ReMAP Real-time Condition-based Maintenance for Adaptive Aircraft Maintenance Planning

Newsletter #2, July 2019

This project has received funding from the European Union's Horizon 2020 research and innocvation programme under grant agreement No 769288

www.h2020-remap.eu

What is ReMAP ?

The goal

ReMAP main objective is to advance the use of Condition Based Maintenance (CBM) in aviation.

In short, this means to bring smart maintenance to the industry - replace parts exactly when they really need to be replaced. Sooner if needed. Later if possible.
CBM nowadays is used in a very limited manner! Click on the next image to watch our video explaining how is aircraft maintenance performed today.

ReMAP will offer an open-source Integrated Fleet Health Management (IFHM) solution for aircraft maintenance.
Discover the Unique Selling Points and learn what makes ReMAP different from other CBM-initiatives, by clicking on the next image.

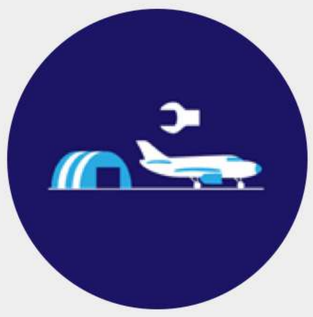
ReMAP will define a common roadmap towards further implementation of CBM in aviation. You can join us on this roadmap and share your ideas. See how in our website: https://h2020-remap.eu/

The partners

ReMAP gathers together 13 partners, from 7 European countries that, by covering the entire value chain for aircraft health management, will establish an innovative framework, that can be used for the implementation and certification of condition-based maintenance at a fleet level, while building up a European common roadmap towards the implementation of CBM.

What is ReMAP?

The expected impact

Data	WI-FI Communication with MCC	Health montoring updated Diagnostics / Prognostics / Alerts	Optimized maintenance schedule and packaging	Updated and Improved aircraft availability
				
Generate around 1GB of health monitoring data per flight Edge computing nd air-to-ground communication Pre-diagnostics Alerts	Improved Health knowledge Improved safety False alarms reduced to 1×10-6 /FH* Missed failures reduced to 10%*	20% less unscheduled maintenance* 4% less technical delay events* €68 000 cost reduction per year	8% less maintenance checks* 2,5% lower maintenance elapse times* 10% less unscheduled removals per year* €42 000 cost reduction per year	1.2 extra days of operations 140 minutes of less delay per year €160 000 extra revenue and lower costs per day

Work Progress

Work Package 2 Requirements Management & Development of the IT Platform

Along the second semester of the project, Work Package 2 (WP2) has had the challenging goal of closing the first version of the system requirements while designing the first approach of the IT platform. This task has been faced using an agile process of continuous requirement elicitation and architecture design in close collaboration with all the work packages.

After several meetings with partners and stakeholders, and holding three workshops oriented to the requirements feedback and the architecture design refinement, WP2 presented its first result in the consortium meeting of June 2019 in Patras (Greece). A set of requirements and an IT platform architecture design was determined which are able to provide all the capabilities and features for implementing a CBM-system and supporting the machine learning algorithms needed.

Read the interview with Paulo Rupino, scientific coordinator from Instituto Pedro Nunes (IPN) which choice has been made: https://h2020-remap.eu/contours-for-european-it-cloud-service-for-smart-aircraft-maintenance-defined/.

Work Package 3 Sensor Technologies for SHM

Work Package 3 (WP3) concerns the procurement, development and integration of the most promising sensor technologies for damage monitoring in aeronautical composite structures.

WP3 has defined the specification of the electronic device for high frequency excitation and detection. These electronics called Lamb Wave Detection System, or LWDS, allows the driving of the sensors both in pitch-catch and pulse-echo modes. A prototype has been designed, manufactured and delivered to ENSAM to perform the functional testing before the reliability testing.

The sensorization of the composite coupons has been clarified in terms of definition, quantity and position of the sensors. The piezoelectric sensors, Optical Fiber sensors, and Acoustic Emission sensors and their dedicated electronics have been selected and partly procured. The integration process of the sensors has been defined and validated on aluminum plates.

A reliability test plan has been performed to test the lifetime of the structure and sensorization under varying load and environmental conditions. Particularly, the health criteria of the sensors have been defined. First composite samples have been produced and will be soon available for integration of the sensors, before testing.

Work Progress

Work Package 4 Structural Health Management – Diagnostics & Remaining Useful Life Prognostics

The main aim of WP4 is to develop validated multi-disciplinary Structural Health Management (SHM) system methodologies that go a step beyond damage detection and diagnosis, towards remaining useful life estimation (prognosis) in the presence of adverse conditions during flight.

In the last six-month period of the project, the main objective for WP4 was to finalize the material procurement and delivery as well as the first manufacturing trials. This was led by Optimal (Portugal). In the meantime, UPATRAS initiated the development of the digital twins i.e. parameterized numerical models of L1 and L2 test articles. Baseline dependent and independent Health Indicators based on static strains have been developed. TU Delft and ENSAM formulated a detailed sensors reliability test plan to assess the performance of the various sensing technologies implemented in ReMAP. CTEC and STEC have been engaged with the development of the hardware – e.g. PZT sensors and actuators, SMARTape manufactured with dual optical fibres and FBGs interrogation simultaneously. EMBRAER studied and proposed a geometry for the L3 i.e. the subcomponent testing.

Work Package 5 System Level Diagnostics, Prognostics and Health Management

To achieve the objectives of CBM in WP5 prognostics and health management methodologies for aircraft systems and components are being developed. The execution of WP5 started in August 2018 focusing on the following two initial tasks: (1) T5.1 – Exploratory data analytics and specific scope & requirement definition (2) T5.2 – Development of Diagnostics & PHM Algorithms for Aircraft Systems and Components.

Between M6 and M12, significant progress has been made in the development of:

(1) Novel deep learning based PHM frameworks with the following primary innovative characteristics which extend the state of the art: a) Explainability. b) Visualization of degradation of systems and components. c) Capability to handle unlabelled data from multiple (possibly unknown) failure modes.
(2) Innovative PHM analytics for predicting degradation of brake system.
(3) An automated methodology for analysing system/component failure and maintenance logs.
(4) A simulator for development and validation of edge computing methodologies.
(5) A framework for automated external failure driver analysis.
(6) An autoencoder based framework for exploratory data analysis of aircraft system data.

Furthermore, a detailed comparative analysis of the state-of-the-art remaining useful life estimation methodologies was also performed.

Work Progress

Work Package 6 Maintenance Decision Support Tool

One of the main ambitious goals of ReMAP is to integrate CBM with overall fleet maintenance planning. WP6 aims to develop the maintenance decision support tool that will be capable of automating planning with diagnostics and prognostics predictions, when available. To pursue this objective, we delineated a path combining research and software development by increasing order of complexity: (1) automate the current planning practices as a baseline; (2) explore novel methodologies to include CBM when planning; (3) integrate the technology developed in a decision support tool to be used by maintenance planners. In the last six months, WP6 focused mainly on points (1) and (2). For (1) an AI based algorithm was implemented to plan periodic checks for an extended time-window. The algorithm serves both as a baseline and as a first step in planning automation. The first results of this algorithm are being validated with data from maintenance planning. In (2) several algorithms have been explored to find state-of-the-art approaches both in improving the decision making when planning but mainly to include CBM diagnostics, explored methods include: genetic algorithms, constraint programming and deep reinforcement learning.

Work Package 7 Integrated Safety Risk Assessment

WP7 aims at assessing the safety of CBM technologies investigated by ReMAP. WP7 will also define recommendations for future regulations in order to pave the way for the adoption of CBM technologies.
The first achievement of WP7 was the organisation of a brainstorming session with various KLM maintenance specialists in order to identify hazards related with CBM. A list of more than 30 hazards was produced and are currently being analysed.

Work Package 8 Technology Integration, Demonstration & Validation

Work Package 8 concerns the execution, integration, verification and validation of the technologies developed under the ReMAP project. A comprehensive identification of all anticipated technologies has resulted into six major use-cases that will be demonstrated either by real-life operations or by computer-simulation. The use cases are:

1. Analysis of current state maintenance practice
2. Optimized maintenance task packaging and scheduling
3. RUL estimation & diagnostics for systems and structures
4. Unscheduled event prevention & diagnostics for systems and structures
5. Maintenance task interval (de-)escalation
6. Maintenance task interval substitution (full CBM maintenance strategy)

Next steps are to identify relevant and measurable KPIs for each use-cases, contributing to the Integration, Verification and Validation strategy.

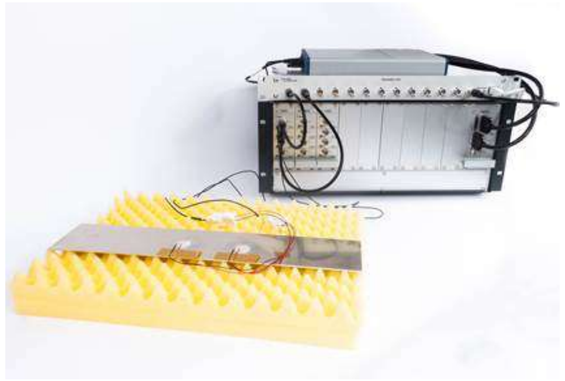
Special Theme

ReMAP Sensing Technology

ReMAP will explore and optimize the use of different sensing technologies for structural health management (SHM). Acoustic emission sensors will be completed with high-frequency piezo-electric sensors and optical fibre sensors. CTEC and ENSAM explains what is needed to implement such techniques.

1-What are the main objectives of the work performed in the sensor technology context?

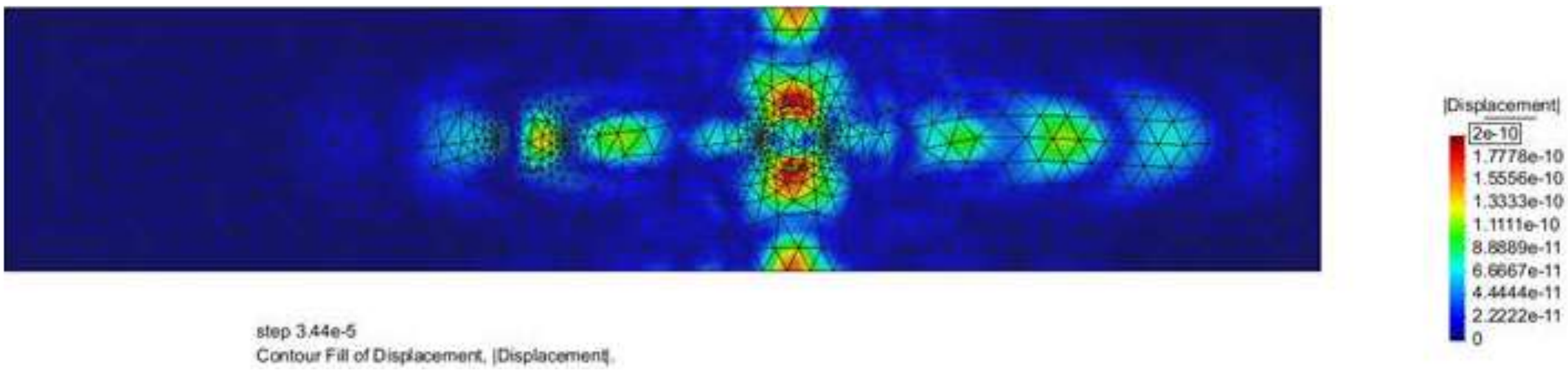
”Today the main concern of CTEC and ENSAM is to develop a LWDS (Lamb Wave Detection System) solution able to detect damages in pre-defined composite structures, as required by University of Patras and EMBRAER. This implies at first to design, build and test a LWDS electronics, to select and procure appropriate piezo patches, to define an accurate position of the patches on the structure, then to glue them on the structure.



LWDS electronic device

Secondly, this hardware will be exploited to define most appropriate excitation detection parameters in either pitch catch or pulse echo technique. Thirdly algorithms will be defined and implemented as software with the goal to ensure the detection and localization of growing damages as far as possible in various conditions. “

2-How will the research in ReMAP improve the reliability of sensor technology?

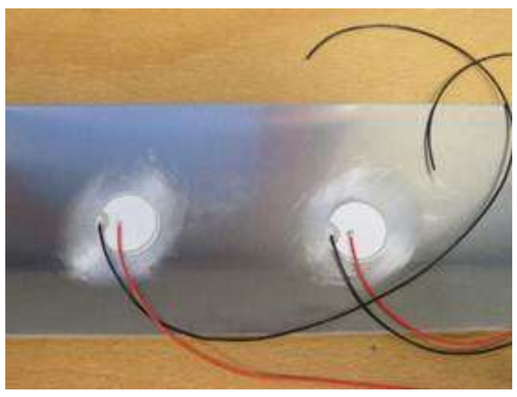


Simulation of Lamb wave propagation in a composite board

“The works on LWDS hardware as regard reliability will consist in characterizing the piezo sensors coupling with the structure and to identify unreliability sources and establish process that offer a good reproducibility and a low aging.

ReMAP Sensing Technology

The assumed main sources are the glue itself because of thermal dependency and aging, and the gluing process which may introduce variations in coupling. However, some variations such as sensors dispersion or sensors thermal dependency may be managed by appropriate calibrations. For that, an auto-diagnostic based on the measurement of the sensor electric impedance can provide a way to check the coupling with the structure is still satisfying and to calibrate the sensor. These calibrations could be implemented in the software in addition to other functions.



Sensorization of a structure

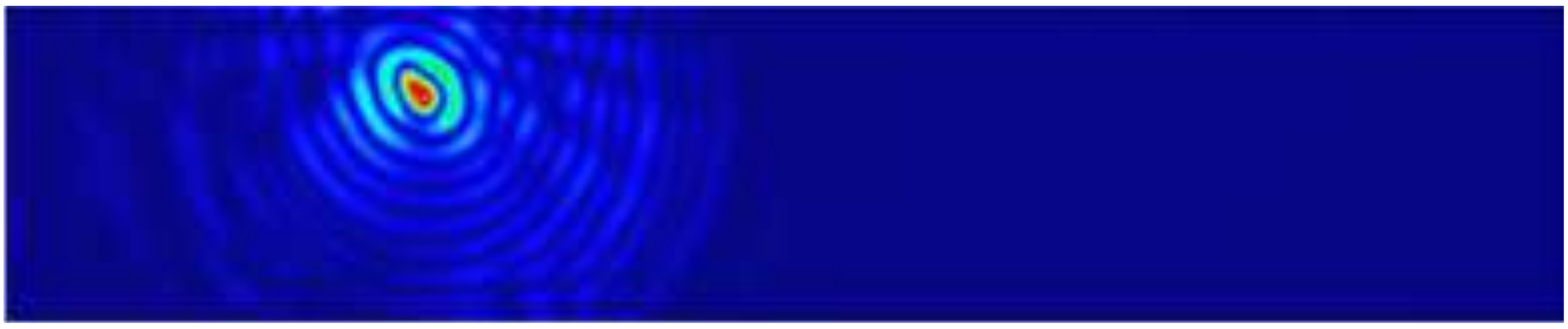
For example, the software might allow to support one fail sensor to provide the required SHM in a reliable way by exploiting all other sensors. Then, if the LWDS complete system is fault tolerant, the SHM would become highly reliable."

3-What is the importance of your work in the overall ReMAP solution?

"The LWDS is a SHM solution able to detect and monitor some damage growth in composite structure that cannot be detected by other techniques. It will be required to implement this monitoring on all Aircraft parts subjected to wear and exposed to impacts, in order to permit a Real-time CBM for Aircraft."

4-What are the main challenges you are facing so far? (e.g., technically, procedural/ organization, procurement)

"Today the LWDS hardware has been developed to get rapidly a platform for algorithm and software development. Efforts are done to add functionalities in the electronics to offer the maximal flexibilities to allow such development. In parallel, works are starting to assess the piezo coupling for sensor reliability. The challenge will be to find the right gluing process to get a good reproducibility.



Simulation of damage detection using Lamb Waves

Later, one usual difficulty is to generate well-defined and reproducible damages such as delamination to test and improve the LWDS. In a longer term, the main challenge for the development of the LWDS will be to make it applicable to very various structural parts and damages and to ensure it detect all types of damages including small one. Lamb waves

ReMAP Sensing Technology

propagation depends on the skin thickness and the presence of stiffeners, in addition to strong frequency dependence. This offers in principle a way to tune the LWDS to the situation, but in practice, the number of situations to manage is maybe larger than can be analyzed in ReMAP framework. Besides these hardware features, the challenges are mainly related with SHM algorithms and the number of active elements as PZT to enables the detection of different damages with small sizes on different materials."

For our French readers, this article gives an overview of the work implemented by CTEC: https://www.cedrat-technologies.com/fileadmin/user_upload/CTEC/Publications/Press%20releases/REMAP_Project.pdf

ReMAP & Science

ReMAP is a project in which industry and scientists work together. At this moment three PhD's work on ReMAP during the whole four years of this programme. Eventually they will promote on these studies. These PhD's are connected to the Faculty of Aerospace of the Technical University of Delft. In this newsletter they are being introduced.

Our PhD students @TUDelft

Agnes Broer

Nationality: Dutch

Age: 25

Degree: MSc in Aerospace Engineering at TU Delft

"One of the main objectives of the ReMAP project is to develop diagnostic methodologies for aircraft structures. In order to monitor possible damage during operation, different sensors will be attached to the structure. Their combination can lead to a more complete image of the damage, since each sensing technique only provides limited information on the damage. One can compare this to the human body: humans use different senses such as the eyes and ears, which each have their own expertise. Hence, rather than choosing one sense, we combine them to get a full image of our surroundings. In my PhD research, I evaluate how a similar concept can be applied to the field of structural health monitoring by focusing on the combination of sensing techniques and the fusion of their data. For this, I am developing a multi-sensing structural health monitoring framework to diagnose disbonds in stiffened composite aircraft structures.

Additionally, I focus on the application of these fusion techniques to more complex structures by investigating the ability to upscale. Methods are often developed at simpler structural elements such as coupons or plates. My research evaluates how the developed methods can be applied to more complex structural elements such as multi-stiffener panels or a wing box. The conclusions and results of this research can be used as a first step towards the ambition of applying the diagnostic methods to aircraft structures."

ReMAP & Science

Daniel Marta

Nationality: Portuguese

Age: 28

Degree: MSc in Aerospace Engineering at Technical University of Lisbon

After concluding his MSc in Aerospace Engineering, Daniel conducted research in robotics, specifically on planning and control at the Institute for Systems and Robotics (ISR-Lisboa). Following that period, Daniel developed and implemented algorithms, as a research engineer in self-driving technology and machine learning, for a start-up (Latent Logic) at an Oxford based hub.

Daniel took ReMAP as a challenge for his PhD project to research and implement novel machine learning conditioned based planning and scheduling algorithms in the scope of aircraft maintenance operations.
One main objective in the ReMAP project is to incorporate diagnostics and prognostics on future decisions, replacing fixed-time replacements with a more comprehensive approach, e.g, taking into account the airworthiness of the components. Daniel's research focusses exactly on that. The result should be a decision-support tool that will assist maintenance planners in their planning of maintenance activities. Daniel will use the data that is now being available from new sensor and diagnostics techniques which are a result from other ReMAP-workpackages.

Juseong Lee

Nationality: South Korea

Age: 28

Degree: MSc in Aerospace Engineering at Korea Advanced Institute of Science and Technology

Simulate the safety risk of CBM aircraft maintenance

Not only higher efficiency but also safety must be ensured to successfully implement CBM for an aircraft. Aircraft maintenance is a dynamic and complex process in which multiple stakeholders are involved. Safety concerns have been limiting the adaptation of CBM as a possible aircraft maintenance process. ReMAP gives the opportunity to define the complete process of aircraft maintenance for the first time for CBM.

Juseong: "I will identify the aircraft maintenance system with the associated hazards and transform this into a model. Not only will I use data-driven analysis of accidents and incidents but I will also use expert opinions to identify the maintenance

ReMAP & Science

system and its hazards. The aircraft maintenance system is modelled as a stochastic process with an agent-based approach. Stochastically dynamically coloured Petri net (SDCPN) will be used to formalize the model. From that, I develop a Monte Carlo simulation tool to assess the safety risk of CBM. I will conduct a sensitivity analysis of aircraft maintenance strategies and assess the impact on safety risks. As a result, I will identify hazards and safety barriers to guide the development of models and provide a methodology to assess the safety risk of the aircraft maintenance system."

ReMAP Seminars **'ACDM on ReMAP. The plan' – one year later**

Building on the first Software Architecture Open Lecture organised one year ago by IPN at the University of Coimbra, a second edition was now given to the Master Students from the Department of Informatics Engineering.
Architecture Centric Design Method (ACDM) is a technical process proposed by Anthony J. Lattanze (Carnegie Mellon University and Software Engineering Institute) to develop the architecture of Software Intensive Systems. A customization of this approach, for requirements elicitation and software architecture development and evaluation, is being used in the Work Package 2 of ReMAP (Requirements Management & Development of the IT platform).
The first edition of this case study was presented to ICT Master Students, to demonstrate the use of ACDM on a real large-scale project and how following a structured and proven process can help address project uncertainties.
The 2019 edition of the seminar focused on the gaps between the plans and reality, and how the ReMAP team addressed the challenges faced so far.

ReMAP & Events

Upcoming Events

SMART 2019 - 9th ECCOMAS Thematic Conference on Smart Structures and Materials

8 - 12 July 2019, Paris, France

SMART 2019 will aim at providing a comprehensive forum for discussing current state of the art in the field of smart structures and materials as well as at developing future ideas on a multidisciplinary level.

IWSHM 2019 - 12th International Workshop on Structural Health Monitoring

10 - 12 September 2019, Stanford, California, USA

The focus of the workshop is to promote applications of SHM technologies and to encourage interaction between industry and academia. The workshop places significant emphasis on industrial applications including aerospace, ground transportation systems, and civil infrastructures.

SMAR 2019 - 5th International Conference on Smart Monitoring, Assessment and Rehabilitation of Civil Structures

27 - 29 August 2019, Potsdam, Germany

The International Conference on Smart Monitoring, Assessment and Rehabilitation of Civil Structures, SMAR 2019, will provide a forum for international scientists, engineers, enterprisers and infrastructure managers to present and discuss the state-of-the-practice and recent advances in testing and monitoring technology, in structural modelling and assessment methods, and in the application of advanced materials for structural rehabilitation. The conference will provide a platform for exploring the potential of international cooperation.

SMART Maintenance Conference 2019

27 - 29 August 2019, Potsdam, Germany

To explore new perspectives in intelligent maintenance systems, this conference gathers renowned speakers from varied backgrounds, including railway, automotive and aerospace industry, academics and others.

Know us - Introduction to ReMAP partners

In the first newsletter the TU Delft was introduced. In this newsletter ATOS and CTEC are presented. The focus of the company as a whole is mentioned and its role in ReMAP.

ATOS: leading the digital transformation

Atos is a global leader in digital transformation with 120,000 employees in 73 countries and annual revenue of € 13 billion. European number one in Cloud, Cybersecurity and High-Performance Computing, the Group provides end-to-end Orchestrated Hybrid Cloud, Big Data, Business Applications and Digital Workplace solutions through its Digital Transformation Factory, as well as transactional services through Worldline, the European leader in the payment industry. With its cutting-edge technologies and industry knowledge, Atos supports the digital transformation of its clients across all business sectors. The Group is the Worldwide Information Technology Partner for the Olympic & Paralympic Games and operates under the brands Atos, Atos Syntel, Unify and Worldline. Atos is listed on the CAC40 Paris stock index.
Atos Research and Innovation is the R&D Hub for emerging technologies and a key reference for the whole Atos group. With almost 30 years of experience in running Research, Development and Innovation projects, they have become a well-known player in the EU context. The multidisciplinary and multicultural team has the skills to cover all the activities needed to run projects successfully, from scientific leadership to partnership coordination, from development of emerging technologies to the exploitation of project outcomes, with a strong focus on marketing, communications, business development, innovation adoption and commercialization.

The Transport Sector at ARI has the mission to design and operate digital services and platforms to support transport players transform for tomorrow’s data-driven, multimodal transport economy, leveraging best of innovative technologies and business models for creating value for private and public stakeholders involved in the mobility and logistics sector. As the world becomes increasingly smart and connected, the sector must respond to customer demands and expectation

Know us - Introduction to ReMAP partners

undergoing unprecedent digital transportation. As ICT provider, ATOS is leading the requirements elicitation & IT platform specification with a special focus on the design of the IT ReMAP ecosystem and the deployment and integration features as part of “Requirements Management and IT Infrastructure” on WP2. Moreover, ATOS will contribute actively to the data analytics services and in the exploitation and business models activities.

Contact point in ReMAP:

German Herrero, Project Manager. E-mail: german.herrero@atos.net

CTEC – Compact, dynamic and precise mechatronics solutions for demanding environments

CTEC is a growing high-tech SME based in the French Innovation Valley close to Grenoble, specialized in the following domains: Smart Actuators based of piezoelectric ceramics, Smart sensors based on magnetic or piezoelectric technologies, Mechatronic systems with several degrees of freedom for various applications like Active Damping or proportional valves, Detection systems dedicated to Structural Health Monitoring (SHM) and Non Destructive Testing (NDT).
In all these domains, CTEC designs, manufactures and tests components, systems and associated electronics following customers’ requirements and keeping the objective to achieve both technical and marketing success. CTEC has developed its expertise from space activities and is now spreading it to aircraft, instrumentation, optics, machine tools and medical applications.

In ReMAP project, CTEC is the leader of WP3 “SHM Sensors technologies” and has the responsibility of providing piezo actuators transducers and sensors with electronics. As a technology provider of these devices, CTEC will design, provide and manufacture these parts, to cover both low frequency sonic range (with APA®) and high frequency ultrasonic range. The integration of the sensors is also part of CTEC’s work and will be carefully defined to make the damage detection more reliable.

Contact Point in ReMAP:

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ReMAP Real-time Condition-based Maintenance for Adaptive Aircraft Maintenance Planning

Fly with us in this trip to the future of aviation

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