19F15
SunTrac Team

To: *Dr. Sarah Oman & Ulises Fuentes*

From: *Kadeja Alhossaini, Nathan Firor, Edwin Smith, & Ethan Vieane*

Date: *2/28/2020*

Subject: *Implementation Memo*

The team's project is to build a braze-welding jig for the manufacturing facility of SunTrac USA. SunTrac manufactures solar panels that contain copper pipes that need to be welded together at certain lengths and angles to result in a completed copper manifold. Our jig will hold the copper manifold pipes in their proper dimensions while they are being welded together as well as accommodate Suntracs four foot, six foot, and eight foot product variants. In addition to being compatible with three size variations, the brazing jig must rotate to provide easy access to all 20 welding locations. Due to these design challenges, the major implementation milestones for our design are that the brazing jig must be able to adjust to the three different sizes of product variations, the jig's skeleton needs to allow easy access to the welding joints, the jig needs to be able to rotate and lock at various locations, and to ensure that the working area is at an accessible height of approximately four feet. These milestones will be discussed in detail in this memo.

1 Implementation

This section details and expands upon different aspects of the current implementation of the design. Details explained in this section include methods of manufacturing, analysis calculations, design changes and design iterations.

1.1 Manufacturing

Methods of manufacturing that will be used to construct and assemble the current iteration of SunTracs' Braze-welding jig include gas metal arc welding, oxy-acetylene torch, vertical bandsaw, chop saw, drill press, grinders, concrete drill, and hand tools to assemble the bolt and nut connections. All parts used in the manufacturing and assembly of the braze welding jig are purchased through McMaster-Carr, Industrial Metal Supply, or Ace Hardware. Once the parts are shipped to SunTracs manufacturing facility in Tempe, Arizona, the first step in the manufacturing process is to use the vertical band saw and chop saw to cut down the metal extrusions to their desired length. The bandsaw is ideal when cutting precise 90 degree cuts while the chop saw is necessary for cutting angles in the extruded metal. The next step is to take the cut metal and use a center punch to accurately mark the location of each hole and use the drill press to cut the holes. Once all pieces have been cut to the desired lengths and have their designated holes, the next step in the manufacturing process is to take a gas metal arc welder and weld the A frame components as well as the jig face components together. The shaft and locking mechanism subassembly will be assembled much in the same way with more bolted connections rather than welded connections. Grinders will be used to perfect angle cuts and smooth out welds in areas of tight tolerance. Finally, the oxy-acetylene torch will be used to heat up the brazing jig to determine if it can tolerate large changes in temperature. All calculations regarding tolerancing and lengths were perfected in the CAD assembly to minimize the quantity of unused or wasted material.

1.2 Design Changes

This section outlines all modifications and revisions made to the projects physical model as well as project scope in general. The first design change to be considered include a change in the scope of the project which took place between the transition from fall semester to spring. This includes a modification in the method used to allow for maintaining a set working height. Other design iterations to be discussed include iterations in the design of the jig frame, telescoping tubes, power screw, and locking assembly.

1.2.1 Design Change 1: Working Height

One of the most critical design changes occurred as a result of the client's request. For the first semester of the teams project, the approach the team took to satisfy the condition of a constant working height for all manifold configurations was a combination of ideas. Either the welder or jig face must be able to change elevation of two feet (as the telescoping tubes contract/expand two feet on either side of the axis of symmetry. To account for this effect the team initially considered a foot stand for the worker to step up and down while the jig face remained stationary. This was considered in collaboration with the rotation of the jig face resulting in a change of working height elevation. Although this idea seemed to fulfil requirements, it ultimately didn’t come to fruition as OSHA requirements restrict the use of such a foot step, also the welding process must occur with a vertically oriented jig face such that the soldered material doesn’t drip off to the side. After communication with the client, a redesign was conducted to satisfy this requirement in a more effective manner.

Initially chosen was the idea of an adjusting rack and corresponding gear, similar to that of the mechanism which a drill press employs. This idea had never been brought to fruition and therefore have no graphical CAD renderings of the concept. Although thought to be feasible initially, this design iteration was ultimately scrapped due to the difficulty in scaling. The custom parts and dimensions needed for this idea to be brought up successfully are beyond the allowable subassembly cost. This inability to employ this concept transitioned into thoughts of another, the winch and guide rail design design. For this design the guide rail mounted carriage is secured to a wire rope, which is connected through a lifting pulley to a winch. Employing a winch lifting setup is chosen as the current design method, as for a similar price the factor of safety in the vertically dynamic jig face is greater than that of a gear and gear rack assembly. Also, built into the guide rail assembly is a fail safe which prevents a haywire jig face from falling off of the suspended guide rail and creating an undesirable and unsafe working condition. This design iteration is illustrated in [Fig. 1].

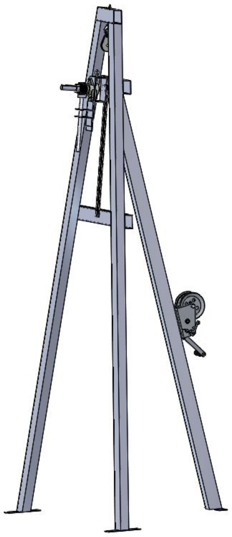


Figure 1. Guide Rail / Winch Design Change

Not contained within [Fig. 1] is the wire rope which will attach the winch to the carriage through the pulley. On top of the fail safe fall prevention, the carriage has a resistance bolt feature which will lock the carriage in place. For these reasons the guide rail and winch system is more desirable and chosen over the gear and rack gear. The next section outlines the revisions made within the guide rail and winch design change.

1.2.2 Design Change 2: Jig Frame

As discussed in the previous section the solution for maintaining a constant working height is to employ the use of a guide rail which the jig face will be mounted on to by means of a carriage. Also required for this subsystem to function properly is a winch, wire rope, pulley, along with respective eyebolts, hex bolts, washers, et cetera. This design solution entails of its own design iterations, first being a design which didn't allow for enough clearance for the wire roper. The second iteration is a redesign of the dimensions of four components of the jig frame assembly, being the top horizontal beam, as well as back leg and two side beams. The first design iteration is depicted below in [Fig. 2].

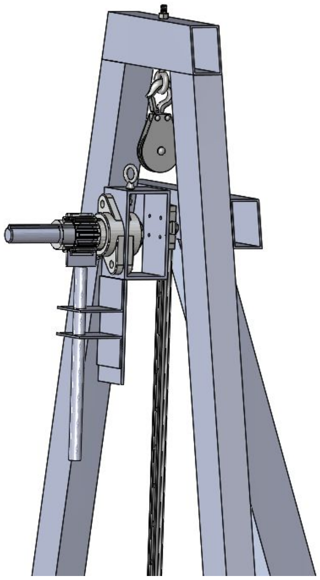


Figure 2a. Front Pulley Clearance Before

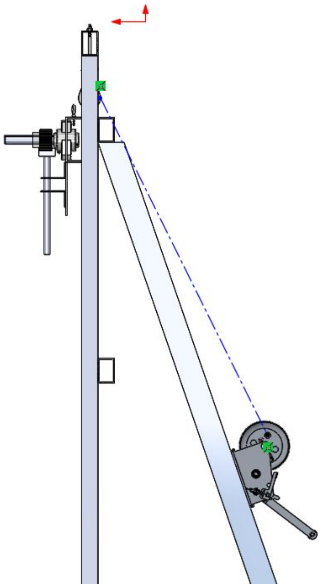


Figure 2b. Back Pulley Clearance Before

It is seen in [Fig. 2a] that there is very little clearance between the pulley and guide rail. It must be considered that the guide rail is 2.5 feet in length when theoretically only the center 2 feet will be used, leaving 3 inches of room for operator preference. With this said, there is 3 inches more clearance than shown in [Fig. 2a] although the displayed height could still be reached. This hinders the pulleys effectiveness to handle a load, which in turn decreases the factor of safety of the entire assembly. [Fig. 2b] displays another major concern, being the obstructed wire rope path. Initially considered was the idea of drilling a hole through the structural beams to allow for the wire ropes clearance. Although, a design iteration was carried out to account for both of the issues presented. This design iteration is illustrated in [Fig. 3] below.

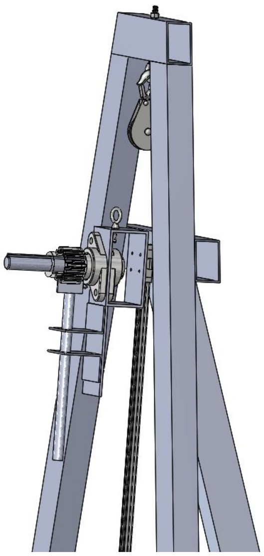


Figure 3a. Front Pulley Clearance After

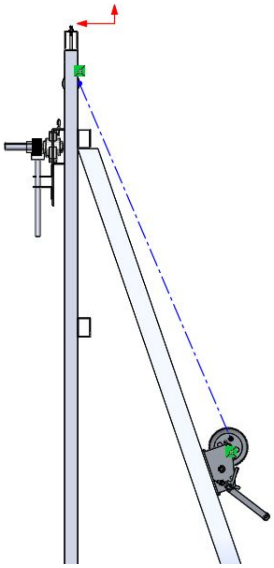


Figure 3b. Back Pulley Clearance After

[Fig. 3a] shows the new and current clearance created for the pulley in relation to the locking assembly.

As in [Fig. 2a] the locking assembly in [Fig. 3a] is connected to the guide rail at the maximum allowable jig face height. This is occupying space reserved for an operator's preference of the positioning of the working height. In theory the maximum carriage height would be 3 inches lower than it is shown in this figure. This new clearance allows for more efficient lifting resulting in a greater load capacity of the pulley. [Fig. 3b] illustrates the clearance behind the jig frame, it is seen that with the updated dimensions the wire rope has no obstruction and is left to freely connect to the pulley and locking assembly. This saves the projects client minor costs associated with manufacturing. Also to consider is that the drilled holes, to compensate for the back leg and middle horizontal beam obstruction of [Fig. 2b], would impact the durability of the structural members. Therefore the solution demonstrated in [Fig. 3] is determined to be the most effective as a small increase in the amount of material used compensates for an ineffective pulley position as well as wire rope obstruction.

1.2.3 Design Change 3: Telescoping Tubes

From the beginning of the semester the team decided to use a telescoping tube design to accommodate the multiple length configurations of copper manifolds used at SunTrac USA. This subsystem has had multiple iterations regarding the number of pins used to lock the length, location of pins, and shape of steel extrusion to make the telescoping tubes. The first design used circular tubes instead of the square tubes that are used in the present design. This iteration was dismissed because circular tubes will spin about their centers which would have decreased the rigidity of the overall design. The next iteration that was used during the first semester of this project was to make all square telescoping tubes be the same length and therefore fit within each other without any extra room. This iteration was used for the first semester's final prototype before being changed during second semester.

Figure 4. Iteration Two Telescoping Tubes

Figure 4 displays the wooden model of the second iteration of the telescoping tubes design. The third iteration of the telescoping tubes design used the same hole placement but added an extra three inches of extruded length of the smallest telescoping tube to give clearance for welds that are needed to assemble the jig. This clearance also made the jig operate smoother by allowing space for expansion due to the added heat of the oxy-acetylene torch. The last iteration of the telescoping tubes took iteration three and minorly changed the overall extrusion lengths to accommodate space for the vertical pipe stabilizing angle iron. This change featured decreasing the overall length of the middle and small telescoping tube by 0.0625 inches.

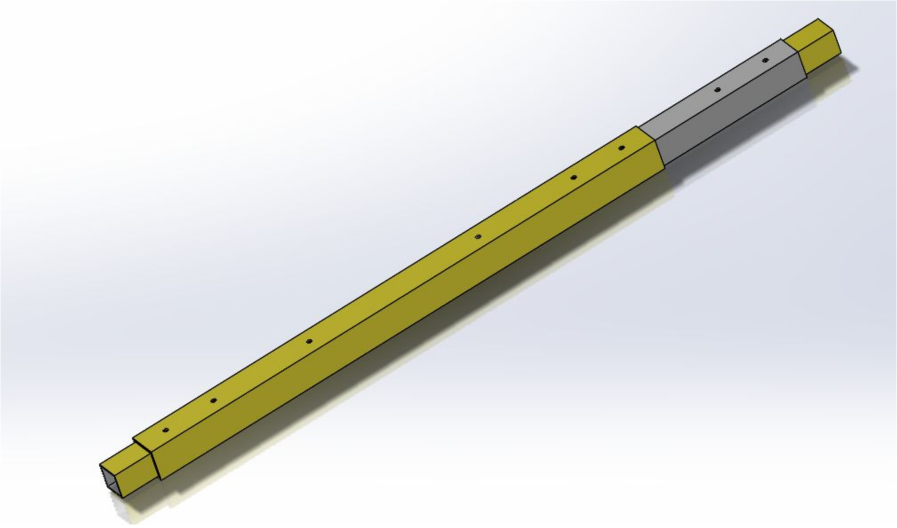


Figure 5. Iteration Four Telescoping Tubes

Figure 5 above shows the final iteration of the telescoping tubes subassembly. The lower left end of the picture displays a four foot configuration and the upper right displays a six foot configuration. This iteration is what is being used in the first stage of the final assembly process.

1.2.4 Design Change 3: Power Screw

The power screw in the design is a custom- made clamp that is designed to hold a specific diameter of pipe in place. There are 4 of them in the assembly and individually clamp the pipe manifold. The original design for the power screw shown in Figure 6.

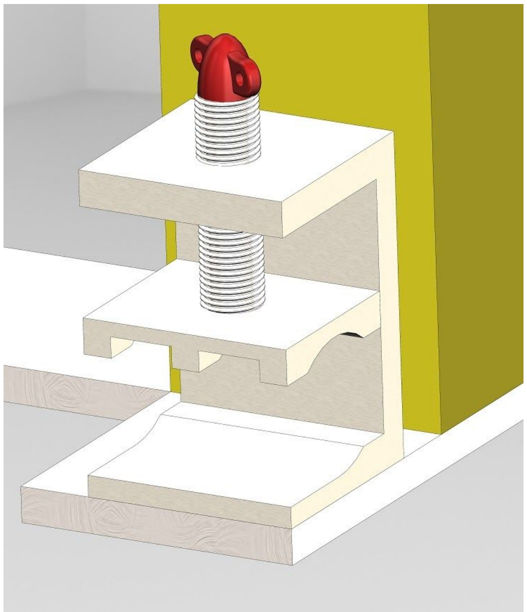


Figure 6. Original Power Screw Design CAD

The power screw features a C- bracket, a 3/8th in 16 TPI threaded rod and an end cap with ribs contoured to clasp the pipe. This design later was found to need changes from feasibility, interferencing, and heat transfer issues. The different power screw design is shown in Figure 7.

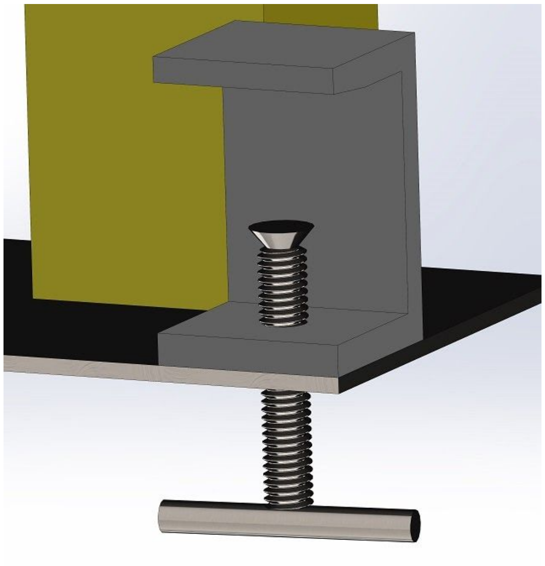


Figure 7. Power Screw Revision

The original design featured a screw cap with contoured ribbing. This component was replaced with a simple flat frustum. The end cap was a bit more difficult to accomplish because it would have to freely rotate on the end of the screw. It would be an extra component to custom make which would drive up cost. The smaller contact area also mitigates heat transfer. The power screw handle is now a simple cylindrical rod and is larger for easier clamping. Then the whole assembly was flipped upside down to avoid the power screw handle from interfering with the rest of the jig face.

1.2.5 Design Change 3: Locking Mechanism

The original locking mechanism design utilizes a foot pedal and a gear. When the foot pedal is pressed, a cable that is attached to it is pulled which in turn pulls down on a metal bar that releases the gear, thus causing the jig frame to rotate. Releasing the foot pedal breaks the tension force acting on the cable which causes the metal bar to lock back into position between the teeth of the gear, thus locking the jig frame.This design has been altered since SunTrac wanted the working area of the jig frame to be at a 4 foot height. This meant that the jig frame will be moving up and down to compensate for the three different sizes of product variants, which causes a problem with the functioning of the cable. If the jig is in the 4 foot configuration, the frame will be lowered to make sure the working area is still at 4 feet. This height alteration will loosen the cable, therefore if the foot pedal is pressed there will no longer be a tension force that acts on it. Figure 8 shows the old design of the foot pedal locking mechanism.

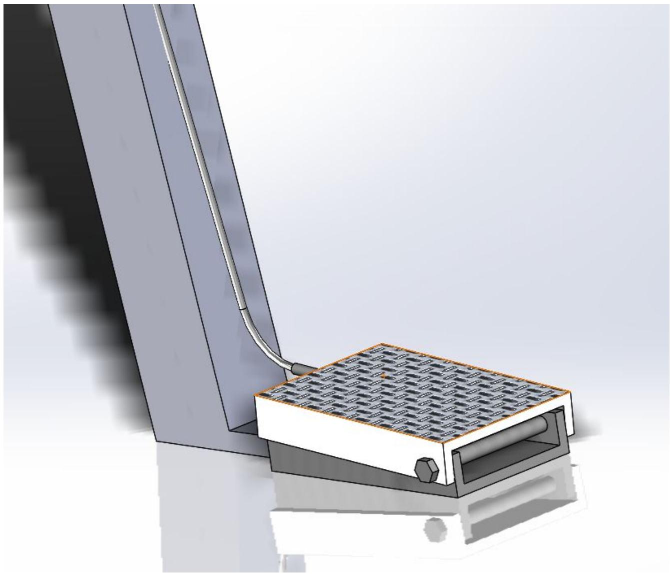


Figure 8. Foot Pedal Locking Mechanism

Since this design is no longer viable, the foot pedal lock was altered into a handle locking mechanism. Instead of having the gear lock by the cable that it attached to the foot pedal; a handle made up of a metal rope locks the gear. By pulling on the handle, the same functionality as the foot pedal occurs. The handle pulls down on the metal bar that locks the teeth of the gear which releases it and once the handle is released, the metal bar returns to its original position. Figure 9 shows the new design.

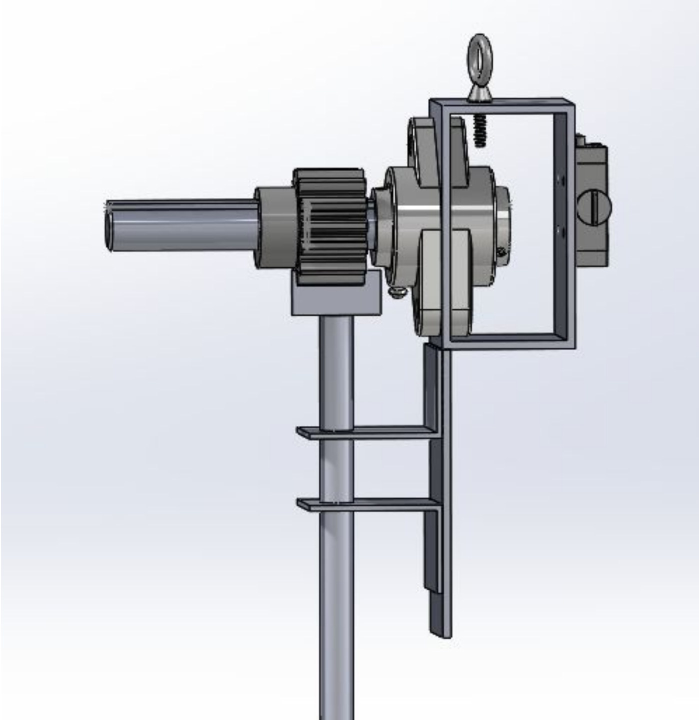


Figure 9. Handle Locking Mechanism

As seen in Figure 9, the gear is locked by a metal bar attached to a rod. This rod will have a hole drilled at the end of it where the metal rope will be attached. When the rope is pulled, the rod will bring the metal bar down with it and the gear rotates, thus rotating the jig. The main change in this design was the alteration of the device that applied the pulling force.

2 Future Implementation

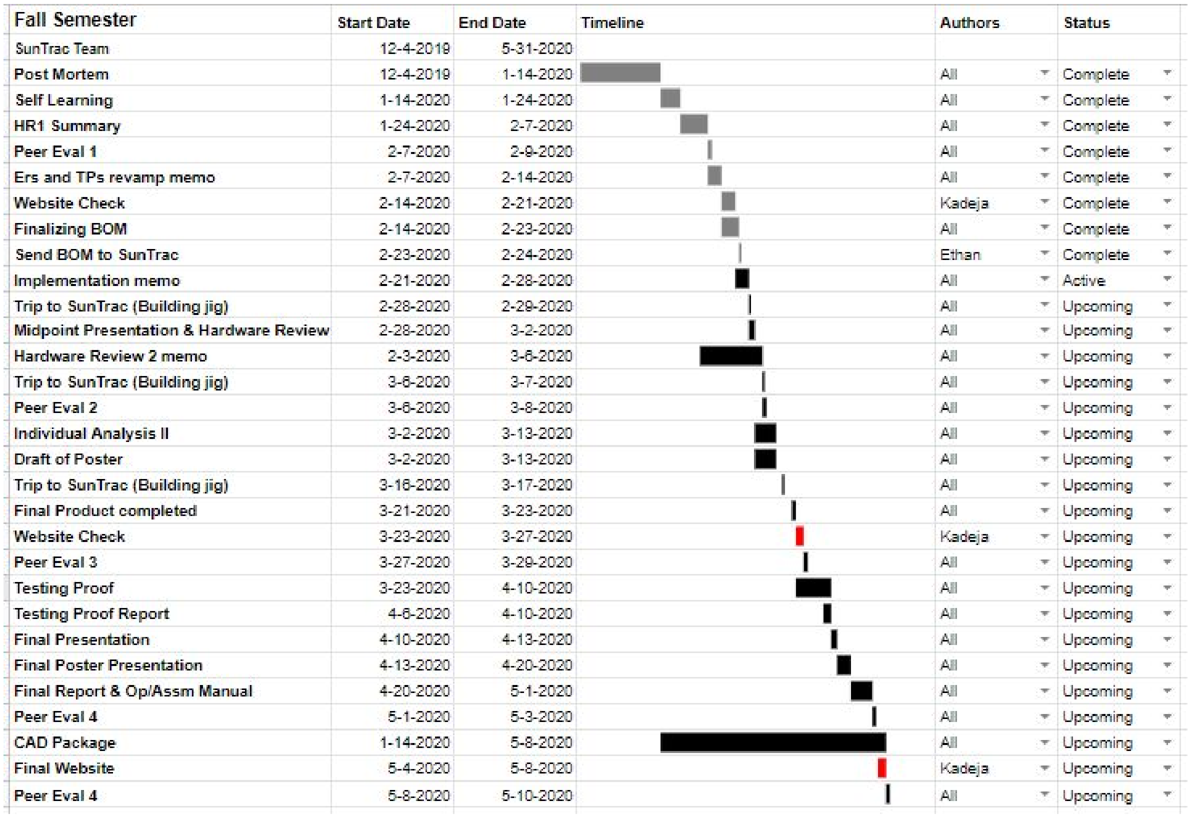
The team intends to continue the process of manufacturing during the next few weeks. All the manufacturing will be in SunTrac, Tempe. Further details about future manufacturing will be discussed below. The goal is to be done with manufacturing and have a final product by the end of Spring break. A schedule breakdown will be discussed below that details the milestones the team aims to accomplish in the upcoming weeks. A Gantt chart was created to provide an organized schedule that the team can easily refer to. Moreover, the team will provide a budget breakdown. Most of the parts have already been ordered from Mcmaster-Carr and shipped. A few parts are expected to be bought in person which will be discussed further below. All the aspects of the system have been already designed and sourced.

2.1 Further Manufacturing and Design

The manufacturing plan is to take trips down to SunTrac where all the welding and assembling will occur. This decision has been made because the jig will need a fairly large working space to weld and assemble. It is also going to be 12 feet high, which is a restriction since most areas the team can work in does not accommodate that height. In addition, it would be easier to hand the jig to the client if it is already in their company. The jig will be heavy and long when it is assembled, which will be difficult and expensive to ship. SunTrac has direct access to the tools and equipment that the team will require to build the jig. Therefore, the team will not need to factor in any costs of buying tools and equipment. In the future, if the team feels it is critical to work on a subassembly at times other than those scheduled at SunTrac, the portable subassembly will be worked on in NAU's machine shop. This will not likely happen, however the team had already thought about that possibility. Moreover, the team feels confident about the current design as many changes have been already made. During the manufacturing process over the upcoming weeks, if the team feels like there is a need for a design alteration due to manufacturing, the team will adjust the CAD package accordingly. Most of the recent design changes factored in manufacturing, therefore the team does not foresee any major design changes in the future.

2.2 Schedule Breakdown

The team created a Gantt chart to keep track of the tasks that need to be done in the upcoming weeks. The Gantt chart contains the future deliverables along with their due dates. The chart also contains milestones that the team has created to be on track with building the brazing jig. Completed tasks are seen to be in grey color. Figure 10 shows the teams Gantt chart.



Fall Semester	Start Date	End Date	Timeline	Authors	Status
SunTrac Team	12-4-2019	5-31-2020			
Post Mortem	12-4-2019	1-14-2020		All	Complete
Self Learning	1-14-2020	1-24-2020		All	Complete
HR1 Summary	1-24-2020	2-7-2020		All	Complete
Peer Eval 1	2-7-2020	2-9-2020		All	Complete
Ers and TPs revamp memo	2-7-2020	2-14-2020		All	Complete
Website Check	2-14-2020	2-21-2020		Kadeja	Complete
Finalizing BOM	2-14-2020	2-23-2020		All	Complete
Send BOM to SunTrac	2-23-2020	2-24-2020		Ethan	Complete
Implementation memo	2-21-2020	2-28-2020		All	Active
Trip to SunTrac (Building jig)	2-28-2020	2-29-2020		All	Upcoming
Midpoint Presentation & Hardware Review	2-28-2020	3-2-2020		All	Upcoming
Hardware Review 2 memo	2-3-2020	3-6-2020		All	Upcoming
Trip to SunTrac (Building jig)	3-6-2020	3-7-2020		All	Upcoming
Peer Eval 2	3-6-2020	3-8-2020		All	Upcoming
Individual Analysis II	3-2-2020	3-13-2020		All	Upcoming
Draft of Poster	3-2-2020	3-13-2020		All	Upcoming
Trip to SunTrac (Building jig)	3-16-2020	3-17-2020		All	Upcoming
Final Product completed	3-21-2020	3-23-2020		All	Upcoming
Website Check	3-23-2020	3-27-2020		Kadeja	Upcoming
Peer Eval 3	3-27-2020	3-29-2020		All	Upcoming
Testing Proof	3-23-2020	4-10-2020		All	Upcoming
Testing Proof Report	4-6-2020	4-10-2020		All	Upcoming
Final Presentation	4-10-2020	4-13-2020		All	Upcoming
Final Poster Presentation	4-13-2020	4-20-2020		All	Upcoming
Final Report & Op/Assm Manual	4-20-2020	5-1-2020		All	Upcoming
Peer Eval 4	5-1-2020	5-3-2020		All	Upcoming
CAD Package	1-14-2020	5-8-2020		All	Upcoming
Final Website	5-4-2020	5-8-2020		Kadeja	Upcoming
Peer Eval 4	5-8-2020	5-10-2020		All	Upcoming

Figure 10. Team SunTrac Gantt Chart

As seen in the Gantt chart, the tasks that are upcoming are mostly going to be completed as a team. The team has also allocated three different dates to visit SunTrac in Tempe and work on building the brazing jig. By spring break, the team's goal is to have the jig built. If there are other trips that need to be scheduled, the Gantt chart will be updated accordingly. The testing proof will be performed right after the final product is completed. So, during spring break the team has allocated a full day to visit SunTrac to perform any testing that is required. Once the tests are completed, the team will hand off the product to the client instead of waiting until the end of the semester. The rest of the semester will be dedicated to producing a high-quality poster, presentation, operation manual, website, and report. Individual tasks will be assigned as the team moves forward and feels the need to break down the workload. Currently, the team is on track with the schedule and expects to continue to do so in the upcoming weeks.

2.3 Budget breakdown

The team designed the braze welding jig to require parts from as few distributors as possible to cut shipping costs and ensure the majority of parts arrive on the same shipment or on similar dates. SunTracs budget for this project was $1600.00 with a goal to keep the project under $1500.00 with shipping included in that price.

Figure 11. BOM Breakdown

As seen in figure 11, the total estimated cost of SunTracs braze welding jig is $1393.13 with an estimated shipping cost of $200.00. The $200.00 shipping cost is an overestimated value that was established after a phone call with a McMaster-Carr sales representative. In addition to the dollar amount listed above, an additional estimated cost of $30.00 will be added after visiting Ace Hardware in person to get several bolts and nuts that are required in the assembly process. After all various costs are added up the total is still nearly $170.00 below the maximum budget and $70.00 below SunTrac's goal budget. Efforts were made to ensure the cheapest part was found that still accounted for our goal factors of safety and load capacities. Due to being under budget and have still purchased excess material for contingency purposes, the budget for this project is successful.