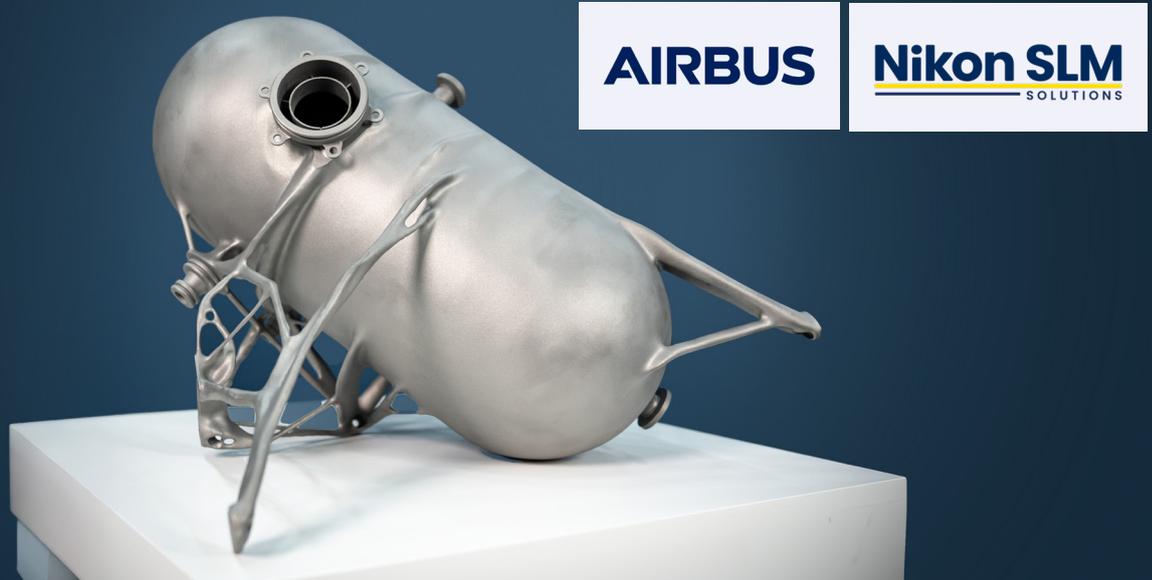# From mass to masterpiece: The Air Separator celebrates design ingenuity

Dr.-Ing. Patrick Mehmert - Senior Research Engineer, Hexagon Manufacturing Intelligence GmbH, Andreas Hellmann - Advanced Design Engineer, Airbus Operations GmbH, Andreas Solbach - Application Engineer Aviation and Space, Nikon SLM Solutions AG

Unlocking efficiency: Additive manufacturing as a key for transformation

The aviation industry stands on the brink of a new era, where innovation and technology are redefining traditional manufacturing boundaries. A remarkable example of this transformation is the recent redesign of the "Air Separator" for the Airbus A330, a collaborative effort between Airbus, Nikon SLM Solutions, and Hexagon. This partnership has not only set new benchmarks in manufacturing efficiency but also compellingly demonstrated the potential of additive manufacturing in the aviation sector.

The Air Separator, a critical component located in the tail fuselage section of the Airbus A330, plays an integral role in the operation of the Auxiliary Power Unit (APU). Originally constructed from over 30 stainless steel parts, it underwent a comprehensive redesign as part of a research case study. The objectives were clear: drastically reduce weight and the number of individual components, lower manufacturing costs, and maintain all functional interfaces.

By leveraging cutting-edge technologies and innovative design processes, the team succeeded in creating a fully integrated component. This new design is not only 75% lighter but also consists of just a single part. This transformation promises significant cost savings, reduced fuel consumption, and a potential CO_2 reduction of approximately 246 tons over the aircraft's lifecycle.

This project serves as a shining example of how additive manufacturing can shape the future of aviation by setting new standards for efficiency, sustainability, and innovation. With the aid of digital tools, it directly leads to functional designs and flawless manufacturing.

"
In aviation, every gram counts. For disruptive lightweight construction with additive manufacturing, structures, geometries, and processes need to be rethought. This component impressively demonstrates, with the help of generatively optimised design, how this can succeed."

Andreas Hellmann
System Integration Design Engineer - Fuel & Bleed, Airbus Operations GmbH

Collaboration for Progress: Redesigning the Air Separator

The aviation industry faces the ongoing challenge of continuously optimising existing technologies and designs to enhance efficiency and sustainability. Against this backdrop, Airbus launched a project at the end of 2023 to redesign the "Air Separator" for the Airbus A330. This component, located in the aircraft's tail, is crucial for ensuring the reliable operation of the Auxiliary Power Unit (APU). Essentially, it consists of a tank-like structure that separates air and water from kerosene.

The separation process relies on a simple physical principle: the differences in density among the substances involved. Air, being the lightest, accumulates at the top of the tank, while water, heavier than kerosene, settles at the bottom and can be drained as needed. The purified kerosene can then be extracted through a dip tube and supplied to the APU.

The conventional Air Separator is composed of over 30 stainless steel parts, welded or riveted together, with a total mass of approximately 35 kg. The project's goal was to achieve a significant reduction in weight and the number of individual components by employing additive manufacturing technologies and innovative design methods, while also lowering manufacturing costs and preserving all functional interfaces.

The specific objectives of the case study were:

- Maximum weight reduction: The aim was to reduce the weight by more than 50%, ideally bringing it down to under 15 kg.

- Reduction of individual components: The number of parts was to be drastically reduced to minimise manufacturing and installation efforts.

- Reduction of manufacturing costs: By transitioning to a single, additively manufactured component, the manufacturing costs were expected to decrease.

- Preservation of all interfaces: Despite the design changes, all interfaces with surrounding components needed to be maintained.

- Achieving acceptable surface roughness: An acceptable level of surface roughness was required at the connection points.

These objectives were achieved with the support of the partners Nikon SLM Solutions and Hexagon, who contributed their expertise in additive manufacturing, simulation and metrology to the project. Utilising advanced software and manufacturing technologies, the team was able to create a fully integrated and weight-optimised component that meets the aviation industry's demands for efficiency and sustainability.

Crafting innovation: Optimising design and manufacturing for the air separator

In the initial phase of the project, the design of the Air Separator was comprehensively optimised and completely reimagined based on the specified loads, boundary conditions, material properties, and required interfaces.


The choice of the additive laser powder bed fusion process as the manufacturing technology allowed for significant design freedom without major manufacturing constraints.

For the design optimisation, the team utilised MSC Apex Generative Design software, which, unlike traditional topology optimisation, conducts volume minimisation directly based on mechanical stresses rather than stiffness-driven criteria. This approach enabled the team to efficiently achieve a weight-optimised design without the need for further iterations of manually set weight targets.

Another advantage was that the software output a smoothed geometry in various formats such as STL, PLY, STEP or Parasolid (based on NURBS surfaces), which could be directly used for subsequent manufacturing preparation. This eliminated the typically time-consuming and costly need for a manual redesign which is usually required for traditional topology optimisation results, as they only provide a conceptual idea of potential final designs. Additionally, this representation of the optimised geometry allowed for immediate in-depth strength analysis, for example with MSC Nastran, which is necessary for aviation certification and can subsequently conducted with the same model after the optimisation run.

Ultimately, a fully integrated design was achieved that met all requirements and consisted of just a single component. The resulting mass is just under 9 kg, representing an impressive weight reduction of approximately 75%!
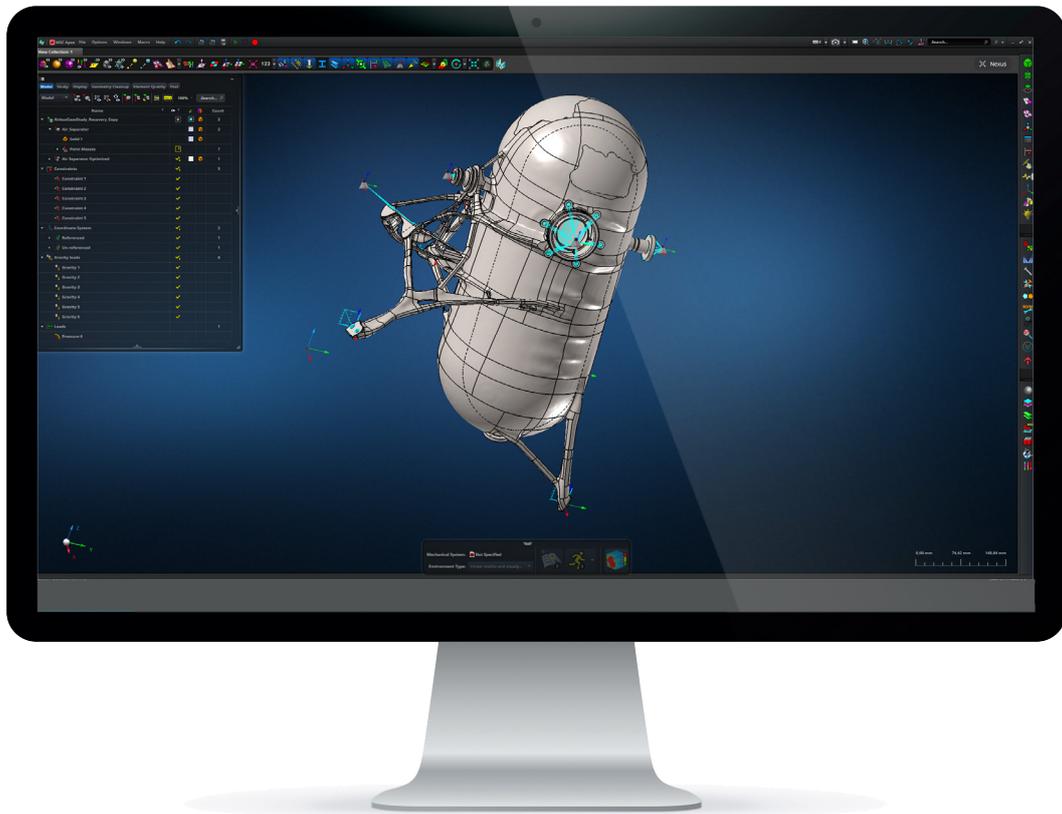
Crafting perfection: Digital simulation as the key to manufacturing success

Once the optimised design was finalised, the digital process chain seamlessly continued with the preparation of the build job. The first step involved carefully aligning the optimised geometry of the Air Separator in the AM Studio software for the planned production on the NXG XII 600 laser powder bed machine from Nikon SLM Solutions. Optimal positioning was crucial to ensure both the quality of the manufacturing process and the efficiency of the build.

In addition, the geometry was equipped with support structures specifically designed to maintain stability during the build process and minimise post-processing. These supports were developed to be easily removable after manufacturing, without compromising the precision of the component.

A critical step was the creation of the digital production data, which included the precise definition of laser paths and speeds for each powder layer. Thanks to the powerful software, this process was completed in a comparably short time—less than 10 minutes.
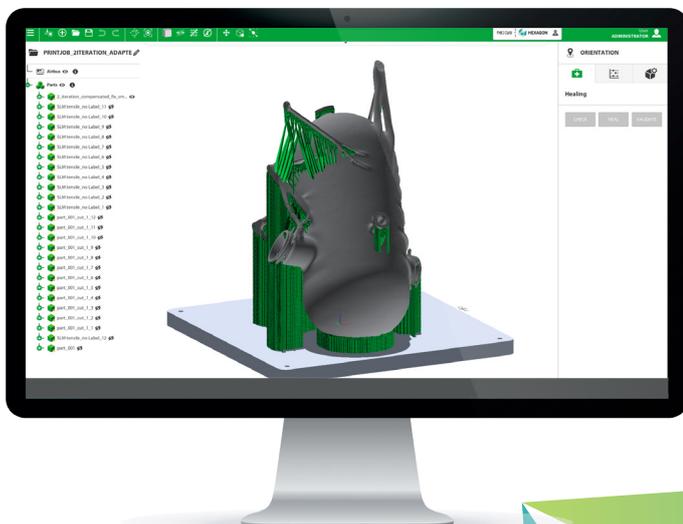
The simulation advantage: Enabling excellence in manufacturing

Before initiating the actual build job on the laser powder bed machine, a virtual simulation of the planned additive manufacturing process was conducted using Simufact Additive software. This step aimed to identify potential manufacturing risks in advance, predict process-related shape deviations, and subsequently minimise them.
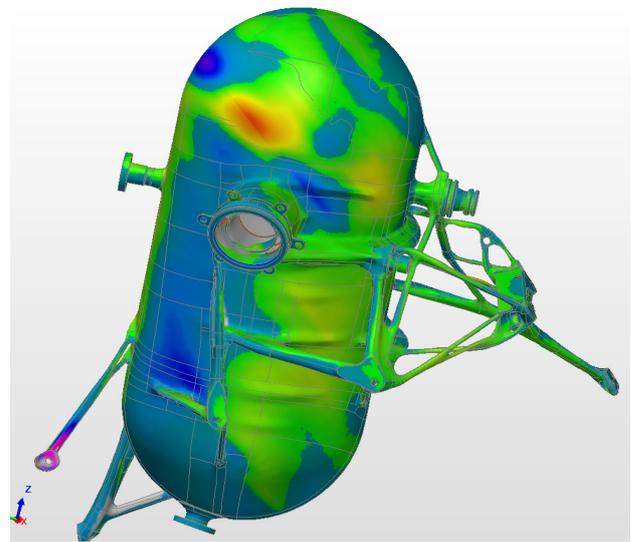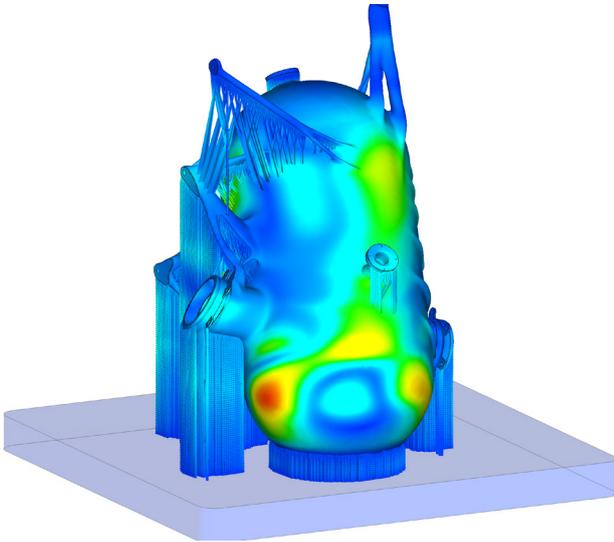

To prepare for the simulation, calibration test data from cantilever specimens provided by Nikon SLM Solutions were imported into the software. After the calibration process, the additive build process of the optimised Air Separator was realistically simulated for the chosen combination of machine and manufacturing parameters. A complete simulation run fit effectively between the end of the workday and the next morning, making it significantly shorter than the actual process. Virtual optimisation loops can thus be conducted more quickly and cost-effectively than "trial-and-error" iterations with actual build jobs.

The key insights from the successful simulation were the relative deformations of the virtually manufactured component compared to the nominal CAD geometry and the resulting stresses within the material. The deformation data were used to assess the risk of the component colliding with the powder coater during the layer-by-layer build. Fortunately, no increased risk of such a potentially fatal event—which could lead to component defects or even process termination—was identified. The evaluation of the simulated stresses also indicated no significant risk of component or support structure failure during the build time.

Additionally, predicted deformations of over 4 mm in some areas were geometrically compensated through multiple iterative pre-deformations. In the simulation, a best-fit alignment showed residual deviations of less than 1 mm at the peak, with deviations under 0.2 mm predicted for approximately 99% of the component.

This paved the way for the production of the real, physical Air Separator with the assurance of avoiding time-consuming and costly component-related issues during additive manufacturing.
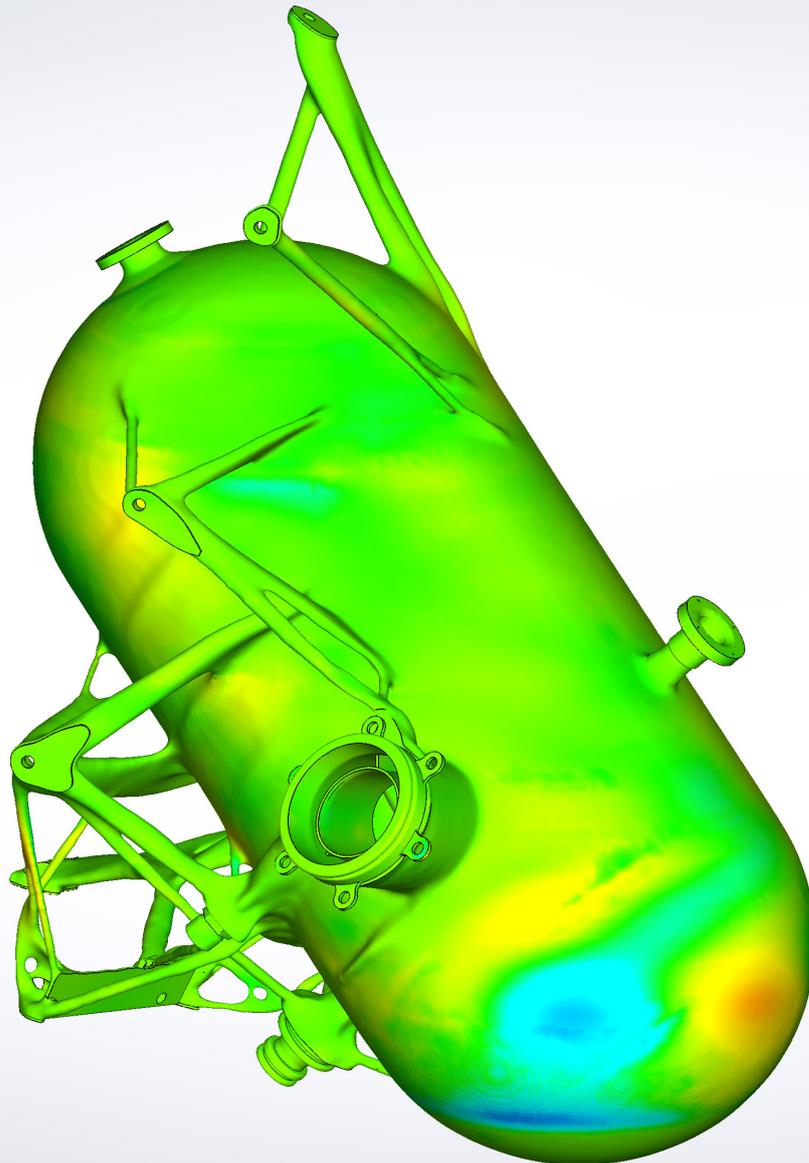
From ideas to reality: The transformative potential of additive manufacturing

To minimise iterations in component optimisation for this complex design and achieve optimal support structures with regard to post-processing, a test build of a critical section of the Air Separator was conducted on the reliable SLM®500 from Nikon SLM. As predicted by the simulation, no critical issues arose that would necessitate changes to the planned build strategy.

Following these thorough preparations, the eagerly anticipated additive manufacturing of the fully design-optimised Air Separator commenced. The component, with a maximum volume of approximately 500 x 600 x 600 mm³, was produced on one of the largest and most productive machines from Nikon SLM Solutions: the NXG XII 600, equipped with 12 lasers, each with a power of 1 kilowatt. After 68 hours, the newly design- and manufacturing-optimised Air Separator was successfully produced on the first attempt, marking a joyful "first-time-right" experience for all project participants.

Before manufacturing the second demonstrator, minor adjustments were made to the support structures, particularly those that posed challenges in accessibility during final processing. This reduced the duration of post-processing. Additionally, the support of a mounting arm was reinforced to prevent oscillation during subsequent milling operations. For safety, these changes were again verified through simulation and deemed non-critical. As expected, the second physical Air Separator was also additively manufactured without issues.

For quality monitoring of strength, tensile bars were produced alongside the Air Separator. These samples were exposed to either 1 or 2 lasers, providing comparative values for single and multi-laser areas. The tensile bars underwent the same heat treatment as the Air Separator and were machined before testing. The results showed that expectations for tensile strength, with an average value of 1045 MPa, and the 0.2% yield strength, with an average value of 965 MPa, were met.

> **Manufacturing large lightweight components at competitive prices requires multi-laser exposure strategies. Nikon SLM has been developing these for over a decade, enabling the production of complex parts with industry-standard quality."**

Andreas Solbach
Senior Application Engineer - Aviation & Space, Nikon SLM Solutions AG

Precision in focus: Elevating quality assurance through precise measurement

To conclude the project, the digital process chain was extended to include optical measurement. Using a Hexagon SmartScan VR800 structured light scanner, the first of the two fully printed demonstrators was optically measured and compared to the nominal CAD geometry.

This process qualitatively confirmed the shape deviations predicted by simulation, although the deviations were slightly higher in reality. It is important to note that the relative positioning of the simulation and measurement results to the CAD geometry was not fully synchronized, which can lead to discrepancies due to different data evaluations. However, a unified alignment of CAD, simulated, and measured geometries is generally possible.

Only two points showed maximum deviations of about 2 mm, while the majority of the printed component exhibited deviations under an absolute value of 0.5 mm. Notably, the critical connection areas achieved impressive accuracy with dimensional precision of approximately ± 0.25 mm, for the component's size and complexity an exceptionally impressive result!

> " In this project, we successfully demonstrated our expertise along the digital process chain in simulation and optical measurement: with lightweight optimisation, manufacturing simulation, and final quality assurance."

Dr. Patrick Mehmert
Senior Research Engineer, Hexagon Manufacturing Intelligence GmbH
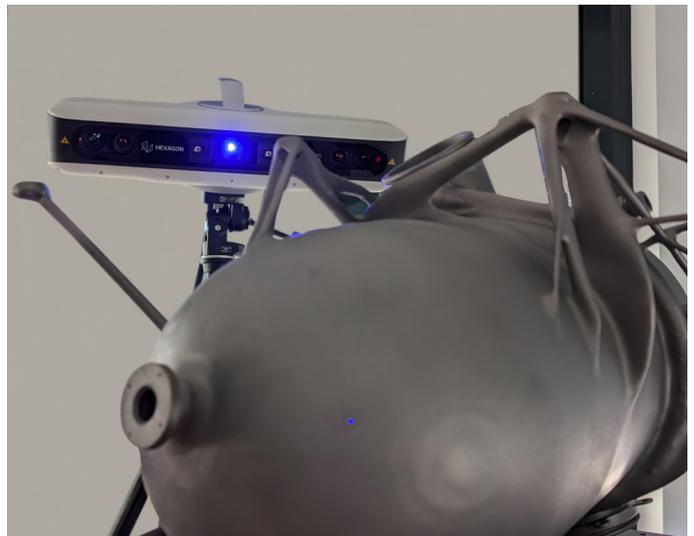
Conclusion: Efficiency meets sustainability - the air separator as a beacon of AM innovation

The Air Separator project has impressively demonstrated the potential of additive manufacturing in general and specifically for aerospace applications. The additional design freedom compared to conventional construction and manufacturing enabled the creation of a novel, fully integral, and weight-optimised component that was previously impossible.

The project also showcased the successful integration of various process steps within the digital process chain. The innovative generative design, combined with state-of-the-art manufacturing preparation, simulation validation, and deformation compensation, allows for the full utilisation of the capabilities of current laser powder bed printers. Subsequent digital metrology further ensures adherence to the targeted geometric tolerances.

The predefined project goals were fully achieved or even exceeded:

Project Goal	Achievement	
Weight reduction > 50%	Weight reduction of 75%	✓
Max reduction of individual parts	Reduction from >30 to 1	✓
Reduction of manufacturing costs	Achieved	✓
Retention of all interfaces	Achieved	✓
Acceptable surface roughness at connection points	Achieved	✓

By employing cutting-edge technologies and innovative design processes, the project not only met but surpassed its primary objectives, resulting in a completely new design that is not only 75% lighter but also consists of a single integral component. This transformation promises significant cost savings, a reduction in kerosene consumption, and a CO_2 savings potential of approximately 246 tons over the lifecycle of an aircraft.

While manufacturing costs were not quantitatively compared in detail within the project, it is highly likely that the resource-optimised production of a single component in 68 hours plus post-processing is more cost-effective and significantly faster than the previous production of over 30 components and their assembly through welding, riveting, and screwing.

Maintaining interfaces during design optimisation is standard practice and was fully achieved. An acceptable surface roughness at connection points is achievable through milling post-processing, made possible by the

achieved geometric accuracies combined with local material allowances at the affected flanges.

This project exemplifies how additive manufacturing can shape the future of aviation by setting new standards for efficiency, sustainability, and innovation. It demonstrates how digital tools can lead directly to functional designs and error-free manufacturing. By leveraging modern software and manufacturing technologies, a fully integral and weight-optimised component was created, meeting the increasing demands of the aerospace industry.

Outlook: Charting new horizons with future innovation

The completed project has clearly demonstrated the feasibility of substituting the conventional assembly with an additively manufactured integral part. In a follow-up project, further improvements could be explored for potential implementation in the A330 series. Among other things, the design could be further adjusted to completely eliminate internal support structures or adapt them so they can remain within the component without issues. Additionally, there is potential to enhance deformation compensation based on optical scans of the actual printed component. Finally, certification-related documentation, such as comprehensive static and fatigue justification, would need to be prepared.

This project impressively showcases the potential to integrate large structures into aircrafts using laser and powder bed-based additive manufacturing processes and the corresponding software. With this demonstrated potential, the expansion of additively manufactured aerospace components should face no significant obstacles, aside from the necessary management decisions.

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