To: Dr. Sarah Oman, Ulises Fuentes

From: Hunter Daniel, Katherine Riffle, Kenyon Rowley

Date: 28 February 2020

Subj: Implementation Memo

The Aneuvas Tech. team is tasked with designing and constructing a portable medical bench to be utilized in the Wettaw Biology building. This bench will assist Dr. Becker and his team in tests and experiments. This memo details manufacturing of the four major components of the bench - tabletop, frame, storage, and wheels - as well as how they are combined to form the full portable medical bench. It additionally discusses design changes that have arisen and future implementation of the device. In regards to the tabletop, the team went through many design changes. The tabletop's original design was to be constructed of oak. This design had a section of wood cutout and replaced with a polycarbonate workplace. This was intended to make the tabletop have a section that could be used for x-ray experiments. The final design is a tabletop manufactured of a wood laminate without a polycarbonate workspace. This design is less complicated than the original but still offers a x-ray compatible tabletop. The frame did not go through a very drastic change in its design. The only change that occurred was the addition of a shelf in order to secure the air filter under the tabletop. The storage aspect of the bench progressed from an L-shaped design to the addition of a drawer at the request of our client, Dr. Becker. The wheels never went through a design change as Dr. Becker was very specific about the wheels he wanted for the bench from the start.

1 Implementation

The implementation section describes the full process of manufacturing of the portable medical bench. It includes updates in the design to the manufacturing process, every iteration of the portable medical bench design, and the reasons for these changes.

1.1 Manufacturing

The following details how the portable medical bench is manufactured. It combines outsourcing and in-house manufacturing. The tabletop and frame are outsourced, the storage is built in-house, and the wheels will be ordered. The components will be combined in-house.

1.1.1 Tabletop

The tabletop will be manufactured by Only Table Tops. The process of getting the tabletop manufactured began with its design. The team analyzed the material that will be used to make the tabletop and calculated the thickness that would be necessary to support the loads of the equipment used in the experiments. The team then created the design in Solidworks and created a drawing. That drawing was then sent to be approved by the company to receive a quote. The company quoted the design for $545.

1.1.2 Frame

The frame is ordered from Mayorga's Welding. The design of the frame was done similar to the tabletop, ensuring it can safely support the loads of the equipment. They quoted around $450 for the design.

1.1.3 Storage

The storage is built in-house. The materials required for storage construction are: a sheet of plywood, nails, wood glue, wood putty, sandpaper, paint primer, paint, and a knob. The team uses specific equipment in order to build the storage: a table saw, hand saw, nail gun, impact drill, tape measure, measuring square, paint brush, paint roller, and a sander. The first step is cutting the necessary pieces from the 4'x8' sheet of plywood. The storage is then assembled one side at a time. The drawer consists of a box inside of a box; due to the drawer being so small, drawer slides have been omitted. After all the pieces are assembled, the storage is sanded. The storage is then coated with primer, covering all the crevices of the wood, because this shows after a coat of paint is on. After this is complete, a coat of black paint is applied to match the tabletop. The storage is then examined to determine if more coats of paint are necessary. Finally, the drawer knob is attached.

1.1.4 Wheels

The wheels are purchased from McMaster-Carr and are attached to the frame with 4 bolts for each wheel. Each wheel is designed to carry a load of 250 lbs., a load support that was decided based on client preference and achieving a factor of safety of about 3 when considering the total weight of the device and the items the device would be carrying.

1.2 Design Changes

This section chronologically discusses the design changes that have occured for the wheels, tabletop, frame, and storage. Changes in design are primarily articulated through SolidWorks. Prototypes are included.The section then discusses the current state of the system manufacturing process.

1.2.1 Revision 0: SEM1

The first iteration of the design focused on the tabletop and on the storage area. After consulting with the client, the chosen wheels are pneumatic tires.

1.2.2 Tabletop

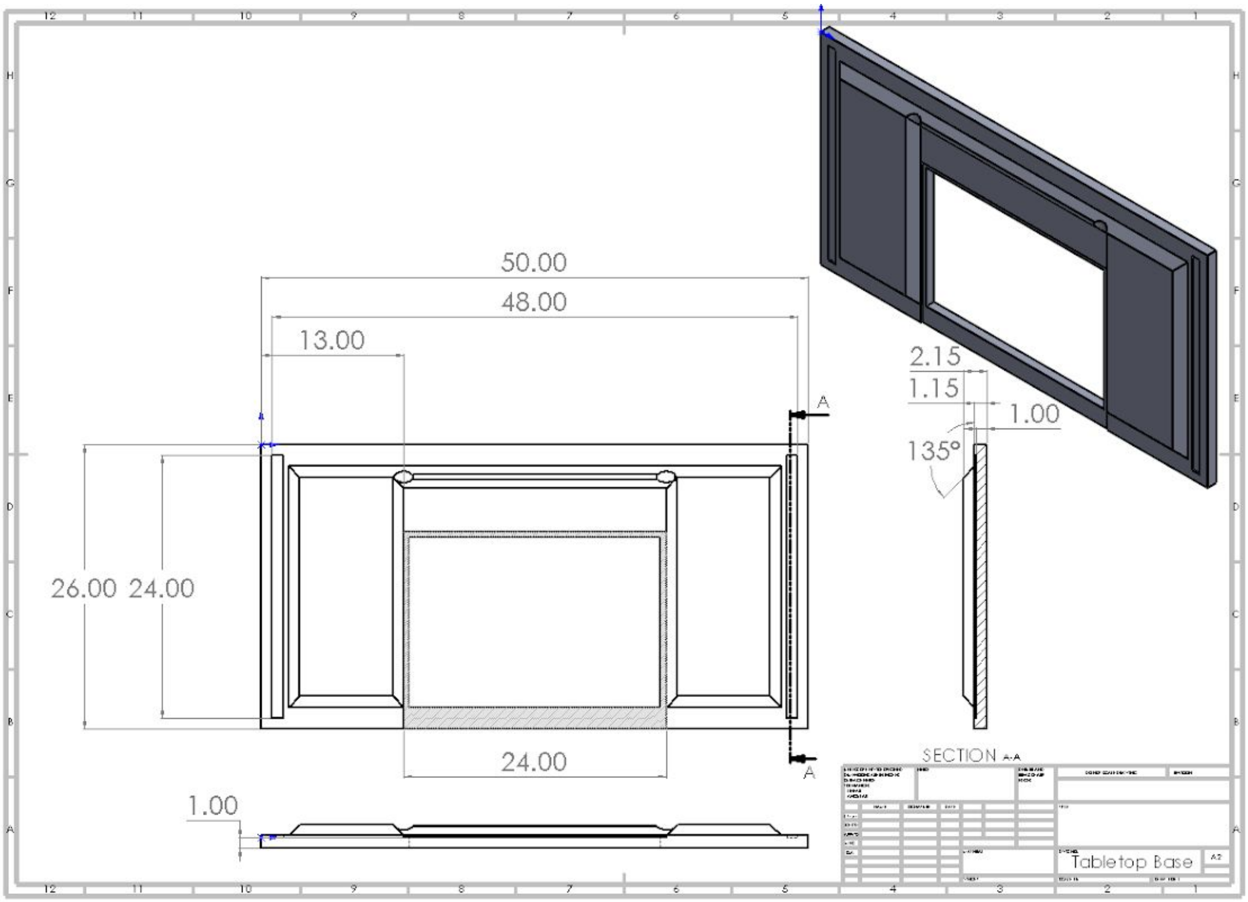

Figure 1: Tabletop REV0

The tabletop for the original design has the horizontal dimensions of the clean room hood that it supports. The design features platforms for the devices to rest on so that they are protected from spills, a polycarbonate workspace for x-ray compliance, and grooves for the clean room hood to rest in. The dimensions are tight with the clean room hood to ensure easy maneuverability and fitting through doorways. The platforms protect devices from workspace spills. The workspace is polycarbonate so that the tabletop is x-ray compliant. The grooves support the clean room hood so that the clean room hood does not fall, improving operational and portability safety.

1.2.3 Storage

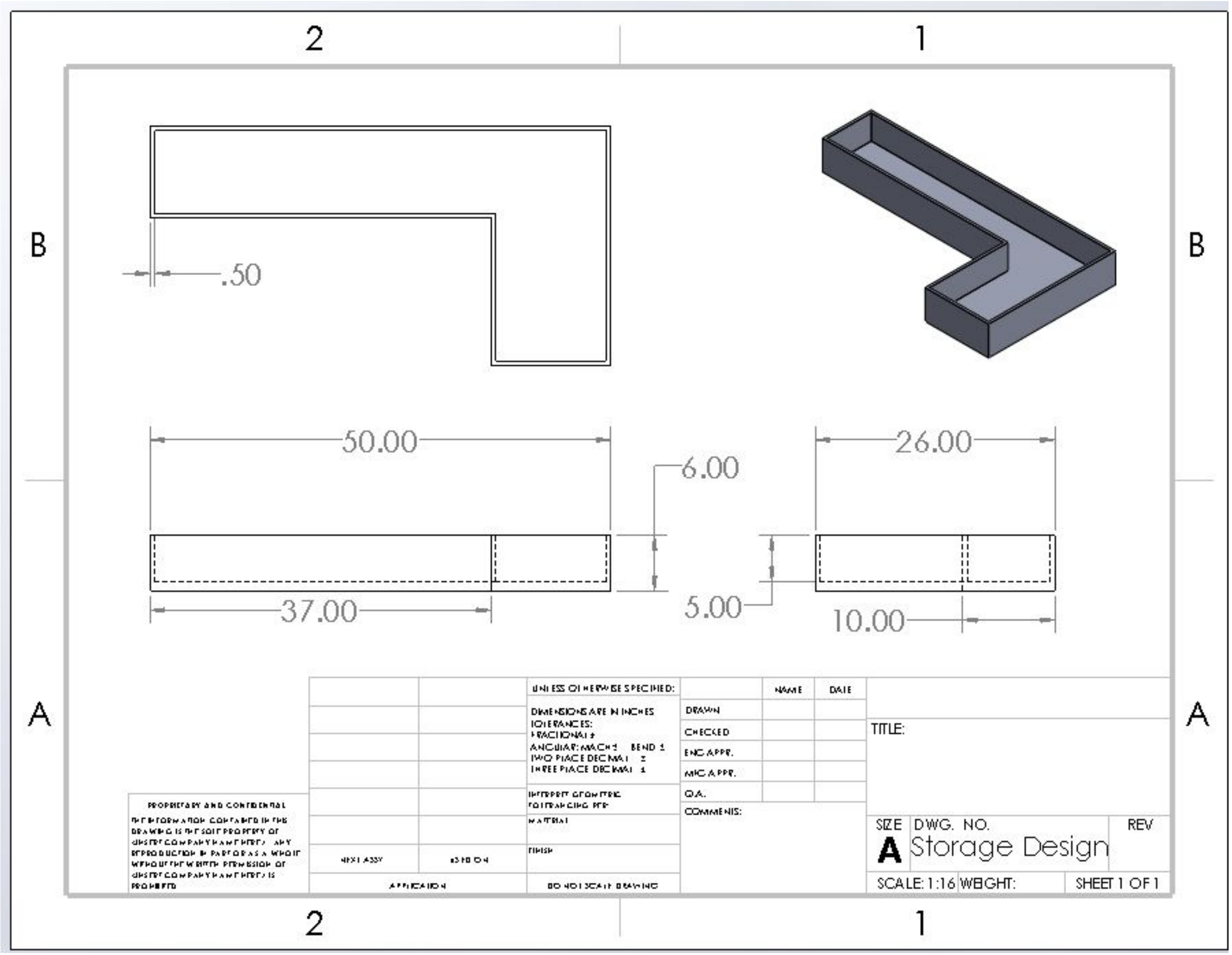

Figure 2: Storage REV0

The original storage design is L-shaped to provide leg-room for the bench to additionally be used for a desk. There is adequate storage for the medical devices required from Dr. Becker. The storage area is also dimensioned so that if there is a leak around the polycarbonate workspace, the spill does not enter the storage area.

1.2.4 Revision 1: SEM1

This section describes the final design for the first semester, comparing it to the original design. Client requests for this revision include increasing the tabletop length to six feet, employing a different type of shock absorbing tires, and providing storage specifications. The design is illustrated through SolidWorks 3D modelling, and through prototypes of some of the design's particular aspects. The final design is communicated by first describing the tabletop, storage, and shock absorption components, then presenting the design as a full assembly, to show how the components fit together with the table legs, and to explain aspect placement.

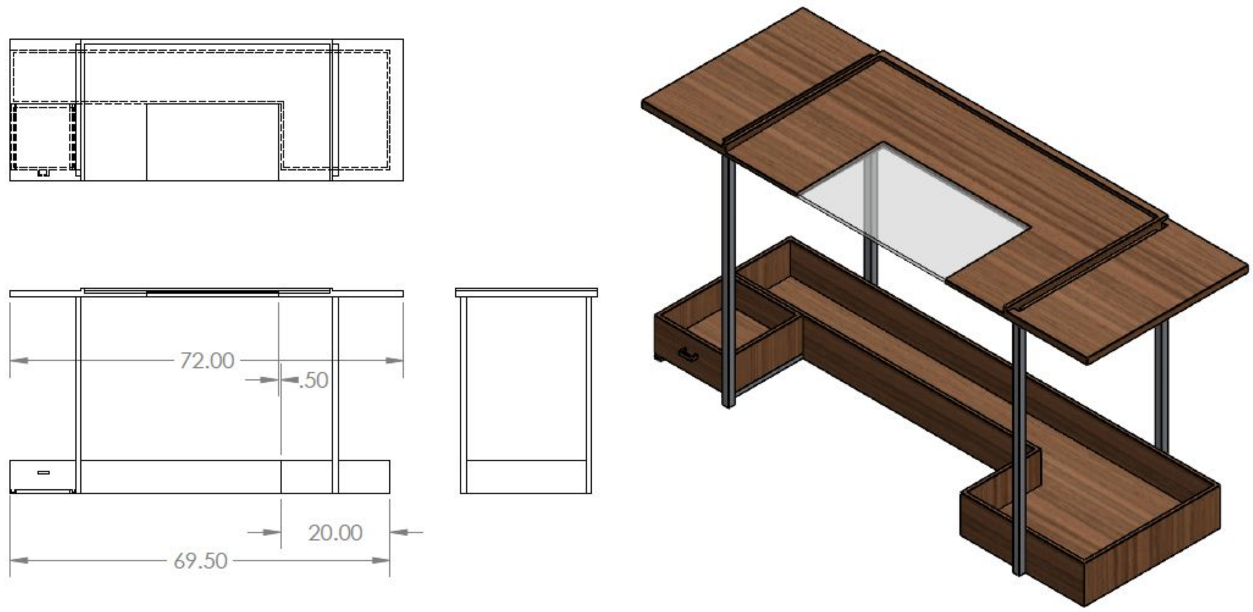

Figure 3: Final Design First Semester

The SolidWorks assembly, shown in Figure 3, depicts the tabletop, with the polycarbonate workspace, fitting together with the storage area and the placement of the table legs. The placement of the table legs is pre-determined by the clean-room hood. The clean-room hood weight will be diverted to the legs, and it reduces the amount of stress on other areas of the tabletop or beams to place the legs directly under the corners of the clean-room hood frame. The aerial view depicts the storage area being separated from the workspace, in case of leakage in the seal. The aerial and front views show that the storage has a shorter length than the tabletop on the right side, but is flush with the tabletop on the left side. The side view shows that the tabletop extends farther than the legs, but that the storage area is contained within the dimensions of the table legs. Polyurethane foam tires are attached to the bases of the legs for shock absorption. This selection was instructed from the client, and has changed from the suggested pneumatic tires from REV0. The polyurethane foam wheelbarrow tires will not deflate or flatten.

1.2.5 Tabletop

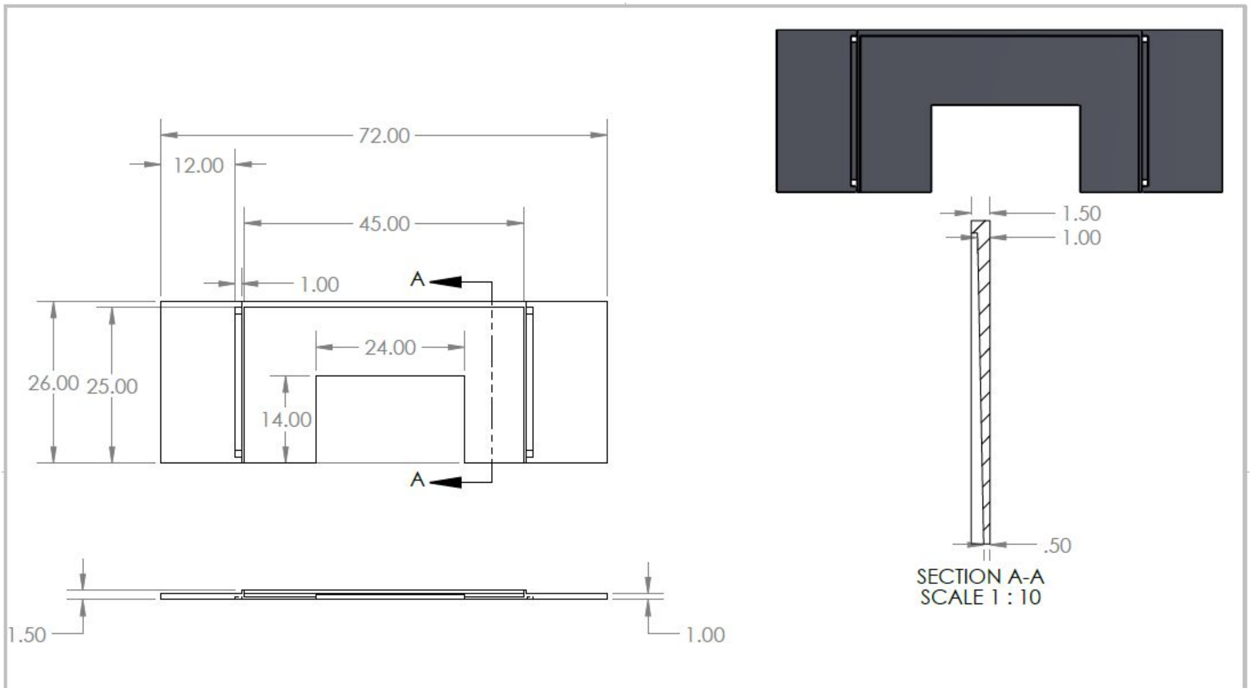

Figure 4: Tabletop REV1

Figure 4 depicts the first semester final design for the tabletop, with measurements in inches. The polycarbonate workspace is attached to the 14"x24" area in the center of the tabletop. This area corresponds to the clean-room hood workspace access. Polycarbonate does not span the entire tabletop because it is not sturdy enough to support devices or normal desktop live loads without movement. The deflection relies inversely on Young's Modulus, measuring elasticity, and the value of Polycarbonate is too low, around 10^6 psi, to allow for a low deflection at such a thin workspace. The workspace area may have to be reduced if, during testing, the polycarbonate is determined to be too flexible for its thickness. A different material is used for the rest of the tabletop because it should be a material that does not require reinforcements across the workspace area, to minimize x-ray videography/imaging interference. The tabletop is made 1.0" thick so that it does not interfere, geometrically, with the x-ray machine, which should reach as close to the top of the workspace through the thickness of the workspace as possible. This thickness has not changed during past revisions. The 25"x45" workspace area in the middle of the tabletop is contained within the clean-room hood area. It features a tilt for liquid spill drainage as shown in Section Cut A-A of Figure 4. This differs from the prior revision, shown in Figure 1, which does not feature the tilt, and instead uses elevated platforms to protect the devices from spills. The tilt is 0.5" downward from the back of the workspace to the front of the workspace and was added as such per client request. The workspace also features a containing spill guard, protecting the clean-room hood grooves from spills, and containing spills from falling behind the cart. This was also featured in the previous revision. The clean-room hood grooves provide an area for the clean-room hood to be placed into. The clean-room hood will be removed or attached by two people, placing it down onto the table, per client instructions, and will not slide off of the table. This was made clear early in the process and has not changed during revisions. The last change to the tabletop from the prior revision is an increase in table length to 72", per client request. This length is added to either side of the workspace, keeping the clean-room hood centered on the tabletop.

The tabletop prototype, shown in Figure 5, is a 3D printed 1:14 scale model of the final SolidWorks design. The prototype provided a visualization for the thickness of the table relative to its length and width. It showed that the thickness will be sufficient relative to the placement of the supports (legs), but that the tabletop thickness will be insufficient to support any of the weight of the clean-room hood. The clean-room hood weight should be placed completely onto the table legs, so a hole was employed through the table, at the ends of the clean room hood and to direct its weight directly to the legs, with no stress supported by the table. These holes are shown in Figure 5.

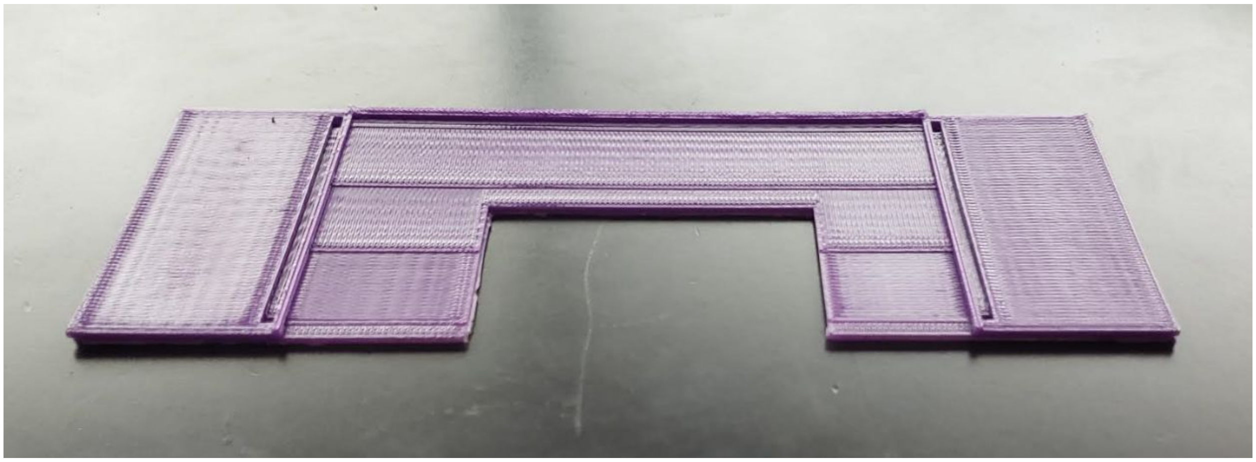

Figure 5: Prototype Tabletop REV1

1.2.6 Storage

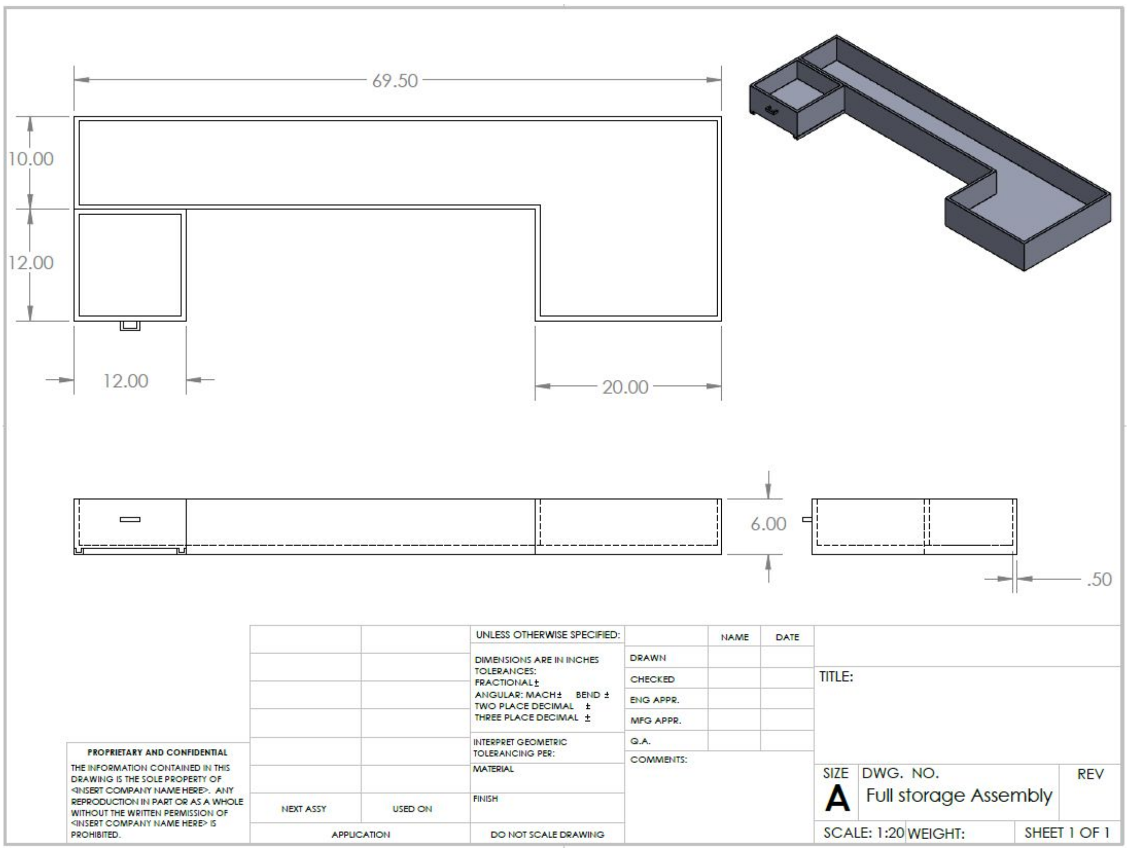

Figure 6: Storage REV2

Figure 6 depicts the first semester final design for the storage, in inches. The U-shape design was chosen for the storage area, so that the cart could be used as a desk with space for sitting. Moreover, this space is necessary to allow for the x-ray machine to fit directly beneath the workspace for videography and imaging. The storage area is almost six feet, the length of the table, but the reasons for its specific dimensions were provided by the client for this revision, an update from the Preliminary Report design, shown in Figure 13. A drawer for office supplies, requested by the client, pulls out for accessibility, and is shown in Figure 12 to be 12”x12”, enough area for office supplies. Its width is the distance from the location of the legs to the edge of the tabletop. It would not be appropriate to extend any of the storage area past the dimensions of the tabletop, due to accessibility and safety issues, aesthetics, and to provide a way to attach a laminate film for clean-room effect within the storage area during transport. The height of the back-most area in the L-shape storage shelf, 10” in the figure, is determined by keeping the storage within the confines of the table legs, and the back of the workspace. It is not susceptible to being leaked on if the workspace leaks where it is sealed; this precaution was emphasized by Dr. Becker. Similar precaution is taken for the storage area on the right, the larger portion of the L-shaped area, shown as 20” wide in the figure. It is dimensioned to be placed right of the above tabletop workspace, but is also centered between the right table legs, so that the storage is balanced. The changes from prior revisions include a wider length, to match the tabletop, and a wider storage area on the right side of the L-shape. The storage area has also been dimensioned to regard the tabletop and legs, since the dimensions for the tabletop have been further verified by the client.

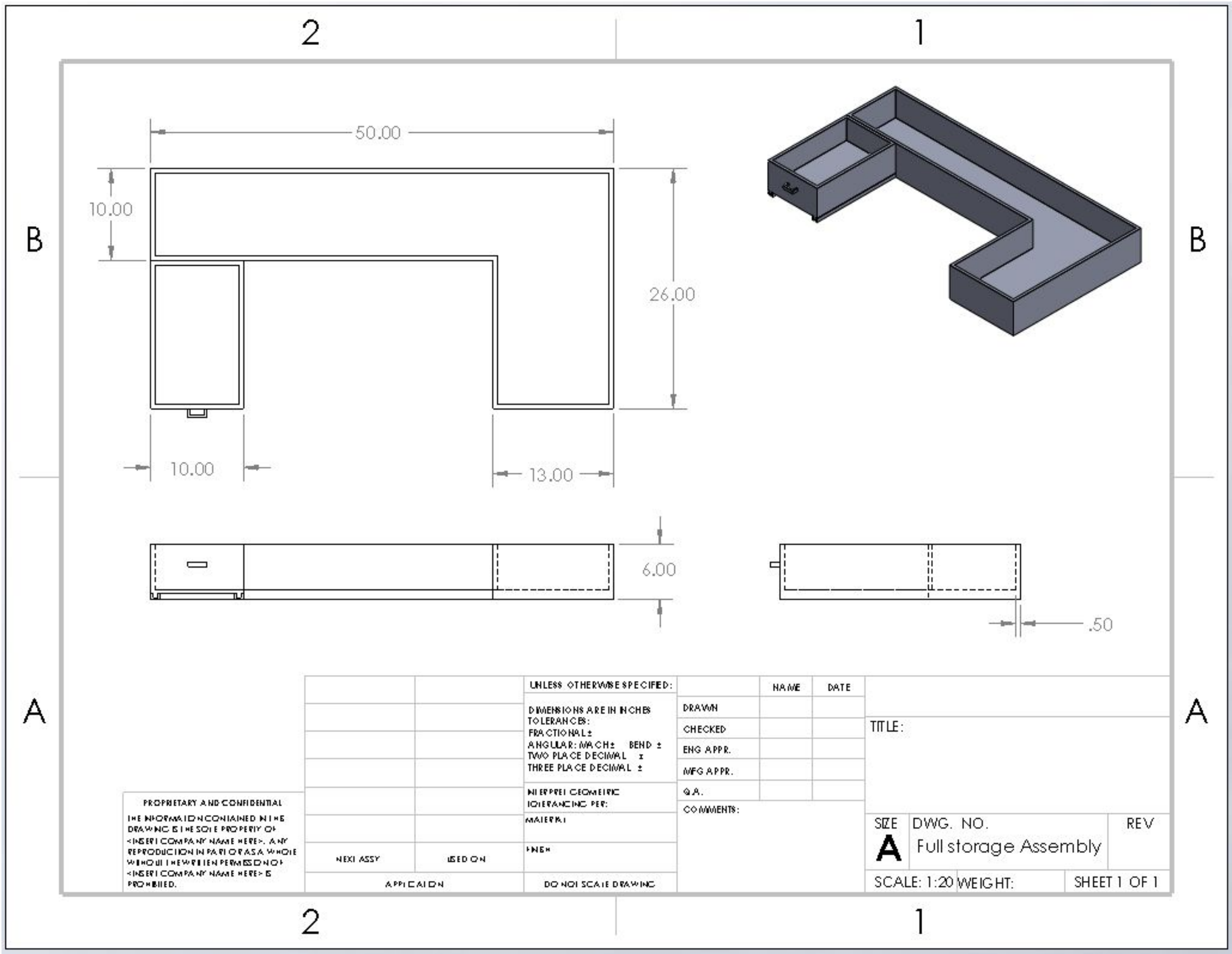

Figure 7: Storage REV1

The storage prototype, shown in Figure 8 below, is a 1:3 scale foam board construction of the final SolidWorks design. Seeing the proportions of the different areas in the storage assembly allowed visualization of what medical devices would be placed in each region. The largest region, the right-most area, will most likely hold the heaviest equipment. Because it will hold the heaviest and largest devices and equipment, that storage area should be balanced between the rightmost legs to allow for balance and equal support.

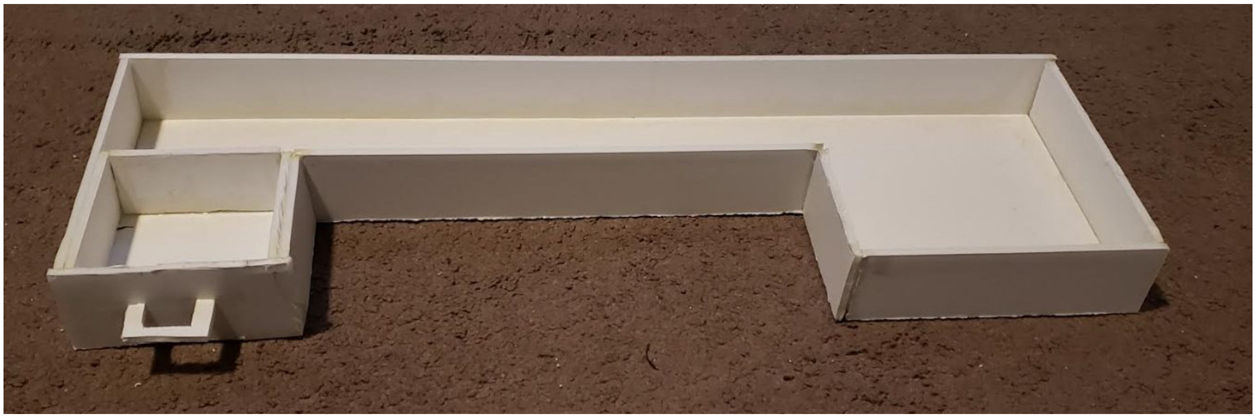

Figure 8: Prototype Storage REV2

The prototype shown in Figure 9 is constructed of wood to 1:3 scale of the design. It displays how the storage aligns with the tabletop, and how both are aligned with the legs. The prototype shows the position of the polycarbonate workspace relative to the tabletop and the storage area. The storage area is not enclosed, so that cords may go from the storage area to the tabletop. The storage is not centered with the tabletop, but instead is appropriately aligned with the polycarbonate workspace and necessarily balanced to be centered between the front and back legs. The clean-room hood frame is to be positioned directly above the legs of the table.

Figure 9: Prototype REV1

1.2.7 Revision 2: SEM2

Revision 2, starting in Semester 2, began by providing the clients Dr. Oman and Dr. Becker with the following options, Figures 10 to 13, to determine the best attributes for the bench. The main options shown are to decide on the width of the frame, whether the width should be the same as the clean room hood for maximum support, or whether the width should accommodate the air filter width for storage during transport. The issue is that the horizontal dimensions of the air filter match those of the clean room hood.

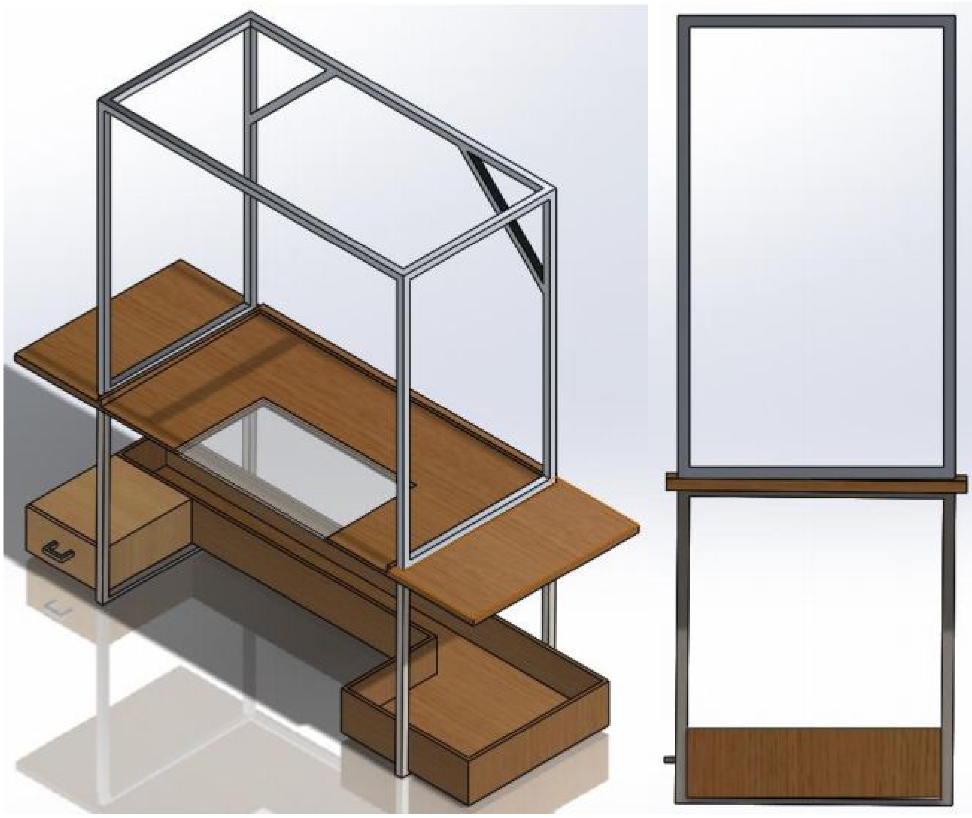

Figure 10: SEM2 Options: In-Line with Clean Room Hood, No Air Filter Support

Figure 11: SEM2 Options: In-Line with Clean Room Hood, shown with Air Filter Dimensions

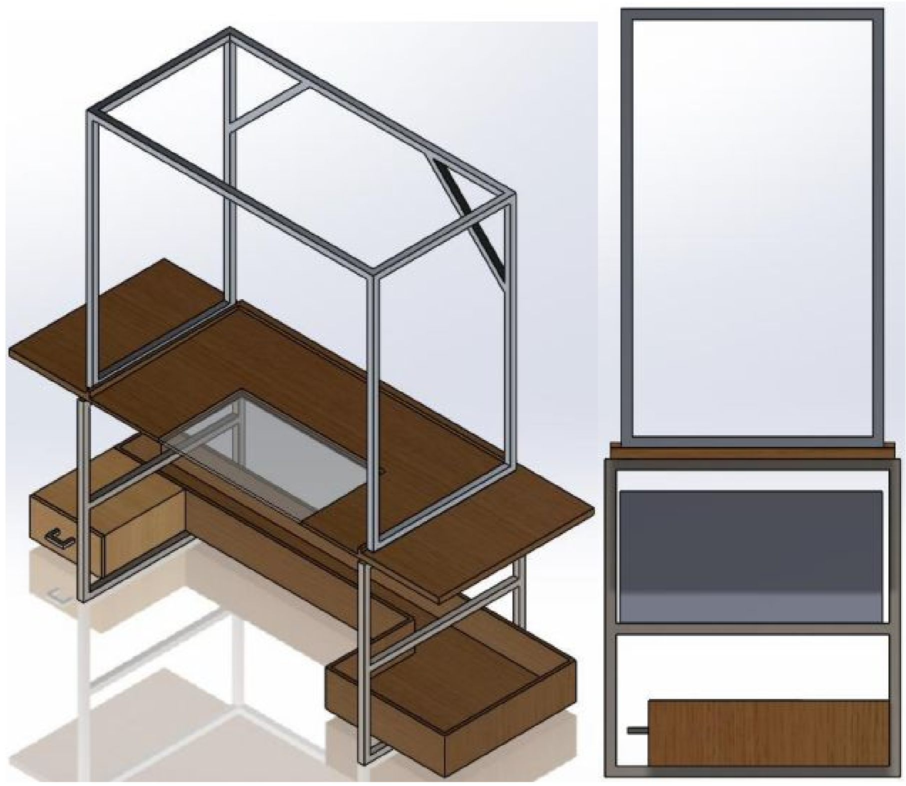

Figure 12: SEM2 Options: Wider than Clean Room Hood, shown with Air Filter Dimensions/Support

Figure 13: SEM2 Options: Frame Width Options with and without support

The options presented to the clients determined the following characteristics for the portable medical bench. The frame should definitely feature air filter storage for transport, as shown in Figure 12, so the frame is widened and support shelves are added. Dr. Oman suggests adding in triangular supports. The final frame design includes the Bolt Plates, detailed in Figure 15. Because this is the frame design used for manufacturing, all dimensions are specified and the Bolt Plates for wheel attachments are included. The frame includes the tilt, as during the meeting the client preferred the frame to have a tilt instead of the tabletop itself. Dr. Becker indicated a preference for 1" tilt downward from back to front. The tabletop will be attached to the frame with brackets.

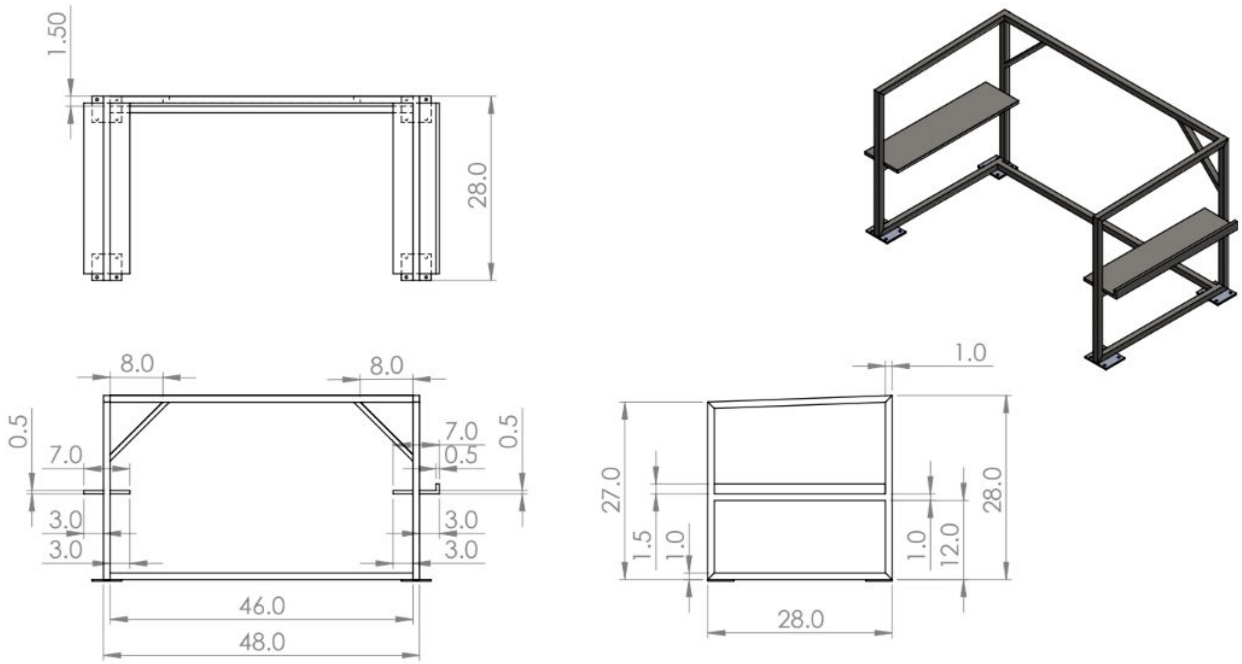

Figure 14: Current Frame: REV2

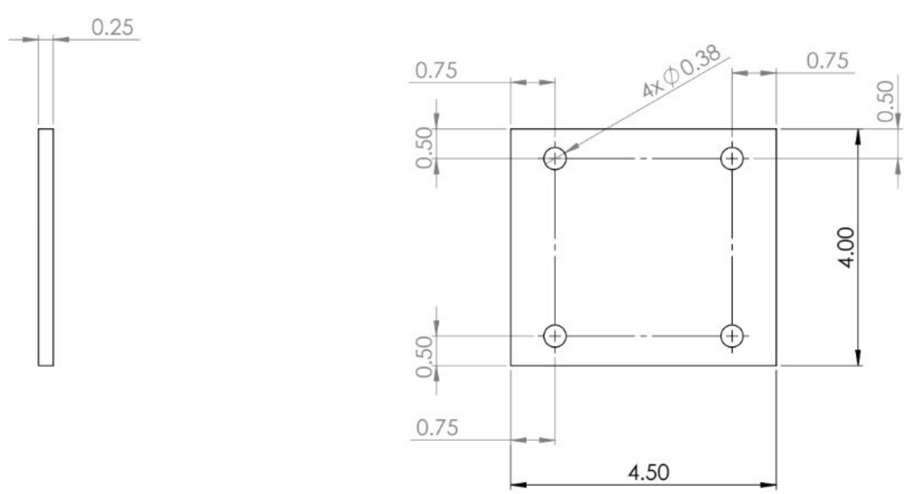

Figure 15: Current Bolt Plate: REV2

The tabletop design was changed almost entirely, no longer featuring a polycarbonate workspace. Instead, for x-ray compatibility and spill-safety, the workspace is constructed of Formica. All features are removed from the tabletop, and the result is shown in Figure 16. Additional features added to the tabletop are shown in the following Figure 17.

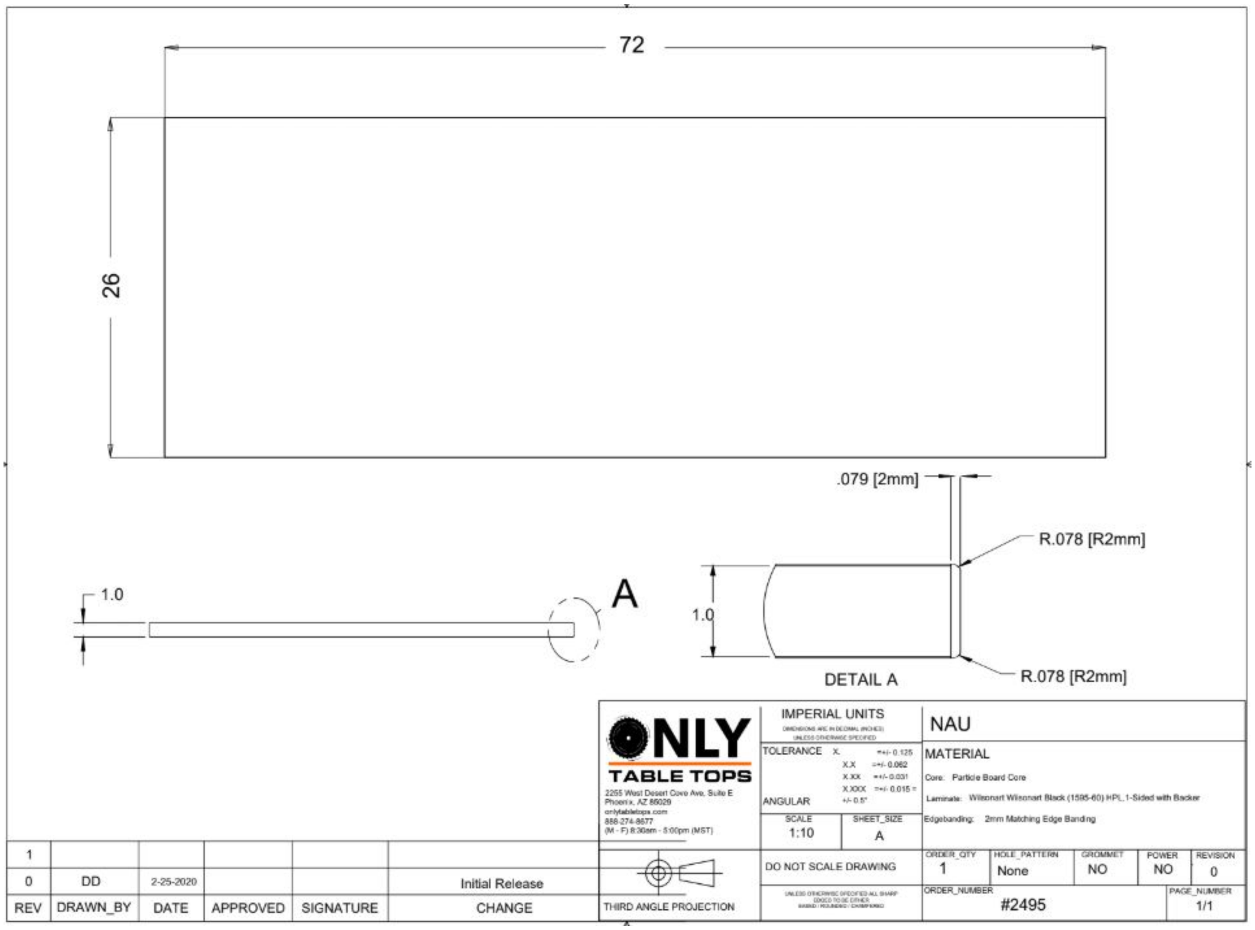

Figure 16: Current Tabletop: REV2

During the meeting, Dr. Becker indicated preference for a gutter tray, shown attached to the tabletop. The tabletop will have a wedge or support attached at the front of the tabletop beneath the clean room hood so that the workspace will feature a tilt for spills, but the clean room hood may still sit flat. Additional spill guards are attached to the tabletop, outside of the clean room hood so that they do not interfere with the clean room hood polycarbonate. The following Figure 17 also illustrates the dimensions of the medical devices that are stored on the portable medical bench. The tires approved by the client are shown in the figure as well.

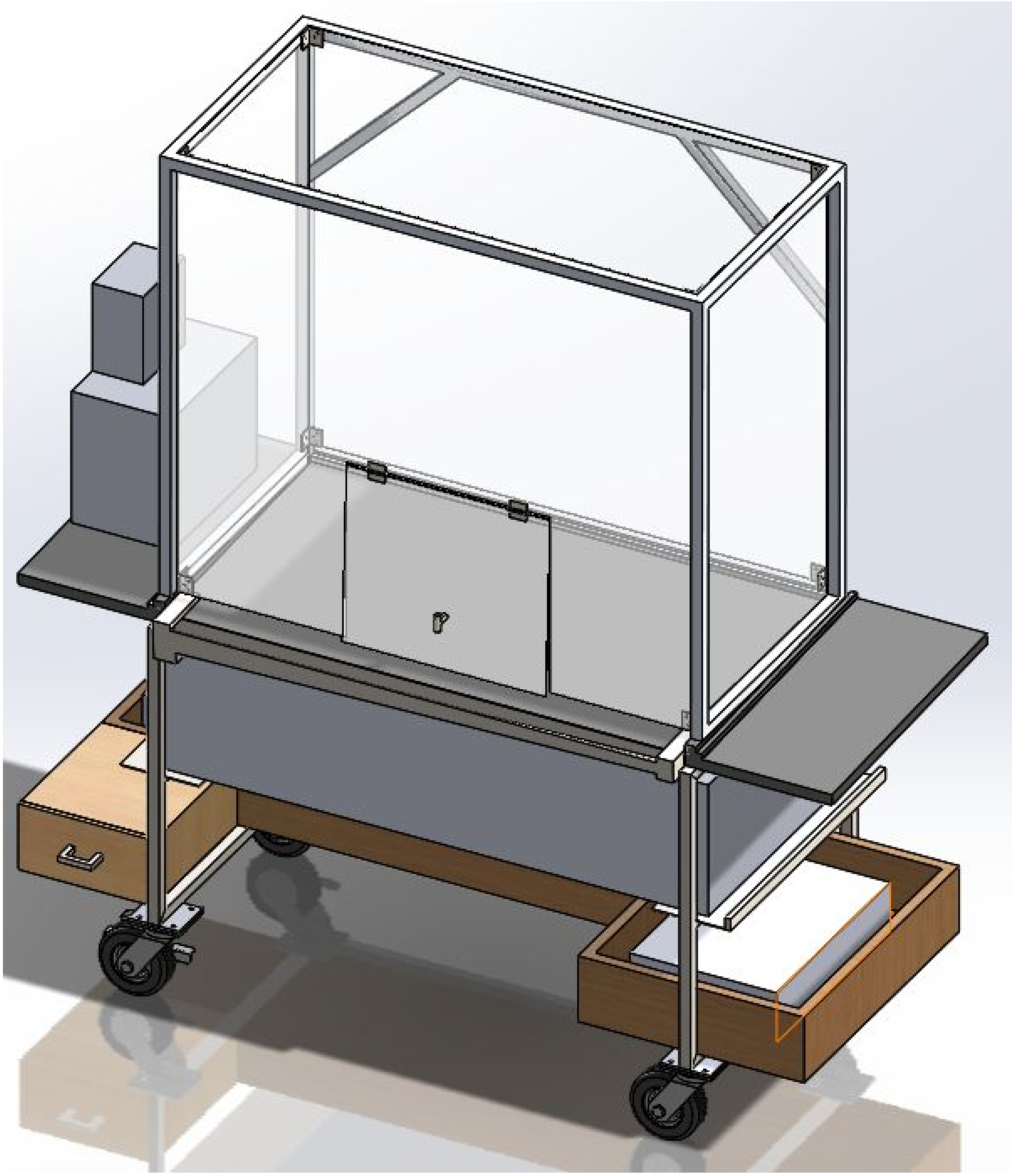

Figure 17: Current Assembly: REV2

The following Figure 17 shows the current state of the storage assembly. Its construction, and relative change, is detailed in the prior section. It is shown as part of the assembly in the previous Figure 17.

Figure 18: Current Storage: REV2

2 Future Implementation

Currently, the team has ordered or completed the manufacture of all parts of the bench besides the frame. The team is currently in contact with a company to manufacture the frame. The team has sent over the drawings of the frame and is waiting on confirmation that the company will build the frame.

2.1 Further Manufacturing and Design

Once all parts of the bench are received by the team, the bench will undergo testing to ensure its performance in the field. The tabletop will be tested to ensure it can withstand supporting the equipment and that it is resistant to spills. The frame will be tested with loads as well including the weight of the tabletop and clean-room hood. Lastly, the wheels will be tested for shock absorption.

2.2 Schedule Breakdown

Project Manager and Financial Manager	Kenyon			
Logistics Manager and Manufacturing Engineer	Hunter			
Test Engineer and CAD Engineer	Katherine			
Task	**Lead**	**Start**	**Due**	**% of Task Complete**
Team Management	Kenyon			60%
Peer Evaluations	All			100%
Meet with Advisor	Hunter			100%
Project Updates	Hunter			100%
Meeting Minutes	Katherine			100%
Website Updates	Katherine			100%
Implementation Memo	**Kenyon**	2/17	2/28	100%
Current State/Construction Instructions	Kenyon			100%
Design Revisions to date	Katherine			100%
Help with other sections/scheduling/future work	Hunter			100%
Midpoint Presentation and Report	**Hunter**	2/17	3/2	0%
Hardware Review 2	Hunter	2/17	3/6	0%
Slides	Katherine			0%
Project Description	Hunter			0%
Design Description	Hunter			0%
Current State of system	Kenyon			0%
Implementation Plan	Kenyon			0%
Testing Plan	Katherine			0%
Individual Analysis II		3/2	3/14	0%

Figure 19: GANTT Chart

Figure 19 displays the team's updated GANTT Chart. Most recently the team has updated the project's website and ordered a majority of the components to the bench. Moving forward the team needs to order the frame of the bench and continue working on the class deliverables. When the ordered parts arrive the team will begin testing.

2.3 Budget breakdown

Aneuvas Tech. Portable Medical Bench Bill of Materials								
Part #	Part Name	Qty	Functions	Material	Dimensions	Unit Cost	Total Cost	Link To Cost Estimate
1	Plywood	1	Store Devices	Wood	4' x 8' x 1/2"	$ 29.99	$ 29.99	Kingman True Value
2	Wood Glue	1	Fasten Storage	Glue	-	-	-	In house
3	Wood Puddy	1	Fill in nail holes	wood paste	-	-	-	In house
4	Sand Paper	1	Sand Plywood	Gritty paper	-	-	-	In house
5	Nails	1	Fasten Storage	Metal	1.25"	-	-	In house
6	Primer	1	Seals the wood	Primer	1 quart	-	-	In house
7	Paint	1	Paint for Wood	Paint	1 quart	-	-	
8	Caster Wheel (rigid)	2	Wheel for frame	Rubber/metal	4.5"x4"x7.5"	$ 47.72	$ 95.44	Caster Wheel (rigid)
9	Caster Wheel (swivel with brake)	2	Wheel for frame	Rubber/metal	4.5"x4"x7.5"	$ 65.76	$ 131.52	Caster Wheel (swivel with brake)
10	Hex Bolts (25-Pack)	1	Fasten Wheels	Galvanized steel	3/8 in. -16 x 1 in.	$ 5.40	$ 5.40	Hex Bolts
11	Flat Washer (25-Pack)	1	Protects bolts	Galvanized steel	3/8 in.	$ 3.98	$ 3.98	Flat Washer
12	Hex Nut (25-Pack)	1	Fasten Wheels	Galvanized steel	3/8 in. -16	$ 3.56	$ 3.56	Hex nut
11	Frame with Bolt Plates	1	Frame	Stainless Steel	28"x28"x48"	$ 450.00	$ 450.00	
12	Tabletop	1	Tabletop	Formica	26"x72"x1"	$ 591.00	$ 591.00	
						Total Cost:	$ 1,310.89	

Table 1: Bill of Materials

Table 1 displays the bill of materials. Initially the team was given a budget of $1,000. Dr. Becker, however, wanted to ensure the quality of the bench and allowed the budget to be increased. The only major component to be added to the bench bill of materials is the steel frame.