## Knee Arthroscopy Manikin

Client: Corinne Henak

Consultants: Corinne Henak, Russ Johnson

Team: Shrey Ramesh (leader), Delaney Reindl (leader), Jack Thurk (accountant), Connor Dokken (communicator), Sierra Reschke (admin), Rachel Dallet (admin)

## Status

*Report Date:* 02/29/2024

*Next Milestone:* Working Prototype

*Deadline:* 03/01/2024

*Status:* on schedule (green), deadline at risk (yellow), deadline unachievable (red)

## Technical Summary

Important aspects of this past week involved progressing each sub-section of the design towards the testing phase as well as attending/giving individual presentations detailing individual contributions to the project thus far. For the enclosure team, PE film bags were ordered for the material enclosure aspect of the design. A flow rate sensor was ordered and the enclosure and bone models were updated, with the enclosure being reprinted. For the pump team, the reservoir box was fabricated, and the second half of the tubing/pump setup (from the outlet of enclosure/inlet of reservoir) was created. The bone team ordered new wire for the cartilage-bone attachment mechanism, and a stress analysis of the enclosure FE model was initiated. Going forward, the entire team intends to complete the first assembly of the model to begin the testing phase of the project.

## New Tasks

### *Bone Team*

| Task Name | Description and Concrete Outcome | Owner | Est. Time |
|---|---|---|---|
| Update BME and ME websites | Add the progress reports to both the ME and BME websites. Update the project status as well. | RD | 0.5 hr |
| After asking clarifying questions, retry the stress analysis. | Sierra and I ran into some issues running a stress analysis that are listed in the technical section below. Clarify with Dr. Henak at the meeting and run it again. | RD | 4 hr |

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|---|---|---|---|
| Experiment with new wire | Some group members are going to Home Depot to test out some new wire. Once we buy that, I need to see how easily it can bend compared to the last wire. | RD | 1.5 hr |
| Work on stress analysis | Ask Dr. Henak about the issues Rachel and I ran into with conducing the stress analysis on the enclosure. Import the new model and try to run the analysis again based on feedback received. | SGR | 3 hr |
| Update attachment mechanism wire | Work with the team to test and order a thinner wire. Once it arrives, work to implement the attachment mechanism with the new wire | SGR | 2 hr |
| Assist with full prototype assembly | Continue working with the enclosure and pump teams to make sure we are all on the same page and begin to start thinking about assembling a full prototype and conducting tests. | SGR | 1 hr |

## *Enclosure Team*

| **Task Name** | **Description and Concrete Outcome** | **Owner** | **Est. Time** |
|---|---|---|---|
| Assemble complete enclosure | Assemble the enclosure using the plastic bag, silicone, and hose clamps. Fill with water to determine points of potential leakage and brainstorm solutions | SKR | 3 hrs |
| Connect the enclosure to the reservoir | Coordinate with the pump team to determine how the enclosure handles fluid flow. | SKR | 3 hrs |
| Help with complete enclosure assembly | Assemble the duct clamps, press-to-close bag, and silicone along with the frame as the first enclosure. Test using water to determine if the assembly prevents fluid leakage. | DR | 3 hrs |
| Finalize material enclosure plan | Determine material enclosure plan for assembly. | DR | 3 hrs |

## *Pump Team*

| Task Name | Description and Concrete Outcome | Owner | Est. Time |
|---|---|---|---|
| Test all components together with enclosure team | Check the reservoir for leakage and put together inlet/outlet/bubbler tubes using suction cup clamps. Test fluid flow rate sensor with pump to see if it is a suitable replacement for pressure gauge (pending shipping time). Test the seal of the ports on the enclosure and assist Shrey with the enclosure testing as necassary, and if all is going well test the entire system except bones/live cartilage. | CD | 4 hr |
| Test current bubbler with dissolved oxygen sensor and resivoir | If possible (or worthwhile) test the current bubbler and reservoir with Nitrogen gas and dissolved oxygen sensor to determine whether or not the current bubbler design can effectively lower dissolved oxygen concentration in the selected reservoir volume. | CD | 2 hr |
| Test the reservoir with nitrogen and the dissolved oxygen sensor. | Now that the reservoir has been fabricated, the bubbler will be fastened in a more permanent way to the bottom of the reservoir. Once fastened, the bubbler and reservoir should be tested with the Nitrogen source and Oxygen sensor to make sure that all runs well. | JT | 3 hr |
| Seal ports to prevent leaks | Once the whole pump system is put together and even tested with the enclosure, sealant should be applied to the ports and connection points to help prevent leaks as well as prevent possible vibrations from loosening the port connections. The sealant that would be used will be biocompatible and would be suitable for sealing connection points between the pressure gauge and T-bracket. However, sealant will not be ordered until the new fluid flow rate sensor Connor ordered has been shipped and tested. | JT | 3 hr |

## Old Tasks

### *Bone Team*

| Task Name | Description and Concrete Outcome | Owner | Est. Time |
|---|---|---|---|
| Update BME and ME websites | Add the progress reports to both the ME and BME websites. Update the project status as well. | RD | 0.5 hr |
| Give individual presentation | Present to peers and TAs on Wednesday at 4pm. Go through my contributions to the project. | RD | .5 hr |
| Perform stress analysis on the enclosure system | Load the CAD into FEBio and perform a stress analysis on it given modulus of elasticity and young's modulus. | RD | 3 hr |
| Order new wire | Talk to Jack and Dr. Henak about our budget. Then either order or obtain new wire from the makerspace. Determine if it's bendable. | RD | 2 hr |
| Implement attachment mechanism changes | Continue working to update the wire, bone models, and sample attachment mechanism based on the main takeaways from testing. | SGR | 2 hr |
| Stress analysis of enclosure | Utilize FEBio to perform a stress analysis on the enclosure FE model and analyze the results. | SGR | 2.5 hr |
| Experiment with and order new wire | Experiment with different wires of different thicknesses to replace the current wire in our attachment mechanism as it is too stiff. | SGR | 1 hr |
| Attend individual presentation. | Present my individual presentation on Wednesday, February 21st and review the presentations of my peers. | SGR | 0.5 hr |

### *Enclosure Team*

| Task Name | Description and Concrete Outcome | Owner | Est. Time |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Order PE film bags | Determine necessary dimensions for the press-to-close bags and place an order through Josh. | DR | 0.5 hr |
| Attend Individual Presentation | Give presentation of individual contributions (Feb 21) thus far and peer review three other groups. | DR | 0.75 hr |
| Research other biocompatible caulk options | Determine if the biocompatible caulk is for sure the material we want to go forward with and find other options and submit the order form through Josh. | DR | 1.25 hr |
| Develop enclosure attachment plan | Draw out a material enclosure plan to highlight where each material will go. | DR | 2.5 hr |
| Order flow rate sensor for Pump team | Request a free sample of the fluid flow rate sensor from Renesas | SKR | .5 hr |
| Reprint Enclosure | Redesign and reprint enclosure based on third iteration of testing | SKR | 3 hr |
| Print Updated Bones | Go the the Makerspace and print the updated tibia and femur models | SKR | 1 hr |
| Assemble Full Enclosure | Using previous enclosure prints and silicone, assemble a full enclosure to test resistance to leaks | SKR | 2 hr |

### *Pump Team*

| **Task Name** | **Description and Concrete Outcome** | **Owner** | **Est. Time** |
|---|---|---|---|
| Fabricate the reservoir box | The plastic was cut but the bonding agent is still being delivered. Once delivered, the bonding agent will be applied to create the box and test it for potential leaks and durability. UPDATE: The bonding agent still has not arrived yet | JT | 3 hr |
| Order various materials needed for project | This week, a lot of time was spent waiting to see if there was indeed a funding string that we would be able to use to order from external vendors. Now that that is cleared up, I will | JT | 1.5 hr |

| | | | |
|---|---|---|---|
| | place various orders for things needed for our project such as clamps for the enclosure team. | | |
| Create second half of medical tube and pump setup (from the outlet of the enclosure to the inlet of the reservoir) | To complete the closed loop for fluid flow, the tubing from the enclosure to the reservoir needs to be made. The system will look very similar and will require another pump system which Shrey is able to find and provide. | JT | 1.5 |
| Finish fabricating reservoir | Still waiting for bonding agent to be shipped, progress was checked with our TA today. Once arrived the reservoir will be assembled. Need to fabricate piece to hold dissolved oxygen sensor as well. | CD | 3 hr |
| Re-evaluate/design bubbler attachments | Decide on a final bubbler attachment and create final prototype, or order selected bubbler stone | CD | 2 hr |
| Research flow rate sensors | Research whether or not the acquired flow rate sensor is compatible with liquids, or if the company offers a similar product that is designed for use with liquids. | CD | 1 hr |

## Technical Section

| | | | |
|---|---|---|---|
| Give individual presentation | Present to peers and TAs on Wednesday at 4pm. Go through my contributions to the project. | RD | .5 hr |

On Wednesday, I gave my individual presentation. I went over my contributions on the bone team this semester. It all went very smoothly with not a lot of questions from the audience.

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|---|---|---|---|
| Order new wire | Talk to Jack and Dr. Henak about our budget. Then either order or obtain new wire from the makerspace. Determine if it's bendable. | RD | 2 hr |

The budget was worked out. Some team members will be going to Home Depot to explore wire options.

| | | | |
|---|---|---|---|
| Perform stress analysis on the enclosure system | Load the CAD into FEBio and perform a stress analysis on it given modulus of elasticity and young's modulus. | RD | 3 hr |

Author: Rachel Dallet and Sierra Reschke

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|---|---|---|---|
| Order flow rate sensor for Pump team | Request a free sample of the fluid flow rate sensor from Renesas | SKR | .5 hr |

Completed

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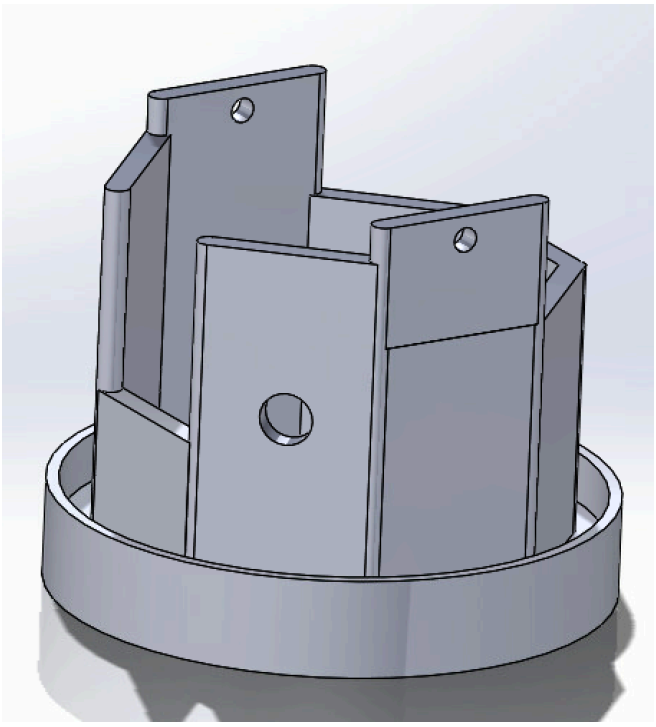
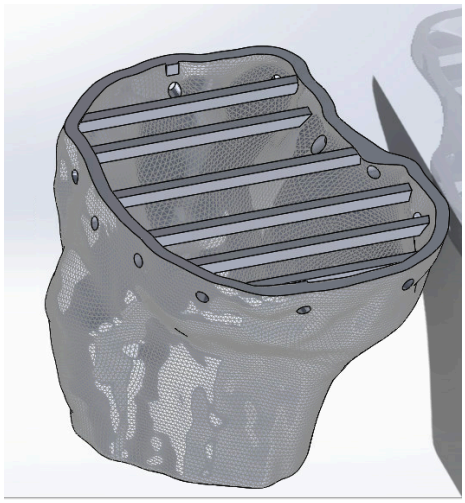
|---|---|---|---|
| Reprint Enclosure | Redesign and reprint enclosure based on third iteration of testing | SKR | 3 hr |

The enclosure has been printed as of Thursday and will be available for feedback on Friday during the group meeting. Since our last meeting there have been two prints with design changes.



| | | | |
|---|---|---|---|
| Print Updated Bones | Go the the Makerspace and print the updated tibia and femur models | SKR | 1 hr |

The updated bone model is being printed as of Thursday. I opted for PLA as it is guaranteed to be biocompatible unlike FormLabs Biomed Clear.



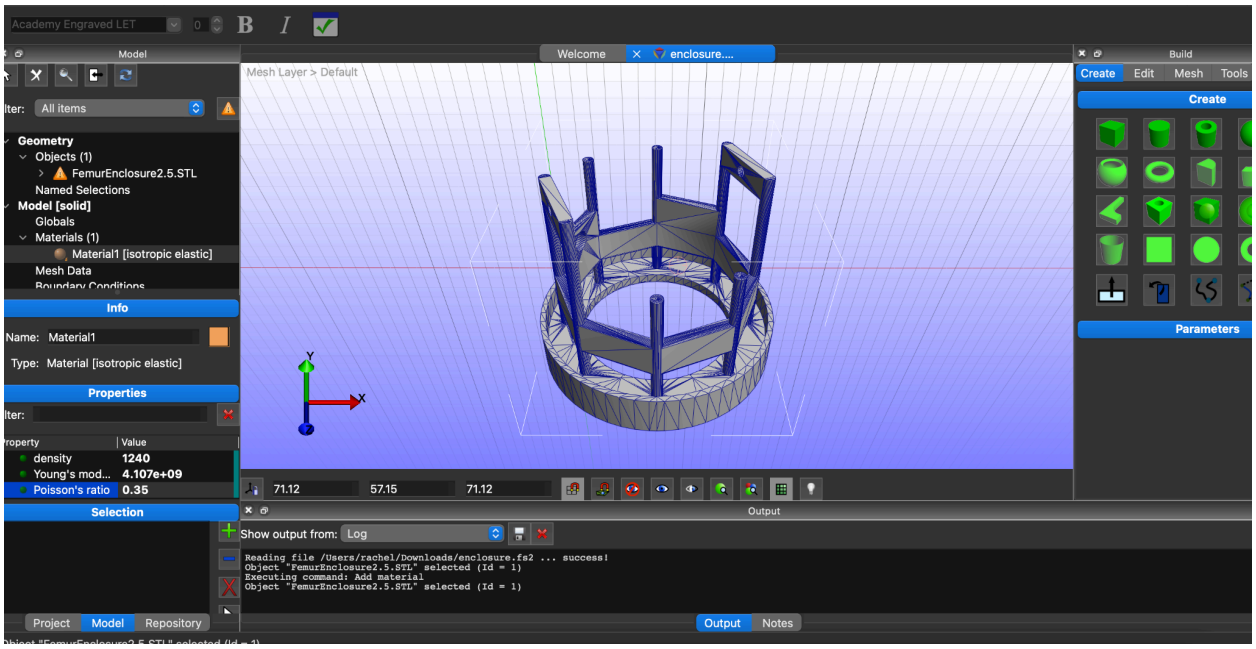



***Figure 1: Material properties***

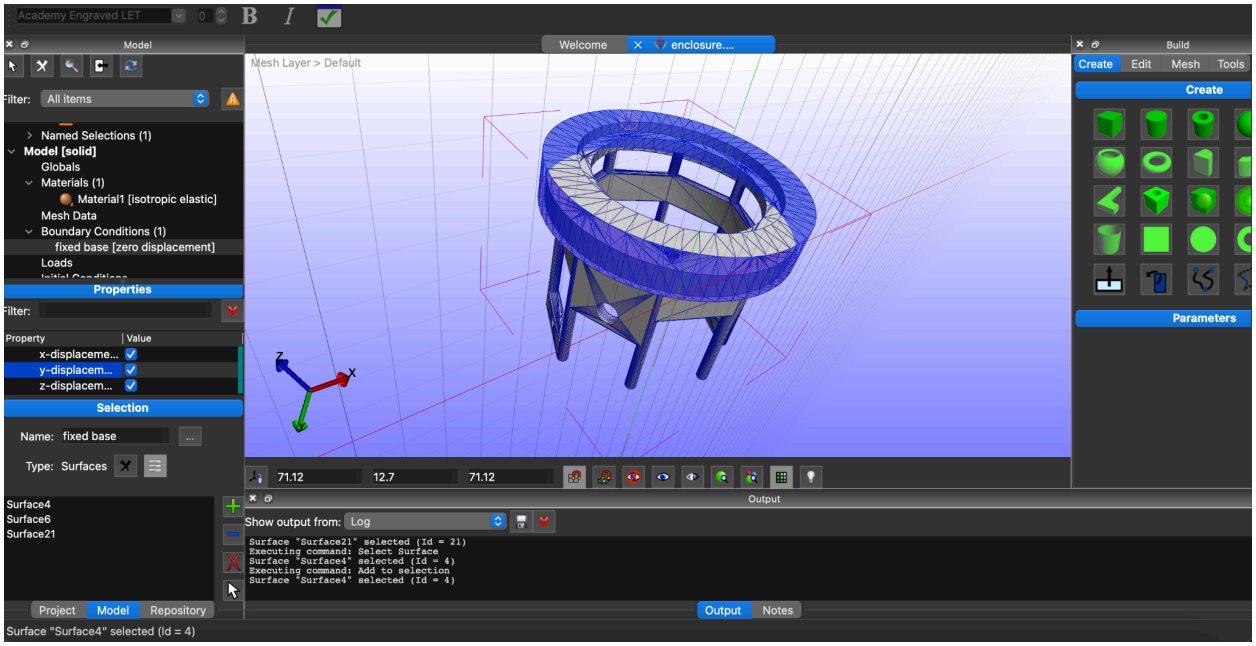



***Figure 2: Fixed boundary***

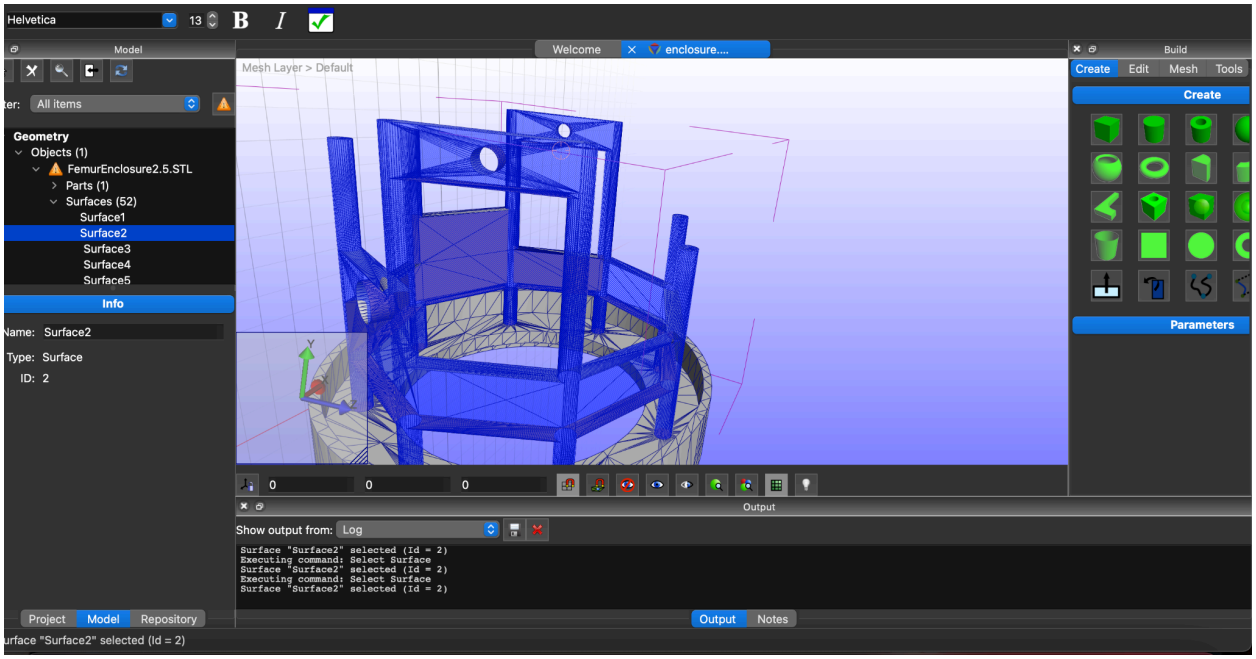



***Figure 3: Issue applying load***

Sierra and I attempted to run an FE analysis in FEBio. The above images are screenshots from our process. The first issue we had was an inability to mesh. Everytime we previously did FE analysis in classes, a mesh was necessary. We weren't sure how to do that with an STL import so we converted the file to a STEP and couldn't load it into FEBio. We proceeded with the STL without the mesh. We looked up the mechanical properties of PLA and inserted those as the

material. We were wondering for material selection, if isotropic elastic should be used. We then attempted to apply a force at the hinges. However, the way Shrey made the part was as a single piece as highlighted in Figure 3. We will run through these issues at the next meeting!

Author: Sierra Reschke

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|---|---|---|---|
| Implement attachment mechanism changes | Continue working to update the wire, bone models, and sample attachment mechanism based on the main takeaways from testing. | SGR | 2 hr |

The bone models have been updated to include a gird for the smaller samples to sit on and more holes around the exterior for attachment via the wire. We will be testing our attachment mechanism and models again once we acquire thinner wire and can schedule another time to go into Dr. Henak's lab.

| | | | |
|---|---|---|---|
| Attend individual presentation. | Present my individual presentation on Wednesday, February 21st and review the presentations of my peers. | SGR | 0.5 hr |

I attended my individual presentation time a lot and successfully gave my presentation to my peers. I also listened to the presentations of other groups and gave both positive and constructive feedback.

| | | | |
|---|---|---|---|
| Research flow rate sensors | Research whether or not the acquired flow rate sensor is compatible with liquids, or if the company offers a similar product that is designed for use with liquids. | CD | 1 hr |

Product offerings by Renesas were evaluated, however, they had limited options for liquid compatible flow rate sensors. The compatible option was chosen and a free sample was requested. The request was confirmed and tracking info will be provided soon.

| | | | |
|---|---|---|---|
| Finish fabricating reservoir | Still waiting for bonding agent to be shipped, progress was checked with our TA today. Once arrived the reservoir will be assembled. | CD | 3 hr |

| | | | |
|---|---|---|---|
| | Need to fabricate piece to hold dissolved oxygen sensor as well. | | |

The reservoir was fully assembled with the bonding agent this week.

| | | | |
|---|---|---|---|
| Re-evaluate/design bubbler attachments | Decide on a final bubbler attachment and create final prototype, or order selected bubbler stone | CD | 2 hr |

A suitable and reasonably priced bubbler stone was with a ¼” barb was not found online, so a new bubbler similar to the bubbler tube design has been fabricated.

| | | | |
|---|---|---|---|
| Fabricate the reservoir box | The plastic was cut but the bonding agent is still being delivered. Once delivered, the bonding agent will be applied to create the box and test it for potential leaks and durability. UPDATE: The bonding agent still has not arrived yet | JT | 3 hr |

The plastic welding finally came in this week and the box was able to be fabricated. The box still needs to be tested for possible leaks and will be a task for this upcoming week. The box should also be tested with PBS and Nitrogen soon to make sure the volume is enough to deoxygenate the liquid to the correct amount.

| | | | |
|---|---|---|---|
| Order various materials needed for project | This week, a lot of time was spent waiting to see if there was indeed a funding string that we would be able to use to order from external vendors. Now that that is cleared up, I will place various orders for things needed for our project such as clamps for the enclosure team. | JT | 1.5 hr |

Materials were ordered for various parts of the project such as duct clamps, and press to close bags.

Author: Delaney Reindl

| | | | |
|---|---|---|---|
| Order PE film bags | Determine necessary dimensions for the press-to-close bags and place an order through Josh. | DR | 0.5 hr |

I finalized and submitted an order for a pack of press-to-close polyethylene bags (w = 8”, h = 10”, thickness = 2 mil). This will be used as the enclosure material covering the bulk of the frame.

| | | | |
|---|---|---|---|
| Attend Individual Presentation | Give presentation of individual contributions (Feb 21) thus far and peer review three other groups. | DR | 0.75 hr |

I gave and attended the individual presentation on Wed 02/21. I shared my individual contributions to this project thus far, where I primarily focused on the material enclosure aspect of the design.

| | | | |
|---|---|---|---|
| Create second half of medical tube and pump setup (from the outlet of the enclosure to the inlet of the reservoir) | To complete the closed loop for fluid flow, the tubing from the enclosure to the reservoir needs to be made. The system will look very similar and will require another pump system which Shrey is able to find and provide. | JT | 1.5 |

The second pump was acquired and the second half of the pump system was also completed. This refers to the pump part that goes from the outlet of the enclosure back into the reservoir.

## Gantt Chart

| Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feb | | | | Mar | | | | Apr | | | | May | | |
| Task | 2 | 9 | 16 | 23 | 1 | 8 | 15 | 22 | 29 | 5 | 12 | 19 | 26 | 3 | 10 |
| Individual Presentations | | | | O | | | | | | | | | | | |
| Testing | X | | | | | | | | | | | | | | |
| Redesign and Fabrication | X | X | X | X | | | | | | | | | | | |
| Presentations | | | | X | | | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Working Prototype Demonstration** | | | | | | | | | O | | | | | | |
| **Redesign** | | | | | | | | | | | | | | | |
| **Fabrication** | | | | | | | | | | | | | | | |
| **Presentation and Demonstration** | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| **Final Presentation** | | | | | | | | | | | | | | | |
| **Testing** | | | | | | | | | | | | | | | |
| **Report** | | | | | | | | | | | | | | | |
| **Presentation** | | | | | | | | | | | | | | | |
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**X = Completed Tasks, O = Milestone Deadlines**