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## Using Part Consolidation to Optimize Parts for Additive Manufacturing

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### Learning Objectives

- Assess how part consolidation can help optimize a design
- Recognize when to apply part consolidation methods
- Identify various ways and methods to consolidate parts
- Apply part consolidation methods to create an optimized design fit for 3D printing

### Description

Additive manufacturing, better known as 3D Printing, is disrupting the manufacturing industry. It has capabilities to create unique and efficient designs that were never possible before. One unique design method to creating optimizing designs is through part consolidation, or by taking a multi-piece assembly and combining and merging the parts to create a single part with no assembly required. This class will focus on the various reasons and use cases to apply part consolidation as well as general design practices to successfully optimize a part using part consolidation.

### Speaker(s)

Alexander Jones is an engineer that supports the Johnson & Johnson 3D Printing Team and leads the 3D printing training/ education efforts and is the manager of a 3D printing lab. He has created and led several in-person and virtual workshops, self-paced trainings, and other educational resources for all in JNJ to understand and utilize 3D printing capabilities. He has also been part of the development process of several 3D printed medical devices and manufacturing tools, jigs, & fixtures.

Luke Ice is an engineer in the Johnson & Johnson 3D Printing Team and leads the Design for 3D printing vertical. He leads the efforts in front end concepting for product lines spanning from orthopaedics to consumer products. He also contributes to training for design resources for product development with 3D printing manufacturing.

## Introduction to Consolidating Parts

Part consolidation is simply the act of taking an assembly and creating the parts in the final assembled form. With machining and other subtractive manufacturing technologies it is more cost and time effective to produce several simple geometries and then assembly them together using welding, pins, screws, or other methods. One of the key benefits to additive manufacturing (AM) or 3D Printing is the ease of creating more complex shapes. This reduces the need for assembling parts after manufacturing them.

### Autodesk Fusion 360

Most manufacturing methods today (both subtractive and additive methods) rely on using 3D models to create the drawings or machine code needed for them to be produced. Most of these models are created using CAD (computer aided design) software. There are many types and brands of CAD software. The one being used for this course is Autodesk Fusion 360.

Fusion 360 is a cloud-based 3D modeling, CAD, CAM, CAE, and PCB software platform for product design and manufacturing. It is a great software for both beginners and experts.

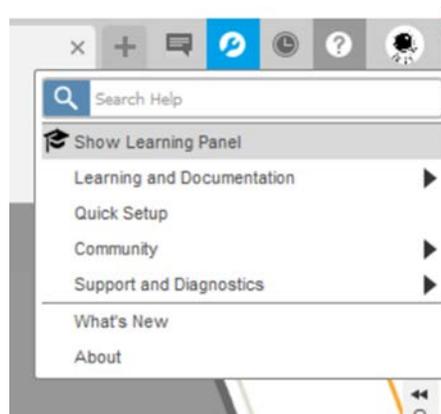


If Fusion 360 or another software is not already owned, there is a free trial that can be utilized. More information on the software package and to purchase it can be found [here](#).

### Learning Panel

While using the software, be sure to turn on the “Learning Panel”. It provides details about how to use most workspace tabs and tools.

To turn the Learning Panel on, go to help tab in the top right of the screen (the “?” icon) and select “Show Learning Panel”

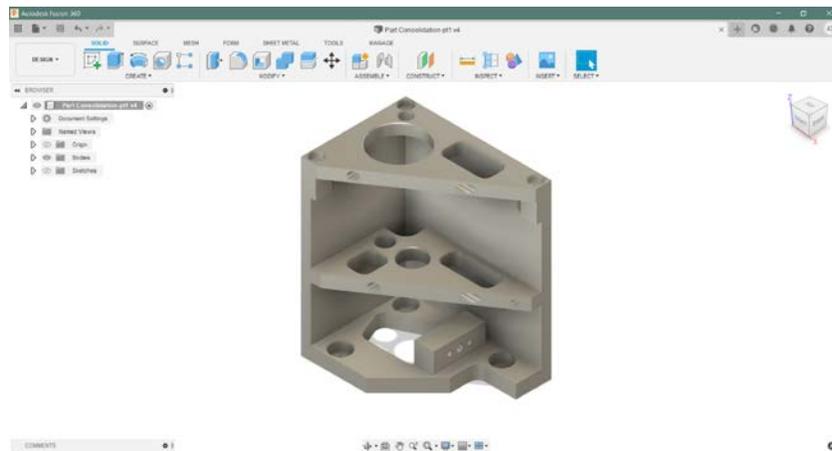


## Part 1: Simple Consolidation of parts

The first part of this hands on demo is doing a simple consolidation of parts. This will entail taking a multi-piece assembly and merging all the bodies into one single body. In addition, the single body will have small modifications made to it to increase the manufacturability in 3D printing.

### Upload The Parts

1. Download the part files from this course to your computer
2. In Fusion, go to File → Open.
3. Then in the bottom left of the pop up, select “**Open from my computer...**”
4. Navigate to the part files from this course and select “**Part Consolidation – pt1.f3d**”



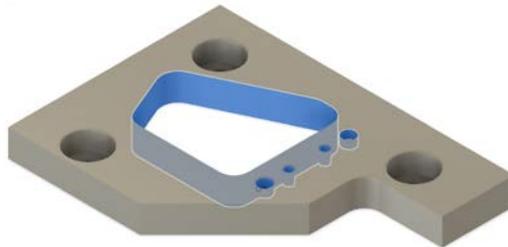
## Removing Features No Longer Required

Many features on the part are designed for assembly (e.g., screw holes) and are not required since it will be printed as one piece. We will remove these features to improve the printability of the part.

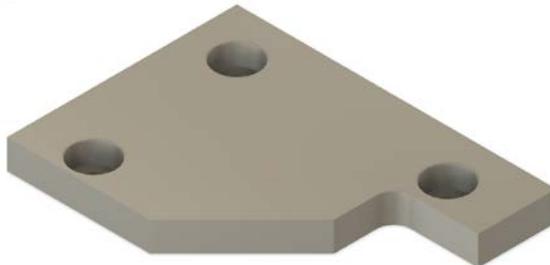
We will go through each body individually. To aid in these steps, it is often helpful to hide the other bodies which can be done by selecting the eye icon to the left of each body.

### Body 1

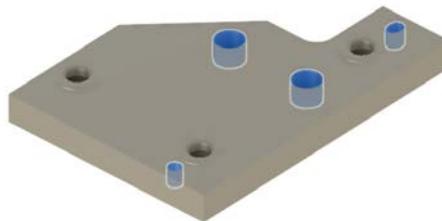
1. Individually, select each other 5 holes shown below, and press “delete”
  - a. Some noncircular holes need to be selected by hitting Ctrl and selecting all the faces



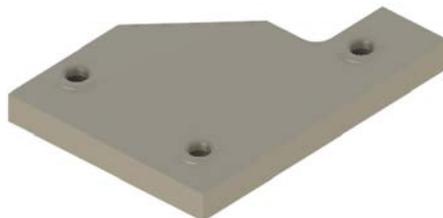
2. The resulting part should look like the image below



3. On the reverse side, do the same thing for these 4 holes



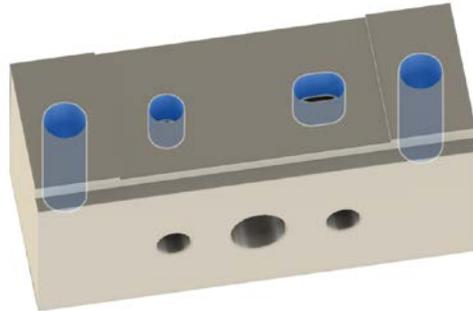
4. Your resulting part should now look like the image below



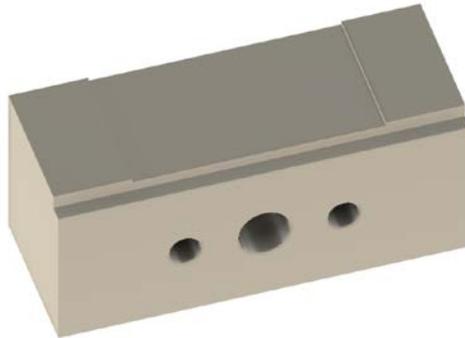
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## Body 2

1. All the holes on the bottom can be removed

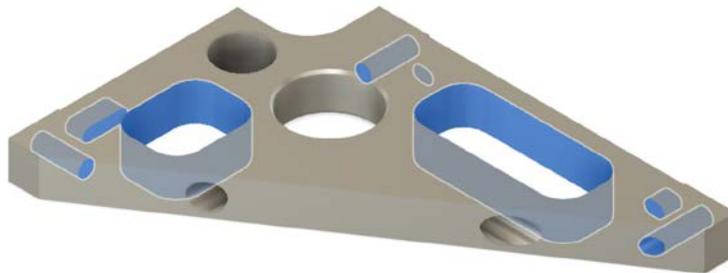


2. The resulting part should look like the below image



## Body 3

1. Individually remove the features highlighted below



2. The resulting part should look like the image below



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## Body 4

1. Individually remove the features highlighted below



2. The resulting part should look like the image below

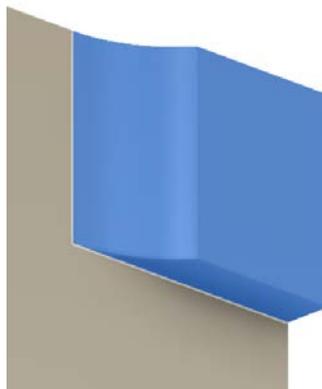


## Body 5

1. Individually remove the features highlighted below



2. The feature in the top right should also be removed. This can be done by selecting the 3 faces shown below and pressing delete



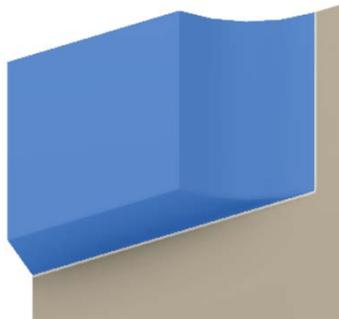
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## Body 6

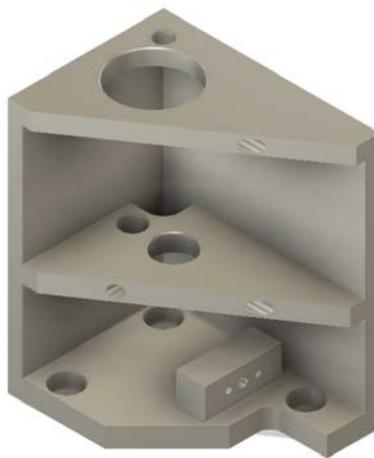
1. Individually remove the features highlighted below



2. The feature in the top left should also be removed. This can be done by selecting the 3 faces shown below and pressing delete



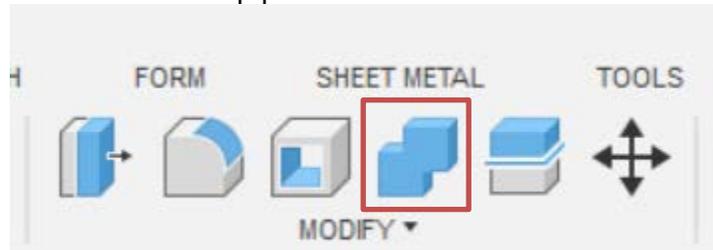
Below shows what the result looks like after removing all unneeded features



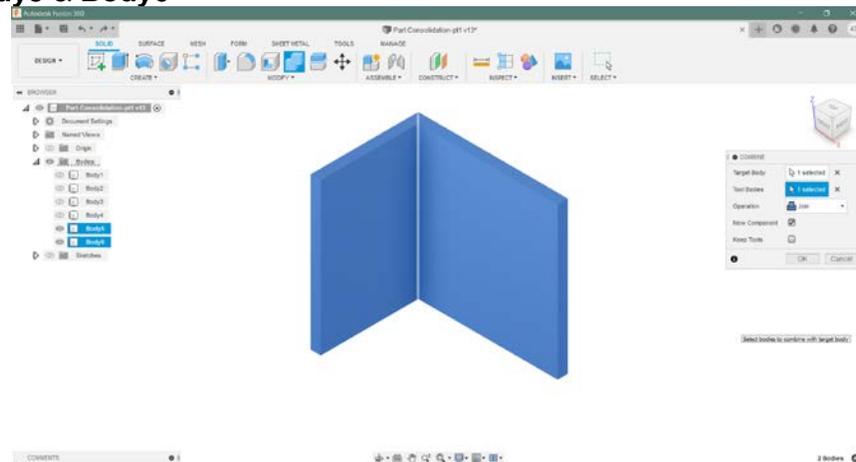
## Improve Printability

Because this is now being manufacturing with additive manufacturing, the part needs small modifications to improve the manufacturability.

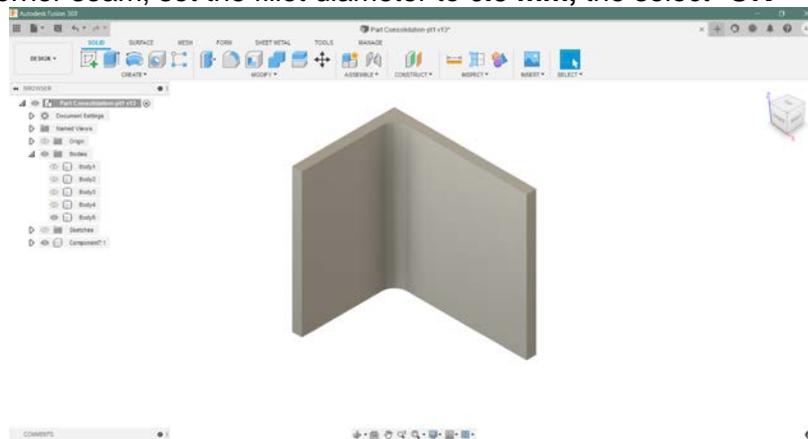
1. Hide all bodies except for Body5 and Body6
2. Select the “**Combine**” in the top panel



3. Select **Body5 & Body6**



4. Select “**OK**” Those bodies are now combined into one single body
5. Under the Modify dropdown, select “**Fillet**”
6. Select the corner seam, set the fillet diameter to **6.5 mm**, the select “**OK**”



7. Unhide the remaining bodies

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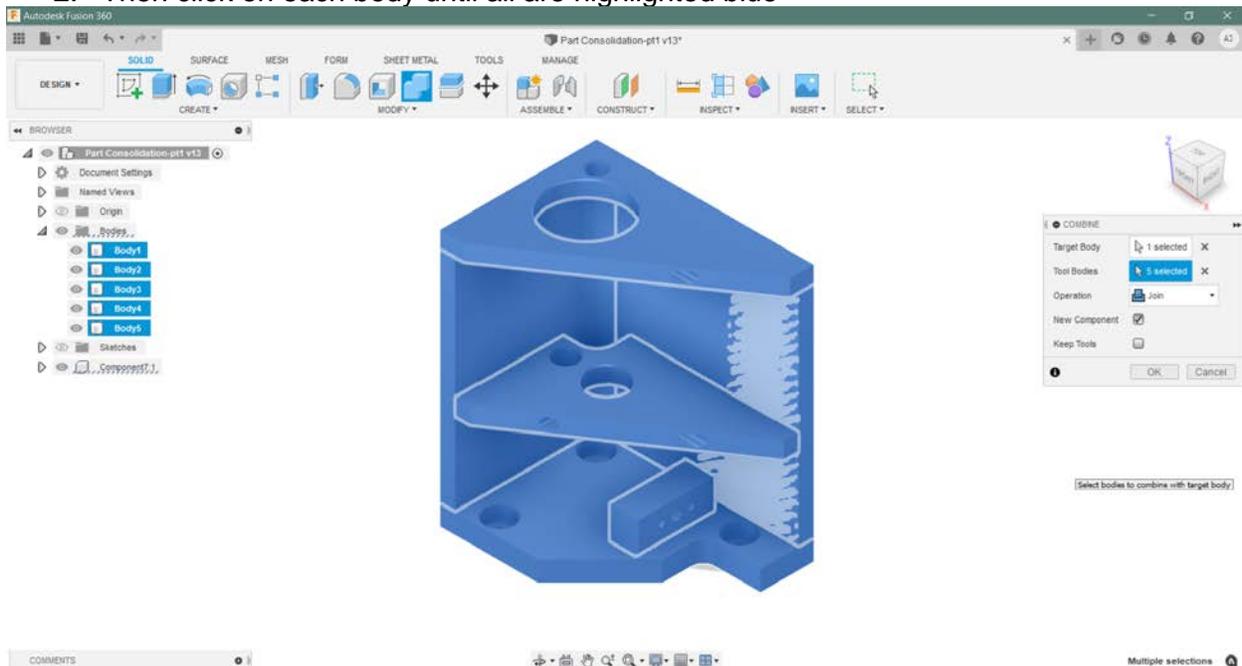
## Merging Parts

The last part will be to merge/combine all the bodies into one single body that will be the final consolidated part

1. Select the “**Combine**” in the top panel



2. Then click on each body until all are highlighted blue



3. Make sure the Operation is defined as “**Join**” then hit “**OK**”

## Exporting Parts

Now the parts are ready to be exported and sent to a 3D printer. Depending on the 3D printing technology being used and how much support structures are desired, more changes can be made to the part to further improve printability.

1. To export the parts, go to **File → Export**
2. Change the “**Type:**” to **STL Files** as that is the most popular file format for 3D printers
  - a. 3MF, STEP and others are also often used in place of STLs
3. Once the file exports, then it is ready to 3D print!

## Part 2: Generative Design

When converting from a subtractive/machined design into 3D printing design there are often features that can be more difficult to 3D print or undesirable. While modifications were done in part 1 to the assembly, there remained many core elements that were designed with the intent of being created with subtractive technologies. One way to counteract this is to capture what you're core needs are and then redesign from scratch. One method of doing this is by utilizing Generative Design.

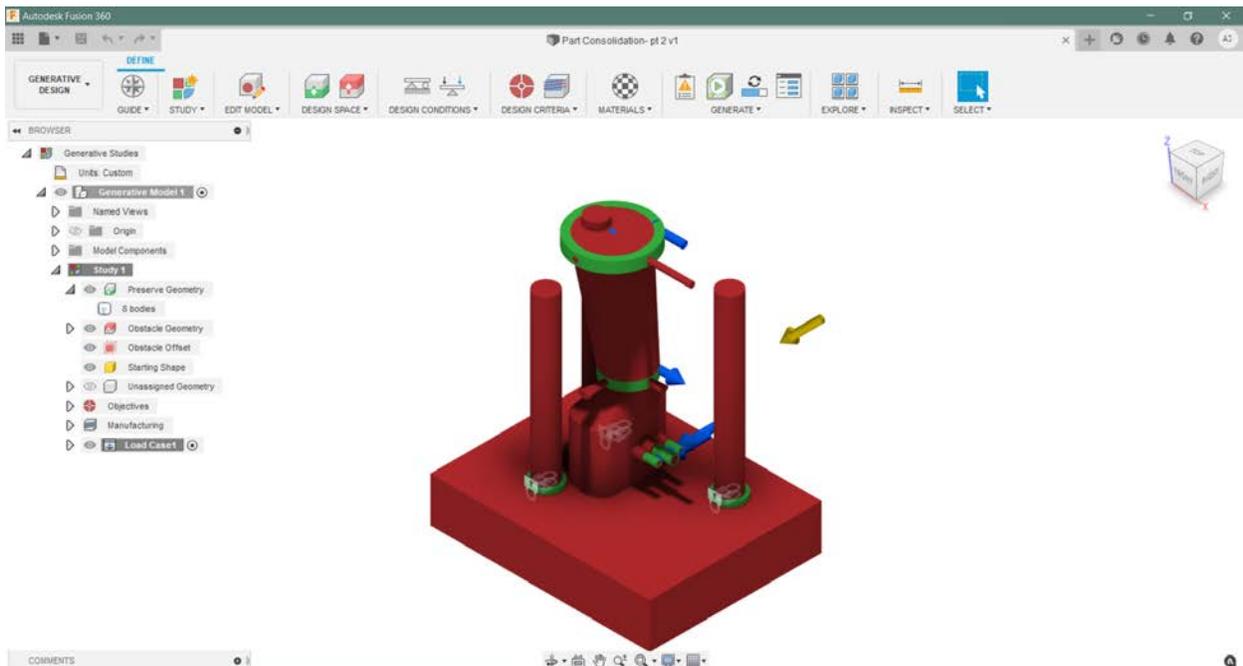
### What is Generative Design

Generative design is a design exploration process. Designers or engineers input design goals into the generative design software, along with parameters such as performance or spatial requirements, materials, manufacturing methods, and cost constraints. The software explores all the possible permutations of a solution, quickly generating design alternatives. It tests and learns from each iteration what works and what doesn't.

### Getting Started

In the top left of the screen, click on “**Design**” then, in the dropdown, select “**Generative Design**”

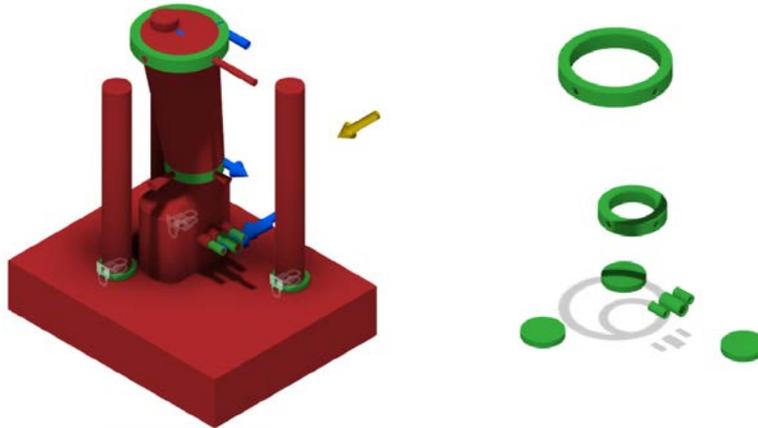
To fully set up a generative design study, we need to define the preserve geometry, obstacle geometry, and the loads seen on the part. Below is an image of all these defined in the study.



## Preserve Geometry

These are the areas of the part that need to remain the same or be preserved. These are typically areas where the parts are supposed to meet with another part and be assembled. In Fusion you need to edit the model and create new bodies for each area to preserve. Often these should be a bit larger than the intended area to preserve to ensure enough material is left.

The green sections in the images below represent the preserve geometries for this example.

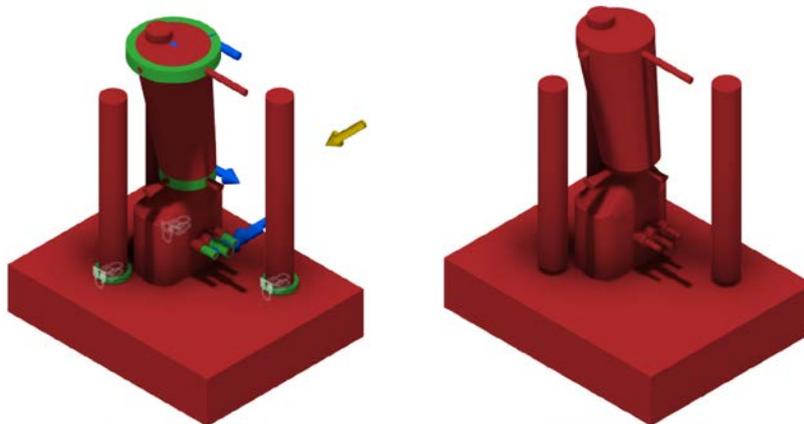


## Obstacle Geometry

These are the areas where no material can be added. Like preserve geometries, new bodies need to be created for each area where material cannot be added.

A common obstacle added is a large base to ensure the part is flat and can be easier to 3D print. To prevent additional material from being added, a large obstacle is created at the base of the part. Additionally, another common obstacle are holes for screws and other fixtures. Without the obstacles, those holes may be accidentally filled.

The red sections in the images below represent the obstacle geometries for this example.

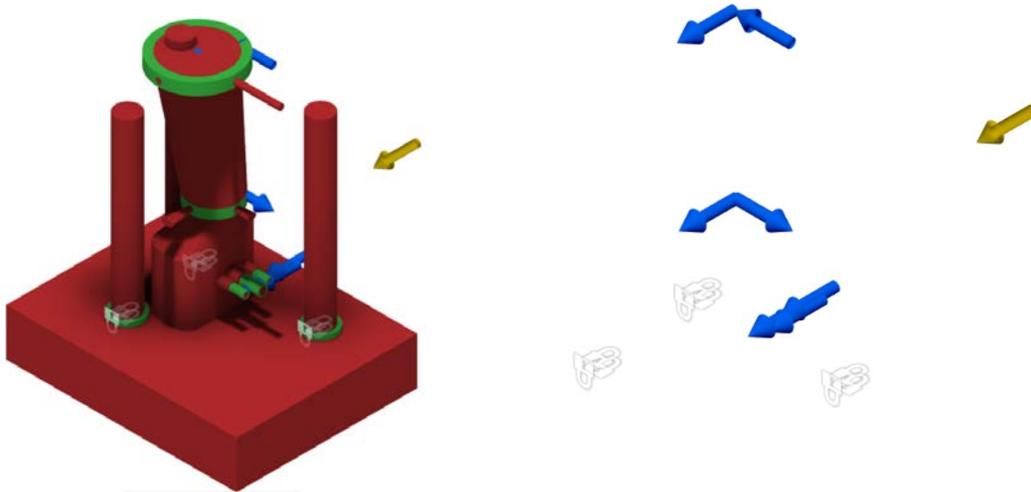


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## Load Cases

These are the areas where loads are seen by the part. These can be fixed/non fixed loads, gravity, etc. Each load is specified by the magnitude and the direction.

The arrows and locks in the images below represent the loads case attributes for this example



## Final Steps

The last parts to setting up the study before generating outcomes are to identify the objectives, the material of the part, and the desired manufacturing method. After those have been set, the study is ready to be generated!

The generation process will take some time and will output several possible outcomes. Often designers will take an outcome and make small changes to the design to improve aesthetics or printability.

For this study the below image is the result.

