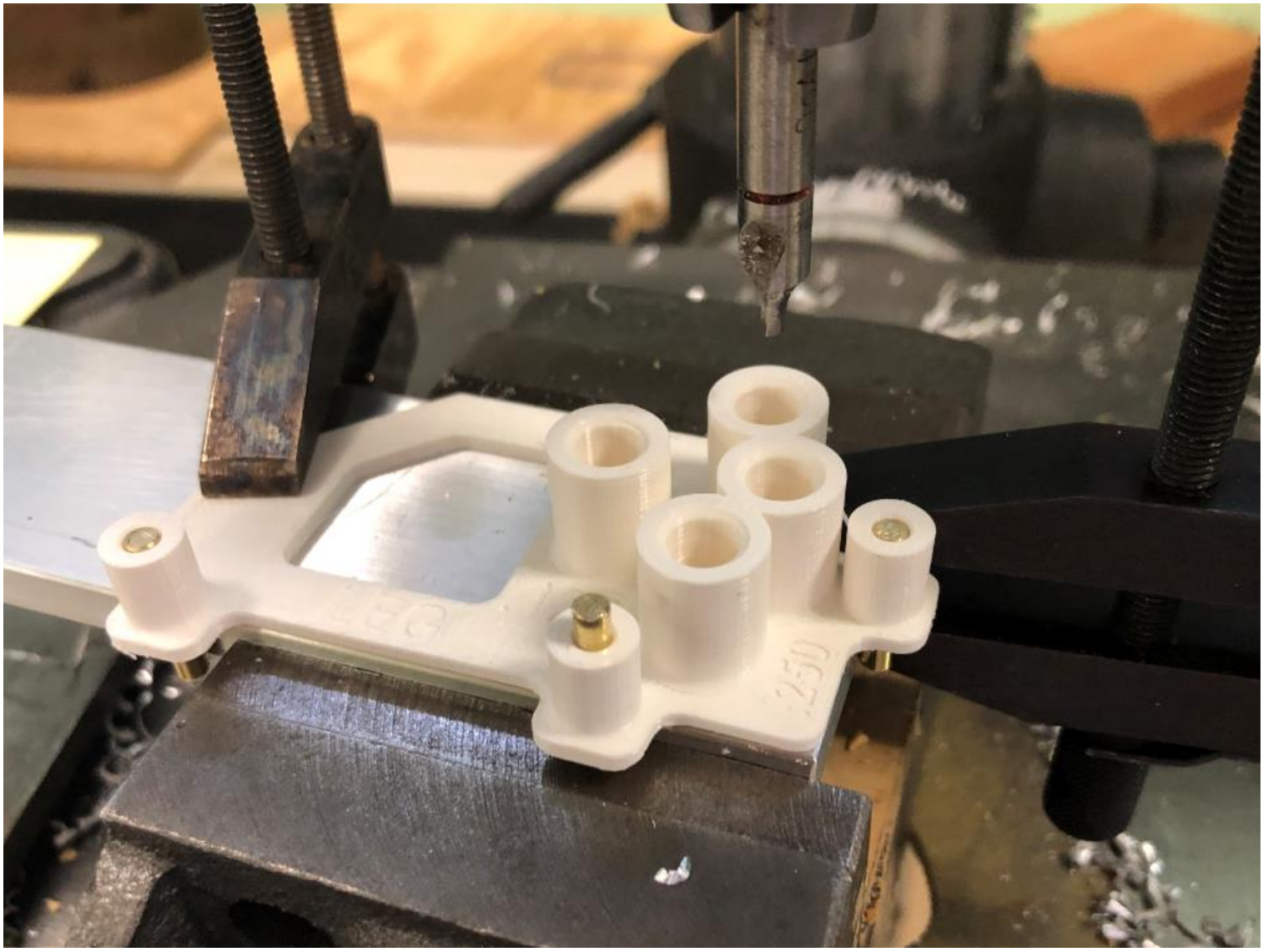
We need a few good holes.

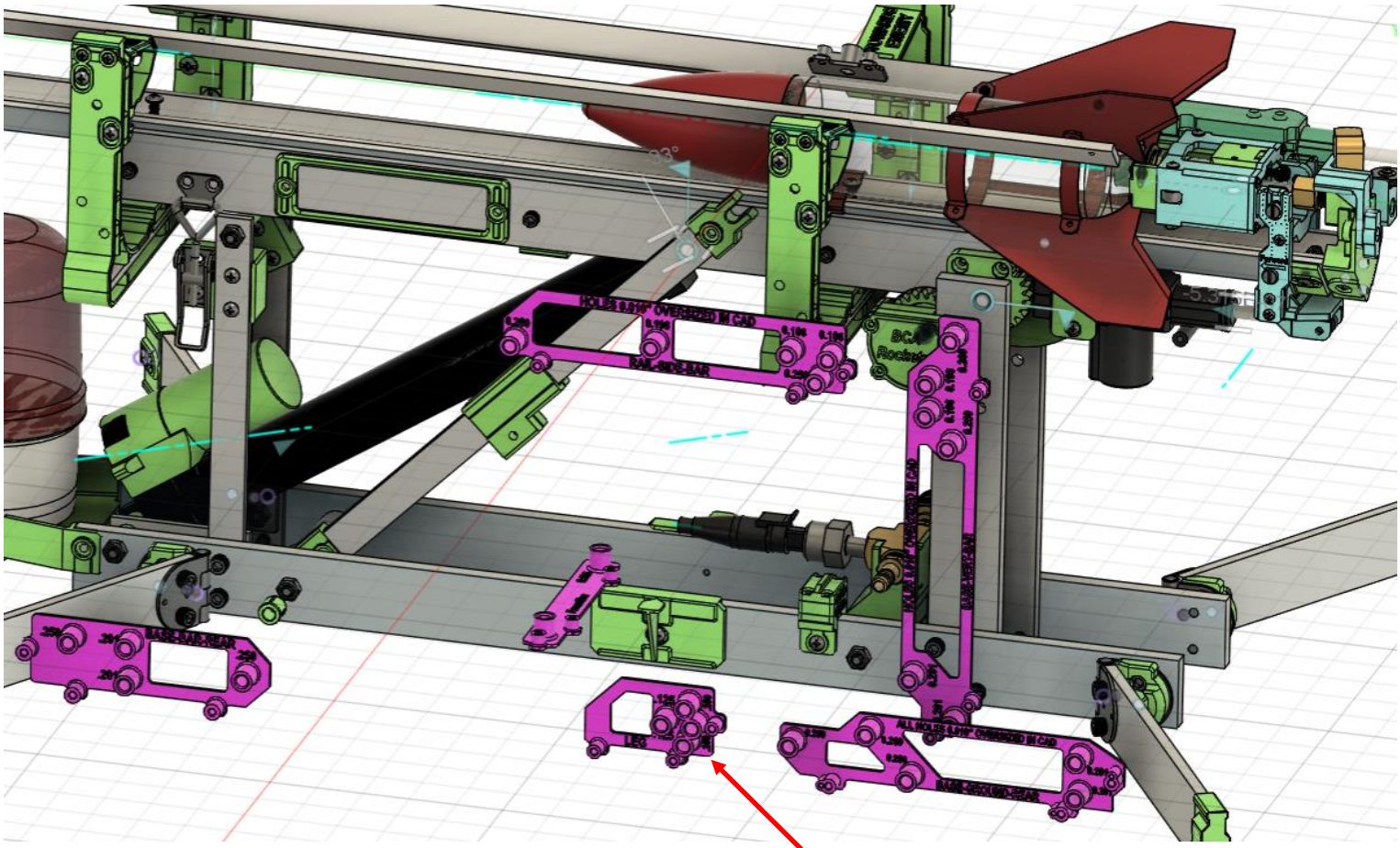


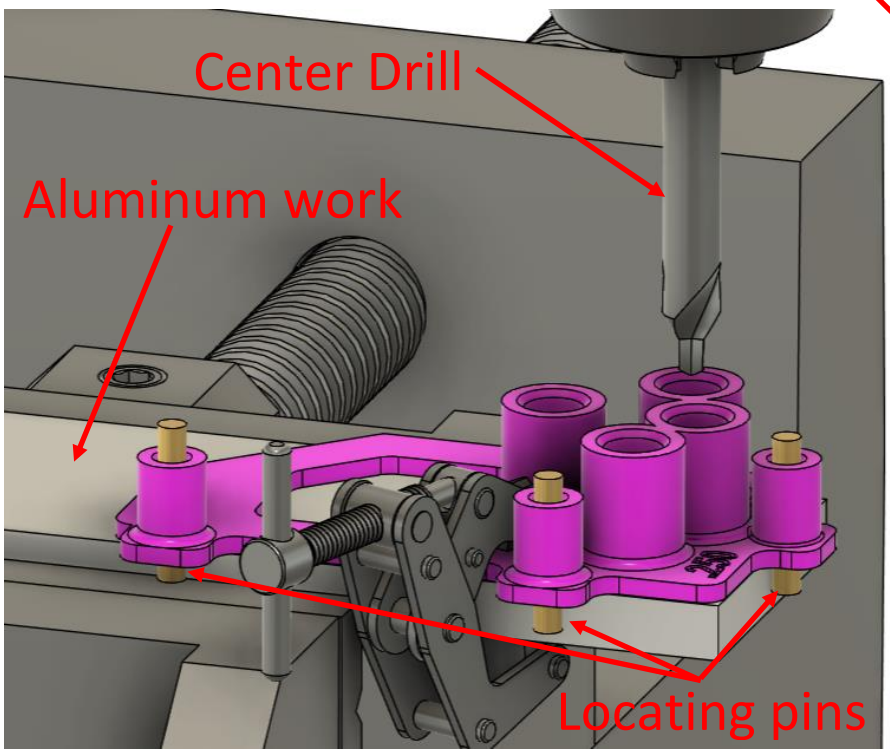
Today's lesson is sponsored by McMaster-Carr.

Contents

3D printing is great for missile launcher fabrication

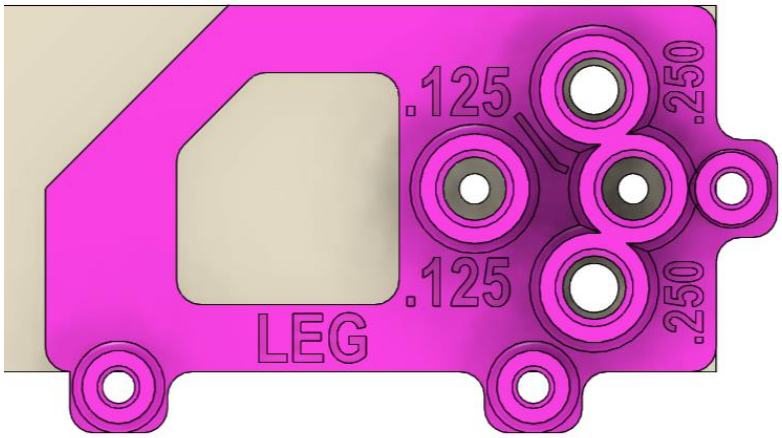
In the below design all green, blue, and red parts are 3D printed for parts used in the launcher. The violet parts were 3D printed to serve as ***tooling***. In particular, they were printed a ***jigs***, to accurately drill holes in the aluminum parts that are gray to the design. A jig is a component that guides a tool and 3D printing lends itself nicely to making custom jigs.

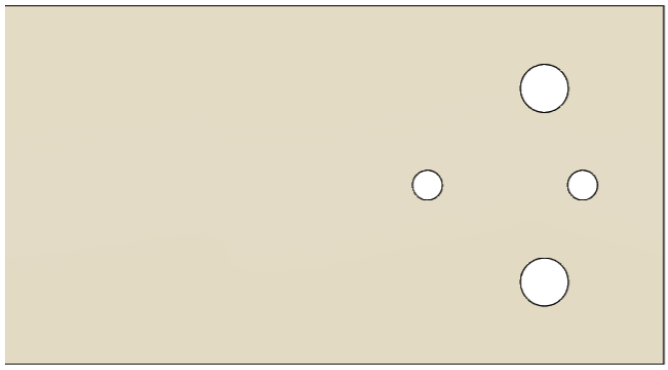




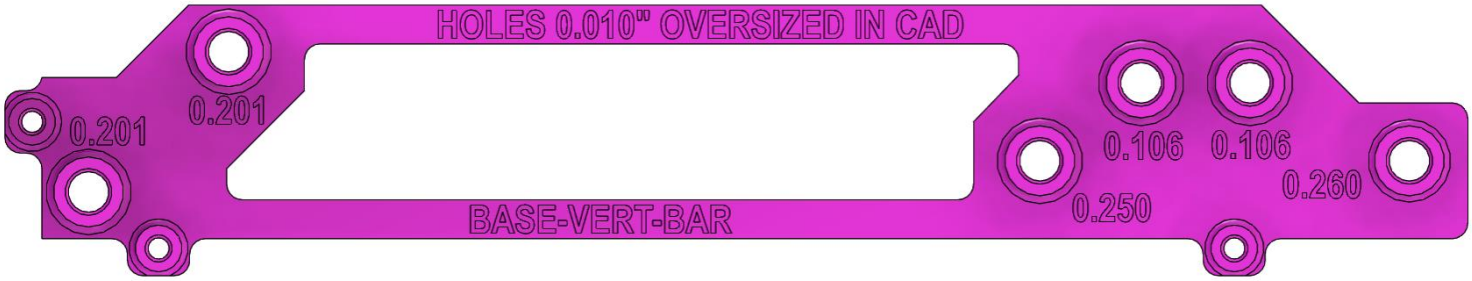
The left screenshot from Fusion shows the small "LEG" jig being used. Each of the four legs has fours holes at one end to accommodate screws for a hinge leaf and a magnet mount.
There are holes in the jig to accommodate 1/8" dia locating pins. Here the color indicates brass, but any 1/8" dia stock can be used.
A 1/4" diameter Center Drill was used as a spot drill to make a small divet to guide a drill bit to finish the hole.
Center Drills have a smooth surface and won't tend to rip up the plastic as a regular drill bit can do.

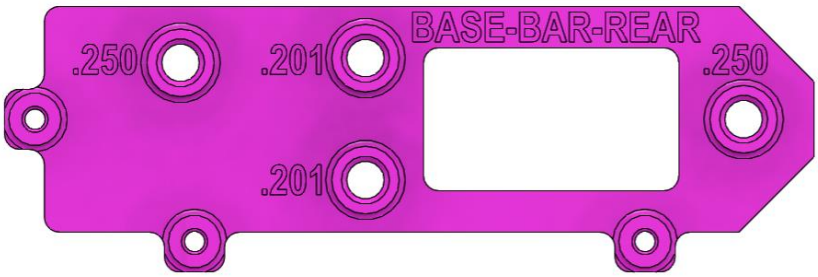
Here is a top view of the jig in Fusion. It is useful to add text for the final hole sizes and the product component that the jig will be used for.

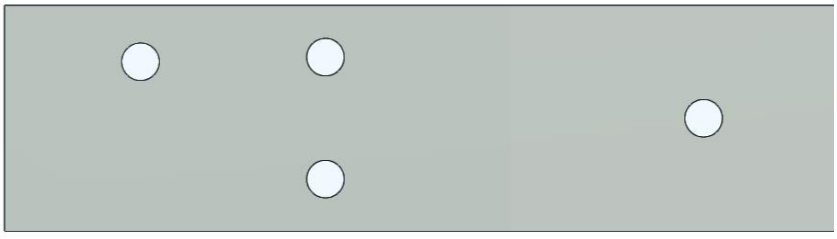




Below are views of two of the larger jigs in Fusion. The 1st is used for the two vertical members of the design and the 2nd is used for one end of each base member. Note that most of the resultant hole diameters differ from the 0.025” diameter of the Center Drill.







Options for Drill Jig construction

Spot Drill:

A ***Spot Drill*** is a short drill without the long flutes of a normal drill bit. This results in a rigid body that won't "walk" when starting a hole. One uses it to create a small divet that will guide the drill bit used for the final hole size.

Center Drills are traditionally used on a lathe for creating a dimple for a live centers to hold stock on a lathe. However, because they a sturdy and don't flex as a drill bit can, it is common to use them as a spot drill and they perform well for this purpose. However, if you are preparing for an apprenticeship with a Swiss watchmaker, you should know about true Spot Drills. McMaster-Carr sells some. They are considerably more expensive and fower options are available, perhaps due to the fact that so many machinists are happy using their center drills.

Either a Center Drill or true Spot Drill will work nicely with a 3D printed jig because of their smooth surface. The 3D printed hole should just be slightly larger. One doesn't want the spot drill to be too tight. The heat from friction will deform the plastic. If the fit is too lose, then accuracy will be lost.

Center Drills

High-Speed Steel

Trade Size	Drill Bit Size	Dia. Body	Dia. Shank	Overall Lg.	No. of Flutes	No. of Countersinking Ends	Uncoated	Each
60° Countersink Angle								
3	7/64"	1/4"	1/4"	2"	2	2	**2915A13**	7.22

Drill-Point Countersink for Lathe Centers, High-Speed Steel, Trade Size 3, 2" Overall Length

Quantity 1 Each

Delivers today 3-5 pm if ordered by 11:35 am

ADD TO ORDER

spot drill

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Hole-Starting Cobalt Steel Drill Bits

120° Point Angle

Standard

Create an accurate starting place in your workpiece. Cut an indent with these bits, then continue drilling with a longer bit. The indent prevents slipping so the final hole is centered and precise. Cobalt steel resists wear to stay sharp when cutting hard materials, such as nickel. Also known as spotting drill bits.

Short Length—The most rigid bits for drilling the straightest holes.

Titanium Aluminum Nitride (TiAlN) Coated—The hardest and most wear-resistant coating, especially at high temperatures. These bits are best for hard and abrasive materials, such as iron, titanium, and fiberglass.

Uncoated—Polished to eject chips, these are also known as bright finish bits.

Drill Bit Size	Decimal Size Equiv.	Overall Lg.	Max. Drilling Dp.	Shank Type	Shank Size	Drill Bit Point Type	90° Point Angle	Each	120° Point Angle	Each
Short Length										
Titanium Aluminum Nitride (TiAlN) Coated										
1/4"	0.25"	2 5/8"	0.9"	Round	1/4"	Standard	27445A203	$48.57	———	—
1/4"	0.25"	2 5/8"	1.38"	Round	1/4"	Standard	———	—	27445A206	$48.57
3/8"	0.375"	3 1/2"	1"	Round	3/8"	Standard	27445A204	58.43	27445A207	58.43
1/2"	0.5"	4"	1.38"	Round	1/2"	Standard	27445A205	76.86	27445A208	76.86
Uncoated										
1/8"	0.125"	2"	0.4"	Round	1/8"	Standard	27445A201	25.03	———	—
1/4"	0.25"	2 5/8"	0.89"	Round	1/4"	Standard	27445A11	31.97	27445A21	31.97
3/8"	0.375"	3 1/2"	1"	Round	3/8"	Standard	27445A12	34.35	27445A22	34.35

Drill bushings

This is the most expensive option. The advantages are 1) the drill jig will last for many uses because there is no rotating tool in contact with the plastic, and 2) drill bushes can be chosen for the final drill size, thus eliminating the spot drilling step.

If you are planning on building an arsenal of hundreds of missile lauchers, this would be the way to go.

Drill bushings can last for many drilling cyles because they are made from hardened steel. McMaster lists the hardness rating for these bushing as Rockwell C61.

Just for this type of drill bushing there are 1,764 different ones available. Buy them all! However, if you're cheap you can find ones for the drill sizes you need. For example, if there are one or more holes with a final diameter of 0.125", a selection of different outer diameters (Ods) and lengths are available. The 1/4" OD with a length of 5/8 will work fine. Note that one will be needed for each hole.

drill bushings

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1,764 Products

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1/4"	1 3/8"	No. 31	0.0001" to 0.0004"	0.0013" to 0.0016"	-0.01" to 0.01"	P	Steel	Rockwell C61	96511A438	11.58	9.78	8.63
0.125" ID												
1/4"	1/4"	1/8"	0.0001" to 0.0004"	0.0013" to 0.0016"	-0.015" to 0.015"	P	Steel	Rockwell C61	8491A037	12.22	10.02	9.11
1/4"	5/16"	1/8"	0.0001" to 0.0004"	0.0013" to 0.0016"	-0.015" to 0.015"	P	Steel	Rockwell C61	8491A595	12.85	10.54	9.58
1/4"	3/8"	1/8"	0.0001" to 0.0004"	0.0013" to 0.0016"	-0.015" to 0.015"	P	Steel	Rockwell C61	8491A057	13.95	11.44	10.40
1/4"	1/2"	1/8"	0.0001" to 0.0004"	0.0013" to 0.0016"	-0.015" to 0.015"	P	Steel	Rockwell C61	8491A077	14.71	12.06	10.96
1/4"	5/8"	1/8"	0.0001" to 0.0004"	0.0013" to 0.0016"	-0.01" to 0.01"	P	Steel	Rockwell C61	96511A439	10.53	8.89	7.84
1/4"	3/4"	1/8"	0.0001" to 0.0004"	0.0013" to 0.0016"	-0.015" to 0.015"	P	Steel	Rockwell C61	8491A066	16.56	13.58	12.35
1/4"	1"	1/8"	0.0001" to 0.0004"	0.0013" to 0.0016"	-0.015" to 0.015"	P	Steel	Rockwell C61	8491A711	18.41	15.10	13.73
1/4"	1 3/8"	1/8"	0.0001" to 0.0004"	0.0013" to 0.0016"	-0.01" to 0.01"	P	Steel	Rockwell C61	96511A440	11.58	9.78	8.63
1/4"	2"	1/8"	0.0001" to 0.0004"	0.0013" to 0.0016"	-0.015" to 0.015"	P	Steel	Rockwell C61	3671N117	35.46	30.20	26.74
5/16"	1/4"	1/8"	0.0001" to 0.0004"	0.0013" to 0.0016"	-0.015" to 0.015"	P	Steel	Rockwell C61	8491A596	10.05	8.24	7.49
5/16"	5/16"	1/8"	0.0001" to 0.0004"	0.0013" to 0.0016"	-0.01" to 0.01"	P	Steel	Rockwell C61	96511A441	7.37	6.22	5.49
5/16"	3/8"	1/8"	0.0001" to 0.0004"	0.0013" to 0.0016"	-0.015" to 0.015"	P	Steel	Rockwell C61	8491A091	11.15	9.14	8.31
5/16"	1/2"	1/8"	0.0001" to 0.0004"	0.0013" to 0.0016"	-0.015" to 0.015"	P	Steel	Rockwell C61	8491A101	11.61	9.52	8.65
5/16"	5/8"	1/8"	0.0001" to 0.0004"	0.0013" to 0.0016"	-0.01" to 0.01"	P	Steel	Rockwell C61	96511A442	9.21	7.78	6.86
5/16"	3/4"	1/8"	0.0001" to 0.0004"	0.0013" to 0.0016"	-0.015" to 0.015"	P	Steel	Rockwell C61	8491A111	12.71	10.42	9.47
5/16"	1"	1/8"	0.0001" to 0.0004"	0.0013" to 0.0016"	-0.01" to 0.01"	P	Steel	Rockwell C61	96511A443	10.79	9.11	8.04
5/16"	1 3/8"	1/8"	0.0001" to 0.0004"	0.0013" to 0.0016"	-0.01" to 0.01"	P	Steel	Rockwell C61	96511A444	12.11	10.22	9.02
1/2"	1/2"	1/8"	0.0001" to 0.0004"	0.0014" to 0.0017"	-0.015" to 0.015"	P	Steel	Rockwell C61	3671N118	11.17	9.41	8.42

Press-Fit Drill Bushings

Also known as jig bushings, these drill bushings fit inside fixture plate holes to precisely guide drill bits, counterbores, reamers, and other cutting tools. They improve accuracy so your drilled holes and cuts are consistent from part to part.

Drill Bushings for Plastic

Serrations line the sides of these bushings to keep them from spinning while you drill. Also known as jig bushings, they're pressed or molded into plastic tooling to guide drill bits, counterbores, and reamers.

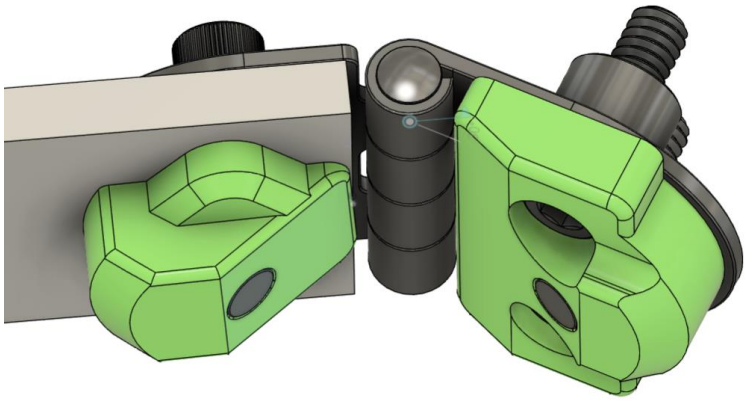
Secure-Hold Drill Bushings for Plastic

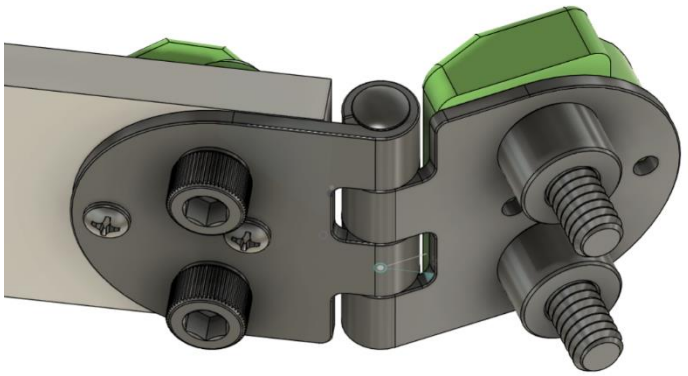
Designed to grip slippery plastic, the knurls on these bushings keep them from spinning while you drill. Their hold is stronger than serrated bushings, so they can withstand more force.

Launcher Leg Assembly

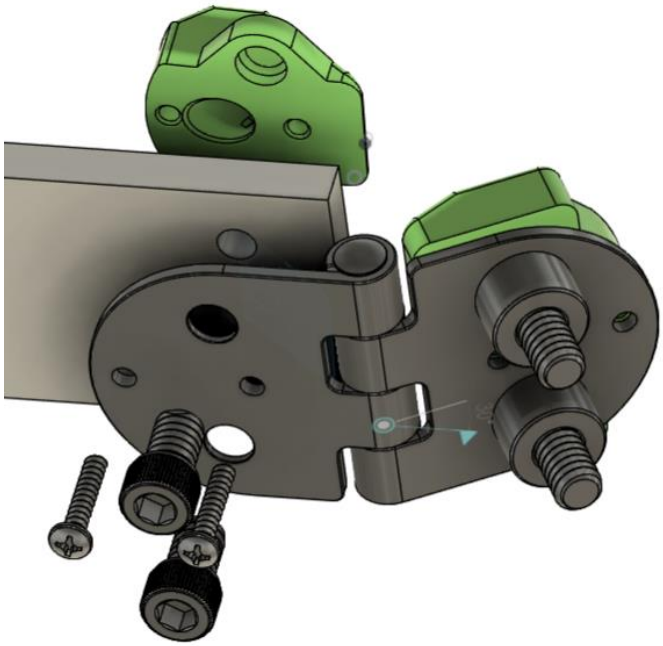
Each leg assembly is comprised of a aluminum 6061 bar stock attached to a 18-8 stainless steel hinge secured to the launcher base members.

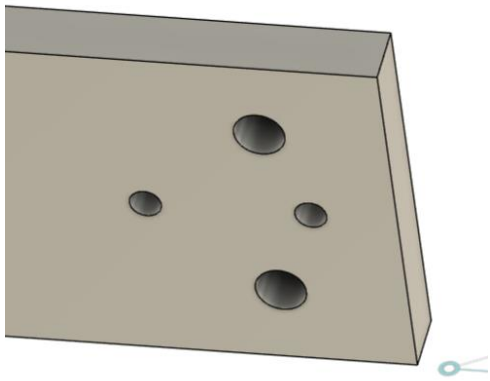
For each leg assembly there are two 3D printed magnet mounts, which hold neodymium magnets. When the legs are deployed, the magnets help hold the legs in the deployed position.





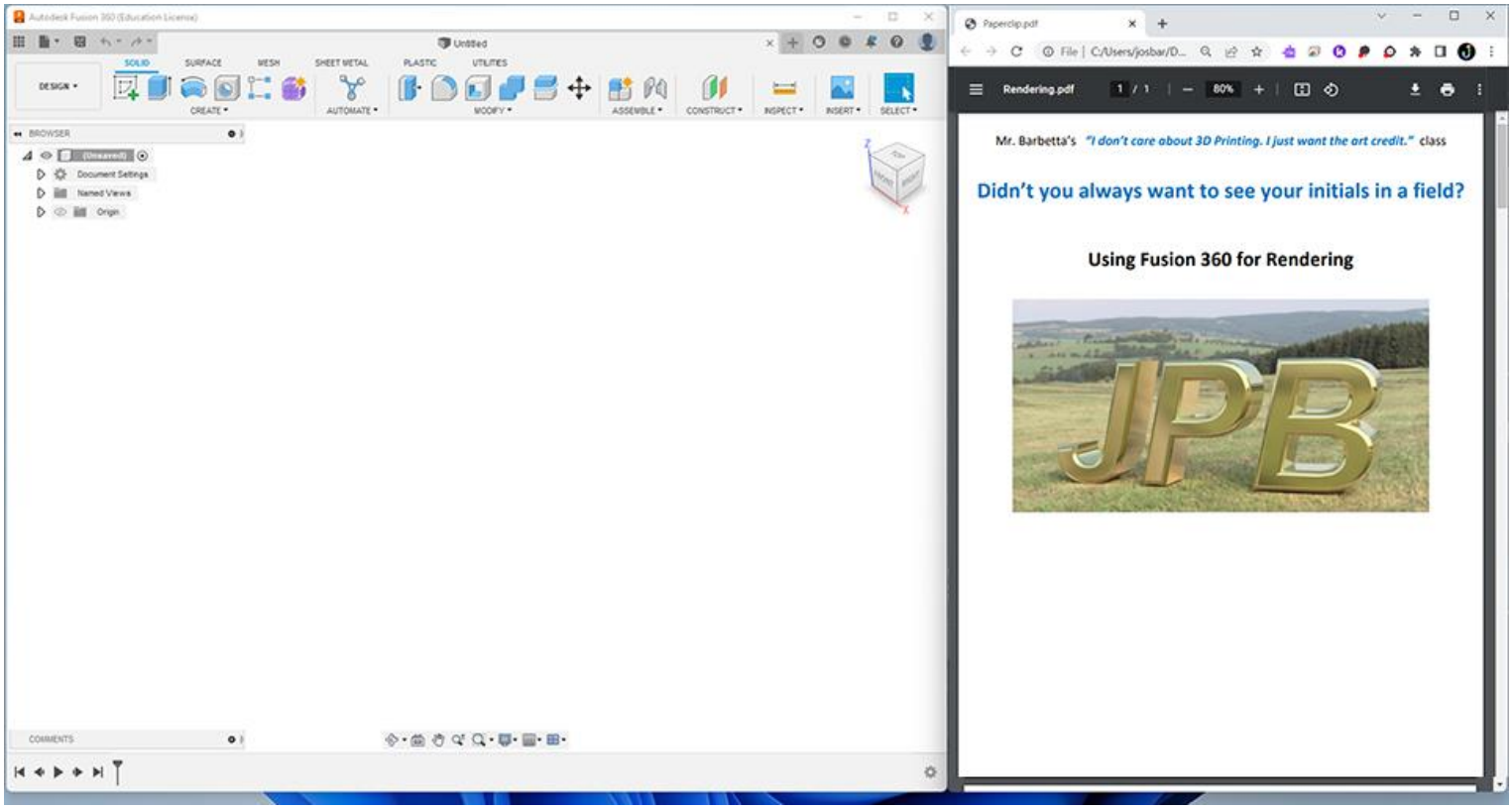
Below is a view showing the 10-32 socket-head screws used to secure the leg bar to the hinge and the #4 self-tapping screws used to secure the magnet mount. The holes drilled are clear holes for these screws.



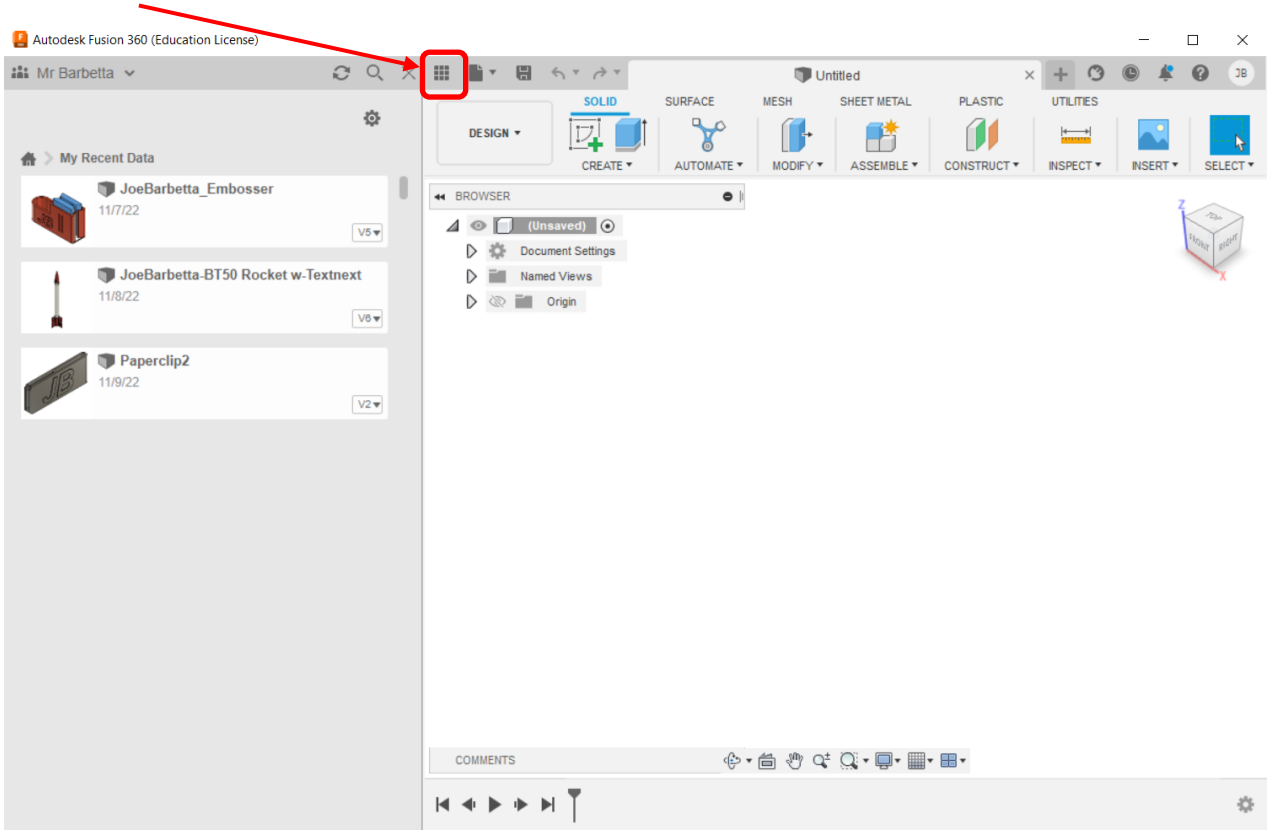


Using This Document

The best way to follow this document is to **reduce the width of the Fusion 360 window** and have this pdf document open in Chrome browser as shown below. This document can be **downloaded from Schoology and then dragged into Chrome** and scaled down to 80%.



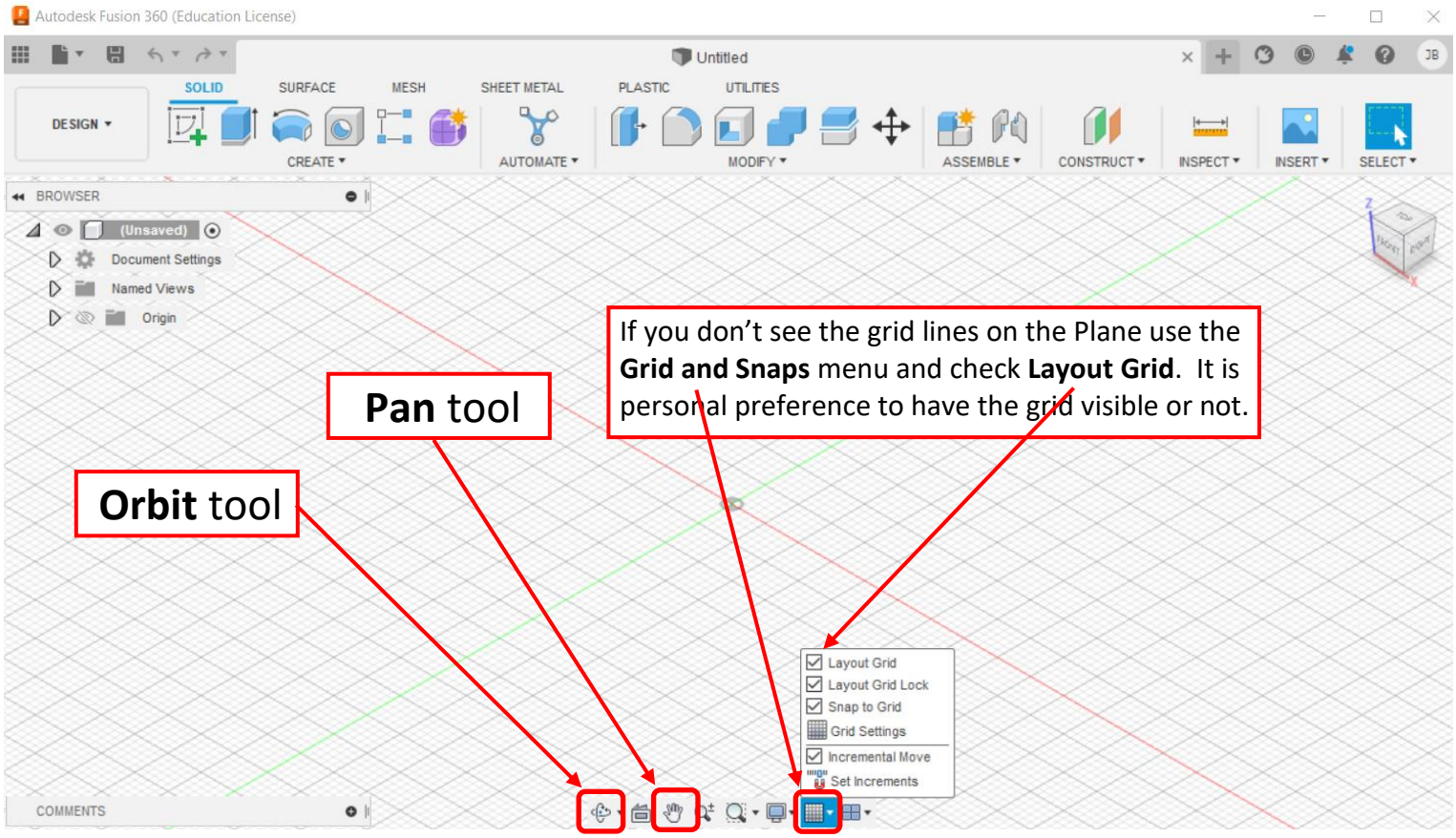
The Fusion 360 window will not allow its width to be reduced much so for smaller computer screens a trick is to click on the **Data Panel icon** and then move the window to the left with the Data Panel off the screen.



Changing the View of a Design

- if you don't see a grid in the Fusion 360 window, as shown below, click on **Grid and Snaps** and check **Layout Grid**. Displaying the *Layout Grid* is a matter of preference. When designing for 3D printing, it can be used to represent the *build plate*.

- click on the **Orbit** tool and click somewhere on the **Grid** to practice rotating and changing the angle of the view.
- click on the **Pan** tool and then on the **Grid** to practice moving the view laterally.
- after using the *Orbit* or *Pan* tool one must press the **Esc key** to exit that mode.
- use the **Mouse Wheel** to practice Zooming in and out.



Here is a close-up of the View Cube at the top right of the window.

- click on the **View Cube** and move the cube while holding the mouse button down. This is another way to rotate the view.
- click on the Top of the View Cube and note how the view just jumped to a Top View.

The View Cube now resembles that on the right.

- click on the **Curved Arrows** at the upper right of the View Cube and practice Rotating the View.
- click on the **Arrows** at the sides of the View Cube to practice jumping to various Views.
- click on the **Home** icon to the upper left of the View Cube. This can always be used to reset the view to the Home View

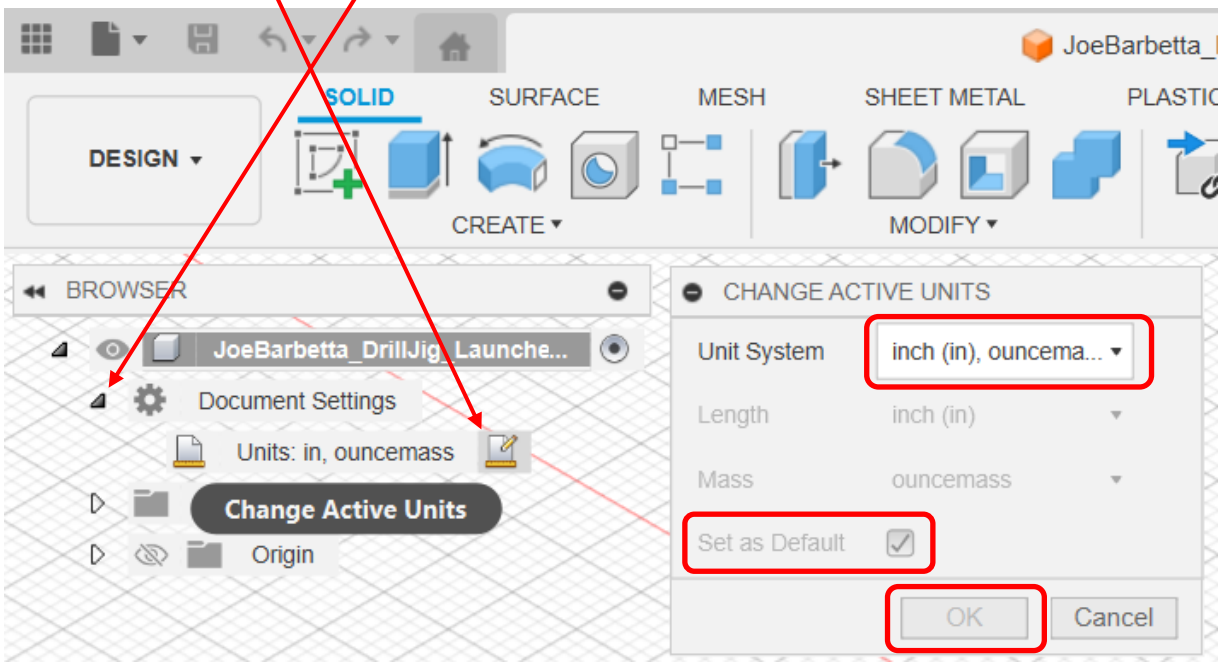
Starting a Design in Fusion (START HERE)

- open **Fusion**. If there is no icon on the Desktop, use the Windows search (magnifying glass icon) and type fusion
- from top **File** icon select **Save** and name the file.
  Use your name followed by **_DrillJig_Launcher** e.g. **JoeBarbetta DrillJig_Launcher** (note the use of the underscore)

Note that by default Fusion saves your project to "the cloud", which are the servers managed by AutoDesk. When you log into Fusion on a different computer, your projects will be available.

As you work you may want to occasionally save your work in case Fusion crashes or we lose power.

- in the left **"BROWSER"** click the **arrow next to Document Settings**
- click on the **edit icon** that appears to the right when you hover over **Units**
- ensure **Active Units** are set to **Units: in, ouncemass** and click **OK**. You can also enable **Set as Default** if it is not grayed out.

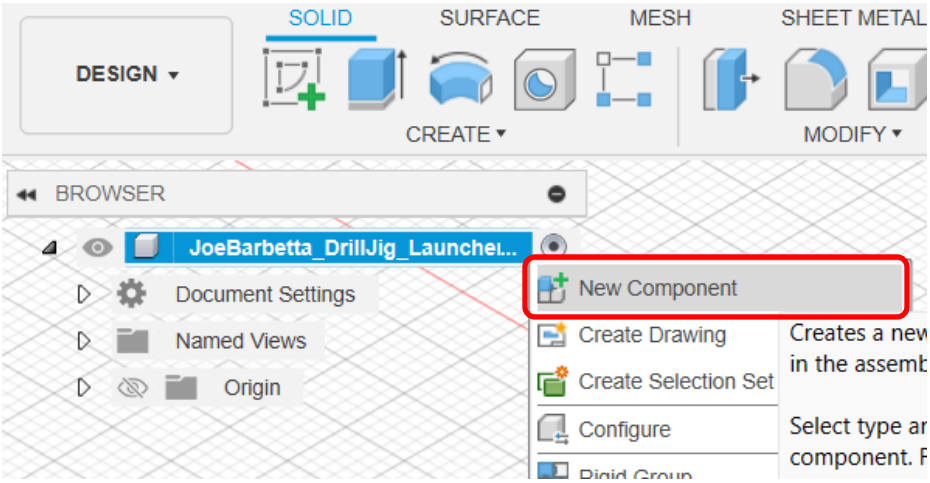


Note that the default units are in mm, which we just changed to inches.

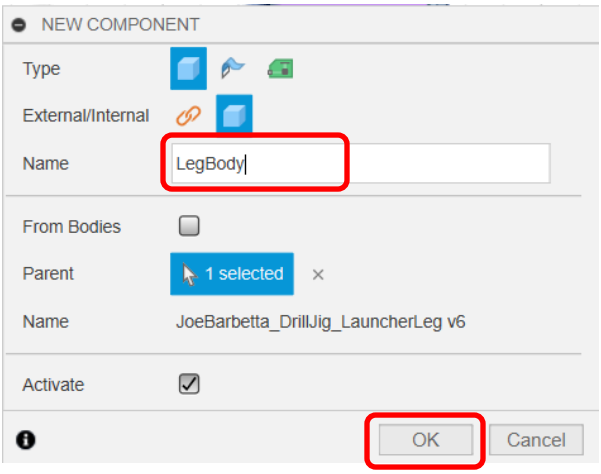
Did you know that the default units have changed over the years? The earliest version used cubits as the default unit.

Creating a Component for the Leg

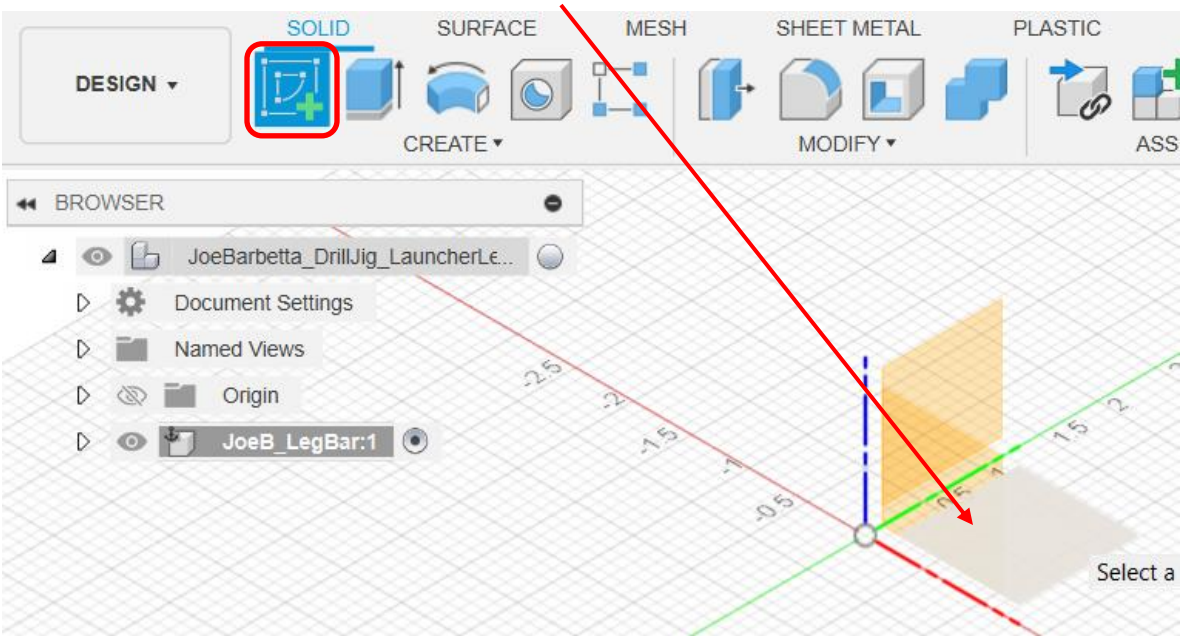
- right-click on the project name and select **New Component**



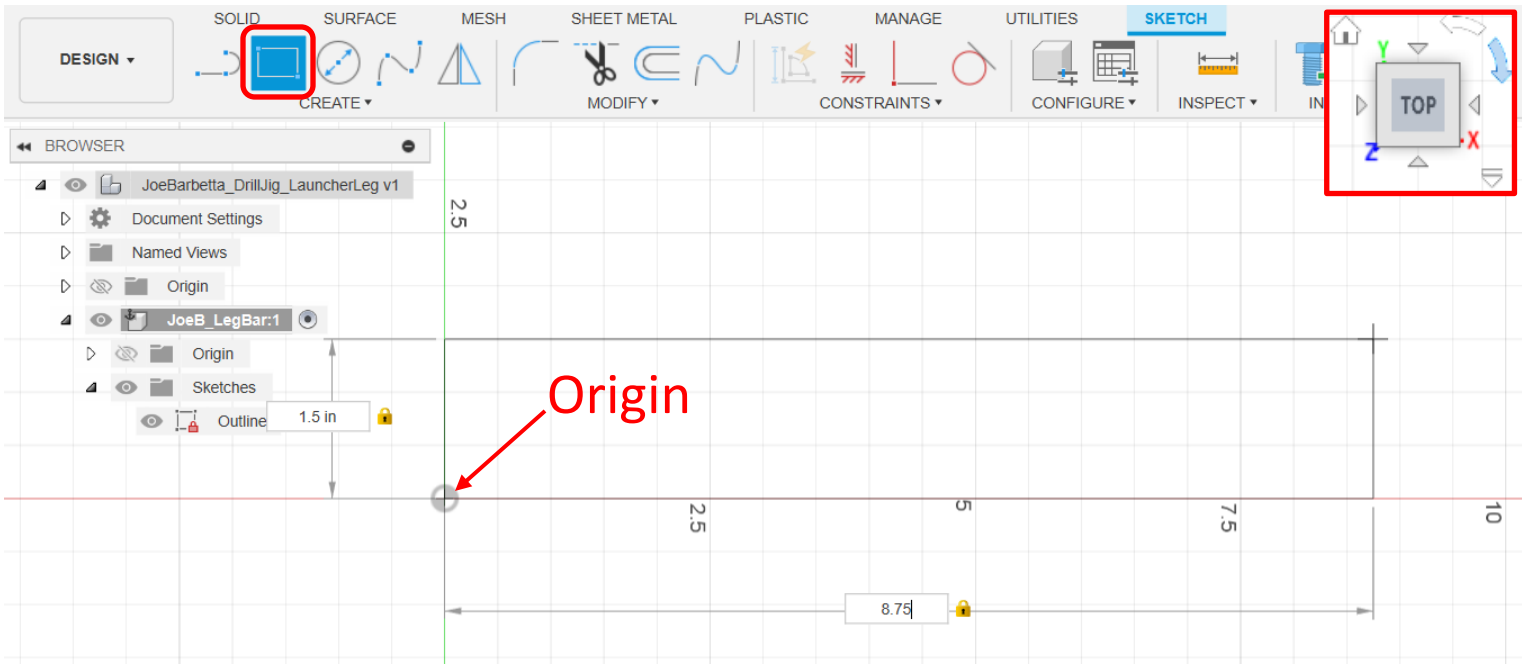
- name it using your **first name**, followed by the **initial of your last name**, followed by **_LegBar**, e.g**. JoeB_LegBar**
- click OK



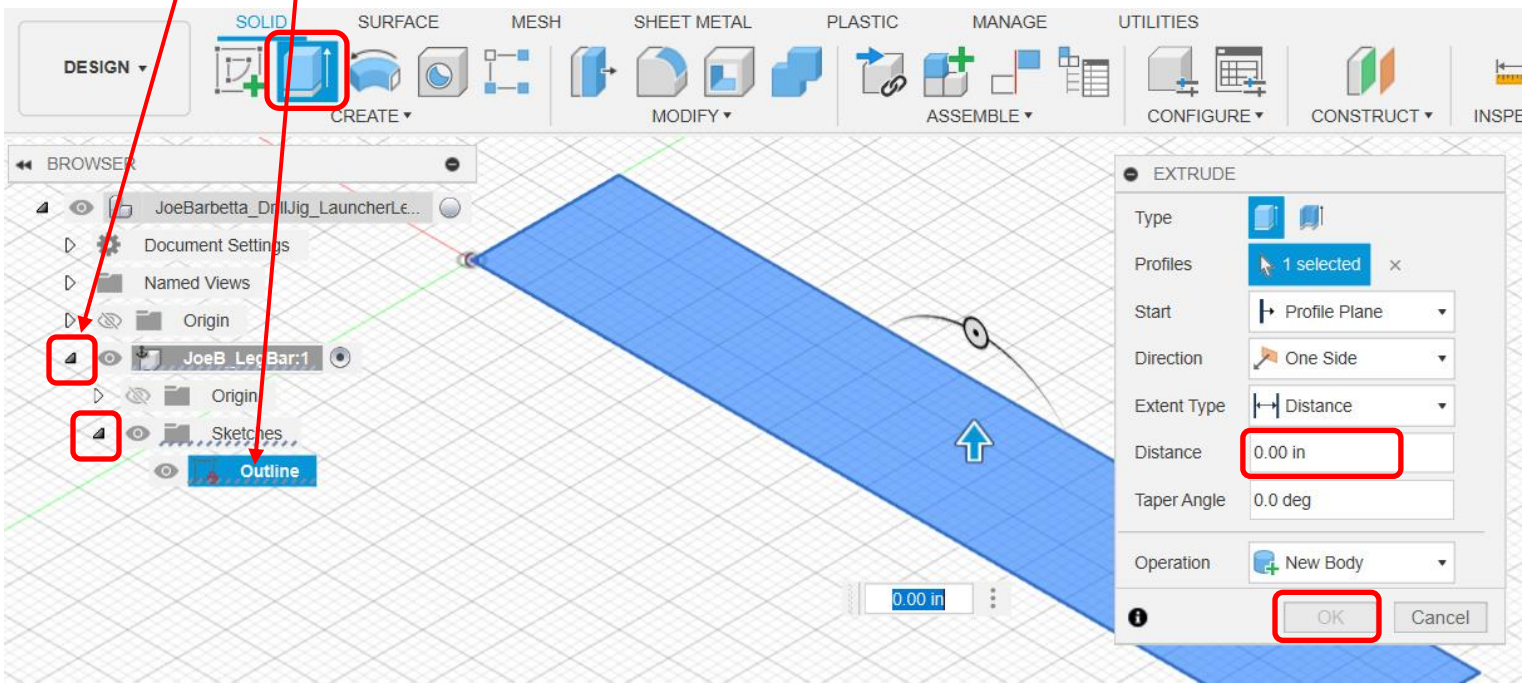
- select **Create Sketch** and click on the **bottom rhombus**



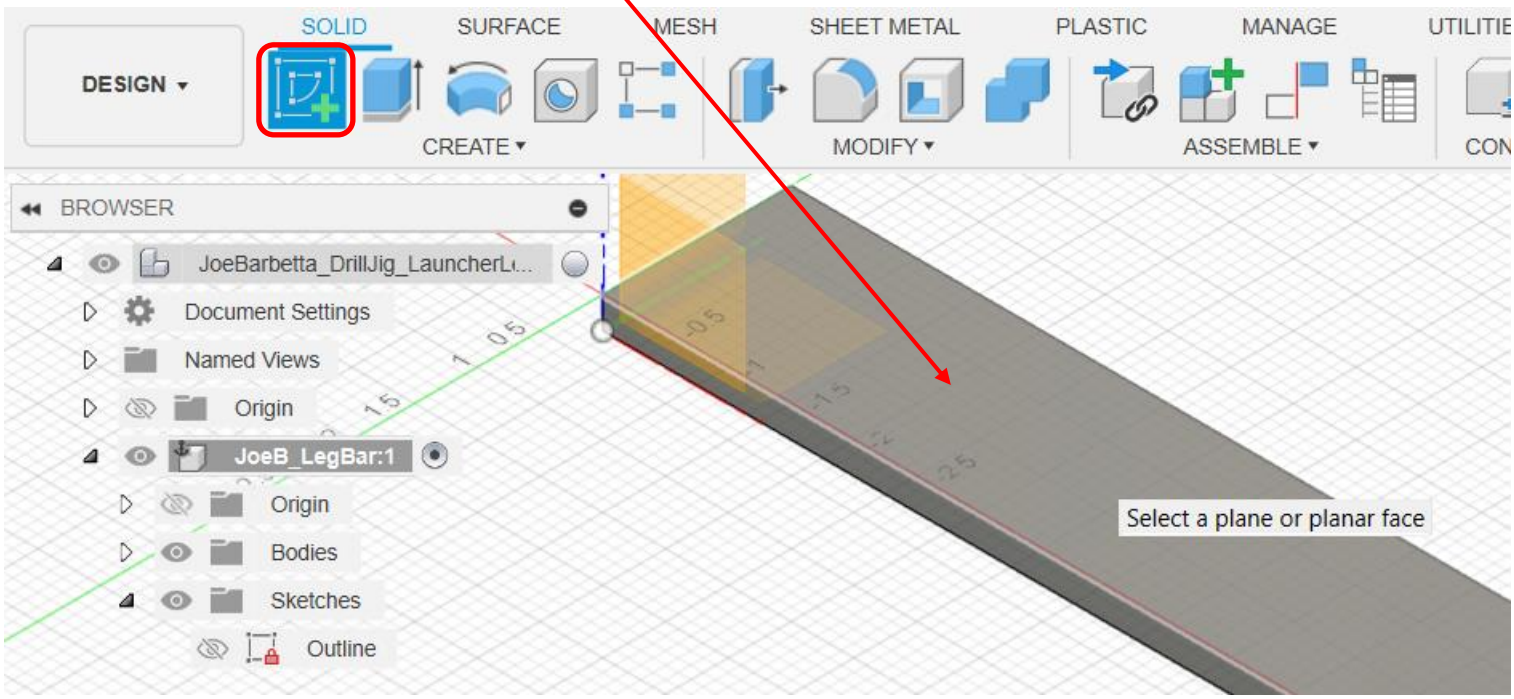
- the **View Cube** should show **TOP**. If the view needs to be rotated click on the curved arrows at the **View Cube**
- zoom out and pan to achieve a view similar to that below. Note the values on the red and green axes.
- select the **2-Point Rectangle** tool. Note that if a tool icon is not visible, the tool can be found in the CREATE menu.
- click on the **origin** and extend the rectangle over to thr right and up
- enter **8.75** for the width and **1.5** for the height. One can use the **Tab key** to switch between the two dimensions.
- click **Finish Sketch**



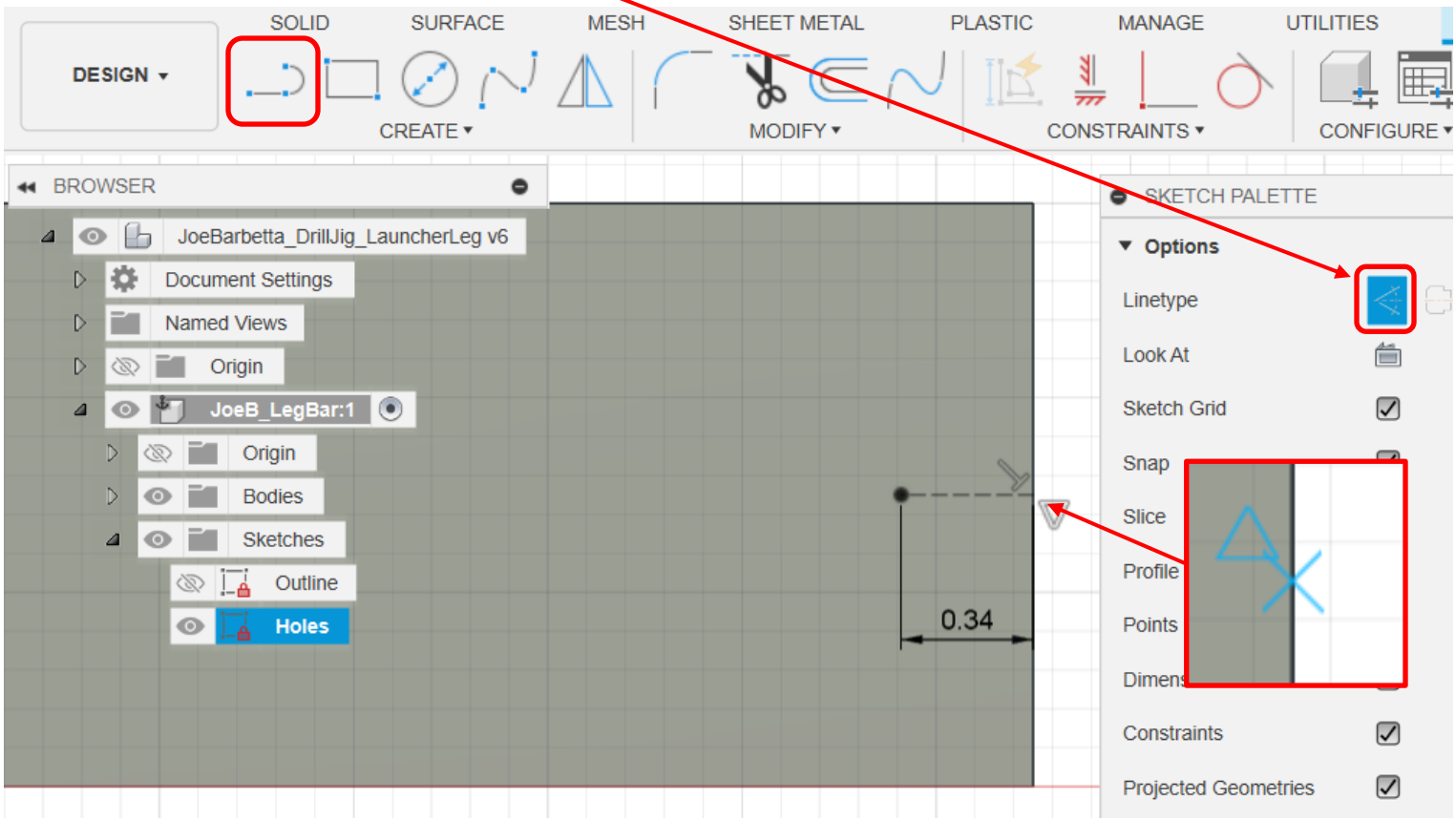
- click on the **Home** icon at the **View Cube**
- click on the **arrows** to view the Sketches
- right-click on the **Sketch name** and rename it to **Outline**
- select the **Extrude** tool and enter a **Distance** of **0.25** and click **OK**



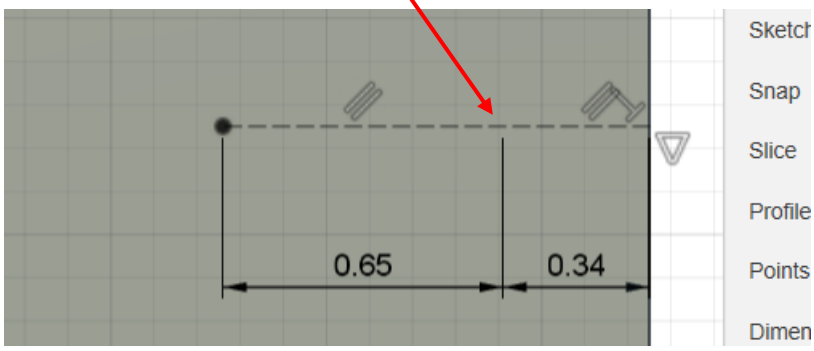
- select the **Create Sketch** tool and click on the **top surface** of the bar



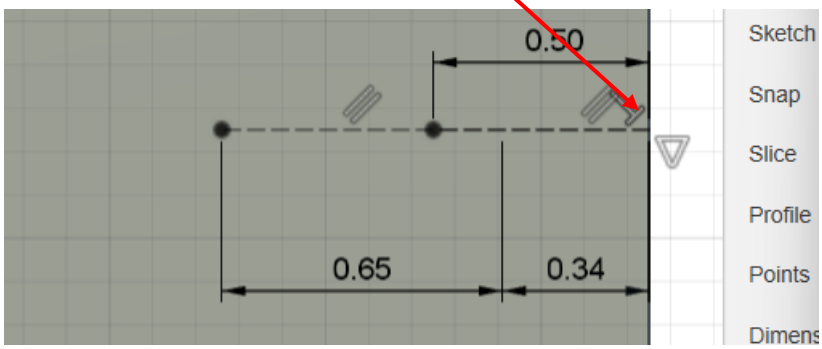
- zoom in and pan (by holding down the mouse wheel) to achieve a view of the right end of the bar similar to that below
- right-click on the new Sketch name and rename it to **Holes**
- click on the **Construction** line icon to highlight it as shown
- select the **Line** tool and move the mouse in the center of the right edge until a **blue triangle** shows and then click
- extend the line to the left, type **0.34** and press the **Enter key**. There should be a dashed line. The thin black lines (one has arrows) are dimension lines and they may look different.



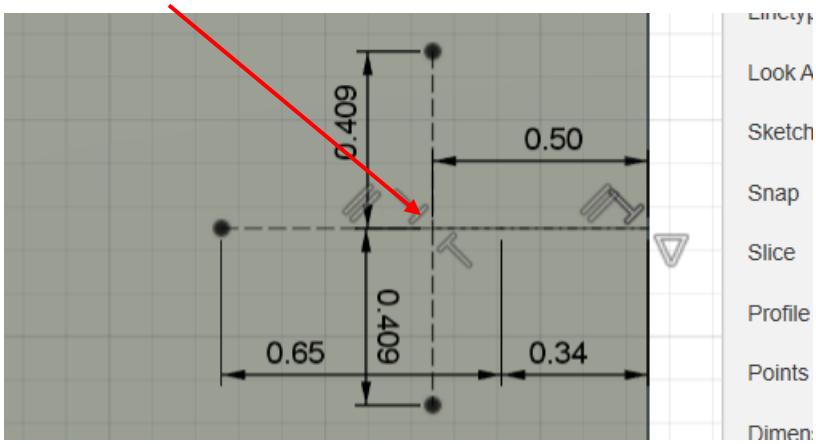
- create another line from the **last point** and over to the left by 0.65



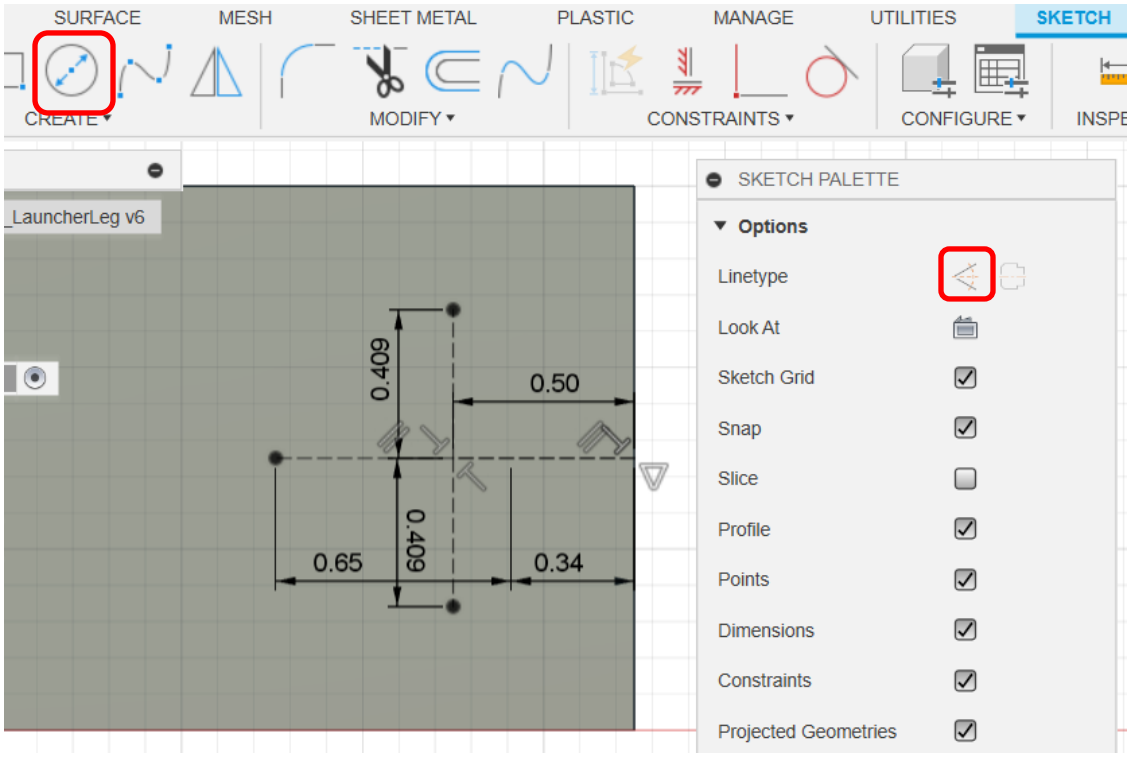
- create another line from the **center point of the right edge** and over to the left by **0.5**
- move the **0.50 dimension line** above that line to reduce clutter



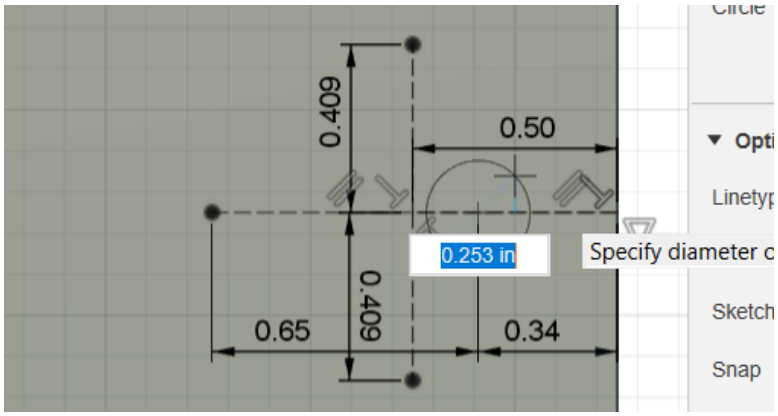
- from the **end of the 0.50 line** create a line upward and one downward by **0.409**



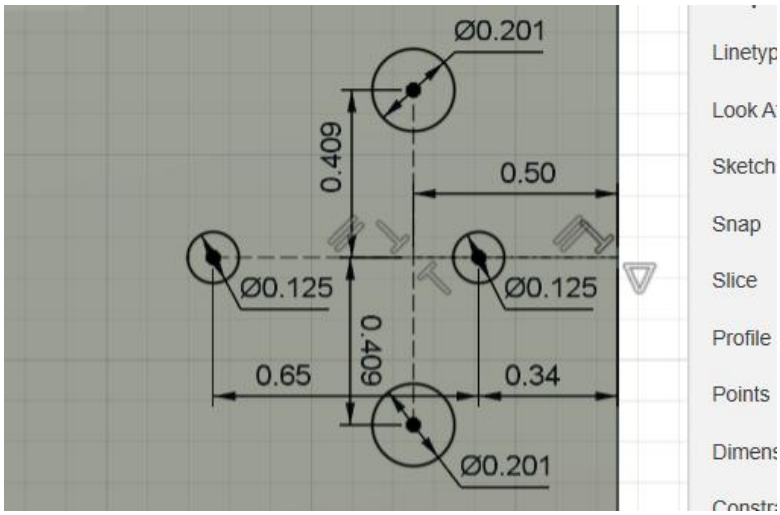
- click on the **Construction** icon to remove the highlighting
- select the **Center Diameter Circle** tool. If it is not visible, select it from the CREATE menu.



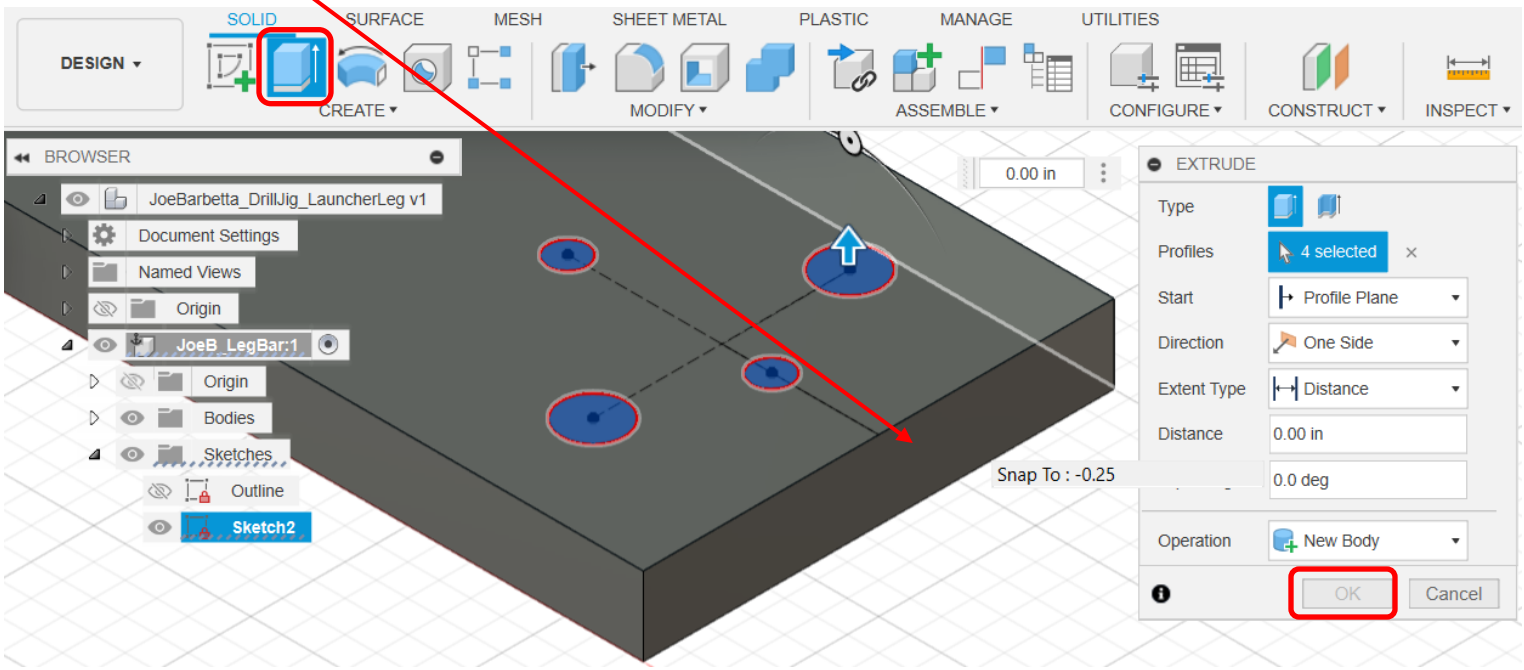
- click on the **point where the 0.34 line ends**, extend the circle outward, type **0.125**, and press the **Enter key**



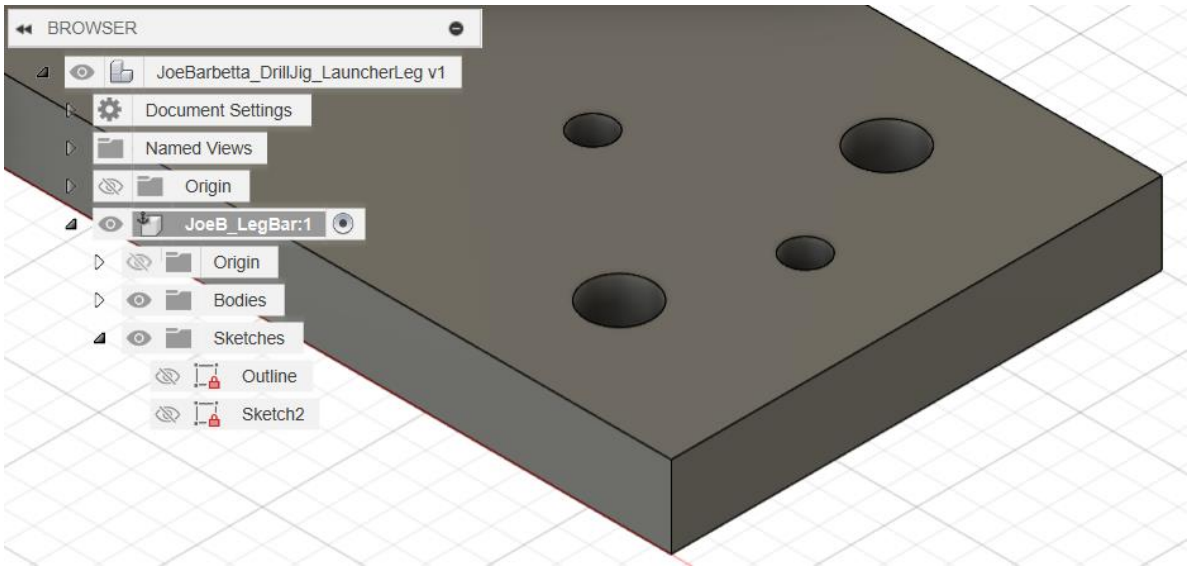
- create **3 more circles** at the **ends of the lines** using the diamters **0.125** and 0**.201** as shown. Click **Finish Sketch**.



- click on the **Home** icon at the **View Cube** and zoom into the end as shown
- select the **Extrude** tool and click on the **interior of the 4 holes** to highlight them blue
- click on the **end surface** to cause the hidden bottom surface to change color and **click**
- click **OK**

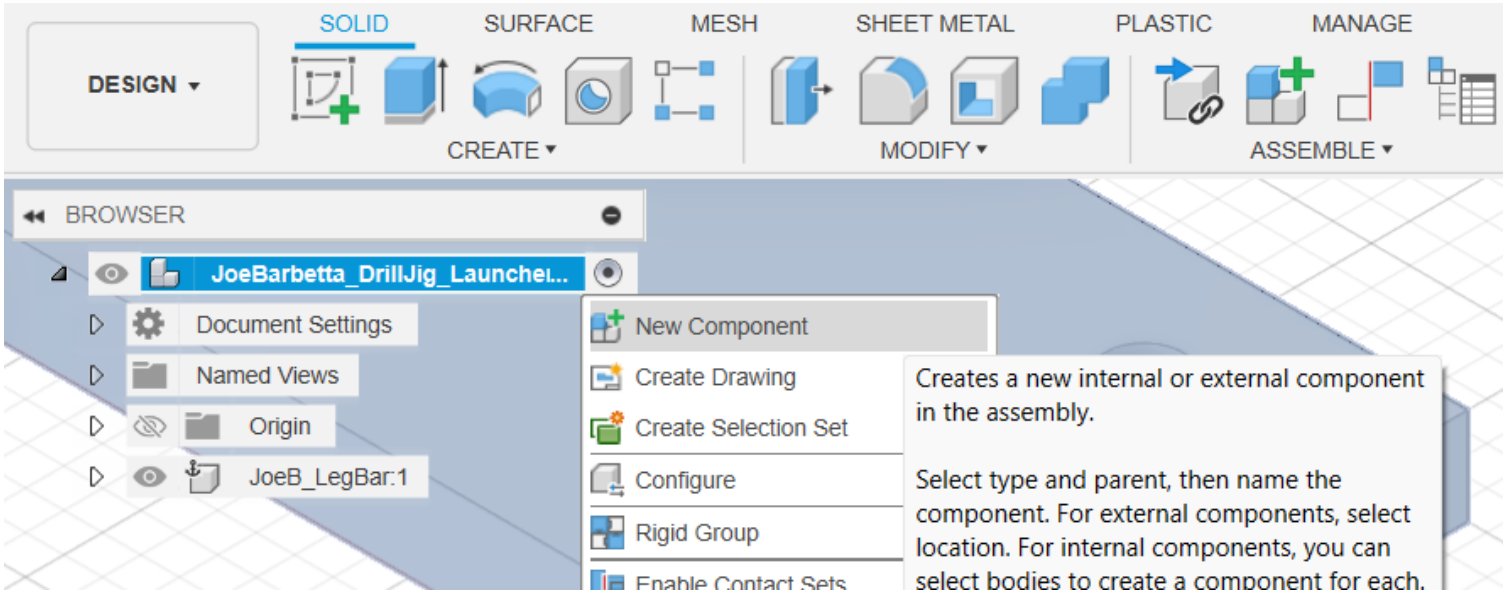


The result should appear as below.
Note that the dimensions just used are revealing some **TOP SECRET missile launcher design parameters**. Please do not share any such information.



Creating the Drill Jig Componenent

- click on the **circle to the right of the project name** to activate it
- right-click on the project name and select New Component and name it using your **first name**, **last name intitial**, followed by **_LegJig**, e.g. **JoeB_LegDrillProx** What is Prox? Why not throw in a medical term. This end is *proximal* to the launcher body. *Distal* would be the other end.



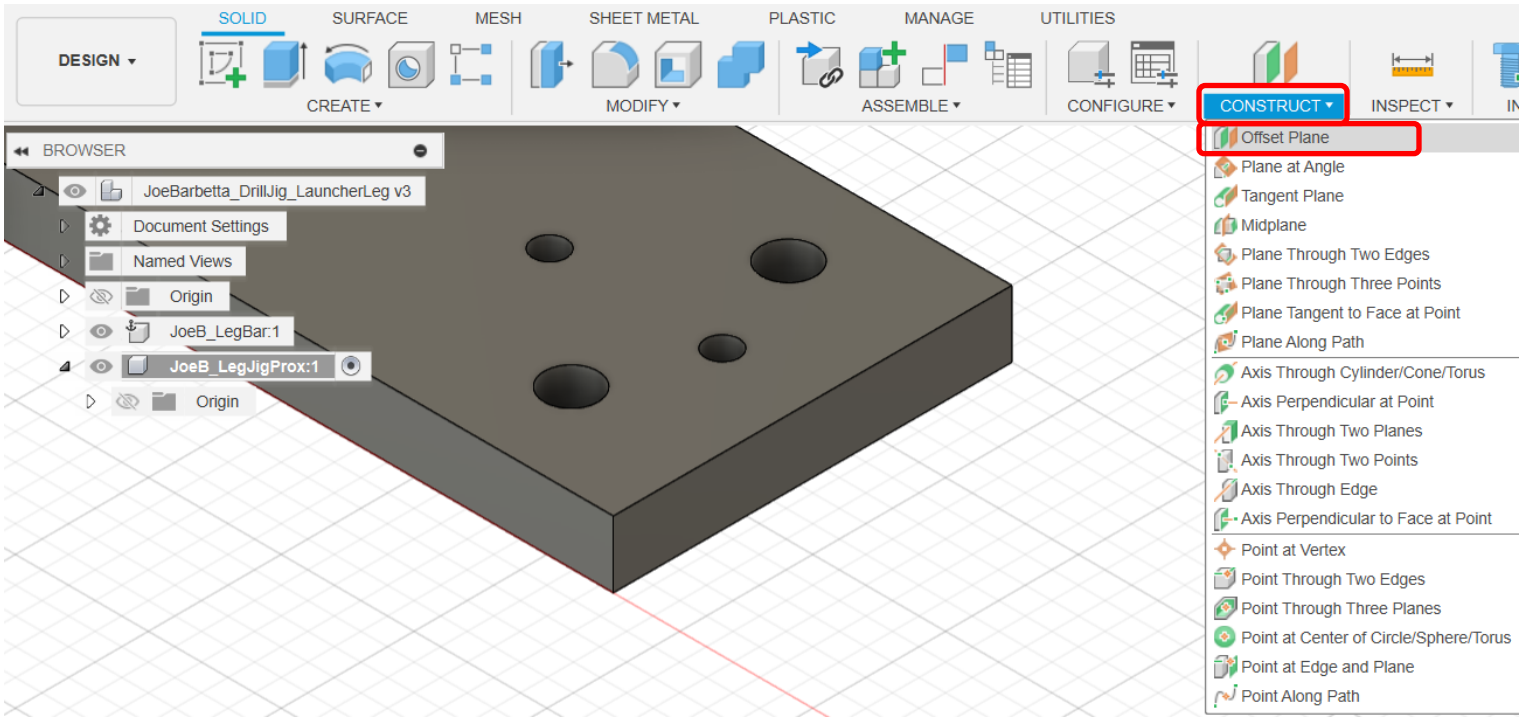
-

Using a Construction Plane

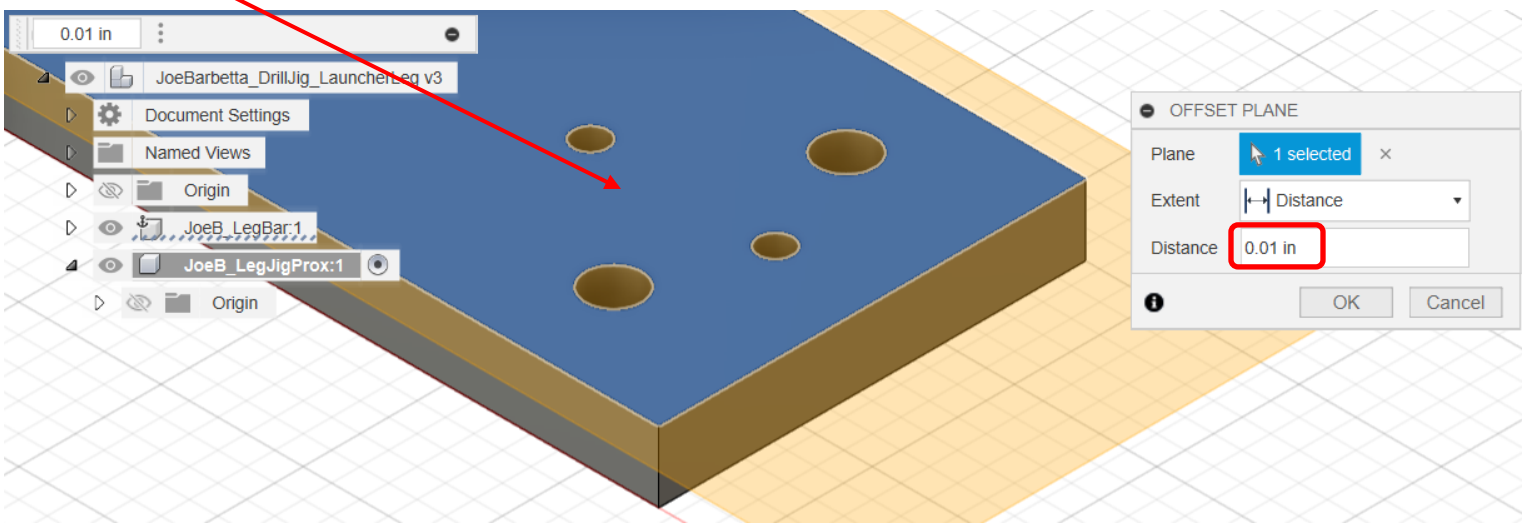
Note how a body for a component is started by selecting a plane at the origin or selecting a face of a body. Sometimes one wants to create a sketch to create a body near another body and/or aligned with another body. The CONSTRUCT menu options allows one to do so using all different methods.

Note that the new component should be automatically activated. Good. This is what we want.

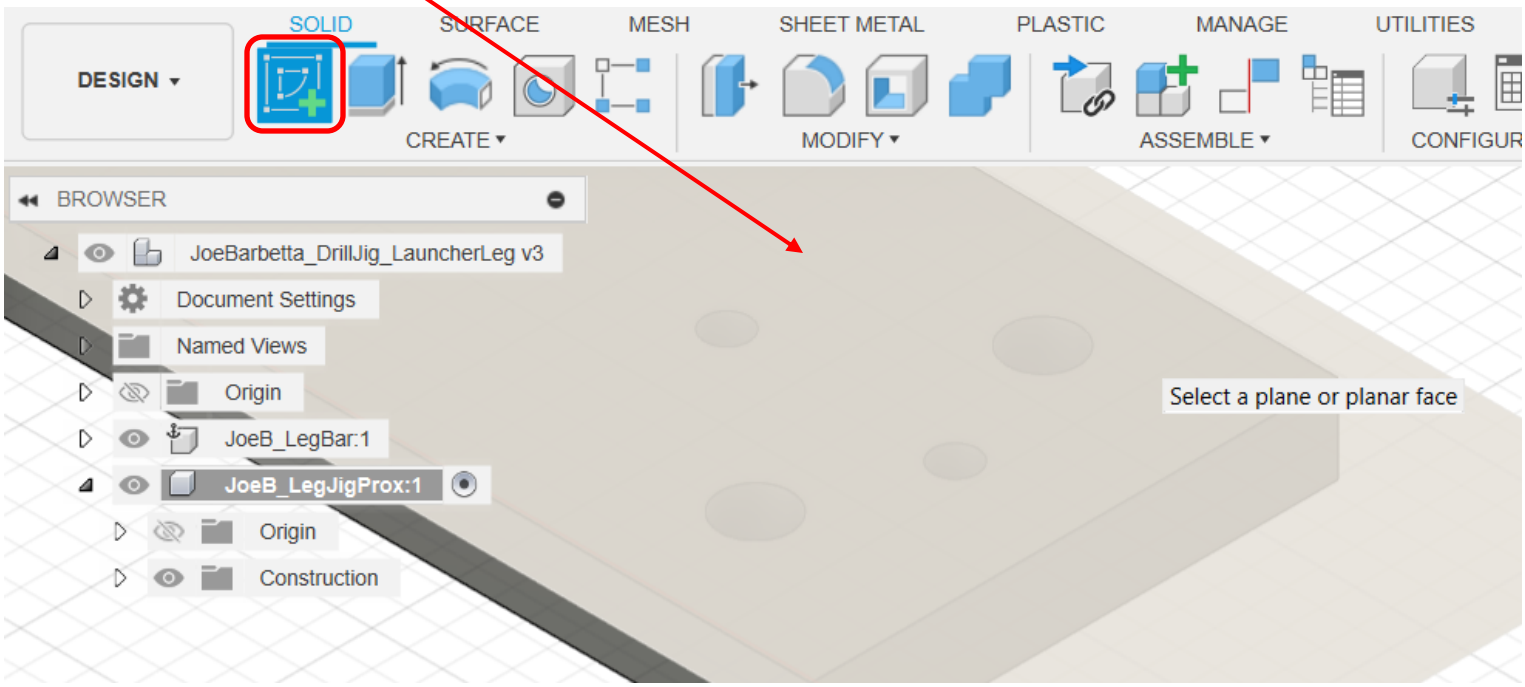
- from the **CONSTRUCT** menu select **Offset Plane**



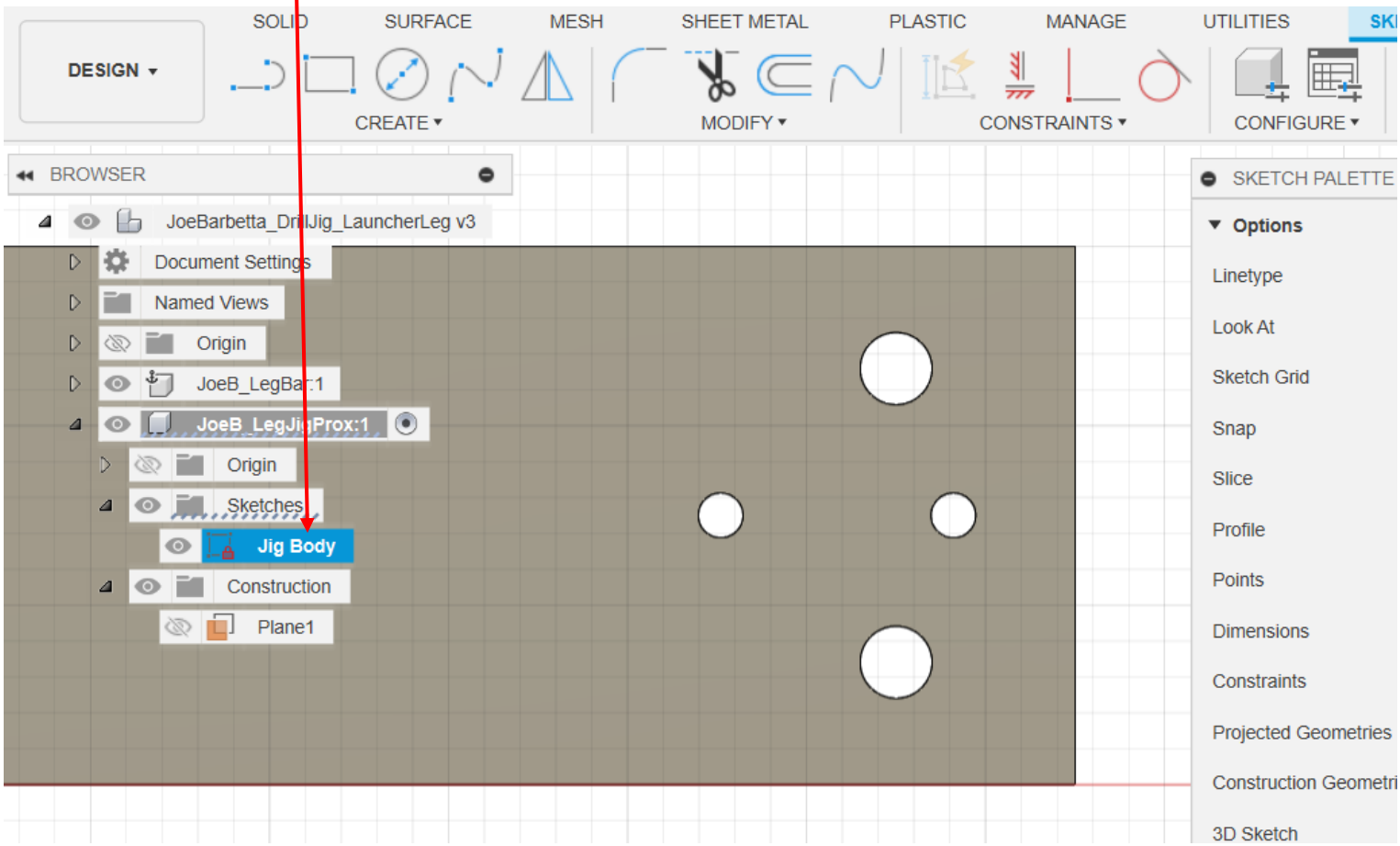
- click on the **top surface** of the bar, enter **0.01** for **Distance**, and click **OK**



- select Create Sketch and then click on the plane



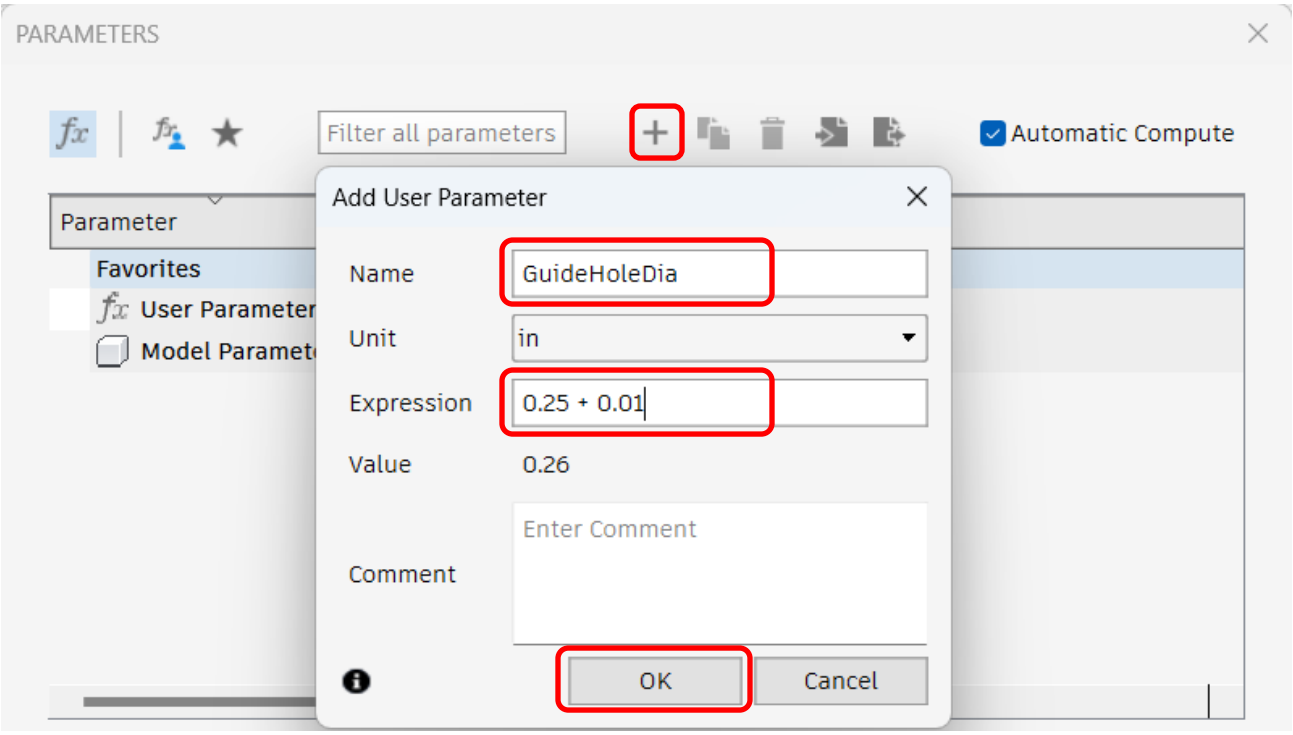
- pan and zoom to achieve a view similar to that below
- rename the Sketch to **Jig Body**



Setting User Parameters

User Parameters allows for the control of dimensions with variables. This is useful especially if there are multiple features, such as holes, using the same dimension. In our application here there are multiple guide holes to accommodate a Spot Drill, Center Drill, or Drill Bushings. If one decides to use a 3/16” center drill instead of a 1/4” center drill, the corresponding parameter can be changed and the diameter of all guide holes will change together.

- near the bottom of the **MODIFY** menu select **Change Parameters**
- click on the **+(plus)** symbol, set the **Name** to **GuideHoleDia**, ensure the **Unit** is **in**, set **Expression** to **0.25 + 0.01**, and click **OK**

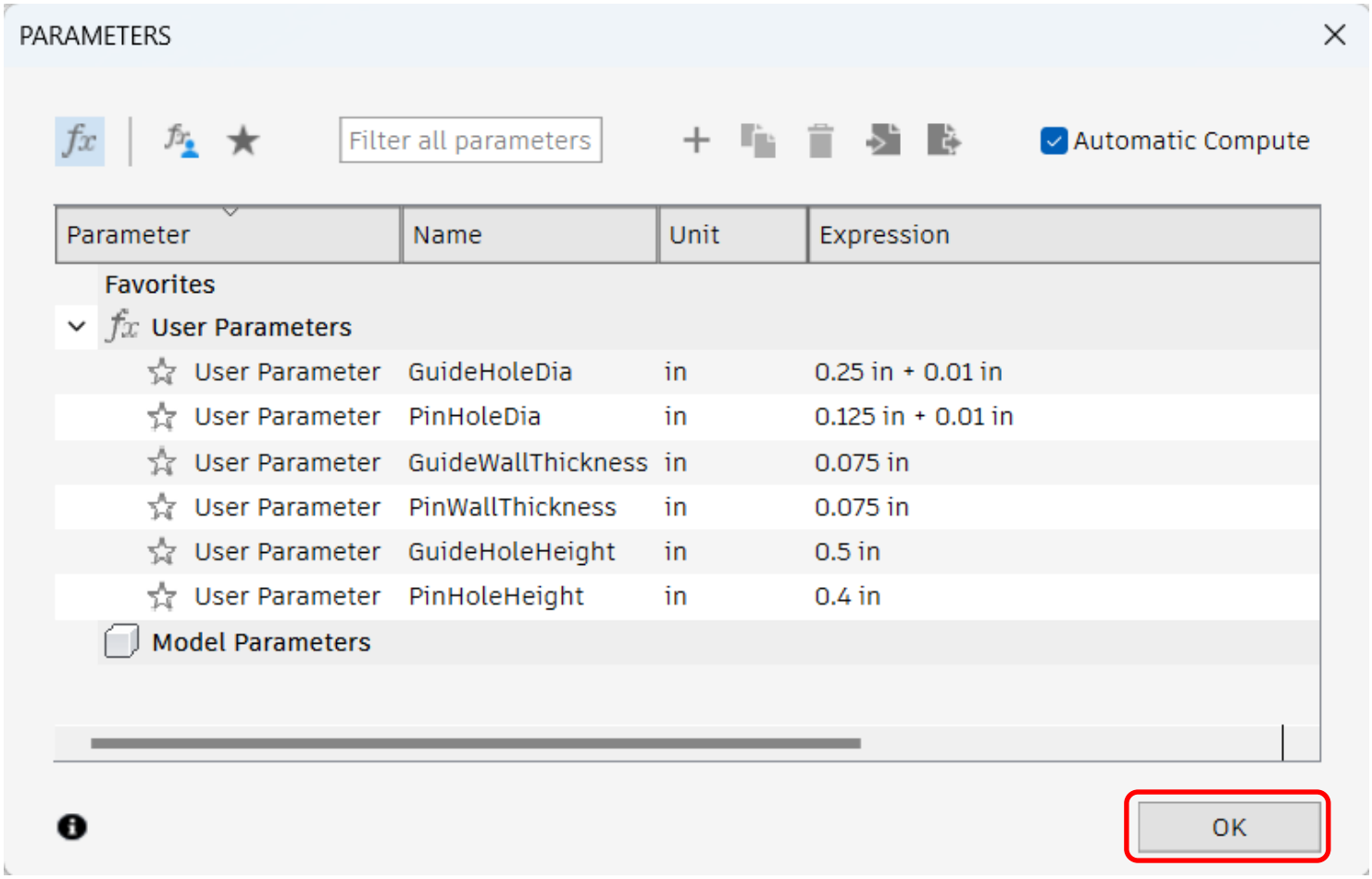


- perform the same operation to add the 5 additional parameter shown below

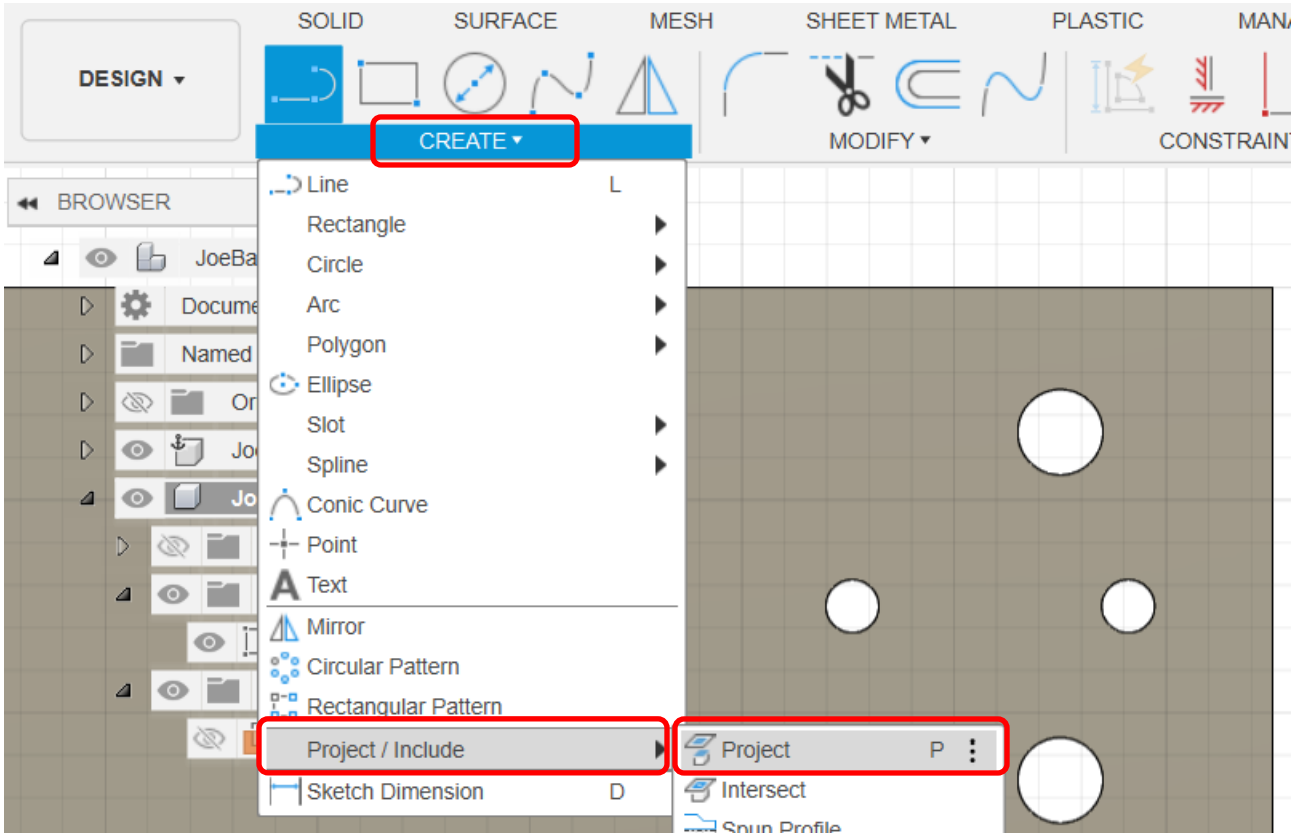
PinHoleDia	in	0.125 in + 0.01 in
GuideWallThickness	in	0.075 in
PinWallThickness	in	0.075 in
GuideHoleHeight	in	0.5 in
PinHoleHeight	in	0.4 in

The parameters should look like that below. Note how we used formulas for the Expression. The 0.01 value can be considered an adjustment value. 3D printing will tend to make holes smaller than that specified so the 0.01 is specifying the holes to be slightly larger. For the drill holes, it can also be used to adjust clearance so the center drill is not too tight in the guide holes. We could have just entered 0.26 and 0.135, but using the formula helps communicate that we are adjusting a standard value. Note that slicer programs, such as Ultimaker Cura, have settings, e.g. Horizontal Expansion, which can correct for hole sizing. These adjustment values can also be changed to 0.00 if adjustment in CAD is not desired.

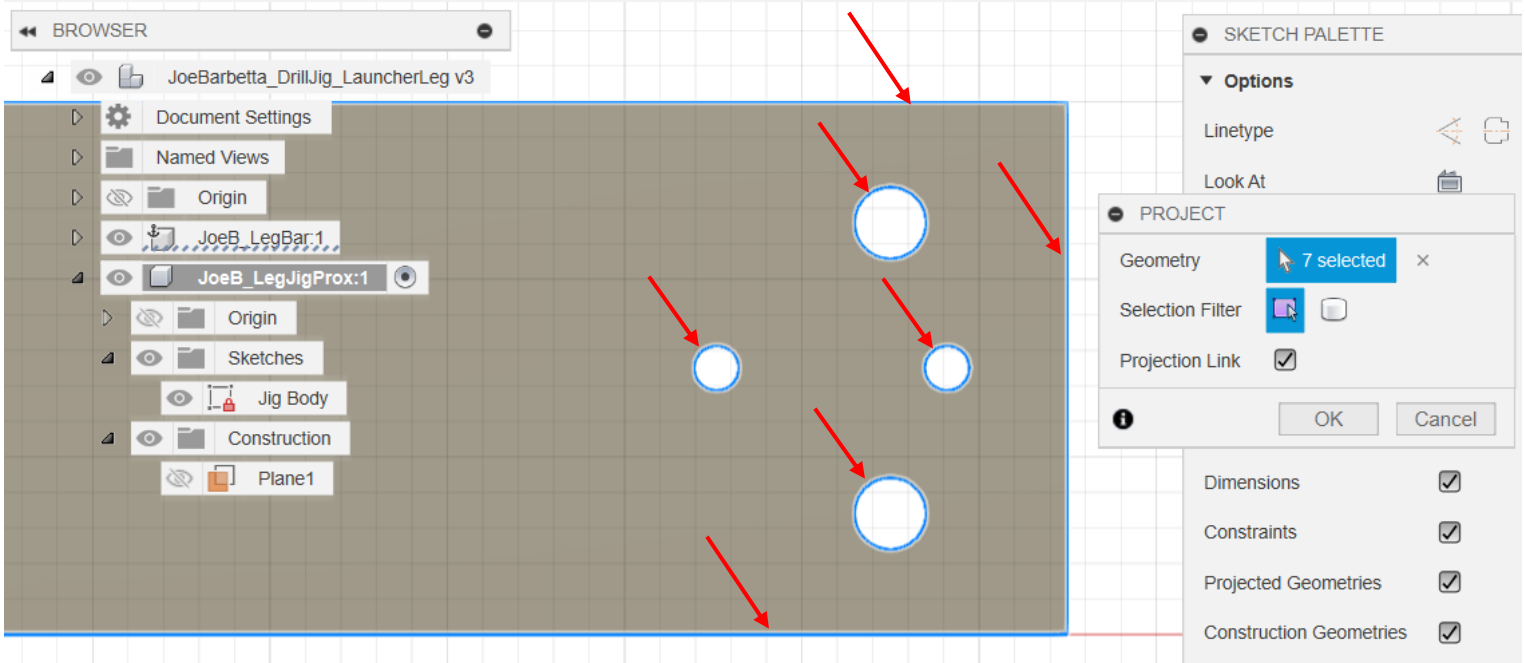
- click **OK** at the bottom of this window



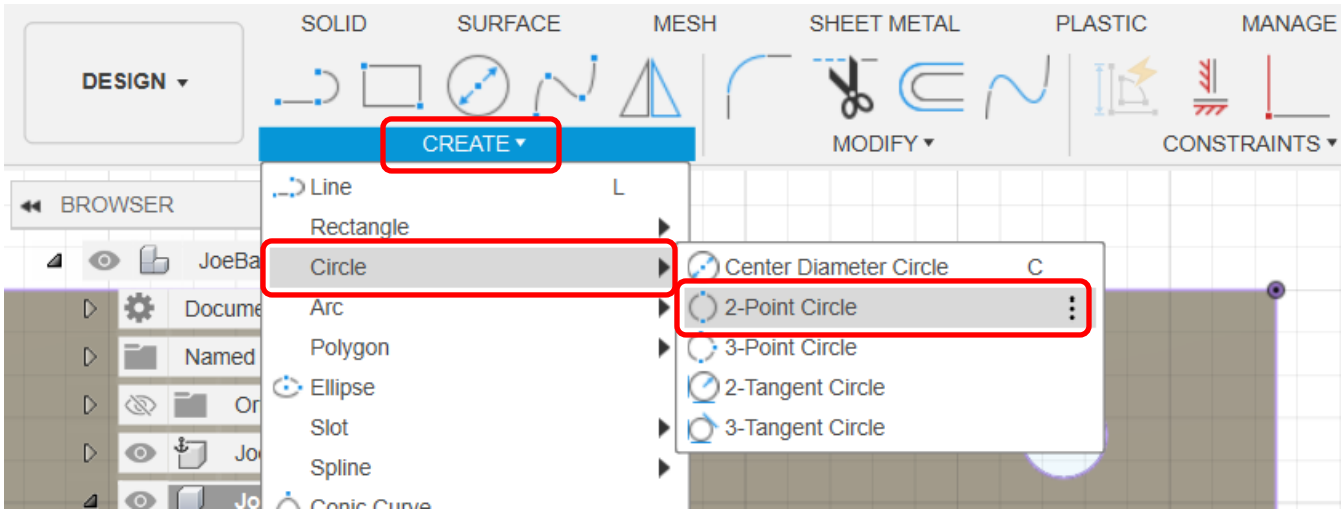
- from the **CREATE** menu select **Project / Include** and **Project**



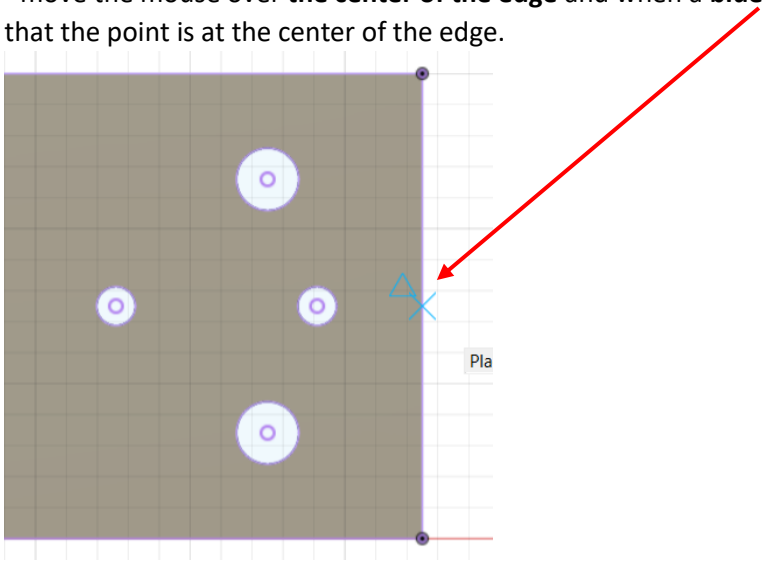
- click on the **top, bottom, and side edges** of the bar and the **edges of the holes**. Note that one can click on the surface of the bar to select all of these in one click. However, there may be holes at the other end that we don't want this jig to handle.
- click **OK**



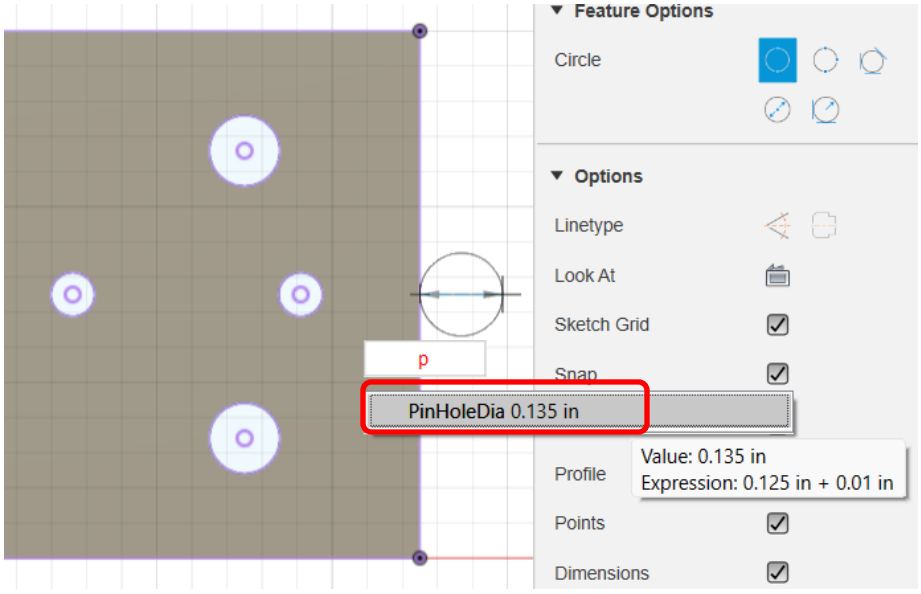
- from the **CREATE** menu select **2-Point Circle**. It's more common to use the Center Diameter Circle where the circle starts at its center point. Here we are using the 2-Point Circle to more easily create a circle tangent to the edge.



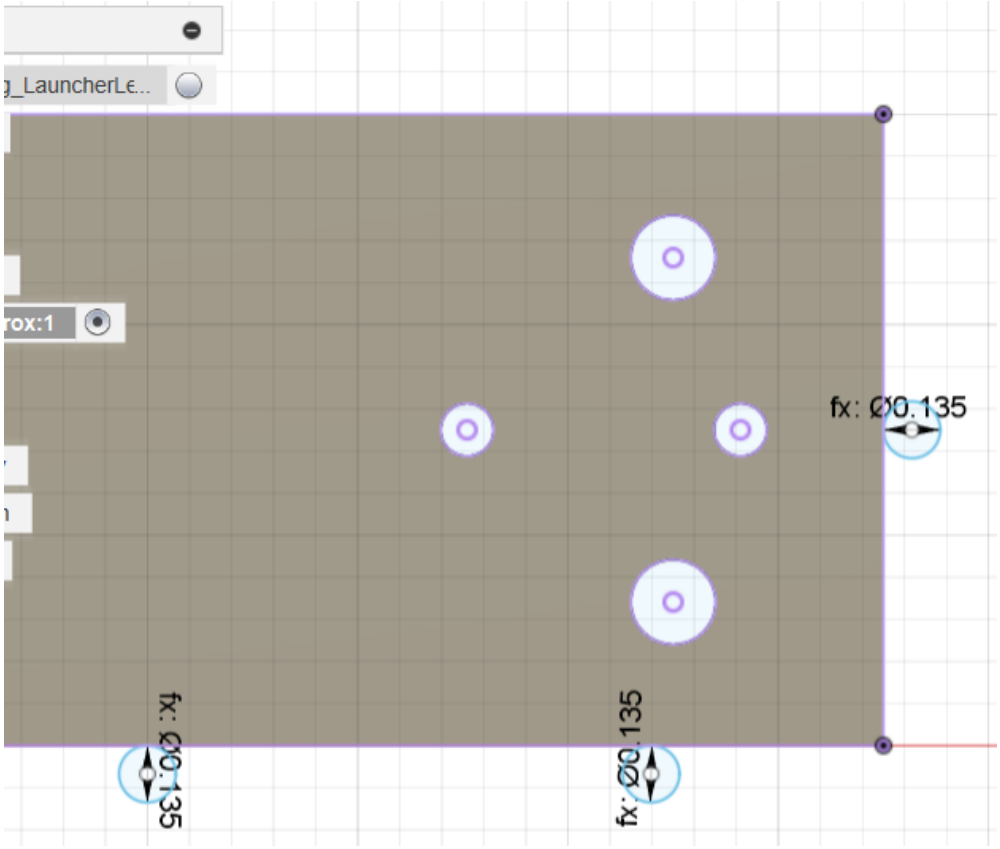
- move the mouse over **the center of the edge** and when a **blue triangle** appears **click at that point**. The blue triangle indicates that the point is at the center of the edge.



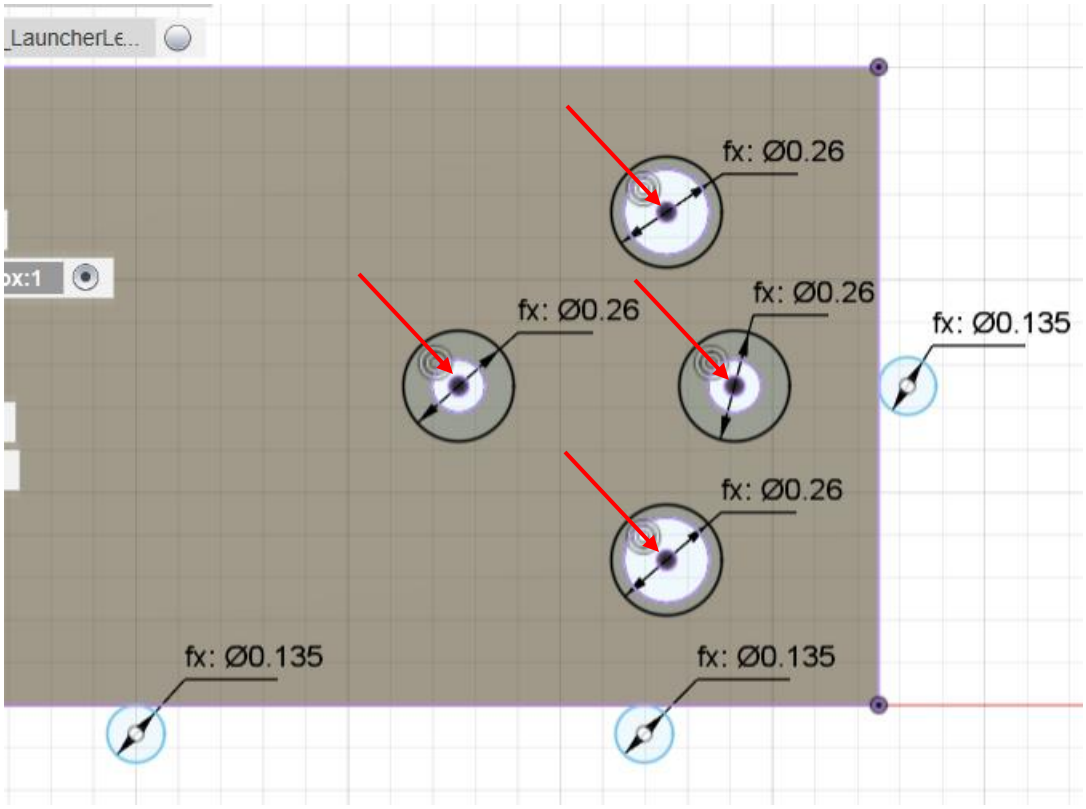
- extend the circle to the right, type **p**, select **PinHoleDia**, and press the **Enter Key**



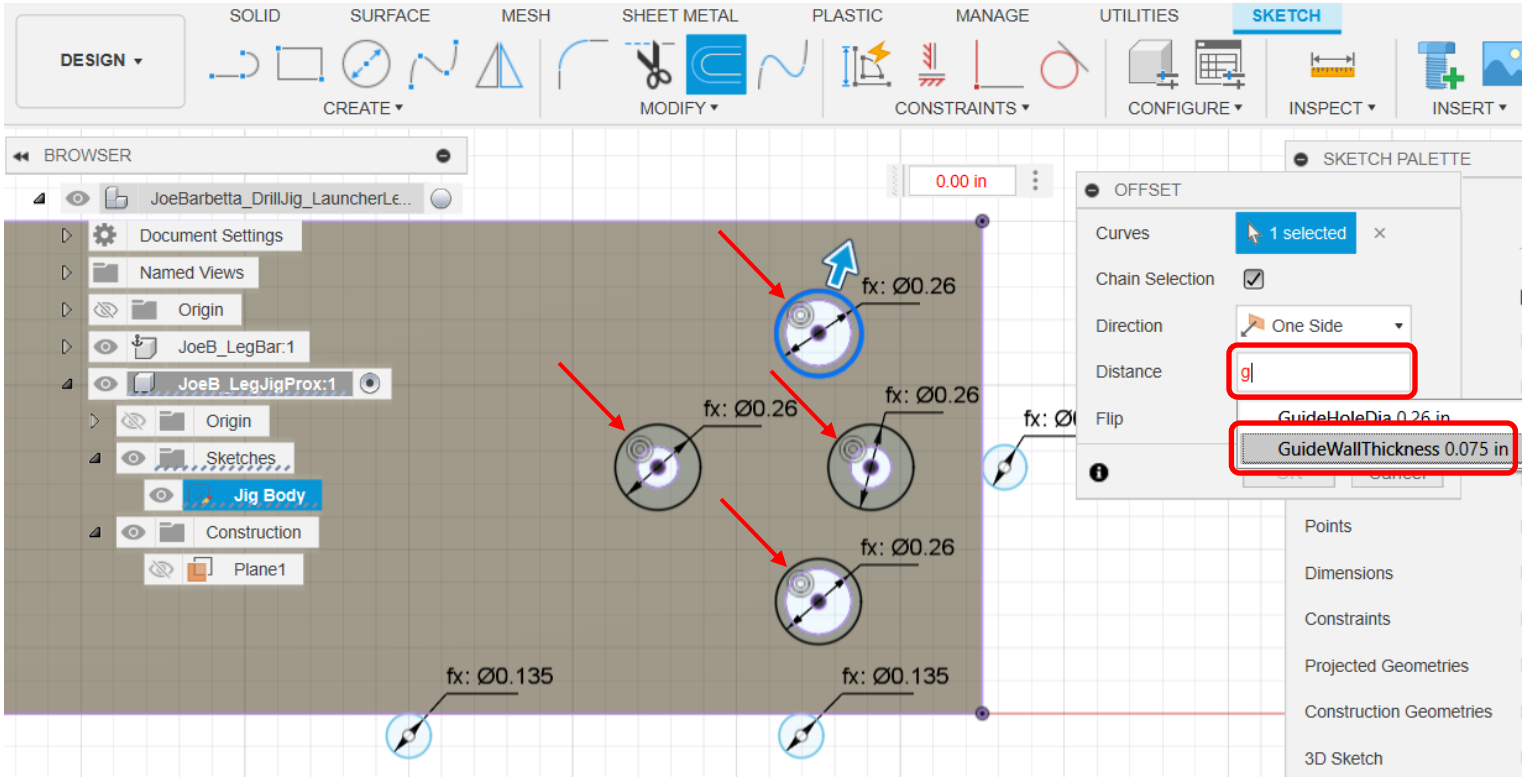
- use the **2-Point Circle** two more times to create the bottom holes, starting at the bottom edge



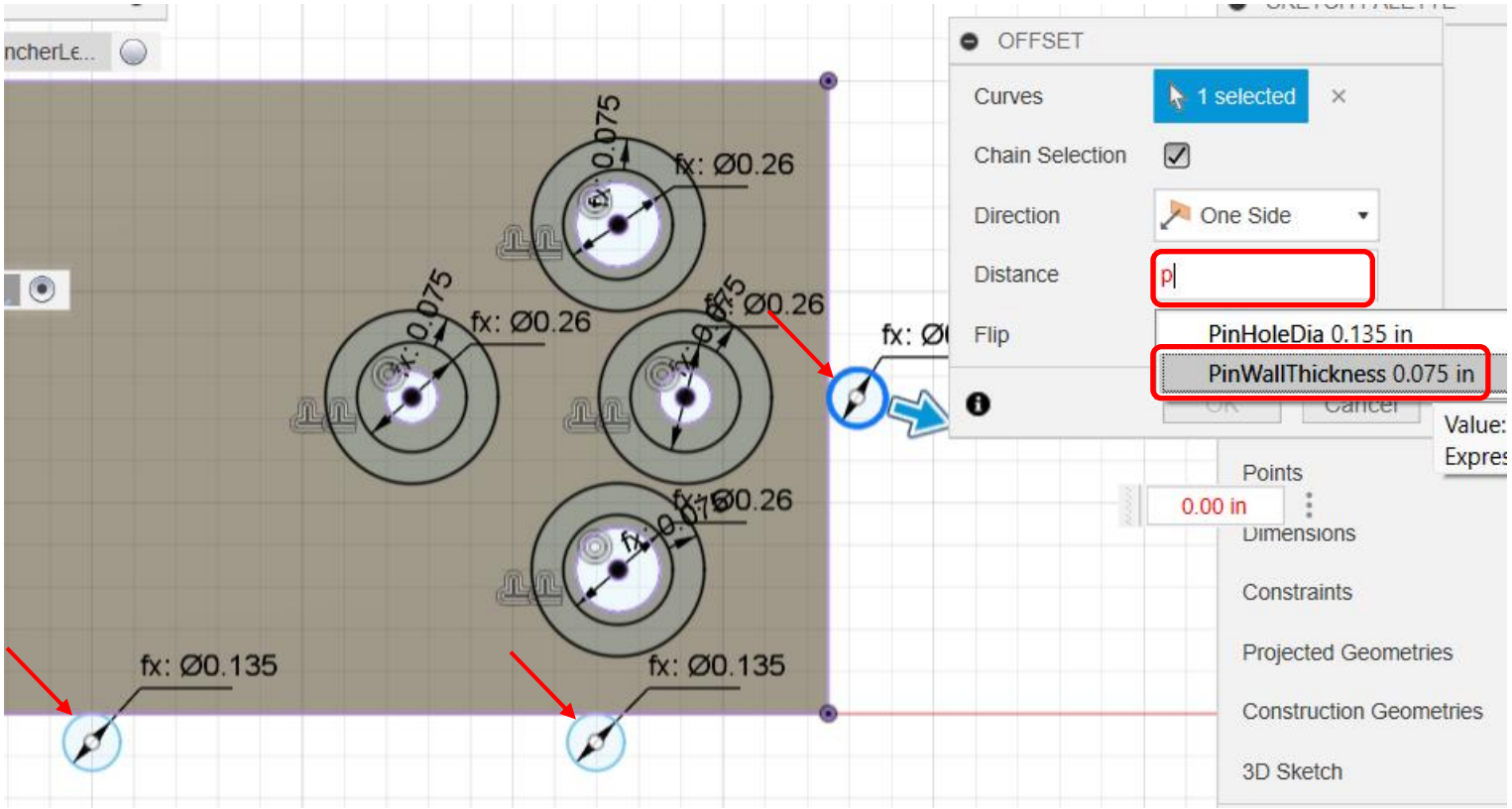
- use the more common Center Diameter Circle, click on the center of a hole, extend the hole outward, type g, select GuideHoleDia, and press the Enter key. Do this for all 4 holes.



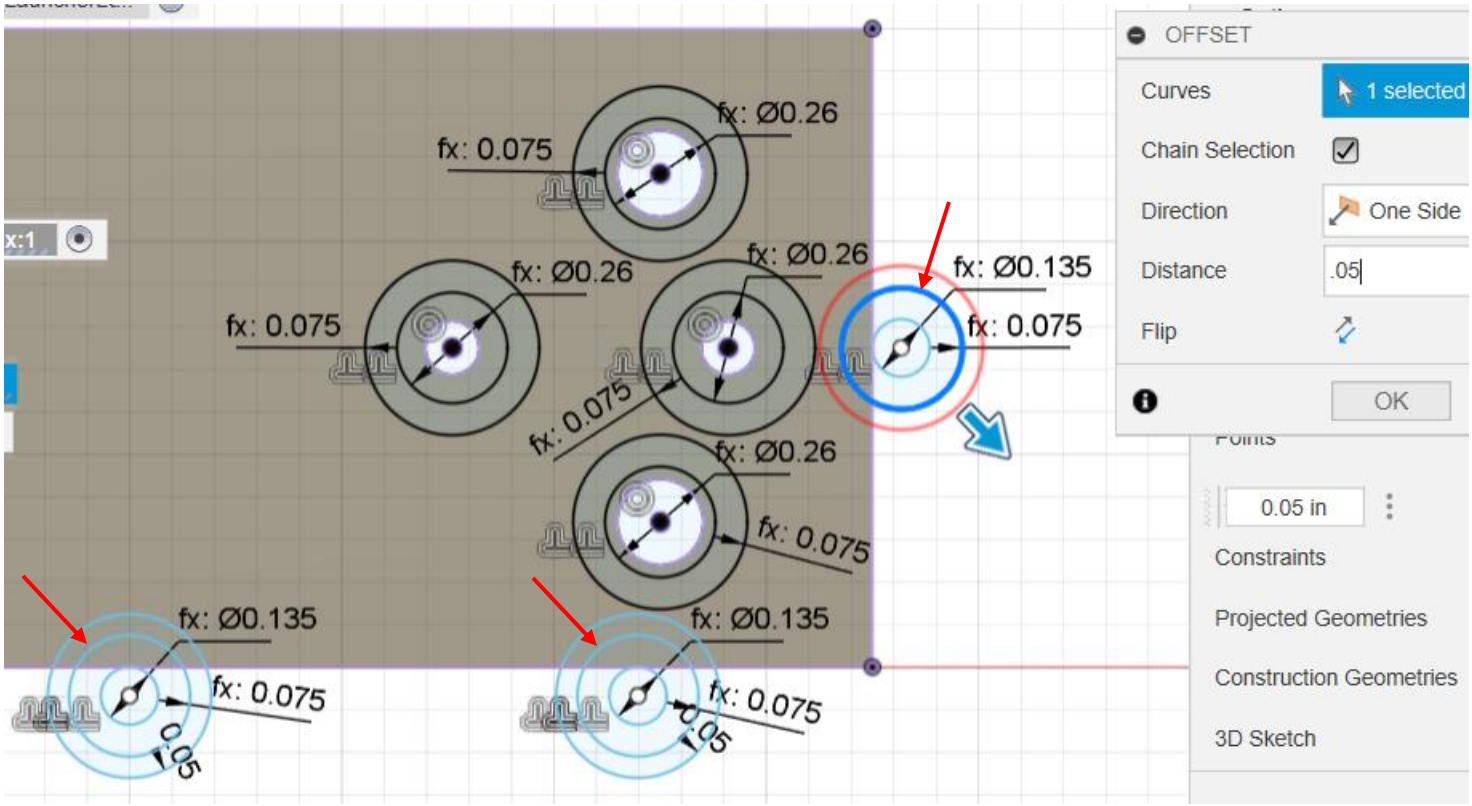
- select the **Offset** tool. If it is not visible select it from the MODIFY menu.
- click on the **edge of a circle** and in the **Distance** box type **g**, and select **GuideWallThickness**
- perform the same operation for the **other 3 circles**



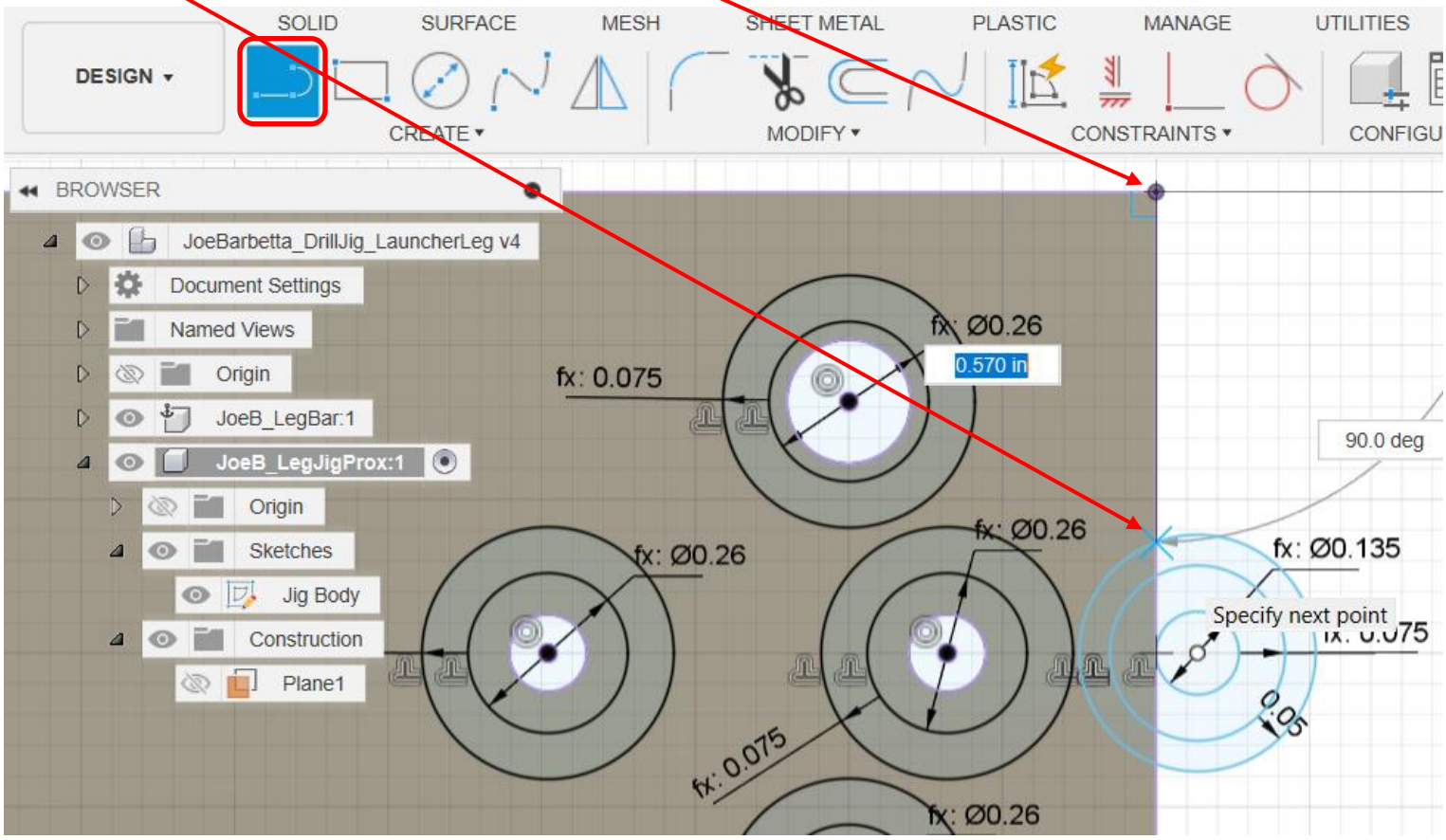
- perform the same operation for the pin hole circles, but type **p**, and select **PinWallThickness**



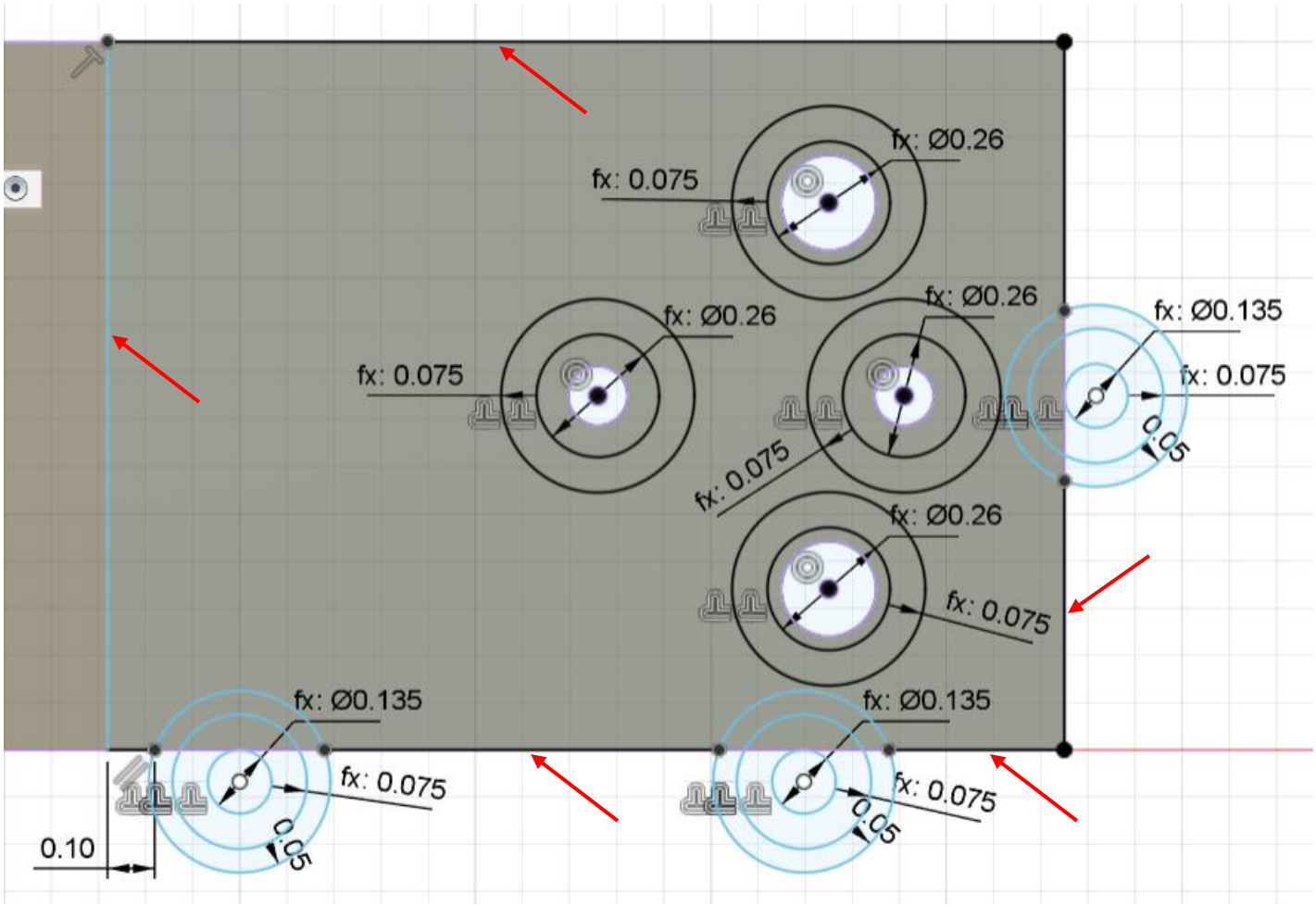
- around each pin add another offset of **0.05**



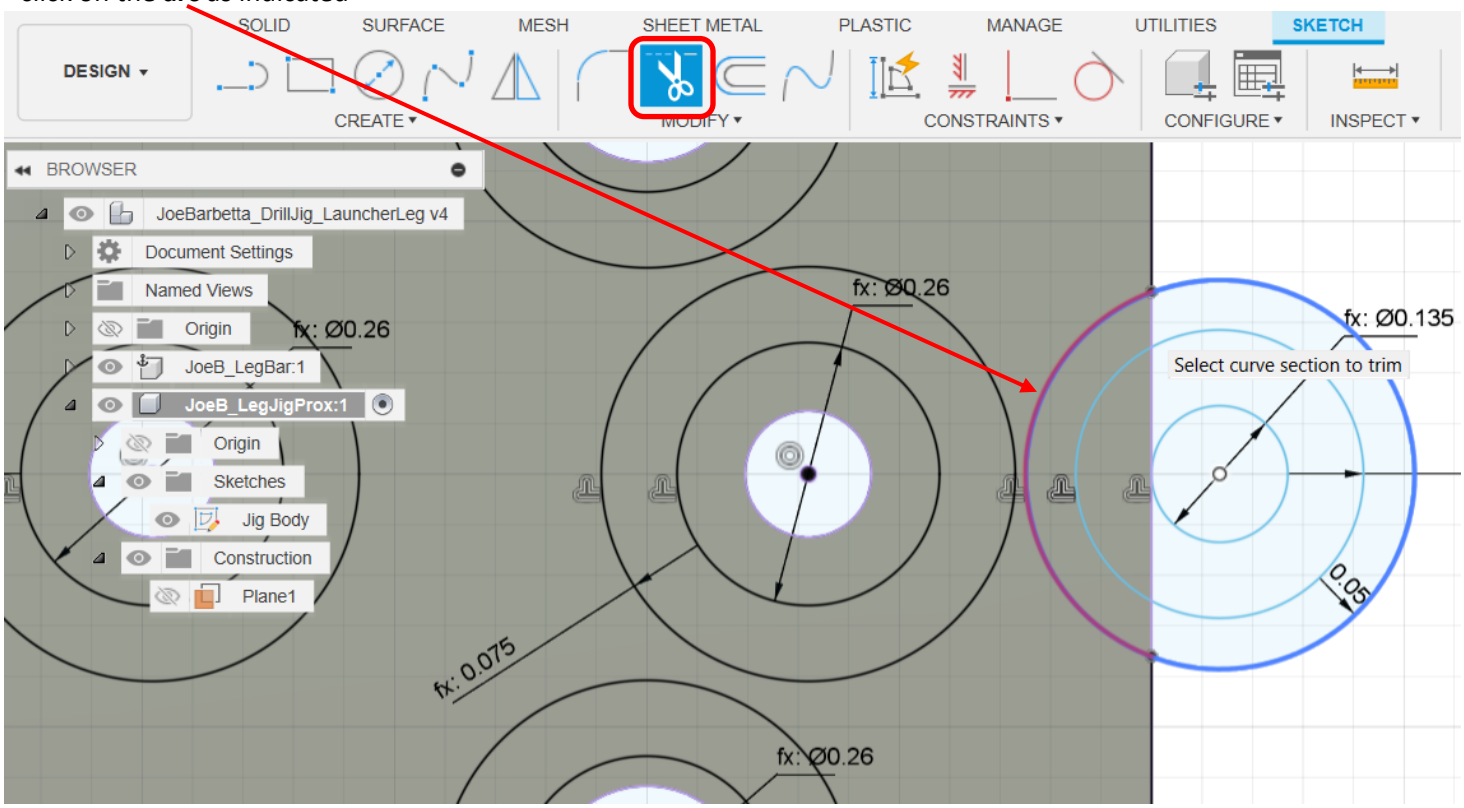
- select the **Line** tool and start a line at the **top right corner** and down to the blue circle. It should snap to the circle, which results in an **X** showing.



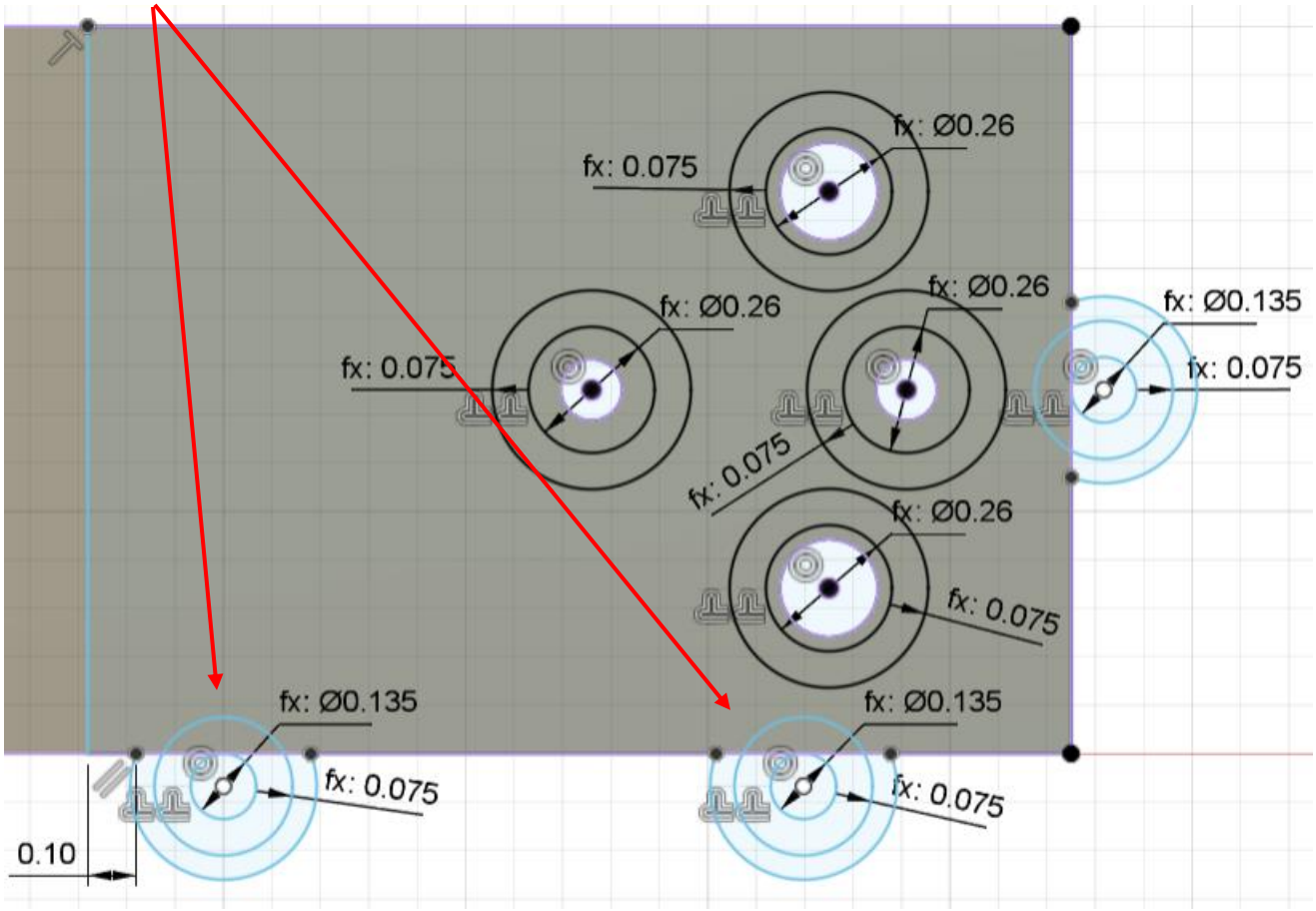
- continue creating lines as shown



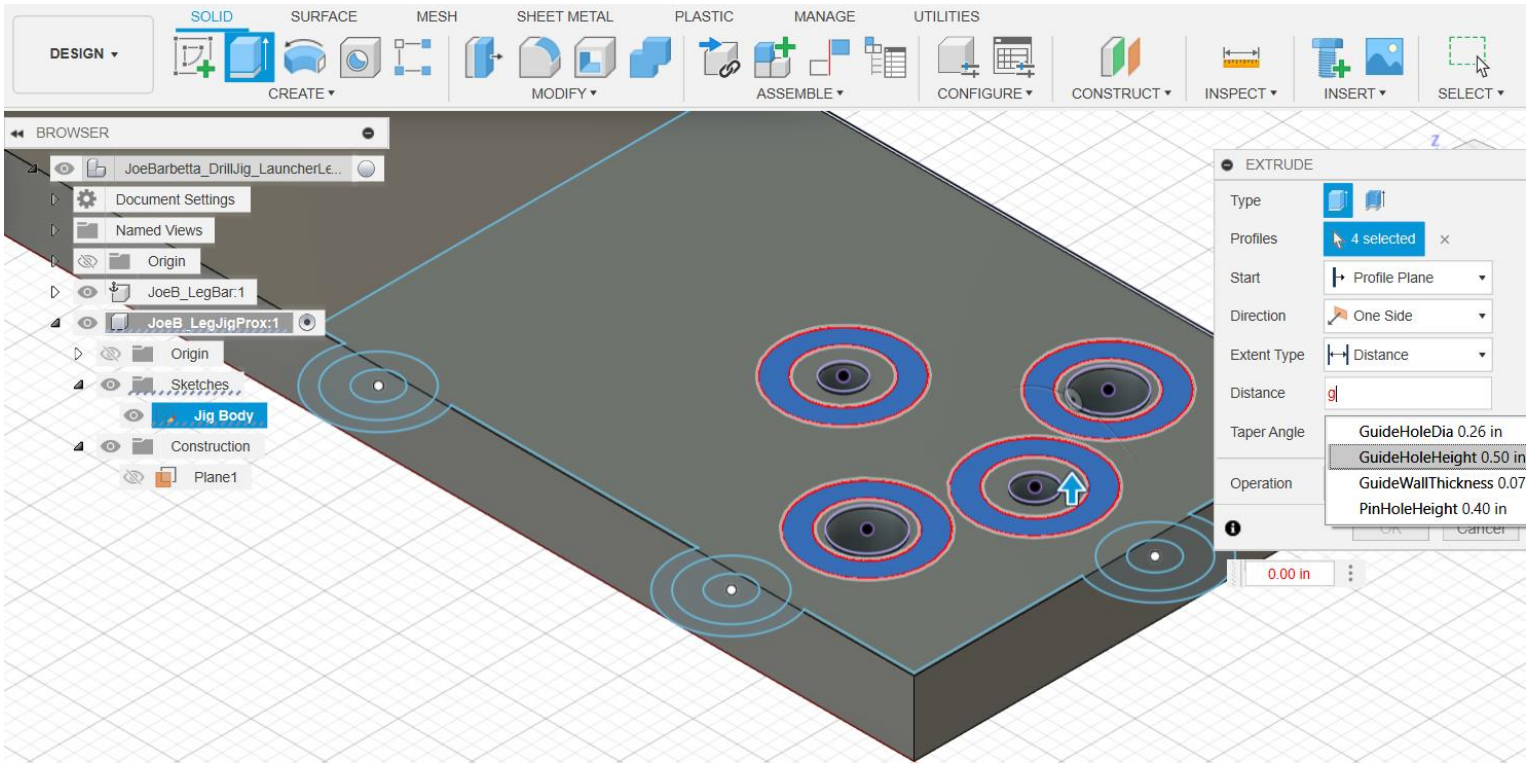
- select the **Trim** tool. If the icon is not visible select it from the **MODIFY** menu.
- click on the **arc** as indicated



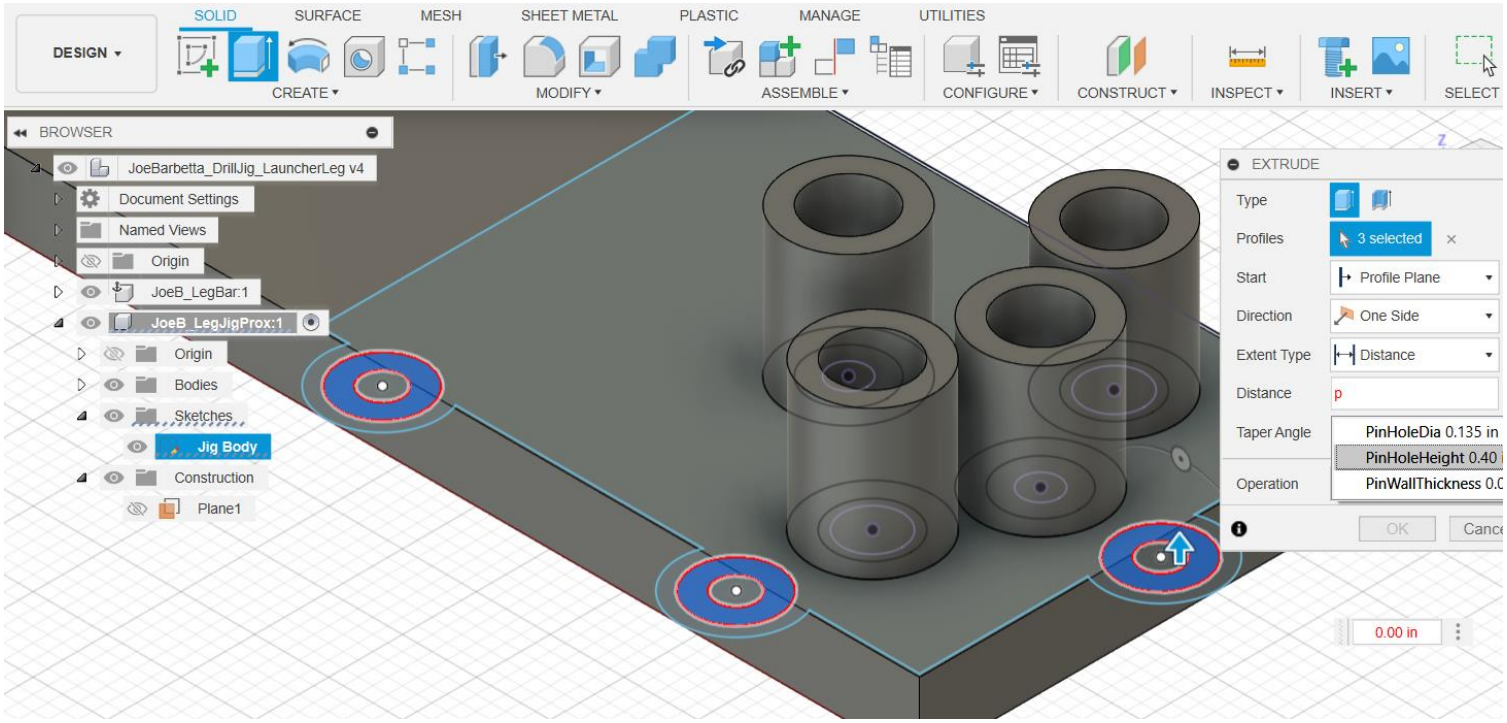
- trim the **arcs** above the 2 bottom holes. This screenshot shows the arcs alreaded trimmed.



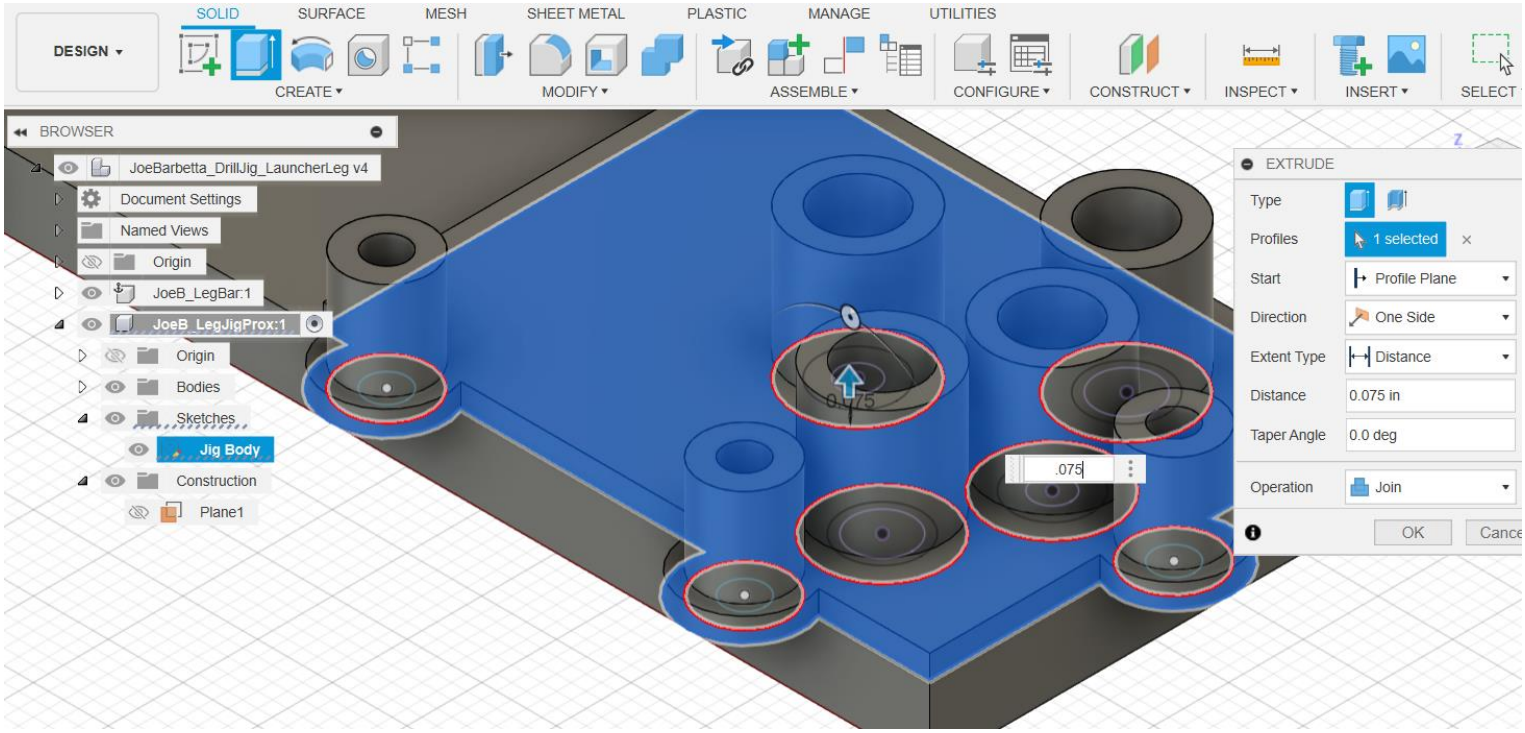
- hold the **Shift key** and click on the **Projection lines** at the indicated locations to select them
- press the **delete key**
- click on **Finish Sketch**



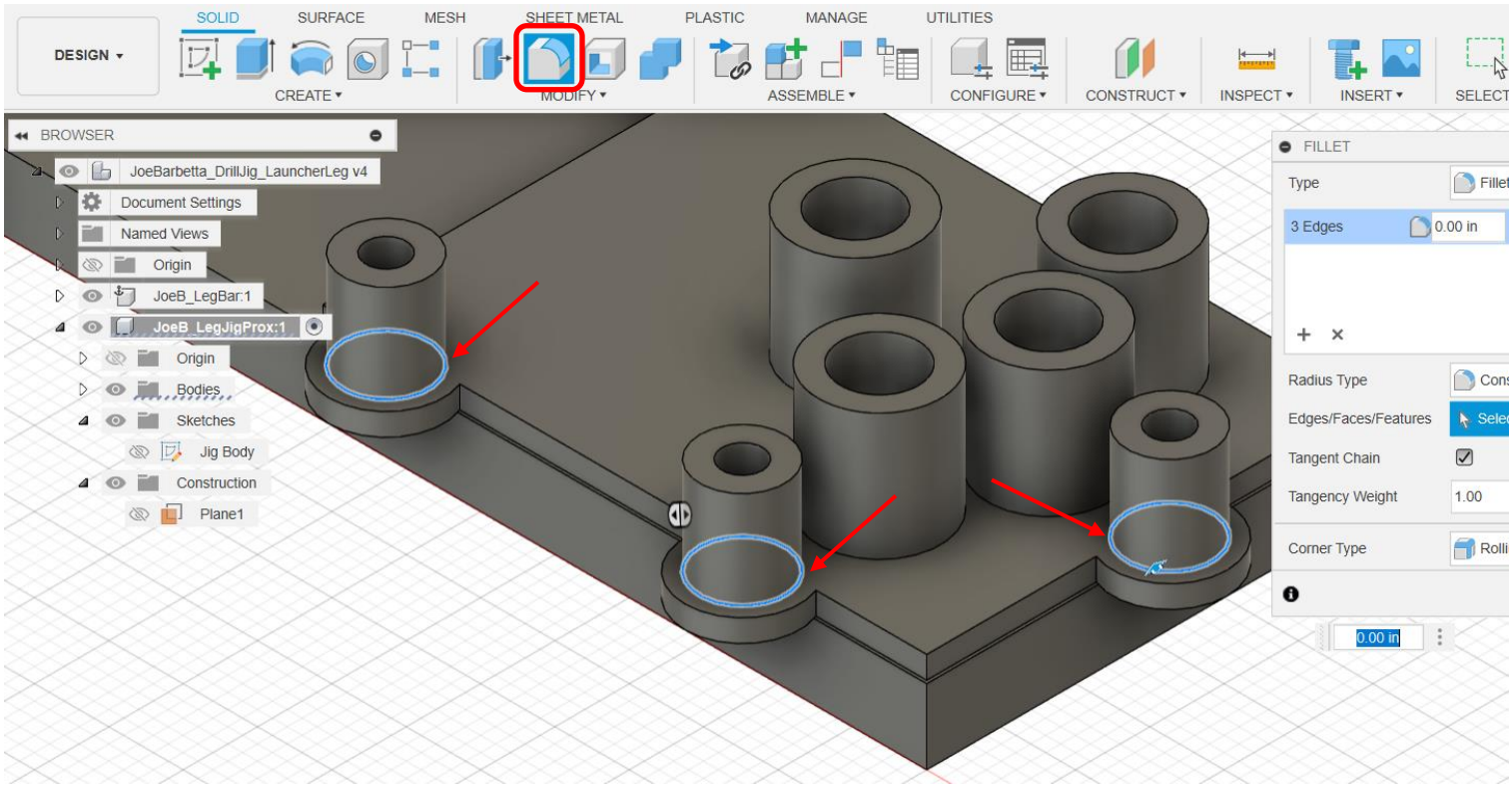
- click on the eye icon next to Jig Body to make the Sketch visible again



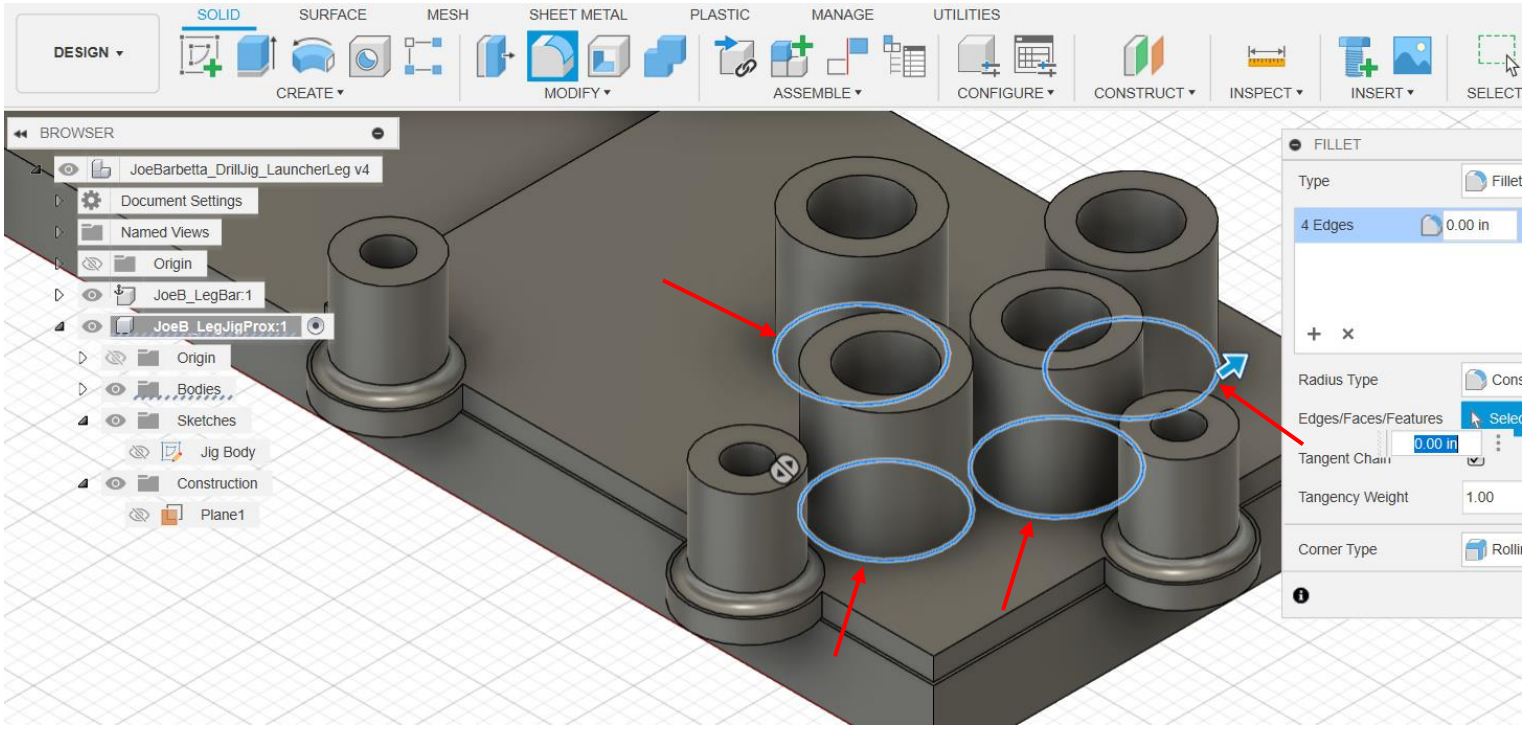
- ensure that the **Operation** is set to **Join**



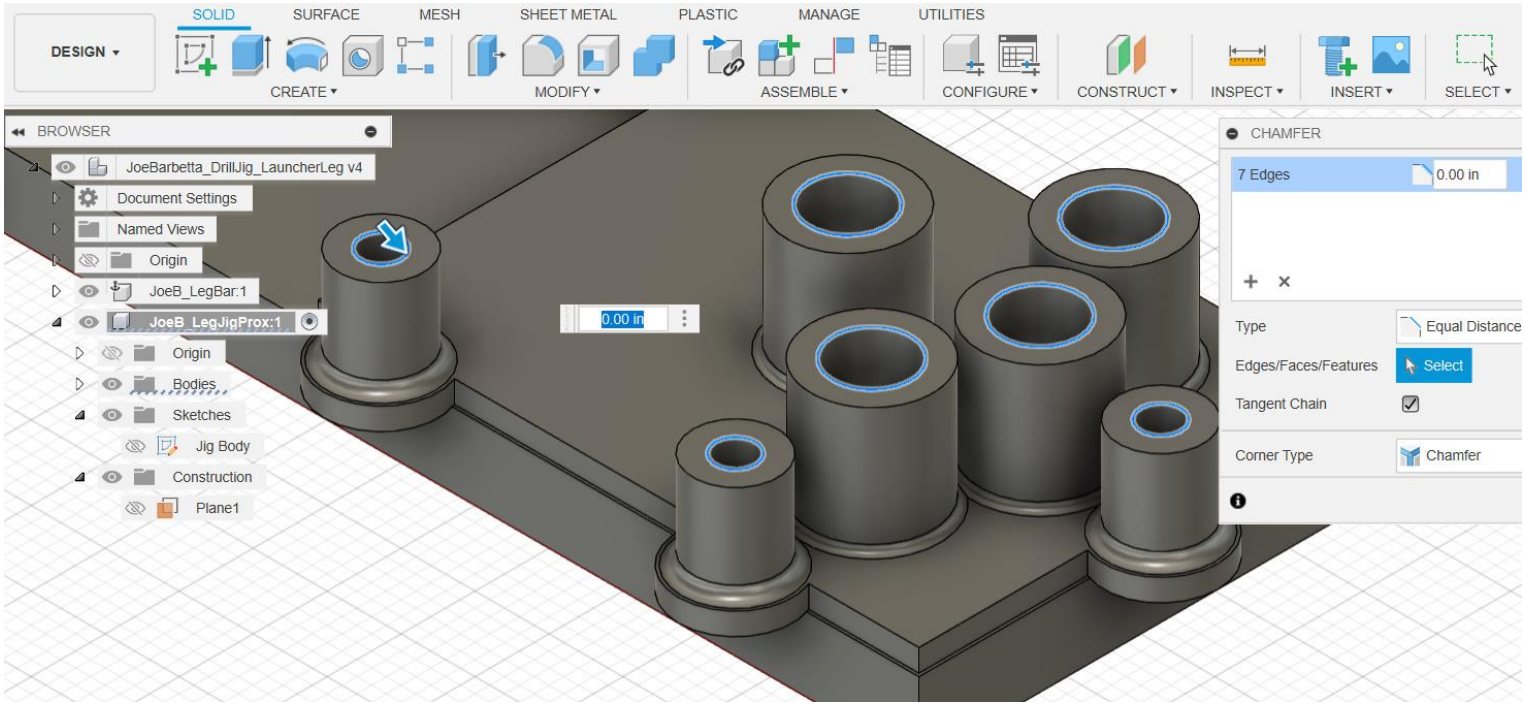
- select the **Fillet** tool. If its icon is not visible, select it from the MODIFY menu.
- click on the **bottom edges of the pin guides**, type **0.04**, and press the **Enter key**



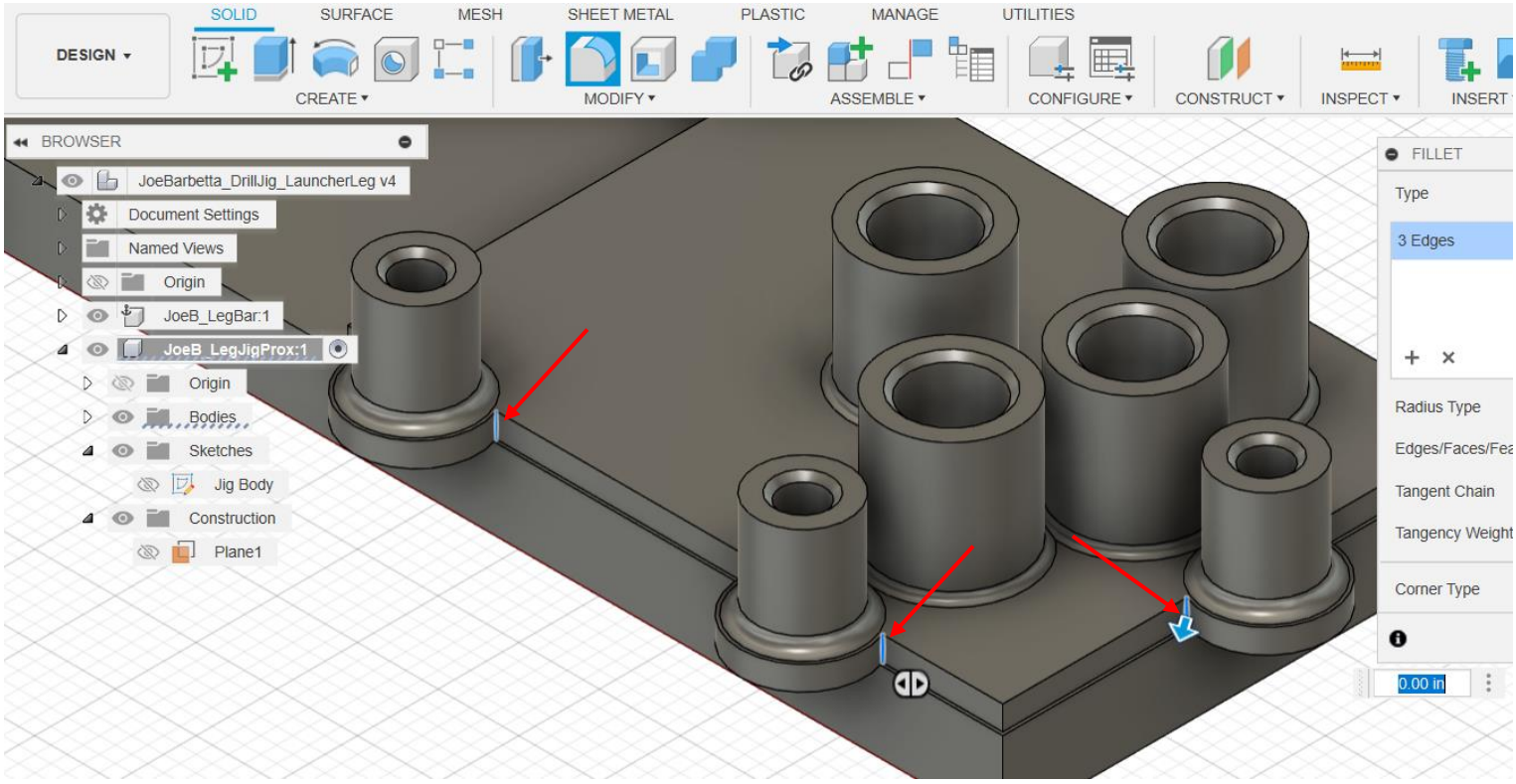
- add fillets to the **bottom edges of the drill guides** of **0.025**. If an error shows, try a smaller value.



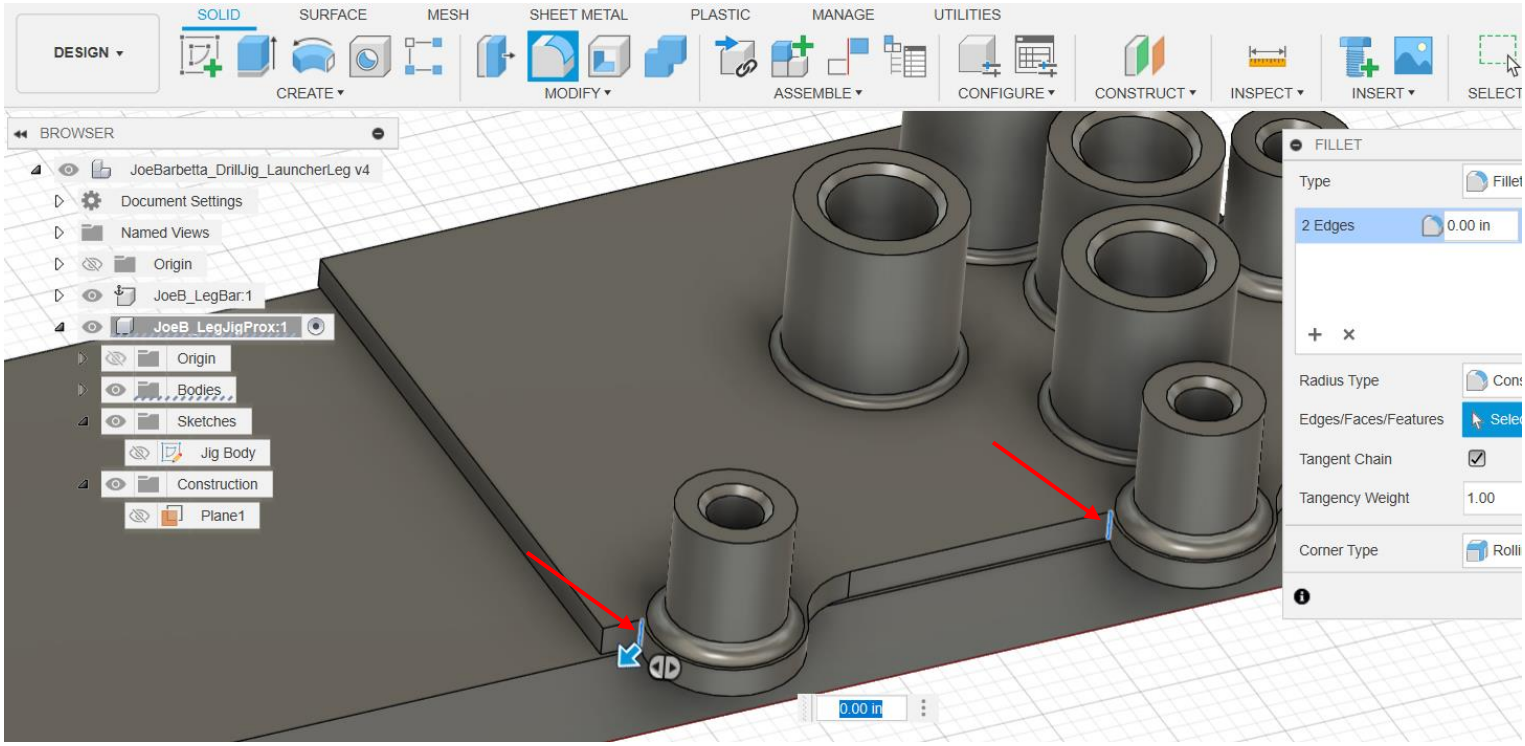
- from the **MODIFY** menu select the **Chamfer** tool
- click on the inner top edge of each drill and pin guide
- enter a value of **0.02** and click **OK**



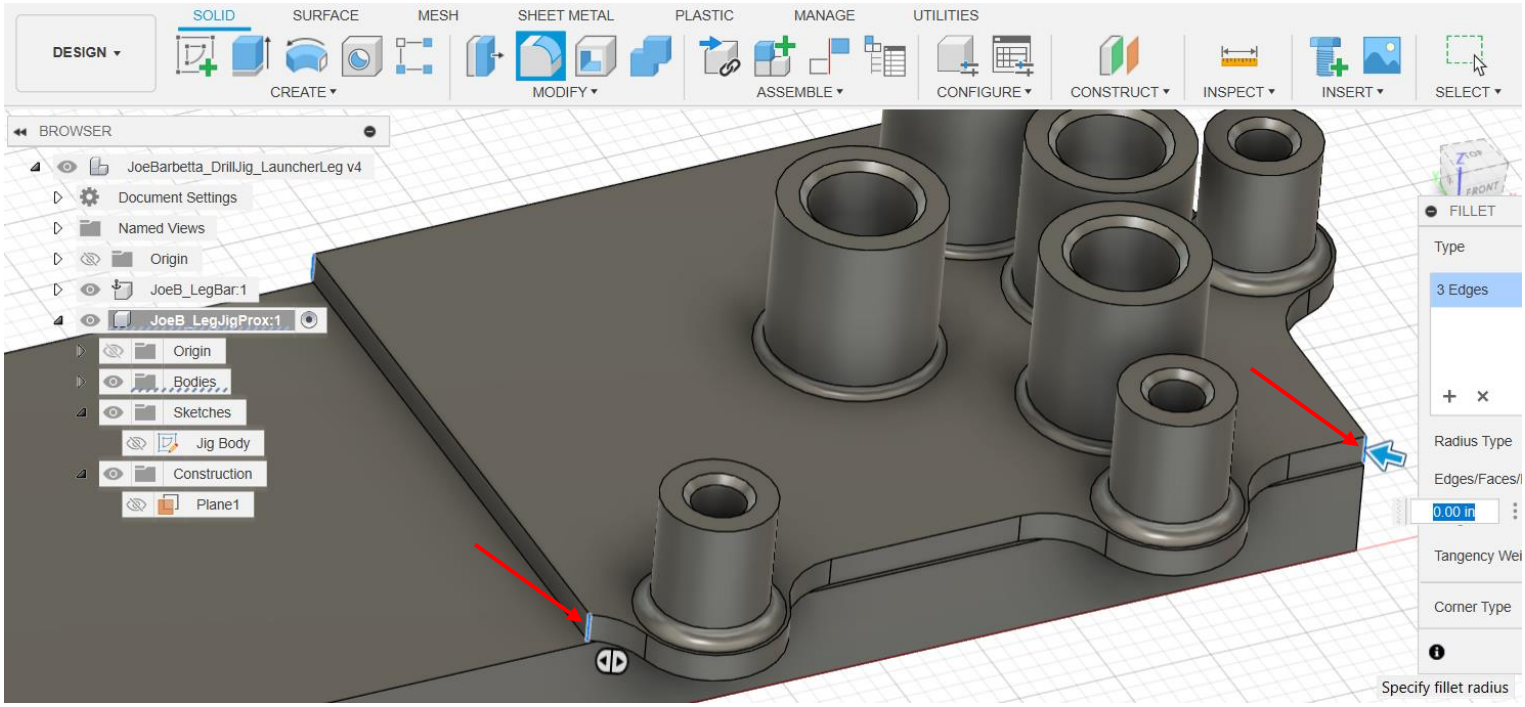
- select the **Fillet** tool and click on the **3 small edges indicated** and use a value of **0.175**



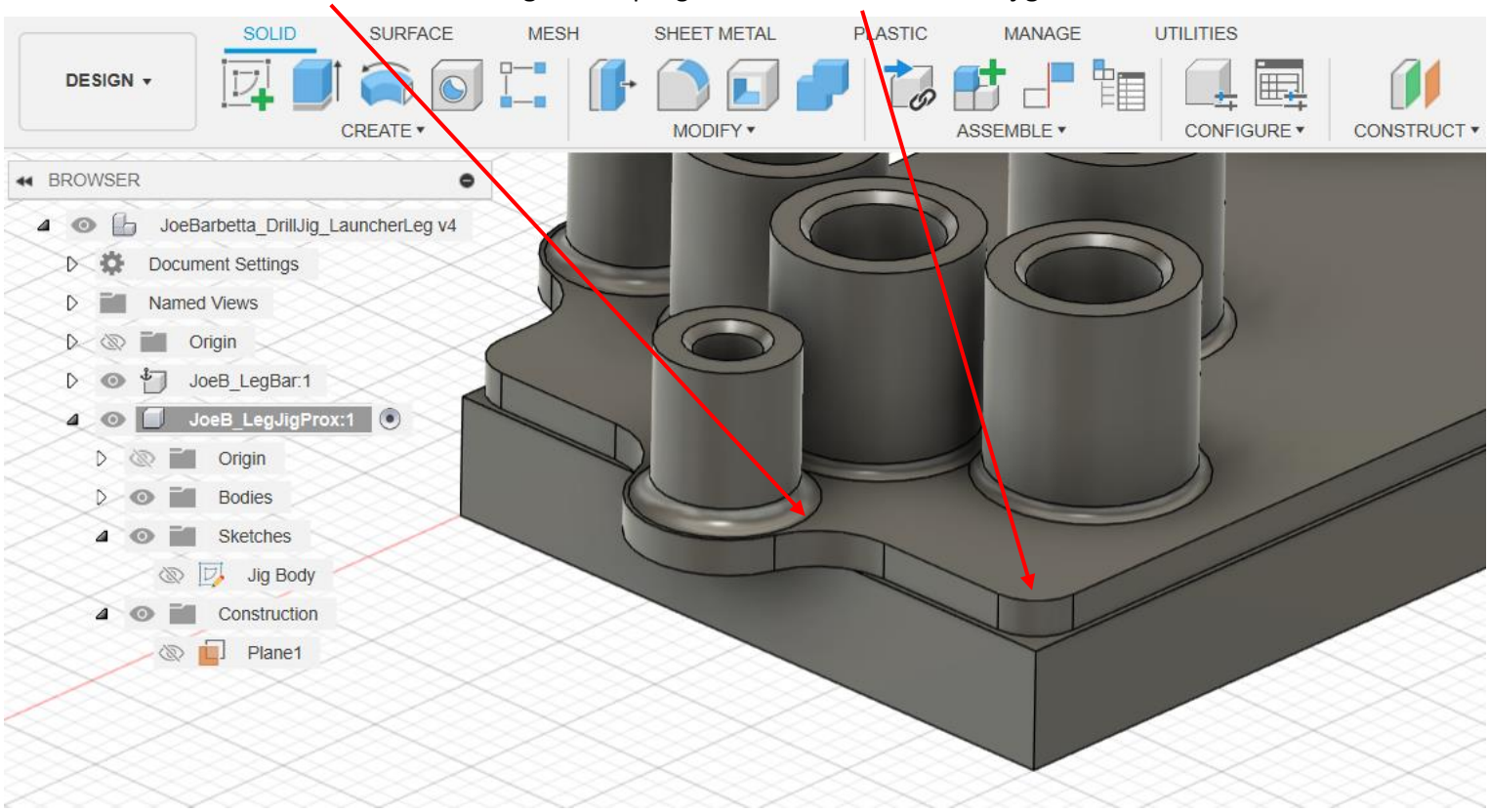
- turn the view to add **0.175 fillets** to the **two edges indicated**



- add **0.1** fillets to the **2 edges indicated**



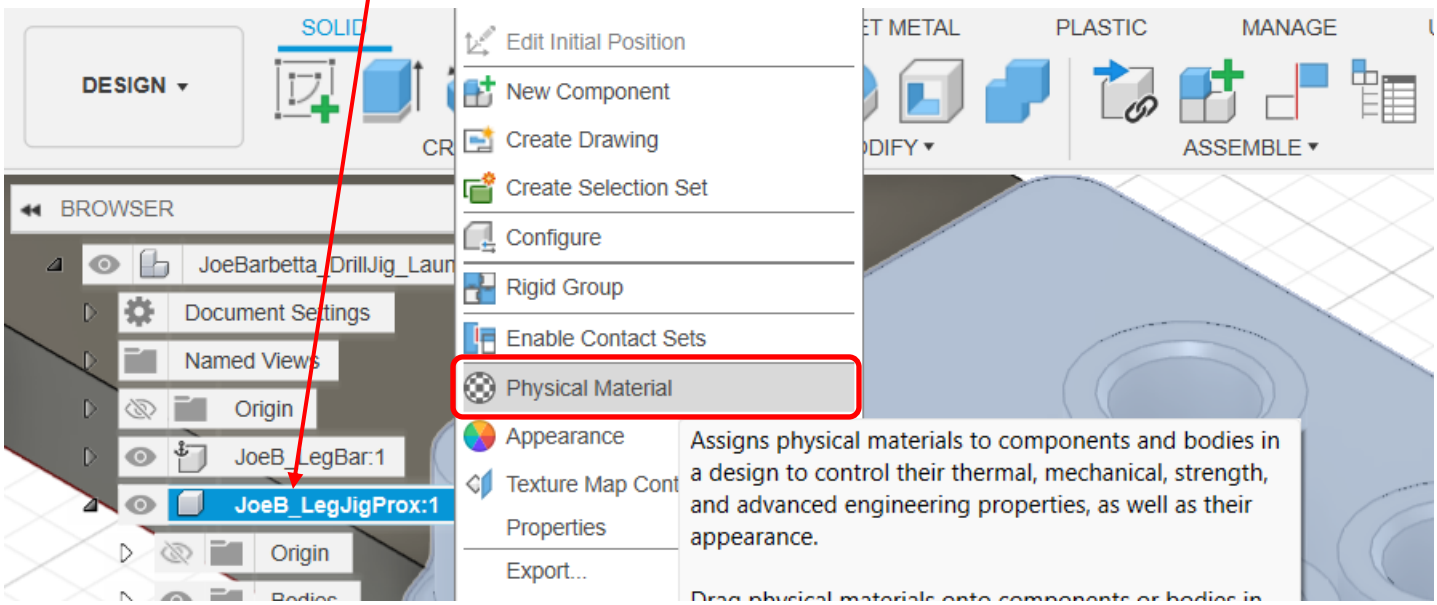
- turn the view to add a **0.175 fillet** to the **edge** at the pin guide and a **0.10 fillet** at the **jig coner**



Setting the Material

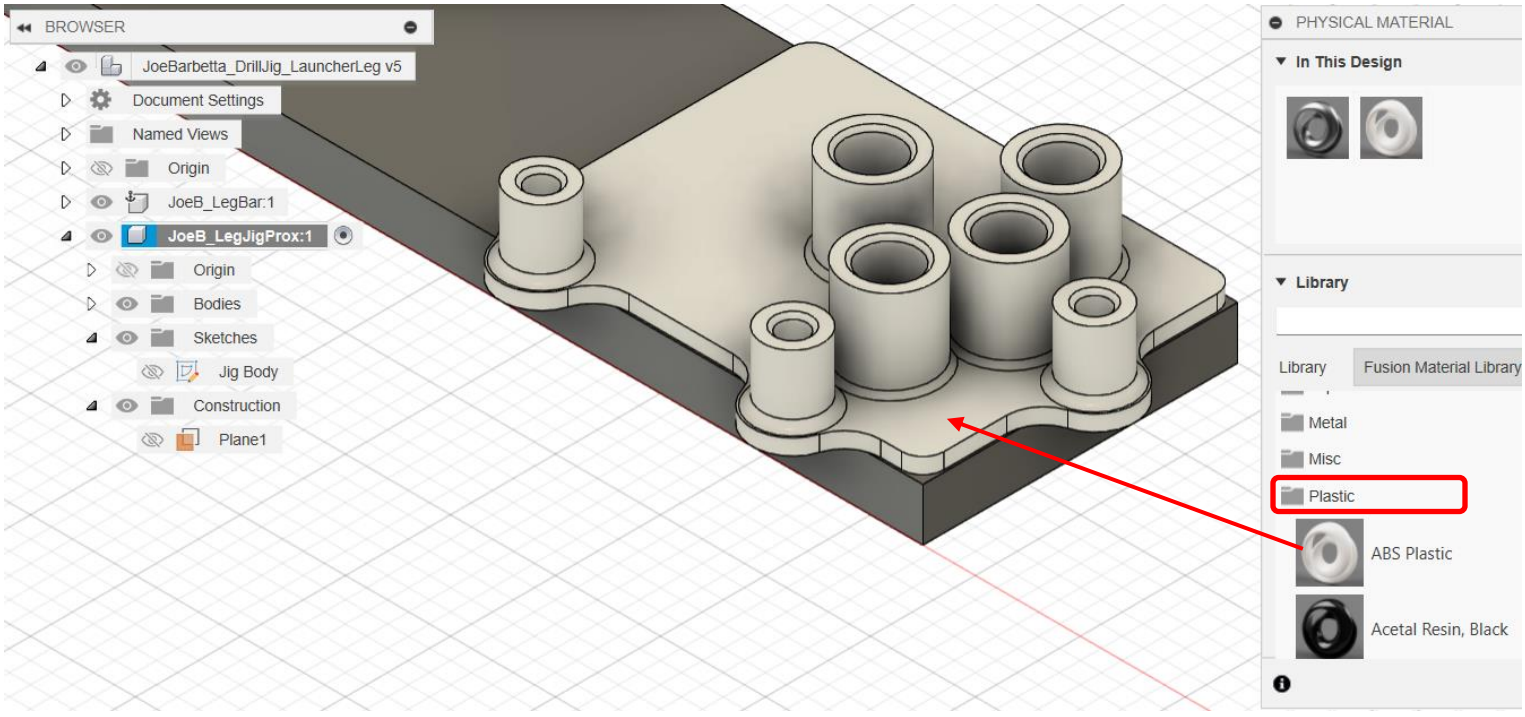
By default, Fusion sets a new body to steel and hence the gray color. For 3D printing the material set in CAD doesn't matter. The item will be printed with the filament loaded into the printer, which is often PLA. However, setting a material and color adds to the aesthetics of the CAD design and can be helpful to distinguish 3D printed parts from purchased or machined parts. 3D printed parts in CAD can also be colored to differentiate "tooling", such as jigs or fixtures, from 3D printed component pieces.

- right-click on the **Jig component name** and select **Physical Material**

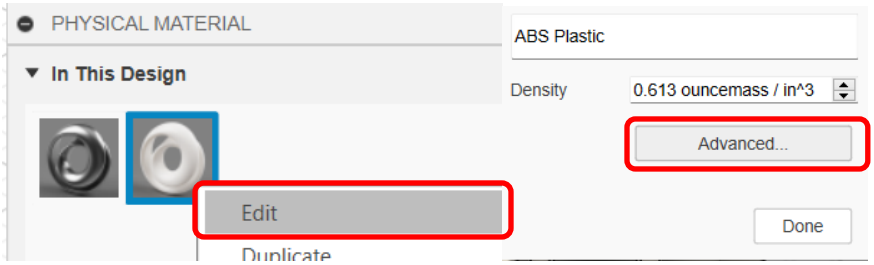


- scroll down to the **Plastics folder** and click on it to open it
- hold the mouse down on **ABS Plastic** and **drag the icon onto the jig body**

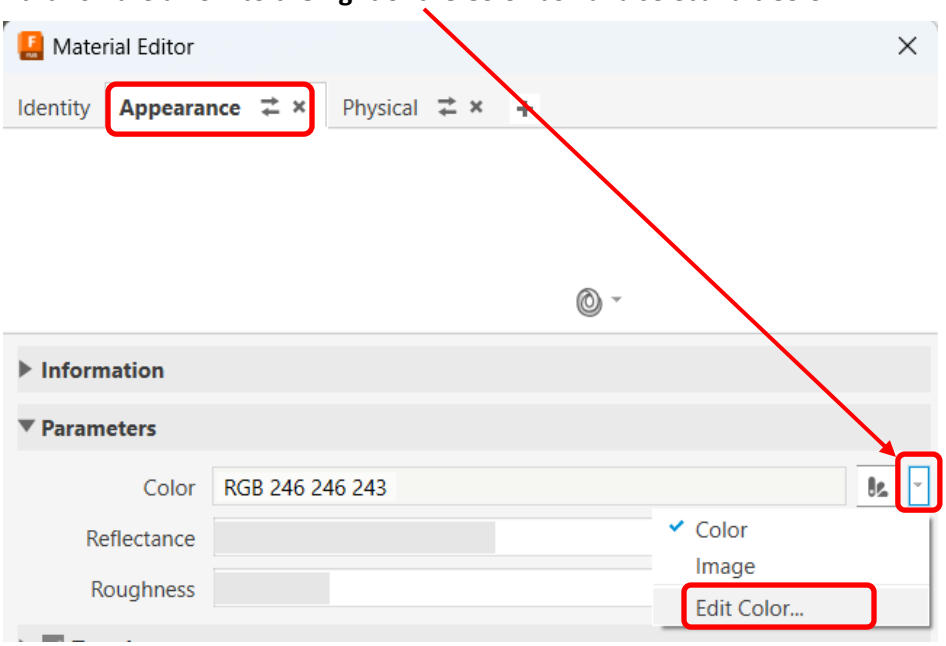
The jig will likely be made from PLA plastic, which may not be in the list. As noted before, what is used in CAD doesn't matter.



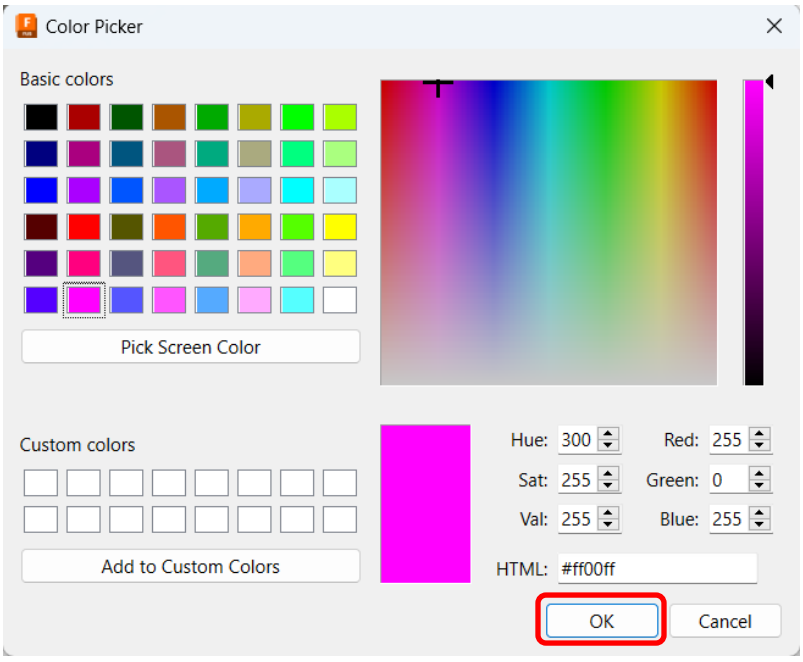
- right-click on the new icon at the top and select **Edit** and then click **Advanced…**



- select the **Appearance tab**
- click on the **arrow to the right of the Color box** and select **Edit Color..**

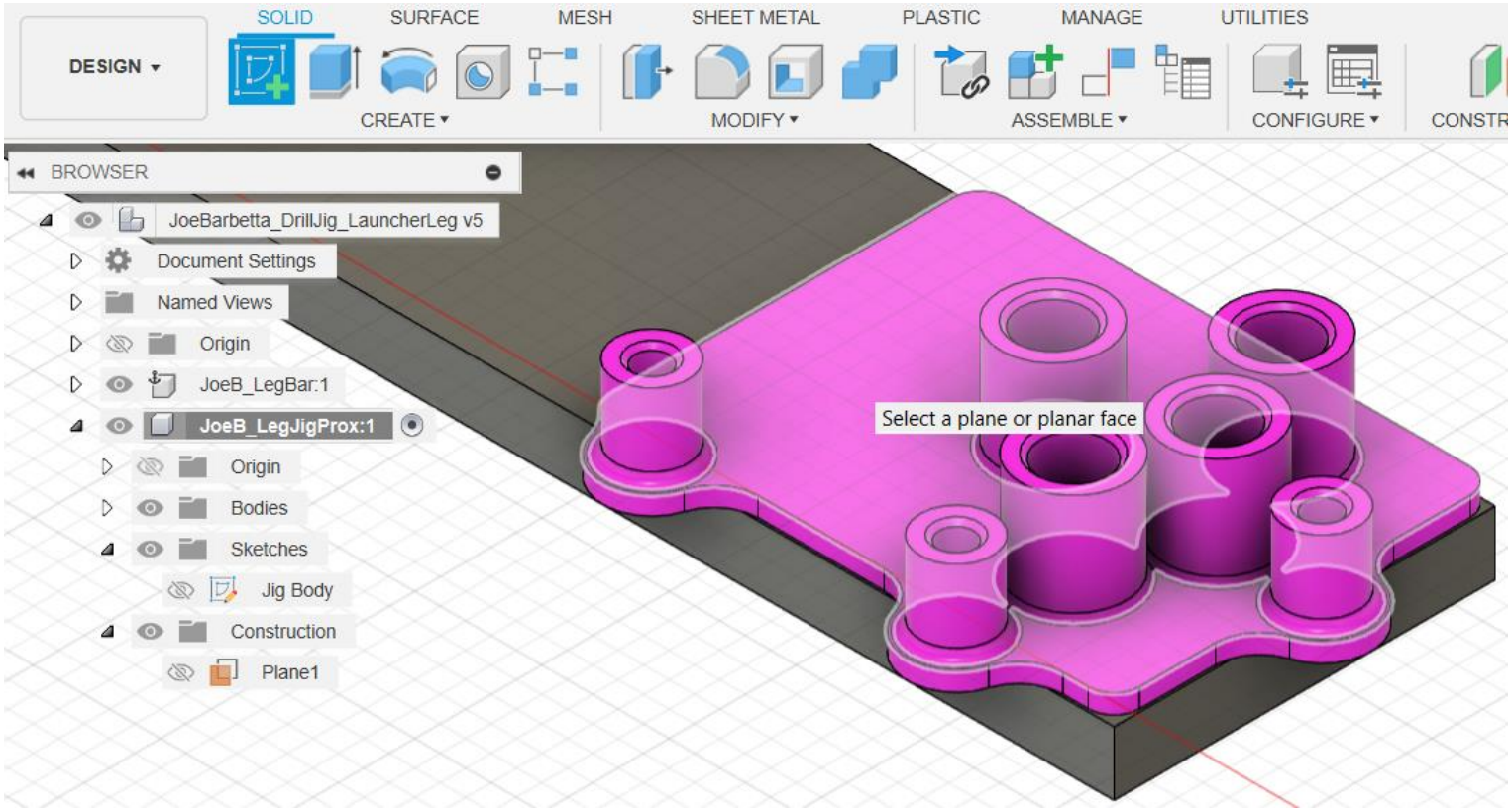


- click on a **Basic color box** or the **color hue/saturation box** and click **OK**
- then click **OK at the bottom of the Material Editor window**. There seems to be a bug in Fusion where the OK button will be grayed out. Click Cancel and the changes are still used.
- click on **the bottom Close button of the Physical Material window**

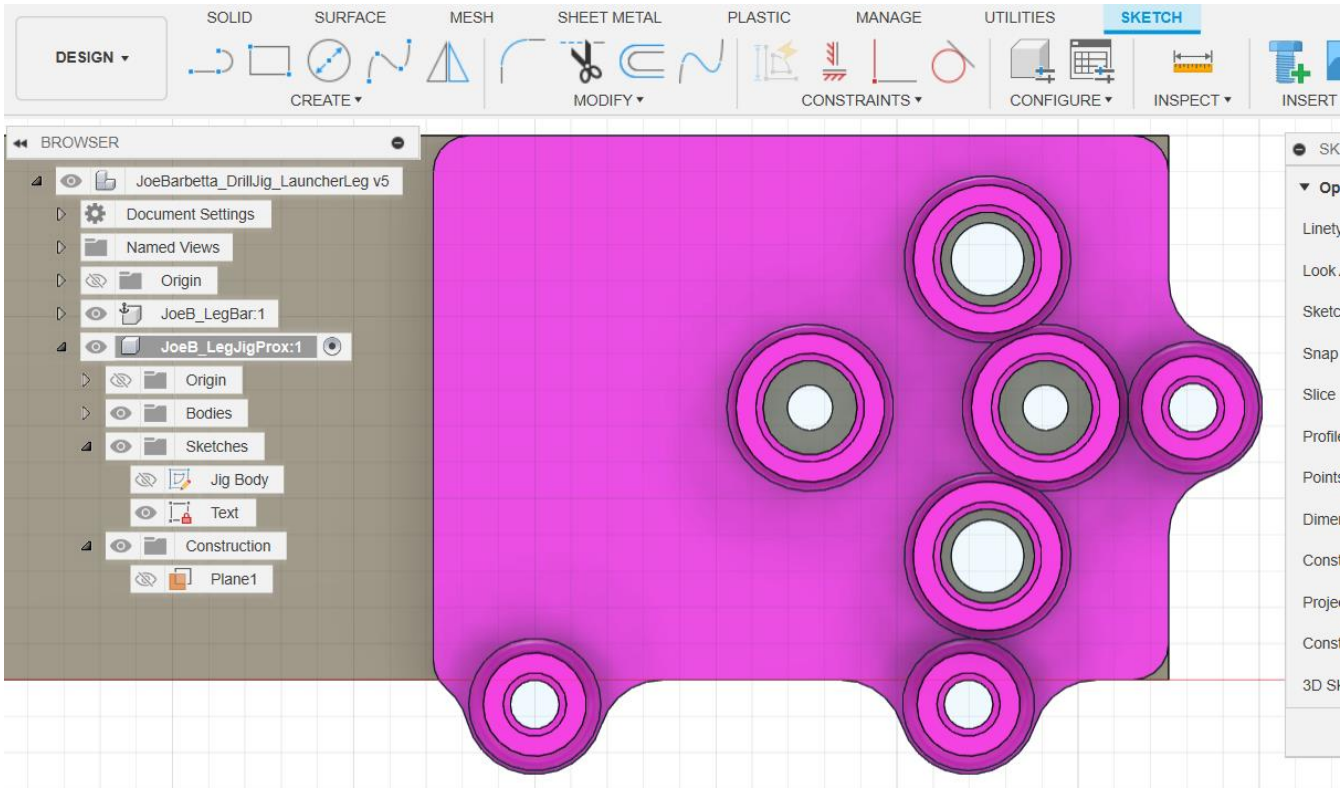


Adding Text

- select Create Sketch and click on the top surface of the jig body

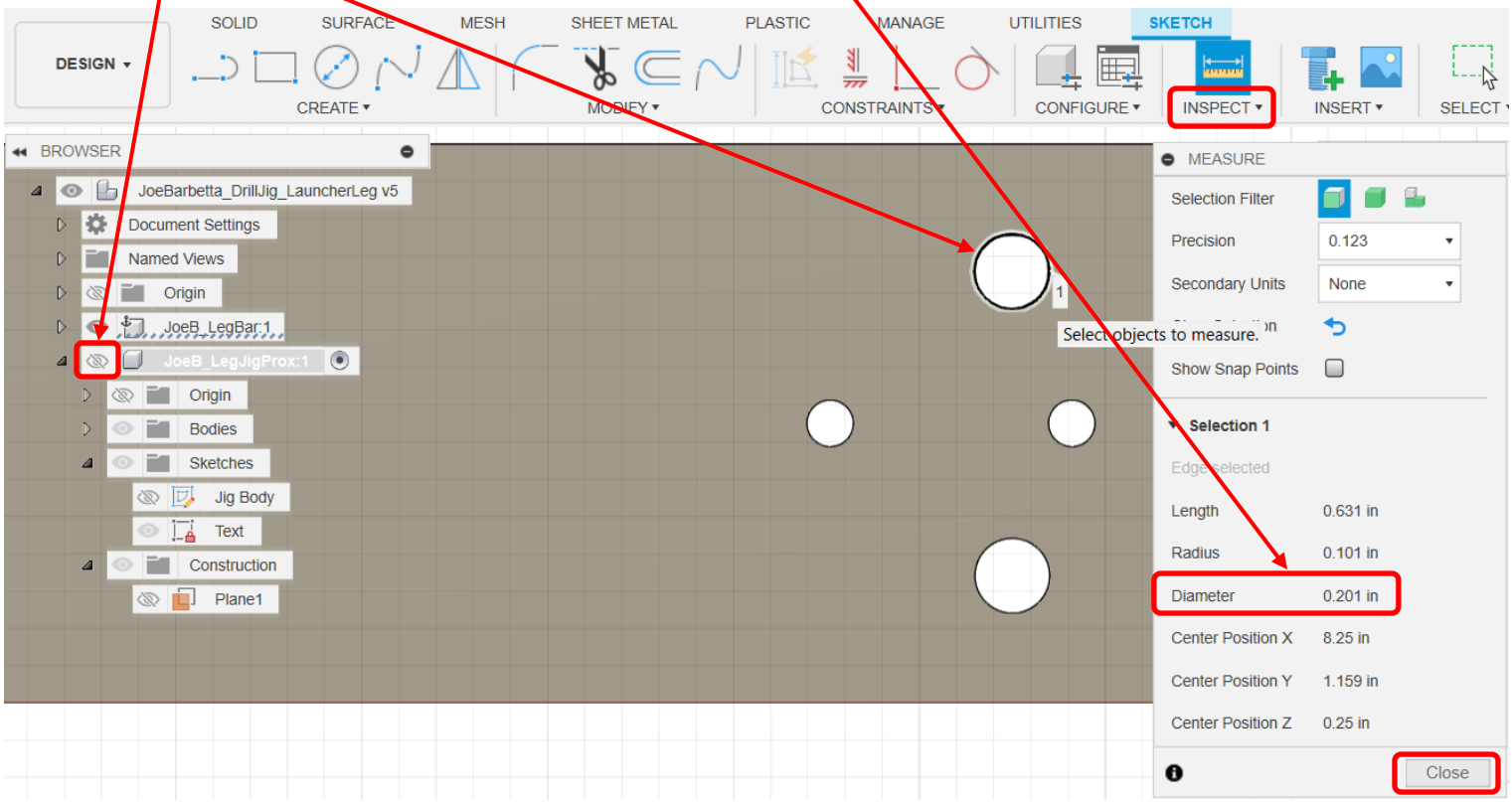


- change the Sketch name to Text and zoom and pan to achieve a view similar to that below

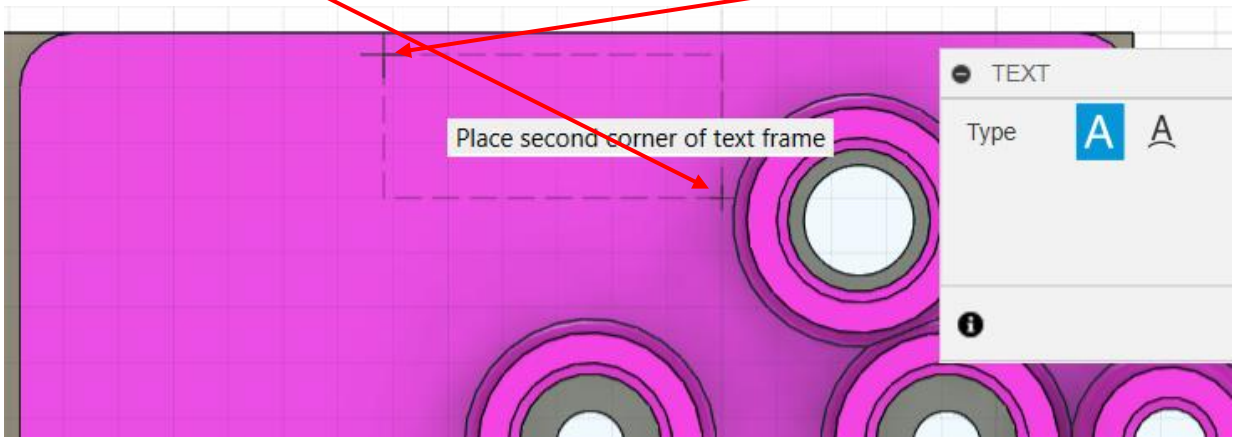


Checking Dimensions

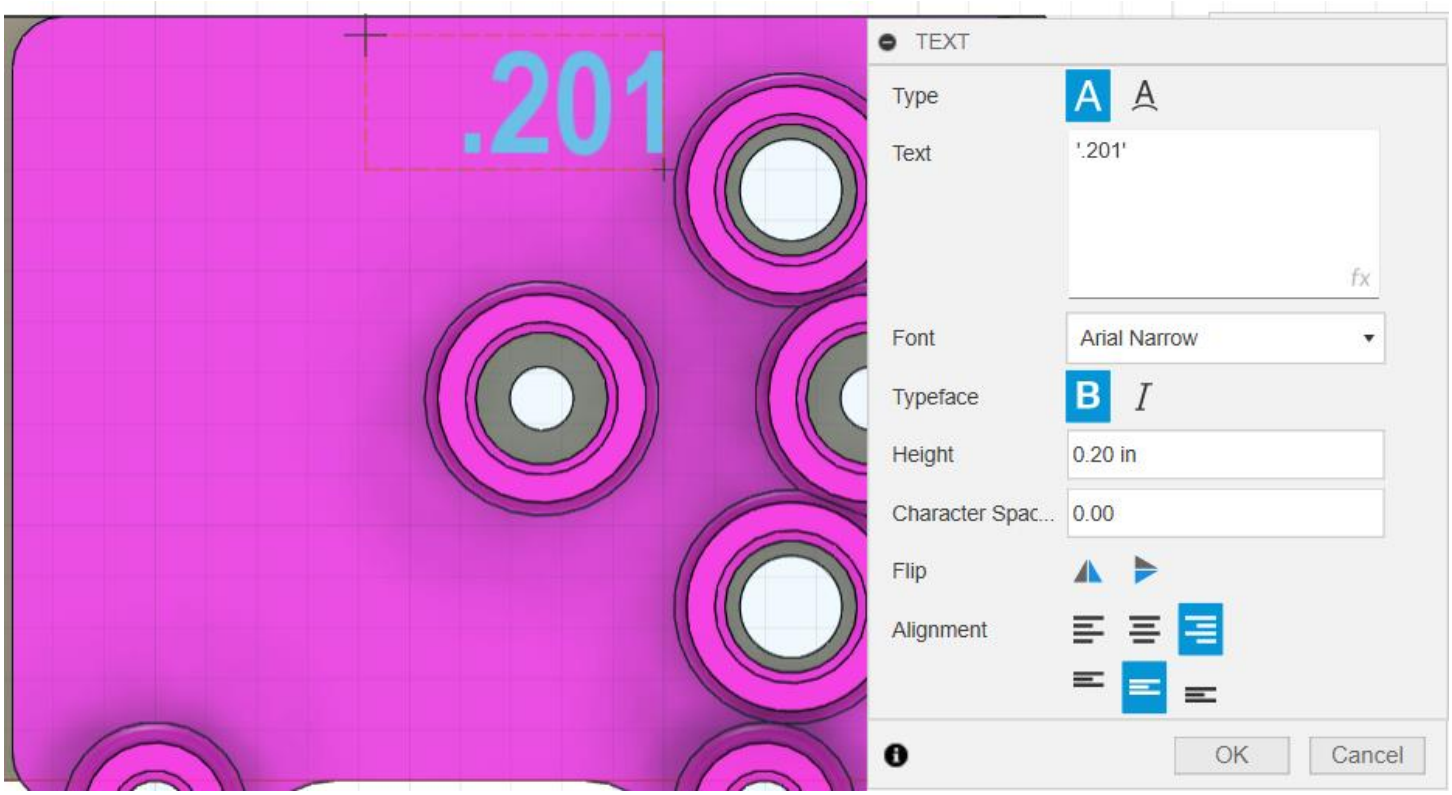
- zoom into the holes
- click on the **eye** icon for Jig to hide it
- from the **INSPECT** menu select **Measure**
- click on the **edge of a hole**. Its **Diameter** should show. Here it is **0.201**
- click **Close** on the MEASURE window



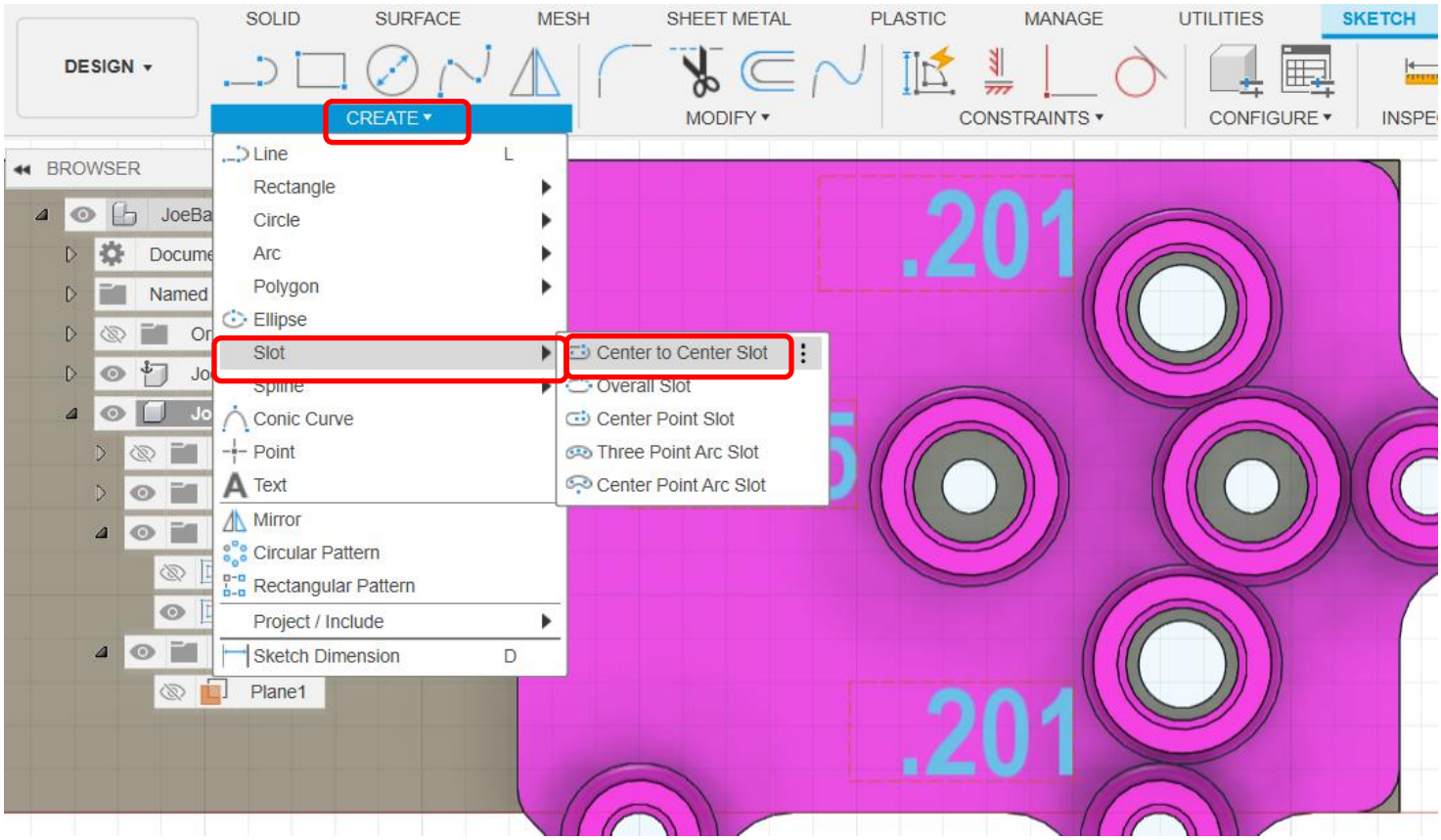
- from the **CREATE** menu select **Text**. If a Text Parameters window pops up click its **OK** button to close it.
- click on a **point near a guide** and extend the rectangle up and to the left and click again. The positions are not critical.



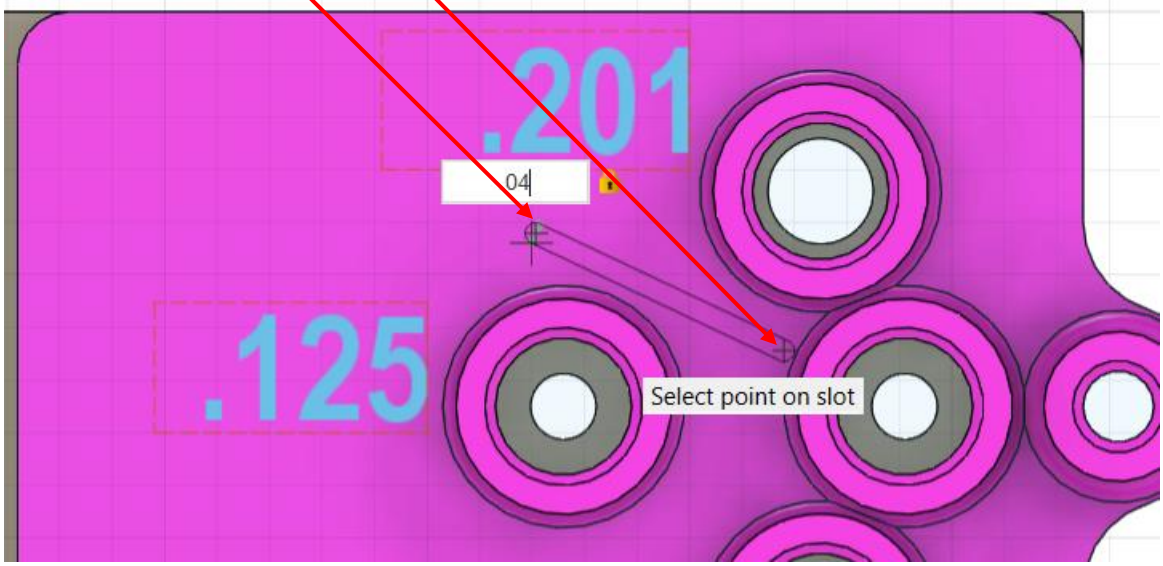
- in the Text box type the **dimension between two single quotes**, **‘.201’**
- change the Font to **Arial Narrow**, set the Typeface to **Bold**, set the Height to **0.20**, and set the **Alignment** options as shown. For other jig designs these parameters can be set differently to best accommodate text. It will also be shown later that text can be moved to better position it.



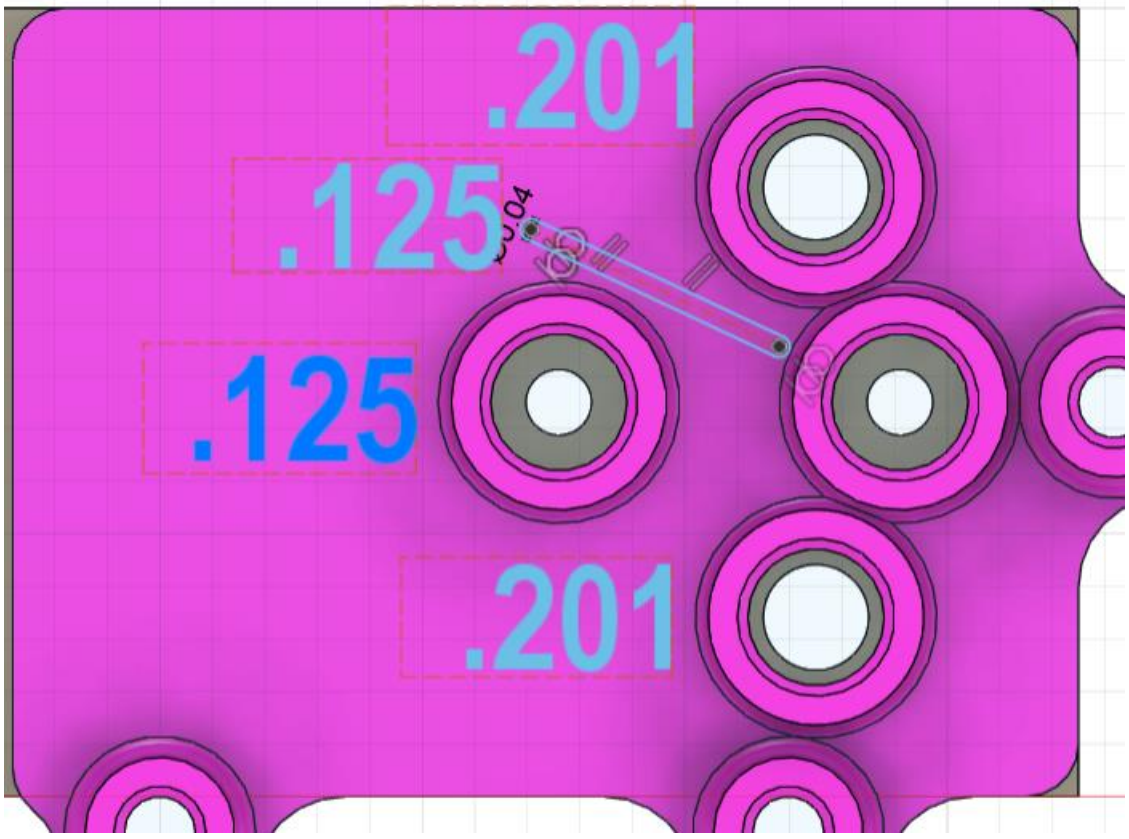
Sometimes text will not fit when adjacent to a guide hole. A slot can be created to associate further text from a guide hole.
- from the **CREATE** menu select **Slot** and **Center to Center Slot**



- click on a **point close to the guide**
- extend the slot to a **point where there is room for text** and enter a value of **0.04** for the slot width



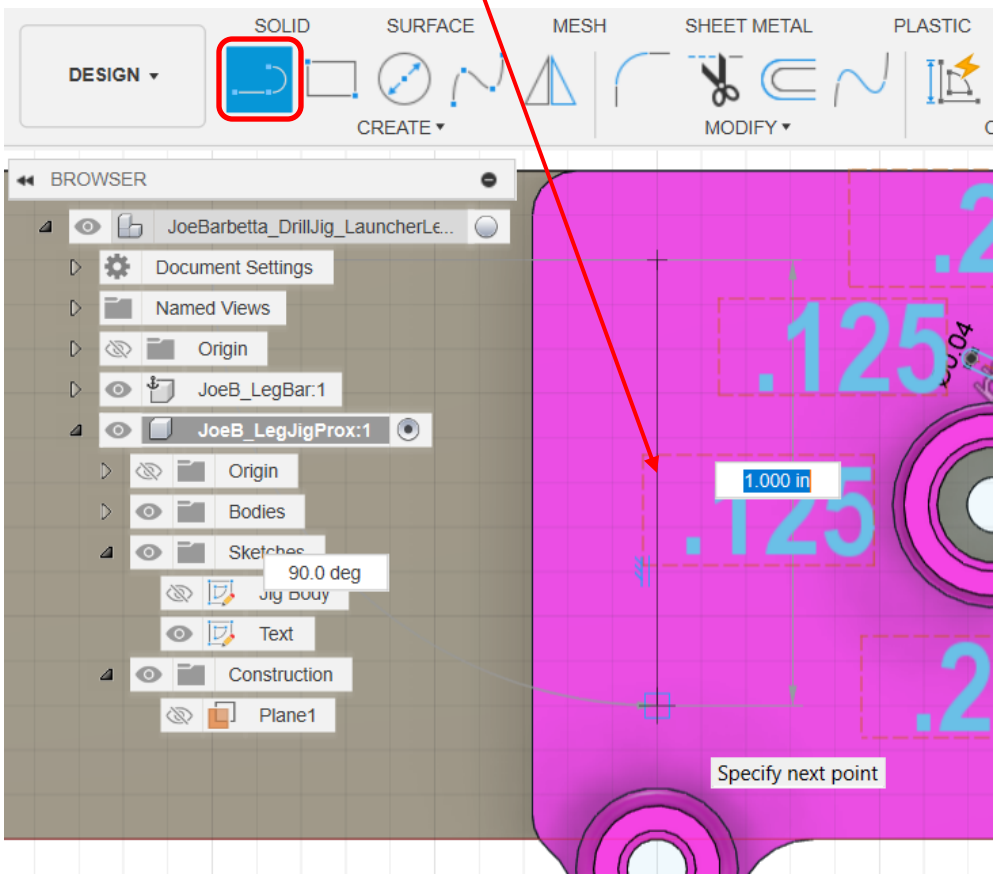
- create **text** for the diameter, **.125**, **near the end of the slot**
- click on any text and move it to optimize spacing



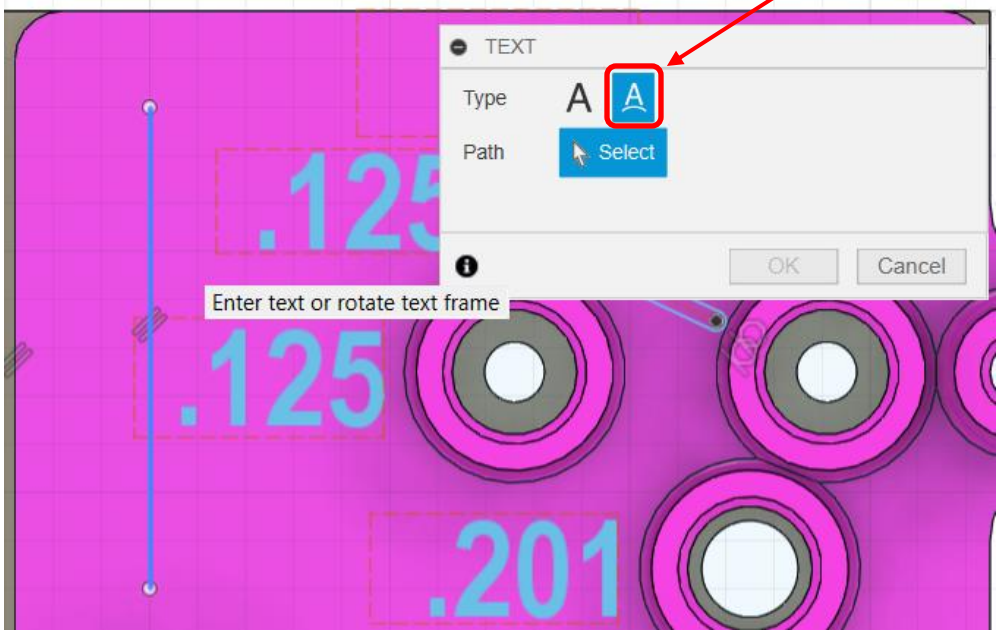
Creating 90 Degree Text

It can be difficult to rotate text in Fusion because when creating text a corner of the text frame, the corner can become constrained to another element. It is easier to create a line and use the Text on Path feature.

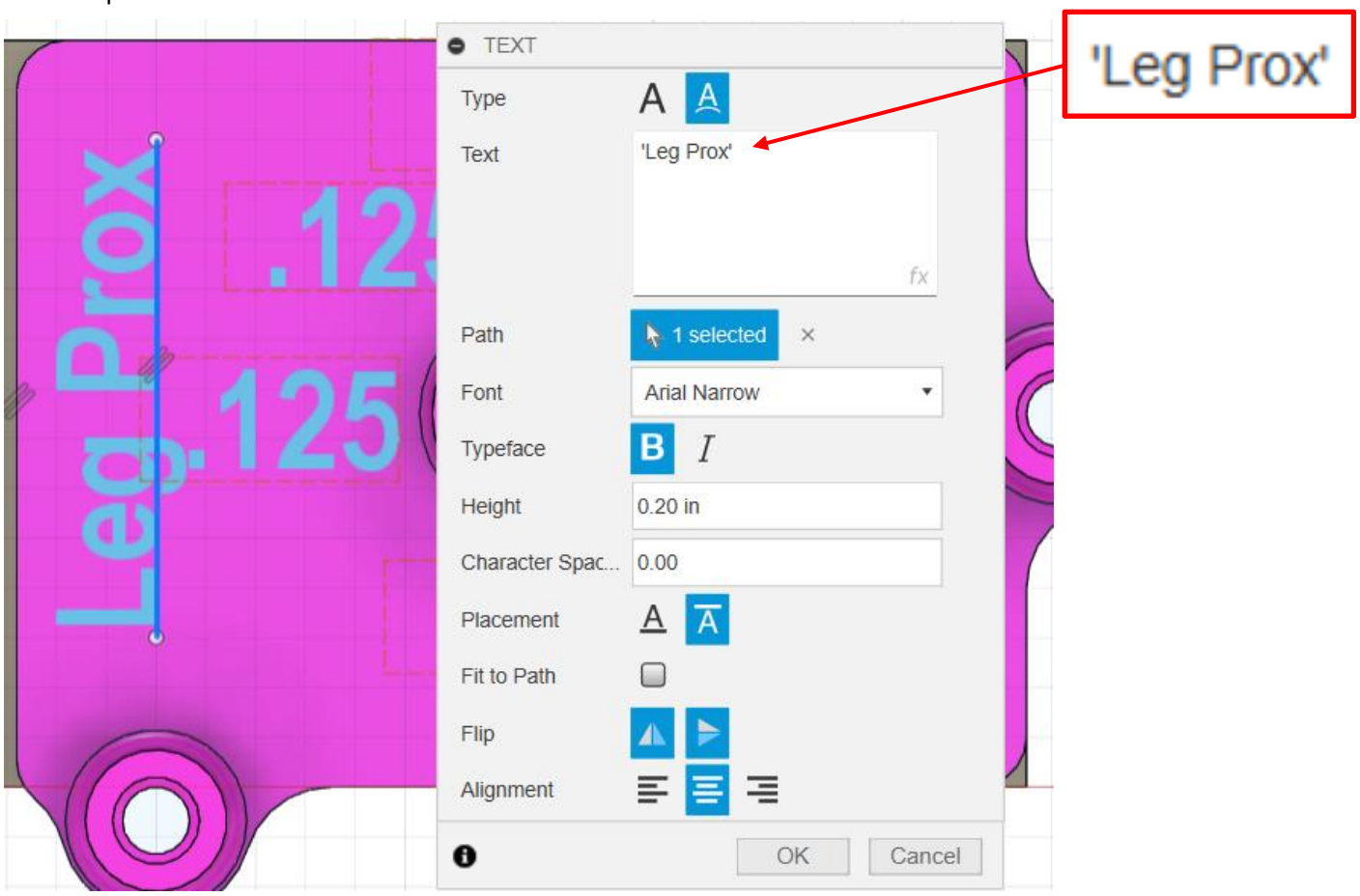
- select the **Line** tool and create a vertical line as shown. The start and end point locations are not critical, but ensure that the line is vertical and far enough from the edge for text to fit.



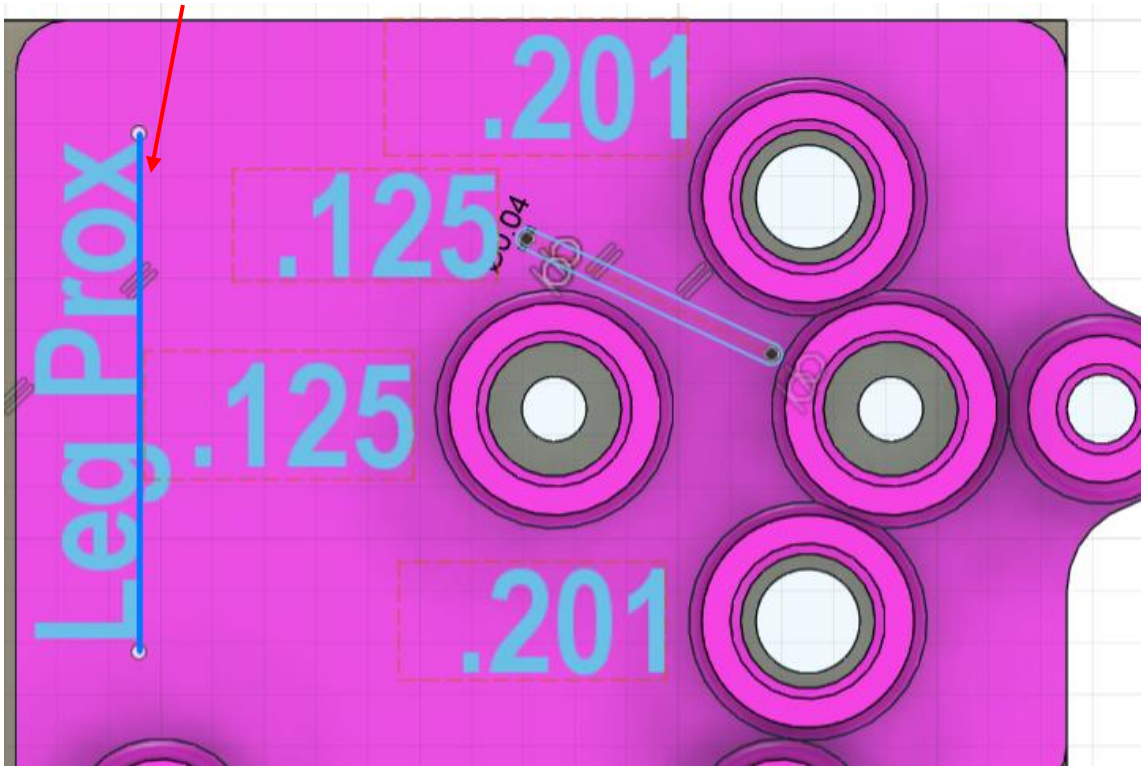
- from the **CREATE** menu select the **Text** tool and click on the **Text On Path** option



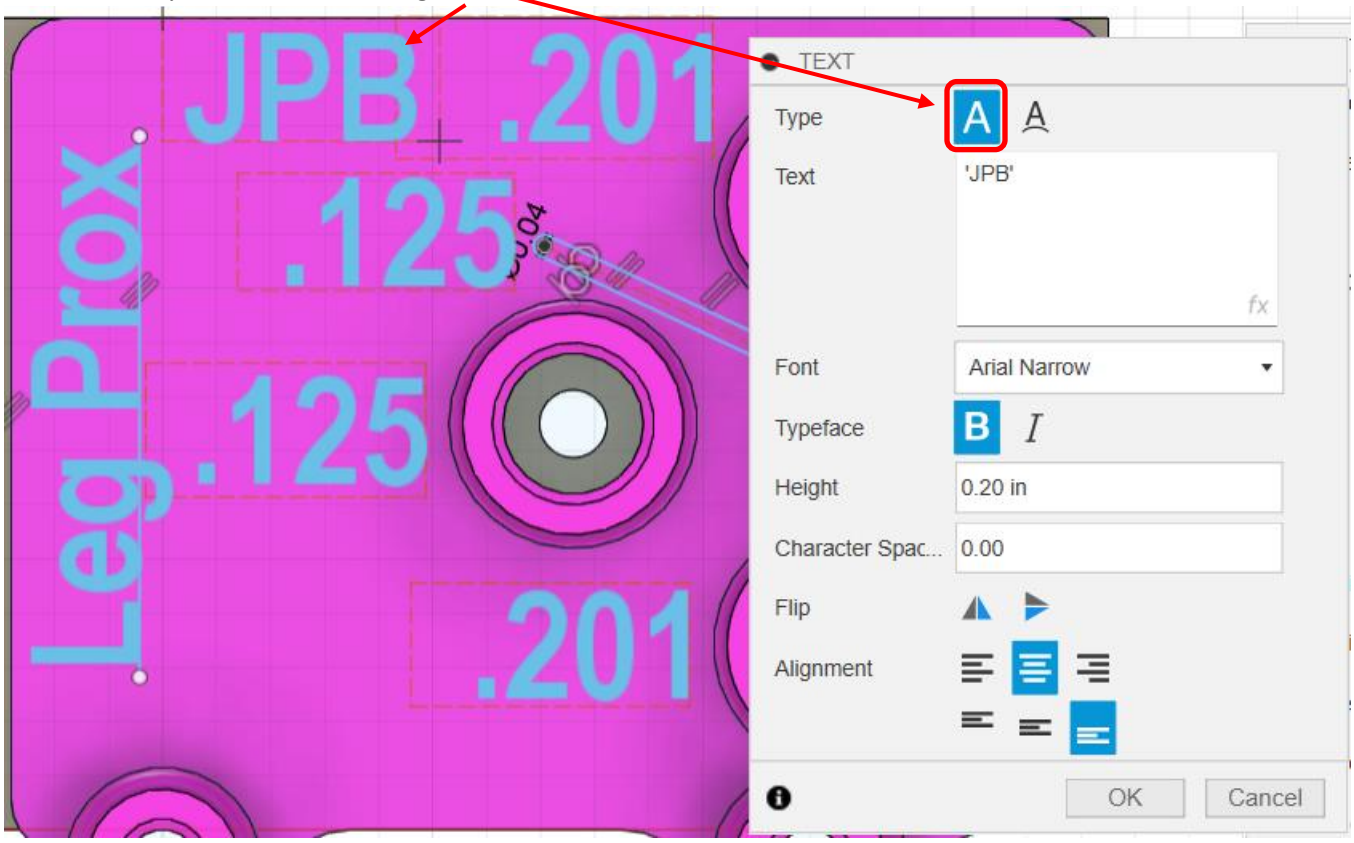
- click on the line that was just created
- type **Leg Prox**, or that of another jig, in the Text box. **Ensure it is surrounded by single quotes**.
- set the parameters as shown and click **OK**



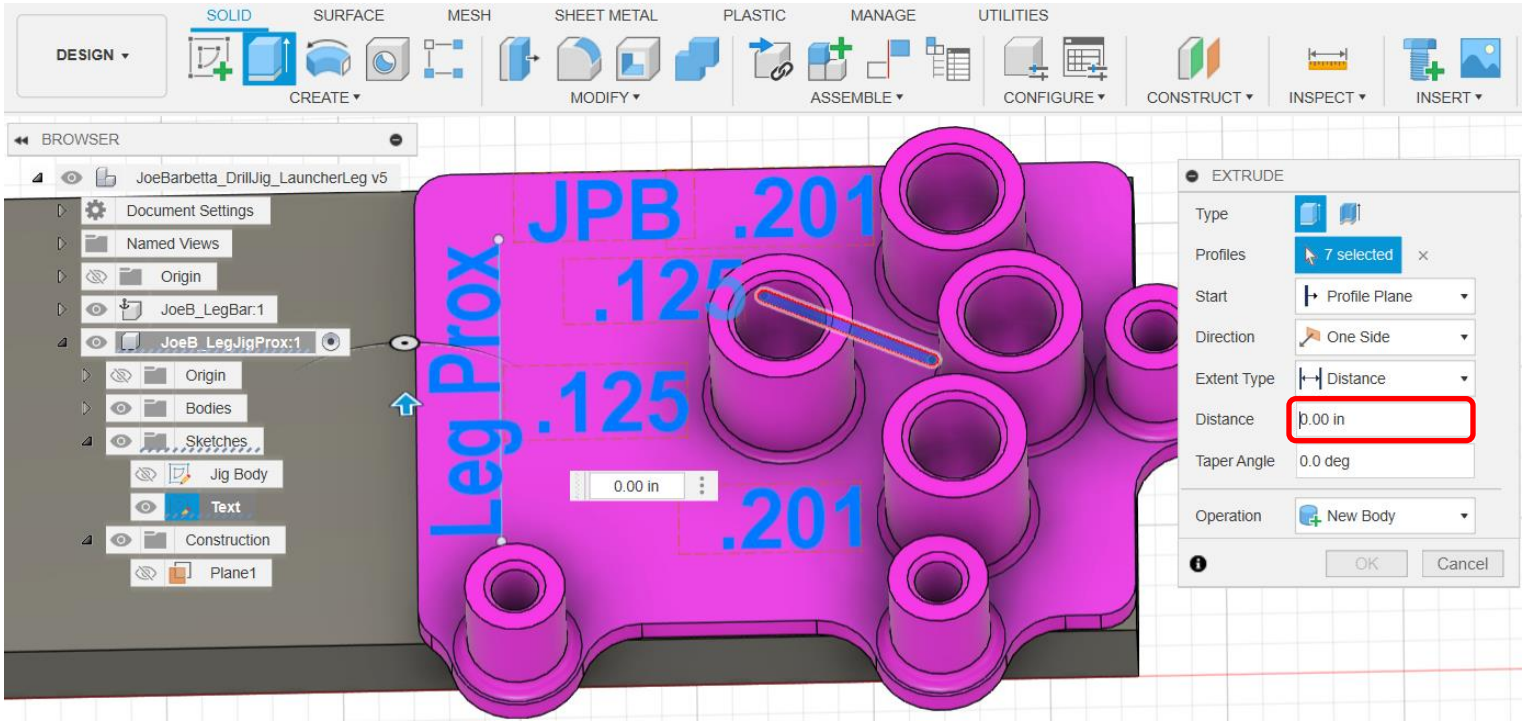
- click on the **line** to move it and the text will follow



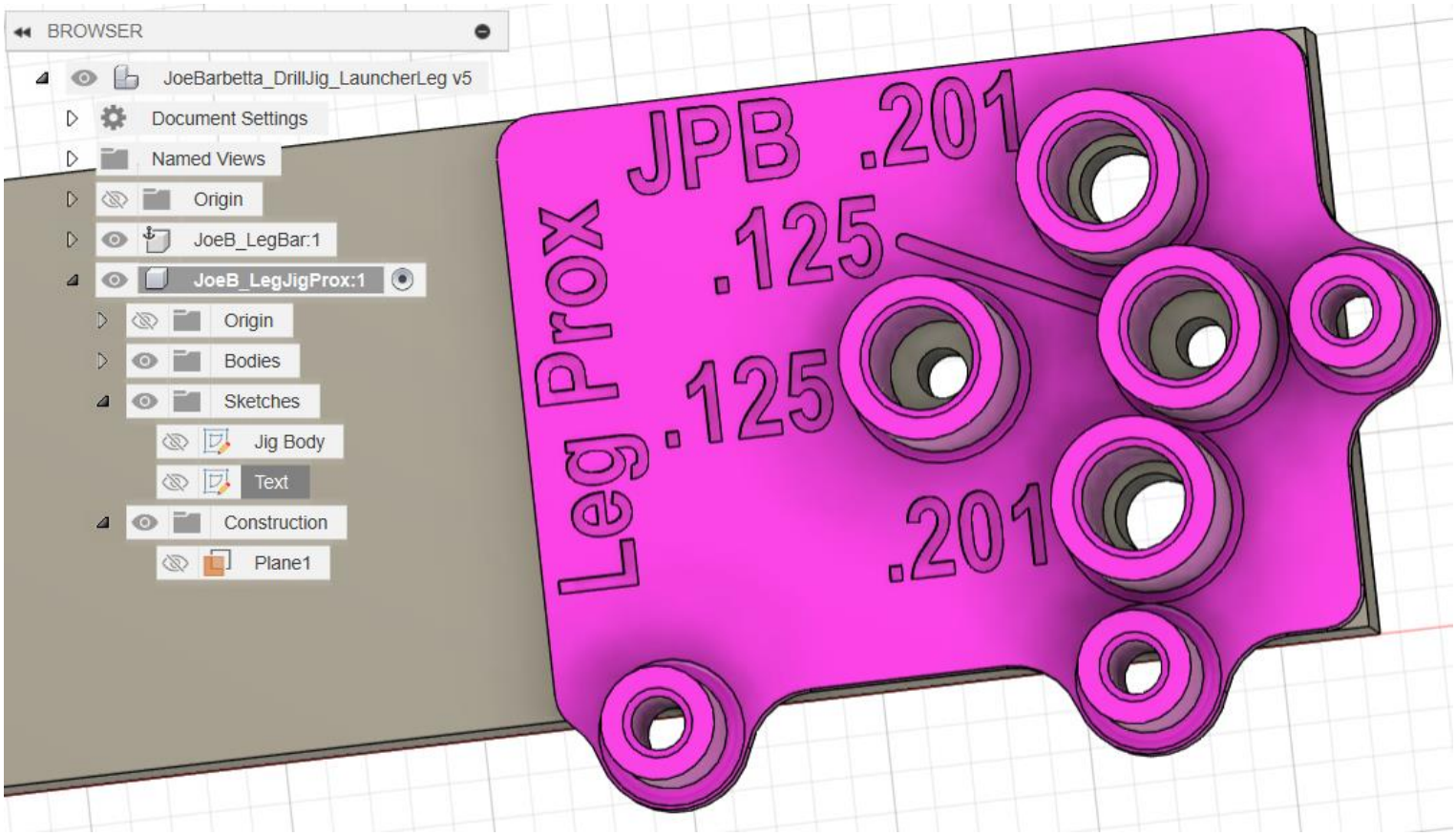
- switch **Type** back to **Text**
- add text for your **3 initials** in this general area



- select the **Extrude** tool and click on **each text group and the slot**. Enter **-0.02** (not the minus sign) for Distance and click **OK**



You are getting closer to starting missile launcher production.



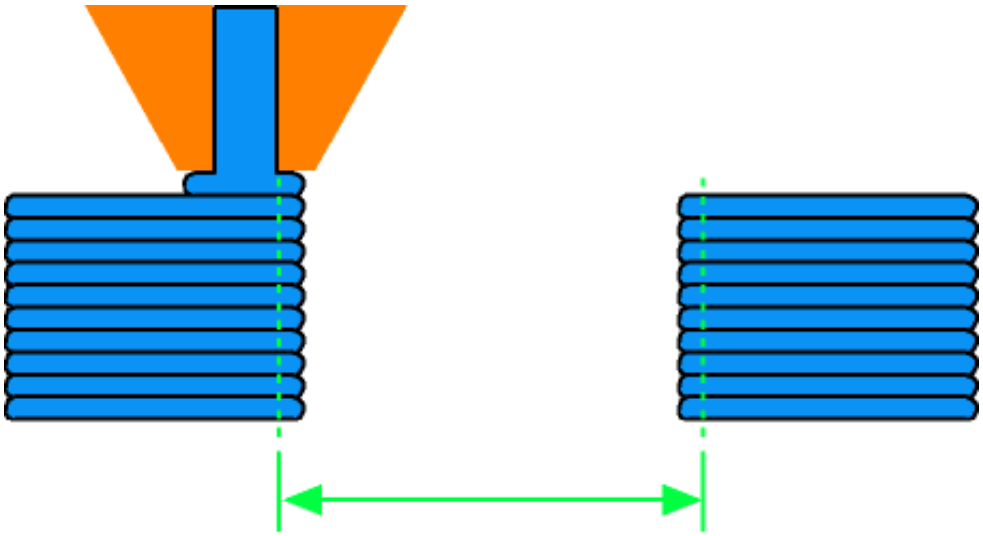
Creating a Test Print

Whenever there are critical dimensions in a design for 3D printing, test prints should be done.

Especially if the drill jig is much larger, it would be a waste of time and plastic to print the entire jig to then find out that the holes are too tight or loose.

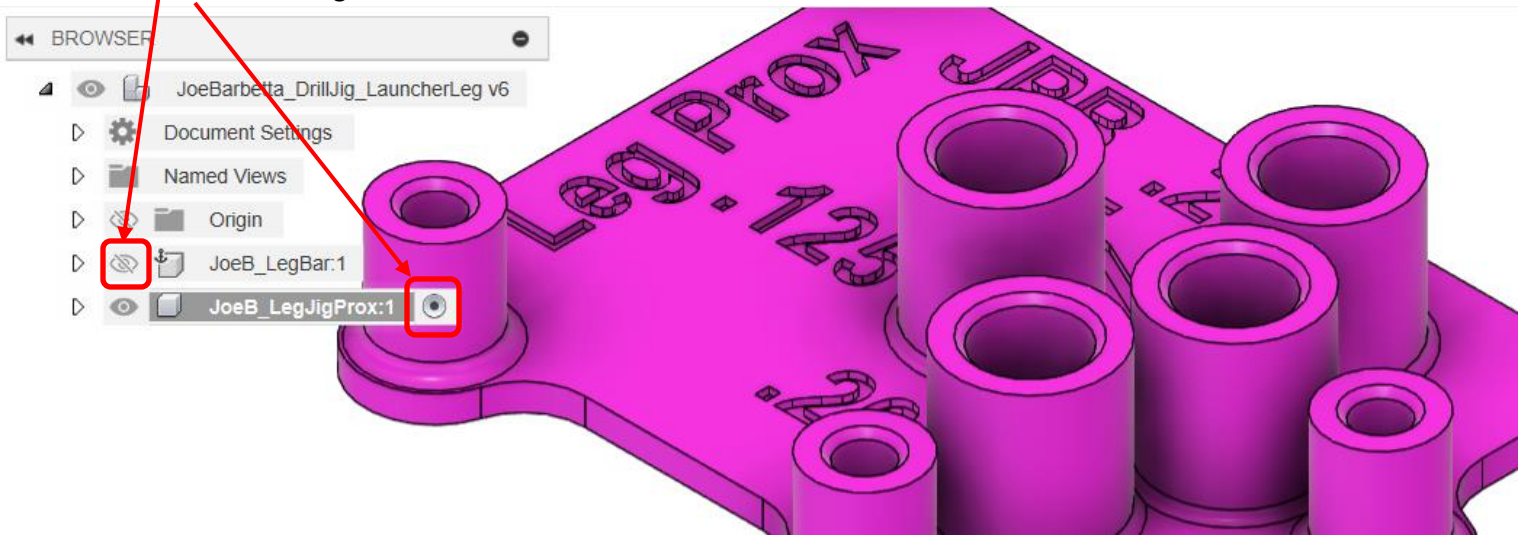
Note that there are settings in slicer programs, such as Ultimaker Cura, that can make some corrections. One such setting is **Horizontal Expansion**, however this will only help for vertical holes. It can also be argued that for **DFM (Design For Manufacturing)** considerations, the actual design should be adjusted to prevent errors due to invalid slicer options. For example, one may forget to adjust these slicer settings before performing the print, or they may be set and then applied to a future print, for which the settings are not appropriate.

Below are illustrations of the mechanisms that can responsible for vertical and horizontal holes. The resulting dimensional errors can vary between printers and can also be influenced by variations in filament, ambient temperature, and slicer settings. Thus, one can appreciate the importatance of performing test prints.



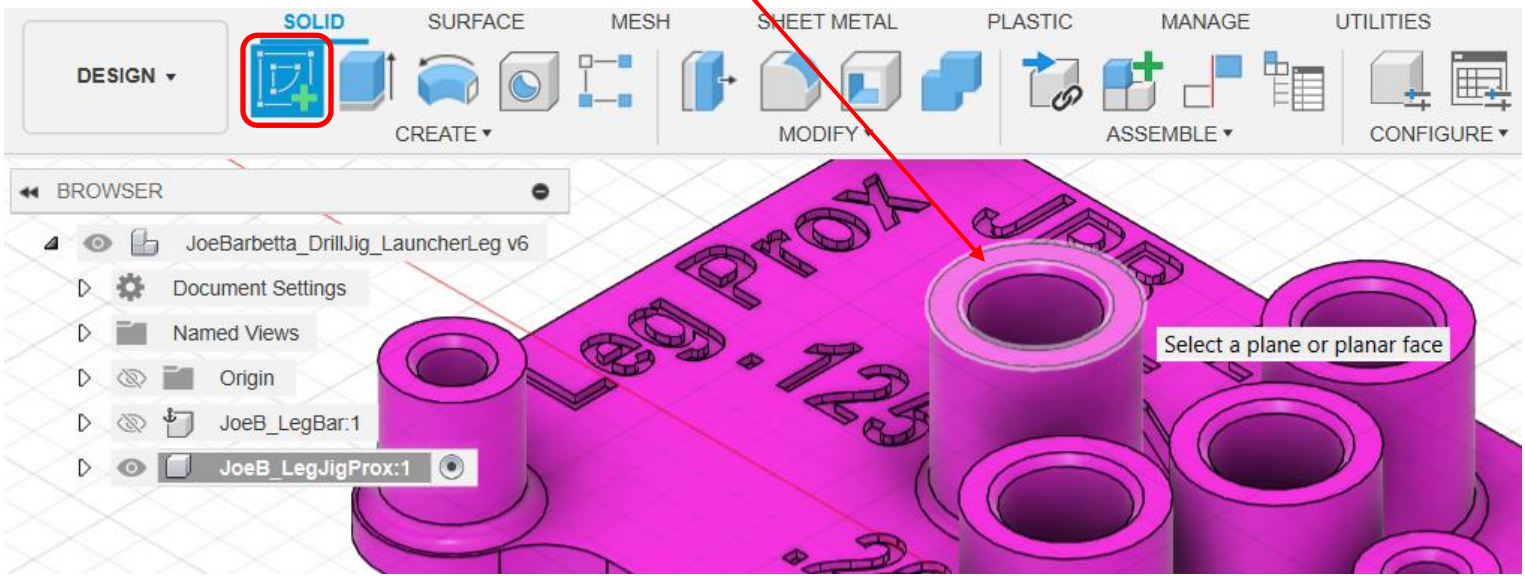
For vertical holes, one mechanism that can be responsible for holes being printed smaller than specified, is the bulging of the plastic upon leaving the nozzle.

- **save you project!** We will be making some temporary changes we don't want in the final jig.
- zoom in to the Jig body as shown
- click on the **eye** icon for the bar to hide it
- click on the **circle** for the Jig to avtivate it

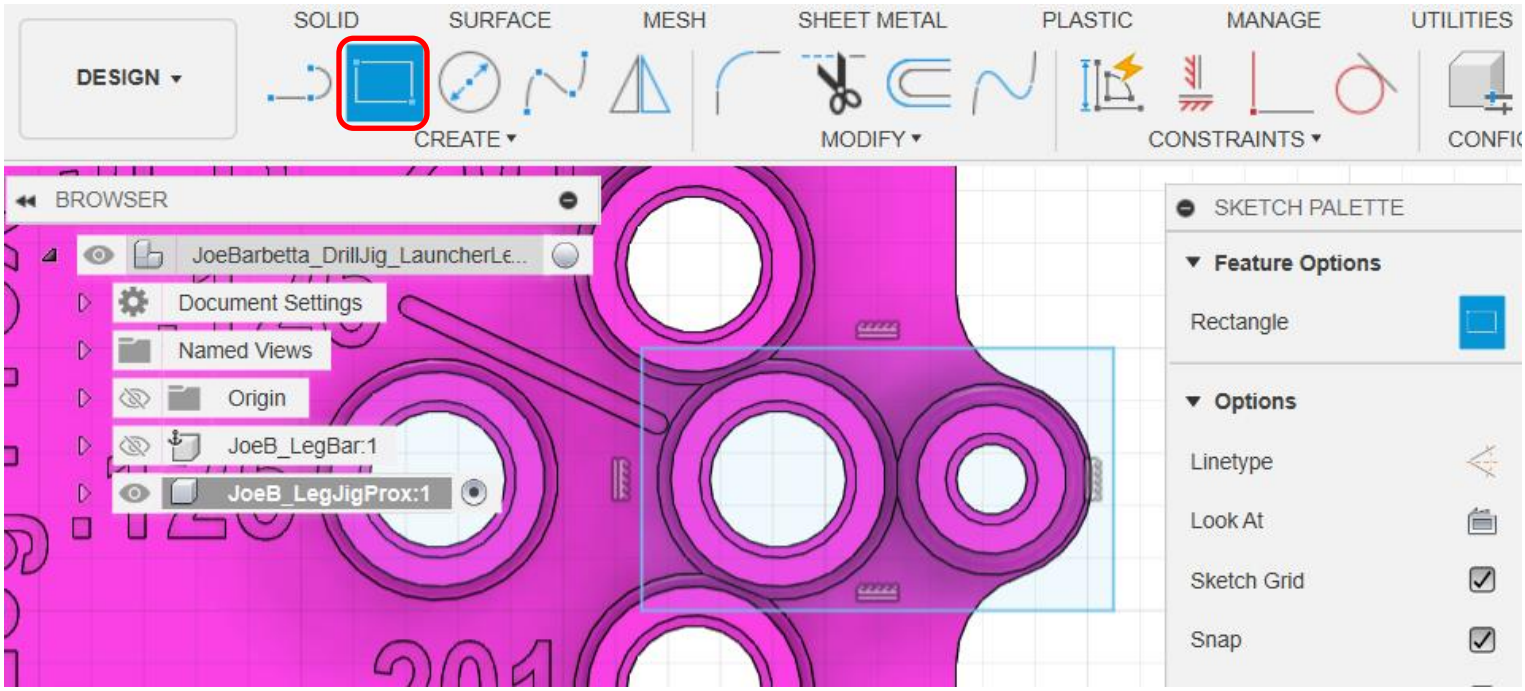


- select the **Create Sketch** tool and click on the **highest surface** of the jig. In this case it is any **top of a hole guide**.

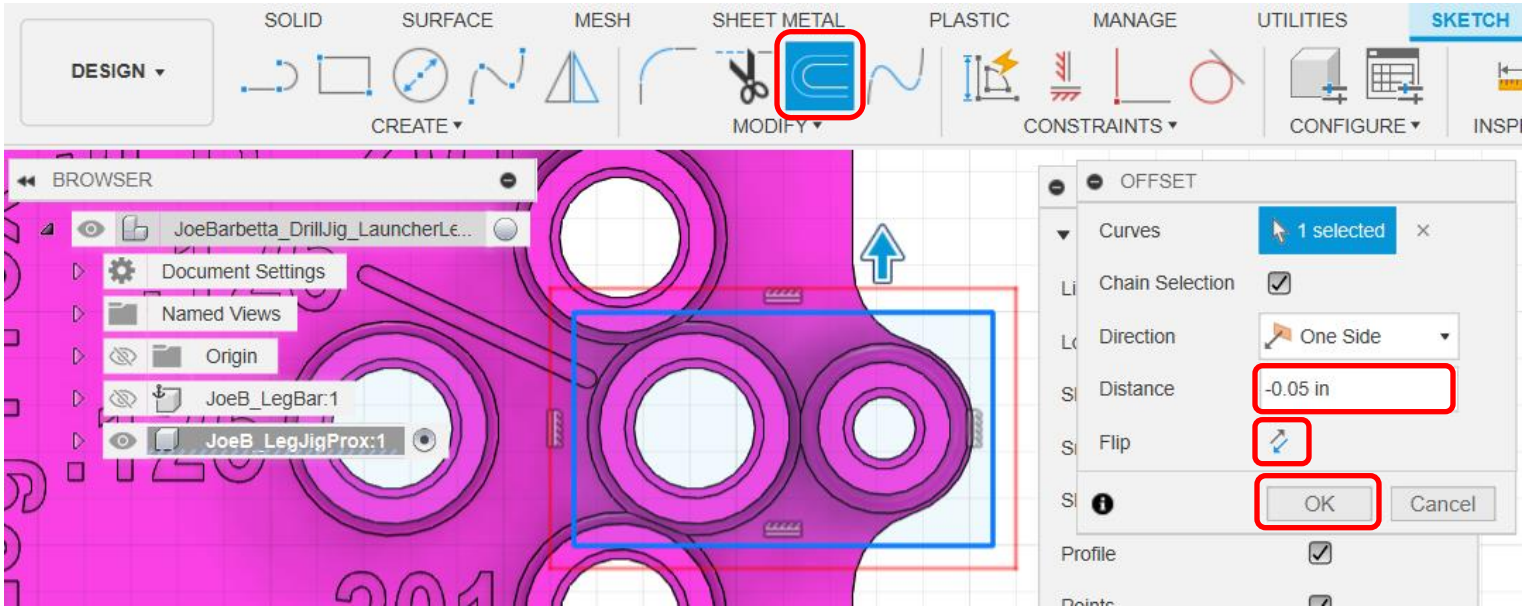
There is no need to rename this sketch. It is only temporary.



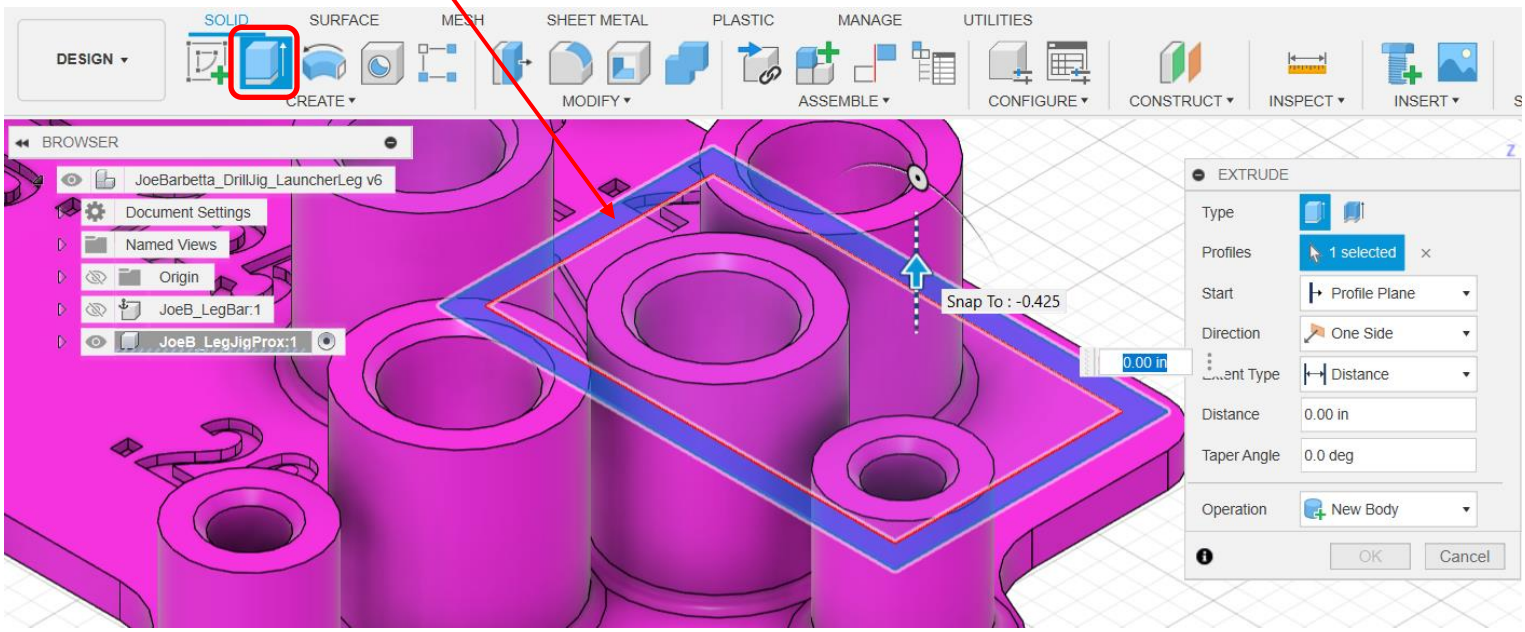
- use the **Rectangle** tool to define a rectangle that encompasses a **Guide Hole** and **Pin Hole**. **The size is not critical**. In this jig there are only these two sized holes. If there were additional sizes, the line tool could be used to define a more complex shape to encompass them or multiple sections could be isolated for test prints.



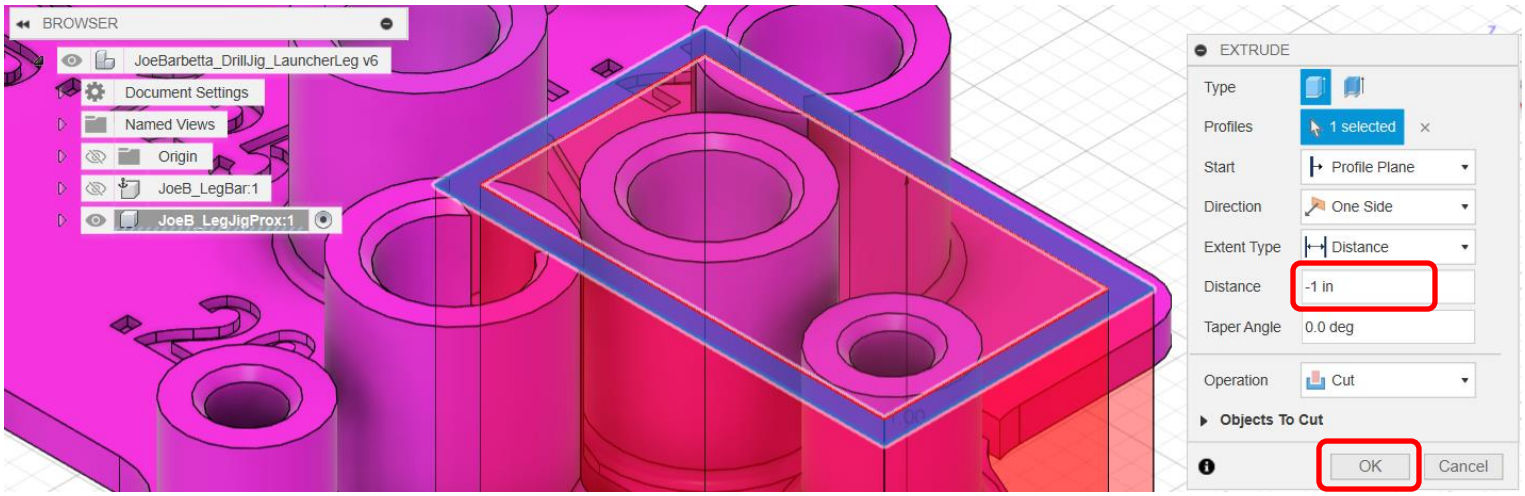
- select the **Offset tool**. (If it is not visible select it from the MODIFY menu.)
- click on the rectangle just created and extend the red rectangle outward and enter a distance of **- 0.05** (note te minus sign)
- if the red rectangle is inside the blue one click the **Flip** icon to ensure it is on the outside
- click **OK**



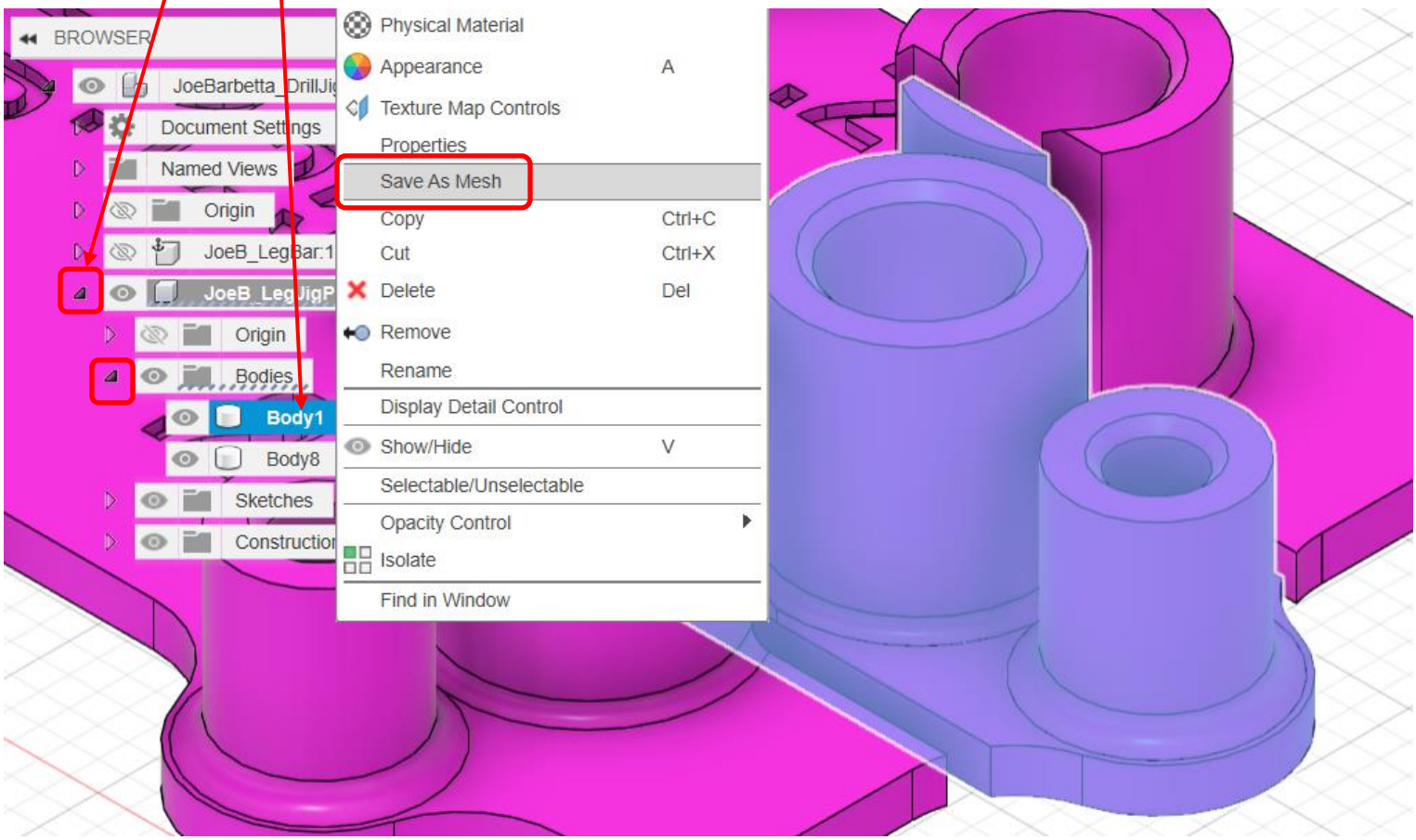
- click **Finish Sketch**
- use the **Home** icon and then zoom and pan to acheieve a view similar to that below
- select the **Extrude** tool
- click on the **region between the two rectangles**



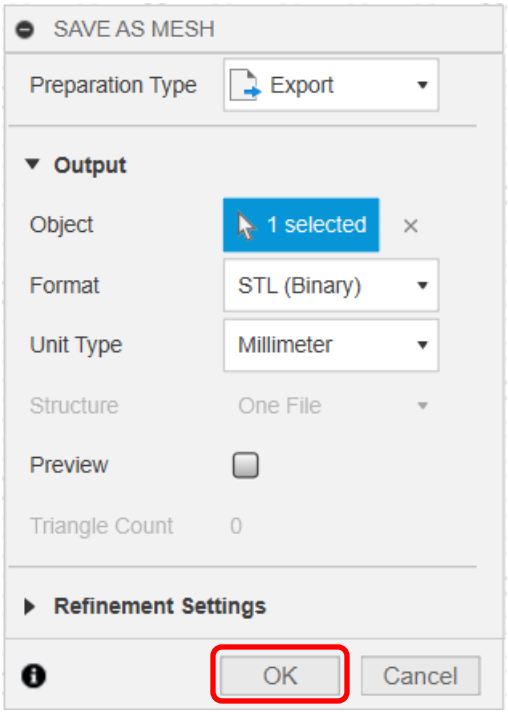
- in the **Distance** box enter a value of **-1** (note the minus sign), which should show the rectangle cutting through the jig. It's sort of a neat effect.
- click **OK**



- click on the **arrows** to open the Bodies folder for the Jig
- select the **body that highlights the test section**
- right-click on that **body name** and select **Save As Mesh**



- set the options as shown below and click **OK**



- enter the name **DrillJig-Test** or whatever is appropriate for your project
- ensure that **Save to my computer** is **checked** and make note of the save location
- click **Save**