

MAKER: CAD Boeing 747-400 Model Redesign and 3D Printing

Mr. Garrett Scott Wiles, Frostburg State University

Mechanical Engineering undergraduate ('18) in the Frostburg State University/University of Maryland, College Park Collaborative Mechanical Engineering Program.

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Mr. Nicholas Ryan Baicar

Mr. Brian Leech, Frostburg State University

Dr. Hugh Jack P.E., Western Carolina University

Dr. Jack is not an author and has submitted this paper on behalf of the authors.

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Garrett Wiles, Brian Leech, and Nicholas Baicar
Frostburg State University, Maryland 21532

Abstract

This student project consisted of rescaled and redesigning for a CAD model of a Boeing 747-400. The description and additional details of an actual scale Boeing 747-400 can be found on www.boeing.com.^[1] The original model was given to a Computer Aided Design 200 level class as a student assignment. After showing interest in the design adjustments made to the model, the instructor recommended that a further remodeling of the 747 assembly be constructed.

Rescaling the airplane to a small model created challenges in the aspects of accurate redesign, assembling with proper tolerance, and manufacturing constraints. The seven major parts including vertical and horizontal stabilizers, engine with rotating blades, wingspans, landing gears front and rear, and fuselage are modified based on appearance and proportionalities. The entire process of design for assembly and manufacture by CAD software has contributed the success of the project. Ultimately, the redesign of the Boeing 747-400 was 3D printed and provided a more accurate representation of the aircraft's appearance.

Introduction

The goal is to create a scaled 3D solid model of Boeing 747-400 to be printed by a Dimension SST 768 printer. The Boeing 747 CAD parts were initially created by following explicit directions provided in the class textbook by Zhang^[2]. These completed parts were in essence for the foundation of the redesign process. Paying close attention to the appearance and general proportionalities of a 747-400 through images on Boeing's official website, regenerated parts were formed and reassembled to create the final model. Every aspect of the plane was then modified from the original 747 model made in class. This ultimately would create varying complications, but after diligently troubleshooting and improving CAD fluency, a satisfactory final product was designed and 3-D printed. The final assembly, modeled to resemble a Boeing 747-400, was completed on November 21st, 2016 using PTC Creo Parametric and rescaled using Autodesk Inventor. The new design has a more aesthetically pleasing and sleeker appearance than its predecessor. After the model was processed and rescaled in Autodesk Inventor, a stereolithographic file was created and sent to a 3-D printer. The project was completed successfully.

Generate Ideas

To complete the scaled redesign project with 3D printer, one of the challenges is to meet constraints of the printing process. It was important to keep in mind the limitations involved with printing a small scaled 3-D model. Given the precision and tolerances of the 3-D printer being used, the smaller parts are at risk of printing errors as well as breaking off. In other words, although a precise redesigned model with maximum detail is ideal, simplifications must also be made for a successful print.

In order to come up with proper sizes and accurate scale for redesign, we studied the description files containing blueprints of the actual Boeing 747-400 plane. The blueprints information helped us to figure out relative sizes of the airplane parts and model of the aircraft. We studied structure, size and characters of each part with drawing, and also assembly all parts with tolerances. The assembly process created the original design as the blueprints shown in Fig.1. Based on the original model, we generated ideas to modify the original design, and created new design of Boeing 747-400 plane as shown in Fig 2.



Figure 1 Original design from Boeing Blueprints



Figure 2 Redesigned Model

Details of Work

The seven major parts including fuselage, vertical stabilizer, horizontal stabilizer, front landing gear, rear landing gear, wings and engines are considered

Fuselage:

The first noticeable difference on the fuselage is the addition of windows. To create the side windows, a simple elliptic cut extrude was made on each side of the fuselage, then using the

pattern tool, two rows of windows were created. The front pilot window is not actually a physical body, but rather an added color to a particular section of the nose. Next, the stabilizer mounts had to be reconfigured. The mounts for the vertical and horizontal stabilizers also had to be reshaped to accommodate the new profile of the redesigned stabilizers.

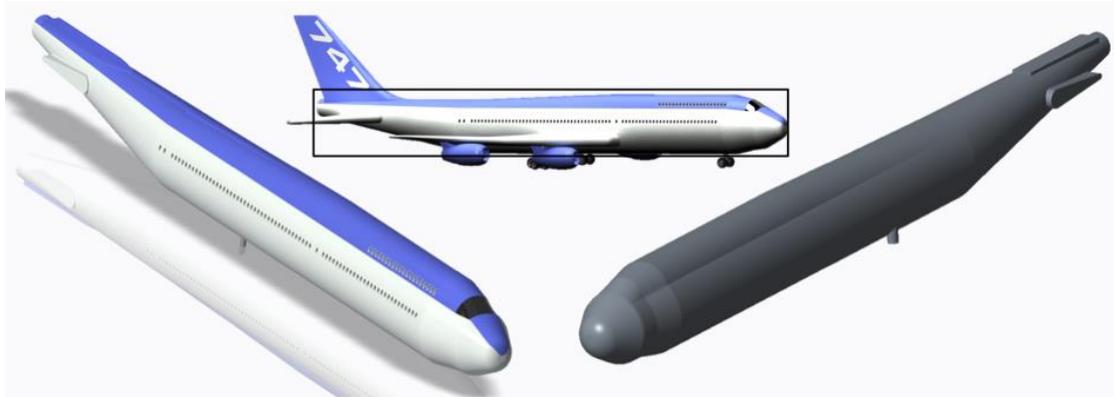


Figure 3 Fuselage with new design and original design

Vertical Stabilizer:

At initial glance, the original vertical stabilizer has a squared off front portion that fails to resemble the actual part on the airliner. In order to combat this, the front and back of the stabilizer were further rounded and the entire part was given a slimmer profile. Furthermore, the vertical stabilizer was angled further towards the back of the fuselage to provide the more aerodynamic appearance that the part has on the 747-400 in real life. The final change was embossing the 747 numbers on both sides of the stabilizer. The 747 decal on the vertical stabilizer has been known to be used by Boeing as a paint design scheme for some of their manufactured planes.

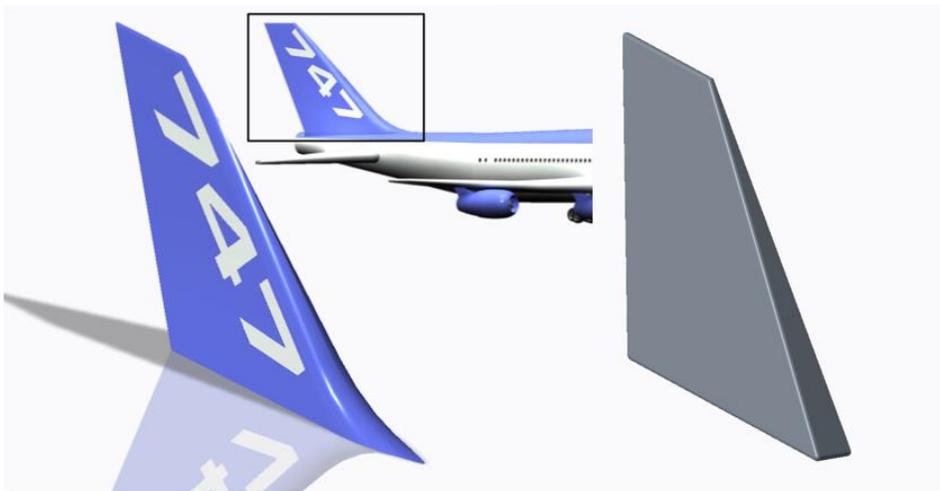


Figure 4 Vertical stabilizer with new design and original design

Horizontal Stabilizer:

For the horizontal stabilizer, the profile was adjusted so that the part was thinned to resemble more of the blade-type appearance of the stabilizers on a 747-400. In addition, the angle at which the horizontal stabilizers attached to the fuselage was enlarged to once again improve on the sleek appearance that the airliner has in real life.

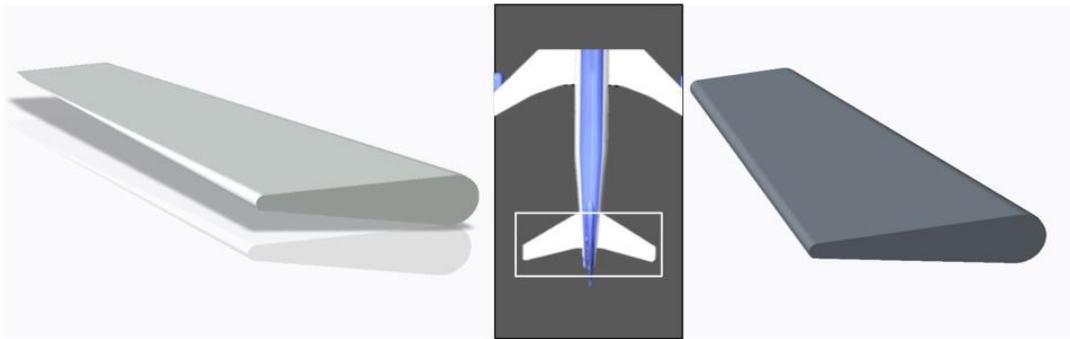


Figure 5 Horizontal Stabilizer with new design and original design

Front Landing Gear:

There were many adjustments made to the front landing gear. First, the diameter of the axle and the axle support was decreased. The axle size to wheel size ratio was disproportional compared to the real life model. To fix this issue, the original revolutions used to create these elements were adjusted accordingly. Next, using cut revolutions, the wheels were redesigned creating a distinction between the wheel and the tire that surrounds it. Finally, aluminum color and a matte black color were added to the metal components and tires respectively

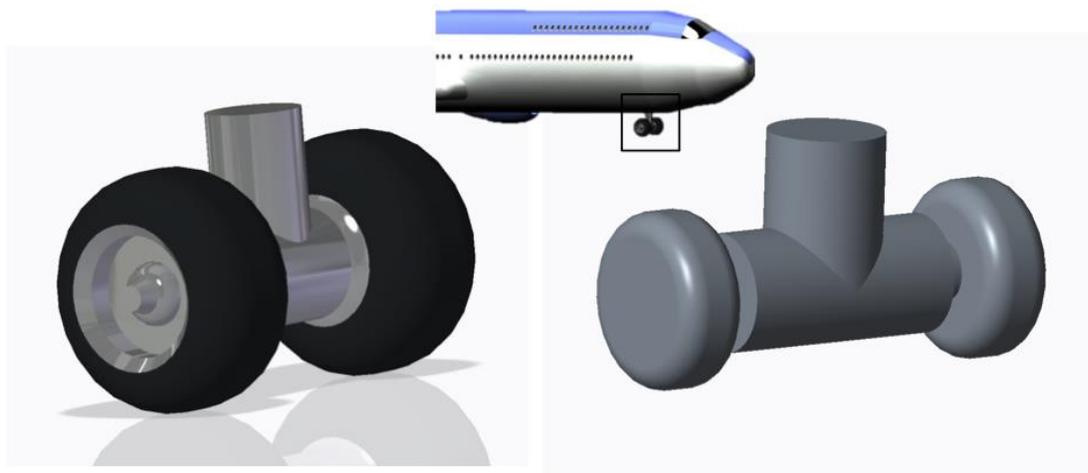


Figure 6 Front Landing Gear with new design and original design

Rear Landing Gear:

Using the same process used for the front landing gear, the size of the axles and wheels were modified, and cut revolutions were used to differentiate the wheels from the tires. The original design had an extruding cylinder coming out of both the front and back axles, so this element was deleted completely for no such cylinder exists on the 747-400 rear landing gear. When comparing the undercarriage of the 747-400 to the original model, the major differences in the location, the arrangement, and the number of wheels per landing gear were recognized. The model originally made had two sets of rear landing gear, both with six wheels, giving it a total of twelve wheels. When the real life design was observed, it had four sets of rear landing gear, each with four tires giving it a total of sixteen wheels. To overcome this issue, a pair of wheels on the original design had to be removed, which meant the shape of the axles had to be completely redesigned to accommodate four wheels as opposed to sixteen. Once the landing gear parts were modified, two more mounts had to be constructed on the wings so that there was a location of the two new landing gear sets to attach to.

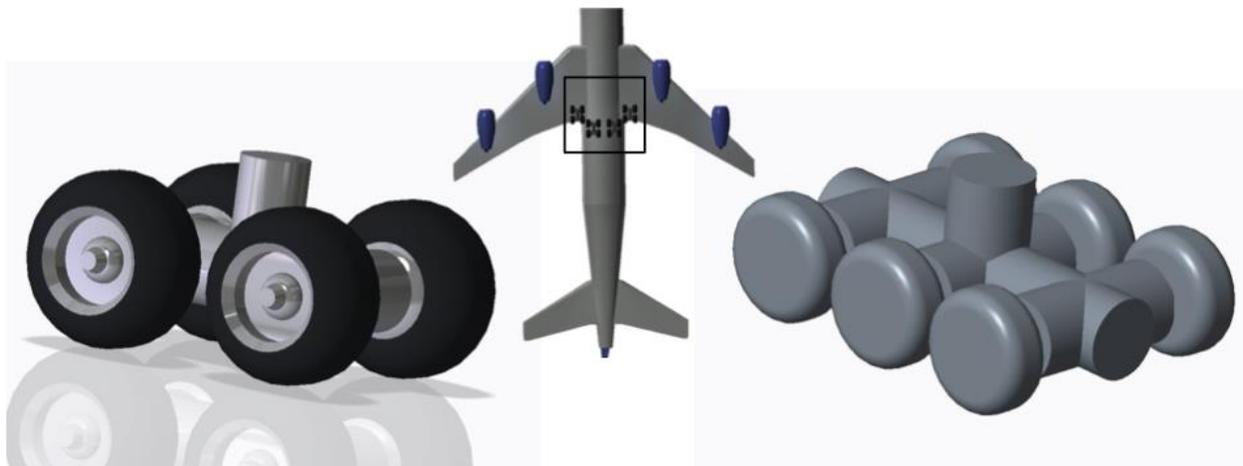


Figure 7 Rear Landing Gear with new design and original design

Wings:

Initially, there were not many noticeable differences between the Boeing 747-400 wings and the original model wings, until the front view was observed more carefully. Noticeably, the wings itself had a slight curve to them that was later found necessary for correctly fitting scaled engines underneath them. To add this curve, a cut extrude with the desired curved profile was acted upon the top and bottom of the wings. Additionally, the location of the wings on the fuselage was lower than that of Boeing's design. To adjust the placement of the wings, the coordinate system used to reference all drawings for the CAD part had to be relocated, because the method of constraint between the wings and fuselage was to coincide the two parts, coordinate systems. After the coordinate system was adjusted for a lower attachment to the fuselage, and curvature at the site of the attachment was corrected, the part successfully relocated. To accommodate the new sets of landing gear as previously stated, two cylindrical mounts coming off the bottom of the wings had to be created. Also, to accommodate newly designed engines, a new engine mount

profile had to be implemented to the underside of the wings. Finally, the front most face of the wings was rounded off to maintain the curved edge along all front wing edges of the 747-400.

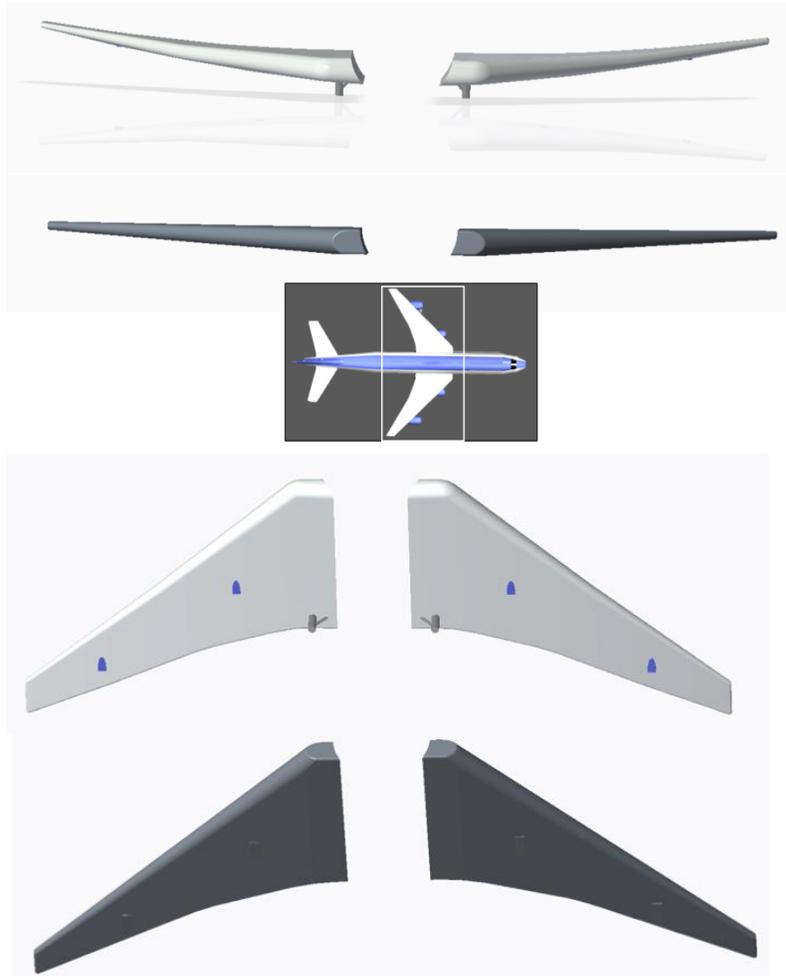


Figure 8 Wings with design and original design

Engines:

The new engine shell had to be redesigned to accurately mimic the shape and size of the turbine used on the 747-400. A revolve command was used on the shell of the new turbine to give it a broader shape than that of the school-issued part. The shape of the attachment was also modified to protrude further from the turbine and rounded to appear more aerodynamic. The location of the attachment of the turbines on the original CAD model was found to be inaccurate, so by relocating the arm that reaches off the turbine to the rear of the shell and by relocating the site of attachment on the wing, this issue was resolved. In addition, the original school-issued design called for the engine element of the 747 to be all one piece; however, to improve the model, the turbine fan was reconstructed as a separate part from the shell, so that the fan could be later animated and work as a moving part. The engines were animated by entering desired angular

velocities for particular time intervals, and then an Eulerian method was used to create a velocity function that starts from zero and increases over time to mimic the start of a turbine engine.

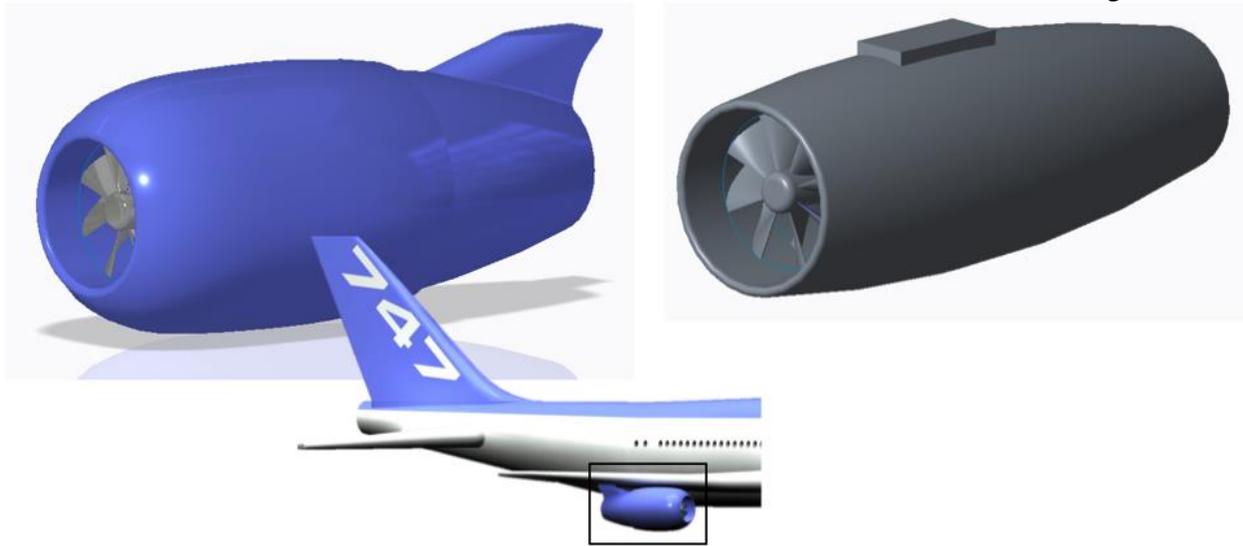


Figure 9 Engine new design and original design

Assembling Process

There are still additional improvements that could be made to the newly design 747-400 model. Given more time to work on the project, the nose cone on the fuselage should be even sharper, more fan blades should be added to the engines, and wing stabilizers should be added to the wings. Moreover, there was an issue that could not be solved. For example, the seam created from the attachment of the wings to the fuselage could not be rounded off because this would be a modification that would attempt to conjoin two separate parts in a way that does not act as an assembly constraint.

3-D Printing Process

The 3-D printing process was the most difficult of tasks within this project. In order to rescale the model from the original dimensions that started this project to a size that would fit within the 3-D printer, the assembly file had to be converted to a STEP file, so that it could be uploaded to Autodesk Inventor from Creo Parametric. This process had to take place, because no method of scaling whole assemblies was found in Creo Parametric. To rescale in Creo Parametric, all parts must be scaled individually, which ultimately would cause errors within the part attachments in the assembly. Once the assembly had been rescaled in Autodesk Inventor, the file was then exported as an STL (stereolithography) file, a format that the 3-D printer can properly read. After multiple prints of the 747-400 model and understanding the importance of print orientation to eliminate complications with support material, a satisfactory model was eventually printed. Furthermore, it was discovered that with the polylactic acid plastic being used, the lighter colored plastic cooled slower than darker colors, therefore there were more printing inaccuracies with a lighter color. The final model was printed in grey, which cooled

properly when being layered by the printer and resulted in a neater construction. The printer used is Dimension SST 768. The dimension for printing area is 8in x 8in x 12in.



Figure 10 From 3-D printer

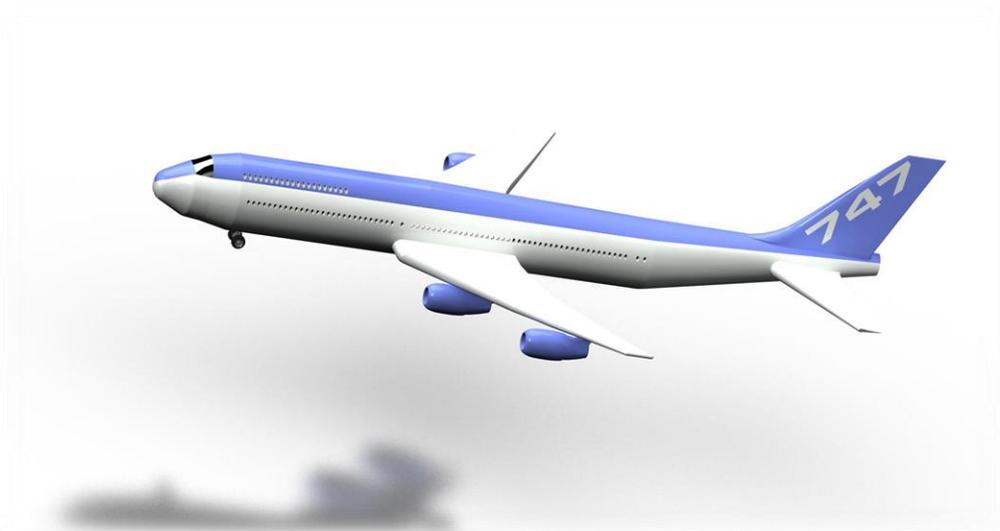


Figure 11 Redesigned model from CAD assembly

Conclusion

Having started with an already completed assembly was helpful when learning ideal ways to assemble the model 747-400, but when it came to redesigning the parts, it might have been more efficient to start each part from scratch. Having to deal with constant error messages and construction conflicts every time a part was modified to become increasingly challenging, because many of the parts were closely tied and used reference geometry off of other parts for

their creation. This project is viewed as a success, having produced a satisfactory 3-D printed model that more accurately depicts a Boeing 747 than its school-issued predecessor.

References

[1] http://www.boeing.com/resources/boeingdotcom/company/about_bca/startup/pdf/freighters/747-400f.pdf

[2] Zhang, Guangming, *Engineering Design and Creo Parametric 3.0*, 2014, College house Enterprises, LLC.

Acknowledgement

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