NEWSLETTER

Issue #1 | Dec. 2023

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Project coordinator
R&D Engineer at ITAINNOVA | Instituto Tecnológico de Aragón

Dear Reader,

I am glad to share with you Issue#1 of the GENEX Newsletter.

The "Next end-to-end digital framework for optimized manufacturing and maintenance of next-generation aircraft composite structures" GENEX is a 42-month Horizon Europe project launched on September 1, 2022. GENEX is led by ITAINNOVA (ITA) and commits to work towards EU goals by developing three pioneering technological assets which, through integration, will lead to a multi-disciplinary digital twin of the component throughout its lifecycle for the next generation aircraft composite structures. The project objectives will be achieved via the development of three main blocks of technological assets.

More than a year since the project started, several targets have been met highlighting GENEX's progress, by analyzing the market of composite materials, testing the capabilities of sensors to monitor the use of the structure, and drafting the digitalization of repair activities.

GENEX fosters tutoring young researchers and employees on the advancements in the next-generation digital aircraft transformation in design, manufacturing, integration, and maintenance by organizing yearly workshops and training courses and delivering a lifelong learning module by the end of the project.

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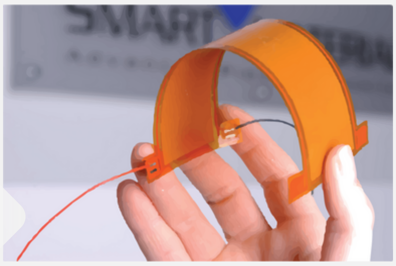
Advanced and efficient manufacturing of recyclable components

This is the first technological block, unfolded in the frame of Work Package 2 (WP2) of the project and led by AIMEN, with the overall scope to develop eco-efficient materials and to validate its processability, by a monitored layup system coupled with numerical models, for optimized manufacturing of novel 3R-resin composites and advanced high-performance ThermoPlastics (TP) composites.

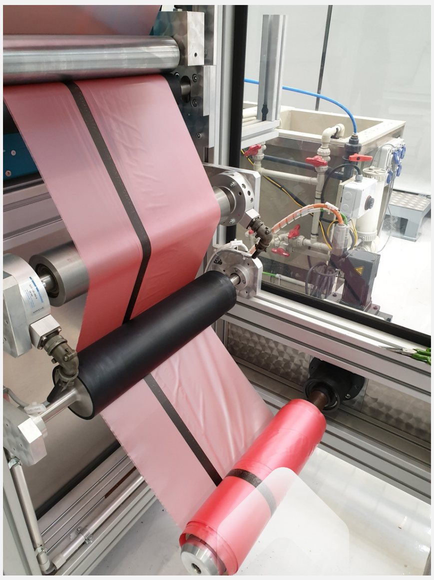
*"Our goal is to produce **eco-efficient materials** and processes, monitoring systems, and numerical models supporting **advanced manufacturing** of composite aircraft components"*

Raquel Pérez Varela
Project Manager R&D&I



Development of optimized MFC piezoelectric sensors

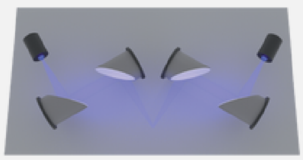
Embedded MFC sensors



Recyclable 3R composite tapes with embedded FOS

Automated Tape Laying (ATL) of 3R tapes for in-situ consolidation

Online control of manufacturing parameters



Online TDS for curing monitoring

The tasks forming the first technological block developed within GENEX

Develop of enduring prepregs for the aeronautical sector base on dynamic epoxy resins

This task is led by CIDETEC and it is consisted of two main objectives:
i) formulation and characterization of aeronautical grade 3R resins and ii) development of carbon fibre (CF) reinforced non-perishable prepreg tapes with integrated fibre optic sensors and based on 3R resins that will be used to obtain composites by AIMEN through the AFP (Automated Fibre Placement) process. CIDETEC´s patented 3R technology allows to develop thermosetting composites that are inherently Reprocessable, Recyclable and Repairable (3R).

Recyclable 3R composite tapes with embedded Fiber Optic Sensors (FOS)

These materials are very interesting for sectors as diverse as energy, transport or construction, since they maintain the high performance of conventional thermoset composites and are processable by common manufacturing technologies. The use of prepregs is one of the methods used to manufacture thermosetting composites and the dynamic character of 3R epoxy resin allows to manufacture novel, non-perishable prepregs (enduring prepregs) with the advantage that they can be stored at room temperature without losing their intrinsic properties for the manufacture of parts with high mechanical requirements for the aeronautical sector.

Advanced composite laminates manufacturing

AIMEN oversees the development of the AFP (Automated Fibre Placement) processing windows for in-situ consolidation of the 3R resin developed by CIDETEC with a complete degree of cure (DoC), and in-situ consolidation for an alternative TP material with a customized degree of Crystallization (DoCr). During the manufacturing process, piezoelectric Macro Fiber composite (MFC) sensors will be embedded in the laminate which will be used for the UGW (Ultrasonic Guided Wave) inspection in WP3.

Among the benefits of the innovative fabrication method of AFP are the fiber direction accuracy and the reduced amount of waste material. Besides, ENSAM is focussed on the modelling of the evolution of the DoC and the DoCr during the lay-up of CF/3R-resin and CF/TP-tapes, respectively, for in-situ consolidation and RECENDT is setting an on-line Terahertz (THz) spectroscopy (TDS)-based in-process monitoring system to quantify the evolution of the DoC and the DoCr during the lay-up process of 3R-resin and TP tapes, respectively.

On a communication level, GENEX was presented at the annual national conference about composite materials, MATCOMP23 (https://www.matcomp23.org/es/), in June, 2023, in Gijón, Spain. The aspirations and objectives of GENEX were presented, by Aratz Genua from CIDETEC, along with the work in progress on the 3R prepregs tapes with embedded FOS for the ATL process in the frame of the project.

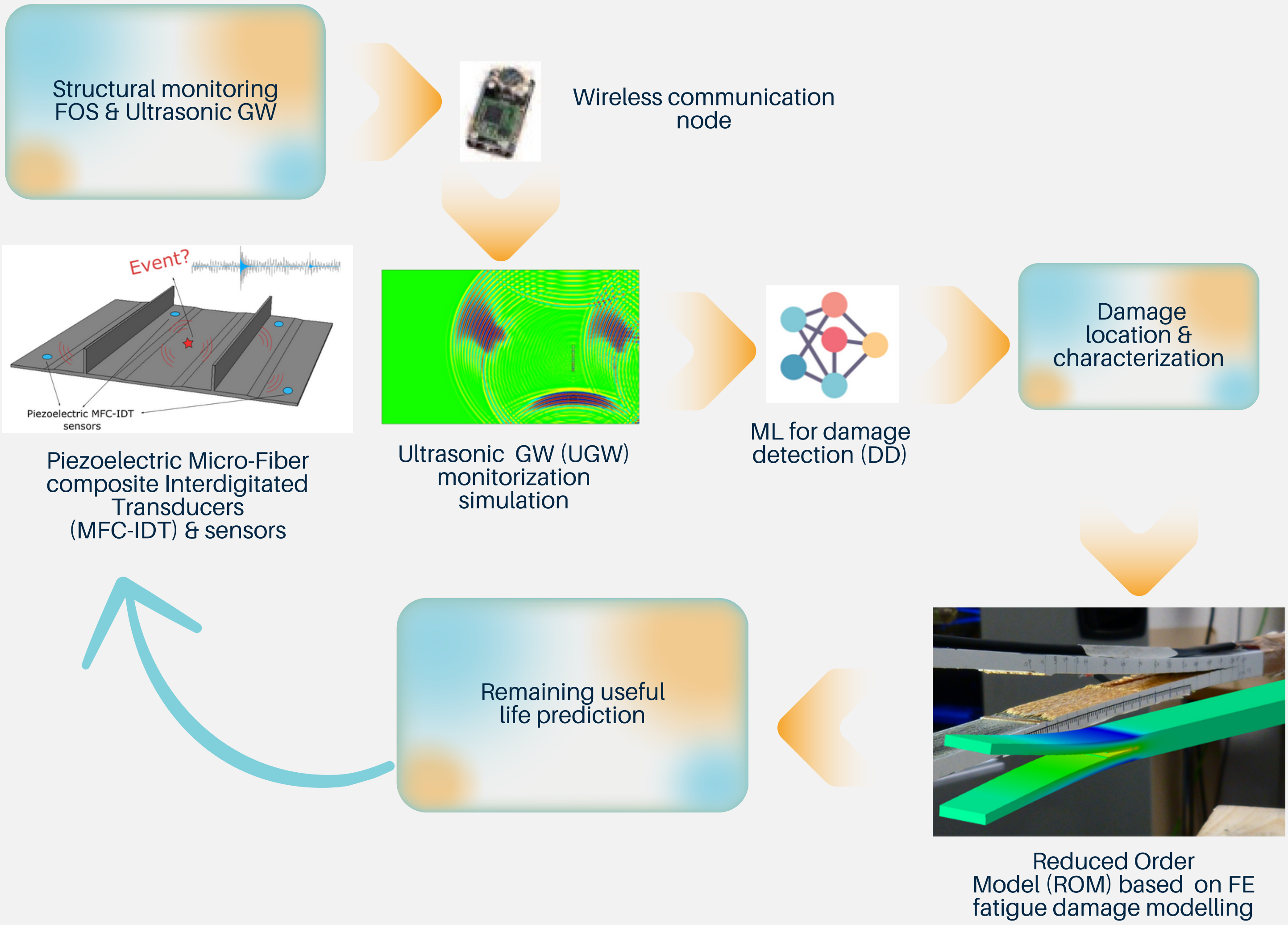
CIDETEC's representative, Aratz Genua, presenting the GENEX project at the MATCOMP 2023, conference, in Gijon, Spain.

Next steps

The advanced and efficient manufacturing of recyclable components (WP2) will contribute to the overall ambition of the GENEX project by developing different technologies: the impregnation of CF-reinforced tapes based on novel thermoplastic-like thermoset resin (named 3D-resin); The AFP for in-situ consolidation of the composite laminate plies; an innovative monitoring system based on THz spectroscopy for quantifying the percentage of cross-linked structures; and a multi-scale fully coupled simulation of the ATL process for real-time process optimization, ensuring the required performance of the final composite part. All these technologies will be validated in WP5 with the elaboration of the two representative prototypes of GENEX's target application case.

Integral health and usage monitoring system of aerostructures

This is the second pioneering technological block, developed within the WP3 of the project aiming to enhance aircraft availability and lifespan by shifting from preventive to predictive maintenance, eliminating periodic inspection and reducing maintenance costs. This involves adopting condition- and usage-based maintenance strategies using data from wireless sensor networks embedded in the structure to achieve effective Health and Usage Monitoring & Management (HUM&M) of the aircraft.



The tasks forming the second technological block developed within GENEX

The leader of this task is ITAINNOVA, while IRES is developing Machine Learning (ML)-based tools to identify damage locations using synthetic data from Finite Element Method (FEM) simulations, from an open-source code developed by KTH.

ITAINNOVA is characterizing composite material damage parameters for numerical modelling, AGH has devised an experimental setup to evaluate MFC directivity patterns and CSEM has created a wireless data prototype to recover MFC sensing network data.

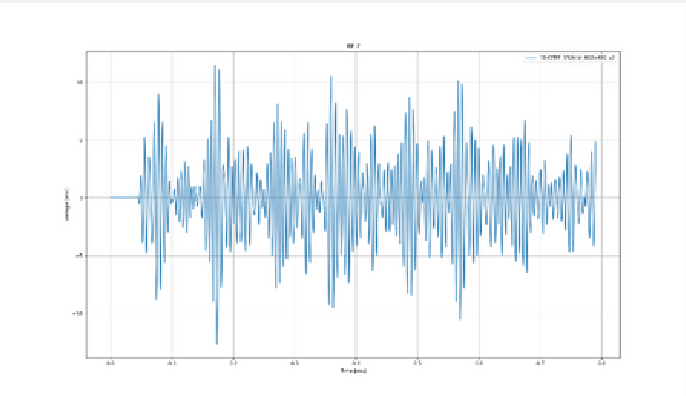
*"Our purpose is to invent a methodology built on **coupled physics** and **data-based algorithms** to improve the assessment of fatigue damage and residual life estimation of the aircraft structure under variable usage scenarios"*

José Manuel Royo
R&D Engineer

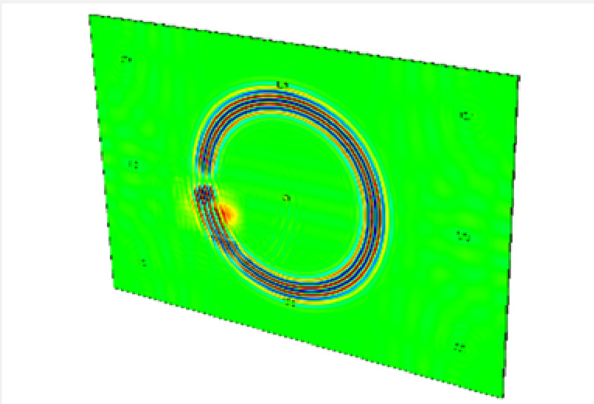
ITAINNOVA INSTITUTO TECNOLÓGICO DE ARAGÓN

Model-based ML algorithms for structural damage prediction

Model-based ML algorithms for structural damage prediction is the first task of WP3, forming Task 3.1, and is led by IRES. A Design of Experiments (DoE) was utilized to analyze a composite plate's damage location FEM simulations. This produced an initial dataset, enabling feature engineering and the creation of a ML regression model for damage location prediction.



Temporal evolution of the simulated voltage output in a transducer obtained by means of FE simulations



FE simulation model of the ultrasonic guided waves propagation in a composite plate with a delaminated area

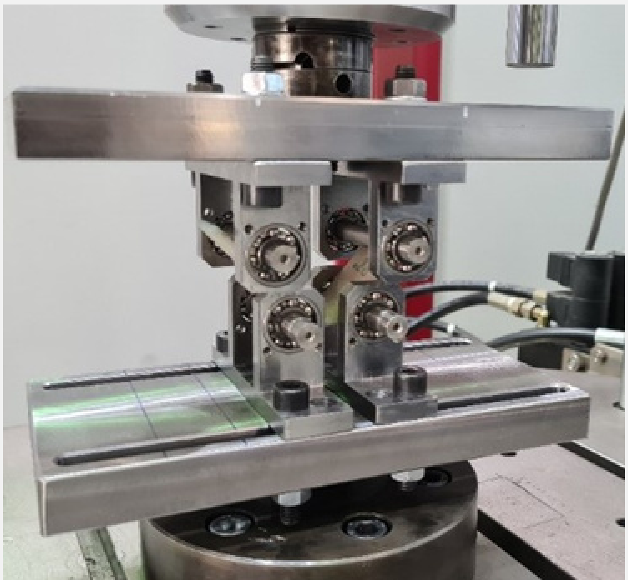
Enhanced damage computational models for real-time structural reliability assessment

The second task of WP3, Task 3.2, involves a comprehensive testing campaign on composite specimens to validate computational models and establish an experimental framework for comparison. Double Cantilever Beam (DCB) specimens with AERN materials were tested, and Macro Fiber Composites (MFC) transducers were employed to validate FEM simulations for Ultrasonic Guided Wave (UGW) inspections. Additionally, a four-point bending test fixture was developed for spar unfolding tests.

Test rig configuration for the DCB characterization tests of composite material fracture properties

DCB specimens manufactured for the test

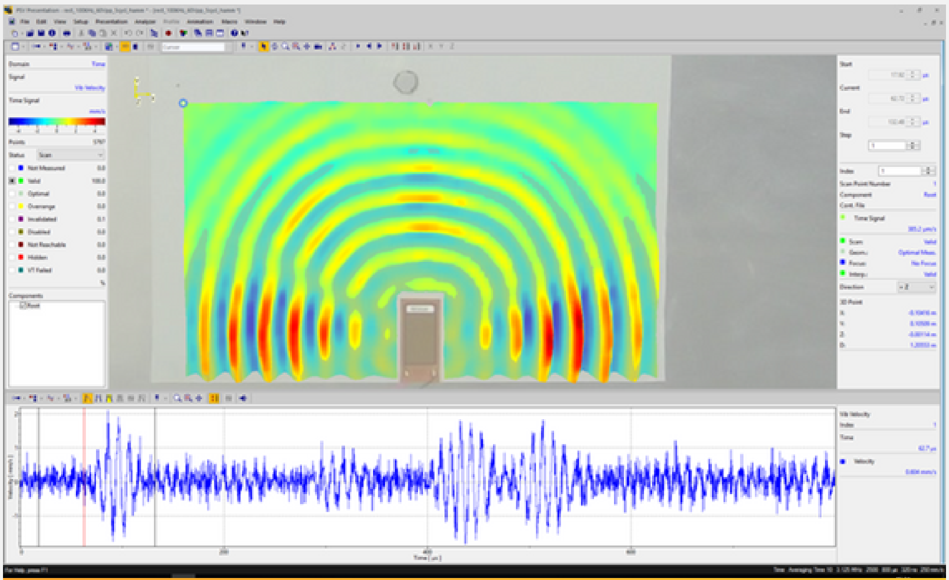
DCB specimen instrumented with MFC transducers to perform UGW tests that will be used to validate FE simulations



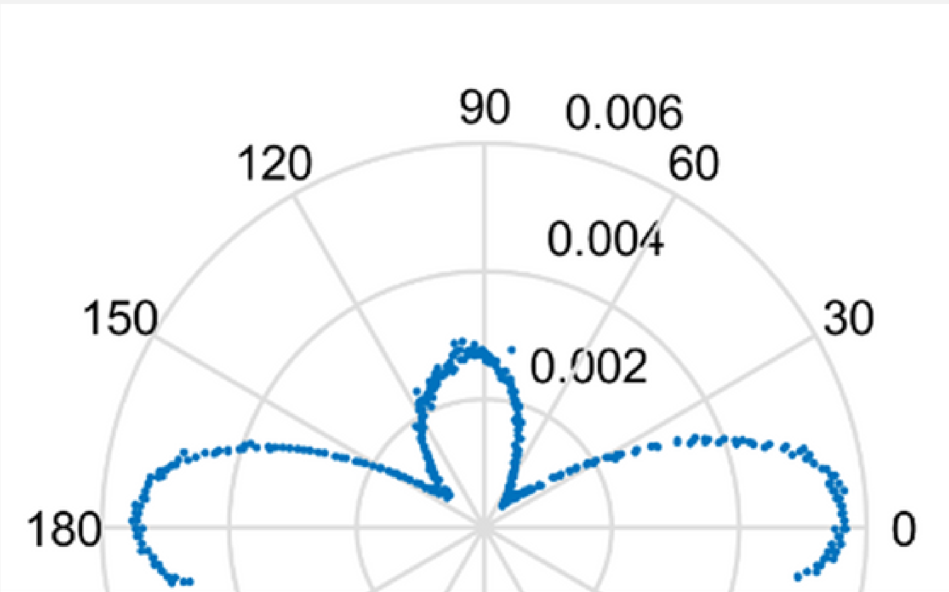
Test fixture for performing four-point bending (4PB) experiments on an L-angle specimen

Piezoelectric MFC sensors optimization

Task 3.3, led by AGH, focuses on characterizing MFC transducers' radiation characteristics and beam-shaping abilities. An experimental setup was devised to evaluate the transducers' directivity patterns.



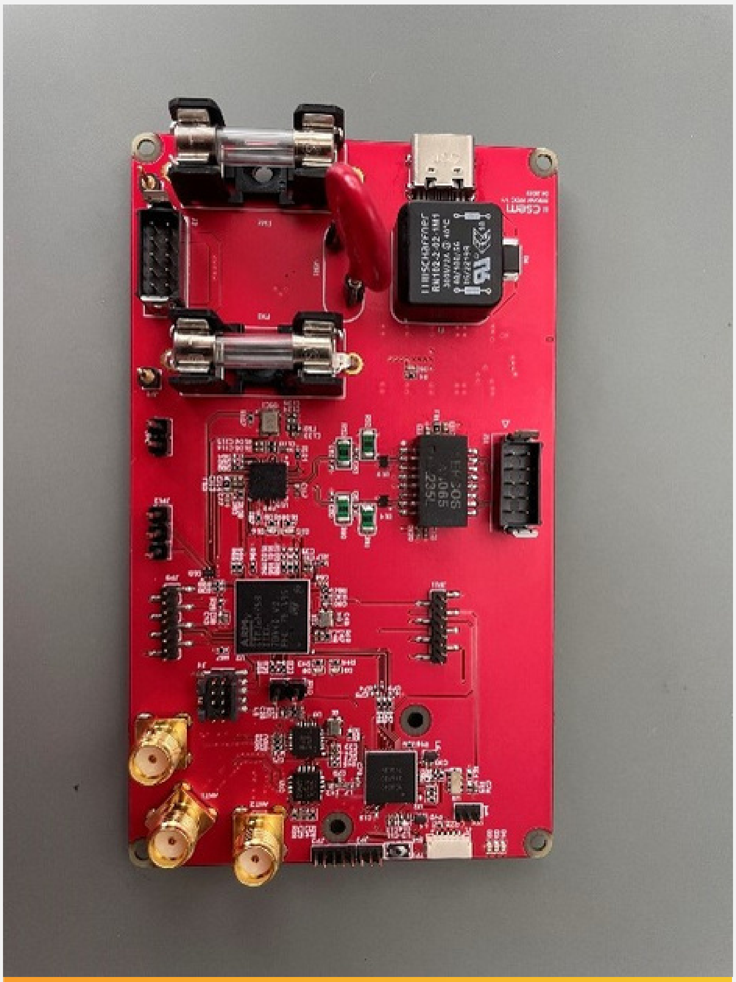
An example of the wavefield generated by the MFC transducer obtained using a scanning laser Doppler vibrometer (SLDV) as a sensor



An example of the directivity pattern generated by the MFC transducer and calculated using the SLDV measurements.

Wireless sensor communication platform

Task 3.4, led by CSEM, centered on designing a wireless data concentrator and developing a demonstrator for piezo control and data acquisition. Piezoelectric burst generation tests were conducted to assess the design's effectiveness.



Prototype of the wireless concentrator node

Next steps

Upcoming activities include developing a FE model for the project’s demonstrator, enhancements to ML algorithms for defect localization, and postprocessing of DCB test results. Characterization of composite material damage parameters and a review of predictive methods for fatigue delamination growth and addressing anisotropy in MFC transducers are also planned. Finally, a radio interface, following the latest WAIC standard and a piezo control and data acquisition system will be developed.

Digitally-assisted repair processes and tools

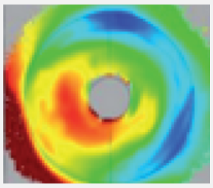
This technological asset forms the third tech block of the GENEX project, is led by DLR, and constitutes the fourth work package (WP4) of the project. The latter is aimed at developing new digital-based processes and tools to support, automate and improve the efficiency and performance of repairing operations applied during the bonded scarf repair of composite laminate prototypes. It will provide innovative repair methods and processes to the GENEX demonstrator.

*"We are devoted to develop **pioneering digital-based processes** and **tools** to optimize **maintenance** and **repair** operations while assisting the digital transformation of composite repair"*

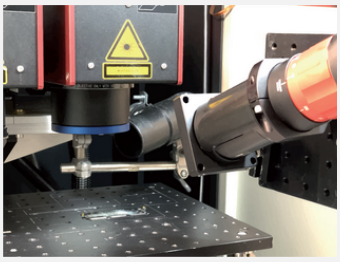
Dirk Holzhueter
Engineer at DLR

DLR Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

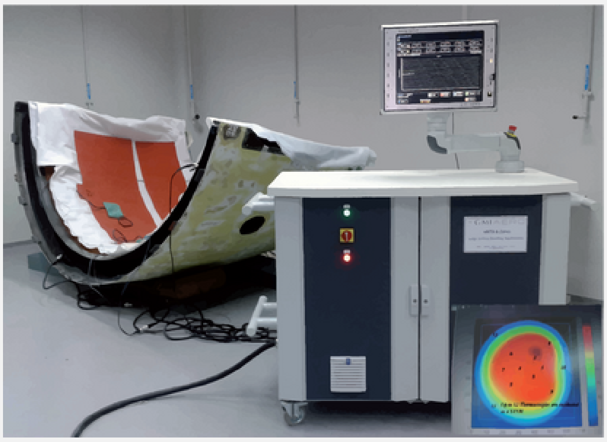
The fourth tech block, developed in the frame of GENEX, comprises four main tasks.



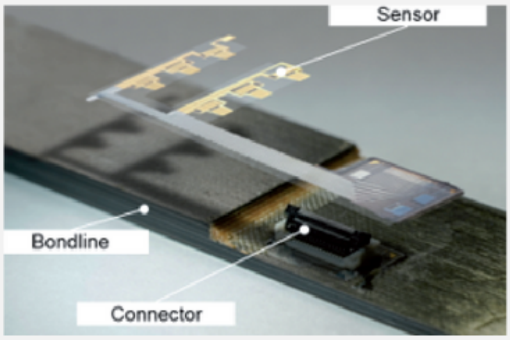
Visual assistance system for manual composite scarf repair

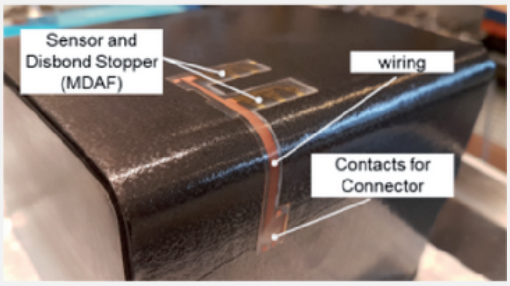


Laser-induced breakdown spectroscopy system for in-situ surface conditioning characterization prior to repair bonding



Digital twin for improved design of the composite repair heating blanket





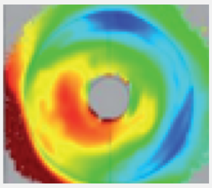
Smart composite repair patch for detecting and stopping cracks

The four tasks forming the third technological block developed within GENEX

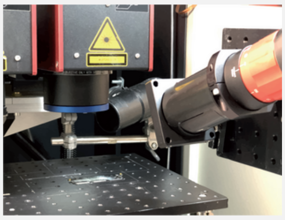
WP4 is expected to result in new digital-based processes and tools to support, automating and improving the efficiency and performance of repairing operations applied during the bonded scarf repair of composite laminate prototypes. It will provide innovative repair methods and processes to the GENEX demonstrator.

Visual assistance system for manual composite scarf repair

The goal of this task, led by DLR, is to support operators during manual grinding of composite scarf repair. A visual assistance system will be mounted using a structured light sensor to scan the geometry and a projector to draw guidance images during the repair process onto the surface. Statistical algorithms will be implemented in the control software (Point Cloud Library) to filter, smooth, and remove noise from the scanned point cloud. A best-fit algorithm based on markers will be used to align the scanned point cloud with the nominal geometry of the scarf to ensure high accuracy. As a result, a colored image will be generated, projected, and continuously updated onto the surface in the form of contour lines, indicating the deviation between the actual and the nominal geometry during the grinding of the scarf. Lab-scale tests will be performed on small damaged flat and curve specimens to evaluate the system's reliability. Trials on non-traditional contours with experienced technicians will be carried out to identify suitable repair scenarios and to quantify/validate the performance of the system.



Visual assistance system for manual composite scarf repair



Novel laser-induced breakdown spectroscopy for cleaning and control of surface preparation of bonding

Laser-ablation system coupled with LIBS module for surface preparation of scarf repair

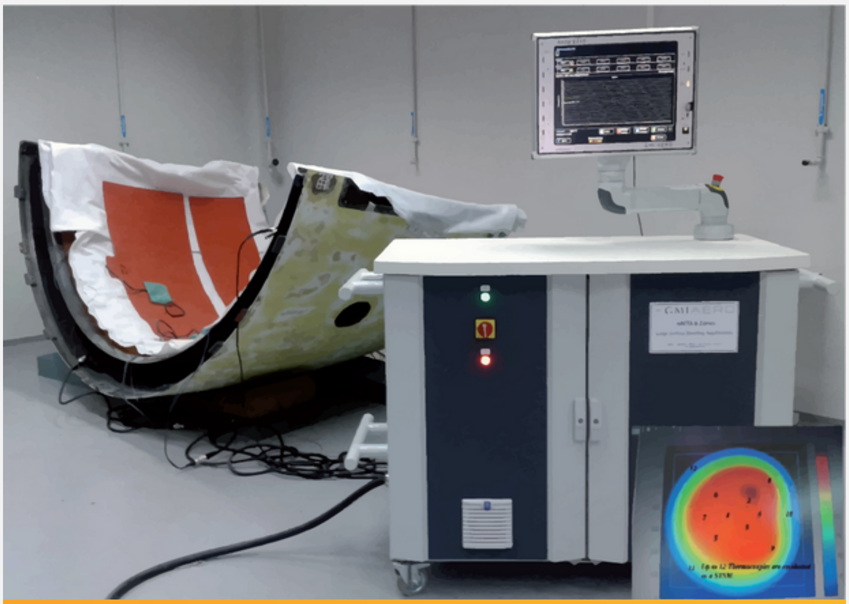
The aim of this task, led by AIMEN, is to develop a novel portable short-pulse laser system to perform surface preparation verfication based on high-resolution Laser Induced Breakdown Spectroscopy (LIBS) monitoring. To verify the effectiveness of the cleaning process of the sample, a high-resolution (spectral, temporal, and spatial) LIBS will be set up to distinguish between desired and undesired elements on the workpiece based on data analysis of the emitted plasma spectrum. The representative features of LIBS data will be investigated and registered synchronously enabling compositional mapping of the surface status at any given time. Based on the previous results, a portable LIBS mapping system will be designed to be employed in the GENEX demonstrator.

At this stage of the project, a first hardware setup of DLRs Visual Assisted Scarf Process has been successfully completed and further trials are planned to adapt the system to the GENEX use cases. More specifically, DLR completed the hardware definition for the visual-assisted scarfing system and started first trials to evaluate scanning precision and projection quality. A first assessment of need interface capabilities was made and a first design of the interface has been developed. Additionally, initial LIBS tests carried out in a lab workstation were successful on discriminating contaminated (e.g. with oil, grease, etc.) from clean surfaces.

Digital transformative composite repair heating

The aim of this task, led by ITAINNOVA, is to provide the composite repair heating process, performed by GMI, with the following digital solutions:

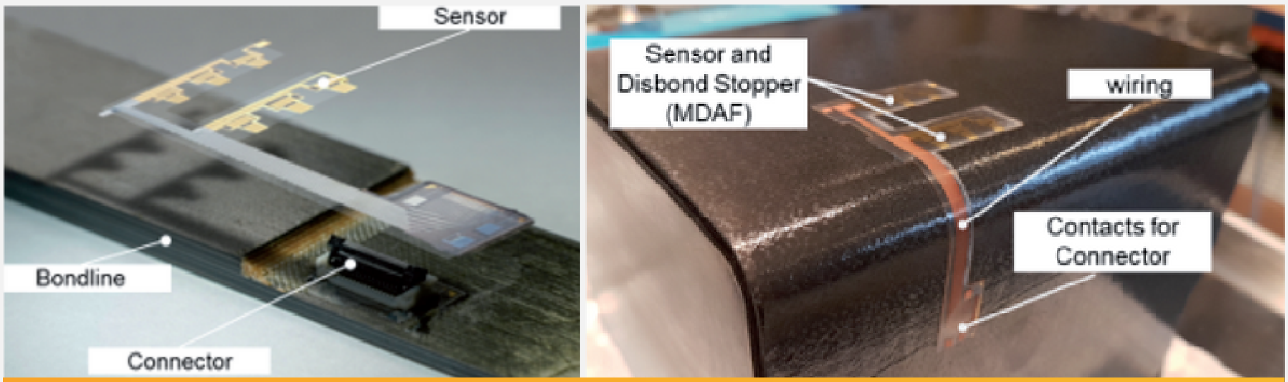
- Digitally assisted blanket design: A design methodology of the heat source geometry will be developed based on a numerical tool to simulate the heat transfer during the bonding process of composite part repairs.
- Online control of the repair bonding process: An advanced strategy for thermal control of the repair bonding process will be developed based on temperature control to optimize the heat generation and diffusion during composite repair.



Digital twin for improved design of the composite repair heating blanket

Smart bonded composite repair solution

The focus of this task, led by DLR, is to investigate a novel multifunctional bondline concept based on a multifunctional disbond arrest feature (MDAF) sensor capable of detecting and stopping cracks and allowing for continuous monitoring of the bondline state.



Smart composite repair patch for detecting and stopping cracks

Next steps

Currently, DLR is working on the definition of a test case as a preparation for the application on the GENEX demonstrator. Further testing of LIBS monitoring by using different laser wavelengths and acquisition components and parameters will be carried out. The laser will be used to ablate the surface and thereby clean any contaminants. Finally, DLR is working on integrating a fibre optics strain sensing system (FOSS) into the multifunctional disbond arrest feature (MDAF) of the smart patch repair to overcome robustness issues of the current design. Meanwhile, GMI and ITAINNOVA are working together on the definition of an efficient numerical model to predict temperature distribution during resistance heating repair.

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