NEWSLETTER

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GENEX

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Dear Reader,

We are glad to share with you **Issue 3 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 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 have been achieved via the development of three main blocks of technological assets.**

The current issue is dedicated to the dissemination activities of the project during the last six months, including the participation of the GENEX partners in prestigious aviation conferences.

Finally, we are pleased to announce the **upcoming final event** in **Zaragoza, Spain**, marking the completion of the project in **February 2026**.

Enjoy the read!

On behalf of **Dr. Andrea Calvo Echenique**
Project coordinator

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GENEX **partners**

All Grating Fiber Sensors Revolutionize Composite Manufacturing

Lightweight yet strong, composite materials are transforming aerospace design from fuselage panels to wing skins. These advanced structures combine a polymer matrix with carbon or glass fibers, delivering exceptional performance. To manufacture them, **Automated Tape Layering (ATL)** places carbon fiber tapes layer by layer, but ensuring perfect consolidation is critical.
For this reason, **Fiber Optic Sensors (FOS),** highly sensitive and immune to interference, are applied.

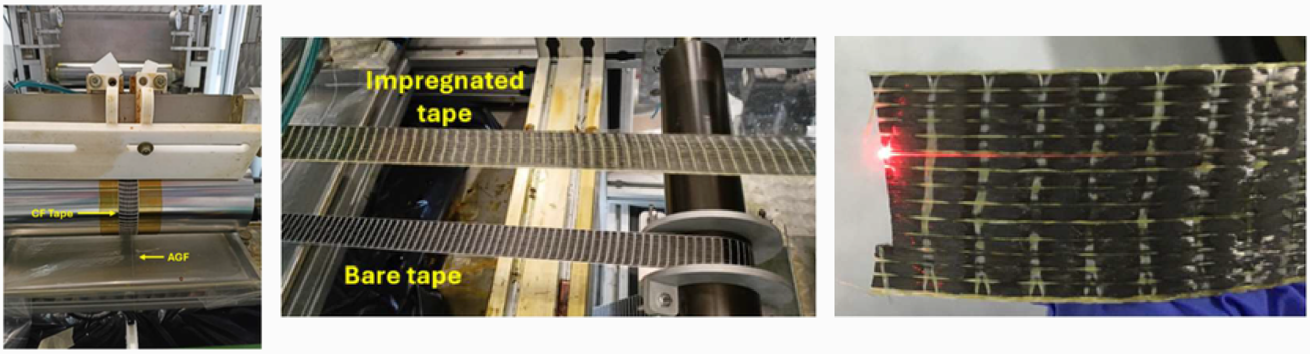

Figure 1. (From left to right): Impregnation of the tape and the FOS; Comparation between the impregnated tape ready to be spooled and the uncoated one (Property of CIDETEC); detail of the fiber embedded in the tape, illuminated by a red diode laser.

In the **GENEX project,** researchers from **AIMEN**, in collaboration with CIDETEC embedded **All-Grating Fiber (AGF)** sensors directly into carbon fiber tapes, creating a distributed monitoring system that tracks temperature and strain in real time. The results? Flawless integration, robust performance, and defect-free fibers, confirmed through microstructural validation. This innovation opens the door to smarter, more reliable composite manufacturing and sets a new standard for ATL process quality.

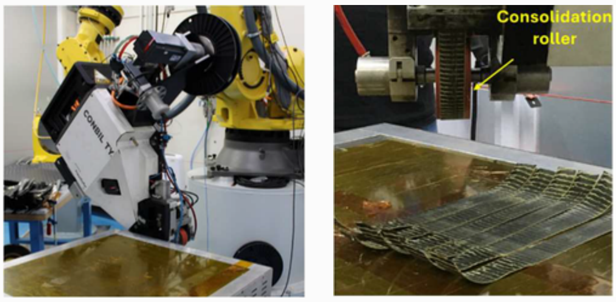

Figure 2. (From left to right): Photographs of the ATL machine; the system with the robotic arm; and the details of the consolidating head, and the roller.

Based on this work, **Marta Castiñeiras Nespereira (AIMEN)** prepared and presented the paper, "***Smart Tape for Monitoring the Automated Tape Layering Process Using All-Grating Fiber Sensors***," at the **29th International Conference on Optical Fiber Sensors,** taking place May 25–30 in Porto, Portugal.

Smart Tape for Monitoring the Automated Tape Layering Process Using All-Grating Fiber Sensors

Boosting Bond Strength: TPU Toughening for Safer Aircraft Structures

Bonded joints are lighter and more efficient than bolted ones, but they can suffer from fatigue cracks under high loads—a critical challenge in aviation. To tackle this, researchers at the German Aerospace Center (DLR) explored local surface toughening using **Thermoplastic PolyUrethane (TPU)** in adhesive joints.

Through rigorous testing, including **Double Cantilever Beam (DCB)** and Single **Lap Joint (SLJ)** tests, the study revealed that TPU strips significantly enhance joint performance—improving fracture toughness by over 15%. This innovation promises greater damage tolerance and fail-safe designs, paving the way for stronger, more reliable composite structures in next-generation aircraft.

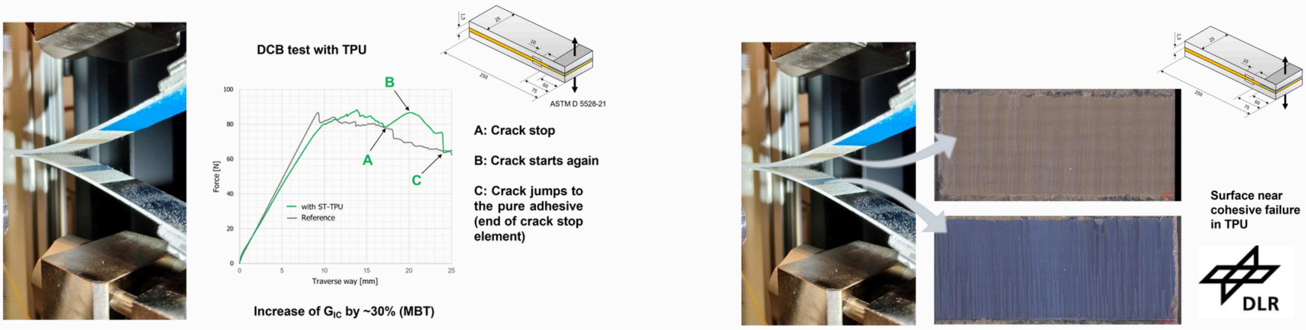

Figure 3. Double Cantilever Beam tests with Thermoplastic PolyUrethane (TPU).

Dr Martin Schollerer (DLR) presented the innovative approach of ***"Local Surface Toughening – Improvement of Stress Resistance by using TPU"***, which improves the strength and reliability of adhesive joints in aircraft structures. While pure adhesive bonds offer weight savings and corrosion resistance, they face challenges under extreme conditions and certification requirements. Traditionally, fail-safe designs combine rivets and adhesives, but these compromise weight and efficiency. This work was presented at the **8th International Conference on Engineering Against Failure**, taking place from June 22 to 25 in Kalamata, Greece.

Figure 4. Martin Schollerer (DLR) at the 8th ICEAF presenting his work on "Local Surface Toughening – Improvement of Stress Resistance by using TPU".

Local Surface Toughening Improvement of Stress Resistance by using TPU

Models for Predicting Fatigue Delamination in Composite Structures

8th ICEAF International Conference of Engineering Against Failure

Composite laminates are the backbone of modern aircraft, but fatigue-driven delamination, especially in curved components, remains a critical challenge. At the **8th ICEAF**, **Dr Carlos Mallor (ITA)** unveiled a breakthrough approach using the **Virtual Crack Closure Technique (VCCT)** to predict how cracks propagate under complex, mixed-mode loading conditions.

The ITA team developed a VCCT-based computational model, integrated into Abaqus via a custom subroutine, to simulate delamination growth using a Paris–Erdogan power-law relationship.

Validated through four-point bending tests on L-shaped CFRP beams with embedded defects, the method accurately forecasts crack evolution under real-world conditions. This innovation enhances predictive maintenance, reduces the risk of catastrophic failures, and deepens understanding of how mixed-mode stresses influence delamination—paving the way for safer, more reliable composite structures in aviation.

Figure 5. Dr Carlos Mallor Turón (ITA) presenting the work on "Predicting fatigue-driven delamination in curved composite laminates under non-constant mixed-mode conditions using a VCCT-based approach" at the 8th ICEAF, in Kalamata, Greece.

Predicting fatigue-driven delamination in curved composite laminates under non-constant mixed-mode conditions using a VCCT-based approach

AI-Powered Monitoring: Smarter Solutions for Composite Safety

8th ICEAF International Conference of Engineering Against Failure

Composite materials make aircraft lighter and stronger, but hidden defects, such as delamination, can compromise safety. The collaborative work between **IRES** and **ITA** takes **Structural Health Monitoring (SHM)** to the next level with AI-driven predictive modeling. This AI-powered SHM approach detects and localizes delamination, predicts damage growth, and bridges the gap between simulations and real-world data.

By combining UGW simulations with experimental tests using piezoelectric sensors, deep learning models for signal analysis and noise mitigation, and advanced feature engineering with wavelet transforms and CNN architectures, the system delivers accurate predictions of damage location and size, even under temperature variations and noisy conditions. Validated on experimental plates with real defects, this method achieves up to **30% improvement** in predictive accuracy through advanced feature extraction. Ultimately, AI-driven SHM promises early failure detection, reduced maintenance costs, and enhanced safety, paving the way for smarter, more sustainable aircraft operations.

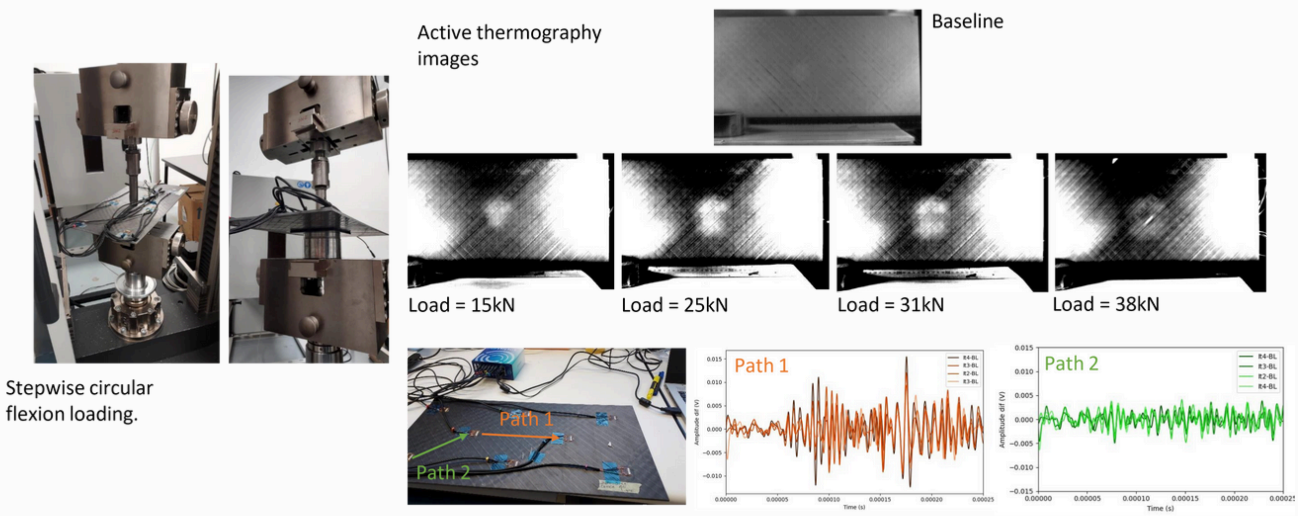

Figure 6. Experimental test for Ultrasonic Guided Waves (UGW) noise characterization

These results stem from a collaborative effort between IRES and ITA, presented under the title "***Leveraging AI for Structural Health Monitoring: Ultrasonic Guided Waves in Predicting Delamination Damage in Aircraft Composites***." The work was showcased by **Panagiotis Kolozis**, Data Scientist at **IRES**, during the 8th ICEAF Conference in June 2025.

Leveraging AI for Structural Health Monitoring: Ultrasonic Guided Waves in Predicting Delamination Damage in Aircraft Composites

Figure 7. Panagiotis Kolozis (IRES) presenting at the 8th ICEAF in Kalamata, Greece.

Laser Vibrometry: Redefining Sensor Design for Smarter Aircraft Monitoring

At the **International Congress on Ultrasonics 2025,** in Paderborn, Germany, **Jakub Spytek,** Assistant Professor at **AGH University** of Kraków, introduced an approach to SHM for composite aircraft structures. The research focuses on optimizing sensor placement and configuration using laser vibrometer-based virtual sensors combined with guided wave techniques.

Optimizing sensor placement is key to maximizing damage detectability in critical regions of composite aircraft structures. This approach leverages guided waves for monitoring both planar and L-bent components, using flexible **Macro-Fiber Composite (MFC)** sensors for seamless integration. By strategically positioning sensors around the **Region of Interest (ROI),** the system ensures precise and reliable detection, paving the way for smarter, more efficient SHM solutions in aviation.

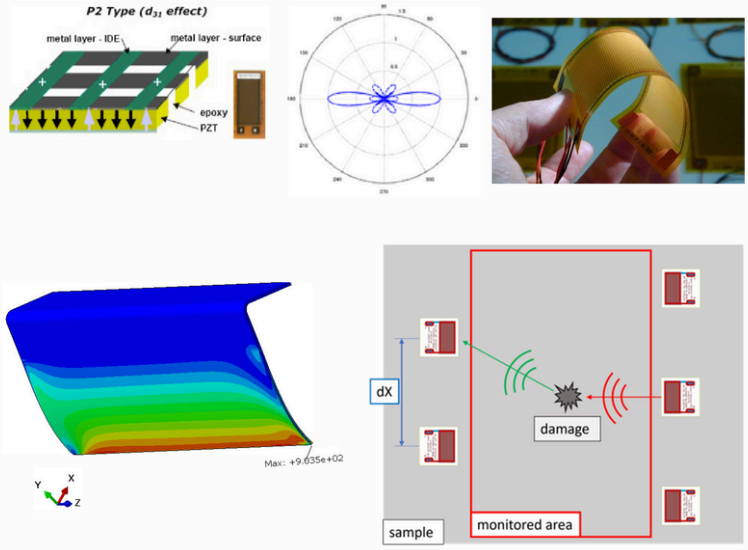

Figure 8. Problem description: Optimizing sensor placement around critical regions ensures maximum damage detectability in composite aircraft structures.

To ensure accurate defect detection in composite aircraft structures, researchers experimentally investigated CFRP specimens, both baseline and samples with artificial defects, using advanced Lamb wave techniques. By exciting waves with PZT discs and capturing responses via a PSV-500 Scanning Laser Doppler Vibrometer, the study analyzed anisotropy, attenuation, and defect sensitivity. Enhanced signal-to-noise ratio through pulse compression delivered precise insights, paving the way for smarter, high-resolution SHM solutions (Figure 9).

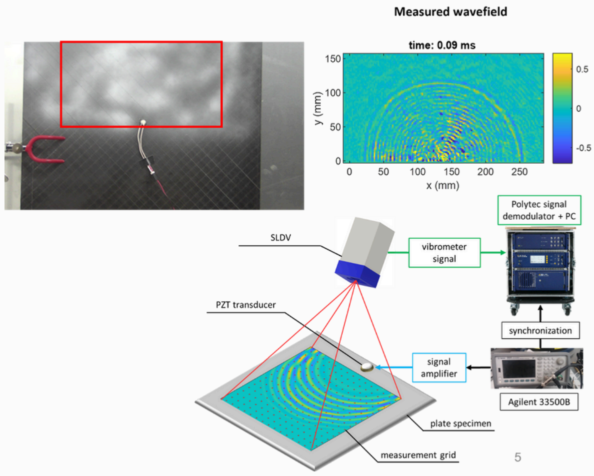

Figure 9. Characterization of the sample

Designing SHM system using laser vibrometer-based sensor synthesis

KTH Royal Institute of Technology receives development access to LUMI HPC

KTH Royal Institute of Technology in Stockholm has taken a major step toward sustainable aviation by securing development access to the LUMI supercomputer in July 2025. Leveraging this **High-Performance Computing (HPC)** power, KTH is advancing data-driven modeling for the GENEX project and help the aviation sector meet EU environmental targets by 2050.

The initiative focuses on Machine Learning models capable of detecting damage in composite components, powered by high-fidelity data from multiphysics simulations. These simulations replicate real-world conditions where piezoelectric sensors send ultrasonic guided waves through aircraft materials, revealing structural anomalies through changes in wave reflections. Running thousands of HPC-enabled simulations was key to building robust predictive models, marking a major step toward smarter, safer, and more sustainable aviation.

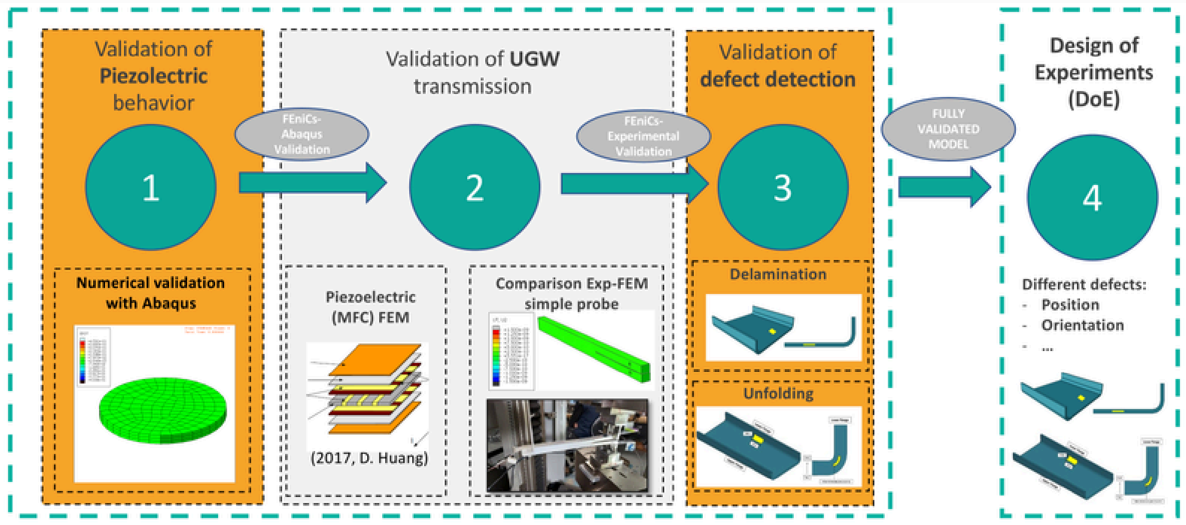

Figure 10. Development and validation of multiphysics solver based on the open-source dolfin-HPC (FEniCS) library.

KTH has developed an advanced multiphysics simulation tool to model ultrasonic guided wave propagation in aircraft composites. Built on the open-source FEniCS framework via the dolfin-hpc library, this HPC-enabled solution replaces costly commercial software. With access to LUMI supercomputer resources, the team successfully validated the tool for accurate aircraft damage detection.

Access to LUMI enabled the KTH team to generate training data for their Machine Learning models within the project's timeline. As a result, the outcomes strengthen the GENEX initiative and advance sustainable aviation research through HPC for aircraft damage detection.

Article published on the **ENCCS website**

Cracking the Code for Damage Monitoring in Composite Structures

EASN 15th International Conference

Researchers from **ITA** and **IRES** unveiled a breakthrough in SHM for composite aerostructures at the 15th EASN International Conference, in October in Madrid, Spain. Their work focuses on UGW, a powerful tool for detecting delamination, but real-world challenges like signal variability and noise remain.

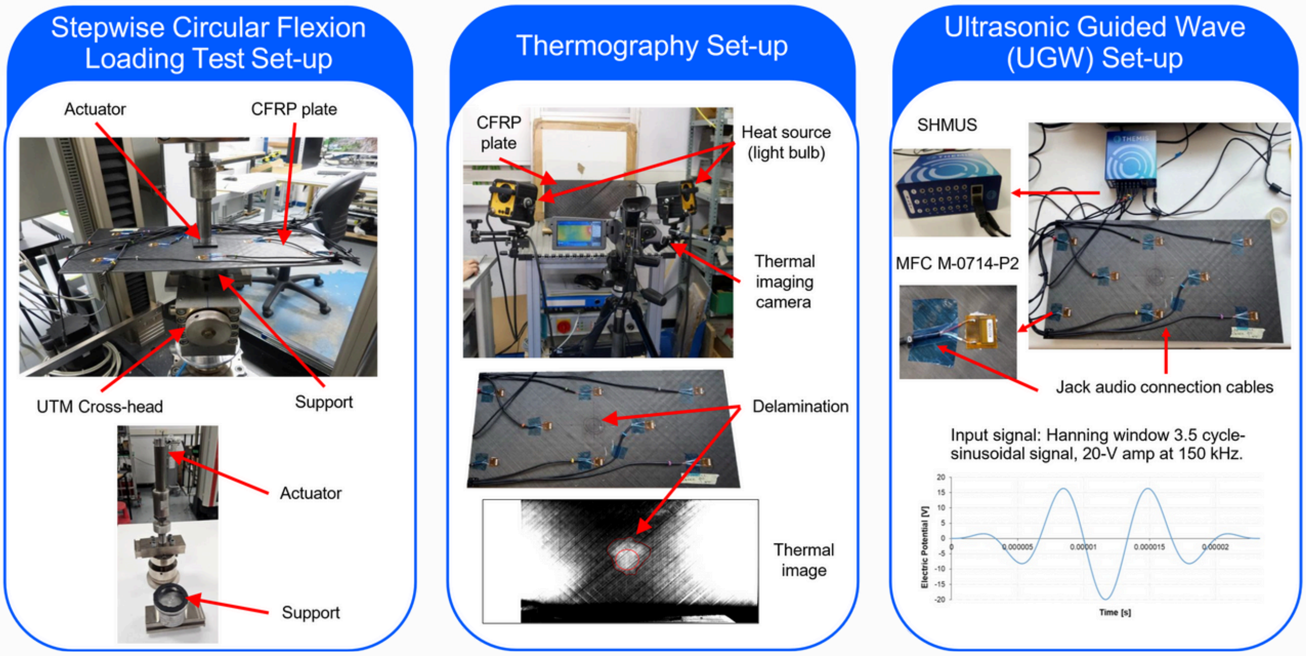

Figure 11. Experimental campaign from the paper "*Numerical Analysis of Experimental Uncertainties in Ultrasonic Guided Waves Propagation for Damage Monitoring in Composite Structures*" by ITA.

UGW-based SHM is emerging as a powerful method for early detection and prognosis of damage in aeronautical composite structures. However, real-world implementation faces challenges such as signal complexity, noise, and sensitivity to structural and environmental variations.

Javier Hernandez-Olivan (ITA) presented a numerical approach to analyze experimental uncertainties—stemming from factors like material inhomogeneities, sensor positioning deviations, and interface quality—that affect signal reliability. The goal is to identify the most damage-sensitive signal features and develop physics-informed indicators for predictive maintenance and machine learning integration. The research combines controlled damage progression experiments on **Carbon Fiber Reinforced Polymer (CFRP)** plates equipped with Macro Fibre Composite sensors and high-fidelity finite element models simulating wave propagation and progressive delaminations.

Numerical Analysis of Experimental Uncertainties in Ultrasonic Guided Waves Propagation for Damage Monitoring in Composite Structures

Predicting Fatigue Delamination in Curved Composite Laminates: Experiments and Simulation Correlation

EASN 15th International Conference

CFRP laminates are the backbone of modern aerospace structures—but predicting their failure under fatigue remains a challenge, especially in curved components where delamination by unfolding occurs.

Carlos Mallor Turon (ITA) presented a study introducing a **Virtual Crack Closure Technique (VCCT)**-based simulation combined with a Paris–Erdogan power-law approach to accurately predict fatigue-driven delamination under non-constant mixed-mode conditions. Implemented as a custom Abaqus subroutine, the method accounts for load ratios and mode mixity, ensuring strong correlation with experimental data.

Validation came through four-point bending tests on L-shaped CFRP beams, with Digital Image Correlation (DIC) tracking delamination growth. The results? A robust predictive tool that enhances structural integrity analysis, supports sustainable design optimization, and informs maintenance and repair strategies—all while improving safety and durability in next-generation aircraft.

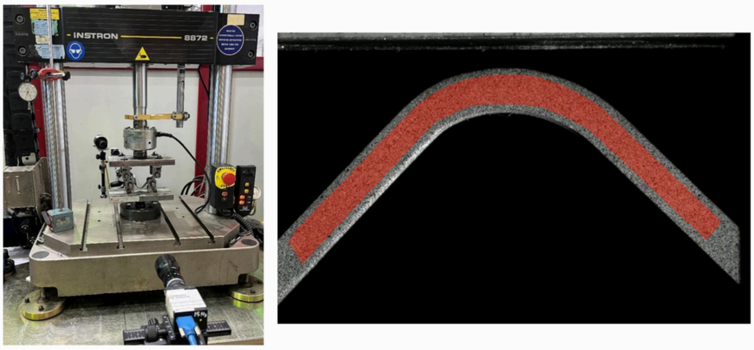

Figure 12. Experimental test configuration: 4PB Mixed-mode on L-angle specimen. No standard for fatigue crack propagation in CFRP → follow the standard for metals ASTM E647-24, 2024

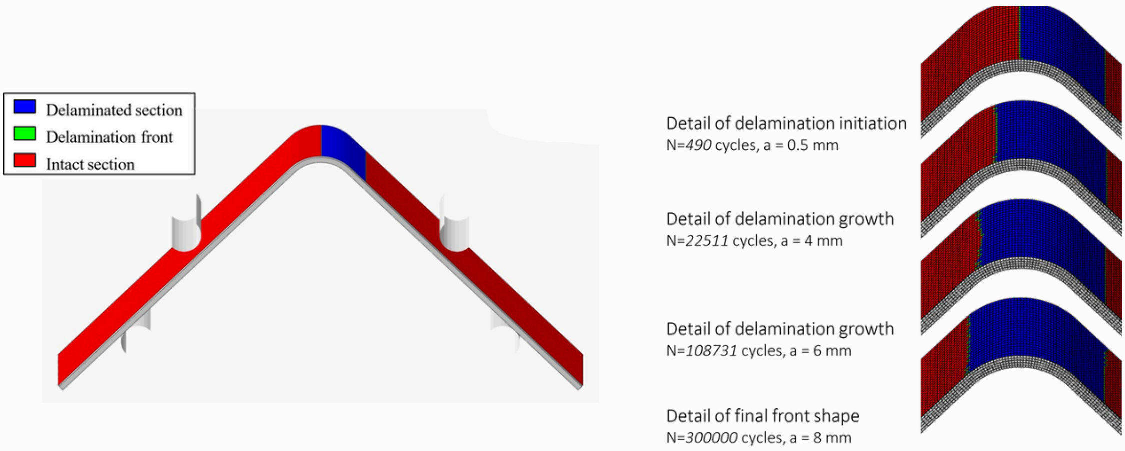

Figure 13. FE-model results: 4PB Mixed-mode on L-angle specimen,
Fatigue: Delamination propagation under fatigue (rendering undeformed shape).

An approach to predict fatigue delamination propagation in curved composite laminates under non-constant mixed-mode conditions: experiments and simulation correlation

Pioneering Sustainable Composite Solutions for Next-Gen Aircraft

EASN 15th International Conference

The GENEX project is redefining aerospace sustainability through thermoplastic composite components and digital-assisted repair technologies. Addressing key industry challenges, such as high manufacturing costs, energy use, waste, and non-recyclable materials, GENEX introduces a holistic approach combining advanced manufacturing, integral health monitoring, and digitally assisted repair.

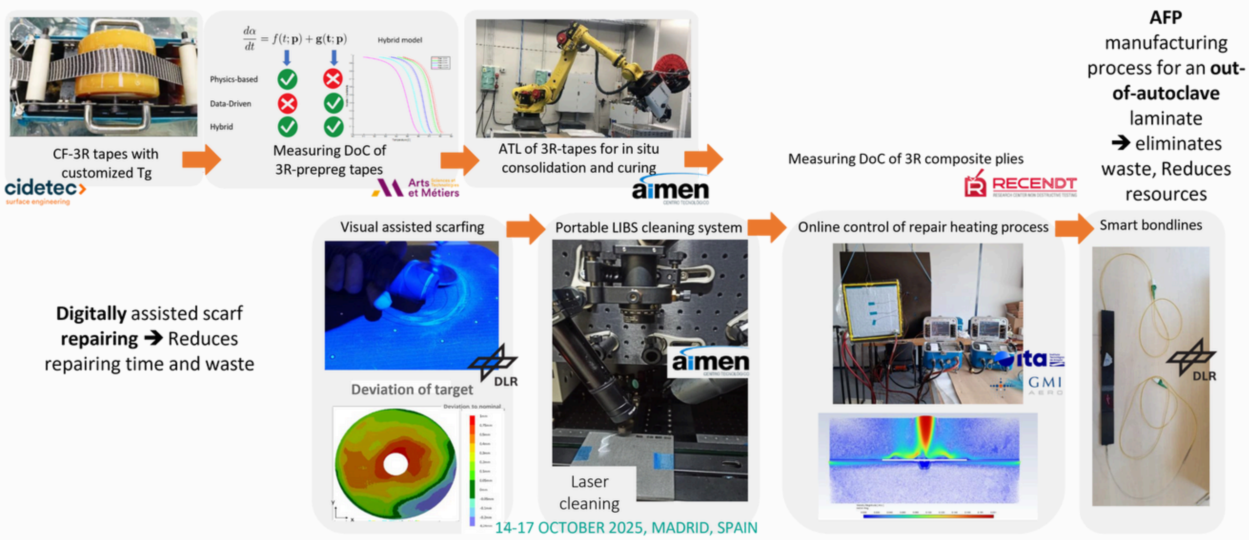

Figure 14. Technology description of GENEX.

By introducing recyclable composites through **Automated Fiber Placement (AFP)** out-of-autoclave processes, the project reduces waste and energy consumption while integrating embedded sensors and digital twins for real-time health monitoring and predictive maintenance. Smart repair solutions—featuring laser cleaning, scarfing assistance, and optimized heating control—further enhance efficiency. These advancements deliver up to **37% lower life cycle costs**, **49% reduced environmental impact**, and significant savings during the use phase through fewer inspections and minimized downtime. Combining physics-based models, machine learning, and digital twins, GENEX paves the way for sustainable design optimization, extended component life, and certified bonded repairs for primary structures.

These conclusions derive from the study *"Life Cycle Assessment and Costing of Thermoplastic Composite Aircraft Component with Digital-Assisted Repair Technologies"* contacted by **Evangelia Stamkopoulou, Materials Engineer (IRES)**, and presented at the **15th EASN International Conference**.

Life Cycle Assessment and Costing of Thermoplastic Composite Aircraft Component with Digital-Assisted Repair Technologies

FINAL EVENT

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TEAM

Shaping the Future of Aviation Manufacturing

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