The True Cost of Late Detection:

Why In-Process NDT is Needed for Composite Manufacturing

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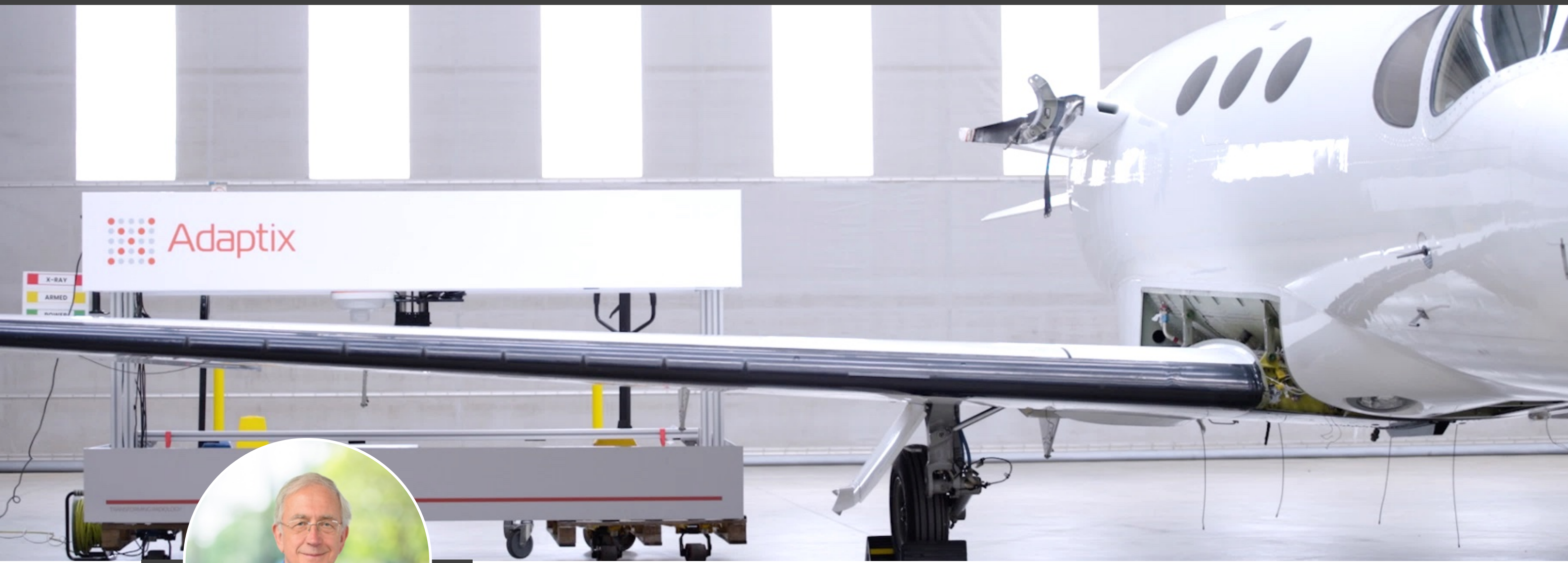

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Across every industry adopting advanced composite components - such as *automotive, aerospace, renewable energy, and medtech* - the dominant inspection model currently places quality assessment at the very end of the process, precisely when the cost of failure is greatest. By the time a defect is detected at the end of the manufacturing line, the full cost of producing that part has already been incurred. Energy, materials, labor and machine time have all been spent. What typically follows is either an expensive rework cycle or scrap - both of which erode margin and extend lead times. With components growing in size and complexity across multiple industries, tolerance for that level of waste is narrowing fast. It is important to remember that the economics of defect detection are not linear. A flaw identified during lay-up might cost relatively little to address; the same defect found after cure or at sub-assembly could cost orders of magnitude more to resolve, even where resolution is possible.

The consequences vary by sector, but the underlying economics do not.

In automotive production, a defective structural composite part identified late in the build sequence disrupts line flow and can lead to costly retooling. In renewable energy, a wind turbine blade found to contain internal delamination after curing may mean a full re-spin of a manufacturing process that has taken days. In marine applications, structural composites that fail inspection after lamination may have to be scrapped entirely. In medtech, late detection can mean high-volume production of non-conforming parts before the problem is caught. In aerospace, delayed discovery extends program timelines and adds pressure to already strained supply chains.

Historically, in-process inspection has been impractical due to the limitations of existing imaging technologies in live production environments.

Ultrasonic testing (UT) is widely used and effective at detecting delamination and porosity, but contact-based methods require careful surface coupling and can be slow on large or geometrically complex parts. Phased-array UT demands skilled operators and significant scan time.

Thermography and shearography offer rapid, non-contact coverage of large surface areas and are well suited to near-surface defect detection, but their sensitivity diminishes with depth, limiting effectiveness on thicker laminates. Conventional X-ray CT delivers the most complete 3D characterization of internal defects, but the time required to acquire and process a full tomographic dataset - and the facility infrastructure involved - make it impractical for most in-process monitoring. As a result, for most components, parts have to travel to specialist inspection facilities, adding time and cost to the process while entrenching a quality model built around late discovery and expensive correction.

Low-power digital tomosynthesis - an approach that sits between conventional 2D X-ray and full CT - takes a series of images from multiple positions and algorithmically reconstructs them to provide cross-sectional slices through a part. The radiation doses involved are a fraction of those associated with conventional CT, significantly reducing the shielding and exclusion zones that have traditionally made X-ray technology difficult to deploy outside of dedicated facilities.

The result is meaningful 3D structural data delivered in a fraction of the time of CT, using equipment compact and flexible enough to be deployed directly on the shop floor. For smaller suppliers and contract manufacturers, this opens up in-house inspection capability that was previously out of reach.

Critically, this technology can be applied to large components and complex geometries that are incompatible with CT.

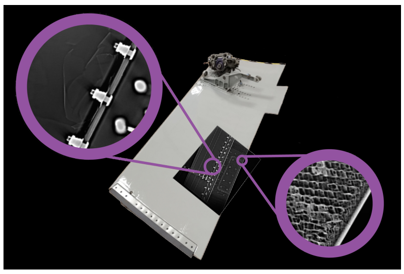
Porosity, delamination, fiber misalignment and other critical defects can now be detected at lay-up, pre-cure, or sub-assembly stages - precisely the points at which intervention is still viable and correction, rather than scrapping, remains cost-effective. This means that components such as fuselage panels, wing structures and propeller blades can be inspected on the shop floor, without the handling risk or production delays associated with transporting parts to a centralized or off-site facility.

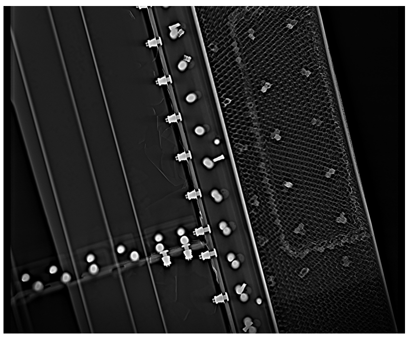
This same portability, which adds value during the manufacturing process, also extends to testing components in service.

For MRO operations, the ability to conduct high-quality imaging of a component on the ground - without moving it or transporting it to an off-site facility - is a real step forward in inspection efficiency. A system deployed in an aerospace hangar, for example, with a modest safety perimeter in place, can assess composite control surfaces or fairings in situ, with findings available in near real time.

Additionally, where in-process inspection data is mapped to a component's 3D model at the point of manufacture, -that data travels with the part. MRO teams examining a component years later can reference the original build record to understand how the structure was made, what anomalies were present from the outset, and how it has changed in service. For automotive industries, that same data can inform warranty analysis and design iterations, while in medtech, it may underpin the device history record.

Crucially, it creates a feedback loop between manufacturing quality and product design that makes the entire process more intelligent over time. Earlier-stage NDT enables a fundamental shift in how quality is built into the manufacturing process, moving from inspection as validation to inspection as control: Scrap rates can be reduced; rework cycles shortened; production flows maintained; and lead times reduced. The data generated can also be fed directly back into process optimization, helping manufacturers identify and address systemic issues before they become embedded in production.





There are real sustainability benefits to this approach too. Reducing scrap means reducing wasted material - a factor growing in importance as composite structures become larger, more technically complex, and more resource-intensive to produce. While composites offer a proven way to lightweight components, they are energy-intensive to make and difficult to recycle so, in a world of interlinked net zero reporting, reducing preventable manufacturing waste is not merely good practice but strategically important. As the industry works toward net zero targets, the ability to eliminate avoidable waste at the point of production matters both economically and environmentally.

Manufacturers who invest in in-process NDT can not only gain an operational edge - such as lower scrap costs, increased throughput, stronger quality data, and greater supply chain resilience - but, as composite components become more common and quality expectations rise, in-process inspection will evolve from a market differentiator to a baseline expectation.

The question is not whether to invest, but whether to do so before or after your competitors?