CA3ViAR Project - 1st Dissemination Event

Leibnitz Universität Hannover

Institute of Turbomachinery and Fluid-dynamics

September 5th - 6th, 2022

Presented by: Nicola Paletta, Project Coordinator (IBK)

Fact sheet

CA³ViAR stands for *Composite fan Aerodynamic, Aeroelastic, and Aeroacoustic VAlidation Rig.*

It is a project funded by Clean Sky 2 JU under the H2020 Research and Innovation Framework Programme

Duration: *48 months*

Budget: *€ 2 296 875.00*

Consortium: *5 partners, 1 SME and 2 University from Germany, 1 SME from Italy, 1 SME from Greece*

Start date: *01/09/2019*

End date: *31/08/2023*

Project Objectives

- To perform a **literature review** of the main issues affecting composite **UHBR** engine fans;
- To **design a low-transonic fan** typical of a future large aircraft UHBR engine, in terms of aerodynamic shaping as well as structural design and analysis to make sure the test article can safely go close to aerodynamic and aeroelastic instabilities in an expected way during WT operations;
- To **design** the test article(s);
- To **manufacture** the test article(s);
- To **instrument** test articles and rig;
- To perform **experimental tests** including fan instabilities due to off-design operation and inlet distortion;
- To perform a **final experimental-numerical assessment** for calibrating and validating numerical models;
- To provide **open access** to all the produced **models, data and documents** for other institutions for in-house developed methods validation, with the objective to establish an “open test-case” for the whole European scientific community, unique in the engine fans landscape.

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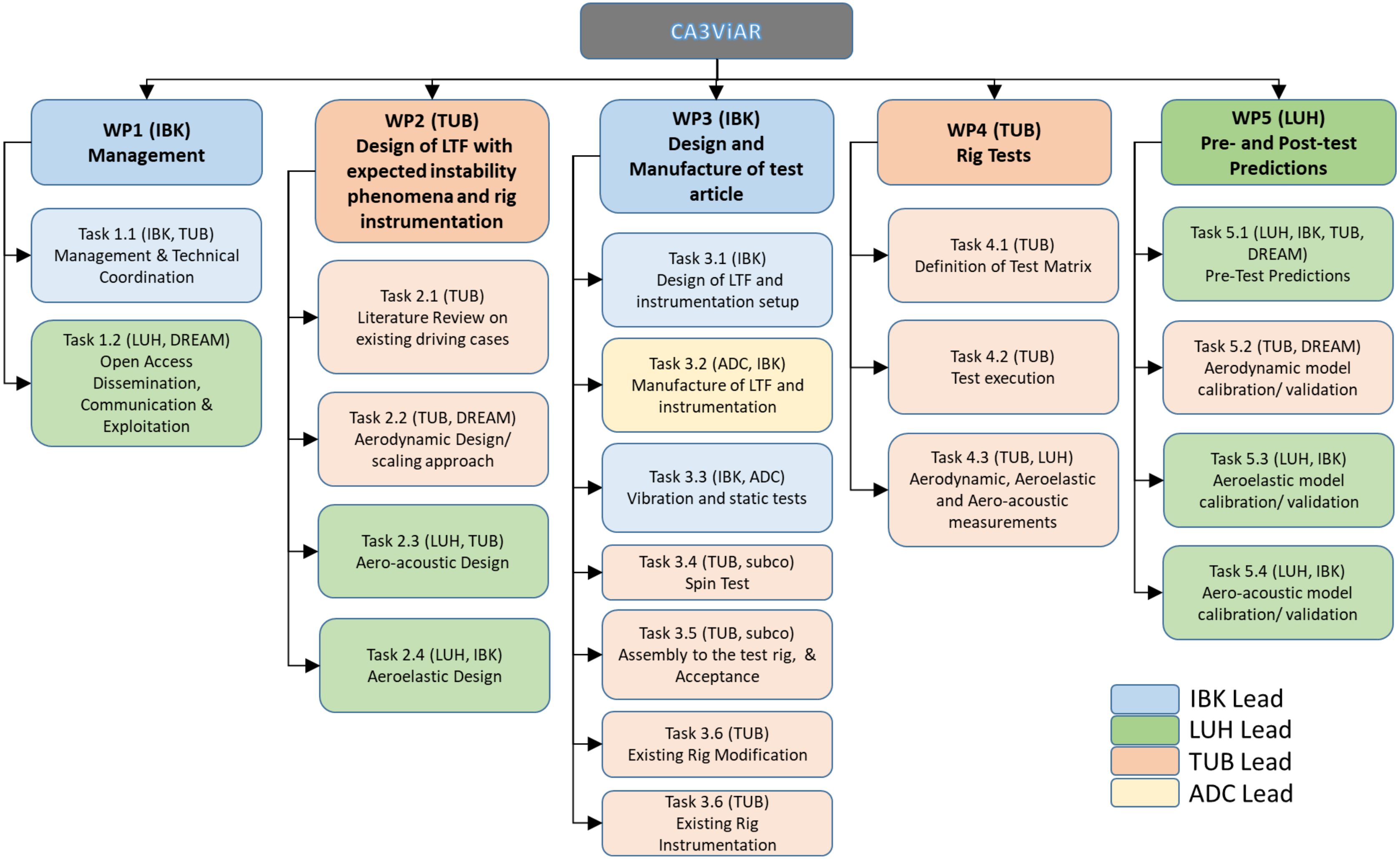
Project Partners

- **IBK** → Project Coordination, support to Low Transonic Fan (LTF) aeroelastic design, test article design leader
- **TUBS** → requirements management, LTF aerodynamic design and scaling approach, rig modification and instrumentation, management of WT tests
- **LUH** → LTF aeroelastic and aeroacoustic design, support to WT test measurements, pre/ post-test predictions
- **DREAM** → Support to LTF design and post-test predictions (CFD)
- **ADC** → Manufacture and instrumentation of test article, support to WT tests

Project Implementation – Work Package Breakdown



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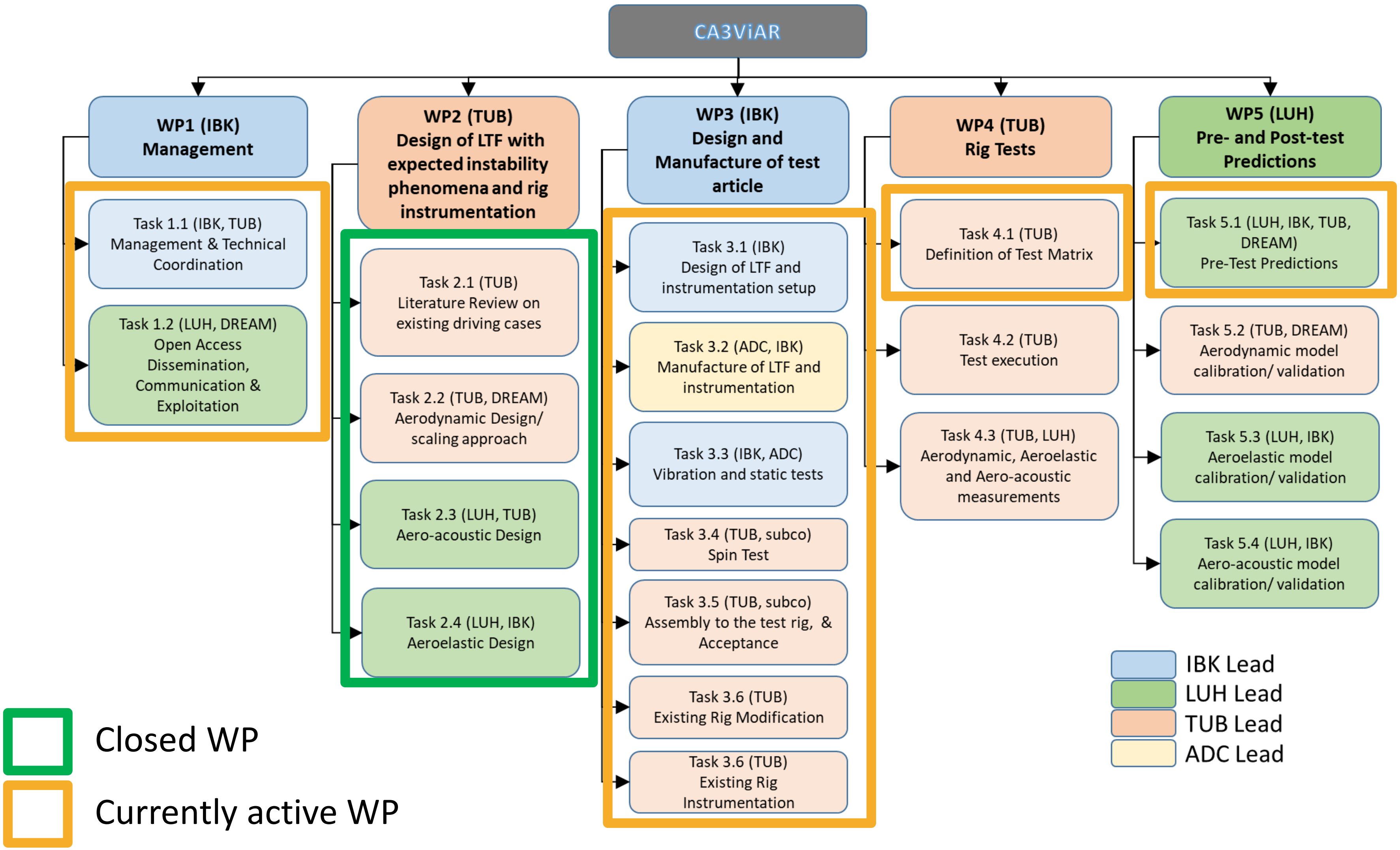
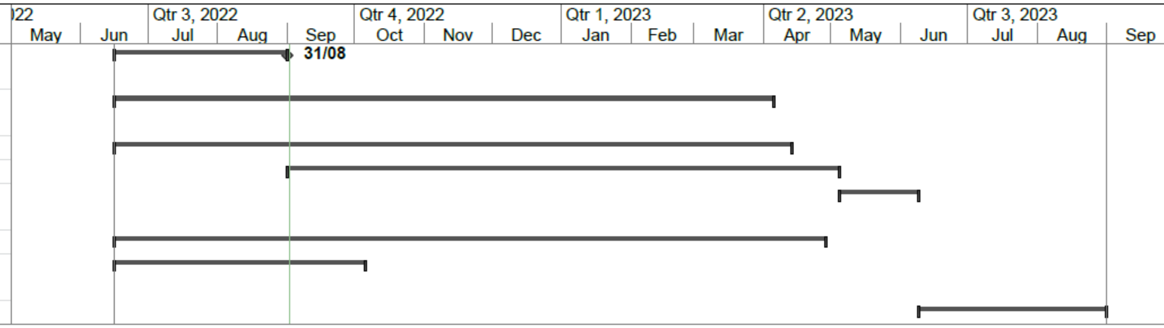


Project Time Line up to Test Campaign

ID	Vorgangsname	Duration	Start	Finish
1	Task 3.1 Design of LTF and instrumentation setup	55 dys	Thu 16/06/22	Wed 31/08/22
3	Task 3.2 Manufacture of LTF and Instrumentation	210 dys	Thu 16/06/22	Wed 05/04/23
17	Task 3.3 Vibration and static tests	216 dys	Thu 16/06/22	Thu 13/04/23
26	Task 3.4 Spin Test	176 dys	Thu 01/09/22	Thu 04/05/23
29	Task 3.5 Assembly to test rig and acceptance	25 dys	Fri 05/05/23	Thu 08/06/23
32	Task 3.6 Existing rig modification	227 dys	Thu 16/06/22	Fri 28/04/23
38	Task 3.7 Existing rig instrumentation	80 dys	Thu 16/06/22	Wed 05/10/22
45	WP4 TESTS	60 dys	Fri 09/06/23	Thu 31/08/23



- Considerations on Project Delay

- The Test Readiness Review (TRR) is subordinated to the end of the INFRa rig implementation. This is a constraint posed by an **external factor** the project is subject to.
- The original project schedule has a **contingency of 4 months** and the project final phase (post-test numerical activities) can be shortened in terms of time by increasing the resources (last phase is made up of activities that can be parallelized)
- As a consequence, there is room for CA3ViAR to postpone the AR without creating further penalties to the project implementation.

Project Implementation – Milestones

MILESTONES TO BE CONDUCTED					
Milestone	**Responsible applicant**	**Title**	**Ref. WP**	**Due Date**	**Means of verification**
M1.1	LUH	**DE1**: Dissemination Event #1	1	T0+19	First Dissemination Event of the project organized and realized
M1.2	LUH	**DE2**: Dissemination Event #2	1	T0+37	Second Dissemination Event of the project organized and realized
M1.3	IBK	**FDE**: Final Dissemination Event	1	T0+48	Final Dissemination Event organized and realized
M1.4	IBK	**M12PR:** M12-Project Review	1	T0+12	First project review with CS2 and Advisory Board organized and passed
M2.1	TUB	**SRR**: System Requirement Review	2	T0+10	System Requirement Review passed
M3.1	IBK	**PDR**: Preliminary Design Review	3	T0+14	Preliminary Design Review passed
M3.2	IBK	**CDR**: Critical Design Review	3	T0+18	Critical Design Review passed
M3.3	IBK/ TUB	**AR**: Acceptance Review	3	T0+29	Test article qualified and implemented into the test rig inside the wind tunnel
M4.1	TUB	**TRR**: Test readiness Review	4	T0+30	Test Matrix and Testing Procedures defined
M5.1	IBK/ LUH	**FPR**: Final Project Review	5	T0+44	Tests completed, numerical models calibrated and validated

Project Implementation – Deliverables

	WP/ Tasks	Resp./ Co	Deliverables	Due Date
1	**Project Management**	**IBK**		
1.1	Management and Technical Coordination	IBK, TUB		
1.2	Open access dissemination, communication and exploitation	LUH, DREAM		
		IBK	*D1.1: Signature of CA*	M1
		DREAM	*D1.2: DMP*	M6
		LUH/ IBK	*D1.3: D&E plan*	M6
2	**Design of LSF with expected instability phenomena and rig instrumentation**	**TUB**		
2.1	Literature review on existing driving cases	TUB		
2.2	Aerodynamic Design/ scaling approach	TUB, DREAM		
2.3	Aero-acoustic design	LUH, TUB		
2.4	Aeroelastic design	LUH, IBK		
		TUB	*D2.1: Literature review and LSF aero design requirements*	M4
		TUB, All	*D2.2: LSF performance and instability analysis, LSF mechanical design req*	M10

Project Implementation – Deliverables

3	**Design and manufacture of test article/ Rig mod.**			
3.1	Design of LSF and instrumentation setup	IBK		
3.2	Manufacture and instrumentation of LSF	ADC		
3.3	Vibration and static tests	ADC, IBK, subco		
3.4	Spin tests	TUB		
3.5	Assembly to the test rig & acceptance	TUB, subco		
3.6	Existing Rig Modification	TUB		
3.7	Existing Rig Instrumentation	TUB		
		IBK	*D3.1: LSF Mechanical Design and instrumentation setup*	M17
		ADC	*D3.2: Acceptance tests and delivery of LSF*	M26
		TUB	*D3.3: Rig modification, instrumentation and acceptance tests*	M29
		IBK	*D3.4: Prediction of manufacturing process distortion and effect on mould design*	M29
4	**Rig Tests**	**TUB**		
4.1	Definition of Test Matrix	TUB		
4.2	Tests execution	TUB		
4.3	Aerodynamic, aeroelastic and aero-acoustic measurements	TUB, LUH		
		TUB	*D4.1: Test Matrix and procedures*	M30
		TUB	*D4.2: Test Report*	M37

Project Implementation – Risks Analysis and SOP #1

#	WP	Identified Critical Risk	Cat.[1]	Impact	Proposed risk-mitigation measures
1	2	Late in the aerodynamic/ aeroelastic/ aeroacoustic design of LTF due to unexpected complexity LEVEL: Possible, Moderate, 6	S, T, C	A delay in the delivery of the requirements to WP 3	Give priority to CA3ViAR with respect to other projects and involve other skilled persons.
2	2	Delay in the CFD/ FEM computations and loads for design justification. LEVEL: Unlikely, Moderate, 4	S	It will cause a delay of design activities	Computations performed in parallel on different IBK machines. If necessary other personnel will be employed.
3	2, 4	Numerically estimated aeroelastic instabilities underpredict aeroelastic instabilities in WT LEVEL: Unlikely, Major, 16	T	Flutter is achieved unexpectedly in the WT	Define limits for condition monitoring to prevent damage due to unexpected flutter. A subsequent change of operating point mitigates flutter
4	2, 4	Numerically estimated aeroelastic instabilities overpredict aeroelastic instabilities in WT LEVEL: Likely, Moderate, 6	T	Fan blades are more stable than predicted numerically	Flutter could be triggered by changing blade loading [27] or changing the shock structures [28]. Both can be achieved by changing the operating point of the fan.
5	2	Material properties for composite material not refined enough for a precise aero-mechanical analysis LEVEL: Possible, Significant, 12	T	Aeromechanical behaviour in test rig deviates from design process	Compare procedure to conservative estimations according to current standards and best-practices. Define limits for condition monitoring
6	3	Not all the required operating conditions can be fulfilled in terms of aerodynamic and aeroelastic instabilities inside PTF LEVEL: Possible, Significant, 12	S, T	It may lead to project requirement relaxation, with possible delays due to discussions with the JU	Cooperate with the JU from the very early phase of the project, to discuss the operating conditions which leads to the achievement of major project objectives
8	3	Simultaneous mechanical integration of different measurement techniques/ devices technically very challenging (risky) or not feasible (e.g. for incompatibility with geometries provided by WP2) LEVEL: Possible, Significant, 12	C, T	It will cause a delay of the whole project and in particular on the test program	Cooperate from the beginning to elaborate/ prioritize the most important aspects in the design and test setup. To evaluate/ propose new geometries to allow performing the simultaneous integration of all the features.
9	3	Interface and integration issues between existing test facilities, new components and Instrumentation LEVEL: Unlikely, Significant, 8	T	Project will return to the previous task for different design solution of the test article.	Clear definition in the communication data, continuous coordination between partners to anticipate possible technical issues.

Likelihood (L)	Impact (I) 1 Minor	2 Moderate	4 Significant	8 Major	16 Catastrophic
1 Remote	1	2	4	8	16
2 Unlikely	2	4	8	16	32
3 Possible	3	6	12	24	48
4 Likely	4	8	16	32	64
5 Almost certain	5	10	20	40	80

Risk not materialized

Materialized – low impact

Materialized – high impact

Project Implementation – Risks Analysis and SOP #2

#	WP	Identified Critical Risk	Cat.[1]	Impact	Proposed risk-mitigation measures
10	3	Delay in the manufacturing of the test article or new stage rig components. LEVEL: Possible, Significant, 12	S	It will cause a delay in the starting of the test campaign	IBK and TUB will involve highly qualified and experienced personnel and companies (subcos). Small parts will be manufactured in parallel by using different machines.
11	3	Not feasible implementation of microphones outside the intake to perform external noise measurements (beam forming) LEVEL: Likely, Significant, 16	S, T	It may cause a project requirement relaxation, with possible delays due to discussions with the JU	Cooperate with the JU from the very early phase of the project, to discuss the operating conditions which leads to the achievement of major project objectives
12	3	Unexpected poor blade/ rotor performance during qualification tests due to poor manufacturing level LEVEL: Unlikely, Major, 16	S, T, C	It will cause a delay in the implementation of rotor into the INFRA-Rig in PTF	IBK will take special care in contracting very qualified and experienced manufacturers, ensuring very high quality of rotating parts
13	3	Unexpected short fatigue life of fan blades detected during spin or productive tests LEVEL: Possible, Significant, 12	S, T, C	It will cause a delay in the test execution, with possible need to go back to the design for updates	A sufficient number of spare parts (at least double the expected) will be foreseen to cope with unexpected short fatigue life of rotating parts. The most robust design will be pursued in the respect of stiffness and inertia distribution requirements.
14	3	Delay in the testing facility instrumentation LEVEL: Unlikely, Minor, 2	S	It can cause a delay in the WT test execution.	TUB and LUH will cooperate with the subcontractors to reduce the risks of delay.
15	4	Poor resolution/ reliability of PSP used for aeroacoustic measurement LEVEL: Possible, Significant, 12	T	It can affect the possibility of direct aeroacoustic measurements	The aeroacoustic field will be evaluated by CFD starting from the aerodynamic pressures measured by PSP and calibrated with absolute values measured by one reference microphone.
16	4	DIC unable to capture LEVEL: Possible, Minor, 3	T	No reliable aeroelastic measurements from DIC available	Concurrent measurement with reliable tip timing measurement will guarantee aeroelastic data
17	4	To many acoustic reflections in the WT pollute the microphone measurements LEVEL: Likely, Significant, 16	T	No reliable aeroacoustic far field measurements	Design an acoustic shield for the microphone on the linear traverse to shield it in direction of the incoming reflections

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Materialized – high impact

Project Implementation – Unforeseen Risks*

UR #	WP	Identified Critical Risk	Category (T, S, C)	Impact	Proposed mitigation measure
U1	2-5	Impact on the physical work within INFRa due to Covid.	T, S	Since the INFRa rig should host CAVIAR test article and instrumentation setup, the following project phases could be affected, with difficulties to estimate the delay in a precise and effective way	A possible recovery plan could be to parallelize manufacturing activities by contracting more manufacturing suppliers or, in case of increasing difficulty, to extend the project duration
U2	2	As DREAM workstations are physically located into a restricted area (due to covid-19). In case for some reasons some of the [illegible] [illegible]ment) to reach them	S	Delay of WP2 to complete the aerodynamic design of LTF	A possible recovery plan could be to get access to [illegible]her [illegible]cated at [illegible] [illegible]ntracting specific computing services
U3	1-5	Risk of project delay due to: - high level of technical challenge associated with the aerodynamic design - lower efficiency caused by the Covid-19 pandemic - the time spent for negotiating the GA accession of ADC		delay of PDR, CDR, AR and end of WT tests. The risk of late project closure is very low.	- Staggered design releases to parallelize manufacturing activities. - Increase of efficiency in manufacturing activities

Risk accounted for during Covid emergency

Risk not materialized

Materialized – low impact

Materialized – high impact

Project Implementation – Unforeseen Risks*

UR #	WP	Identified Critical Risk	Category (T, S, C)	Impact	Proposed mitigation measure
U4	3-4	Static tension test not enough representative to prove the safety of the blade against pull-out and combined aerodynamic and centrifugal loads	T	Not being able to perform productive tests at PTF for lack of confidence on blade structural safety	To replace the previously planned test with two tests: - A simplified pull-out with a very limited portion of the blade (spanwise) - A spinner test with the CA3ViAR hub and a reduced number of blades (e.g. 2) to prove the blade safety up to maximum operating speed plus a suitable margin
U5	3-4	Spinner test (mitigation action of risk U3) too expensive and not affordable with CA3ViAR budget	C	Not being able to perform productive tests at PTF for lack of confidence on blade structural safety	Reduce the amount of effort dedicated to activities of WP 5 to save the budget needed to cover the cost of the unforeseen spinning test

Risk not materialized

Materialized – low impact

Materialized – high impact

* Already documented on Sygma

Communication Activities

- The **project** has been **presented** to the **EASN 2020 Virtual Conference** with a presentation entitled
  - CA3ViAR: a step forward towards modelling and testing aerodynamic and aeroelastic instabilities experienced by Low Transonic Fans made of composite material
- A **project webpage** entirely dedicated to CA3ViAR has been built as part of the **IBK website**, “projects” section.
- Project coordinator and partners are **advertising project outcomes** and **news** also on social media (e.g. **LinkedIn**)
- **A project webpage** entirely dedicated to CA3ViAR has been prepared and is accessible at: **https://www.ca3viar-project.eu/**. The website is equipped with dedicated sections for news, data sharing and management of contacts
- A **lecture** has been given by the coordinator to the students of **LUH**, in the framework of the lecture series: “From the practice of energy and process engineering”, speaking, among other topics, also about the CA3ViAR project
- **The first dissemination event has been organized by LUH according to the project implementation plan**

Dissemination Activities

- **Scientific papers have been already published and others are foreseen in the next months.**
- **Peer-reviewed proceedings and articles, according to D1.3:**
  - T. Eggers, J. Friedrichs, J. Gößling, J. Seume, N. Natale, J. P. Flüh, N. Paletta, "*Composite UHBR Fan for Forced Response and Flutter Investigations*", GT2021-58941, ASME 2021 Turbomachinery Technical Conference & Exposition TURBO EXPO 2021 June 07-11, 2021, Pittsburgh, PA, USA
  - Paletta N. Flüh J. Lindemann J., Seume J., Gößling J., Friedrichs J., Eggers T., Russo S., Natale N., Vlachos D., Mazarakos D., Baltopoulos A., Vavouliotis A., "*The preliminary design of a scaled Composite UHBR Fan for a wind tunnel test campaign*", presented at EASN 2021, peer-reviewed and going to be published by IOP.
  - N. Natale, T. Eggers, J. Friedrichs, S. Russo, "*Aerodynamic Analysis of a scaled UHBR Fan*" , presented at EASN 2021, peer-reviewed and going to be published by IOP.
  - Gößling J., Seume J., Flüh J., Paletta N., Eggers T., Friedrichs J., Natale N., "Aerodynamic Damping of Composite UHBR Fans Under the Consideration of Acoustic Intake Reflections", GT2022-81777, accepted for publication at ASME 2022 Turbomachinery Technical Conference & Exposition TURBO EXPO 2022
- **Other two presentations are being prepared for EASN 2022, including two peer-reviewed conference proceedings**

Conclusions

- **Despite the delays already presented, the project is running with no or very minor criticalities**
- **The project activities are progressing and returning very interesting results for the benefit of the whole aeronautical scientific community**
- **The delay is considerable but the risk of affecting project implementation and achievement of project objectives is very low**
- **Technical and Financial Risks are taken under control, and suitable mitigation measures are identified in case of risk materialization**

Q&A

https://www.ca3viar-project.eu/

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