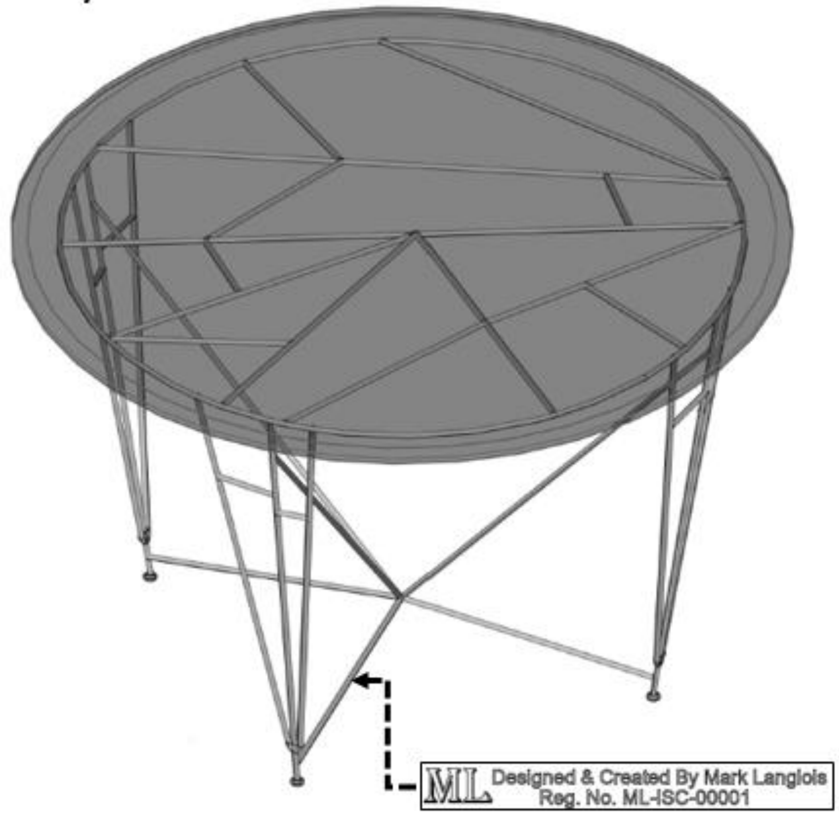
Design & Development Part I

Ideation to Creation By Mark Langlois--May--2021

Certification of Authentication and Registration Of Ownership

Free Form Geometric Patio Table in 3/8 Steel Bar
Original Design By Mark Langlois, Created By Mark Langlois

Purchased By ___________*N/A*______________
Date Purchased ___*N/A*__________
Color __*Gloss Black*_____
Design Iteration Number 121775-1A
Registration Number ML-ISC-00001



Registration Tag Location

Certificate of Registration

This Certificate issued under the seal of the Copyright Office in accordance with title 17, *United States Code*, attests that registration has been made for the work identified below. The information on this certificate has been made a part of the Copyright Office records.

Acting United States Register of Copyrights and Director

Registration Number
VAu 1-383-371
Effective Date of Registration:
August 12, 2019
Registration Decision Date:
February 12, 2020

About the man behind the design and creation of your table and author of this book, detailing its development and construction.

Name: Mark Bradford Langlois
Status: Married with Children, Grandchildren
Education: B.S. Liberal Arts, Central Michigan University
Career: Design, Engineering, Product Life Cycle Management, IT Consultant, Software Development
Music: J.J. Cale, Jackson Brown, Mark Knopfler, Snowy White, Jazz, Classical
Favorite Book: Catcher in the Rye, by J.D. Salinger
Drink: Oban Single Malt Scotch, Jack Daniels or whatever you have
Cigar: Rocky Patel Vintage 1990, 1992, Undercrown Maduro Robosto
Hobbies: Travel, Photography, Music, Art, Creative Design and Engineering

Acknowledgments:
A very special note of thanks to my wife Marianne, who has supported me in every way throughout this entire project.

To John and Edward Darnbrook, Oneida Tool Company. Thank you both for your avid interest, advice and continued support in the development of my project.

Book Completed: May 5th, 2021

Ideation to Creation, History and Background

I was a young college student attending Central Michigan University from 1975 to 1980. I was pursuing a Bachelor of Science Degree in Sociology with a Minor in Industrial Technology. While my degree was in Sociology, I also took many classes in Computer Science, Art and Industrial Technology.

My industrial technology classes were focused on manufacturing and hands on practical applications in casting, welding, machining, computer assisted design and manufacturing (CAD/CAM), manufacturing communications and in the new industrial applications associated with the emergence of simple pick and place robots.

During the semester associated with the hands on application of my industrial technology course work, my instructor had a set of defined projects we were to complete. In addition, we were required to complete one project of our own design and present it to the rest of the class.

My selected project was to create two tables made from 3/8 inch steel rod. I had no particular design in mind other than they were going to be 30 inches high, have a round top and made of welded construction.

The industrial technology lab, had only limited equipment; the steel I needed, a MIG Welder, and space that I had to share with other students. I had to bend the 40 inch diameter table top around a plywood form that I made by hand; clamp it and weld it. The result was a top that was not completely round and I had to work the metal hoop in as close to a circular shape as I could get. I spent the rest of the semester in the industrial technology lab every free minute I could get; creating and welding the free form design for the top and designing and welding the legs and cross members. I had two tables completed by the end of the semester and was very pleased with the results.

My instructors were also quite amazed with what I had been able to accomplish in a single semester along with all of my other assigned projects.

I gave the tables to my parents as a graduation present in 1980. They used them in their home for many years. My parents eventually moved into an apartment and I regained ownership of the tables I had made.

I have had these tables and used them for more than 30 years; both inside my home as a dining table, office desk, living room table and outside as patio tables. I enjoy them very much both from an aesthetic standpoint and in the way they are constructed; functional, solid and strong.

In late 2019, I was sitting at one of the tables I had made on the patio and it came to me that I had created these tables using my own creative energy using an ad hoc design approach; the tables had no established origin or documentation. The tables existed, but there was nothing to establish how or when they were made or that I was the individual that created them (other than historical fact). They really didn't exist in any other form other than some hard work and creative energy that came to pass in a small college lab in 1980, which now date these original creations to roughly 40 years ago.

I have spent the better part of 37 years working in the field of computer aided manufacturing, computer aided design, computer simulation, managing assembly structures and software development. In consideration of the existence of these tables without any actual design content, I decided to chart a path to formally define the design and creation of these tables and to capture the major steps in the process to produce them.

My vision was to provide some historical documentation in the transformation of what it takes to go from an idea or metaphysical muse, to the physical existence of that dream—"Ideation to Creation".

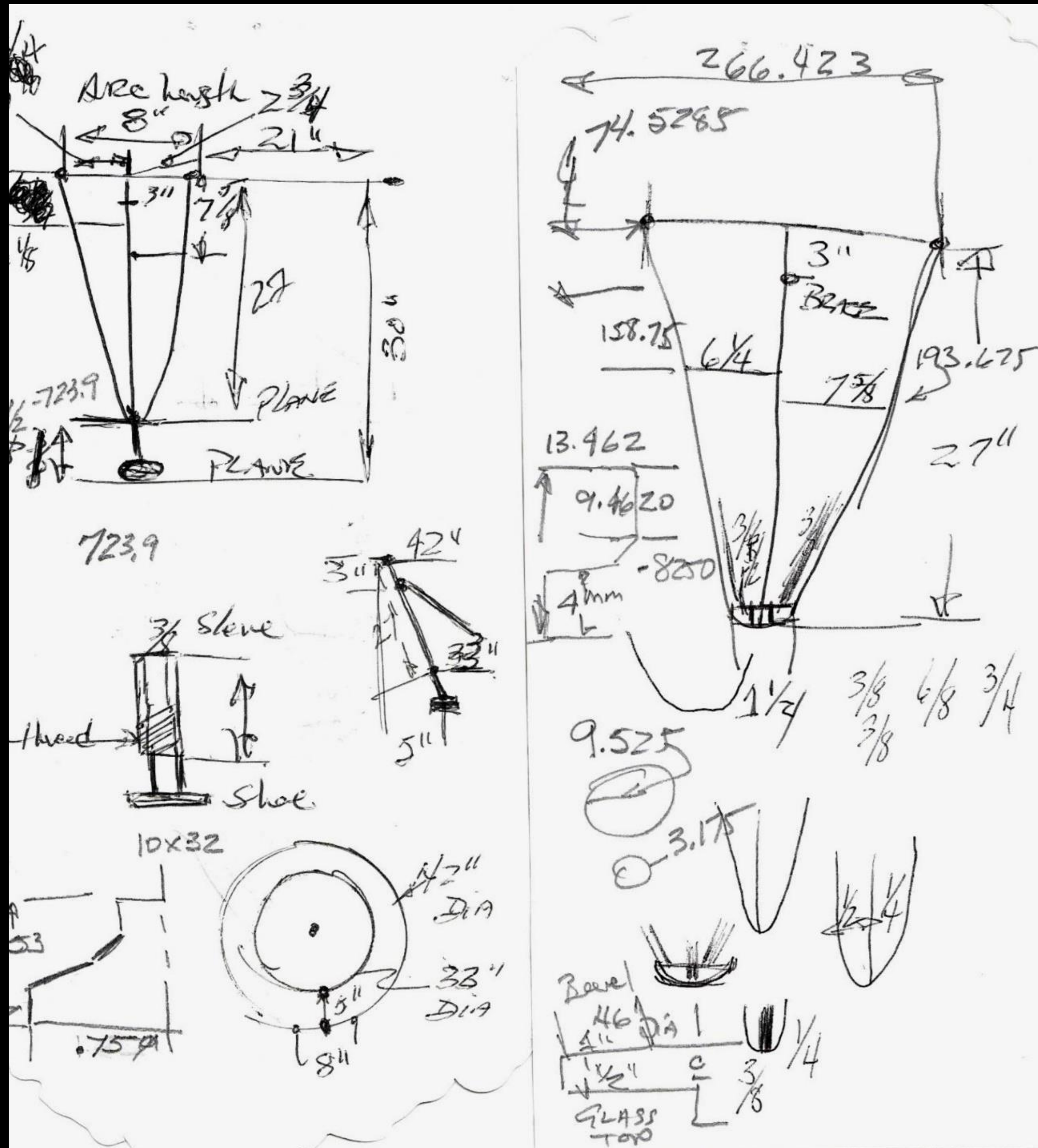
Historical Reference: This is a photograph of my son and daughter taken approximately 27 years ago (1993). My son is close to 8 months old and my daughter is 2 years old. You can see both the tables that I made in college in the background of this photo.

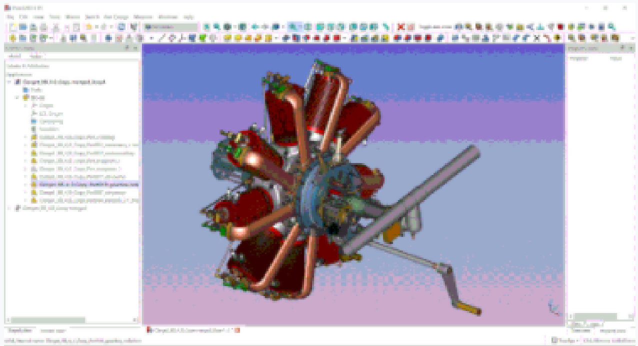
This is a shot of one of the original tables designed and made by me some 40 years prior. The table is a contemporary geometric design that creates an intentional 3D perspective looking down through the top. This table was the conceptual basis for the development of the new documented design that has been created. The elemental constructs of this design has been incorporated into the new table design.

I started the process to capture the new design by creating a napkin drawing with some of the basic sizes and dimensions from the existing original tables.

This served as the starting point for capturing the height, diameters, basic shapes, angles and the desired changes in design from the originals. One of the desired changes was incorporating leveling feet into the new design so the tables can adjust for minor unevenness and will not rock.

Basic Design Criteria:
Diameter of top: 42 Inches
Height: 30 Inches
Material: 1018 Cold Rolled Steel
Size: 3/8 Inch Steel Rod
Construction: Welded
Weight: 30 pounds
Top: 48 Inches Diameter
Glass: 1/2 Inch Thick, Beveled, Gray





FreeCAD Screen of Version 0.19

Original author(s)	Jürgen Riegel, Werner Mayer, Yorik van Havre[1]
Initial release	29 October 2002; 18 years ago
Stable release	0.18.5 / 25 November 2019; 12 months ago
Preview release	0.19_pre / 3 November 2019; 13 months ago
Repository	github.com/FreeCAD/FreeCAD
Written in	C++, Python
Operating system	GNU/Linux macOS Unix Windows
Type	3D Modeling, CAD, BIM, FEM
License	LGPLv2+
Website	freecadweb.org

In order to create the three dimensional solid model of the new tables I intended to design, I had to research and select a computer aided design (CAD) software application to do the work.

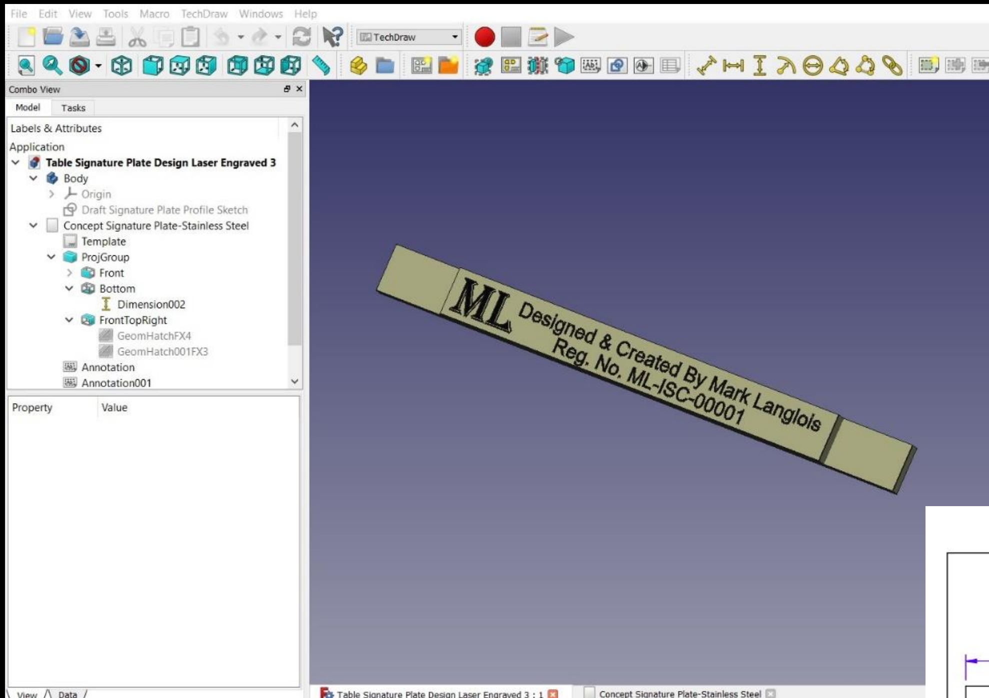
In my 37 plus years doing design and engineering using CAD/CAM systems, I had access to many "top of the line" design applications used by large companies. These software applications were well known to me and very capable, providing different options that assisted greatly in creating solid models.

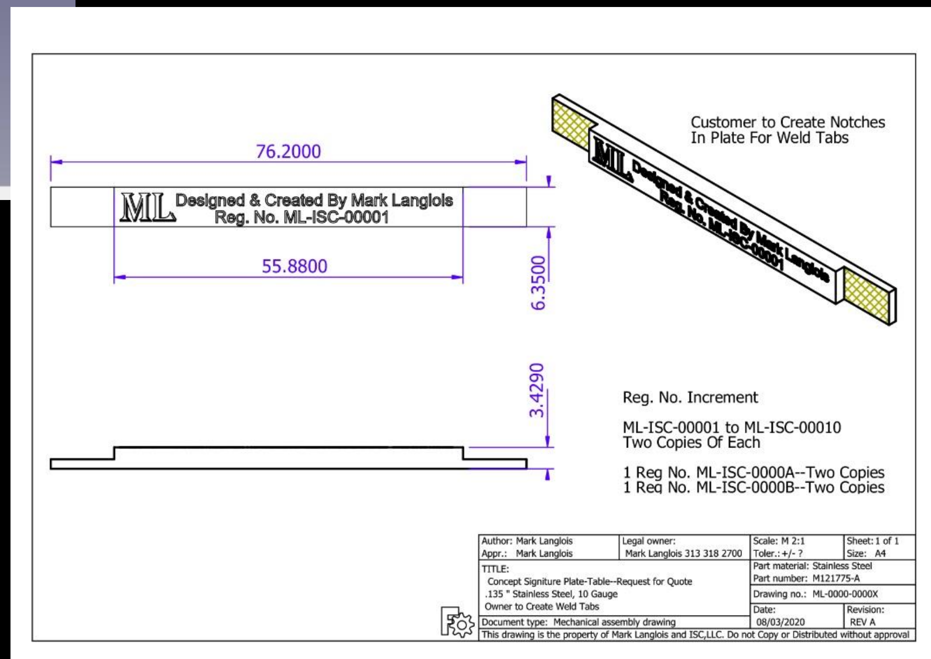
However, these software applications are quite expensive to acquire and use. They have licensing levels (cost based on capability) depending on the tool sets you require.

I needed a solution that was capable and cost effective. During my Internet search I came across several potential CAD applications that I downloaded and tested for the functionality and user interface that I felt would satisfy the complexity of the design and included a build and edit structure that allowed me to easily manipulate the design components.

I selected an open source CAD software application called FreeCAD. This CAD software is a free download and worked very well for the design of my project. In addition, "open source" means that apart from the initial CAD software development, other developers can create additional tools and compile them so that they are compatible with the source system.

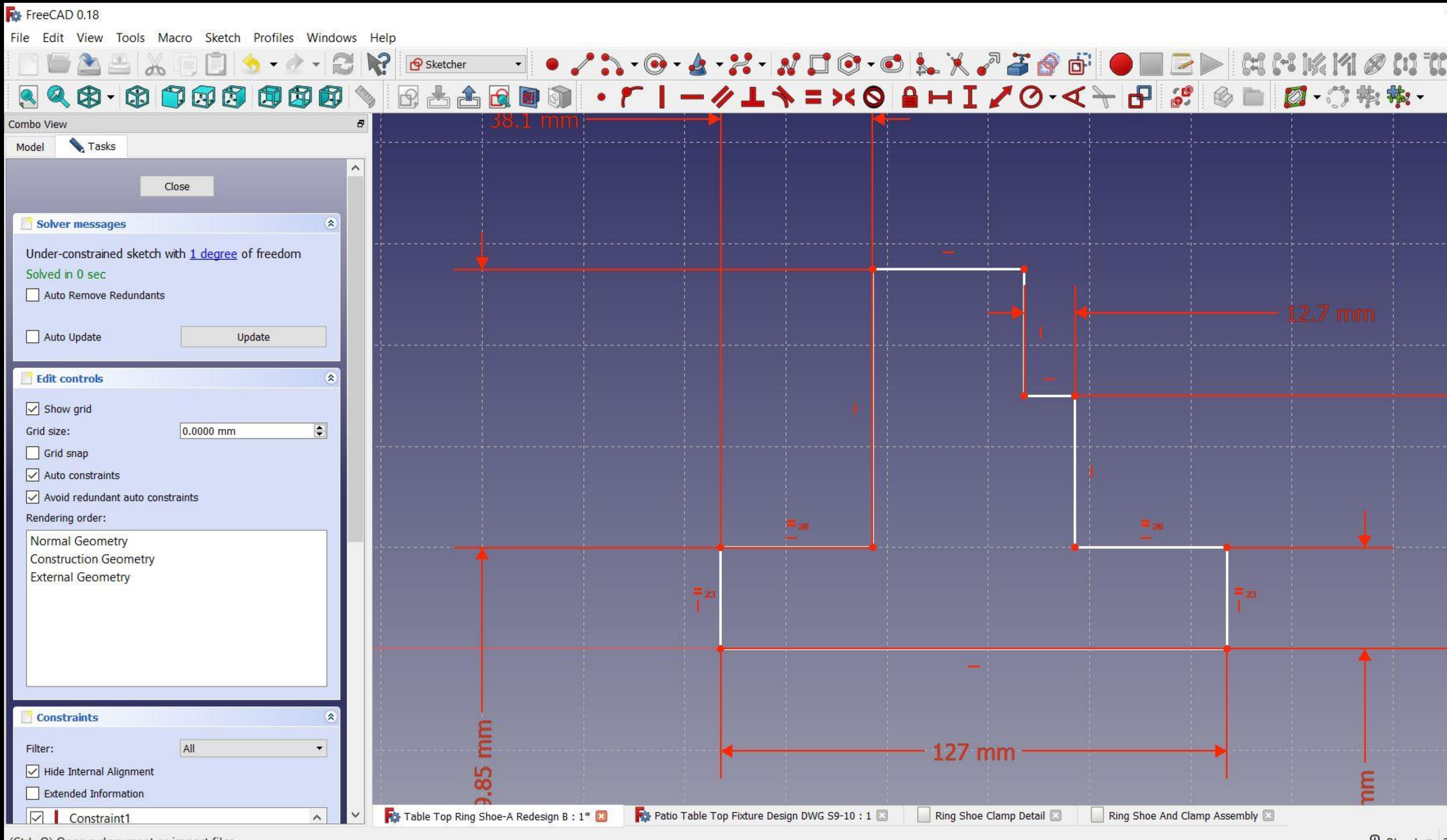
Picture, Source Reference: https://en.wikipedia.org/wiki/FreeCAD



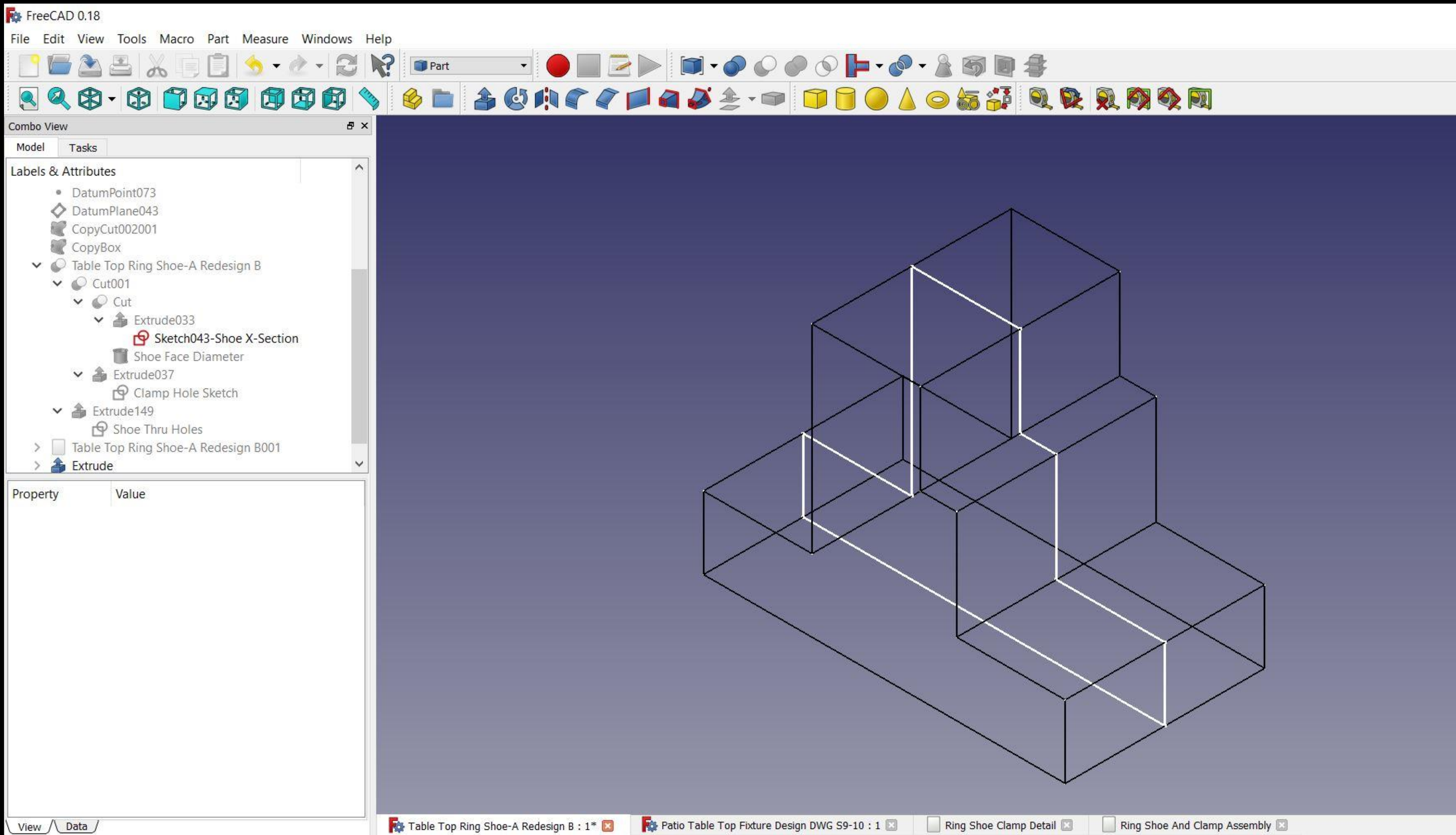


The FreeCAD design application software is displayed above, showing a solid model and drawing of my signature plate to identify the table's designer and builder.

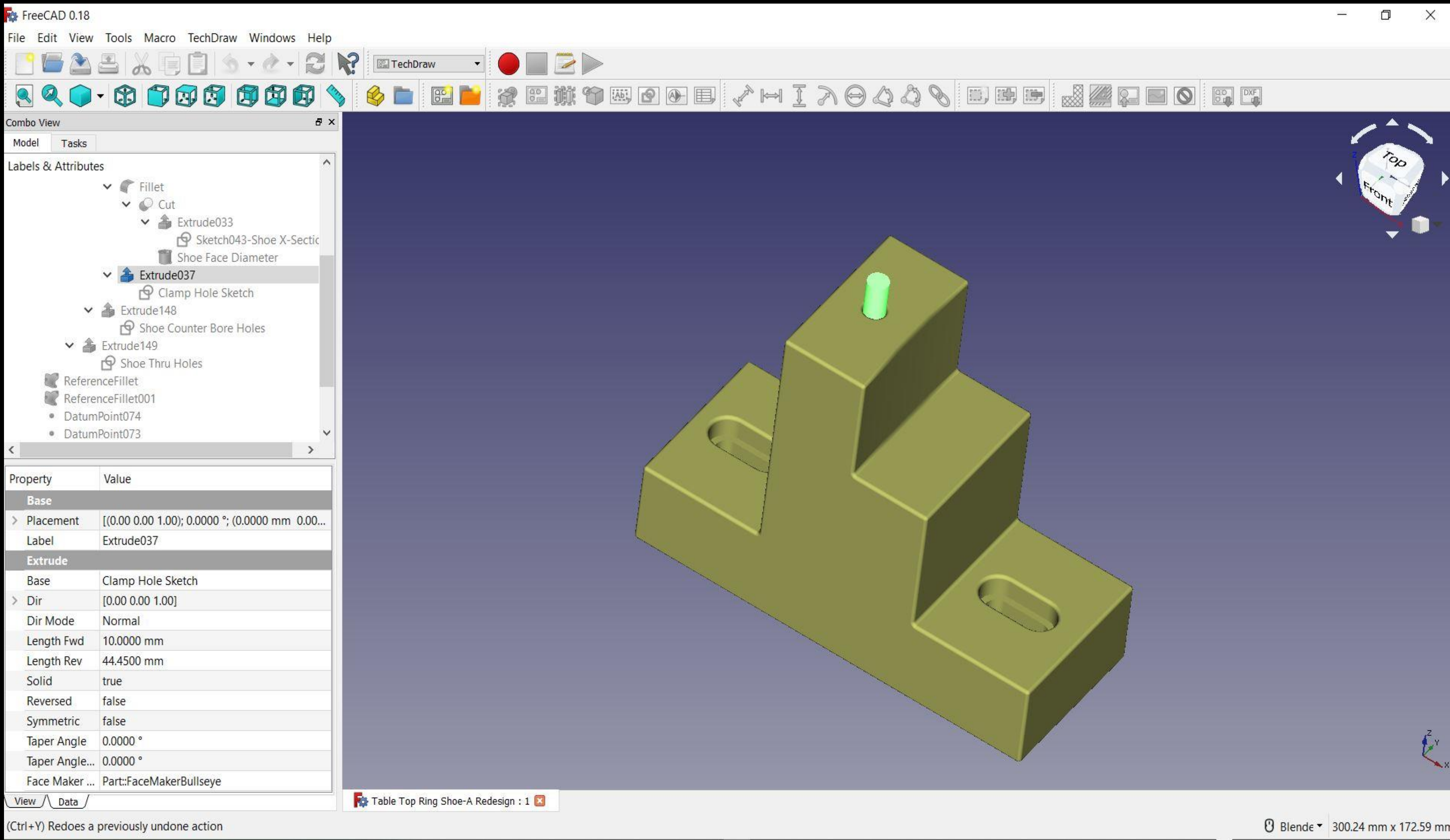
**FreeCAD Software Web Site: https://www.freecadweb.org*



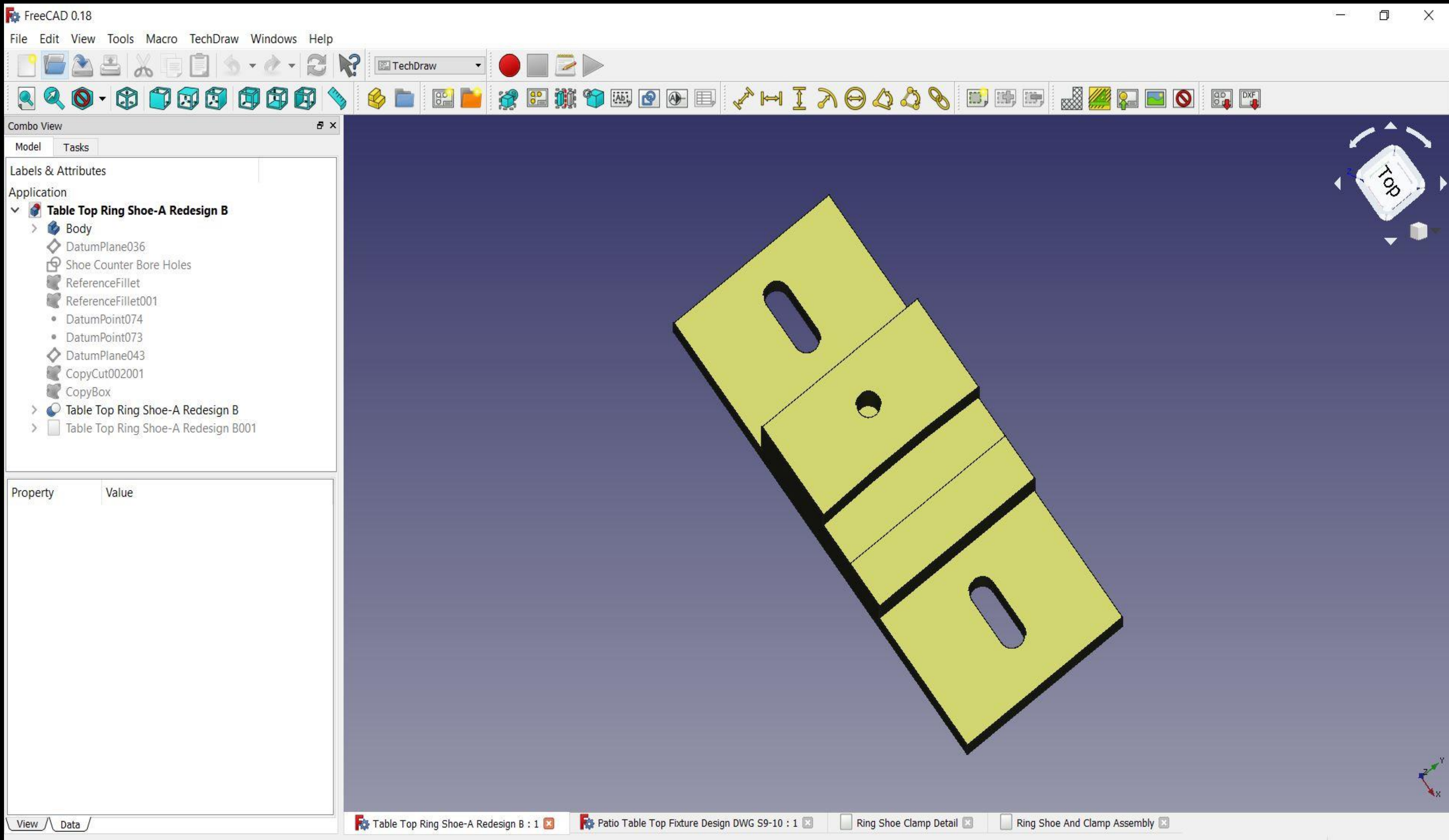
A brief introduction to CAD design as it relates to the creation of my new table. Many CAD systems have as a key component, the ability to create a dimensioned and constrained sketch that provides the application with information on how to construct a solid shape. The benefit of a sketch, is that it allows the user to change the dimensions and or constraints and the solid construct will update to match the changes. The example profile shape shown above is created and then saved in a tree structure so that it can be modified later or utilized by other CAD tools within the application.



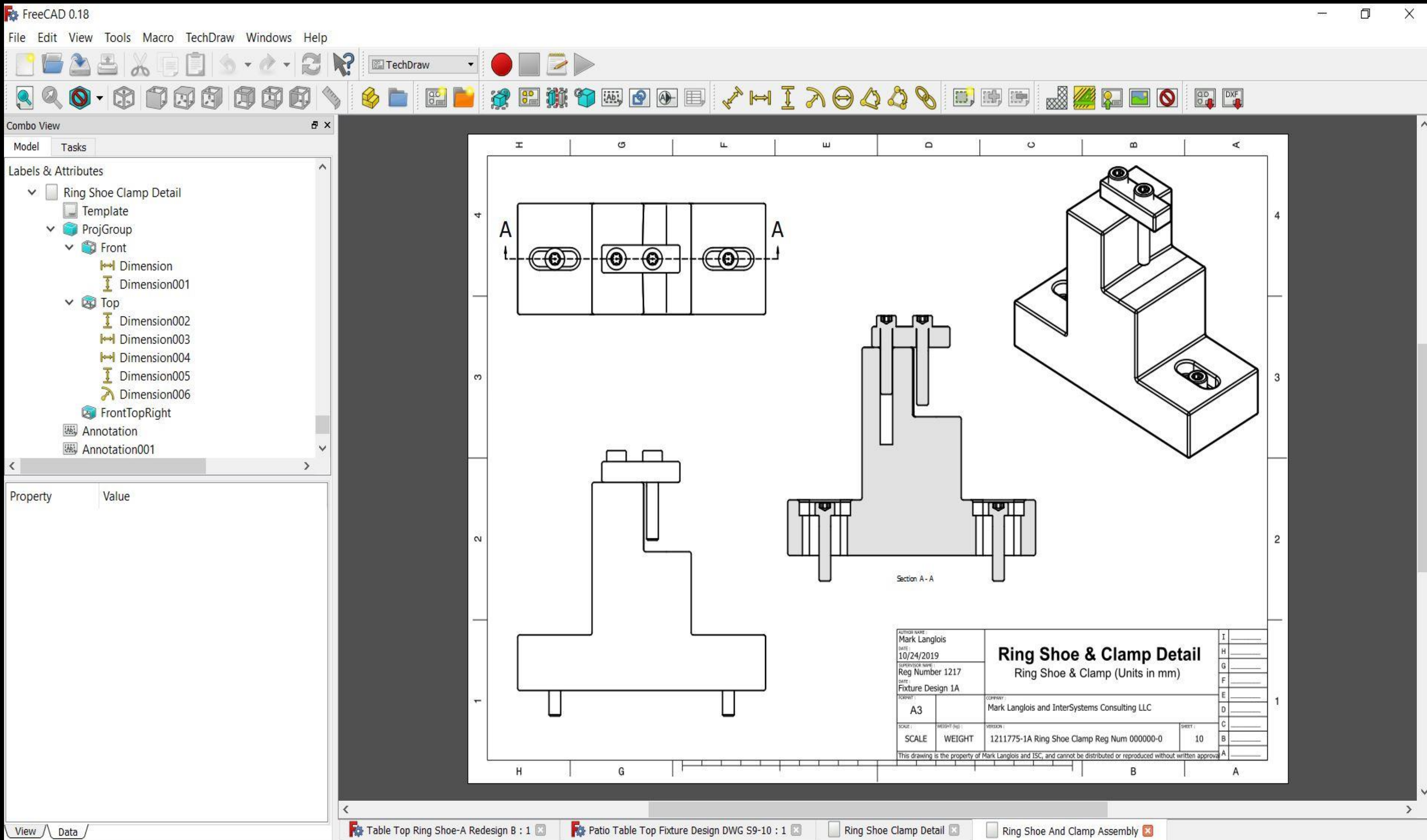
Using the sketch profile I created from the previous page, the profile was "extruded" (another common CAD application tool) to create the solid shape above. The sketch profile shown in white, overlays the extruded solid profile shown in black (the shaded solid model is shown on the next page). I created numerous sketch profiles and extrusions in this same way, to create my new table and the tooling to make it.



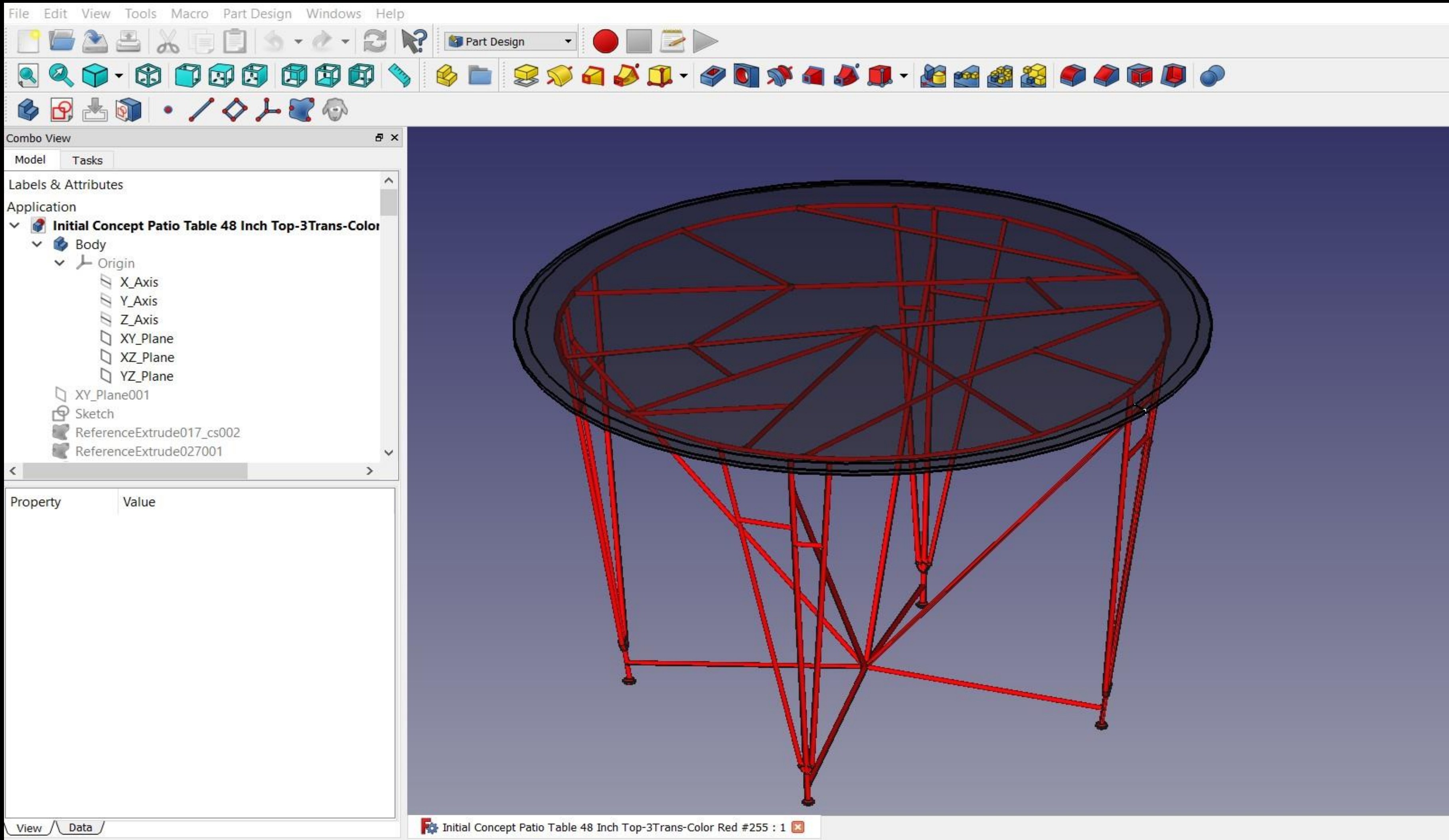
Another common solid modeling practice found in most design applications today, is the ability to construct a number of other solid shapes using sketches or by using other design tools, and then add, subtract or intersecting these features to progressively define the intended shape or design. These operations are generally referred to as Boolean operations. In the picture shown above, I created a new solid cylinder highlighted in green using a sketch, and extruded it. This new solid cylinder can now be used to perform operations on the existing solid body.



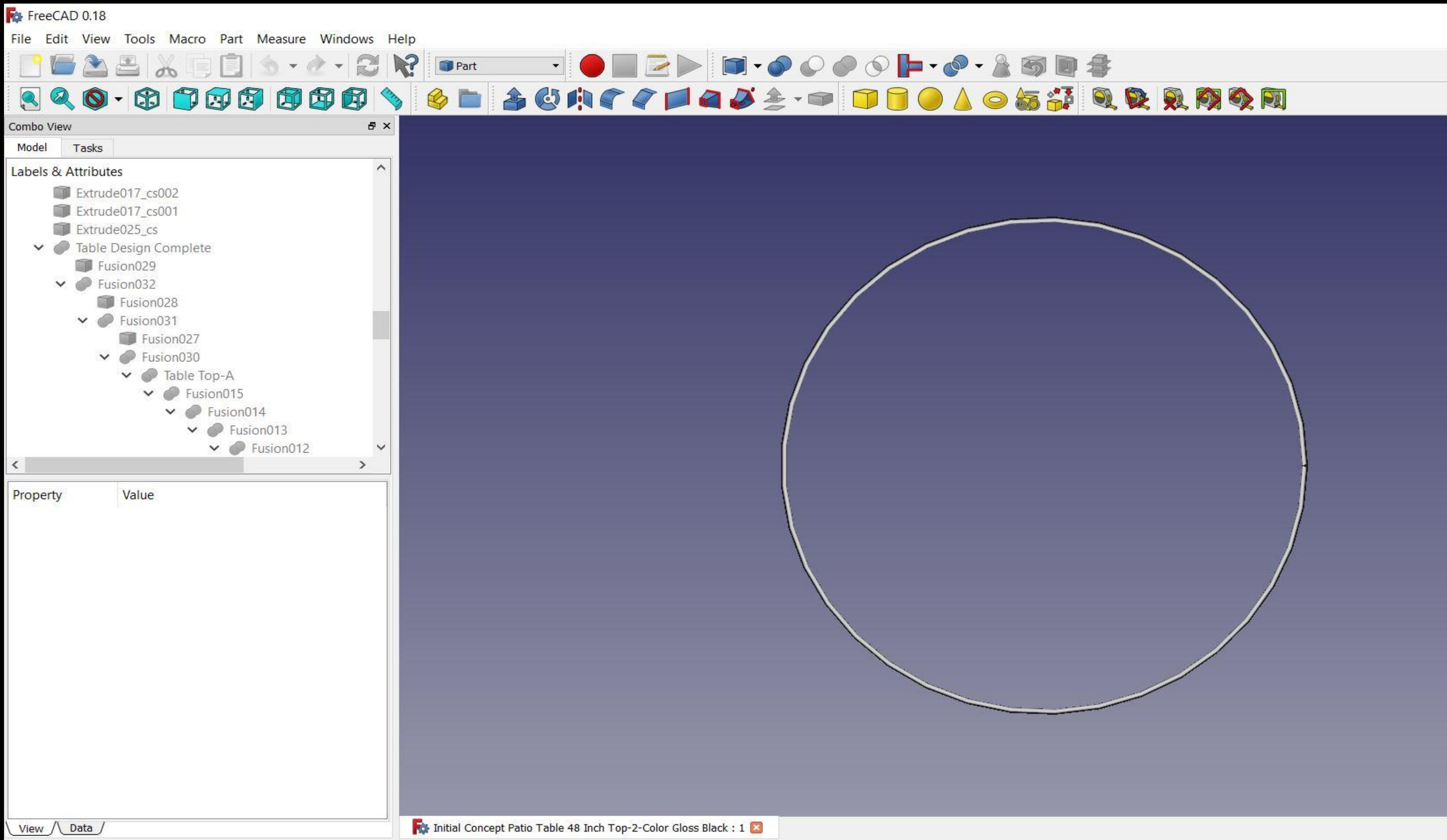
On the previous page, the new solid cylinder highlighted in green was "subtracted" from the solid body (the physical space defined by cylinder was removed from the existing solid), leaving the representation of a drilled hole in the top of the part being created. I used many of these types of operations to create the components necessary to make my new table.



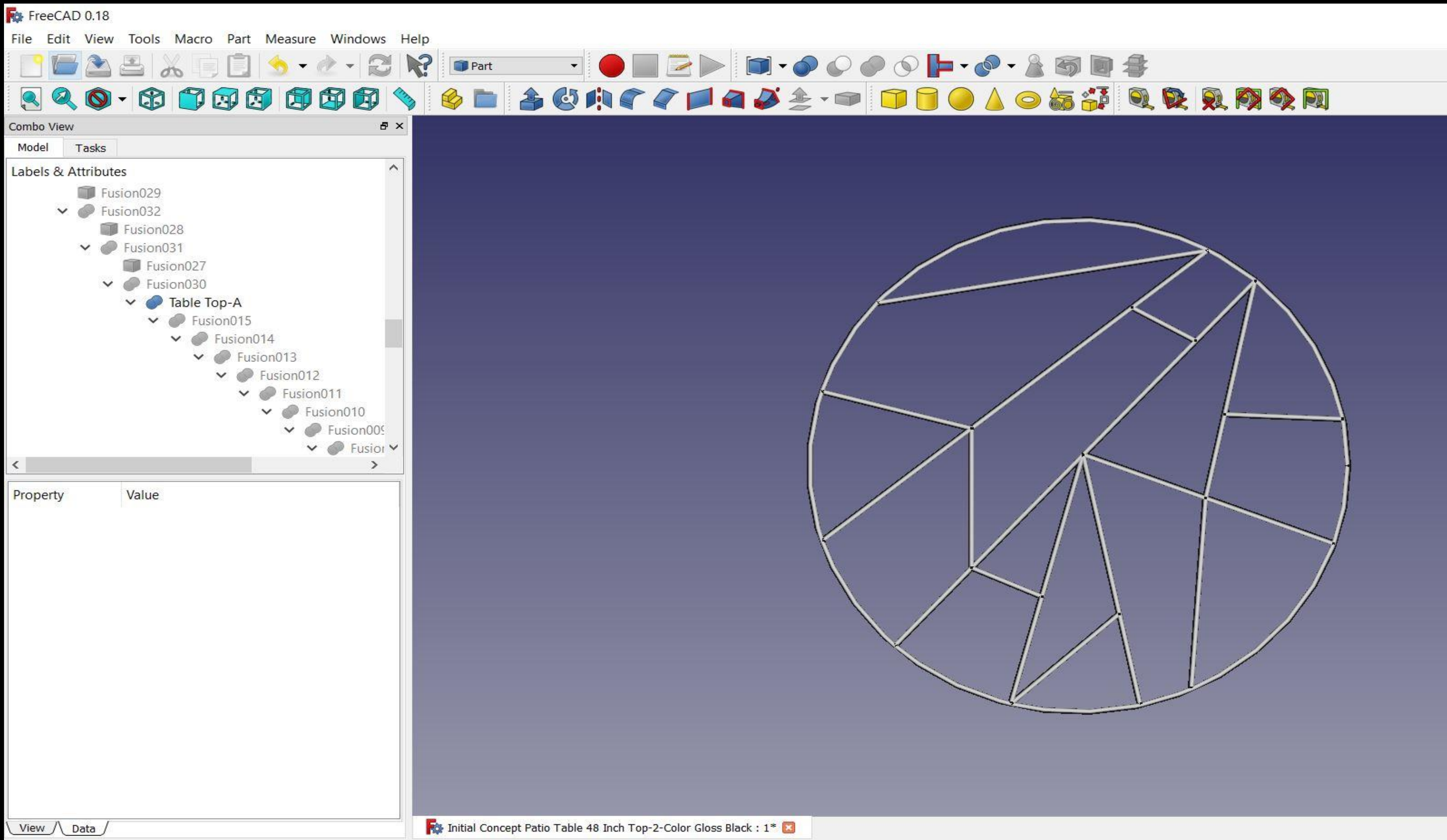
In addition to sketches and solid modeling tools, drawings may also be necessary to provide more detailed information. The solid model itself, in some cases, is all that is necessary for a machine to create the part. However, other information regarding type of material, datum locations, tolerance, tap hole size, surface finish and validation of the specific version in the design iteration are not necessarily associated with the 3D solid model. They are still conveyed to suppliers and vendors using a drawing. I make the drawings I need by creating views and dimensions of the part designed as a solid model.



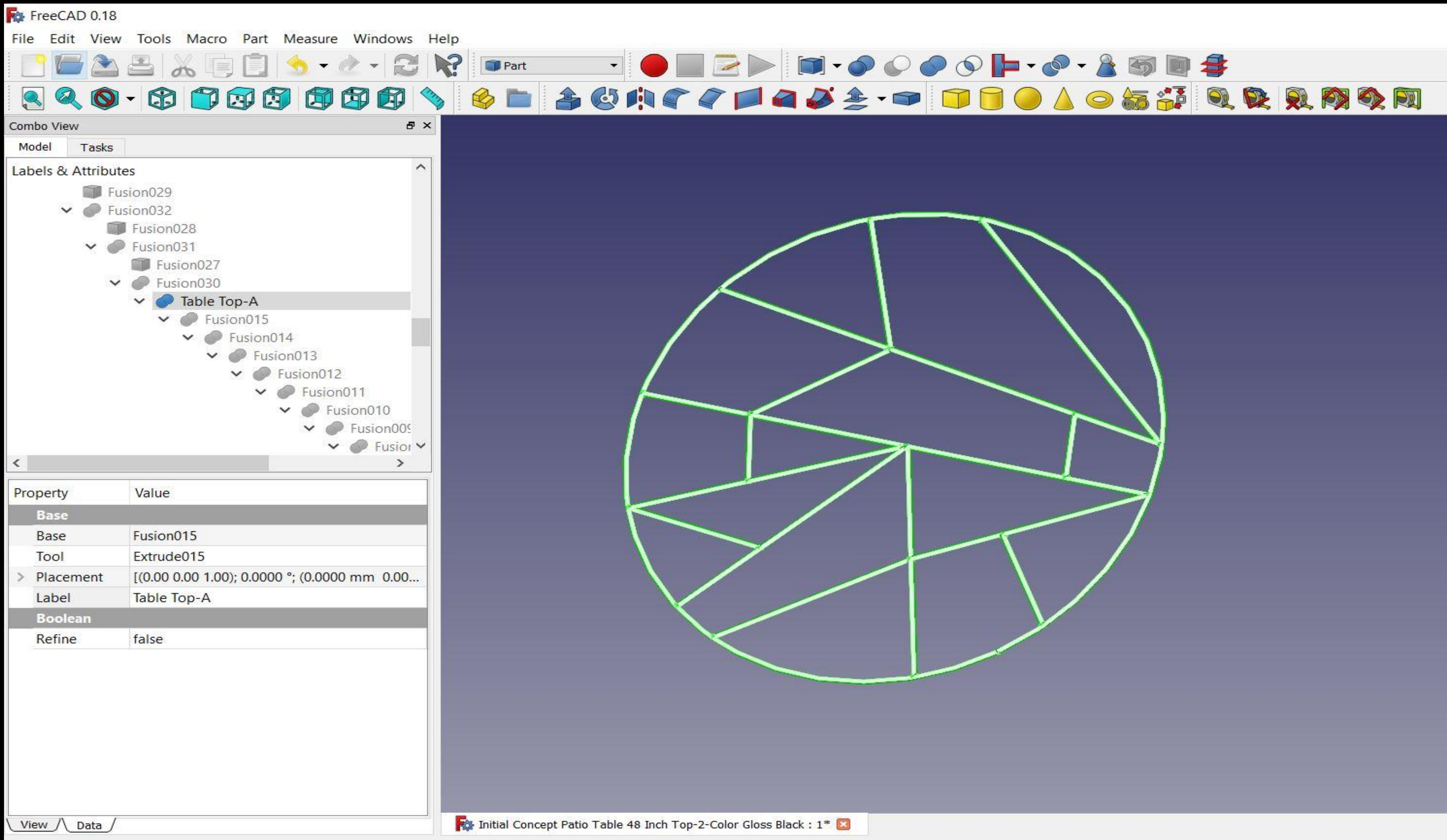
Pictured above, is a CAD rendering of my finished table design. This table design is shown here in red, complete with leveling feet and 1/2 inch, gray glass top with a 1 inch bevel. In the next section of this book, I will detail the individual development stages I went through to create my new table design as a 3D solid model.



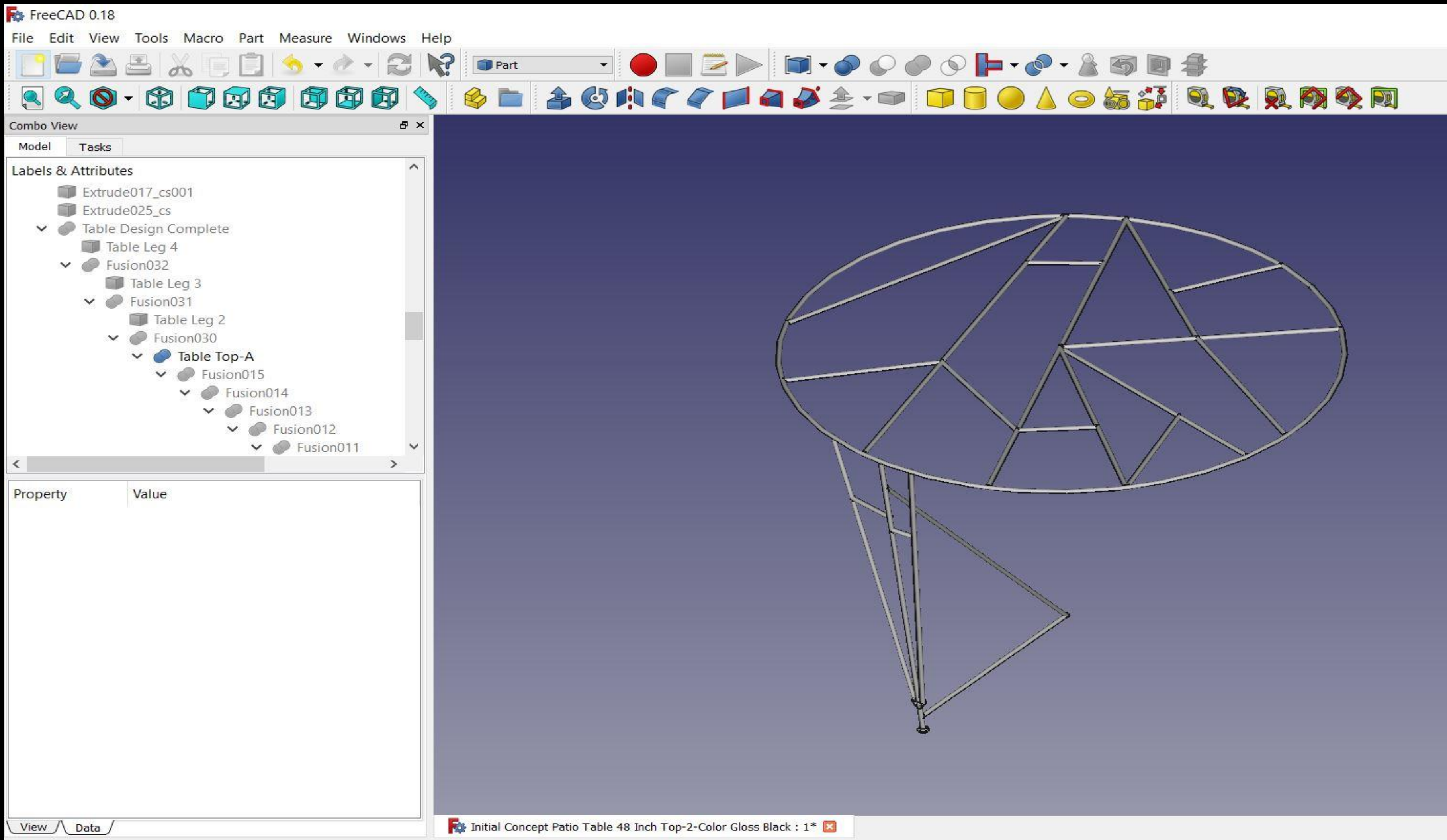
The first component that I created in the design process to construct the table, is the solid model representation of the table top ring. This ring will define the outer boundary of the table top as well as define the limits for the tops interior components. I created this ring by developing a sketch of the ring cross section; a circle 3/8" in diameter and sweeping this sketch 360 degrees around the circle center to create a solid circular ring.



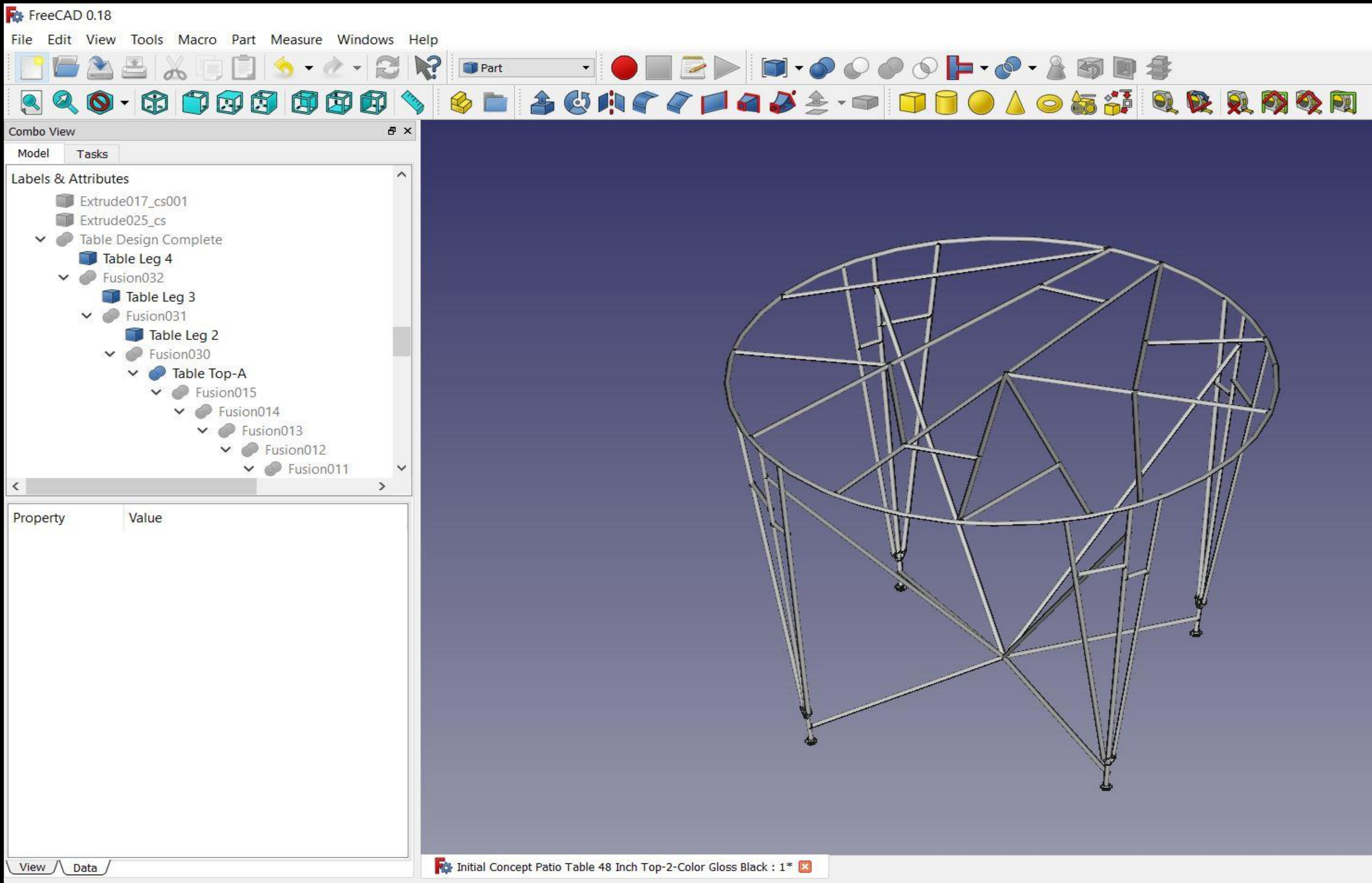
Now that I have the table ring defined, I can develop the interior geometric design. This is a multi-step process. First, I must define a plane in the correct orientation for each component part being constructed. Second, I need to create a sketch of a 3/8" diameter circle at the correct elevation and location on the defined plane. Third, I must extrude this sketch to create a solid 3/8" diameter shaft that intersects the existing outer diameter or other interior components. Last, I have to unite or integrate each of these newly constructed components so that they represent a single solid model.



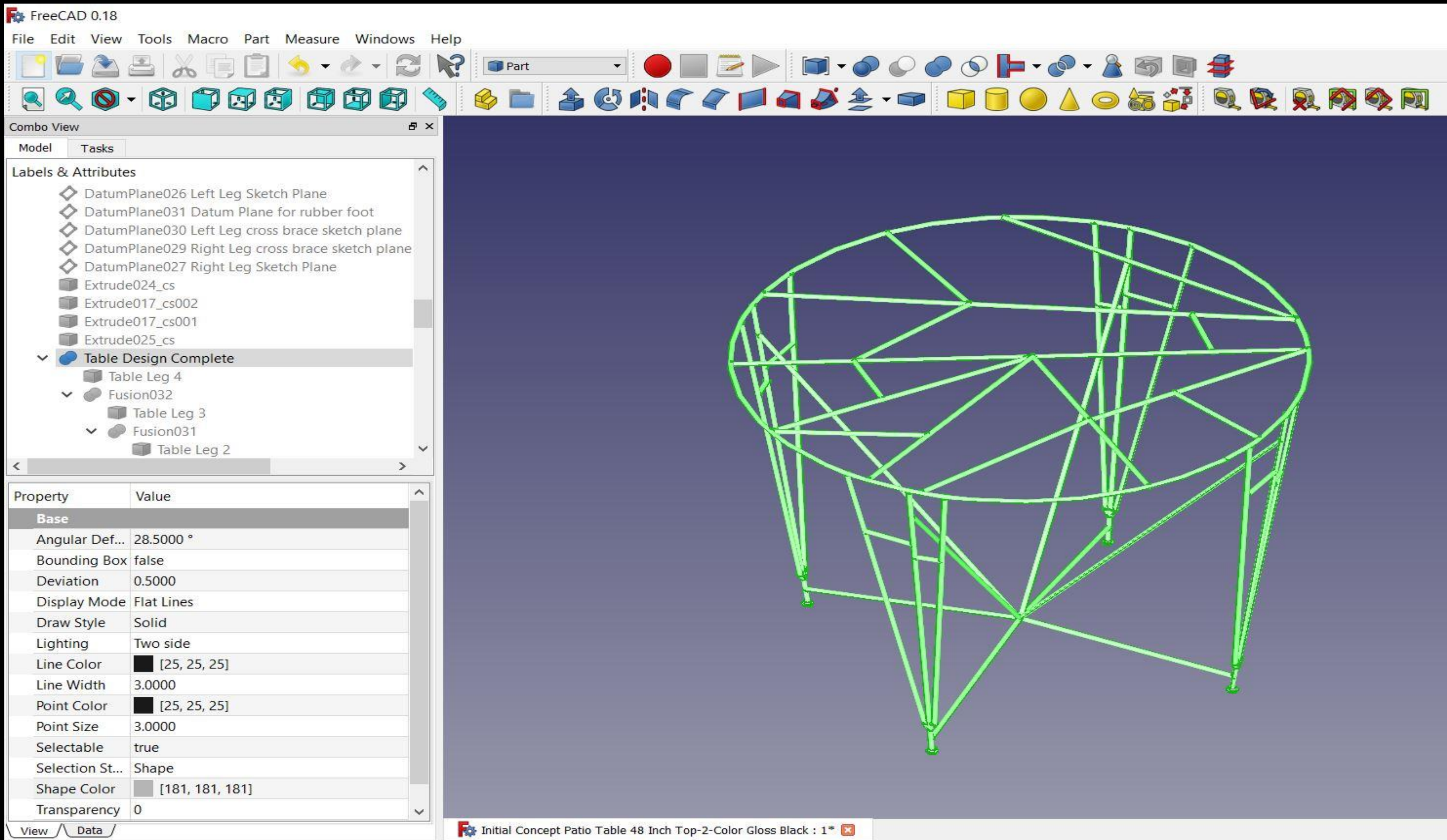
I have completed the geometric interior design for my table top. The highlighted top includes the previously defined table top ring and all of the interior geometric components. This means that the table top is represented as a single solid model; the individual collection of components I have constructed are now one.



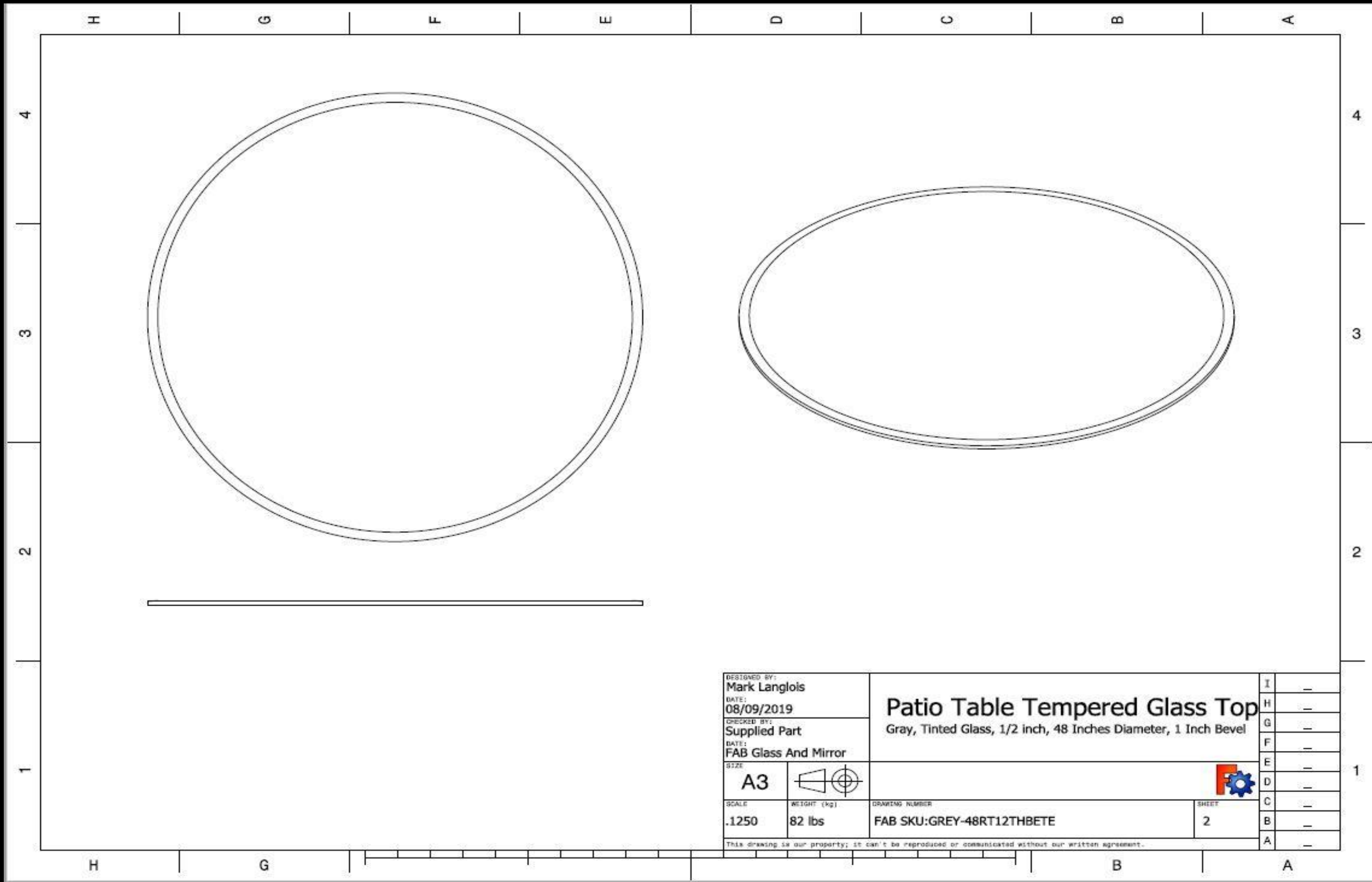
Having completed the table top design, the next components I need to construct are the legs for the table. The construction process, in this case, is the same approach I used to create the top. I will create one leg that incorporates all my design criteria and integrate that into a single solid model. Once I have completed the design of one leg, I can produce the other three legs for the table by copying the one leg and rotating it about the table center to create the other three legs.



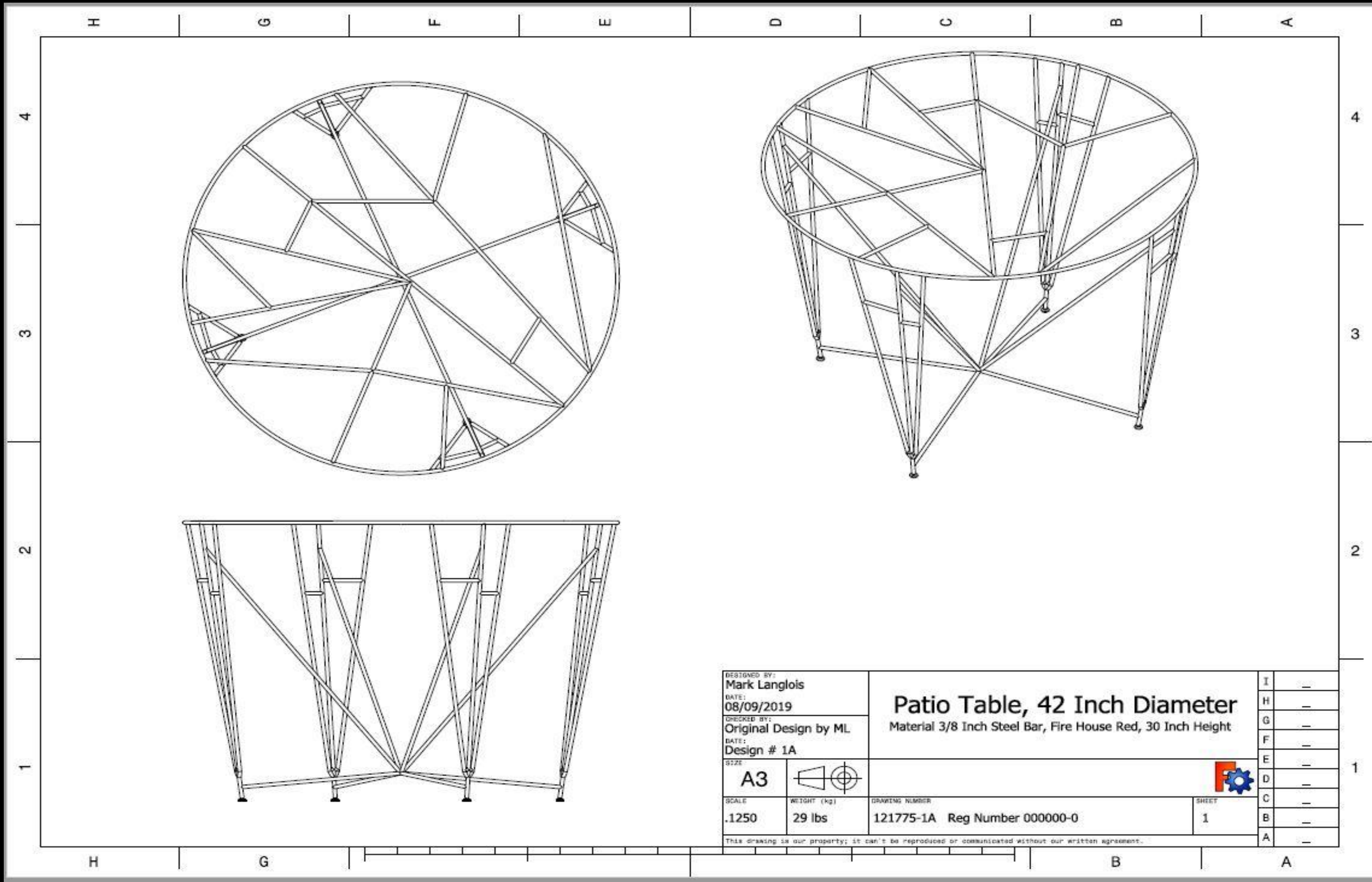
I have replicated the other three legs by rotating them around the table top ring center point. Currently, each leg represents a single solid body, along with the table top. I still need to integrate or unite each leg to the table top so all the components are incorporated into a single solid body. Once I perform this operation, the design of my new table will be complete.



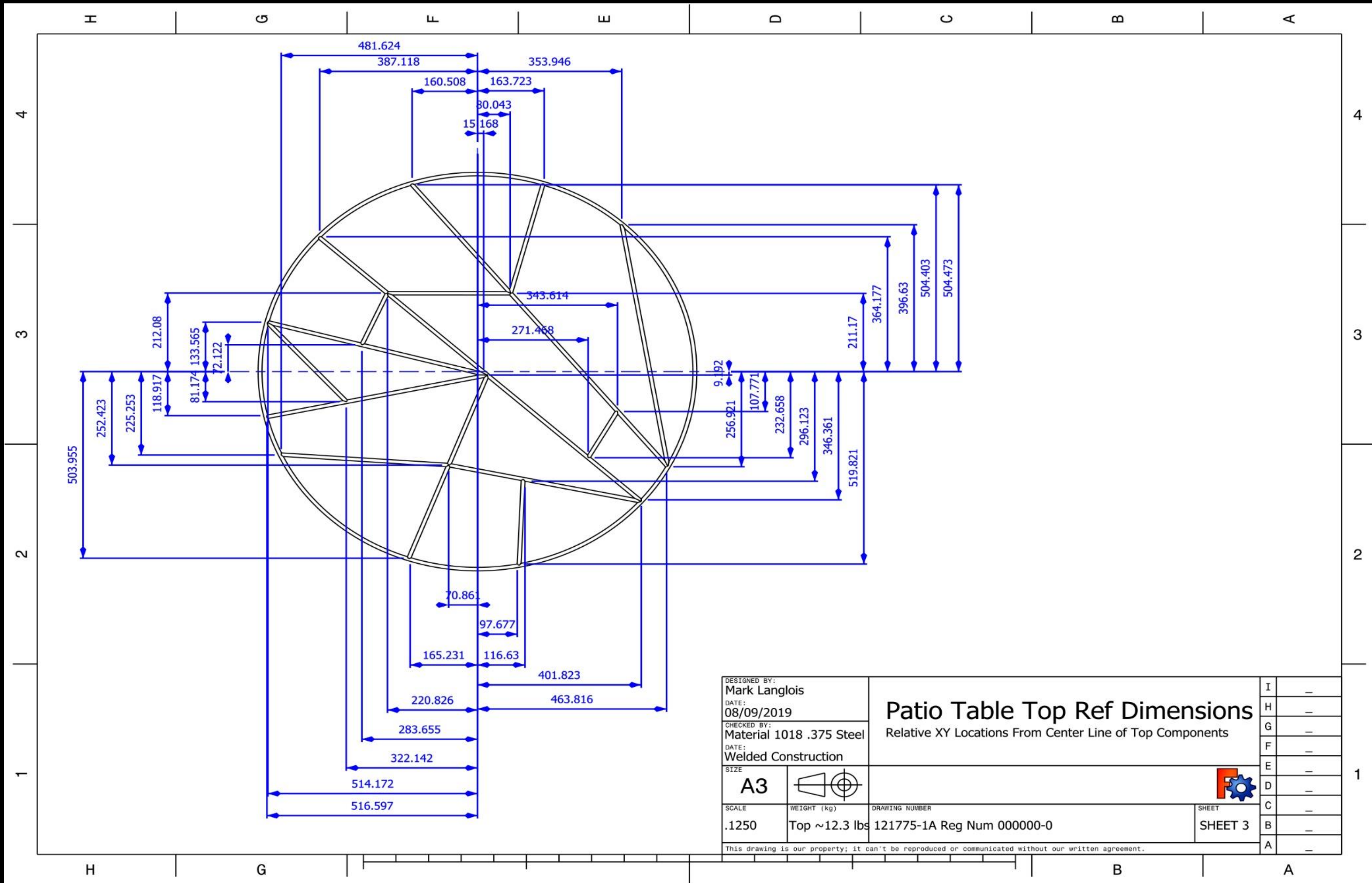
Having executed the Boolean operation to unite all of the table's remaining individual components. The highlighted table indicates that the legs are now integrated with the table top as a single solid. All of the design constructs and CAD operations required to create the table are captured in a tree structure. This tree structure allows me to select any of the individual components (table top ring, interior geometry, and leg components) and view or modify them if necessary.



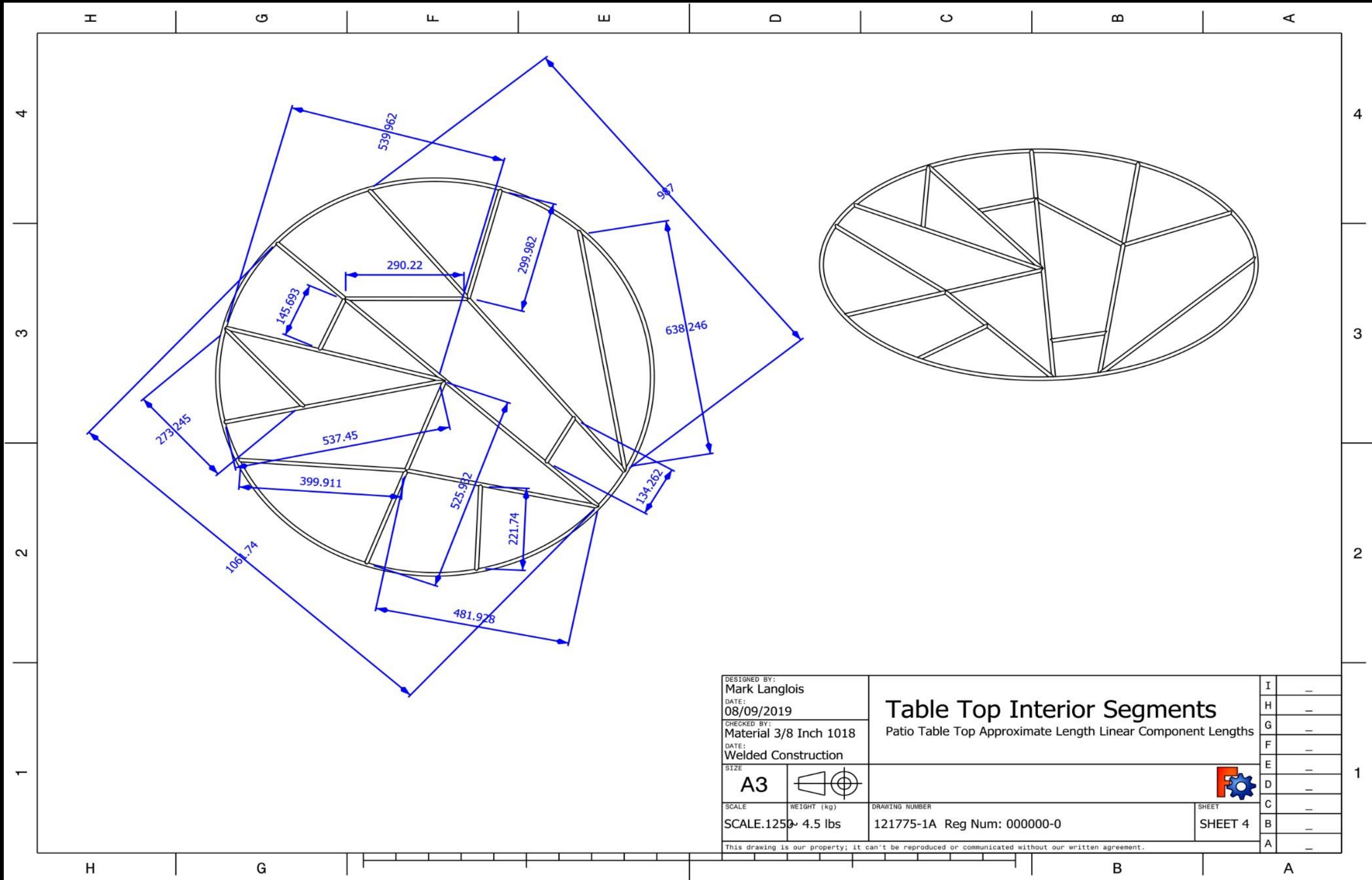
Having completed my table design, I have the option to capture and export pictorial representations of the design in both the solid form as a picture and in the context of a drawing. While the CAD files themselves can be shared, they must be exported in a format that can be imported into another CAD application.



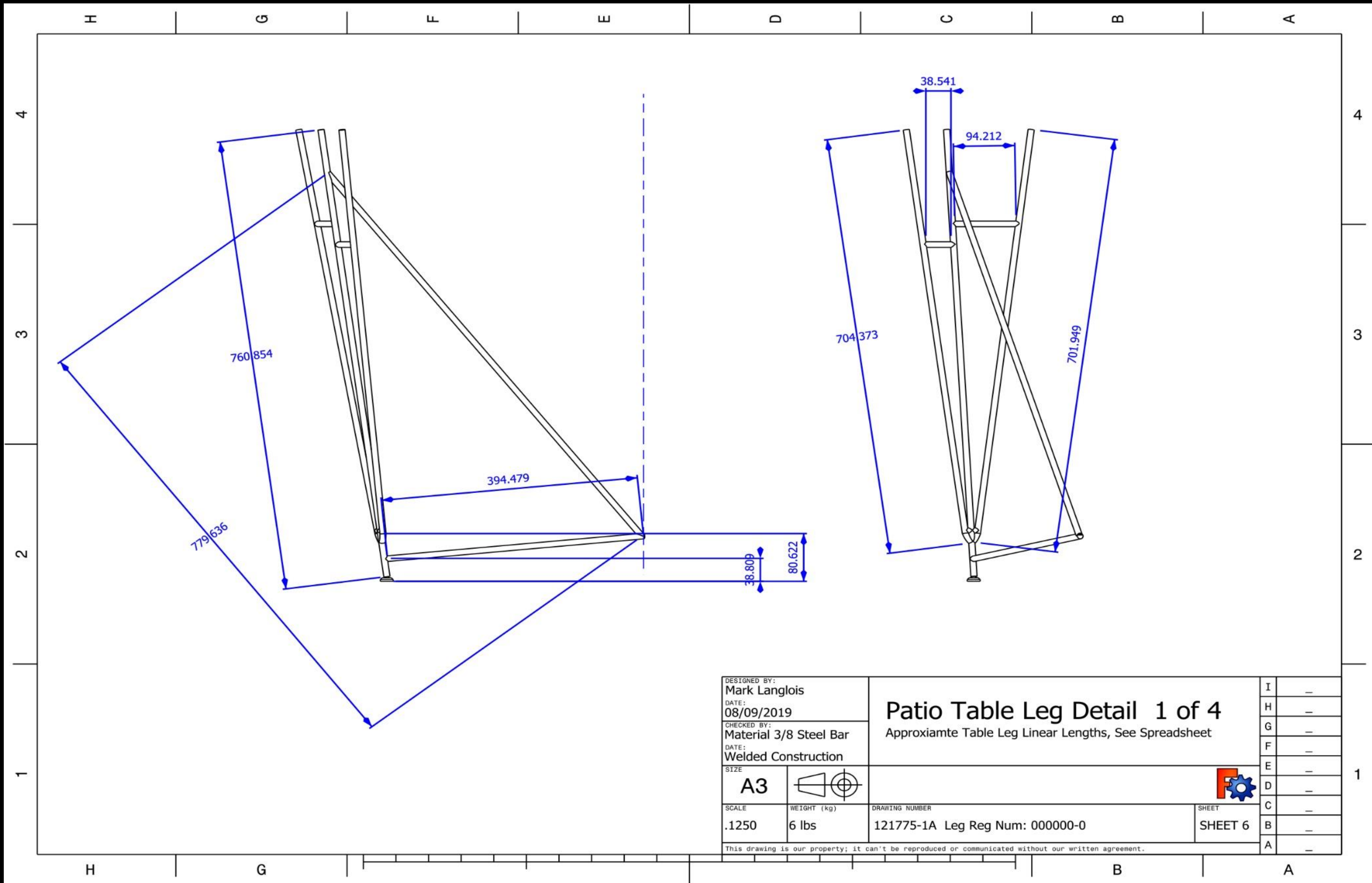
Pictorial representations in the form of PDF files, JPEG files or other formats, allow users of CAD applications to transmit and share lightweight images of design ideas and design information by email, messaging, stored on a mobile phone or other device or printed as a hard copy. I carried a large number of drawings and part designs on my iPhone to share with vendors, send as an email and for reference.



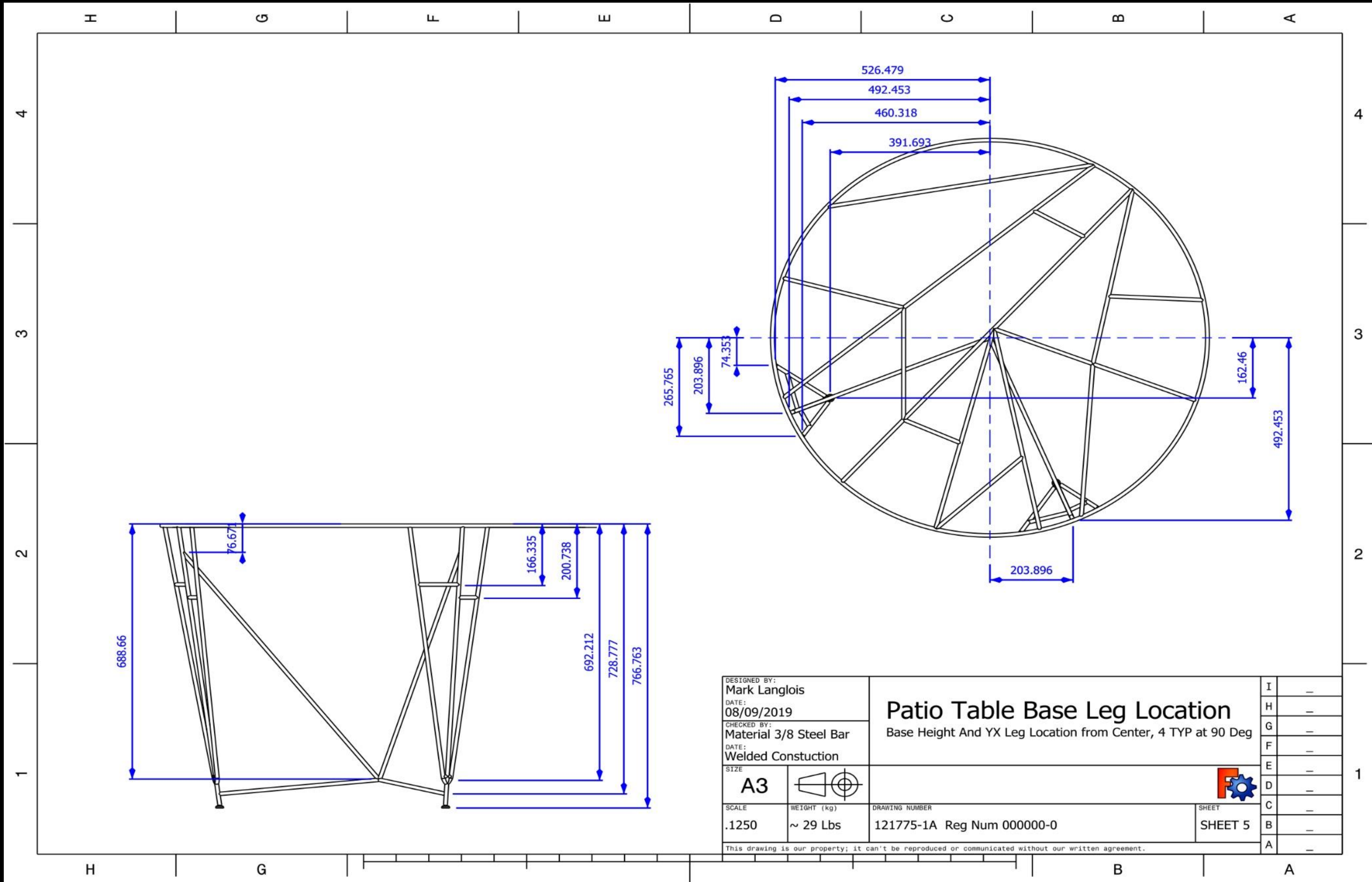
Exporting drawings and images of the component parts of my design also allows me to reference specific information without having to use the CAD application and view the model. In addition, it alleviates the necessity for me to have to repeat measurements that have already been captured. These drawings and images can also remain in a digital format, making them portable, accessible and easily viewed.



Completing the solid model that represents my table is a big first step. If I intend to bring this design into the physical world, there is a lot more work to complete. Now, I need to capture critical information that will allow me to understand the key attributes associated with this design. Capturing the true lengths of the table top interior segments is an example of the kind of information I need to evaluate.



Capturing the true lengths of each of the leg segments is another necessary key piece of information that I need. The true length measurement for each of these component segments, is the distance measured along the segment's axis or centerline.



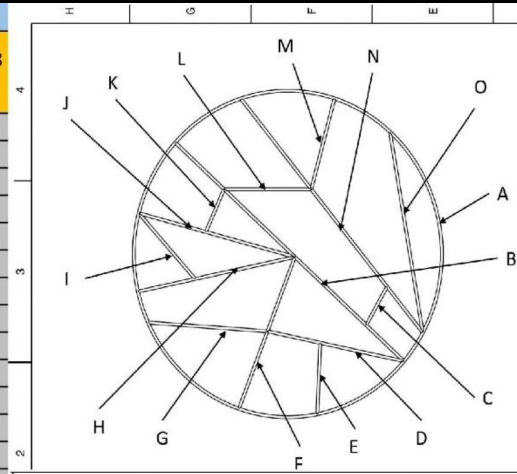
Additional key criteria that I need to evaluate, are locations and positions where rod segments are joined or oriented.

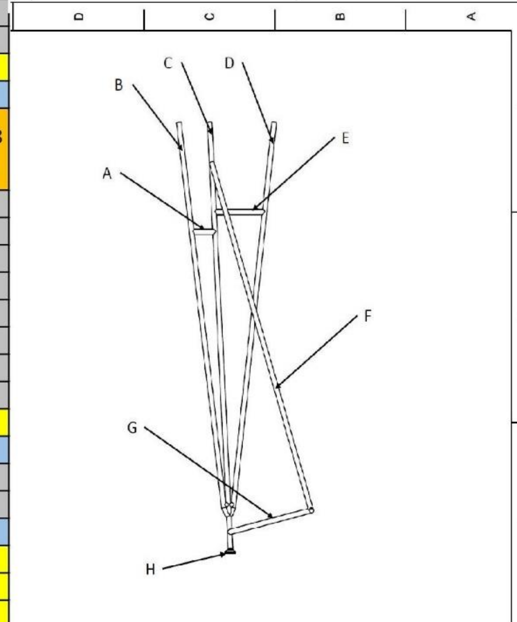
To evaluate the solid model design content associated with the table, I constructed a component breakdown chart identifying and labeling each rod segment in the completed design.

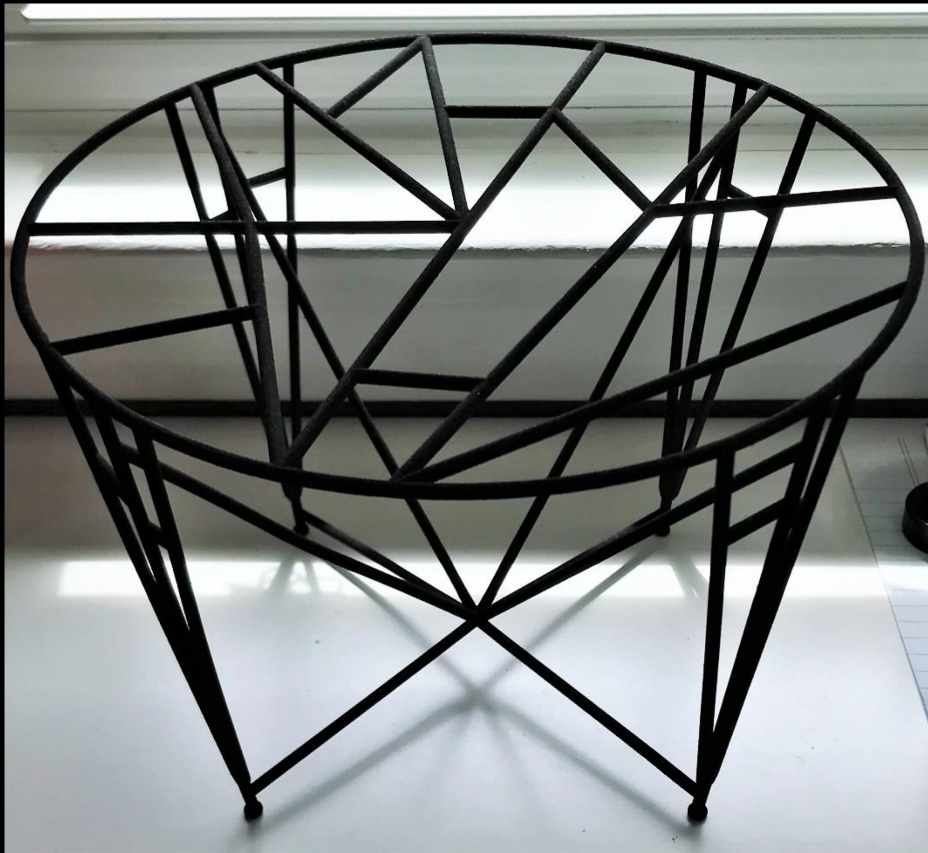
I included the true lengths captured from the previous drawings for each rod segment in the table top and for the legs. This allowed me to approximate the total linear feet of steel I would need to make a table, the approximate weight and total number of welds.

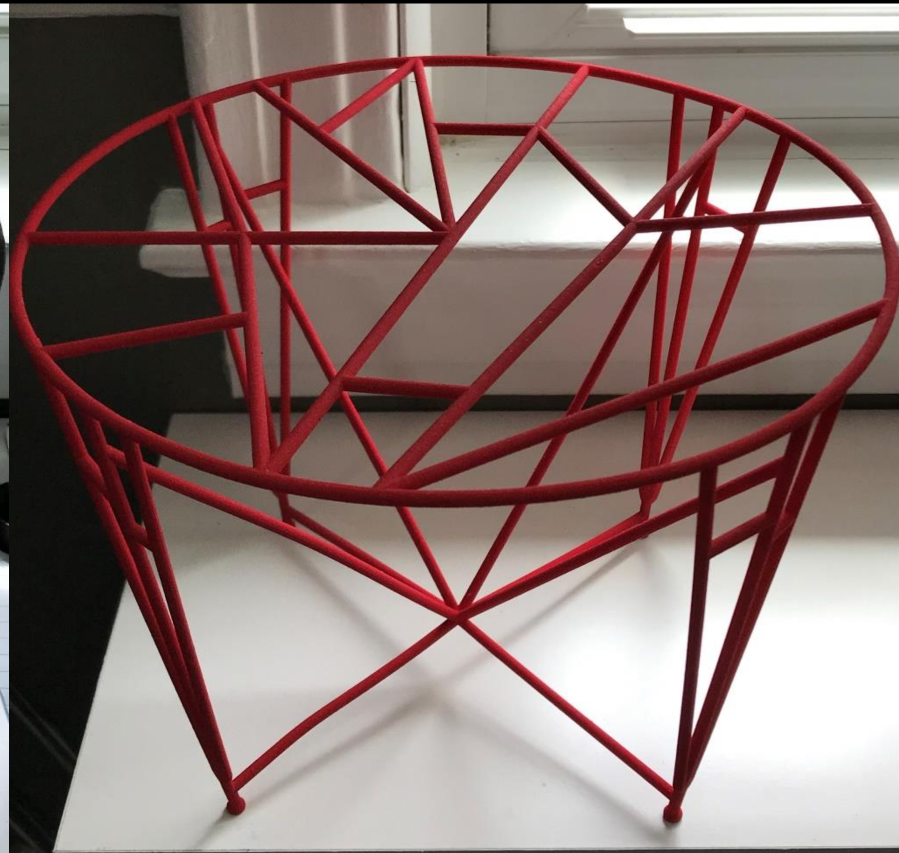
Creating this type of chart also provided the ability to forecast some initial cost estimates for material, shipping, equipment and tooling.

Patio Table Top Component Chart					
Label	Optimized Linear Length In inches	Optimized Fractional Size In Inches	Appr. Linear Length in Feet	Material Weight in lbs	Material 1018 Num Welds
A	156.0000	156.0 Inches	13.000	4.888	1
B	41.5000	41-1/2 Inches	3.458	1.300	4
C	5.3125	5-5/16 Inches	0.443	0.166	4
D	18.2500	18-1/4 Inches	1.521	0.572	4
E	8.7500	8-3/4 Inches	0.729	0.274	4
F	20.6250	20-5/8 Inches	1.719	0.646	4
G	16.0000	16.0 Inches	1.333	0.501	4
H	21.2500	21-1/4 Inches	1.771	0.666	4
I	11.0625	11-1/16 Inches	0.922	0.347	4
J	21.5000	21-1/2 Inches	1.792	0.674	4
K	5.6875	5-11/16 Inches	0.474	0.178	4
L	11.7500	11-3/4 Inches	0.979	0.368	4
M	11.5000	11-1/2 Inches	0.958	0.360	4
N	38.2500	38-1/4 Inches	3.188	1.199	4
O	24.9375	24-15/16 Inches	2.078	0.781	4
Totals	412.375		34.365	12.921	57
Patio Table Legs (4) Component Chart 1 Leg					
Label	Optimized Linear Length In inches	Optimized Fractional Size In Inches	Appr. Linear Length in Feet	Material Weight in lbs	Material 1018 Num Welds
A	1.6875	1-11/16 inches	0.141	0.053	4
B	27.1875	27-3/16 Inches	2.266	0.852	4
C	30.0000	30.0 Inches	2.500	0.940	4
D	27.4375	27-7/16 Inches	2.286	0.860	4
E	3.7500	3-3/4 Inches	0.313	0.118	4
F	30.3750	30-3/8 Inches	2.531	0.952	4
G	16.6250	16-5/8 Inches	1.385	0.521	4
H	0.0394	N/A	0.003	0.001	0
Totals	137.102		11.425	4.296	112
Total Approx. Patio Table Base & Top--Linear Length and Weight					
A	Linear Length ft.		80.065		
B	Table Weight lbs		30.105		
Total Welds, Top, Legs, Leg to Table Top, Center Bars To Center Bars					
A	Weld Legs to Top				12
B	Weld Center Bars To Center Bars				8
Totals	Total Number of Welds				189

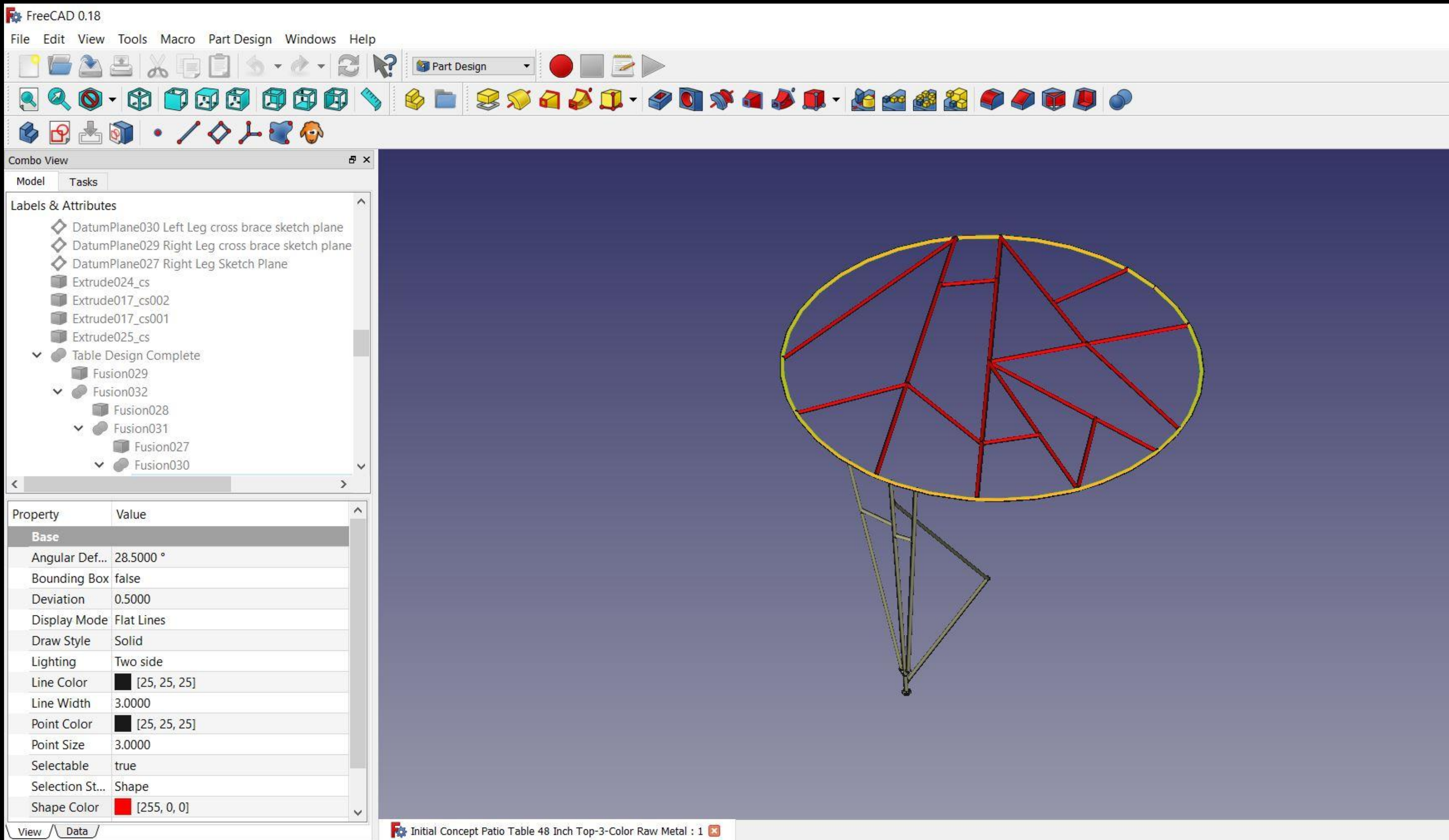






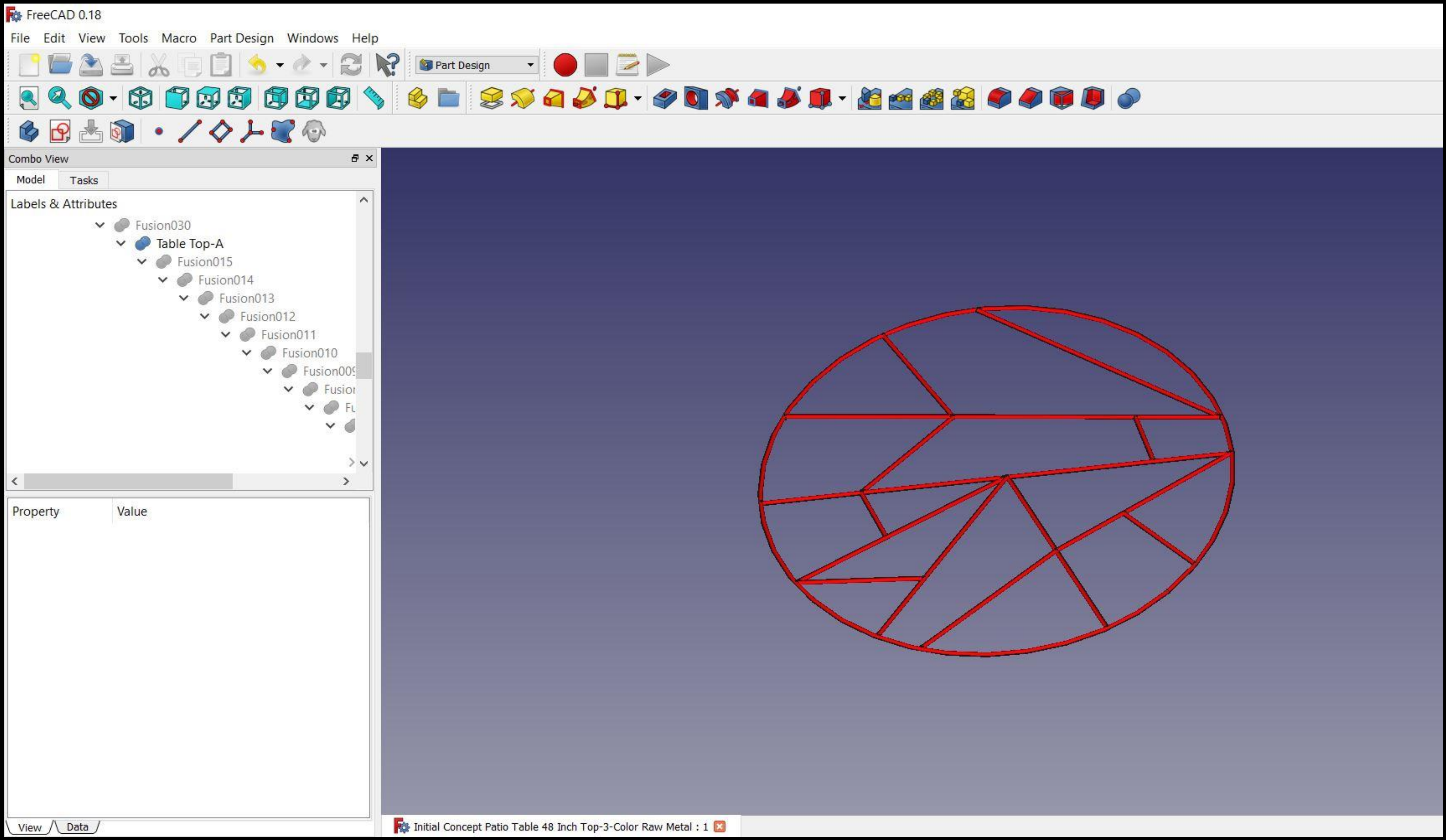


While I have completed the initial table design, extracted some important information from the model and charted some estimates on component build criteria, the decision to go forward and make the table has not yet been determined. Up to this point, all of the work that has been accomplished has been an investment in my individual time. The decision to bring the table as designed represented by the CAD solid model, now requires an investment in cash. The first sum of money that I spent in the creation of these tables, was to have a 3D printed model made so that I could see a physical representation of my design. Validating the CAD Model with a physical model, was important for me in deciding to move ahead with further development.   After evaluating the 3D printed models and some serious thought, I decided to move forward with the next step in the process and create the fixtures necessary to make this table as designed.

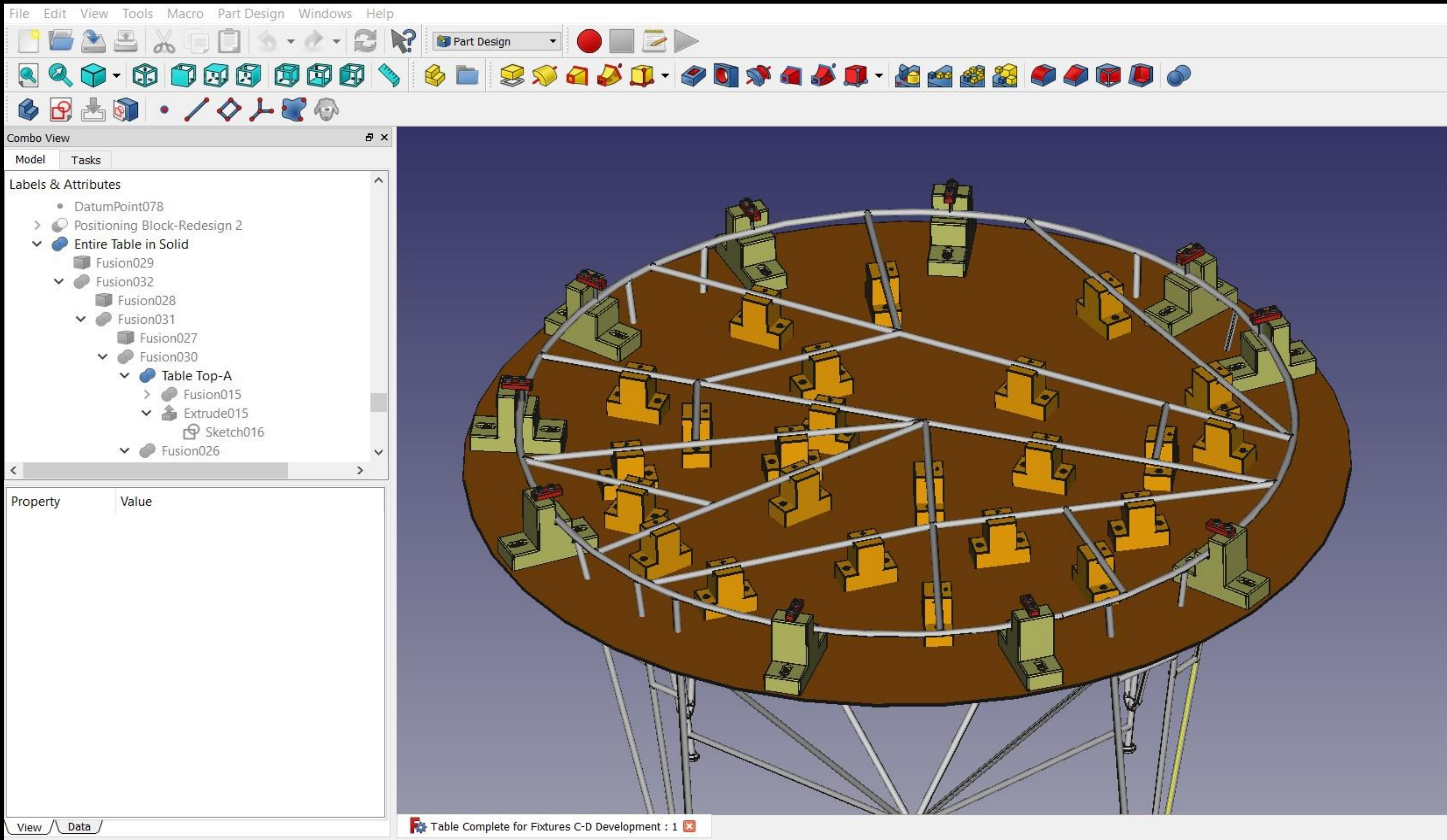


The table as designed is made of steel and the components are welded together. There are three major components in the construction of my design. The first, being the table top ring (shown in orange), the second, are the interior components that define the geometric design in the table top (shown in red), and the third component, is the leg that support the table top (shown in olive). The leg is constructed once and copied three more times, spaced 90 degrees apart.

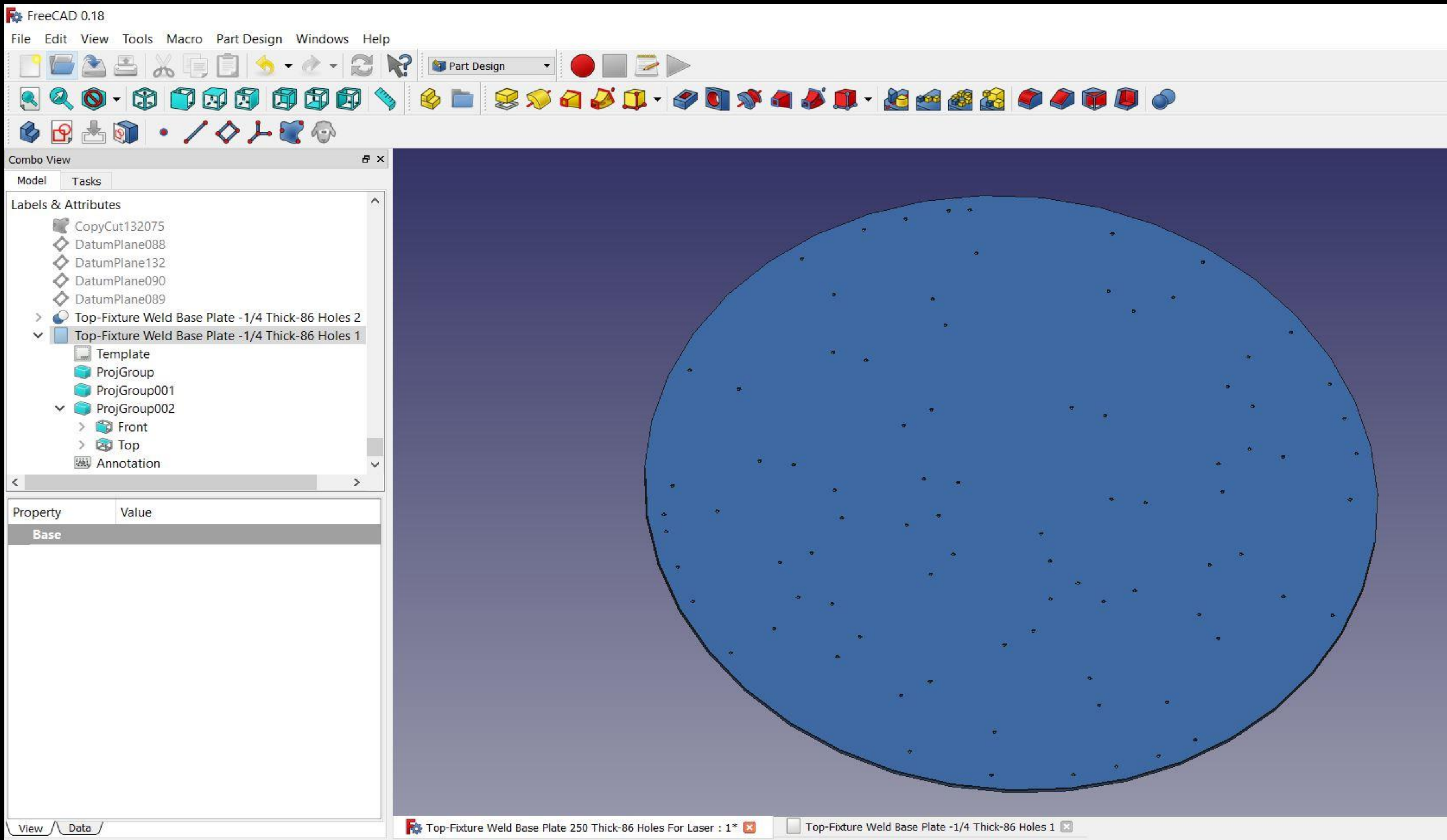
The First Component, The Table Top Ring: The table top ring is a purchased, manufactured component. The reason for this is simple. I didn't have the space or equipment to make the ring. The last time I made this ring 40 years ago, I hand bent 13 feet of steel rod around a plywood form and welded it. My ring was never really round. This ring is roll formed and butt welded; it is round. I hand finished each welded ring so there is no visible seam.



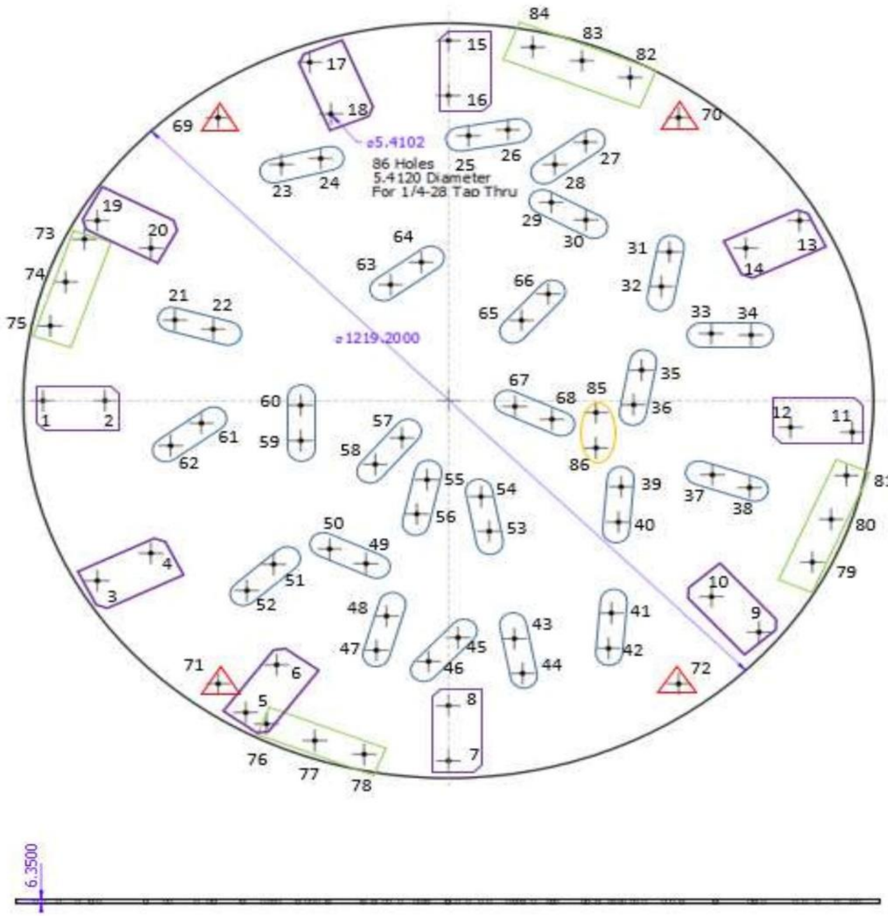
The Second Component, The Geometric Interior Segments For The Table Top: This second component includes the first component, the outer table top ring. At this point, we enter into a new phase of design and development; design for manufacture. In this phase, I need to design work holding and positioning devices that will keep the top in the correct location, orientation and in the correct plane. To do this, I will need to use existing elements of the table solid model to create the necessary tools and fixtures. This design approach is often called "Design in Context".



The picture above shows the basic concept of "Design in Context". The geometric elements that define the table solid model are leveraged to locate, position, orient and shape the tooling required to make the table top. To construct the table top what do I need? I need a base plate; to attach, locate and position the work holding devices. I need to design some fixtures to hold the table top ring and I also need some fixtures to locate, position, and orient the interior components for the top.



Weld Fixture Base Plate: The weld fixture base plate that I designed is 48 inches in diameter, 1/4 inch thick, A36 steel plate. The plate is used as a weld fixture base for the construction of the table top only. The solid model of the plate is shown above, with holes in the plate that are extrusions sized for a 1/4-28 tap drill and subtracted from the solid body. All holes are tapped with a 1/4-28 tap through the plate.



See (X,Y) Hole Locations From 48 inch Diameter Center
Corresponding to Number Shown. All Holes, 1/4-28 Tapped Holes

Note: Footprint grouping of holes done for visual clarity only

Fixture Base & Weld Skirt Hole Locations: Units in mm					
Ring Shoe Hole Locations From 1219.2 Dia. Center Point: 1/4-28 Tapped Holes All Holes					
Hole Number	Location X	Location Y	Hole Number	Location X	Location Y
1	-581.5172	0.0000	2	-492.6172	0.0000
3	-503.6086	-290.7586	4	-426.6190	-246.3086
5	-290.7586	-503.6086	6	-246.3086	-426.6190
7	0.0000	-581.5172	8	0.0000	-492.6172
9	445.4680	-373.7920	10	377.3666	-316.6482
11	579.3043	-50.6826	12	490.7426	-42.9344
13	503.6086	290.7586	14	426.6190	246.3086
15	0.0000	581.5172	16	0.0000	492.6172
17	-198.8906	546.4474	18	-168.4850	462.9087
19	-503.6086	290.7586	20	-426.6190	246.3086
Position Block Hole Locations From 1219.2 Dia. Center Point					
Hole Number	Location X	Location Y	Hole Number	Location X	Location Y
21	-392.4053	130.2626	22	-337.2448	115.3147
23	-239.4051	381.4279	24	-183.0913	391.1685
25	28.9569	427.8539	26	85.2707	437.5945
27	196.7242	417.6224	28	152.6165	381.2818
29	147.5402	320.2420	30	197.1332	291.8403
31	316.9471	240.2478	32	305.3398	184.2889
33	377.0267	108.3445	34	434.1227	105.8610
35	277.2371	49.2878	36	265.6298	-6.6711
37	378.7341	-119.7080	38	431.9851	-140.4555
39	247.7406	-139.0432	40	243.8244	-196.0588
41	233.7481	-342.9742	42	229.7324	-399.9829
43	94.6292	-384.3201	44	106.2993	-440.2659
45	13.7501	-382.6157	46	-28.5111	-421.0879
47	-103.4225	-403.0823	48	-88.8060	-347.8330
49	-118.2094	-263.0398	50	-170.3028	-239.5366
51	-250.6781	-264.2169	52	-288.9638	-306.6472
53	58.5313	-210.9122	54	46.8612	-154.9664
55	-30.6890	-127.7210	56	-45.3055	-182.9703
57	-66.6781	-60.2981	58	-104.9638	-102.7284
59	-211.6661	-64.5683	60	-211.6483	-7.4183
61	-354.2758	-36.3776	62	-398.3835	-72.7182
63	-82.8835	187.2818	64	-38.7758	223.6224
65	104.8362	129.8558	66	143.1219	172.2861
67	95.3741	-9.3270	68	148.6251	-30.0745
Weld Base Lift Block Hole Locations From 1219.2 Dia. Center Point					
Hole Number	Location X	Location Y	Hole Number	Location X	Location Y
69	-330.2000	457.2000	70	330.2000	457.2000
71	-330.2000	-457.2000	72	330.2000	-457.2000
Top-Leg Assembly Locating Block, 4 Places					
Hole Number	Location X	Location Y	Hole Number	Location X	Location Y
73	-522.0638	260.8012	74	-549.0170	191.7253
75	-570.9240	120.8872	76	-260.8012	-522.0638
77	-191.7253	-549.0170	78	-120.8872	-570.9240
79	522.0638	-260.8012	80	549.0170	-191.7253
81	570.9240	-120.8872	82	260.8012	522.0638
83	191.7253	549.0170	84	120.8872	570.9240
Assembly Top Orientation/Position Block					
Hole Number	Location X	Location Y	Hole Number	Location X	Location Y
85	211.7137	-76.2978	86	211.6959	-19.1478

Author: Mark Langlois Appr.: Mark Langlois	Legal owner: Mark Langlois	Scale: M 1:4 Toler.: +/- .2 mm	Sheet: 1 of 1 Size: A2
TITLE: Fixture Weld Base Plate, Top, 48 In. Dia, Redesign for Laser Laser Cut .213 in (5.4102 mm) Diameter, 86 Holes Tap All Holes 86 Holes, 1/4-28 Thread Thru		Part material: Steel Plate, A36, 1/4 In. Part number: ML-0000-A100-2 Drawing no.: ML-121775-A100-2	
Document type: Mechanical assembly drawing		Date: 05/14/2020	Revision: REV C

Base Plate Drawing: The base plate has 86 holes that were laser cut using an exported .step file. The table on the drawing provides the X-Y hole locations for reference and correspond to the hole number on the plate. I made the drawing showing the holes grouped with different outlines to identify the component fixtures located on the plate. The holes outlined with a diamond are for lift hooks; the plate without fixtures weighs close to 400 lbs.

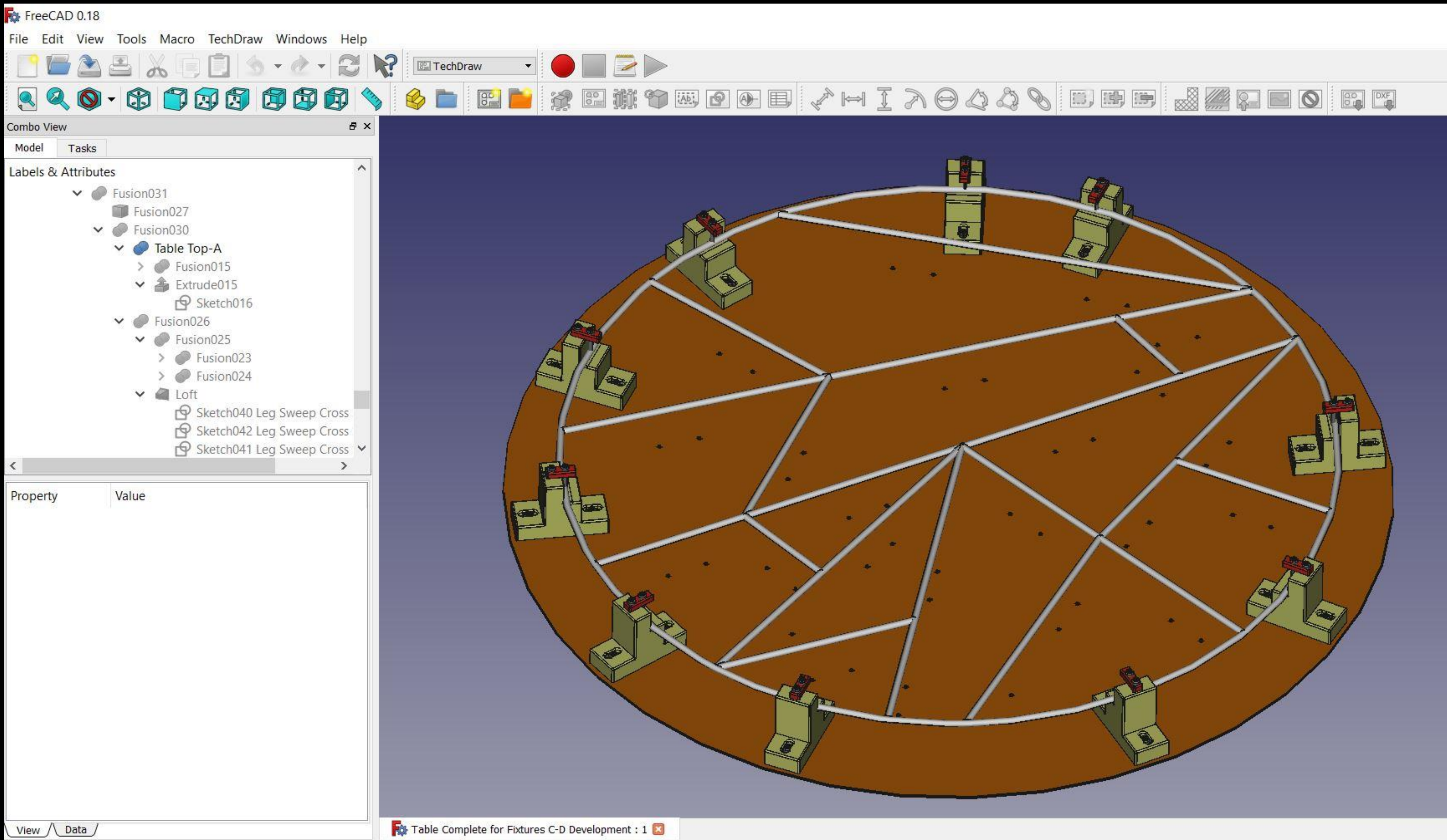


Table Top Ring Weld Shoes: I designed the table top ring weld shoes to perform a number of functions. They are a work holding device to secure the table top ring in place. They also elevate the ring off of the base plate 2.5 inches. The shoes are located and spaced so that they don't interfere with the interior table components that get welded to the inside ring diameter. Each weld shoe can move in a direction perpendicular to the table top ring diameter. The ten ring weld shoes provide a consistent level of support around the ring diameter and also keeps the ring in plane.

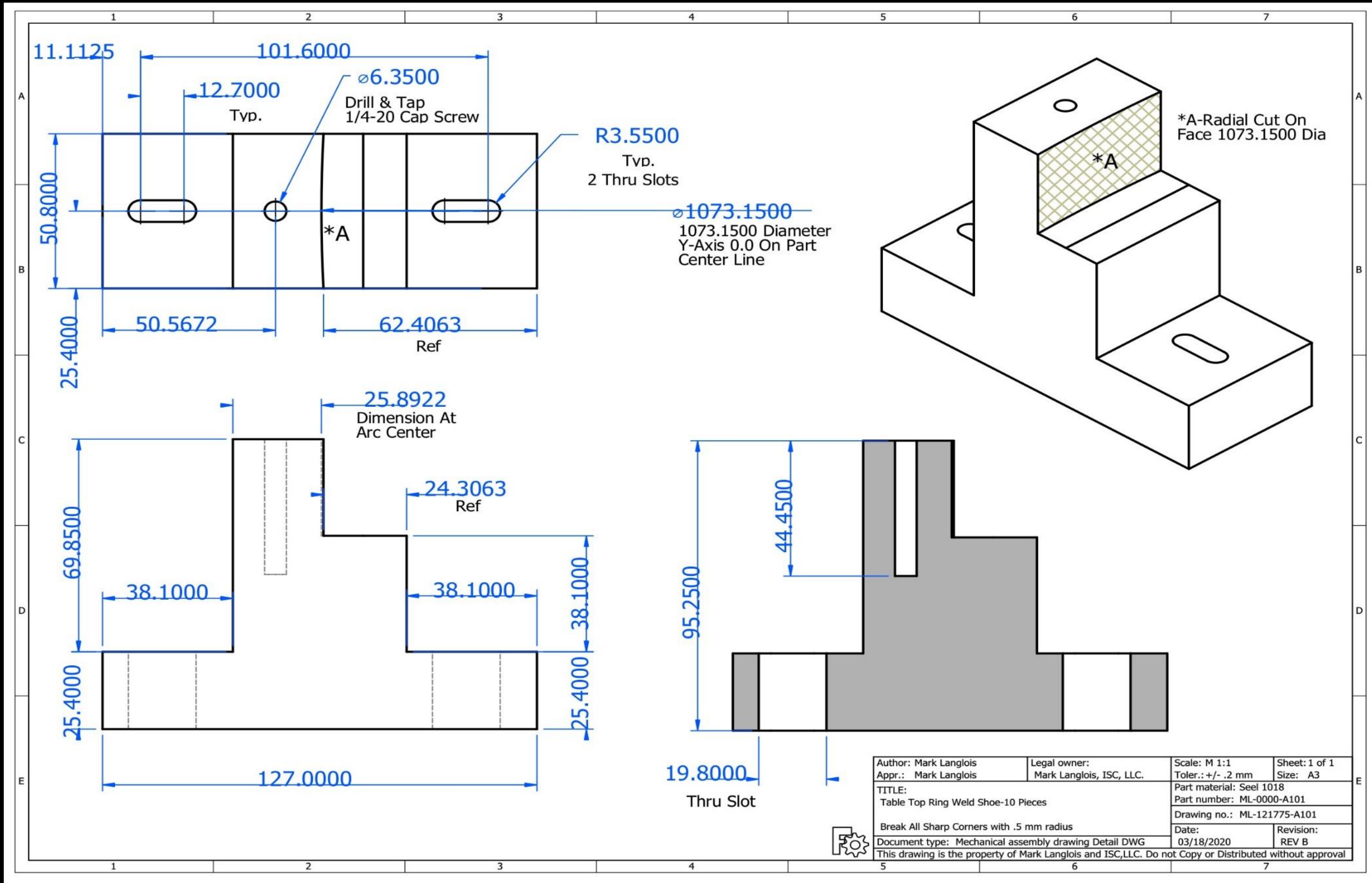
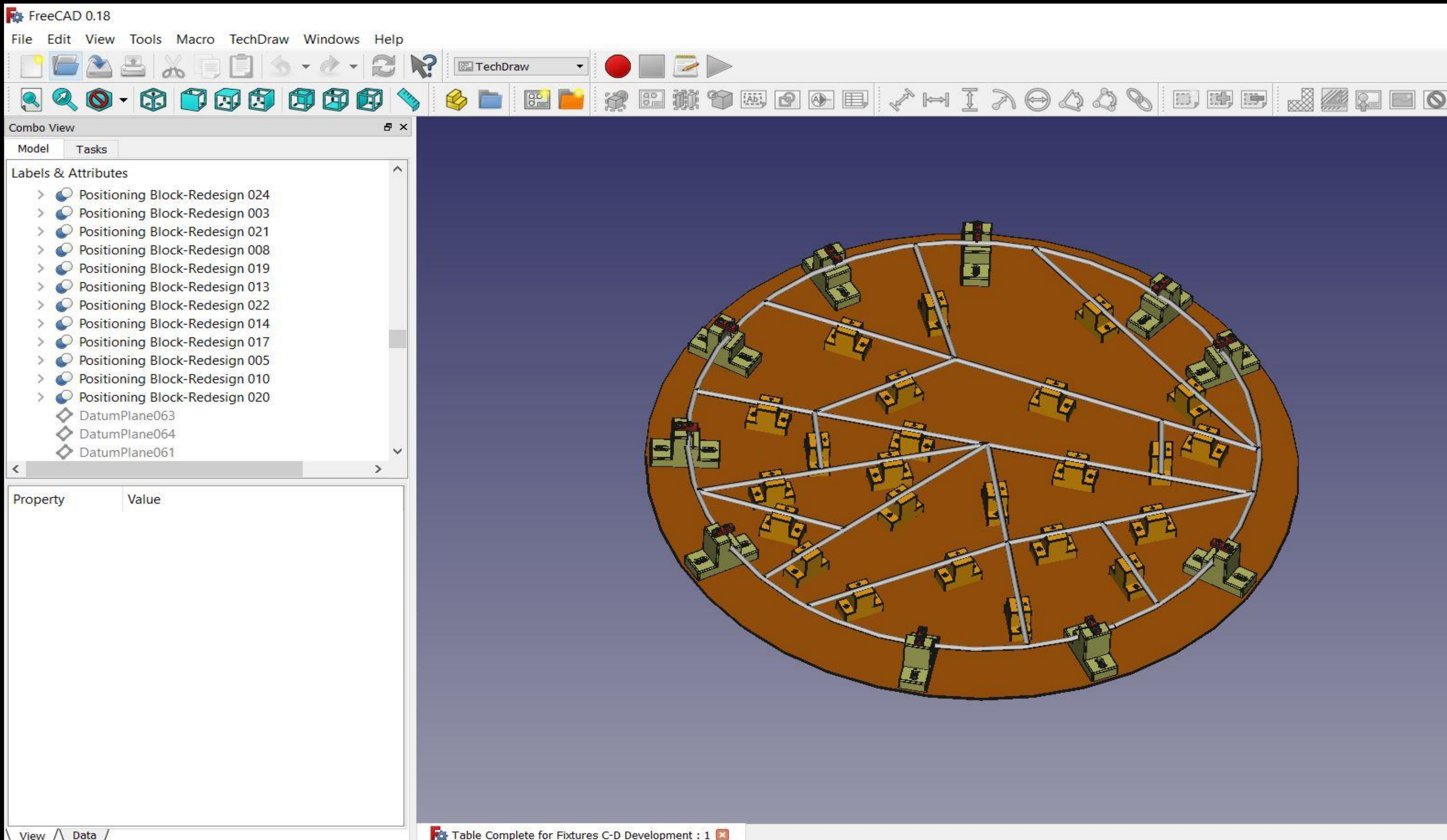
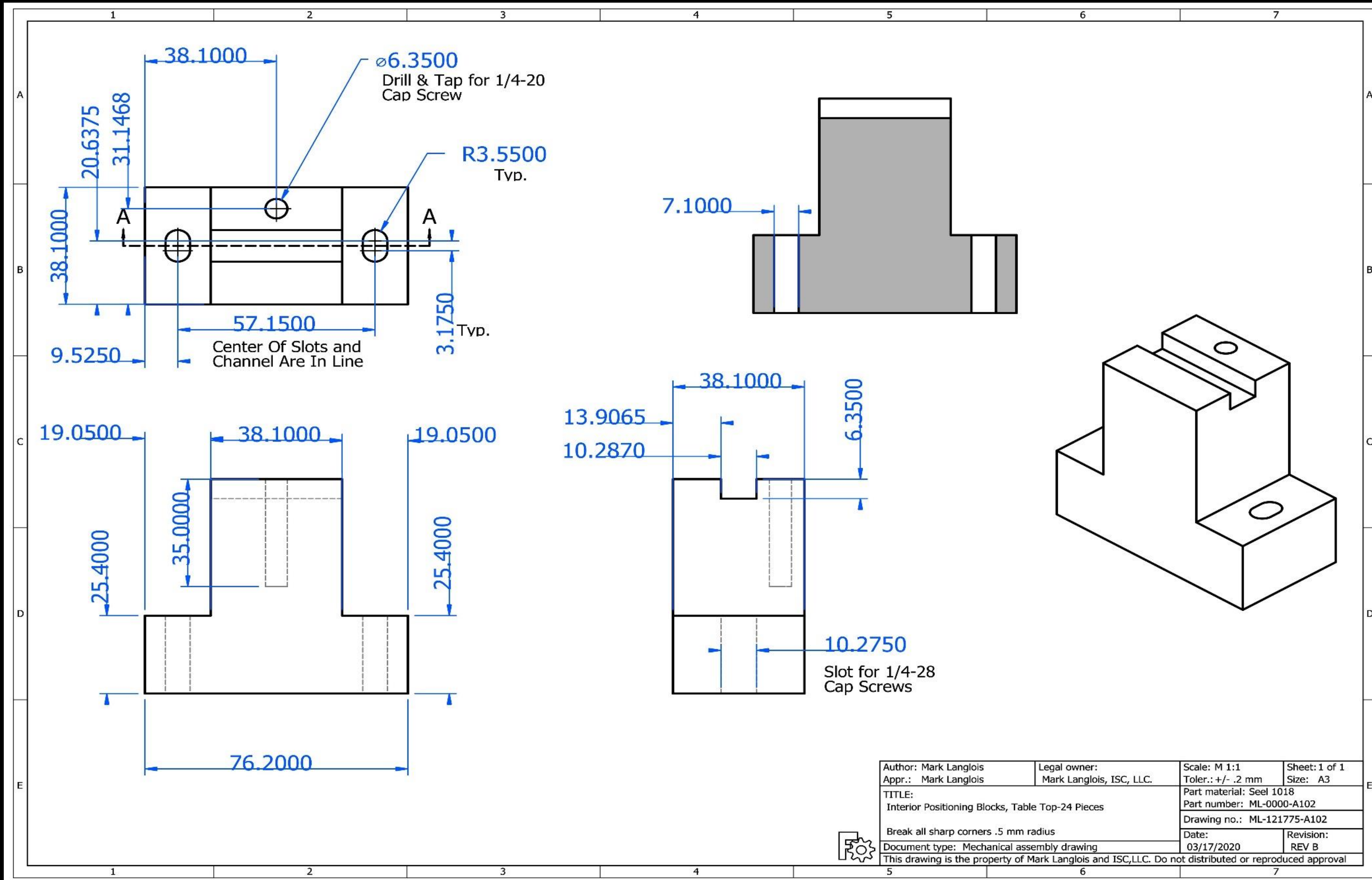


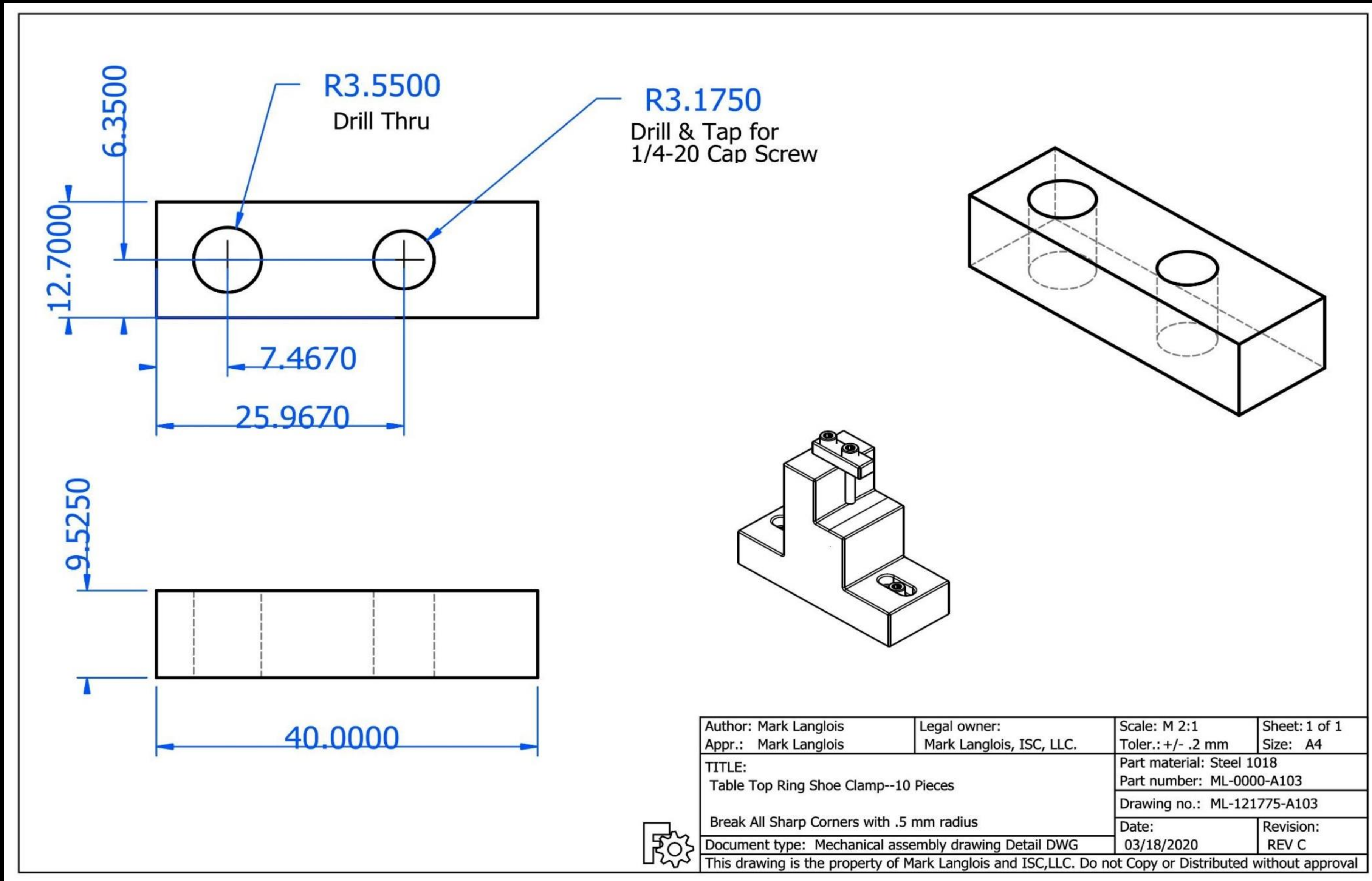
Table Top Ring Weld Shoe Drawing: The ten top ring weld shoes were made by my supplier using CNC machining. The outer diameter of the table top ring is machined into the upper face on all of the ring shoes to allow for consistent contact and easy alignment (Face *A on the print). A clamp secures the table top ring to the weld shoe on the bottom of Face *A.



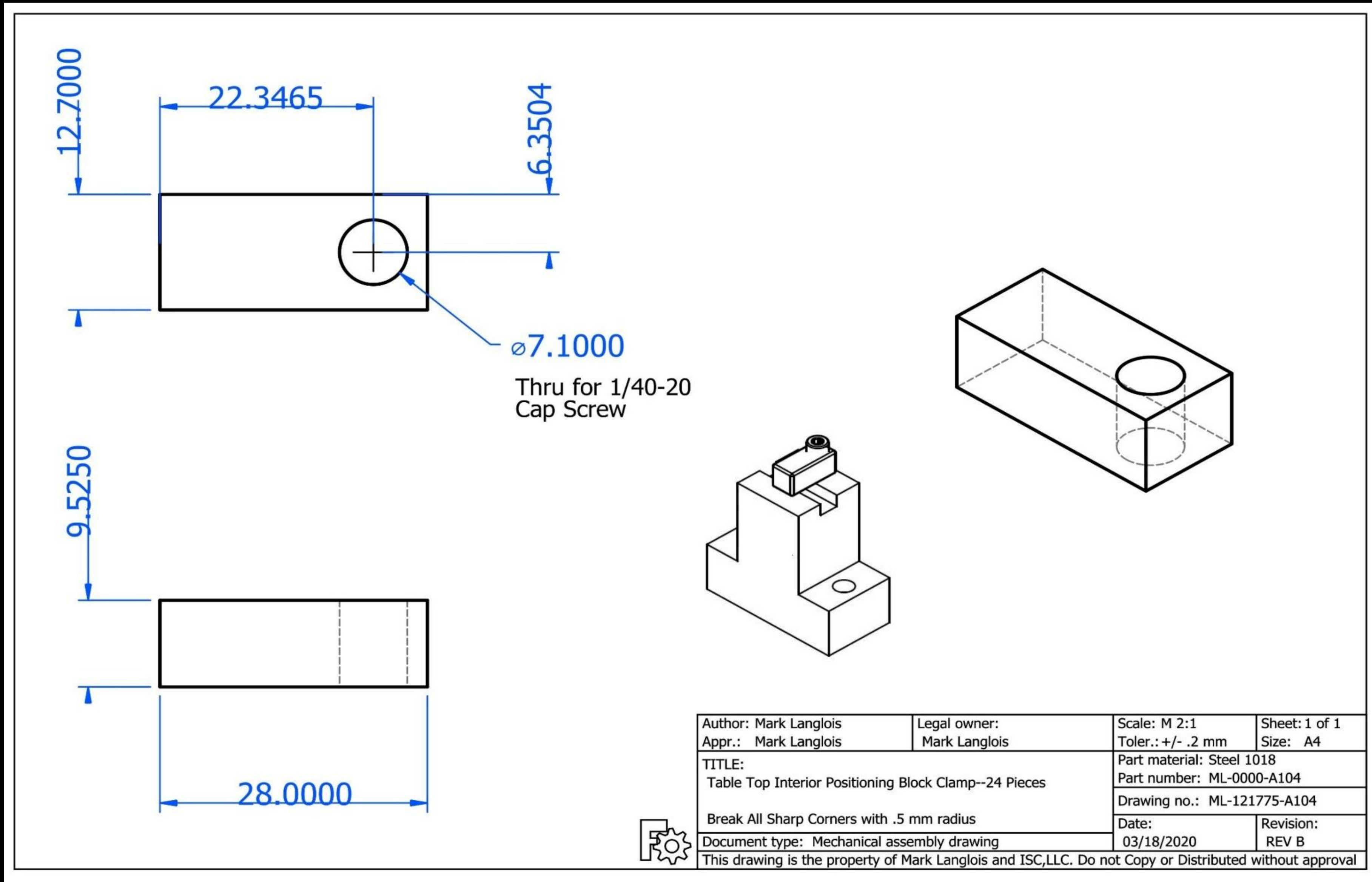
Interior Positioning Blocks: The interior positioning blocks shown above in orange, were designed to align and clamp the steel bar that defines the interior of the table top. The positioning blocks locate the steel bar segments in the same plane as the table top ring and supports the bar across the length of the segment. The longer segments however, require more blocks. My objective in designing these blocks was to provide the functional support in a simple fixture with a small footprint and easy to make.



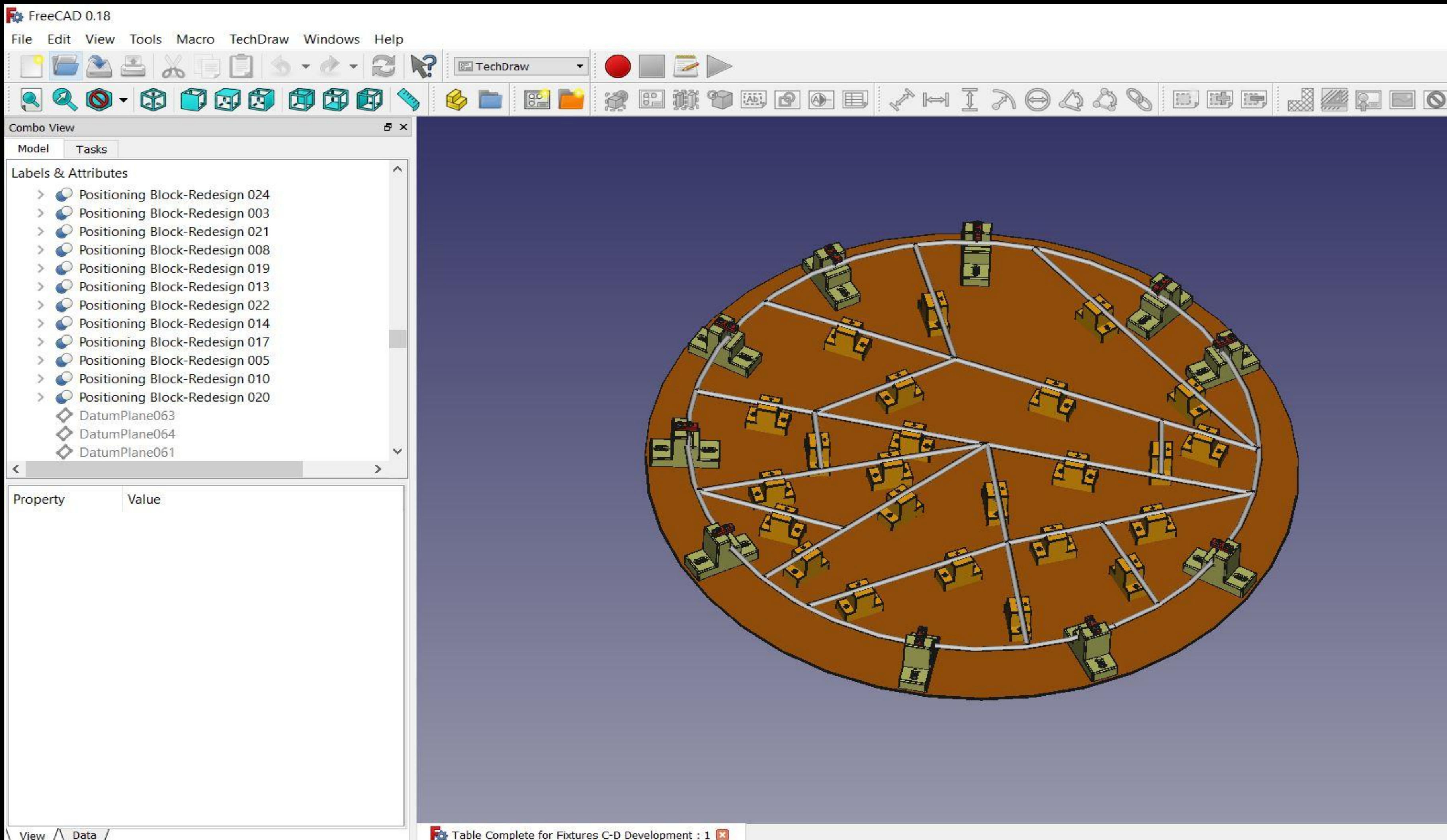
Interior Positioning Block Drawing: There are 24 positioning blocks that are paired with the interior steel rod segments. The blocks were CNC machined by my supplier. Each of the block's hole positions were aligned with the axis of each steel rod segment and transferred to the weld base plate. The positioning blocks locate on these holes. The slotted holes in the blocks allow the blocks to float slightly, perpendicular to the steel rod segment axis for alignment.



Ring Weld Shoe Clamps: My clamp for the table top ring weld shoes was designed to hold the table top ring in position with a set screw, clamping the ring on the center line of the ring diameter. There are 10 of these clamps, one for each of the ring weld shoes.



Interior Positioning Block Clamps: There are 24 of these clamps. I designed these clamps as a simple strap clamp, where the clamp body lays on top of the steel bar. When the screw on the back is tightened down, the clamp forces the round steel bar into the positioning block's channel, locking it in place. Both the weld shoe clamps and the positioning block clamps were CNC machined by my supplier.



My Table Top Fixture Design Complete: 1) Weld Base Plate, 2) Table Top Ring Weld Shoes, 3) Interior Positioning Blocks, 4) Ring Weld Shoe Clamps, 5) Interior Positioning Block Clamps.

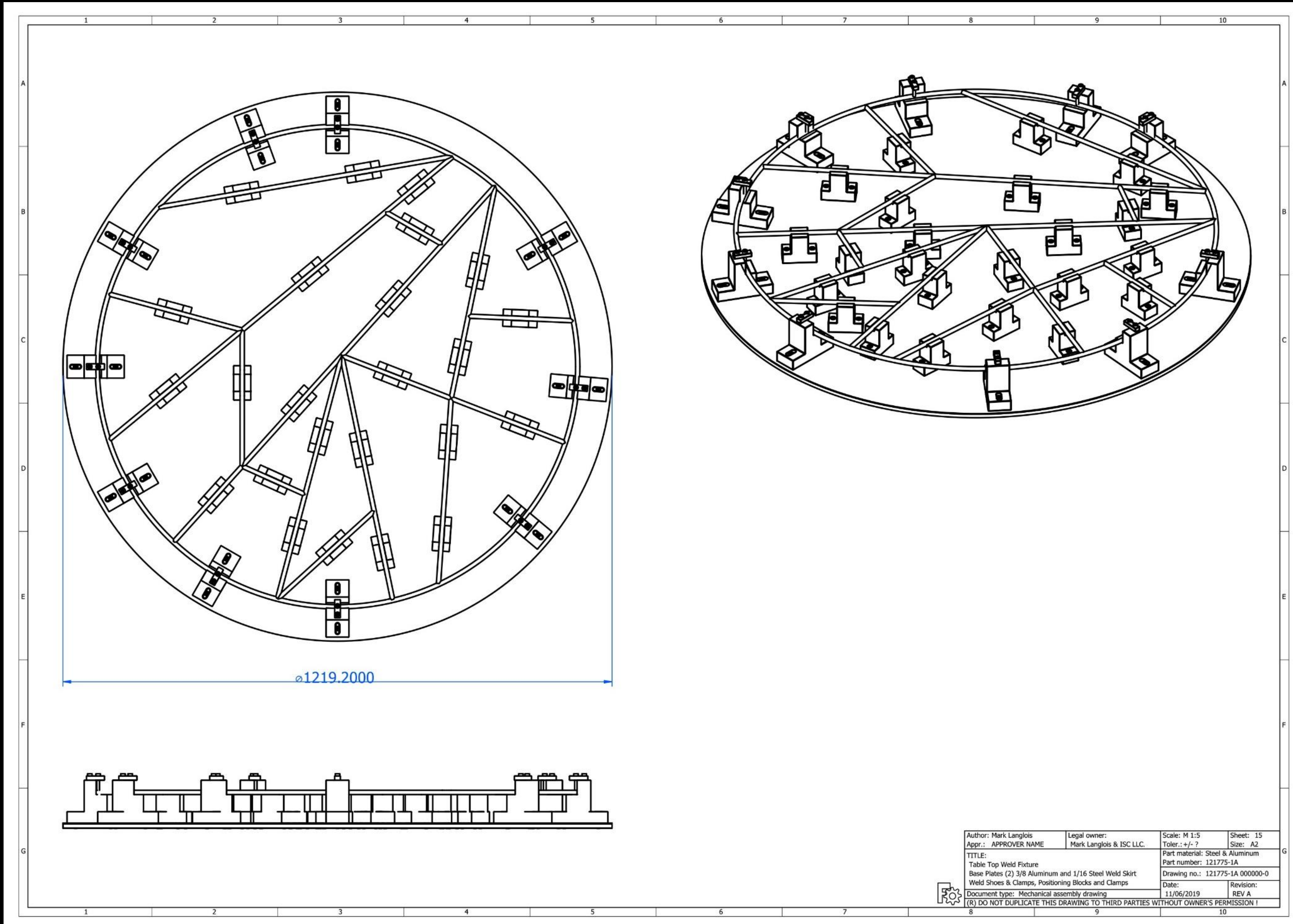
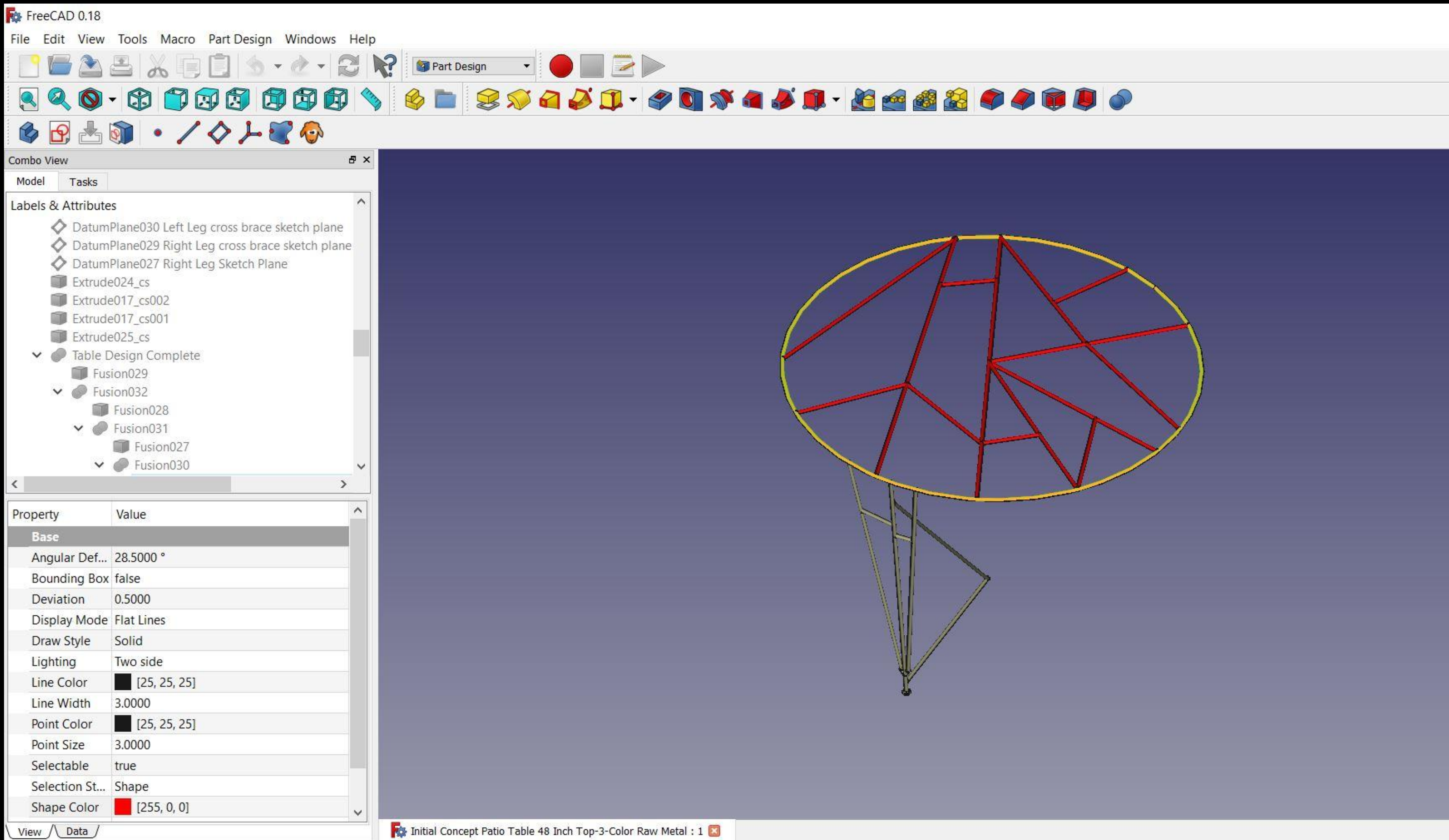
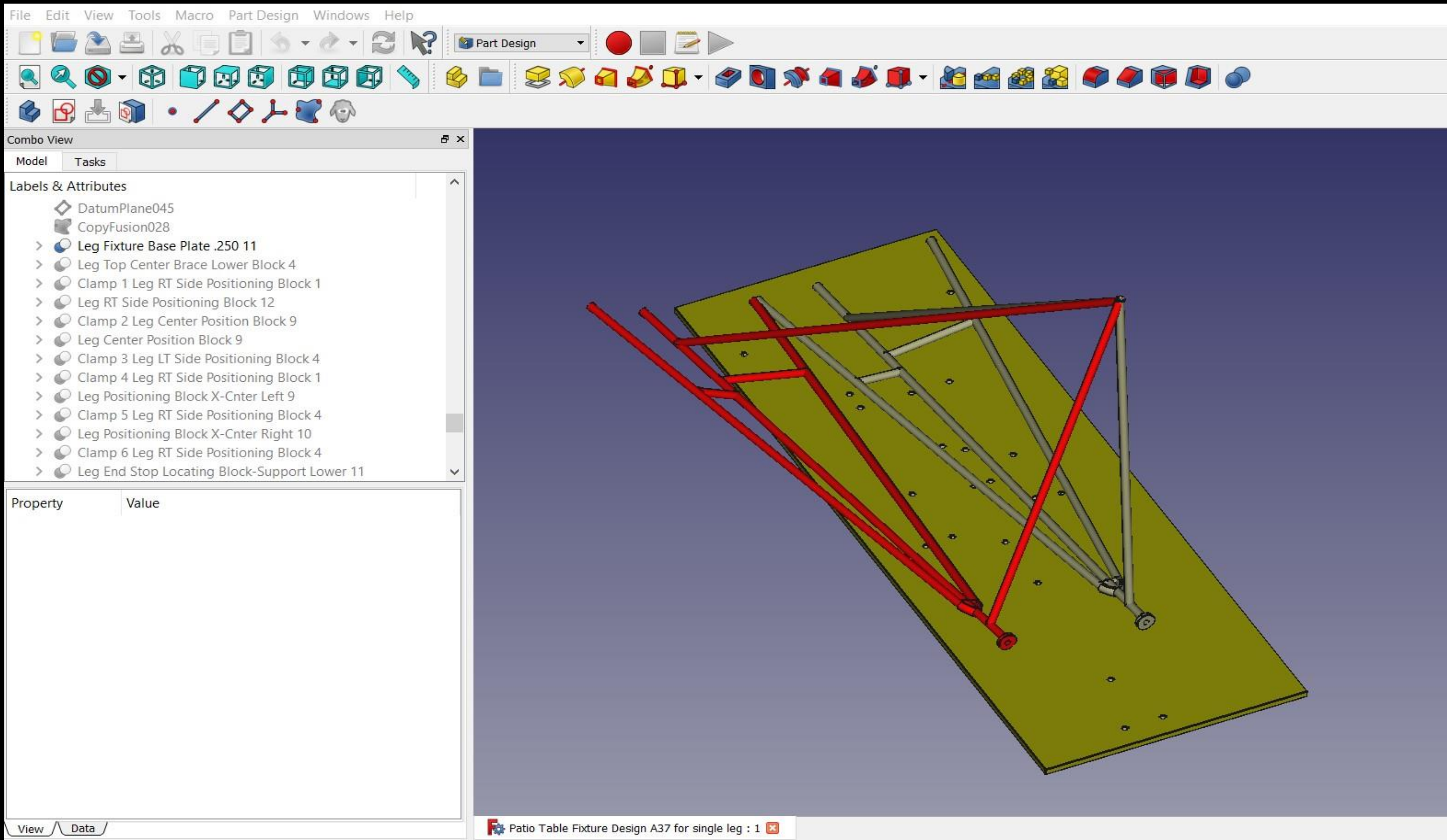


Table Top Fixture Assembly Drawing.



The Third Component Is The Leg: The leg component not only requires using "Design in Context" (using the existing solid model to assist in the development of tools and fixtures), it requires that I orient this solid model into a suitable build position. While the leg tooling could be designed to be welded in a vertical position as shown, I believe it would be more difficult. I designed the fixture and tooling to build the leg, in a plane parallel with the table top. This required making a copy of the leg and taking it out of its initially designed position.



The leg in the new build position will be constructed in a plane parallel with the table top. In the solid model design, the position of the leg (shown in red), is at an angular orientation off of the table top centerline location at 0 degrees. I need to rotate the leg component so that the center rod segment is in the new position (shown in gold), on the table centerline at 0 degrees. In this position, the design complexity necessary to create fixtures for the leg is greatly reduced. Creating the leg in this "build" position will have no impact on the original design. Each leg will be assembled in its original design position.

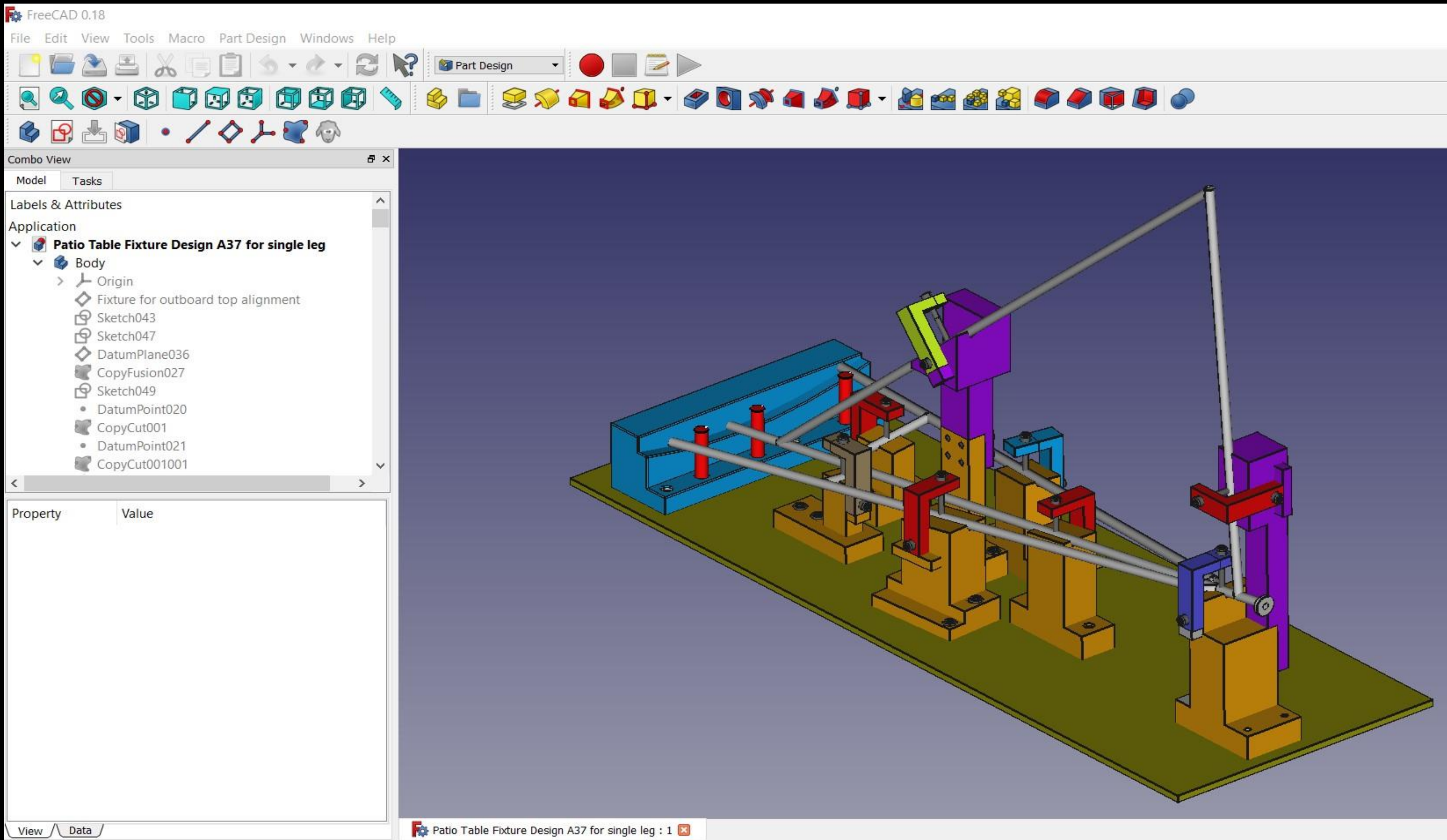
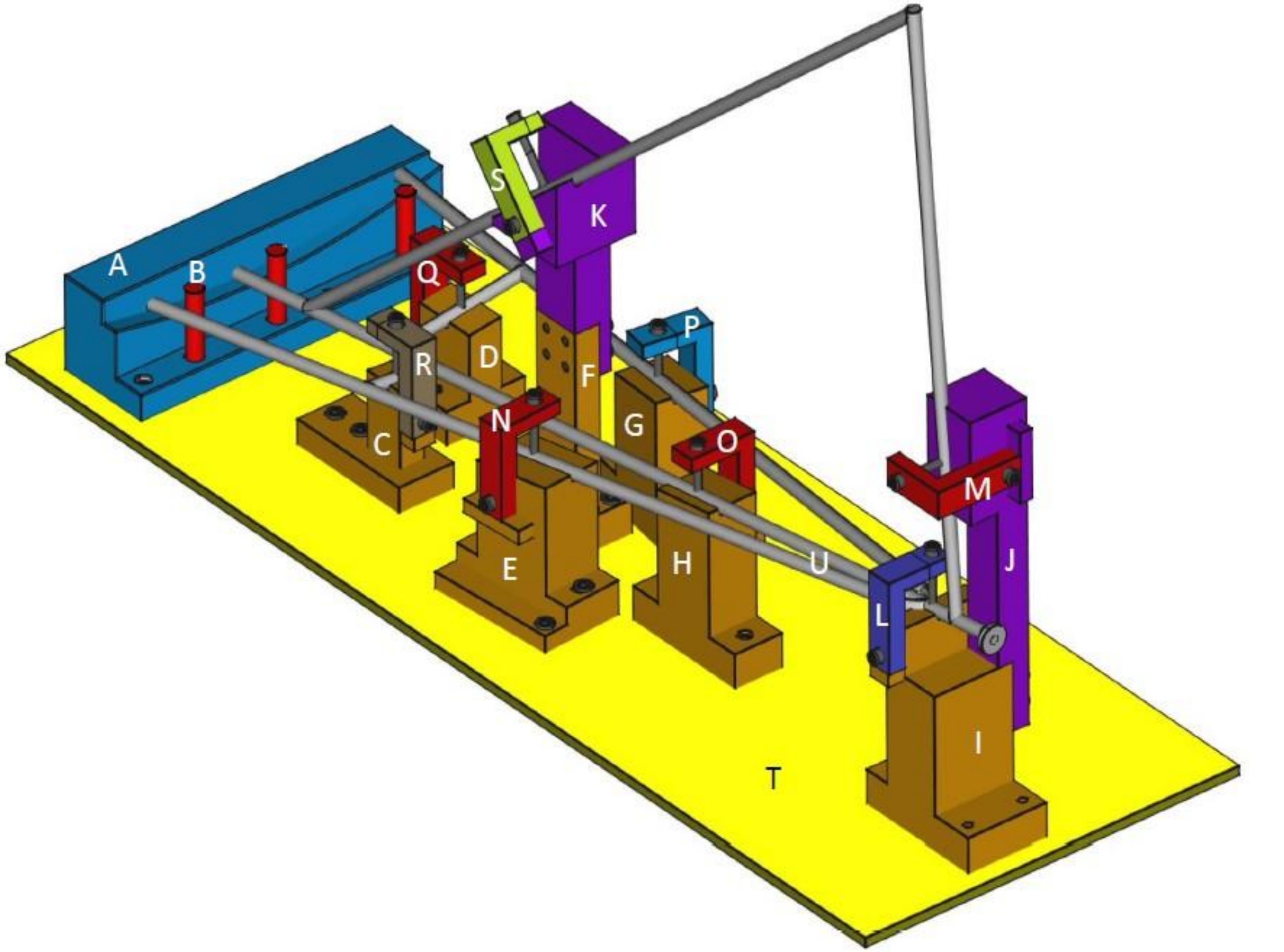
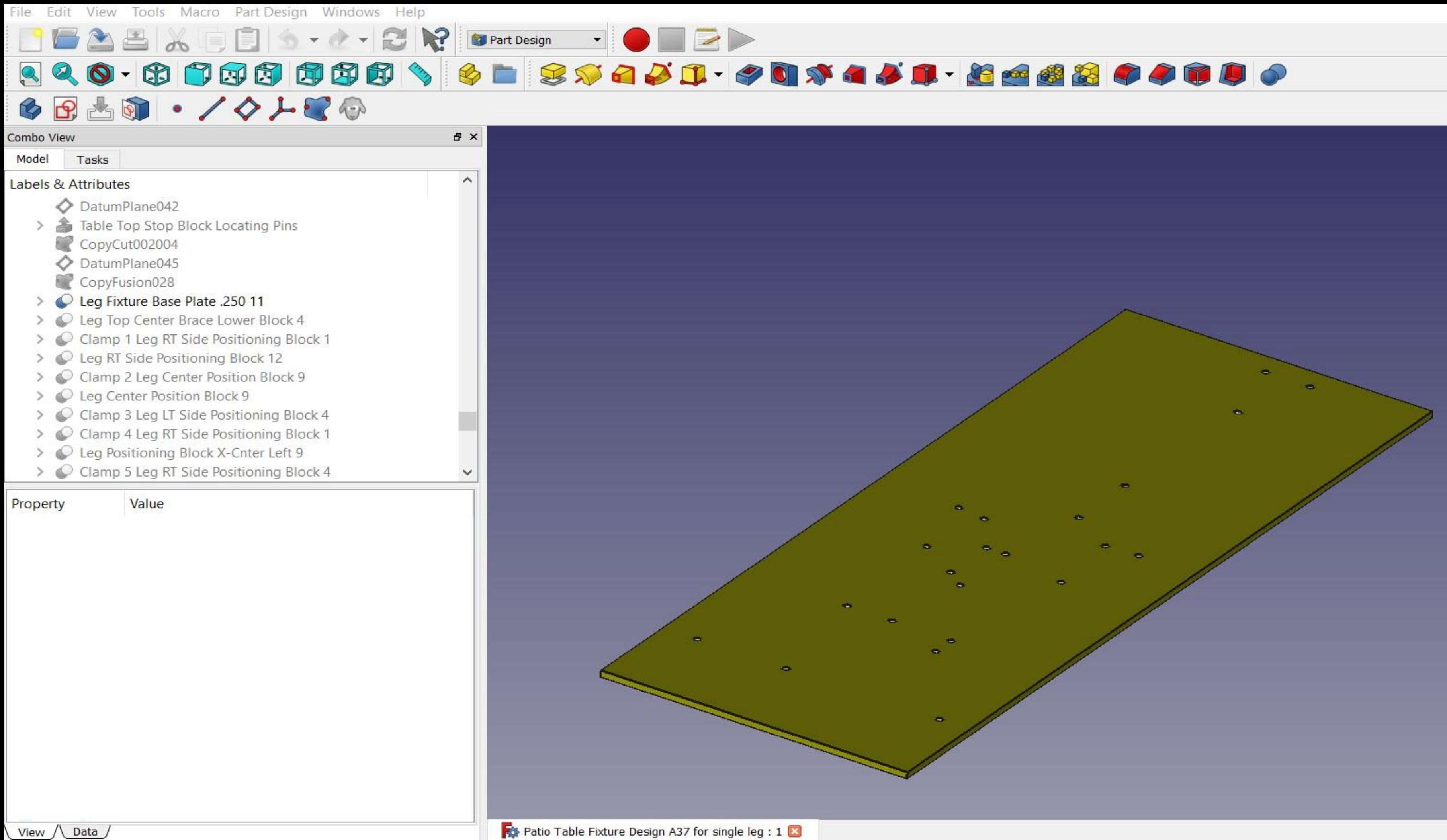


Table Leg Fixture: The leg is made up of 7 pieces of steel rod. From its appearance, it looks like a rather simple component to create. However, that is not the case, I experienced a number of challenges in creating this fixture. The top of the legs sweep the centerline of the table top ring and the legs are on a 7 degree angle inboard of the table top ring diameter. The leg center segment is in the same plane as the two center cross members, and each rod segment is at a different height and angle that needs to be held in the correct position.

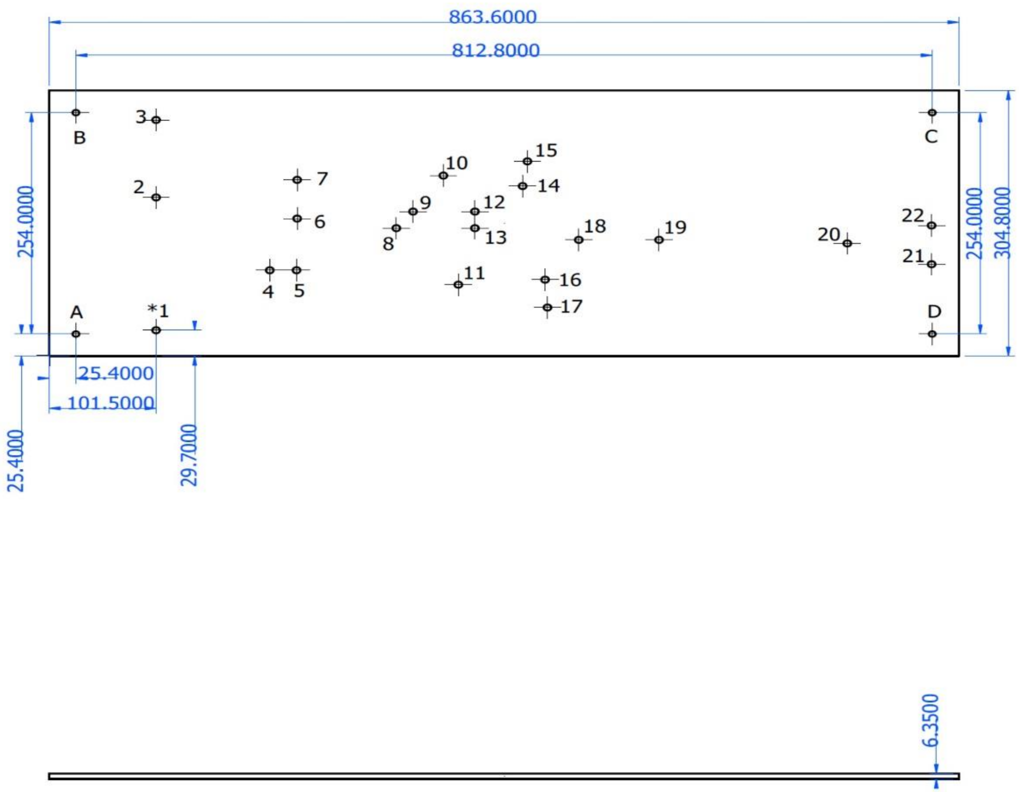
A. Table Top Diameter End Stop Block
B. Table Top Diameter Stop Block Pins
C. X-Brace Positioning Block-Right
D. X-Brace Positioning Block-Left
E. Right Leg Positioning Block
F. Center Bracket Assembly, Lower, Upper Leg Support
G. Left Leg Positioning Block
H. Center Positioning Block
I. Leg End Stop Block-Lower Assembly Block, Leg Lower Support
J. Lower Leg Center Support Positioning Block, Assembly-Upper
K. Upper Leg Center Support Positioning Block, Assembly-Upper
L. #6-Clamp-Leg End Stop Block
M. #1-Clamp-Upper Bracket-Lower Center Leg Support
N. #2-Clamp-Right Leg Positioning Block
O. #3-Clamp-Leg Center Positioning Block
P. #8-Clamp-Left Leg Positioning Block
Q. #4-Clamp-X Brace Positioning Block-Left
R. #5-Clamp-X Brace Positioning Block-Right
S. #7-Clamp-Upper Bracket-Upper Leg Center Support
T. Base Plate
U. Table Leg 3/8 Steel Rod



A parts list for the leg fixture is shown above. The leg design itself looks fairly simple, however, the feature content in the design and the fixtures required to maintain the design intent, is not so simple. I had to design 17 unique fixture components to maintain the leg in design position. In comparison, the table top required only 5. The fixture design allows all of the individual leg components to be welded together in a single pass. Each individual fixture block maintains the leg rod segment at the correct angle, height and on the correct radial sweep and spacing between segments.



Leg Fixture Base Plate: I used the same design method to create the leg base plate that I did for the table top. The leg fixture base plate is not large, 12 inches wide by 34 inches long. The base plate is made out of 1/4 inch thick, A36 steel plate. All of the fixture components to construct the leg are bolted to this plate. The plate has 4 holes dedicated to leveling feet to allow the plate to be in plane. The relatively small size of the plate is in relation to the actual physical part dimensions as designed. As with the table top fixture, one leg is welded on this fixture at a time and the raw components needed to make the next, are reloaded.



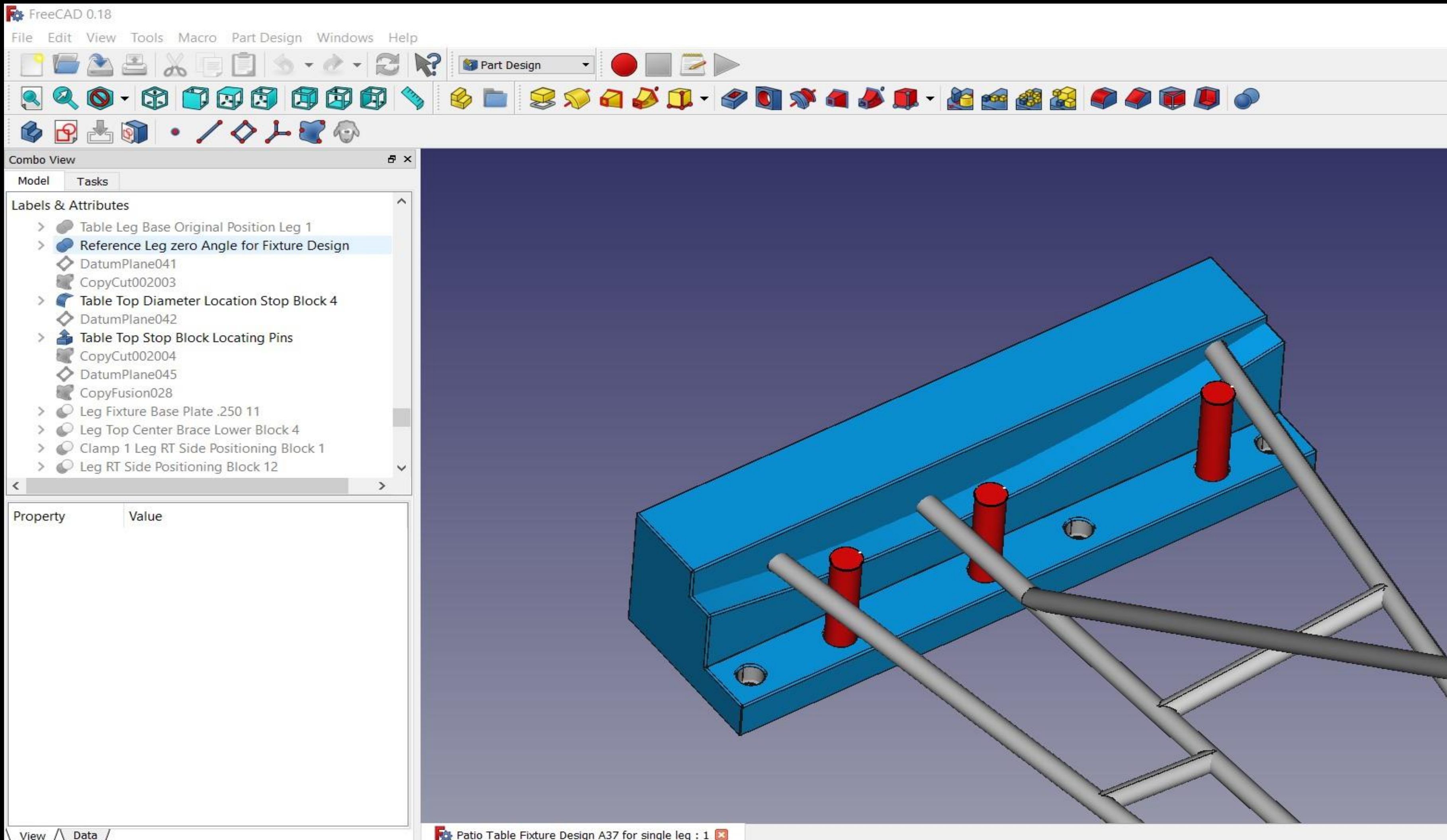
Fixture Base & Leg Assembly Hole Locations: Units in mm					
Lift Shoe Hole Locations Tapped 1/4-28					
Hole Number	Location X	Location Y	Hole Number	Location X	Location Y
A	25.4000	25.4000	B	25.4000	254.0000
C	254.0000	812.8000	D	812.8000	25.4000
Positioning Block Fixture Hole Locations From Reference Hole Position 1, Tapped 1/4-28					
Hole Number	Location X	Location Y	Hole Number	Location X	Location Y
1*	101.5000	29.7000	2	101.5000	152.4000
3	101.5000	88.9000	4	107.9052	68.8693
5	133.3052	68.8693	6	133.9005	128.1215
7	133.9005	172.5715	8	228.0250	117.1250
9	243.9000	136.1750	10	272.6826	177.4549
11	286.8985	52.2797	12	302.6375	136.1750
13	302.1750	117.1250	14	347.9377	165.4473
15	369.2474	193.7805	16	369.2474	58.0381
17	371.5000	26.0901	18	401.2095	103.7191
19	477.4095	103.7191	20	656.1161	99.6344
21	736.1161	75.7524	22	736.1161	120.2024

Drill and Tap for 1/4-28 Cap Screw, All Holes, Thru

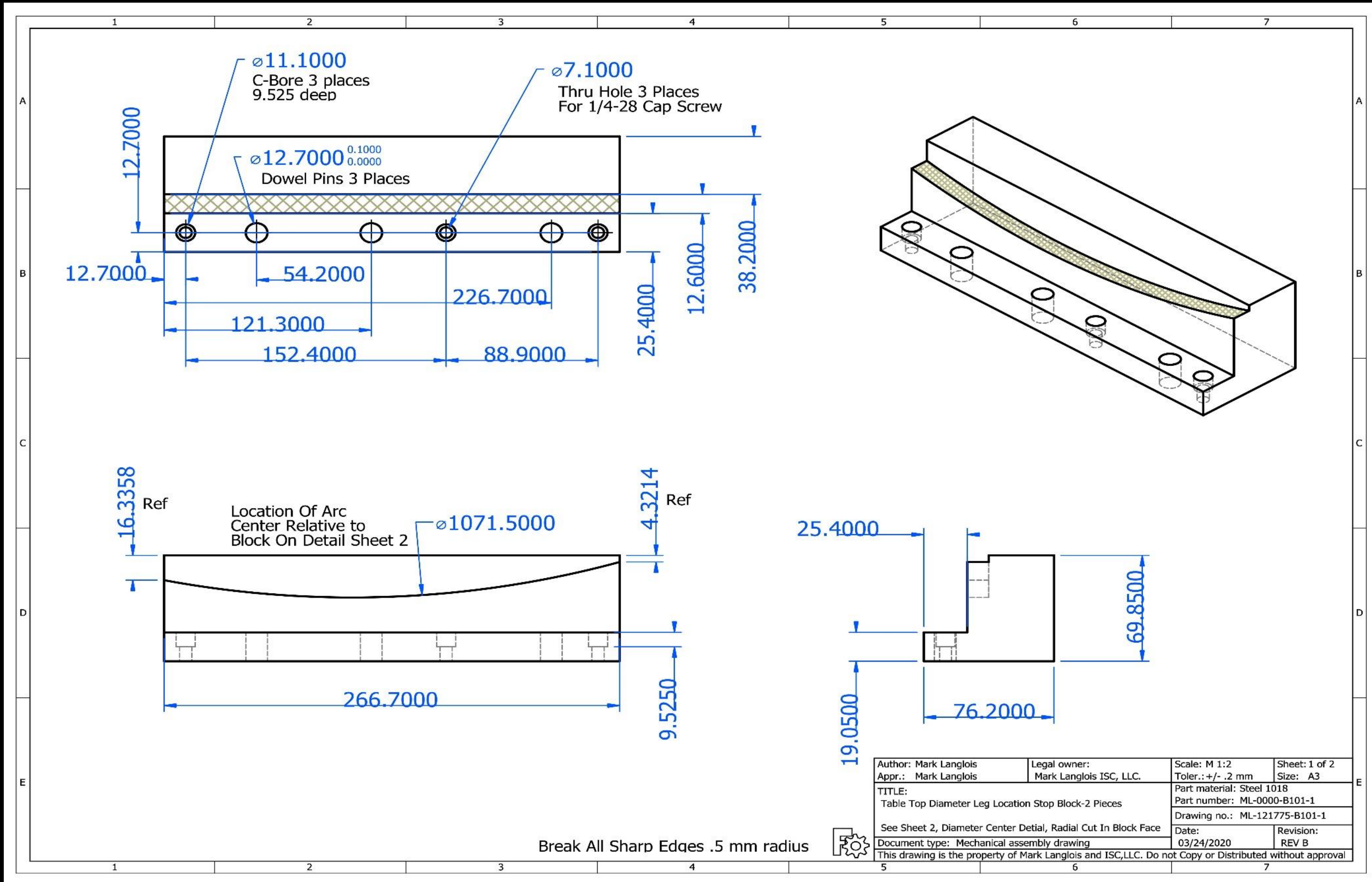
Break All Sharp Edges .5 mm

Author: Mark Langlois Appr.: Mark Langlois	Legal owner: Mark Langlois ISC, LLC.	Scale: M 1:3 Toler.: +/- .1 mm	Sheet: 2 of 2 Size: A2
TITLE: Steel Plate Fixture Base, Leg Assembly 26 Holes, Drilled And Tapped, 1/4-28 Thru See Hole Location Chart and Reference Notes On Drawing		Part material: 1/4 A36 Steel Plate Part number: ML-0000-B100	
		Drawing no.: ML-121775-B100-2	
Document type: Mechanical assembly drawing		Date: 03/24/2020	Revision: REV B

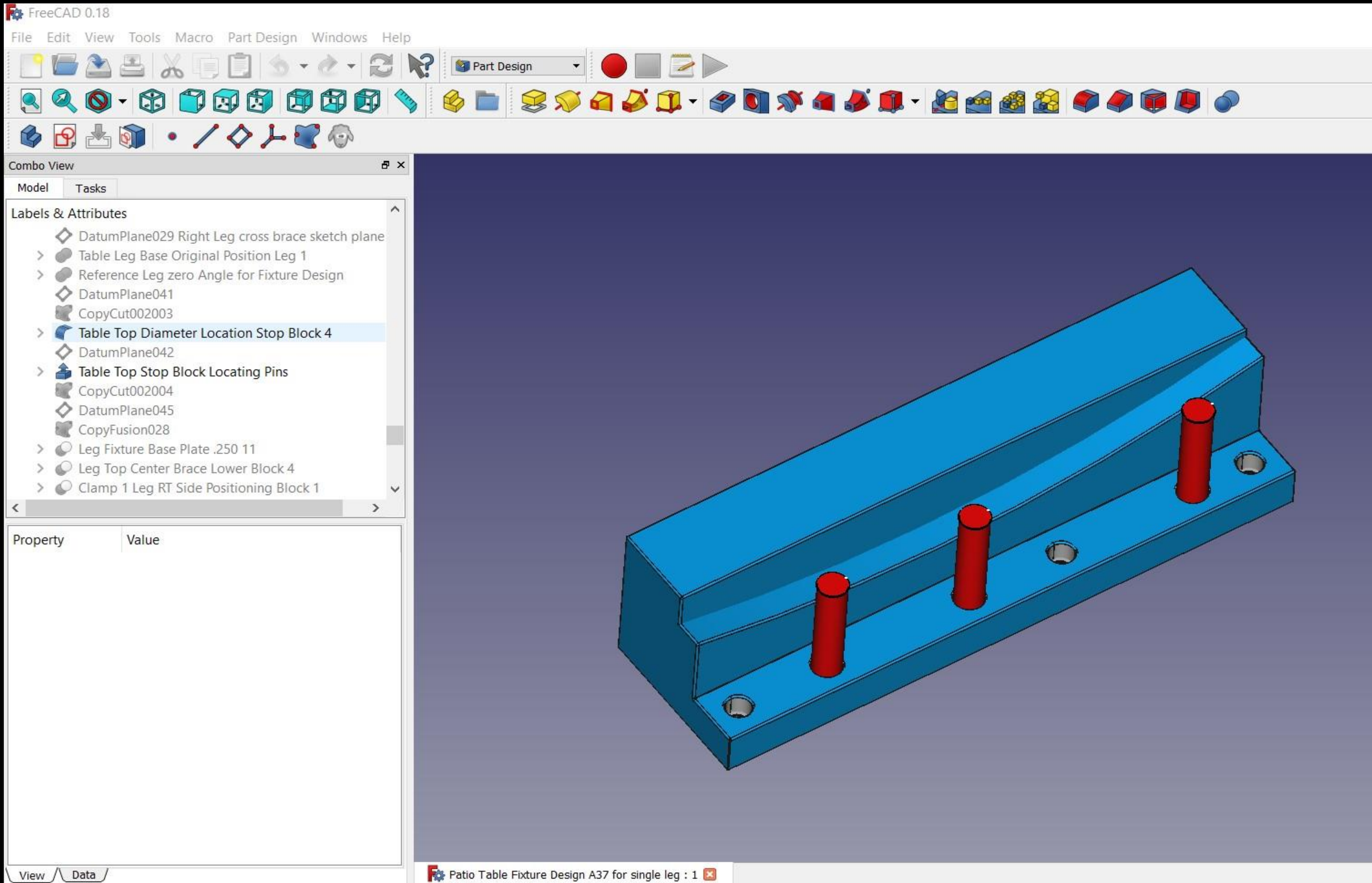
Base Plate Drawing: The base plate has 22 holes that were laser cut for a 1/4-28 tap drill to accommodate the fixture blocks. I put four holes in the corners of the base plate for leveling feet so I can level out the fixture plate. All of the holes in the plate were tapped for a 1/4-28 thread. The reason I chose to use a 1/4-28 fine thread was to provide some additional thread engagement to hold and tighten the fixture blocks. I believe the 1/4 inch plate will work well in this case, but is still not all that thick.



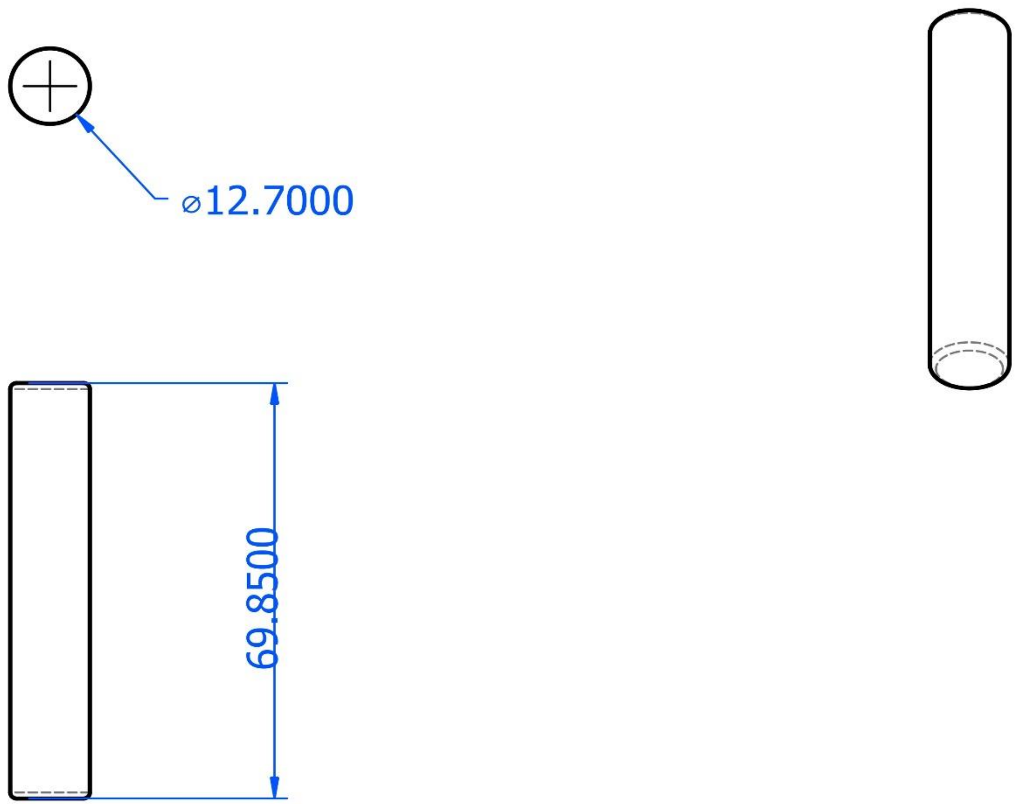
Top Diameter End Stop Block: I designed this fixture component to keep all three steel rod leg segments radially located on the centerline of the table top ring. The leg rod segments must follow the radial sweep of the table top because these three rod segments get welded to the top during assembly. The radial sweep of the table top has been machined into this stop block to position each leg on the table top centerline. The dowel pins shown in red, locate the leg rod segments at the correct angle and distance apart on this radial sweep.



Top Diameter End Stop Block Drawing: This fixture component is critical because it not only radially positions the orientation of each leg segment to the table top centerline, it also makes each center leg rod segment the same length. The leg, as an assembly component (1 of 4), requires that I consistently replicated the correct orientation, angle, spacing and length for the three rod segments positioned in this block, in order to assemble (weld) them to the table top as designed.

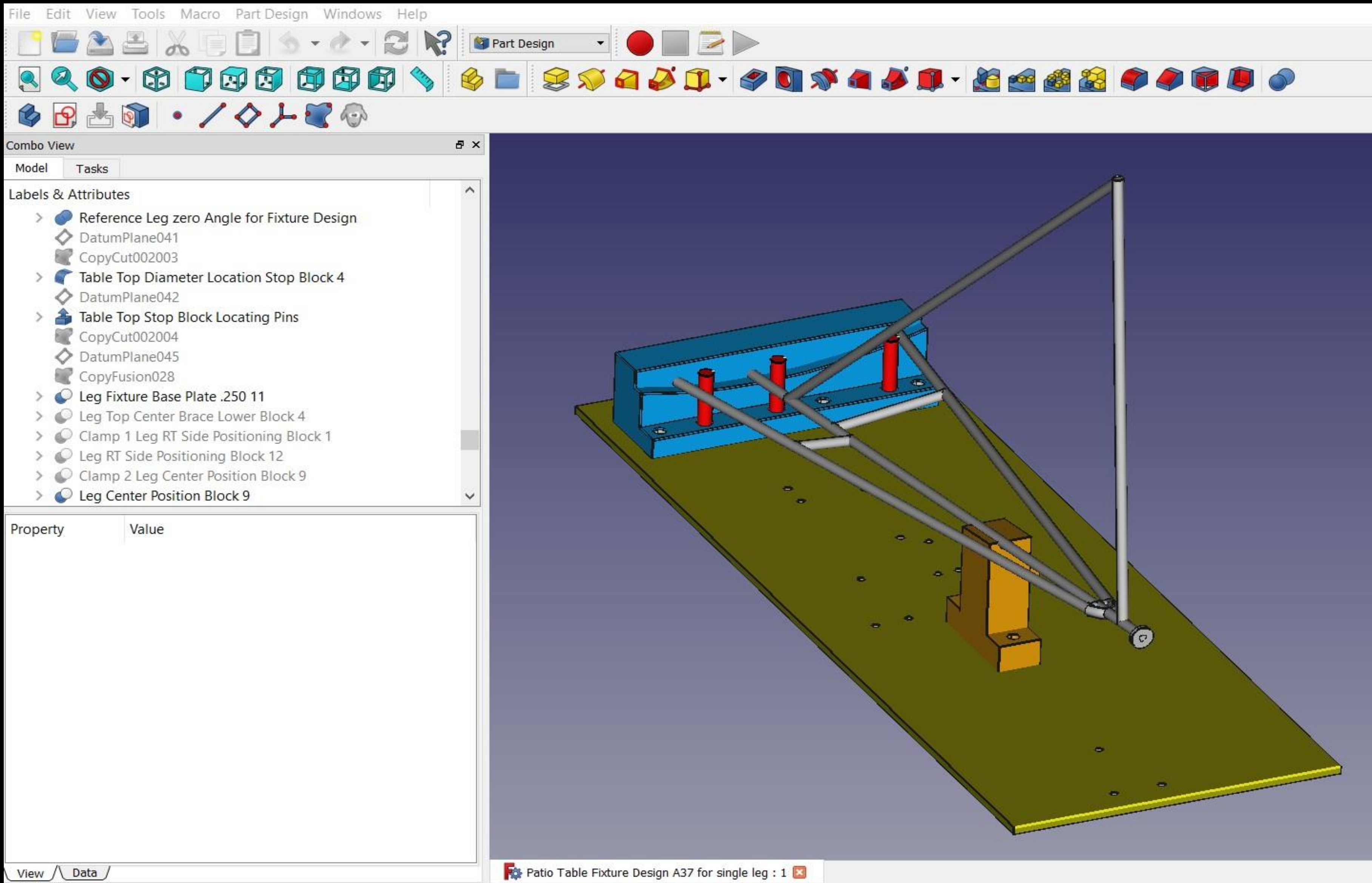


Dowel Pin Component: I used 1/2 inch diameter dowel pins that are positioned precisely in the stop block to accurately locate the three main rod segments that define each leg. Each of the rod segments, the center, right and left, sit on the outside sweep diameter of the table top that has been machined into this block and is tangent (contacts the pin outside diameter) to each of the locating pins.

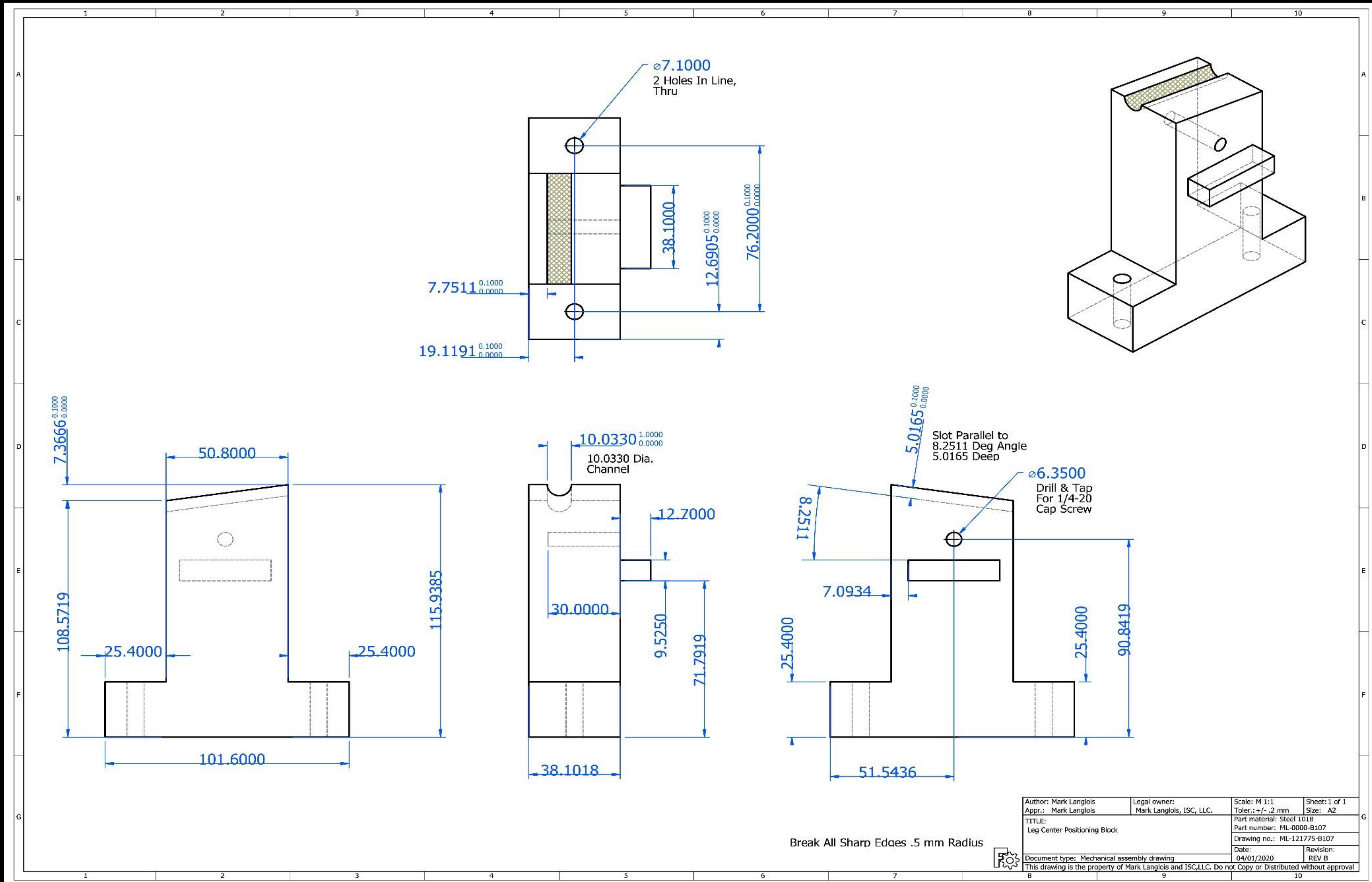


Author: Mark Langlois Appr.: Mark Langlois	Legal owner: Mark Langlois, ISC, LLC.	Scale: M 1.1 Toler.: +/- .1 mm	Sheet: 1 of 1 Size: A4
TITLE: Top Diameter Leg Locator Stop Block Dowel Pins, 3 Pieces Purchased Part		Part material: Steel Part number: ML-0000-B102	
		Drawing no.: ML-121775-B102	
Document type: Mechanical assembly drawing		Date: 03/24/2020	Revision: REV B
This drawing is the property of Mark Langlois and ISC,LLC. Do not Copy or Distributed without approval			

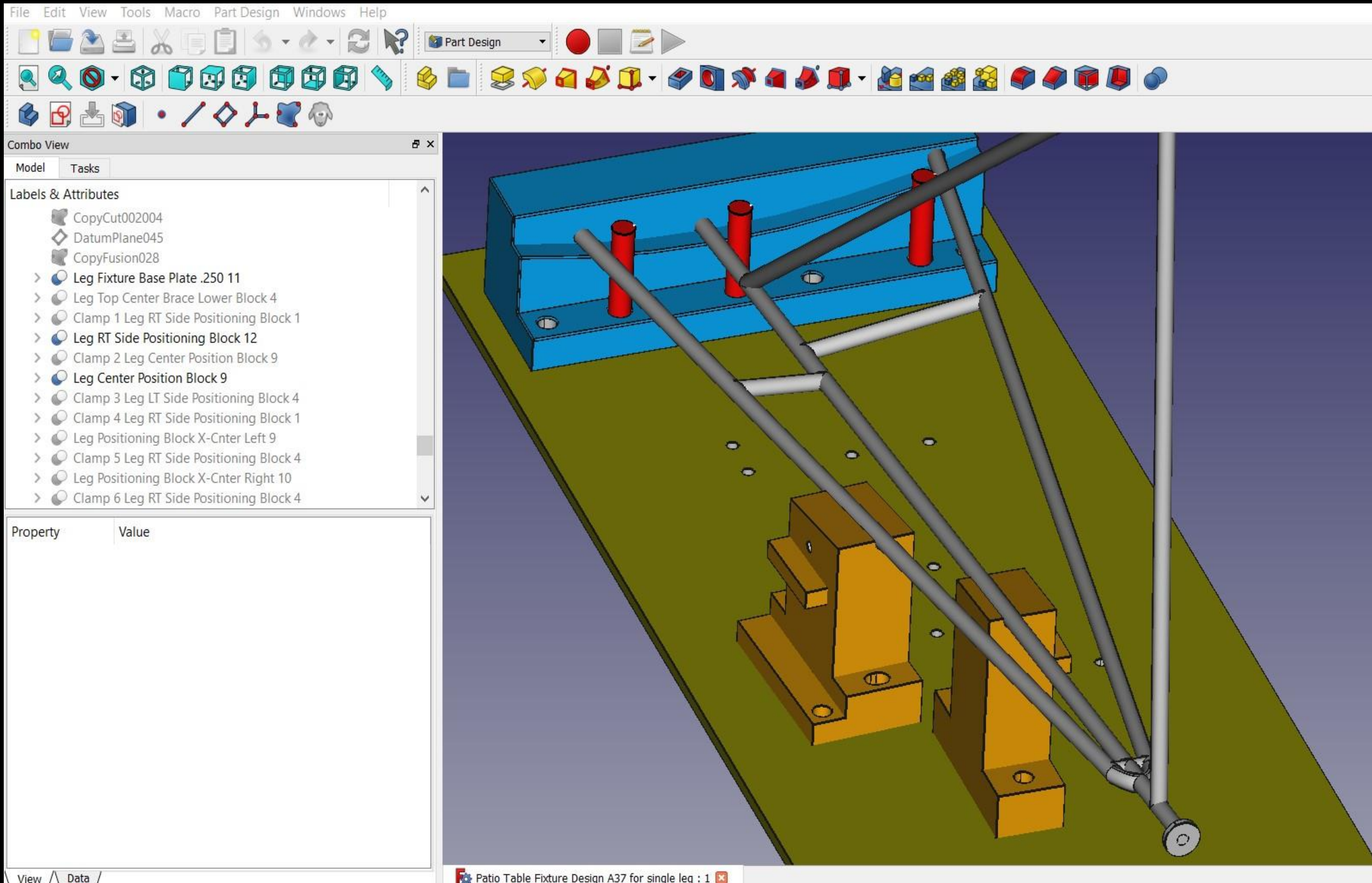
Dowel Pin Component Drawing: My stop block design tolerance calls for a precise location and hole size for the dowel pin components. The dowel pins are inserted into holes in the stop block with just enough room to fit without applying any force. The dowel pins are a purchased item that I ordered from a tool supply company. Dowel pins are a common fixture component and are easily purchased in many sizes.



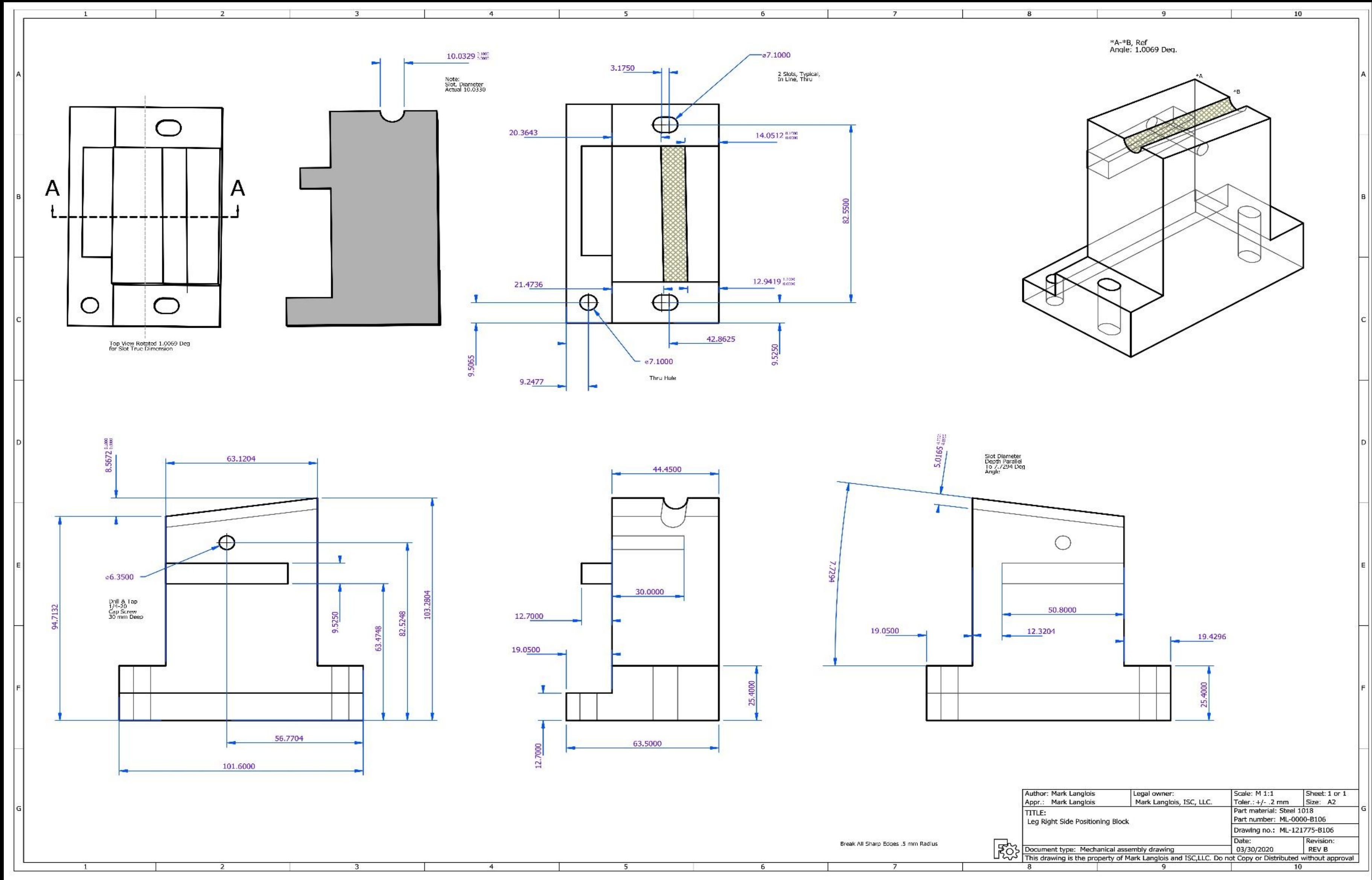
Leg Center Positioning Block: The leg center positioning block locates the steel rod center leg segment at the correct height to maintain the 7 degree inboard angle required by my design, It also sets up the initial position for all of the other rod segments in my leg fixture. The center rod segment is tangent to the center dowel pin in the stop block and is clamped into the groove in the center positioning block.



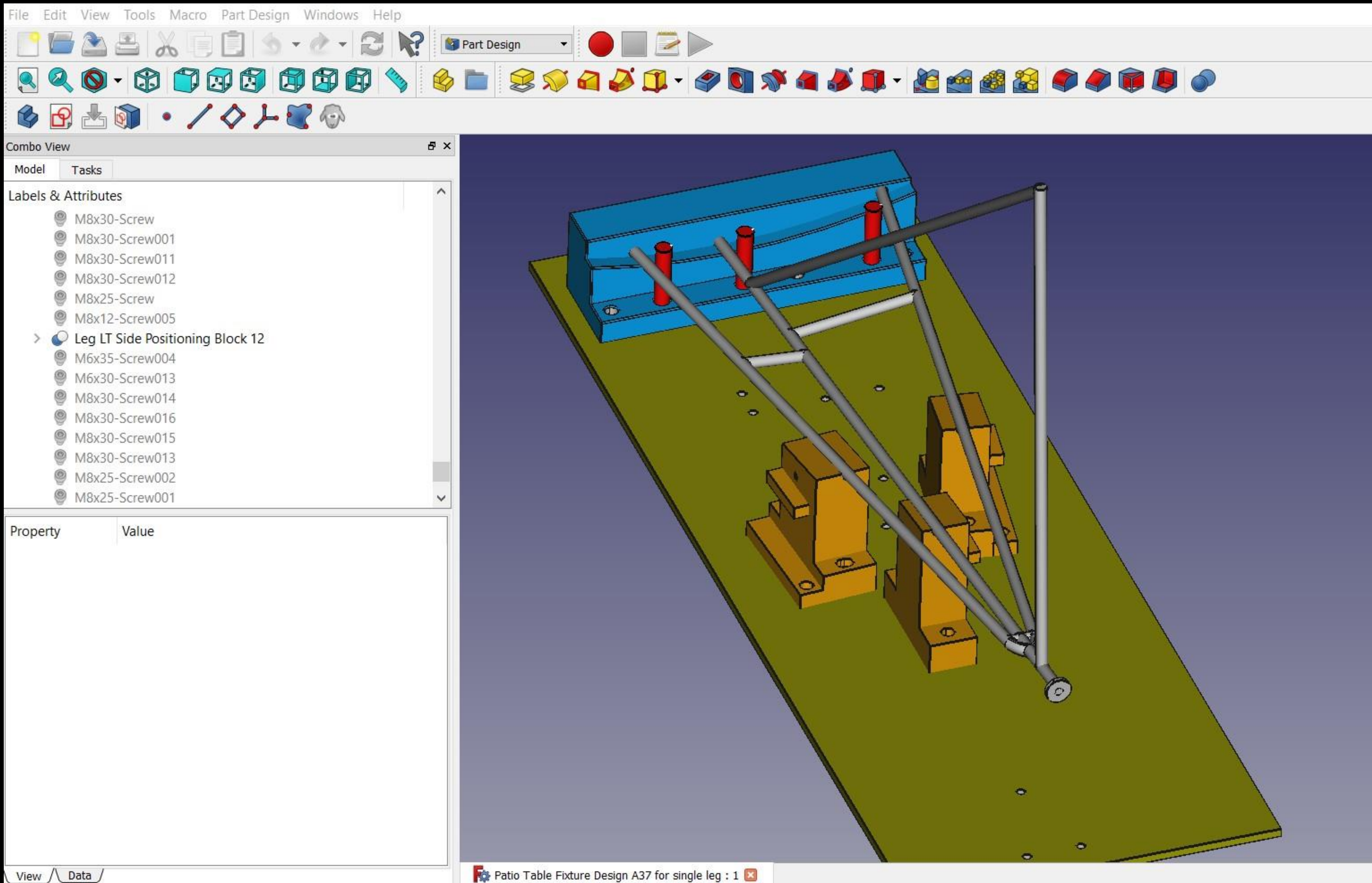
Leg Center Positioning Block Drawing: The leg center positioning block and all of the other fixture block locations are managed by the mating holes in the leg base plate. The location and orientation of each of the blocks is important because it defines the height and angle of the groove in the block. The height and angle must be precise so that each rod segment is closely aligned to its mating rod segment center line.



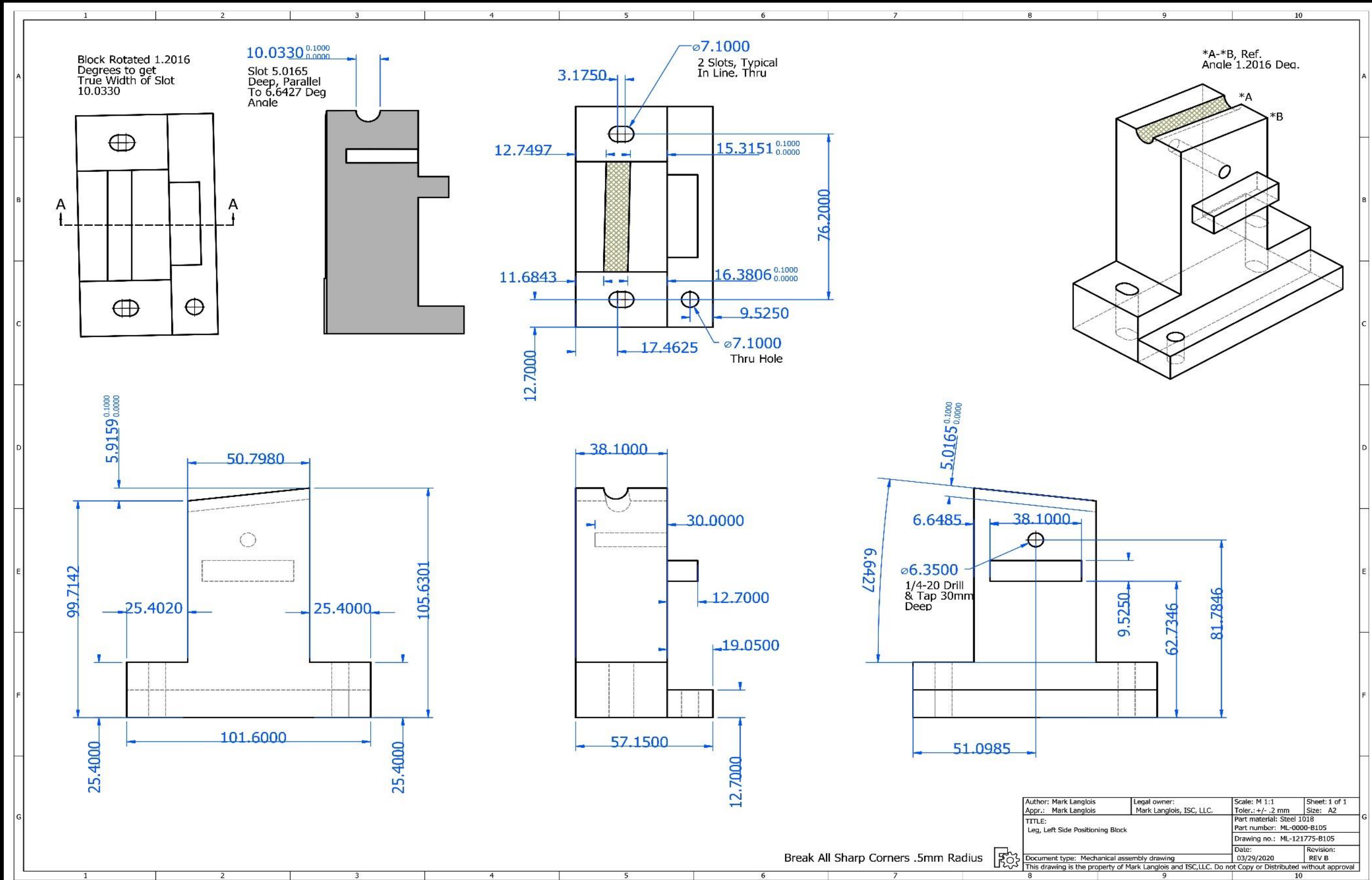
Leg Right Side Positioning Block: The right side positioning block locates the rod segment tangent to the dowel pin on the table top diameter on the right and locates the height and angle of the rod segment so that the rod follows the 7 degree inboard angle to meet with the center rod segment. I designed the block to allow minor adjustments perpendicular to the right side leg angle defined by the base plate hole locations. (Note: Right and Left is viewed from behind the blue stop block looking toward the leveling foot.)



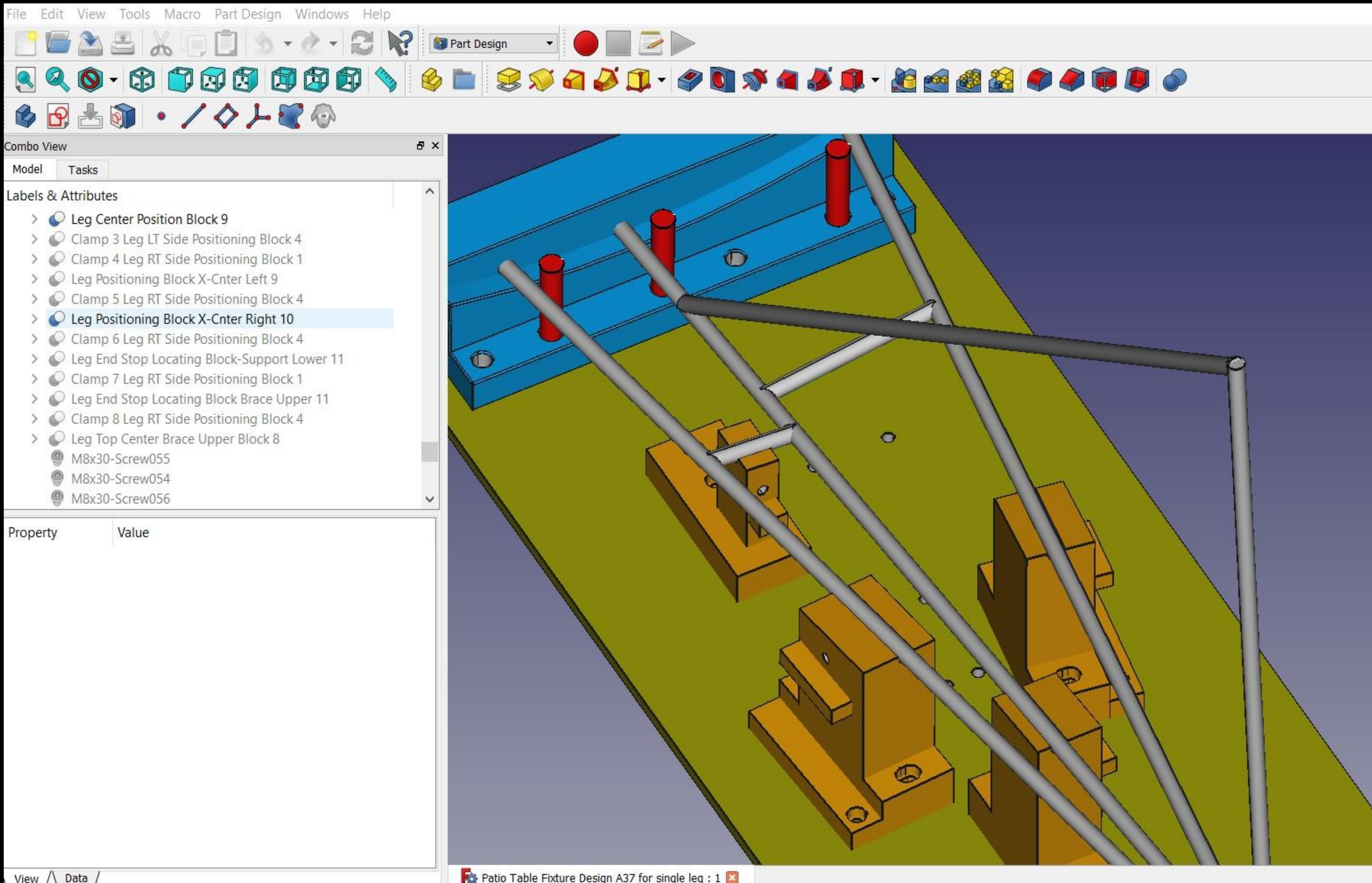
Leg Right Side Positioning Block Drawing: The right side positioning block locates the leg rod segment, tangent to the dowel pin, on the right side of the leg and at the correct angle and height to meet with the center leg, on its center line. In each of these block drawings I made, the heights, location of the groove and the groove angle are different due to its location on the base plate and the rod segment angle.



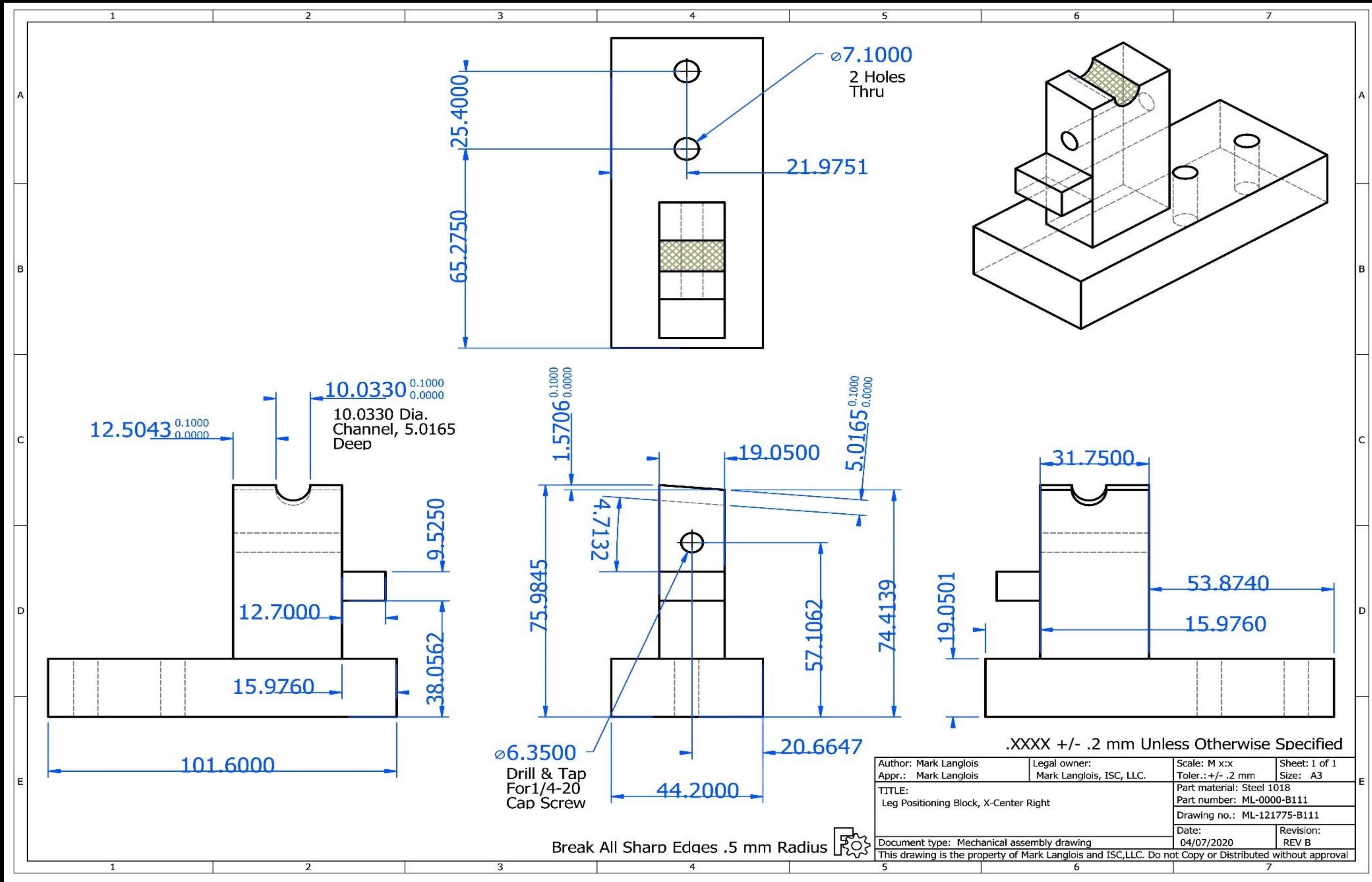
Leg Left Side Positioning Block: The left side positioning block locates the rod segment tangent to the dowel pin on the table top diameter on the left and locates the height and angle of the rod segment so that the rod follows the 7 degree inboard angle to meet with the center rod segment on its centerline.



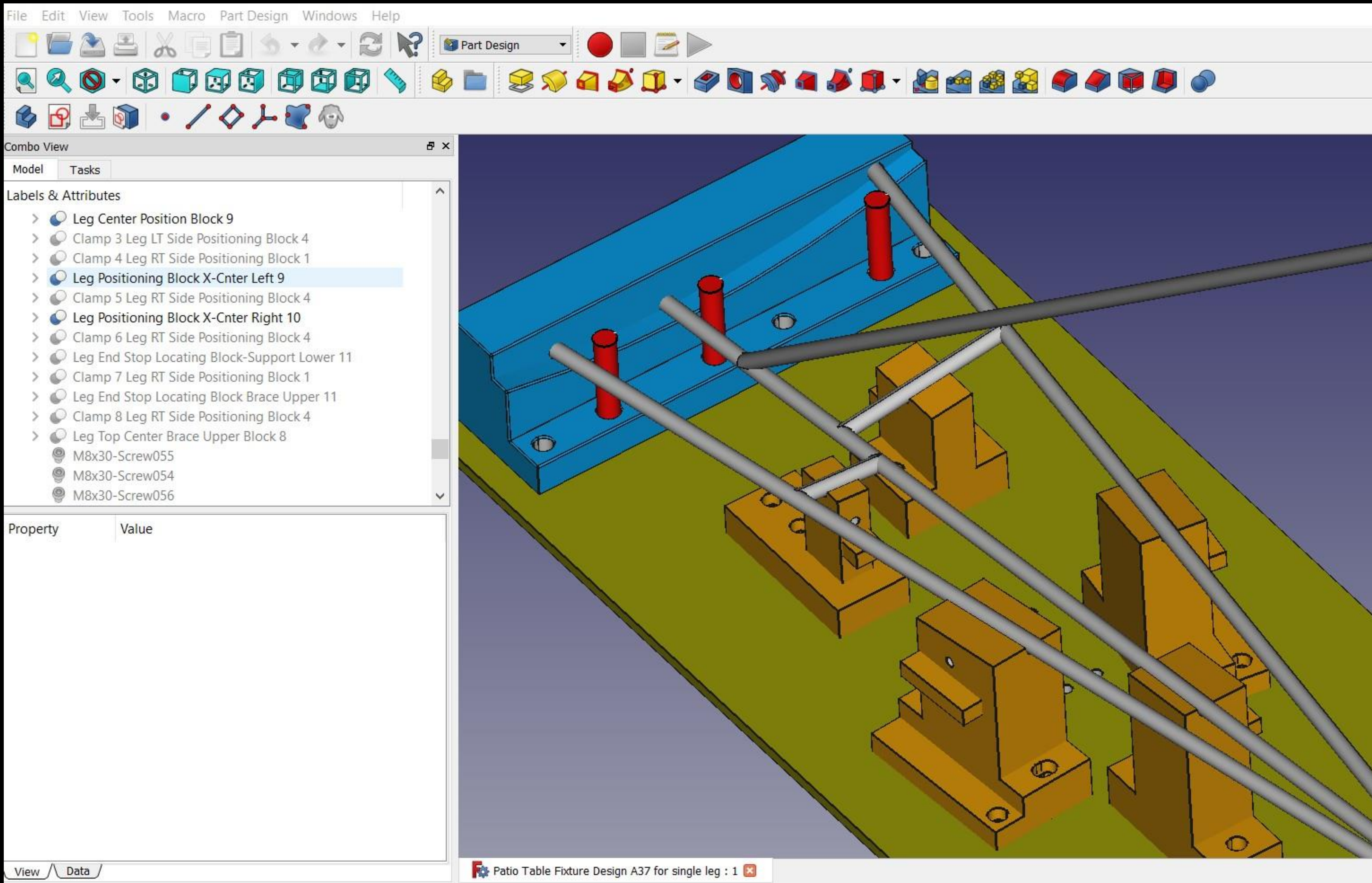
Leg Left Side Positioning Block Drawing: The left side positioning block locates the leg rod segment, tangent to the dowel pin, on the left side of the leg and at the correct angle and height to meet with the center leg, on the center line. Like the right side positioning block, I designed it to allow minor adjustments perpendicular to the angle defined by the hole locations in the base plate.



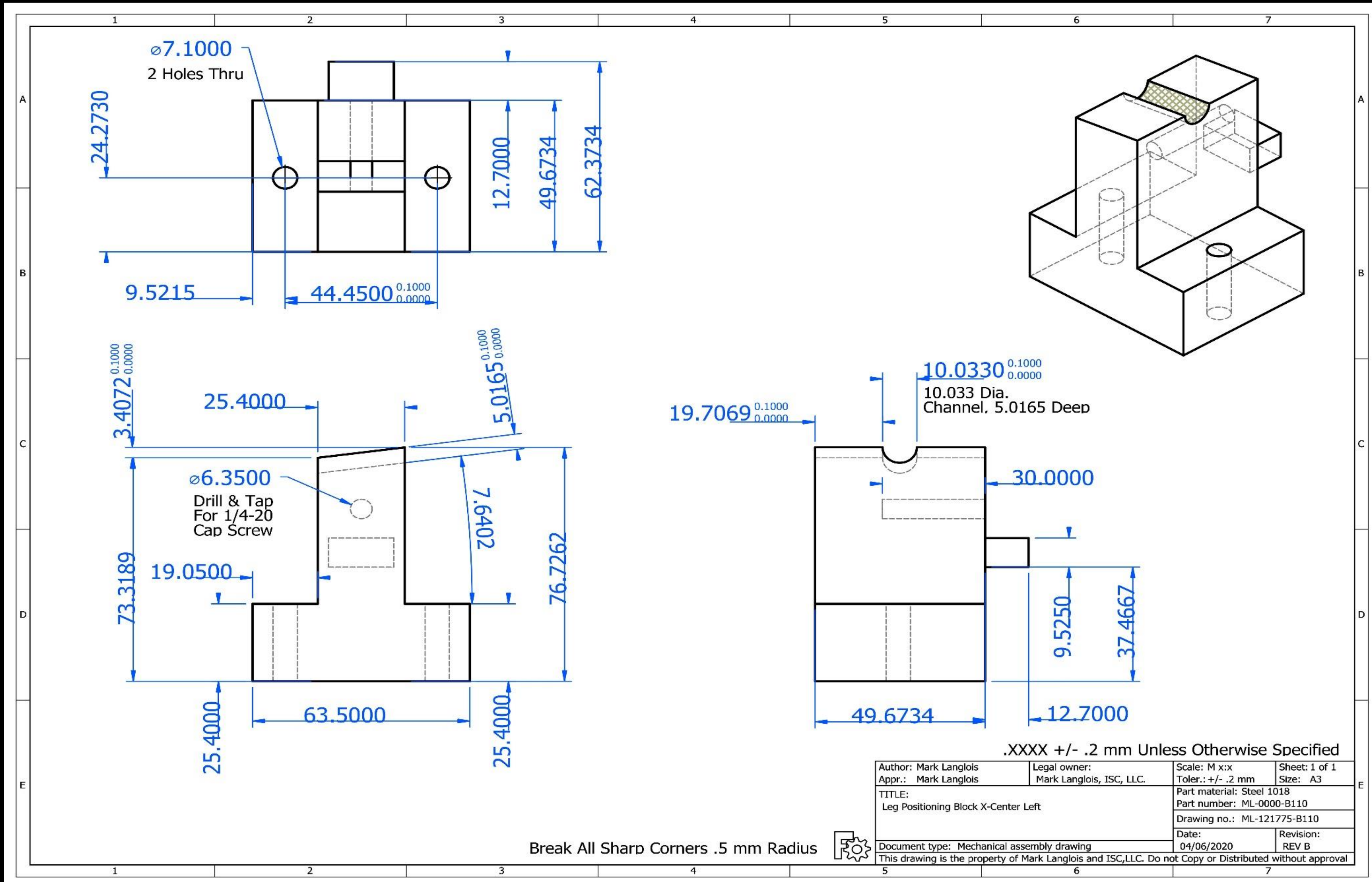
Leg Positioning Block, X-Center Right: This positioning block locates the right cross member steel rod segment of the leg. This rod segment is on a compound angle. The angle is both inboard to the table top diameter and also at an angle between the right and center rod segments. The height manages the angle inboard and the angle of the groove aligns the cross member to the centerline of the right and center rod segments.



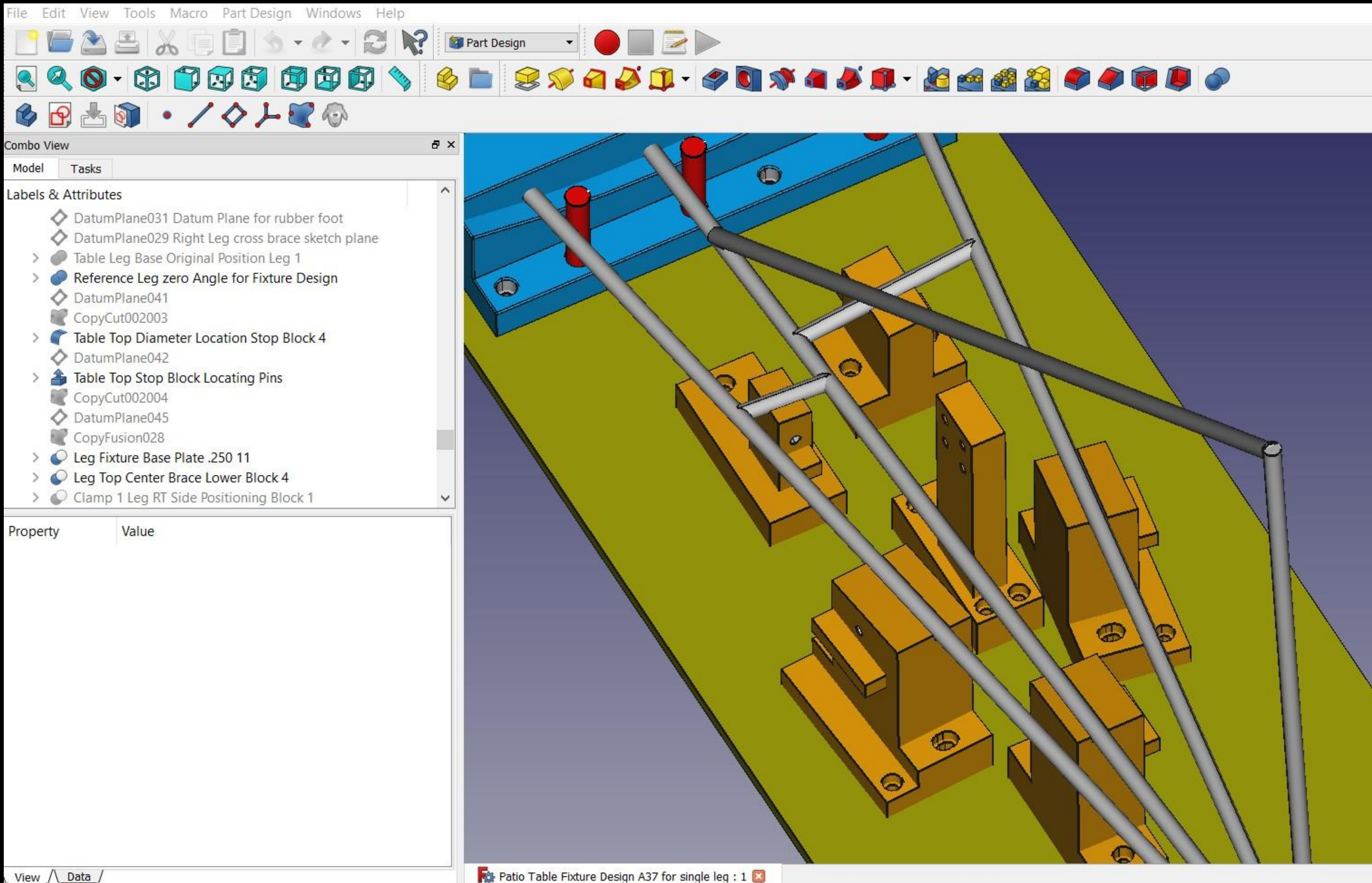
Leg Positioning Block, X-Center Right Drawing: I have to design each positioning component for more than just the functional alignments required for the design. Each block's size, shape and location on the base plate must allow me to access the locating screws, give me room to load the rod segments, clamp the rod segments in place, provide sufficient space to weld and finally, remove the finished leg.



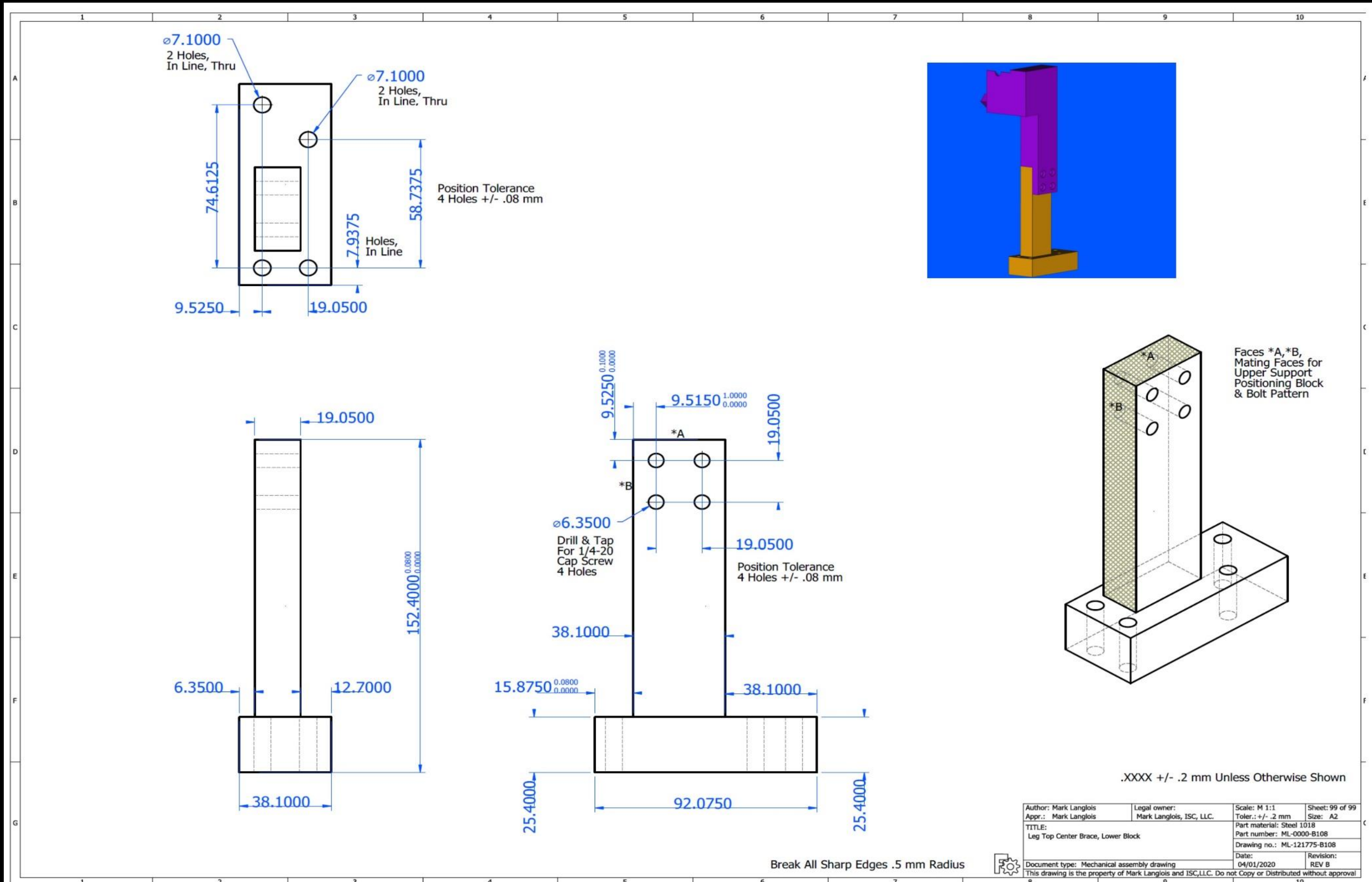
Leg Positioning Block, X-Center Left: This positioning block locates the left cross member steel rod segment of the leg. This rod segment is on a compound angle as well. The angle is both inboard to the table top diameter and also at an angle between the left and center rod segments. The height manages the angle inboard and the angle of the groove aligns the cross member to the center of the left and center rod segments.



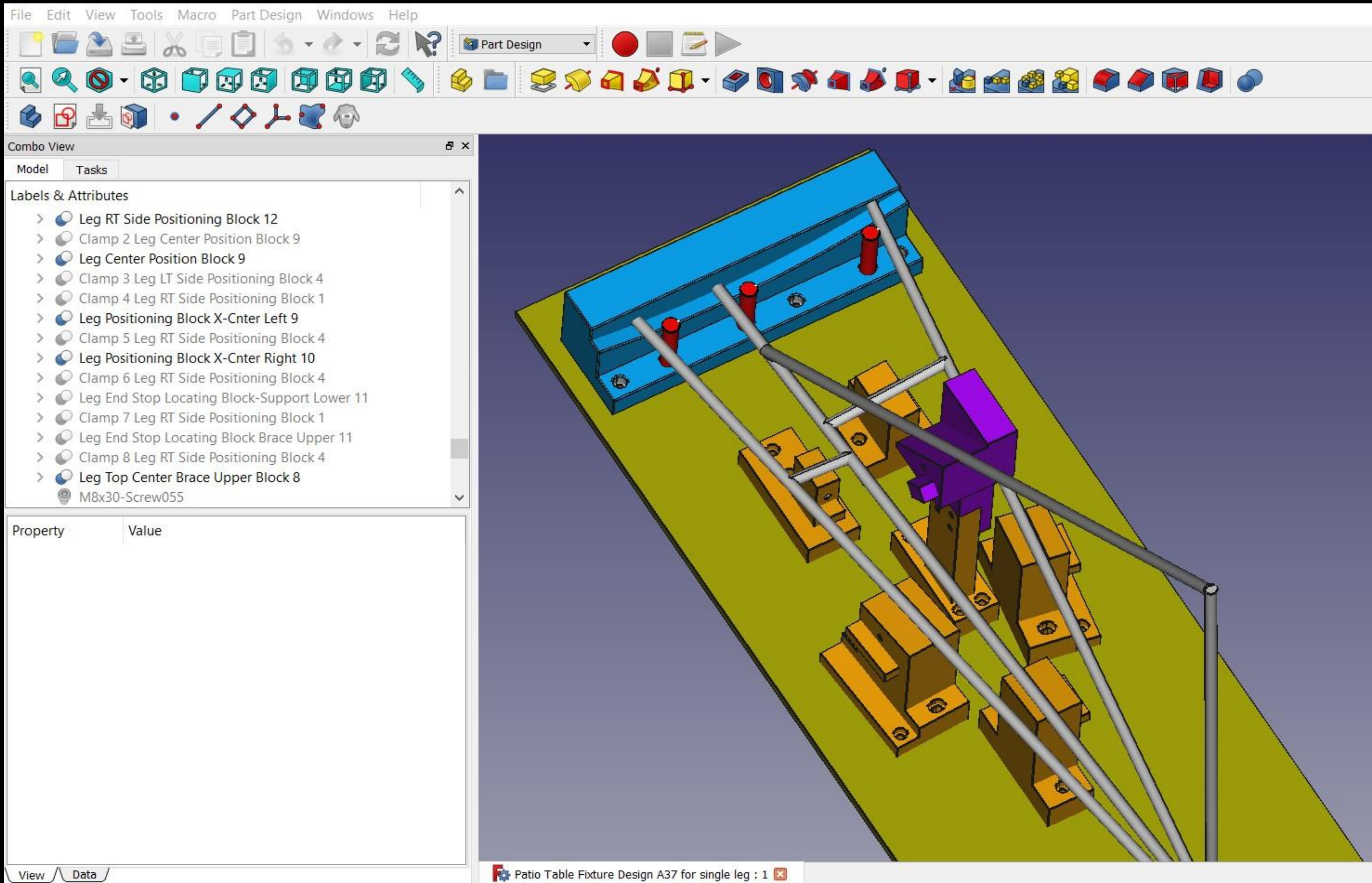
Leg Positioning Block, X-Center Left Drawing: I designed the left cross member positioning block wider then the right block. I did this to allow the block to more accurately locate the left cross member rod segment. Because it is a longer rod segment, the additional groove width helps keep the rod segment in alignment and easier to load.



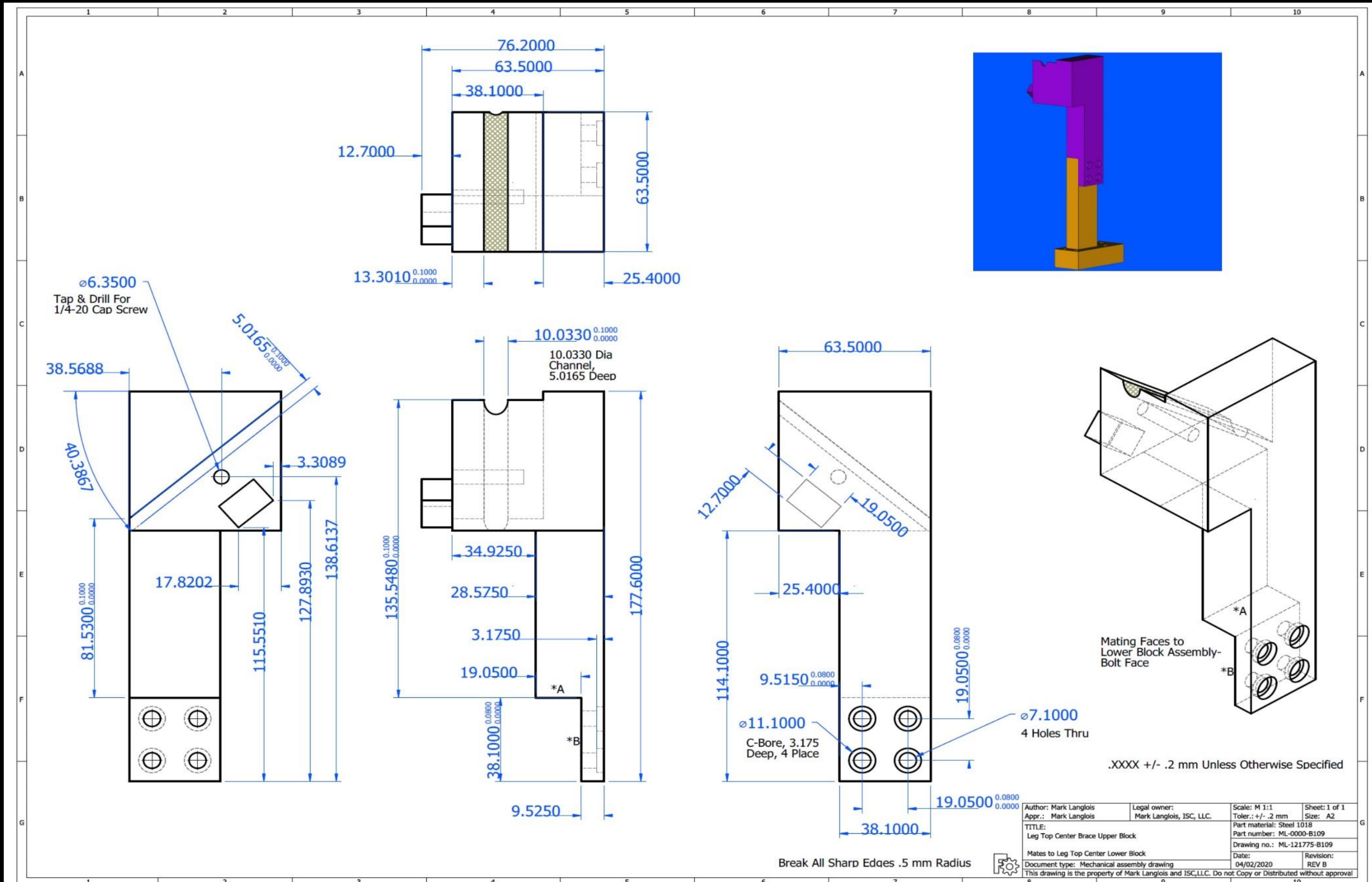
Leg Top Center Brace, Lower Block: I designed this positioning block as part of an assembly. This fixture block is elevated above the leg center rod segment. The top of this block and right side are locating faces for the upper block assembly. This block was necessary because the upper center brace rod segment is in the same plane as the center rod segment. The upper positioning block that mates to this block, must be above and extend over the center rod segment.



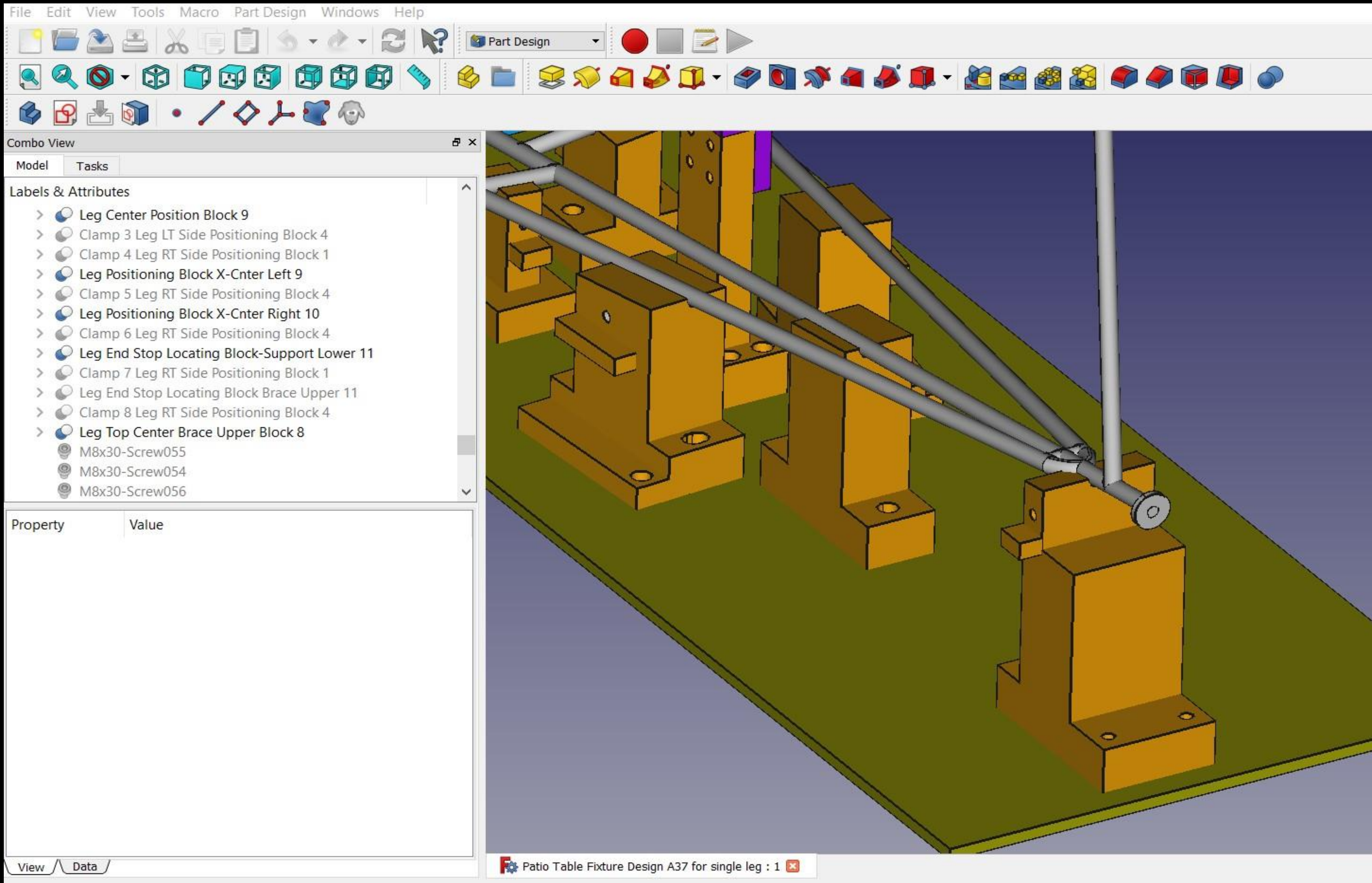
Leg Top Center Brace, Lower Block Drawing: I designed this block as an assembly for two reasons. First, breaking this positioning block down into two smaller parts made the components less complex and easier to make (cost effective). Second, I wanted the option to disassemble the upper positioning block to remove the leg from the fixture after welding, if that were necessary. As you can see, the fixture space is getting tight.



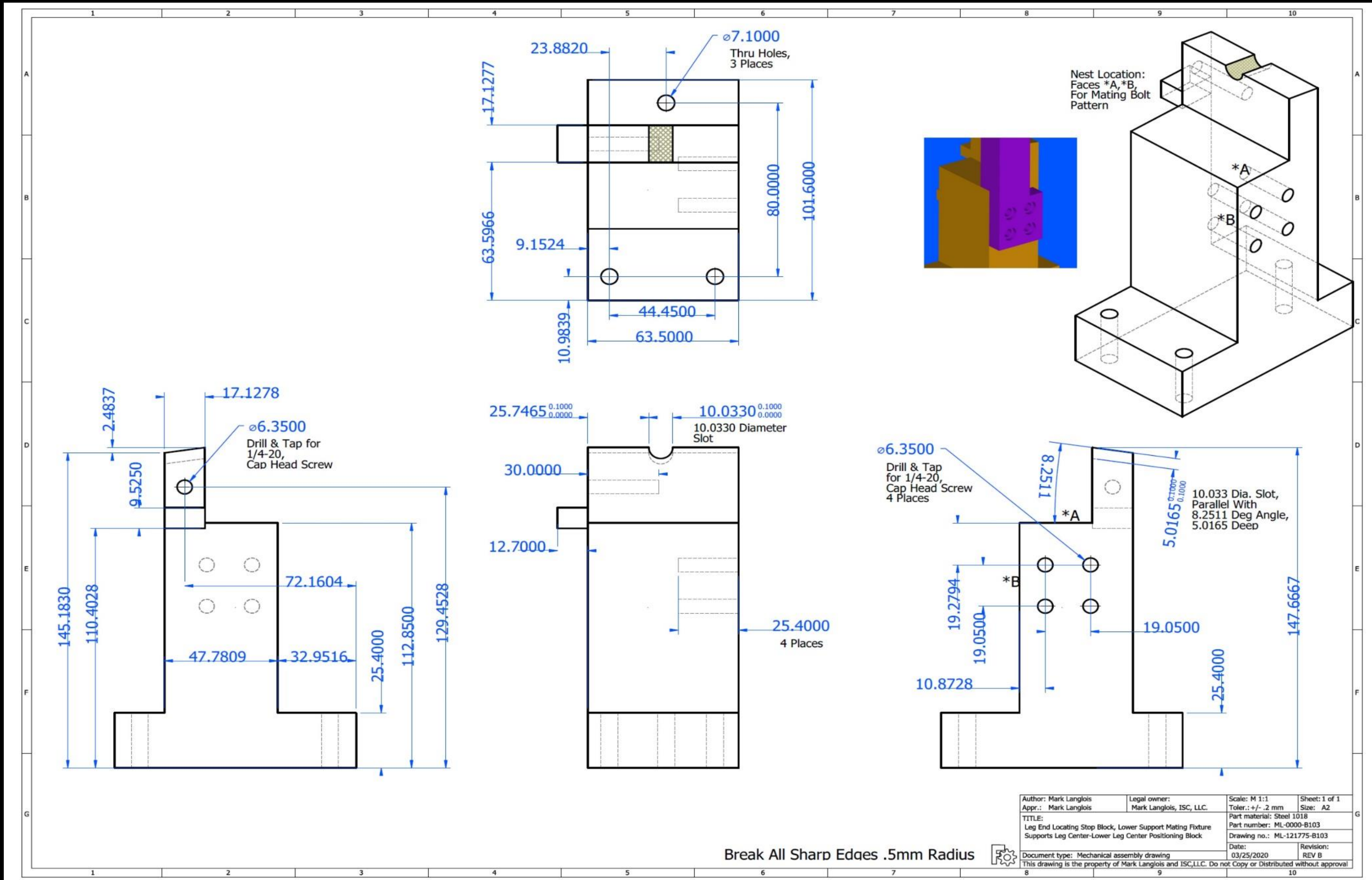
Leg Top Center Brace, Upper Block: This assembly block mates with the lower positioning block, locating the leg top center brace. The positioning block locates the brace position at the top of the leg, holds the brace in plane with the leg center rod segment and aligns the center brace rod segment to meet with the lower brace rod segment. I created these positioning blocks with some strength and mass so they can secure the top center brace accurately.



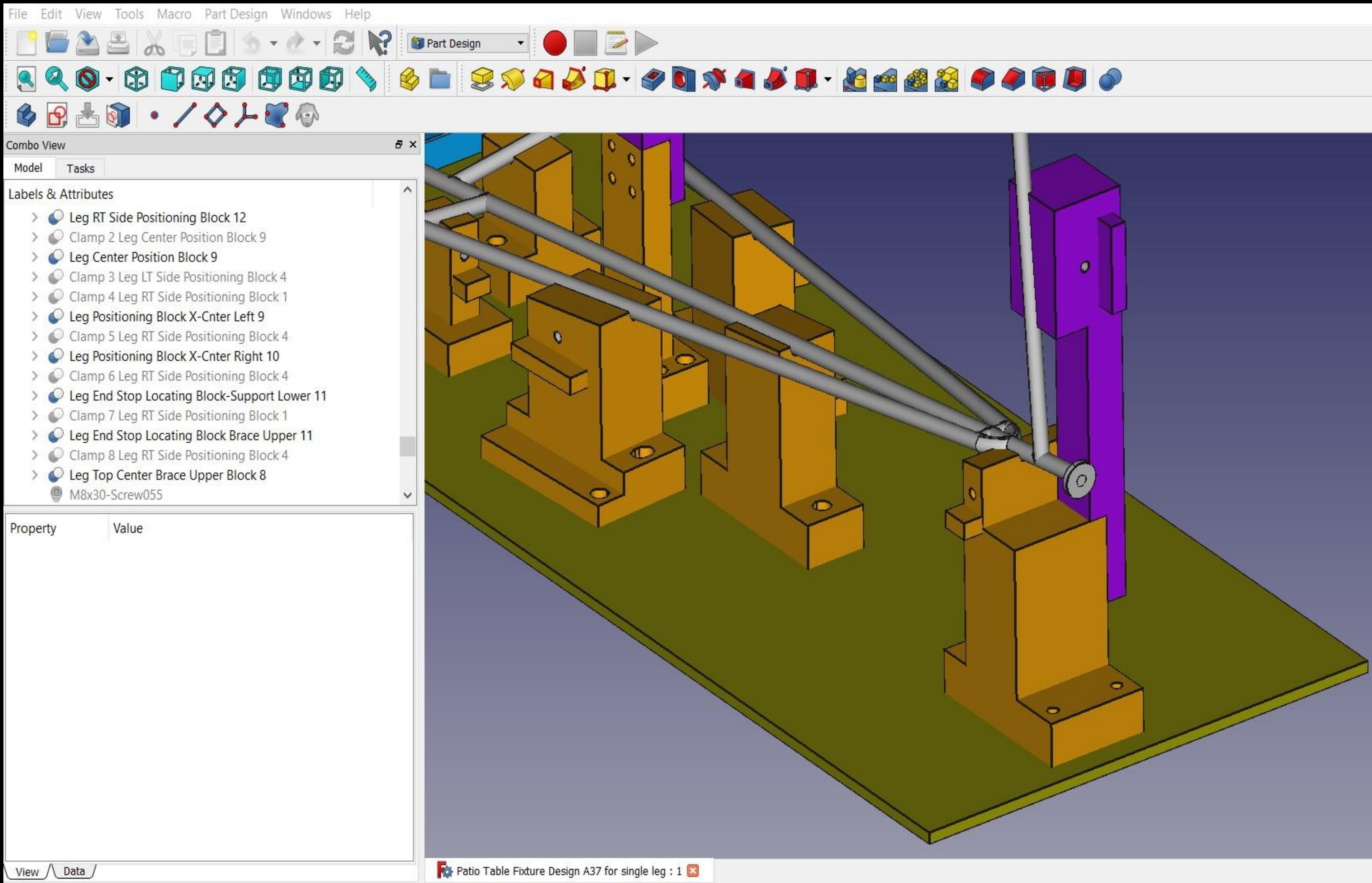
Leg Top Center Brace, Upper Block Drawing: This positioning block is doing a lot of work, positioning and clamping leg center brace. The leg center brace is also the longest rod segment component in construction of the leg. It took me some considerable time to conceptually visualize how I was going to hold and clamp this leg top center brace before coming up with this assembly configuration.



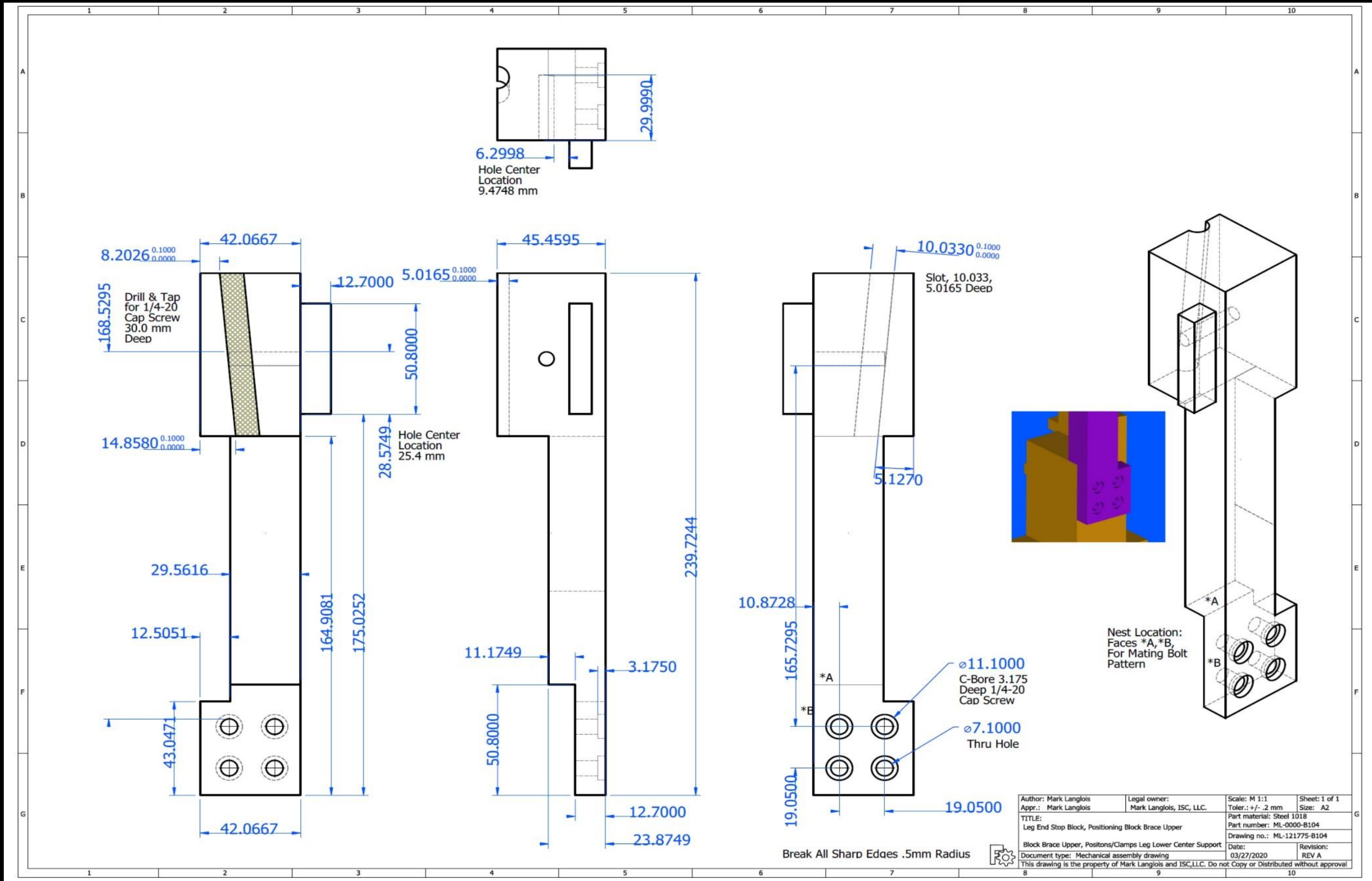
Leg End Locating Stop Block: The leg end locating stop block is also an assembly component. This block mates with the Positioning Block-Brace Upper. I designed this as an assembly for the same reasons as the other mating block components. The leg end stop block supports the center leg rod segment at a junction, whereby, the right and left rod segments are welded to the center rod segment on the one side. On the other side, the lower center brace rod segment is welded to the center leg rod segment.



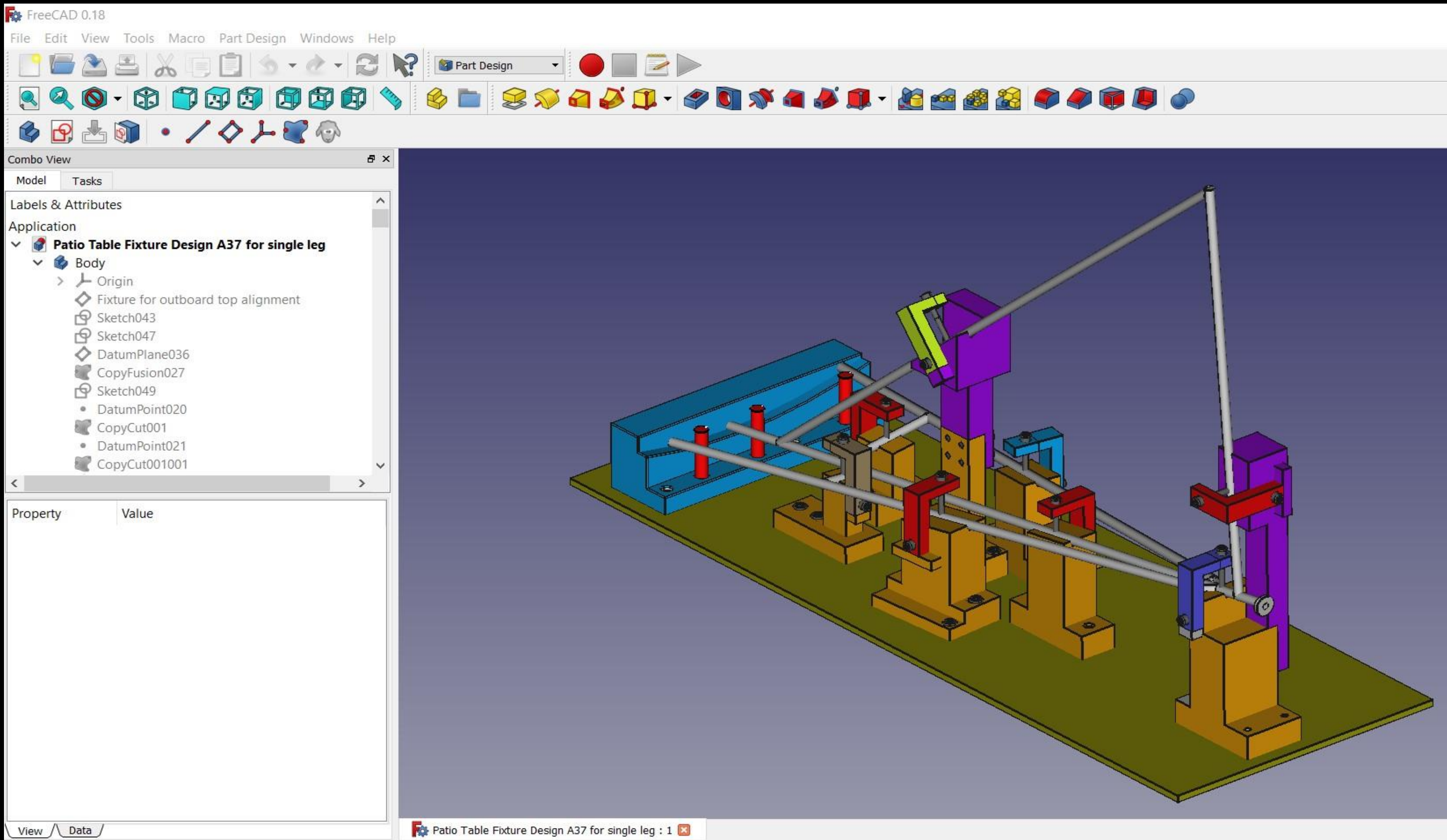
Leg End Locating Stop Block Drawing: The leg end stop block maintains the leg center rod segment at the correct angle and height in conjunction with the center positioning block. The end locating stop block marries the right and left leg rod segments at the 7 degree inboard angle to the center rod segment. It also positions the center leg segment, in plane, to accept the lower center brace rod segment positioned by its mating assembly block.



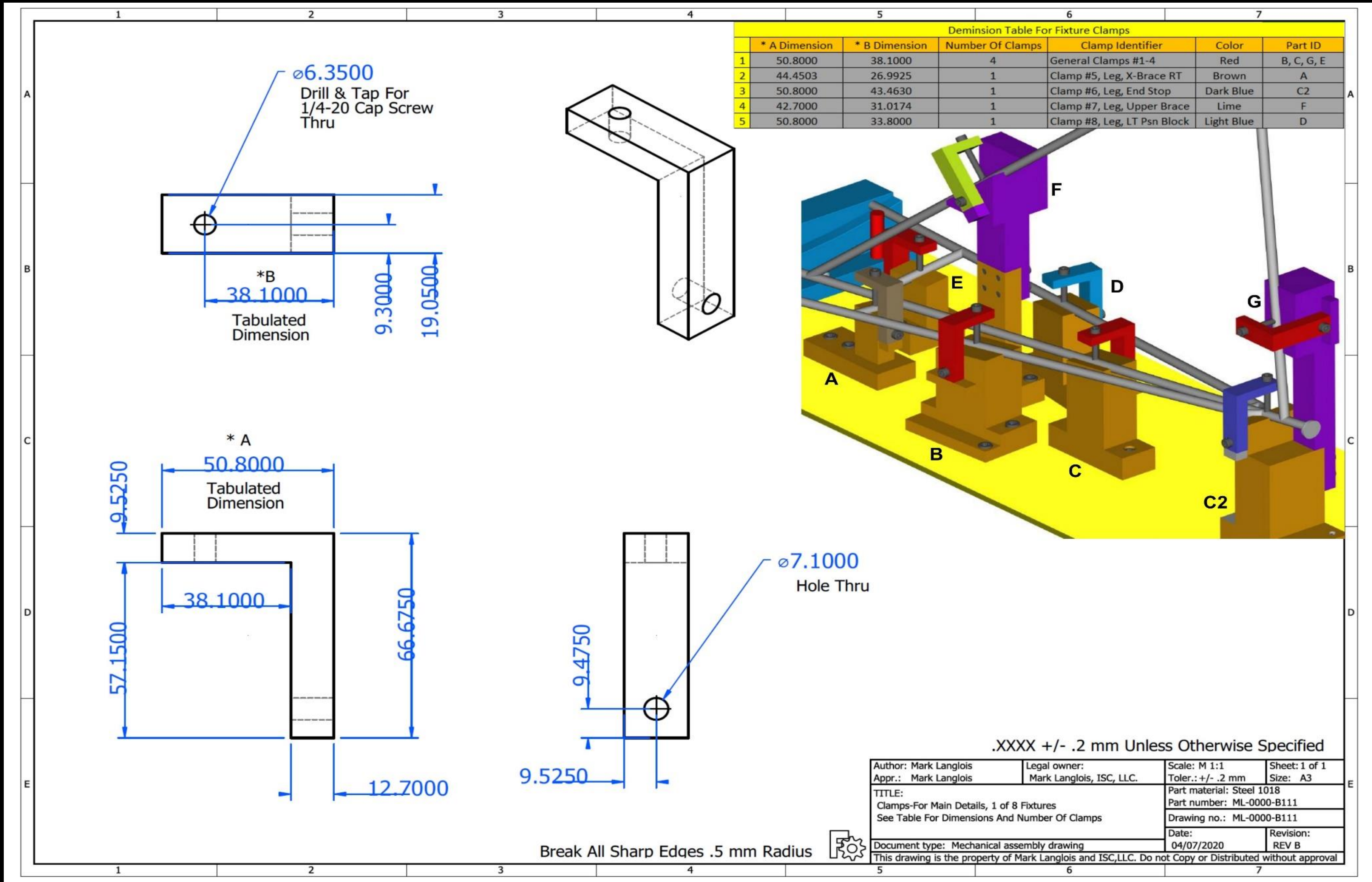
Leg End Stop Block-Positioning Brace Upper: This upper assembly component to the leg end stop block, positions the lower center brace in the same plane as the leg center rod segment and the upper center brace. All Three are aligned in plane with the center leg rod segment when clamped. It also locates the lower center brace rod segment in the correct weld location on the center rod segment.



Leg End Stop Block-Positioning Brace Upper Drawing: One of the critical concerns with respect to my design of the leg fixture positioning components, was having enough clearance and space to weld the components and not weld the fixtures holding the rod segments. This positioning block and the mating lower assembly, was very tight on sufficient room in that respect. Note: Need to find a good welder!

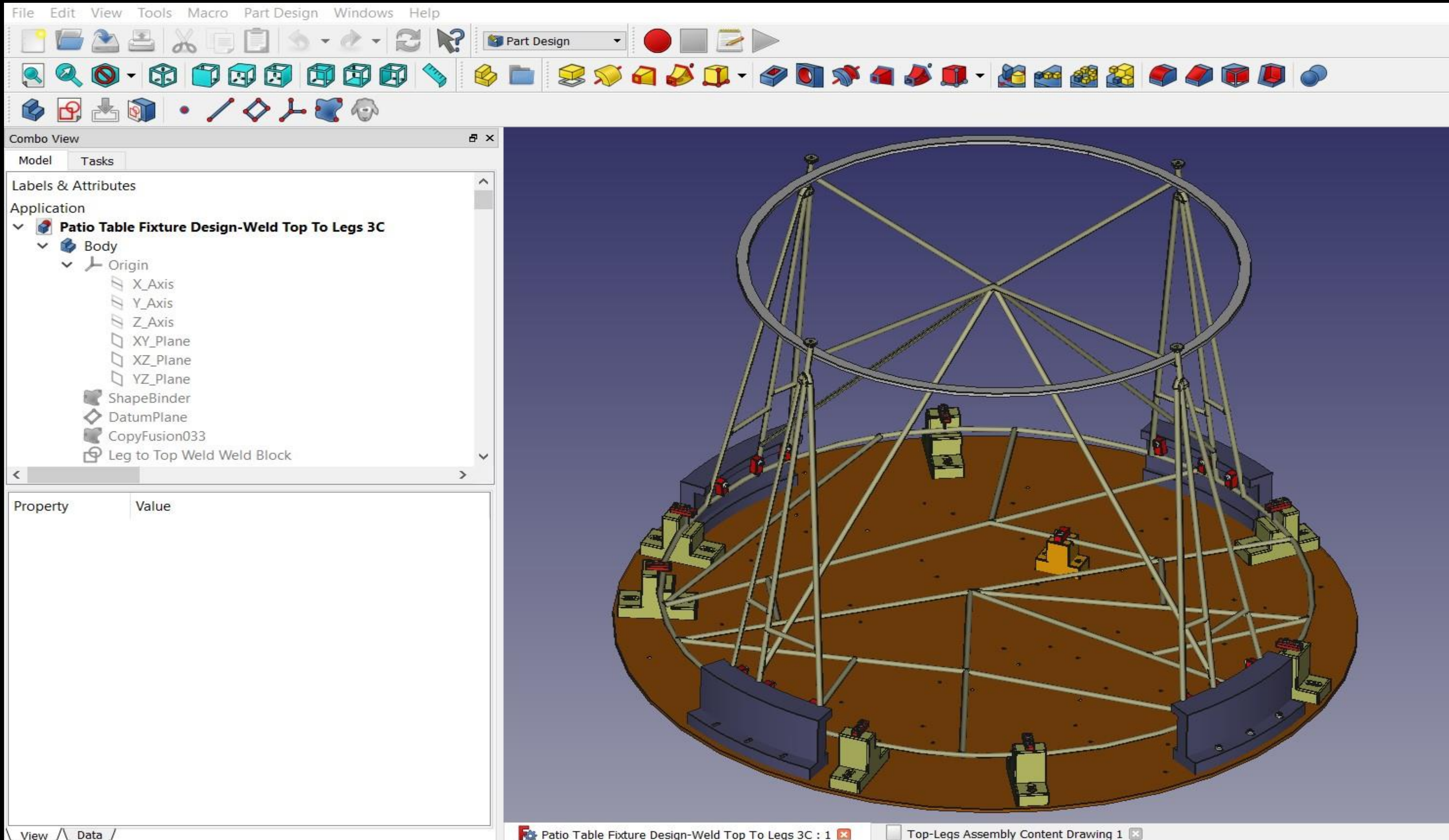


Leg Fixture Clamps: The clamps that are associated with each positioning block, in some cases, are the same length and have the same hole locations (shown in red, pictured above) and in the tabulated drawing on the next page. The specific angle and location of each positioning block groove requires that the location of the clamp be centered on the axis of the rod segment being clamped. This is an ideal outcome. In reality, if the clamp is within an allowable margin, I can use the same size clamp to lock the rod segment securely in position.

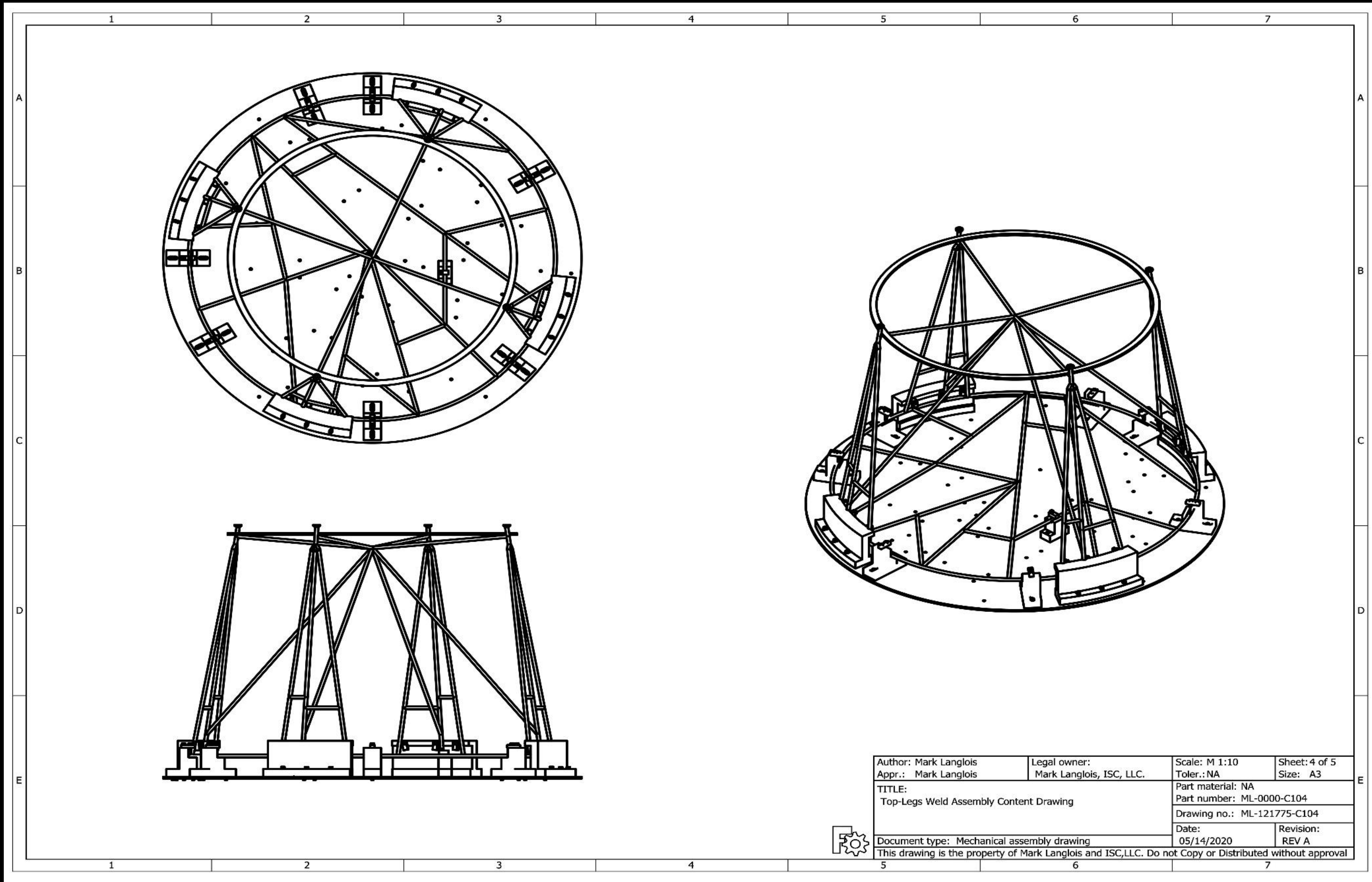


	* A Dimension	* B Dimension	Number Of Clamps	Clamp Identifier	Color	Part ID
1	50.8000	38.1000	4	General Clamps #1-4	Red	B, C, G, E
2	44.4503	26.9925	1	Clamp #5, Leg, X-Brace RT	Brown	A
3	50.8000	43.4630	1	Clamp #6, Leg, End Stop	Dark Blue	C2
4	42.7000	31.0174	1	Clamp #7, Leg, Upper Brace	Lime	F
5	50.8000	33.8000	1	Clamp #8, Leg, LT Psn Block	Light Blue	D

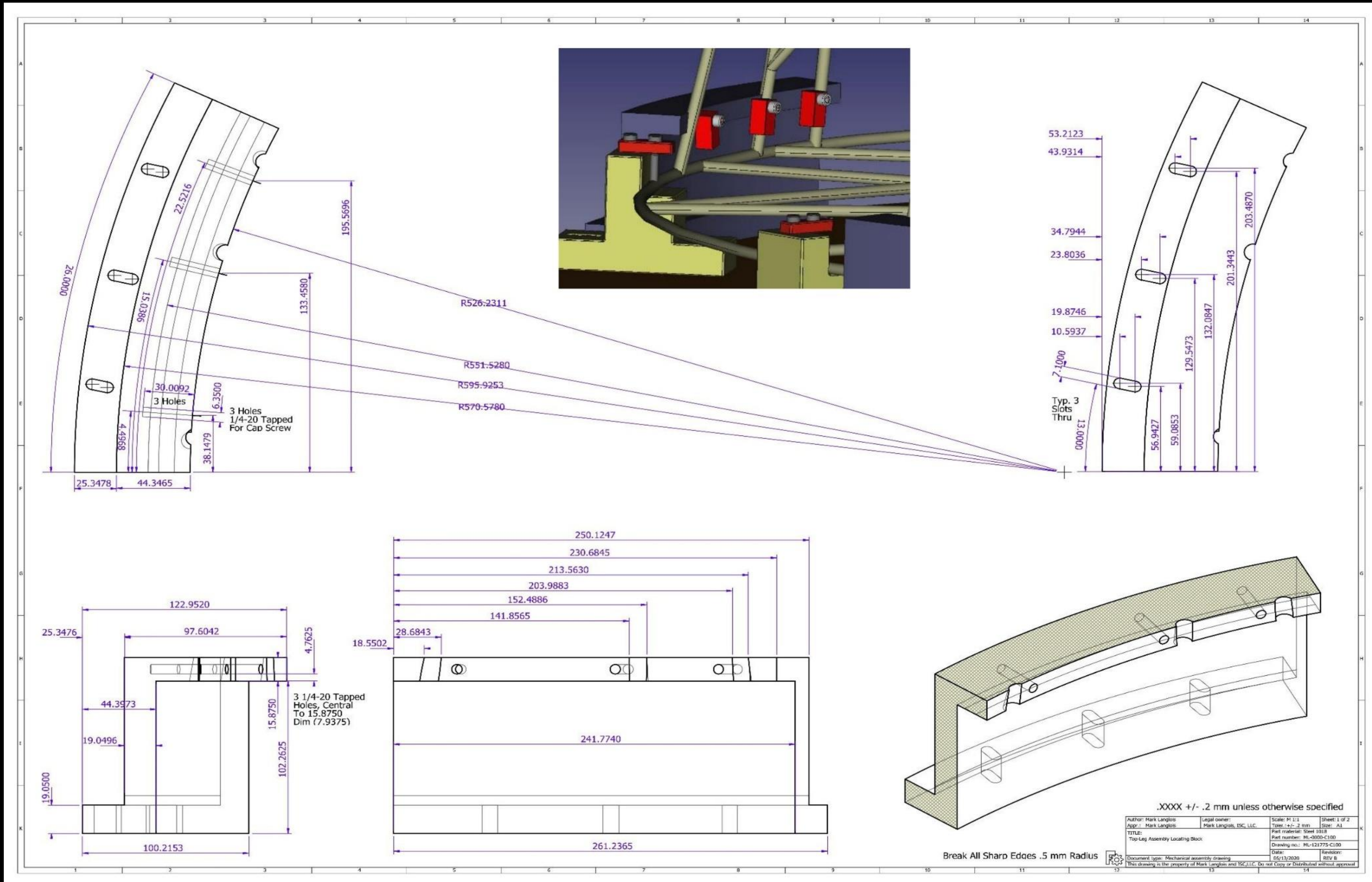
Leg Fixture Clamps-Tabulated Drawing: I created this tabulated drawing showing the common dimensions for the 4 red clamps. The remaining 4 clamps use the dimensions from the table. The *A dimension "length" in the (front view) from the back face to the end of the clamp. The *B dimension shown (top view) provides the dimension to the hole center location as called out in the table.



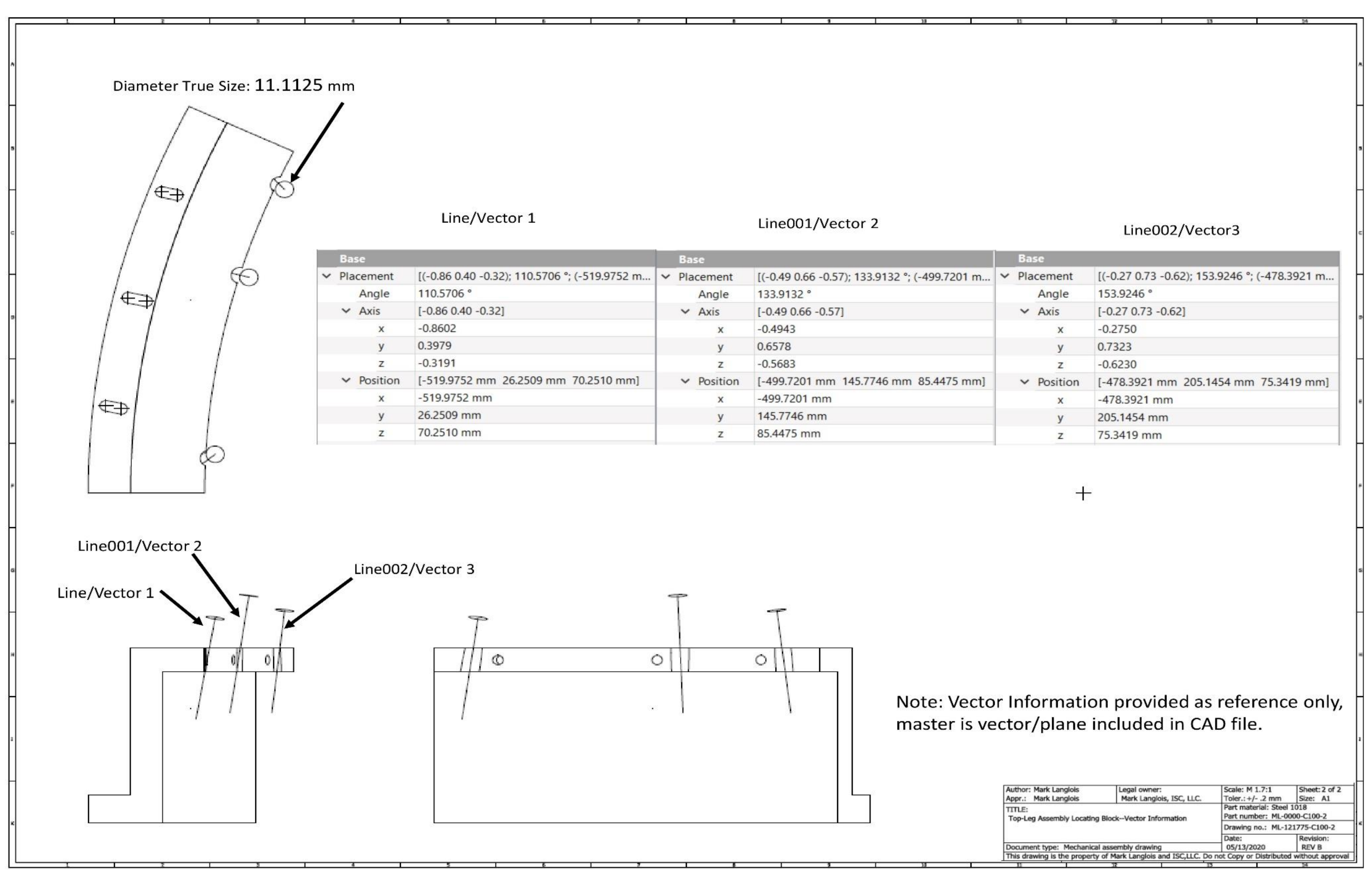
Assembly Fixture Components-Mating The Legs To The Top: The last fixtures that I designed were 4 assembly positioning blocks that locate the legs spaced 90 degrees apart. It also positions the top of the right, center and left leg rod segments on the center line of the table top ring and incorporates slots cut into the block face to orient and clamp the right, center and left leg rod segments to maintain the correct spacing on the outer diameter. In addition, I designed a ring gauge to locate each of the 4 legs at the proper inboard diameter.



Assembly Fixture Component Drawing: In addition to the assembly positioning blocks and ring gauge, I leveraged the existing weld base plate and 7 of the table top ring weld shoes from the previous component weld operations to hold and position the table top.



Top-Leg Assembly Locating Block Drawing 1: I designed the top-leg assembly block to position the right, center and left leg rod segments on the center line of the table top ring. Slots are cut into the radial diameter to position and clamp the right, center and left rod segments. This radial diameter, is the sweep of the welded leg assembly, approximately 34 mm below the table top ring.



Line/Vector 1

Base	
Placement	[(-0.86 0.40 -0.32); 110.5706 °; (-519.9752 m...
Angle	110.5706 °
Axis	[-0.86 0.40 -0.32]
x	-0.8602
y	0.3979
z	-0.3191
Position	[-519.9752 mm 26.2509 mm 70.2510 mm]
x	-519.9752 mm
y	26.2509 mm
z	70.2510 mm

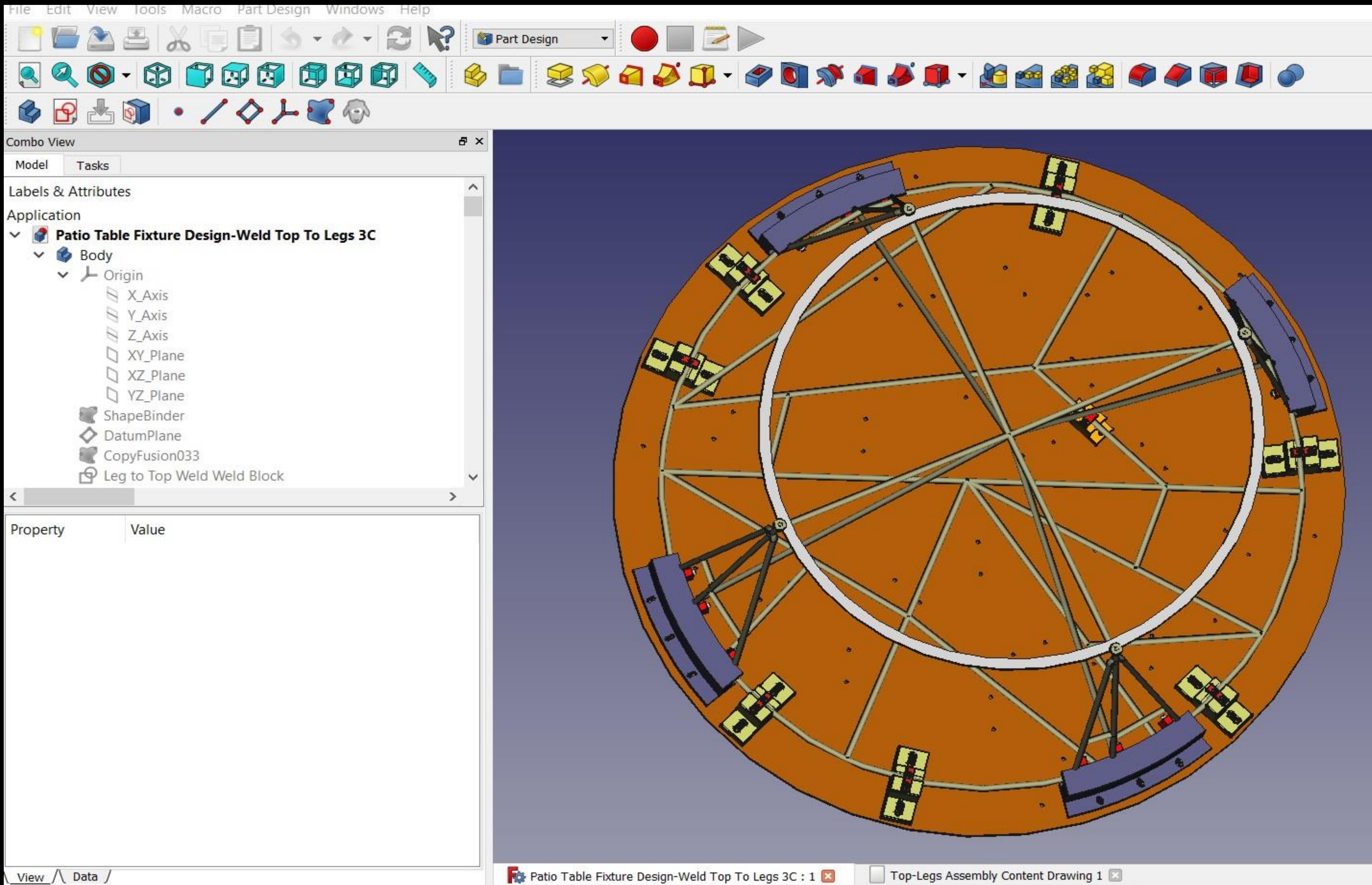
Line001/Vector 2

Base	
Placement	[(-0.49 0.66 -0.57); 133.9132 °; (-499.7201 m...
Angle	133.9132 °
Axis	[-0.49 0.66 -0.57]
x	-0.4943
y	0.6578
z	-0.5683
Position	[-499.7201 mm 145.7746 mm 85.4475 mm]
x	-499.7201 mm
y	145.7746 mm
z	85.4475 mm

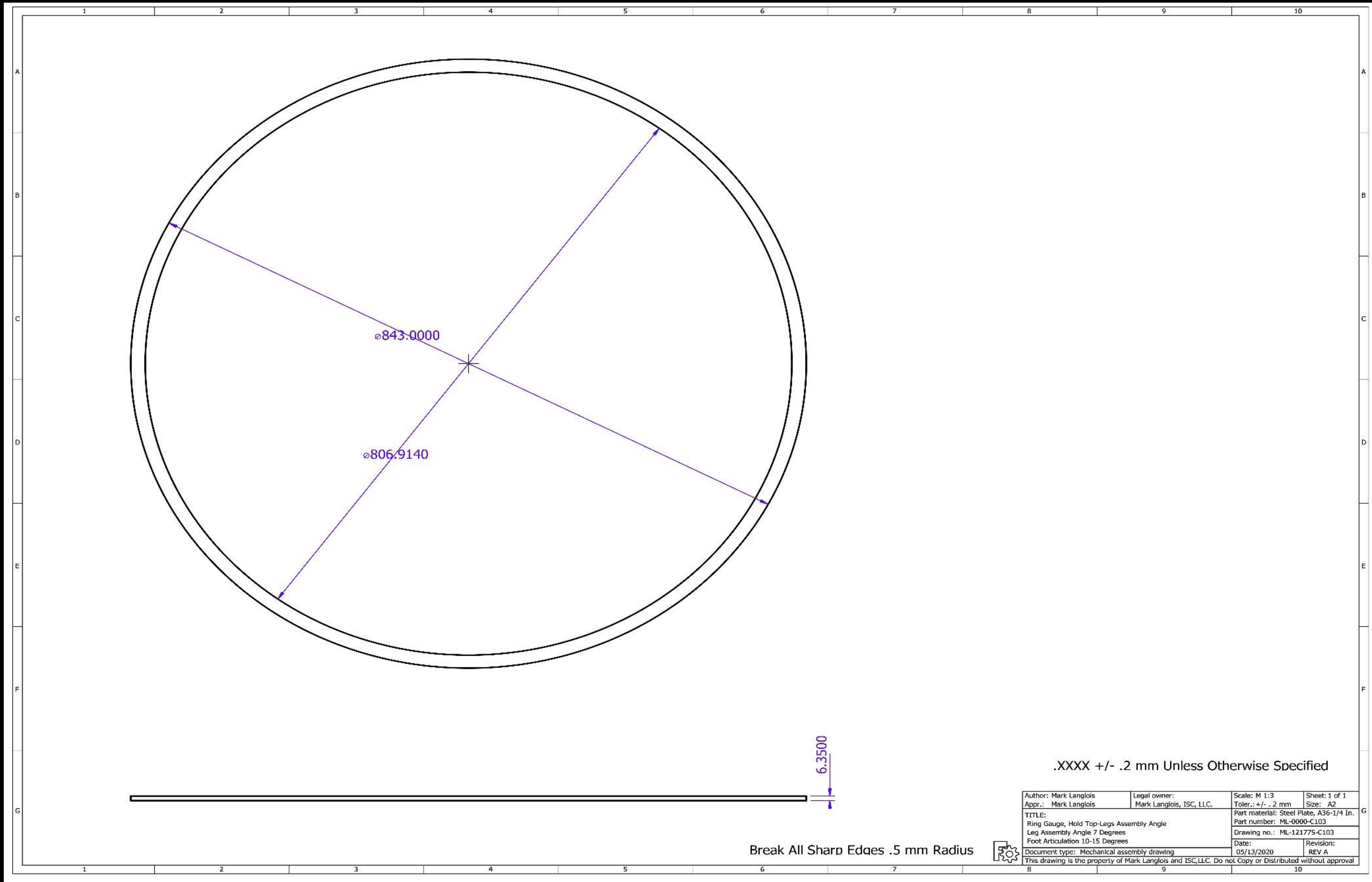
Line002/Vector3

Base	
Placement	[(-0.27 0.73 -0.62); 153.9246 °; (-478.3921 m...
Angle	153.9246 °
Axis	[-0.27 0.73 -0.62]
x	-0.2750
y	0.7323
z	-0.6230
Position	[-478.3921 mm 205.1454 mm 75.3419 mm]
x	-478.3921 mm
y	205.1454 mm
z	75.3419 mm

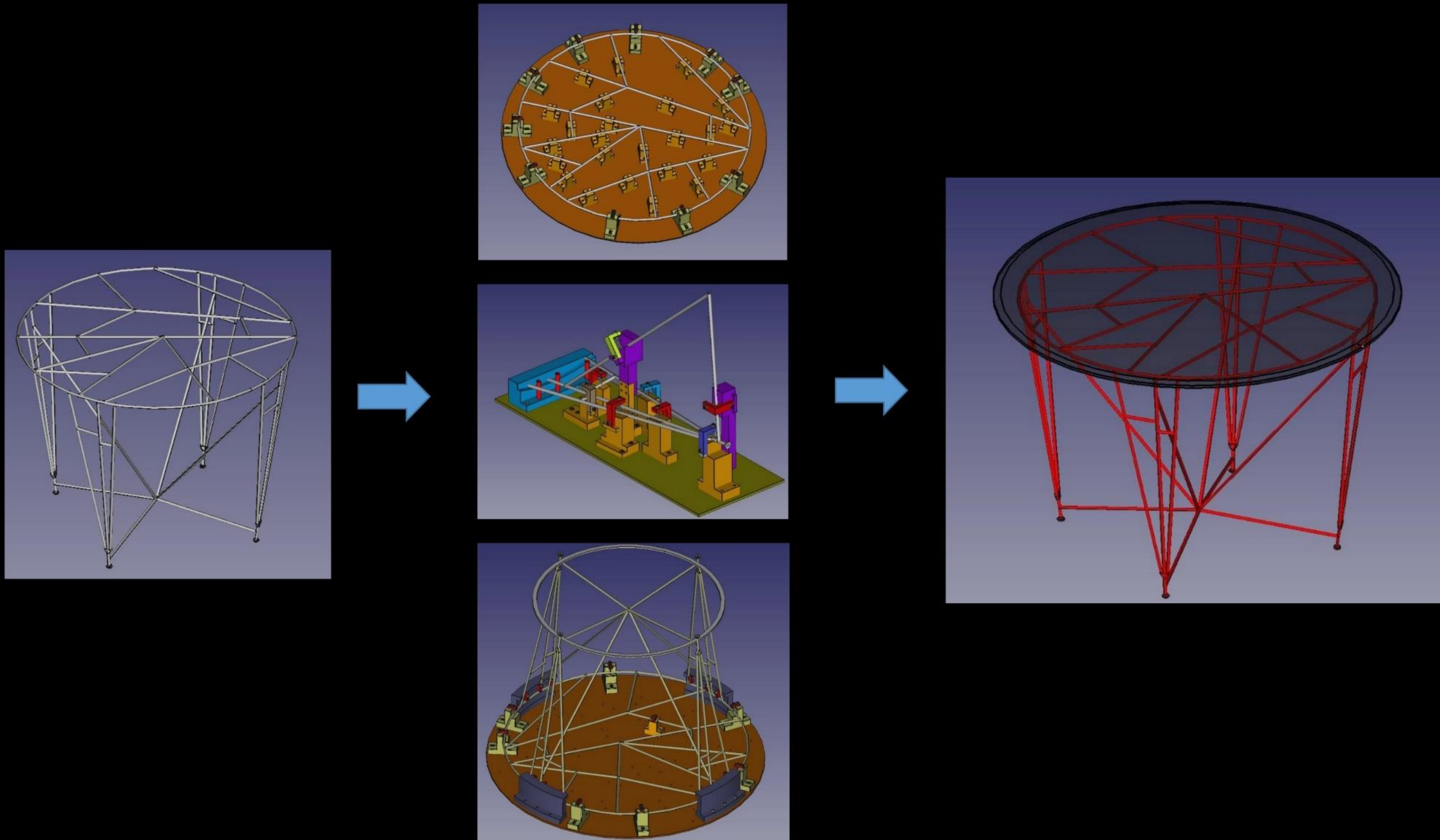
Top-Leg Assembly Locating Block Drawing 2: I created this drawing to provide my vendor with the necessary vector information to make this assembly block. My vendor will need the vector information for each of the rod segments as it passes through the radial sweep in the block. The right, center and left leg rod segments are all oriented along a different vector through the block. These vectors were also included as part of the CAD file to assist the vendor in making the cuts.



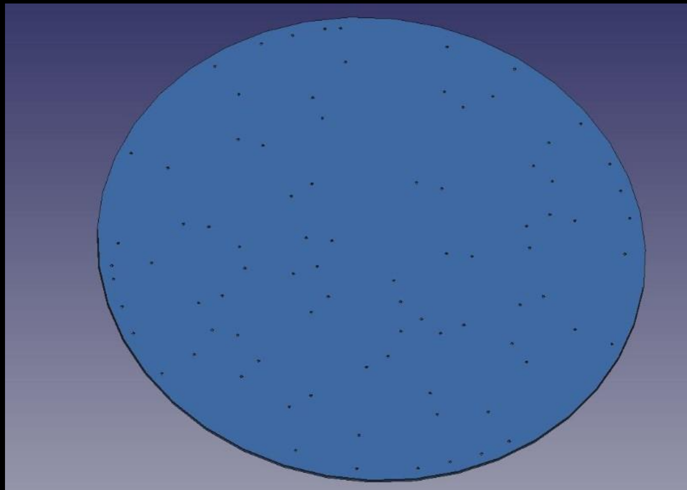
Ring Gauge Component: The ring gauge is a steel ring that has been cut to the inboard diameter where each of the legs should be located. The ring gauge is both a locating and measuring tool to keep each leg at the same angle. However, this gauge is not fixed in position and allowed to float. I anticipate that the welded construction will result in some assembly deviation. The ring gauge can show me how much variation and will assist in making balanced adjustments.

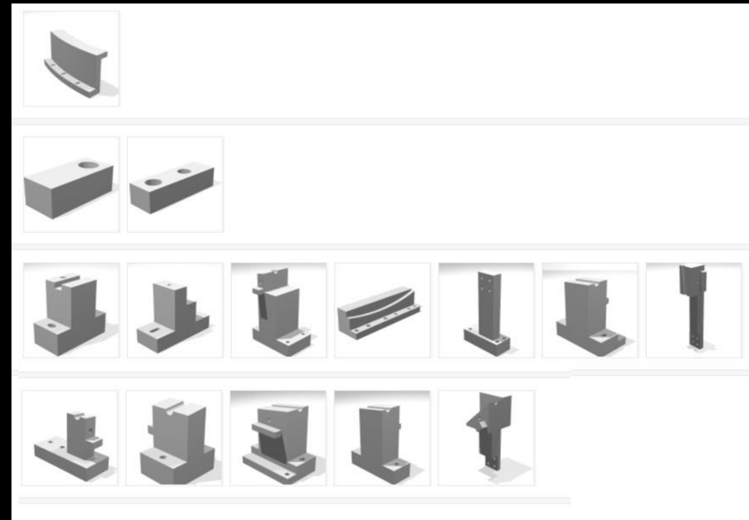


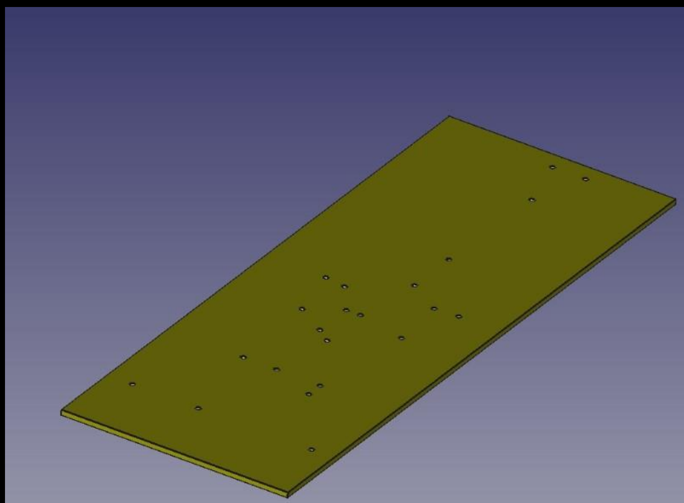
Ring Gauge Component Drawing: The ring gauge is 3/4 of inch wide and 1/4 inch thick and cut from A36 steel plate. I designed this ring to be placed between each of the legs to balance and measure the inboard leg angle. The ring gauge outside diameter is the diameter defined at 7 degrees inboard from the outside diameter of the table top ring. This ring was laser cut by the same vendor that made both of my base plates.

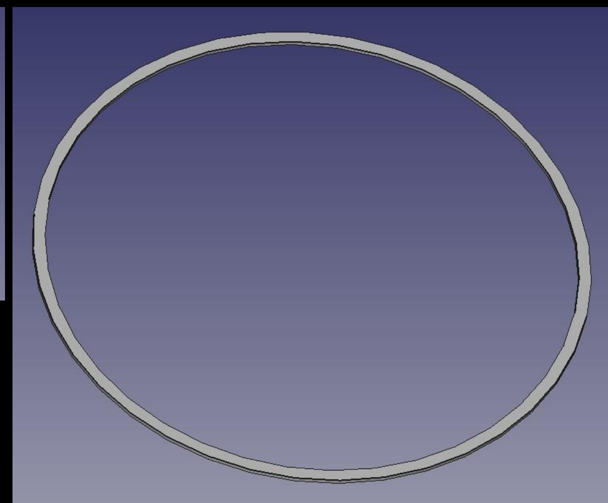


I have created a 3D solid model of the table. I have leveraged the table solid model to design all of the fixtures necessary to maintain the design intent. So now it's time to make an important decision. Do I build the table? The table, its design, and the creation of all of the fixtures has been an expenditure of my own time; with the exception of having the 3D printed models made. Actually making the table will cost money and the probability of additional unknown problems to solve. My decision; go forward and build the table using the designed fixtures and tooling.









Locate Machining Vendors And Make The Tooling: I put in a good amount of effort into contacting fabricators and tooling vendors, getting material costs and machining quotes. The material costs associated with the tooling is not that expensive. However, machining the fixture details, is not inexpensive. I needed to find the right vendor, get and accept a quote, send the vendor the CAD files that define the part detail along with all of the drawings and other necessary information, and then, get my credit card out!