

Aircraft Cooling Impeller Redesign

NAVAIR Fleet Readiness Center - East



PROBLEM STATEMENT

NAVAIR can no longer source the outdated impeller for an aircraft, as the company has stopped manufacturing them. The aircraft has a history of overheating, and the impeller's performance is believed to be a contributing factor. The current airfoil design of the impeller, developed in the 1960s, may be considered inefficient by modern standards. A comprehensive redesign of the blower impeller is needed to improve the aircraft's thermal management, possibly improving the manufacturability, efficiency, and lifespan.

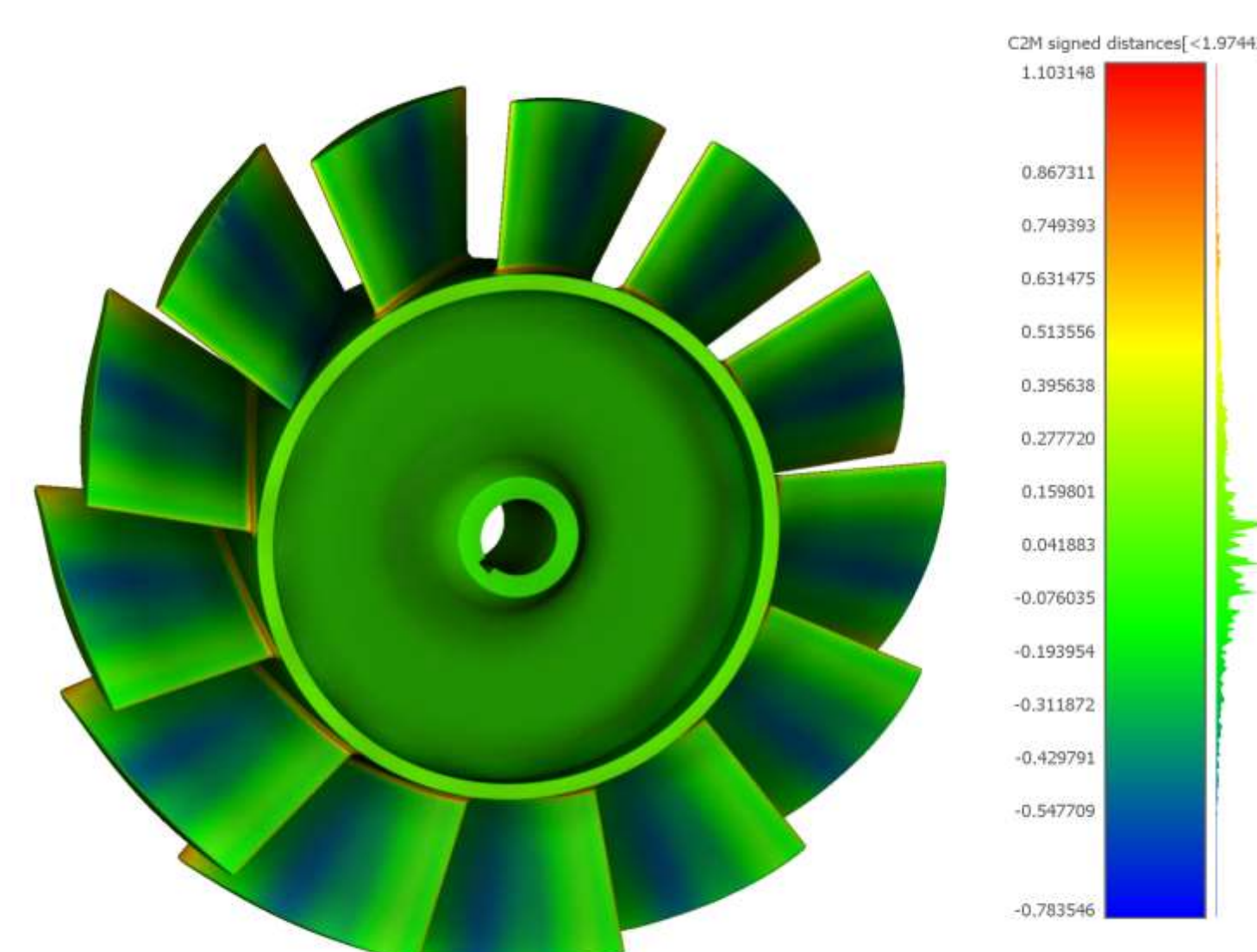
REQUIREMENTS

#	Description
1	The optimized impeller must improve volumetric flow rate of air, with a target of at least 3%.
2	The optimized impeller must withstand all dynamic stresses at a minimum factor of safety of 1.5.
3	Create a parametric impeller within 1mm of the original impeller geometry at any given point.
4	The prototype impeller must be delivered by the end of April 2025.

Point Cloud Analysis

NAVAIR provided us with a 3D scanned model of the original impeller. First, we had to create an accurate parametric CAD model based on this 3D scan by:

- Generated a parametric CAD model from the 3D scanned mesh.
- Conducted a point cloud analysis to compare our CAD model with the original scanned model within ± 1 mm.

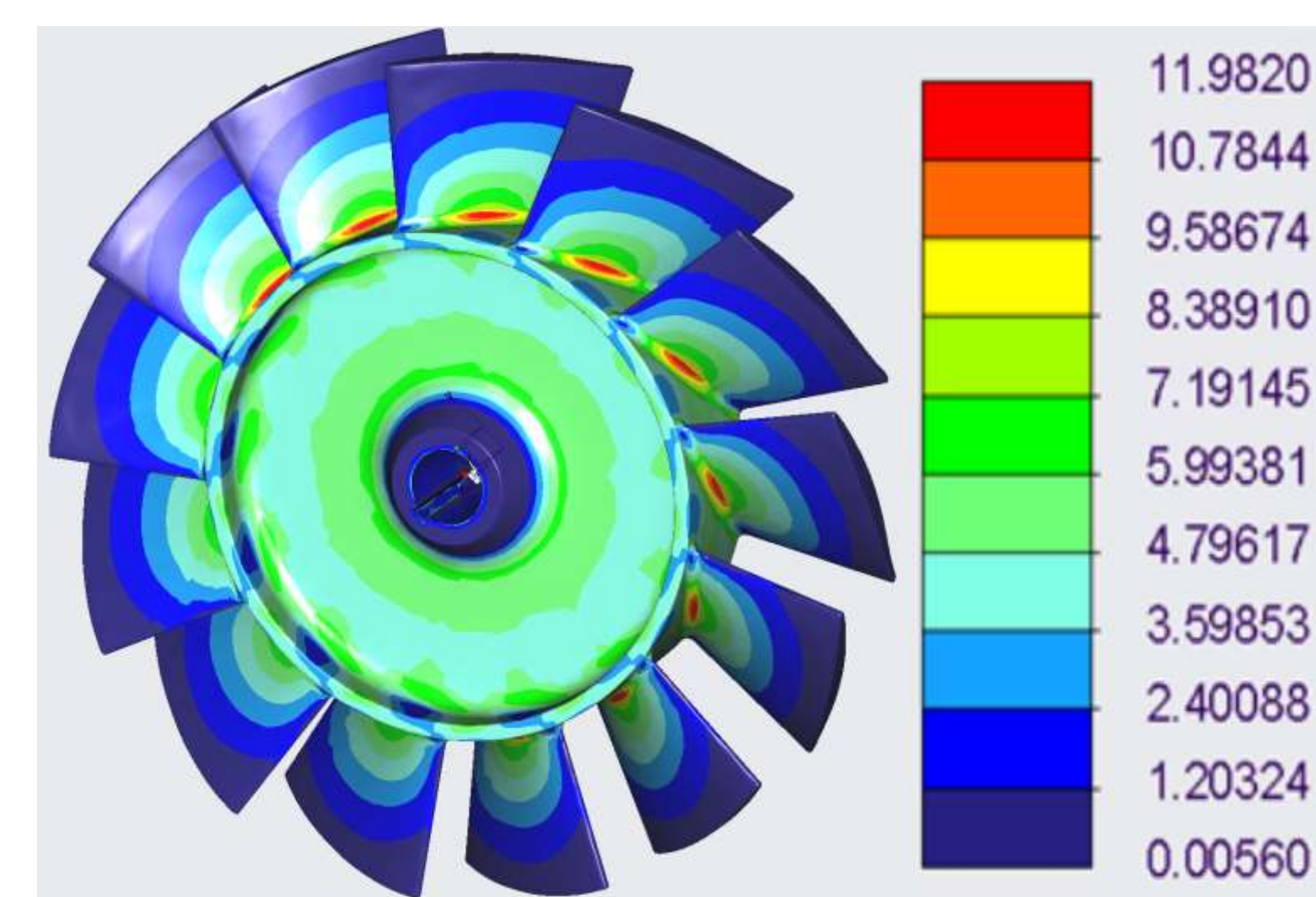


The image above shows our point cloud analysis results, confirming compliance.

Finite Element Analysis

The original impeller is made from a Mg-Al alloy and NAVAIR tasked us with producing an additive manufactured product. We decided on ULTEM-9085 3D printing filament, because NAVAIR provided verification on the material. We conducted finite element analysis (FEA) by:

- Determining the forces acting on the impeller through centrifugal forces and pressure acting on the blades.
- Researching the strength data on ULTEM-9085 provided by Stratasys. Strength at break being measured at 39.4 MPa.
- Using Creo Simulate: apply known forces of a centrifugal force from the rotation and a baseline pressure force given by initial CFD analysis of roughly 0.0032 MPa on each blade.
- The results given were a max stress of 11.98 MPa giving us roughly a 3.3 factor of safety. This exceeds our goal of having a factor of safety of 2.

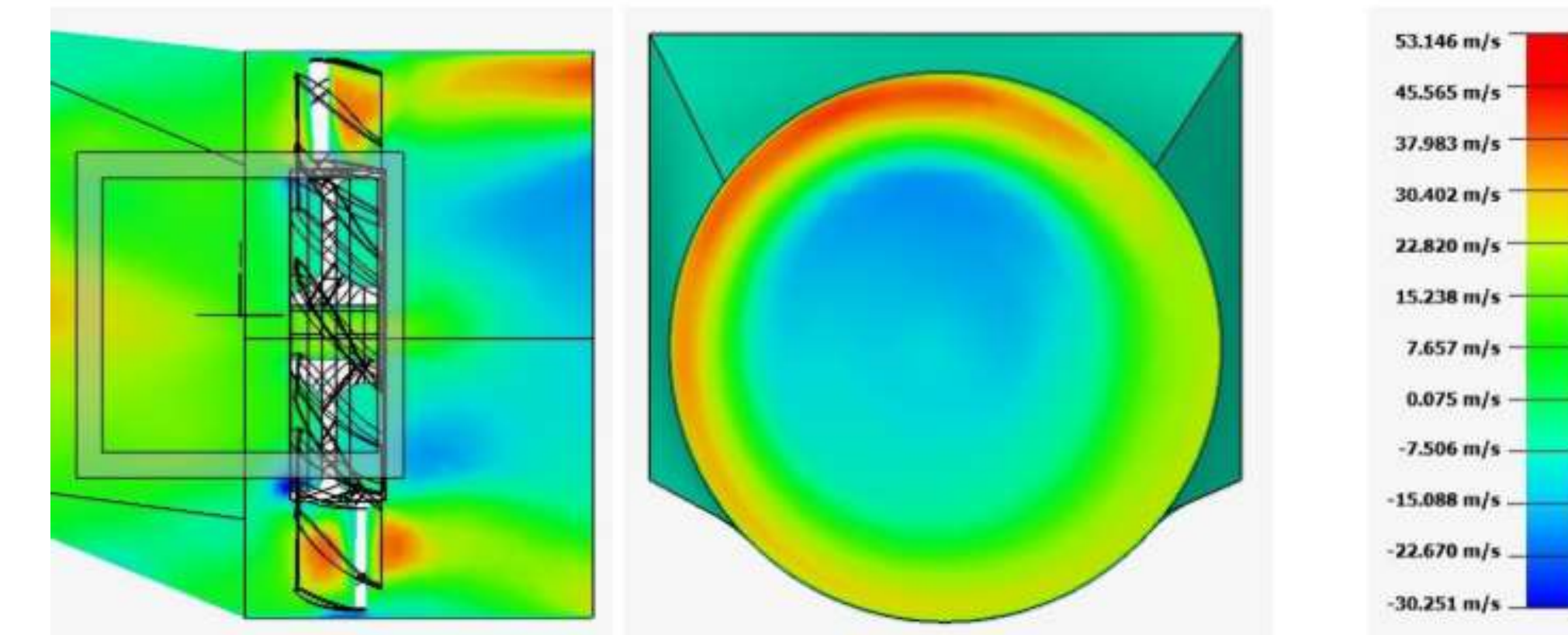


The image above shows our finite element analysis which confirms that we are within the standard of factor of safety. (units in MPa)

Computational Fluid Dynamics

We performed computational fluid dynamics (CFD) analysis on the parametric CAD model that was previously evaluated during the point cloud analysis and FEA testing. We ensured that the parametric CAD model matched the mass flow rate of the original impeller, based on physical tests conducted on the aircraft.

We conducted axial flow CFD simulations using both ALTAIR and ANSYS Fluent software and cross-referenced the results from each. Our testing utilized a steady-state simulation, with the impeller rotating at the correct RPM.



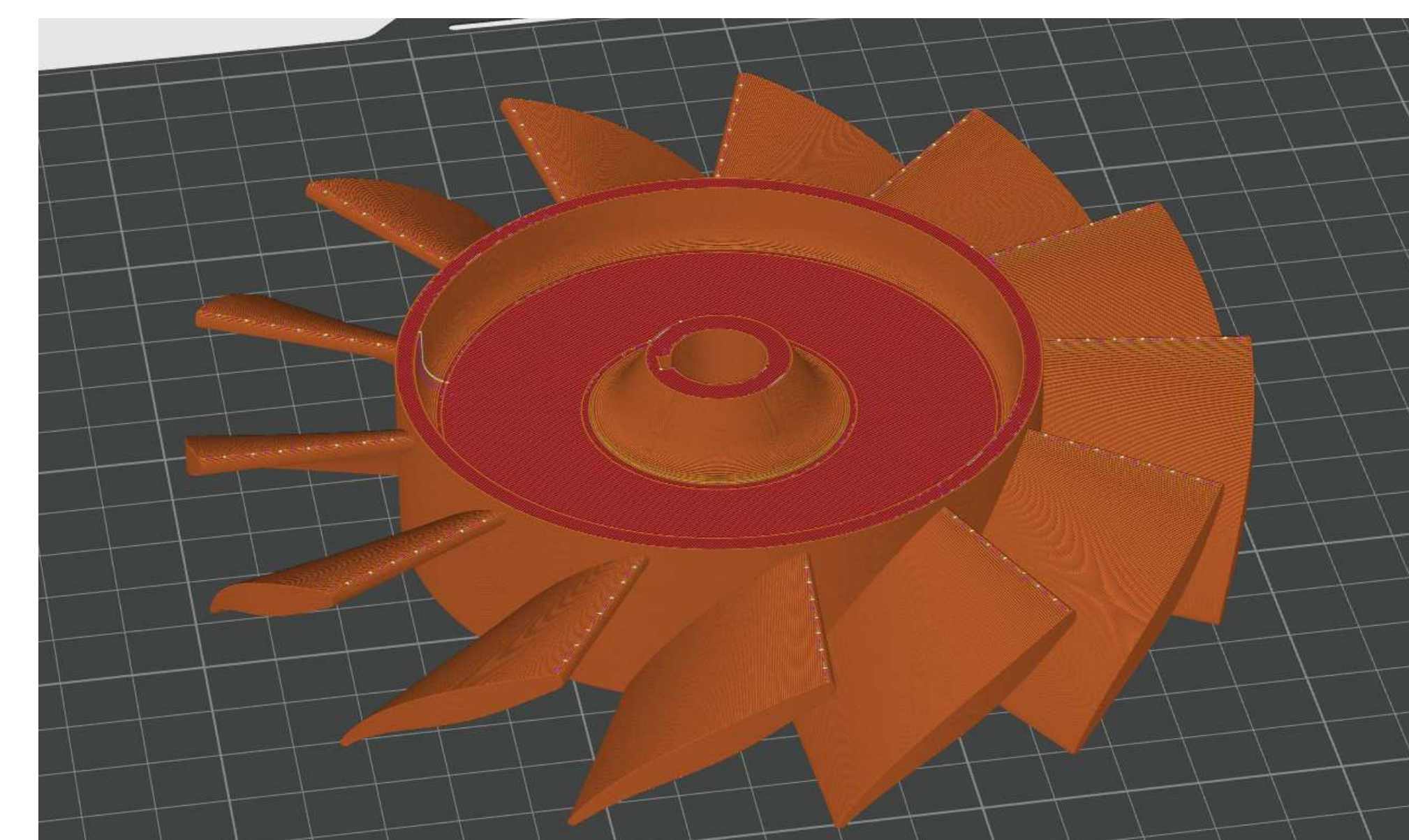
The image above shows the CFD data which confirms that our impeller matched the original data that was taken from the aircraft.

Final Design 3D Printing

The 3D printed impeller was oriented with its flat, bottom geometry facing down on the build plate, as shown in the photo below. This orientation was chosen for two main reasons: to optimize the layer line direction and to minimize the need for support material.

In 3D printing, layer lines represent the weakest part of the final print. To address this, we positioned the impeller so that the layer lines would have maximum surface area contact and strong adhesion to the central hub, which is the most structurally robust part of the design. This significantly reduces the impact of the layer lines on the overall strength and durability of the part.

Additionally, this orientation minimizes the amount of support material required during the printing process. Among all possible orientations, this one demands the least support, making the print more efficient and reducing post-processing time and material waste.



The image above shows the CFD data which confirms that our impeller matched the original data that was taken from the aircraft.

SUMMARY AND CONCLUSIONS

We redesigned an obsolete aircraft cooling impeller, originally designed in the 1960s, to address overheating issues and unavailability. The new impeller aims to improve thermal management, manufacturability, and lifespan. Requirements include a 3% + increase in airflow, operational durability, system compatibility, geometric accuracy (± 1 mm), and prototype delivery by April 2025. Using a 3D scan, a parametric CAD model was created and validated via point cloud analysis. The impeller will be 3D-printed with ULTEM-9085, with finite element analysis ensuring structural integrity.

FUTURE WORK

With additional time, we would continue CFD analysis to refine the original impeller design by adjusting pitch angles and airfoil geometries, aiming to improve aerodynamic performance. Once an optimized configuration is identified, the revised blade geometry would be incorporated into the hub model and fabricated using 3D printing or other rapid prototyping methods.

In the meantime, we will focus on finalizing the manufacturing process to ensure structural reliability and integration with the aircraft's propulsion system, with the goal of successfully installing the impeller in the aircraft.

TEAM & ACKNOWLEDGEMENTS

- Team Members:
 - Ty Antonson (Mechanical Engineering, BSE)
 - William Coffey (Mechanical Engineering, BSE)
 - Nick Foland (Engineering Technology, BS)
 - Tristan Stevens (Mechanical Engineering, BSE)
- Faulty Mentor: Martin Tanaka