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# **Group 19 Project Binder**

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## ***A Robotic System for Tracking the Ulnar Nerve***

### ***Sponsor***

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### ***Team Members and Roles***

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# ***Project Plan***

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## ***A Robotic System for Tracking the Ulnar Nerve***

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# 1. Project Background

## Summary of Need

Ulnar Neuropathy, or pain in the fourth and fifth fingers caused by compression of the ulnar nerve, is the second most common nerve damage to happen in the hand after carpal tunnel syndrome. This issue can cause tingling, numbness, loss of feeling, and even loss of function in the forearm, which can become a serious issue for dexterous movement of the hand. This issue, also called bicyclers neuropathy, can be caused by many things, but is generally caused by extended pressure on the elbow or the base of the palm, and is prevalent in old age patients, but can happen earlier. As our society moves to a more digital era, and people work from home more and more, these two vulnerable regions of the arm can become more susceptible to these kinds of injuries, and damage can create a larger hindrance in our day to day lives.

This is a problem that healthcare professionals have tried to solve, using physical therapy, targeted exercise, and surgery, but this strategy still has an alarming rate of failure. We are trying to solve that issue by bringing data and 3-D imaging into the field, which we believe could improve patient outlook, and reduce the failure rate by making the surgery tailored to the patient, and identifying specific areas of damage or entrapment. The treatment of Ulnar neuropathy is in need of a 21st century rework, using the powerful tools at our disposal to allow a computer to do the hard work instead of the doctor.

## Industry Served

We anticipate that by the end of the semester, we will have a robotic system that can be moved by hand to track the path of the Ulnar nerve in a patient. We plan on implementing a 6-DOF robot arm to hold the sensor, that will allow the servo motors to complete the complicated movement required to get viable data from the ultrasonic wand. We plan on implementing this robotic arm with “5 revolute joints including tool, wrist, elbow, shoulder, waist or base joints. Each joint is actuated through servo motors.” (6). Eventually, this system will become autonomous, and will allow for precise and repeatable data for the researcher, but we plan on delivering all of the mechanical components with motors attached, without any software or electronic controllers. Our sponsor, Dr. Miller has expressed that our design should be a proof of concept, that will eventually lead to more funding and hopefully end up as a research tool. We would also like to add the functionality of visual and computed data that can allow for the calculations of strain and bending in the nerve, which should give better insight, and could allow for a heat map type display for a doctor who is using this system, which could make it easily understandable for the doctor and patient alike.

In the medical field, Ulnar neuropathy is treated in one of two ways: nonsurgically, with physical therapy and an emphasis on strengthening the ligaments and tendons that surround the nerve, or surgically, where they remove a small portion of the tissue surrounding the nerve to relieve some pressure. The non surgical option is usually explored first, as it is usually much less money and time. When these practices do not work, the surgical approach is then explored, as it is the only other current option. This surgery can be done in two different ways, which result in slightly different chances of complication, and is done at the discretion of the surgeon. The first strategy is to do the surgery open, which means cutting a wound the length of the section you are working with, and removing the excess tissue that surrounds and pinches the nerve. This procedure usually has about a 15% failure rate (1), and the reasoning behind that failure is still largely unknown. The other strategy is endoscopically, where the surgeon cuts a small incision and inserts a tool with a camera on the end, that then cuts at the tendons and ligaments in a similar fashion. This procedure has a slightly higher failure rate, but can be more minimally invasive. After this surgery is completed, the main distinguishing factors for relief of

symptoms was, “absence of post-operative subluxation, greater body weight, normal pre-operative two-point discrimination (2-PD), and a more recent date of operation” (6). The main point of worry is that they found that the date of the operation affected the normal movement, which means that the way the surgery is currently done could just be a stopgap, and might not really solve the problem.

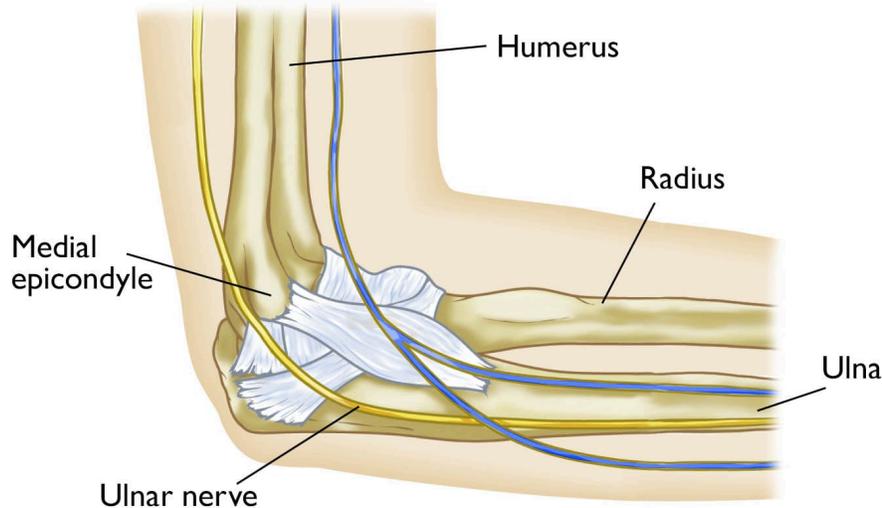


Figure 1: Diagram showing the path that the Ulnar nerve takes through the arm (4)

The problems that we would like to solve with the tracking of the Ulnar nerve is that we want to be able to generate a 3-D model of the nerve itself and how it sits in the bones of the arm, so as to gather repeatable and measurable data on what might be causing the the entrapment and how best to perform the surgery. This will provide invaluable data to the researchers and doctors in the field, and should allow for a more scientific and data driven approach to the problem of Ulnar neuropathy. We understand that this is the first step in a long line before any patient's outcomes may be affected, but we feel that this methodology is the next important step forward in improving medical outcomes in general, putting more tools in the hands of the doctors who meet with patients, and informing them on the best decisions individually. This strategy has been employed in other areas of the body, like the knees, where many robotic arm systems have tracked the movement and improved the medical knowledge of the specific kinematics related to that joint. For example, the Lokomat Robotic Orthosis is a machine that was designed to track and assist the gait movements of people who have illnesses that prevent them from walking with a normal kinematic motion.(5).

### End User

The overall goal of our project is to provide a way for researchers and doctors to be able to better treat their patients, who are the end users. Ultimately, this will become a tool for the doctors to be able to spot unique and complicated issues in the geometry of the arm, which will in turn allow for a more personalized approach to the specific issues that each patient has, and increase the success rate of the surgeries when they have to take place. We believe that our product will be the first step in furthering the treatment and knowledge base of doctors for Ulnar neuropathy, which improves the lives of the end users. Our novel approach completes the task of mapping the ulnar nerve in the arm robotically, which allows for repeatability and the collection of useful data, which can then be translated using the ultrasonic sensor into a realistic and accurate model of the nerve in a patient's arm. This product could force doctors to look at the specific methods of treatment for Ulnar nerve entrapment in a

different light, and allow them to tailor the surgery to each person, get a better view of the whole nerve, and change the procedure of the surgery based on collected research data. An advantage of our proposed solution is that there are very few risks involved, as there is minimal risk to any patients, and the possible benefit to those affected who might otherwise find no relief is massive.

### Motivation

Our sponsor, Dr. Miller, is currently researching human motion, with an emphasis on elbow kinematics and the mechanical aspect of orthopedic surgery. This experience has led him to look into the ways we currently repair nerves in the arm, and the issues that are currently affecting the standard practice. This led him to propose the idea of finding a way to robotically track the path of the Ulnar nerve as it moves in the arm. Dr. Miller saw a gap in the methodology of diagnosing and solving this nerve issue, and sees a way that we can fill in that gap using our mechanical engineering skills.

### Significance and Impact

We believe that this idea could create a study that takes data from lots of different patients, with Ulnar neuropathy and without, to see if we can find similarities in the issues that patients are having, that could potentially lead to a reworking of how the Ulnar nerve entrapment surgery is performed around the world. “We do not know when to treat a person with this condition (Ulnar neuropathy) conservatively or surgically.” (2) as stated in a 2015 article, which exemplifies the tone of the medical field, and reflects that they might need a new voice that can potentially optimize their procedures from a scientifically rigorous perspective. This condition, which is a relatively unknown ailment, affects a wide range of populations, including, “ pregnancy, diabetes, rheumatoid arthritis, and patients with occupations involving periods of prolonged elbow flexion and/or wrist dorsiflexion. Cyclists are particularly at risk of Guyon's canal neuropathy. Patients typically present with sensory deficits of the palmar aspect of the fourth and fifth digits, followed by motor symptoms, including decreased pinch strength and difficulty fastening shirt buttons or opening bottles.” (3). This shows how degrading this condition can be to a person’s normal life, and how many different groups of people, from all walks of life, can see harsh symptoms from the nerve damage. Dr. Miller is at the forefront of orthopedic surgery, and has done ultrasonic scanning of the Ulnar nerves by hand before, and has told us that the complex movements required by the ultrasonic sensor to get a clear picture of the nerve would make taking repeatable and measurable data impossible by hand, which is why we need to automate the process and put sensors on every degree of freedom to get a full picture of the movement that occurs during data collection. (1)

### Project Continuation

This is the first iteration of our project.

## **2. Specifications and Requirements**

### Project Design Constraints

- The robot holding the sensor must be able to reach from the wrist to halfway up the upper arm
- The robot must be able to be moved by hand
- The design of the robot must include the ability to easily add motors
- The patient’s arm must be held at about 30 degrees from the body

- The robot must be able to move the sensor along the arm when it is straight out, bent at 90 degrees or any where in between
- The mount holding up the patient's arm must not block the Ulnar nerve
- The mount for the patient's arm must be comfortable
- It must use an ultrasonic sensor
- The robot must be able to be operated by one person
- The system must be built within the given budget
- The design must be able to account for different arm sizes and lengths
- The system must be able to be track itself along the arm
- The patient's arm must be constrained so that it does not move

## Requirements & Specifications

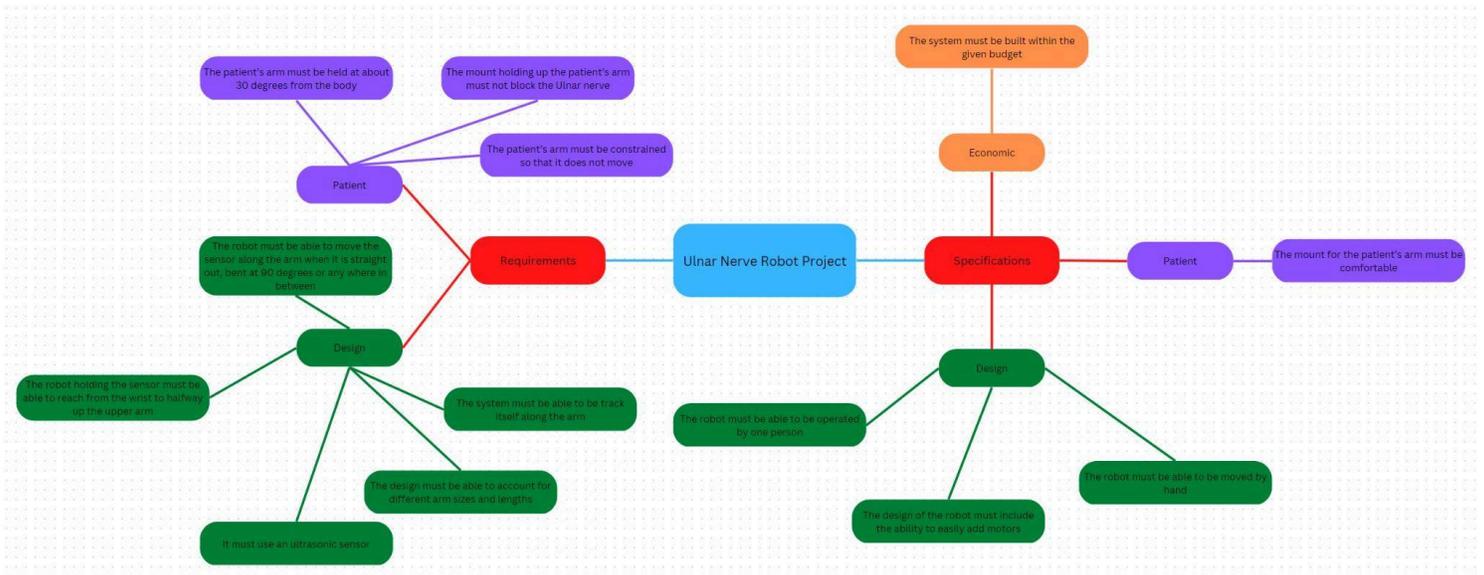
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## Summary Mind Map or Quad Chart



## 3. Project Objectives

### Project Goal

Develop a system that is able to track 6 degrees of freedom, 3 translational positions and 3 rotational orientations, of a sensor along the path of the ulnar nerve in a live subject's arm. The system should also support the subject's arm while constricting motion to maintain a constant position in the arm. The system does not need motorized control of the sensor, but should be designed with this ability in mind.

### Objectives

Objective 1 - Preliminary Design: Develop different methods of achieving the final goal, that satisfy the requirements and constraints. Create sketches and basic CAD models of each method, which will be presented to the team and project sponsor. The group will deliberate and decide on a method which will be pursued.

Objective 2 - Position Measuring System: Create detailed design of position measuring system. This will include the structural components as well as the system of sensors. The design will be modeled in detail in CAD and broken into a bill of materials required. Load analysis will also be done to ensure the structural integrity of the device. A simple prototype will be developed to ensure validity and functionality.

Objective 3 - Arm Holder: Create design for structure that will support and constrain the subject's arm. Load analysis of the structure will be executed for the expected range of loads. A CAD model will be developed and added to the model of the position measuring system. The required materials will be placed in a bill of materials. A simple prototype will be developed to ensure validity and functionality, which will be added to the prototype of the position measuring system.

**Objective 4 - Obtain Materials:** The team will order the materials and mechanisms needed for assembly. Parts that the team manufactures will be either 3-D printed or machined in the machine shop based off of 3-D models created previously.

**Objective 5 - Assemble the System:** The final system will be assembled as parts and materials are available. The team will ensure that ordered and manufactured parts are in accordance with the design and will ensure that the system is constructed correctly and has the necessary mechanical functions.

**Objective 6 - Develop Software and Test:** Create software that connects to the sensors in the system, reads the signals provided, and computes the values desired. Initially the software will just read and display the positional and rotational values through the test. If time permits it will be developed to output the 3 dimensional path that the system measures. Tests will be run to ensure that the system works as intended and achieves the final goal. Adjustments will be made as needed.

#### Endpoints – Deliverables and Metrics for Success

- (1) A complete CAD model of the whole system
- (2) *Conceptual designs that led to the final product*
- (3) *Software required to run the test*
- (4) *Test results*
- (5) *Bill of Materials*
- (6) *Working Prototype*

## **4. Project Planning**

### Resources

Materials needed will most likely be aluminum, steel, and some form of plastic. This will be for the construction of the frame as well as the arm itself. Some components might need to be custom made but we hope most if not all can be found and integrated into our design using vendors such as 8020. For prototypes, 3D printed PLA will work fine but we anticipate that a different polymer will be needed for the final design for parts that benefit from being plastic instead of metal. Motors and potentiometers will be needed as well as all components needed for a control system (buttons, wires, microchip, etc.). These can be sourced online from vendors like Adafruit or RoboShop.

Resources like SCPI and the machine shop in Benedum will most-likely support all machine work that will be needed. As stated before, 3D printers will be needed and are supplied in multiple spaces throughout Benedum.

Software components will be Solidworks for designing and prototype iterations. Additionally, Solidworks and software like Ansys Workbench can be implemented for finite element analysis and load analysis. MATLAB can be used for kinematic calculations and equations of motion. Microchip studio will be needed to program controls if we reach that point and Bantam tools for custom PCBs although it is unlikely we make it to this point given our time frame.

### Anticipated Design Iterations

There are three core components of our design that are going to require multiple interactions. The frame supporting the patient's arm, the frame controlling motion in a x-y plane, and the six DOF arm that will hold the ultrasonic sensor. For each component, initial designs will be drawn and roughly sketched. Once discussed, those ideas which are agreed to be the most promising will be designed in CAD. This will help for load analysis which could point out potential problems which would warrant more redesign. After this step, parts will be sent to the shop for customization if need be and assembly will begin. Ideally at this stage the only problems arising are small which quick thinking and tinkering can solve.

### Support from Project Sponsor

Support needed from our sponsor is design requirements and any new considerations that might come up as the project continues. An ultrasonic sensor also will be provided from our sponsor along with monetary funds to purchase agreed upon components such as potentiometers, motors, raw materials, etc.

### Support from Swanson Center for Product Innovation

Support from Swanson Center for Product Innovation will include machines such as 3D printers, laser cutters, and heavy machinery in the machine shop.

### Support from Subject Matter Experts

Subject areas that we might need additional consultation for could be in fields like mechatronics, kinematics, and controls.

### Potential Risks and Anticipated Failures

There are no true risks associated with the project other than losing money on a design that does not work but with proper planning and implementation this will be avoided. Failures are that the robot itself does not function properly in one of the degrees of freedom or that the machine is not easily used or accessible for patients.

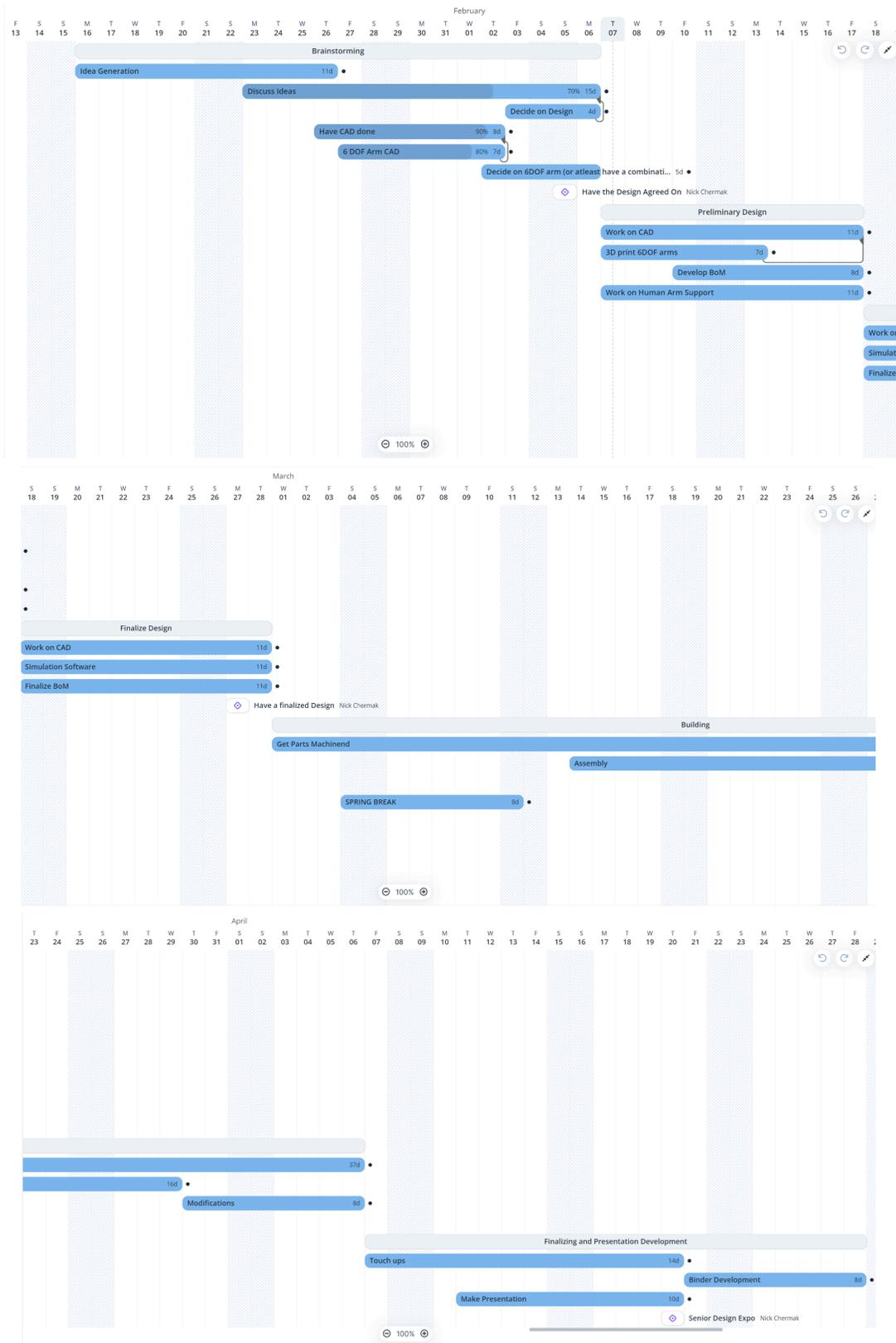
### Milestones

Markers include agreeing on a design and how the design will tackle the six DOFs. Next will be having the kinematics worked out as well as a CAD model proving functionality. Next will be having some part in the machine shop before spring break. Finally, the last will be built and functioning as designed.

### Budget

Our final budget will be 1,500 dollars, which consists of the standard MEMS senior design project budget of 400 dollars, and the rest was funded from our sponsor Dr. Miller.

# Timeline



This timeline is subject to change as time goes on. As can be seen, the tasks later in the spring are more bare bones and will be filled accordingly as those tasks get approached.

## 5. Project Execution

### Analysis & Design

The main type of analysis to be used on the project is a kinematic analysis, but it will also require stress, structural, and failure analyses. The kinematic analysis will allow us to track the movement of the sensor attached at the end of the arm. The various other analyses will be to ensure that our design is structurally sound and will be reliable enough for repeated use. Once the robot is constructed, there will need to be a mechatronics/controls analysis to create a software that will display the translational and rotational positions throughout the arm's use. If there is time, this will be expanded into calculating the 3-dimensional path that the arm takes.

### Verification

To verify that the robotic arm has the degrees of freedom required, we will use it to manually trace the approximate location of the ulnar nerve in one of our arms. If it can move from the wrist, all the way around the elbow, and to the upper arm, the robotic arm has a satisfactory range of movement. We must also verify that the positional display is correct. To do this we will move the arm to predetermined positions and ensure that the display is accurate.

## 6. Project Organization

### Team Meetings

Each week we will meet Monday 11 AM-12 PM, Tuesday 6 PM-7 PM, and Thursday 12:15 PM-2 PM. There is no set location for these meetings, but typically they are held in either the Benedum library room, Benedum G26, or Benedum G04 (the lab). If necessary, we will schedule more meetings in order to stay on schedule. The presenters are responsible for taking meeting notes during all meetings. Communication between in-person meetings will be held via text and zoom calls if necessary.

### Work Space

We will work on our project in various rooms in Benedum, including the library room and G26. When not working on the project we will store the materials in Benedum room SB27.

### Sponsor Meetings

We will meet with our project sponsor every Monday from 11AM to 12PM. More meetings will be scheduled as necessary. It has already been determined that Thursday's from 1PM-2PM is another time our sponsor is free to meet. All meetings will be in-person, typically in either the Benedum Library room, Benedum G26, or Benedum G04.

## Sharing, Distribution and Archival of Project Data

To share and archive data, our team will use a shared GoogleDrive. All documents relating to the project will be found here. Assignments can also be found on Teamwork after the due date.

## Return of Equipment

The ultrasound sensor is the only piece of equipment that will be borrowed from our sponsor. All other materials will be ordered or manufactured. At the conclusion of the project, Nick will ensure that the ultrasound sensor is returned to Dr. Miller.

## **7. Project Outcomes**

### Community

The first group that will be impacted by the success of our project are researchers interested in the mechanics of the ulnar nerve, and should the use of ultrasound continue to develop to observe nerve behavior, other nerves in the body. This is a topic that is not widely understood, and this can be a tool to allow for future developments. The second group that will be impacted will be doctors treating patients with ulnar nerve issues. It is intended to allow doctors to observe the behavior of the nerves and develop the most effective treatment. The final group impacted will be the patients who undergo ulnar nerve surgery. 15% of operations are unsuccessful and the patients remain in discomfort or have their condition worsened. With doctors able to better understand the cause of the patients' issues, hopefully this rate decreases.

### Educational

- Improve on automated data reception and analysis via software
- Gain skills in machining and other forms of fabrication
- Experience with complex constructions and systems

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# ***Preliminary Design Concepts***

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## ***A Robotic System for Tracking the Ulnar Nerve***

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We had multiple ideas to choose from when determining how to measure the position of the ultrasonic sensor, these are the 4 that were considered.

Design 1: Movable Rail Design Concept:

A 4 DOF arm mounted upon a rail that is rigidly attached to the patient’s arm, this rail would be able to bend as the patient’s arm bends. The arc of the rail would be measured along with the respective position of the arm.

Requirements and Specifications:

Requirements:	Specifications:
Holds the arm in a comfortable and form fitting way	Reasonably Small
Allows for the 90 degree bend in the elbow	Easily anchored and stable platform
Provides a way for the robot arm to gain access to the wrist of human arm	Accommodates all sizes and shapes of arm
Allows for manual control	Rigidly supports the robot arm

Design Strengths and Weaknesses:

Strengths:	Weaknesses:
Reduces the number of DOF’s required for the robot arm	Lots of complicated little parts
Takes up very little space	Much of it would have to be machined in house, increasing required time to complete the project
Reduces the motor requirement and therefore power requirement	Would cost a large amount of money with multiple different materials

Design 2: 3 DOF Movable Plane with 3 DOF Robot Arm Design Concept:

The base of the mechanism would be similar to that of a 3-D printer with a 3 DOF arm attached to the end.

Design Requirements and Specifications:

Requirements:	Specifications:
Provides a stable base for the robot arm	Reasonably Small
Provides infrastructure to create the supporting structure the human arm	Easily anchored and stable platform
Allows for integration of sensors and motors for future iterations	Accommodates all sizes and shapes of arm
Moveable and adjustable by a technician	Rigidly supports the robot arm

Design Strengths and Weaknesses:

Strengths:	Weaknesses:
Allows for much more versatility in what is being tracked where it is on the body	Heavy
Much easier to assemble and buy	Takes up a lot of space
Much cheaper	Everything is bigger so everything has to support more weight and forces
Allows for manual control	Need to design a human arm holding system around it

Design 3: Suspended Wire System Design Concept:

A System similar to a NFL wire TV camera, but with an array of joints to reach various angles, likely 3 or more.

Design Requirements and Specifications:

Requirements:	Specifications:
Structurally supports the human arm	Reasonably Small
Gives the sensor enough DOF's to completely sense the nerve	Easily anchored and stable platform
Not too expensive	Accommodates all sizes and shapes of arm
Allows for manual control	Rigidly supports the robot arm

Design Strengths and Weaknesses:

Strengths:	Weaknesses:
Fairly cheap	Would require a lot of tension in the wires to achieve the required stability
Unique and interesting	Hard to calibrate
Makes the robot arm require much less DOF's	Hard to code and control
Easily used manually	Difficult to build

Design 4: 6 Degree of Freedom Robot Arm:

A robotic arm with 6 joints similar to a Faro arm which is used to precisely measure position.

Design Requirements and Specifications:

Requirements:	Specifications:
Structurally supports the human arm	Reasonably Small
Gives the sensor enough DOF's to completely sense the nerve	Easily anchored and stable platform
Not too expensive	Accommodates all sizes and shapes of arm
Allows for manual control	Rigidly supports the robot arm

Design Strengths and Weaknesses:

Strengths:	Weaknesses:
Flexible in regards to angles and positions needed	Complex design with a lot of moving and interfacing parts
Plenty of examples in use	Is limited in reach and can get “stuck” where desired movement is not possible due to the angle of the joints
Adaptable to our needs	Hard to code and control
Easily used manually	Difficult to build

### Potential Analysis for Validation:

We would like to perform some initial torque and moment calculations on the robot arm and the selected support to make sure that they can all support themselves and the loads they need to carry. Once we have selected a design, we would also like to perform some FEA on simplified models to both confirm our initial paper calculations in terms of force and stress, but also catch any areas where we can optimize the structural positions to eliminate wasted space or structural material. In the future, we would also potentially like to place the finished machine in the hands of an ultrasound technician and receive honest feedback on how we would improve the handling capabilities or the machine's ease of use.

### Optimal Selection Methodology:

Our selection methodology would consist of multiple variables: cost, time, and ease of use. These are the main variables that our sponsor has expressed to us are important, we will ultimately weigh all of them to select the best possible solution. We also see a potential to combine some of our ideas, and in this case we would try to take the aspect of a design within our defined variables where it succeeded, and add it to a different design that succeeded in a different variable. We will then get this potential solution approved by our sponsor and move forward with the design and manufacturing process.

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# ***Design Review and Updated Summary***

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	Rebecca LeSturgeon	<a href="mailto:REL72@pitt.edu">REL72@pitt.edu</a>

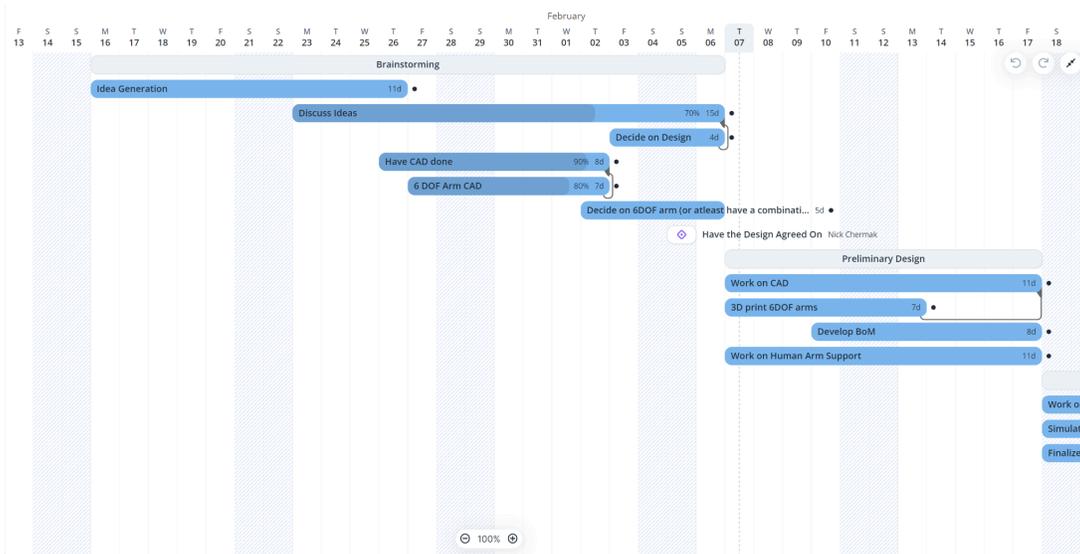
## Design Review Summary

1. Overall, our team received positive feedback about our design which can help improve our final goals and function. Main points made were to ensure user comfort via padding and ergonomics. Additionally, they recommended possibly having some type of video or simulation to better convey how certain parts of our system works. Also they recommended breaking it down into different parts for presenting with each part having a distinct purpose.
2. We intend to use these suggestions to help better our project. Most if not all of the suggestions given were focused on communicating the concept and purpose of the system to an audience. Given that this team was the first group of people who had an almost mini presentation about our project as a whole, we should take their suggestions seriously. This includes reorganizing how we present the system as a whole. We think it will break up the system when explaining it to have people first understand the individual components then present the system as a whole. Also the use of some type of example video will be useful to help better communicate that idea.
3. Zinjun Zhou, Yifan Zuo, Min Gao

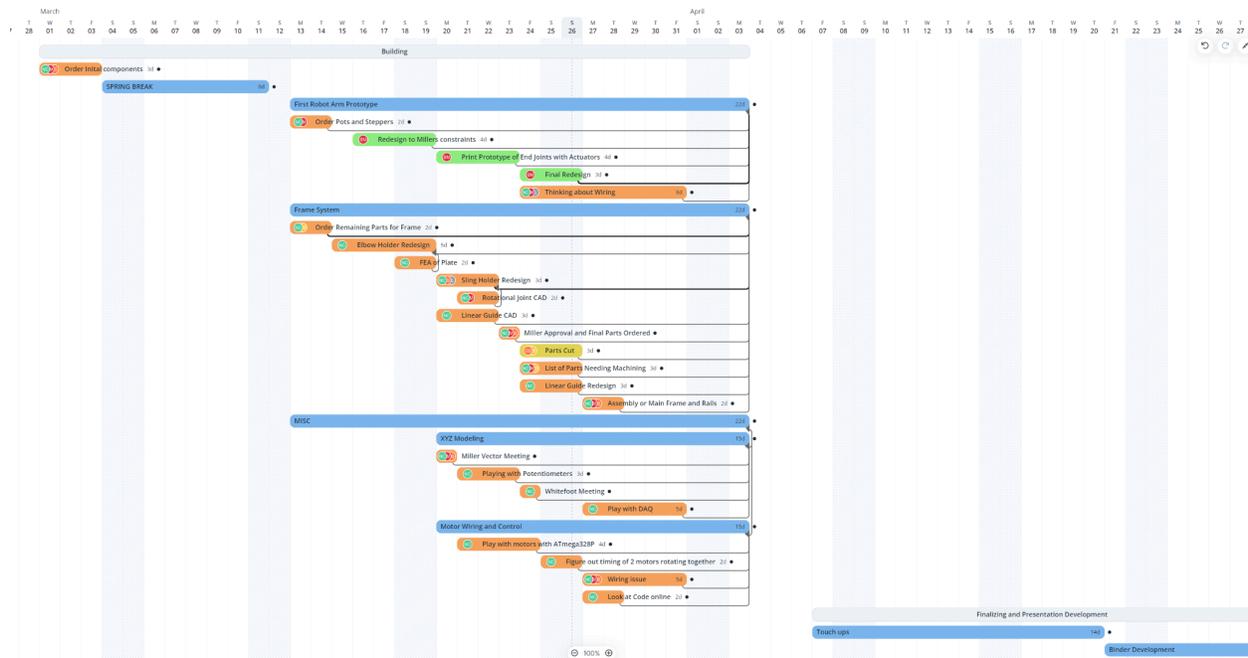
## Updated Project Summary

Nothing major changed that had a drastic impact on the project as a whole. Linear String Transducers were added in place of stepper motors on the rail system for measurements, due to the untreaded waters of using motors to passively measure position. A few small redesigns were necessary on different linkages of the Robotic Arm in order to comply with chosen components, specifically the carriage that it would be mounted upon. Finally, a 3D printed joint was designed to act as a swivel for the wrist sling. The biggest change to our project timeline came from lead times for certain parts which significantly pushed back our time for building.

## Old Timeline:







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## ***Adopted Design Concept***

---

### ***A Robotic System for Tracking the Ulnar Nerve***

#### ***Sponsor***

Dr. Mark C. Miller  
Email: [mcmlr@pitt.edu](mailto:mcmlr@pitt.edu)  
Phone: 724-980-1426

#### ***Team Members and Roles***

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Presenters:	Benjamin Moyer	<a href="mailto:BEM112@pitt.edu">BEM112@pitt.edu</a>
	Rebecca LeSturgeon	<a href="mailto:REL72@pitt.edu">REL72@pitt.edu</a>

Pugh Chart

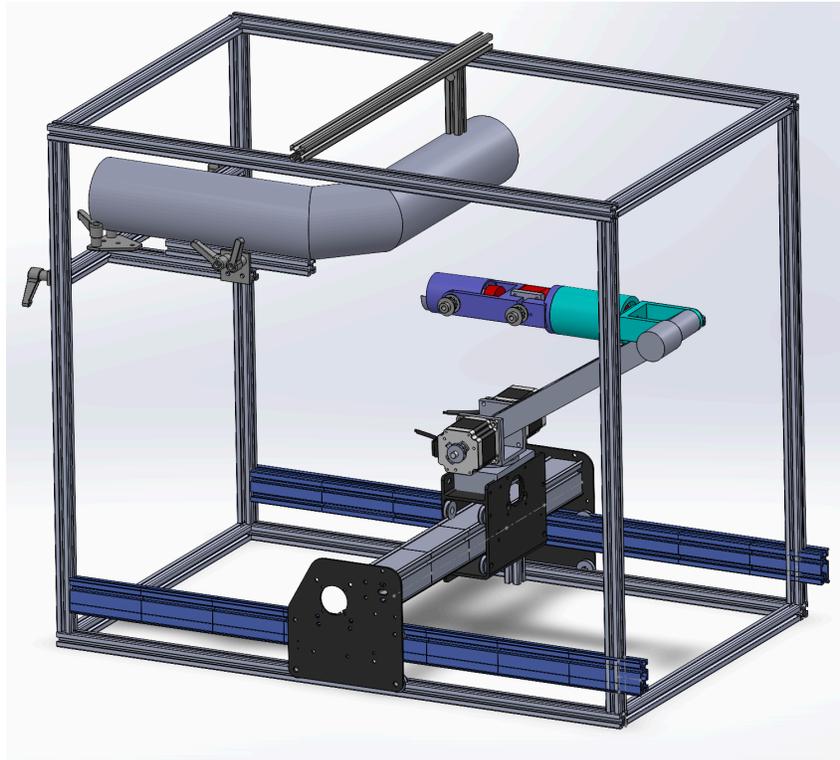
Evaluation Criteria	Flexible Rail Design	6 DOF Arm Design	X-Y-Z Movement with 3-DOF Arm	X-Y Plane w/ 6-DOF Design
Ease of Use	2	1	1	1
Ability to Adjust to Multiple Elbow Angl	0	2	2	2
Flexibility of Reach	0	1	2	2
Accuracy of Position	2	2	2	2
Material Availability	1	2	1	2
<b>Total</b>	5	8	8	9

Final Decision:

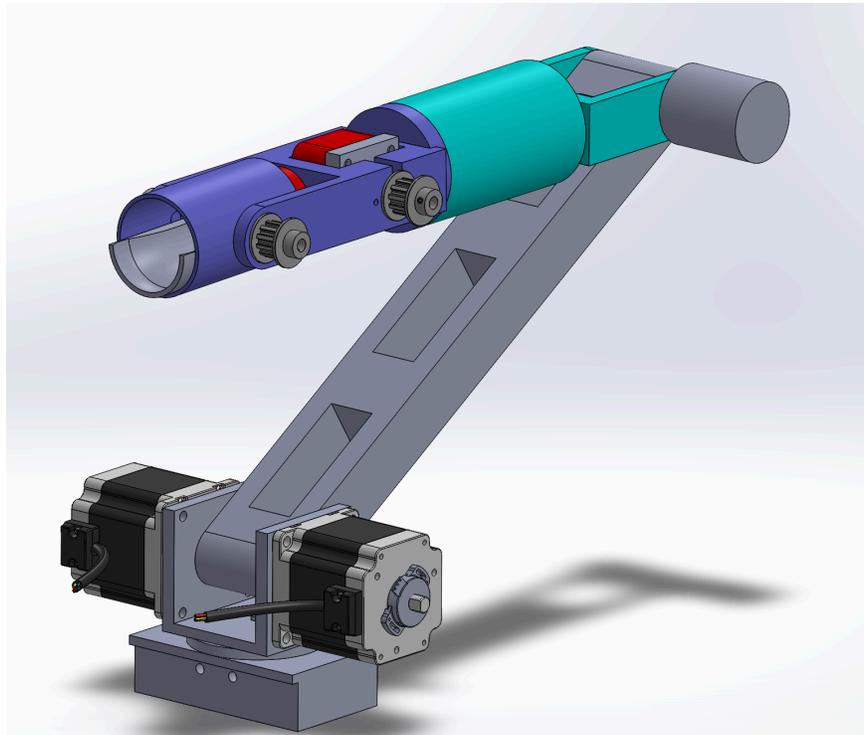
We selected Option 4, the X-Y plane with a 6 degree of freedom arm for our final design. This is a combination of the other two designs, using the best parts of each. The 6 degree of freedom arm, adopted from Option 2, will give the arm the flexibility to move in any orientation that may be needed. The X-Y plane, adopted from Option 3, will make it easier for the arm to move around and reach every position inside the frame due to the planar movement. Option 1 was eliminated mostly because of its rigidity. This design had a track/rail system that would follow the ulnar nerve along a patient’s arm, but if the nerve deviated significantly from the expected path it would be unable to adapt. All of this would be mounted in a rectangular frame of 8020 Aluminum Extrusions to allow for the east mounting of the device and the human arm support structures. Option 2 was a viable option, but there were concerns about whether a static arm would be able to easily reach all necessary positions. Option 3 was discontinued due to the issue of supporting the weight in the vertical direction while being easily able to manipulate it in the same direction.

The decisions regarding the support of the patient's arm was heavily dependent on the positional system that we chose, so that it would not interfere with the operation of the system and we had a base to mount it off of. Our final design consisted of two components, one of which was a cantilever beam which would support the elbow of the patient, specifically the knob at the end of the humerus, which would bear the majority of the arm's weight. This beam would have the ability to extend in length, move up or down, and move horizontally to account for various patient arm lengths and different scenarios in which the device would be used, left versus right handedness. The second component is a wrist support. This would consist of an adjustable strap with a supporting plastic piece which would physically hold the wrist and allow for various wrist sizes. This strap would then be supported by a vertical piece of aluminum which would hang from a beam stretching across the frame and be allowed to rotate freely to prevent pinching. This vertical column would have the ability to slide along the beam and the beam will also have the ability to slide along the length of the frame. This will create a 2 dimensional plane on which the wrist support can move along giving us more mobility in positioning and angling the arm.

CAD



Frame dimensions: 79cm wide x 50cm deep x 68cm high  
All parts of the frame and sling will be purchased (see BOM).



The colored portions of the 6 DOF arm will be 3-D printed with PETG. The remaining sections will be machined from aluminum stock. All other components will be purchased (see BOM).

BOM

Item	Quantity	Price per Unit (\$)	Total Price (\$)	Link
20-2020 T-Slotted Frame	10 meters	12.49 per meter	124.90	<a href="#">20-2020   20mm X 20mm T-Slotted Profile - Four O T-Slots (8020.net)</a>
20 Series T Bracket	8	10.01	80.08	<a href="#">20-4080   20 Series 5 Hole - "T" Flat Plate (8020.net)</a>
20 Series 3 Hole Bracket	16	5.69	91.04	<a href="#">20-4176   20 Series 3 Hole - Inside Corner Bracket (8020.net)</a>
25 Series 4 Hole Bracket	8	6.06	48.48	<a href="#">25-4115   25 Series 4 Hole - Tall Inside Corner Bracket (8020.net)</a>
25 Series Gusseted Bracket	4	8.46	33.84	<a href="#">25-4136   25 Series 4 Hole - Tall Gusseted Inside Corner Bracket (8020.net)</a>
20 Series M4 T-Nut Block	140	0.32	44.80	<a href="#">14159   M4 Slide-in Economy T-Nut Block (8020.net)</a>
M4 Screw	200	10.09 per 100	20.18	<a href="#">Button Head Hex Drive Screw, Passivated 18-8 Stainless Steel, M4 x 0.70 mm Thread, 8mm Long   McMaster-Carr</a>
Side Rail 0.75m	2	18.99	37.98	<a href="#">MakerSlide - Black Anodize - 5M Tapped   Inventables</a>
Mid Rail 0.75m	1	39.00	39.00	<a href="#">Wide MakerSlide   Inventables</a>
Side Carriage	2	18.99	37.98	<a href="#">Gantry Side Plate   Inventables</a>
Mid Carriage	1	37.99	37.99	<a href="#">X Carriage Extrusion   Inventables</a>
Wheel	20	84.99 per 20	84.99	<a href="#">Dual Bearing V-Wheel Kit   Inventables</a>
Straight Bracket	8	5.01	40.08	<a href="#">20-4107   20 Series 2 Hole - Straight Flat Plate (8020.net)</a>
Gusseted Corner Bracket	8	9.33	74.64	<a href="#">4336   15 Series &amp; Ready Tube 4 Hole - Tall Gusseted Inside Corner Bracket (8020.net)</a>
Simple Corner Bracket	24	4.27	102.48	<a href="#">20-4119   20 Series 2 Hole - Inside Corner Bracket (8020.net)</a>
M5 Screw/Nut	120	2.45 per 4	73.50	<a href="#">T-Slotted Framing, End-Feed Single Nut with Button Head M5 Thread Size   McMaster-Carr</a>
M5 Screw	50	7.40 per 25	14.80	<a href="#">Medium-Strength Class 8.8 Steel Hex Head Screw, M5 x 0.80 mm Thread, 20 mm Long   McMaster-Carr</a>
Washer	100	3.40 per 100	3.40	<a href="#">18-8 Stainless Steel Washer, for Number 12 Screw Size, 0.234" ID, 0.5" OD   McMaster-Carr</a>
M5 Locknut	100	4.89 per 100	4.89	<a href="#">Low-Strength Steel Nylon-Insert Locknut, Zinc-Plated, M5 x 0.8 mm Thread   McMaster-Carr</a>

Plastic Ball Bearing 8mm	2	11.03	22.06	<a href="#">Plastic Ball Bearing, with Glass Ball, Trade No. 608, 8 mm Shaft Diameter   McMaster-Carr</a>
Plastic Ball Bearing 6mm	6	8.23	49.38	<a href="#">Plastic Ball Bearing, with 316 Stainless Steel Ball, Trade No. 606, for 6 mm Shaft Diameter   McMaster-Carr</a>
Plastic Ball Bearing 25mm	1	22.71	22.71	<a href="#">Plastic Ball Bearing, with Glass Ball, Trade No. 600, 25 mm Shaft Diameter   McMaster-Carr</a>
Thrust Bearing	1	2.84	2.84	<a href="#">AXK32442 Thrust Needle Roller Bearing 32x43.7x20   Bearings Direct</a>
Timing Belt	1	5.94	5.94	<a href="#">Dust-Free Timing Belt, T5 Series, Trade No. T5-245   McMaster-Carr</a>
Timing Belt Pulleys	2	10.71	21.42	<a href="#">XL Series Lightweight Timing Belt Pulley, 28 mm OD, 12 Teeth   McMaster-Carr</a>
Fifth Joint Motor	1	9.84	9.84	<a href="#">Nema 17 Bipolar Stepper Motor 1.8deg 16Ncm (22.0oz.in) 1A Extruder Motor 42x42x20mm 4 Wires - 17HS08-1004S STEPPERONLINE (omc-stepperonline.com)</a>
Fourth Joint Motor	1	27.60	27.60	<a href="#">HG37-060-AA-00 Nidec Copal Electronics   Motors, Actuators, Solenoids and Drivers   DigiKey</a>
Third Joint Motor	1	27.60	27.60	<a href="#">HG37-060-AA-00 Nidec Copal Electronics   Motors, Actuators, Solenoids and Drivers   DigiKey</a>
Second Joint Motor	1	49.31	49.31	<a href="#">Dual Shaft Nema 23 Bipolar 1.9Nm (269oz.in) 2.8A 57x57x76mm 4 Wires - 23HS30-2804D   STEPPERONLINE (omc-stepperonline.com)</a>
First Joint Motor	1	9.84	9.84	<a href="#">Nema 17 Bipolar Stepper Motor 1.8deg 16Ncm (22.0oz.in) 1A Extruder Motor 42x42x20mm 4 Wires - 17HS08-1004S STEPPERONLINE (omc-stepperonline.com)</a>
Small Potentiometer	1	1.00	1.00	<a href="#">PT15RV02-473A1010-S Amphenol Piher   Mouser</a>
Big Potentiometer	7	15.00	105.00	<a href="#">RH24PC Series   Hollow Shaft Potentiometer   P3 Automation</a>
Base Gear	1	63.12	63.12	<a href="#">Module m 0.5, 120 Teeth, Spur Gear - 792YK3 SS0.5-120A - Grainger</a>
<b>TOTAL</b>			<b>\$1,412.71</b>	

To test that our design has all six required degrees of motion, we will put one of our arms into the device and manually trace the approximate location of the Ulnar Nerve. If the design is successful the device will be able to follow the ulnar nerve from the middle of the upper arm to the wrist without any interference from the frame, sling, or human arm. The device must also output positional data as it moves. To validate the data, we will move the device from one known location to another while following a predetermined path. If the positional data matches the expected output within +/-0.5mm, the design is successful. Dr. Miller has approved our design concept.

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## ***Summary of Deliverables and Risk Plan***

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### ***A Robotic System for Tracking the Ulnar Nerve***

#### ***Sponsor***

Dr. Mark C. Miller  
Email: [mcmlr@pitt.edu](mailto:mcmlr@pitt.edu)  
Phone: 724-980-1426

#### ***Team Members and Roles***

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Planner:	Gabriel Stay	<a href="mailto:GJS58@pitt.edu">GJS58@pitt.edu</a>
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	Rebecca LeSturgeon	<a href="mailto:REL72@pitt.edu">REL72@pitt.edu</a>

- Team Binder:
  - A binder that documents all of our work and progress throughout the entire project
  - This is low risk because it is being completed throughout the project
  
- Poster and Presentation:
  - A poster and presentation to show the final result of our project and how we got there
  - This is low risk because it will come from our binder and meeting notes
  
- Animation Video:
  - A video with an animation of our project moving in 3D space
  - This is high risk because it will take time away from the construction of the physical prototype. This will be dropped if more time is required for building
  
- Validation Data:
  - This will include all of the data that was taken into account for the selection and optimization of the design, as well as the MATLAB and Arduino code that was written to take the potentiometer data from the arm and 2-D plane.
  - This is medium risk because it will partially come from data already taken, and partially from the code will be written to take data from the sensors.
  
- Full CAD Models:
  - We will deliver completed Solidworks files for every part that was designed by our team on the system as well as .stl files for all of the parts that were 3-D printed to give the next engineering team that works on this system full access to the system. These files will also come with full assemblies of each subsystem so that the idea can be well conveyed, and issues can be identified quickly.
  - This is low risk as these models are constantly being refined and redone to accurately represent the current state of the system, so these will be done once the system reaches its final state.
  
- Physical Prototype:
  - The prototype including the human arm holder, robot arm, and frame will be delivered to Dr. Miller for use in his lab, and for future teams to iterate on for improvements and motorization.
  - This is high risk due to the large amount of parts that it requires and this makes it the area where the most problems can occur.

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# ***Supporting Analysis***

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## ***A Robotic System for Tracking the Ulnar Nerve***

### ***Sponsor***

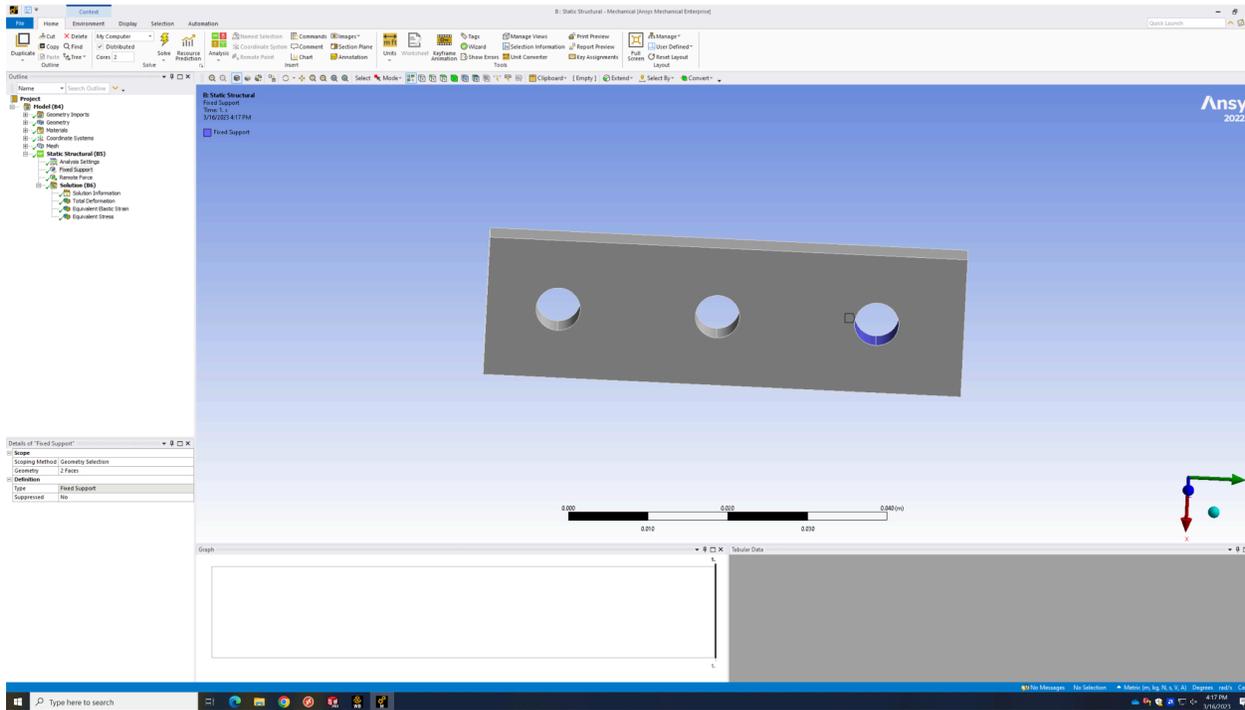
Dr. Mark C. Miller  
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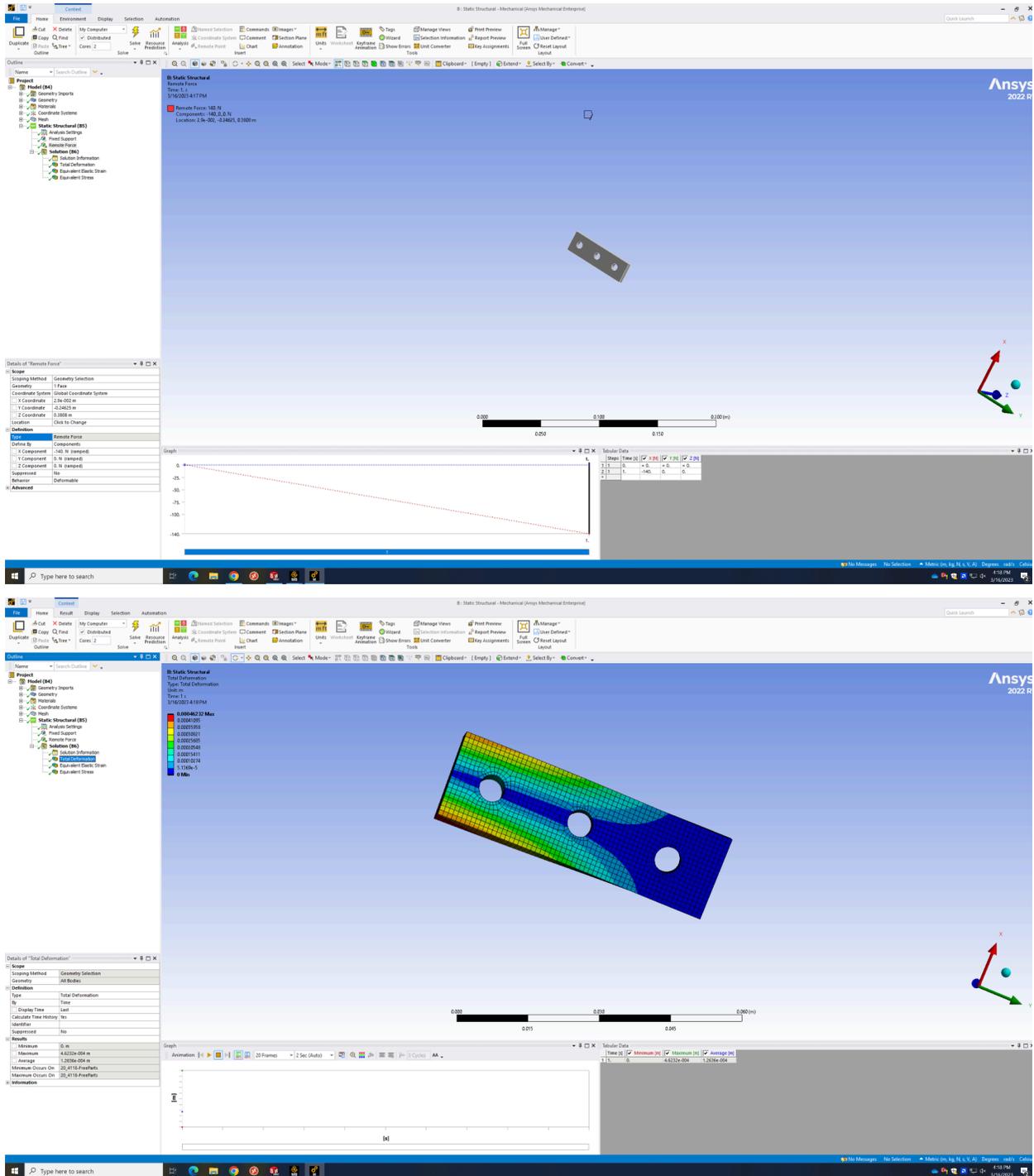
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## Computational Force Simulations:

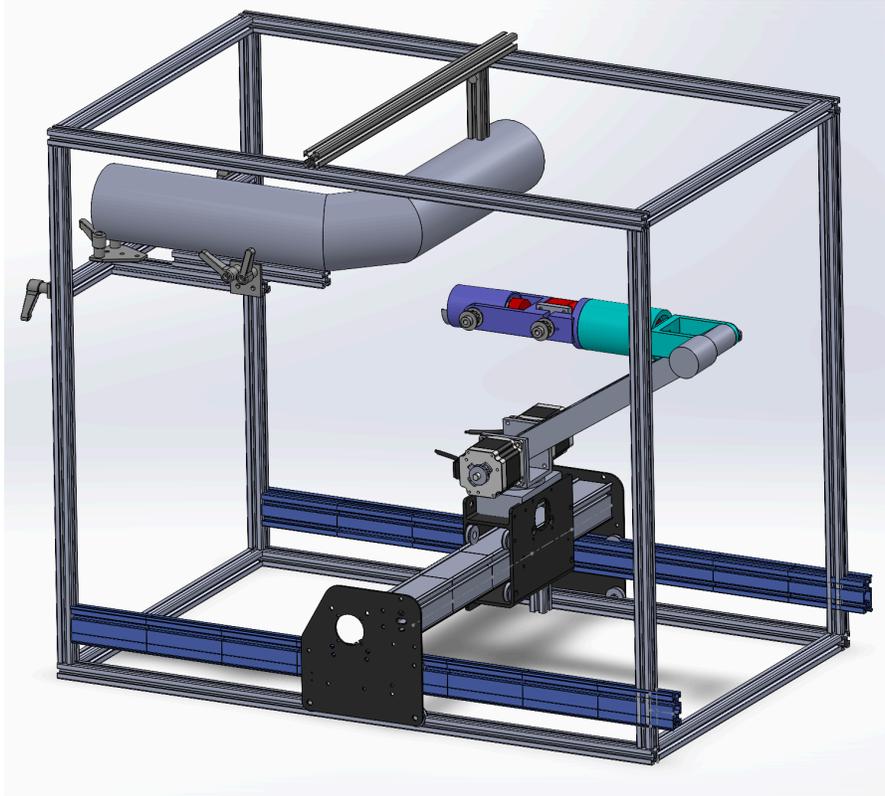
Computational Simulations knowledge was used to do analysis on the bracket to make sure that the force of the arm would not fracture the bracket. This fulfills the requirement that the system must hold the arm.





The MATLAB code will be used to track the system and the location of the ultrasonic sensor is in 3-D space. This uses information from Dynamic Systems to create the equations needed to accomplish this task. This satisfies the requirement that the arm must be able to track itself along the arm. (in progress)

Solidworks was used extensively for many different reasons, but the main reason was to make sure that the dimensions of the box and arm were reasonable and that the robot arm could reach everywhere it needed to. This uses the abilities we acquired from MEMS 0024 to create and manipulate models in Solidworks. This satisfies the robot arm can reach from the wrist to halfway up the upper arm.



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# ***Archive and Clean-Up Plan***

---

## ***A Robotic System for Tracking the Ulnar Nerve***

### ***Sponsor***

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## Archiving of Documentation

There will be both a digital and physical collection of all documentation for this project. The team's Google Drive is the digital collection of documentation and it will also be placed on a flash drive. The physical collection will be in the senior design project binder with all the documentation. The physical binder will go to Dr. Schmidt and a copy will also go to Dr. Miller. The digital collection will be given directly to Dr. Miller.

### Materials to Archive:

1. Final, working prototype
2. Any extra materials
3. Complete BoM
4. CAD files for all 3-D printed parts
5. Drawings for all machined parts
6. CAD assembly of the entire design
7. MATLAB code
8. All pictures and diagrams explaining the project
9. All assignments and project updates
10. Mini presentations
11. Final presentation
12. Data sheets for motors, potentiometers, and transducers
13. Next steps for future groups
14. Copy of the final project binder

## Project Materials

Using the materials listed above, a future cohort will be able to operate the prototype, replace parts, and continue to improve the design. These materials will all be given to our sponsor, Dr. Miller, at the conclusion of the project. All of the project documentation will be archived digitally on a thumb drive. The binder will be given to Dr. Schmidt at the end of the semester and a copy of the binder will also be given to each team member as well as Dr. Miller. The extra 8020 aluminum extrusions will be given to Dr. Schmidt for use in future senior design projects. The leftover stock aluminum will go to SCPI for use in some other future project that requires stock aluminum.

## Workspace Cleanup

The team is focused on a thorough cleanup of all supplies and materials. A large amount of tools were borrowed from the measurements lab, so those will be returned to their rightful place. All garbage will be recycled if possible and if not it will be thrown away. The all extra nuts, screws, and bolts will be given to Dr. Miller to allow for reuse or reference.

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# ***Final Deliverables***

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## ***A Robotic System for Tracking the Ulnar Nerve***

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	Rebecca LeSturgeon	<a href="mailto:REL72@pitt.edu">REL72@pitt.edu</a>

### Final Deliverables:

We will deliver our finalized prototype, along with all of the CAD files and Arduino code to our sponsor Dr. Miller in the days after the Design Expo and MEMS Symposium. Dr. Miller will then make the decision on who works on the system, whether that is a graduate student in his lab or it is another Senior Design team in future iterations of the class.

### Final Prototype:

- We have completed a fully built prototype that includes the built robot arm, both parts of the human arm support, and the surrounding structure with the 2-D X-Carve plane. This is assembled and currently sitting in a section of the sub-basement of Benedum Hall.

### CAD Models:

- We will deliver a .zip file that includes every Solidworks file and .stl file that was used in the creation of the robot arm. This will include some parts that were not on the robot arm, as some of the parts were cut or otherwise altered in the creation of the prototype, so those changes will be archived in the models and drawings. We will also submit all previous iterations of every subsystem at the request of our sponsor.

### Arduino Code and Electronics:

- We will submit the wiring diagrams and the Arduino code, which is listed in this binder, that operates and controls the potentiometers and their data, and then plots that data on the 3-D graph to allow the operator to track and archive the end effector position.

### Presentation:

- We will submit all 5 of our Mini Presentations that were given during class time, and the full document of our Final Presentation, which does include videos, but will appear as stills in the document. This presentation will also be given in its entirety at the MEMS Symposium, as it was chosen as 1 of the 9 best presentations in the class.

### Poster:

- We will submit the full poster that was created using our archived work over the semester, and was printed out and presented at both the MEMS Symposium and the Design Expo.

**Validation Data:**

- We will submit all of the validation data that is taken in MATLAB over the course of our design validation phase. This data will consist of matrices that are taken at a high sampling rate that encode the position of every rotational and translational joint on the arm and 2-D plane.

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# ***Design Validation***

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## ***A Robotic System for Tracking the Ulnar Nerve***

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## Requirements

1. The robot holding the sensor must be able to reach from the wrist to halfway up the upper arm.

This has been validated by placing one of our own arms into the system and approximately tracing the location of their ulnar nerve. The robot arm is able to reach from the wrist to the middle of the upper arm.

2. The patient's arm must be held at about a 30 degree decline from the body.

While comfort was one of our main concerns, this requirement was not able to be fully met. The support for the elbow joint was made with what essentially acts as a cantilever beam. It can also slide up and down the side of the frame allowing for subjects of varying heights. With both of these facts in mind, it is possible to have the arm at 30 degrees if the bar is lowered and extended to the point where a patient's elbow rests leaving the arm at 30 degrees. So our system does allow for the arm at 30 degrees but it is not a set position meaning that various other positions are also attainable. We thought that this versatility might be beneficial versus constraining the arm in a set position for the comfort of the patient.

3. The robot must be able to move the sensor along the arm when it is straight out, bent at 90 degrees or anywhere in between.

The robot arm is able to be moved along the patient's arm in any position that the human arm can be positioned. The 2-dimensional plane moves the robot arm so that

4. The mount holding up the patient's arm must not block the Ulnar nerve.

The human arm support is a cantilevered beam at the patient's elbow. This simple design takes up minimal space along the patient's arm, lessening the risk of interfering with the robot arm's ability to reach the ulnar nerve. The beam sits on the inside of the patient's arm and the ulnar nerve runs along the back of their arm.

5. It must use an ultrasonic sensor.

The system uses an ultrasonic sensor to track the ulnar nerve. The end of the robot arm was designed for the ultrasonic sensor to fit into.

6. The design must be able to account for different arm sizes and lengths.

All parts of the human arm support are adjustable, allowing any size arm to fit into the system. The wrist support can be tightened and loosened, similarly to a backpack strap. The cross bar for the wrist support is able to be moved by loosening two knobs and sliding it across the frame, making it easily adjustable for shorter or longer arms. The elbow support can also be extended or shortened to account for different arm lengths. The elbow support can be adjusted vertically to account for various table heights and arm angles.

7. The system must be able to track itself along the arm.

The system uses six potentiometers, one at each robot arm joint, and two string transducers on the 2-dimensional plane to collect data on the movement of each joint. This data is collected by an Arduino and fed into MATLAB, which uses matrix multiplication to output the position of the end effector.

8. The patient's arm must be constrained so that it does not move.

The human arm support is able to hold the patient's arm mostly still. If the patient is uncooperative they will be able to move their elbow and slightly wiggle their wrist from side to side. This could be improved in future iterations by shaping the elbow support so that the patient's elbow will fit snugly into the space. The wrist movement is limited by a 3-D printed casing around the strap.

### Specifications

1. The robot must be able to be moved by hand

The robot arm is able to be moved by hand, although with some difficulty. The 6 degree-of-freedom arm along with the 2-dimensional plane system makes up a lot of moving joints, so although it is possible to move the arm manually it may require more than one person to move the robot arm in a specific motion.

2. The design of the robot must include the ability to easily add motors.

The robot arm already has motors built into it, so a redesign will not be required to install motors into the system. These motors are not functional right now, but a future group will be able to wire and program the motors to automate the system.

3. The mount for the patient's arm must be comfortable.

The human arm support is made with foam pads, making it comfortable for the patient to rest their arm. In the future this could be improved upon to make the support softer and more comfortable. A better material, possibly high density foam or something similar, could be used.

4. The robot must be able to be operated by one person.

The robot arm is not easily operable by one person. The final product was larger and heavier than expected and the 6 degrees-of-freedom of the robot arm plus the 2 planar degrees-of-freedom are difficult to manage with only two hands. Although this specification was not met, the overall end goal is to fully automate the system so there is no need for a technician at all.

5. The system must be built within the given budget.

Our given budget was a combination of the standard MEMS budget given to us by the department, as well as external funding from our project sponsor, Dr. Mark Miller. In total our budget came out to be \$1,500. At the end of our process we came out just under our budget by spending a total of \$1,412.71 dollars succeeding in remaining under budget.

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## ***Mini Presentations***

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### ***A Robotic System for Tracking the Ulnar Nerve***

#### ***Sponsor***

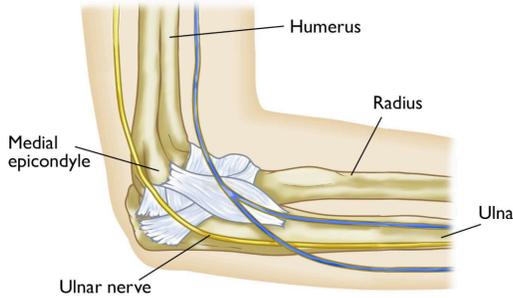
Dr. Mark C. Miller  
Email: [mcmlr@pitt.edu](mailto:mcmlr@pitt.edu)  
Phone: 724-980-1426

#### ***Team Members and Roles***

Coordinator:	Nick Chermak	<a href="mailto:NAC136@pitt.edu">NAC136@pitt.edu</a>
Planner:	Gabriel Stay	<a href="mailto:GJS58@pitt.edu">GJS58@pitt.edu</a>
Resource Manager:	Will Becker	<a href="mailto:WJB49@pitt.edu">WJB49@pitt.edu</a>
Presenters:	Benjamin Moyer	<a href="mailto:BEM112@pitt.edu">BEM112@pitt.edu</a>
	Rebecca LeSturgeon	<a href="mailto:REL72@pitt.edu">REL72@pitt.edu</a>

### 1. Industry and Impact:

15% of Ulnar nerve surgeries do not result in improvement of symptoms.



### 2. Requirements and Specifications:

Robotic Mapping is the best way to track the position and movement of the Ulnar Nerve.

<p><b>Operational Environment:</b></p>	<p><b>Functions:</b></p>
<p><b>Specifications:</b></p>	<p><b>Performance Criteria:</b></p>

### 3. Teach a Concept:

**Teach a concept: taking positional data**

By: Team 19

**Finding position from joint angle measurements**

Joint Coordinates:  $\theta_1, \theta_2, \theta_3$   
 Task Coordinates:  $x, y, \alpha$

Forward Kinematics (FK)  $\rightarrow$   
 Inverse Kinematics (IK)  $\leftarrow$

### 4. Challenges:

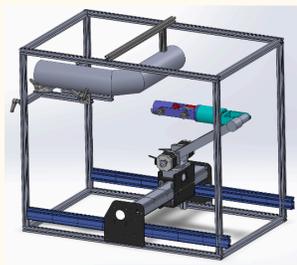
**Sensing changes in angle**

- Rotary Potentiometers
- A/D conversion
- Arduino data collection

Challenges have led to multiple design iterations and goal adjustments

### 5. Deliverables and Budget:

An Unpowered Robotic System that Tracks the Ulnar Nerve and Will Visualize Data in a 3D Plotter.



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# ***Final Presentation***

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## A Robotic System for Tracking the Ulnar Nerve

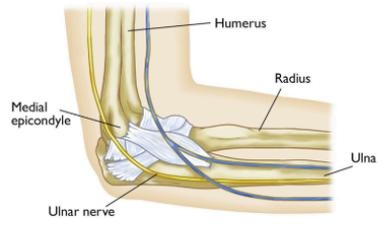
By: Ben Moyer, Will Becker, Rebecca LeStoutgeon, Gabriel Stay, Nick Chermak

Sponsored by: Dr. Mark Miller



1

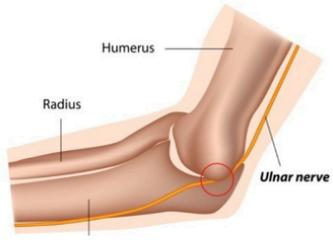
### What is the Ulnar Nerve?



2

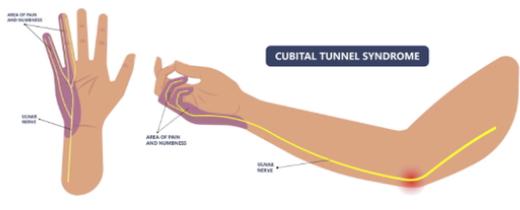
### Ulnar Nerve Entrapment

Approximately 80,000 people in the US per year are diagnosed with Ulnar Nerve Entrapment



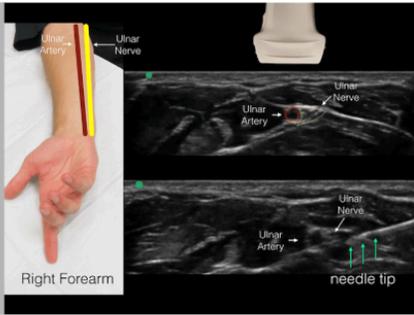
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10-25% of Ulnar Nerve Entrapment surgeries do not result in complete improvement of symptoms



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### Ultrasound Imaging



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### Overall Project Goal

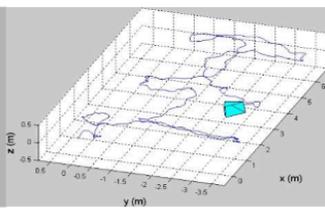
Create an automated system that combines an ultrasound sensor and 3D tracking to create a digital model of the Ulnar Nerve to assist in medical research.



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### Our Semester Objective

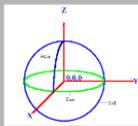
Track an end effector that is manually moved throughout 3-D space as it moves along a human arm, while supporting the arm of the patient.



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### Requirements

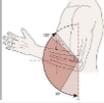
- Measures position and orientation of the sensor
- Hold a human arm in a locked position, limiting movement
- The system must be easy to move manually




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## Specifications

- Human arm must be able to move 90° about the elbow
- Adjustable for different sizes of arms
- Comfortable for the patient
- Have implementation of motors built into design to enable future automation



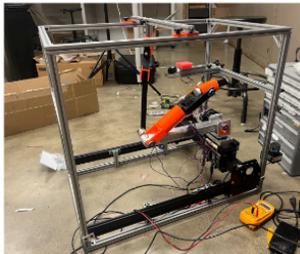
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## Initial Brainstorming



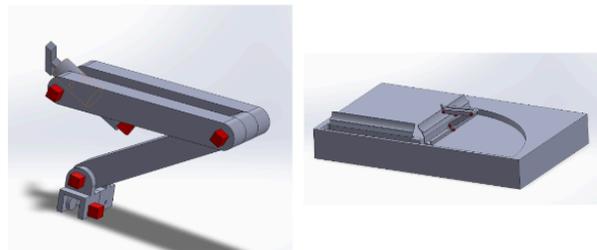
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## This is What We Decided On and Accomplished

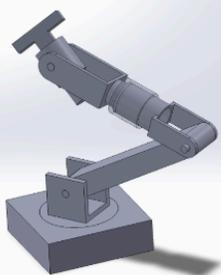


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## Robot Arm Iteration 1



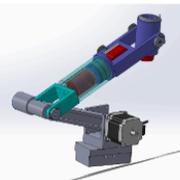
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## Robot Arm Iteration 2

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## Robot Arm Iteration 3



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## X-Carve used as Inspiration for 2-D Plane Design



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## Implementation into Final Design



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The human arm support can accommodate the full range of motion of the elbow



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The focus of the human arm support design was adjustability and comfort

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Sensors - Potentiometers



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Hardware Options?

Data Acquisition Unit

Arduino



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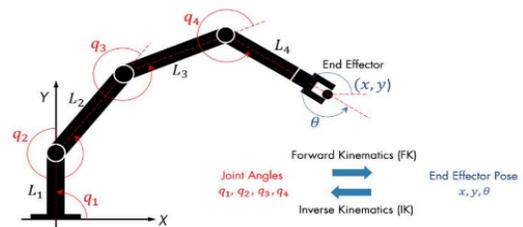
Decision: Arduino



- Hardware available
- More comfortable
- Cheaper

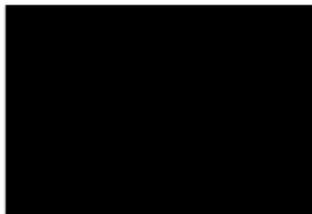
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Forward Kinematics



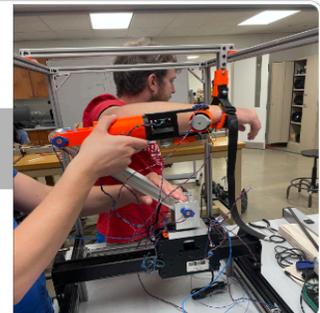
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MATLAB Live Plot



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Combination of all 3 systems



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## Validation Video



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## Challenges

Started with an Idea

Complex



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## BoM (price per subsystem) with overall budget

Subsystem:	Cost:
Robot Arm	\$417.66
Frame and Rail System	\$980.25
Human Arm Support	\$42.78
<b>TOTAL</b>	<b>\$1440.69</b>

Our Budget (with external funding) : \$1,500.00

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## Next Steps

- Validate accuracy of the system
- Automate the system to mirror path
- Optimize electronics
- Increase patient comfort



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## Acknowledgements



Dr. Mark Miller  
Dr. David Schmidt  
Dr. Nikhil Bajaj  
Dr. John Whitefoot  
Dr. William Clark  
Ms. Heather Manns  
Ms. Kelly Wodnicki  
SCPI Machinists



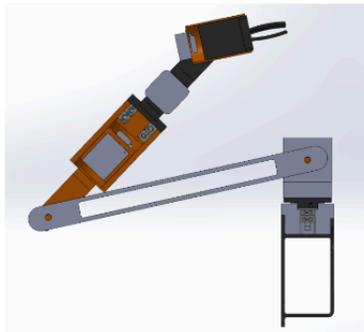
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## Thank You!



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## Extra slide: Arm Section View



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## Transform Matrices

$$R_x(\theta) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos \theta & -\sin \theta \\ 0 & \sin \theta & \cos \theta \end{bmatrix}$$

$$R_y(\theta) = \begin{bmatrix} \cos \theta & 0 & \sin \theta \\ 0 & 1 & 0 \\ -\sin \theta & 0 & \cos \theta \end{bmatrix}$$

$$R_z(\theta) = \begin{bmatrix} \cos \theta & -\sin \theta & 0 \\ \sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

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# **Poster**

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# A Robotic System for Tracking the Ulnar Nerve

Project Engineers: William J. Becker IV, Nicholas A. Chermak, Rebecca L. LeSturgeon,  
Benjamin E. Moyer, Gabriel J. Stay  
Project Advisor: Dr. Mark C. Miller



## Abstract

This is a 6 degree-of-freedom system that records the positional data of an ultrasonic sensor that is moved along a patient's arm. The overall goal of this project is to become a research tool that doctors can use to better understand the anatomy and the mechanics of the ulnar nerve.

## Introduction

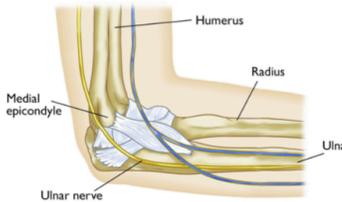


Fig. 1: Ulnar Nerve Diagram  
Source: <https://orthoinfo.aaos.org>

The ulnar nerve is one of the main nerves in the arm. As seen in Figure 1, the ulnar nerve runs along the outside of the elbow. When this area of the nerve is bumped, it is commonly referred to as "hitting your funny bone". This nerve can get irritated or pinched between the radius and humerus bones causing chronic pain, tingling, numbness, and discomfort in the arm and hand. This is known as ulnar nerve entrapment.

Doctors are able to diagnose ulnar nerve entrapment by moving an ultrasonic sensor, seen in Figure 2, along the patient's arm to view the nerve. There is surgery to resolve ulnar nerve entrapment, but this surgery does not improve symptoms in 10-25% of patients [1].



Fig. 2: Ultrasonic Sensor  
Source: <https://www.pittpa.com.au/>

## Project Sponsor's Goal

The goal of our sponsor is to create a system that automatically tracks along the ulnar nerve using ultrasonic imaging, which will then combine the imaging and positional data to create a digital model of the ulnar nerve. The use of these models can then be used by medical researchers to better understand ulnar nerve entrapment and the mechanics of the ulnar nerve, based on cross section and bunching of the nerve. Additionally, surgeons could use this imaging to better diagnose and treat their patients

## Our Objective

Our goal for the semester was to create a system that will hold an ultrasonic sensor while tracking the location and orientation of it as it is manually moved along the path of the ulnar nerve on a subjects arm. This data will then be used to determine the track the sensor took. Additionally, we needed to create a system that would support and restrain the subjects arm in a comfortable way.

## Design Criteria

### Device Requirements

- Must measure 3-dimensional position and orientation of sensor as it is moved through space
- Digitally store and display the measurements
- Fully support the weight of the human arm
- Limit possible movement of the arm when desired
- The system must be able to be smoothly and easily manipulated manually

### Device Specifications

- Elbow must have a range of motion of 90 degrees
- Support for human arm should not cause discomfort
- Adjustable for various arm sizes
- Prevent deflection in components supporting the sensor
- Keep future automation in mind when building system (motors incorporated into design)

## System Design

The overall design consists of 4 sub-systems, 2 for motion tracking and 2 for supporting the human arm.

**2-D Plane:** To achieve movement along the 2-D plane, a system of rails and wheeled carriages were used. This same rail system is utilized in the X-Carve CNC mill, and was chosen due to the accuracy of the system and the ability to carry a heavy load. This also only required us to implement it into our system as opposed to creating it ourselves.

**Robot Arm:** The 6 Degree of Freedom robot arm is partially built from aluminum and 3-D printed PETG materials. The arm sits on top of the center carriage of the X-Carve and holds the ultrasonic sensor to allow for manual control and the ability to integrate motor control in the future.

**Wrist Support:** The wrist support can rotate freely and can move along sliding bar, which allows it to move along a 2-D plane allowing for various elbow angles. The strap is also adjustable to allow for any wrist size.

**Elbow Support:** A cantilever beam design was adopted to prevent interference with the positional system. It was also made adjustable to accommodate different arm lengths.



## Positional Tracking Validation

After assembly of the mechanical subsystems, MATLAB software was developed and implemented using potentiometer voltage data and Arduino Uno's for data acquisition. The code was written to acquire voltage data to convert into each joint's measured displacement. After utilizing forward kinematics and transform matrices, the program live plots the location of the end effector while saving the data for later analysis.

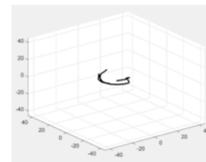


Fig. 3: XYZ Positional Data

## Next Steps

The immediate future of this project involves activating the motors already built into the system. They must also be automated to follow a predetermined path that an operator creates by moving the device by hand first and the sampling rate of the path data needs to be increased. The patient comfort must also be improved through replacing the red foam with better padding material like memory foam or a similarly comfortable material. Padding and support should also be added to other spots like under the shoulder as needed.

## References

- [1] Natroshvili, Tinatin, et al. "Results of Reoperation for Failed Ulnar Nerve Surgery at the Elbow: A Systematic Review and Meta-Analysis." *Journal of Neurosurgery*, vol. 130, no. 3, 2019, pp. 686–701., <https://doi.org/10.3171/2017.8.jns17927>.

## Acknowledgements

- Dr. David Schmidt, Associate Professor, University of Pittsburgh SSOE  
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Dr. John Whitefoot, Assistant Professor, University of Pittsburgh SSOE  
Dr. William Clark, Professor, University of Pittsburgh SSOE  
Ms. Heather Manns, MEMS Undergraduate Student Administrator, SSOE  
Ms. Kelly Wodnicki, MEMS Administrative Assistant, SSOE  
Mr. Andrew Holmes and Mr. Zolten Glasso, SSOE SCPI Machinists