bigrep

From the Print Bed to the Sky

3D Printing Aerospace-Grade Parts

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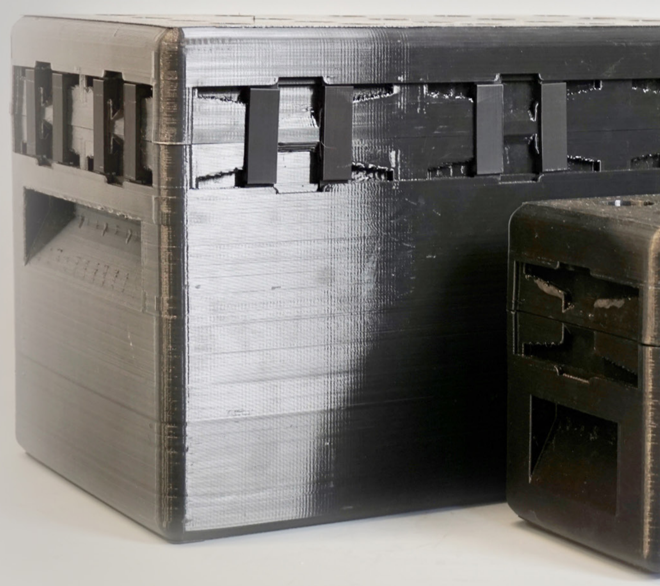
Additive manufacturing gives aerospace companies purpose-built, qualified tools to explore the skies and beyond. From on-demand production of MRO equipment (Maintenance, Repair, and Overhaul) for commercial aviation to stabilizing defense helicopters aboard ships at sea, the sector has realized that AM capabilities can go anywhere.

Aerospace-ready materials like high-performance polymers and composites have further strengthened 3D printing's space in the sky. They are now used in manufacturing robust end-use parts in place of traditional metal components and are lighter than their metal counterparts. Resistant to high temperatures, pressure, impact, chemicals, and various factors, they can qualify to meet the stringent demands of the aerospace industry.

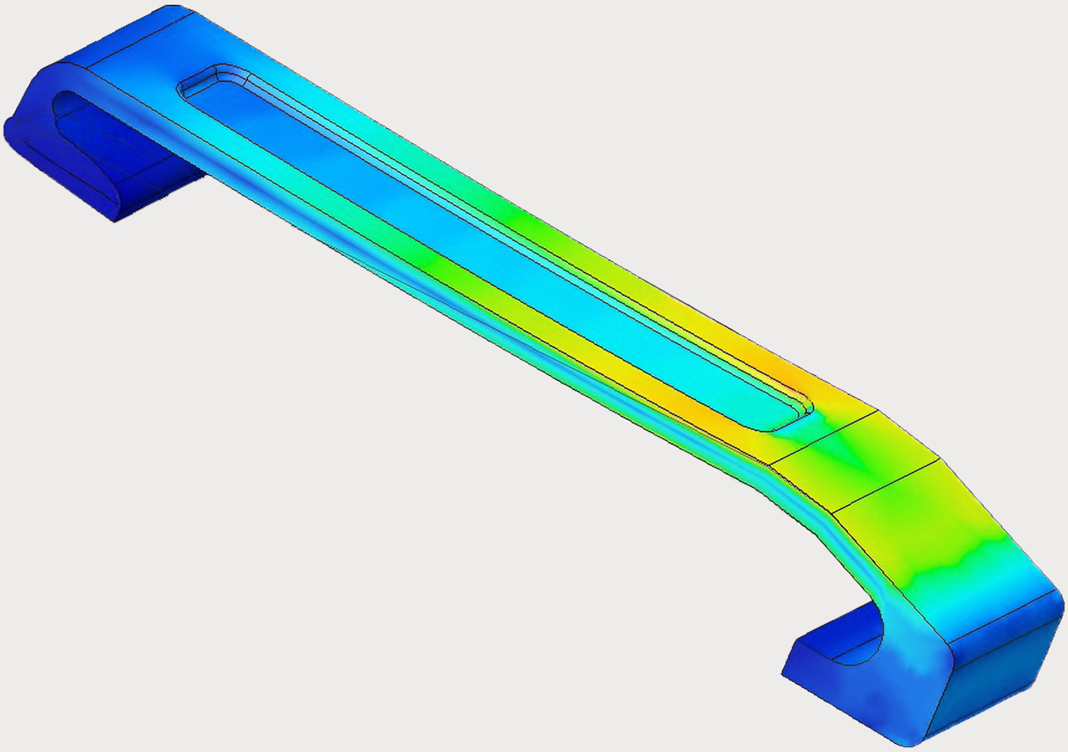
Testing methods include both internal certification of 3D-printed parts, processes, and materials, as well as specific certifications developed by OEMs or suppliers. Whether it's a 3D-printed armrest surviving the rigors of every flight use or a critical component like propellers for UAVs exposed to the environment, every fabricated part goes through a rigorous validation process.

Validating Airworthy Parts and MRO



Aircraft interiors see a wide range of additive manufacturing applications. 3D-printed cabin components such as ducts, vents, electrical housings, and TV frames are commonly found in almost every aircraft. All of the parts are tested to meet certain requirements like thermal resistance and flame, smoke, and toxicity (FST) ratings. Thermal resistance tests qualify the part's ability to withstand high temperatures without deforming, melting, or releasing harmful gases, and also help contain the spread of flames and protect people on-board.

Structural tests are also conducted on end-use aerospace parts like air ducts, overhead bins, and trim panels to check if they can withstand pressure differentials, impacts, compression, vibrations, and other stresses. Though prototypes, tooling, jigs, and fixtures aren't end-use parts, they also go through tests to check if they can handle the forces and stresses associated with assembly, machining, and handling processes.

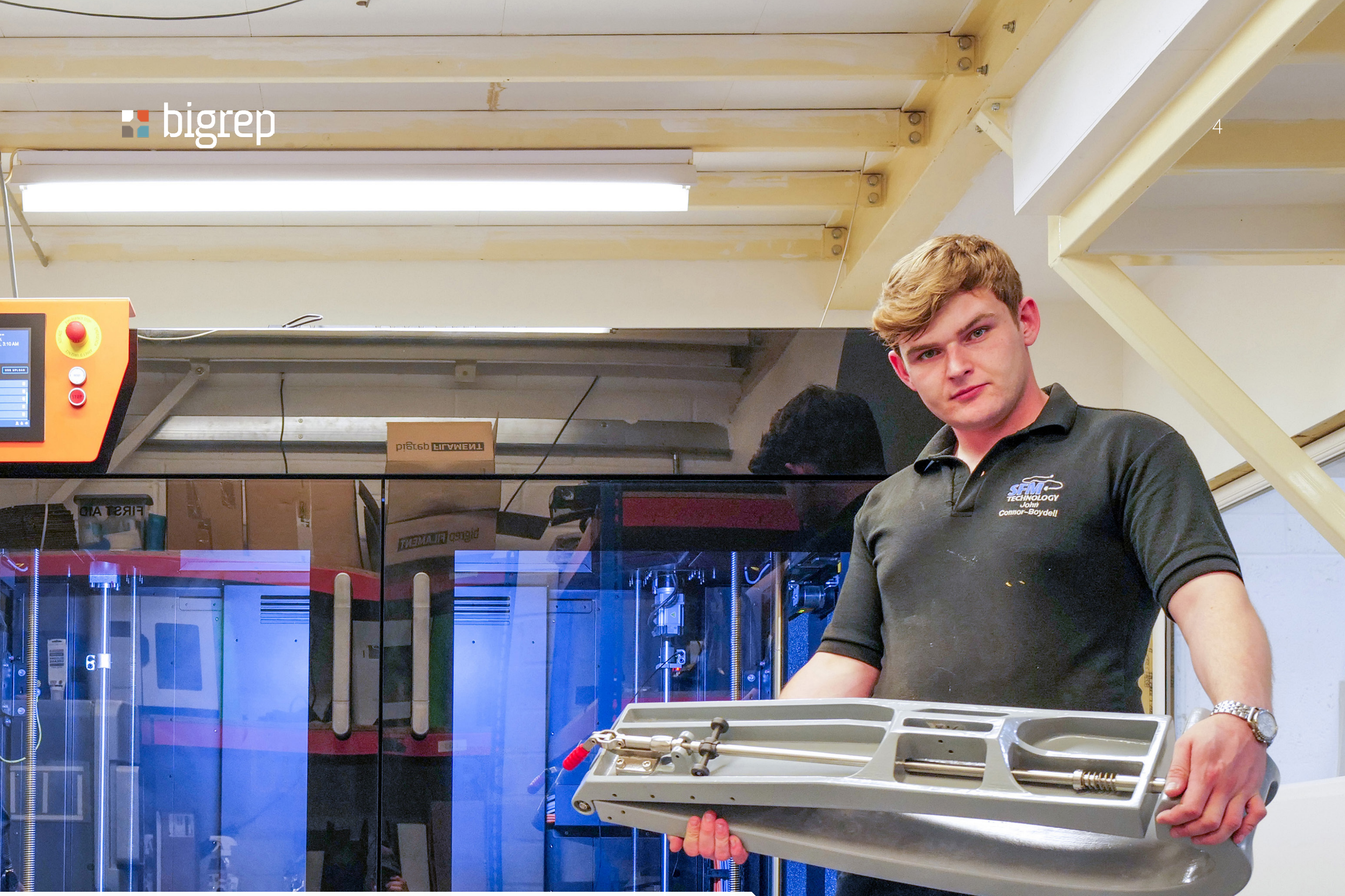


Finite Element Analysis (FEA) for Robust Aerospace Parts

Finite Element Analysis (FEA), a simulation method, is commonly used in tandem with other tests to validate 3D-printed aerospace parts. This enables engineers to predict and optimize the part's structural integrity, performance, and reliability in diverse operating conditions.

Unlike traditionally produced metal components, 3D-printed parts are not isotropic. This is why physical structural tests along with FEA are necessary to fabricate parts that can withstand anticipated loads and still weigh a fraction of their metal counterparts. Engineers can account for the potential lack of structural strength by adjusting the infill, where the stress points have a higher amount of infill than the rest of the part.

Both simulated and physical assessments provide invaluable data to validate design choices and refine prototypes and end-use parts. However, the ultimate test is when they are translated into real-world applications. Bridging the gap from meticulous testing protocols of the 3D-printed parts to putting them to use, we have compiled 3 use cases demonstrating the versatility of AM in aerospace.



SFM Certifies Performance of 3D Printed Helicopter Cradles

Leonardo, a key player in aerospace and defense, tasked with providing defense helicopters, for the Royal Navy, encountered challenges with their existing rotor blade restraint cradles. Turning to SFM Technology's AeroAdditive department, they introduced the ***first ever 3D-printed rotor blade restraint cradle****, measuring 900 x 230 x 160mm. The post-processed restraints can now withstand weather and seawater, outperforming former metal parts made using traditional methods.*

When helicopters are on-boarding a ship, they face the challenge of staying stable on the flight deck or being stored in the ship's hangar. Stabilization becomes crucial for smooth embarkation, so the blades don't flap around. The automatic folding system, similar to a bumblebee's wings, folds the blades to decrease the space needed for storage. The blades are then firmly held in place with the restraint cradles.

SFM Technology, under time constraints, leveraged the **BigRep PRO as a production and prototyping machine**. The 3D printer produced 63 cradles made from Hi-TEMP CF, demonstrating the efficiency and strength of additive manufacturing.

Putting the 3D-Printed Cradles Through the Paces

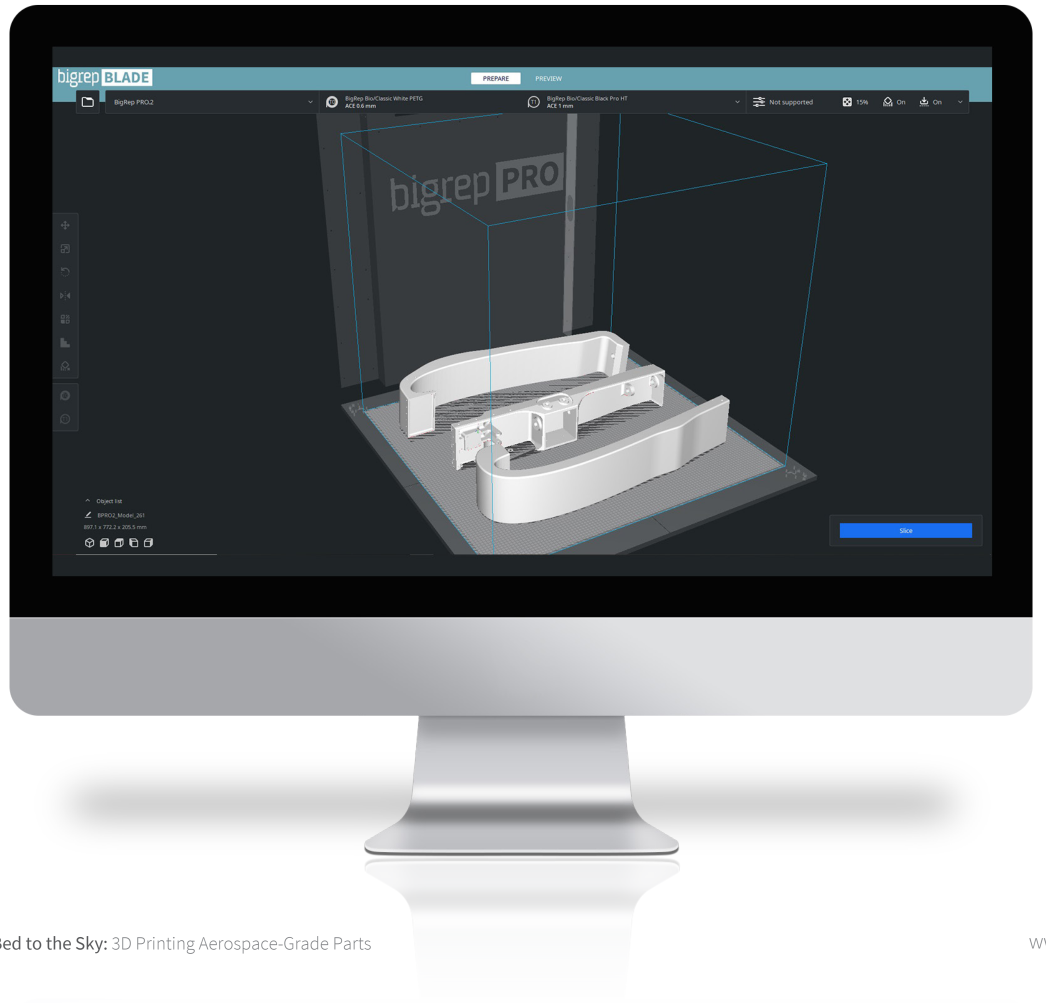
The cradles underwent rigorous testing to verify **strength, stiffness, and impact strength** to ensure they were robust and reliable. After seven design iterations taking up to eighteen months, with each design going through the testing phases, SFM produced the **first-ever 3D-printed rotor blade cradle.**

Leonardo, the customer, was presented with the **Finite Element Analysis (FEA)**, containing results from stress analysis software and physical tests qualifying the material (BigRep's **HI-TEMP CF**) and the parts. **Materialize,** a software for triangulation, and **Patran, for stress analysis**, gauged how the rotor blades would respond in real-world conditions.

The combination of these software helped identify and rectify structural weaknesses by adjusting the infill's density, shape, and orientation to optimize the design and improve its strength and stability. More infill was added at the sections that would be under larger stress almost to the point of being solid and reduced in other areas to make the cradle lighter. This helped save material without compromising on the performance.

To assess **impact strength**, the cradles were dropped from the height of the helicopter, simulating real-world conditions. The previous restraint cradle made of fiberglass and metal didn't survive the impact, but the 3D-printed one was left with minimal damage, proving they remained fully serviceable.

A universal testing machine conducted **tensile (pulling) and compressive (pushing) tests on the cradles** which were vital to measure strength and stiffness. While doing the tests, SFM went beyond the customer's specifications and the cradle remained unscathed.



Gary Wilson, head of Technical Sales at SFM's AeroAdditive division tells us:

> *We basically pushed the cradle beyond customer specification to see the forces it could withstand. We actually beat the specification and the cradle was intact, exceeding our expectations and also Leonardo's.*

The next series of tests assessed how they performed under the forces of nature. The cradles' **resistance against environmental conditions**, including rain, sun, and saltwater was under the lens. SFM sent samples of the material, both untreated and post-processed by sanding and painting, to the Ministry of Defence's testing laboratory. The samples were immersed in saltwater tanks, subjected to sunlight exposure, and tested for resistance to degradation. The cradles also underwent a **six-month deployment** and **rigorous testing at sea.**

Despite being pushed to the limits, the cradles held up in all environments - simulated, staged, and real-world scenarios, which were crucial for their deployment. The resilience of the cradles in physical conditions ranging from the Arctic to the tropics affirmed the effectiveness and reliability of the 3D-printed main rotor blade restraint cradles.

Airbus Embarks on Certifying 3D-Printed Shipping Cases

> *Airbus leveraged BigRep's large-format 3D printers to **eliminate a regular expense** of up to **$10,000** by reinventing a traditional manufacturing workflow. In collaboration with application engineers at BigRep, Airbus designed TPU boxes for delicate aviation equipment and set on a path to **certify the 3D-printed equipment.***

The logistical intricacies surrounding the transportation of delicate aviation equipment present a considerable challenge. Businesses, especially those dealing with aerospace imaging cameras, face the daunting task of predicting their need for investment cases years in advance. This is caused by prolonged wait times due to the highly manual **production process of up to 9 months**, certification for individual investment shipping cases, and a limited number of suppliers. As a result, the **waiting time for the cases often exceeds two years –** a disastrous lead time for businesses.

In response to these challenges, Airbus, in collaboration with BigRep, is pioneering a solution that places a strong focus on **testing and certifying the entire process** instead of certifying a case at a time. Leveraging data driven design and using BigRep's TPU filament, Airbus aims to streamline the manufacturing of custom investment shipping cases. The approach capitalizes on the dynamic material properties of TPU and Fused Filament Fabrication's (FFF) common infill patterns to replace traditional foam cushioning.

TPU exhibits firm material properties when printed into a thick wall. But in thinner compositions, it is soft and flexible, making it highly shock absorbent. The equipment's shape is left hollow in the infill, resulting in a design that can be manufactured as a single unit in a completely automated process. Latches are created parallelly in a second firm material and can be added to cases by end users.

Testing the 3D-Printed Investment Shipping Cases

> *"We've already started testing to qualify the design for certifications,"* said Ralf Schlueter, Managing Director, of Flugzeug Union Süd (an Airbus subsidiary). *"So far the TPU cases have been drop tested, successful in deceleration of 20 to 40 Gs, and had no physical changes in high temperature tests."*

During high-temperature testing, the shipping cases were tested for their thermal stability, resistance to thermal expansion, material degradation, and thermal stress. The testing process involved exposing the components to temperatures well beyond normal operating conditions and monitoring their behavior, structural integrity, and functionality throughout the duration of the test.

For the drop tests, the shipment cases were subjected to deceleration of 20 to 40 Gs, meaning they endured forces 20 to 40 times greater than the force of gravity. These tests indicated the case's ability to manage and mitigate high levels of force during impact, which is crucial in ensuring the safety of the delicate equipment it is designed to carry.

By exploring the **certification of the entire manufacturing process, instead of certifying individual cases, Airbus envisions a scalable solution offering businesses a more responsive and efficient solution** for managing complex logistics.

CNE's Solution for Scandinavian Airlines: Getting Certified, Covered, and Grounded

> *The COVID-19 pandemic halted most travel grounding 62% of passenger planes and triggering a domino effect in global supply chains. This was particularly challenging for the aviation industry as planes are not designed to be on the ground for extended periods. The industry was overcome with unforeseen problems that they had to tackle in a very short time such as lack of parking real estate and skyrocketing maintenance costs.*

The Scandinavian Airlines (SAS), as most of its planes were exposed to Norway's typically harsh winter, had to act quickly when the pandemic stranded their planes. The airlines needed covers for the engine exhaust and wrapping and unwrapping them was a daunting task that took hours of manual labor. Also, limited supplies and increased demand made ordering exhaust covers impossible. SAS turned to CNE, a specialized local engineering company that provided support to the airline. Shortening the supply chain to harness more locally available resources using 3D printing emerged as the solution but, they needed a machine large enough to produce engine exhaust covers. This is where BigRep's large-scale 3D printing capabilities helped create a local and agile supply chain.

Qualifying the Cast Engine Covers

CNE utilized two BigRep machines to 3D print molds for producing cast urethane parts, employing different materials for various components. BigRep's bio-based PLX, HI-TEMP CF, as well as TPU were chosen for outer shells, center cores, and insert molds, respectively.

The material of the cast engine covers had to go through **extensive testing and prove to withstand high temperatures and exhibit chemical and UV resistance.** It also had to be soft enough to not damage the engine upon removal and installation. Based on these requirements, castable urethane, a widely available and low-cost material, emerged as the best option.

Nathan Brown, Managing Director of CNE, said:

> *There was an opportunity to not only fill their need for this tool they couldn't acquire through the normal supply chain, but we also saw the opportunity to make it better.*

Reimagining the Production Workflow with BigRep

CNE Engineering fulfilled three key aspects of their design with their BigRep 3D printers. First, a range of material options enabled them to test and experiment with the final cast. Second, the build volume (1m3) of the BigRep ONE was large enough to meet the dimensions of the jet engine exhaust with single-piece prints. Further, the print-line orientation of the mold design enabled the ease of casting and mold release.

The large-format 3D printing capability enabled CNE to meet SAS's tight timelines, with the molds printed within days and castings completed in a matter of hours. SAS received its initial order within just two months of the kick-off meeting. Orders continued with similar quantities in various sizes for the different airplanes. The hours-long endeavor of wrapping and unwrapping jet engines is now a matter of minutes for a maintenance technician and these custom-built covers.

The Future of Flight

Safety is one of the biggest concerns in the aerospace industry and 3D-printed parts in general undergo more rigorous testing than traditionally manufactured parts. Given the conformance quality of the printed components and the range of materials, additively manufactured parts, processes, and materials qualify for certifications and testing parameters. This makes the flight, repairs and maintenance, and prototyping more agile, resulting in safer aircraft taking swiftly to the skies.

AM's ability to maintain a digital inventory and produce spare parts on the fly is also one of the primary reasons aerospace embraces 3D printing technologies. This reduces warehouse and logistics costs, ensuring critical parts are available when needed. Also, FFF makes use of readily available local materials cushioning supply chain disruptions and reducing aircraft downtime in the long run.

These advantages along with rapid prototyping and quick iterative design processes, speed up the testing and certification processes which accelerate innovation and enable the development of next-generation aerospace technologies.

REDEFINING **ADDITIVE**

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