This project has received funding from the European Union´s Horizon Europe Research and Innovation Program under grant agreement Nº.101056884 and it is an initiative of the factories-of-the Future (FoF) Public Private Partnership.

INFINITE

Aerospace composites digitally sensorized from manufacturing to end-of-life

D6.2
Manufacturing component validation report

Deliverable name	D6.2- Manufacturing component validation report
Due date	31/03/2025
Delivery date	30/06/2025
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Version	Version 1
Dissemination level	Public

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3. EXECUTIVE SUMMARY

ABSTRACT / EXECUTIVE SUMMARY	
Abstract	This deliverable presents the protoype execution of an automated and digitalized manufacturing process using INFINITE monitoring technology. The setup integrates laser triangulation for fabric positioning and continuous surface monitoring with the INFINITE reader, both mounted on a robot, enabling in-process control during composite part manufacturing. The INFINITE technology is applied on wired fabrics produced in the project and monitors the initial state of fabrics, the preforming stage, the infusion and the curing, demonstrating full-cycle integration and traceability. The collected data lays the foundation for future AI-based process optimization in intelligent manufacturing environments.
Keywords	AUTOMATION, DIGITIZATION, ROBOTIC, MANUFACTURING

4. INTRODUCTION

This deliverable describes the prototiped execution of an automated liquid resin infusion (LRI) manufacturing process integrating INFINITE reader into a robotic platform. The focus is on the demonstration of the integration into an automated manufacturing process, for instance the ADMP system described in deliverable 1.1, rather than solely the validation of the readings themselves. The aim is to demonstrate how such a system can be effectively embedded into an automated and digitalized manufacturing workflow, simulating in-process control in realistic pre-industrial conditions.

This work builds upon the foundations established in the previously submitted deliverable 1.1, which defined and described the manufacturing of sensorized composite components using dry multiaxial NCFs and liquid resin infusion as the selected process. While that document focused on the configuration of materials, process definition, and defect-oriented demonstrator design, the present deliverable focuses on the practical validation and integration of a monitoring system across the manufacturing chain, from dry fabric handling to the post-curing stage.

To achieve this, the INFINITE portable reader was mounted on a robotic arm and complemented with a laser triangulation system for accurate positioning and shape control of the ply. The robot autonomously executes edge detection and proceeds with measurement routines in both flat and preformed geometries. This integration represents a key step toward a fully digitalized manufacturing line, where in-process monitoring becomes part of the automated production logic, enabling real-time decision-making and reducing reliance on manual inspection.

Beyond demonstrating feasibility, this implementation lays the foundation for the systematic accumulation of high-quality process data, essential for the development of future AI-based analysis and optimization tools. The collected data will serve as a reference for training machine learning models capable of identifying defects, predicting process deviations, and proposing corrections—accelerating the transition to intelligent, adaptive manufacturing environments. Having in mind that the current readiness level of INFINITE sensing technology is below a pre-industrial condition, the main interest of the validation is demonstrating that an integration of that kind is representative of the potential integration of such digital systems in manufacturing processes traditionally performed with a high component of hand-work. This prototype integration of sensors in an automated digital environment shows high potential for high-value added manufacturing processes in aeronautic sector.

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5. RESULTS

To validate the automation and digitalization capabilities developed within the project, the INFINITE portable reader was integrated into a robotic platform. This configuration simulates real-time, automated measurement of the composite layup during manufacturing. The solution was designed to reduce manual intervention and enable consistent, repeatable acquisition of surface and shape-related data.

Along the activities carried out in INFINITE it has been concluded that the current development level of the technology does not make the reader and the configuration of wires prone to detect the position of the plies after lamination. To address this, a complementary laser triangulation system was implemented (see Figure 1). This system was mounted on a robotic arm and programmed to perform edge detection prior to lay-up inspection measurement. Once the edge of the fabric is accurately located by the triangulator, the robot autonomously repositions itself and places the INFINITE reader at the correct starting point, ensuring optimal alignment and consistency. This workflow emphasizes the automation aspect of the system, where the robot dynamically adapts to the position of the material and executes the measurement cycle with minimal user input.

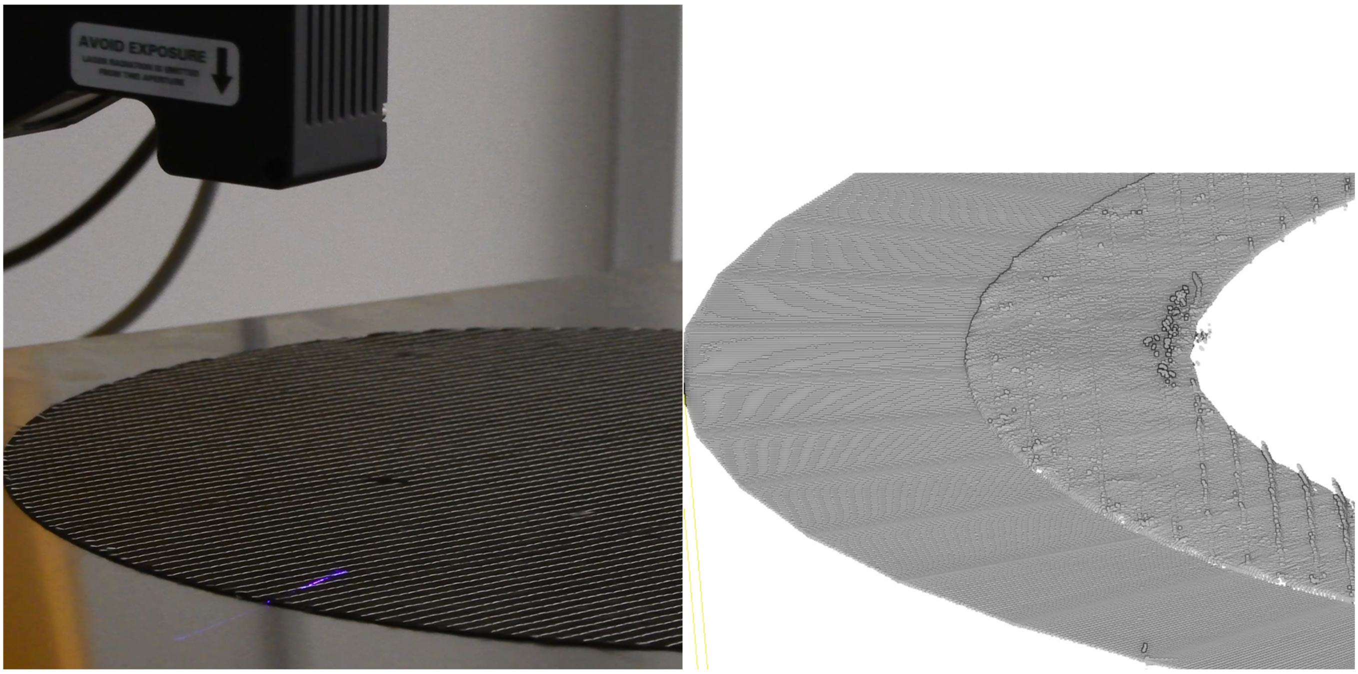

Figure 1: Laser triangulator and generated archive

The measurement sequence began with data collection on a flat surface as seen in the Figure 2: . The INFINITE reader, aligned parallel to the MW, performed measurements at defined positions. These readings were stored as reference values.

To replicate forming conditions, the same ply was subsequently placed onto a spherical dome to create a preformed geometry. The robot repeated the measurement sequence over the dome as depicted in Figure 3: , maintaining identical position coordinates, thus enabling direct comparison between flat and formed configurations.

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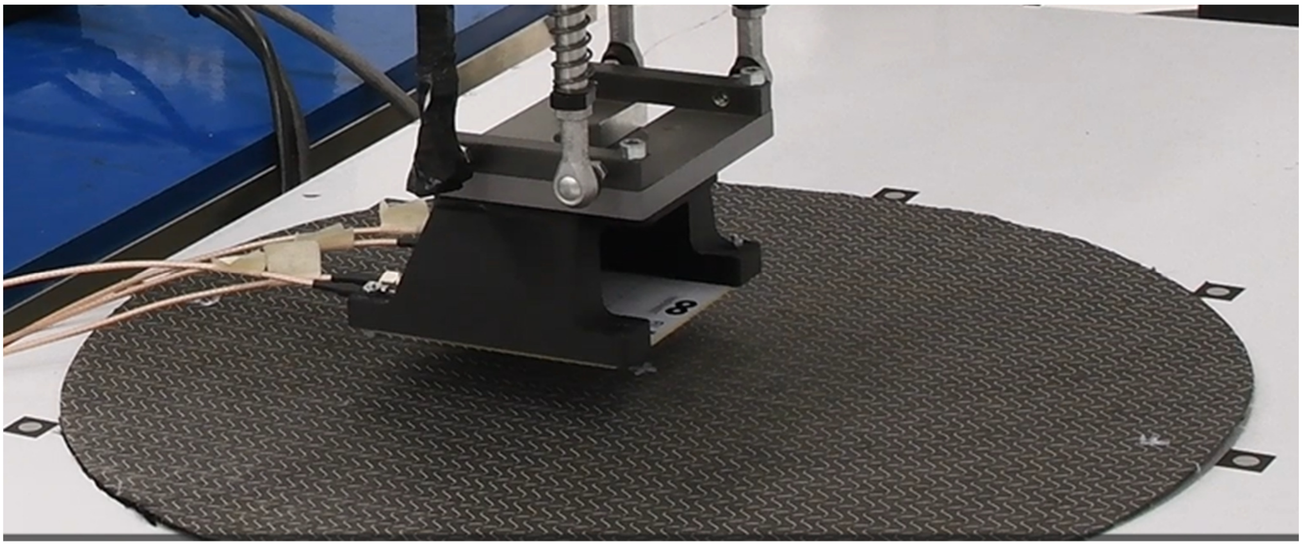

Figure 2: Readings in the flat disposition

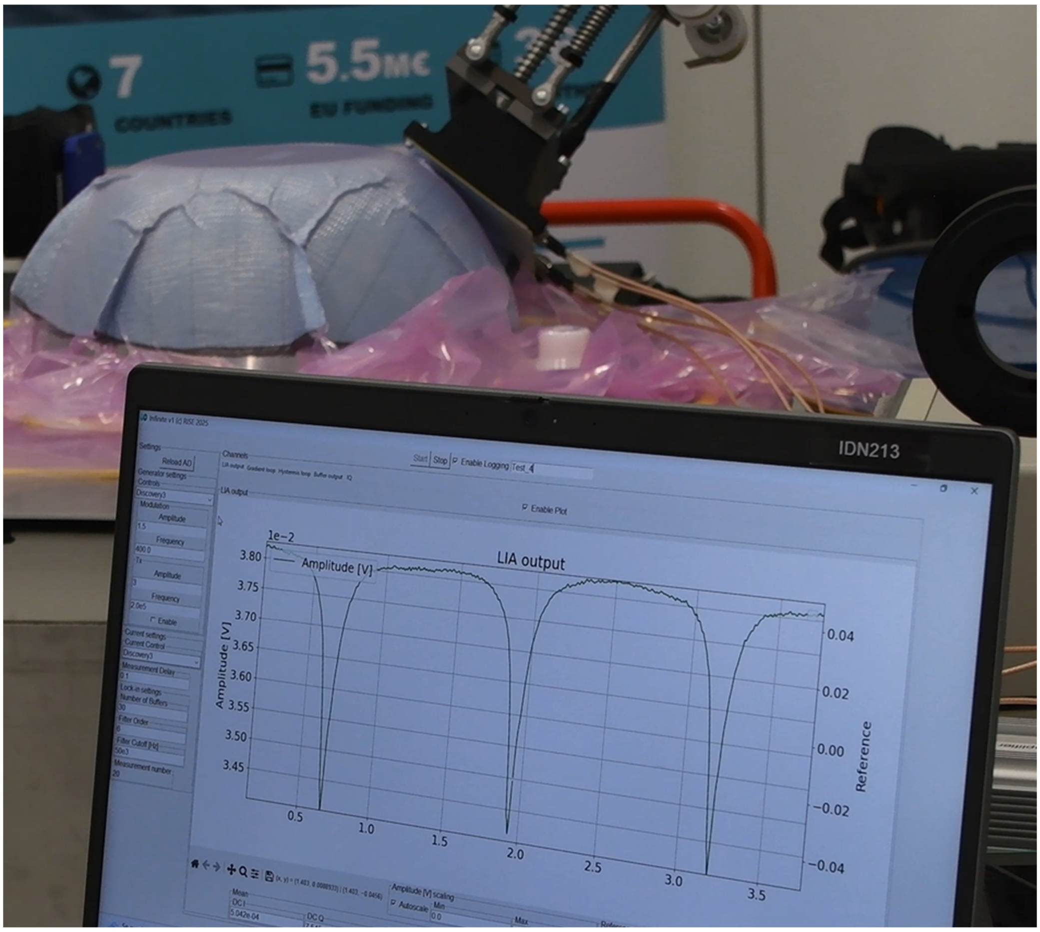

Figure 3: Readings in the curved disposition

It must be noted that, in this demonstration, the repositioning of the ply was done manually, introducing positional inaccuracies between steps. This had a measurable impact on the repeatability and robustness of the signal. Despite this limitation, the system was able to capture significant differences between measurements in various regions of the preform.

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Observations indicate that the presence and orientation of wrinkles in the fabric strongly influence the INFINITE signal. Referring to Figure 4: , as seen in Figure 5: , in regions such as C-1 and A-1, where no wrinkles were observed, the measurements remained consistent. In contrast, in Line 3, where wrinkles appeared perpendicular to the machine working direction, a clear increase in the peak height of the signal was recorded. In quadrant B-2, where multiple wrinkles emerged, noticeable signal variations were again observed. However, in areas like C-2 and A-2, where the wrinkles were smaller and aligned with the machine direction, no major signal changes were detected. This suggests that the reader is particularly sensitive to wrinkle orientation, with perpendicular wrinkles having a greater influence on the measurement response. A second reading in B-2 also showed signal variation caused by a wrinkle, although the expected increase in peak height was not observed. This remains under further investigation.

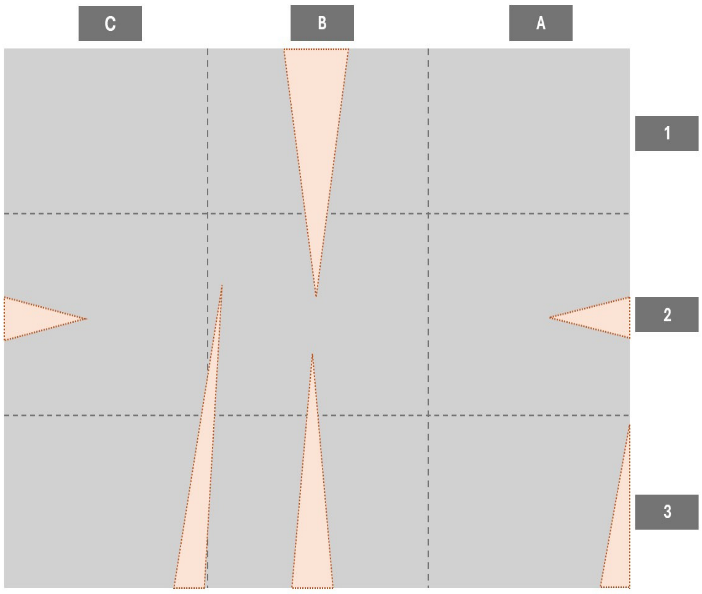

Figure 4: Measurement regions to compare between flat and preformed disposition

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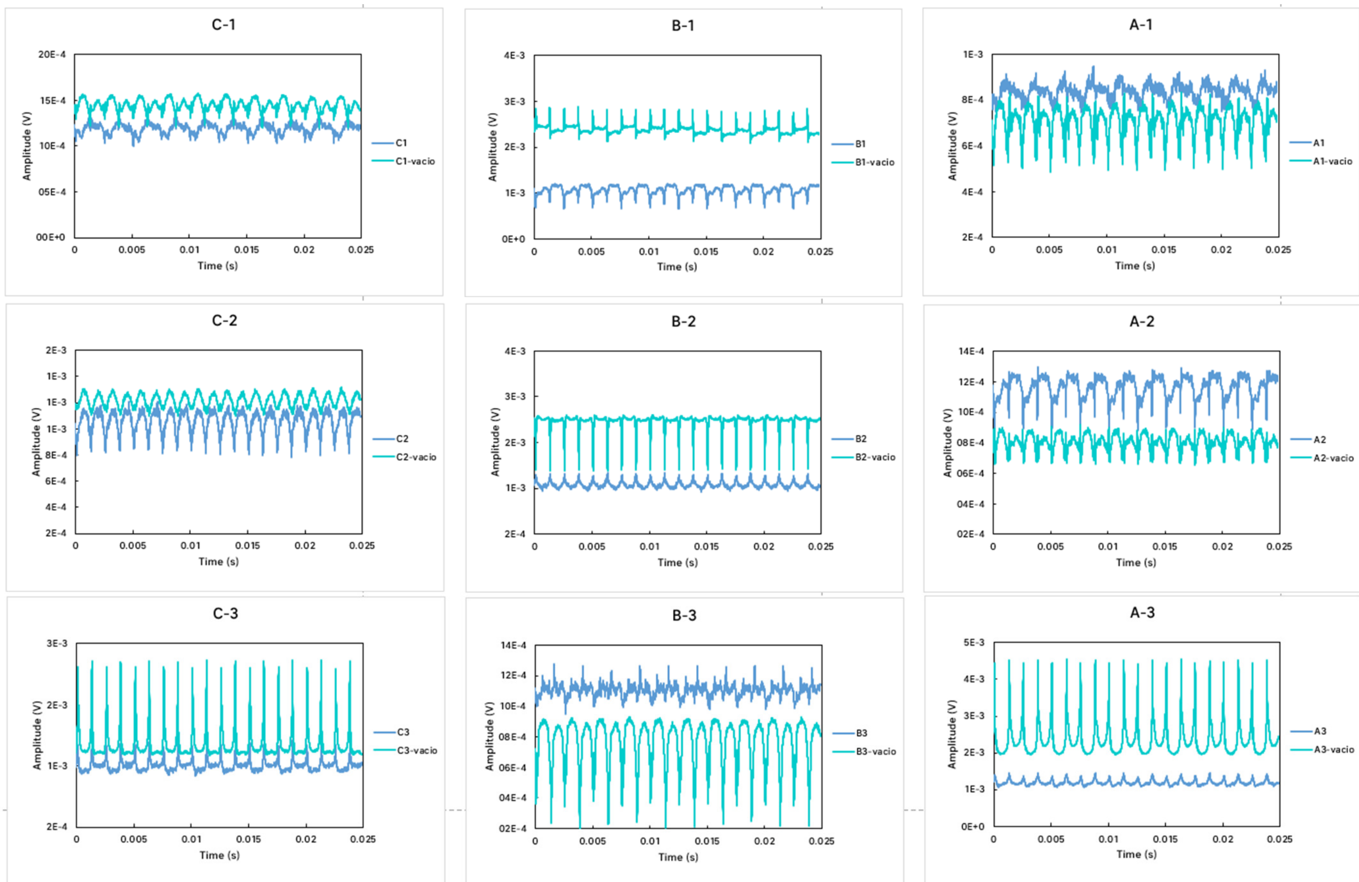

Figure 5: Measurements comparisons of flat and preformed disposition

In addition to the preforming stage, the automated system was also employed to continuously monitor the infusion and curing phases of the manufacturing process. The aim was to evaluate the system's potential for end-to-end digital process tracking. The same robotic setup was configured to follow the part through these final manufacturing steps, recording data continuously to assess any detectable changes or signatures during resin infusion and thermal curing. While initial results did not reveal substantial variations in the measured signal under the current setup, the activity successfully demonstrated the system's capability for uninterrupted monitoring throughout the full manufacturing cycle, setting the groundwork for future enhancements in sensor sensitivity and process interpretation.

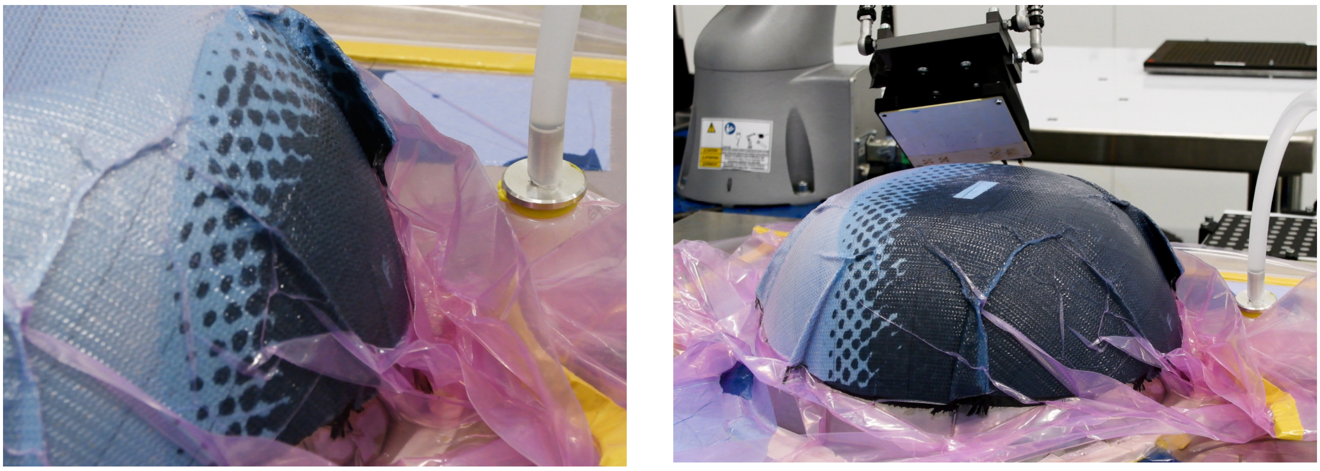

Figure 6: Resin front progresion during infusion

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Edge detection

- Laser triangulator
- Generate archive of edge points
- Control exact position and shape of ply

Flat inspection

- INFINITE reader
- Control of integrity
- Reference measurement for coming sequence

Lamination

- Lamination on tool and preparation for infusion.

Control of wrinkles

- INFINITE READER
- Reference areas measured after preforming
- 1 measurement per area

Infusion

- INFINITE reader
- Measurements in reference areas
- Continuous measurements

Curing

- INFINITE reader
- Measurements in reference areas
- Continuos measurements

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6. CONCLUSIONS

The results of this activity confirm the technical feasibility and added value of integrating in-process measurement systems into an automated manufacturing workflow. The robotic setup—combining laser triangulation for edge detection and the INFINITE reader for process monitoring and quality assessment demonstrated a high degree of flexibility and adaptability, simulating industrial operation conditions. Despite manual repositioning steps introducing some variability, the system could detect relevant differences in the preform geometry.

This work represents a small step toward data-driven manufacturing, where sensors, robots, and digital tools interact. The ability to gather consistent and structured measurement data during production opens the door to long-term process optimization through AI and machine learning, enabling predictive control strategies, automated quality checks, and continuous improvement loops.

In conclusion, the demonstrated integration supports the strategic move toward intelligent manufacturing systems, where automation and digitalization are not limited to mechanical operations, but extended to monitoring, traceability, and future decision support. This positions the technology for further scaling and industrial deployment in advanced composite manufacturing environments.