

Shaping the future of

Aviation Manufacturing

A Leap Toward Smarter Aerospace
Maintenance, Repair and Overhaul by
delivering the Digital Twin Vision



Funded by
the European Union

Welcome to GENEX



Dr. Andrea Calvo Echenique
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GENEX, led by ITA, is a 42-month Horizon Europe project launched on September 1, 2022. Three pioneering technological assets have been developed which, through integration, lead to a promising, multi-disciplinary digital twin.

From Concept to Cockpit: The GENEX Digital Framework

A digital twin ecosystem for next-gen aircraft composite structures built on three core technological pillars:



ECO-EFFICIENT COMPOSITE MANUFACTURING

Advanced and efficient manufacturing or recyclable composites.



SMART HEALTH & USAGE MONITORING

Integral health & usage monitoring system of aerostructures



DIGITALLY-ASSISTED REPAIR TOOLS

Digitally-assisted repair processes & tools transforming the composite repairs.



Why GENEX ?

The integration of a multidisciplinary digital twin for aircraft components is a cutting-edge approach enabling the creation of a dynamic, continuously updated virtual model that mirrors the physical state and performance of the aircraft in real time.

Eco-efficient composites manufacturing reaches new heights

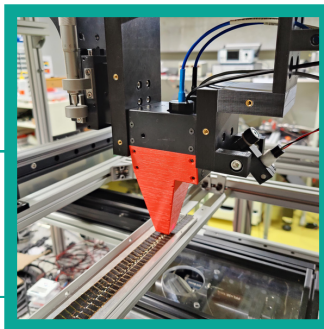
In just 30 months, GENEX has reshaped aerospace manufacturing with eco-efficient composites and intelligent production. Its pioneering out-of-autoclave process, powered by 3R-resin and embedded Fibre Optic Sensors, sets a new standard for sustainable, high-performance aircraft structures

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CENTRO TECNOLÓGICO

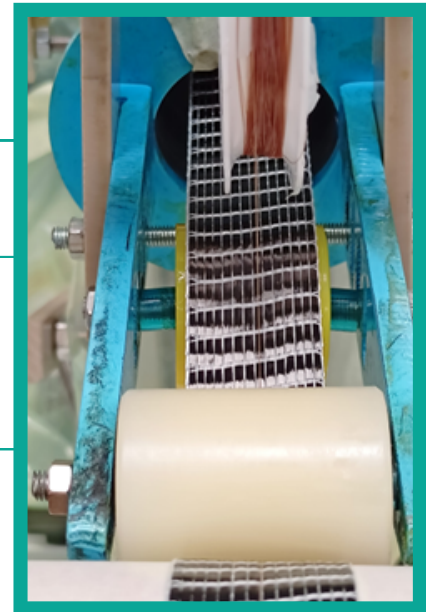
Revolutionizing Composite Manufacturing

GENEX has revolutionized Automated Fibre Placement with AI-powered multi-physics simulation and real-time terahertz spectroscopy, enabling intelligent control and superior composite quality in aerospace manufacturing.

THz monitoring system in lab environment during tests on 3R resin tapes



Embedded Fibre optic sensor (FOS)



Optimized AFP with Embedded Intelligence

GENEX has refined Automated Fibre Placement (AFP) with embedded intelligence, integrating Fiber Optic and piezoelectric sensors into 3R-tape and thermoplastic layups. This innovation enhances manufacturing precision while enabling real-time structural health monitoring—paving the way for next-generation aerospace composites.

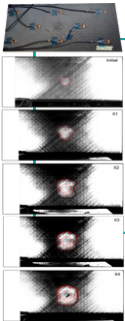
Intelligent Monitoring for Sustainable Aviation

Health and Usage Monitoring & Management (HUMM) is redefining aviation maintenance through real-time diagnostics and predictive analytics—boosting safety, extending asset life, and driving operational efficiency for a more sustainable future.

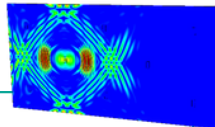


AI-enhanced multiphysics solver revolutionizes composite damage detection

A cutting-edge open-source solver, paired with deep learning, enables precise simulation and early detection of delamination in complex composites. This breakthrough accelerates inspections and empowers smarter, more reliable maintenance for next-generation aerospace systems.

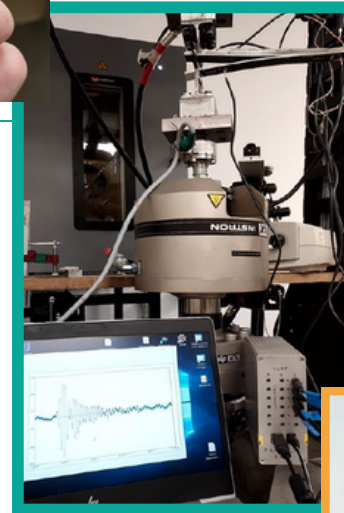


Experimental UGW inspection of delamination propagation on a thermoplastic test coupon



Finite Element Method (FEM) simulation of the UGW propagation on a thermoplastic test coupon

11th EWSHM 2024 Conference



Monitoring Techniques and Ultrasonic Guided Wave (UGW) inspection

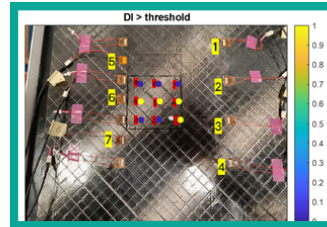


Monitoring Techniques: Ultrasonic Guided Waves (UGW) Inspection

- Performs on-demand interrogation of a structure while the structure is still in service as an active method.
- Uses arrays of PWAS bonded to a structure for both transmitting and receiving ultrasonic waves to achieve damage detection.
- The flexibility of the MFC allows it to adhere to curved surfaces.

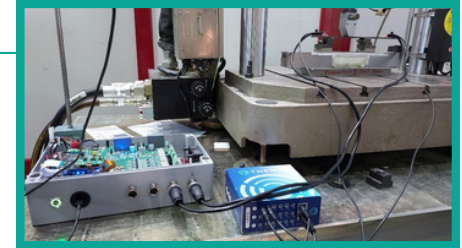
Virtual Sensor Network Optimization and Communication Node Achieved

Innovative concepts such as virtual transducers and virtual damage modeling have been developed to enhance sensor network optimization, specifically aimed at improving the detection of planar delaminations in complex structural components.



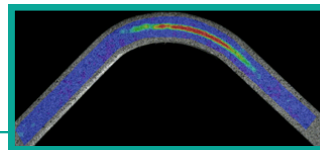
Validating the optimization of the sensor network

Testing of sensor node prototype for UGW inspection

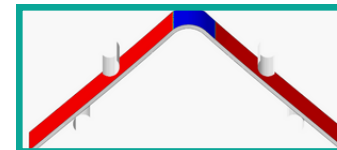


Fracture Characterization and High-Fidelity Propagation

A robust methodology has been established for modeling fracture propagation in both commercial thermoplastics and advanced Automated Fiber Placement (AFP)-3R laminates, demonstrating strong alignment between experimental and simulated results.



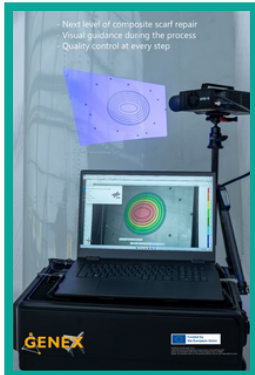
Experimental characterization of unfolding damage progression at sample level



FEM simulation of unfolding damage progression at sample level

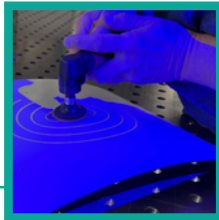
Precision Repairs, Digitally Delivered

DLR's Visual Assisted Scarfing (VAS) System brings precision repair within reach of any user. By projecting real-time guidance onto the component surface, it simplifies complex tasks and supports diverse geometries—paving the way for intuitive, high-quality repairs in aerospace maintenance.



Setup of the Visual Assisted Scarfing (VAS) System projecting an elliptic scarf contour onto the surface of an Airbus A320 outboard flap

Setup of the VAS System projecting onto an Eurofighter Airbrake



Manually grinding a sample with the VAS system

Optimized AFP with Embedded Intelligence

AIMEN's flexible Laser-Induced Breakdown Spectroscopy (LIBS) module enables real-time detection of surface contaminants and guides laser cleaning with precision. Validated for both integrated and standalone use, it advances automated maintenance in aerospace applications.



(Left) Stand-alone and out-of-the-lab LIBS system implementation; (Right) Software interface for control and LIBS analysis

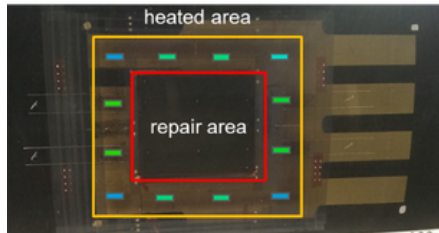


Combined LIBS module and laser cleaning. Control and analysis GUI detects contaminated areas. Processed samples were contaminated and correctly analyzed and cleaned.

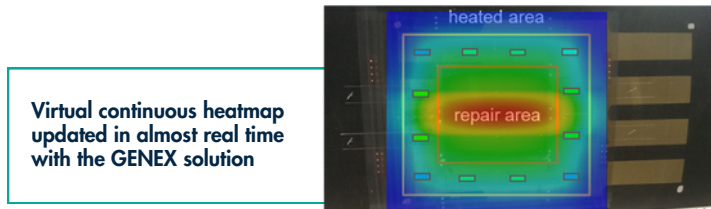
Optimized Heating Blanket Configuration for Omega-Stiffened Panel Repairs

A tailored heating blanket solution for omega-stiffened panel repairs has been optimized through advanced thermal modeling and experimental validation. A fast Reduced Order Model (ROM) enables accurate temperature prediction for single-blanket setups, while a new optimisation procedure ensures effective multi-blanket configurations—streamlining complex composite repairs with precision.

Comparison of the temperature distribution of a repair



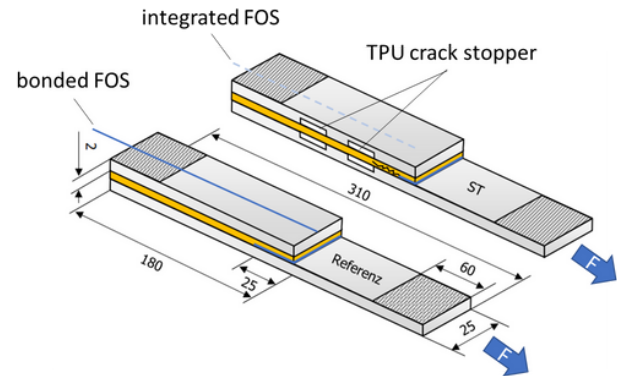
Discrete temperature measurements without the GENEX solution



Virtual continuous heatmap updated in almost real time with the GENEX solution

Integrated Crack Detection and Arrest System Advances Toward Aerospace Readiness

DLR has pioneered a dual-function system that combines real-time crack detection with crack-arresting technology. Using high-precision fibre optic sensing and a novel fatigue-resistant material, it achieves a 30% boost in static peel resistance—setting a new benchmark for structural health monitoring in aerospace.



Design of Reference Crack Lap Shear Specimen (left) and specimen with integrated crack stopper and crack sensor

From Lab to Life: GENEX in Action

GENEX brings smart technologies to life by integrating intelligent components with a real-time IoT platform. At its core, a dynamic digital twin manages each component's lifecycle, enabling seamless data exchange, operational insight, and adaptive performance in aerospace systems.



Real Aircraft Component Integration, IoT Connectivity & Digital Twin Lifecycle Management

GENEX reaches a major milestone with the integration of its smart technologies into a real aircraft component. Featuring seamless connectivity to an intelligent IoT platform and a dynamic digital twin, this demonstrator enables continuous data flow, predictive maintenance, and enhanced efficiency, setting a new benchmark for connected, sustainable aviation.

Real Aircraft Component Integration

VAS System:

Validated on the Airbus A320 outboard flap and Eurofighter airbrake, this system projects real-time geometry deviations onto the surface, enabling precise scarfing repairs.

Crack Detection and Arrest System:

Combines fibre optic strain sensors with crack-arresting materials in real composite specimens, enhancing fatigue resistance and demonstrating real-world applicability.

IoT platform connectivity

Sensor Node for SHM Networks:

A prototype node for Ultrasonic Guided Wave (UGW) inspection was developed and tested, designed for seamless integration with SHM networks for scalable deployment.

Virtual Sensor Network Optimization:

Incorporates virtual transducers and damage modeling to enhance IoT-based sensor network performance, improving delamination detection in complex aircraft structures.

Digital Twin Lifecycle Management

Digital-Physical Twin for Repair Control:

An online control system integrates real-time data into a digital twin that mirrors physical repair processes, ensuring precision and traceability.

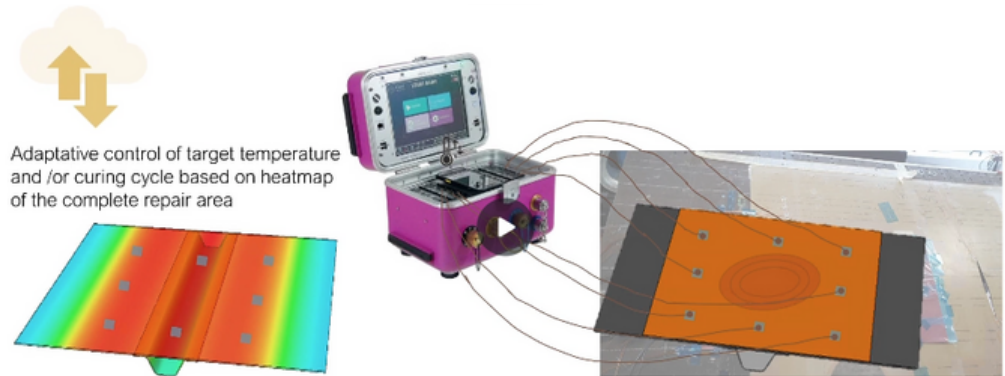
Lifecycle Assessment Integration:

Supported by Life Cycle Assessment (LCA) and Life Cycle Costing (LCC), the digital twin framework benchmarks composite technologies against conventional methods for sustainable decision-making.



Watch now!

Digital-Physical Twin:
On-line control of
the repair bonding process



Aviation Reimagined: GENEX's Lasting Legacy

GENEX drives sustainability and efficiency through eco-friendly 3R-resin composites, AI-enabled predictive maintenance, and detailed life cycle assessments. By reducing manufacturing costs and supporting workforce upskilling with intuitive repair tools and training alignment, the project sets a new standard for intelligent, connected aerospace systems.

Sustainability

Eco-Efficient Composite Manufacturing:

GENEX introduced a novel 3R-resin for carbon-fibre composites, combining thermoset durability with thermoplastic-like recyclability, significantly reducing environmental impact.

Life Cycle Assessment (LCA):

Detailed LCA studies revealed that CF/PEKK laminates have a 6% higher environmental footprint than CF-3R, with renewable energy integration identified as a key factor in reducing carbon fiber production impact.

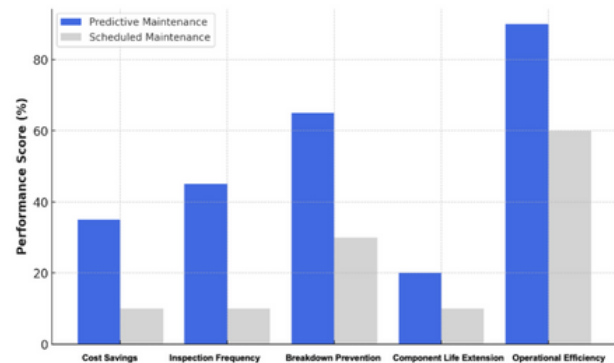
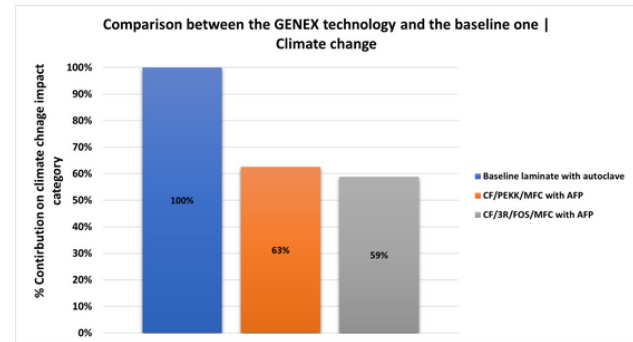
Predictive Maintenance

AI-Enhanced Damage Detection:

GENEX developed a multiphysics FEM solver and deep learning model to predict delamination damage in composites, enabling early detection and proactive maintenance planning.

Digital-Physical Twin Integration:

Real-time monitoring of repair bonding processes via digital twins allows for predictive insights into component health, improving reliability and reducing downtime.



Cost-Efficiency

Life Cycle Costing (LCC) Analysis:

GENEX found that fibre optic sensors account for 88–94% of total material costs, highlighting the need for cost-effective sensor solutions in aerospace applications.

Out-of-Autoclave Manufacturing:

The optimized process for composite tapes using 3R-resin reduces reliance on energy-intensive autoclave systems, lowering production costs while maintaining high performance.

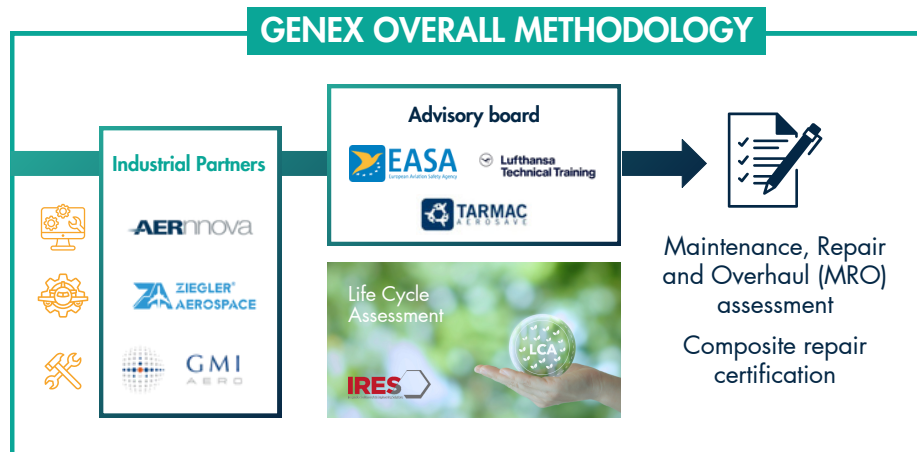
Workforce Upskilling

VAS System:

This tool enables even untrained personnel to perform precise composite repairs by projecting real-time guidance onto aircraft surfaces, democratizing repair capabilities.

Industry Collaboration for Certification:

GENEX engaged with EASA, Lufthansa Technical Training, and other stakeholders to align innovations with certification standards, fostering knowledge transfer and skill development across the aerospace workforce.



Watch the Future Unfold

GENEX's video series:
Shaping the future of aviation
manufacturing: The GENEX approach!



GENEX video episodes
Season 01
Episodes E01-E04



S01 | E01
Dr. Andrea Calvo Echenique



S01 | E02
Ibon Aranberri Askargorta



S01 | E03
Ibon Beatriz Simoes Pereira Gomes



S01 | E04
Jose M. Royo & Carlos Mallor



Voices of GENEX

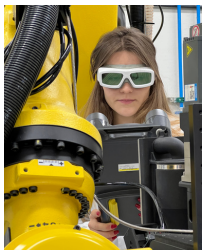
Ibon Aranberri Askargorta
Senior Researcher, CIDETEC

"The fabrication of carbon fiber/3R resin prepregs was carried out at a process rate of 10 m/min with an 80°C bath temperature. These prepregs can be stored at room temperature without compromising their properties, making them ideal for producing high-strength aeronautical components."



Beatriz Simoes
Advanced Composites Technology, R&D division, AIMEN

"Through AFP there will be a reduction in the manufacturing costs of the composite laminates due to the use of low temperature curing 3R resins and commercial thermoplastics using energy efficient, near-zero waste, and out-of-autoclave processes."



Dirk Holzhuetter
Engineer, DLR

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



Jose Manuel Royo
R&D Engineer, ITA

"Imagine a scenario where, just as you can sense a gust of wind or a sudden jolt, an aircraft can automatically detect and assess events that occur during a flight. It's a system that tells us not only what happened, but also where it happened and how severe it is"



Fast Facts & Figures



42

MONTHS



15

PARTNERS



4

TECHNOLOGIES

Beyond GENEX: The Journey Continues

Future applications, scalability, and potential for industry adoption

Demonstration Phase Launch

GENEX is entering a pivotal phase focused on constructing a representative aircraft component. All developed technologies will be integrated into the IoT platform to enable continuous lifecycle data flow.

Integrated UGV Inspection Capabilities

The next milestone involves full integration of models and algorithms into the industrial IoT framework, including interoperability with a communication node for periodic UGV inspections.

Validation Trials for Intelligent Repairs

GENEX will conduct trials to measure time savings and precision in repairs. These will be supported by a software interface that uploads process data to the digital twin platform.



Contamination Detection and Digital Twin Sync

Additional trials will validate contamination detection methods, with results stored in the digital twin environment to enhance repair traceability and control.

Fatigue Testing of Crack-Stopping Materials

New crack-sensing materials and fibre optic sensors will undergo fatigue loading trials to confirm performance under operational stress.

Manufacturing Demonstrator Development

A demonstrator targeting curved scarf repair geometries will be built to showcase real-world feasibility and integration of GENEX technologies.



New end-to-end digital framework for
optimized manufacturing & maintenance of
next-generation aircraft composite structures

START DATE: **01.09.2022**

END DATE: **28.02.2026**

Get In Touch



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