Description**	**Type**	**Due Date**
M1.1	Comparison between virtual and experimental results for validation of defect models	R	T0 + 13
M2.1	Test Results (for Specimens)	R/D	T0 + 8
M3.1	Test Results (for Elements)	R/D	T0 + 12
M4.1	SHM software outputs (maps) for sub component pristine vs flaws stressed by typical loads	R/D	T0 + 15
M5.1	SHM software outputs (maps) for full scale components pristine vs flaws stressed by typical loads	R/D	T0 + 18

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

- Skill 1 - Design CATIA V5 capability.
- Skill 2 – Stress analysis , Nastran/Patran capability.
- Skill 3 – Composite specimens fabrication facilities and capability.

- Skill 4 – NDI facilities and capability.
- Skill 5 – Mechanical test facilities and capability including impact damage.
- Skill 6 – Software capability.

5. Abbreviations

FEM	Finite Element Method
NDI	Non Destructive Inspection
SHM	Structural Health Monitoring
TRL	Technology Readiness Level

II. JTI-CS2-2019-CFP10-REG-01-19: Innovative Noise Generation System for testing of Regional Cabin Interior Noise reduction

Type of action (RIA/IA/CSA):		IA	
Programme Area:		REG	
(CS2 JTP 2015) WP Ref.:		WP 3.2	
Indicative Funding Topic Value (in k€):		550	
Topic Leader:	Leonardo Aircraft Division	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	14	**Indicative Start Date (at the earliest)[46]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-REG-01-19	**Innovative Noise Generation System for testing of Regional Cabin Interior Noise reduction**
Short description	
Research of innovative solutions for the design of Noise Generation System (iNGS) and, based on results of such research activities, design, development, manufacturing and integration of an innovative Noise Generation System to test and validate new technologies for Regional Cabin Interior Noise reduction. The activity shall include the definition and implementation of advanced algorithms able to automatically simulate the real noise spectrum distributions and levels for all the flight conditions.	

Links to the Clean Sky 2 Programme High-level Objectives[47]	
This topic is located in the demonstration area:	Regional Aircraft – Fuselage / cabin
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:	

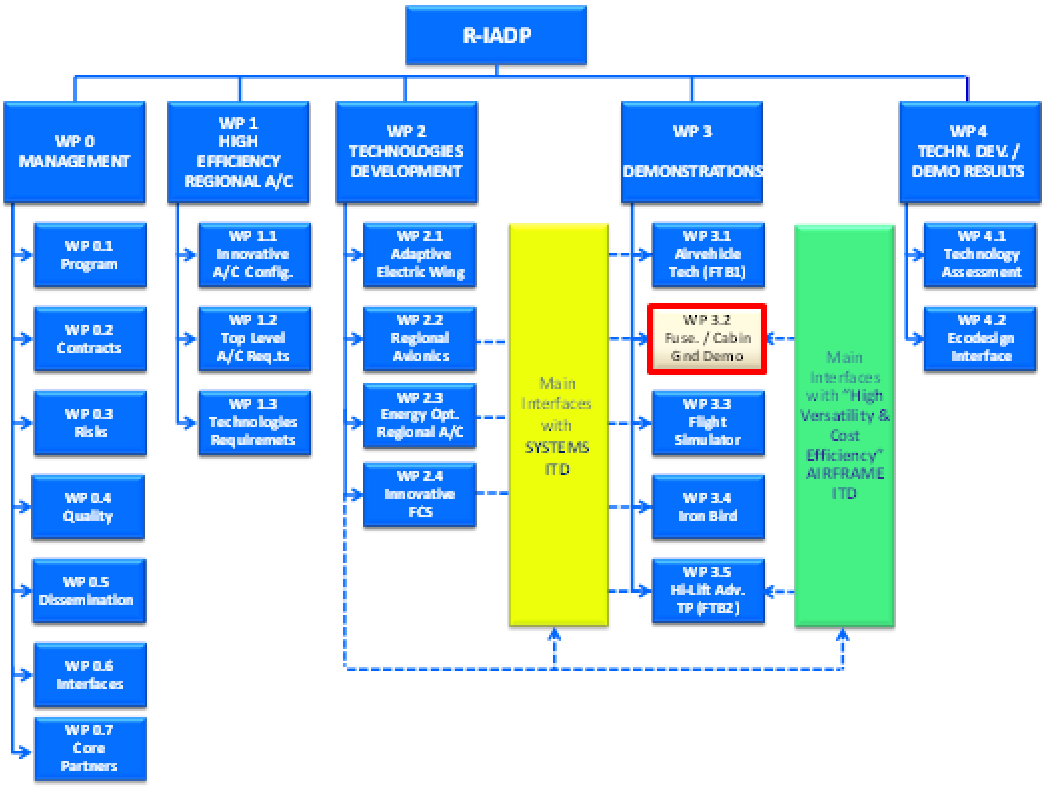
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☐	☐	☐	☒	☐

[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

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 this CfP is to research innovative solutions for the design of Noise Generation System (iNGS) and based on the result of this research to develop, manufacture and integrate an innovative Noise Generation System (iNGS) to test and validate new technologies for Regional Cabin Interior Noise reduction.

The iNGS will be designed to be used on Clean Sky composite fuselage of 3.45m diameter, but will be adaptable to any fuselage diameter and type. It will be able to reproduce the external sound field around a fuselage section of regional aircraft in order to measure the cabin interior noise distribution map.

The sound field around the fuselage will be generated by setting multiple arrays (at least three) of loudspeakers around the fuselage to ensure the correct sound pressure distribution in circumferential and axial direction. The generated acoustic field shall be controlled by placing an array of control microphones between the loudspeakers and the fuselage using advanced control strategies.

The selected candidate will conduct a review of the state of the art of Noise Generation System and will exploit innovative solutions to overcome the limitations of the current system used in Leonardo.

The iNGS can be composed at least by three main components:

- Main control sub-system for runtime sound waveform calculation
- Sound waveform generation and acquisition sub-system
- Electroacoustic sub-system

Tasks		
Ref. No.	***Title – Description***	***Due Date***
Task 1	Requirements Analysis	T0+1
Task 2	Design of iNGS	T0+3
Task 3	Production of hardware and software	T0+5
Task 4	Integration and Validation	T0+14

<u>Task 1: Requirement Analysis</u>

In the present task the selected Applicant will conduct a review of the of the state of the art of fully circumferential fuselage Noise Generation System.

The current system can be used on a fix fuselage diameter and fix position of the fuselage. A change of any of the two parameter require a cost effective and time consuming modification in the hardware mechanical part of the system. Another limitation is total absence of a control closed loop for the sound generation, thus in presence of a reverberant environment the setting of the sound source, for flight condition, even with few loudspeakers is very time consuming (about a week).

The target is to implement an innovative closed control loop with control strategies in order to reduce this time to less than half a day.

Another restriction, to be covered with an innovative solution, is the input to the system that actually must be filled by hand on a keyboard for each 3/8 octave band for each loudspeaker and this is not efficient also in the process of tuning of the system.

After a review of the state of the art the selected Applicant will analyse the basic requirement here described to overcame the limitation of the current system used in Leonardo:

a. The Main Control subSystem (MCsS) shall consist of a computer system with a massive computational power, parallel computing using multicore processors and multiprocessor architectures shall be exploited, in order to process the algorithms in real time and provide the computed waveforms to the sound waveform generation and acquisition sub-system without any losses.
b. A multiple monitor feature must be implemented to plot in real time acquisition and generation acoustic field.

c. The software to be developed will real time interface with hardware and software environment used at Leonardo.
d. The user will build the configuration (number of loudspeakers, number of circumferential array) in a graphical user interface to rapidly and easily change and optimize configurations.
e. It will be possible to automatically import the required noise profile and graphically assign and modify the profile to each loudspeaker.
f. Starting from a review of state of the art control algorithms existing in the literature the selected candidate will develop an innovative control methodology to obtain high speed performance and thus enabling control over narrow acoustic band. Development of control strategy and pre-test analysis shall be aimed to reduce the number of control microphone and all related hardware that are required to reduce time and costs in the test set-up.
g. The iNGS shall generate a noise footprint on the fuselage equivalent to the cruise condition in which boundary layer flow is simulated by a white noise characterized by different amplitudes for each 3/8 band. The expected max amplitude is 130dB. During other operating condition the propeller noise is completely dominant over the other noise sources, to simulate this condition the iNGS shall be able to generate combined sine waves at different frequencies.
h. The Sound Waveform Generation and Acquisition subSystem (SWGAsS) will be compatible with the platform that is currently used for the DAQ in Leonardo acoustic laboratory (24bit ADC, 92kHz bandwith, 150 db dynamic range).
i. The SWGAsS will be integrated with the existing hardware. Leonardo will provide microphones, cards and frames for the microphones acquisition only.
j. The hardware must be configured using a master-slave combination to allow flexibility and scalability.
k. The selected candidate will exploit the possibility to integrate third parts or ad hoc developed HW to control the electroacoustic amplifier functions and/or other characteristics of the system.
l. The Electroacoustic subSystem (EsS) is composed by a multiple circumferential array of loudspeakers arranged around the CS2 fuselage Demonstrator.
m. Due to the very small fuselage diameter of the Regional A/C, each circumferential array shall include as many loudspeakers as possible (finding an innovative solution to reduce physical envelope) to increase spatial resolution while still meeting all the requirement listed in terms of power and frequency band.
n. The arrays of loudspeakers will be moved in forward/aft direction on the fuselage so the entire structure will be equipped with wheels. The entire structure must be easy disassembled for transportation.
o. A digital control technique of the amplifiers by means of digital signals or digital bus will exploited in order to minimize cables length and signal to noise ratio.
p. The EsS will have a protection to avoid system overload and will give feedback to the MCsS about its status and integrity. The loudspeakers will be provided with a damping system to minimize the transfer of vibration to the structure.
q. Modal analysis of the structure must be conducted to ensure that no vibration will occur that can the corrupt the sound field. It must be possible to adapt the EsS to other fuselage of different diameter, with minimal or no modification of the structure.
r. Sound power amplifiers must be selected in order to provide enough power to each loudspeaker for all test duration. The duration of the test is typically ten minutes up to one hour for comfort test.

s. Together with this requirements the applicant will generate a set of additional requirements that will provide a character of innovation with respect to the state of the art of the fully circumferential fuselage Noise Generation System.

Task 2: Design of iNGS

Starting from the work in Task 1 the selected applicant will design the MCsS, SWGAsS and EsS to satisfy the all the basic and additional requirements.
In addition the Applicant will design any other system or equipment needed to satisfy the character of innovation of the iNGS required in this CfP.
A preliminary version of the CAD Drawings will be released by the applicant in order to check that requirement are correctly implemented.
At the end of this task a beta version of the GUI shall be available, in order to verify the usability and allow possible modification. Also a demonstration of the control algorithm with few control channel shall be performed to assess the correct implementation.
Particular care must be taken in the equipment design of the components of the iNGS to be accommodate in 42U rack with wheels and a front and rear cover to easy allow transportability
All the documentation required for allowing the correct interfaces with the CS2 fuselage acoustic demonstrator together with all the characteristic of microphones and related DAQ will be provided to the selected Candidate as an input at the early stage of the Project.

Task 3: Production

This task involves the construction of the project result. Hardware will be build according to the design approved in the Task 2 and the algorithms and the related software will be encoded in order to meet the performance requirement established in the previous tasks. The selected candidate will monitor the production phase carefully and inform on the progress the CfP manager on a regular basis. Leonardo will provide microphones, cards and frames for the microphone acquisition system.
At the end of this task the applicant will ship the system to Leonardo together with the relevant documentation (installation manual, user manual, maintenance and service manual).

Task 4: Integration and Validation

The selected candidate will integrate the system at Leonardo Pomigliano d'Arco site. Prior of the validation the Applicant will prepare an Acceptance test procedure including a means of compliance table to be approved by Leonardo. Finally the validation tests will be executed proving that the system is correctly installed and properly working.

3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref. No.	**Title - Description**	**Type**	**Due Date**
D1.1	Analysis phase: Requirements matrix and support documentation.	R	T0+1
D2.1	Preliminary CAD drawing.	R+D	T0+3
D2.2	CAD Drawings release.	R+D	T0+5
D3.1	Hadware and software produced and documented	R+HW	T0+13
D4.2	System integration and validation: Validation tests report.	R	T0+14

Milestones			
Ref. No.	**Title – Description**	**Type**	**Due Date**
M1.1	Analysis phase Review	R	T0+1
M2.1	Software GUI beta release	R	T0+5
M3.1	Hardware delivery	HW	T0+13
M4.1	System Integration and validation	R+HW	T0+14

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

- Expertise in Acoustic Data acquisition and Generation System
- Recognized experience in advanced control system techniques
- Experience in laboratory or industrial test benches design, manufacturing and installation
- Experience in aerospace R&T and R&D programs is an asset
- System requirements capture and analysis
- Demonstrated expertise in project participation, international cooperation, project and quality management.

5. Abbreviations

iNGS	innovative Noise Generation System
MCsS	Main control sub-system
SWGAsS	Sound Waveform Generation and Acquisition subSystem
ESS	Electroacoustic subSystem
DAQ	Data Acquisition System
PDR	Preliminary Design review
CDR	Critical Design review
DDP	Declaration Design Performance
QA	Quality Assurance

III. JTI-CS2-2019-CFP10-REG-02-06: SHMS and Dynamic fields sensors development

Type of action (RIA/IA/CSA):		RIA	
Programme Area:		REG	
(CS2 JTP 2015) WP Ref.:		WP 3.5	
Indicative Funding Topic Value (in k€):		350	
Topic Leader:	Airbus Defence & Space	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	36	**Indicative Start Date (at the earliest)**[48]**:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-REG-02-06	**SHMS and Dynamic fields sensors development**
Short description	
The research of the topic is focused on the evolution of the current wired sensors used in SHM Systems and Dynamic fields into miniaturized , wireless and self-power harvesting units. This is one on the steps beyond in future SHM Systems applicable to multi-missions regional aviation. Those with potential use on Structural Health Monitoring Systems with incorporated data acquisition and processing and wireless data transmission to an aircraft computer into the sensor component. The electrical power supply of the sensor component must be obtained directly from operational and environmental conditions at sensor position using an energy harvester.	

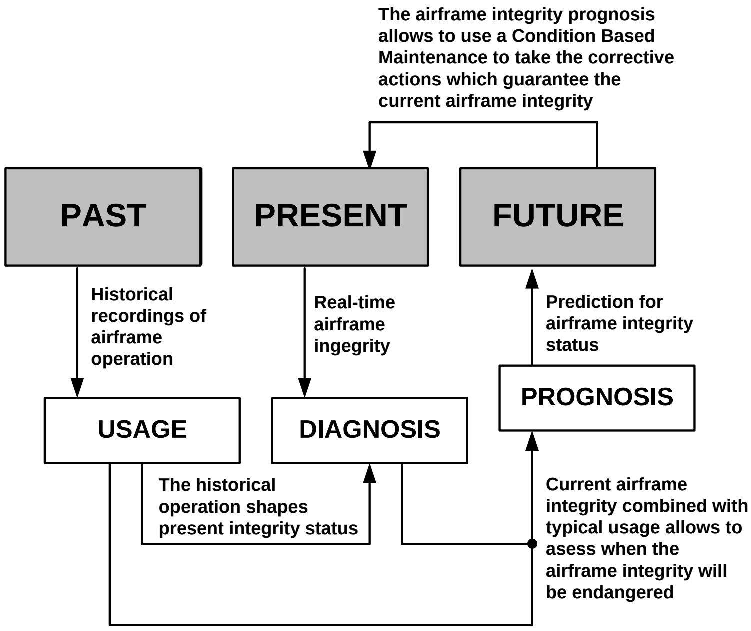
Links to the Clean Sky 2 Programme High-level Objectives[49]				
This topic is located in the demonstration area:		Regional Aircraft – FTB#2		
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter:		Multi Mission Regional Aircraft		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x 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

During the last years the technologies involved in the integrity assurance of the Airframe have experienced a great development. They are the so called Airframe Health Monitoring Technologies, including the Structural Health Monitoring (SHM) development started during Clean Sky I in Green Regional Aircraft.
Currently the Aircraft Maintenance Program is based on A/C certification fixed results and tests. This maintenance program ensures the continued airworthiness of the airframe.
The structure of the aircraft on multi-mission role or performing non-conventional operations, such as maritime patrol or firefighting, are very sensitive to the usage. The A/C individual tracking provided by the introduction of a Structural Health Monitoring (SHM) system could allow the modification of the A/C certified maintenance program according to a real operation.



The main advantages of a Condition Based Maintenance are: A/C platform availability figures improvement, maintenance scheduling and maintenance cost optimization. All these advantages ensure a cost reduction in the operation of the A/C and also have an important impact on certification principles of the monitored elements.
One of the key elements on the SHM system is the data acquisition using specific or non-specific SHM sensors. The aim of this topic is the evolution of current wired sensors which are used in SHMs systems into miniaturized and wireless, self-power-harvesting versions:

- Data acquisition
- Data processing
- Wireless data transmission to A/C computers
- Self-powered using surrounding energy sources (mechanical, thermal, electromagnetic, etc.)

The qualification of SHM system sensors functionality to be checked in complex dynamic scenarios will demand new functionalities of dynamic sensors being used.

2. Scope of work

One of the drawbacks of actual SHM systems for regional aviation is wiring complexity and associated extra weight. This challenge can be solved through specific sensors design and miniaturization. The scope of the work is focused on the step beyond of this type of sensors focused on main capabilities:

- Data acquisition
- Data processing
- Wireless connectivity
- Energy harvesting
- Miniaturization

The topic proposed a step by step approach towards future devices where these capabilities are included. Thus first, it is necessary a study of the current state of the art of sensors followed by incremental research to include wireless connectivity and energy harvesting capacity. Finally the work will conclude with qualification of the new devices and potentially test in representative operational environment of Regional flight test bed. It is therefore to evolve current sensors configuration and functionalities to include local data acquisition and processing, wireless data transmission and self-power harvesting capabilities

This elimination of wiring and the integration of processing capabilities in the sensor's side of the system will contribute to fulfill the target, helping to enhance current SHM systems architecture, improving USAGE monitoring capabilities and providing significant advanced DIAGNOSIS capabilities.

Therefore the main objective of this work is the exploration to build up new sensors and new ways of using existing sensors with enhanced functionalities for dynamic field usage primarily focused onto Structural Health Monitoring considering the introduction of MEMS-based sensor technologies using **wireless data acquisition** nodes, **energy harvesting** suitability and some level of data acquisition and processing capability covering:

- Usage and Operational Loads Monitoring, including:
  - A/C digital buses acquisition
  - Additional sensors for A/C loads measurement
- Events and Damage diagnosis, including, the following events/damages:
  - Impact and multi-impact
  - Buckling and overload
  - Overtemperature
  - Lightning strike
  - Delamination
  - Corrosion
  - Cracks
- Local structural dynamic vibration control
  - Hardly accessible locations
  - High temperature environment (i.e. close to engine)

Sensors specifications are foreseen to deal with:

- Data acquisition
- Enhanced architecture of standard sensors to:
  - Keep or improve quality of electrical and/or optical signals in complex scenarios (i.e. EMI/EMC) or data compression protocols
  - Base technology onto MEMS concept
- Wireless data transmission protocols from sensor nodes to storage and processing boxes
- Sensor clustering into acquisition nodes as 2nd step of data processing.
- Sensor and sensor nodes energy harvesting possibilities.

Besides this and depending on operational characteristics being assigned following bandwidths information can be considered:

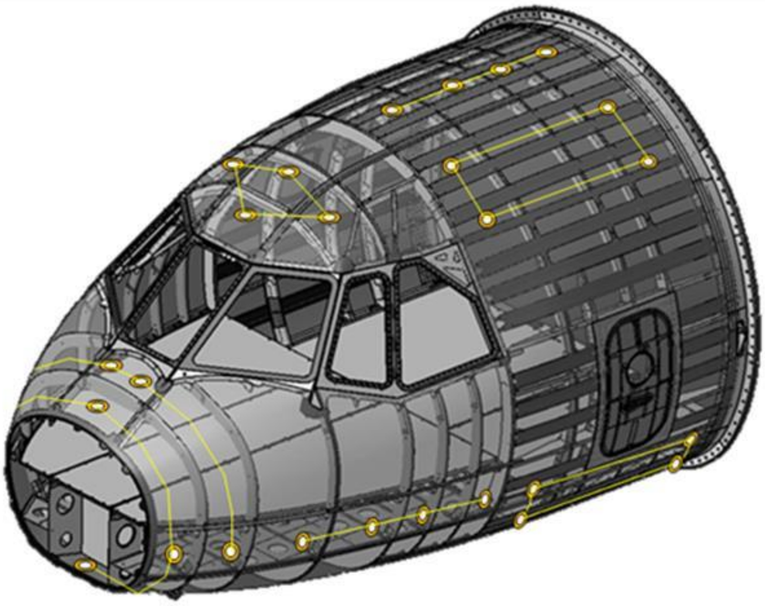
Indicative Data	Physical Magnitudes	Amplitude Ranges	Typical sensors	Measurement magnitude	Frequency bandwidth	Transmission bandwidth (2)
USAGE monitoring (1)	N/A	N/A	N/A	N/A	50 Hz	1 Mbit/s (1 bus)
Operational Loads Monitoring	Strain	+/- 5000 με	Strain gauge FBG FOS (Raleygh)	Electrical Optical Optical	200 Hz 200 Hz 200 Hz	10 Kbit/s 10 Kbit/s 50 Mbit/s
Vibration dynamic DIAGNOSIS	Acceleration	+/- 500 g	Accelerometer	Electrical or Optical	8 kHz	128 Kbit/s
	Sound pressure	+/- 1 kPa	Microphone	Electrical	40 kHz	1 Mbit/s
Event DIAGNOSIS	Strain	+/- 10000 με	Strain gauge Piezoelectric FBG FOS (Raleygh)	Electrical Electrical Optical Optical	200 Hz 250 kHz 250 kHz 200 Hz	10 Kbit/s 5 Mbit/s 5 Mbit/s 50 Mbit/s
	Sound pressure	+/- 1 kPa	Microphones	Electrical	40 kHz	1 Mbit/s
	Acceleration	+/- 50 g	Accelerometers	Electrical or optical	250 kHz	5 Mbit/s
	Rotation	+/- 45 DEG	Rotation sensors	Electrical	250 kHz	5 Mbit/s
	Temperature	-70 / 300 ºC	Thermistor FBG FOS (Rayleigh)	Electrical Optical Optical	50 Hz 50 Hz 50 Hz	1 Kbit/s 1 Kbit/s 10 Mbit/s
Damage DIAGNOSIS	Strain	+/- 10000 με	Piezoelectric FBG	Electrical Optical	5 MHz	N/A(3)

(1) Usage monitoring can be obtained directly from digital buses already installed on A/C.
(2) Per sensor assuming 16 bit data sample acquisition.
(3) Depending on the DIAGNOSIS schema.

In addition, it is expected that some of the current "in use" existing sensors will be evolved.
Among other possible considerations, sensor development and implementation will be based on the following aspects:

- Sensitive feature (what the sensor measures from the structure)
- Sensor technology (sensor way of work and basement technology, MEMS)
- Sensor data acquisition (wired to the sensor and wireless to the data storage box)
- Wireless data transmission
- Sensor installation
- Sensor and node energy harvesting

Following figure can provide a general view to get rough interpretation of previously described system application. Yellow spots represent typical location of potential sensors for SHM system.



The variety of sensors needed in SHM system is wide to be dependent of the type of the event being monitored. Current SHMS development handle the sensors listed below. This baseline list is open to be refined upon further developments, experience and suggestion from de applicant in coordination with TP It is considered useful to set a ration quotation of the tasks being proposed.

The topic is focused not just in the type of sensor / equipment selected, but in the methodology of having the capabilities of wireless connectivity, energy harvesting and miniaturization (size reduction) and the realistic scenario of for its application and usage.

Sensor / Equipment	Enhancement
1. Piezoelectric (PZT)	Architecture
2. Fibre optic sensors (Fibre Bragg Gratings, FBG, Raleigh)	Performance in hostile environment (vibration, EMI,EMC)
	Local data acquisition and processing
3. Accelerometers	Wire / Wireless transmission
4. Classical strain gauges	Miniaturization (MEMS)
5. Temperature sensors	Energy harvesting
6. Sensors combinations, PZT+FBG 7. Rotation sensors 8. Microphones	Interface with DAQ & transmission data protocols

Communications protocols

Terms of communications protocols, will be defined in a later state to be compatible with A/C constraints. When the functionality might be interrupted, some level of back up recording should be provided

Enviromental scenario

Altough main development tasks will be proved in laboratory, final performance will be checked on flight. In consecuence, foreseen enviromental realistic scenario will be identified during the

development phase.
In principle, any type of structure i.e fuselage or lifting surfaces is candidate for being monitored during flight campaign what will require suitable number of sensors to prove foreseen system functionalities.

Sensor Qualification Assessment
The sensor qualification requiremets (accuracy in hostil scenarios and calibration) for the selected sensors will be explored (further details will be defined by ADS). The sensor qualification assessment will be required as deliverable before the flight test.

Flight test definition
As conclusion of the research, the sensors may be potentially installed in structural representativce components of Regional FTB#2 demonstrator where functional tests could be done under representative operational conditions. Flight tests decision witll be done after passing a Fligth Acceptance milestone in agreement with the Topic Manager.

Work organization proposal
The Topic should be organized in four technical Work Packages (WPs):

- WP1: Requirements. Exploration of SHM requirements for new sensors and specification of SNS, WDAQ and EH requirements. Requirements will be stablished in cooperation with the Topic Manager to be usable for measurements of SHMs in Regional aviation context –generally described above-. The work will start with the sensor set selection milestone, then the requirements for each type of sensor. The requirements will cover the specific operational range and accuracy of sensors and also the specificities requested by wireless connectivity and energy harvesting capabilities. Requirements will be agreed between the applicant and the Topic Manager.
- WP2: Sensor set selection. Design, development, manufacturing and test of sensors. This WP is devoted to the selection of the sensors that complies the requirements of WP1, the acquisition and complete characterization –if needed. The WP is devoted exclusively to the sensing capacity.
- WP3: Wireless connectivity: research and integration with sensor. Design, development, manufacturing and test of wireless DAQ + sensors. This WP is the first step of increasing capabilities of the sensors. It is devoted to design and develop the wireless connectivity. WP1 and WP2 are the sources of information and inputs for the design in this WP. The scope is to deliver the set of sensors that include the Wireless Data Acquisition integrated. Testing will confirm the functionality of the sensor and the wireless DAQ with respect to the requirements defined in WP1.
- WP4: Energy harvesting capability: research and integration. Design, development, manufacturing and test of energy harvester + DAQ + sensors. The second step of the topic is focused on the energy harvesting capability that need to be included in the results of the previous WP. The core of the WP is the selection of the energy harvester that allows working the sensor without additional source of energy. In the same way than the previous WP, testing will assess the deliverable against the requirements.
- WP5: Qualification and test**.** *S*ensors qualification assessment and tests. The final WP is devoted to comply with qualification tests of the final result of the topic. The qualification procedure will be established in agreement with the Topic Manager. The final demonstration will be done in controlled conditions, eventually in flight in the Regional FTB#2 demonstrator.

Tasks

Tasks		
WP1	***Requirements***	***Due Date***
WP1.T1	Exploration of SHM requirements for new sensors	T0 + 3
WP1.T2	Sensors specification and requirements	T0 + 6
WP1.T3	Wireless DAQ specification and requirements	T0 + 6
WP1.T4	Energy Harvester specification and requirements	T0 + 6
WP2	***Sensor set selection***	***Due Date***
WP2.T1	Sensors design or selection	T0 + 9
WP2.T2	Sensors manufacturing or acquisition	T0 + 12
WP2.T3	Sensors testing	T0 + 18
WP3	***Wireless Connectivity Research and Integration with Sensors***	***Due Date***
WP3.T1	Wireless DAQ design or selection	T0 + 9
WP3.T2	Wireless DAQ manufacturing or acquisition	T0 + 15
WP3.T3	Wireless DAQ + Sensors testing	T0 + 21
WP4	***Energy Harvesting Capability: Research & Integration***	***Due Date***
WP4.T1	Energy Harvester design or selection	T0 + 9
WP4.T2	Energy Harvester manufacturing or acquisition	T0 + 18
WP4.T3	Energy Harvester + Wireless DAQ + Sensors testing	T0 + 24
WP5	***Qualification for Flight Test***	***Due Date***
WP5.T1	Energy Harvester + Wireless DAQ + Sensors qualification for flight test	T0 + 30
WP5.T1	Energy Harvester + Wireless DAQ + Sensors installation for flight test	T0 + 32
WP5.T2	Energy Harvester + Wireless DAQ + Sensors flight test	T0 + 34

3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1	Sensors + Wireless DAQ + Energy Harvester requirements	R	T0 + 6
D2	Sensors + Wireless DAQ + Energy Harvester design/selection document	R	T0 + 9
D3	Sensors	HW+R	T0 + 12
D4	Wireless DAQ	HW+R	T0 + 15
D5	Energy Harvester	HW+R	T0 + 18
D6	Sensors testing	R+D	T0 + 18
D7	Wireless DAQ + Sensors testing	R+D	T0 + 21
D8	Energy Harvester + Wireless DAQ + Sensors testing	R+D	T0 + 24
D9	Final implementation of Energy Harvester + Wireless DAQ + Sensors for ground & flight testing	HW	T0 + 24

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D10	Final implementation of Energy Harvester + Wireless DAQ + Sensors qualification report	R+D	T0+30
D11	Flight test installation	R+D+HW	T0+32
D12	Final implementation of Energy Harvester + Wireless DAQ + Sensors flight test plan	R	T0+34
D13	Final report and system implementation delivery documentation	R+D+HW	T0 + 36

Milestones			
Ref. No.	**Title – Description**	**Type**	**Due Date**
M1	KOM		T0
M2	Final list of sensors to be developed		T0 + 3
M3	PDR		T0 + 6
M4	CDR		T0 + 9
M5	Sensors acceptance		T0 + 18
M6	Wireless DAQ acceptance		T0 + 18
M7	Energy Harvester acceptance		T0 + 24
M8	Acceptance of hardware final implementation		T0 +24
M9	Acceptance of hardware qualification		T0 + 30
M10	System ready to flight acceptance		T0 + 32
M11	Flight test acceptance		T0 + 34
M12	Final acceptance		T0 + 36

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

- Solid knowledge and experience in the following directives/guidance: DEF-STAN 00-970 Part1 Sect3, SAE-ARP-6461, MIL-STD-704, AMD-24, DO-160 and ABD100.1.8.
- Solid knowledge and capabilities for designing and manufacturing mechanical, electrical and electronic components.
- Deep knowledge in transducers/sensors development including MEMS-based, energy harvesting and wireless technologies.
- Solid knowledge of CAD mechanical/electrical design.
- Solid knowledge of control and acquisition systems, included SW open code development related based on National Instruments (LabVIEW/Veristand & Teststand, Matlab/Simulink).
- Engineering software and licenses for Computer Aided Design (CAD), and appropriate high performance computing facilities.
- Engineering software and licenses for LabVIEW/Veristand & Teststand, Matlab/Simulink, and appropriate high performance computing facilities.
- Capability of specifying, performing and managing, in collaboration with the Leader, the following:
  - Analysis of the mechanical, electrical and control/acquisition requirements.
  - Structural Health Monitoring (event and damage diagnosis) data acquisition
  - Power supply control/acquisition system definition.
  - Trade-off for selection of the industrial elements
  - Mechanical and Electrical CAD design for sensors and equipments manufacturing.
  - SW specification for control, acquisition, analysis and test report generation system.
  - Acceptance Test Procedure Definition.

- Quality System international standards (i.e. EN 9100:2009/ ISO 9001:2008/ ISO 14001:2004).
- CE marking.
- Experience in Structural Health Monitoring (for structure, systems and power plant).
- Experience in military and civil aircraft certification standards (structure, systems and power plant).
- Experience in aircraft structural tests and experience in aircraft systems tests.
- Experience in structure/systems reliability assessment.

5. Abbreviations

A/C	Aircraft	HW	Hardware
AC	Alternate Current	MEMS	MicroElectroMechanical Systems
CfP	Call for Proposal	PDR	Preliminary Design Review
CAD	Computer Aided Design	SHM	Structural Health Monitoring
CDR	Critical Design Review	MSN	Multitype Sensors Net
DAQ	Data Acquisition Equipment	SW	Software
EH	Energy Haverester	WP	Work Package
KOM	Kick-Off Meeting		

6. Clean Sky 2 – Fast Rotorcraft IADP

IV. JTI-CS2-2019-CFP10-FRC-01-28: Innovative concepts to incorporate multiple functions within a movable surface

Type of action (RIA/IA/CSA):		RIA	
Programme Area:		FRC	
(CS2 JTP 2015) WP Ref.:		WP 1.2.2	
Indicative Funding Topic Value (in k€):		500	
Topic Leader:	Leonardo Helicopter Division	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	24	**Indicative Start Date (at the earliest)[50]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-FRC-01-28	**Innovative concepts to incorporate multiple functions within a movable surface**
Short description	
For the NGCTR configuration a movable surface able to be used for multiple functions (download alleviation, flap, aileron) shall be investigated. The aim of this Topic activity is then to investigate innovative concepts for such a complex system and to address potential actuators families and installation schemes to incorporate those functions.	

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 CO_2 emissions	**Reducing NO_x 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

The NGCTR-TD configuration hosts several innovative wing aerodynamics components (inner large flaperon movable surface, external aileron) that will be flight tested in the framework of Clean Sky 2.
To manage and control those components, dedicated and complex kinematics mechanisms have been developed and integrated within the wing overall design, including the actuators and their systems.
In the NGCTR-TD each specific wing movable surface has been conceived to have a dedicated and specific function:

- An inner large flaperon up to +70 deg (down) deflections for download reduction, flap role
- An external aileron from -35 deg (up) up to +70 deg (down) deflections for roll control and download reduction

For the future NGCTR design and development the possibility to have a single movable surface able to incorporate multiple functions is worth being investigated. This solution, however, needs a careful study of the aerodynamics and kinematics of the system, together with the associated actuators deployment.
This study is the objective of this topic.

2. Scope of work

The Applicant shall structure its Proposal into five main Work Packages as hereafter described:

Tasks		
Ref. No.	***Title - Description***	***Due Date***
WP0	Management and project coordination	T0+24
WP1	Capture of the relevant subsystem requirements to be satisfied	T0+3
WP2	Preliminary study of 3 different proposed concepts	T0+12
WP3	Feasibility study of the selected concept	T0+24
WP4	Mock-up of the selected concept	T0+24

WP1: Capture of the relevant subsystem requirements to be satisfied
With the support of IADP leader, the Applicant shall capture the requirements that the movable subsystem has to guarantee, in agreement with the general aircraft behaviour and control, in a fully integrated manner with the other relevant wing components. The Workpackage will culminate in a SRR meeting where all requirements are set and captured. The key flight conditions to be explored for design substantiation will be defined by the IADP leader.
Inputs from IADP leader:

- NGCTR architecture, configuration and requirements – T0

Outputs from the Applicant:

- SRR meeting minutes and requirements frozen and captured - T0 + 3M

WP2: Preliminary study of 3 different proposed concepts
The Applicant, following the requirements capture, shall investigate and propose three different concepts able to fit the SRR outcomes. These three concepts will be discussed at the SFR meeting with IADP where, as entry criteria, each concept shall allocate specific functions in order to match the SRR needs. The outcome of this task is the selection, in agreement between Applicant and IADP leader, of the more promising concept to be further developed in next Work Package WP3. In this Work Package WP2 the studies will benefit from preliminary aerodynamic analysis support, even at zero-order level (i.e panel method) for a first evaluation of the associated loads, , including the aerodynamic loads during the surfaces deployment.

Outputs from the Applicant:

- Concepts schemes release – T0 + 12M
- SFR meeting minutes and concept selection - T0 + 12M

WP3: Feasibility study of the selected concept

The Applicant shall develop in detail (up to PDR level) the concept chosen in WP2 (exit of SFR) in order to guarantee the accomplishment of the concept PDR where the movable surface solution and its kinematic mechanism totally fit the integration within the tiltrotor wing. This Workpackage will be supported by a most accurate aerodynamics analysis (CFD) in order to identify the necessary set of loads acting on the movable surfaces during the deployment phase and at the fixed position.

Outputs from the Applicant:

- Chosen concept 3D CAD drawings and supporting documentation – T0 + 24M
- PDR meeting minutes - T0 + 24M

WP4: Mock-up of the selected concept

At the PDR the Applicant will support the functionality of the developed concept by means of a full scale mock-up of the movable system. The Mock-up shall include all the relevant items that characterize the concept, as embedded into the associated specimen of the fixed part of the wing. The mock-up is not a flyable item: anyway, it shall be fully representative of the concept. Availability of the Mock-up is part of the exit criteria of the PDR.

Outputs from the Applicant:

- Mock-up release - T0 + 24M

3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref. No.	**Title - Description**	**Type**	**Due Date**
WP2	Concepts descriptions (as per SFR)	R	T0+12
WP3	Chosen concept substantiation (as per PDR)	R	T0+24
WP3	Mock-up of the chosen concept	R,H	T0+24

Milestones			
Ref. No.	**Title – Description**	**Type**	**Due Date**
WP0	Kick-Off meeting	R	T0
WP1	SRR accomplished	R	T0+3
WP2	SFR for 3 proposed concepts accomplished	R	T0+12
WP4	PDR of the selected concept accomplished	R	T0+24

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

The Applicant must have qualified and demonstrated skills in Engineering study of advanced kinematics of movable surface and actuators management. Considering the peculiarity of the problem, the capability to evaluate the movable surface aircraft loads (aerodynamics, actuators) is then requested.

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
- Knowledge in actuator kinematics
- Capability to evaluate aerodynamics loads
- Capability in engineering integration of devices and subsystems
- Proven capability to manage projects by gathering several and different specialistic skills (numerics, flow field analysis, optimization) and demostrated capability to guarantee the project scheduling and milestones.
- A Consortium of partners is encouraged to apply this proposal

5. <u>Abbreviations</u>

IADP	Innovative Aircraft Demonstrator Platform
CFD	Computational Fluid Dynamics
SRR	System Requirement Review
SFR	System Functional Review
PDR	Preliminary Design Review
NGCTR	Next Generation Civil Tilt Rotor
TD	Technology Demonstrator

V. JTI-CS2-2019-CFP10-FRC-01-29: Smart Active Inceptors System development for Tilt Rotor application

Type of action (RIA/IA/CSA):		IA	
Programme Area:		FRC	
(CS2 JTP 2015) WP Ref.:		WP 1.2.3	
Indicative Funding Topic Value (in k€):		3500	
Topic Leader:	Leonardo Helicopter Division	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	39	**Indicative Start Date (at the earliest)[52]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-FRC-01-28	**Smart Active Inceptors System development for Tilt Rotor application**
Short description	
The present activity involves the design, development and qualification of smart fly-by-wire active inceptors system for the future generation cockpit of a civil tiltrotor. The design will be focused at improving functionalities for tilt rotor application capitalising on active features, and at optimising weight, dimensions and integration within novel distributed fly-by-wire Flight Control System. Activities will cover manufacturing of lab units as well as flightworthy units to be used in flight on NGCTR Technology Demonstrator.	

Links to the Clean Sky 2 Programme High-level Objectives[53]				
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 CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☐	☐	☐	☒	☒

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

[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 aim of the Fast Rotorcraft (FRC) project is to use technologies developed through the Clean Sky Programme to demonstrate a compound rotorcraft configuration that combines the vertical lift capability of the conventional helicopter with the speed capability of a fixed wing aircraft in a sustainable way. In the framework of Clean Sky 2 FRC IADP, the present Call requires Applicant/s (company or consortium) to provide innovative engineering solutions for the Tiltrotor NextGen CTR demonstrator cockpit inceptors. The present document describes also the general requirements that JU shall consider for the selection of the appropriate Applicant/s for this technology development.
The main objective of this new technology is to make piloting of Tilt Rotor more intuitive and effective; to achieve this, inceptors design has to be developed for this peculiar aircraft. Hence, the design has to focus on inceptors' mechanical interface and ergonomics so that FCS augmentation can be further improved. Moreover, increased situational awareness allowed by active inceptors can be made more specific by tailoring dedicated functionalities to Tilt Rotor application.
Finally, although active inceptors technology has reached a level of maturity adequate to allow deployment onto civil aircrafts, the most part of the commercially available active stick units relies on conventional avionic interfaces (analogue, ARINC 429, etc.). Typically, modern active stick units embed sufficient processing capability to control and monitor the active force-feel features of the controller, whereas they make use of Flight Control Computer I/O and processing capability to demodulate, monitor and select/vote the redundant flight critical stick positional sensor signals. Tiltrotor NextGen CTR will exploit an innovative Flight Control System design based on distributed processing power and high-speed digital broadcasting between Flight Control Computers and "smart" Flight Control equipment. The NGCTR cockpit flight controls will be hence required to operate as "smart" devices and to be interfaced with this innovative avionic architecture..

2. Scope of work

The main objective of this technology line is to design, develop, manufacture and qualify the cockpit inceptors system needed to translate the NGCTR pilots' basic inputs (pilot and co-pilot) into suitable digital commands to the aircraft Fly-By-Wire Flight Control System, whilst providing adequate cues to the crew.
The activity of the present call shall culminate with the achievement of SOF (Safety of Flight) qualification of the system in order to permit flight trials activities, and with the delivery of a shipset to be installed on NGCTR demonstrator aircraft. Flight activities using this shipset will fall beyond CleanSky2 framework and will be object of a separate and independent agreement between WAL and Applicant.
The Inceptors System shall allow aircraft control by translating the pilots' and co-pilot's basic inputs into suitable digital commands to the aircraft FCS, by means of

- pilot's and co-pilot's right-hand active inceptors
- pilot's and co-pilot's left-hand active inceptors
- pilot's and co-pilot's pedals[54]

It will be required to optimise design in order to define the best configuration, considering weight, volumes, power consumption, complexity, integration, availability, reliability.
Inceptors ergonomic and functionality shall be designed having pilot comfort and workload reduction as a target.
Each pair of right- and left-hand inceptors (i.e., pilots' and co-pilot's right-hand inceptors, pilots' and co-pilot's left-hand inceptors), shall be controlled to simulate a mechanical linkage between the two grips

[54] Pedals are intended as inceptors, as per SAE ARP 5764.

and to ensure that pilot and co-pilot inputs are coordinated and consistent. Pilots' and co-pilot's pedals shall be mechanically linked.
The whole system shall be suitable for dual-pilots operation. As basis of certification, single-pilot IFR operation has to be considered[55]; final decision will be taken before system preliminary design review.
Safety-wise, the system is a flight critical components of the FCS, and its design shall guarantee adequate integrity (for instance, leveraging on redundancy, design dissimilarity and other safety provisions defined during contract negotiations) to make sure that single or combined failures (within processing, electrical or mechanical domain) causing the pilots' command to get stuck, lost or corrupted are probabilistically irrelevant. The impact of relevant safety provisions (if any) and qualification aspects will be thoroughly analysed and discussed with WAL.
Finally, in order to support NextGen CTR Flight Control System development and integration tasks, the Applicant/s will develop, share with WAL and maintain for the whole project life a modelling and simulation tool of the flight control inceptors. The use of modelling and simulation tool, in its final version at the end of the project, will be granted to WAL also after the project termination.
The detailed requirements for the system interfaces with the aircraft shall be part of dedicated discussion with selected Partner(s), following the signature of dedicated NDA or equivalent commitment.
A preliminary system specification will be provided by WAL at starting of activities. The definitive specification will be issued within following 6 months.

Active functionalities

Every inceptor[56] shall be capable to provide feedbacks to the pilot by means of real-time force and/or haptic feedbacks (for instance, as described in SAE ARP 5764, variable spring gradients, force breakouts, detents, ramps, gates, soft/hard stops, etc)
Detailed definition of these feedbacks will be defined as a result of WAL operative requirements analysis, and will be aimed at improving pilots-FCS interaction for a tiltrotor application.
All functionalities will be programmable run-time by FCS. For instance, FCS can require run-time specific force gradient, friction values, and apparent mass, can require a detent, a soft-stop, a hard-stop, a stick-shaker, can request inceptor back-drive. The complete definition of these functionalities, their priority and how they will be commanded by FCS will be defined during project negotiations.

Interface with FCS

The Active Inceptors System shall be part of a distributed FCS.
It shall be capable of managing all its functionalities autonomously, for instance power supply, analogue and discrete signal conditioning, redundancy management, inceptors control, built-in test, self-monitoring, failure isolation capability, etc.
All buttons and switches located on inceptors' system, including grips, shall be managed (as defined in previous paragraph) by Active Inceptors System.
The Active Inceptors System shall communicate with FCS via digital busses only. Main protocol will be AFDX. A second bus protocol has to be considered; detailed requirement will be frozen during project negotiations.
The Active Inceptors System shall interact with FCS in order to receive commands specifying, for instance, mode of operation and/or functions parameters, and to provide feedback on inceptor position, grips discrete, system status. The complete list of signals to be exchanged will be defined during

[55] This could be achieved in different ways, for instance implementing an internal mechanical backup or reconfiguring the whole FCS Control Laws in a degraded mode in case of Active Inceptors System failure. Final decision will depend on actual implementation and will be agreed during negotiation phase.
[56] Including pedals.

development.
Care must be taken to ensure that FCS performance is not compromised by latency and jitter, which shall be reduced at acceptable level (to be defined during project negotiations).

Physical characteristics
Care must be taken in order to minimize system weight and dimensions, while taking into account its operational lifecycle, its operative condition and required functionalities and performances.
It will be required to optimise design with respect to installation, in order to facilitate pilots ingress and egress into the cockpit while minimising interface with other cockpit systems.

Tasks description

Tasks		
Ref. No.	**Title – Description**	**Due Date**
T1	Preliminary Design: Development of Active Inceptors System configuration and support of Preliminary Design Review. Preliminary digital mock-up models (DMU) and simulation models are prepared in support of PDR. This activity does not include left-hand inceptor design.	T0+16 months
T2	A-models delivery: Implementation of HW/SW design defined at PDR. The HW is manufactured (mock-ups / A models), the SW coded and tested; the equipments are functionally representative of the preliminary design, ready to be integrated at WAL's premises (for a single pilot configuration).	T0+20 months
T3	Detailed Design: Definition and development of detailed HW (inceptor bodies and control units) and SW design (ICUs embedded SW), support to smart inceptors Critical Design Review; the simulation models and analysis tools undergo a significant review and refinement process, the level of complexity is agreed between WAL and the Applicant/s.	t0+28 months
T4	B-models delivery (rig/sil): Fully representative units (EFA candidates, dual pilot configuration) are manufactured, incorporating feedbacks from Detailed Design and rig integration (activities T3 and T4). Support to WAL for integration into Flight Control System rig and into Tilt-Rotor cockpit, at WAL's facility.	T0+31 months
T5	B-models delivery (aircraft): Manufacturing of EFA flight-worthy units for WAL, incorporating possible feedbacks coming from qualification activities into B models design standard.	T0+36 months
T6	EFA Qualification testing: Following agreement of qualification test procedures and inceptors Test Readiness Review for EFA qualification, EFA qualification testing (environmental and functional qualification of HW, formal SW testing and qualification). Preparation of Qualification Test Reports and Declaration of Design and Performances (DDP) to allow start-up of experimental flight trials.	T0+36 months

A further activity to support flight activities and continued airworthiness shall be guaranteed beyond the timeframe of CleanSky2 by means of a separated and independent agreement between WAL and Applicant/s.

3. **Major Deliverables/ Milestones and schedule (estimate)**

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

Deliverables			
Ref. No.	**Title - Description**	**Type**	**Due Date**
D.1	Configuration development and Preliminary Design Review deliverables	R / D	t0 + 16 months
D.2	One functionally representative single-pilot rig shipset (A models), provided with a Preliminary DDP	HW / R	t0 + 20 months
D.3	Detailed HW and SW design, Critical Design Review deliverables	R / D	t0 + 28 months
D.4	Two fully representative rig shipsets (EFA candidates, B models, dual-pilot), provided with a Preliminary DDP	HW / R	t0 + 31 months
D.5	Technical documentation supporting TRR, Qualification Test Plan and Procedures, Validation Reports.	R	t0 + 31 months
D.6	One EFA shipset and spare units	HW	t0 + 37 months
D.7	Qualification Test Reports, EFA DDP	R	t0 + 39 months

Milestones			
Ref. No.	**Title – Description**	**Type**	**Due Date**
M1	System Requirement Review	RM	t0 + 2 months
M2	Preliminary Design Review	RM	t0 + 16 months
M3	Critical Design Review	RM	t0 + 28 months
M4	Test Readiness Review	RM	t0 + 31 months
M5	Experimental Flight Approval	RM	t0 + 39 months

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, either cockpit flight control systems, avionic systems (embedding complex HW and DAL-A SW) or both, according to RTCA-DO-160, RTCA-DO-178 and RTCA-DO-254 (or other civil or military equivalent standards) for safety critical equipments.
- 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 (or integration) in the following technology fields:
    - Cockpit flight controls, with particular emphasis on active stick design as per SAE-ARP-5764 guidelines.
    - High performance DC brushless servomotors and drive systems,
    - Compact and reliable sensors and switches.
    - High integrity control electronics.
    - Grip ergonomic design and optimisation.
- Capability to develop, manufacture, and qualify mechatronic devices

- 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.
- Experience in Safety assessment process according to SAE-ARP-4754A 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).
- Shape, component design and structural analysis using CATIA v5 and NASTRAN, or compatible SW tools.
- Capacity to optimize the HW and SW design, to model mathematically/numerically complex mechatronic systems with suitable simulation tools (Matlab/Simulink, Dymola/Modelica, etc.) and to analyse 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

AIS	Active Inceptor System
BIT	Built In Test
CAN	Controller Area Network
CDR	Critical Design Review
CS2	Clean Sky 2
DAL	Design Assurance Level
DDP	Declaration of Design and Performance
DMU	Digital Mock Up
DOA	Design Organization Approval
EFA	Experimental Flight Approval
EMC	Electro-Magnetic Compatibility
EMI	Electro-Magnetic Interference
FBW	Fly By Wire
FCS	Flight Control System
FRC	Fast RotorCraft
IADP	Innovative Aircraft Demonstrator Platform
ITD	Integrated Technology Demonstrator
JU	Joint Undertaking
FPP	Key Performance Parameters
NDA	Non Disclosure Agreement
NGCTR	Next Generation Civil TiltRotor
PDR	Preliminary Design Review
PR	Problem Report
SCU	Stick Control Unit
SIL	System Integration Laboratory
SOF	Safety of Flight
SRR	System Requirement Review
TBC	To Be Confirmed
TBD	To Be Defined
TTP	Time Triggered Protocol
TRL	Technology Readiness Level
TRR	Test Readiness Review
WAL	Work Area Leader

VI. JTI-CS2-2019-CFP10-FRC-01-30: Multipurpose bench for Tiltrotor equipment functional test

Type of action (RIA/IA/CSA):		IA	
Programme Area:		FRC	
(CS2 JTP 2015) WP Ref.:		WP 1.3	
Indicative Funding Topic Value (in k€):		800	
Topic Leader:	Leonardo Helicopter Division	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	36	**Indicative Start Date (at the earliest)[57]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-FRC-01-30	**Multipurpose bench for Tiltrotor equipment functional test**
Short description	
Innovative approach to perform functional testing at aircraft level through execution of simultaneous and integrated electro-avionics checks on aircraft equipment in order to reduce final assembly times. The main content of this Topic is to design, manufacture, test, develop and implement innovative Equipment that will reduce operator activities through automatic routines launched and witnessed. Emulation of electro-avionic equipment concept is also required to anticipate functional testing, avoiding installation and subsequent availability of valuable components. The activity will be splitted in two phases, one of which oriented to the Next Generation Tiltrotor Aircraft Demonstrator acting on Electrical Functional Test (Mainly Electrical Power Generation System) while the other one oriented on Development of automated Testing of Multiple Electro-Avionic Tiltrotor Functional Test and scalability analysis for larger Tiltrotor Aircraft.	

Links to the Clean Sky 2 Programme High-level Objectives[58]				
This topic is located in the demonstration area:			Tiltrotor Assembly	
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 CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☐	☐	☐	☒	☐

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

[58] 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

Functional Test activities are required during the Final Assembly of an Aircraft in order to verify If after the installation of the equipments, the functional requirements are in conformity with the design data set. Normally during this test phase operators spend huge amount of hours to:

- Install Electro-avionic equipments
- Complete electrical connections
- Run the test
- Detect errors
- Track the root cause
- Apply the corrective actions

All this activities present significative criticalities, that can be summed up:

- **Repetition of Standard activities:** operator during functional test spend different hour to connect/disconnect cables, generating time consuming that in several industrial application are superseed by automation.
- **Error Detection:** During functional test activity, if the operator detects anomalies, he has to stop the test and troubleshoot the problem, or, in worst case, escalate to manufacturing Engineering and Engineering Department to solve the issue.
- **Working Capital:** Functional test requires Electro-avionic equipments available; this represent an anticipation of high value components and, in case they are not available, cause the delay of functional test completion with negative impact at Aircraft Final Assembly Level.

All this criticalities can be solved by the implementation of a new concept of automated FTP :

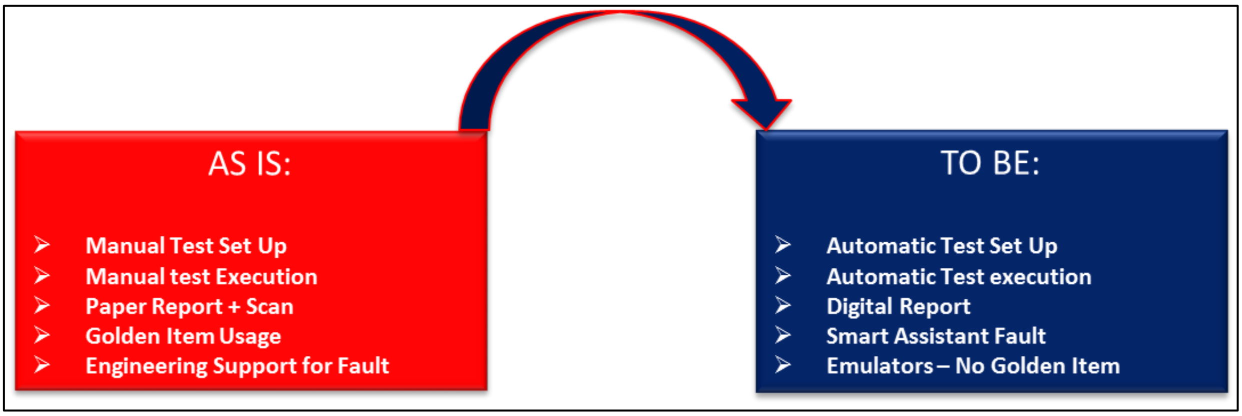


Figure 1

2. Scope of work

The Main Content of this Topic is to design, manufacture and test an innovative equipment to perform functional testing at aircraft level through execution of simultaneous and integrated electro-avionics checks on aircraft equipment in order to reduce final assembly time.

The new Testing approach will allow the following main targets:

- Human Factor Reduction (operator-ground technician activity limited)
- Troubleshooting Time Reduction
- Working Time Reduction
- New FTP-design approach customized to the new testing bench

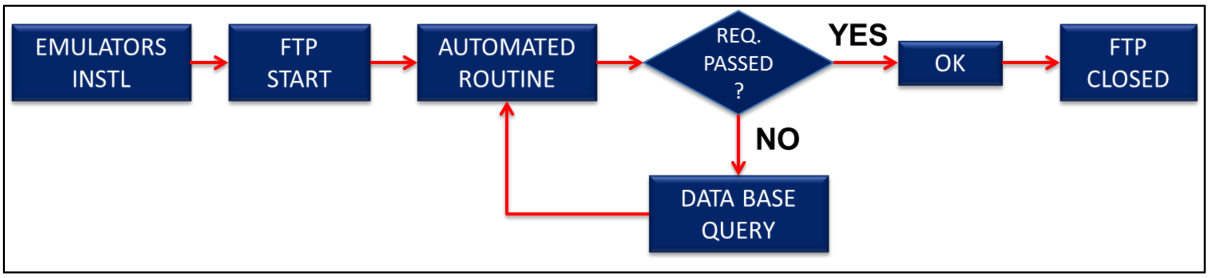


Figure 2 - Functional Testing flow

<u>Time Frame</u>

The aim of this Topic is to have a tested FTP Equipment available for TD final assembly and a development study for future family of Tiltrotors, and so a two-phase project is envisaged:

- **Phase 1:** For the NGCTR TD first flight phase (across 2023) the main activity will be oriented to generate an equipment able to manage with an automated process the testing required for, as a minimum, the Electrical Power Generation System, keeping avionic FTPs' as an option.
- **Phase 2 (Parallel/subsequent TD flight testing phases):** During this phase a Development activity will be conducted to analyze and simulate the multi-integrated FTPs, including Avionic requirements, with reference of TD configuration and further analysis for larger Tiltrotor.

Following such an assumption, the Applicant shall structure its Proposal into eight main tasks as hereafter described:

- **Task 0**: Management and project coordination
- **Task 1**: Phase 1 - Analysis and Design review
- **Task 2**: Phase 1 - Architecture and manufacturing of Electro-avionic equipment Emulators
- **Task 3:** Phase 1 - Test Bench manufacturing
- **Task 4:** Phase 1 – Firmware Development
- **Task 5:** Phase 1 – User Interface development
- **Task 6:** Phase 1 – Fault Data base development
- **Task 7:** Phase 2 – Analysis and Design review
- **Task 8:** Phase 2 – Development of Multipurpose FTP Test Bench

<u>Task 0: Management and project coordination</u>

Main objectives of this task are:

- Provide timely communication for the project with the Topic Manager and the CSJU Executive Team
- Perform risk evaluation analysis and regularly update the contingency plans
- Ensure that the agreed project objectives and deliverables are achieved, and ensure quality of work
- Facilitate communication and co-operation between project participants

<u>Task 1: Phase 1 -Analysis and Design review</u>

Functional Test Procedure of Electrical Power Generation and Requirement Specification will be transmitted to the applicant in order to analyse the "As is Process" in order to develop one or different proposals to achieve the targets.

Preliminary data from existing aircrafts will be shared as representative as input for the development phase of the project.

The Applicant is requested to investigate and to propose any approach that, in his knowledge and experience, can satisfy the requirement. Moreover the proposal should consider the possibility to adapt the system to the final configuration.

If multiple solutions are offered the final one will be discussed and agreed during the negotiation phase with the IADP Leader in order to clearly define the entry criteria for Task 1.
In order to properly manage possible conflicting requirements, the Applicant is requested to conduct trade-off studies on the subjects listed below:

- Emulators definition
- Automated procedure definition
- Fault and corrective actions data Base Definition

Inputs from IADP Leader at T0:

- Existing Functional Test procedures
- List of Electro-avionic equipment needed for the FTP
- Production Flow "As is" to be analysed with detailed schedule

The above data will be subjected to updates during Next Generation Tiltrotor Aircraft Configuration review and the requirements shall absorb those modifications.
Outputs from the Applicant at T0+8M:

- Report describing the proposals (Trade Off) from "as is " vs "To Be" methodology
- Detailed foreseen schedule
- Time reduction report

Task 2: Phase 1 - Architecture and manufacturing of Electro-avionic equipment Emulators
Task 2 includes the activities necessary for the design of the emulators needed for the Phase 1 FTP.
Electro-avionic equipment Emulators represent a key aspect of the proposed Automated FTP execution. This items will be used instead of the real components (that have an high Industrial Cost) during the Functional Testing Stage of Aircraft Assembly. Emulators will be kept installed until the Electro-avionic equipment installation will be required. The removal of emulators should not compromise the integrity of the previous installation done on the Aircraft, during the previous Stages.
With reference to the outcomes of the previous Task 1, the applicant shall design and manufacture electro-avionic equipments emulators and their integration inside the functional test procedure.
For the Electrical Power generation System functional test following Emulators will be needed:

- Power Distribution Units (PDU)
- Control Panel
- Circuit Breaker Panel

Inputs from IADP Leader Consortium:

- List of minimum Electro-avionic equipment needed

Outputs from the Applicant at T0+12M:

- PDR (Preliminary Design Review – go ahead with model detailed design)
- Preliminary Design Report

Outputs from the Applicant at T0+16M:

- Electro-avionic equipment Emulators
- Electrical Schemes
- Usage Manual

Task 3: Phase 1 - Test Bench manufacturing
Test Bench should be realized with commercial features that allow to manage multiple features (voltage, isolation, cross check, signal generation, active output generator) in order to perform all the steps needed for the ATP completion. This should reduce troubleshooting time of the ground technician. The reduction of cable connection is also required, in order to minimize time for cabling and space optimization, i.e. by the usage of Wi-Fi technology.
The software that manages the bench should be realized with an Open Access Software (Labview or

equivalent) and should support the operator showing the test executed versus the test planned, with the indication of target values and real values.
The applicant must be able to provide:
Bill Of Material;

- Bench integration;
- Test of Acceptance;

Outputs from the Applicant at T0+18M:

- Hardware delivery

Task 4: Phase 1 – Firmware Development
Firmware development and implementation will be articulated by the following features:

- Voltage measurement controlling
- Relays controlling
- External Power distributor controlling

Outputs from the Applicant T0+18M:

- Firmware Installation
- Documentation (Approved by IADP)

Task 5: Phase 1 – User Interface development
User Interface Development is needed to help operator activity and should be "user friendly" in order to facilitate also training.
The main activities should be:

- Graphic Interface Development
- Test Sequence Implementation
- Test Sequence Control and Validation

Outputs from the Applicant at T0+20M:

- Labview Application and source
- Documentation

Task 6: Phase 1 – Fault Data base development
Data Base should keep track of all executed Test on each Aircraft (also failed Test should be recorded in order to conduct statistical analysis). Level of data Storage will be set according to the real necessity.
Operator should produce queries through a mask and receive following information:

- Steps and description of failed test
- Useful information for the operator in order to solve issues (datasheet/images)
- Corrective Actions

When the operator accept the proposed corrective action, it will be possible to integrate further information. If other solutions can be adopted, it will be possible to update the database. This new solution should be accepted also by the Quality Control Area.
Outputs from the Applicant at T0+26M:

- Database e Software Module

Task 7: Phase 2 – Analysis and Design review
The automated FTP process for different Electro-Avionic Applications is complex and requires a robust analysis to demonstrate the real advantage respect the standard and current process. The Applicant is requested to investigate and to propose any approach that, in his knowledge and experience, can satisfy the requirement. Moreover the proposal should consider the possibility scale up to larger Aircraft Hypothesis (Scalability Concept).

Main topics that will be considered are the following functional Testing:

- Verification of the correct Avionic Equipment integration by software interrogation
- Fault detection, tracking and recording the message from avionic system
- Arinc 429, AFDX, Ethernet, Can Bus Protocol compatibility requirement

Inputs from IADP Leader:

- Functional Test procedures
- Production Flow "As is" to be analysed

Outputs from the Applicant at T0+20M:

- Report describing the proposals (Trade Off) from "as is " vs "To Be" methodology
- Time reduction report
- Detailed Schedule

Task 8: Phase 2 – Development of Multipurpose FTP Test Bench

The Applicant is requested to produce a study supported with the following equipment to demonstrate the efficiency (not at Aircraft level):

- Automated procedure definition
- Fault and corrective actions data Base Definition
- Firmware

Outputs from the Applicant at T0+32M:

- Hardware for Development Only
- Documentation
- Report of Return of Investment

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	Phase 1 - Analysis and Design review	T0+8 m
Task 2	Phase 1 - Architecture and manufacturing of Electro-avionic equipment Emulators	T0+16 m
Task 3	Phase 1 - Test Bench manufacturing	T0+18 m
Task 4	Phase 1 – Firmware Development	T0+18 m
Task 5	Phase 1 – User Interface development	T0+20 m
Task 6	Phase 1 – Fault Data base development	T0+26 m
Task 7	Phase 2 – Analysis and Design review	T0+20 m
Task 8	Phase 2 – Development of Multipurpose FTP Test Bench	T0+36 m

3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref. No.	**Title - Description**	**Type**	**Due Date**
D1	Design review	RM	T0+8 m
D2	Phase 1 Report describing the proposals (Trade Off) from "as is " vs "To Be" methodology	R	T0+8 m
D3	Design review	R	T0+12 m
D4	Electro-avionic equipment Emulators/ Electrical Schemes/ Usage Manual	D	T0+16 m
D5	Hardware delivery (for TD)	D	T0+18 m
D6	Firmware Installation (for TD)	D	T0+18 m
D7	System Documentation release	R	T0+18 m
D8	Interface Application and source	D	T0+20 m
D9	SW Documentation release	D	T0+20 m
D10	Database e Sofware Module release	D	T0+26 m
D11	Design review	RM	T0+16 m
D12	Phase 2 Report describing the proposals (Trade Off) from "as is " vs "To Be" methodology	R	T0+20 m
D13	Phase 2 Hardware delivery (full FTP development)	D	T0+32 m

Milestones			
Ref. No.	**Title – Description**	**Type**	**Due Date**
M1	Kick-off meeting	RM	T0
M2	Design review	RM	T0+8 m
M3	Report	R	T0+8 m
M4	Electro-avionic equipment Emulators Design review	RM	T0+12 m
M5	Electro-avionic equipment Emulators/ Electrical Schemes/ Usage Manual	D	T0+16 m
M6	Hardware delivery (for TD)	D	T0+18 m
M7	Firmware Installation (for TD)	D	T0+18 m
M8	Interface Application and source	D	T0+20 m
M9	Database and Software Module	D	T0+26 m
M10	Design Review	RM	T0+20 m
M11	Report	R	T0+20 m
M12	Hardware delivery, Documentation, ROI (for full FTP)	D	T0+32 m
M13	Final Meeting	RM	T0+36 m

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

The Applicant must have qualified and demonstrated knowledge in Electro-Avionic Aerospace together with proven expertise in Functional Test Equipment Design, Manufacturing and test. Program management is another fundamental required skill, being this topic a multidisciplinary project that needs firm control on schedule, cost, and risk.

Key components/capabilities of the applicant are listed below:
Project Manager: Resoponsible for Project Management, Cost & Schedule
Technical Leader: Hardware and Software Integration, Control, Coordination
HW Designer: Proven Experience in Electrical Power Application
SW Developer: Proven Experience in labview/simulink or simalar tool
Process Expert: Experience in lean & process improvement

5. Abbreviations

NGCTR	Next Generation Civil Tilt Rotor
TD	Technology Demonstrator
FTP	Functional Test Procedure
EPGS	Electrical Power Generation System
FAL	Final Assembly Line
PDU	Power Distribution Unit

VII. JTI-CS2-2019-CFP10-FRC-01-31: Engine exhaust wake flow regulator for Tilt Rotor

Type of action (RIA/IA/CSA):		IA	
Programme Area:		FRC	
(CS2 JTP 2015) WP Ref.:		WP 1.5	
Indicative Funding Topic Value (in k€):		1600	
Topic Leader:	Leonardo Helicopter Division	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	48	**Indicative Start Date (at the earliest)[59]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-FRC-01-31	**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[60]				
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 CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☒	☒	☒	☐

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

[60] 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 + 20
T05	Test Activity	T0 + 30
T06	System flight qualification	T0 + 42

(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**
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 + 20
D07	Failure Modes, Effect and Criticality Analysis (FMECA)	REPORT	T0 + 20
D08	Safety/Hazard Analysis	REPORT	T0 + 20
D09	Stress Analysis	REPORT	T0 + 20
D10	Final 3D models and layout drawing	CATIA FILES	T0 + 20
D11	Acceptance Test Procedures (ATP)	REPORT	T0 + 20
D12	Qualification Test Procedures (QTP)	REPORT	T0 + 20
D13	Qualification by Similarity and Analysis (QSAR)	REPORT	T0 + 30
D14	Production and Spare Unit, and relevant Data Conformity Documentation	HARDWARE and REPORT	T0 +30
D15	Final Performance Analysis	REPORT	T0 +30
D16	Acceptance and Qualification Test Reports	REPORT	T0 + 42
D17	Instruction for Continued Airworthiness	MANUAL	T0 + 42

Milestones			
Ref. No.	**Title – Description**	**Type**	**Due Date**
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 + 20
M05	Critical Design Review	DESIGN REVIEW	T0 + 20
M06	First Article Inspection	DOCUMENT	T0 + 24
M07	Test Readiness Review	DESIGN REVIEW	T0 + 24
M08	Production units delivered to Leonardo Helicopters for flight tests	HARWARE AVAILABILITY	T0 + 30
M09	Flight Qualification Closure	DOCUMENT & DESIGN REVIEW	T0 + 42

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:
  o Conventional exhaust system development for aircraft, helicopter or tiltrotors
  o Actuation systems
- 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

7. Clean Sky 2 – Airframe ITD

I. JTI-CS2-2019-CFP10-AIR-01-41: Low speed handling quality and innovative engine integration of a new configuration aircraft

Type of action (RIA/IA/CSA):		IA	
Programme Area:		AIR	
(CS2 JTP 2015) WP Ref.:		WP A-1.3	
Indicative Funding Topic Value (in k€):		700	
Topic Leader:	Dassault Aviation	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	24	**Indicative Start Date (at the earliest)[61]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-AIR-01-41	**Low speed handling quality and innovative engine integration of a new configuration aircraft**
Short description	
The purpose of this topic is to design, manufacture (using Additive Layer manufacturing technology) and test at low speed a model representative of a new configuration. This model will consist of a new fuselage, new tails and new nacelle and an existing wing in high-lift configuration (that will set the model scaling). Wind tunnel tests will be performed to analyse the handling quality, air intake distortion and flow topology (using PIV for example) of this new configuration in low speed configuration. Different geometries will be tested on the fuselage and the tail. New measurement techniques as PSP and PIV will be applied to low speed wind tunnel tests in order to better understand local phenomena.	

Links to the Clean Sky 2 Programme High-level Objectives[62]				
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:		Low speed Business Jet		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☒	☐	☒	☐

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

[62] 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 this topic is to analyse the handling quality, inlet distortion and flow topology of a new configuration of business jet in low speed conditions for a wide variation of angles of attack and sideslip. This new configuration will be based on an existing wing. The wing scale is 1/10 with mean aerodynamic chord equal to 0.25 m and spanwise length equal to 2.5 m (full span). The planform of the wing is presented on Figure 1. The high-lift configuration of this wing already exists.

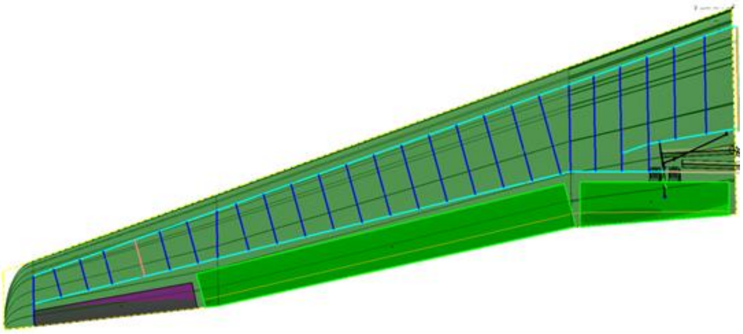


Figure 1 : Planform of the wing that will be used

The remaining parts of the model to design and to manufacture are:

- A new fuselage that will have to be adapted to the existing wing in high-lift configuration. Removable parts will have to be provided on the fuselage in order to allow changes of shape. The maximum length of the fuselage will be 2.2 m (scale 1/10).
- Three variants of geometry for HTP.
- Three variants of geometry for VTP.
- Three nose cones.
- Two sets of nacelles. The nacelles will be transparent.
- Two geometries of after-body for the fuselage.

These different parts will be manufactured by using Additive layer manufacturing technology.

During this topic this model will be tested in a low speed wind tunnel for a Reynolds number corresponding to 1 - 1.6 million (based on mean aerodynamic chord equal to 0.25m). A wide variation of angles of attack and sideslip will be performed.

Interaction between fuselage and engine will be analysed during wind tunnel tests:

- Distortion will be measured in the nacelle inlet with a rake to be designed, manufactured and tested
- PIV will be used to visualize the flow interaction between the nacelle and the fuselage.

Visualization of pressure distribution on the fuselage will be performed by using PSP measurement technique.

2. Scope of work

The activities to be performed by the applicant are summarised below:

Fuselage design and manufacturing

Wing in high-lift configuration will be provided by the Topic Manager.

The Applicant shall design and manufacture by using Additive Layer manufacturing technology:

- A new fuselage that will have to be adapted to the existing wing in high-lift configuration. Removable parts will have to be provided on the fuselage in order to allow changes of shape. The maximum length of the fuselage will be 2.2 m (scale 1/10).
- Three variants of geometry for HTP.
- Three variants of geometry for VTP.
- Three nose cones.
- Two sets of nacelles. The nacelles will be transparent.
- Two geometries of after-body for the fuselage.

These parts of the model must be made of aluminium or steel.

Design and manufacturing of rake for distortion measurement in nacelle intake

The Applicant shall design, manufacture, calibrate and test the rake that will be used during wind tunnel tests to measure distortion in the nacelle intake. The rake will be equipped with unsteady pressure measurement sensors.

Wind Tunnel Test

The Applicant will test this new aircraft configuration in low speed conditions (Mach number around 0.2 – 0.3) with wide variation of angle of attack α and sideslip β: $-5° < \alpha < 25°$ and $-25° < \beta < 25°$. Reynolds number based on mean aerodynamic chord 0.25 m will be around 1 – 1.6 millions.

Different geometrical variants of the fuselage, HTP and VTP will be tested in take-off and landing configurations. Efficiency of HTP and VTP will be assessed.

The variants will include:

- Two variants of after-body (including nacelles)
- Three sets of HTP and VTP
- Three variants of nose cones.

The Applicant shall suggest innovative visualization means including:

- PSP on the fuselage to visualize pressure distribution and to identify flow separation areas.
- PIV to visualize flow interaction between nacelle and fuselage

It is proposed to structure the technical activities in the following tasks:

Tasks		
Ref. No.	**Title - Description**	**Due Date**
T1	Design of the fuselage and its different variants	T0+6
T2	Manufacturing of the fuselage and its different parts	T0+9
T3	Design of the rake for distortion measurement in nacelle intake	T0+12
T4	Manufacturing and test of the rake for distortion measurement	T0+14
T5	Perform WTT	T0+18
T6	Write the test report	T0+24

3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1	Fuselage geometry and its variants	HW	T0+9
D2	Rake for distortion measurement in nacelle intake	HW	T0+14
D3	Test results	D	T0+20
D4	Test report	R	T0+24

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	PDR for fuselage and its variants	RM + Rt	T0+3
M2	CDR for fuselage and its variants	RM + R	T0+6
M3	PDR for Rake for distortion measurement	RM + R	T0+9
M4	CDR for Rake for distortion measurement	RM + R	T0+12
M5	Entry in the tests section	RM	T0+18
M6	Tests results	D+ R	T0+24

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

- The Applicant shall have a large experience in designing and manufacturing model parts by using Additive Layer manufacturing technology.
- The Applicant shall have a large experience in designing and manufacturing a rake for distortion measurement in nacelle intake (unsteady pressure measurement).
- The Applicant shall have a large experience in PSP and PIV measurement techniques.
- The Applicant shall be proficient in using software compatible with CATIA V5 r20 (Design modules in particular) in order to exchange easily geometry models data with Topic Manager.
- The Applicant shall have a large experience in testing at low speed conditions and low Reynolds number.
- The applicant shall have confidential agreement(s) with all partners participating in the new aircraft configuration to which this topic is related. To be managed by the Topic Manager.

5. Abbreviations

WTT	Wind Tunnel Test
PSP	Pressure-sensitive paint
PIV	Particle Image Velocimetry
HTP	Horizontal Tail Plane
VTP	Vertical Tail Plane

II. JTI-CS2-2019-CFP10-AIR-01-42: Development of a methodology (test, measurement, analysis) to characterize the behaviour of composite structures under dynamic loading

Type of action (RIA/IA/CSA):		RIA	
Programme Area:		AIR	
(CS2 JTP 2015) WP Ref.:		WP A-1.4	
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)[63]:**	> Q1 2020

Topic Identification Code	Title
JTI-CS2-2019-CFP10-AIR-01-42	**Development of a methodology (test, measurement, analysis) to characterize the behaviour of composite structures under dynamic loading**
Short description	
The purpose is to develop a methodology (including innovative tests, measurements, and analysis methods) to properly characterize the dynamic behaviour up to rupture of composite structures submitted to a dynamic loading. Typical structural items (material, stacking, geometries, fasteners etc.) will be provided by the Topic Manager. Simulations could be used to prepare and analyse tests. A methodology will also be developed to demonstrate prediction capabilities.	

Links to the Clean Sky 2 Programme High-level Objectives[64]				
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:		Low Sweep Business Jet		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☐	☐

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

64 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

Into the ITD Airframe part A, this CfP is linked to WP A-1.4 oriented to virtual modelling for certification and specifically to WP A-1.4-2 on advanced criteria for rapid dynamic / crash modelling for safety.

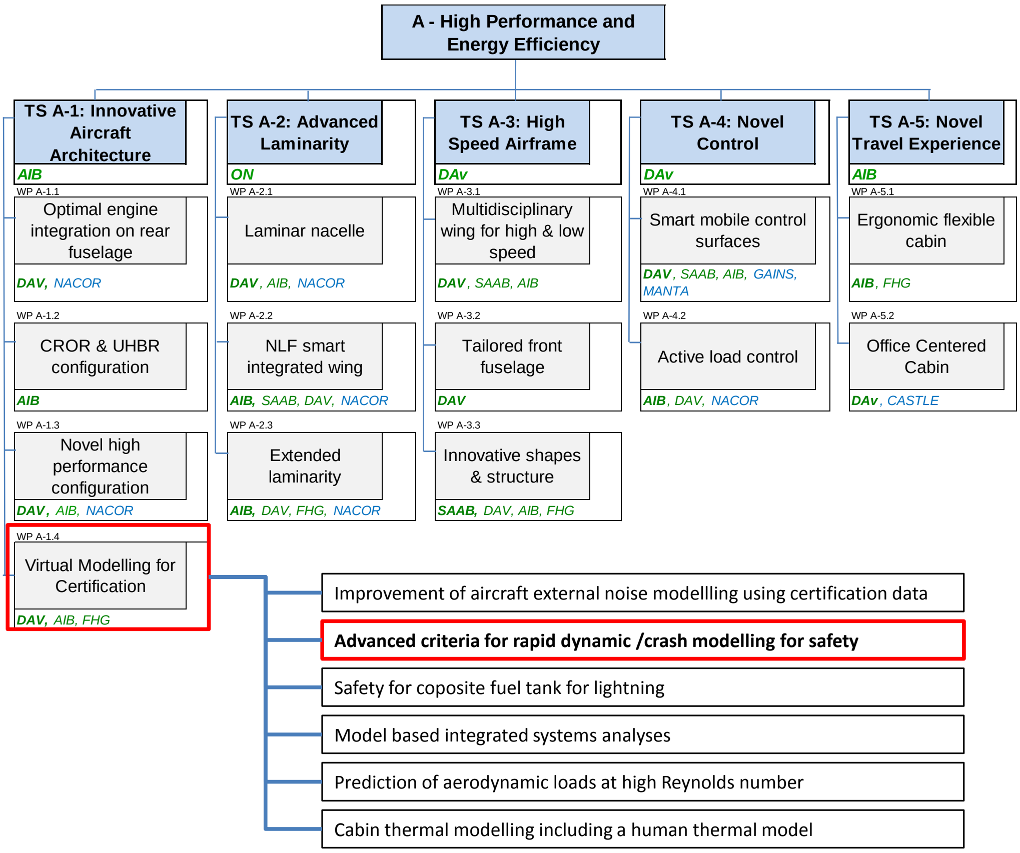


Figure 1 - ITD Airframe Activity Line A WBS structure

Emergency situations (bird strike, tire debris impact, engine fragment impact, crash, etc.) are key issues for the safety assessment of an aircraft. They are therefore fully integrated to the certification process required by aviation regulation authorities. Besides pilot and crew management, systems analyses, etc., aircraft manufacturers must demonstrate the capability of the structure to withstand resulting loading conditions and induced damages.

The specificity of these emergency situations analyses is mainly that the aircraft structure is subjected to very high and dynamic loads leading to large deformations, damage initiation and propagation, and possibly rupture. For long, classical analysis methods not being able to accurately handle these specific behaviours, associated design and certification have mainly relied on dedicated tests, most often at full scale or component level. During past decades, to reduce delays, costs and risks, numerical analysis methods have been developed and improved. The achieved maturity level allows aircraft manufacturers to introduce these methods in design phases and more recently to certification processes. Nevertheless, the calibration and validation of the associated structural and material models is still a key challenge, especially heading to certification by analysis.

The classical building block approach relies on four levels and constitutes the basis for model calibration and validation. The linked, parallel, and complementary process between simulations and tests is a key issue to achieve a robust and cost effective design and certification.

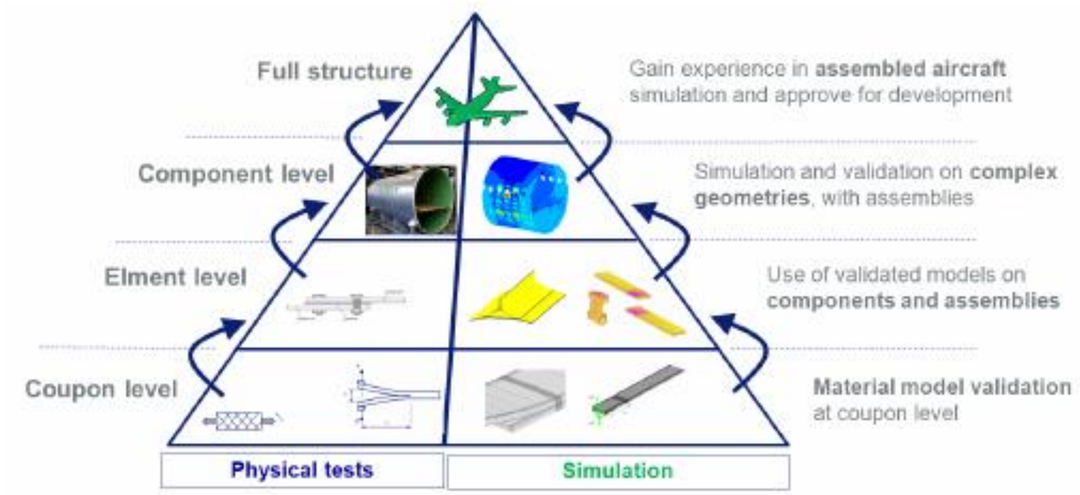


Figure 2 - Pyramid of tests as a basis for model calibration and validation

For static or fatigue purposes, tests and analysis methods to define material and structural characteristics at the lower levels of the pyramid have been widely developed and standardized to industrial uses. For rapid dynamic purposes, these methods are still mainly under development at research level. Calibration and validation of numerical models are then based on component or full structure tests associated to static characteristics at coupon and element levels. This approach may be valid for most of the classical airframe metallic alloys, such as aluminium 2024, as their mechanical properties are not very sensitive to strain rate effects. Composite materials, on the other hand, exhibit more strain rate effects. Robust and industrial dedicated dynamic coupon and element level tests, analysis and modelling methods may then be necessary to design and certify composite airframe structures to emergency situations.

AIR ITD WP A-1.4-2 main objectives are to:

- Identify available dynamic structural and material modelling, tests and analysis methods.
- Develop a calibration and validation process at coupon and element levels suitable for industrial application.
- Demonstrate how the new methods contribute to more efficient and robust design and certification processes.

Figure 3 illustrates the WP high level work-breakdown structure as well as the collaboration scheme between Topic Manager and partners:

- The Topic Manager will contribute to industrial state of the art and specification of needs as input for the partner activities.
- Within the scope of the CfP, partners will develop both experimental and modelling approaches to define dynamic structural and material properties. The CfP activities are divided into five tasks as described in next section.
- The Topic Manager will implement the developed process and demonstrate its contributions on use cases.

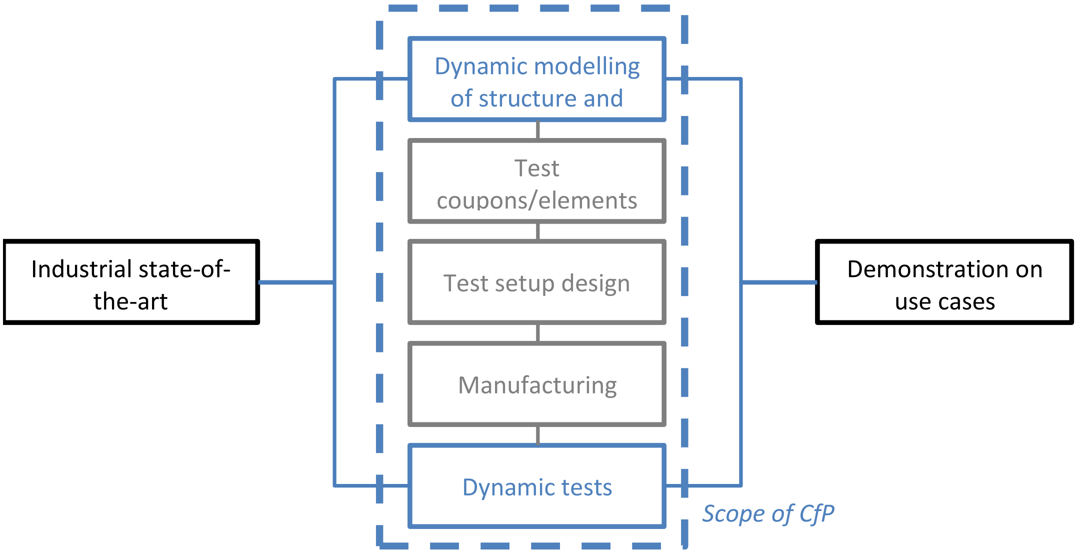


Figure 3 – WP Advanced criteria for rapid dynamic / crash modelling for safety WBS

2. Scope of work

It is proposed to structure the technical activities in the following tasks:

Tasks		
Ref. No.	**Title - Description**	**Due Date**
T1	Dynamic modelling of structure and material	T0 + 36
T2	Test coupons / elements design	T0 + 12
T3	Test setup design	T0 + 12
T4	Manufacturing	T0 + 24
T5	Dynamic tests	T0 + 30

The objectives of the technical activities proposed are the following:

- Define a modelling approach suited to industrial needs for emergency situations applications (e.g. bird strike on a composite structure)
- Define associated dynamic tests (samples, experimental setup, etc.)
- Define a calibration and validation process
- Demonstrate and evaluate the proposed methodology based on tests performed within the CfP activities

The focus will be on the characterization of the material properties at various strain rates necessary to analyse the behaviour and rupture of a composite panel under impact. The panel may include assembly zones (e.g. bolts or rivets) and co-bonded stiffeners. The composite of interest is an epoxy-carbon fibre prepreg.

T1 – Dynamic modelling of structure and material

Based on the industrial state-of-the-art and specification of needs provided by the Topic Manager, partners will propose a modelling strategy (modelling methods and associated calibration and validation process) compatible with industrial needs. Selected methods, structural and material models, and tools will be used to:

- design tests (sample designs, experimental setup, instrumentation, loadings etc.) in tasks T2 and T3,
- analyse tests results from task T5,

- demonstrate the calibration and validation process proposed.

Modelling methods shall be either implemented in widely used commercial software (e.g. Abaqus, RADIOSS, NASTRAN, etc.) or in an open source alternative.

T2 – Test coupons / elements design

Partners will propose and define test samples dedicated to the dynamic characterization of the composite material associated to test setups defined in task T3. The characterization shall encompass:

- Tension, compression, shear and flexion behaviour and rupture
- Notch effects
- Stacking sequence effects
- Bearing effects
- Behaviour of co-bonded interfaces

The industrial specification of needs provided by the Topic Manager will limit the number of configurations to be explored to two stacking sequences, two notch/fasteners diameters, and one type of co-bonded interface. Selection of test specimen designs will be performed in cooperation with the Topic Manager.

T3 – Test setup design

Partners will propose and define test setups dedicated to the dynamic characterization of the composite material associated to test specimen defined in T2. The definition shall encompass:

- The type and category of test machines
- Adapted mounts or test rigs if needed
- The instrumentation (e.g. strain gauges, dynamic load cells, digital image correlation, thermography, etc.)
- Various loading conditions (strain rate effects)

Selection of test setups will be performed in cooperation with the Topic Manager.

T4 – Manufacturing

Partners will manufacture test specimen based on tasks T2 and T3 designs with the specified composite material (epoxy-carbon fibre prepreg) to be tested in task T5. Test coupons shall be manufactured using prepreg-autoclave process. Manufacturing process specifications will be provided by the Topic Manager. If needed, partners will be asked also to manufacture necessary parts to adapt test specimen to existing machines.

T5 – Dynamic tests

Partners shall perform dynamic tests as defined in task T3 by using samples manufactured in task T4. The test program shall be agreed with the Topic Manager. A test report including measurement data will be delivered. Test results will be analysed in task T1.

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

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1.1	Description of the proposed modelling strategy	R	T0 + 6
D2.1	Tests specimen definition	R	T0 + 12
D3.1	Experimental setups definition	R	T0 + 12
D4.1	Test specimen	HW	T0 + 24

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D5.1	Test program	R	T0 + 18
D5.2	Test report	R	T0 + 30
D5.3	Test data	D	T0 + 30

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	Modelling methods available	R	T0 + 6
M2	Tests specimen and setups definition approved	R	T0 + 12
M3	Specimen manufacture review	R	T0 + 24
M4	Test readiness review	R	T0 + 25
M5	Test evaluation review	R	T0 + 30

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

Expected special skills:
- Proven experience in dynamic composite numerical modelling (nonlinear Finite Element Method)
- Proven experience in composite design and manufacturing
- Proven experience in static and dynamic testing of structural materials
- Proven experience in dynamic measurements for material characterization
- Proven experience in technological research and development
- Proven experience in working with suppliers of composite material
- Proven experience in collaborating with aeronautical companies

Capabilities required:
- Suitable manufacture and machining facilities for test specimen production
- Composite curing facilities
- Laboratory facilities for dynamic mechanical testing

5. Abbreviations

CfP	Call for Partners	WBS	Work Breakdown Structure
ITD	Integrated Technology Demonstrator	WP	Work Package

III. JTI-CS2-2019-CFP10-AIR-01-43: Verification of advanced simplified HLFC concept with variable porosity

Type of action (RIA/IA/CSA):		RIA	
Programme Area:		AIR	
(CS2 JTP 2015) WP Ref.:		WP A-2.3	
Indicative Funding Topic Value (in k€):		750	
Topic Leader:	German Aerospace Center, DLR	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	18	**Indicative Start Date (at the earliest)[65]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-AIR-01-43	**Verification of advanced simplified HLFC concept with variable porosity**
Short description	
The main objectives of this topic are: • Verification and validation of the aerodynamic and structural design of the advanced, simplified Tailored Skin Single Duct (TSSD) HLFC suction segment, featuring variable porosity and an easily demountable leading edge in low-cost design. • Realization (design, manufacturing, calibration and application) of a high-precision mass flow measurement, necessary for the validation of single suction duct concepts within wind tunnel tests. • Investigation of "natural transpiration" effects (adverse off-design condition)	

Links to the Clean Sky 2 Programme High-level Objectives[66]				
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:		Ultra-advanced Short/Medium range		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☐

[65] The start date corresponds to actual start date with all legal documents in place.
[66] 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 order to reach the goals of Flightpath 2050, a significant decrease of fuel consumption of passenger aircrafts is mandatory. Today boundary layer laminarization trough hybrid laminar flow control (HLFC) appears to be one of the most promising technologies to make the necessary step forward.
State of the art HLFC suction panels are designed with an internal chambering to provide the chord-specific suction distribution on the outer skin. This leads to a number of constraints between aerodynamic, structural design and manufacturing. Also the manufacturing itself is highly complex due to a large number of internal chambers.
Current activities of the German Aerospace Center DLR have the goal to simplify this suction nose layout by omitting the internal chambers. For this reason the so-called Tailored Skin Single Duct (TSSD) concept was developed. The TSSD is based on a multi-layered tailored outer skin with an intrinsic pressure loss distribution. A micro-perforated metallic foil to ensure a homogeneous control of the boundary layer realizes the outer surface. A specific laminate on the backside of the outer layer provides the necessary chord-wise suction distribution. By using this tailored outer skin, only one internal collector duct with a fixed plenum pressure is necessary.
Due to this approach, the design of the HLFC leading edge could be optimized regarding structural requirements – like bird strike resistance and less weight penalty compared to non-HLFC leading edges. Also the manufacturing is drastically simplified. Due to the absence of individual chambers it is possible to create a full demountable leading edge design, which will, as an additional advantage, enhance the accessibility for cleaning and repair as well as the interchangeability of components.
To validate this design concept a real scale wind tunnel test is necessary. For this reason a 2.0 m TSSD leading edge segment will be manufactured and mounted on a surrogate fin for the wind tunnel test. The goal of the test is to validate the function of the TSSD concept by measuring the laminar flow, the transition and the mass flow of the boundary layer suction. Also the effect of outflow caused by unsymmetrical flow conditions and low suction pressures, the so-called natural transpiration, should be tested and validated.

2. Scope of work

It is proposed to divide the technical activities related to this CfP into four main tasks, as described below.

Tasks		
Ref. No.	***Title - Description***	***Due Date***
T1	Definition of global test plan and schedule	T0+3
T2	High-precision mass flow measurement: concept definition, instrument design and manufacturing	T0+10
T3	Preparation of wind tunnel test	T0+12
T4	Performing of wind tunnel tests and documentation of the results	T0+18

The main focus will be on the execution of the wind tunnel test campaign. The objective of the wind tunnel test is to verify and validate the aerodynamic and structural design of the TSSD concept developed for the purpose of HLFC. Figure 1 shows the schematic design of the leading edge and the outer skin to be tested.

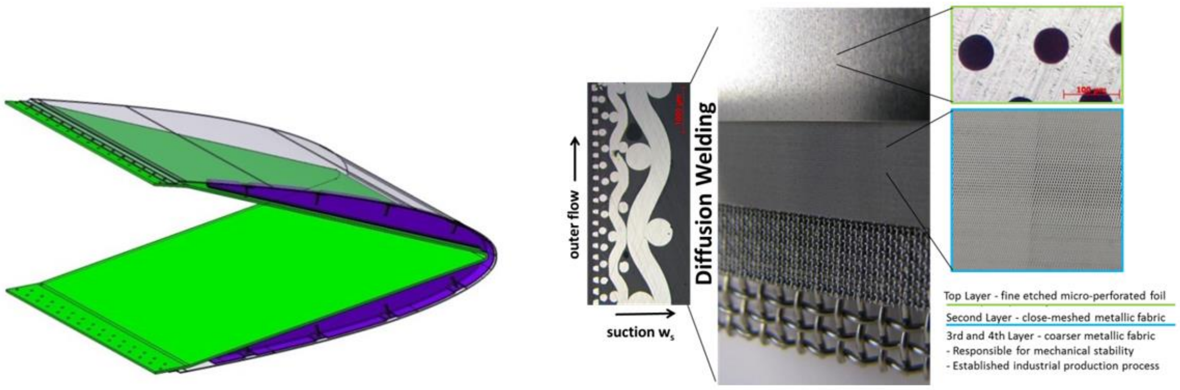


Figure 1. Structural design of nose (left), TSSD leading edge concept; multi-layered hybrid suction skin (right)

Of course, precise measurement of the suction mass flow rates needed to prevent early transition due to crossflow instability is a crucial point for the assessment of the TSSD concept with respect to the prediction of performance gains in future applications. However, from a scientific point of view, another very relevant reason for high precision mass flow measurements is connected with the transition prediction based on the N-factor method.
Currently, limiting N-factors for both, Tollmien-Schlichting and crossflow instabilities are used that, in cases where boundary layer suction is applied, are substantially lower than those for transition in natural laminar flow (NLF).
In order to improve confidence into the N-factor method, this discrepancy needs to be investigated and hopefully can be resolved. As it can be seen from Fig. 2, the fin model to be used in the tests will allow for transition detection behind the TSSD panel as well as on a NLF reference panel, located more towards the top of the fin. However, for a N-factor correlation with and without suction based on data from these tests it is mandatory not only to measure free stream values, surface pressure distribution and transition location, but also the suction mass flow rates as accurately as possible.
Therefore, after the initial planning and definition of the timetable (applicant together with Topic Manager), a high precision mass flow measurement system has to be developed and prepared for wind tunnel implementation. Measurement range of the system shall be 0.05kg/s to 0.20kg/s with a relative error of the measurement not higher than +/- 1% FSO. Accuracy of the system has to be demonstrated by comparative measurements against a calibrator.
For the wind tunnel test itself, the test hardware, consisting of the HLFC leading edge segment and the carrier fin, will be provided by the Topic Manager. The wind tunnel model (Figure 2) comprises:

1. A carrier fin which was aerodynamically designed in order to replicate the surface pressure distribution and Reynolds number of an A320 VTP in cruise flight for test conditions in a low speed facility. The fin has an aft-swept mono-trapezoid planform with a chord length of 4.9m at root, 2.224m at tip and a span (or height, respectively) of 4.45m. Leading edge sweep is 40.38°. The profile shape is symmetrical with 12% relative thickness.
2. An exchangeable leading edge segment that allows for boundary layer suction to suppress unstable disturbance that might lead to premature transition. For the planned TSSD tests, the suction nose, structurally designed by the Topic Manager, consists of an outer, micro perforated skin from hybrid material that is connected via ribs to a triangular shaped splitter (see Fig. 1).
3. A remotely controlled rudder, with the rudder hinge line located at 70% chord.

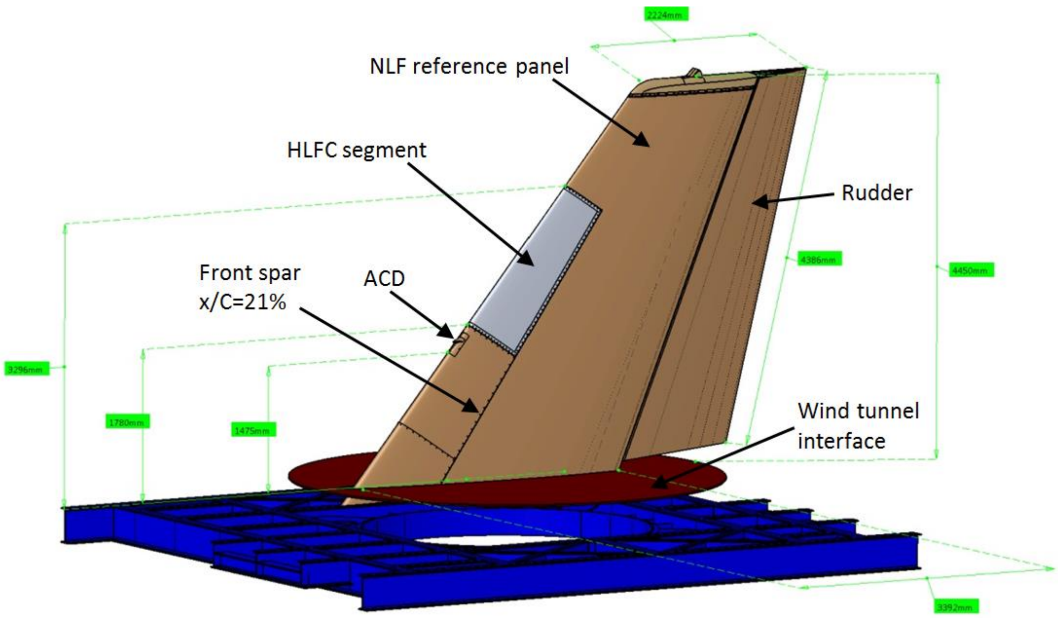


Figure 2. Carrier fin with exchangeable HLFC nose segment

The applicant has to ensure a safe mounting of the model on the tunnel turn table by providing appropriate adapters to the model bearing blocks. Furthermore, streamlined fairings to seal the model against the tunnel floor have to be provided / adapted by the applicant. Figure 3 gives a rough overview to the needed installation space. The specific mounting and installation details will be clarified within the Task 3 – Preparation of wind tunnel test.
In order to match the aerodynamic layout of the model with respect to Reynolds and Mach number, test conditions in the tunnel shall allow for wind speeds up to 100m/s at ambient static pressure and temperature of the standard atmosphere at mean sea level. For the laminarization tests, it is necessary to vary the side slip angles in the range of +/- 4° and rudder deflections of +/-2°.

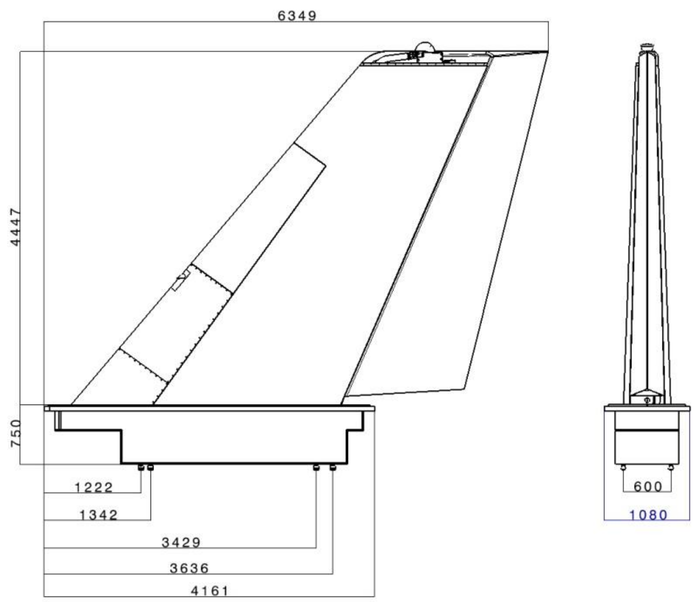


Figure 3. Installation space and mounting dimensions

The instrumentation of the model allows for measuring the surface pressure, the boundary layer state

at the attachment line as well as all relevant suction plenum and duct quantities (pressures, differential pressures and temperatures). Transition of the boundary layer flow from laminar to turbulent flow downstream of the suction panel will be determined by infrared imaging with IR-cameras located in the tunnel side walls. In order to enhance quality of the IR-images, the carrier fin is equipped with remotely controlled heating mats. The underpressure in the plenum has to be provided by pumps located outside of the model and the wind tunnel test section, respectively.
The model (HLFC segment as well as the carrier fin) is already equipped with all pressure taps, temperature sensors and hot-film sensors needed. The interface to pressure hoses and wiring from the sensors is located at the root of the model.

The following equipment has to be provided by the applicant:

- Pressure transducers, signal conditioners for temperature and hot-film sensors as well as data acquisition and storage systems.
- Suction pump(s) to provide the underpressure in the plenum of the HLFC nose. Pumps have to deliver a pressure difference between ambient static pressure and plenum ranging from 500Pa to 8000Pa at mass flow rates ranging from 0.05kg/s to 0.2kg/s.
- Provision for optical access allowing for infrared imaging from the tunnel side-walls. If not available, IR-cameras and equipment can be provided by the Topic Manager.

In addition to the laminarization tests, the test matrix shall cover the investigation of the effect of "natural transpiration". Natural transpiration occurs in case the suction system is off which will lead in zones of high surface pressure, i.e. at the attachment line and its vicinity, to an inflow into the nose box while in regions of low pressure there will be an outflow. The outflow, which eventually can become a more or less strong blowing through the micro-perforation, may lead to an early separation of the boundary layer flow. Test runs will be performed in order to check this effect and to build up a data basis for validation of subsequent numerical investigations on this issue.
In addition, instrumentation for these tests shall consist of tufts and boundary layer rakes to be provided by the applicant.

Tasks		
Ref. No.	**Title - Description**	**Due Date**
1	Management, coordination & report	T0+23
2	Survey and report of previous work and publications	T0+1
3	Biochemical modification of hemolymph	T0+13
4	Identification of physico-chemical key factors of surface contamination	T0+9
5	Development of surface coating solutions	T0+17
6	Development of self-repairing slippery surface	T0+17
7	Development of pre or post contamination cleaning solution	T0+17
8	Wind tunnel test, erosion test and flight test of the developed anticontamination and cleaning solutions	T0+29

3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1	Mass flow measurement system manufactured and accuracy demonstrated	HW	T0+10
D2	Raw data available for further analysis by Topic Manager	D	T0+12
D3	Final technical report on laminarization tests	R	T0+15
D4	Final technical report on natural transpiration tests	R	T0+18

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	Test matrix agreed	R	T0+3
M2	Design Review on mass flow measurement concept and instrument design	R	T0+6
M3	Adapters for installation of model on w/t turn table, suction pumps and all other equipment necessary for tests available and ready for use	HW	T0+10
M4	Wind tunnel tests performed and documentation of test results completed	R	T0+18

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

(E) - Essential; (A) - Appreciated

- The applicant should have a strong knowledge and experience in the performance of large-scale wind tunnel tests (E).
- The applicant should be able to perform the relevant flow measurements (E).
- The applicant must have the capability to provide a mass flow system with the required measuring range and accuracy (E).
- The applicant has to provide the adapters for mounting the model on the wind tunnel turn table (E).
- The size of the cross section of the wind tunnel test section should be at least 6m x 8 m. Additionally, the test section has to be closed. Optical access from the tunnel sidewalls is necessary (E).
- The wind tunnel has to provide wind speeds up to 100 m/s at constant temperatures (E).
- The applicant shall have the skill to process, analyse and assess the raw measurement data (E).

5. Abbreviations

ACD	Anti-Contamination Device
DLR	German Aerospace Center
FSO	Full Scale Output
HLFC	Hybrid Laminar Flow Control
NLF	Natural Laminar Flow
TSSD	Tailored Skin Single Duct

IV. JTI-CS2-2019-CFP10-AIR-01-44: Development of a methodology to optimize a wing composite panel with respect to tyre damage certification requirement

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€):		1400	
Topic Leader:	Dassault Aviation	Type of Agreement:	Implementation Agreement
Duration of the action (in Months):	28	Indicative Start Date (at the earliest)[67]:	> Q1 2020

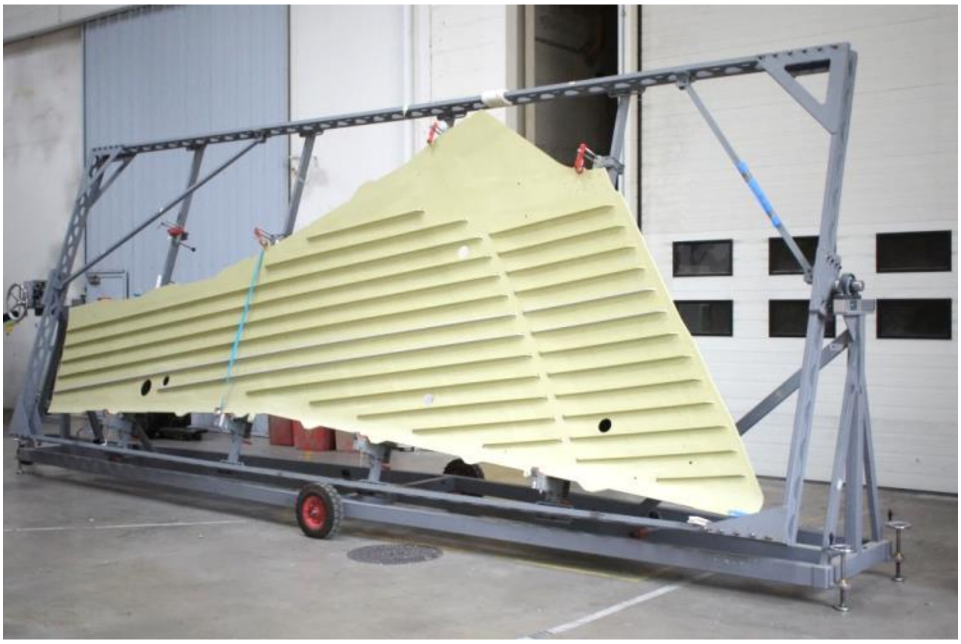
Topic Identification Code	Title
JTI-CS2-2019-CFP10-AIR-01-44	Development of a methodology to optimize a wing composite panel with respect to tyre damage certification requirement
Short description	
The objective is to develop the criteria and the methodology to predict adequately the behaviour of a composite stiffened wing panel with respect to the tyre impact threat. Based on tyre impact and mechanical test campaign of typical configurations, both simulations and failure criteria will be developed for damage and residual strength predictions capability. This development shall lead to a simple methodology applicable to support the design of composite wing panels, allowing to take into account certification constraint while minimising weight penalty. This exercise will be performed on a panel geometry provided by the Topic Manager.	

Links to the Clean Sky 2 Programme High-level Objectives[68]				
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 CO_2 emissions	Reducing NO_x emissions	Reducing Noise emissions	Improving EU Competitiveness	Improving Mobility
☒	☐	☐	☒	☐

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

[68] 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



Typical composite wingbox panel

The development of composite wingbox for business jets is an attractive solution which can significantly contribute to the weight reduction of the aircraft and therefore help achieve one of the main goals of the cleansky2 programme, i.e. the reduction of CO2 emissions.
However, this solution is considered as a novel design compared to existing metallic architectures, and additional requirements are formulated by the certification authorities. One of them is the demonstration of sufficient robustness of the exposed parts of the composite wings in case of tyre burst with tyre components hitting the wing surface. Requirements and threats to be considered are detailed in paragraphs CS 25.734, CS 25.963(e) and related AMC 25.734 and 25.963(e). In the frame of this CfP, works will be focused on impacts of small and large tyre debris as defined in AMC 25.734 on wing fuel tank zones. Main objectives will then consist in minimizing penetration, deformation and leakage risks, as well as demonstrating the residual strength and damage tolerance.
It is important to be able to adequately integrate these requirements on the wing design in an optimised way to avoid compromising the assets of the composite solution.
Therefore, the objective of this project is to develop a methodology able to evaluate precisely the behaviour of a composite wing structure with respect to the different threats of tyre burst and to provide simple tools and design rules to adapt or validate an existing design in an optimised way.
A framework for initial composite panel configurations will be provided by the Topic Manager as a starting reference point (materials, general panel geometry with supporting substructure, typical loads, existing panel configurations, layup and thicknesses including stiffeners). The architecture relies on blade stiffened panels assembled with fasteners on composite spars and metallic ribs.
The project will perform a number of representative tyre impacts on components at different levels of complexity, analyse the damages and will then perform mechanical test to assess the residual stress of the structure. This experimental base will be used to develop the criteria and methodology to predict the structure behaviour, the level of damage and the residual strength, and to derive simple rule to adapt existing design to tyre burst requirements.

2. Scope of work

In collaboration with the Topic Manager, the applicant will have to analyse the certifications requirements and to translate them into a limited number of impact scenarios in line with the wing architecture used for the project. The relevant parameters to be accounted for will be identified at this stage (impactor shapes, weights and speeds, nature of damage, leakage, residual strength, etc.)
Based on this preliminary analysis, a test campaign at different levels of complexity will be elaborated to identify properly the impact behaviour of test specimens ranging from elementary plate level to more complex structures representative of the wing panel.
The applicant is asked to develop a methodology and failure criteria to predict in a simple way the level of damage and if necessary the residual strength of the proposed architectures. The capability to predict properly the effect of a tyre impact will be demonstrated through large size test of multi stiffened composite panels with the representative substructure boundary conditions. The capability to use the methodology to adapt an existing design will be demonstrated through an exercise to optimize a reference wing structure with regards to tyre impact
The proposed Work Breakdown Structure is as follows:

Tasks		
Ref. No.	***Title - Description***	***Due Date***
WP1	Definition of the methodology	T0+04
WP2	Development of the experimental base	T0+16
WP3	Methodology to predict tyre impact effect	T0+24
WP4	Validation phase	T0+28

WP1 – Definition of the methodology
The purpose of WP1 is to define the methodology and the detailed workplan of the project.
The framework for this activity will be defined by the Topic Manager at the beginning of the project and will include:

- description of impact conditions (impactor definition, velocity, etc.) in accordance with the certification requirements
- description of the panel configurations subjected to tyre impact: architectures of stiffeners , thicknesses, lay-ups, geometries. It is already settled that the study will deal with T stiffened panels and the stiffeners will be co-bonded with the skin. The stiffener will be composed of 2 L's with symmetrical lay-up and a center part for the web.
- materials and manufacturing process for the panel. In particular M21EV/IMA prepreg tape from Hexcel will be used for the skin and stiffeners. The skin will be precured and the stiffeners will be cobonded with FM300 adhesive.
- loading and environmental conditions of the panel.
- a few configurations of reference with a complete definition of skin thickness, lay-ups and stiffener architecture. This will serve as the baseline for the work to be performed.

The presence of fuel should also be considered in the analysis to evaluate if it may be influent on the structural behaviour.

The applicant shall:

- analyse the certification requirements for tyre damage
- develop a philosophy to be able to predict properly the effect of tyre impact, as specified by certification, on the considered composite structure
- define the different types of test which will be necessary to evaluate properly the behaviour of the structure. A large test matrix covering different levels of complexity is expected, and in particular:
  - Simple elementary tests to characterize the composite material behaviour (modulus,

elementary failure modes)
  - Elementary tests to characterize and validate the tyre debris model at impact
  - Flat panel tests under impact to provide database for laminate response to tyre impact
  - Stiffened components (~1500mm x 1000mm)
  - Residual test of some of the previous elements
- describe the philosophy for modelling and the way to derive a simple methodology to predict a panel response to tyre impact and support the design phase of the panel.

WP2 – Development of the experimental base
Based on the methodology and experimental workplan defined in WP1 the applicant will perform the test campaign necessary to support the methodology.
In detail, the following actions are required:
- manufacture of laminates and panels necessary to extract the test components as defined in the test programme.
- prepare the test components and the test set-up
- perform the mechanical tests
- perform the tyre impact tests
- perform the residual strength evaluation

Necessary instrumentation and parameter monitoring shall be defined for the different kind of tests.
Tyre impact tests could be subcontracted to a specialized facility.

WP3 – Methodology to predict tyre impact effect
The objective of this WP is to come up with a methodology to predict the effect of tyre impact on a composite wing structure with stiffened panels that will be derived to provide simple tools and design rules to adapt or validate existing design to tyre burst requirements. The different components tested in WP2 will be modelled with the required representativeness according to the simulation strategy. The simulation supported by the test results will be used to develop a methodology to predict the effect of tyre impact on a stiffened panel (type and level of damage, residual strength, etc.).
The developed tools and design rules must be simple enough to be used in a design phase to evaluate the robustness of a composite panel with regard to tyre impact and to help improving the design with an optimized weight penalty. This WP will be carried out in cooperation with the Topic Manager to ensure its applicability to OEM design process.

WP4 – Validation phase
The methodology will be applied to a multi-stiffened large panel (typically 5 stiffeners for one panel 2500mm x 1500 mm) which configuration will be provided by the Topic Manager.
Prediction of the panel behaviour will be performed. The panel will be manufactured and impacted under boundary conditions representative of the wing substructure.
A comparison will be performed between the test results and the predictions to validate the suitability and relevance of the overall methodology.

3. <u>Major Deliverables/ Milestones and schedule (estimate)</u>
**Type: R=Report, D=Data, HW=Hardware*

Deliverables

Ref. No.	Title - Description	Type*	Due Date
D1.1	Methodology and workplan	R	T0+04
D1.2	Test plan	R	T0+04
D2.1	Component manufacture and inspection report	R	T0+12
D2.2	Test results	D	T0+16
D3.1	Component tests simulation report	R	T0+22
D3.2	Methodology for tyre impact effect report	R	T0+24
D4.1	Panel test report	R	T0+28
D4.2	Validation of methodology report	R	T0+28

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1.1	Workplan established	R	T0+04
M2.1	Experimental base established	D	T0+16
M3.1	Readiness of methodology for impact prediction	R	T0+24
M4.1	Validation of methodology	R	T0+28

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

- Proven experience and capability to manufacture composite co-bonded T stiffened panels with thermoset materials in autoclave according to the aeronautical standards.
- Strong background in the modelling of composite structures.
- Proven experience in developing damage and failure criteria aimed at supporting design and sizing of composite structures.
- Proven experience in tyre impact damage on composite structures.
- Proven skills and experience in design, sizing and certification of composite primary structures for aeronautics.
- Extended experience in testing composite structures at the component level.
- Availability of test equipment and infrastructure suitable to perform mechanical test of panel components.

5. Abbreviations

OEM	Original Equipment Manufacturer
WP	Work-Package

V. JTI-CS2-2019-CFP10-AIR-01-45: Coupon and element testing and manufacturing of test article for morphing technologies

Type of action (RIA/IA/CSA):		IA	
Programme Area:		AIR	
(CS2 JTP 2015) WP Ref.:		WP A-4.1	
Indicative Funding Topic Value (in k€):		900	
Topic Leader:	Fokker Aerostructures	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	36	**Indicative Start Date (at the earliest)[69]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-AIR-01-45	**Coupon and element testing and manufacturing of test article for morphing technologies**
Short description	
In line with the Clean Sky 2 objectives, the main objective of this topic is to contribute to the reduction of fuel consumption and CO2 emissions by increasing the effectivity of movables through application of morphing technology. The applicant will develop a test plan and execute coupon and elements tests. Furthermore, the applicant will use a simulation tool to correlate the test results with analysis results. In addition, the applicant will develop a manufacturing process for a morphing structure using fluid actuated cells. Based on this, the applicant will manufacture and deliver a full-scale test article, which will be used for further testing, which is not part of this call.	

Links to the Clean Sky 2 Programme High-level Objectives[70]				
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:			Advanced Short/Medium range	
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☐

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

[70] 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

One of the key objectives of the Clean Sky 2 programme is to minimize the impact of aviation on the environment through key innovation. A way to achieve this is to increase the effectiveness and enlarge the functionality of the control surfaces of an aircraft. This may lead to a performance increase as it allows the reduction of the structural weight, which has a direct result on the fuel burn and emission of the aircraft.
The objective of the Airframe ITD is to identify promising innovative technology building blocks and to mature this technology to TRL 4 or 5. Within Technology Stream A-4 "Novel Control", several innovative movable concepts are developed with as primary aim to increase its effectiveness.
A way to increase the effectiveness of a movable is through the application of morphing technology.
The figure below shows an impression of the winglet of a large passenger aircraft with morphing technology. The trailing edge tab of this winglet could be adapted by morphing technology.

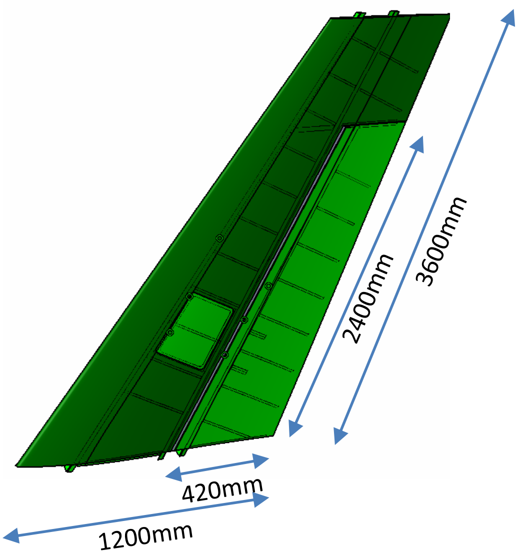


Figure 1: Impression of winglet with morphing technology

The considered morphing technologies are:

A. Adaptive trailing edge composite structure with conventional actuation
B. Morphing structure with fluid actuated cells.

<u>Adaptive trailing edge composite structure with conventional actuation</u>
The adaptive composite structure will be deformed under actuation loads in an unconventional manner when compared to the application in conventional aircraft control surfaces. Very limited data is available on the behaviour and characteristics of typical aerospace grade materials under these typical conditions. Specific simulations and tests on coupon and element level are required to determine the behaviour and properties of these materials and the typical geometrical shapes required for this technology.

Figure 2: Proof of Concept Winglet morphing TE Flap

The results of these tests and simulations will be used to determine the allowables for thermoplastic composite materials under morphing conditions. The insight gained with these tests will allow for possible design optimisations in terms of weight and performance. Results will be used to prepare the full-scale test of a Winglet morphing TE Flap (example is shown in Figure) to be performed in AIR ITD Technology Stream A-4.

Morphing structure with fluid actuated cells

A more radical approach to morphing trailing edge devices is the use of so-called pressure cells (FAMoUS – Fluid Actuated Morphing Unit Structures). With such a technology, conventional hinges and actuation systems can be omitted. An essential advantage is the feasibility to realize a morphing structure even at small profile heights. This results in a higher design freedom for the wing shape and promises a reduction of the overall weight of such a trailing edge including the weight for actuation in comparison to conventional devices. On the other hand pressure cells can allow a deflection of the trailing edge also in curved areas (with a non-planar trailing edge) giving more design freedom for the layout of wing movables.

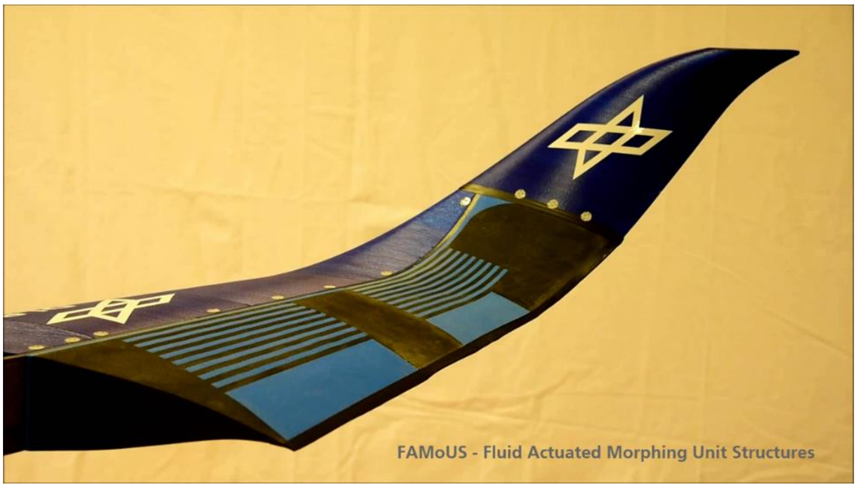


Figure 3: Fluid Actuated Morphing Unit Structure

General feasibility of the FAMoUS-technology could yet be demonstrated only through small-scale tests using materials not applicable under flight conditions. In addition, a sensory concept allowing for positioning control of the morphing device is not implemented so far. For further investigation on the applicability of pressure cells on larger devices (such as for commercial transport aircraft) tests need to be performed in full size. The specialty of this technology is that it requires measuring equipment and sensors to be implemented in the test article, requiring special manufacturing skills.

2. Scope of work

This topic will focus on two aspects of morphing:

A. Morphing material characterization testing of coupons and elements
B. Design and manufacturing of morphing pressurized cell demonstrator

A. Morphing material characterization testing of coupons and elements

The applicant will provide an experimental set-up for the investigation of strength and stiffness of (thermoplastic) composite materials in a representative environment. The applicant shall execute element and coupon tests, according to a self-prepared qualification test plan. The foreseen tests are coupon and element bending tests, with and without impact damage, under cyclic loading. The applicant will be responsible for the design and manufacturing of any test equipment, which is needed to correctly execute the tests according to the applicable test standards.
In addition, the applicant will develop a simulation tool to predict material characteristics of the morphing structure under different conditions. The applicant will process and evaluate the results from the tests for correlation with the results of the simulation tool.

B. Design and manufacturing of morphing pressurized cell demonstrator

The applicant will investigate on the feasibility of manufacturing pressurized cells with integrated measurement equipment based on a given FAMoUS design. Based on the manufacturing approach the applicant will manufacture and deliver a test article, which can be used for further demonstration of the technology.

It is proposed to organise the activities in the following tasks:

Tasks		
Ref. No.	***Title - Description***	***Due Date***
A-1	Execute coupon and element testing	T0 + 24
A-2	Evaluate and correlate simulation with test results	T0 + 36
B-1	Develop a manufacturing process for FAMoUS	T0 + 12
B-2	Manufacturing of a FAMoUS-demonstrator	T0 + 24

Task A-1: Execute coupon and element testing

As part of this task, the applicant will compile a development plan, supported by the Topic Manager, who will define detailed input, such as materials and typical geometries. The applicant is responsible for the development of necessary test equipment and for the manufacturing of test articles. The applicant is encouraged to propose innovative manufacturing or testing methodologies and/or the use of advanced measurements devices. Coupon and element tests will be executed according to the applicable test standards. The Topic Manager will also witness the tests and support the applicant in case of unexpected events.

Task A-2: Evaluate and correlate simulation with test results

The applicant will create test evaluation reports in which the measured results (strain levels, displacements, loading) are compared to predictions. The prediction will be obtained from a detailed FEM or simulation tool, which is able to predict loads and strain levels under morphing conditions. The Topic Manager will supply the geometrical and applied loads data to the applicant for the creation of the morphing finite element model. The applicant will use this simulation tool to predict and evaluate results from the full-scale adaptive Winglet test. The execution of this full-scale test including test articles and test equipment is excluded from this topic. The Topic Manager will supply the results from this full-scale test to the applicant for comparison and evaluation.

Task B-1: Develop a manufacturing process for FAMoUS

The FAMoUS design concept consists of pressurized elastic bodies made from elastic material like EPDM in combination with stiff constraining layers. The applicant will develop a manufacturing process feasible to combine these elastic and stiff materials and additionally integrate a sensory concept based on optical glass fibres. The developed process shall be able to reach the high geometric fidelity required for aviation applications and ensures high processing quality for the connection and arrangement of the various materials and geometric elements. For process development, the Topic Manager will provide a detailed list of requirements like surface quality or positioning tolerance of sensory devices.

Task B-2: Manufacturing of a FAMoUS-demonstrator

The applicant will manufacture a FAMoUS-demonstrator and pass it over to the Topic Manager including the measurement equipment. This includes the procurement of the semi-finished products, the measurement equipment and sensory devices, the raw material as well as any tooling or additional item needed for the developed manufacturing process. It can be expected the chord of the tab of test article will be as proposed in Figure 1, but that the test article will have a limited span width. The Topic Manager will provide the exact geometrical data.

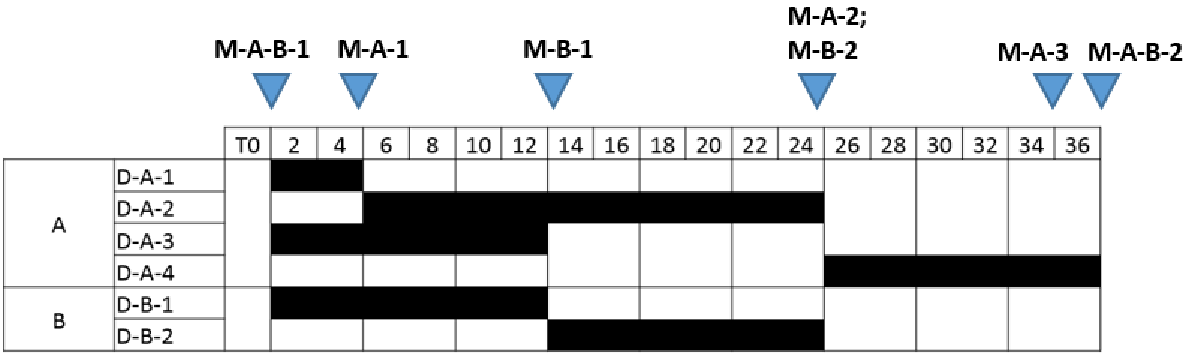
Please note that the Topic Manager foresees that the combined level of effort for tasks A-1 and A-2 will be twice as much as for the combined tasks B-1 and B-2.

3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D-A-1	Development Plan	R	T0 + 04
D-A-2	Test Result Report	R	T0 + 24
D-A-3	Simulation tool	D	T0 + 12
D-A-4	Test evaluation and correlation report	R	T0 + 34
D-B-1	Description of the manufacturing process for FAMoUS	R	T0 + 12
D-B-2	FAMoUS-demonstrator	HW	T0 + 24

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M-A-B-1	Kick-off Meeting	R	T0 + 1
M-A-1	Development Plan Review	R	T0 + 04
M-A-2	Test Results Review	D	T0 + 24
M-A-3	Full scale test evaluation	R	T0 + 34
M-B-1	Manufacturing process for FAMoUS available	R	T0 + 12
M-B-2	FAMoUS-demonstrator delivered	HW	T0 + 24
M-A-B-2	Project End review	R	T0 + 36



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

- The applicant shall be able to demonstrate sound technical knowledge in the field of asked contributions;
- 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 applicant should have experience in management, coordination, and development of testing methods and the execution of a test program;
- The applicant shall have demonstrated experience in the development and advanced simulation of adaptive structures in aerospace or other industries;
- The applicant shall have demonstrated experience with and access to CAD software CATIA V5® (or a compatible software) and FEM software NASTRAN to ensure data exchanges with the Topic Manager (inputs and deliverables);
- The applicant shall have workshop facilities (test equipment and manufacturing facilities) in line with the proposed deliverables and associated activities or, if such equipment is not available, have existing relation with institutions or companies that accommodate such equipment;
- The applicant shall have solid knowledge in the manufacturing of hybrid structures like the combination of EPDM and metal, in the handling of fibre optical sensors and in the manufacturing of composite structures;
- The applicant should have experience in the design of complex tooling with cores, sliders and inserts.

5. Abbreviations

CAD	Computer Aided Design
EPDM	Ethylene propylene diene monomer
FAMoUS	Fluid Actuated Morphing Unit Structures
FEM	Finite Element Model
TE	Trailing Edge

VI. JTI-CS2-2019-CFP10-AIR-02-77: Increasing the efficiency of pulsed jet actuators for flow separation control

Type of action (RIA/IA/CSA):		RIA	
Programme Area:		AIR	
(CS2 JTP 2015) WP Ref.:		WP B-1.4	
Indicative Funding Topic Value (in k€):		700	
Topic Leader:	Airbus	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	24	**Indicative Start Date (at the earliest)**[71]**:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-AIR-02-77	**Increasing the efficiency of pulsed jet actuators for flow separation control**
Short description	
The objective is the optimization of pulsed jet actuators for flow control leading to a minimized demand of net mass flow for the actuation. Several new types of actuator layouts shall be developed, designed and manufactured. The subsequent tests shall be done in a medium scale wind tunnel. The design of the actuators shall be backed by numerical simulations. Furthermore a comprehensive analysis and characterization of the free stream flow influenced by the jets shall be assured using the test results and numerical simulations.	

Links to the Clean Sky 2 Programme High-level Objectives[72]				
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:		Ultra-advanced Short/Medium-range		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☐

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

[72] 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

Several R&T projects have demonstrated the effectivity of the active flow control (AFC) technology using net mass flow to delay or suppress flow separation when applied on aerodynamic surfaces.
The technique of active flow separation control using a net mass flow is considered today as being the only method to provide the requested effectivity and maturity to delay flow separation on real aircraft applications. Other methods, like synthetic jet actuators (SJA) or plasma actuation, proved not being effective at high Re numbers corresponding to real aircraft flight conditions or not being mature and robust enough with respect to real aircraft environmental conditions encountered during normal operation like rain, icing, sand and very low temperatures.
The state of art of today active flow control technology using net mass flow is seen as being the technology of pulsed jet actuators (PJA). The advantage of PJA consists in the reduced mass flow by about 40% compared to the continuous blowing technology and an increased effectivity due to the formation of vortices downstream the actuator exhaust.
The application of the AFC technique with a net mass flow on aircraft is relying on two potential sources of compressed air: bleed air off-take from the engines or stand-alone compressors generating the needed pressure and mass flow for the flow control actuation. Both of the sources have a negative impact on the total aircraft performance. The bleed air off-take has a negative impact on the engine performance during take-off and climb and the stand alone compressor solution needs additional electrical energy, affecting also the overall performance of an aircraft.
In case the AFC technology would be applied yet to control large aerodynamic areas (e.g. large parts of the wing span) the amount of air required by the flow control technology is too high for relevant industrial applications. The provision of the required mass flow would annihilate the performance gain on overall aircraft level realized through the AFC technology. Therefore there is a strong request to reduce the used net mass flow as much as possible while maintaining the already known effectivity of the flow separation control technology.
The objective of the project is to assess experimentally and by means of numerical simulations the effect of an increased spacing between the blowing jets, of the variation of the jets chordwise position and the variation of the aspect ratio of the actuator exhaust, using pulsed jet actuators (PJA). Several layouts of PJA shall be developed, designed, manufactured and installed into the leading edge of a wind tunnel model. The subsequent tests shall be done in a medium scale wind tunnel using a 2.5D wind tunnel model.
The design of the actuators shall be backed by numerical simulations. Furthermore a comprehensive analysis and characterization of the outer flow influenced by the jets shall be assured using the test results and numerical simulations.

2. Scope of work

The studies to be performed have to include the following aspects:

- Modification of an existing wind tunnel model so that a system of pulsed jet actuators (PJA) is installed into the leading edge of the WT model.
- Development, design and manufacturing of PJA including several variations of their design.
- Ground testing of the new type of PJA.
- Numerical simulations of the internal and of the outer flow including the interaction between the AFC jets and the outer flow.
- WT Testing of the AFC technology

It is proposed to organise the technical activities in the tasks described below:

Tasks		
Ref. No.	**Title - Description**	**Due Date**
T1	Modification of the model, including the integration of the baseline pulsed jets actuator system.	T0+8
T2	WT Test for the baseline PJA including numerical simulations of the flow with AFC.	T0+10
T3	Development, design and manufacturing of new types of PJA. Numerical studies of the flow inside the PJA and ground testing of the PJA.	T0+14
T4	WT Test for the new types of PJA methods including numerical simulations of the flow with AFC.	T0+22
T5	Evaluation of the actuation methods, recommendations and delivery of the final report.	T0+24

Task 1: Modification of the model, including the integration of the baseline pulsed jets actuators system

The partner shall build or use an existing configuration like an extruded 2.5D airfoil. The geometry used shall be a 2.5D airfoil (swept constant-chord half-model) with a flap and an aspect ratio of at least 2.

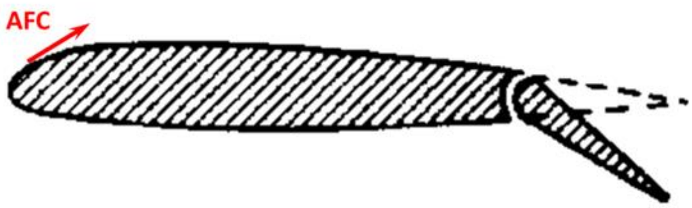


Fig1: Main wing element with installed flow control at the leading edge

The existing WT model will be modified in order to enable the installation of AFC hardware and systems for the test of the actuators into the unprotected leading edge of the wing (see Fig.1). The actuation length of AFC system shall extend to the full wing span.

In terms of AFC systems installations preference is clearly given to easily removable, interchangeable inserts for testing and comparing the different technology concepts of flow control with reduced effort. Additionally, there shall be assured a change in the chord wise position of the PJA.

A baseline PJA system shall be designed, manufactured and installed into the leading edge of the wing element (see Fig2).

Task 2: WT Test for the baseline PJA including numerical simulations of the flow with AFC.

A first step includes numerical studies and wind tunnel experiments of the wing model without AFC, investigating the high lift characteristics of the wing (Cl vs. alpha). The Reynolds (Re) number related to the Mean Aerodynamic Chord (MAC) of the model must be higher than 1 Mio.

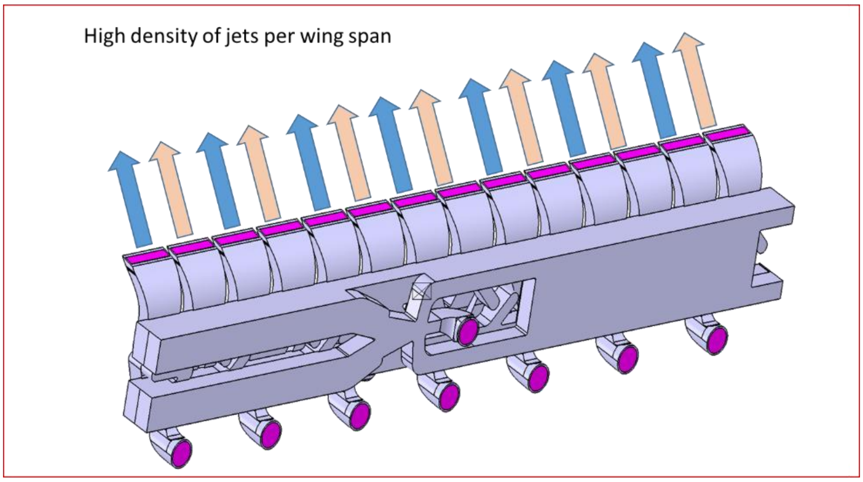


Fig2: Example of a baseline PJA configuration

During the second step numerical studies and wind tunnel experiments of the wing model with a baseline PJA shall be done (see Fig2), investigating the effect of flow control on the wing flow separation. There shall be done also a variation of the chordwise position of the PJA to investigate the most effective position of the flow control actuators (see Fig.3). The Mach (Ma) number of the wind tunnel free stream has to be adjusted between 0.1 and 0.2 and the Re number must be higher than 1 Mio based on the Mean Aerodynamic Chord (MAC) of the model and freestream conditions.
The test matrix will comprise a variation of the angle of attack, of the Ma number and of the velocities of the flow control jets. The Ma number of the jets has to be adjustable between Ma = 0.4 and 0.9.

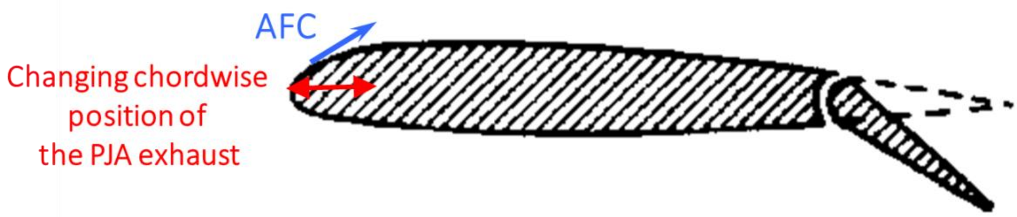


Fig3: Changing chordwise position of the PJA exhaust

Task 3: Development, design and manufacturing of new types of PJA. Numerical studies of the flow inside the PJA and ground testing of the PJA.

Task 3 will include development, design and manufacturing of new types of PJA.
The following variations of the PJA design shall be conducted:

1. Increasing the spacing between the single pairs of actuators (see Fig4), thus generating increased non-blowing areas between the single actuators. This means, there will be in total less actuators installed across the whole wing span. The spacing between the actuators shall have values of 0.5, 1.0, 1.5 and 2.0 times the actuator width.
2. Variation of the aspect ratio of the PJA exhaust (see Fig.5). There shall be manufactured actuators with three different aspect ratios. The range of the aspect ratio shall be between 3 and 6.

Ground testing (w/o free stream flow) of the new type of PJA shall be done, characterizing the velocity profiles of the jets at the exit of the actuators in a pulsed working mode, as well as the uniformity of the jets in spanwise direction.

Numerical studies of the flow inside the PJA shall be done, indicating the velocity profiles of the jets at the exit of the actuators connected to different values of the net mass flow.

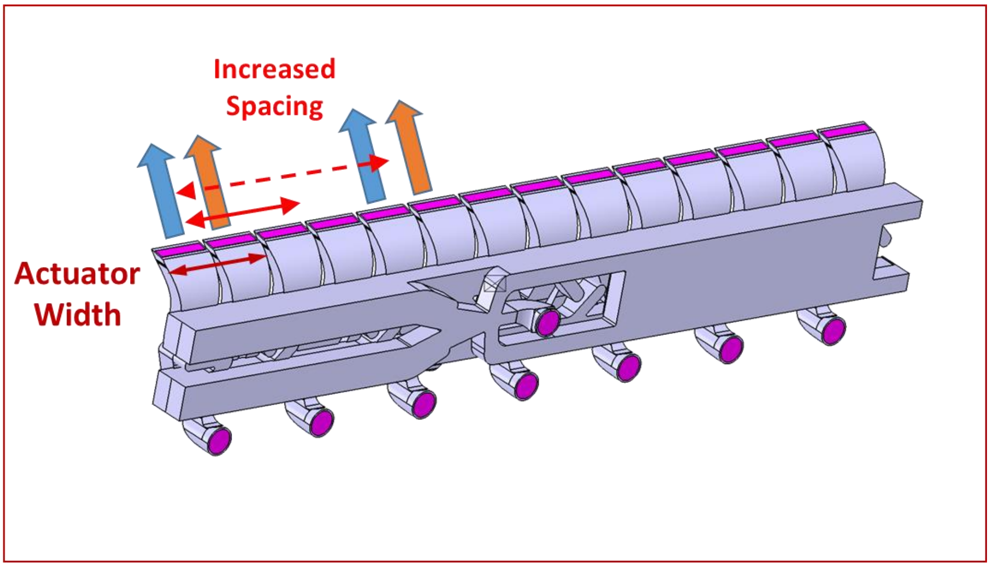


Fig4: Increased spacing between the single pairs of actuators

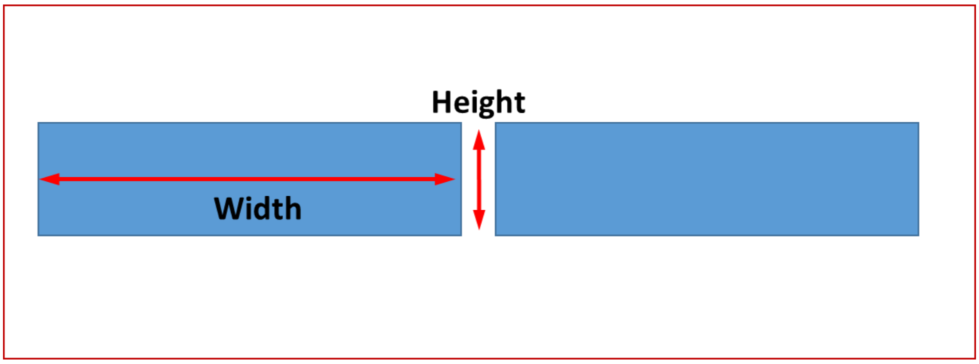


Fig5: Pair of PJA exhaust openings

Task 4: WT Test for the new types of PJA methods including numerical simulations of the flow with AFC.

The first set of actuators shall be installed on the wing geometry covering the full wing span (Fig 1). The PJA shall be installed at the chordwise position shown to be the most effective during Task 2.
Subsequent wind tunnel tests with the given variation in the spacing between the single actuators shall be conducted, backed by numerical simulations of the outer flow.
During the wind tunnel tests the Ma number of the free stream flow shall be varied between 0.1 and 0.2. Also the Ma number of the jets of the actuators shall be varied between Ma = 0.4 and 0.9., giving insight into the sensitivity of the actuation method to changing parameters.

The second set of actuators shall be installed on the wing geometry covering the full wing span (Fig 1). The PJA shall be installed at the chordwise position shown to be the most effective during Task2.
Subsequent wind tunnel tests with the given variation of the aspect ratio of the PJA exhaust shall be conducted, backed by numerical simulations of the outer flow.
For both sets of WT tests the effectivity of the flow control methods to delay flow separation and the impact on the free stream flow shall be shown using multiple-hole probes and PIV measurement

techniques downstream the actuator position.
Flow visualization techniques (e.g. tuft visualisation) shall be applied downstream the position of the actuators.
The planned test will include measurements of the overall forces acting on the model (balance measurements), as well as pressure distributions on the wing surface. In addition, the mass flow of the air supply for the flow control actuators will be measured and the pressure inside the settling chamber of the actuators.
The experimental data will be used to validate the numerical simulations. The emphasis of the numerical simulations shall be on the interaction between the jets of the PJA and the freestream flow, indicating the mechanism leading to the delay of the flow separation.

Task 5: Evaluation of the actuation methods, recommendations and delivery of the final report.

The data of the wind tunnel test are to be analysed and results to be delivered. This analysis will include overall measurements (balance), pressure measurements on the wing and flap surface and data about the flow control characteristics (mass flow, pressures). Comparison to the numerical simulations shall be done.

A final report shall be delivered, exhibiting information about the different actuation methods and the used actuation parameters.

3. Major Deliverables/ Milestones and schedule

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1	Modification of the wind tunnel model, including the integration of the baseline pulsed jets actuator system.	HW / R	T0+8
D2	Report on the WT Test and numerical simulations of the baseline PJA.	R	T0+10
D3	Report on the numerical simulations and ground test results of the new types of PJA.	R	T0+13
D4	Delivery of the new types of PJA.	HW	T0+14
D5	Final Report of wind tunnel tests and numerical simulations.	R	T0+24

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1	Modification of the wind tunnel model, including the integration of the baseline pulsed jets actuator system.	HW / R	T0+8
D2	Report on the WT Test and numerical simulations of the baseline PJA.	R	T0+10
D3	Report on the numerical simulations and ground test results of the new types of PJA.	R	T0+13
D4	Delivery of the new types of PJA.	HW	T0+14

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

- The applicant will have expertise in the area of wind tunnel model modification and model instrumentation.

- The applicant will have expertise in the area of wind tunnel testing, data post processing and flow visualization (tufts).
- The applicant will be able to prepare, conduct and evaluate PIV measurements.
- The applicant will provide the required amount of mass flow for the flow control system, including as well the needed system to feed the actuators with the pressurized air flow.
- The applicant shall have profound knowledge and experience in developing and maturing of active flow control technology with net mass flow, being familiar with the actuation method of pulsed jet actuators (PJA).
- The applicant shall have a sound R&T background in testing and demonstration of flow control techniques in wind tunnel facilities suitable for models of the size mentioned above.
- The applicant shall have expertise in conducting numerical flow simulations of internal and external flows.

5. Abbreviations

AFC	Active Flow Control
PIV	Particle Image Velocimetry
PJA	Pulsed Jet Actuators
WT	Wind Tunnel

VII. JTI-CS2-2019-CFP10-AIR-02-78: Application of graphene based materials in aeronautical structures for de-icing, lightning strike protection, fire barrier and water absorption prevention purposes

Type of action (RIA/IA/CSA):		IA	
Programme Area:		AIR	
(CS2 JTP 2015) WP Ref.:		WP B-3.1	
Indicative Funding Topic Value (in k€):		500	
Topic Leader:	Leonardo SpA Aircraft Division	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	30	**Indicative Start Date (at the earliest)[73]:**	> Q1 2020

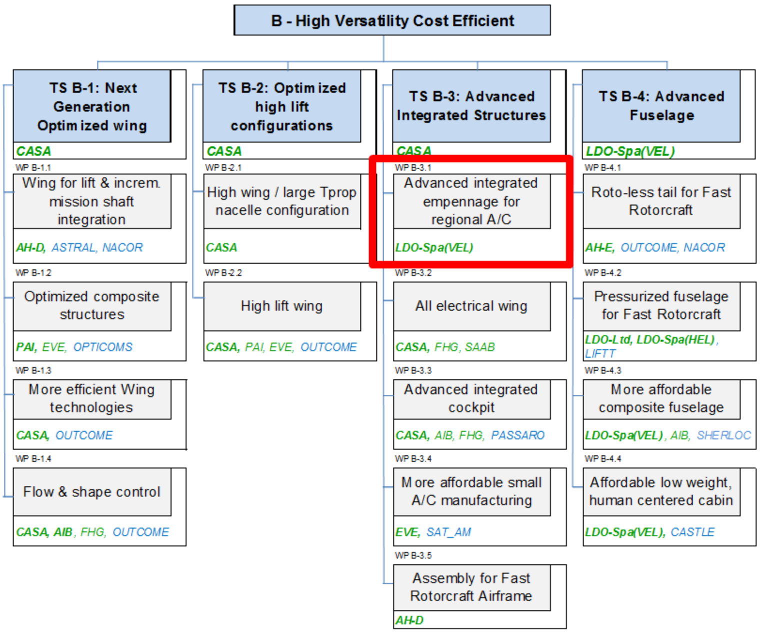
Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-AIR-02-78	**Application of graphene based materials in aeronautical structures for de-icing, lightning strike protection, fire barrier and water absorption prevention purposes**
Short description	
The topic aims are to take advantage from electrical, thermal and impermeable properties of graphene and to investigate the benefits of the use of graphene on composite aeronautical structures, in order to identify the most suitable solution (in terms of amount and form of graphene) for thermal de-icing systems, lightning strike protection, fire barrier and water uptake prevention. The proposed solutions will be verified through fabrication and testing of dedicated small scale subcomponents.	

Links to the Clean Sky 2 Programme High-level Objectives[74]				
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:		Advanced/Innovative Turboprop		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☐

73 The start date corresponds to actual start date with all legal documents in place.
74 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 Airframe ITD of Clean Sky 2. In particular, the Work Package B-3.1 "Advanced integrated empennage for regional A/C" is incorporated within the Technology Stream B-3 and represents the field where activities requested to the Applicant will be performed. The relevant ITD Work Breakdown Structure is shown below putting in evidence the WP B-3.1:



More in detail, the activities of the WP B-3.1 will pursue the development of innovative solutions for regional aircraft composite empennage main box and edges.

Composite materials are experiencing a continuous growing level of utilization in the aircraft structures for their elevated specific mechanical properties (i.e. properties vs. density), associated to affordable costs, and obtained mainly through the application of optimized peculiar processing techniques. Despite of that, the potentiality of composites hasn't been completely exploited yet, because of some issues affecting design. Some issues related to the use of composite materials in aeronautical structures are, water accumulation as ice outside the structures during the flight, water absorption in the material, fire propagation in composite materials. All the above issues cause a possible reduction of mechanical properties with subsequent weight increase due to the application of protection materials (de-icing systems, application of fire retardant substructures, sealants and paint).

A possible solution to be investigated can be the use of graphene as layer or as additive of composite thermosetting resin. Graphene is a two-dimensional atomic crystal made up of carbon atoms arranged in a hexagonal lattice. It is the thinnest compound known to man at one atom thick (a million times thinner than a human hair), the strongest compound discovered (between 100-300 times stronger than steel), the lightest material known (with one square meter weighing approximately 0.77 milligrams), and is extremely flexible.

It is also impermeable to molecules, and is electrically and thermally highly conductive. Graphene enables electrons to flow much faster than silicon; graphene can conduct electricity even better than copper and this gives graphene endless applications. It is also a transparent conductor, combining electrical and optical functionalities in an exceptional way.

These exceptional basic properties combined with graphene's little dimensions and high flexibility make graphene the best candidate to create multifunctional composite materials and systems embedded or highly integrated into composite parts.

Figure 1 – Graphene possible benefits

The activities of this call for proposal will cover the development and production of new Graphene based material to be used in aeronautical structures, the manufacturing of representative test articles and testing activities to assess mechanical and functional properties.

2. Scope of work

The scope of the present topic is to take advantage of electrical, thermal and impermeable properties of graphene in order to improve the basic properties of aeronautical composite material. The functional properties of graphene based material shall be assured also after damages like scratches or hail impact. The activities to be performed are divided in the tasks listed below:

Tasks		
Ref. No.	**Title - Description**	**Due Date**
1	Feasibility study of the use of graphene based materials for de-icing systems, lightning strike protection, fire barrier and water uptake prevention and conceptual material definition for each application	T0+6
2	Graphene based material development and production for thermal de-icing application and integration, with electrical connections included, in aeronautical composite and aluminum panel	T0+20
3	Graphene based material development and production for lightning strike application and integration in aeronautical composite panel	T0+20
4	Graphene based material development and production for fire barrier application and integration in aeronautical composite panel	T0+20
5	Graphene based coating development and production for water absorption barrier and integration in aeronautical composite panel	T0+20
6	Application of de-icing system on a subscale component with the possible integration with other GBM functionalities at Topic Manager site	T0+30

The Applicant shall be responsible for:
- Graphene Based Material development and application with relevant material specification issue.
- Purchase of all components needed for graphene based material fabrication.
- Definition of quantity and form (cured or not) of structural substrate or aluminum to be provided by

the Topic Manager (TM)

- Test matrix definition to be agreed with TM, relevant coupons fabrication, NDT, visual and dimensional test and report issue
- Fabrication of basic panels and the small scale item.
- Characterization of mechanical, micrographic, chemical-physical and functional of basic panels and the first small scale manufacturing trial.
- Producibility evaluation report to verify material and parts producibility using the selected innovative processes.
- Functionality tests, relevant reporting and issue of procedures and instructions for de-icing system management.
- Fabrication of small scale item and functionality test of embedded de-icing system at TM site (only for task 6)

Task 1: Feasibility study of the use of graphene based materials for thermal de-icing, fire barrier and water uptake issue and conceptual material definition for each application

In the present task, the selected Applicant is requested to develop the material, driven by selected property improvement (e.g. de-icing, fire barrier, water absorption prevention, etc.). Additional drivers will be weight and cost reduction and the easy producibility both for the material itself and its application/integration on aeronautical structures.

The candidate aeronautical structures to focus on for each application are the following:

- Carbon Fiber epoxy laminate leading edge for de-icing issue
- Carbon Fiber epoxy laminate horizontal stabilizer and fuselage for lightning strike
- Carbon Fiber epoxy laminate bulkhead for FST issue
- Carbon Fiber epoxy laminate and sandwich structure for water absorption issue

In the present task the Applicant shall show a detailed list of possible graphene based material solutions, with associated main features in terms of their specific application, object of the call. The proposed solutions shall ensure the integration/embedding of the desired system and/or of the functionality into the composite material constituent of the aeronautical components.

In addition the Applicant shall describe the theoretical working principles and how the proposed solutions can be integrated in aeronautical structure.

At the kick off meeting the Topic Manager will communicate the aeronautical composite materials to be considered. Specifically, those are carbon fiber pre-preg materials with toughened epoxy resin system, that is polymerized into autoclave at 180°C, 6 and 3 bars under vacuum bag.

The proposed solutions should be able to stand and to be operative at the following airplane service environmental conditions of temperature and humidity: - 55° C / + 80 °C, from 15% up to 97%.

The Applicant can propose more than one solution for each application and its down selection shall be agreed with TM in the related task.

Task 2: Graphene based material development and production for thermal de-icing issue and integration in an aeronautical composite and aluminum panel

The Applicant will develop the concepts selected in the Task 1 for thermoelectric embedded de-icing applications / systems. The study will be focused on the power characterization of graphene heaters as de-ice device. The intrinsic material properties of anti-erosion and anti-contamination could drive the improvement of heaters layer, eliminating the external protective cover, typical of current thermal design solution. The main goal is the improvement of layer thermal efficiency with the aim to drive the heat flux towards the external surface. The good compromise between higher thermal/electrical conductivity and erosion/contamination protection has a good application for laminar wing design.

The development and validation activities have to cover also the applicable electrical circuits and systems required to properly heat up the resistance made up of selected graphene based material.

In this phase the applicant shall verify the compliance of the material and of the innovative low power thermal de-icing system with aeronautical requirements, shall assess if the proposed solution can affect the structural capability of the CFRP material and aluminum through mechanical, destructive and non-destructive characterization and shall demonstrate the functionality of the de-icing system in accordance with hereafter listed general requirements and assure its functionality also in case of cosmetic damage or minor structural damages (e.g. hail impact).

A report describing the manufacturing process of Graphene Based Material, its integration into a composite and aluminum panel, its electrical connection with power supply, and the instructions of de-icing system activation shall be issued by the Applicant at completion of development and validation activities.

Graphene heaters will be tested to characterise energy consumption.

The Applicant shall develop and perform a technology development plan including at least the following main sub-tasks/activities:

- Integration of graphene based material (circuit) into composite and onto aluminum panels and thermo-electrical system development and that includes:
- Assessment of the feasibility at lab scale level, in fact the new graphene based material will be fabricated and coupled with standard toughened epoxy resin composite material and Aluminum alloy (AL 2024 TE) for aeronautical structural applications. Definition of the configuration of flat manufacturing trials /panels (it shall include the position of graphene based circuit into the panel's stack up, the position and type of connectors, the definition of eventual F/G plies to be used as insulator on both sides of the circuit, and so on); for this sub task the TM will provide a design concurrence in order to take into account aeronautical component's applicable materials and representative thickness/configuration (i.e. the outer ply of a composite leading edge has to be a lightning strike protection).
- Manufacturing of flat panels with toughened epoxy resin composite material for aeronautical structural applications and with the embedded graphene based circuit and application of graphene based circuits on aluminum panels
- Selection and definition of the best electrical circuit made out of graphene based material (shape, dimensions should be defined in this phase)
- Measure and characterize the electrical resistance of the circuit by means of conductivity tests.
- Development of connectors suitable to be integrated into composite parts and on aluminum panels.
- Define the wiring and proper connection with Power supply.
- Test for electrical current measurements at fixed voltage.
- Characterize thermal behaviour and evaluate energy consumption.
- Temperature measurements with thermal camera for T max and uniformity evaluation (Tmax of the resistance cannot exceed 80°C once integrated in epoxy CRFP material).
- Perform a simplified thermodynamic analysis and the heat transmission balance to predict/calculate the required wattage for the de-icing purpose in three different conditions: in flight, considering the most critical conditions, in climatic chamber at -30°C, and at room temperature.
- Coupled simulation involving external typical icing condition and internal heat conduction.
- Verification that the wattage/power produced by the resistance is adequate for the scope, at least at room temperature and in climate chamber at - 30°C without damaging the composite substructure, the interface CFRP/GBM, the aluminum substructure and the interface Al/GBM
- At the end of this task the electrothermal system and graphene based material have to be verified and the relevant process parameters have to be collected in material and system specifications.
- Non-destructive and destructive characterization of the manufacturing flat trials, performing at minimum thickness measurements, NDI/T, microscopy analysis for morphology characterization, Tg and DSC in local coupons cut near graphene based circuit
- Quality assessment of hybrid material (graphene based material embedded into composite

material)
In this phase test coupons have to be fabricated and tested to evaluate the hybrid material properties and its potential detrimental effect of mechanical properties of composite based material and on aluminum panel paying particular attention on corrosion effects of Graphene/Aluminum coupling. The Applicant has to prepare a test matrix to identify number and configuration of mechanical testing to be performed for comparison to base material properties. This test matrix has to be reviewed and approved by TM. Beyond the functional benefit, the minimum properties to be assessed shall be tension and compression both notched and unnotched, shear both interlaminar and in plane, compression after impact. Fatigue tests and Kevlar cycles have to be performed too. A minimum number of 6 coupons for each test have to be considered. The proper test conditions for each test (Room Temperature, Dry Cold, Dry Hot or Hot Wet) have to be defined too. All the tests shall be conducted by a laboratory certified per ISO17025. Test methods era according to ASTM standards. For this activity the Applicant shall issue a laboratory test report.

With reference to the test article, the selected Candidate shall define:

- Configuration for test
- Lab test Instrumentation for monitoring of thermal behaviour
- Control logic for de-ice activation /de-activation
- Detailed planning and procedure for Lab Test
- Test Article structure integrated with resistance material.

Task 3: Graphene based material development and production for lightning strike application and integration in aeronautical composite panel

The Applicant will develop the concepts selected in Task 1 for lightning strike applications. In this phase the applicant shall verify the compliance of the material with aeronautical requirements and shall assess if the proposed solution can affect the structural capability of the material through destructive and non-destructive characterization. A report describing the manufacturing process of Graphene Based Material and its application on a composite panel shall be issued by the Applicant.

In order to assess the feasibility on a lab scale level, the new graphene based material will be fabricated and coupled with standard toughened epoxy resin composite material for aeronautical structural applications panels. Finally, test coupons will be cut and tested to evaluate the de-icing properties of the new material and its potential detrimental effect of mechanical properties of composite based material. If the innovative graphene based material has to be applied on composite part surface specific tests have to be performed for verification of its compatibility with typical aeronautical primers and gel coats or paintings (i.e. adhesion test, scratch test, etc.). Beyond the functional benefit, the minimum properties to be assessed shall be tension and compression both notched and unnotched, shear both interlaminar and in plane, compression after impact. All the tests shall be conducted by a laboratory certified per ISO17025. Test methods are according to ASTM standards. TM is in charge to identify number and configuration of mechanical testing to be performed for comparison to base material properties. For this activity the Applicant shall issue a laboratory test report

In addition, a small scale test article, representing a simplified HS or fuselage panel shall be manufactured and subject to NDT, visual and dimensional test before performing test aiming at verifying the compliance with lightning strike requirements; the test will aim also to validate the processability of the new material system and to freeze process parameters.

The conductive system for a regional empennage shall have a maximum resistance between 12 and 85 mΩ depending upon the thickness of the part and the lightning zone of application (Ref. SAE ARP 5414); these values are the typical resistance requirements applicable to standard metallic aeronautical conductive foil (copper, bronze) used for lightning strike applications.

Task 4: Graphene based material development and production for fire barrier issue and integration in an aeronautical composite panel

The Applicant will develop the concepts selected in Task 1 for fire barrier applications. In this phase the applicant shall verify the compliance of the material with aeronautical requirements and shall assess if the proposed solution can affect the structural capability of the material through destructive and non-destructive characterization. A report describing the manufacturing process of Graphene Based Material and its application on a composite panel shall be issued by the Applicant.

In order to assess the feasibility on a lab scale level, the new graphene based material will be fabricated and coupled with standard toughened epoxy resin composite material for aeronautical structural applications panels. Finally, test coupons will be cut and tested to evaluate the fire barrier properties of the new material as per FAR 25853 Appendix F and its potential detrimental effect of mechanical properties of composite based material. If the innovative graphene based material has to be applied on composite part surface specific tests have to be performed for verification of its compatibility with typical aeronautical primers and gel coats or paintings (i.e. adhesion test, scratch test, etc.). TM is in charge to identify number and configuration of mechanical testing to be performed for comparison to base material properties. Beyond the functional benefit, the minimum properties to be assessed shall be tension and compression both notched and unnotched, shear both interlaminar and in plane, compression after impact. All the tests shall be conducted by a laboratory certified per ISO17025. Test methods era according to ASTM standards. For this activity the Applicant shall issue a laboratory test report

In addition a small scale test article, representing a simplified bulkhead panel shall be manufactured and tested verifying the compliance with fire barrier requirements as per FAR 25853 Appendix F, the test will aim also to validate the processability of the new material system and to freeze process parameters.

Task 5: Graphene based material development and production for water absorption barrier and integration in an aeronautical composite panel

The Applicant will develop the concepts selected in Task 1 for water uptake prevention applications. In this phase the applicant shall verify the compliance of the material with aeronautical requirements and shall assess if the proposed solution can affect the structural capability of the material through destructive and non-destructive characterization. A report describing the manufacturing process of Graphene Based Material and its application on a composite panel shall be issued by the Applicant.

In order to assess the feasibility on a lab scale level, the new graphene based material will be fabricated and coupled with standard toughened epoxy resin composite material for aeronautical structural applications panels; the configuration of the panels shall be both in solid laminate and in sandwich. All the panels will be tested by NDT, visually and dimensionally. Finally, test coupons will be cut and tested to evaluate the water uptake prevention properties of the new material; the environmental condition shall be the ones specified in the applicable standard EN 2823. The typical humidity absorption of carbon fiber epoxy matrix composite is 1% by weight Beyond the functional benefit, the minimum properties to be assessed shall be tension and compression both notched and unnotched, shear both interlaminar and in plane, compression after impact. Fatigue tests and Kevlar cycles have to be performed too. If the innovative graphene based material has to be applied on composite part surface, specific tests have to be performed for verification of its compatibility with typical aeronautical primers and gel coats or paintings (i.e. adhesion test, scratch test, etc.). A minimum number of 6 coupons for each test have to be considered. The proper test conditions for each test (Room Temperature, Dry Cold, Dry Hot or Hot Wet) have to be defined too. All the tests shall be conducted by a laboratory certified per ISO17025. Test methods are according to ASTM standards. For this activity the Applicant shall issue a laboratory test report.

Task 6: Application of de-icing system on a subscale component with the possible integration with

other GBM functionalities at Topic Manager site

The present task will target the integration of de-icing system at subscale component to the other functionalities developed and testing in accordance with a test matrix agreed with TM in order to assess the possible combined effect of different solutions. Applicant shall issue a laboratory test report to validate the functional properties.

On the small scale item, representative of the simplified curved leading edge(L = 400 mm, W = 200 mm approx.) with embedded de-icing system, it is also requested to repeat the functionality tests performed in task 2 at room temperature, in climatic chamber at -30°C and eventually in "in flight" conditions. The TM will provide a design concurrence in order to take into account aeronautical component's applicable materials and representative part's geometry.

The Applicant shall develop and provide specific control logic. Robust control laws and monitoring means should be provided for the testing in order to allow: activation / deactivation of de-icing system, power regulation, monitoring of the reached temperatures to avoid overheating of the structure. At the end of this task the functionality of the de-icing system has to be demonstrated including testing for the validation of the multifunctionality (e.g. de-icing/water absorption, de-icing/lightning strike protection, etc.). A complete report has to be issued; the reporting shall include the description of the electrical connection of the de-icing system with power supply, and detailed instructions and procedures for de-icing system management.

The Applicant will provide the graphene based materials already prepared in the format suitable for the selected application, the tools/moulds needed for demonstrator fabrication, and all devices and instruments required to perform the functionality test of the de-icing system (electrical connections, power generator, temperature sensors and controller, and so on).

3. Major Deliverables/ Milestones and schedule

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1.1	Detailed summary report	R	T0+6
D2.1	Graphene Based Material process instruction	R	T0+10
D2.2	Basic panel lab test report for de-icing system both for composite and aluminum	R	T0+14
D2.3	Functionality test report and procedure of de-icing system management	R/D	T0+20
D3.1	Graphene Based Material process instruction	R	T0+10
D3.2	Basic panel lab test report for lightning strike protection	R/D	T0+14
D3.3	Functionality test report and procedure for lightning strike protection	HW/R	T0+20
D4.1	Graphene Based Material process instruction	R	T0+10
D4.2	Basic panel lab test report for fire barrier applications	R	T0+14
D4.3	Functionality test report and procedure for fire barrier applications	HW/R	T0+20
D5.1	Graphene Based Material process instruction	R	T0+10
D5.2	Basic panel lab test report for water absorption prevention	HW/R	T0+14
D5.3	Functionality test report and procedure for water absorption prevention	R	T0+20
D6.1	Small scale element and functionality test at Topic Manager site	HW/R	T0+27

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D6.2	Test report on functional properties	R	T0+30

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	Detailed summary report	R	T0+6
M2	Functionality test report and procedure of de-icing system management	R/D	T0+20
M3	Functionality test report and procedure for lightning strike protection	HW/R	T0+20
M4	Functionality test report and procedure for fire barrier applications	HW/R	T0+20
M5	Functionality test report and procedure for water absorption prevention	R	T0+20
M6	Small scale element and functionality test at Topic Manager site	HW/R	T0+27

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

- Demonstrable competencies and knowledge of graphene material and its main applications
- Demonstrable capability to develop and produce graphene based material for research and production purposes
- Proven competence in management of complex research projects.
- Proven experience in composite material use and fabrication of small/mid components with advanced composite materials.
- Required facilities for coupons and trials fabrication: clean room and autoclave
- Proven experience in composite experimental testing (NDT, visual and dimensional, mechanical, FST, micrographic and chemical-physical analysis) at coupon and sub scale level, laboratory certified per ISO17025.
- Experience in instrumentation data acquisition, recording and monitoring
- Proven experience in the design and development of electro-thermal circuit/system with low power absorption
- Availability of appropriate tools required to optimize Electro-Thermal power consumption and provide associated system architecture definition

5. Abbreviations

CFRP	Carbon Fiber Reinforced Polymer
DSC	Differential Scanning Calorimetry
F/G	Fiber Glass
FST	Fire Smoke and Toxicity
GBM	Graphene Based Material
HS	Horizontal Stabilizer
KOM	Kick-Off Meeting
IA	Innovation Action
LDO VEL	Leonardo Aircraft
TM	Topic Manager
Tg	Glass Transition Temperature

NDI/T	Non-Destructive-Inspection/Testing

VIII. JTI-CS2-2019-CFP10-AIR-02-79: Development of FEM fastener parametric/adaptable sizing tool including EMC impact, and manufacturing and EMC/LSP testing of demonstrators

Type of action (RIA/IA/CSA):		IA	
Programme Area:		AIR [SAT]	
(CS2 JTP 2015) WP Ref.:		WP B-3.4.2	
Indicative Funding Topic Value (in k€):		475	
Topic Leader:	EVEKTOR spol. s r.o.	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	30	**Indicative Start Date (at the earliest)[75]:**	> Q1 2020

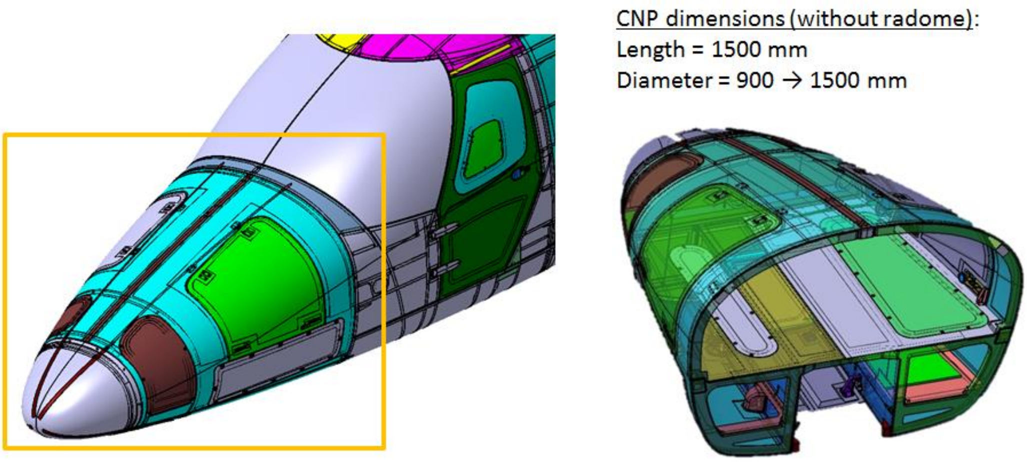
Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-AIR-02-79	**Development of FEM fastener parametric/adaptable sizing tool including EMC impact, and manufacturing and EMC/LSP testing of demonstrators**
Short description	
The scope of the project is to develop FEM sizing methodology and parametric/adaptable sizing tool for CFRP-metal or CFRP-CFRP joint interfaces. The Topic manager will provide experimental data of tested specimens and appropriate CAD data to facilitate completion of FEM models and manufacturing of innovative composite part referring to the nose part of EV-55. The sizing tool shall be free-expandable for different fasteners, providing that developed sizing methodology will be kept together with appropriate strength/EMC test validation. Final evaluation of innovative joining solutions will be carried out by EMC tests on reference and innovative demonstrators conducted in relevant EMC test facilities.	

Links to the Clean Sky 2 Programme High-level Objectives[76]				
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 CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☐	☐	☐	☒	☒

[75] The start date corresponds to actual start date with all legal documents in place.
[76] 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 refers to the Clean Sky2 ITD AIRFRAME technology stream TS B-3.4 "More affordable small A/C manufacturing" and more specifically it contributes to WP B-3.4.2 "Effective joining method of metal-composite hybrid structures" that is connected to SAT (Small Air Transport) Transversal activities with a view to bring new technologies developed by big companies or innovative current technologies within the segment of small aircraft, thus increasing competitiveness of European small A/C manufacturers. Of course, this will depend on the applicability of the proposed manufacturing procedures and technologies.
For small companies, like Evektor, the aircraft production according certification specifications CS-23 is a major challenge, and the company has to cover a broad portfolio of knowledge with a small team of people and budget constraints. This may lead to lack of adequately comprehensive test data and limited advanced knowledge. The consequence could be the use of conservative (obsolete) methods that do not match modern trends with their quality and therefore may increase weight (= operational costs) and decrease safety of structure.
The reference aircraft EV-55 is a full-metal 9-seater aircraft with a Composite Nose Part (CNP) of the fuselage, which is the only primary structure made of composite (CFRP). The CNP acts as a reference demonstrator within WP B-3.4.2 for verification and validation of investigated innovative technologies with respect to currently applied poor know-how like: manufacturing of composite parts (handmade wet lay-up), joints' sizing and EMC issues protection (Cu-mesh, diverter straps).

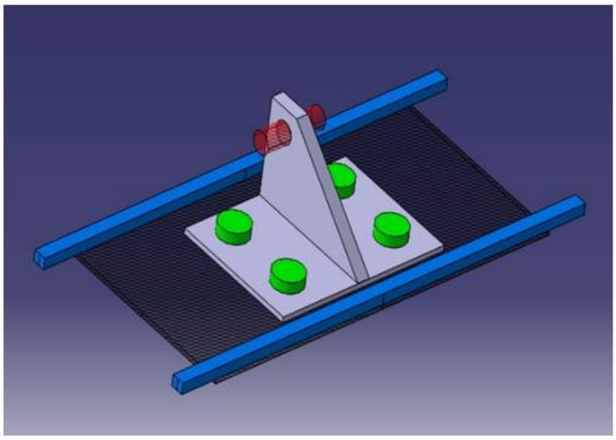
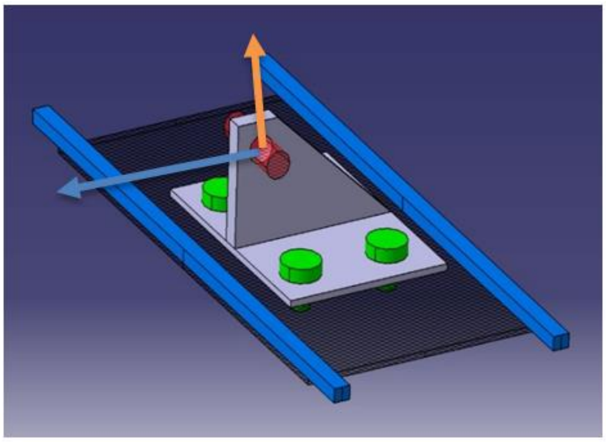


Designing of metal-composite or composite-composite joints is a complex multidisciplinary task that makes the design, sizing and manufacturing of CNP and its joints even more challenging especially together with EMC issues (LSP, HIRF).
Regarding the design and manufacturing of joints, the activities foreseen under WP B-3.4.2 will cover the following targets:

- **Optimization and improvement of electromagnetic (EMC) properties of CNP joints**
  - Development of manufacturing technology and methodology for innovative joints.
  - Re-design and optimization of joints with application of different (but appropriate) standard methods such as bonding, welding, etc. or new innovative joining methods developed recently.
  - Strength of innovative joints should be at the same level or better and costs reasonably preserved.
- **Gathering of strength test data of CNP joints for development of sizing methodology**

Selected reference CNP joints are going to be manufactured and tested (strength + EMC testing) during 2019 as part of on-going CS2 activities. Based on the test results, innovative design of joints will be proposed for manufacturing and testing. As final step, the innovative joints will be integrated into the CNP structure (virtually, 3D Catia) and manufacturing process (methodology) for developed innovative joining concepts will be summarized. To get an idea about design of joints, a list of reference joint specimens follows:

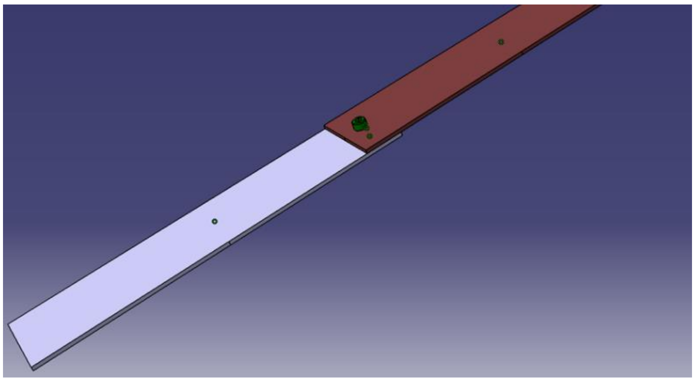
Joint 1 – DOOR HINGE

Scheduled tests are focused on the strength of the connection between metallic hinge and CFRP part:

- Strength tests – 2 or 3 load configurations
- High Current test → Strength tests … evaluation of strength reduction as a result of HC test

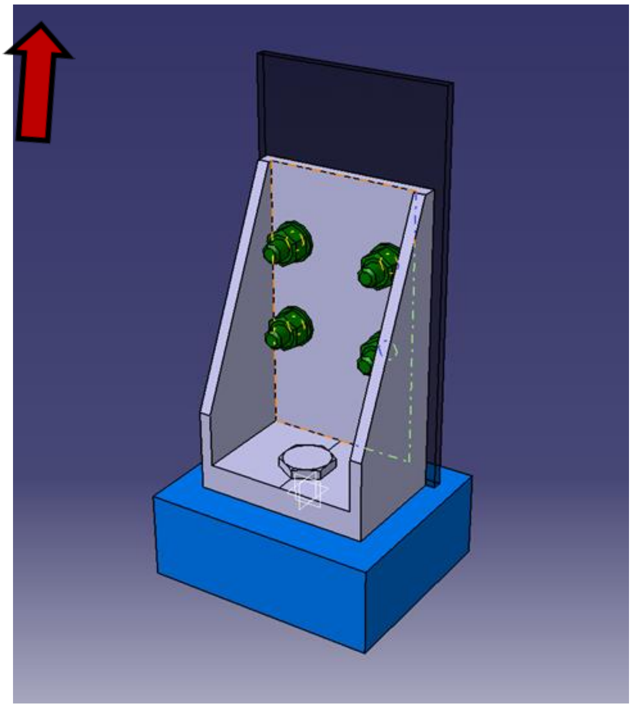
Joint 2A - FUSELAGE HINGE (simple coupon)



Scheduled tests are focused on the single-lap strength of the CFRP-CFRP connection (no EMC test):

- Strength test - fastener with countersunk and cheese head

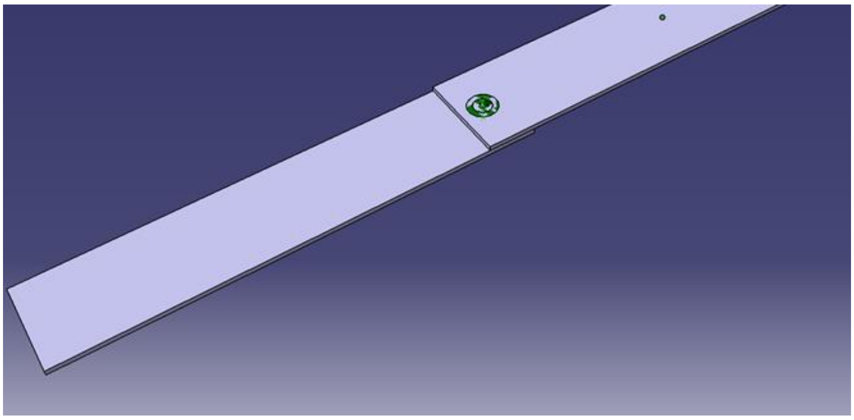
Joint 2B - FUSELAGE HINGE (assembly)



Scheduled tests are focused on the strength of whole CFRP-hinge assembly with countersunk and cheese head fasteners:

- Strength test – tension test for 2 hinge configurations:
  4 fasteners – failure close to fasteners anticipated
  6 fasteners – failure close to fuselage bolt anticipated
- High Current test → Strength test … evaluation of strength reduction as a result of HC test

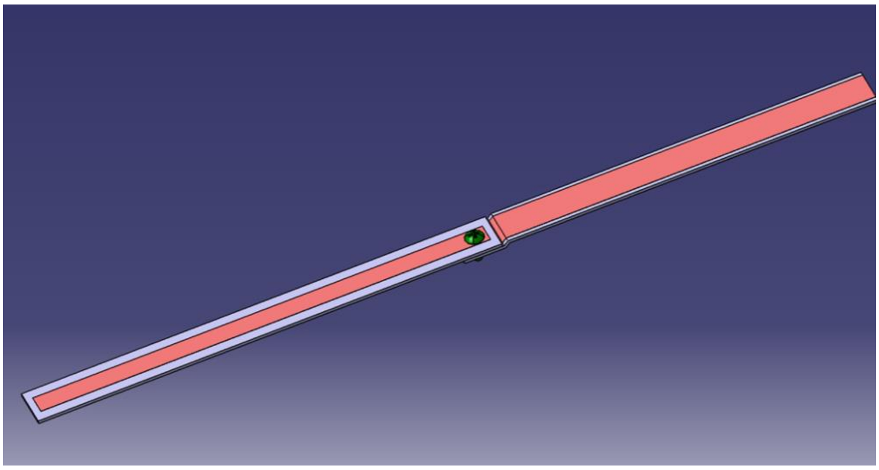
Joint 3 – CAMLOC fastener



The focus of this test is the entire joint area rather than the Camloc itself, ensuring the novel methods meet both the EMC needs and the strength required at this point when compared to the current standard.

- Strength (shear) test
- EMC test will focus on directing the current away from the fastener and creating a path through the materials for the current to flow with limited damage in the joint region

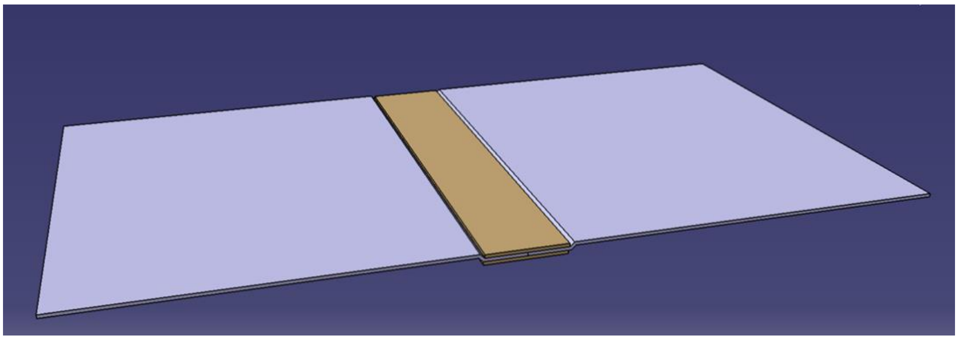
Joint 4 – GROUNDING DIVERTER STRIP (coupon)



Concept of current transfer from radome to CNP (Cu-mesh is not visualized) – new innovative concept is expected (no strength test):

- EMC test – low/high current

Joint 5 – CFRP JOINING STRAPS



Concept of current transfer between CNP R/L halves (Cu-mesh is not visualized):

- EMC test – low/high current transfer in different directions

2. Scope of work

The main scopes of the present topic are as follows:

- **Development of joint sizing methodology and sizing SW-tool**
  - The sizing methodology will be based on outcomes of activities performed by the Topic Manager and on FEM-analyses that shall be executed within this Topic.
  - The sizing SW-tool should be parametric/adaptable for hybrid or CFRP-CFRP fasteners. Sizing tool should be open source and free-expandable for different fasteners and metallic/CFRP materials providing that developed sizing methodology will be kept together with appropriate strength/EMC test validation.
- **Providing of 2D/3D-design (Catia) and manufacturing of innovative CNP demonstrator**
  - Catia model/drawings will integrate the innovative joint methodology into the whole CNP
  - Topic Manager will be able to share manufacturing tools/moulds to keep the outer shape of CNP demonstrator
- **High current and LSP tests of reference and innovative demonstrators**
  - Reference demonstrator will be delivered by Topic Manager

- Test specification of reference demonstrator will be issued by the Topic Manager at the end of 2019, however, applicant review/update is expected with respect to joint innovations

An indicative work-plan as well as a description of tasks to be performed is provided below:

	T0 + 1	T0 + 2	T0 + 3	T0 + 4	T0 + 5	T0 + 6	T0 + 7	T0 + 8	T0 + 9	T0 + 10	T0 + 11	T0 + 12	T0 + 13	T0 + 14	T0 + 15	T0 + 16	T0 + 17	T0 + 18	T0 + 19	T0 + 20	T0 + 21	T0 + 22	T0 + 23	T0 + 24	T0 + 25	T0 + 26	T0 + 27	T0 + 28	T0 + 29	T0 + 30
Task - T1				D1																										
Task - T2						D2				D5																				
Task - T3												M1		D8																
Task - T4								D4					D7																	
Task - T5															M2		D9													
Task - T6						D3						D6						D10						M4						
Task - T7																				M3										
Task - T8																					D11			D12						
Task - T9																												M5		
Task - T10																														D13

Tasks		
Ref. No.	***Title - Description***	***Due Date***
T1	Initial phase - data collecting (Topic Manager) + definition of Topic strategy	T0 + 3
T2	Reference specimens – computational FEM & EM models	T0 + 10
T3	Reference demonstrator – computational FEM & EM models + design update proposal to Topic Manager	T0 + 12
T4	Innovative specimens – computational FEM & EM models	T0 + 13
T5	Innovative demonstrator – computational FEM & EM models + design update proposal of CNP model	T0 + 15
T6	Sizing methodology + sizing SW-tool	T0 + 24
T7	Innovative demonstrator – finalization of Catia 2D/3D design	T0 + 18
T8	Innovative demonstrator – manufacturing	T0 + 24
T9	LSP (DEOL, HIRF) testing – reference + innovative demonstrator	T0 + 28
T10	Project summary report	T0 + 30

T1 – Initial phase

This task is dedicated to collect the inputs needed for the successful progress of project and definition/refinement of project strategy (based on applicant proposal) focused on methods, procedures, tools, software that will be used in the project. In this phase, close cooperation among all participants is expected as well as frequent meetings to keep foreknowledge.

MSC NASTRAN solver is envisaged for FEM analyses that will be performed within this project (SOL400 is acceptable for nonlinear analyses). However, additional implementation of other well-known solvers (Ansys, Abaqus, Optistruct, etc.) can be proposed to make developed sizing SW-tool (task T6) applicable more widely. As for pre/post-processor software tool, Ansa/Meta (Beta-Cae Systems) is preferred; however, other tools can be proposed by the applicant

Outputs from this task will contribute to D1 - Initial phase summary and description of project strategy.

T2 – Reference specimens – computational FEM & EM models

Reference joints (1, 2A, 2B, 3) will be analysed by the most suitable FEM method better matching FEM analyses and available tests' results. The proposed approach is to investigate joints' performance in a

step-by-step approach in the following way: a) intermediate level – FEM models ready for preliminary static sizing of joints; b) detail level – detailed FEM models suitable for more accurate (nonlinear) analyses or for sub-modelling.
Joints 4 & 5 are more associated with EMC issues (high current transfer) and with the manufacturing of demonstrators (conductive connection between CNP halves or CNP and radome). Thus, for them, a FEM strength analysis is not required.
From the electromagnetic point of view, EM models of reference specimens (1, 2B, 3, 4, 5) shall represent their basic electrical parameters in a way that allows their efficient implementation into demonstrator's EM model (see T3).
Outputs from this task will contribute to D2 describing the selected FEM modelling approach and to D5 - Delivery of FEM & EM analyses – reference specimens.

T3 – Reference demonstrator – computational FEM & EM models – design update

FEM and EM model of reference CNP demonstrator will be prepared with respect to Catia data provided by Topic Manager and given load subcases. Based on outcomes from task T2, it is expected that joint areas will be modelled. Proposed modifications (lay-ups, etc.) shall be based on FEM and EM analyses of the reference demonstrator.
Outputs from this task will contribute to Deliverable D8.

T4 – Innovative specimens – computational FEM & EM models

This task is similar to task T2 but addresses to innovative joint specimens.
Joints 4 & 5 are more associated with EMC issues (high current transfer) and with the manufacturing of demonstrators (conductive connection between CNP halves or CNP and radome). Thus, for them, a FEM strength analysis is not required.
EM models of innovative joint specimens shall represent their basic electrical parameters in a way that allows their implementation into innovative demonstrator (see T5).
Outputs from this task will contribute to Deliverable D4 that describes selected FEM and EM modelling approach on innovative joint specimens and to deliverable D7 consisting in the delivery of FEM and EM models.

T5 – Innovative demonstrator – computational FEM & EM models + design update proposal of CNP model obtained from C-JOINTS

FEM and EM model of innovative CNP demonstrator shall be prepared with respect to Catia data provided by Topic Manager and given load subcases. It is expected that joint areas will be modelled with respect to outcomes from task T4. Proposed modifications (lay-ups, etc.) shall be based on FEM and EM analyses of the innovative demonstrator.
Outputs from this task will contribute to Deliverable D9.

T6 – Sizing methodology + sizing SW-tool

It is expected that the robustness and adaptability of sizing tool (with respect to the implemented sizing methodology) will be based on general well-known parameters and variables (e.g. knock-down factors, failure modes, etc.) based on laminate theory, data from literature or applicant past experiences. Sizing tool for hybrid or CFRP-CFRP joints should be also free-user-expandable e.g. by fulfilment of tool databases (e.g. materials, fasteners). A further refinement of the developed tool will be done, whenever applicable, on the basis of available test results provided by the Topic Manager.
Outputs from this task will contribute to deliverables D3, D6 and D10.

T7 – Innovative demonstrator – finalization of Catia 2D/3D design

Catia 2D/3D design shall be finished (milestone M3) including proposed updates coming from task T5. This design will be used for innovative CNP manufacturing.

T8 – Innovative demonstrator – manufacturing

A general list of materials for manufacturing of reference CNP-demonstrator follows. It is expected that most of them will be applied also on innovative demonstrator:

- Tenax Style 450-5 … primary CNP material

- Glass EE280P … protection layer
- Epoxy resin Letoxit PR 217 + hardener Letoxit EM 317 - http://www.5m.cz/cz/epoxy-resins/
- Cu-mesh for high-current dissipation
- Common Al-alloys for metallic hinges (Al 2024 T3511, Al 2124 T851)
- DIN/ISO fasteners
- Extra bolts (Ph13-8Mo H1000)

Detailed specification of materials will be provided by Topic Manager during T1 – Initial phase.

To keep manufacturing costs as low as possible, Topic Manager will be able to share tools/moulds used for manufacturing of reference demonstrator to applicant if deemed appropriate. It is expected that radome will be provided by Topic Manager if its design (particularly interface between CNP and radome) will stay similar to reference design.

Outputs from this task will contribute to deliverable D11 - technology specifications, description of manufacturing process and deliverable D12 - delivery of manufactured innovative CNP.

T9 – LSP (DEOL, HIRF) testing – reference + innovative demonstrator

DEOL and HIRF tests will be conducted on both CNP demonstrators with respect to test specifications that will be released by Topic Manager. Review/update of test specifications by applicant EMC specialist with respect to innovative joints is expected.

Evaluation of differences between demonstrators is expected together with report about performance of tested areas of CNP assemblies (milestone M5).

Reference CNP demonstrator (with radome and part of metallic fuselage) will be delivered by Topic Manager. It is expected that metallic part of fuselage will be removable and usable also for testing of innovative CNP demonstrator.

T10 – Project summary report

Summary report that will evaluate and describe achieved goals together with evaluation of possible shortcomings or limitations found during the project. Proposal for possible future activities that avoid the identified shortcomings/limitations is also expected.

3. Major Deliverables/ Milestones and schedule

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1	Initial phase summary and description of project strategy	R	T0 + 4
D2	Selection of FEM & EM approach for ref. specimens	R	T0 + 6
D3	“How to” proposal for sizing methodology/tool	R	T0 + 6
D4	Selection of FEM & EM approach for innovative specimens	R	T0 + 8
D5	Delivery of FEM & EM analyses – reference specimens	D	T0 + 10
D6	Progress of sizing methodology/tool development	R	T0 + 12
D7	Delivery of FEM & EM analyses – innovative specimens	D	T0 + 13
D8	Update of the reference CNP design	R+D	T0 + 14
D9	Proposal of innovative CNP design update	R+D	T0 + 17
D10	Progress of sizing methodology/tool development	R	T0 + 18
D11	Specification of innovative demo. manufacturing	R	T0 + 21
D12	Delivery of manufactured innovative demonstrator	HW	T0 + 24
D13	Project summary report	R	T0 + 30

Milestones (when appropriate)

Ref. No.	Title - Description	Type*	Due Date
M1	Delivery of FEM & EM analyses – reference demonstrator	D	T0 + 12
M2	Delivery of FEM & EM analyses – innovative demonstrator	D	T0 + 15
M3	2D/3D final design of innovative demonstrator	D	T0 + 20
M4	Finalization of sizing methodology and SW-tool	R+D	T0 + 24
M5	LSP (DEOL) tests + evaluation	HW+D+R	T0 + 28

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

- Proven experience in strength FEM analysis (MSC NASTRAN, etc.) focused on joints and composite aircraft structures
- Proven experience with design of composite parts, tooling design and joint design
- Proven experience in manufacturing of composite parts (vacuum resin infusion) with capability to implement innovative manufacturing techniques
- Proven experience in fields of electromagnetics and EMC (DEOL, HIRF)
- Proven experience in programming of applications – processing of FEM analysis outputs
- Proven experience in technological research and development for innovative products and processes
- Proven experience in collaborating with aeronautical companies in Research and Technology programs

In addition, the applicant(s) is required to have an access to the following capabilities:

- CATIA CAD software – V5 R21 is preferred due to its interconnection with internal data management system in Topic Manager organisation
- MSC NASTRAN software – FEM analysis solver
- Pre/Post-processor is optional but Ansa/Meta (Beta-Cae Systems) is preferred
- Manufacturing and machining (prototype) workshop for composite parts and assemblies
- Facility with capability for “tufting in the composite material” and “metallic thermal spraying” Facility with capability for high-current and lightning strikes tests

5. Abbreviations

TM	Topic Manager
CNP	Composite Nose Part
SAT	Small Air Transport – part of Clean Sky2 programme dedicated to small airplanes
WP	Work-package
EM	Electromagnetic
EMC	Electromagnetic Compatibility
FEM	Finite Element Method
LSP	Lightning Strike Protection
DEOL	Direct Effect of Lightning
HIRF	High Intensity Radiated Field
SW	Software
HW	Hardware
CAE	Computed Aided Engineering

IX. JTI-CS2-2019-CFP10-AIR-02-80: Innovative flight data measurements to support the aerodynamic analysis of a compound helicopter demonstrator

Type of action (RIA/IA/CSA):		IA	
Programme Area:		AIR	
(CS2 JTP 2015) WP Ref.:		WP B-3.5	
Indicative Funding Topic Value (in k€):		1200	
Topic Leader:	Airbus Helicopters	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	36	**Indicative Start Date (at the earliest)[77]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-AIR-02-80	**Innovative flight data measurements to support the aerodynamic analysis of a compound helicopter demonstrator**
Short description	
The aim of this topic is to provide means and sensors for measurement of aerodynamic data (pressure, air velocity, temperature) during flight tests of a high speed compound helicopter demonstrator. Specific focus and objectives will lie on the non-intrusiveness of these means as well as on their ease of installation.	

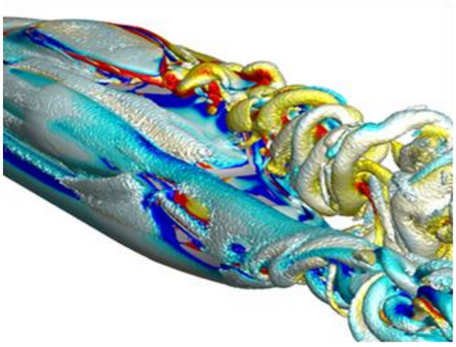
Links to the Clean Sky 2 Programme High-level Objectives[78]				
This topic is located in the demonstration area:		RACER Compound Helicopter		
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter:		Compound helicopter		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☐	☐	☐	☒	☒

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

[78] 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 final goal of the Racer demonstration program is to mature the compound rotorcraft configuration and pave the way for the development of future products fulfilling expectations in terms of door-to-door mobility, protection of the environment and citizens' wellbeing better than conventional helicopters.
To accompany the demonstration on the ground, in hover and forward flight of such a novel architecture, a fine analysis of the aerodynamic environment and phenomena that will be met is required to consolidate and valorise the prediction models. This analysis relies on local information such as time evolution of velocity components and pressure levels on specific helicopter areas.



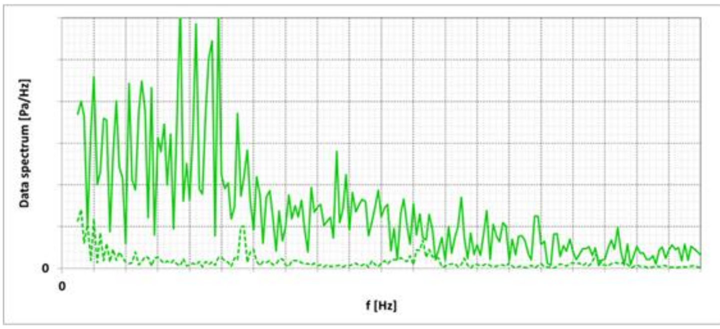


Illustration of an aerodynamic wake impinging tail and the resulting spectral density of pressure

This Call for Partners looks for the selection, preliminary test and delivery of innovative measurement systems (sensors and associated processing unit, if needed). The applicant shall propose instrumentation in agreement with the specifications and constraints described by the Topic Manager, deliver it and support the Topic Manager for its use.

2. **Scope of work**

It is proposed to structure the activities into four main Tasks (see Table below), with the associated Deliverables and Milestones as described in the following.

Tasks		
Ref. No.	***Title - Description***	***Due Date***
0	**Project Management**	T0+36
1	**Characterization of the instrumentation** Presentation of sensors that meet the technical specifications	T0+18
2	**Delivery and installation of the instrumentation** Demonstration of the instrumentation performance embedded on helicopter	T0+36
3	**Data exchange and synthesis** Data and software delivery to the Topic Leader and Summary of the achieved results.	T0+36

Task 0: Project Management
The task accounts for all project management activities of the Applicant.
Task 1: Characterization of the instrumentation

To accompany the Topic Manager in the development of a novel compound rotorcraft, the applicant is asked to identify and propose instrumentation able to provide the following data for the different prescribed area:

A. Average and dynamic variation of pressure level on:

a. the vertical and horizontal stabilizers with a linear distribution of 1 probe/10cm
b. the tailboom with a linear distribution of 1 probe/10cm
c. the wing with a linear distribution of 1 probe/10cm
d. the aft cowling with a surface distribution of 20 probes/m2
e. the intermediate cowling in the vicinity of the engine air intake with several tens of probes
f. the rotor head fairing with a radial distribution of a dozen of probes located from the centre to the maximal radius between two blades

For these elements and the associated investigated aerodynamic phenomena, the typical values of speed, temperature and frequencies are in the respective range of [0-300kt], [250-470K] and [0-200Hz], meaning an acquisition frequency up to 5 kHz.
The pressure sensors should be able to work in a [650-1010 hPa] range depending on the flight conditions. For one flight condition, the expected pressure variation should be lower than 400 Pa and the expected resolution is 10 Pa.

The systems shall be able to operate to altitudes up to at least 12000ft.
The illustration here after provides the rough dimensions of the area to be investigated and their resolution:

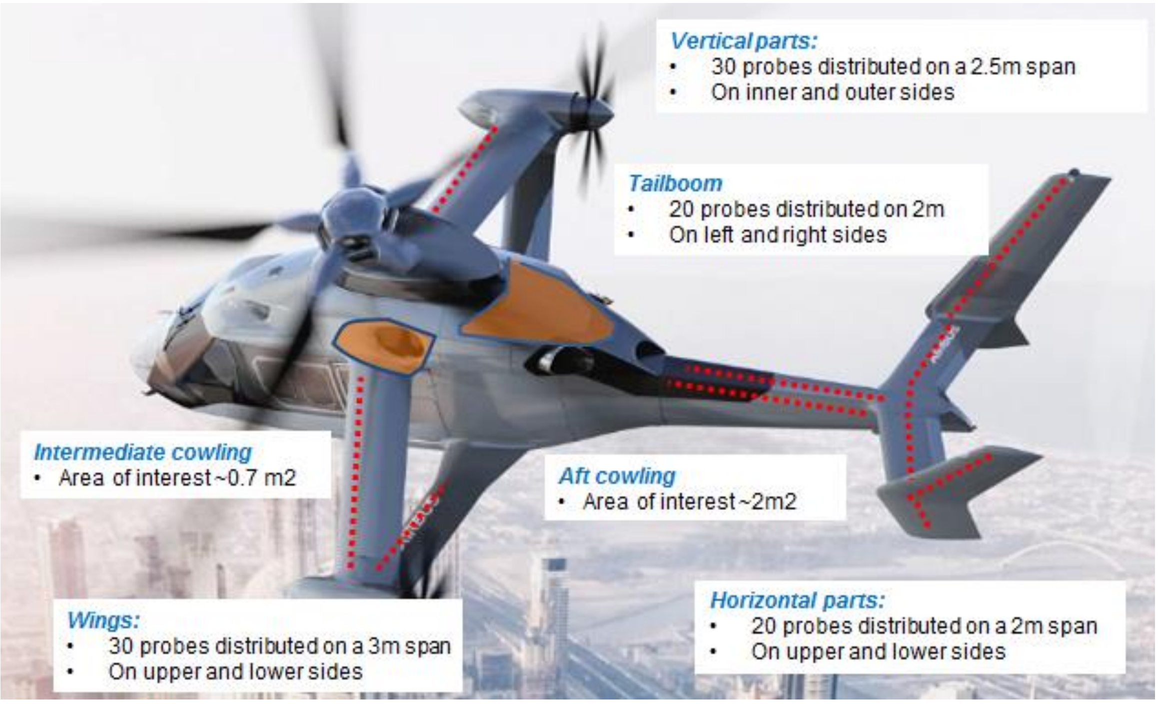


Illustration of the areas of addressed to be instrumented

B. The inflow characteristics (velocity components and pressure level) for the following areas:

a. in the outside vicinity of the engine air intake and inside its duct with an azimuthal distribution of 8 probes
b. in the front part of the engine inlet duct
c. in the outside vicinity of the air intake for the lateral rotor and inside its duct with an azimuthal distribution of 8 probes

d. inside the main gear box cooling duct with a volume distribution of 8 probes

For these elements and the associated investigated aerodynamic phenomena, the typical values of speed, temperature and frequencies are in the respective range of [0-300kt], [250-470K] and [0-200Hz], meaning an acquisition frequency up to 5 kHz.

The pressure sensors should be able to work in a [650-1010 hPa] range depending on the flight conditions. For one flight condition, the expected pressure variation should be lower than 400 Pa and the expected resolution is 10 Pa.

The velocity sensors should be able to work in a [0-200 m/s] range depending on the flight conditions and the expected resolution is 1% of the maximum surrounding velocity.

The systems shall be able to operate to altitudes up to at least 12000ft.

C. Velocity components of the external air flow:

a. in the vicinity of the lateral rotors, so as to get representative cartographies, from the spinner till blade tip, between the wing and the lateral rotor and downstream of the lateral rotor.

For these elements and the associated investigated aerodynamic phenomena, the typical values of speed, temperature and frequencies are in the respective range of [0-300kt], [250-400K] and [0-200Hz], meaning an acquisition frequency up to 5 kHz.

The velocity sensors should be able to work in a [0-200 m/s] range depending on the flight conditions and the expected resolution is 1% of the maximum surrounding velocity.

The systems shall be able to operate to altitudes up to at least 12000ft.

D. Temperature and velocity mapping between the primary and secondary engine nozzles, with an azimuthal distribution of at least twelve probes

For this purpose, the surrounding temperature is in the range of [400-800K] and the expected resolution is 1 K.

The velocity sensors should be able to work in a [0-20 m/s] range depending on the flight conditions and the expected resolution is 1% of the maximum surrounding velocity.

E. Visualisation of the thermal conditions surrounding the upper deck during ground tests.

For this purpose, the surrounding temperature is in the range of [250-800K].

The partner is asked to provide the sensors and the unit systems that will be interfaced with the standard existing flight test instrumentation of the Topic Manager so as to ensure the data synchronization.

To perform this synchronization, it is required that the developed systems provide a ETH output compatible with the dating/synchronization standard of type “PTPV1/V2”. The Grand Master, which is responsible for the clocking, will be ensured by the Flight Test Instrumentation.

Further details and synthesis for the mentioned purposes will be given at the kick off meeting and comprehensively described through the technical specification documentation, so as to provide the comprehensive list of architecture and data format constraints.

For each of the proposed instrumentation, the applicant will demonstrate its usability and performance by simulation or experimental assessments with relevant environment and boundary conditions according to the specifications provided by the Topic Manager and the following planning:

- proposal and description of the measurements system description **(M1.i)**
- a report of validation of the system will be provided **(M2.i)**
  for i=A,B,C, D and E as above described

The system shall be able to be synchronized with the existing flight test instrumentation of the Topic

Manager.

Task 2: Delivery and installation of the instrumentation
The activities to be performed in the task are as follows:

- To deliver the user and installation manuals for each system (**D1.i**).
- To deliver the measurement unit **(D2.i).**
- To run the acceptance test with the Topic Manager so as to demonstrate the respect of integration requirements and the performance of the systems for aerodynamic data measurements during flight tests within the helicopter environment (vibration, temperature) **(M3.i)**.
- To provide a calibration mean to ensure the absence of bias and drift of measurement during the flight test campaign **(M4.i)**.
- To provide spare parts of sensors and electronic boards during the flight test campaign according to the sensor lifetime and environment.

Task 3: Data exchange and synthesis
At project kick-off (T0), the applicant will receive the detailed technical specifications (environment, range of measurements, required accuracy, architectural constraint, data format and protocol for exchange)**.** Then the applicant will provide progress status through the regular meetings and will provide the system description according to the schedule described in section **Error! Reference source not found.**.
The input provided by the Topic Manager will be updated (T0+12**)** according to the findings out of the flight test campaigns which will first focus on hover and low speed conditions before exploring the high speed cases. These updates will be based on conventional instrumentation used at the beginning of the flights.

At the end of the project the applicant shall deliver an exhaustive document (**D3)** summarising the achievements, the difficulties encountered and the lessons learned.

It is proposed to structure the activities into four main Tasks (see Table below), with the associated Deliverables and Milestones as described in the following.

Tasks		
Ref. No.	***Title - Description***	***Due Date***
0	**Project Management**	T0+36
1	**Characterization of the instrumentation** Presentation of sensors that meet the technical specifications	T0+18
2	**Delivery and installation of the instrumentation** Demonstration of the instrumentation performance embedded on helicopter	T0+36
3	**Data exchange and synthesis** Data and software delivery to the Topic Leader and Summary of the achieved results.	T0+36

Task 0: Project Management

The task accounts for all project management activities of the Applicant.

Task 1: Characterization of the instrumentation
To accompany the Topic Manager in the development of a novel compound rotorcraft, the applicant is asked to identify and propose instrumentation able to provide the following data for the different prescribed area:

A. Average and dynamic variation of pressure level on:

a. the vertical and horizontal stabilizers with a linear distribution of 1 probe/10cm
b. the tailboom with a linear distribution of 1 probe/10cm
c. the wing with a linear distribution of 1 probe/10cm
d. the aft cowling with a surface distribution of 20 probes/m2
e. the intermediate cowling in the vicinity of the engine air intake with several tens of probes
f. the rotor head fairing with a radial distribution of a dozen of probes located from the centre to the maximal radius between two blades

For these elements and the associated investigated aerodynamic phenomena, the typical values of speed, temperature and frequencies are in the respective range of [0-300kt], [250-470K] and [0-200Hz], meaning an acquisition frequency up to 5 kHz. The systems shall be able to operate to altitudes up to at least 12000ft.

The illustration here after provides the rough dimensions of the area to be investigated and their resolution:

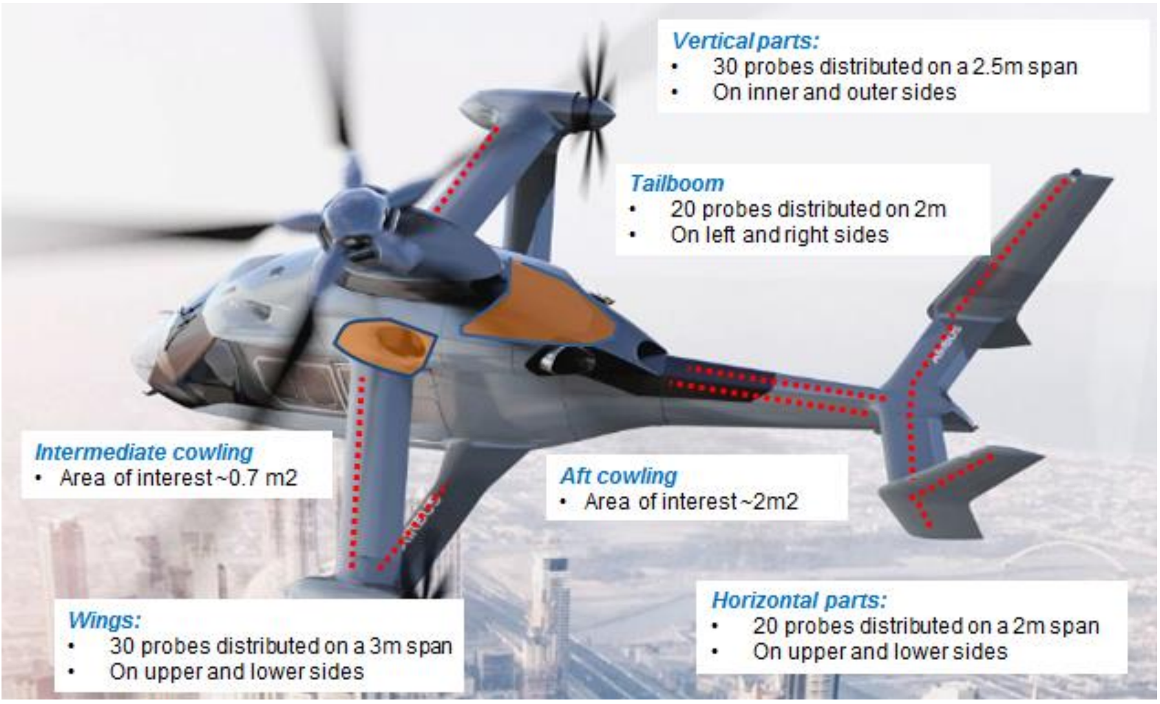


Illustration of the areas of addressed to be instrumented

B. Velocity components of the internal air flow:

a. in the outside vicinity of the engine air intake and inside its duct with an azimuthal distribution of 8 probes
b. in the outside vicinity of the air intake for the lateral rotor and inside its duct with an azimuthal distribution of 8 probes
c. inside the main gear box cooling duct with a volume distribution of 8 probes

For these elements and the associated investigated aerodynamic phenomena, the typical values of speed, temperature and frequencies are in the respective range of [0-300kt], [250-470K] and [0-200Hz], meaning an acquisition frequency up to 5 kHz. The systems shall be able to operate to altitudes up to at least 12000ft.

C. Velocity components of the external air flow:

a. in the vicinity of the lateral rotors, so as to get representative cartographies, from the spinner till blade tip, between the wing and the lateral rotor and downstream of the lateral rotor.

For these elements and the associated investigated aerodynamic phenomena, the typical values of speed, temperature and frequencies are in the respective range of [0-300kt], [250-400K] and [0-200Hz], meaning an acquisition frequency up to 5 kHz. The systems shall be able to operate to altitudes up to at least 12000ft.

D. Temperature mapping between the primary and secondary engine nozzles, with an azimuthal distribution of at least twelve probes

For this purpose, the surrounding temperature is in the range of [400-800K].

E. Visualisation of the thermal conditions surrounding the upper deck during ground tests.

For this purpose, the surrounding temperature is in the range of [250-800K].

For each of the proposed instrumentation, the applicant will demonstrate its usability and performance by simulation or experimental assessments with relevant environment and boundary conditions according to the specifications provided by the Topic Manager and the following planning:

- proposal and description of the measurements system description **(M1.i)**
- a report of validation of the system will be provided **(M2.i)**
  for i=A,B,C, D and E as above described

The system shall be able to be synchronized with the existing flight test instrumentation of the Topic Manager.

To perform this synchronization, it is required that the developed systems provide a ETH output compatible with the dating/synchronization standard of type “PTPV1/V2”. The Grand Master, which is responsible for the clocking, will be ensured by the Flight Test Instrumentation.

Further details and synthesis for the mentioned purposes will be given at the kick off meeting and comprehensively described through the technical specification documentation.

Task 2: Delivery and installation of the instrumentation

The activities to be performed in the task are as follows:

- To deliver the user and installation manuals for each system (**D1.i**).
- To deliver the measurement unit **(D2.i).**
- To run the acceptance test with the Topic Manager so as to demonstrate the respect of integration requirements and the performance of the systems for aerodynamic data measurements during flight tests within the helicopter environment (vibration, temperature) **(M3.i)**.
- To provide a calibration mean to ensure the absence of bias and drift of measurement during the flight test campaign **(M4.i)**.
- To provide spare parts of sensors and electronic boards during the flight test campaign according to the sensor lifetime and environment.

Task 3: Data exchange and synthesis

At project kick-off (T0), the applicant will receive the detailed technical specifications (environment, range of measurements, required accuracy, architectural constraint, data format and protocol for exchange)**.** Then the applicant will provide progress status through the regular meetings and will provide the system description according to the schedule described in section **Error! Reference source not found.**.
The input provided by the Topic Manager will be updated (T0+12**)** according to the findings out of the flight test campaigns which will first focus on hover and low speed conditions before exploring the high speed cases. These updates will be based on conventional instrumentation used at the beginning of the flights.

At the end of the project the applicant shall deliver an exhaustive document (**D3)** summarising the achievements, the difficulties encountered and the lessons learned.

3. Major Deliverables/ Milestones and schedule

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1.i i=C,D and E	Delivery of the user and installation manuals	R	T0+18
D2.i i=C,D and E	Delivery of the measurement system	HW	T0+18
D1.i i=A and B	Delivery of the user and installation manuals	R	T0+24
D2.i i=A and B	Delivery of the measurement system	HW	T0+24
D3	Synthesis document	R	T0+36

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1.i	Proposal and description of the measurements system	R + RM	T0+6
M2.i i=C,D and E	Report of validation of the system	R + RM	T0+6
M3.i i=C,D and E	Acceptance test	R + RM	T0+18
M4.i i=C,D and E	Delivery and demonstration of the calibration mean for each system	HW + RM	T0+18
M2.i i=A and B	Report of validation of the system	R + RM	T0+12
M3.i i=A and B	Acceptance test	R + RM	T0+24
M4.i i=A and B	Delivery and demonstration of the calibration mean for each system	HW + RM	T0+24
M5.i	Spare parts delivery and assistance	HW + RM	T0+36

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

- Qualified and demonstrated skills via track records in the field of aero-thermodynamic test (flight and wind tunnel).
- Proven experience in former research and industrial projects in the relevant technical field of the topic.

5. Abbreviations

ETH	Ethernet

X. JTI-CS2-2019-CFP10-AIR-02-81: Active Flow control on Tilt Rotor lifting surfaces

Type of action (RIA/IA/CSA):		RIA	
Programme Area:		AIR	
(CS2 JTP 2015) WP Ref.:		WP B-4.2	
Indicative Funding Topic Value (in k€):		600	
Topic Leader:	Leonardo SpA Helicopter Division	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	24	**Indicative Start Date (at the earliest)[79]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-AIR-02-81	**Active Flow control on Tilt Rotor lifting surfaces**
Short description	
The aim of the Topic is to investigate the application of pulsed air blowing devices with Zero Net Mass Flux (ZNMF) to control the vortical flow on the relevant lifting non-rotating surfaces (empennages, wing) on a Tilt Rotor configuration. For this application the objective is to determine the optimal flow control actuation parameters and the optimal jet positioning aimed to maximize the lifting surfaces efficiencies. The chosen configuration for this investigation is the NGCTR-TD.	

Links to the Clean Sky 2 Programme High-level Objectives[80]				
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 CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☒

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

[80] 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 Fast Rotorcraft (FRC) IADP of Clean Sky 2 includes a demonstrator, the Next Generation Civil TiltRotor (NextGenCTR or NGCTR), leader - Leonardo Helicopters. This fast rotorcraft concept aims to deliver superior vehicle productivity and performance with reduced environmental impact, and through this, to deliver an economic advantage to users.

NextGenCTR will design build and fly specify key technologies aimed at an innovative next generation civil tiltrotor aircraft, the configuration of which will go beyond current architectures of this type of aircraft. This tiltrotor concept will involve tilting proprotors mounted in fixed nacelles at the tips of relatively short wings. These wings are composed by fixed inboard and outboard portion next to nacelle. A specific flap is mounted on the outboard wing portion and it move in coordination with the proprotors, to minimize rotor downwash impingement in hover and increase efficiency. Demonstration activities will aim at validating its architecture, technologies/systems and operational concepts. They will show significant improvement with respect to current Tiltrotors. New specific activities will also be launched in Clean Sky 2 in particular concerning drag reduction of the proprotor, airframe fuselage and wing. In Clean Sky 1, noise reduction was mainly addressed through the optimization of flight trajectories. In Clean Sky 2 the same approach will be used for tiltrotor noise reduction objective, nevertheless architectural choices, like new engine/nacelle integration, would drive to possible further noise abatement. These transversal subjects will be validated at full scale and in real operational conditions.

The NGCTR configuration hosts several innovative aerodynamics components (inner large flaperon movable surface, external aileron, V-tail with ruddervators) that will be firstly flight tested on the Technology Demonstrator (TD). Those aerodynamic components will benefit from dedicated studies to further maximize their efficiencies. One of these studies is the evaluation of the application of active flow control devices on selected regions of the lifting surfaces.
Among others, the Zero Net Mass Flux (ZNMF) devices are the subject of the investigation to be covered by this Topic. In these devices the flow control is based on piezoeletric transducers that do not need to embark any compressed air reserve to feed them.
The direct CFD modelling of these specific devices within the complete tiltrotor configuration at different flight conditions and attitudes is not affordable due to the huge computational resources required to manage the different scale lengths of the flow phenomena past the whole aircraft. For this reason, it is required the Applicant to insert the ZNMF effects as a local modifications of the flow solver boundary conditions. This synthetized effect, i.e. reduced order model to be implemented through the use of User Defined Function (UDF) into the CFD solver, shall be yet available at the Applicant (with proof of methodology validation) and applied to the specific problem of the Tilt Rotor.
The outcome of the Topic is to report recommendations and guidelines for the installation of the active devices on NGCTR.

2. Scope of work

It is proposed that the Applicant structures the activities into five main Work Packages as hereafter described:

Tasks		
Ref. No.	**Title - Description**	**Due Date**
WP0	Management and project coordination	T0+24

Tasks		
Ref. No.	**Title - Description**	**Due Date**
WP1	Capture of the relevant flow field behaviour	T0+8
WP2	Modelling of the ZNMF effects	T0+14
WP3	Optimization of the location and performance of active control devices	T0+22

WP 0: Management and project coordination

The main objectives of this Work Package are:

- Provide timely communication for the project with the Topic Manager and the CSJU Executive Team;
- Perform risk evaluation analysis and regularly update the contingency plans;
- Ensure that the agreed project objectives and deliverables are achieved, and ensure quality of work;
- Facilitate communication and co-operation between project participants.

WP1: Capture of the relevant flow behaviour

With the support of the Topic Manager, the Applicant shall analyse by CFD the flow field development past the tilt rotor configuration to identify the key and relevant locations prone to separated and vortical flows that can benefit from active devices to control/delay/cancel them. Considering the features of the phenomena, a solver of the unsteady compressible Navier-Stokes equations is required by the Applicant. The flight conditions to be simulated by means of ZNMF will be then identified in agreement with the Topic Manager. The range of flight conditions to be analysed spans from a very low speed and high aircraft angle of attack (namely Mach=0.1 at a Pitch angle of 20 deg nose up) up to high speed (Mach=0.6 at a Pitch angle of 0 deg). The range of altitude for simulation is between 0 and 25000 Feet Pressure Altitude, while the OAT (Outside Air Temperature) is bounded between -45°C (constant at all altitudes) and ISA + 35°C. As additional information, to better characterise the scale lengths of the involved phenomena, the Applicant shall consider that, at full scale, the wing chord is 1900 mm, while the empennage chord is 1100 mm, having the empennage a VTAIL configuration.

Inputs from Topic Manager (T0):

- CAD model in CATIA V5 format of the Tilt rotor NGCTR-TD configuration

Outputs from the Applicant (T0+8):

- Report describing the identified area for ZNMF application

WP2: Modelling of the ZNMF effects

The Applicant shall model the ZNMF devices effects by inserting appropriate boundary conditions into the basic flow solver used in WP1. These boundary conditions require that the Applicant demonstrates, in the Proposal, to have yet developed and applied a robust methodology to synthetize the complex active devices flow field behaviour when embedded in an external shear flow (It is out of the scope of this project to develop this synthetized method). The ZNMF location will be based on the outcome of the WP1. ZNMF parameters like actuation frequencies, velocities and pulsed jets orientation will be defined by the Applicant according to its experience in the field. The main aim of this Work-Package is to evaluate the efficiency of the active devices as applied in the selected regions identified in WP1.

Outputs from the Applicant (T0+14):

- Report describing the basic application of ZNMF

WP3: Optimization of the location and performance of active control devices

The Applicant shall now optimize the location and the active parameters of the ZNMF devices, in order to achieve some target aerodynamics benefits, as quantified by the Topic Manager. The flight conditions to be simulated by means of ZNMF will be then identified in agreement with the Topic Manager.

Inputs Topic Manager (T0+14):

- Target aerodynamic values for optimization

Outputs from the Applicant (T0+22):

- Report describing the optimized application of ZNMF

WP4: Summary and recommendation for ZNMF application

The activity culminates in a summary Report where all benefits/drawbacks of the application of the ZNMF on Tilt rotor surfaces will be described, giving recommendation and guidelines for the installation of such devices to maximise the aerodynamics efficiencies of the surfaces.

Outputs from the Applicant (T0+24):

- Final Report describing the ZNMF application

3. Major Deliverables/ Milestones and schedule

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1	Analysis of tiltrotor configuration	R,D	T0+8
D2	Prediction of the ZNMF effects in the baseline position	R,D	T0+14
D3	Prediction of the ZNMF effects in the optimized position	R,D	T0+22
D4	Final Project Report: recommendation on the application of active flow control devices on tilt rotor	R	T0+24

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	Kick-Off meeting	R	T0+1
M2	Analysis of ZNMF devices accomplished	R	T0+14
M3	Optimization of ZNMF devices accomplished	R	T0+22
M4	Final meeting	R	T0+24

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

The Applicant must have qualified and demonstrated skills in numerical simulation (in particular CFD) and multi-objective optimization. It would even be preferred if it has already conducted activities on the same subject (active flow control by CFD).

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 flow analysis and optimization
- Proven capability to handle and model active flow controls devices
- Proven capability to manage projects by gathering several and different specialized skills (numerical simulation, flow field analysis, optimization) and demonstrated capability to guarantee the project scheduling and milestones.

5. Abbreviations

IADP	Innovative Aircraft Demonstrator Platform
CFD	Computational Fluid Dynamics
ISA	International Standard Atmosphere
ZNMF	Zero Net Mass Flux
NGCTR	Next Generation Civil Tilt Rotor
TD	Technology Demonstrator
UDF	User Defined Function

XI. JTI-CS2-2019-CFP10-AIR-02-82: Innovative approaches for interior Noise Control for Next Generation Civil Tilt Rotor

Type of action (RIA/IA/CSA):		RIA	
Programme Area:		AIR	
(CS2 JTP 2015) WP Ref.:		WP B-4.2	
Indicative Funding Topic Value (in k€):		650	
Topic Leader:	Leonardo SpA Helicopter Division	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	36	**Indicative Start Date (at the earliest)[81]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-AIR-02-82	**Innovative approaches for interior Noise Control for Next Generation Civil Tilt Rotor**
Short description	
The aim of the topic is to investigate the following subjects: • Advanced Transfer Path Analysis (ATPA) applied to a Tiltrotor in order to allow more precise quantification of airborne and structure-borne transmission paths and related ranking in a more sophisticated way compared to a standard TPA. • Advanced active control systems to mitigate tonal noise associated with turbo-propeller BPF (fundamental blade passing frequencies and harmonics) sources, in order to improve cabin comfort at low-medium frequency range (up to 300÷400 Hz), where passive solutions are not effective. The innovation is also related to specific customization as far as new smaller transducers, lower cost and weight components, increased reliability, etc.	

Links to the Clean Sky 2 Programme High-level Objectives[82]				
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:			Next Generation Tilt-Rotor	
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☐	☐	☐	☒	☒

[81] The start date corresponds to actual start date with all legal documents in place.
[82] 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.

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The Fast Rotorcraft (FRC) IADP of Clean Sky 2 includes a demonstrator, the Next Generation Civil TiltRotor (***NextGenCTR or NGCTR)***, leader - Leonardo Helicopters. This fast rotorcraft concept aims to deliver superior vehicle productivity and performance with reduced environmental impact, and through this, to deliver an economic advantage to users.

NextGenCTR will design build and fly specify key technologies aimed at an innovative next generation civil tiltrotor aircraft, the configuration of which will go beyond current architectures of this type of aircraft. This tiltrotor concept will involve tilting proprotors mounted in fixed nacelles at the tips of relatively short wings. These wings are composed by fixed inboard and outboard portion next to nacelle. A specific flap is mounted on the outboard wing portion and it move in coordination with the proprotors, to minimize rotor downwash impingement in hover and increase efficiency. Demonstration activities will aim at validating its architecture, technologies/systems and operational concepts. They will show significant improvement with respect to current Tiltrotors. New specific activities will also be launched in Clean Sky 2 in particular concerning drag reduction of the proprotor, airframe fuselage and wing. In Clean Sky 1, noise reduction was mainly addressed through the optimization of flight trajectories. In Clean Sky 2 the same approach will be used for tiltrotor noise reduction objective, nevertheless architectural choices, like new engine/nacelle integration, would drive to possible further noise abatement. These transversal subjects will be validated at full scale and in real operational conditions.

The interior noise has now more importance than in the past, as customers are asking more and more comfort and the possibility to fly without headset. Moreover to predict the interior noise level, the development of the numerical vibro-acoustic model needs a dedicated experimental activity, called Advanced Transfer Path Analysis (ATPA in short). By this way noise sources (like main gearbox, hydraulic pumps, engines, etc.) and their related vibro-acoustic loads, transmitted to the fuselage, are characterised.
Tilt-rotor in airplane mode configuration is very similar to a classic turboprop where interior noise related to the propellers is very annoying for the passengers. Being this source essentially tonal and with a low frequency content, passive systems (i.e. soundproofing) are not efficient for noise abatement. Due to this reason an advanced active noise control is required to mitigate this source inside the cabin.

2. Scope of work

It is proposed that the Applicant structures the activities into three main Work Packages subdivided in sub-Work Packages as hereafter described:

Tasks		
Ref. No.	***Title – Description***	***Due Date***
WP0	Management and project coordination	T0+36
WP1	Advanced TPA	T0+16
WP1.1	Clustering of vibro-acoustical systems	T0+6
WP1.2	ATPA application and collection of results useful for ANC design	T0+10
WP1.3	Vibro-acoustic factors from ATPA	T0+16
WP2	Advanced ANC (Advanced Noise Control)	T0+36
WP2.1	Assessment on aircraft noise environment	T0+12

Tasks		
Ref. No.	***Title – Description***	***Due Date***
WP2.2	ANC design and components sizing/locations	T0+30
WP2.3	Aircraft Integration and Testing	T0+36

WP 0: Management and project coordination

The main objectives of this Work Package are:

- Provide timely communication for the project with the Topic Manager and the CSJU Executive Team;
- Perform risk evaluation analysis and regularly update the contingency plans;
- Ensure that the agreed project objectives and deliverables are achieved, and ensure quality of work;
- Facilitate communication and co-operation between project participants.

WP1: Advanced TPA

The classical Transfer Path Analysis (TPA) has the objective to provide the contributions of the sources at the receiver points, independently of their transmission path.
Using the ATPA technique, the transmission paths are quantified and ranked. This technique complements the possibilities of the classical TPA method by allowing the determination of the relative contributions of the selected structure and airborne transmission paths. Using the information extracted from the application of this theory, the mechanical component to be modified can be identified. From that point, the decision can be taken to act directly on the source or on the structural elements.
This approach has never been applied in the aerospace field and in particular to an aircraft.

In order to reach the final target, the whole activity has to follow the next steps:

1. Definition of the framework to be studied: knowing the noise contributions at a receiver point inside the aircraft at particular flight conditions.
2. Study of the partition in several subsystems of the aircraft's area under study: choice of the significant subsystems of the problem.
3. Analysis of the limitations at experimental level for the ATPA test.
4. Perform the ATPA test on the aircraft. It includes a static test, with the aircraft stopped on ground, and a dynamic test, with the aircraft at the defined flight conditions.
5. Calculate the numerical parameters from ATPA results.

WP1.1: Clustering of vibro-acoustical systems

Most of ATPA noise problems aim to obtain the contribution of different "parts" of the system under study to the total noise in a target location. These "parts" are the so-called subsystems of the ATPA application.
One of the preliminary steps of any application of the ATPA method to a noise contribution problem is to choose how to split the main aircraft frame into several subsystems, to be analysed.
The aim of this WP is to obtain an objective method to identify a suitable partition in subsystems, in order to detect the contribution of each structural part to the overall noise level. This system subdivision is also applicable to the related numerical models.

Inputs from Topic Manager (at T0):

- Mathematical 3D model (FEM and/or CAD)

Outputs from the Applicant (at T0+6):

- Report describing the results of the vibro-acoustical clustering

WP1.2: ATPA application and collection of results useful for ANC design

This work package consists on the experimental execution and the post-processing of the ATPA. The aim of the ATPA test is to provide information on the vibro-acoustic paths and the contributions of each element of the aircraft to the overall interior noise.

The on-ground test consists in measuring the Global Transfer Functions (GTF), which are the transfer functions between subsystems, when exciting each one of them. GTF functions are obtained by means of hammer impacts or specific acoustic excitation.

GTFs are measurable functions, but superposition principle is not applicable to these functions. The required functions for applying ATPA are the Direct Transfer Functions (DTF), which represent the transfer function between two subsystems when all the rest are blocked. As DTF's are not directly measureable without modifying the structure under study, this blocking is done mathematically.

Once the DTF's are obtained by post-processing the measured GTF, they can be multiplied to the operating signal at each subsystem to obtain the subsystem contribution to overall noise. The in-flight tests are needed to collect the experimental measurements, in order to feed the above process.

During the operational test, the noise at the target position is also measured and its value is only used to check if the sum of the contributions obtained from ATPA process corresponds to the total measured noise.

Inputs from Topic Manager (at T0+6):

- Aircraft fuselage for the tests

Outputs from the Applicant (at T0+10):

- Experimental procedure for the ATPA test
- Report describing the results of the experimental activity (ATPA)

WP1.3: Vibro-acoustic factors from ATPA

Vibro-acoustic simulation model is used to predict wide-bandwidth noise and vibration and the accuracy of a prediction is based on the consistency of the input parameters. One of the main difficulties in the construction of a numerical model is the capability to correctly model the junctions between the subsystems and the energy dissipation of each subsystem. Sometimes, the database of the software is not sufficient to guarantee this accuracy, therefore this lack can be filled using information given by the ATPA.

In this project the proposed approach is to obtain the Statistical Energy Analysis (SEA) coupling loss factors from energetic direct transfer functions and the internal loss factors. The internal loss factors can be found, in turn, from the impact tests performed during the ATPA test.

Once the subsystem internal loss factors are known, this method provides a procedure to compute the subsystem coupling loss factors from the direct transfer functions (DTF). These functions can be obtained from the application of the ATPA method.

Outputs from the Applicant (at T0+16):

- Report with the extracted numerical parameters for vibro-acoustic model

WP2: Advanced ANC

As outlined above, tilt-rotor in airplane mode is affected by a very annoying noise generated by propellers. The nature of this sound and its frequency contents are such that ANC is the only efficient way to mitigate the interior noise, while classic passive noise control systems are useless. Moreover the nature of the problem in a tilt-rotor is amplified, with respect to a turboprop, for the huge size of the propellers and their location (tight gap between tip blades and fuselage).

The ANC is based on a counter-phase cancellation wave generated by an actuator driven by a control unit connected to some error sensors. Noise cancellations system today are of different kind and able to

reduce noise locally (quiet bubble around passenger's head) or to reduce noise globally in the cabin (set of actuators or sensors distributed in the whole passenger compartment)
The aim of the work is to define a suitable system for a tilt-rotor on the basis of the most advanced technology available today in the market and able to offer a remarkable tonal noise reduction without penalty for the weight and with acceptable cost.

WP2.1: Assessment on aircraft noise environment

The aim of this WP is the collection of all experimental data (noise and vibration) useful to give the aircraft environment scenario needed for the following design phase. Applicant will be responsible for the required inputs (kind and position of the sensors, acquisition system parameters and configuration, etc.), data acquisition and related post-processing. Topic Manager will be responsible for the related test plan and overall activity supervision.

Inputs from Topic Manager (at T0+6):

- Relevant acoustics signature info
- Aircraft for test flight

Outputs from the Applicant (at T0+12):

- Technical content to feed Test Plan about aircraft vibro-acoustic environment
- Technical content to feed related Test Report

WP2.2: ANC design and components sizing/locations

The parameters of the ANC system will be defined and estimation of the expected noise reduction will be evaluated using suitable testing and/or mathematical model. On the basis of this investigation, the project will produce the proposed architecture of the system (number and location of actuators, error sensors and related type, electrical wires, power supply interfaces, etc.).
As part of this task, the hardware and the software architecture of the ANC system will be completely defined and all the components related to ANC will be prepared to be installed on the aircraft for testing.

Inputs from Topic Manager (at T0):

- Aircraft characteristics and mathematical models (CAE, CAD, etc.).

Outputs from the Applicant (at T0+30):

- ANC whole system (HW & SW) for propeller noise reduction inside cabin

WP2.3: Aircraft Integration and Testing

In order to test the ANC system, all the components defined in the design and development phase will be integrated into the aircraft for performance assessment. Some in-flight tests will be performed in order to tune the ANC algorithm parameters and to check if reached tonal noise abatements are in accordance with initial target and previous predictions.

Inputs from Topic Manager (at T0+30):

- Aircraft for ANC system test and tailoring

Outputs from the Applicant (at T0+36):

- ANC system for propeller noise reduction inside cabin

3. Major Deliverables/ Milestones and schedule

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1.1	Results of the vibro-acoustical clustering	R	T0+6
D1.2	Experimental procedure for the ATPA test Results of the experimental activity (ATPA)	R R,D	T0+10
D1.3	Extracted numerical parameters for vibro-acoustic model	R,D	T0+16
D2.1	Test Plan and test report about aircraft vibro-acoustic environment	R,D	T0+12
D2.2	ANC whole system (HW & SW) for propeller noise reduction inside cabin	R,HW, SW	T0+30
D2.3	ANC system for propeller noise reduction inside cabin	R, D, HW	T0+36

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M0	Kick-off meeting	R	T0+1
M1.1	Results of the vibro-acoustical clustering	R	T0+6
M1.2	ATPA test	R	T0+10
M1.3	Parameters for vibro-acoustic model	R	T0+16
M2.2	ANC design and components sizing/locations	R, HW	T0+30
M2.3	ANC Aircraft Integration, Tuning and Testing	R, D, HW	T0+36

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

The Applicants must have qualified and demonstrated skills in testing (ATPA, TPA), simulation (FEM, BEM and SEA) and active control methodologies (ANC). It would even be preferred if it has already conducted activities on the same subject.
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 dynamical testing (FRF, TPA, ATPA) of structures.
- Proven capability to interface experimental and numerical activities (extrapolation of model parameters).
- Proven capability in the development of ANC architectures for aircraft.

5. Abbreviations

ANC	Active Noise Control
ATPA	Advanced Transfer Path Analysis
BEM	Boundary Element Method
BPF	Blade Passing Frequency
CAD	Computer Aided Design
CAE	Computer Aided Engineering
DTF	Direct Transfer Functions
FEM	Finite Element Method
FRF	Frequency Response Function
GTF	Global Transfer Functions
HW	Hardware

NGCTR	Next Generation Civil Tilt Rotor
SEA	Statistical Energy Analysis
SW	Software
TD	Technology Demonstrator
TPA	Transfer Path Analysis

XII. JTI-CS2-2019-CFP10-AIR-02-83: Innovative weight measurement system for Tiltrotor application

Type of action (RIA/IA/CSA):		IA	
Programme Area:		AIR	
(CS2 JTP 2015) WP Ref.:		WP B-4.2	
Indicative Funding Topic Value (in k€):		800	
Topic Leader:	Leonardo SpA Helicopter Division	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	24	**Indicative Start Date (at the earliest)[83]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-AIR-02-83	**Innovative weight measurement system for Tiltrotor application**
Short description	
Innovative automatic weight measurement system for tiltrotors aimed at improving the accuracy of weight and balance data (including conversion moment calculations), reducing Flight Line operations times and improving operators' safety. Once Aircraft assembly is completed Functional Tests including weight measurement are required in the two operative configurations: Helicopter Mode (VTOL) and Airplane Mode (A/P). Further to aircraft set-up for the first flight weight and balance is then performed during the demonstration phase every time that a change in configuration and/or envelope/performance exploration is required. This system is therefore aimed at providing a robust answer to the need of accuracy and repeatability in the frame of an ergonomic environment for the operators.	

Links to the Clean Sky 2 Programme High-level Objectives[84]				
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 CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☒

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

[84] 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 Civil Tilt Rotor will be developed under FRC and AIRFRAME to ultimately substantiate the possibility to combine in an advanced aircraft the high cruise speed, low fuel consumption and gas emission, low community noise impact, and productivity for operators. A real scale flightworthy demonstrator, based on existing tiltrotor fuselage, and embodying the new tiltrotor architecture and technologies will be designed, integrated and flight tested.

The Fast Rotorcraft Project (FRC) aims to demonstrate that tiltrotor configuration, implementing and combining cutting-edge technologies, as from the current Clean Sky 2 Program, opens up to new mobility roles that neither conventional helicopters nor fixed wing aircraft can currently cover in a sustainable way, for both the operators and the industry.

Innovative structures development under AIRFRAME is one of the key pillars of the Project, including design, manufacturing, assembly, integration and relevant testing.

Measuring and tracking aircraft weight and balance in respect of the technical configuration required for the specific demonstration objective is a key ground testing activity required for release to flight.

This functional test is performed by means of equipment composed by hydraulic tools with force sensors integrated and connected with a centralized acquisition system.

To date aircraft levelling is performed by manual positioning of the hydraulic tools and consequently is not accurate per se, requiring several iterations before weight & balance objectives are achieved, and with the following weaknesses:

- Set up of the system is time consuming and requires more than two operators at a time;
- Repeatability is not guaranteed;
- Ergonomics is limited.

2. Scope of work

The scope of this project is to develop an innovative automatic weight measurement system for tiltrotors aimed at improving the accuracy of weight and balance data (including conversion moment calculations), reducing Flight Line times and improving operators ergonomics.

The new measurement system layout shall be implemented aiming to the following main targets:

- Possibility to execute the weight measurement in a dedicated area;
- Optimisation of the complete measurement operation cycle;
- Optimisation of number of operators required to complete the activity (target 2 operators);
- High accuracy and repeatability of the measurements;
- High ergonomics for the operators;
- High safety standards;
- Possibility of self-check/diagnostic of the system;
- Automatic recording of data weight;
- Statistical Analysis capability in respect of tiltrotor different configurations.

General Requirements:

- Aircraft Positioning: +/- 1mm
- Aircraft orientation: 0.1 deg (Pitch/Roll)
- Repeatability error: < 1 Kg

A system based on controlled footboards with high level of automation is required, with the possibility to move Aircraft with AGV and capability to be fully integrated with Topic Manager data acquisition systems.

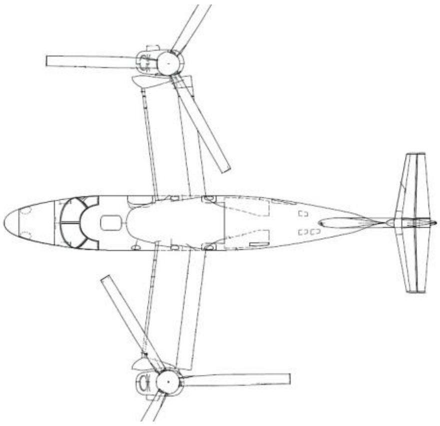


Figure 1 – Helicopter mode Configuration

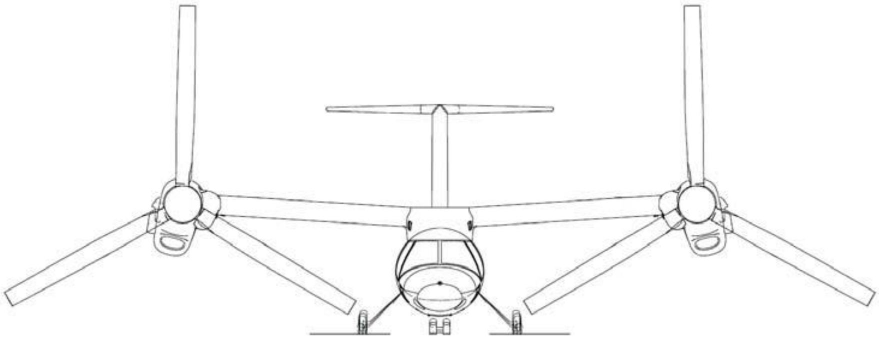


Figure 2 – Airplane mode Configuration

It is proposed that the Applicant structures the activities into five main tasks as hereafter described:

Tasks		
Ref. No.	**Title - Description**	**Due Date**
T0	Management and project coordination	T0+24
T1	Analysis and Design review	T0+8
T2	System, Hardware, footboards Manufacturing	T0+16
T3	Software, PLC, System management, User Interface development	T0+20
T4	Testing and Final Acceptance	T0+24

Task 0: Management and project coordination

The main objectives of this task are:

- Provide timely communication for the project with the Topic Manager and the CSJU Executive Team;
- Perform risk evaluation analysis and regularly update the contingency plans;
- Ensure that the agreed project objectives and deliverables are achieved, and ensure quality of work;
- Facilitate communication and co-operation between project participants.

Task 1: Analysis and Design review

Current Functional Test Procedure of Weight and Conversion Moment measurement and Requirement

Specification in use in Topic Manager organisation will be transmitted for reference only to the applicant in order to analyse the "As is Process" and develop one or different proposal in order to achieve the targets. The applicant is requested to investigate and to propose any innovative approach that, in their knowledge and experience, can satisfy the requirement.

The applicant is requested to conduct trade-off studies on the subjects listed below:

- Automated measurement cycles, to achieve Aircraft centre of gravity (CG) and pitch/roll zero angle evaluation;
- Calibration and manual operations on the system;
- Remote access to manage system status, alarm, data download, update of the product line program.

The proposal and relevant schedule will be discussed during the Design Review and if all requirements will be adequately covered the formal go-ahead for Task 2 will be formalized.

Inputs from Topic Manager at T0:

- Current Functional Test procedure in use in Topic Manager organisation
- State-of-the-Art Aircraft Configuration

Outputs from the Applicant at T0+8:

- Report describing the proposals (Trade Off) from "as is " versus "To Be" methodology
- Time reduction report
- Detailed Schedule

Task 2: System, Hardware, footboards Manufacturing

Task 2 includes the activities required for the design and manufacturing of the system, according to the following high level requirements:

- Process Cycle for weight measurement: in order to properly develop the equipment. The following steps represent the target condition to achieve an optimised process for the weight & balance measurement activity:
  - The aircraft is moved by operator(s)/AGV to the station for the measurement activity;
  - The aircraft is constrained by operator(s) in reference points position;
  - The operator moves to the control system, accesses with their code, selects the product program, starts the automatic measurement routine;
  - The System lifts the footboards in order to level Aircraft to roll/pitch zero degrees;
  - The System starts the routine to detect centre of gravity (CG) and weight data in each footboard both for Helicopter mode (VTOL) and Airplane mode (A/P), including Conversion Moment calculation;
  - The System returns Aircraft on ground;
  - The System records all of the data and returns a feedback on the conformity of the operation;
  - The Aircraft returns available for next operations.
- Painting/Treatments shall be in accordance with Topic Manager standard for environmental protection;
- The Measurements System shall be designed to manage different Aircraft configurations
- The Control System shall be designed to manage the footboard position (including auto level positioning) and monitor the overall status, connected with ethernet base and fully integrated with Topic Manager ERP (Enterprise Resource Planning) system.

Outputs from the Applicant at T0+12:

- PDR (Preliminary Design Review – go ahead with detailed design)
- Preliminary Design Report

Outputs from the Applicant at T0+16:

- Hardware delivery
- 2D Drawing of the layout
- 3D Drawing of the structure (Catia V5 R22)
- FEM Analysis
- Calibration certificate
- Conformity
- Electrical Schemes
- Usage Manual

Task 3: Software, PLC, System management, User Interface development
Software architecture shall be based on the following components:

- **PLC Programmable Logic Control Module**: direct control of the footboards and relative utilities, measurement cycle management, calibration management
- **CS Module**: Computer Software data management, measurement data integration, operator interface, integration with external systems
- **PC Module**: Log in/ Log Out , Home page –select menu, Automatic cycle Page, Program page, Diagnostic page, Configuration page

Outputs from the Applicant at T0+20:

- Software delivery

Task 4: Testing and Final Acceptance
Equipment will be tested and formally approved by Topic Manager through implementation of an agreed final acceptance procedure on the NGCTR Technology Demonstrator.
Outputs from the Applicant T0+24:

- Final Installation report
- Test report

3. Major Deliverables/ Milestones and schedule

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1	Design review	R+D	T0+8
D2	Hardware Delivery	R+HW	T0+16
D3	Software delivery	R+SW	T0+20
D4	Testing and Final Acceptance	R+D	T0+24

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	Kick Off	RM	T0
M2	Design review	RM	T0+8
M3	Hardware Delivery	HW	T0+16
M4	Software delivery	SW	T0+20
M5	Testing and Final Acceptance	RM	T0+24

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

The Applicant must have qualified and demonstrated knowledge in Automated Measurement Systems together with proven expertise in Functional Test Equipment Design, Manufacturing and Test. Program management is a fundamental skill, being this topic a multidisciplinary project that needs firm control on schedule, cost, and risk.

5. Abbreviations

IADP	Innovative Aircraft Demonstrator Platform
NGCTR	Next Generation Civil Tilt Rotor
AGV	Automatic Guided Vehicle
VTOL	Vertical and Take Off
A/P	Airplane
CG	Centre of Gravity

XIII. JTI-CS2-2019-CFP10-AIR-02-84: Modular Platform development for TiltRotor final assembly

Type of action (RIA/IA/CSA):		IA	
Programme Area:		AIR	
(CS2 JTP 2015) WP Ref.:		WP B-4.2	
Indicative Funding Topic Value (in k€):		1000	
Topic Leader:	Leonardo Helicopter Division	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	20	**Indicative Start Date (at the earliest)[85]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-AIR-02-84	**Modular Platform development for TiltRotor final assembly**
Short description	
The aim of the activity is to design and produce an innovative multi-functional Jig in order to perform structural assembly of Next Generation Civil Tilt Rotor wing, wing systems installation, nacelle installation and relevant functional test. The jig will require laser alignment system and tilting concept for ergonomic purpose. Moreover through Information Technology it will possible to implement Visual progress of the assembly activities on the Jig in terms of Job Card and Overall Schedule Progress Status.	

Links to the Clean Sky 2 Programme High-level Objectives[86]				
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:		Next-Generation Tiltrotor		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☐	☐	☐	☒	☒

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

[86] 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 Civil Tilt Rotor will be developed under FRC and AIRFRAME to ultimately substantiate the possibility to combine in an advanced aircraft the high cruise speed, low fuel consumption and gas emission, low community noise impact, and productivity for operators. A real scale flightworthy demonstrator, based on existing tiltrotor fuselage, and embodying the new tiltrotor architecture and technologies will be designed, integrated and flight tested.
The Fast Rotorcraft Project (FRC) aims to demonstrate that tiltrotor configuration, implementing and combining cutting-edge technologies, as from the current Clean Sky 2 Program, opens up to new mobility roles that neither conventional helicopters nor fixed wing aircraft can currently cover in a sustainable way, for both the operators and the industry.
Innovative structures development under AIRFRAME is one of the key pillars of the Project, including design, manufacturing, assembly, integration and relevant testing.
This innovative architecture leads to the need of new suitable methods and tools to ensure the assembly of this demonstrator in a more efficient way, with particular attention to wing assembly, system and subsystems installation and nacelle integration

2. Scope of work

The overall objective of this Topic is to develop a new Jig concept for Tiltrotor Final Assembly Line in order to integrate the following activities in a multipurpose jig:

- **Structural Completion of Wing Assembly:** activities that deal with the completion of wing sub-assembly from the structural standpoint (e.g. Leading Edge, Trailing Edge, Provision Installation), including but not limited to installation of reinforcement plates/brackets, alignment of provisions, shimming. Managing of rework needed during assembly activity
- **Systems Installation inside/outside Wing Torque Box:** activities that deal with the installation and functional harmonisation of aircraft systems (e.g. Fuel System, Hydraulic, Harness, De-Ice, Interconnect Drive System) within wing torque box, including but not limited to installation of supports, alignment of provisions. Managing of rework needed during assembly activity
- **Nacelle Dressing and Installation**: which require tight tolerance alignment between LH/RH assembly

and Wing tilt rotor, including but not limited to installation of supports, alignment of provisions. Managing of rework needed during assembly activity
- **Functional test:** Systems installed will be then tested on the same jig in order to guarantee full completion of activities before Wing Installation on Fuselage (next step of Final Assembly)

The following key pillars are the main drivers of this Call Topic activity:
- Jig design and manufacturing
- Laser Alignment System Application
- Laser projection Application
- Tilting Capability Architecture
- Pneumatic System Application
- Vacuum System Application
- Electrical System
- Panel for Job Card and Progress Schedule Visualization Inspection
- Manual and Report Development

It is proposed that the Applicant structures the activities into five main tasks as hereafter described:

Tasks		
Ref. No.	**Title - Description**	**Due Date**
T0	Management and Project Coordination	T0 + 20
T1	Concurrent Phase with Topic Manager Engineering for requirements definition	T0 + 3
T2	Design and Development of the Multipurpose Jig	T0 + 9
T3	Manufacturing and Inspection of the Jig	T0 + 18

Task 0: Management and project coordination
The main objectives of this task are:
- Provide timely communication for the project with the Topic Manager and the CSJU Executive Team;
- Perform risk evaluation analysis and regularly update the contingency plans;
- Ensure that the agreed project objectives and deliverables are achieved, and ensure quality of work;
- Facilitate communication and co-operation between project participants.

Task 1: Concurrent Phase with Topic Manager Engineering for requirements definition
The concurrent Activity with Topic Manager Engineering is needed to ensure that the jig manufacturing capability in terms of dimensional and geometric tolerances is in accordance with wing assembly technical requirements.
The main items to be analysed for the concurrent activity are:
- Drive System Machined Parts installation
- Pylon Support Assembly/Wing ribs axis Alignment
- Interconnect Drive Train Supports Installation
- Wing Assembly Accessibility Inside Torque Box

Released tolerance layout design from engineering is mandatory to authorize the manufacturing of the jig.

Task 2: Design and Development of the Multipurpose Jig

The following features/auxiliaries are required:

- Laser Alignment System
- Laser projection
- Tilting Capability for Ergonomic Purpose
- Pneumatic System (10 locations, minimum)
- Vacuum System
- Electrical System
- Panel for Job Card and Progress Schedule Visualization

The jig shall be designed in accordance to referred flight coordinates.

Inputs from Topic Manager (T0):

- Wing and fuselage Assembly and systems installation provisions Drawing

Outputs from the Applicant (T0 +9):

- 2D drawings (printed and CATIA format)
- 3D drawings (CATIA format)
- Detailed design and stress report
- Material properties and characteristics

Task 3: Manufacturing and Inspection of the Jig

This task deals with the manufacturing and the inspection of the Jig.

Outputs from the Applicant (T0+18):

- Jig;
- Jig control register using a format provided by Topic Manager;
- Quality report for jig components and laser tracker reports;
- Relaxed weld structure certificate;
- User and Maintenance manual for jigs;
- Certificate of Conformity to Italian laws for working in security.

Task 4: Final Acceptance of the Jig

This task includes:

1. Transport and Assembly/Installation in Topic Manager Plant (Varese area)
2. Final Check of golden Points
3. Final Check of Auxiliary features

3. Major Deliverables/ Milestones and schedule

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1	Design specification	R+D	T0 + 3
D2	Final Design and Analysis Report - Comprehensive Documentation Package (CATIA 3D, 2D manuf. drawings)	R+D	T0 + 9
D3	Jig Delivery	HW	T0 + 18
D4	Jig Acceptance	R	T0 + 20

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	System Requirements Review	RM	T0 + 3
M2	Design Review of the Multipurpose Jig	RM	T0 + 9
M3	Jig Delivery	D	T0 + 18
M4	Jig Acceptance	R	T0 + 20

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

The Applicant shall have proven capabilities and skills in each of the specific areas of this Call Topic, in particular experience in Aerospace Jig manufacturing

5. Abbreviations

NGCTR Next Generation Civil Tilt Rotor
TD Technology Demonstrator

XIV. JTI-CS2-2019-CFP10-AIR-02-85: Development of a multifunctional system for complex aerostructures assembly, assisted by neural network softwares

Type of action (RIA/IA/CSA):		IA	
Programme Area:		AIR	
(CS2 JTP 2015) WP Ref.:		WP B-4.3	
Indicative Funding Topic Value (in k€):		900	
Topic Leader:	Leonardo Aircraft Division	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	18	**Indicative Start Date (at the earliest)[87]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-AIR-02-85	**Development of a multifunctional system for complex aerostructures assembly, assisted by neural network softwares**
Short description	
The aim of the Topic is to develop and validate a multifunctional assembly cell, based on neural network software, able to interface mixed/augmented reality devices and co-robot technologies. The Artificial Intelligence system with neural network will integrate different technologies, in order to achieve higher aircraft quality targets and to reduce to zero the risk of failures due to manual activities. The system will dramatically innovate the method to assembly and inspect aerostructures, with significant cost reduction and improved competitiveness. The system will be validated at Topic Manager Plant for REG IADP Fuselage/Cabin full scale demonstrator assembly.	

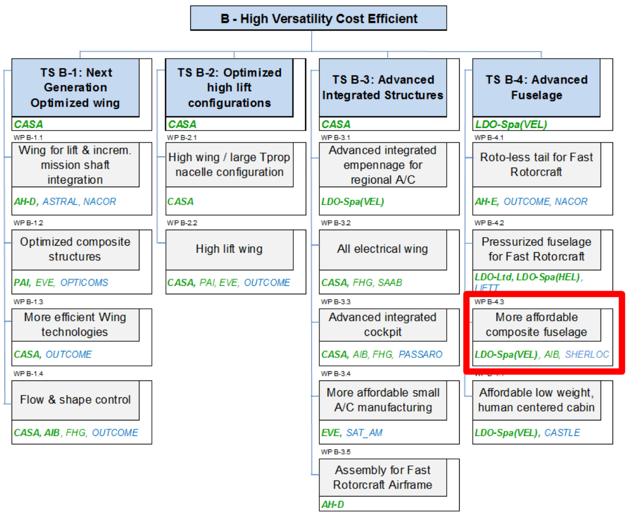
Links to the Clean Sky 2 Programme High-level Objectives[88]				
This topic is located in the demonstration area:		Advanced Manufacturing		
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter:		Advanced/Innovative Turboprop		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☐	☐	☐	☒	☐

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

88 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 activities to be performed according to the present Topic description are included in a wider context of work in the framework of the Airframe ITD of Clean Sky 2. In particular, the Work Package B-4.3 “More Affordable Composite Fuselage” is incorporated within the Technology Stream B-4 and represents the field where activities requested to the Applicant shall be performed. The relevant ITD Work Breakdown Structure is shown below putting in evidence the WP B-4.3:



More in detail, the activities of the WP B-4.3 will pursue the development of the technologies and methodologies studied in Clean Sky - GRA ITD and in other EU projects addressed to the feasibility of a composite fuselage for a Regional Turbo Prop aircraft. The objective is to drive the development of that technologies and methodologies to innovative solutions which take into consideration driver factors indispensable for the industrialization: increased structural integration, reduced total costs and structural weight, enhanced multifunctional materials, reduced environmental impact and extended duration of aircraft life.

2. Scope of work

The scope of the Topic is to develop and validate a multifunctional assembly cell, able to assist manual activities as the typical fuselage systems and equipment installation, including cabling through the cabin structures. These activities are complex because of high number of similar part, path and accessibility, aircraft customization, etc. Manual operations may bring to wrong and unsafe installations, as Foreign Object Damage (FOD) and reworks.

The multifunctional assembly cell which is the aim of the topic and will be based on state-of-art technologies such as neural network software, mixed reality, augmented reality and collaborative robots, will reduce to zero the above risks, by mean of guiding information, model holograms overlapping real state of installation, image analysis and various sensors.

Its main objectives are:

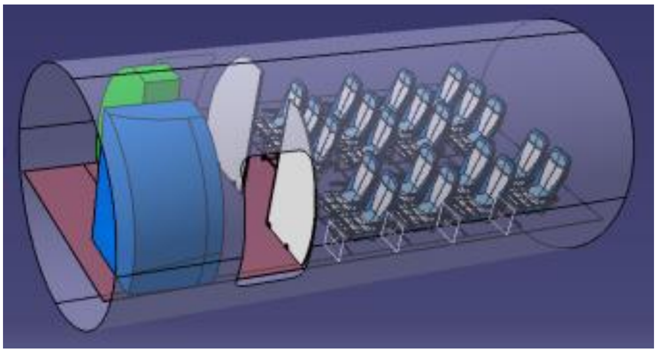
- Create a robust assembly process capable to achieve higher aircraft quality targets, than traditional assembly process. In this way it could be possible to have designs with more restrictive targets in terms of weight and performance.
- Reduce to zero the risk of failures due to manual activities. This means waste reduction in production line (for example scrap material due to reworks).

- Significant reduction of production cost, in terms of reduction of times / flows, in particular for complex manual activities. It will improve competitiveness.
- Innovative methodology to obtain manufacturing instructions directly from engineering models.
- A paperless approach.
- Use of artificial intelligence (AI) for automatic quality check on assembly line, with the intent to reduce or eliminate quality check effort and assuring safety.
- Direct implementation of “as built” configuration and design changes management.
- Advantages in case of multiple and complex installations, by mean of access to technical data and instructions during manufacturing phases.
- Use of artificial intelligence for Automatic FOD recognition and control.

The cell to be developed and validated will be focused on an AI software with neural network and will be made by the following main hardware:

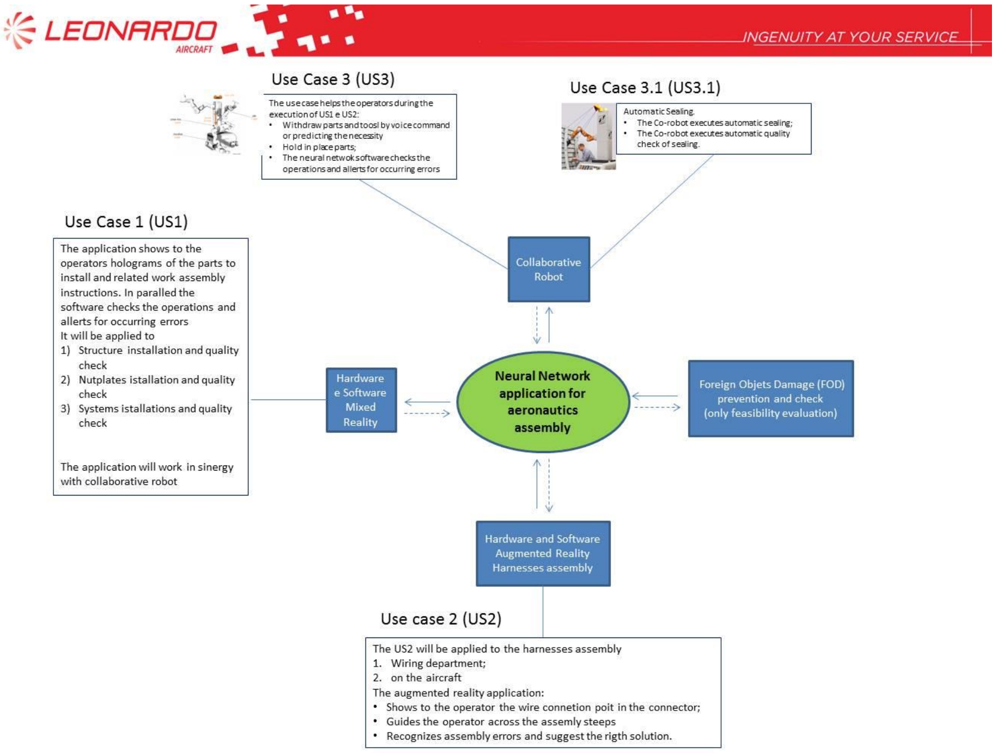
- Co-robot for assembly, automatic sealing/paste dispensing and quality checks.
- Helmet for mixed reality application
- Glass for augmented reality application
- PC, HD Cameras and sensors to implement applications and AI software.

The demonstrator for multifunctional assembly cell will be a fuselage barrel, already designed to test Pax Cabin features, and including on board systems and advanced solutions for increasing passenger comfort and safety as: FAS, Galley, Lavatory, EC Seat, T/A Insulation, Lining, Service Area, Stowage Bin, Lighting & Cabin Layout, E-ECS and systems.



Cabin demonstrator layout

This item has been considered as suitable demonstrator for the Topic objectives and tasks.
The assembly cell architecture overview as well as a brief description of “Use Cases”, and project tasks definition and timelines are presented below.



Assembly cell architecture overview

It is proposed to structure the technical activities in the following tasks:

Tasks		
Ref. No.	**Title - Description**	**Due Date**
Task 1	Trade-off Analysis for Use Cases	T0 + 2
Task 2	AI assisted cell architecture study and definition	T0 + 4
Task 3	Engineering and manufacturing requirements definition	T0 + 8
Task 4	AI assisted cell development	T0 + 12
Task 5	Use Cases development	T0 + 12
Task 6	AI assisted cell validation	T0 + 18

Task 1 Trade-off Analysis for Use Cases:
Based on mixed reality, augmented reality and collaborative robot, all assisted by neural network application, a predictive cost-benefit analysis shall be performed for the 4 cases described above. This will be confirmed with actual data after completion of Task 5.

Task 2 AI assisted cell architecture study and definition:
General requirements and specifications for the whole cell will be defined, on the basis of use cases application in collaboration with the Topic Manager.

Task 3 Engineering and manufacturing requirements definition:
Study and development of technical guidelines and release of suitable models to be used in Tasks 4 and 5.

Task 4 AI assisted cell development:
Detailed design and development of the whole cell shall be performed. Neural network application shall

be developed and verified. A list of needed HW, SW and materials will be defined for acquisition. Intermediate reviews will be performed to better address the project.

Task 5 Use Cases development:
According to Topic demonstrator assembly, Use Cases will be defined in detail and tested with AI assisted cell devices. In particular, also by mean of simplified/sub-component tests, the application on barrel will be defined taking into account all requirements and constraints for safe, quality acceptable and industrially suitable operations. This task will be partially performed at Topic Manager site**.**

Task 6 AI assisted cell validation:
Cell architecture, SW, HW and neural network application will be applied to perform the requested Use Cases. A final verification of assumptions and estimate of Task 1 will be done. This task will be mainly performed at Topic Manager site.

3. Major Deliverables/ Milestones and schedule

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1.1	Trade-off Analysis for Use Cases	R	T0 + 2
D2.1	AI assisted cell architecture study and definition	R	T0 + 4
D3.1	Engineering requirement guideline	R	T0 + 4
D3.2	Engineering models	D	T0 + 5
D3.3	Manufacturing requirement guideline	R	T0 + 8
D4.1	AI assisted cell Preliminary Review	R	T0 + 6
D4.2	AI assisted cell Final Review	R	T0 + 12
D5.1	AI assisted cell HW acquisition	HW	T0 + 6
D5.2	Use Cases Preliminary review	R	T0 + 6
D5.3	Use Cases Final review	R	T0 + 12
D6.1	Test book for use cases	R	T0 + 13
D6.2	AI assisted cell and use cases preliminary test	R	T0 + 15
D6.3	AI assisted cell and use cases validation test	R	T0 + 18
D6.4	Final Report with trade-off validation	R	T0 + 18

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	AI assisted cell architecture definition	R	T0 + 4
M2	AI assisted cell HW acquisition	HW	T0 + 6
M3	AI assisted cell Final Review	R	T0 + 12
M4	Test book for use cases	R	T0 + 13
M5	AI assisted cell and use cases validation test	R	T0 + 18

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

- Proven experience in aircraft assembly process;
- Proven experience in automatic machine for aerospace;

- Proven experience in manufacturing process analysis and optimization;
- Proven experience in systems integration;
- Proven experience in mixed reality and machine learning application
- Proven experience in cost estimation at industrial level for composite structure assembly

5. Abbreviations

AI	Artificial Intelligence
Co-Robot	Collaborative robot
MR	Mixed reality
AR	Augmented reality
FOD	Foreign Object Damage

XV. JTI-CS2-2019-CFP10-AIR-02-86: Development of equipment for composite recycling process of uncured material

Type of action (RIA/IA/CSA):		IA	
Programme Area:		AIR	
(CS2 JTP 2015) WP Ref.:		WP B-4.3 (linked to activities in WP C-2.1.4)	
Indicative Funding Topic Value (in k€):		800	
Topic Leader:	Leonardo Aircraft Division	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	36	**Indicative Start Date (at the earliest)[89]:**	> Q1 2020

Topic Identification Code	Title
JTI-CS2-2019-CFP10-AIR-02-86	**Development of equipment for composite recycling process of uncured material**
Short description	
The objective of the call is to develop a key process for recovery and recycling of CFRP uncured scraps, coming from lamination activity. In particular activities to be performed are: design, feasibility study, development and validation of an equipment that is able to cut and distribute the CFRP wet scraps in such a way to generate a new pre-impregnated material.	

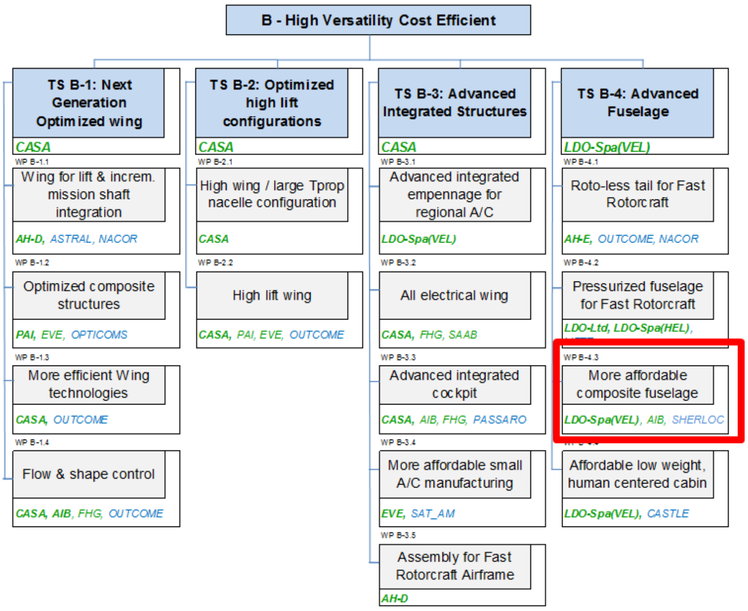
Links to the Clean Sky 2 Programme High-level Objectives[90]				
This topic is located in the demonstration area:			Advanced Manufacturing	
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter:			Advanced/Innovative Turboprop	
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☐	☐	☐	☒	☐

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

[90] 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 Airframe ITD of Clean Sky 2. In particular, the Work Package B-4.3 “More Affordable Composite Fuselage” is incorporated within the Technology Stream B-4 and represents the field where activities requested to the Applicant shall be performed. The relevant ITD Work Breakdown Structure is shown below putting in evidence the WP B-4.3:



More in detail, the activities of the WP B-4.3 will pursue the development of the technologies and methodologies studied in Clean Sky - GRA ITD and in other EU projects addressed to the feasibility of a composite fuselage for a Regional Turbo Prop aircraft. The objective is to drive the development of that technologies and methodologies to innovative solutions which take into consideration driver factors indispensable for the industrialization: increased structural integration, reduced total costs and structural weight, enhanced multifunctional materials, reduced environmental impact and extended duration of aircraft life.

2. Scope of work

During lamination activities (both manual and automated) with CF pre-impregnated materials, a lot of scraps are generated due to different ply orientations and specific boundaries required. These scraps are also very difficult and costly to be disposed due to national and European regulations. The objective of the present Topic is therefore to develop a key process for recovery and recycling CFRP uncured scraps.
As a matter of fact the Topic Manager (TM) has already developed an uncured CFRP scraps recycling process concept aimed to re-use, rather than waste, material scraped during lamination. This process is therefore background proprietary information owned by the TM Company and covered by patent in Italy, Europe and USA. The scope of the present call is, starting from and within the limits of the patent, to define in details the process parameters of automated material cutting and distributing, and to develop, realize and validate the relevant equipment.
Property of background information and results of the work performed within this Call for Proposal will be handled according to the rules of Clean Sky 2.

The uncured CFRP scraps - coming in different shape and dimension from pre-impregnated excess material cutting during unidirectional plies lamination - have to be cut using a suitable device in small elements, after backing paper removal (if any). These elements, in the following “CFRP chips”, have to be of defined dimensions: 8 mm transverse to fibre direction and 50 mm parallel to fibre dimension. After cutting, the CFRP chips must be distributed rather uniformly over a backing paper to obtain a raw uncured roll or (if not feasible) sheets of about 500 mm x 1000 mm to be subsequently used as raw material to produce light weight structural elements or tooling.
The objective of the project is the development and realization of equipment modules that are able to cut and distribute uniformly the above chips, according to the following requirements.
The cutting module shall be able to:

- be rechargeable of CF scraps in a continuous manner;
- be easy to maintain;
- cut both in the longitudinal and transverse directions in a precise and clean way;
- avoid winding the cut strips on the cutting blades;
- have all equipment properly cooled to maintain material tack inside optimal range;
- have continuous cutting;
- have simple construction;
- have capacity to operate even in presence of different scraps geometries;
- have a system able to verify the correct orientation of the fibers in input to the system;
- be integrated perfectly with the distribution module;
- be capable to separate cut chips (50 mm x 8 mm) from residual material of smaller dimension to be disposed.

Moreover, the distribution module has to be able to receive CFRP rectangular chips coming from cutting stage with rather constant rate and to, at random, orient and distribute the chips over a plate covered by a suitable backing paper (separate sheets of 500 mm x 1000 mm or continuous roll can be considered as valid options).
In addition, the distribution module shall ensure:

- final CFRP material areal weight of 800 (+/-200) gr/sqmt;
- quasi isotropic fibre orientation; i.e. 0°: 25 (+/-5)%, +/-45:50 (+/-5)%, 90°:25 (+/-5)%;
- equipment productivity equal to: 2.5 ÷ 4.5 kg/h (for the first prototype it is allowed a lower productivity);
- The total working flow shall not exceed 8 h (including de-freezing time of raw materials).

Any other suggestion regarding the distribution module in terms of repeatability of fiber orientation distribution in the final recycled material (i.e. overlying chips distribution with pre-defined orientation is a valid option) are welcome and will be considered by TM.
Finally the modules have not to contaminate or alter CFRP chips and in particular the distribution system must ensure repeatability of the properties of the recycled material (with the possible presence of a dedicated control system and auto-calibrated device). Anyway, the machine shall process the material into temperature and humidity controlled environments.
Only allowed contact materials will be used and any process that can heat or cool or wet the materials shall be reviewed by Topic Manager before application.
The raw uncured material needed for the execution of overall project will be provided to the applicant by the Topic Manager in frozen sealed bags. The main characteristics of this raw material are listed below:

- single layer (thickness range 0.1 ÷ 0.3 mm);
- irregular shapes ;
- epoxy resin;

- standard intermediate and high modules unidirectional CF;
- prepeg layer supported by backing paper or backing polyethilene film (if any).

__Work Breakdown Structure__

A proposed Work Breakdown Structure and activities description are as follows:

WP	Title	Due Date
WP1	***Trade-off Study***	
Task 1.1	Feasibility studies for overall recycling equipment	T0+6
Task 1.2	Trade-off between different approaches	T0+9
Task 1.3	Main parameters and key components definition for the selected process	T0+16
Task 1.4	Definition of suitable method for fiber areal weight and fiber orientation distribution measurement for recycled material	T0+18
WP2	***Design and Manufacturing***	
Task 2.1	Detail design of recycling equipment (cutting and distribution modules)	T0+21
Task 2.2	Fabrication of equipment modules	T0+25
Task 2.3	Integration of recycling equipment modules (cutting and distribution systems)	T0+27
Task 2.4	Feasibility tests for recycling equipment validation	T0+33
Task 2.5	Recycled material basic structural characterization	T0+36

__WP Description__

WP1 - Trade-off study

Task 1.1 - Feasibility studies for overall recycling equipment
The objective of the task is to identify different methods/mechanisms for chips cutting and distribution; i.e. blades geometry, knives and counter knives, mat belts and rollers, air stream, vibrating tables, etc. For each method, the key parameters and components shall be identified. In this task, the geometrical constraints that impact the overall system need also to be defined.

Task 1.2 - Trade-off between different approaches
The different methods/mechanisms shall be compared in terms of compliance with the requirements described above and costs, and the most suitable for implementation will be selected. This task involves a close interaction with the Topic Manager to check compatibility with the overall TM proprietary concept.

Task 1.3 - Main parameters and key components definition for the selected process
In this task the parameters and key elements of the equipment for the selected approach shall be completely defined.

Task 1.4 - Definition of suitable method for fiber areal weight and fiber orientation distribution measurement for recycled material
The task will be devoted to define suitable methods to measure fiber areal weight and fiber orientation distribution in at least 20 square zones (dim. 100 mm x 100 mm) randomly identified into the resulting CFRP sheet after material recycling. Alternative methods can be proposed by the applicant based on a statistic approach of relevant measures taken on the entire CFRP sheet.

WP2 - *Design and Manufacturing*

Task 2.1 - Detail design of recycling equipment (cutting and distribution modules)
The task will be devoted to the detailed design of cutting and distribution modules. The output of the task will be the related drawings.
Task 2.2 - Fabrication of equipment modules
The task will be devoted to the fabrication of a working cutting and distribution modules. In order to assess process parameters, prototypal modules shall be fabricated and tested in advance.
Task 2.3 - Integration of recycling equipment modules (cutting and distribution systems)
The task will be devoted to the integration of the longitudinal/transversal cutting module with the distribution module.
Task 2.4 - Feasibility tests for recycling equipment validation
The objective of the task is to perform functional and operative tests in order to verify the feasibility of recycling equipment and that all the requirements identified above are met. To demonstrate that, at applicant site, a production of a minimum of 10 sheets of recycled material shall be performed (starting from CFRP uncured scraps) and in particular CFRP areal weight and fiber distribution shall be verified as defined into Task 1.4. In addition production rate will be verified according to the requirement described above.
After completion of the task, the overall equipment shall be transferred and installed at Topic Manager plant and 500 sqm of recycled material will be produced with this equipment under applicant supervision.
Task 2.5 - Recycled material basic structural characterization
Once verified the correct functioning of the system in terms of repeatability of the production of the recycled material, some panels shall be laminated and cured in order to extract specimens (approximate number of coupons: about 100) for preliminary mechanical characterization of the recycled material. Tension, compression, Filled Hole Tension, Open Hole Compression, Unnotched Tension, Unnotched Compression, Interlaminar Plane Shear are the main properties to be verified.
Recycled sheets will then be produced and inspected at Topic Manager site in collaboration with applicant. Panel lamination, bagging and autoclave cure are under the Topic Manager responsibility. The applicant must take care of coupons cutting, testing and data reporting.

Intellectual Property
The text of this topic contains the basic information for the applicant to understand the need of the Topic Manager. However, more detailed data will be available in a separate info package that can be provided on request to the interested applicant. Due to the confidential content of this additional information, it will be necessary to sign a Non-Disclosure Agreement (NDA) with the Topic Manager Company. Questions concerning the confidential data delivered will be handled in a dedicated Q/A document, which will only be circulated to those applicants who have signed the Confidentiality Agreement.

3. Major Deliverables/ Milestones and schedule

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

Deliverables

Ref. No.	Title - Description	Type*	Due Date
D1	Definition of possible approaches	R	T0 + 6
D2	Selection of most suitable approach and definition of key parameters/components	R	T0 + 9
D3	Measurement of fibre areal weigh and fibre orientation module definition	R/D	T0 + 18
D4	Detail design of recycling equipment (cutting and distribution modules)	R/D	T0 + 21
D5	Fabrication of equipment modules and integration of recycling equipment module	R/D/HW	T0 + 27
D6	Functionality and feasibility tests of recycling equipment	R/D	T0 + 33
D7	Material basic structural characterization activities and final assessment	R	T0 + 36

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	Definition of equipment components	R	T0 + 9
M2	CDR of cutting and distribution module	R/D	T0 + 21
M3	Cutting and distribution modules on site at Topic Manager facility	R/HW	T0 + 33
M4	Structural recycled material characterization	R	T0 + 36

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

- Competence in management of complex projects of research on manufacturing technologies.
- 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.
- Proven experience in the use of design, analysis and configuration management tools.
- Proven competence in drawings and realization of mechanical device for uniform distribution of chips in any other fields and/or have a know-how on specific technique useful for the above application.
- General knowledge of uncured composite material storage and handling conditions.
- Proven experience in experimental testing.
- Proven experience in the Industrial Automation field.
- Proven experience in the detection field.
- Competence in measures and data analysis with statistical approaches.
- Testing skills to allow mechanical and chemical characterization of samples made by new technologies.

5. Abbreviations

A/C	Aircraft
CFRP	Carbon Fiber Reinforced Plastic
CF	Carbon Fibre

EoL	End of Life
C/E	Carbon/Epoxy
TM	Topic Manager

XVI. JTI-CS2-2019-CFP10-AIR-03-07: End of Life (EoL) for biomaterials

Type of action (RIA/IA/CSA):		RIA	
Programme Area:		AIR	
(CS2 JTP 2015) WP Ref.:		WP C-2.1.1	
Indicative Funding Topic Value (in k€):		350	
Topic Leader:	INVENT GmbH	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	30	**Indicative Start Date (at the earliest)[91]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-AIR-03-07	**End of Life (EoL) for biomaterials**
Short description	
The aim of this topic is the development of new innovative and green technologies for End of Life (EoL) of either common used bio-fibres (flax, hemp, kenaf, etc.) or bio-resins or both. Different approaches have to be evaluated including among others: recycling, reclaiming, incineration and others. The roadmap will cover all scientific area from small scale (proof of concept) to big real components EoL.	

Links to the Clean Sky 2 Programme High-level Objectives[92]				
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 CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☐

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

[92] 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

Composite materials have gained an ever-increasing share of the market not only in their main application fields Aerospace and Transportation but increasingly in every day sectors. So, they are now applied in the field of home and industrial construction, sports and home equipment's, etc. The direct result is that the use of composites is growing and the global market for composite products is expected to reach $95bn globally by 2020, an increase of 40% from 2014. Key advantages of composite materials are their high mechanical properties as well as their very low weight compared to traditional metallic materials and the ability to offer design freedom in the most stressed and loaded directions.
On the other hand, composites and specifically the composite matrix based on thermosetting plastics in comparison to conventional metallic materials are disadvantaged in their recycling due to several reasons. For example in UK, GFRP end-of-life waste is likely to be around 50-60kT per annum but waste classification does not distinguish between FRP and other material so no accurate figure is available. End-of-life waste for CFRP is still small, estimated at 3kt per year. In addition manufacturing waste has to be considered estimated at 10% of manufactured parts.
During last 2 years additive manufacturing offers and alternative solution because there is ability to produce carbon fiber parts with minimum production waste of material but as technology is not mature and there is no ability to produce right now structural CFRP components for critical uses using this method. Another aspect is high prices of the general components of composites (fibers and matrix) which are related with raw materials. Based on the above mentioned, lot of efforts have already begun to develop ways to recycle components made from composites to either fully recycle or re-use their components. Until today the most promising ways of recycling for the conventional composites is the mechanical recovery process; different variants of thermal pyrolysis like chain conveyor, fluidised bed, microwave assisted pyrolysis; chemical/thermochemical processes like solvolysis and finally cement kiln. But at the same time the above mentioned proposed recycling processes are not environmentally compatible and have high impact in terms of energy consumption, e. g. chemical recycling needs 21-90 MJ per kg, pyrolysis needs 25-30 MJ per kg, microwave pyrolysis needs 5-10 MJ per kg and finally mechanical needs 0.1-4.8 MJ per kg, compared with energy needs for the production of the virgin fibers which reaches averagely 240 MJ per kg for carbon and about 30 MJ per kg for glass fibers.

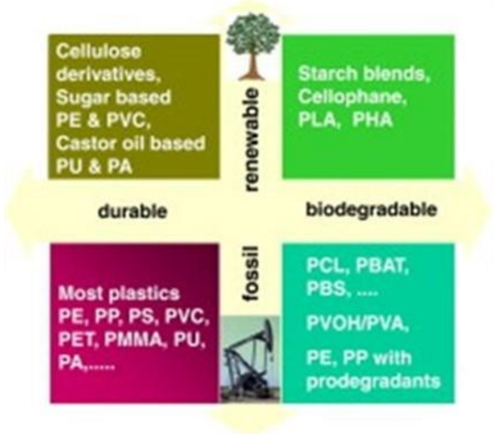


Figure 1: Recycling of bioplastics, their blends and biocomposites: A review |Azadeh Soroudi Ignacy Jakubowicz

Based on this, the use of bio-composites has been significantly increased lately since there is a potential replacement of glass epoxy composites already used in the automotive and aerospace industries, especially in secondary structures such as aircraft and cars interiors, household uses, sports, etc. The challenge of making products for cars/aircrafts and also for every days uses from "green" composite

materials with mechanical properties comparable with state of the art composites, but more environmentally friendly leads to investigate advanced materials with desired properties. Bio-composites use natural based fibers such as jute, sisal, flax, hemp, bamboo, etc., which are mainly obtained from plants, instead of synthesized fibers (carbon, Kevlar, glass, etc.). At the same time, natural matrix materials based on natural rubber, sugar, corn, vegetable oils, etc., are partly produced from green resources and significantly reduce the use of crude oil based chemical products normally used for epoxy resins, vinyl ester, etc. These bio-based polymers offer comparable mechanical properties making them capable for applications in very different products, and in some cases bio-composites offer very promising thermomechanical, electrical and chemical properties, making their application even more attractive in the coming years.
The advantages of bio-composites such as lower density compared to glass fiber composites, the usage of renewable resources and their sustainability make them attractive for future applications.
In order to answer the question of recyclability or other sustainable methodology of disposal for this new generation of bio-composites which are already confronted with conventional composites, it is mandatory to develop innovative and also cost-effective EoL technologies for bio-composites as soon as possible.

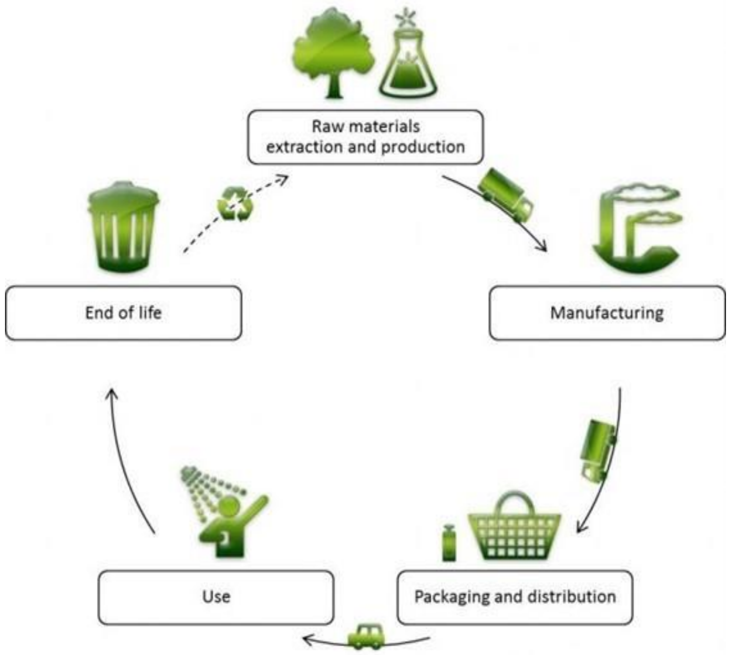


Figure 2: Life cycle analysis (LCA) comprises the whole life cycle of a certain product, from raw material to final disposal | Credit: sci-env.ch

Based on that, it is very important to propose and evaluate ways of initiating recycling planning or other ways that will reduce their environmental footprint after use, as well as their widespread use in the future. Among others, it is necessary to investigate and based on that thinking out of the box ways of cost-effective and innovative solutions such as reclaiming, incineration, re-using plan for bio-composites, re-melted resins, fiber and matrix recovering, cement kiln processing, etc. At the moment it is not clear if incineration with the recovery of energy is a more sustainable concept compared to mechanical or chemical methods with the recovery of raw materials. For that reason, the main objective of the present project shall be a comparison of the advantages and disadvantages of EoL concepts based on mechanical, thermal and chemical methods of waste material treatment in terms of cost and sustainability. Optionally, biological methods such as biodegradation shall be considered in addition. EoL waste is mandatory while manufacturing waste is optional to be considered in the project. The main aim of the project is to identify the best practice for EoL of bio-based composites and to proof this concept by theoretical assessment as well as by experimental work on material coupons and real demonstrators to be provided by the Topic Manager.

2. Scope of work

The scope of the topic is to develop technologies for End of Life (EoL) of either commonly used bio-fibers (flax, hemp, kenaf, etc.) or bio-resins or both. Different approaches have to be developed and evaluated including among others: Mechanical (e. g. recycling, re-use, reclaiming), thermal (e. g. incineration, pyrolysis) and chemical (e. g. solution, extraction) and optional biological (e. g. composting, biodegradation) methods. All approaches have to be analyzed and ranked with respect to usability, cost, sustainability and applicability in an industrial scope with the aim to identify the best candidates for experimental assessment. The roadmap will cover all scientific area from literature review of existing disposal solutions, theoretical assessment, small scale (proof of concept) experimental analysis to demonstration of EoL methods on real composite parts.

It is proposed to organise the activities in the following tasks:

Tasks		
Ref. No.	**Title - Description**	**Due Date**
0	Management	T0+30
1	Literature review and preliminary EoL concept definition	T0+6
2	Development of mechanical, thermal, chemical and/or biological EoL concepts for bio-based composites	T0+12
3	Theoretical assessment and ranking of mechanical, thermal, chemical and/or biological EoL strategies	T0+18
4	Experimental proof of concept of the best candidates	T0+24

Task 0: Management
Activities in this task are management activities such as coordination of the project, communication towards the Topic Manager and reporting of the final project results.

Task 1: Literature review and preliminary EoL concept definition
Initial point of the work shall be a study of the state of the art, in detail a review of already existing EoL methods for the respective materials. The study shall also include possible EoL methods and strategies for conventional FRPs (glass or carbon fiber based) that could be adapted to natural fiber based composites. Second activity in task 1 is the first definition of general EoL ideas to be further developed (e.g. shredding, incineration, pyrolysis, etc.). In particular, thermosetting polymers shall be considered as matrix for the composites.

Task 2: Development of mechanical, thermal, chemical and/or biological EoL concepts for bio-based composites
Aim of task 2 is the further development of EoL concepts based on the information collected in task 1. Potential ideas for recycling and disposal of natural fiber based composites shall be further developed and described (e.g.: shredding of the material and using the particles as filler for polymers, pyrolysis and extraction of monomers or chemical raw materials for new polymers, chemical or bio-chemical degradation of polymer and re-use of the fibres, etc.). Outcome of the task shall be a list of potential EoL

methods for different strategies (mechanical, thermal, etc.) and for each point of the list a preliminary dataset of relevant information shall be collected (e.g. ecological impact to be expected, ratio of re-usable raw material, effort to be expected, etc.)

Task 3: Theoretical assessment and ranking of mechanical, thermal, chemical and/or biological EoL strategies
Based on the Results of task 2 an assessment of the developed methods shall be performed. Aim of the ranking is the down-selection of the most promising concepts for the further development and the following experimental analysis. Appropriate ranking criteria shall be defined, including among others the aspects environmental impact and sustainability, cost and efficiency as well as technical feasibility.

Task 4: Experimental proof of concept of the best candidates
The most promising EoL methods developed in the previous tasks shall be experimentally tested in laboratory scale at coupon level. The experimental setup shall be defined based on the nature of the EoL methods developed in the previous tasks. Appropriate test criteria shall be defined and described in a test plan. Aim of the task shall be not only the experimental proof of concept but also the preparation for the further evaluation in demonstrator scale. That means that necessary up-scaling steps shall be considered during the experimental work.

Task 5: Evaluation of full-scale demonstrator and LCA data collection
The EoL methods with the best outcome shall be demonstrated on basis of a scalable demonstrator. A possible demonstrator could be a flat or curved panel with the size of 1 sqm. The final nature of the demonstrator shall be agreed with the topic manager. Part of this task is the collection of necessary data for LCA.

3. Major Deliverables/ Milestones and schedule

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1	Report on literature review	R	T0+6
D2	Preliminary concept definition	R/D	T0+6
D3	Final EoL concept definition	R	T0+12
D4	Assessment report	R	T0+18
D5	Test plan for experimental analysis	R	T0+18
D6	Test report of experimental analysis	R	T0+24
D7	Review of test full scale demonstrator outcome and LCA data	R/D	T0+30

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	EoL concept definition	R	T0+12
M2	Review of concept assessment	R	T0+18
M3	Review of test specimen outcome	R	T0+24
M4	Review of test full scale demonstrator outcome	R	T0+30

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

- Proven experience in recycling methodology based on mechanical, thermal and chemical (optional biological) processes
- Capability to understand Eco Design and measure and collect LCA data for industrial processes
- Proven experience in manufacturing and testing of composite materials and bio composites.

5. Abbreviations

CFRP	Carbon fiber reinforced plastics
EoL	End of Life
FRP	Fiber reinforced plastics
GFRP	Glass fiber reinforced plastics
LCA	Life Cycle Analysis/Assessment

XVII. JTI-CS2-2019-CFP10-AIR-03-08: Disassembly and recycling of innovative structures made of different Al-Li alloys

Type of action (RIA/IA/CSA):		RIA	
Programme Area:		AIR	
(CS2 JTP 2015) WP Ref.:		WP C-2.1.4	
Indicative Funding Topic Value (in k€):		350	
Topic Leader:	Aero-Magnesium	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	30	**Indicative Start Date (at the earliest)[93]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CFP10-AIR-03-08	**Disassembly and recycling of innovative structures made of different Al-Li alloys**
Short description	
The activities in this topic will be focused on developing innovative End of Life procedures for integral welded panels that are under development for new lightweight and cost effective aircraft structures. These panels can be manufactured using several Al-Li alloys, enabling welding technologies, as well as Cr-free surface treatments and primers. The development of new disassembly and recycling procedures are part of the activities.	

Links to the Clean Sky 2 Programme High-level Objectives[94]				
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 CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☐

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

94 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 is part of the AIRFRAME ITD, Activity line C (Eco-Design) and WP C-2 (Eco-Design for Airframe). The WBS of the AIRFRAME ITD is shown in *Figure*.

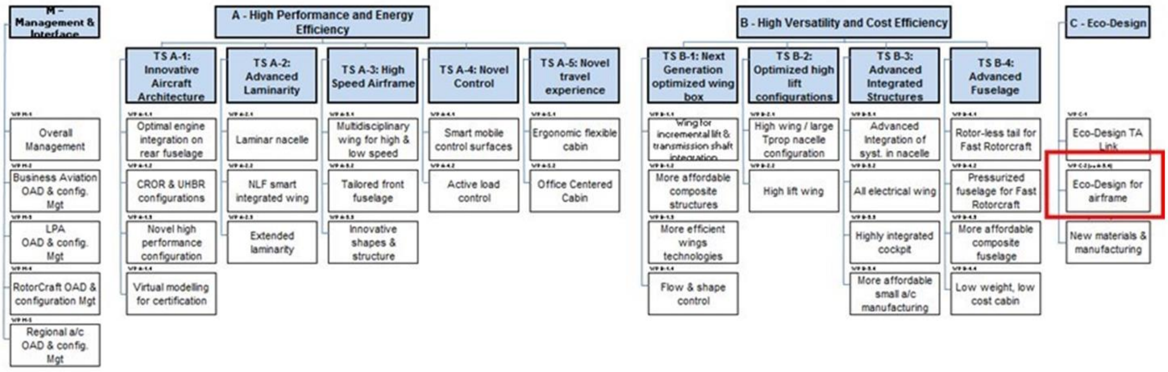


Figure 1: WBS of the AIRFRAME ITD

Previous R&D activities carried out in Clean Sky 1 investigated the dismantling and recycling potential of riveted fuselage structures. As a result, methodologies for separating different aluminium alloy families by rivet elimination were developed followed by remelting processes that allowed to obtain ingots of aluminium with possibilities to be reprocessed and transformed in new raw materials. However, these methodologies are not applicable for fuselage sections based on integral welded structures. For this type of structure, separation of alloys can present more difficulties. Therefore, in order to increase the recycling potential and easiness, it is advisable to use aluminium alloys with similar chemical composition for the construction of fuselage structures. 3rd generation Al-Li alloys offer such possibility using extrusions, sheet and other components so that separation before remelting could possibly be avoided. However, the chemical compositions of the resulting ingots after remelting of mixed alloy systems (without prior separation) is not known and the alloys' suitability for re-processing without significant chemical composition adjustments have to be investigated.

Within WP C-2, the Core Partner project “ecoTECH” consortium works to evaluate the potential of different cutting edge technologies (materials, production methodologies and surface treatments) to reduce the environmental footprint of the aviation industry in the airframe related parts.

The 3rd generation Aluminium-Lithium alloys (Al-Li) are an attractive new family of Aluminium alloys aimed to provide higher specific properties via weight reduction of the chemical composition (lithium has the density of slightly above 0.5 gr/cc), solid solution strengthening mechanism in the α(Al) phase matrix and precipitation hardening due to formation of meta stable ($AlLi_3$) phase.

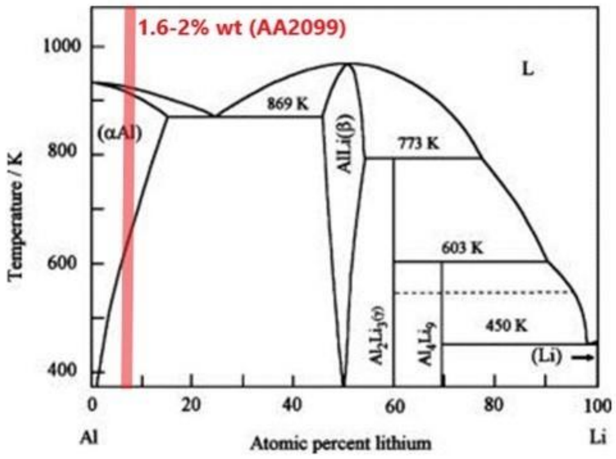


Figure 2: Al-Li phase diagram [Takeo Kasajima et al. J. Electrochem. Soc. 2004; 151: E335-E339]

The 3rd generation Al-Li family of alloys, especially the case study of AA2196, AA2099, AA2198 and AA2060, pose a major technological potential due to their high specific properties. The Topic Manager working in "ecoTECH" is developing panel demonstrators composed of different Al-Li alloys to evaluate the alloy's potential. The panels can be composed of sheet Al-Li (AA2198/AA2060) skin with reinforcing stringers made from extruded Al-Li (AA2099/AA2196). Some other Al-Li alloys of interest could also be considered. Innovative manufacturing processes are being implemented for the manufacturing of panel demonstrators. These include joining technologies such as Laser Beam Welding (LBW) and/or Friction Stir Welding (FSW); new Cr-free surface treatments such as Thin Film Sulfuric Acid Anodizing (TFSAA) and/or Sol-Gel techniques; as well as new Cr-free primers and top coats. Parts obtained as a result of these activities are shown in Figure 3 – Figure 5, at coupon and small panel level.
In order to support the industrialization of Al-Li alloys and innovative manufacturing technologies in the aerospace industry a further technological development and environmental information is still missing from the available knowhow. This topic seeks to evaluate and advance the End of Life (EoL) impact of this type of panel demonstrators as a case study for Al-Li parts. It is necessary to evaluate the need to separate the different alloys prior to the recycling operation. Applicants are expected to suggest procedures to scrap (dismantle and sort the different alloys, if necessary) the panel and evaluate the recycling potential of the alloys/coupons/panels via experimental validation and advance in the metallurgical understanding of recycling process.

2. Scope of work

The activities to be performed will be directed to define new End of Life procedures for recycling innovative reinforced panels manufactured using Al-Li alloys, taking into account advanced welding technologies, as well as Cr-free surface treatments and primers. It is expected that this case study will provide insights for the EOL methodology in future advanced Al-Li parts. The activities will include:

- Development of suitable disassembly process for integral welded panels produced by LBW or FSW.
- Selection and adaptation of suitable cutting process to optimize the size of the welded panels without alloy separation.
- Development of suitable process for surface treatment and coating (primer + top-coat) elimination.
- Remelting of separated Al-Li components (extrusions, sheet…); or cut sections with welded

extrusions and sheets.

- Analysis of the feasibility of the remelted ingots or billets to be reprocessed and transformed in new raw materials. This analysis could include chemical composition analysis, microstructural examination, evaluation of homogeneity of properties, evaluation of the presence and effects of impurities, etc.

All these activities will be performed using welded coupons and panels produced by LBW and FSW, using several Al-Li alloys. The main objective will be to evaluate and compare their recycling potential including the comparison with the state of the art technologies (recycling of riveted fuselage), and create eco-statements indicating the environmental impact of conventional versus new technologies developed.

The objectives pursued are described as follows:

- Develop innovative recycling methodologies for reinforced panels made by Al-Li alloys, welding technologies, new Cr-free surface treatments and new Cr-free primers and top coat.
- Investigate the recyclability of reinforced panels made with stringers and sheets welded by FSW.
- Investigate the recyclability of reinforced panels made with stringers and sheets welded by LBW.
- Investigate the influences of different filler wires used for LBW (mainly ER4047 and/or AA2319; new filler wires could also be considered).
- Investigate the effects of Cr-free surface treatments (TFSAA and/or Sol-Gel) and Cr-free primers+topcoats in the recyclability. Need and methodologies for previous elimination.
- Collect the LCA data of the developed technologies (disassembly, sorting, remelting, etc.) and provide these data to the Topic Manager.

The Topic Manager will provide the coupons and panels that are required for the activities to be performed. First activities and screenings will be carried out with single-stringer welded coupons (approximate size 100x150 mm^2) as shown in *Figure 3***Error! Reference source not found.** and *Figure***Error! Reference source not found.**. It is expected that these samples will be used to develop the recycling methodology and provide a deep metallurgical understanding of the process' effects on the alloy. In this context the re-melting and possible melt-treating technologies are sought after. The need to dismantle and sort different alloys should be evaluated based on the properties (chemical composition…) of the resulting billets, ingots, etc. and their potential to be re-processed. Different alloy combinations mainly using AA2196, AA2099, AA2198 and AA2060 will be explored. The final definition of the alloys and panel configuration will be carried out in collaboration between topic managers and the winning consortium during the initial stage of the project.

In a second stage of the project, multi-stringer welded panels will be used (approximate size 500x500 mm^2) to evaluate a scalable process, which will be produced with the most promising alloy combination and welding technology selected from the results obtained with the welded coupons. Conclusions obtained in the precious work with single-stringer coupons shall be used to select the most promising alloy combinations that will be used to produce the multi-stringer panels. In this phase it is expected that the recycled Al-Li material will be evaluated for its properties, correspondence to standard composition / mechanical properties and general re-usability potential.

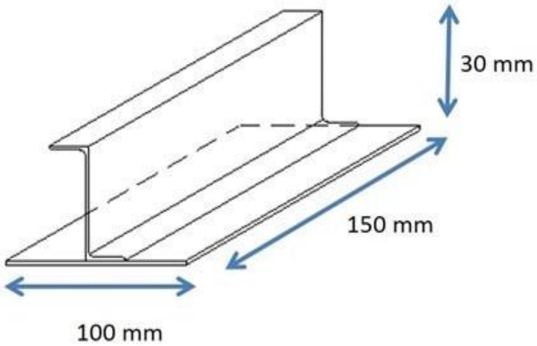


Figure 3: FSW/LBW coupon made with AA2196 extrusion and AA2198 sheet

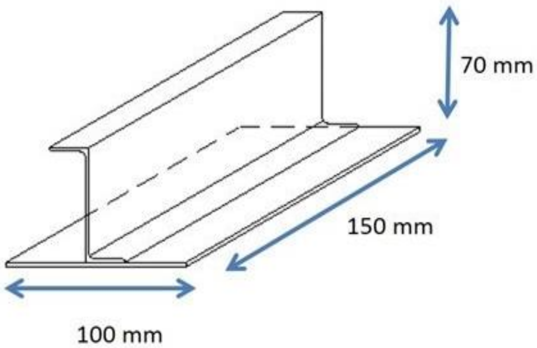


Figure 4: FSW/LBW coupon made with AA2099 extrusion and AA2060 sheet

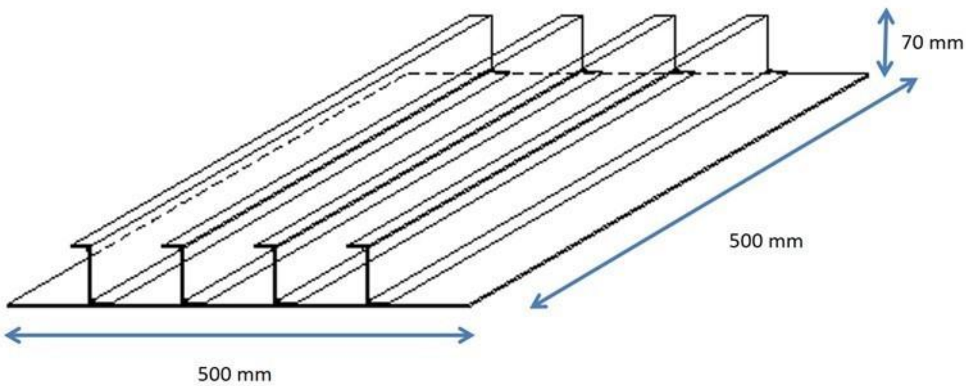


Figure 5: FSW/LBW panel made with AA2099 extrusions and AA2060 sheet (the number of stringers is indicative)

It is proposed to structure the activities in the following tasks:

Tasks		
Ref. No.	***Title – Description***	***Due Date***
T1	Management	T0+30
T2	Scraping methodology	T0+12
T3	Recyclability development	T0+20
T4	Metallurgical and properties evaluation.	T0+30
T5	Recycling demonstrator	T0+30

T6	LCA data collection and analysis	T0+30

Task 1: Management
Reporting, communication, dissemination and other management activities will be conducted during the whole duration of the project. Coordination and design – program organization, Technological study and experimental design within the partners, overall analysis and risk management.

Task 2: Scraping methodology
The activities will include:
- Investigation of dismantling and sorting options and analysis of pre-recycling scrap.
- Investigation of the need to eliminate the primers and top coats and identification of suitable means and processes.
- A preparation of detailed guidelines for scaled up dismantling process based on experimental validation.

Task 3: Recyclability development
The activities will include:
- Lab scale (experimental) screening of recycling approaches, set – ups and parameters for the different Al-Li alloys working at coupon level.
- Estimation of recycling strategies (Melt technologies), parameters and trends evaluation, samples supply for Task 4 to obtain an overview of the possible methodologies and technological trend for recycling Al-Li.
- Initial supply of data for Task 6.

Task 4: Metallurgical and properties evaluation.
Different metallurgical studies, chemical composition measurements and mechanical properties measurements to obtain understanding and validation of the developed process shall be performed. The feasibility of the obtained ingots for re-processing without significant chemical composition adjustments will be investigated. This shall include the analysis of the homogeneity of chemical compositions and microstructural properties, as well as the evaluation of the presence and effects of impurities sourced at the manufacturing and EOL technologies. Comparison with standards or state of the art technologies and processes will be done.

Task 5: Recycling demonstrator
The activity will consist in the set up and (experimental) validation and optimization of a scalable recycling methodology; making use of the "full" panel parts.

Task 6: LCA data collection and analysis
In this task all relevant data of the developed technologies will be collected in order to evaluate their environmental impact. These data will include energy consumption, waste of materials, emissions and other relevant variables involved in the disassembly (if necessary), remelting and other required processes developed for the recycling of the integral welded panels. The Topic Manager will provide guidance (templates will be provided) on how to collect data in order to create eco-statements comparing environmental impacts of conventional and new technologies developed in this work. This activity must be performed throughout the project including the first stages until the final End of Life procedure definition.

3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref No.	**Title – Description**	**Type***	**Due Date**
D1.1	Technical survey (literature state of the art and experimental screening approach)	R	T0+3
D1.2	Mid-term report – Scrapping & Experimental screening results, technological insights and trends.	R	T0+12
D1.3	Final report - Advancement beyond the state of the art, experimental and main results , elaborated scalability potential	R	T0+30
D2.1	Analysis of scrapping methodology, main results and technological aspects.	R	T0+11
D2.2	Scrapped parts ready for recycling experiments	HW	T0+12
D3.1	Set-up for experimental screening of recycling methodologies	HW	T0+14
D3.2	Guidelines towards a scalable recycling process	R	T0+20
D4.1	Analysis of pre and post scrapping materials	D	T0+14
D4.2	Analysis of (post) lab scale recycled sample	R	T0+22
D4.3	Analysis of (post) scalable recycled sample	R	T0+30
D5.1	Scalable recycling system set up	HW	T0+24
D5.2	Set-up and parameters optimization (samples)	HW	T0+28
D6.1	Data Collection (DC) for different possible recycling routes	D	T0+20
D6.2	DC for scalable and optimized process	D	T0+30
D1.1	Technical survey (literature state of the art and experimental screening approach)	R	T0+3

Milestones			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	Scrapping methodology validated	R	T0+10
M2	Lab scale recycling set-ups	HW	T0+14
M3	Potential and technological trends in Al-Li recycling (towards correspondence with ecoTECH for recycling development)	R	T0+18
M4	Scalable system running	HW	T0+24
M5	Optimized Al-Li recycled samples analysis	R	T0+30
M6	DC sheets complete	D	T0+30
M7	Final report - minimal environmental impact recycling of Al-Li panels including general Al-Li recycling insights and guiding-rules for the case study	R	T0+30

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

Expected skills by the applicant are:
- Deep metallurgical understanding (Al alloys)
- Metallurgical analysis expertise (Al alloys)

- Experience with processing of molten Aluminium
- Experience in power consumption monitoring for tracking of resources usage
- Experience with ecological / environmental assessments

In addition, the applicant(s) is required to have access to the following capabilities:
- Laboratory scale R&D in the field of Al recycling
- Scrapping of Aluminium metal samples
- Chemical and mechanical measurement (preferred accredited)
- Advanced Metallographic analysis equipment
- Molten Aluminium handling (preferred also severe plastic deformation capabilities for evaluation of re-use option)
- Suitable facilities for remelting Al-Li alloys

5. Abbreviations

Al-Li	Aluminium – Lithium (Aluminum alloys with Li alloying)
ITD	Integrated Technology Demonstrator
WBS	Work Breakdown Structure
ecoTECH	Acronym of the JTI-CS2-2015-CPW02-AIR-01-03 Core Project: "Development of innovative and ECO-friendly airframe TECHnologies from design to manufacturing to improve aircraft life cycle environmental footprint"
FSW	Friction Stir Welding
LBW	Laser Beam Welding
LCA	Life Cycle Assessment
TFSA	Thin Film Sulphuric Acid Anodizing
DC	Data Collection

XVIII. JTI-CS2-2019-CFP10-AIR-03-09: Scrapping of carbon reinforced thermoplastic materials

Type of action (RIA/IA/CSA):		RIA	
Programme Area:		AIR	
(CS2 JTP 2015) WP Ref.:		WP C-2.1.4	
Indicative Funding Topic Value (in k€):		350	
Topic Leader:	Netherlands Aerospace Centre NLR	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	24	**Indicative Start Date (at the earliest)[95]:**	> Q1 2020

Topic Identification Code	Title
JTI-CS2-2018-CFP09-AIR-03-09	**Scrapping of carbon reinforced thermoplastic materials**
Short description	
The aim of this topic is the investigation of suitable scrapping methods for scrapping of carbon reinforced thermoplastic structures. Part of the activities will be the characterization of the scrapped material and the manufacturing of test panels using the compression moulding process. The test panels will be tested to define the basic material properties.	

Links to the Clean Sky 2 Programme High-level Objectives[96]				
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 CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☐

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

[96] 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 is part of the AIRFRAME ITD, Activity line C (Eco-Design) and WP C-2 (Eco-Design for Airframe). The WBS of the AIRFRAME ITD is shown below.

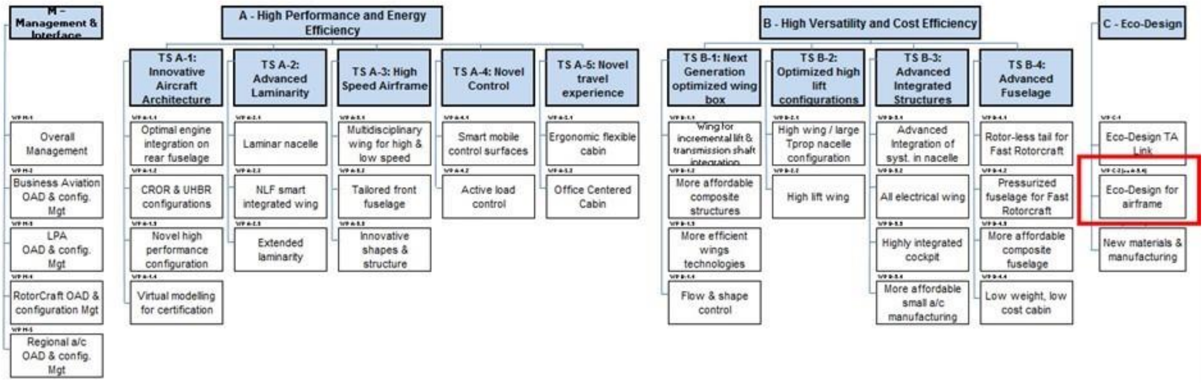


Figure 1: WBS of the AIRFRAME ITD

Within the WP C-2 , WP C-2.1.4 'End of life', aims to explore ecological friendly manufacturing and recycling technologies. The Thermoplastic (TP) technology stream is one of the main streams in this program and one of the topics is to improve the recycling process of carbon reinforced thermoplastic structures.

2. Scope of work

Within the TP technology stream the mechanical grinding of PEKK/AS4 material was investigated. The technology used was a conventional method using an UNTHA shredding machine with 19 mm knifes (See Figure 2).

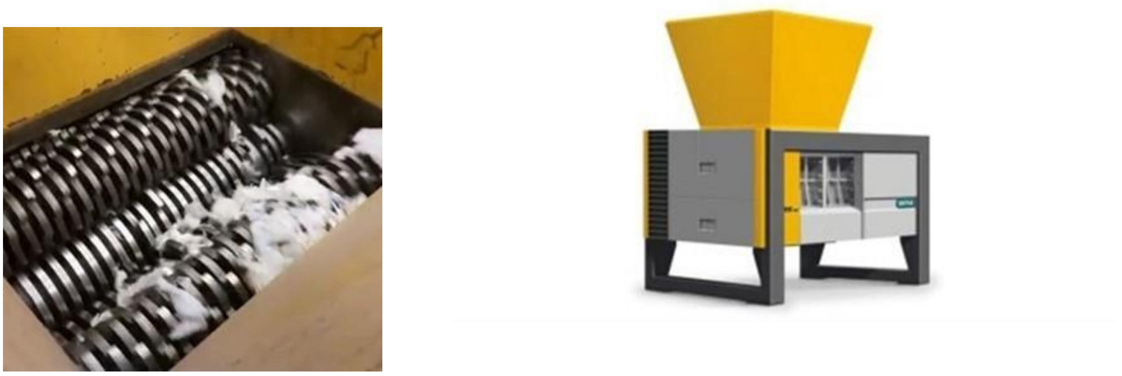


Figure 2 Mechanical shredder (courtesy of UNTHA shredding technology GmbH)

The resulting scrap material could not be used for compression moulding as the material was reduced in size but not delaminated and an additional process was needed to delaminate the scrap material.
Therefore within this CfP a commercially attractive scrapping process shall be explored capable

of scrapping carbon reinforced TP material to a size and shape that can be used for compression moulding of high quality parts.
The input material consists of a number of PEKK/AS4 continues fibre panels sized 100 x 100 x 3 mm^3 (16 plies laminate with equally divided fibre directions) to be delivered by the Topic Manager and the same quantity of an alternative TP system. This second TP system still has to be defined; options are PPS/Carbon, PEEK/AS4, PPS/Glass.

The output material (scrap) shall be suitable for the compression moulding process, as an indication the scrap particles should match the size of 2” chopped UD tape (see Figure 3) as good as possible (about 50 x 6 x 0.15 mm^3).

Figure 3 Chopped PEKK/AS4 tape

The applicant will characterize the scrapped material of the two TP systems and report the results in a detailed manufacturing report including:

- Size/weight distribution of the flakes
- LCI/LCA data
  - Energy consumption
  - Efficiency
  - Environmental aspects
  - Etc.
- Cost indication
- Fibre/Volume content
- Equipment used
- Description of the process

The applicant will manufacture some test panels for defining the mechanical properties. Part of the scrapped material will be delivered to the Topic Manager for manufacturing of a demonstrator (see Figure 4) out of the scrapped material.

Figure 4 Compression moulded window frame

The Topic Manager (TM) is responsible for:

- Supplying the input material.
- Defining the test matrix for testing of the test panels
- Compression moulding of the demonstrator

It is proposed to structure the activities in the following tasks:

Tasks		
Ref. No.	***Title - Description***	***Start / End***
T1	Project management	T0 / T0+24
T2	Definition of the process	T0+1 / T0+8
T3	Perform manufacturing trials (two TP systems)	T0+9 / T0+12
T4	Scrapping of the input material (two TP systems)	T0+13 / T0+17
T5	Manufacturing and testing of the test panels	T0+18 / T0+21
T6	Reporting LCI data	T0+22 / T0+24
T7	Evaluation and reporting	T0+22 / T0+24

Task 1: Management

The main activities will consist in the coordination of the project within the applicant's organization, communication towards the Topic Manager and reporting of the final project results. Progress meetings (physical or Skype) will be scheduled at start of the activities (kick off) and at the end of every quarter.

Task **2: Definition of the process**

The activity will start with the review of the different options and selection of the most promising scrapping processes for further evaluation in Task 3. The results of the review and motivation of the process selection will be presented during the PDR. The LCA data for each of the evaluated process will be presented and will include energy consumption as well as ecological data like chemicals used, outgassing, etc.

After PDR approval, the Topic Manager will process the TP materials for trials in Task 3.

Task 3: Perform manufacturing trials

Composite panels composed out of the two TP systems will be supplied to the applicant for the performance of manufacturing trials with the processes selected in Task 2. The applicant will select the final scrapping process and reports the results to the TM during the CDR.

Task 4: Scrapping of the input material
After CDR approval by the TM the input material of both TP systems will be supplied to the applicant. The applicant will use the selected scraping process to produce the scrap including a manufacturing report with material characterization, process parameters, LCA data, etc.

Task 5: Manufacturing and testing of the panels
Part of the scrap material will be supplied to the TM for manufacturing of a demonstrator and the remaining scrap material will be used by the applicant to produce a number of flat test panels by using the compression moulding process. The panels will be cut into test coupons and tested according the test matrix provided by the TM.

Task 6: Reporting LCI data
Within this task, the LCA data will be collected and reported for integration into the LCI database of the CleanSky 2 ECO Transverse Activity (TA).
Task 6 deliverable contains the LCA data in the LCI format of the ECO TA.

Task 7: Evaluation and reporting
Within this task the final conclusions will be drawn and reported including lessons learnt and recommendations for further development of the process towards application at an industrial scale, including recommendations for the processing of the scrap material and applications for parts manufactured from scrap material.

3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1	Process definition	R	T0+8
D2	Manufacturing reporting	R	T0+17
D3	Test results	R	T0+21
D4	LCA data for integration into the LCI database	R, D	T0+24
D5	Final report	R	T0+24

Milestones			
Ref. No.	***Title - Description***	***Type****	***Due Date***
M1	PDR, Review process selection	R	T0+8
M2	CDR, Selection of scrapping process	R	T0+12
M3	Delivery of scrap material to the TM	HW	T0+17
M4	Test panels ready for test	HW	T0+19
M5	Tests performed / start evaluation and LCI data reporting	R, HW	T0+21
M6	Project end	R	T0+24

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

Expected skills by the applicant are:

- Awareness of available scrapping methods and their pro's and con's for scrapping composites
- Proven experience in analysing scrap materials regarding size distribution, fibre volume, etc.
- Awareness of economical / environmental aspects
- Proven experience in transferring lab scale processes into large scale industrial environment
- Proven experience in mechanical testing of composite materials

The following capabilities/facilities are required:

- Lab scale scrapping process (or access to such processes)
- Microscopes, analyse equipment, etc., for characterizing the scrap
- Test benches for mechanical testing of the coupons
- Compression moulding equipment for test panel manufacturing

5. Abbreviations

TM	Topic Manager
CfP	Call for Proposals
TP	ThermoPlastic
PDR	Preliminary Design Review
CDR	Critical Design Review
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
TA	Transverse Activity

8. Clean Sky 2 – Engines ITD

I. JTI-CS2-2019-CfP10-ENG-01-43: 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 Helicopter Engines	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	36	**Indicative Start Date (at the earliest)[97]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-ENG-01-43	**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[98]				
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 Regional Multimission TP, 70 pax		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☒	☐	☐	☐

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

[98] 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 enablers 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 of 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 1 shows the work breakdown structure of WP3 demonstration platform.

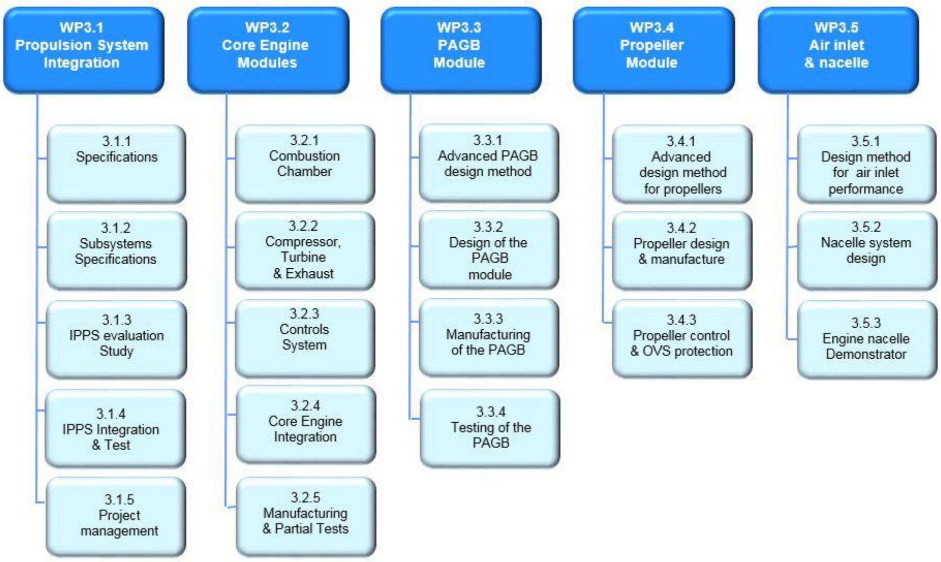


Figure 1: WP3 Work breakdown structure

2. Scope of work

The purpose of the study is threefold :

a) to propose development paths for low-emissions (NOx and soots) spinning combustion injection systems,
b) to characterize experimentaly at least two SCT injector configurations,
c) 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.

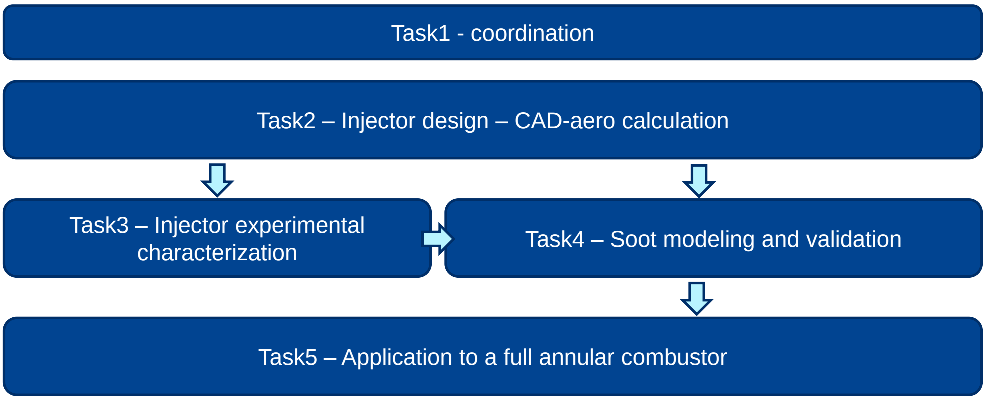


Figure 2: Project breakdown structure

<u>Task 1: Management and coordination</u>

<u>Organization:</u>

- 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

<u>Time schedule and work-package description:</u>

- 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

<u>Progress reporting and reviews:</u>

- 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

<u>Task 2 : Injector design, CAD and manufacturing</u>

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 puropose, 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 combustior 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 profil 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, openning 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

Deliverables			
Ref. No.	**Title – Description**	**Type***	**Due Date**
D2	Manufactured SCT injectors	D	T0 + 10 month
D3	Report on injector design and simulation	R	T0 + 12 months
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 air mass flow rate is also mandatory.

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. <u>Abbreviations</u>

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)

II. JTI-CS2-2019-CfP10-ENG-04-08: Revalorisation of Recycled Carbon Fibers and CFRP preparation through Eco design [ECO]

Type of action (RIA/IA/CSA):		IA	
Programme Area:		ENG [ECO]	
(CS2 JTP 2015) WP Ref.:		WP 9.2	
Indicative Funding Topic Value (in k€):		1750	
Topic Leader:	Fraunhofer	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	36	**Indicative Start Date (at the earliest)[99]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-ENG-04-08	**Revalorisation of Recycled Carbon Fibers and CFRP preparation through Eco design**
Short description	
The aircraft industry uses high performance and costly materials for the production of composite components. In some cases, the manufacturing process generates a significant amount of carbon fiber scraps having still good potential properties. This topic aims to investigate technologies to manufacture new semi-products such as yarns, non-crimp fabrics, mats or short fiber reinforcements, which permit to reuse these recycled carbon fibers in semi-structural composite components for engine industry. Procedures to extent the shelf-life and enable the use of unused uncured prepreg material will be investigated as well.	

Links to the Clean Sky 2 Programme High-level Objectives[100]				
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		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☐

[99] The start date corresponds to actual start date with all legal documents in place.
[100] 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 recent decade, the physical recovery of carbon fibers from production scraps and old parts has become industrially feasible – technically as well as in terms of recyclable composite volume at the recycling facilities. But despite many endeavours to bring recycled carbon fibers into large volume industrial applications, aviation industry has yet to show that through recycling carbon fibres it can become a more effective circular industry.
A key challenge of the widespread application of recycled carbon fibres (rCF) is their current price-performance-ratio. Either the derived materials are too expensive for large scale applications compared to non-recycled materials of the same performance level (e.g. in injection molding applications), or the performance is too low compared to same-price-level materials. In addition, 10% of the production scrap are uncured prepregs that exceeded their shelf-life and therefore cannot be used anymore.

As a consequence, two main overall targets shall be tackled by this topic:

1. Improve the quality of collected materials through implementation of on-site segregation and industry wide collection and logistic of carbon fibre waste
2. Increase the performance of semi-finished products made from rCF and industrialize their production and supply chain

The quality and the potential sales prices of recycled carbon fibres are governed by intrinsic factors of the waste and the waste producing and recovering entities:

- Degree of waste segregation,
- Logistics,
- Processing volumes,
- The recycling technology itself,
- As well as external factors like legislation
- And market situation.

This project should therefore as well focus on those aspects. With waste segregation being an internal factor to each company, the applicants will work closely with the Engine ITD WP9.2 (Recycling and Re-use of Composites) to define a proper segregation system based on the circumstances and the needs inside the facilities. Furthermore, this project shall target the unification of waste streams to decrease the degree of decentralization of waste sources as well as provide processable amounts and thereby enable a decrease in cost for the recovered carbon fibres and an increase in quality of the provided waste streams through the advantages gained by increasing amounts and process scale.

The relatively low mechanical performance of non-woven fabrics and short fibre injection molded parts compared to the virgin endless fiber performance relates mainly to the physical form of the recycled fibre – a then short fibre –, not a decrease in performance through the recycling process itself. The un-oriented form of the fibres in these products severely limits the achievable performance and fiber volume contents desired. Several technologies (as solvolysis, pyrolysis) have been developed and permit to remove organic matrix and recover carbon fibers from composite materials to produce oriented textiles from short fibers, but the actual applications focus mainly on other sectors such as the automotive industry, coatings or thermoplastics industry.

2. Scope of work

The defintion of an appropriate segregation, collection and logistic system for carbon fibre scraps are a crucial part of this topic as well as the development of a test/analytical procedure to extend the shelf-life of currently unused prepregs. The topic work will develop semi finished products from recycled carbon fibers, coming initially from production scrap provided by WP9.2 (end of bobbins, dry yarns cut off, short carbon fibers cut off, cured CFRP parts and uncured prepregs).

The material has to be characterized concerning its mechanical properties (e.g. as coupons), to demonstrate that semi-finished products can achieve the technical specifications to be used in semi structural applications. Consequently,

- The weaving capacity of the yarns will be evaluated (production of 2D and interlock fabrics),
- Stitching process of non woven fabric will be evaluated as well as molding capacity, where as well test material will have to be provided to WP 9.2,
- Finally, thermoplastic composite molding properties and mechanical performances will also be measured.

Furthermore, once mechanical properties of the semi-finished products are available, an intermediate review meeting will take place in the WP 9.2 context to define alternative or additional demonstrators that can be produced by the applicant. Anyway the applicant shall propose already with his proposal potential applications and demonstrators in and outside the aviation industry for each group of semi-finished product.
Suggestions for applications targeted with this project are amongst others non-structural covers, engine cowlings, interior parts, smoke detector housings, yarns to replace virgin fibres i.e. in RTM process.
This project will target at setting up an industrial supply chain to produce highly oriented rCF textiles including the development of a portfolio of rCF consumer part applications, specifically focused on demonstrating the applicability of oriented rCF products for high performance applications defining clear business cases in- and outside the aviation industry.

In addition, an economic analysis will be performed to compare the final price of products made with recycled carbon fibers and virgin ones. The economic analysis will take into account the scrap recovery and treatment (e.g. pyrolysis, cutting process), the logistics and the production costs to obtain the final semi product.
Furthermore Life Cycle Inventory data will have to be collected along the process (segregation, collection, logistic, processing to product) and have to be provided annually to the Topic leader for all selected processes and technologies to enable the preparation of LCA based ecostatements. A proper training will be provided by the Topic leader if needed.

Tasks			
Ref. No.	**Title**	**Description**	**Due Date**
WP 1	**Life extension of prepregs**		**T0+18**
Task 1.1	Procedure	Definition and proof of an analytical or testing procedure to extent the shelf-life of uncured prepregs.	T0+12
Task 1.2	Composite production	Measurement of mechanical performances on composite coupons	T0+18
WP 2	**Semi-finished products from rCF**		**T0+24**

Tasks			
Ref. No.	**Title**	**Description**	**Due Date**
Task 2.1	Specifications	Selection of the technical processes to produce semi products from recycled carbon fibers using dry virgin fiber cutoffs and recycled fibers after thermal or chemical removal of the matrix	T0+4
Task 2.2	Fiber valorization	Application of technical processes to produce semi products from recycled carbon fibers (virgin or after thermal or chemical recovery). Technical specification of the used fibers and semi-finished products.	T0+12
Task 2.3	Composite production	Manufacturing properties of the semi products and measurement of mechanical performances on composite coupons	T0+18
WP 3	**Demonstrator production**	**Application survey and production of demontrators with tested prepregs beyond their official shelf-life and from semi products from recycled carbon fibers, non-wovens and yarns.**	**T0+36**
WP 4	**Segregation and Logistic**		**T0+36**
Task 4.1	Review of legal framework	Review of the legal framework for the collection and the distribution of carbon fibre and carbon composite production residues	T0+6
Task 4.2	On site CF and CFRP waste segregation	Set-up of a smart and customer oriented segregation system for CF containing production residues to be applied in aviation industry	T0+18
Task 4.3	Innovative logistic system	Set-up of a logistic system for CF containing production residues taking into account different facilities of one and of different companies	T0+24
Task 4.4	Industrial supply chain of highly oriented rCF textiles	Design of the industrial supply chain for highly oriented rCF textiles taking into account especially the application in the aviation industry. Conduct a market survey	T0+36
WP5	**LCI-Data Collection and Provision**	**Economical and ecological analysis of demonstrators and parts. This includes the collection of LCI data for the performance of LCA**	T0+36

Tasks are described in more details hereafter:

<u>WP 1: Life extension of prepregs</u>

WP 1 aims at the development of a simple analysis or testing procedure to extent the life of uncured prepregs and enable a continous use in aviation industry. Part of this WP is the production and testing of coupons and the proof of the test procedure.

<u>WP 2: Semi-finished products from rCF</u>

This WP will be dedicated to the development of the semi products from carbon fiber scraps which will be supplied by WP9.2.

Task 2.1: Specifications

This Task will be dedicated to the selection of the technical processes to produce semi-finished products from recycled carbon fibers using dry virgin fiber cutoffs and recycled fibers after thermal or chemical removal of the matrix.

Task 2.2: Valorization

Carbon fiber yarn made from recycled carbon fibers

The yarns shall have the highest mechancial properties possible and will be woven to produce 2D and interlock fabrics. The influence of deconstruction process will also be studied by studying the effect of the sizing removal on the manufacturing process using virgin fibres and fibres without and with new sizing.

Non woven carbon fiber fabrics

Influence of different production processes of recycled CF based non woven fabrics, on the final weight surface of the product and its mechanical properties.

- Evaluate different processes (carding, airlaid), for production of non woven with a surface weight from 100g/m² to 700g/m².
- Evaluation of different linking technics (stiching, needling, use of binder) on the final properties of non woven fabric.
- Evaluation of different TP binders mixed with rCF during manufacturing process of non woven fabrics
- Mechanical and process comparison between performances of fabrics obtained with rCF from pyrolysis with and without new sizing and virgin production cut-off carbon fibers which have not been in contact with a matrix before.
- The properties for the different fabrics will be evaluated on composite panels in Task 2.3.
- Detailed fabric specifications will be defined in Task 1 together with WP 9.2.

Cut CF as discontinuous reinforcement for composite structures

The objective will be the development of a automatised process for dispersion of short CF in an organic matrix (TP or TS) in order to obtain a isotropic composite material, or a C/C ceramic material. In case of TS matrix, the study will be carried out with epoxy resin.

Task 2.3: Composite production

Evaluation of the processability of semi products and their mechanical performances in composite materials.

- **Wovens:** Weaving capacity of yarns produced with recycled carbon fibers. The evaluation of weaving properties of the yarns will be done for interlock and 2D fabrics.
    - Composite coupons will be produced using thermoset resins e.g. epoxy by appropriate processes e.g. RTM.
    - Mechancial performances of composite material will be measured at room temperature (considering static testings)
- **Non-woven:** Stiching properties of non woven fabric will be evaluated. Parts will be produced with appropriate resin and processing technology e.g. epoxy resins in RTM to measure mechanical properties of composite material.
- **Discontinous long fibers:** Moulding of coupons by compression molding and evaluation of mechanical properties of composite material.

WP 3: Demonstrator production

Production of demonstrators for secondary structural parts from studied materials. The applicant shall provide parts finally selected with the Topic leader and the WP 9.2. The demonstrator parts and specimens will be provided to the Topic leader.

WP 4: Segregation and Logistics

Task 4.1 - Review of legal framework:
This Task aims at the review of the legal framework for the collection and the distribution of carbon fibre and carbon composite production residues. Special focus will lay on reviewing the specifications for cross boarder shipment, special documentation, involved authorities as well as a discussion under which circumstances the production residue is "waste" and when it can be declared as by-product.
Task 4.2 - On site CF and CFRP waste segregation:
The separate collection of different residue qualities like virgin cut-offs, uncured prepregs or cured CFRP with fibres of different quality is crucial to ensure the recovery of the highest fibre quality possible. Therefore, this Task aims at setting-up a functional, simple and cost efficient segregation system for CF containing production residues and apply it in the aviation industry.
Task 4.3 – Innovative logistic system:
This Task aims at setting-up a logistic system for CF containing production residues taking into account different facilities of one company as well as of different companies and competitors. Beside a proper discussion of security measures to ensure confidentiality about material collected at other facilities, the collection system shall be flexible and approach the facilities whenever a container is full.
This task includes the definition of a proper link to the segregation system e.g. through smart IT systems.
Task 4.4 - Industrial supply chain of highly oriented rCF textiles:
Design of the industrial supply chain for highly oriented rCF textiles taking into account especially the application in the aviation industry. This includes conducting a market survey (potential market volume for applications in and outside the aviation industry) and an evaluation of the distribution of the final rCF textiles to potential stakeholders.

WP 5: LCI-Data Collection and Provision
Task 6 consists of calculating the production costs of the semi products and the final demonstrator parts which will be selected according to their technical properties, considering each step of production, from collection of scraps and parts, recovery of recycled carbon fibers, and production of semi products and parts. This includes the segregation and logistic as well.
A Life Cycle Inventory has to be created (Bill of Materials and Bill of Processes) along the processing chain. Recyclability of the developed composite systems has to be taken into account as well as the segregation and logistics. The Life Cycle Inventory has to be provided to the Topic leader and Eco-TA ITD for Life Cycle Assessment. The selected applicant will receive back a simplified Eco Statement (LCA result). For the data collection a data collection sheet can be provied by the Topic leader as well as a training on proper data collection. The modelling of the data and final eco statement preparation will be done by EcoTA.

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	Report on the analysis or test procedure for the life extension of uncured prepregs and definition of potential use cases.	R	M18
D2.1	Report on the available technical processes for semi-product production including a discussion on industrial maturity, cost performances and limitations	R	M4
D2.2	Fiber valorization report describing the performance of rCF semi-finished products.	R	M12

Deliverables			
Ref. No.	**Title – Description**	**Type***	**Due Date**
D2.3	Technical report on the manufacturing processes and performances of the different rCF materials in composites cupons.	R	M24
D3	Report on the production of the demonstrators	R	M36
D4.1	Legal framework report	R	M 6
D4.2	Segregation system and implementation example description	R	M 18
D4.3	Innovative logistic system	R	M 24
D4.4	Industrial supply chain definition	R	M36
D5.1	Life Cycle Inventory Concept Report	R	M06
D5.2	Annual LCI-Data Report (Y1)	R	M12
D5.3	Annual LCI-Data Report (Y2)	R	M24
D5.4	Final LCI-Data Report	R	M36
D5.5	Business case study: cost for production of semi products with recycled carbon fibers	R	M36
D5.6	Provide documented data set (LCI) to allow LCA analysis of the technologies studied in the project	D	M36

Milestones (when appropriate)			
Ref. No.	**Title – Description**	**Type***	**Due Date**
M1	Selection of technologies for production of semi products (yarns, non-woven fabric, etc.)	R	M6
M2	Anaylsis or test procedure for life extension of prepregs is defined and proofed	R	M18
M3	Semi-finished products are ready for testing	HW	M18
M4	Mechanical performance tested	R	M24
M5	Segregation system defined and tested	R	M 18
M6	Logistic system is developed and implemented	R	M24
M7	Industrial supply chain is defined	R	M 36
M8	Demonstrator produced and provided	HW	M36
M9	Economic analysis	R	M36
M10	Documented data set (LCI) as BOMs/BOPs has been delivered to Topic Manager	D	M36

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

- The applicant has proven experience in fiber processing and testing and production of carbon fiber composite parts and textile components (yarn, non-woven until final fabric).
- The applicant needs to proof access to alternative material and processing technology e.g. pyrolysis or solvolysis.
- The applicant must have proven understanding in collection of production residues, on-site segregation and logistics/legal frameworks of waste material management.
- Applicant must have a detailed knowledge about the state of the art in carbon fiber recycling and processing technologies as well as existing market and legal barriers.
- Capability to measure and collect economic and LCI data for industrial processes.

5. Abbreviations

BOM	Bill of Materials
BOP	Bill of Processes
CfP	Call for Proposal
CF	Carbon Fibers
CFRP	Carbon Fiber Reinforced Polymer
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
rCF	Recycled Carbon Fibers
TP	Thermoplastic
TS	Thermoset
UD	Unidirectional reinforcement

9. Clean Sky 2 – Systems ITD

I. JTI-CS2-2019-CfP10-SYS-01-15: Enhanced digital georeferenced data models for cockpit use

Type of action (RIA/IA/CSA):		IA	
Programme Area:		SYS	
(CS2 JTP 2015) WP Ref.:		WP 1.3	
Indicative Funding Topic Value (in k€):		1000	
Topic Leader:	Thales	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	24	**Indicative Start Date (at the earliest)[101]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-SYS-01-15	**Enhanced digital georeferenced data models for cockpit use**
Short description	
This call is for partners to evaluate use of georeferenced data used in enhanced cockpit applications. Objectives of such applications are to contribute to crew workload reduction, enhance safety, and provide in-flight decision support. This initiates a step to Single Pilot Operations. It is envisaged that there will need for high quality data (high resolution terrain, geographic and cultural representation, and obstacle representation).	

Links to the Clean Sky 2 Programme High-level Objectives[102]				
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:	Enabling technologies			
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☐	☐	☐	☒	☐

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

[102] 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

Digital georeferenced data models are currently used in on-board aviation applications for terrain awareness & alerting, and for 2D and 3D synthetic representations.

Operational concepts are now evolving to exploit **higher levels of fidelity** and **richer information.** Flight crew will become reliant on high fidelity representations and on functional output (e.g. alerts or avoidance routes). The evolved concepts imply higher levels of support and more rapid decision making cues to flight crew though enhanced representations and through synthetized functional output.

Processing of georeferenced data and associated attributes are a core element of these concepts.

The **suitability of georeferenced data** and **sources of this data**, on which these operational concepts are based, will depend on several factors. The factors encompass inter alia, operational environment factors and the aircraft / rotorcraft mission types and conditions:

- Height above ground
- Flight phase (en-route vs. departing/approaching)
- Speed and manoeuvrability

Moreover, georeferenced data and sources will have to meet the regulations that apply to the aviation environment and it may be expected that performance, safety and security criteria will apply.

The call is addressed to specialised partners skilled in the establishment, delivery and use of georeferenced data.

To ensure a large coverage, a consortium of several geomatics providers and associated expertise is expected.

The work objectives are to evaluate the sources and the suitability of georeferenced data use in the context of enhanced cockpit applications described above. Data is expected to be pre-loaded to the on-board applications. Worldwide coverage is expected.

Several application uses are targeted:

- Terrain high resolution (~1" arc) for synthetic representation, and for terrain collision functional processing
- Geographic and cultural representations, necessary to be associated with terrain representation
- Obstacles (point & linear) representations which will also be associated with terrain representation and also with collision functional processing

The expected benefits for THALES as a supplier of data and for the end user of the data (aircraft operator and flight crew) are:

- Enhanced cockpit applications use of georeferenced in concepts which address crew workload reduction, enhance safety, and provide in-flight decision support as a step to Single Pilot Operations.
- High quality data capability (high resolution terrain, geographic and cultural representation, and obstacle representation), with quality and accuracy meeting intended functional use described above.
- Economic, cost efficient schemes

2. Scope of work

The activities should cover multi source data acquisition:

- Survey of adequate data sources including open sources (including licensing, business model)

- Evaluation of the data characteristics against conditions of the mission types / use cases and comparison of the operational effectiveness of different characteristics, which may have to consider consolidation mechanisms for multiple sources.
- Processing, tools transformations and overall architecture to generate datasets adapted to the use cases, and feasibility conclusions for each of the application cases above (terrain, geographic and cultural, obstacles)

Applicant is expected to have data sources, or will be able to access them.

The main activities are as follows:

Tasks		
Ref. No.	**Title – Description**	**Due Date**
WP1	Technical and Operational requirements	T1 + 3 months
WP2	Market analysis on geographic data providers, including open data	T1 + 7 months
WP3	Processing, tools , Algorithms definition	T1 + 15 months
WP4	Application Prototyping	T1 + 24 months

WP1 : Operational requirements

The objectives of this work package are to:

- Define use cases
- Define technical requirements (interfaces, accuracy, performance…)

WP2: Market analysis

The objectives of this work package are to:

- List of available data and associated quality level
- Rules to use data (protection)

WP3: Processing, tools, Algorithms definition

The objectives of this work package are to:

- To mix different type of data
- Correlation with several kinds of data (ex correlation with A424 data, oceanographic data…..)
- To validate data and make the correlation between them
- To define their quality level (granted)
- To build a high resolution database

WP4: Application Prototyping

The objectives of this work package are to:

- Validation during Integration with avionics function for laboratory evaluations (Integration is performed by Thales Avionics)

3. Major Deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	**Title – Description**	**Type**	**Due Date**
D1	Technical Resources and Requirements document	R	T1 + 3 months
D2	Market Analysis Document	R	T1 + 7 months
D3.1	Algorithms definition dossier (validation, correlation with all kind of existing positioning data)	R	T1 + 15 months
D3.2	Data lake with elevation, cultural and obstacles data	R	T1 + 16 months
D3.3	Data characterized with a granted status	P,R	T1 + 18 months
D3.4	Database terrain with high resolution with enhanced georeferenced data	P,R	T1 + 20months
D4	Awareness avionics function using the georeferenced data	P, R	T1 + 24 months
D1	Technical Resources and Requirements document	R	T1 + 3 months
D2	Market Analysis Document	R	T1 + 7 months

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

Experienced in collection, analysis/processing of geomatic data.

Geomatics, Geographic Information Systems

- Data collection and data sourcing encompassing acquisition of all types (e.g. database queries, dataset delivery, …), capture, storage and including all applicable information protection rules.
- Data / image analysis.
- Skill in using data in the aviation environment will be an advantage.

Big data & validation techniques

- Data lake management, data analysis skills, validation skills.
- Correlation skills to select and validate the most representative data set and to model shapes from data sets

To ensure a large coverage, a consortium of several geomatics providers and associated expertise is expected.

II. JTI-CS2-2019-CfP10-SYS-01-16: Innovative processing for flight practices improvement

Type of action (RIA/IA/CSA):		IA	
Programme Area:		SYS	
(CS2 JTP 2015) WP Ref.:		WP 1.3	
Indicative Funding Topic Value (in k€):		600	
Topic Leader:	Thales	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	24	**Indicative Start Date (at the earliest)[103]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-SYS-01-16	**Innovative processing for flight practices improvement**
Short description	
Reduction of direct operating costs is a permanent must for airlines. Complementary to open world flight optimization applications connected to classical avionics FMS, the objective is to foster methods and tools for support services allowing mission optimization.	

Links to the Clean Sky 2 Programme High-level Objectives[104]				
This topic is located in the demonstration area:		Cockpit and 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 Advanced Short/Medium Range		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☐	☐	☐	☒	☐

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

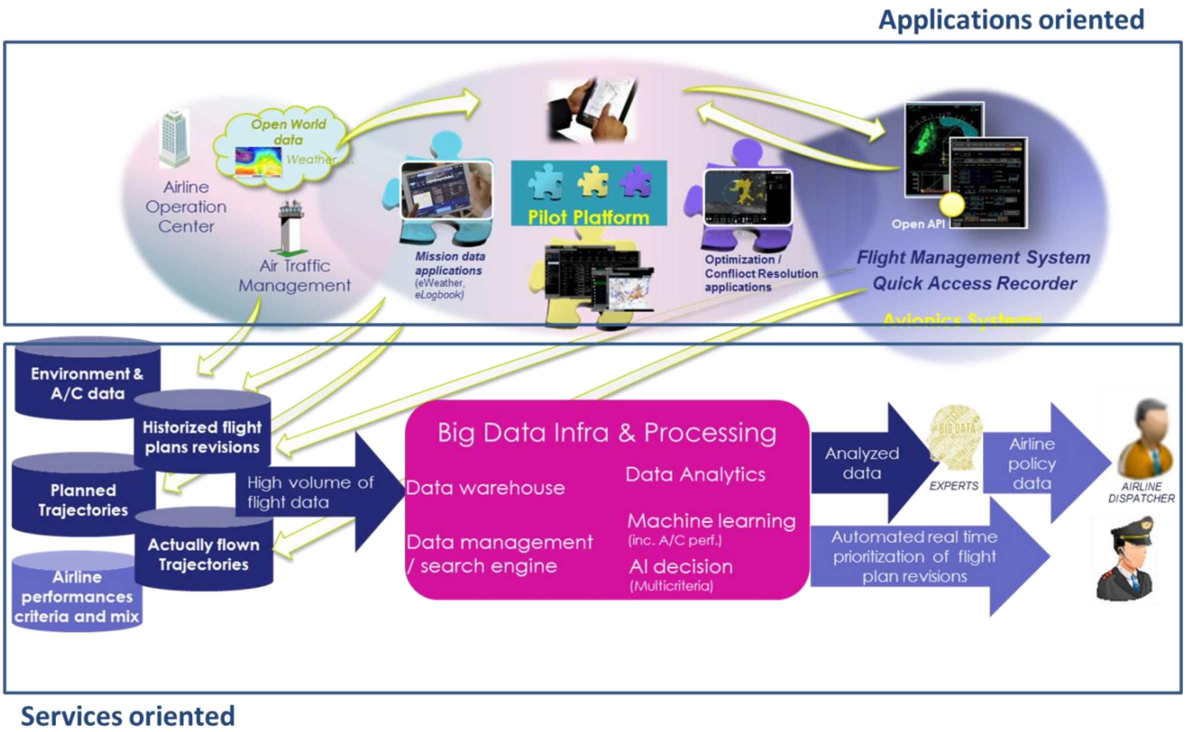
[104] For further info see Chapter 1 "Introduction to the Programme Scene Setter / Objectives" with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Background

In the context of the mission driven operations for civil aircrafts, pilots should have on board a better understanding of the stakes of the current mission – from the perspective of the business objectives of the airline - and all the controls to improve the adherence to the intended mission. Specifically, reduction of direct operating costs is a permanent must for airlines.

In the frame of CleanSky II ITD System, strategic functions for flight management are looked after. Several individual functionalities for flight alternatives assessment, flight optimisation for specific phases and diversions capabilities are matured. Up to now, these functionalities are pursued through dedicated model driven software applications.

Another approach consists in using a more data driven perspective: complementary to open world flight optimization applications connected to classical avionics FMS, support services derived from data analysis, allowing mission optimization, are envisaged.



Indeed, huge data sets linked to actual flights are continuously produced by Airlines Operations Centers to prepare flights and during each flight.

Proposed innovation lies in analysing these past flights information on given routes through big data analytics to propose optimisations adapted to the current context of a flight on a given route.

The objective of the call is to design and implement specific software means in order to capitalize on past flights of an airline, identifying correlations between destination airport, flight conditions (meteo, traffic), period of operations (season, hour in the day) and successful flight plans modifications (for instance probability of a short cut to be accepted when arriving near the destination).

2. Scope of work

The topic work will allow to:

- Define data engineering and big data analytics processing to identify and propose to pilots mission optimization actions ,
- Develop a customized prototype software means suite implementing the proposed solution

Expected output is:

- Customized prototype software means suite allowing to clean, synchronize, analyse past flights data (flight plans and trajectories data) and classify them semi-automatically or automatically, in order to derive potential optimisations for future flights.

Note that the intended means are for crew assistance oriented services and that such advisory aid will not have to be treated from the functional safety point of view in the frame of this call.

Applicant will contribute to:

- Flight policies input data gathering required for this work. These data are pertaining to airline way to operate. Teaming with the operations directorate of an airline is henceforth highly recommended. These could be either available with the applicant or collected from other sources, in which case, applicant should have means to collect and process those data.
- Flight plans and actual trajectories data required for this work. They encompass at least:
    - Off-line global data: Operational Flight Plans (OFP) as filed by an airline for ATC, Computerized Flight Plans (CFP) prepared by Airline Operations Center (FOC) for crew,
    - Flight data : actually flown trajectories data gathered in aircraft Quick Access Recorder (QAR) recoverable after each flight, ADS-B data, correlated meteorological data recoverable from meteo data providers over flight zone.
- These could be either available with the applicant or collected from other sources, in which case, applicant should have means to collect and process those data.
  Commercial confidentiality of flight policies data and privacy issue linked to operated flights are to be tackled within applicant's answers.

The main activities and deliverables are sketched in the table below, however, applicant are encouraged to propose alternate approach to ensure achievement of the topic objectives and to facilitate their workflow.

Tasks		
Ref. No.	**Title – Description**	**Due Date**
WP1	Technical resources and problem definition	T1 + 3 months
WP2	Flight policies, flight plans and trajectories data collection	T1 + 7 months
WP3	Domain driven data engineering techniques	T1 + 10 months
WP4	Domain driven data analytics techniques	T1 + 15 months
WP5	Customized prototype software means suite development	T1 + 20 months
WP6	Customized prototype software means suite validation	T1 + 22 months

WP1 : Technical resources and problem definition

The objectives of this work package are to:

- describe technical resources (input data)
- define technical problem:
    - selection of a set of routes, data to be modelled;

- data cleaning, missing data inter/extrapolations, synchronisation of data obtained from different sources;
    - classification of planned/actual trajectories : closed to the initial planification, altered trajectories, correlation of the alterations to root causes (ATC orders, meteorological hazards avoidance)
- define technical requirements with regards to customized software means suite (interfaces, sizing…)

WP2: Flight policies, flight plans and trajectories data collection

Activities of this work package are:

- establish a data collection plan encompassing the list of data to be collected
- define precisely the nature of provided data
- describe the data processing to be performed on rough collected data for subsequent use
- provide the data

WP3: Domain driven data engineering techniques

The objective of this work package is to:

- define processings for:
    - data cleaning, missing data inter/extrapolations
    - time stamping, synchronisation of data obtained from different sources
- define and describe corresponding validation tests plan

WP4: Domain driven data analytics techniques

The objectives of this work package are to:

• define and describe algorithmic solution for :

o detecting for mission pairs (airport A to airport B), alterations from planned flight ,

o classifying these deviations and correlating them to external events (ATC orders, meteorological conditions)

• define and describe validation tests plan (scenarii, success criteria).

WP5: Customized prototype software means suite development

The objectives of this work package are to:

- develop software modules according to the design established in WP3 and WP4,
- document the architectural description of the prototype and usage guidelines

WP6: Customized prototype software means suite validation

The objectives of this work package are to:

- define prototype software means suite validation test plan,
- apply validation test plan and analyse results.

WP7: Evolution and update

The objective of this work package is to provide a support for possible prototype software means debugging and/or tools evolutions before the delivery of the final version.

3. Major Deliverables/ Milestones and schedule (estimate)

Deliverables			
Ref. No.	**Title – Description**	**Type**	**Due Date**
D1.1	Technical Resources and Problem definition	R	T1 + 3 months

Deliverables			
Ref. No.	**Title – Description**	**Type**	**Due Date**
D2.1	Trade-off report on multi-criteria decision making techniques	R	T1 + 6 months
D3.1	Flight policy data collection report	R	T1 + 9 months
D4.1	Crew Assistant Decision model description	R	T1 + 17 months
D4.2	Crew Assistant Decision model software package (first release)	P,R	T1 + 17 months
D5.1	Crew Assistant Decision Model Validation Test Plan and Report	R	T1 + 20 months
D6.1	Crew Assistant Decision model description and software package (final release)	P,R	T1 + 24 months

Milestones (when appropriate)			
Ref. No.	**Title – Description**	**Type**	**Due Date**
M1	Prototype Development Readiness Review		T1 + 10 months
M2	First release Results Review		T1 + 20 months
M3	Final Acceptance		T1 + 24 months

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

- Experience and strong background on mathematical multi-criteria decision making modelling techniques is sought. Background in applying these techniques in other transportation domain is a plus.
- Collaboration with airlines is encouraged to collect flight policy data and to validate multi-criteria decision making model against experienced flight preferences.
- Data collection and processing: Capability to collect and process flight policy data.
- Modeling technologies: Knowledge and background in the multicriteria decision making techniques is a prerequisite.
- Trajectory computation and optimization: Background in aircraft trajectory computation and optimization is a nice to have additional feature.

5. Abbreviations

FMS	Flight Management System
WP	Work Package

III. JTI-CS2-2019-CfP10-SYS-01-17: New Efficient production methods for 94 GHz (W-band) waveguide antennas

Type of action (RIA/IA/CSA):		IA	
Programme Area:		SYS	
(CS2 JTP 2015) WP Ref.:		WP 1.3.5	
Indicative Funding Topic Value (in k€):		500	
Topic Leader:	SAAB	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	20	**Indicative Start Date (at the earliest)[105]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-SYS-01-17	**New Efficient production methods for 94 GHz (W-band) waveguide antennas**
Short description	
Development of efficient and affordable production methods for high precision mm-wave waveguide antennas. A new method and solution is required to reach the performance, quality and cost targets to a TRL5 level which will enable future implementation of the next generation of radar sensor technology in EFVS operations.	

Links to the Clean Sky 2 Programme High-level Objectives[106]				
This topic is located in the demonstration area:		Avionics Extended cockpit		
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter:		Regional and Large passenger aircraft		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☐	☐	☐	☒	☐

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

[106] 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 Clean Sky 2 Systems workpackage on Advanced Vision and Awareness, explores innovative and new capabilities to develop a total Enhanced Vision Solution utilizing a combination of affordable IR-sensors, novel terrain database sources, navigation and computing technologies, and a new generation mm-Wave (mmW) sensor. This topic aims to extend knowledge and capability by conducting research and development to enable critical steps toward the possible next generation of mmW sensors, a 94GHz mmW-radar.

Enhanced vision solutions provide vision and awareness functionally to enable more efficient landing and approaches. Affordable landing approach radar systems require small-sized equipment and high resolution antennas. This leads to solutions with high gain mm-W antennas with narrow beam width. The antenna is required to cover a certain angular area either by mechanical or electrical scanning in one or two dimensions. An attractive solution, to avoid movable parts, is to use AESA (Active Electronically Scanned Array) antennas to be able to control the beam in one or two dimensions electronically.

This mm-wave solution will enable high resolution landing radar presentation and requires a complex antenna aperture with a large number of elements. A cost-effective antenna solution using a minimum number of transceivers and a low cost solution is therefore necessary. The antenna elements must therefore be arranged in sub-groups connected by low-loss transmission lines. A waveguide solution is therefore desired. This particular application will therefore require a new type high frequency antenna array solution. The target price for this application also calls for affordable solutions.

Active circuits (e.g. amplifiers, phase shifters etc) will then be tightly connected to the individual antenna elements or group of elements. This can be done using connector and cable interfaces. However this will introduce losses and a better solution would be to integrate the active circuits with the antenna aperture.The inclusion of active electronics is not foreseen for the demonstrator in this project but the antenna design and the production method shall be chosen in such a way that this integration is feasible at a later stage. One aspect of this is that it is highly desirable if the antenna also can doubleact as a heatsink for the active electronics, i.e. it is preferably if the antenna is manufactured by metal or another material with equally good thermal conductivity.

The antenna aperture is rather large in terms of wavelengths and may require an extensive feed network within each group of antenna elements. This can also introduce severe losses. It is therefore attractive to use waveguide antennas for this kind of application. If used in combination with high conductivity surface treatment they will offer much lower losses than e.g. microstrip or stripline antennas.

Waveguide antennas for mm-W applications are traditionally manufactured by milling and dip-brazed or soldered together. As the wavelength gets smaller, extremely good tolerances are required. Furthermore good RF-connection must be provided by galvanic contact or by other means which makes the above mentioned methods difficult.

The aim of this work package is therefore to investigate, suggest and implement efficient and affordable production methods for high-precision mm-wW waveguide antennas. The final antenna shall be designed for limited azimuth (±20°) scan which needs to be considered when choosing waveguide dimensions and other critical measures also for the demonstrator. All technologies developed in this topic need to be free of any ITAR (or similar export) restrictions.

2. Scope of work

The overall scope of the project is to propose and demonstrate an efficient and affordable production method for high-precision waveguide antennas with integrated electronics. However, the focus for this project is on the production method and that no electronics shall be included in the demonstrator.

To demonstrate the feasability of the proposed production method, a demonstrator shall be designed, manufactured and tested. The demonstrator array shall be according to below:

- Array with at least 6 vertically oriented slotted waveguides
- Each waveguide comprising at least 10 longitudinal slots each
- Center frequency 94 GHz. Bandwidth approximately 5 %
- Waveguide separation 2.4mm
- Corporate feed network from each waveguide to one common input waveguide port (EIA Standard WR10). The demonstrator is made as a fixed beam antenna for demonstration purposes only
- Uniform amplitude and phase for all waveguides and slots
- Surface treatment for very low loss required

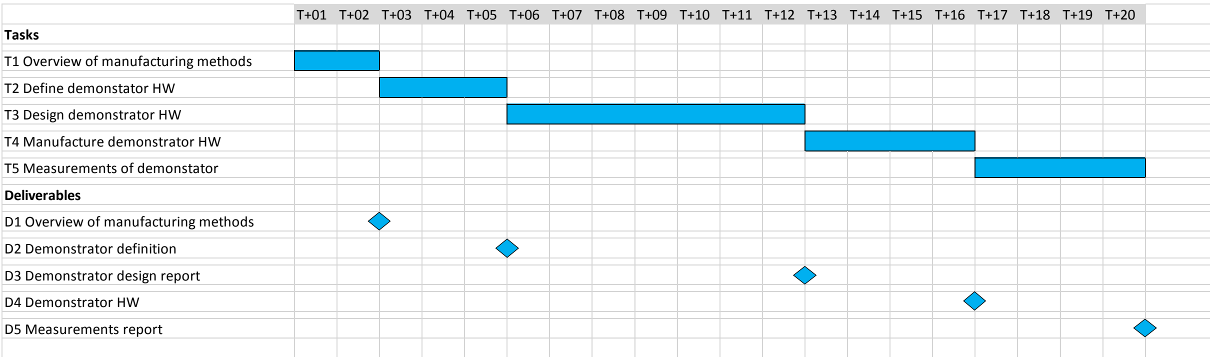
Tasks		
Ref. No.	***Title - Description***	***Due Date***
T1	Overview mm-wave waveguide antenna manufacturing methods Description of preferred manufacturing method with pros and cons relative other methods. Easy integration with electronics shall be considered. However, no electronics shall be included in the demonstrator within this project. Low-cost methods for 100-1000 unit volume production shall be focused on.	T0+2 months
T2	Define - demonstrator HW Define antenna demonstration hardware according to above. Shall be possible to measure with respect to antenna pattern and loss.	T0+5 months
T3	Design - demonstrator HW Mechnical and RF-design of demonstrator	T0+12 months
T4	Manufacture - demonstrator HW Manufacture of a prototype, suitable for measurements, testing and demonstration.	T0+16 months
T5	Measurement - demonstrator Measurement of antenna pattern, gain and directivity.	T0+20 months

3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D1	Overview mm-wave waveguide antenna manufacturing methods	R	T0+2 months
D2	Demonstrator definition	R	T0+5 months
D3	Demonstrator design report	R	T0+12 months

Deliverables			
Ref. No.	***Title - Description***	***Type****	***Due Date***
D4	Demonstrator hardware	HW	T0+16 months
D5	Measurements report	D+R	T0+20 months



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

- Knowledge in high frequency antenna design
- Design capability for high frequency antennas, including access to all required software
- Measurement capability in the 93-100 GHz range regarding S-parameter and antenna pattern test

5. Abbreviations

AESA	Active Electronically Scanned Array
EFVS	Enhanced Flight Vision Systems
ITAR	International Traffic in Arms Regulations
mmW	Millimeter-Wave
PA	Power Amplifier
RF	Radio Frequency

IV. JTI-CS2-2019-CfP10-SYS-01-18: Low-profile/drag electronically steerable antennas for In-Flight Connectivity

Type of action (RIA/IA/CSA):		IA	
Programme Area:		SYS	
(CS2 JTP 2015) WP Ref.:		WP 1.4	
Indicative Funding Topic Value (in k€):		1400	
Topic Leader:	Thales	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	24	**Indicative Start Date (at the earliest)[107]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-SYS-01-18	**Low-profile/drag electronically steerable antennas for In-Flight Connectivity**
Short description	
The objective is to study and prototype the next generation of low-profile airborne antennas that will be used for In-Flight Connectivity in the horizon 2022-2025. Such project will have to demonstrate that the use of electronically steering can meet the stringent requirements of commercial aircraft connectivity, while bringing significant benefits such as reduced maintenance, low drag and weight.	

Links to the Clean Sky 2 Programme High-level Objectives[108]				
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:		Enabling technologies		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☐	☐	☐	☒	☐

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

[108] 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 industry has deployed a wide set of broadband networks and services to offer high-speed connectivity to passengers and crews. Those systems take advantage of high bandwidth available, for instance in the Ku and Ka frequency bands, to deliver the capacity required for each aircraft. Examples of solutions are Satellite Communications (Satcom) using geostationary constellations (GEO) or emerging satellites operating in Low Earth and Medium Earth Orbits (LEO, MEO), as well as Air-to-Ground systems based on latest generation cellular network infrastructure.

Such solutions are highly complex and decompose into many system elements such as the ground infrastructure, the satellites, the aircraft terminal and the in-cabin wireless networks. In particular, the aircraft terminal includes a critical component; the antenna system. Its characteristics have a significant impact on the Total Cost of Ownership for the Airlines connectivity services. In particular, a highly-efficient antenna can lead to reduced over-the-air data costs, a low drag coefficient minimizes the fuel consumption and its MTBF (Mean Time Between Failures) impacts the maintenance costs.

The new generation of airborne directional antennas can be classified into three categories:
- Multi-gimbal steerable passive array, which includes antennas with 2 and 3 mechanical axis,
- Single-gimbal steerable passive array with one single axis to steer the beam and control polarization (e.g. VICTS: Variably Inclined Continuous Transverse Stub),
- Electronically steerable active phased array or Electronically Steerable Antenna (ESA), where the antenna is stationary leading to ultra-low-profile systems.

The ARINC 791 aviation standard (Aviation Ku-band and Ka-band satellite communication system) has been defined by the AEEC KSAT Sub-committee and used for the development of line-fit solutions. Those specifications have been optimized for passive arrays such as the two first types of antennas described above. This Sub-committee is working on the definition of the next generation terminal, which is optimized for two tandem flat electronically steerable panels (i.e. ESA).

The Electronically Steerable Antennas are intended to provide significant benefits for In-Flight Connectivity applications in the horizon 2022-2025:
- Minimization of the drag coefficient with a positive impact on fuel consumption,
- Reduction of the antenna footprint and weight,
- Improvement of the MTBF, because those systems have no moving parts,
- Fast and agile beam steering to support MEO and LEO satellite constellations,
- And in the Air-to-Ground case reduced inter-cell interference.

However the introduction of those new flat panel solutions in the aviation industry is facing roadblocks and in particular the following critical challenges need to be addressed:
- Power consumption and heat dissipation: An ESA system is composed of many antenna elements, which are all associated with a power amplifier and switch path. Such a design consumes a lot of power and generates heat that has to be dissipated.
- Recurring cost: The need to use large area arrays with a high number of RF components also has a significant impact on the cost of the solution.
- Performance at low elevation angles: Peak antenna performance occurs when the surface area is aligned to the satellite and hence fixed antennas suffer from reduced satellite illumination with increased scan angle.

The objective of this project is therefore to tackle those challenges and propose low-profile and highly efficient antenna solutions for the next generation of In-Flight Connectivity services.

The selected Partner(s) will be part of the Systems ITD WP1.4.4 (Communication Platform), which is studying the challenges and potential benefits of new radio-communication architectures for commercial aircraft, including distributed radio configurations, new communication waveforms and routers, communication management functions and flat-panel/low-drag antennas. The main objective of all those activities is to reduce the impact of the communication systems on the aircraft drag, SWaP (Size, Weight and Power) and associated fuel consumption.

2. Scope of work

This project aims at studying the installation of ESA systems on commercial aircraft with a focus on Large Passenger Aircraft (i.e. single-aisle and wide-body). The solution is intended to be offered on both retrofit and linefit markets, which implies the need to take into account the corresponding standards and in particular the ARINC 792 specifications for next-generation low-profile antenna provisions.

The primary use case for this activity is Satellite communication services delivered in Ka-band using GEO, MEO and LEO satellite networks. An initial set of desired antenna characteristics is provided hereafter and will have to be consolidated with the Systems ITD WP1.4.4 partners:
- G/T: at least 13 dB/K over scan range,
- Frequency range in reception: 17.3 – 20.2 GHz (500 MHz instantaneous bandwidth),
- Frequency range in transmission: 27.5 – 30.0 GHz (200 MHz instantaneous bandwidth),
- Elevation scan range: 5 – 90 degrees,
- Polarization: simultaneous dual circular,
- High isolation from Adjacent Satellite Interference (ASI).

The project will also look at other use cases such as Air-to-Ground (A2G) systems in order to identify potential synergies in the development of RF components and overall system design by conducting a full analysis of those solutions in partnership with the other WP1.4.4 partners.

The expected outputs of the project are a set of reports presenting the results of the studies and prototypes of an antenna system that illustrate the benefits of ESA technologies and at the same time demonstrate the capability to overcome the technology limitations described above. For instance, a ground-based Ka-band Satcom solution could be proposed to demonstrate over-the-air communications with a GEO and/or a MEO satellite.

The main activities and deliverables are summarised in the table below, however applicants are encouraged to propose alternate approaches to ensure achievement of the topic objectives.

Tasks		
Ref. No.	**Title - Description**	**Due Date**
WP1	Requirement definition	T0 + 8 months
WP2	System analysis	T0 + 6 months
WP3	Technology assessment	T0 + 12 months
WP4	Demonstrator	T0 + 18 months
WP5	Validation testing	T0 + 24 months

WP1: Requirement definition

This work package aims at analysing and consolidating the requirements for the next generation aviation electronically steerable antenna system.

It consists of the following tasks:

- Collect stakeholder needs using the technical characteristics described in the previous section of this document and the WP1.4.4 requirement analysis for future antenna systems,
- Analyse those requirements and identify the potential gaps or missing information,
- Study the ARINC 792 standard and propose potential evolutions that could provide competitive advantages,
- Describe the analysis of the standard, the identified requirements and key associated challenges in the Initial Requirement Analysis Report (D1.1),
- Update the Requirement Analysis Report after having conducted the system analysis in WP2 (D1.2).
- Perform similar tasks, as appropriate, to consolidate requirements for electrically steered antennas in the Air-to-Ground system use case.

WP2: System analysis

The objectives of the second work package are to study the impact of the use cases (e.g. GEO, MEO and LEO satellite constellations, and A2G) on the antenna definition and establish reference architecture for the antenna system.

The WP2 should include the following tasks:

- Analysis of the technical characteristics for the different system configurations including GEO, MEO, LEO and potentially A2G (e.g. tracking speed resolution and accuracy, elevation scan range, etc),
- Study the scalability requirements to address different aircraft configurations from single-aisle to wide-body aircraft (business jet and regional aircraft could also be considered),
- Perform trade-off analysis for some of the key decisions to be made (e.g. multi-beam capability for seamless satellite or basestation handover),
- Define a reference architecture for the antenna system (including power supply, power amplifier, aperture, stabilization and tracking),
- Present the system analysis and reference architecture in a report (D2.1),
- Generate associated system-level requirements to be injected in the Final Requirement Analysis Report (D1.2).

WP3: Technology assessment

This work package intends to perform a first-level assessment of the proposed technologies using paper analysis and potentially building prototypes.

This work package consists of the following tasks:

- Define a set of proposed solutions for the RF technologies, which is consistent with the reference architecture and solution requirements (D2.1),
- Perform an assessment of those solutions using paper analysis (including MTBF calculation) and potentially demonstration of critical building blocks,
- Analyse the potential commonalities between some of the end-to-end system configurations (e.g. GEO and MEO Satcom and A2G), as well as operating frequencies (Ka, Ku, C, and S bands),
- Select one technology for the demonstrator that will be developed in WP4 (in coordination with the Work Area Leader and the other WP1.4.4 partners),
- Present the output of those analyses in the Technology Assessment Report (D3.2).

The technology assessment and demonstrator definition shall take into account the compatibility and interoperability with Thales FlytLive Ka-band infrastructure (Jupiter-based aero system) or Thales 4G/LTE based A2G system, as appropriate.

WP4: Demonstrator

The objective is to develop a prototype of the technology selected in the previous work package for lab demonstrations (i.e. anechoic chambers) and potential over-the-air communication with a Satellite and/or ground infrastructure.

This work package consists of the following tasks:
- Specification of the demonstrator using the output of the previous WPs (D4.1),
- Description of the development strategy and integration / verification plan (D4.2),
- Development of the technology components and antenna integration,
- Perform system integration / verification tests and provide the associated report (D4.3),
- Delivery of two antenna prototypes to the WP1.4.4 partners for the testing phase (D4.4).

It shall be noted that those prototypes will not be used for flight tests and thus the environmental and EMC requirements can be minimized accordingly.

WP5: Validation testing

The last work package of this project aims at conducting an important set of tests in order to validate the antenna and system behaviour with regards to the stakeholder requirements.

It consists of the following list of tasks:
- Preparation of the validation plan, which shall include the validation criteria (D5.1),
- Definition of the validation test procedures,
- Conduct validation tests and analyse test results,
- Present the validation test results and associated analysis in a report (D5.2).

3. Major Deliverables/ Milestones and schedule (estimate)

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

The following tables describe the expected deliverables and example milestones.

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1.1	Initial Requirement Analysis Report	R	T0 + 3 months
D1.2	Final Requirement Analysis Report	R	T0 + 8 months
D2.1	System Analysis Report	R	T0 + 6 months
D3.1	Description of the Candidate Technologies	R	T0 + 8 months
D3.2	Technology Assessment Report	R	T0 + 12 months
D4.1	Demonstrator Detailed Specifications	R	T0 + 15 months
D4.2	Demonstrator Development and Test Plan	R	T0 + 15 months
D4.3	Integration and Verification Report	R	T0 + 18 months

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D4.4	Antenna Prototypes	P	T0 + 18 months
D5.1	Validation Plan	R	T0 + 20 months
D5.2	Validation Test Results and Analysis	R	T0 + 23 months

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	Antenna System Requirement Review	M	T0 + 8 months
M2	Technology Assessment Review	M	T0 + 12 months
M3	Antenna Prototype Design Review	M	T0 + 15 months
M4	Antenna Prototypes Test Review	M	T0 + 20 months

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

Generally speaking, the applicants shall have the skills and capabilities to deliver the defined analysis reports and fully validated antenna prototypes using the most advanced RF and antenna technologies.

The selected Partner(s) shall demonstrate relevant skills and knowledge in the following areas:
- Antenna system design, development and qualification principles,
- Electronically steerable antenna core technologies (e.g. RF integrated circuit, liquid crystal, optical lens, amplitude and phase/delay varying networks),
- Satellite communication in Ka band (Ku and C/S bands are also of interest), including standards for Ku and Ka-band Satcom airborne terminals (ARINC 791 and/or 792),
- Thermal management in RF designs.
- Low drag radomes

The following set of capabilities is required to complete this project successfully:
- Antenna performance characterization using simulations and measurements,
- Recognized antenna manufacturer(s) with the capability to design highly-efficient active scanned array,
- Previous implementation of electronically steerable antennas for ground infrastructure or ground transportation,
- Demonstrated capability to minimize power consumption of ESA systems.

It shall be noted that the capability to design Satcom and/or Air-to-Ground antennas for commercial aircraft is a benefit. Nevertheless the experience of the aviation domain is not mandatory as the WP1.4.4 partners will provide guidance for the system analysis.

For demonstration purposes and system analysis, the experience of a satellite service and/or ground infrastructure provider could be beneficial but it is not essential.

5. Abbreviations

A2G	Air-to-Ground
AEEC	Airlines Electronic Engineering Committee
ARINC	Aeronautical Radio Incorporated

ASI	Adjacent Satellite Interference
ESA	Electronically Steerable Antenna
GEO	GEostationary Orbit
G/T	Gain-to-noise-Temperature
ITD	Integrated Technology Demonstration
KSAT	Ku/ka-band SATcom
LEO	Low Earth Orbit
MEO	Medium Earth Orbit
MTBF	Mean Time Before Failures
RF	Radio Frequency
Satcom	Satellite Communication
SWaP	Size Weight and Power
VICTS	Variably Inclined Continuous Transverse Stub
WP	Work Package

V. JTI-CS2-2019-CfP10-SYS-01-19: VOC Filtration device for inerting system

Type of action (RIA/IA/CSA):		IA	
Programme Area:		SYS	
(CS2 JTP 2015) WP Ref.:		WP 2.3	
Indicative Funding Topic Value (in k€):		900	
Topic Leader:	Zodiac Aerospace	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	27	**Indicative Start Date (at the earliest)[109]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-SYS-01-19	**VOC Filtration device for inerting system**
Short description	
The aim of this topic is to increase the life duration and availability of an inerting system in protecting the separation membranes. The objective is to design and manufacture filtration devices to get rid of the volatile organic compounds present in the system feed air and harmful for the system.	

Links to the Clean Sky 2 Programme High-level Objectives[110]				
This topic is located in the demonstration area:	Innovative cabin passenger / taylored 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 and short / medium range			
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☐

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

[110] 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 frame of SYSTEMS ITD WP2.3 (cabin and cargo systems), a cargo compartment fire-suppression system is being developed to replace the existing Halon-based suppression system. This new system will avoid any dispersion of CFC gases (components with high Ozone Depletion Potential and high Global Warming Potential), hence it will reduce the aircraft impact on the degradation of the atmosphere. It is composed of a knock-down system interfaced with an on board inert gas generation system (OBIGGS) to maintain an inert atmosphere in the cargo compartment.
This inerting system is based on the use of polymeric membranes that separate the air gases. The membrane, also called ASM (Air Separation Module), is fed with compressed air coming from the bleed air circuitry or from a dedicated compressor. By a phenomenom of diffusion, part of the oxygen is removed from the feed air. The Nitrogen Enriched Air (NEA) recovered at the end of the membrane is injected in the cargo compartment to reduce the oxygen percentage below 12% of the air volume and maintains an inert atmosphere. NEA is not detrimental to the earth's atmosphere.
Similar types of inerting systems are already operated to protect the fuel tanks. A trend for the future is to use the same equipment for fuel tank inerting and fire-suppression in the cargo bay. The stream of gas would be injected in the fuel tanks during the flight and automatically diverted to the cargo compartment as soon as a fire alarm occurs. As the fire-suppression system is essential (unlike the fuel tank inerting system), priority would automatically be given to the first one. The inerting system would be mainly defined according to the fire-suppression function requirements.
Fuel tank inerting system is permanently fed with bleed air during the flight. The feed-back of the nearly 10 first years of worldwide operation has shown that the ASMs were susceptible to certain contaminants. Filtration chains have been installed in the existing OBIGGS: it is mainly composed of a first HEPA-type filter, that stops more than 99,9% of the particles and more than 99% of the aerosol as well as an ozone converter, mainly based on a catalytic technology, that destroys more than 90% of the ozone contained in the air. But nothing has been developped to stop the vapours known as Volatil Organic Compounds (VOC) such as aldehydes. Contamination from VOC will harm the ASM and degrade the performance by accelerating the ageing of the epoxy tubesheet and reducing its lifetime.
The objective of this project is to develop an innovative filtration device that will protect the ASM against VOC. It will improve the reliability of the ASM, hence the availibility of the OBIGGS. Furthermore, increasing its life time will drive a reduction of the possession cost. At last, a damaged membrane will consume more bleed air, hence impact the fuel consumption and CO_2 production.

2. Scope of work

The objective of this project is to develop, build and test a demonstrator at TRL 6 that will stop more than 80% of the VOC found in the bleed air stream.
A technical specification defining the air characteristics (pressure, flow and temperature) as well as the environmental conditions will be provided at the start of the project by the Topic Manager. Note that the temperature of the bleed air will generaly be around 75°C.

The project is split in several tasks.

Task 1: Collect the list the VOC that can be found in the pressurized air used in the ASM. One should keep in mind the different air sources can be used : usually, pressurized air is drawn from a high pressure compressor stage of the engine and is called "bleed air". Another solution is to use a dedicated electrical compressor which will pump air from the atmosphere or in the cabin. A list of VOC will be made for each of these solutions.
A list of VOC to be tested in a further phase will be presented and agreed at the end of this task.

Task 2: Review of the technologies available to filter the VOC. Evaluation of the pros and cons, according to the gas specification requirements delivered by the Topic Manager at the beginning of the project.

Task 3: selection of the best candidate technology. Evidences of the efficiency of the technology will be delivered, based on analysis, similarity and development tests if deemed necessary.
The objective is to successfully pass a TRL3 review.

Task 4: Design of an equipment based on the selected technology. This task will include not only the study of the mechanical/chemical characteristics, but also reliability and safety aspects.

Task 5: Ten prototypes will be manufactured. A prototype includes the filtering element as well as its mechanical envelop and interfaces.

Task 6: Filter efficiency verification campaign
An extensive test campaign will be carried out to prove that the equipment achieves the specified requirements.
This test campaign will integrate at least:

- The verification of the filter efficiency for each of the selected contaminant. These tests will be performed in the temperature and pressure conditions defined in the specification.
- A test with a combination of contaminants injected together to ensure that the filter keeps its efficiency.
- Long term endurance testing to evaluate the life duration of the equipement.
- At last, vibration tests will be carried out to make sure that there is no risk of degradation of the selected media during the life of the filter.

The objective is to reach a TRL6 at the end of the project

Tasks		
Ref. No.	**Title – Description**	**Due Date**
T1	Review of the bleed air VOC	T0+3
T2	Review of the existing filtration technologies	T0+6
T3	Selection of the best candidate technology	T0+10
T4	Prototype design	T0+14
T5	Prototype manufacturing	T0+18
T6	Verification test campaign	T0+24

3. <u>Major Deliverables/ Milestones and schedule</u>
*Type: R=Report, D=Data, HW=Hardware

Deliverables			
Ref. No.	**Title – Description**	**Type***	**Due Date**
D1	List of the bleed air VOC	R	T0+3
D2	List of the filtration technologies	R	T0+6
D3	Selection of the filtration technology	D	T0+10
D4	Design review file, including reliability activities, qualification procedures	R	T0+14

Deliverables			
Ref. No.	**Title – Description**	**Type***	**Due Date**
D5	Filter prototypes (qty 10)	HW	T0+18
D6	Test report	D	T0+27

Milestones			
Ref. No.	**Title – Description**	**Type***	**Due Date**
M1	Technical review		T0+6
M2	Technical review		T0+10
M3	CDR and TRL3 milestone		T0+14
M4	Technical review – completion of test campaign – and TRL6 milestone		T0+27

		Months																										
Task N°	Task name	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
1	Review of the bleed air VOC	■	■	■																								
2	Review of the existing filtration technologies				■	■	■																					
3	Selection of the best candidate							■	■	■	■																	
4	Prototype design											■	■	■	■													
5	Prototype manufacturing															■	■	■	■									
6	Verification test campaign																			■	■	■	■	■	■	■	■	■

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

- Specialist in gas filtration
- Capability in design. By design, it is understood generation of the specification, technical studies and associated deliverables, safety analysis and redaction of the qualification tests plans and reports.
- Strong capability in testing. The applicant will organise the test campaign and conduct it. In house test facilities would be appreciated.
- Strong capability in Project management
- Aware of aerospace processes, as presented in EN9100 or certification approach.
- Aerospace background. The applicant will give a track record of its aerospace applications.

5. Abbreviations

ASM	Air Separation Module
HEPA	High Efficiency Particle Arrestor
NEA	Nitrogen Enriched Air
OBIGGS	On Board Inert Gas Generating System
TRL	Technology Readiness Review
VOC	Volatil Organic Compound

VI. JTI-CS2-2019-CfP10-SYS-01-20: Innovative high flow rate constant pressure valve for inert gas discharge from pressurized vessels

Type of action (RIA/IA/CSA):		IA	
Programme Area:		SYS	
(CS2 JTP 2015) WP Ref.:		WP 2.3	
Indicative Funding Topic Value (in k€):		700	
Topic Leader:	Diehl Aviation	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	24	**Indicative Start Date (at the earliest)[111]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-SYS-01-20	**Innovative high flow rate constant pressure valve for inert gas discharge from pressurized vessels**
Short description	
High pressure inert gas storage vessels are used for a novel water mist and inert gas based fire suppression system for aircraft cargo compartments, within WP2.3. Other than today's commonly used Halon based fire suppression systems, the mass flow rates and supply pressures for these systems are much higher, resulting in a series of challenging requirements which are not met by today's available system.hardware. The applicant shall develop an innovative high pressure and very high mass flow valve for inert gas, which is capable of providing a constant output pressure over a broad spectrum of input pressures. Any proposed solution shall meet the aviation specific requirements such as reliability, environmental requirements and lightweight design, in addition to the extreme performance requirements necessary for an inert gas fire suppression.	

Links to the Clean Sky 2 Programme High-level Objectives[112]				
This topic is located in the demonstration area:		Cargo systems		
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter:		SMR and LR aircraft		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☐

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

[112] 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

Fire suppressions systems are mandatory for all modern large aircrafts which comprise a Class C cargo compartment. These systems currently use the environmentally hazardous extinguishing agent Halon 1301. Due to its ozone depletion and global warming potential, Halon 1301 was banned from production by the Montreal Protocol. The further use of Halon 1301 for cargo compartment fire suppression was limited by EU regulations and is only permitted until the end of 2018 for new type certificate aircrafts. Diehl Aviation developed an environmentally friendly replacement technology based on water mist and nitrogen, which has been proven to be the, so far, only available and officially tested alternative for the current Halon based systems. The development of specific system componenents and the integration of an on board inert gas generation (OBIGGS) are part of Cleansky 2 ITD Systems WP 2.3 - Cabin and Cargo Systems. The described task in this call shall support these efforts by providing a high flow rate constant pressure valve for inert gas discharge from a pressurized storage vessel.

These valves will be an essential part of the newly developed halon-free cargo compartment fire suppression system. Similar valves are currently used throughout many different industries such as process technology, automotive applications and even several fire suppression applications. However, all these valves do not meet one or the other requirement which is essential for aerospace applications:

- Industrial valves may handle the high flow rates, and are robust, but they are too heavy and do not meet safety and reliability requirements.
- Current valves which are used in halon-based fire suppression systems of aircrafts can neither handle the high input pressures nor the high flow rates.
- Valves in automotive applications e.g. for hydrogen or CNG are not as heavy as industrial valves, but they cannot handle the high flow rates, and reliability for a safety critical aircraft system (i.e. the fire suppression system) is not given.

[113] [114]

Figure 1: Examples for currently available valves for inert gas discharge

[113] www.spectron.de - http://www.spectron.de/spectron_de/img/produkte/spectrotec/druckregler/u47/de/GDS_U47_0211.pdf

[114] www.siemens.com - https://w5.siemens.com/spain/web/es/building_technologies/protecc_incendios/Documents/Sinorix_CDT_0-92035_En.pdf

The specific requirements for the envisaged valve will be clarified in close collaboration between the WP Leader and the applicant. The main function of the valve will be to provide a high inert gas flow rate of at least 160 g/s at a constant output pressure, while the input pressure from the gas storage vessel decreases over time, starting at 344 bar at 21.1.°C ambient temperature.
In addition the valve shall provide the following functions:

- Start (and stop) inert gas flow from an attached pressurized storage vessel
- Port for filling an attached storage vessel with inert gas, provided by an external source
- Monitoring of pressure levels within an attached pressurized storage vessel
- Overpressure protection

Lightweight and even non-metal materials e.g. plastics, thermoplastics are prefered for the envisaged valve in terms of weight and production cost reduction. In addition to the main functional requirements, the manufactured valve shall fulfill the specific requirements of civil aircrafts with respect to high and low temperatures, vibrations etc.. Further details are described in RTCA Do160 Rev. G. Notably, temperature decrease caused by gas expansion at low operational temperatures leads to gas temperatures of less than -100°C.

2. Scope of work

After clarification of the specific requirements, the first objective of the project will be to identify the most suitable basic technology for the constant pressure valve. This project phase also may include the development of new functional principles for the high flow rate constant pressure valve.
The technologies identified shall also consider the valve to be designed in such way, that it is either directly integrated within or externally attached to a storage vessel. Both of these variants shall be developed and designed, to compare their specific capabilities, benefits and limitations. The following key characteristics of the innovative high flow rate constant pressure valve shall be addressed:

- Inert gas storage pressure of 344 bar (at 21.1°C), considering proof and burst pressure load factors
- High flow rate capabilities of at least 160 g/s
- Operational ambient temperatures of -40°C and gas temperatures of <-100°C
- Ports for monitoring pressure, filling the tank and over pressure protection
- Lightweight design and high reliability
- Proof of safe valve operation under operational conditions

Tasks		
Ref. No.	**Title - Description**	**Due Date**
Task 1	Definition and Clarification of Requirements, Boundary Conditions, Testing Metrics and Test Procedures	T0+3
Task 2	Selection of valve technology(s) for high flow rate inert gas discharge from a pressurized storage vessel at constant output pressure	T0+7
Task 3	Development and design of prototype valves	T0+15
Task 4	Verification tests and performance assessment of the developed valves	T0+19
Task 5	Adaption and integration of valve into an inert gas storage demonstrator	T0+24

Task 1: The requirements related to functional performance, safety and reliability properties, temperature, mechanical robustness as well as specific aviation requirements shall be jointly defined in

cooperation with the topic leader. The requirements shall be documented in the "Requirement Document". Test procedures for functional tests and verification of the prototypes shall be defined.

Task 2: An overview of potentially applicable basic technologies shall be elaborated, resulting in a conceptual and comprehensive study to select the most suitable basic technologies. As part of the innovation action the technology(s) shall be further developed to meet the specific functional and aerospace requirements.
Most promising technology(s) shall be tested in a proof of concept test program especially with regard to flow rate capability, temperature stability, robustness and reliability properties. Critical system conditions shall be evaluated using numerical simulation methods. The task is completed with the provision of a report including investigated technologies, evaluation as well as simulation results and proof of concept test report (Deliverable D1).

Task 3: Develop a detailed design for a high flow rate constant pressure valve capable of being fully integrated into a storage vessel and a second design for a valve capable of being externally attached to said vessel. In addition, suitable test equipment/test bench for functional testing shall be developed. The goal of this task is to provide at least two identical valves of each of the two developed designs, as well as functional test equipment. These prototype valves are further used for verification, performance and necessary safety relevant tests (Task 4).

Task 4: The test program that was defined in Task 1 shall be conducted in order to demonstrate feasibility, performance and safe operation of the developed prototype designs (refer to Task 3).

Task 5: The first action within this task comprises the selection of one of the prototype designs for subsequent adoption and integration into the inert gas storage demonstrator. The selection is based on the test results gathered during Task 4 and will be jointly agreed with the Topic Leader. For adoption and integration of the selected prototype valve, an optimization loop may be performed to account for findings during Task 4.
The task will be completed by manufacturing and integrating high flow rate constant pressure valves into the inert gas storage demonstrator.

3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1	Concept evaluation report	R	T0+7
D2	Reference documentation for valve prototypes	D	T0+15
D3	Valve(s) for functional testing incl. test bench	HW	T0+15
D4	Verification test report	R	T0+19
D5	Valve(s) integrated into inert gas storage demonstrator	HW	T0+24

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	Specification document submitted	R	T0+3
M2	Review of selected technology and preliminary design of valve prototypes	R	T0+7
M3	Design review of valve concepts/hardware	R	T0+11

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M4	Reference documentation for valve prototypes submitted	D	T0+15
M5	Verification test report submitted	R	T0+19
M6	Demonstrator parts provided and integrated into inert gas storage demonstrator	HW	T0+24

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
T1	Definition and Clarification of Requirements, Boundary Conditions, Testing Metrics and Test Procedures			M1																					
T2	Selection of valve technology(s) for high flow rate inert gas discharge from a pressurized storage vessel at constant output pressure							D1 M2																	
T3	Development and design of prototype valves											M3				D2 M4									
T4	Verification tests and performance assessment of the developed valve															D3				D4 M5					
T5	Adaption and integration of valve into an inert gas storage demonstrator																								D5 M6

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

- The applicant shall have capabilities to design, manufacture and test high pressure inert gas expansion valves
- The applicant shall have profound experience in high pressure inert gas expansion valves
- The applicant shall have capabilities or shall have access to test facilities allowing to perform safety relevant (e.g. proof/burst pressure) and performance tests

5. Abbreviations

OBIGGS	On-board inert gas generation system
CNG	Compressed natural gas
RTCA Do160 Rev. G	Environmental Conditions and Test Procedures for Airborne Equipment Do-160

VII. JTI-CS2-2019-CfP10-SYS-01-21: Grey water container with reduced biofilm growth

Type of action (RIA/IA/CSA):		IA	
Programme Area:		SYS	
(CS2 JTP 2015) WP Ref.:		WP 2.3	
Indicative Funding Topic Value (in k€):		700	
Topic Leader:	Diehl Aviation	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	21	**Indicative Start Date (at the earliest)[115]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-SYS-01-21	**Grey water container with reduced biofilm growth**
Short description	
Objective of the CfP is the development of a grey water storage vessel made of plastic with long lasting reduced biofilm growth. Biofilm growth reduction is a key challenge for all components of the Grey Water Reuse System (GWRS) which are in contact with nutritious grey water. Inhibition of biofilm growth may be realized by different methods such as adding antimicrobial substances to the plastic compound, by surface coating or painting, by dirt repellent or very smooth surfaces. Scope of work is the identification of the most effective method and manufacturing of a grey water container, which employs the preferred biofilm inhibition method. Based on this container, it shall be demonstrated that besides biofilm growth reduction also aircraft specific requirements are fulfilled.	

Links to the Clean Sky 2 Programme High-level Objectives[116]				
This topic is located in the demonstration area:		Equipment for cabin and cargo		
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter:		Cabin and Cargo systems		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☐	☐	☐	☒	☐

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

[116] 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 addtion to the well-known Potable Water and Waste Water System, an aircraft also has a Grey Water System. This system is employed for the disposal of water, which is used for hand washing in the lavatories and in some airplanes also for water from the galley sinks. Grey water is usually discharged from the aircraft by a drain mast. Reuse of water from the wash basins for toilet flushing would allow a reduction of the required potable water amount by about 30%. The development of a Grey Water Reuse System (GWRS) is part of Cleansky 2 ITD Systems WP 2.3 - Cabin and Cargo Systems. GWR may contribute to a significant weight reduction of mid- and long-range passenger aircrafts.

The described task in this call shall support these efforts by providing a grey water container with reduced biofilm growth.

Deposits and also biofilm growth on the surfaces of GWRS components are undesirable for different reasons:

- The functions of the equipment e.g. filtration are impaired
- Maintenance efforts for GWRS components are increased and the service life is reduced
- Hygienic requirements are not fulfilled
- Biofilms may cause unpleasant odor and appearance of the equipment.

Figure 1: Container with significant biofilm growth due to wet surfaces and presence of organic materials

The first objective the project will be to identify the most suitable procedure(s) and material(s) to reduce biofilm growth over a long period of time. The developed or selected method(s) shall be applied in a storage container for grey water. Lightweight and non-metal materials e.g. plastics, thermoplastics are prefered for the envisaged storage container in terms of weight and production cost reduction. In addition to the prevention of biofilm growth, the manufactured container and the selected method for biofilm growth prevention shall fulfill the specific requirements of civil aircrafts with respect to high and low temperatures, vibrations etc.. Details are described in RTCA Do160 Rev. G. Furthermore, grey water from the wash basin may contain not only dirt and soap, but also different aggressive substances like alcohol or aceton so that long term resistance against these substances is required.

Formation of deposits and biofilm growth on GWRS surfaces are particularly promoted by a high content of organic substances of grey water espcially on non-metallic surfaces, such as thermoplastics. Furthermore, wet surfaces foster growth of biofilm.

In general, inhibition of biofilm growth may be realized by different methods such as adding of antimicrobial substances to the plastic compound or by applying antimicrobial surface coatings or

paints. Biofilm growth may also be reduced when surfaces are kept dry and sticking of organic materials to surfaces is prevented. This effect can be achieved by dirt repellent or very smooth surfaces.
Dirt-repellent and easy-to-clean (ETC) coatings for products made of glass in automotive applications like car windscreens or residential applications like shower walls have been used for many years. The main drawback of these coatings is their short lifetime and a fast descreasing functional performance. The application of well-known dirt repellent coatings like PTFE requires high process temperatures which exceed the maximum allowable temperature of relevant thermoplastic materials like PEI.

2. Scope of work

Tasks		
Ref. No.	**Title - Description**	**Due Date**
Task 1	Definition and Clarification of requirements, boundary conditions, testing metrics and test procedures	T0+3
Task 2	Selection of method(s) for prevention of biofilm growth and selection of material(s)	T0+6
Task 3	Development of application process on coupon level and on complex geometries	T0+12
Task 4	Process Verification tests and performance assessment of the developed coatings. Improvement of process.	T0+18
Task 5	Development of grey water container hardware and application of method for biofilm prevention	T0+21

Task 1: The requirements related to the container's and materials' performance with respect to antimicrobial properties, temperature, mechanical resistance as well as specific aircraft requirements shall be jointly defined in cooperation with the topic leader. The requirements shall be documented in the "Requirement Document". Test procedures and metrics for the evaluation biofilm growth prevention shall be defined.

Task 2: A comprehensive overview of potentially applicable materials and corresponding manufacturing processes shall be elaborated. Materials that have proven their high performance potentials e.g. in industrial applications may be employed. As part of the innovation action, materials and application processes shall be further developed to meet the specific aerospace requirements. Results shall be summarized in an assessment matrix.
Most promising methods and materials shall be tested in a screening test program especially with regard to durability, abrasion resistance and biofilm growth properties. The task is completed (Deliverable D1) with the provision of a report with different methods, a summary of the evaluation and screening test results.

Task 3: The process for adding antimicrobial agents to the compound, the manufacturing of smooth surfaces or the application of coatings on components with more complex geometries e.g. cylindrical or other non-flat shape parts shall be developed. The process has to be demonstrated on materials, which are relevant for the grey water container. The goal of this task is the development of an automated, cost efficient production process with high homogeneity, reproducibility and durability. By variation of process parameters, the performance and production costs shall be optimised.
Task 4: The test program that was defined in Task 1 shall be conducted in order to demonstrate feasibility and performance of the developed materials and processes.

Clean Sky

Task 5: This task comprises the specification and the design of the grey water container and finally the application of the developed biofilm prevention method. The task will be completed by providing grey water containers with enhanced biofilm prevention performance for the purpose of demonstration.

3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1	Material selection study	R	T0+6
D2	Report with manufacturing process description incl. process parameters, employed equipment and materials	R	T0+15
D3	Coated equipment samples	HW	T0+21

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	Specification of requirements completed	R	T0+3
M2	Material selection study completed	R	T0+6
M3	Review of selected materials and preliminary description of coating process	R	T0+11
M4	Design review of container concept/hardware	R	T0+13
M4	Test report with manufacturing process description submitted	R	T0+15
M6	Demonstrator parts provided	HW	T0+21

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
T1	Requirements, boundary conditions, testing metrics and test procedures			M1																		
T2	Selection of method(s) for prevention of biofilm growth and selection of material(s)						D1 M2															
T3	Development of coating/manufacturing process for plastic substrate materials											M3										
T4	Process verification tests and performance assessment of the developed coating(s)/material(s)															D2 M5						
T5	Development of grey water container hardware and application of method for biofilm prevention													M4								D3 M6

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

- Broad availablity of or access to potential technologies to prevent biofilm growth
- The applicant shall have profound knowledge in material science/ chemistry of materials
- Access to testing capabilities for performance evaluation of mechanical endurance, antimicrobial and repellent properties

5. Abbreviations

ETC coating	Easy to clean coating
GWR	Grey Water Reuse
GWRS	Grey Water Reuse System
PEI	Polyetherimide
PTFE	Polytetrafluoroethylene
RTCA Do160 Rev. G	Environmental Conditions and Test Procedures for Airborne Equipment Do-160

VIII. JTI-CS2-2019-CfP10-SYS-02-58: Automatic Haptic System Test Bench for Active Inceptors

Type of action (RIA/IA/CSA):		IA	
Programme Area:		SYS	
(CS2 JTP 2015) WP Ref.:		WP 3.2.5	
Indicative Funding Topic Value (in k€):		700	
Topic Leader:	Safran	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	12	**Indicative Start Date (at the earliest)[117]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-SYS-02-58	**Automatic Haptic System Test Bench for Active Inceptors**
Short description	
The new generation of active inceptor provides new functionalities and especially haptic behaviour to improve the flight experience and the crew coordination. It is therefore important to have means of test able to support these new and high level functionalities. The goal of the project is to design and manufacture a new generation of system test bench, fully automatized/robotized, able to receive and to control a shipset of generic active inceptors developed in the frame of ITD SYS. The test bench must simulate the haptic behaviour of the pilots' hands and needs to be adaptive to the various configurations and combinations compatible with generic inceptor : fixed wings, rotary wings, cyclic and collective functions, throttle type,...).	

Links to the Clean Sky 2 Programme High-level Objectives[118]				
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:			Regional Multimission TP, 70 pax	
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☐

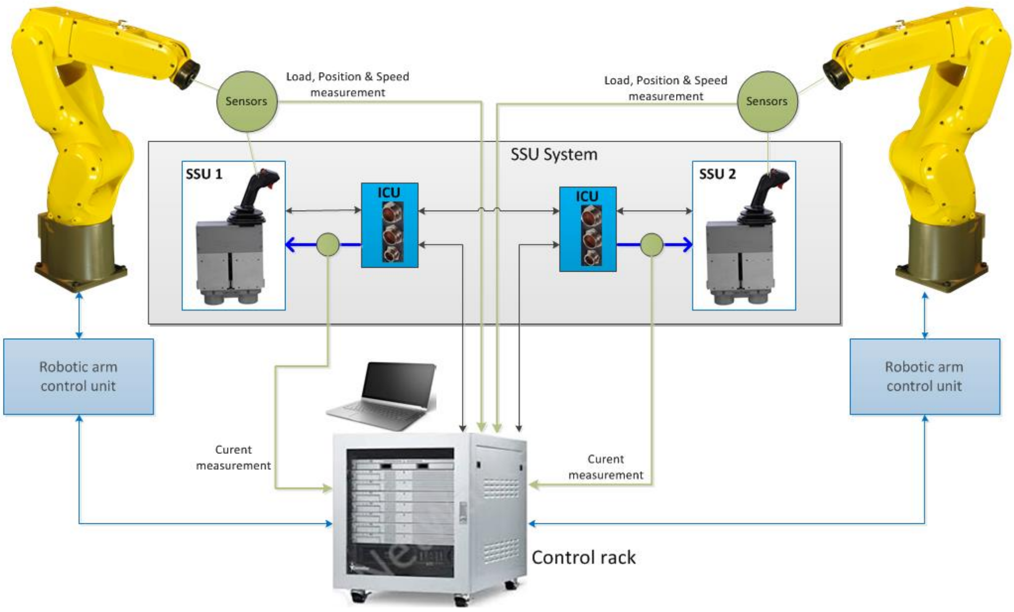
[117] The start date corresponds to actual start date with all legal documents in place.

[118] 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 is a part of the SYS WP 3 Innovative Electric Wing.
Flight Controls for new or innovative aircrafts (fixed wings, rotary wings, convertible, …) have a high level of complexity due to aircraft architecture. Active inceptor is a mean to improve flight information shared between pilots and FCCs, and by this way improve safety during flight.
With the progressive disappearance of mechanical links between aerodynamic control surfaces and piloting inceptor devices and the wide use of FBW (Fly By Wire), 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.
This new generation of inceptors is an opportunity to provide piloting crew more information thanks to a lot of functionalities, especially new kind of functionalities (e.g. : different profile laws, modification of profile laws in real time, coupling of both sticks, different handle designs and its associating functionalities, very high level of haptic feedback,…).

The objective of the topic is to develop an innovative haptic system test bench able to adapt to different Smart & Active Inceptor configurations (A/C, H/C cyclic and collective, throttle type,...) and able to verify and qualify such new functionalities. Basically the bench will simulate the behaviour of the pilot(s) hand(s) and measure and validate the haptic performance of the inceptor(s).
Due to the large scope of applications (fixed wings, rotary wings,…), this kind of bench must have a high level of versatility, both on mechanical side and electronical side. For example, it may be able to test a shipset of two generic active inceptors representative of a commercial A/C configuration and evaluate the haptic behaviour of each inceptor independently or combined in a coupling mode.



Innovative haptic system test bench synoptic

The interest of realizing a haptic and automated system bench is to guarantee the repeatability of the tests with a similar behavior to the human hand. Repeatability is assured regardless of the configuration of the equipment tested and whatever the operator.

Emphasis will be placed on the automation and usability of the test bench, with the aim of optimizing the test campaigns to cover a multitude of scenarios.

The system will allow to program an infinity of movements simulating the behavior of the hand to the nearest reality (A/C and H/C). Scenarios including simulation of conflicting pilot actions can be simulated.

As a central part of the system, the control rack manages:

- The robotic arm controller(s) to simulate the pilot hands behavior:
    - profile generations including normal flying mode, Auto-pilot mode (backdrive), coupling mode/interactions between pilots
    - multiple flight scenarios generation
- The acquisition of position and force sensors
    - To evaluate the inceptor answer to the robotic order
    - To measure and record the haptic behavior of the inceptor(s)
- A “FCC simulation box” to simulate the information and orders requested by the inceptor(s)

Climatic chambers will be available on the bench to allow high and low temperatures conditions for the tests.

2. Scope of work

Description of activities:

This topic encompasses following studies.

1.1. Functions to be studied

- Analysis:
    - Haptic request to be compliant with hands behavior profiles generation
    - Measurement accuracy for performances compliance
- Equipment selection / definition :
    - Robotic arm (6 axis) with control unit
    - Control rack components
    - Central data acquisition system
    - Robot tooling functionalities including specific sensors
    - FCC simulation box
- Design and manufacturing
- Integration and validation step by step
- Acceptance test

1.2. Implementation and means to perform

- Play multiple flight scenarios -> Automation of the movement (robotic)
- Real time acquisition (up to 10 kHz)
- Record
- Remote control and Visualization
- Reproductibility (configuration tests)
- Improvement of competitivity (optimized configuration set-up and tests duration)
- Adapt to different active inceptor configurations
- Climatic conditions simulation (-70°C to 100°C)

The test bench have to be smart and flexible to integrate users experiences by mean of hand user recording input.

Tasks		
Ref. No.	**Title - Description**	**Due Date**
T1	Preliminary Analysis	T0+2 months
T2	Preliminary design	T0+3 months
T3	Design	T0+5 months
T4	Manufacturing	T0+9 months
T5	Integration/Validation	T0+12 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 Analysis	Document	T0+2 months
D2	Preliminary design	Document	T0+3 months
D3	3D Models, drawings	Files	T0+5 months
D4	Integration/Validation	Report	T0+12 months
D5	User manual	Report	T0+12 months
D6	System test bench	Hardware	T0+12 months

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
PDR	Preliminary Design Review	Review + Documents	T0+3months
CDR	Critical Design Review	Review + Documents	T0+5months
FAT	Factory Acceptance Test	Review + Documents	T0+9months
OSAT	On Site Acceptance Test	Review + Documents	T0+12months

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

Knowledge on:

- Test bench Architecture
- Robotics
- Ergonomics
- Control loop
- Software
- Signal processing
- Power drive
- Mechanics
- Climatic

5. Abbreviations

A/C	Aircraft
AIU	Active Inceptor Unit
CDR	Critical Design Review
FAT	Factory Acceptance Test
FCC	Flight Control Computer
H/C	Helicopter
ICU	Inceptor Control Unit
OSAT	On Site Acceptance Test
PDR	Preliminary Design Review
SSU	Side Stick Unit

IX. JTI-CS2-2019-CfP10-SYS-02-59: Innovative DC/DC converter for HVDC power sources hybridization

Type of action (RIA/IA/CSA):		IA	
Programme Area:		SYS	
(CS2 JTP 2015) WP Ref.:		WP 6.4	
Indicative Funding Topic Value (in k€):		800	
Topic Leader:	Airbus	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	24	**Indicative Start Date (at the earliest)[119]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-SYS-02-59	**Innovative DC/DC converter for HVDC power sources hybridization**

Short description

HVDC power network is the future power network for the more electrical aircraft and is an enabler for sources hybridization as new functions. The More Electrical Aircraft HVDC network sources hybridization function requires a dedicated HVDC DC/DC converter to manage the appropriate interface between the HVDC power sources, the distribution network, and the HVDC power storage. This innovative converter shall be designed, simulated, developed and integrated into Airbus HVDC network demonstrator. The expected innovations are:

- converter control laws allowing parallelization of different HVDC sources at demonstrator level
- demonstration of high power density and high efficiency based on:
  - disruptive topologies and switching control
  - introduction of new components technologies
  - innovative filtering topologies with new solutions investigating active and passive designs compliant with HVDC power quality

Links to the Clean Sky 2 Programme High-level Objectives[120]				
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 Advanced Short/Medium-range Ultra-advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☐	☐	☐	☒	☒

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

[120] 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 Objective of the WP is to develop an innovative DC/DC converter and associated control laws, interfaced with HVDC battery and HVDC network up to TRL4 demonstration.
Upon Airbus high level specifications, the applicant shall specify, design, simulate, develop an equipment which will be further integrated into the Airbus More Electrical Aircraft HVDC Network demonstrator to demonstrate a TRL4 maturity level.
The innovation in this DC/DC converter lies in the implementation of specific control laws allowing the parallelization of multiple HVDC sources.
DC/DC converter will comply with Airbus defined HVDC requirements/characteristics.
Design and prototype of the DC/DC converter will demonstrate high power density (25kW/kg – disruptive integration technologies) and high Efficiency (99% - wide band gap technology).
DC/DC converter will be Reversible, 100kW ouput DC power, air cooled, with a 100 000 flight hours reliability target and will be used for solutions Ground demonstration.

Work Package (WBS)

WP1 (AIRBUS) included in WP5.0, outside of this call:
- Converter specification / requirements
- Design reviews
- Converter performance evaluation

WP2 (Applicant, subject to this call):
WP management
- Project management
- Design reviews
- WP follow up

Converter Design
- Topologies and internal architecture trade off
- Passive and active component Technologies trade off
- Filtering and Thermal solutions trade off
- Lifetime, reliability and reccurrent cost assessment,

Converter manufacturing and integration
- Function integration (cooling, Filtering, power core)
- Electrical and Mechanical interface

Controls and monitoring definition
- Voltage and current control and monitoring
- Power management laws
- Behavioural Matlab/ Simulink Model

Demonstrator
- TRL4 converter prototype delivery to Airbus for ground test bench integration
- Performance demonstration and tests Results
- Support to Airbus integration and ground tests

WP3 PROVEN Demonstration (Airbus included in ITD SYS WP6.4, outside of this call):
- Converter integration, performance demonstration and tests results on PROVEN Test bench

2. Scope of work

Work Package	Title	Description	Due date
T1	Topologies and internal architecture trade off	T0+6	Applicant
T2	Passive and active component Technologies trade off	T0+6	Applicant
T3	Filtering and Thermal solutions trade off	T0+6	Applicant
T4	Lifetime, reliability and reccurrent cost assessment,	T0+12	Applicant
T6	Function integration (cooling, Filtering, power core)	T0+12	Applicant
T7	Electrical and Mechanical interface design and manufacturing	T0+12	Applicant
T8	Voltage and current control and monitoring design	T0+12	Applicant
T9	Power management laws design and integration	T0+12	Applicant
T10	Matlab/ Simulink Models elaboration	T0+14	Applicant
T11	TRL4 converter prototype delivery	T0+18	Applicant
T12	Ground tests for function and Performance demonstrationin applicant facilities before prototype delivery	T0+18	Applicant
T13	Integration and ground tests support for converter integration on Airbus Proven test bench	T0+24	Applicant

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

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D	***Converter specification***	***R***	T0
D1	Topologies and internal architecture trade off outcomes	R	T0+6
D2	Passive and active component Technologies trade off outcomes	R	T0+6
D3	Filtering and Thermal solutions trade off outcomes	R	T0+6
D4	Selection of the DC/DC converter embeded Passive and active component Technologies	R,D	T0+6
D5	Selection of the DC/DC converter Topology and architecture	R,D	T0+6
D6	Selection of the DC/DC converter Filtering and Thermal solutions	R,D	T0+6
D7	Voltage and current control and monitoring function principles and performance description	R	T0+12
D8	Power management function principles and performance description	R	T0+12
D9	Initial Matlab/ Simulink Model delivery	R,D	T0+8
D10	Electrical and Mechanical interface definition	R,D	T0+12
D11	Lifetime, reliability and reccurrent cost assessment outcomes	R	T0+12
D12	Final Matlab/ Simulink Model delivery	R,D	T0+14
D13	Voltage and current control and monitoring performance results	R,D	T0+18
D14	Power management function performance results	R,D	T0+18
D15	Function integration (cooling, Filtering, power core) Results	R,D	T0+18
D16	Ground functional and Performance test demonstration Results	R,D	T0+18
D17	Prototype delivery	HW	T0+18
D	Proven Integration DC/DC converter performances tests results	R	T0+24

Milestones (when appropriate)			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	Kick OFF meeting	review	T0
M2	Preliminary Design and acceptance Review	review	T0+6
M3	Critical Design Review	review	T0+12
M4	Prototype Unit Acceptance Review	review	T0+18

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

- Electronic and Power electronic innovative design competence.
- Aeronautical standard friendly (DO160, ABD 0100, development processes),
- Knowledge in high direct current voltages
- Integrated design team abilities to provide complete answer to performance, cooling and EMI management of the DC/DC converter.

5. Abbreviations

EMI	Electro Magnetic Interferences
DC/DC	Direct current to Direct Current convertion
HVDC	High Voltage Direct Current
TRL	Technology readiness level

X. JTI-CS2-2019-CfP10-SYS-02-60: Toward a Digital Twin ECS and thermal management architecture models : Improvement of MODELICA libraries and usage of Deep Learning technics

Type of action (RIA/IA/CSA):		IA	
Programme Area:		SYS	
(CS2 JTP 2015) WP Ref.:		WP 6.1	
Indicative Funding Topic Value (in k€):		600	
Topic Leader:	Liebherr	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	36	**Indicative Start Date (at the earliest)**[121]**:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-SYS-02-60	**Toward a Digital Twin ECS and thermal management architecture models : Improvement of MODELICA libraries and usage of Deep Learning technics**
Short description	
Following results from the MALET CfP, it underlines the major challenges of modelling Environmental Control System (ECS) and thermal management architectures. A first topic is related to modelling the ECS for covering the full usage envelop, including starting and on/off phases that constitute themselves a real challenge. More specifically, the heat exchanger performances modelling in presence of moist air and refrigerant is one of the major issue for ECS modelling. A second topic is related to the capability to accurately compute electrical losses for system application without compromising the overall computational cost. From detailed developed models in the project, the usage of data analytics technologies should enable to achieve the digital twin with expected accuracy and computational costs.	

Links to the Clean Sky 2 Programme High-level Objectives[122]				
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 Short/Medium-range		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☐

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

[122] 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 frame of Clean Sky 2 - Systems ITD (WP6.1), several technological bricks are developed to address the ambition of more electrical aircraft by considering mainly the need for a future electrical Environmental Control System (eECS), which allows significant benefits compared to conventional pneumatic solutions:

- Fuel consumption reduction through more efficient use of A/C energies
- Improvement of A/C availability by increasing systems reconfiguration capabilities

In this approach, the studied architecture integrates a supplemental cooling system; called Vapor Cooling System (VCS). The VCS is an efficient technology to extract heat from heating system based on the fluid phase changing phenomena. The main components contributing to the system efficiency are the heat exchanger (evaporator & condenser) where this phase changing phenomena mainly occurs (cf. Figure 1).

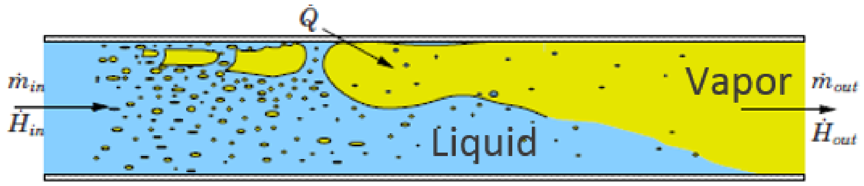


Figure 1 - Phase changing phenomena

The system simulation domain offers capabilities to masterize the product behaviour and functions during the whole development cycle. System modelling challenges relies on the capability to represent accuractly complex phenomena using fast analytical models based on accurate data. This kind of model represents a system that will be integrated within its environement as an Aircraft model for instance.To achieve integrated simulation (system + environment), models are required to be numerically efficient in term of robusteness, calculation time and accuracy.

This project shall address this challenge by combining classical simulation approaches with data analytics technics. The project will produce advanced modelling capabilities for Vapour Cooling system with a special attention on phase-changing heat exchangers and electrical heat losses.

2. **Scope of work**

Work Package	Title	Due date
1	**System Thermo-fluid modelling**	
1.1	VCS - Heat Exchanger Modelling	T0+18
1.2	VCS – System Modelling	T0+24
1.3	VCS – HX & System Surrogate Modelling	T0+30
2	**System Electrical modelling**	
2.1	Electrical - Detailed Losses Modelling	T0+12
2.2	Electrical - Losses Surrogate Modelling	T0+24
3	**System Thermal-Electrical modelling**	
3.1	Simulation of integrated electrical and thermofluid models	T0+36

Task 1.1 – VCS – Heat Exchanger Modelling

Basic modelling of VCS heat exchanger is well described in the litterature. The challenge addressed in this project is to derive a robust, efficient and accurate model of such heat exchanger taking into account the whole operational envelop and transients features.

The model shall cover several operating modes :

- Switch-off mode / by-pass mode : the heat exchanger, or at least one side of the heat exchanger has a null mass flow rate that reduces the heat exchange,
- Reverse flow : In transient operations, the flow direction could be reversed, for each pass independently from the other,
- Hot / Cold side inversion: the heat exchange that occurs usually in one direction could be inversed to cover transient or failure cases.

The developed model shall be physically accurate for the normal modes. For other modes, a physical qualitative behavior could be accepted to obtain a robust and efficient numerical model.

The physical phenomenon involved in the required HX models are listed below :

a) Multi-phase heat exchange

The main difficulty of modelling the behavior of a refrigerant heat exchanger lies in the phase changing fluid during the heat exchange process. This implies significant modifications of the fluids properties and then of the capability to efficiently exchange heat. The three phases could be observed in the same heat exchanger for common operating points. But other configurations are also encountered (cf. Figure 2).

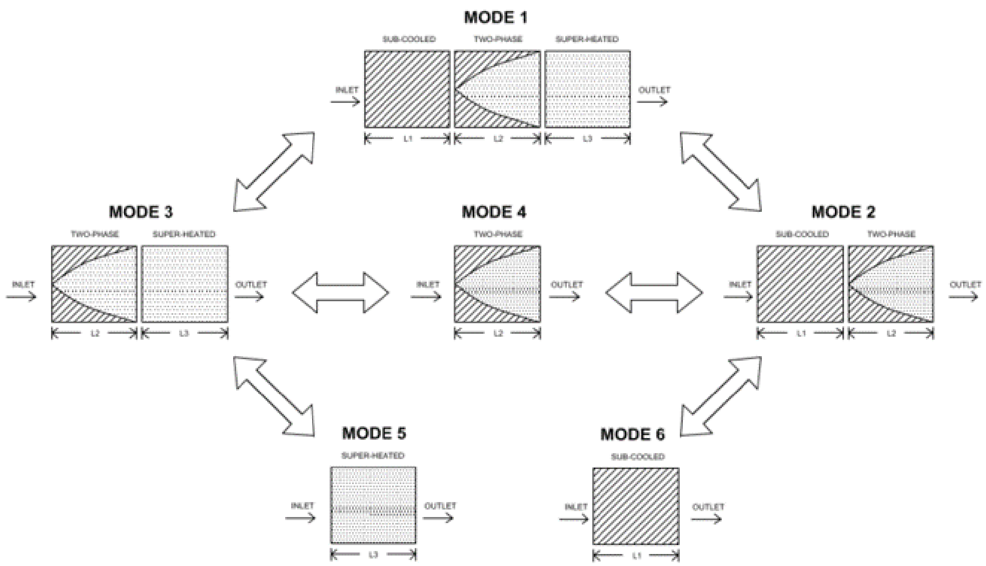


Figure 2 - Phases transitions

The heat exchanger configuration (number of refrigerant phases) and the phase proportions (percentage of the whole heat exchanger volume for each phase) are determined by the current operating point. This difficulty increases as the operating point for a vapor cooling unit is determined by the equilibrium of the whole closed-loop system.

a) Moist air effects

The usage of moist-air in an heat exchanger could improve its efficiency by evaporation or condensation of water. The heat exchanger model shall be representative of such situation where using moist air in specific conditions will lead to improve/modify the heat exchange.

b) Physical heat exchange

The usage of models shall compute physically behavior where the heat exchange always occurs from higher temperature to lower one. This property shall be verified for all situations (normal and other simulation modes).

c) Thermal inertia

The refrigerant heat exchanger possesses a thermal inertia that modulates the thermal response time. The model shall be representative of such thermal inertia.

Task 1.2 – VCS – System Modelling

The topic manager will provide Dymola/Modelica libraries (cf. **Error! Reference source not found.**) that covers modelling of other components excepts the heat exchanger to enable the partners validating the new heat exchanger model.

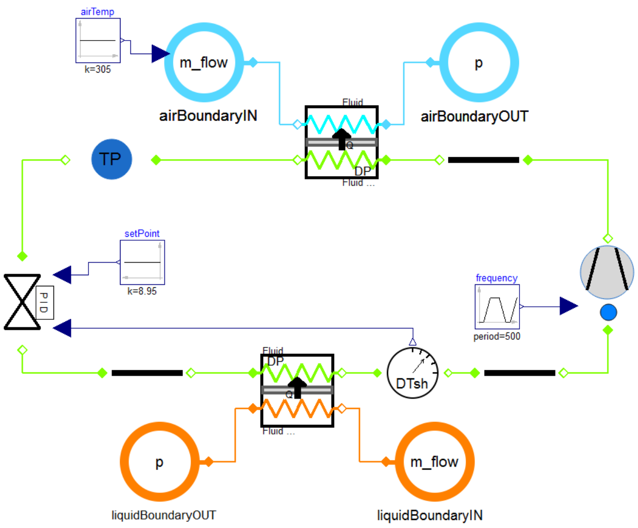


Figure 3- Simple VCS Model

The partners shall use the topic manager libraries to build the VCS models. The integration of the new heat exchanger model shall be demonstrated in term of accuracy, robusteness and computational time. The test scenarii will be provided by the topic manager covering the whole system operating envelop and modes (on/off, start-up,…).

Task 1.3 – VCS – HX & System Surrogate Modelling

Starting from the previously developed models, the objective of this task is to derive both “static”(time independent) and “transient” (time dependant) surrogate models for :

- Reducing the computational cost for similar accuracy,
- Enhancing model accuracy versus real product

To fulfill these expectation, the surrogate modelling method shall be able to reduce both equipement & system physical model and shall be improved by using test bench results. This approach will enable the topic manager to generate a digital twin of the physical system. Data analytics technics should be used like deep learning methods (recursive neural network for transient surrogate models) to address

training from simulation results and improvement with test results.
The transient surrogate model shall be at least fixed step. Capability to derive variable step transient model should be envisaged.
The generated surrogate models shall be integrated wihtin Dymola/Modelica and shall be independent from a specific environment or framework.

Task 2.1 – Electrical - Detailed Losses Modelling

Using basis of topic manager libraries, the partners shall derive models representative of actual electrical component from standard datasheets inclding an accurate evaluation of heat losses. The models shall cover several levels of details (switching and non switching models) and adequate heat losses models. The list of electrical components to be developed will be agreed with the topic manager but contains at least an electrical motor, power inverter, ATRU, IGBT and MOFSET.
Then, the main objective of this task is to build an actual component database from datasheets enabling engineers to use such components easily when modelling electrical models. The database shall be validated versus reference tools (plex) or test results (if available).

Task 2.2 – Electrical - Losses Surrogate Modelling

Similarly to the task 1.3, the objective of this task is to derive both “static” and “transient” surrogate models for reducing the computational cost for similar accuracy level. The objective is to obfuscate the electrical characteristic time constant that is not compatible with whole system simulation but keeping the main system effects related to thermal losses or to specific electrical power transients (electrical power peak when starting an electrical motor,…). The electrical components database shall be then exported to surrogate models.
The transient surrogate model shall be at least fixed step. Capability to derive variable step transient model should be envisaged.
The generated surrogate models shall be integrated wihtin Dymola/Modelica and shall be independent from a specific environment or framework.

Task 3.1 – Simulation of integrated electrical and thermofluid models

This task consist in demonstrating that all developed models (detailled and surrogate) could be combined to simulate the complete electro-thermo-fluid VCS system in an efficient and accurate way. The topic manager will provide validation data.
This task will demonstrate the capability to generate digital twin models for the topic manager.

Important Remark : all the MODELICA libraries and models developed during the project shall be compatible with Dymola/MODELICA technology and delivered as license free source MODELICA code to the topic manager.

3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D1.1	VCS Heat Exchanger Library Report	R	T0+18
D1.2	VCS System Library Report	R	T0+24
D1.3	VCS Surrogate Modelling Method and Library Report	R	T0+30
D2.1	Electrical Libray Report	R	T0+12
D2.2	Electrical Library Database	D	T0+18

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
D2.3	Electrical Surrogate Modelling method and library Report	R	T0+24
D3.1	Integrated System Modelling & Simulation Validation Report	R	T0+36

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

Skills

- Thermo-fluid System modelling
  - Theoritical and Numerical background regarding phase changing physical phenomenon, evaporator and condenser heat exchangers
  - Theoritical and Numerical Vapour Cooling System modelling background for choosing adapted modelling technics,
  - Dymola/MODELICA background to produce expected models using this language,
- Electrical System modelling
  - Theoretical and Numerical background egarding power electronics modelling in an efficient way,
  - Dymola/MODELICA background to produce expected models using this language,
- Surrogate modelling
  - Data analytics backgroud to derive deep learning models,
  - Software Development background to provide autonomous deep learning models for their integration within Dymola/MODELICA

Capabilities

- Data analytics framework / environment,
- Dymola/MODELICA tool

5. Abbreviations

ECS	Environmental Control System
HX	Heat Exchanger
VCS	Vapour Compression System

XI. JTI-CS2-2019-CfP10-SYS-02-61: Vapor Cycle System - Heat Exchanger performance 3D modeling with different new low GWP refrigerants

Type of action (RIA/IA/CSA):		RIA	
Programme Area:		SYS	
(CS2 JTP 2015) WP Ref.:		WP 6.1	
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)[123]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-SYS-02-61	**Vapor Cycle System - Heat Exchanger performance 3D modeling with different new low GWP refrigerants**
Short description	
The objective of this topic is to gain knowledge on physics involved inside two-phase heat exchangers and more explicitly in evaporators, and in particular to understand the impact on performance and pressure drop of the following parameters: gravity field, titer quantity and spacial distribution, mass flow rate of refrigerant, HX structure. Hence a multi-scale modeling approach is awaited in order to focus on various physical phenomenon induced in the heat exchanger. This numerical approach shall be validated by experimental developments led under a design of experiments.	

Links to the Clean Sky 2 Programme High-level Objectives[124]				
This topic is located in the demonstration area:		Boundary Layer Ingestion		
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 Ultra-advanced Short/Medium-range		
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☐

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

[124] 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

Project global context

Hydrofluorocarbons (HFCs) are greenhouse gases commonly used in a wide variety of applications, including refrigeration, air-conditioning, building insulation, fire extinguishing systems... But HFCs have a high global warming potential (GWP), raising concern about their environmental impacts. To control HFCs emissions, the European Union has adopted in 2014 the new 'F-gas Regulation' with the ambitious target to cut by two-thirds the emissions by 2030 (compared with 2014 levels); offering opportunities of driving innovation in the refrigeration and air conditioning sector.
Air conditioning systems for aeronautical application are not covered yet by the ban of HFCs. But considering some potential market impacts due to the ban in other sector (fluids price increase, supply issues,…) and the increasing societal demand supported by very ambitious environmental objectives defined by the Advisory Council for Aeronautics Research in Europe (as part of Flightpath 2050 strategic agenda) the Topic Manager initiated research activities to prepare the substitution of HFCs in air conditioning systems for aeronautical application. Those research activities might lead to the study of several substitution routes towards low-carbon technologies; such as the use of Hydrofluoro-Olefin (HFO), HFO mix or even CO2. And to support the investigation of those different substitution options, it is essential to improve the modeling capabilities to better assess the performances of the air conditioning systems at the design phase.

Project technical context

Air conditioning systems architectures for aeronautics sometimes rely on vapour cycle systems to meet the required performance under severe thermal environment. These cycles are very efficient but also complex to optimize while considering integration issues inside the aircraft ; mass, volumes, orientation and accelerations. Among the several bricks of technology implied in a VCS (compressor, valves…) the Topic Manager suggests to work on heat exchangers. The conventional technology stands on plate-fins heat exchangers (CHX) functioning with refrigerants such as R134A. But next generation heat exchangers will benefit from new HFO fluids, HFO mix, even CO_2. Design can also be oriented on mini-channels, micro-channels (MCHX) and very new shapes obtained by additive layer manufacturing.
(NB: Issues dealing with oil are not to be adressed by the project but oil quantity inserted inside the system during tests shall be managed and measured as accurately as possible.

The Topic is clearly focused on evaporators manufactured for such VCS on which performance issues need to be identified very early during the design process. The work needs to address both the exchanger core and the headers; we know that refrigerant flow mal-distribution is a key challenge in improving heat exchanger performance. Two-phase physics inside headers is hardly addressed with conventional tools and each aircraft needs a specific design which cannot be designed by 3D two-phase fluidic and thermal calculation. Even heat exchangers suppliers do not take the risk to developp pre-design tools because the whole performance of the cycle is integration dependant.
That is why the Topic Manager needs validation materials for its internal calculation workflow described hereafter.

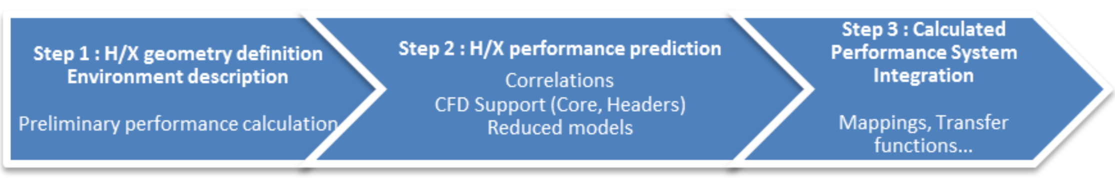
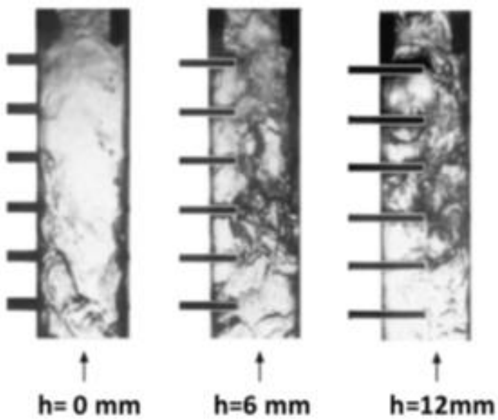


Figure 1 – Calculation workflow for H/X design

Litterature is mainly focused on automative tubular headers as illustrated below, where headers are mainly cylindrical with longitudinal two-phase flows. The mal-distribution of fluid can then be corrected using insertions of various lengths. For more cubic shapes headers, as mainly used in aeronautics, the two-phase flow is closer to a spray expanding from a small tube inside a large space in two dimensions.



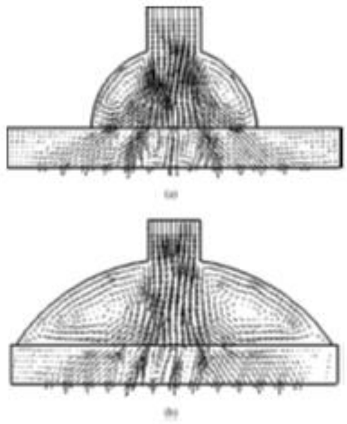


Figure 2 – Header distribution and optimization in various headers technology (Source [2], [4])

The Topic shall mainly focus on Step 2 where the dedicated chain lies on reduced models based on return of experiment of detailed CFD calculations. The main goal is to consolidate the detailed CFD step delivering accurate conclusions for the calibration of reduced models.

The second phase of the topic is dedicated to experimental validation of the models. Amongst other, the infrared imaging method is suggested by litterature [5] to study the effects of flow distribution. Such methodology or others shall be developped in a test rig dedicated to the present Topic heat exchangers.

<u>References</u>

[1] A Simulation Study on Two-Phase Microchannel Evaporator Header Distribution Using Computational Fluid Dynamics Header Model and Segmented Heat Transfer Tube Model, Long HUANG, Motohiko FUKUOKA, Toshimitsu KAMADA, Noriyuki OKUDA, 2018 Purdue Conference

[2] Review on two-phase flow distribution in parallel channels with macro and micro hydraulic diameters: Main results, analyses, trends, Applied Thermal Engineering 59 (2013) 316e335

[3] CFD simulation for flow distribution in manifolds of central-type compact parallel flow heat exchangers, Jian Zhou, Zhongning Sun, Ming Ding, Haozhi Bian, Nan Zhang, Zhaoming Meng, Applied Thermal Engineering 126 (2017) 670–677

[4] CFD simulation on inlet configuration of plate-fin heat exchangers, Zhe Zhang, YanZhong Li, Cryogenics 43 (2003) 673–678

[5] Developing Adiabatic Two Phase Flow in Headers—Distribution Issue in Parallel Flow Microchannel Heat exchangers, Hrnjak, P.S. 2004, Heat Transfer Eng, 25, 61-68

2. <u>Scope of work</u>

Tasks		
Ref. No.	**Description**	**Due Date**
1	Bibliography of the recent (academic and industrial) research on VCS evaporators	T0+12
2	Implementation of CFD strategy for two-phase headers and exchanger core	T0+12
3	Set up of the optimization chain	T0+18
4	Development of the test bench and methodology to validate CFD calculations (Measurement and observation)	T0+30
5	Validation of the calculation methodology based on a conventional geometry and an optimized design	T0+36

<u>Task 1 : Bibliography of the recent (academic and industrial) research on VCS evaporators</u>
Bibliography should focus on recent developments on VCS heat exchangers technologies. Both core and headers need to be addressed to identify clearly driving parameters of a good design and also innovative tricks and technologies in this field. The study should point these elements in the framework of fluids of interest listed above and for both conventional H/X manufacturing methods and next generation H/X (AM, micro-channels…).
This bibliography should also highlight methodologies adapted to such a development in order to update the Topic Manager calculation workflow with new elements.
Finally, this step shall deliver scientific basement for Milestones 1 (M1): Delivering the literature background for CFD two-phase calculation under specified conditions of mass flow, titer and accelerations;

<u>Task 2: Implementation of CFD strategy for two-phase headers and exchanger core</u>
The best modelling method using well adapted tools shall be implemented in this phase to fit to H/X conditioning and specificites. This methodology shall be developped for calculations on two significantly different fluids, one adapted to high temperature and the other adapted to low temperature.
Secondly, one of these fluid shall be selected to perform calculations and comparisons on an H/X of higher power capacity (# 40 kW).
Finally, the methodology shall also be developed to an approach on CO2.

Calculation cases	Specificity
1.1	Low temperature HFO (LT HFO) – 10 kW
1.2	High temperature HFO (HT HFO) – 10 kW
2.1	1.1 or 1.2 reference
2.2	1.1 or 1.2 fluid – 40 kW
3.1	CO_2

Calculation cases 1.1 and 1.2 will be used for validation situations under experimental tests in task 4.

<u>Task 3: Set up of the optimization chain</u>
This stage of the project needs to set up an optimization strategy to deliver the best way of building the best header under a certain amount of environmental constraints. This task needs to be managed using a Design of Experiment to achieve the following goals:

- Establish a response mapping for common header geometries in the field of aeronautics applications under functioning for a signle HFO;
- Define the best original design for a header geometry meeting the requirement described by a specification for an application on the same fluid.

Task 4: Development of the test bench and methodology to validate CFD calculations (Measurement and observation)

The test rig is obviously focused on the evaporator but should also include the rest of the VCS loop (compressor, ai ventilation, valves…) in order to reproduce specific boundary conditions of the eexchanger. This facility shall be centered on the following range for air performance :

- [-10°C; 60°C] temperature range;
- [0.010 kg/s; 0.500 kg/s] mass flow range;
- [0 ; 10 kW] cold power range.

The evaporator maximum volume is limited into 250 x 400 x 400 mm3 (volume for 10 kW)

Adaptations on an existing test bench shall be run if necessary to fit to specific H/X delivered by the topic manager.

Complementary to this adaptation task focused on the Candidate facilities, the project should propose experimental methods susceptible to be exported to the Topic Manager facilities for further headers and core characterizations. These methods shall as much as possible rely on conventional metrology such as pressure and temperature sensors, IR thermography… This shall be described in details inside deliverable L3.

Task 5: Experimental validation of the calculation methodology based on a conventional geometry and an optimized design

The awaited test rig shall be used to observe and validate calculation assumptions mainly in terms of flow patterns and phase distribution on :

- A conventional design header stressing attention on mal-distribution issues:
  - Validation configuration on LT HFO;
  - Validation configuration on HT HFO;

- An innovative design manufactured for the project that should improve distribution issues and validate the CFD approach.
  - Validation configuration on one single fluid.

In both cases, heat exchangers and headers shall be delivered by the Topic Manager to the party in charge of tests. The Topic Manager foresees to perform tests on two conventionnal "heat exchangers + headers" subassemblies and one "innovative header + conventionnal heat exchanger" subassembly.

3. Major Deliverables/ Milestones and schedule (estimate)

*Types: R=Report, D-Data, HW=Hardware

Deliverables			
Ref. No.	**Description**	**Type***	**Due Date**
D1	Bibliography of the recent (academic and industrial) research on VCS evaporators	R	T0+12
D2	Methodology and optimization chain for headers and core calculation	R	T0+18
D3	Portable measurement methodology to the Topic Manager	R	T0+24
D4	Final report describing ▪ Experimental results ▪ Calculation validation based on experimental results	R	T0+36

Milestones (when appropriate)			
Ref. No.	***Description***	***Type****	***Due Date***
M1	Pre-validation of CFD methodology based on literature background	R	T0+12
M2	Optimized design of an innovative "header+H/X" subassembly	R & D	T0+18
M3	Exportable experimental methodology freezing for Topic Manager	R	T0+24
M4	Final model validation based on experimental results	R	T0+36

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

Skills

- Thermodynamics applied to H/X
- H/X design
- CFD computations
- Experimental skills

Capabilities

- Computing facilities in order to be able to run two-phase flow thermofluidic calculation
- Testing facilities compatible with cores and headers subassemblies 388haracterization with air (temperature range: -10°C/+60°C , air flow range: 0.01kg/s; 0.5kg/s, refrigerant flow range up to 80 g/s) and corresponding refrigerant pressure and temperature levels. Corresponding maximum cold power is approximately 10 kW.

5. Abbreviations

AM	Additive Manufacturing	**HFO**	Hydrofluoro-Olefin
CFD	Computational Fluid Dynamics	**HT HFO**	High Temperature HFO
CHX	Compact Heat Exchangers	**H/X**	Heat Exchanger
DOE	Design of Experiment	**LT HFO**	Low Temperature HFO
ECS	Environmental Control System	**MCHX**	Mini or Micro Channel Heat Exchangers
GWP	Global Warming Potential	**VCS**	Vapor Cycle System
HFC	HydroFluoroCarbons		

XII. JTI-CS2-2019-CfP10-SYS-03-23: Electro-Mechanical Landing Gear system integration for Small Aircraft

Type of action (RIA/IA/CSA):		IA	
Programme Area:		SYS [SAT]	
(CS2 JTP 2015) WP Ref.:		WP 7.2	
Indicative Funding Topic Value (in k€):		600	
Topic Leader:	Piaggio Aero	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	36	**Indicative Start Date (at the earliest)[125]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-SYS-03-23	**Electro-Mechanical Landing Gear system integration for Small Aircraft**
Short description	
This topic aims at integration of electro-mechanical landing gear and brake system (which are being developed as part of other research projects for small aircraft) in an “aircraft zero” (iron-bird) integration and test environment, enabling its advancement from TRL3 / TRL4 to above TRL5.	

Links to the Clean Sky 2 Programme High-level Objectives[126]				
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:	19-pax Commuter			
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☐	☐	☒	☐

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

[126] 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 at enabling and facilitating introduction of more electric aircraft technology in the small aircraft sector with a view to reduce costs, complexity and risks of system integration and aircraft development flight testing, specifically for landing gear and wheel brake systems currently in development under other research projects.

There are a number of potential benefits in replacing legacy hydraulic-powered systems with more electrical ones:

- The combination of brake-by-wire control technology and electro-mechanical brake/LG actuation is expected to facilitate the implementation of advanced braking logics (possibly including antiskid function) also for small aircraft platforms.
- Electric braking/actuation is also expected to increase reliability, allow for health monitoring and reduce scheduled and unscheduled maintenance costs, also by including diagnostic/health data processing capability into maintenance tools (compatibility with “big data” philosophy).
- The replacement of hydraulic systems may bring weight savings and bring energy efficiency gains.
- The removal of hydraulic fluids eliminates the risk of leaks and the associated fire and safety concerns.
- As for safety requirements, typically satisfied through redundant architectures and fail-safe design criteria, electric actuation and health-monitoring / prognostic functions may bring simplification without reducing the level of safety.

For small aircraft platforms, there is a significant difficulty in advancing more electric LG/brake systems to TRL5 and TRL6, first because classic laboratory /iron-bird environments are often not enough realistic and comprehensive for LG/brake systems which introduce significant new technology, second because testing on aircraft, although perceived as more realistic and cost-effective with respect to the first, involves safety risk if new technology is not sufficiently proven.

2. Scope of work

The project aims at developing an “aircraft zero” (iron-bird) environment specifically conceived for integration and testing of novel technology electro-mechanical brake/LG actuation (developed as part of other research projects) on a Landing Gear system.
The effort involves use of modular design and cost-effective testing technology to reproduce representative landing gear characteristics, dynamic runway conditions and external loads/ enviromnment and to provide power supply and inputs to the system under test. The aim is to test and characterize the integrated system in a wide variety of conditions and be able to test full-scale runway/tire/brake/ gear/structure interactions so to verify stability/performance (while brake control software optimization will be conducted within the frame of other research projects).
The effort is expected to include:

- adaptation and interfacing of Landing Gear system prototype hardware –or building suitable representative dummy hardware– so to permit best integration of electro-mechanical brake/LG actuation equipments (developed as part of other research projects and made available),
- modular design of test facilities, interfaces and loading system to ease subsystem integration and troubleshooting, possibly including automated test / data processing tools, which may be the basis for advanced system diagnostic and maintenance tools,
- validation test campaign (laboratory tests) in a number of conditions representative of actual aircraft environment including failure cases, endurance and reliability testing, input data

generation and output data collection and post-processing.

Specific attention is required to the innovation aspect, which is aimed at guaranteeing the highest degree of versatility and cost-effectiveness of the proposed infrastructure.

The project may be organized along the following tasks:

Tasks		
Ref. No.	***Title - Description***	***Due Date***
T01	*Detailed technical requirements for the landing gear /brake /actuation system integration & test facility* The partner will concur with the Topic Manger in the definition of the integration requirements (i.e. characteristics of system components under test, performances, mass, envelope, reliability maintenance, Input/Outputs, testing capabilities and safety aspects) and propose/agree a test scope/plan.	T0 to T0+2
T02	*Preliminary design of the landing gear /brake /actuation system integration & test infrastructure* The partner will provide preliminary studies supported by sketches and analyses in order to evaluate possible alternative designs, suitable for maximizing test scope/capabilities within the agreed constrains. Technical requirments will be frozen at the end of this phase.	T0+3 to T0+6
T03	*Final design of the landing gear /brake /actuation system integration & test infrastructure* The partner will finalize the design of the test facility and all necessary equipment and will define integration/test plan to ensure the brake & actuation system can be integrated within landing gear system and interfaced appropriately for validation/verification purposes.	T0+7 to T0+12
T04	*Rig(s) manufacturing and system interfacing* The partner will ensure the construction, validation and preliminary testing of the test rig(s), identify and perform interfacing and adaptations to the system under test suitable for testing scope and define test protocols maximizing collected data and usefulness for validation purposes.	T0+12 to T0+20
T05	*Actuation systems integration testing in full LG* The partner shall test and verify demonstrator actuation system integration within the entire landing gear in aircraft-representative environment and provide test outputs suitable to validate integration, performance and diagnostic/maintainability aspects.	T0+21 to T0+24
T06	*Brake systems integration testing in full LG* The partner shall test and verify demonstrator brake system integration within the entire landing gear in aircraft-representative environment (including runway simulation) and provide test outputs suitable to performance validation and optimization. This should include enough iterations for validation and verification of antiskid functions and diagnostic/maintainability aspects	T0+25 to T0+36
T07	*Reliability and maintainability testing* The partner shall perform system reliability tests including failure cases, in accordance with the technical specifications, for verification of diagnostic, safety, reliability and health monitoring characteristics, and possible validation of maintenance concepts.	T0+25 to 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	Detailed technical requirements	R	T0+2
D2	Design of landing gear /brake /actuation system integration & test facility	R	T0+12
D3	Actuation system test final report	R	T0+24
D4	Brake system test final report	R	T0+36
D5	Endurance and reliability testing final report	R	T0+36

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
M1	PDR	RM	T0+6
M2	CDR	RM	T0+12
M3	Validation of rig manufacturing and interfacing	D	T0+20
M4	Actuation system test report approval/validation	R	T0+25
M5	Final test report approval/validation	R	T0+36

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

- Previous experience in design and development of advanced test facilities in the field of aeronautical landing gear system technologies, preferably direct experience in design, development / integration testing and qualification of such products;
- Proven experience in international R&T collaborative projects with industrial partners, institutions, technology centers, universities;
- Quality and risk management capabilities demonstrated through applications on international R&T projects and/or industrial environment;
- Proven experience in the management of testing and in typical tools / methodologies of data acquisition / post-processing for aeronautical industry;
- Knowledge on electrical and mechanical component and system integration;
- Preferably, proficiency in data processing tools/techniques and experience in use of data for diagnostic and prognostic purposes;
- Preferably, experience with landing gear testing and dynamic braking test rig capable to deal with high temperature.

5. Abbreviations

LG	Landing Gear
PDR	Preliminary Design Review
CDR	Critical Design Review
R&T	Research & Testing
TRL	Technology Readiness Level

XIII. JTI-CS2-2019-CfP10-SYS-03-24: Power Semiconductor Device module using Silicon Carbide devices for a relatively high-frequency, 100kW aircraft motor drive applications

Type of action (RIA/IA/CSA):		IA	
Programme Area:		SYS	
(CS2 JTP 2015) WP Ref.:		WP 100.1	
Indicative Funding Topic Value (in k€):		620	
Topic Leader:	University of Nottingham	**Type of Agreement:**	Implementation Agreement
Duration of the action (in Months):	18	**Indicative Start Date (at the earliest)[127]:**	> Q1 2020

Topic Identification Code	**Title**
JTI-CS2-2019-CfP10-SYS-03-24	**Power Semiconductor Device module using Silicon Carbide devices for a relatively high-frequency, 100kW aircraft motor drive applications**
Short description	
This CfP will result in a programme of work for the development of a SiC power electronic device module for a 100kW multi-level power converter. The design will enable the minimization of the power converter's weight and volume as well as enabling the functionality, requiring innovation and technology adoption for manufacturability.	

Links to the Clean Sky 2 Programme High-level Objectives[128]				
This topic is located in the demonstration area:	Boundary Layer Ingestion			
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 Ultra-advanced Short/Medium-range			
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☐	☐	☐	☒	☐

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

[128] 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 CfP project will develop and supply a Power Semiconductor Device module using Silicon Carbide devices for a relatively high-frequency, 100kW aircraft motor drive application. The multi-level power converter topology is known and theis the result of an optimised design and trade-off process already completed within Clean Sky 2. The benefits of Silicon Carbide devices in this application are well understood and have already been fully quantified. This CfP is about the design and construction of a manufacturable and reliable power converter module to enable this technology to meet its full potential in terms of competitiveness against current solutions.

The power converter topology itself has been chosen following a design and optimisation process based on commonly available descrete power semiconductor devices. The objective of this work is therefore the packaging of suitable Silicon Carbide (SiC) power semiconductor devices to allow the full potential of this technology to be demonstrated in an aerospace application using an existing Clean Sky motor drive test bed.

The output of this work will therefore enable this demonstration of the complete power converter as well as proving the manufacturability of the hardware solution. It is the increase in the manufacturing technqiues and associated reliability that is the focus of the innovaion required in this CfP project. This an important step in the adoption of this technology and will result in aircraft level benefits in terms of weight and volume reduction of equipment way beyond that achieved in the power electronic converter alone.

This CfP project should create a lot of additional value as well as innovation to the development work associated with larger SiC based power electornic modules for future aerosapce applications. Whereas the core work within the associated Clean Sky 2 programme has led to the development of the power converter topologies and modulation/control, this CfP is about increasing the manufacturability and making sure that the required power electronic device modules that will be needed in the implementation can be available. The work in this CfP therefore requires a partner with the desire to implement, innovate and supply advanced SiC based power electronic modules to the aerospace industry supply chain in the future something that is not availaible in the market today.

Table 1: Indicative Device Specification

Parameter	Value	Notes
Operating Temperature	50°C (max)	Ambient air
DC Link Voltage	540V (nominal)	Conforms to MilStd704
Converter Power	100kW	Maximum under nominal operating conditions
Device Switching Frequency	15kHz	Typical target value
Device Voltage	650V (max)	Transient maximum voltage
Device Current	250A (max)	Maximum in steady state operation
Storage Temperature	-55°C to 100°C	Ambient
Cooling	Forced air	Not part of this CfP, suffienct cooling can be assumed
Efficiency	>97.5%	Target at nominal power
AC Input Voltage	230V (nominal)	Typically from from AC Generator

2. Scope of work

Tasks		
Ref. No.	***Title - Description***	***Due Date***
1	Initial outline design of the power module based on a provided specification of the 100kW multi-level power converter topology and device requirements for the target application	M3
2	Detailed design including chosen semiconductor devices (SiC MOSFET and associated diodes) and proposed performance specification	M6
3	Gate drive circuit design and implementation plan based on the power module design	M8
4	Completion of power module and gate drive hardware building as well as functional testing and demonstration of the minimised weight/volume including design features for reliability and the target environment.	M12
5	Testing of final power module in the proposed application on an existing Clean Sky 2 funded test bed	M16
6	Assessment of manufacturability, long term in service reliability and scalability for future aerospace applications	M18

3. Major Deliverables/ Milestones and schedule (estimate)

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

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
1	Completed, tested SiC power electronic device modules and associated gate drive	H	M12
2	Technical report on the manufacturability and calculated reliability of the power electronic module	R	M18

Deliverables			
Ref. No.	**Title - Description**	**Type***	**Due Date**
1	Design of the power electronic module and integrated gate drive circuit – design review	R	M8
2	Test results and evaluation of the performance of the power module within the target applciation	R	M16

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

- Capability to source the latest SiC power semiconductor device die (MOSFETs and Diodes
- Capability and skills to design and build SiC based power modules
- Capability to undertake the future manufacture of SiC based power modules to aerospace standards

5. Abbreviations

SiC	Silicon Carbide
MOSFET	Metal Oxide Semiconductor Feild Effect Transistor

PART B: Thematic Topics

1. Overview of Thematic Topics

List of Topics for Calls for Proposals (CFP10) – Part B

Identification Code	Title	Type of Action	Value (Funding in M€)
JTI-CS2-2019-CFP10-THT-07	Ultra-High Aspect ratio wings	RIA	2.00
JTI-CS2-2019-CFP10-THT-08	Experimental and numerical noise assessment of distributed propulsion configurations	RIA	2.00
JTI-CS2-2019-CFP10-THT-09	Disruptive Active Flow Control for aircraft engine applications	RIA	1.50
JTI-CS2-2019-CFP10-THT-10	Non-intrusive, seedless measurement system: design, development, and testing	RIA	1.50

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 "*Third Amended Work Plan 2018-2019*"[129] and the "*Rules for submission, evaluation, selection, award and review procedures of Calls for Proposals*"[130].

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 Part B of this Annex .

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.

- **Number of winning proposals**

Under the Thematic Topics, more than one proposal per topic may be funded.

- **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)

[129] Doc. ref. CS-GB-2019-04-09 Third Amended WP and Budget 2018-2019, available on the Participant Portal and the Clean Sky website
[130] Doc. ref. Written Proc. 2014 -11 CS2 Rules for submission CfP, available on the Participant Portal and the Clean Sky website

introduced below:

- The 16 Leaders of JU listed in Annex II to Regulation n° (EU) No 558/2014 and their affiliates[131] **may not apply** to the topics listed in Part B of this Annex .

Please note that proposals may include the commitment from the European Aviation Safety Agency (EASA) to assist or to participate in the action without EASA being eligible for funding.

3. Programme Scene setter/Objectives

In accordance with Article 2 of the COUNCIL REGULATION (EU) No 558/2014 of 6 May 2014[132] 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 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."

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

131 See the definition under Article 2.1 (2) of the H2020 Rules for Participation
132 JOL_2014_169_R_0006

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 – Thematic Topics

I. JTI-CS2-2019-CFP10-THT-07: Ultra-High Aspect ratio wings

Type of action (RIA/IA/CSA):		RIA	
Programme Area:		N/A	
(CS2 JTP 2015) WP Ref.:		N/A	
Indicative Funding Topic Value (in k€):		2000	
Topic Leader:	N/A	**Type of Agreement:**	N/A
Duration of the action (in Months):	42*	**Indicative Start Date (at the earliest)[133]:**	> Q1 2020

**The JU considers that proposals requesting a contribution of 2000k€ over a period of 42 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-CS2-2019-CFP10-THT-07	**Ultra-High Aspect ratio wings**
Short description	
The most "easy" way to improve the aerodynamic efficiency and performance of an aircraft is to increase its aspect ratio of its wings. Increasing the aspect ratio has a direct effect on the induced drag. Increasing the aspect ratio while satisfying the design constraints that have to date limited aspect ratios of modern transport aircraft wings, such as aero-elasticity and buffeting; structural design and weight limitations; fuel capacity; and practical issues such as airport runway/taxiway and gate dimensions may yield a sizeable potential benefit in fuel burn and emissions. Long, slender wings may necessitate radically different structural and manufacturing concepts. Load control systems may prove essential to the feasibility of very high aspect ratio designs. Optimal wing span may lead to the need for folding outer wing sections. This topic aims to provide a preliminary design study involving the capture of the current state of the art, an analysis of potential gains through the use of very high aspect ratio wings in the various transport aircraft market segments [regional, short-medium and long range]. Different design concepts should be analysed, paying particular attention to design constraints such as those mentioned above. A proposed 'best in class' conceptual/preliminary design should be completed, starting from a selected reference aircraft for comparison in terms of performance. The estimated gains should be validated experimentally by scaled model wind tunnel tests, at least in terms of aerodynamic performance, possibly in terms of noise performance as well.	

Links to the Clean Sky 2 Programme High-level Objectives[134]				
This topic is located in the demonstration area:			NA	
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter:			NA	
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☒	☒	☒	☒

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

[134] 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

Most large transports today operate within the best cruise L/D range of 18-20 using the conventional cantilever wing design. Although this configuration has led to marginal improvements in aerodynamic efficiency over this past century, mitigating aviation's contribution to climate change through its various emissions requires more disruptive configurations. Some activities are currently on-going in this sense in the Cleansky AIRFRAME ITD WP A1. Among the others, Ultra-High aspect ratio wing design is seen as a promising step toward more aerodynamic efficient aircrafts. Indeed, the general trend in wing design seems to be towards greater aspect ratios procuring less induced drag and better fuel efficiency. This is made possible by the adoption of newest materials that can enable a long and thin wing to be structurally sound and operationally reliable. On the other side, structural aspects related to conventional cantilever wing configurations prevent further increase in wing span and/or reduction of thickness to chord ratio.

Within this context, studies on ultra-high aspect ratio wings have sought to develop tools and methods accounting for structural and aeroelastic aspects that have pushed towards the development of more modern high aspect ratio wing configurations such as the Strut-Braced-Wing (SBW) or the Truss-Braced Wing (TBW). Those aircraft concepts are designed to be aerodynamically efficient by employing higher aspect ratio wings which are braced at a certain location of the wingspan by struts of trusses for structural purposes. However, while some results have highlighted the potential benefits of such a configuration from structural and aerodynamic points of view (e.g. truss-braced wings can be thin and with reduced sweep; both also relevant for achieving laminar flows), the issue of interference aerodynamic drag penalties and the impact on dynamic and aeroelastic behaviours need further investigation. The noise performance of such configurations also needs to be assessed.
This topic asks for a multi-disciplinary design and optimization aimed to improve the wing aerodynamics, structural efficiency and flight performance of high aspect ratio wings accounting for relevant aircraft design parameters. For a selected reference aircraft and mission (take-off, landing, cruise, range, altitude, etc.), a new A/C configuration and/or wing layout shall be defined (e.g integrating SBW, TBW or other technologies). Trade-off studies will be aimed at minimizing induced drag and wave drag in all the mission phases (high-lift, cruise, etc.). It is expected that the successful implementation of the concept requires preliminary flight loads evaluations and structural analysis to prove the viability of the proposed new aerodynamic configuration. Indeed, geometry (e.g. wing layout, stiffness, etc), aerodynamic, aero elastic and manoeuvrability aspects could be key drivers for the design of the optimal Ultra-High Aspect ratio Wing. On the other side, aspects such as weight limitations; fuel capacity; and practical issues such as airport's airfield constrains (runway/taxiway and gate dimensions) could represent serious challenges for further development of the proposed technologies.

2. Scope

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 alternative ultra-high aspect ratio wing A/C architectures.
For the selected reference A/C, a holistic optimization approach (aerodynamic, structural, aero-elastic) is necessary at the aircraft level to define optimal layout towards more efficient A/C configuration (e.g. optimized for minimum drag, fuel/emissions). To this aim, the most relevant design variables shall be identified including geometric aspects (e.g wingspan; wing thickness-to-chord ratios, chords, sweep single-jury or two-jury TBW, SBW, others). In order to assess performances of the identified configurations, aerodynamic and structural parametric models of the selected high aspect ratio wing aircraft shall be created by means of reliable engineering methods. Finally, a consolidated optimization

strategy shall be built accounting for relevant design and aerodynamic constraints that are depending on the selected reference A/C and mission (eg take-off and landing field lengths, minimum rate of climb after take-off, maximum wing deflection, cruise altitude, cruise speed, manoeuvrability, flutter, airfield constraints, etc).
The main purpose is to identify the best compromise and balance between the aerodynamic and structural performances of the concepts. Benefits in terms of aerodynamic efficiency of the identified optimal configuration with respect to the reference A/C configuration shall be finally assessed through high fidelity CFD simulations. Clear and quantified environmental performance predictions must be stated for the proposed architecture(s) in terms of CO_2, NO_x and Noise.

The scientific and technical challenges (through categorization and specification of gaps from the current SoA) shall be identified and for each of them, technical solutions shall be proposed allowing the successful deployment of the proposed architecture (e.g. Foldable wingtip concepts could make the developed wing concept compatible with the airport dimensions and airfield requirements).
A scaled mock-up of the defined innovative A/C configuration shall be realized for communication of other dissemination purposes (e.g to be presented at relevant events and workshops) and promoting project achievements.
The proposed concept shall be tested experimentally at the level of a scaled model wind tunnel test in order to assess its aerodynamic and possibly noise performance.

3. Expected outcomes/impact

The expected outcome of the project would be the completion of the design phase up to the concept exploration and benefits analysis and thus, to collect all elements necessary to proceed to a next step such as concept development and demonstration (that are however outside of the scope of this topic).
Expected project tasks and outcomes are:

TASKS Description		
Ref N°	**Title**	**Expected Outcomes**
1	Literature review	Analysis and literature review of State of the Art [SoA] of research and/or developments underway in the field of future Ultra- high aspect ratio wing A/C architectures with a focus on state of technology readiness. Identification of the reference Aircraft and mission.
2	Design - Aerodynamic and structural models development.	Identification of relevant design variables for the Aerodynamic and structural parametric models. Integration of developed sub-models in a common working environment.
3	Optimization - Definition of the optimal design architecture.	Conceptual and multi-objective optimization design of aircraft in compliance with weight, manoeuvrability, aeroelastic, aeroacoustic, airfield, other constraints.
4	Assessment through high fidelity computation.	Final verification and assessment of aerodynamic efficiency of the identified optimal A/C configuration through high fidelity methods. Assessment of the noise performance of the identified optimal A/C configuration both at aircraft and subsystem levels.

TASKS Description		
Ref N°	**Title**	**Expected Outcomes**
5	Experimental validation	Scaled model wind tunnel tests
6	Impact Analysis and Roadmap development	Quantification of the expected environmental impacts for the down-selected architecture. Identification of the scientific and technical challenges for the successful future deployment of the proposed architecture and present a roadmap for the development of the proposed technologies.

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.

- **Number of winning proposals:**

Under the Thematic Topics, more than one proposal per topic may be funded.

- **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[135] **may not apply** to the topics listed in this call text document.

5. Abbreviation/acronyms

A/C	Aircraft
CFD	Computational Fluid Dynamic
D	Drag
L	Lift
SBW	Strut-Braced Wing
TBW	Truss-Braced Wing

[135] See the definition under Article 2.1 (2) of the H2020 Rules for Participation

II. JTI-CS2-2019-CFP10-THT-08: Experimental and numerical noise assessment of distributed propulsion configurations

Type of action (RIA/IA/CSA):		RIA	
Programme Area:		N/A	
(CS2 JTP 2015) WP Ref.:		N/A	
Indicative Funding Topic Value (in k€):		2000	
Topic Leader:	N/A	**Type of Agreement:**	N/A
Duration of the action (in Months):	42*	**Indicative Start Date (at the earliest)[136]:**	> Q1 2020

**The JU considers that proposals requesting a contribution of 2000k€ over a period of 42 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-CS2-2019-CFP10-THT-08	**Experimental and numerical noise assessment of distributed propulsion configurations**
Short description	
This thematic topic focuses on the assessment of noise reduction opportunities associated to new aircraft configurations, more specifically those related to electrically driven propulsors. The expected project outcome is to deliver an improved understanding of key noise aspects involved in such distributed electric propulsion (DEP) configurations, at experimental and numerical level. This will enable an initial assessment of the overall noise level achievable for typical DEP options including the evaluation of key noise contributors and efficiency of their respective mitigation means.	

Links to the Clean Sky 2 Programme High-level Objectives[137]				
This topic is located in the demonstration area:			NA	
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter:			NA	
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x 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. Specific challenge

This topic addresses the general objective of noise assessment and noise reduction related to new aircraft configurations, and more specifically those related to electrically driven propulsors.
Novel aircraft configurations with distributed electric propulsion (DEP) are showing good prospects for further environmental benefits relative to advanced "Tube and Wing" / UHBR configurations. They are seen as a promising direction to achieve the 2035+ objectives set for Clean Sky 2 at TRL4 for shorter range aircraft categories.

However, such aircraft architectures raise key noise engineering issues, specific of the design options and largely unaddressed until now, in particular related to propulsor installation. To assess the possible benefits that can be associated with various distributed electric propulsion options, a baseline has to be established to layout the foundations for further combined optimisation of such configuration options with respect to noise as well as gaseous emissions.

The project is then aimed at developing the necessary knowledge that will allow an increased confidence in DEP application prospects, supporting an assessment of typical options in terms of overall noise reduction potential, backed by appropriate parametric experiments. This will also help to point out the key areas to address in larger scale demonstrations.

2. Scope

Whereas propellers and electric motors can be reasonably well modelled independently, and combined as a single (isolated) propulsive component, the interaction noise between unducted propellers is not well understood. This relates to the interaction noise between adjacent propellers such as in a distributed propulsion concept as well as wing-propeller interaction, depending also on the configuration, i.e. leading edge or trailing edge mounted propellers.

Proposals are expected to provide both an experimental study in an adequate acoustic test facility complemented by a numerical validation. The wide variety of combinations in terms of the configuration (number of propellers, spacing between propellers, propeller diameter and rotational speed, position on wing, etc.) may require an upfront optimization study or design of experiment based on the current state of modelling knowledge to define the most relevant test case(s).

For configurations involving tighter integration of the propulsors within the wing leading edge, the assessment study should also cover implementation of innovative noise reduction means such as advanced acoustic liners (metamaterials, active or adaptive concepts) fitted in the vicinity of the rotating parts.

At last, an investigation of possible noise source mechanisms associated with other constitutive elements of the DEP concepts will be carried out.

3. Expected outcomes/impact

The project will deliver an improved understanding of key noise aspects involved in distributed electric propulsion (DEP) configurations, i.e.:

- Wing-propeller and propeller-propeller installation effects, covering the influence of parameters such as position of propellers with respect to the wing as well as propellers respective positions, propellers diameter and rotational speed, number of blades and phasing effects,….

- Innovative noise reduction solutions to address concepts with propulsors integrated within wings leading edge.
- Other noise generation mechanisms associated with DEP configuration elements, such as electric motors.

Globally, the project outcome will enable an initial assessment of the overall noise level achievable for typical DEP options including the evaluation of key noise contributors and efficiency of their respective mitigation means. These results will support further optimisation of propulsion systems installation from a noise standpoint, thus strengthening opportunities of turning innovative aircraft concepts into viable configurations.

In the process, a comprehensive noise database of numerical and experimental results will be developed, available to support higher TRL investigations of DEP architectures.

An analysis and literature review of the State of the Art [SoA] of noise assessment capabilities related to distributed electric propulsion concepts should be provided, as well as a technical roadmap for future research in the field.

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.

- **Number of winning proposals:**

Under the Thematic Topics, more than one proposal per topic may be funded.

- **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.

[138] See the definition under Article 2.1 (2) of the H2020 Rules for Participation

III. JTI-CS2-2019-CFP10-THT-09: Disruptive Active Flow Control for aircraft engine applications

Type of action (RIA/IA/CSA):		RIA	
Programme Area:		N/A	
(CS2 JTP 2015) WP Ref.:		N/A	
Indicative Funding Topic Value (in k€):		1500	
Topic Leader:	N/A	**Type of Agreement:**	N/A
Duration of the action (in Months):	42*	**Indicative Start Date (at the earliest)[139]:**	> Q1 2020

**The JU considers that proposals requesting a contribution of 1500k€ over a period of 42 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-CS2-2019-CFP10-THT-09	**Disruptive Active Flow Control for aircraft engine applications**
Short description	
Reducing aviation emissions calls for disruptive technologies to go beyond the most efficient projected improvements in current technologies. Achieving this goal requires a ground breaking improvement of flow control devices to push engine efficiencies beyond their current limits and improve their operability. Despite the vast range of existing flow control solutions, most of the active flow control systems described in the literature are still far from being implemented on engines. Thus there is a need to explore the design of compact actuators compliant with aeronautics requirements in terms of weight, volume, reliability, and integration (thermal management). Moreover, several flow control technologies, such as plasma based technologies, seem very promising but require a non-negligible amount of energy to function. Therefore, the development of disruptive actuators is closely linked to the proposal of an innovative energy supply. Hence, the aim of this topic is to increase the Technology Readiness Level (TRL) of active flow control technologies for engine applications. Proposals are expected to provide the design and manufacturing of an actuator system fitting control specifications and compliant with aeronautics requirements, before demonstrating its ability to achieve reliable control performance and fuel burn reduction, justifying a TRL 4 achievement of the control technology.	

Links to the Clean Sky 2 Programme High-level Objectives[140]				
This topic is located in the demonstration area:			NA	
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter:			NA	
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	**Reducing NO_x emissions**	**Reducing Noise emissions**	**Improving EU Competitiveness**	**Improving Mobility**
☒	☒	☐	☒	☒

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

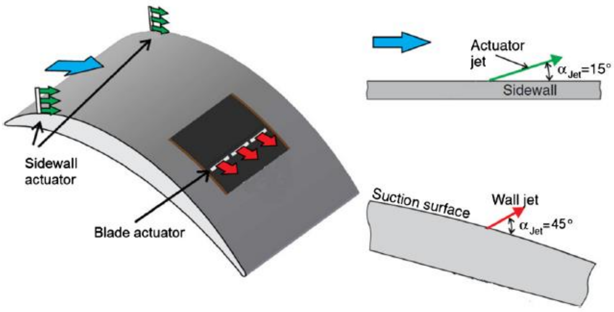
[140] For further info see Chapter 1 “Introduction to the Programme Scene Setter / Objectives” with key technology themes / demonstration areas. Detailed information available in the CS2 Development Plan accessible via the Clean Sky JU Website and EC Participant Portal.

1. Specific challenge

It is now well accepted that flow control is a key technology to improve aerodynamic performance beyond actual aerodynamic design, which can lead to reducing fuel burn, CO_2 or NO_x emissions.
In order to actively control the flow in an engine, efficient actuators are needed, which must be compact enough to allow an easy integration, and compliant with aeronautics requirements.

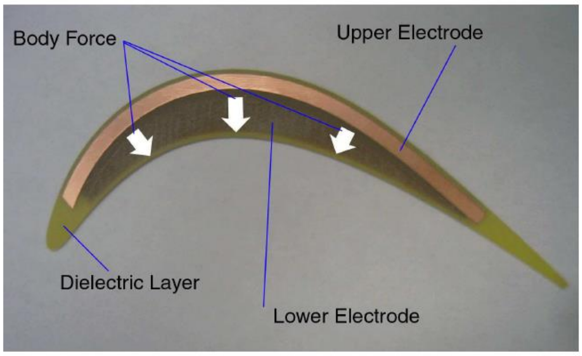
A large number of actuator types are mentioned in the active flow control literature, with specific advantages and drawbacks [1]. A first category can be referred to as moving-surface actuators, which rely on body shape modifications in order to control the flow. Examples of such moving-surface actuators include flapping devices, piezo-electric actuators able to deform surfaces or modify the twist of a blade, or deployable vortex generators [2]. More specifically in the engine-related field, active piston actuation [3] has been proposed to stabilize compressor surge by dissipating the plenum energy. For the same application, a variable area throttle valve has been tested in [4], with feedback from pressure measurements.

A second category consists in fluidic actuators, such as synthetic and pulsed jets, or flow aspiration. Such technologies may be used on engines intakes, where forcing flow reattachment can help limiting the occurrence and magnitude of surge phenomena [5]. In [6], flow simulations were performed on a compressor stator cascade to compare the control abilities of synthetic jets and continuous jets, and have demonstrated a reduction in total pressure losses. In [7], a boundary layer aspiration study is mentioned, in order to reduce boundary layer separation downstream of shock waves on engine intakes.



Stator cascade with injection slots. Source: [6]

A third category includes plasma actuators, which are able to accelerate the flow in a specific region through ionization [8]. The accelerated charged particles transfer momentum to the surrounding gas adjacent to the surface via collisions with neutral particles. Also, the ionized air, in the presence of the electric field produced by the electrode geometry, results in a body force vector that acts on the ambient air. Those actuators are gaining popularity due to their low mass, easy installation capabilities, and rapid time response, but require high voltage electrodes to ionize the flow. Plasma actuators capabilities to impede flow detachment and control tip clearance flow were investigated both on compressor and turbine applications. In [9], an unsteady plasma actuator was mounted on the tip of a turbine blade, and tested experimentally on a low pressure turbine cascade. Micro plasma actuators have been tested on compressor and turbine numerical models [10, 11], and more specifically in [12] on a curved wall plate representative of a low pressure turbine suction surface. The manufacturing of those micro plasma actuators relies on micro-electronic technology, and the production of electrodes with photolithographic techniques. In [13], tip leakage flow in a compressor is controlled using plasma actuators localized in the compressor casing. Several directions of the electromechanical force were tested, both numerically and experimentally.



Mounted Blade Tip Plasma Actuator. Source: [9]

Active control has also shown a capability to reduce noise. For instance, [13] investigated an array of loud speakers mounted on the inlet of the engine, creating a sound field which destructively interferes with the fan tonal inlet noise.

Those are non-exhaustive examples revealing the vast range of existing flow control solutions. However, not many of the active control solutions proposed in the literature have transitioned from a laboratory prototype to a real world aeronautic application, and several challenges must be overcome to achieve this purpose. For instance, the need for *small scale, compact and low weight* systems may impact the necessity to review the design of existing actuator technologies and their manufacturing constraints. *Cost criteria* also need to be taken into account when an engine integration is considered. Moreover, for safety reasons the actuator technologies must reach *high reliability*, which imposes constraints in terms of mechanical resistance, accurate control of the motorization, kinematics, and power distribution, as well as accessibility for maintenance.

Overcoming those challenges requires two approaches complementing each other: on the one hand, the increasing understanding of fluid mechanics should enable to control a flow with smaller amplitude forcing, therefore the possibility to reduce actuator power, therefore size, and mass [14]. In parallel, challenges in hardware development must be addressed in order to build an actuator meeting targets in terms of electrical efficiency, robustness, size, weight and cost, while limiting the generation of heat, sound, and electrical noise [1]. Notably, the weight and integration of the energy supply need to be taken into account in the actuator design.

2. Scope

The objective of this topic is to increase the Technology Readiness Level (TRL) of active flow control technologies for engine applications. For this purpose, an actuator system at a TRL 4, corresponding to a given control strategy, fitting control specifications and compliant with aeronautics requirements will be designed, developed and validated. Moreover, the actuator technology will be tested in conditions which justify a TRL 4 achievement of the control technology.
This study should propose and develop a demonstrator system for a compact actuator compliant with aeronautics requirements (compacity, low cost, low weight and reliability), and able to improve stability and performance (reduction of CO_2 and NOx emissions, fuel burn and noise) by controlling an identified flow phenomenon in aero-engines.
The applicant will need to define the phenomenon to be controlled, and associated quantified benefits in terms of performance, operability and reliability in the proposal.
The outcomes of this study will be:

- The design and manufacturing of an actuator, able to perform control specifications and respecting engine integrability requirements. The desired TRL level of the actuator system is TRL 4.
- The proof, in realistic conditions, i.e. validated by experiments at component level (compressor/turbine tests) that the active flow control technology is efficient and benefits performance and stability. The test strategy will enable to justify a TRL 4 achievement of the control technology.

3. Expected outcomes/impact

The project will identify/deliver

- Literature review and State-of-the-Art of active flow control technologies in engines.
- The target component(s) within the engine and quantified objectives in terms of stability/performance improvements at component level (compressor, turbine, intake, ducts, …)
- Specification of the active control strategy (control parameters) and actuator specifications (type, compacity, reliability, cost, weight, energy efficiency, integrability,…)
- Specification of test strategy and risk analysis : test model and test conditions
- Actuator design and prototyping, including qualification testing and acceptance
- Test system integration and calibration
- Testing and validation of the control technology (control efficiency at component level, i.e. on a compressor/turbine test rig, or a TRL 4 representative rig)
- A global conclusion and synthesis of the project, as well as a roadmap for the manufactured actuator technology to reach higher TRL

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.

- **Number of winning proposals:**

Under the Thematic Topics, more than one proposal per topic may be funded.

- **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.

5. References

[1] Louis N. Cattafesta III and Mark Sheplak, Actuators for Active Flow Control, Annual Review of Fluid Mechanics 2011 43:1, 247-272

[2] Ternoy F., Dandois J., David F., Pruvost M. Overview of ONERA Actuators for Active flow control.

[141] See the definition under Article 2.1 (2) of the H2020 Rules for Participation

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[12] Haideng, Z., Yun, W., Yinghong, L., Xianjun, Y., & Baojie, L. (2019). Control of compressor tip leakage flow using plasma actuation. Aerospace Science and Technology.
[13] Burdisso, R., Thomas, R., Fuller, C., and O'Brien, W., Active Control of Radiated Inlet Noise from Turbofan
Engines, SAE Technical Paper 931285, 1993
[14] Theofilis V. Role of instability theory in flow control. See Joslin & Miller 2009, pp. 73–114, 2009

IV. JTI-CS2-2019-CFP10-THT-10: Non-intrusive, seedless measurement system: design, development, and testing

Type of action (RIA/IA/CSA):		RIA	
Programme Area:		N/A	
(CS2 JTP 2015) WP Ref.:		N/A	
Indicative Funding Topic Value (in k€):		1500	
Topic Leader:	N/A	Type of Agreement:	N/A
Duration of the action (in Months):	36*	Indicative Start Date (at the earliest)[142]:	> Q1 2020

**The JU considers that proposals requesting a contribution of 1500k€ 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-CS2-2019-CFP10-THT-10	**Non-intrusive, seedless measurement system: design, development, and testing**
Short description	
Inlet flow distortion measurements are usually carried out using discrete pressure and temperature rakes. These devices are however poorly adapted to highly distorted flows where non-intrusive methods could be better suited. Well known non-intrusive methods usually require seeding particles, the use of which can be troublesome during engine operation and can account for significant release of fine particles in the atmosphere. The main objective of the current topic is to design, develop a non-intrusive, seedless measurement system, set-up and validate it at laboratory level and provide a demonstrator which will then be tested on a realistic aerodynamic test rig.	

Links to the Clean Sky 2 Programme High-level Objectives[143]				
This topic is located in the demonstration area:			NA	
The outcome of the project will mainly contribute to the following conceptual aircraft/air transport type as presented in the scene setter:			NA	
With expected impacts related to the Programme high-level objectives:				
Reducing CO_2 emissions	Reducing NO_x emissions	Reducing Noise emissions	Improving EU Competitiveness	Improving Mobility
☒	☒	☐	☒	☒

[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

Novel aircraft configurations rely on boundary layer ingestion to provide fuel burn reduction through aero-propulsive efficiency improvement. However, such configurations require ever closer integration of the main power plants into the airframe, thus generating significant inlet flow field distortion which can have a dramatic impact on fan design, performance and operability.

Figure 1 - Propulsive Fuselage – NASA's STARC-ABL turboelectric Plane Concept (Jansen, 2017)

Figure 2 – 180° BLI – ONERA NOVA concept (Wiart, 2016)

Usually inlet conditions characterization campaigns are carried out using pressure probes located in discrete locations. In conventional configurations, the axisymmetry of the incoming flow limits the required number of intrusive pressure probe. However, in highly distorted conditions, the required number of probes can be problematic, causing significant flow disruption and affecting the reliability of the measurement.

Less to non-intrusive flow characterization techniques such as Laser Doppler Velocimetry or Particle Image Velocimetry have much less disruptive effect on the oncoming measured flow, and are well established. They however require seeding of the measured flow which can prove problematic in real engine testing applications. Seeding must be as homogenous as possible, with yet the proper seeding particle size and density to resolve flow features. Liquid seeds while easy to generate and adjust can be an issue due to their low life expectancy, requiring close to measurement plane injection and leading to liquid accumulation on engine surfaces and measurement viewport. Solid particles though having longer lasting lifetime, generate significant fine particle pollution and prove harder to fluidize and to use in a large volume application.

Figure 3 : Boundary Layer Ingestion propulsion concept undergoing high-speed testing in the NASA Glenn 8'x6' wind tunnel. Credits: Dave Arend/NASA (Hughes, 2018)

Seedless measurement methods such as Cross-correlation Doppler global velocimetry based on Rayleigh and Mie scattering, have recently been investigated (Boyda, 2018) for their potential at alleviating part of the constraints associated with seeded flow characterization techniques and have shown great promises. Using such techniques, average velocity and temperature fields can be known with good accuracy along with the pressure field yet with higher levels of uncertainty.

2. <u>Scope</u>

The objectives of this study are to design, develop, validate and test a demonstrator system for non intrusive, seedless inlet flow charaterization.

The scope of work will should cover the following stages:

- <u>System Specifications:</u> This task will be dedicated to
  - Literature review and state-of-the-art.
  - Define the high level requirements for the measurement system, including target accuracy relative to the flow variables to be measured.
  - Evaluate the feasibility of using the system as a flight test measurement system.
  - Define the validation plan at laboratory level and the test plan, including the choice of test rig (a BLI configuration is considered of prime interest, but not mandatory).
- <u>System design and prototyping:</u> This task will address the design and development of the system, and assembly of a prototype.
- <u>Laboratory testing and system calibration:</u> This task will address the system testing and calibration in a laboratory environment:
  - Carrying out partial testing of system components in laboratory environement
  - Carrying out prototype testing and validation in laboratory environment
  - Assessment of the measurement uncertainty

- Validation and rig testing: This task will be addressing the selection of a suitable test rig, the system assembly, sytem setup and test rig characterizations using the new system.

  The test rig will be designed/used in order to be representative of future aeronautic systems. Complex flow field measurements such as engine test bed or wind tunnels should be envisaged.

After validation at laboratory level and in a representative test rig, an outlook on the potential of the system to be used for in-flight measurements should be given.

3. Expected outcomes/impact

The project will identify/deliver:

- A literature review establishing the State-Of-the-Art related to non-intrusive, seedless measurement techniques in various applications (flow field measurements, inlet distortion, combustion, etc.)
- The definition of the high level requirements for the measurement system and subsequent validation and test plan : specification of test strategy and risk analysis : test model and test conditions
- Measurement system design and prototyping, including qualification testing and acceptance, based on the high level requirements
- Assessment of the measurement uncertainty relative to the flow variables to be measured
- Test system integration and calibration
- Testing and validation of the system
- Evaluate the potential of the system to be used in real conditions (i.e. in-flight measurements).

4. Topic special conditions

Special conditions apply to this topic:

- **Page limit:**

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