Axolo METRICS

Dr. Andrew Rawicz
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Dear Dr. Rawicz,

Please find Axolo Metrics' ProsthetiSense Post-Mortem enclosed for our 440W capstone project. ProsthetiSense is a tool to be used by prosthetists that identify pressure points and shear forces within a prosthetic socket. ProsthetiSense ensures patients have the most comfortable fit to their prosthesis, and consequently avoids skin breakdown in the case of unwanted forces within the socket.

The enclosed document includes a collection of the finalized design and learning outcomes from the ProthetiSense project. It includes a final overview of the system design, a business case for the product, and the actual timeline for the project. In addition, it includes any encountered problems with the product or team and the tasks completed by each team member. In the appendices can be found some final team reflections and meeting slides from the development of the product.

Axolo Metrics is comprised of five hard working and knowledgeable fourth year engineering students: Daniel Dixon, Joshua Barrett, Kirill Shestakov, Tanner Frison, and Vijay Parameswaran. If you have any further questions, please do not hesitate to contact me by phone at 778-384-0335 or by email at drdixon@sfu.ca.

Sincerely,

Daniel Dixon
CEO Axolo Metrics

# ProsthetiSENSE

## Prosthetic Socket Pressure Sensor Array

Post-Mortem

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Chief Executive Officer

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Vice-President Technology

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**Revision** 1.0

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# EXECUTIVE SUMMARY

Prosthetic technology has been constantly evolving over the past many years, and modern prosthetics gives those amputees the ability to live life to the fullest. While amputees have access to very advanced prosthetics, if they don't fit perfectly to their body, they cannot take full advantage of their prosthesis. Improper fitting can lead to discomfort to the patient, and skin breakdown in some cases.

In response to this issue Axolo Metrics has developed ProsthetiSense. ProsthetiSense is a device to be used by prosthetists to help correct the distribution of forces inside of the prosthetic socket. A sensor array will be placed inside of the socket which will report the shape and normal forces of the limb to a microcontroller. This microcontroller will then send this data via bluetooth to a mobile application. This application will receive the data and turn it into a 3D pressure map. Using this pressure map the prosthetist can then determine what changes need to be made to the prosthesis.

An initial budget and timeline were set for this project. During development some deviations were made from these. The changes were primarily due to a change of scope which was incurred during the development. Rather than building a proof-of-concept with coverage over a small area of the socket the team opted to create a full scale product capable of reading all the forces acting within the prosthesis. This meant that more sensors and assembly time was required, resulting in deviations from budget and timeline.

In terms of business viability, ProsthetiSense is posed to be a success product. The existing competition is more expensive and offers less functionality than the current state of ProsthetiSense. In future manufactured iterations ProsthetiSense could easily take a majority hold in this market.

There were few technical and group problems during the development process. The technical problems were easily solved through proper use of documentation and increased labor hours. The group problems were usually due to a lack of communication but were solved swiftly internally.

Overall the initial development process of the ProsthetiSense system was a huge success. The product will be carried on through the partnership of BioInteractive Technologies and Barber Prosthetics.

# 1. Introduction and Background

Ensuring patients an optimal fit to their prosthetic socket is essential for their quality of life. If a prosthetic socket is improperly fit is can lead to skin breakdown and further amputation. Axolo Metrics has designed and implemented a proof of concept force sensor array system, ProsthetiSense. ProsthetiSense will be used by prosthetists to assist in the customization and fitting of prosthetic sockets for patients with lower-limb amputations. By generating a 3D pressure map, prosthetists will ensure their patient's socket fits perfectly, avoiding discomfort and skin breakdown.

# 2. System Overview

Utilizing a large array of sensors and microcontroller, ProsthetiSense will collect and transmit data wirelessly to a mobile application. A 3D model will be generated and updated in real time, to provide both the patient and prosthetist, a quantitative and visual map of high pressure areas inside the socket. A high level overview of the system is shown below in **figure 1.**

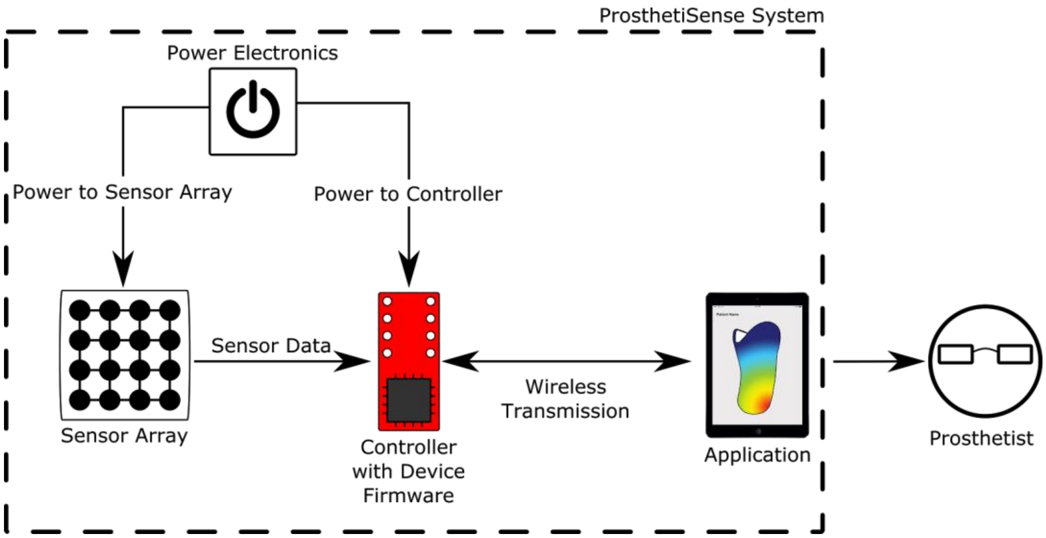



**Figure 1 –** A high level overview of the ProsthetiSense System

## 2.1 Sensor Array

The final sensor array uses a combination of 48 pressure sensors and 24 flex sensors arranged on two layers of cloth. The pressure sensors report the normal forces acting on them and the flex sensors report the current curvature of the array. The data collected by this sensor array is read by a microcontroller.

## 2.2 Microcontroller

The microcontroller has a very rudimentary but absolutely essential contribution to the ProsthetiSense system. It reads the FSR and flex analog data from the sensor array, encodes the data for transmission, and transmits the data over Bluetooth Low Energy. This component is battery operated for maximum portability and safety. The battery is rechargeable for convenience and sustainability. No calculations or extra processing is performed on the microcontroller itself, in an effort to increase transmission speed. Other methods, such as turning off the flex sensor reading and transmission, were also employed to increase data throughput to the iOS Application.

## 2.3 iOS Application

The iOS application has three main functions. The first is to connect to the microcontroller via Bluetooth Low Energy and decode the received data. This data is then passed on to the 3D model for further processing. The second main function is to hold the JavaScript 3D model that holds the core functionality of the app. And finally, the application must manage defaults, and save items to local files for non-volatile data storage (including settings and calibration data).

## 2.4 3D Modeling

Once sensor data becomes available to the iOS application, 3D modelling is performed using pressure and flex sensor data, where flex sensor data is interpreted to create a shape of the sensor array, while pressure sensor data is displayed in color. The iOS app performs 3D modelling by going through flex sensor readings one by one, obtaining their 3D coordinates, coloring them using the pressure sensor readings, and plotting those points on the main screen of the iOS app.

### 2.4.1 Other App Features

To get a clearer picture of 3D shape and pressure areas, the user can, intuitively, pinch to zoom in or zoom out, and touch to rotate. In the settings screen, the user can enable and disable the real time feature of the 3D shape, in order to avoid unneeded variations in the shape once the sensor array is already put in place. The app is capable of performing the shape calibration and saving it so that it does not have to be recalibrated at the next app startup. The users can also define their own pressure-to-color map, i.e. determine which pressure corresponds to which color. This feature is very useful for the prosthetists because the pressure will vary with every patient. The app also includes a few fail-safe mechanisms such as allowing user to restore their default settings in case calibration or color map have failed.

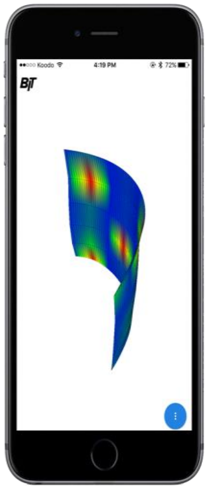


**Figure 2**- Main screen of the application

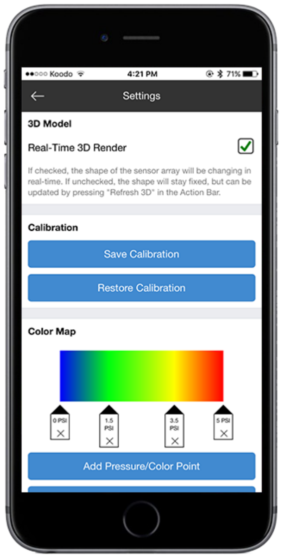



**Figure 3**- Settings screen of the application

# 3. Financials

The following table provides both the anticipated and actual costs of the ProsthetiSense project.

**Table 1-** A summary of the estimated and actual costs incurred for this project

| Item | Estimated Cost | Actual Cost |
|---|---|---|
| Genuino 101 Microcontroller | $50 | $94.71 |
| Bluetooth LE Transceiver | $40 | - |
| Liner Materials (Fabric) | $50 | $24.11 |
| Printed Circuit Board | $80 | - |
| Soldering Materials | $25 | - |
| Force Sensitive Resistors | $300 | $565.40 |
| Strain Gauges | $300 | $18.72 |
| Flex Sensors | - | $371.21 |
| Multiplexing Electronics | - | $15.97 |
| Power Supply Electronics | $30 | $61.37 |
| 20% Contingency | $175 | - |
| Apple Developer License | - | $133.28 |
| Cypress BLE Pioneer Development Board | - | $118.29 |
| Expedited Shipping/Handling + Duty Charges | - | $53.18 |
| Wiring + connectors | - | $22.70 |
| **Total** | **$1050** | **$1478.94** |

The total cost of the ProsthetiSense proof of concept is 41% more than anticipated. This is due to a variety of factors, namely the redundancy of some components, and volatile project plans.

Firstly in redundancy, we purchased two Genuino 101 boards for the sake of parallel development and in case one of the boards had issues. We also purchased a second development kit platform, the Cypress BLE board. This secondary board was purchased to mitigate problems if the Genuino was not powerful enough, however it was not used.

The changing scope and implementation strategy had the greatest effect on the ProsthetiSense budget. We initially planned to incorporate both FSRs and strain gauges for measuring forces. Further research and discussion led to the conclusion that only FSRs were required for useful force detection. The shear forces could be identified as the areas where the normal forces are changing in a repeated manner during a periodic dynamic movement. Thus, the final design included 48 FSRs and 24 flex sensors, while not incorporating strain gauges.

Due to Axolo Metrics' external funding, and customer need, it was deemed appropriate to increase the budget. The proof of concept would still be possible on the budget originally proposed, it just would have had a decreased resolution of sensors.

# 4. Business

While the product in its current state is not one which would be taken to market, a complete business plan can still be seen. The following table is a breakdown of the costs associated making a second model of the product prototype (ie: costs which would be repeatedly incurred).

**Table 2-** A breakdown of the costs required to build a second prototype

| **Item** | **Cost** |
|---|---|
| Genuino 101 Microcontroller | $47.36 |
| Fabric Materials + Electrical Tape | $8.76 |
| Sensors (Force & Flex) | $490.48 + $278.45 |
| Multiplexing Electronics | $8.13 |
| Power Supply Electronics | $48.66 |
| Wires and Connectors | $11.00 |
| **Total** | **$892.84** |

It can be seen that the total costs associated with creating a second product would be 892.84. Thus it would not be unreasonable to seek a market cost of $1,500 resulting in a 60% profit margin. While this product in its current state will not be taken to market, it is encouraging to note that it easily could for a fair price.

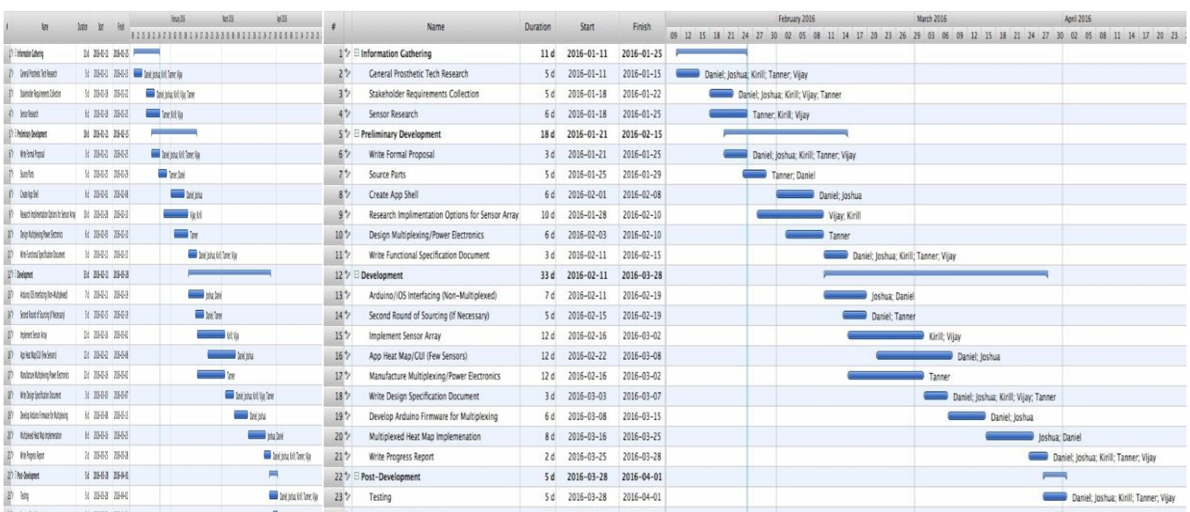
The market for lower-limb amputations is not a huge one. However, this product may have many additional applications. For instance, it is still helpful to prosthetists to gain information about the fit of sockets other than ones occurring on lower-limb amputations. The ability to create a shape and pressure map on the fly is one which many biomedical applications may find very useful.

In terms of competition, a system has been created by the company Pressure Guardian which has similar functions to ProsthetiSense. It uses four sensors, placed anywhere within the socket, and displays the forces acting on these locations in the form of a plot over time. In order for this information to be useful to a prosthetist they must gather this data over a variety of spots in the leg. Unfortunately, the Pressure Guardian system does not properly allow them to do this. In addition to this issue the price of the Pressure Guardian system has been estimated at $5,000, far more expensive than what the ProsthetiSense could be sold for.

All of these factors considered, moving forward the ProsthetiSense system has the ability to gain some market traction. Due to the low number of solutions available to prosthetists a large market penetration could be achieved.

# 5. Schedule

The following figure contains Axolo Metrics' proposed project schedule.



| # | Name | Duration | Start | Finish | Resources |
|---|---|---|---|---|---|
| 1 | **Information Gathering** | **11 d** | **2016-01-11** | **2016-01-25** | |
| 2 | General Prosthetic Tech Research | 5 d | 2016-01-11 | 2016-01-15 | Daniel; Joshua; Kirill; Tanner; Vijay |
| 3 | Stakeholder Requirements Collection | 5 d | 2016-01-18 | 2016-01-22 | Daniel; Joshua; Kirill; Vijay; Tanner |
| 4 | Sensor Research | 6 d | 2016-01-18 | 2016-01-25 | Tanner; Kirill; Vijay |
| 5 | **Preliminary Development** | **18 d** | **2016-01-21** | **2016-02-15** | |
| 6 | Write Formal Proposal | 3 d | 2016-01-21 | 2016-01-25 | Daniel; Joshua; Kirill; Tanner; Vijay |
| 7 | Source Parts | 5 d | 2016-01-25 | 2016-01-29 | Tanner; Daniel |
| 8 | Create App Shell | 6 d | 2016-02-01 | 2016-02-08 | Daniel; Joshua |
| 9 | Research Implimentation Options for Sensor Array | 10 d | 2016-01-28 | 2016-02-10 | Vijay; Kirill |
| 10 | Design Multiplexing/Power Electronics | 6 d | 2016-02-03 | 2016-02-10 | Tanner |
| 11 | Write Functional Specification Document | 3 d | 2016-02-11 | 2016-02-15 | Daniel; Joshua; Kirill; Tanner; Vijay |
| 12 | **Development** | **33 d** | **2016-02-11** | **2016-03-28** | |
| 13 | Arduino/iOS Interfacing (Non-Multiplexed) | 7 d | 2016-02-11 | 2016-02-19 | Joshua; Daniel |
| 14 | Second Round of Sourcing (If Necessary) | 5 d | 2016-02-15 | 2016-02-19 | Daniel; Tanner |
| 15 | Implement Sensor Array | 12 d | 2016-02-16 | 2016-03-02 | Kirill; Vijay |
| 16 | App Heat Map/GUI (Few Sensors) | 12 d | 2016-02-22 | 2016-03-08 | Daniel; Joshua |
| 17 | Manufacture Multiplexing/Power Electronics | 12 d | 2016-02-16 | 2016-03-02 | Tanner |
| 18 | Write Design Specification Document | 3 d | 2016-03-03 | 2016-03-07 | Daniel; Joshua; Kirill; Vijay; Tanner |
| 19 | Develop Arduino Firmware for Multiplexing | 6 d | 2016-03-08 | 2016-03-15 | Daniel; Joshua |
| 20 | Multiplexed Heat Map Implemenation | 8 d | 2016-03-16 | 2016-03-25 | Joshua; Daniel |
| 21 | Write Progress Report | 2 d | 2016-03-25 | 2016-03-28 | Daniel; Joshua; Kirill; Tanner; Vijay |
| 22 | **Post-Development** | **5 d** | **2016-03-28** | **2016-04-01** | |
| 23 | Testing | 5 d | 2016-03-28 | 2016-04-01 | Daniel; Joshua; Kirill; Tanner; Vijay |
| 24 | Prepare Final Presentation | 3 d | 2016-03-30 | 2016-04-01 | Daniel; Joshua; Kirill; Tanner; Vijay |

**Figure 4** - The projected schedule for the ProsthetiSense project

The Information Gathering and Preliminary Development stages were completed on schedule, as proposed at the beginning of the ProsthetiSense project. However, our progress did deviate from the schedule in the Development phase. The direction of the project had changed after the original proposal.

In software development, a strong effort was put into the 3D modelling of the socket, which Axolo Metrics had not originally anticipated. However, the firmware code and application shell were completed faster than anticipated. This allowed Axolo Metrics to shift resources when needed, and assured work was constantly being done with all members of the team.

In hardware development, the multiplexing electronics manufacturing did fall slightly behind schedule, but was offset by the early completion of a small scale functional prototype. While the actual manufacturing of the full sized proof of concept was extremely time consuming, all team members assisted to complete the sensor array on time.

# 6. Problems and Challenges

One issue encountered by the Axolo Metrics team was in accurately reading sensor values. Testing of the sensors found that when multiple sensors were powered by one multiplexer pin, a change in one sensor reading would affect the readings of the other sensors powered by the same pin. Initially, this issue was thought to be cross-talk, where the sensors were unintentionally affecting one another. However, through closer inspection, this issue was found to be caused by a finite series resistance at the output of the multiplexer. As sensors were activated, they would draw more current, which would cause the voltage powering the sensors to decrease, affecting the value read by the microcontroller. Various corrections were considered, including the use of voltage regulators and alternative multiplexer configurations. Testing of the multiplexer revealed that it was possible to calculate this voltage decrease, and a solution to this issue was implemented in software. Testing the setup with this correction eliminated the affected readings and allowed us to accurately read sensor data.

Ensuring enough data throughput over Bluetooth Low Energy was a challenge. BLE is designed for very small amounts of data, but ProsthetiSense requires sending 72 analog sensor readings several times a second. By designing an encode/decode method, we are able to send 10 sensors per BLE transmission, allowing greatly improved speed nearing real time.

After conducting a clinical trial at Barber Prosthetics, it was discovered that the pressures in the socket were much greater than anticipated. As a result, the FSRs in some high pressure regions of the socket became saturated, leading to a loss of precision in the pressure map. Theoretically the issue is easily resolvable by replacing the current FSRs with those of higher pressure tolerance, which are currently available off the shelf. However, taking time and cost into consideration, Axolo Metrics decided against replacing all 48 FSRs for the initial proof of concept. All further iterations will include the appropriately rated FSRs.

# 7. Group Dynamics

The team was initially organized into individual roles. Daniel as Chief Executive Officer, Tanner as Vice President (VP) of Electronics, Vijay as VP of Hardware, Joshua as VP of Software, and Kirill as VP of Technology. These roles reflected what the member's experiences were coming into the project.

Because the roles were assigned so close to the beginning of the project they did not all accurate reflect the actual tasks that each member undertook. For a detailed breakdown of the responsibilities and tasks please see the chart below. A brief summary is the Daniel worked on the iOS app, Tanner worked on electronics, Vijay worked on sensor array design, Joshua worked on firmware, and Kirill worked on 3D modelling. The most laborious task ended up being the construction of the sensor array and so all members worked on this.

The team was very cooperative and brought skills to the table which were all complimentary, as a result there were few problems. Some members did not get the opportunity to undertake the tasks that they wanted to. To solve this, the members who were working on these tasks took some of their spare time to explain what they were doing to other members. Any other problems usually arose out of frustration of being in the labs for too long. But these didn't last and overall it was a civil team atmosphere.

# 8. Workload Distribution Chart

The following table (table 3) describes the workload that each member of our team contributed to a given portion of the project. In the chart, "xx" indicates primary responsibility, and "x" indicates some responsibility.

Table 3- A breakdown of the workoad distribution among group members

| High-Level Task | Tanner Frison | Vijay Parameswaran | Joshua Barrett | Kirill Shestakov | Daniel Dixon |
|---|---|---|---|---|---|
| Design Sensor Array | x | xx | | x | |
| Construct Sensor Array | xx | x | x | | x |
| Design Multiplexing Circuit | xx | x | | x | |
| Parts Sourcing | xx | x | | | |
| Manufacture Multiplexing Shield | xx | x | | | |
| Implement Battery Power Electronics | xx | | x | | |
| Characterize Sensors | | xx | | x | |
| Create Calibration Technique | | x | x | x | |
| Design Firmware | | x | x | | xx |
| Design/Implement BLE | | | | | xx |
| Create iOS Shell Application | | | | | xx |
| Create User Interface | | | | xx | |
| Generate 3D Model | | | | xx | |
| Implement Interactive Calibration | | | | xx | |
| Create Device Enclosure | x | x | xx | | |
| Module and System Testing | x | x | x | x | X |
| Documentation | x | xx | x | x | X |
| Administrative Tasks | x | x | | | X |

# 9. Conclusion

Axolo Metrics has produced a functionally sound proof-of-concept device in ProsthetiSense. The team has been successful in delivering a product which is capable of displaying the forces acting on an amputee's limb in an intuitive manner. A functioning sensor array, microcontroller, and iOS application have been created to accomplish this goal.

The sensors are capable of measuring normal forces acting on the residual limb. In addition, they can measure the curvature of the leg in order to produce an accurate 3D model. This force and curvature data is sent by a microcontroller via BLE to an iOS application. Upon receiving the data, the application can construct a real time 3D model which displays forces acting on the limb in a heat map. Upon comparison to the test plan it may be concluded that this final iteration is a success.

Looking towards the future, ProsthetiSense may be carried on by the partnership of BioInteractive Technologies with Barber Prosthetics. It will be taken through to a more practical model for use by the prosthetists at Barber. Furthermore, it may be taken through more final stages of development by this partnership, though its final fate is still uncertain. The involvement of the team at Axolo Metrics is unlikely in the near future as they are in pursuit of alternate individual professional goals. A return to the project at some point may be a possibility for some team members.

# Appendix I – Individual Reflections

## Daniel Dixon

Working with my team over the past four months has been an extremely rewarding experience. Being part of a project from its inception to the final proof of concept has been a great for me to grow professionally as an engineer, but also furthered my interpersonal and leadership skills. I will take away the invaluable experience I've had here and will be able to apply it when I graduate and begin life in the workforce.

Working for a customer, in our case Barber Prosthetics, our team had the experience of gathering information from the customer and ensuring their needs were met. Requirements engineering was something I had only learned about before in class, but we now had the opportunity to apply what we learned to an actual client. Deciphering what the customer needed, creating and prioritizing goals, and staying in communication with the customer was a unique experience that we were lucky to have in an academic setting.

While we had all assumed roles within Axolo Metrics (mine being CEO), the titles seemed to mean less as time went on. Everyone was contributing, but the roles weren't heavily defined. When one part of the project struggled, others would come and help that person out. Our chosen communication tool, Slack, was a great way for us to be updated on all aspects of the project. Conversations could be separated by subject (ie. Firmware, Hardware, Software, etc.) and this added another level of organization, while still maintaining transparency between the components. I attribute the cohesiveness of our team to our previous friendship. We have known each other for almost the duration of our undergraduate careers, and were well aware of other's strengths and weaknesses.

On a technical aspect, I got to work with new technologies I haven't had the opportunity to work with before. The technology I immersed myself most in was Bluetooth Low Energy (BLE). Using the Genuino 101 as a BLE peripheral, and an iOS device as a BLE central, I was able to both receive raw sensor data at optimized speeds, and write status bits to the Genuino device itself. I was able to apply what I learned at my previous co-op in firmware design to optimize the Genuino code, and my CMPT 275 experience to create the iOS application. Being able to harness these past experiences helped accelerate development, and I was able to contribute to the project in a meaningful way.

Overall, this project has been a positive experience for me. The hours were often long, but the in my opinion, the work has paid off. We have a proof of concept that may be able to help the quality of life of those who rely on prosthetics. Being part of a biomedical technology advancement that can impact patients directly gives me immense satisfaction. I want to thank all of the members of my team, and Lukas at BioInteractive Technologies for being supportive of this project.

## Vijay Parameswaran

This capstone project has been an interesting experience. It showed me what it was like working in a small, tight-knit team to develop a product in a short period time. The knowledge I gained from this project will surely be of use in future endeavours.

This project was a unique experience in that we, Axolo Metrics, had not only a project, but also a client, Barber Prosthetics, who was interested in the results of our project. This added another layer of challenge to the project, as we not only had to meet the requirements of the ENSC 440W/305W class, but also the needs of the client. Along with this challenge, however, came invaluable experience in communicating with clients and an added motivation to do well on this project.

My role within this project mainly revolved around modelling and characterising the sensors, designing and constructing the sensor array, and writing the documentation. My previous co-op as a documentation specialist helped me write and format the project documentation in a clear manner. On the technical aspect, my work with sensors allowed me to apply my existing knowledge of electric circuits and testing to this project, and I also developed new methods and techniques for testing and developing sensors. My work on constructing the sensor array allowed taught me about what considerations that had to be made when constructing any device. For example, in the sensor array, each column is powered by one power line with 8 taps instead of 8 individual power lines, which saved space and made it easier to wire the sensors. While in the future, it will be rare that I will be working with cloth and FSRs, the same considerations about space, positioning, and convenience still apply to real PCBs and circuits. I also got to help write some of the firmware code. This exposed me to programming with Bluetooth Low Energy, which is something I had no prior experience in.

Our group worked and developed the product to a further extent than we originally predicted, which is something I am extremely proud of. We had originally forecasted that the 3D modeling would not be implemented in the application for the proof of concept. However, we not only implemented a functional, near real-time 3D modeling system, we also managed to implement it in a fully functional app. This is in no small part due to our group dynamics. Each one of us have known each other for long before this capstone project, and as a result, we knew each other's strengths and weaknesses well. We were able to assign our roles and distribute our work accordingly.

I am overall happy with the work that was done at Axolo Metrics. I am not only pleased with the quality of our work, but also with the fact that our product was so well received at Barber prosthetics. Seeing that reaction means that all our late nights and hard work were worth the effort. For this opportunity, I would first like to thank my team at Axolo metrics. I would also like to thank BioInteractive Technologies and the team at Barber Prosthetics for supporting this project.

# Joshua Barrett

In this capstone project I was given an opportunity to learn and grow as an engineer like nothing else in my undergraduate studies. This was a unique and safe environment to practice my technical, written, and communication abilities while working with a team of extraordinary gentlemen. There was plenty of opportunity for me to contribute to and learn from this team.

In terms of contribution, I was the Vice President of Software. This title came because of my computer engineering background and experience working in the software industry. However, despite the title I fell into a more jack-of-all-trades roll. My software specialities have more to do with database development, which was not required in this iteration of the product. Instead, I worked on the first iteration of the firmware to make it organize data more efficiently and send it to the app. Also in the early stages of the product, I was involved with creating the methods for calibrating the flex sensors. During later stages of development the software became less of a concern and my focus shifted to assisting with the creation of the sensor array itself. I ended up focussing on the placement of the sensors onto the cloth sheet as well as preparing wires and sensors for soldering. Towards the end of the project I took the lead on finalizing a device enclosure. Finally, I attempted to create an android application in addition to the one on the iOS platform. Unfortunately the application didn't make it to a place where it could be presented alongside its iOS counterpart, but it was a good learning experience. In addition to all these tasks I participated in writing much of the content for the documentation aspect of the course.

This project has been a huge learning experience for me. I gained much technical experience as well as having the opportunity to grow my communication skills. The most valuable technical experience gained was primarily the work I did with the hardware aspects of the project. This is a task that I potentially will not have the opportunity do in the future given my computer engineering background. As a result this hardware experience was very valuable to me. Actually having the chance to write long technical documentation was not one that I have had before and so this too was very helpful.

All this considered, my experience with working in a small team will likely prove to be the most helpful aspect of this course moving forward. I have not had the opportunity to work in a team which has such diverse backgrounds. It was a very rewarding challenge to figure out where our talents fit together, who should take the lead on what, and where we needed to step out of our comfort zones. The importance of communication really presented itself during this project. A vast majority of issues that we had with the project could have been avoided by more consistent communication.

The final aspect of this project which gave me valuable experience was the partnership with Barber Prosthetics and BioInteractive Technologies. The chance to act as a 'contracting' company to these partners gave me insights into the business world which I could not have gained elsewhere in my undergrad.

Overall, this course and project will be what comes to mind when I recount my time at SFU. The knowledge and experience gained will stick with me for many days to come.

# Tanner Frison

This capstone project will surely be remembered as the most iconic course of my undergraduate engineering degree here at Simon Fraser University. The opportunity to apply the conglomeration of knowledge that I have come across in the past 4 years towards a practical project in a startup like environment is one that will be invaluable to my future as an engineer. Many before have said that Capstone is the true test to whether the student has what it takes to be a true engineer. I believe this notion is spot on as this course was equally as challenging physically and mentally as it was rewarding.

I was able to apply the previous experience that I gained in my co-op with MENRVA labs at sfu working with FSR sensor technology and really enhance it to another level. Executing tasks such as characterizing the sensors and obtaining corresponding pressure data in tangible units like PSI was really eye-opening to the endless possibilities of engineering. Previous experience using the 16 channel Multiplexer was very useful in terms of brainstorming potential configurations for reading large amounts of sensors. One of my most significant accomplishments was fully understanding the reasoning behind the "cross-talk" like effects between sensors in the same power branch. Through diligent circuit analysis I determined problem is inherent to the design and is not actually true cross talk between the sensors. After I sifted through the multiplexer chip datasheet and performed many measurements, I identified the precise source of error, understood and characterized it, and with the help of my firmware wizard teammates, mitigated the problem with a tremendous software solution. This was an invaluable experience of pushing our chosen technology to operate as close to ideally as possible.

Working on this fast-paced project in a small team really emphasized the need for clear effective communication. Receiving feedback from my teammates on my hardware designs was extremely helpful to merge our visions for the product. Further, this was essential to make sure that my refined designs would be able to seamlessly mesh with the software and firmware development. Our team utilized slack, a messaging application for teams to keep our communications organized into different channels for documentation, hardware, software, sensors etc. This app was extremely beneficial in terms of bringing progress updates to the light of other team members and making it possible to organize progress reports for our weekly meetings with Lukas from BioInteractive Technologies.

It was really transformative to execute the full circle design of taking a real problem, learning about it and gaining insight from the prosthetists, and then designing a product. Even more, designing a product to work towards meeting their specifications and proving that the product concept is truly viable. Furthermore, having that external pressure to perform because our funders expectations needed to be met and where possible, exceeded, was invaluable experience to gain before graduating. After over 24 personal man hours of soldering wiring to sensors and to connectors on our controller, it was extremely rewarding to see the array work properly when used in a real patient trial at Barber prosthetics. Contributing to biomedical technology advancement really gave me great satisfaction once I saw our product in action. I want to thank all of the members of my team for their attention to detail and tremendous efforts throughout the semester, and also Lukas from BioInteractive Technologies for his guidance and support along the way.

I think it is very important that we experienced and learned the importance of engineering specialization in a team environment. The advantages of having a well-rounded team are endless as it is amazing to see how experience and knowledge from different areas can come together to create a comprehensive product. Throughout the semester my teammates and I were able feed off each other strengths and compensate for each other weaknesses. Although there were natural bumps along the way before settling in, we eventually became a well-oiled engineering design machine with each member being a vital cog in the operation. I was often blown away by the work that my teammates did and hence I am very proud to be a part of this team of brilliant engineers.

## Kirill Shestakov

Working in a small team for this capstone project was a very educational experience, both in terms of technical and soft skills I've learned.

I've learned that the group dynamics is very significant to the overall quality of work and the satisfaction of the group members. When there is even one person, who was given a lot of responsibilities, yet is not performing as much work as needed, it can be stalling for the entire group. Other group members might feel discouraged to work because of that, and the project's outcome can suffer. It can be especially difficult to express the concerns on the group dynamics if the group members are your friends. In such case, what seemed to work was having enough will to start working independently, obtain the results, and show them to the entire group so as to encourage them by serving as an example of successful work.

Another soft skill was the ability to handle disagreements. It was surprising to learn that disagreements can arise over all sorts of seemingly unintelligible reasons and follow you for a while. However, the reason for those disagreement makes total sense from the point of view of the disagreeing party. In order to resolve the conflict, it is, firstly, important to understand the other side of the argument, and acknowledge if it has valid points. Consensus should be found when possible, and when not, the argument should be resolved with an appropriate and non-coercive reasoning.

I’ve learned how to be an encouraging part of the team, and how to use humour to foster a positive working spirit among the team members. I’ve learned how to trust your group members to do their part, and avoid being too controlling in terms of the overall work on the project.

I've also learned many technical skills. Working with Git, a service for a team work on a software project, is crucial for many software jobs. Performing 3D modelling in a modern, responsive and cross-browser way is definitely the most important technical skill that I've learned in this capstone project. This skill looks very good on a resume, and is likely to attract many employees. I've learned a multiplexing technique in hardware, and was happy to make a small but important contribution to the firmware.

I've learned that I can work the best when I do a big chunk of work non-stop, without breaks. Breaks can often be distracting, while work requires a lot of concentration. I've also improved my brainstorming skills, ability to weigh the solutions and discuss them with friends. Problem solving skills were among the most important technical skills I’ve improved.

Overall, my experience with this capstone project covered all important areas of development such as hardware, firmware and, more than others, software. It was a very useful and educational experience that will definitely help me to be a better engineer with much better qualifications.

# ProsthetiSENSE

## Prosthetic Socket Pressure Sensor Array

List of Meeting Agendas and Meeting Minutes

**Daniel Dixon**
Chief Executive Officer

**Kirill Shestakov**
Vice-President Technology

**Joshua Barrett**
Vice-President Software

**Tanner Frison**
Vice-President Electronics

Vice-President Hardware

**Contact:** Daniel Dixon
drdixon@sfu.ca

**Submitted to:** Dr. Andrew Rawicz – ENSC 440W

Mr. Steve Whitmore – ENSC 305W

School of Engineering Science
Simon Fraser University

**Issue Date:** 12th April, 2016

**Revision** 1.0

5th January, 2016
Meeting Notes
All Team Members Present

We will be working with a socket for above/below knee amputees (we have a model).

- The prosthetic leg is attached to this socket.
- The issue: *the fit is not always perfect. They need the socket to fit comfortably.*
- The method they use right now is a sort of "trial and error." They will place the socket, analyse the patient's movements/ask how it feels, and then will perform adjustments.
- This is not only a slow, and maybe inaccurate process, but it is cumbersome and painful on the amputee as well.

What we will try to do is find a way to measure the pressure in the socket when it is being fitted, so that the prosthetic fitters can easily find where there is a lot of pressure, and make the fitting more comfortable.

There are some companies/products which do this already:

- Tekscan's F-Scan system (https://www.tekscan.com/products-solutions/systems/f-scan-system)
    - We'd need to research more into this. Are there others like this?
    - They use force sensitive resistors. However, they have to move them each time. This is better, but still cumbersome.

We need to make it more comfortable and easy to measure.

We can start by looking into existing arrays of pressure sensitive resistors/sensors. There is something called *Carbon Black (? This is what I remember hearing, is this what it is called Tanner?)*

- Lukas said we can get these arrays from Digi-Key/Adafruit/Sparkfun. Tanner should know more.

Requirements (This is a very preliminary and probably incomplete list, just what we got from today's meeting)

- We need to measure normal and shear forces on the socket with the sensors. Can we measure both at the same time? Or maybe we can only do one at a time.
- We should be able to give a 3D map of the pressure in the socket.
- We should be able to wirelessly transmit the pressure data to an application (most likely running on a tablet or phone).
    - We could implement a function where we take 'snapshots', so we can show the pressure at different points of the gait.
- We should also be able to calibrate the sensor pad.

Research and other things to do:

- We need to research information about lower limb amputees. What are the causes of amputations? About how many are there in Canada?
- Lukas mentioned that many amputees are diabetic, as diabetes causes them to lose sensation in their limbs. As a result of this, they might not notice when skin dies, gets infected, etc. resulting in more amputations or other complications. We need to find out what sort of challenges amputees, diabetic or not, face when it comes to fitting their prosthesis.
    - When a prosthesis needs to be fitted, currently fitters ask the amputee for feedback. In these cases where the amputee doesn't have sensation, they won't be able to give accurate feedback. How does the fitter know if the fit is good then? It's pretty much a guess.
        - We need to find out what sort of challenges the prosthesis *fitters* face when determining a good fit.
- We need to find out what sort of parts we could possibly use. Lukas suggested *strain gauges*, so we could have a stretchable fabric.
- We need to figure out the physics and dynamics of shear, strain and normal forces and how to measure them. How would they apply in this system?
- We need to consider what sort of wireless transmission we will use.
- The primary R&D part will come under this.
- We also need to develop the application that will display all this information.

FUNDING:
The company can provide funding, but we will need to provide a budget, of course. As part of our project proposal that's probably due at the end of January, we have to provide a budget. However, Lukas encourages us to go through the official channels for funding, so we get practice pitching our concept. A lot of the research above is relevant to these pitches as well.

We can get the cheques and company could potentially recompense them to the original donors *(is this what he said?)*.

MEETING MINUTES-- Friday 15th January, 2016

All Team Members Present:

Josh Barrett

Dan Dixon

Tanner Frison

Kirill Shestakov

Vijay Parameswaran

//----------------------//

Product Breakdown:

The Product will be broken down as follows:

Hardware

- Sensor Array
    - Normal Force Sensors
    - Shear (Parallel) Force Sensors
        - we need to figure out what sorts of parts we can use for these (strain gauge? do we have to make our own?)
- Microcontroller
    - Possible Controllers
        - ESP 8266
        - Arduino
    - Sensor Array Connection to controller
    - How to send the data from controller to computer
        - Will we use Wifi or Bluetooth?
            - Probably bluetooth
    - Use multiplexing for detecting multiple sensors?
- Powering the system and power consumption.

Firmware

- Microcontroller
    - Sensor Array Connection to controller

- How to send the data from controller to software
    - Will we use Wifi or Bluetooth?
        - Probably bluetooth
- Use multiplexing for detecting multiple sensors?
    - Will this multiplexing be a critical path?

Software

- Platform:
    - Android
    - iOS
    - MATLAB
- Software Functionality:
    - Display a real-time pressure map
        - 2D or 3D. (Probably 2D, 3D is not very feasable)
    - Store pressure maps at different times.

- Sensor calibration

Current Issues/Notes:

- US DOD is making a Sandia prosthetic socket that works similar to this but is made of a separate material that performs the detection (Source?)

- TekScan Fsocket seems to only put a 2D map. Does it only measure pressure in a socket?

APP:

- Dan believes that the app constiutes a completely separate app.
    - Everyone in agreement
    - We will demonstrate potential for app
    - But we will only work on the App if we have time, we will focus on image reconstruction in MATLAB.

- Josh Idea:
    - Create a reference point on the plaster cast of the leg and the sensor array sheet. These two will line up and can be used to figure out which sensor corresponds to which part of the body.

ACTION ITEMS:

1) Soft Copy ESSEF Proposal

2) Hard Copy ESSEF Proposal

3) Presentation for ESSEF Proposal

    3.1) Requires a rough estimate of part costs. <- Tanner

    3.2) Interfacing for sensors to host estimate <- Josh

4) Figure out how to measure shear forces <- Kirill and Vijay

5) Arrange a meeting with Barber Prosthetics <- Tanner

# AXOLO METRICS PROSTHETISENSE PROJECT

CAPSTONE MEETING OUTLINE

FEB 11TH, 2016

# MEETING ATTENDANCE

All members present

# UPDATES

- 2x Arduino 101 microcontrollers have arrived
- Robotshop order of 20x FSR / 5x Flex sensors have arrived
- Preliminary testing of the Flex sensors has been done

# OBSTACLES

- Will soon need a pressure threshold from Barber to determine what constitutes a “high pressure area”
- We have just received the Arduino 101’s and have not yet determined whether or not they will be suitable for our project
  - New product may be poorly supported and could have technical bugs
  - Alternative microcontroller/Bluetooth solution should be identified

# ACTION ITEMS

- Further testing and characterization of flex sensors will be done today
- Testing the signal integrity preservation of conductive thread with our FSRs
- Construct a simulation of the diode toggling config for reading sensors
- Complete draft of Functional Specification by Friday afternoon

# AXOLO METRICS PROSTHETISENSE PROJECT

CAPSTONE MEETING OUTLINE

FEB 17TH , 2016

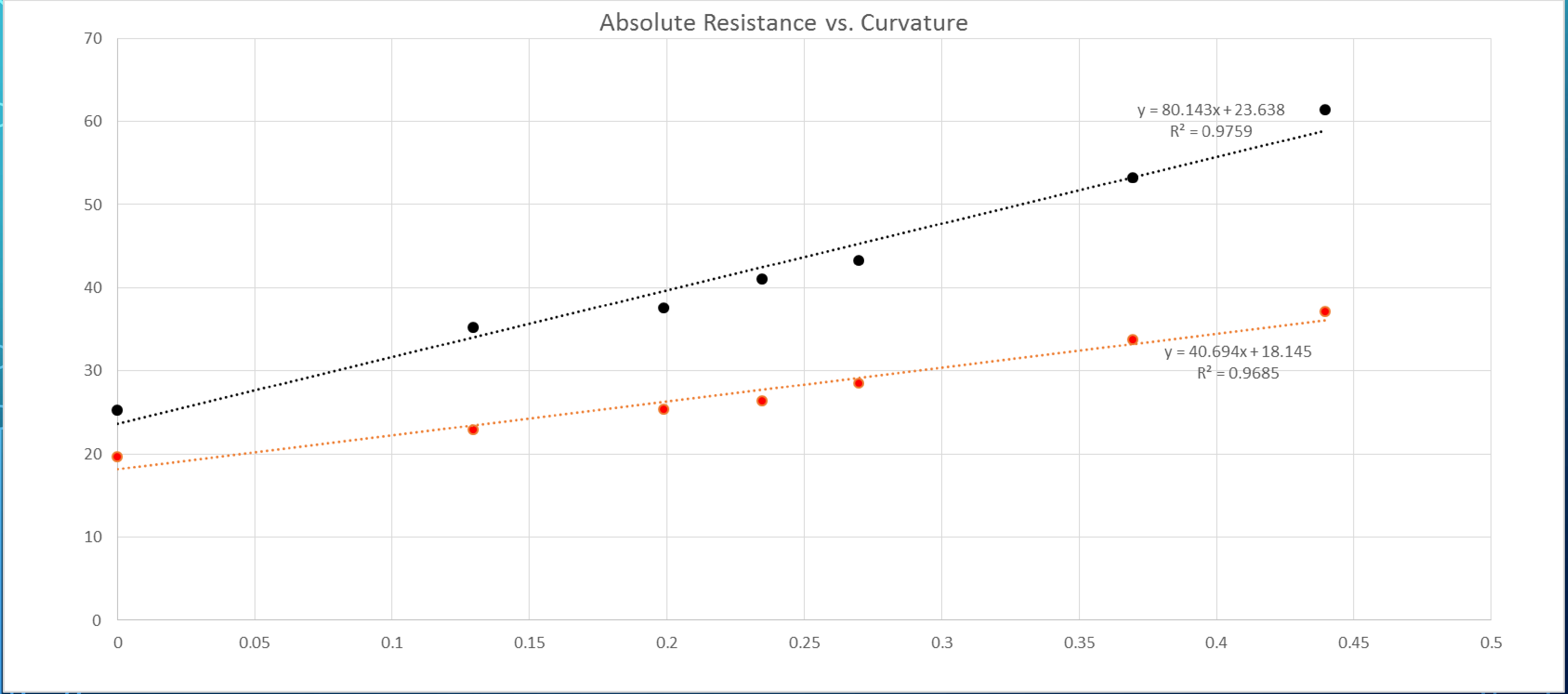
# MEETING ATTENDANCE

All members present

# UPDATES

- Beginning to work with Bluetooth LE (via Genuino 101)
  - Connection with phone established
- Conductive thread tests deemed the thread not appropriate for carrying Analog signals from FSRs
- We are reasonably confident that the flex sensors act linearily
- One flex sensors damaged post heat-shrinking. Need to be extra careful in the future if heat-shrink will remain the primary method of insulation for sensor leads
- Tested 4 FSRs with the MUX in a shared node analog reading configuration
  - Sensors did not affect each other

# UPDATES – FLEX SENSOR CHARACTERISTICS



# CONCERNS

- Worried that the Bluetooth LE may not have enough throughput for real time
  - Should be okay for static
- Lack of resources for the Bluetooth module on the Genuino 101
  - Suppose this is due to its integration in the Intel Curie Chip
  - May need to consult another team (Richard's) for tips on using the BLE to its full potential
- *Midterms*

# ACTION ITEMS

- Begin to send analog sensor data to custom application and display values (non-multiplexed)
- Create static pressure map with dummy data
- Buy supplies such as wire, heatshrink, flux pen and other essential materials from Digi-Key in the next few weeks
- Create schematic drawings of the system
  - Backup schematics using different microcontroller/Bluetooth setups

# AXOLO METRICS PROSTHETISENSE PROJECT

CAPSTONE MEETING OUTLINE

FEB 26TH , 2016

# MEETING ATTENDANCE

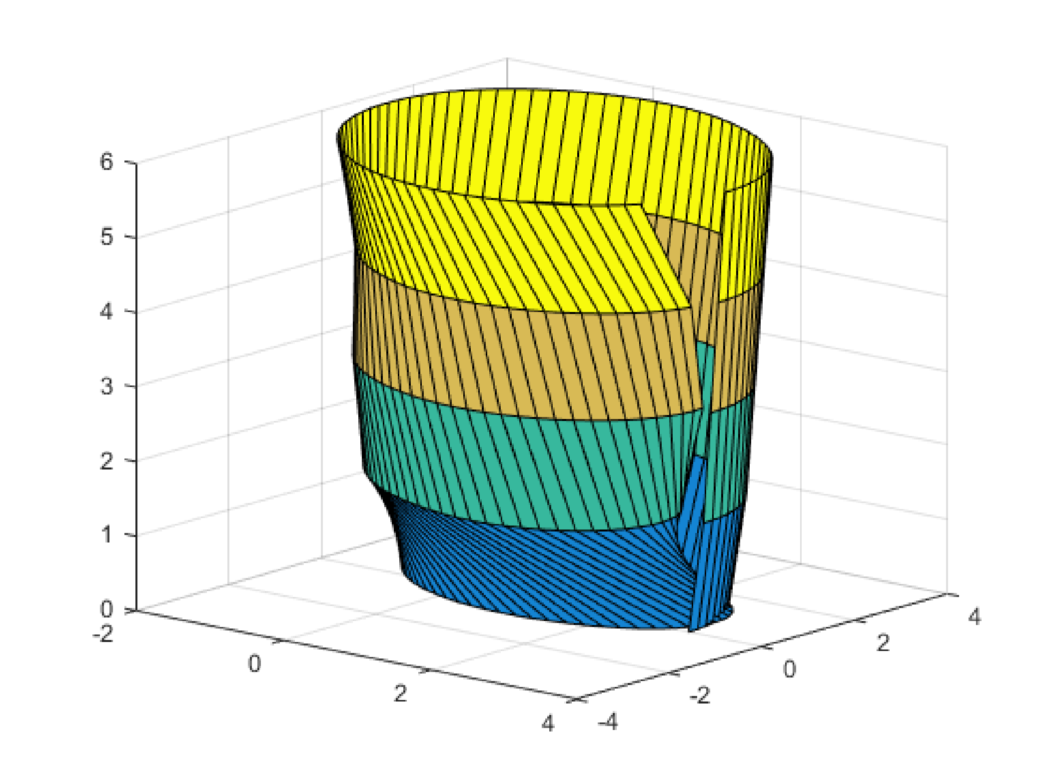
All members present

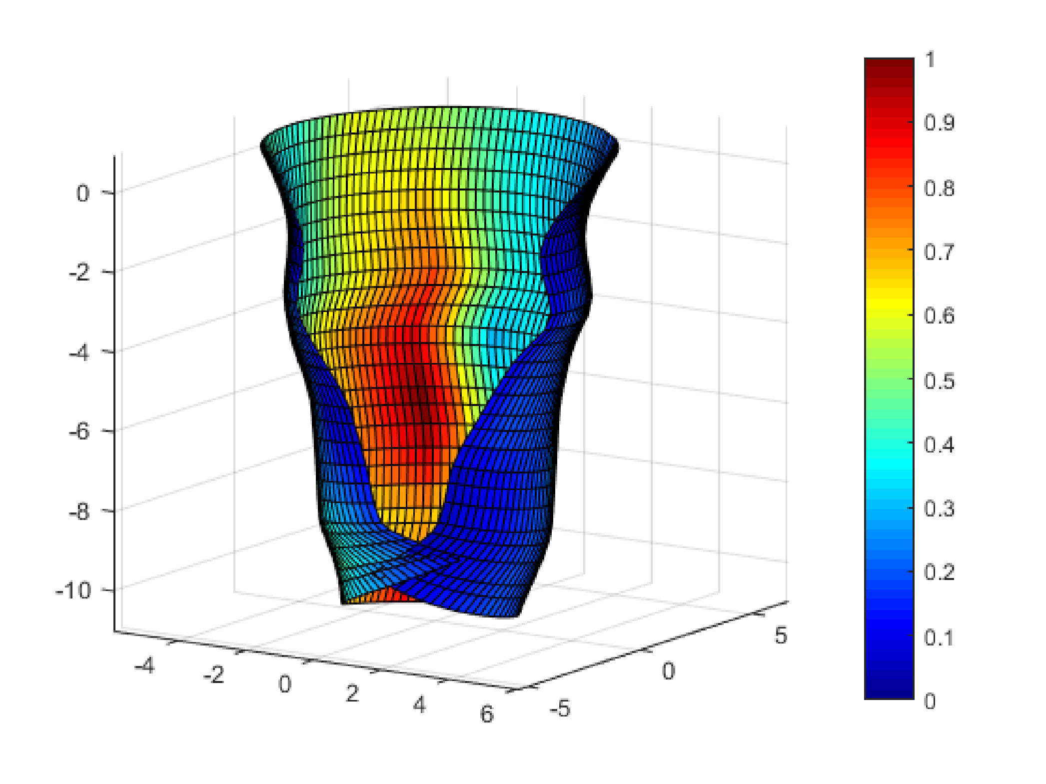
# UPDATES

- Ordered CY8CKIT-042-BLE Bluetooth® Low Energy (BLE) Pioneer Kit
- Now have multiple characteristics and services over BLE with Genuino 101
  - Confident in sending multiple and distinguishable sensor readings over BLE
- Genuino code written to calibrate and retrieve readings from Flex Sensors
- Created an algorithm for 3D modelling in Matlab given the curvature and pressure data
- Contacted Spectra Symbol, they did not provide any additional information

# 3D MODELLING PROGRESS

Using dummy data for both FSRs and Flex Sensors



# CONCERNS

- Although we are now able to send multiple pieces of data over BLE, throughput is still a concern
- Ability to develop on two platforms at once (Genuino 101/Cypress)

# ACTION ITEMS

- Begin to send real analog sensor data to custom application and display values (iOS Application)
  - Integrate FSR reading code with BLE code
- Create static pressure map with dummy data
- Create schematic drawings of the system
  - Backup schematics using different microcontroller/Bluetooth setups
- Map out number and configuration of sensors required for proof of concept
  - Order more flex sensors and FSRs from Robot Shop as necessary
- Work on Design Specification

# AXOLO METRICS PROSTHETISENSE PROJECT

CAPSTONE MEETING OUTLINE

APR $7^{TH}$, 2016

# MEETING ATTENDANCE

All members present

# FIRMWARE

- UPDATES
  - No New Updates
- CONCERNS
- ACTION ITEMS

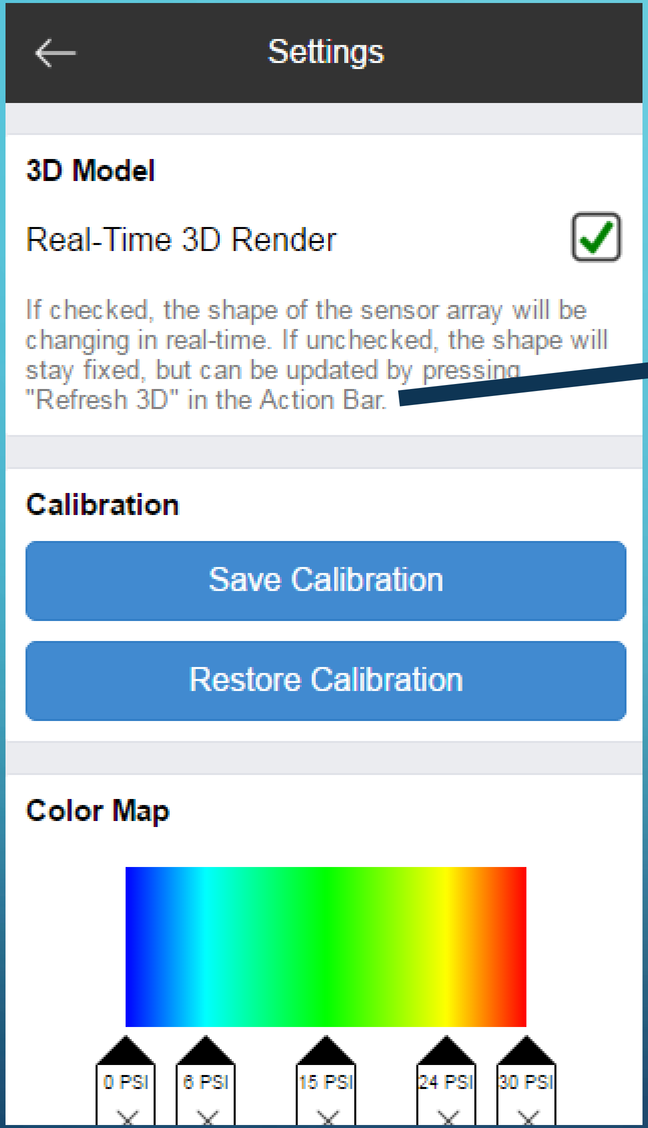
# SOFTWARE

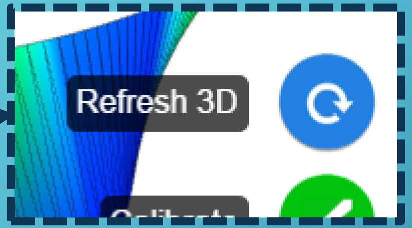
- UPDATES
  - Added support for “Refresh 3D”
    - Allows users in non-real time mode to update the 3D model with new flex sensor data
  - Added information banners to relay to user BLE connection status
  - Removed old code/refactored
- ACTION ITEMS
  - Testing

# 3D MODELLING

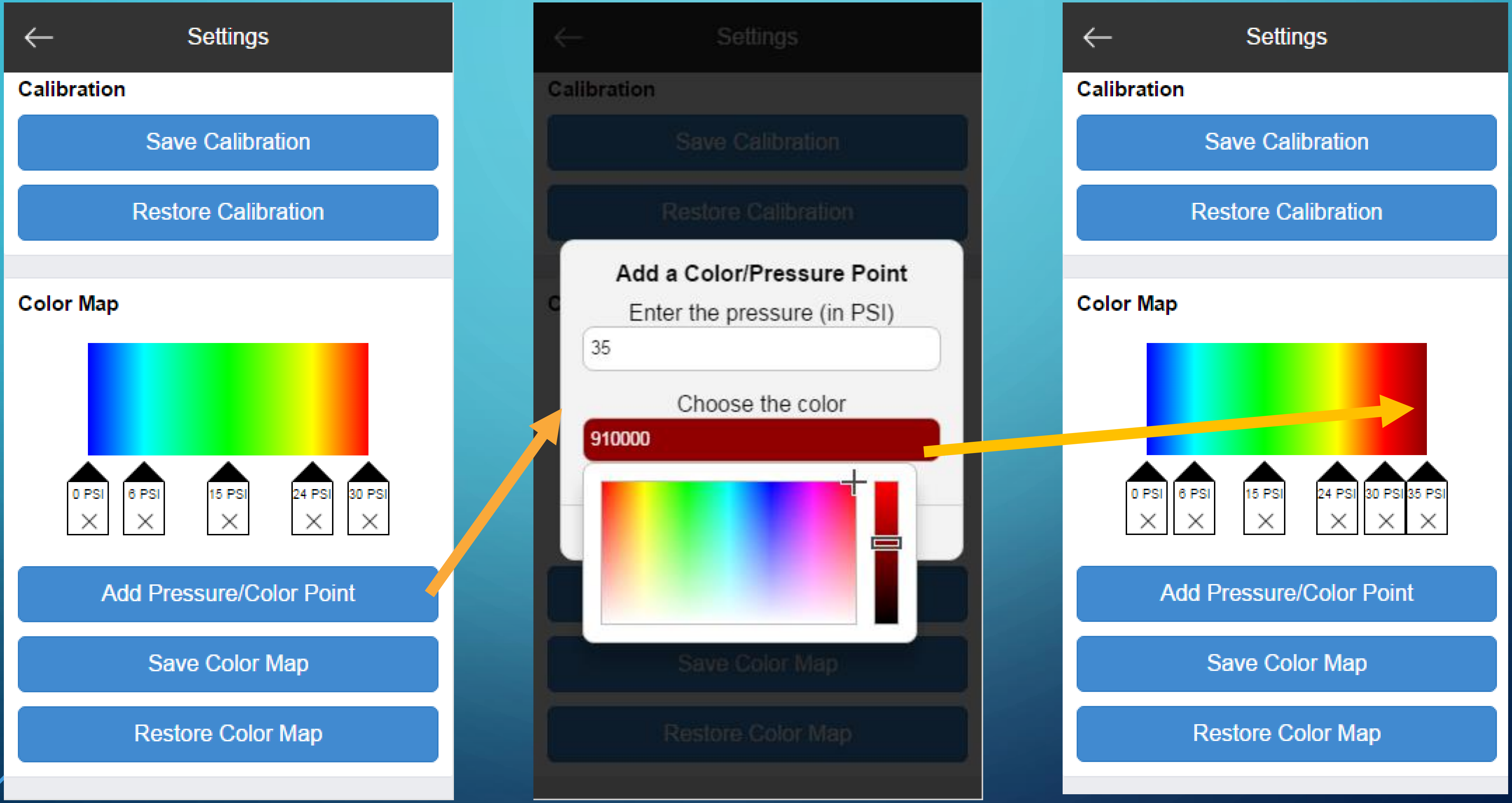
- UPDATES
  - Added the support for starting/stopping the Real Time 3D shape in firmware
- CONCERNS
- ACTION ITEMS
  - Tweak software as necessary after testing

# 3D MODELLING (LAST WEEK)



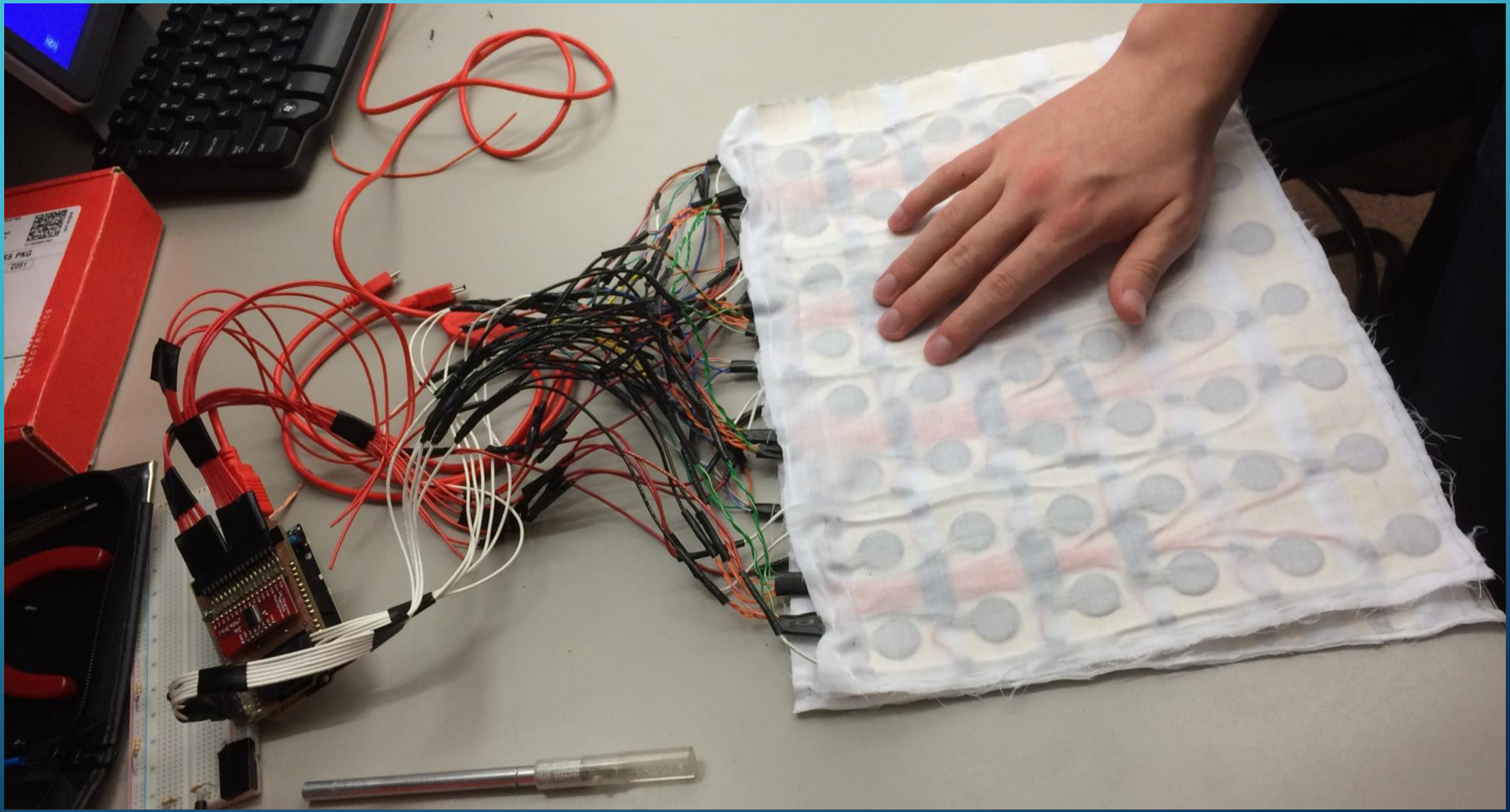
# 3D MODELLING (LAST WEEK)



# SENSOR ARRAY

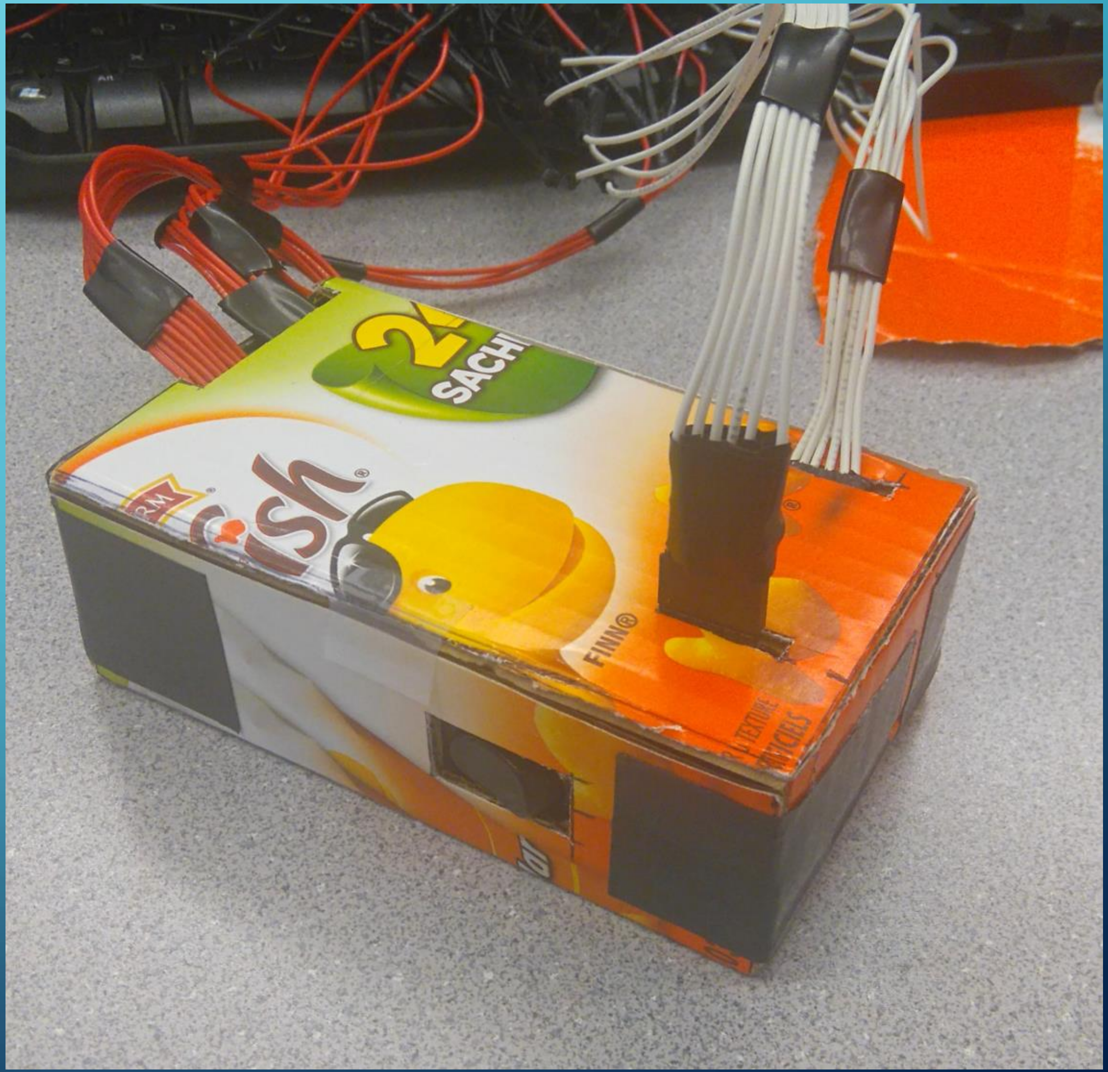
- UPDATES
  - Analog connections to array sheets have been wired in a modular fashion
  - Sensor sheets sewed together with foam placed between
- CONCERNS
  - Thickness of net array (not a big concern)
  - Alignment of the two sheets
- ACTION ITEMS

# SENSOR ARRAY



# CONTROL HARDWARE

- UPDATES
  - Enclosure created for battery, controller, and wiring housing
- CONCERNS
  - N/A
- ACTION ITEMS
  - N/A



# AXOLO METRICS PROSTHETISENSE PROJECT

CAPSTONE MEETING OUTLINE

MAR 3RD, 2016

# MEETING ATTENDANCE

All members present

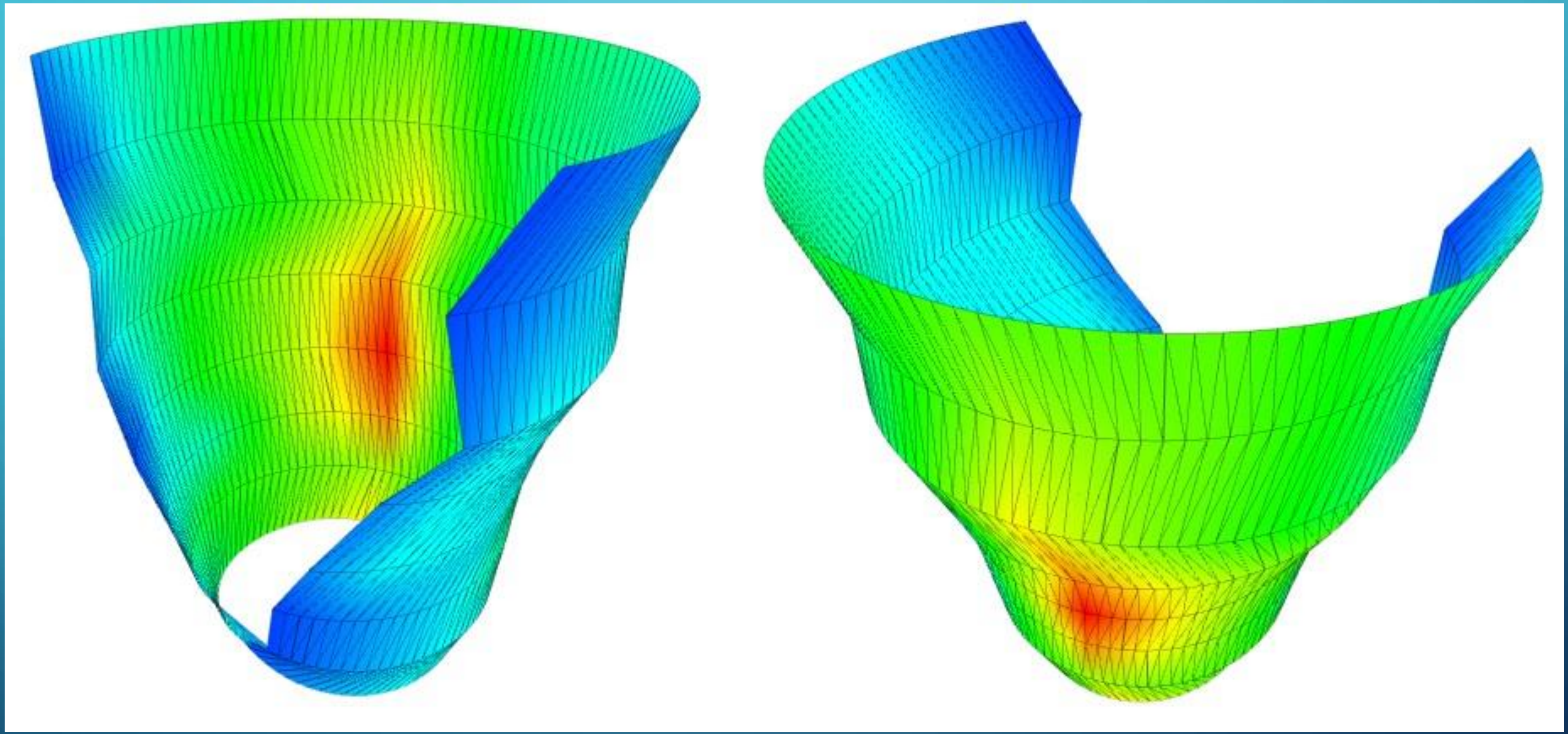
# FIRMWARE

- UPDATES
  - Code written to read data from the flex sensor and send to iOS app (see animation of result in 3D modelling section
  - Code written to calibrate the flex sensor to find the curvature vs. resistance characteristic for each sensor
- CONCERNS
  - The consistency of values read by the flex sensor
- ACTION ITEMS
  - Determine what is the bottleneck of the system: Sensor reading or Bluetooth sending
  - Write code to read FSRs and classify the pressure ranges for a heat map

# 3D MODELLING

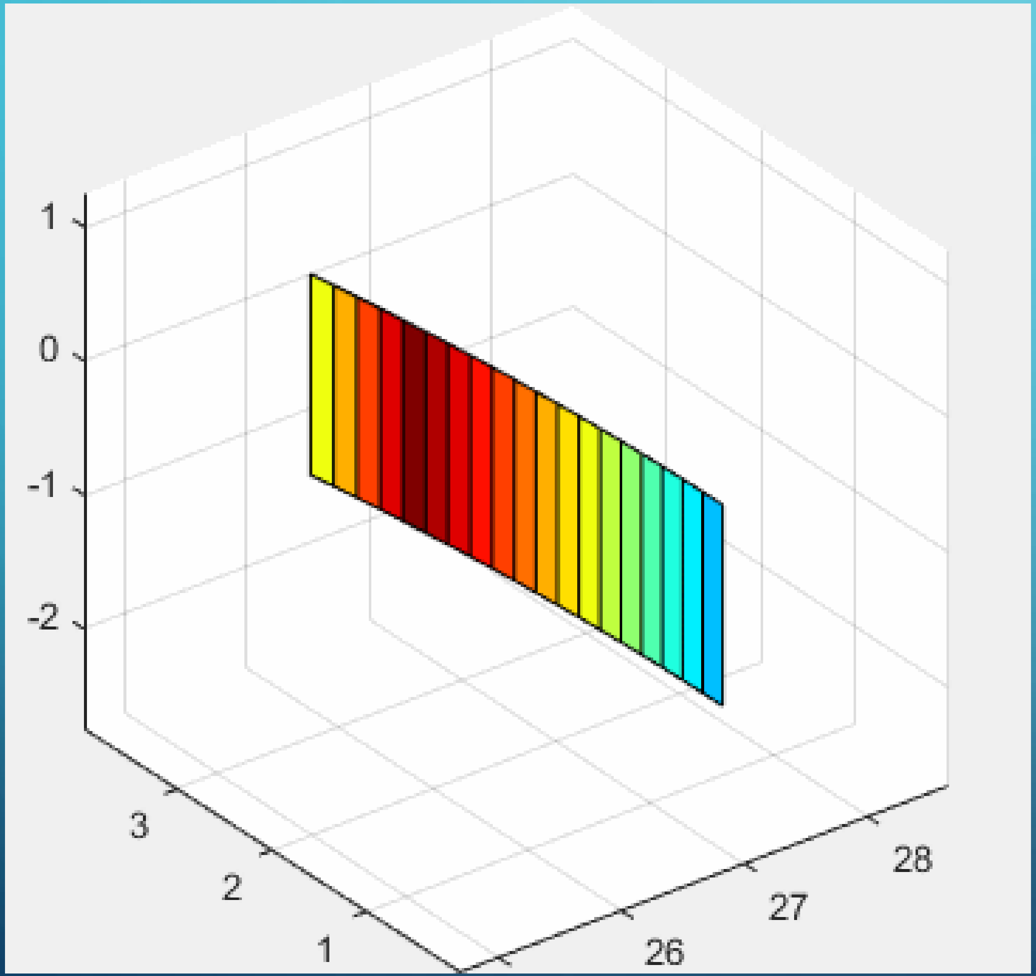
- UPDATES
  - Progress on 3D modelling using iOS: using Three.js library to perform 3D graphics in a browser
  - We will be able to perform 3D modelling in any modern browser: including Android and iOS
  - Advantage of doing 3D modelling in a browser (with WebGL) is cross-browserness and easiness
  - Advantage of using Three.js is simplification of WebGL modelling and no need for writing engine
- CONCERNS
  - The ability to rotate 3D model with gestures (pinch to zoom, touch to rotate, etc) might be difficult to implement
  - Need to find a way to help prosthetist match pressure areas on a 3D model and the real sheet
- ACTION ITEMS
  - Figure out animation with Three.js
  - Figure out how to combine 3D modelling core with iOS shell (will use iOS WebView as a browser within the app)
  - Adjust the 3D modelling to the real characteristics of the sensor sheet (width, height, sensor location, etc)

# 3D MODELLING



3D modelling in the browser using JS, WebGL, Three.Js Library

# 3D MODELLING




Making an animation of Flex sensor from real data sent from the microcontroller to iOS App

Note: The pressure map here is created with dummy data

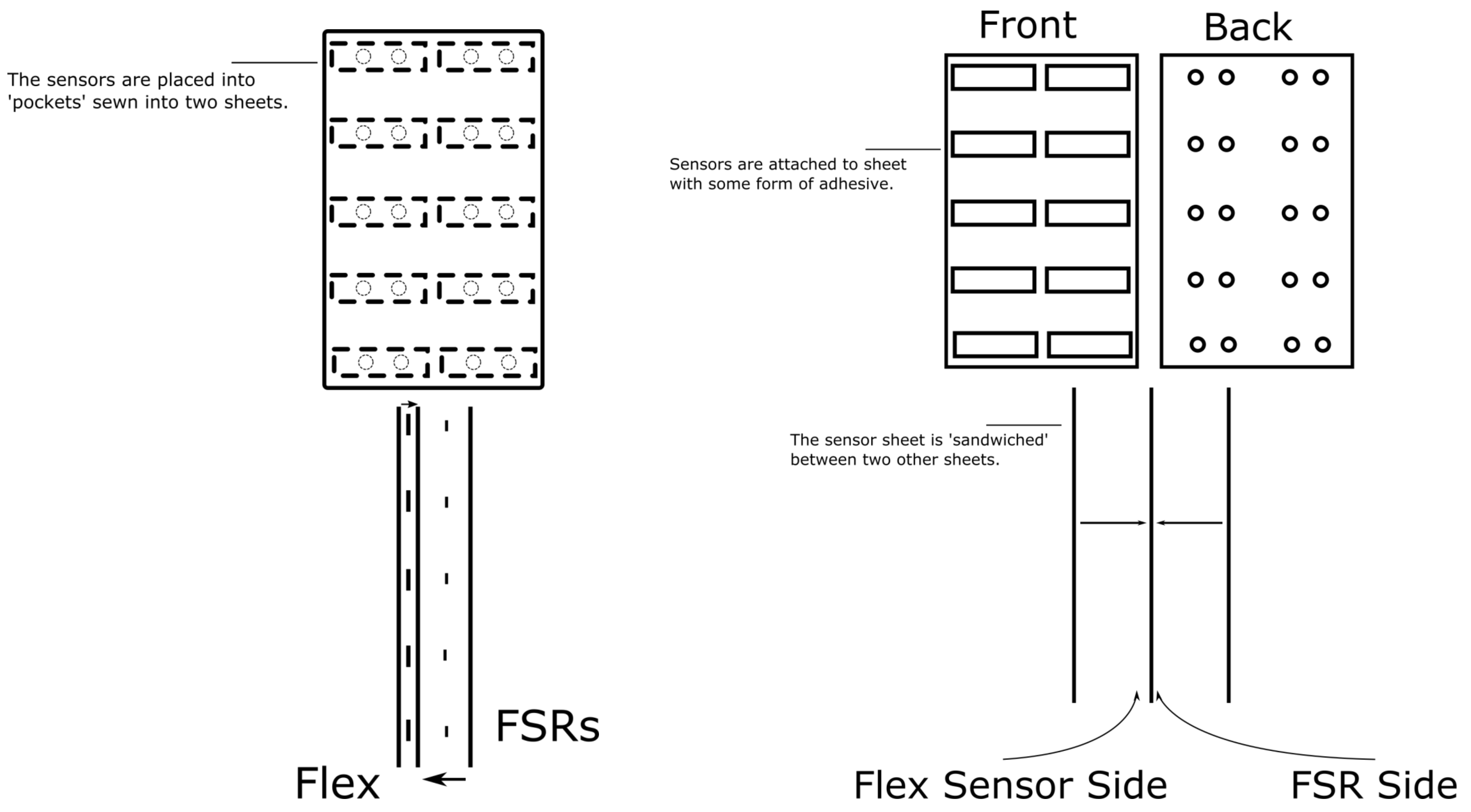
# SOFTWARE

- UPDATES
  - Application receives, interprets, and stores multiple Genuino AnalogReads over BLE
  - Support for multiple data types over BLE
- ACTION ITEMS
  - Create WebView for 3D Model JS Script
  - Develop general GUI elements
    - Create a ”Connecting to Peripheral” screen

# SENSOR ARRAY

- UPDATES
  - RobotShop order placed for more FSRs and Flex Sensors (35 and 20 total respectively)
  - 4 different fabrics purchased
- CONCERNS
  - Resolution required for the Proof of Concept
  - Additional thickness created by wiring and solder connections in the sensor array
- ACTION ITEMS
  - Create drawings of potential configurations for sensor array implementation in fabric
  - Identify optimal configuration and begin assembly

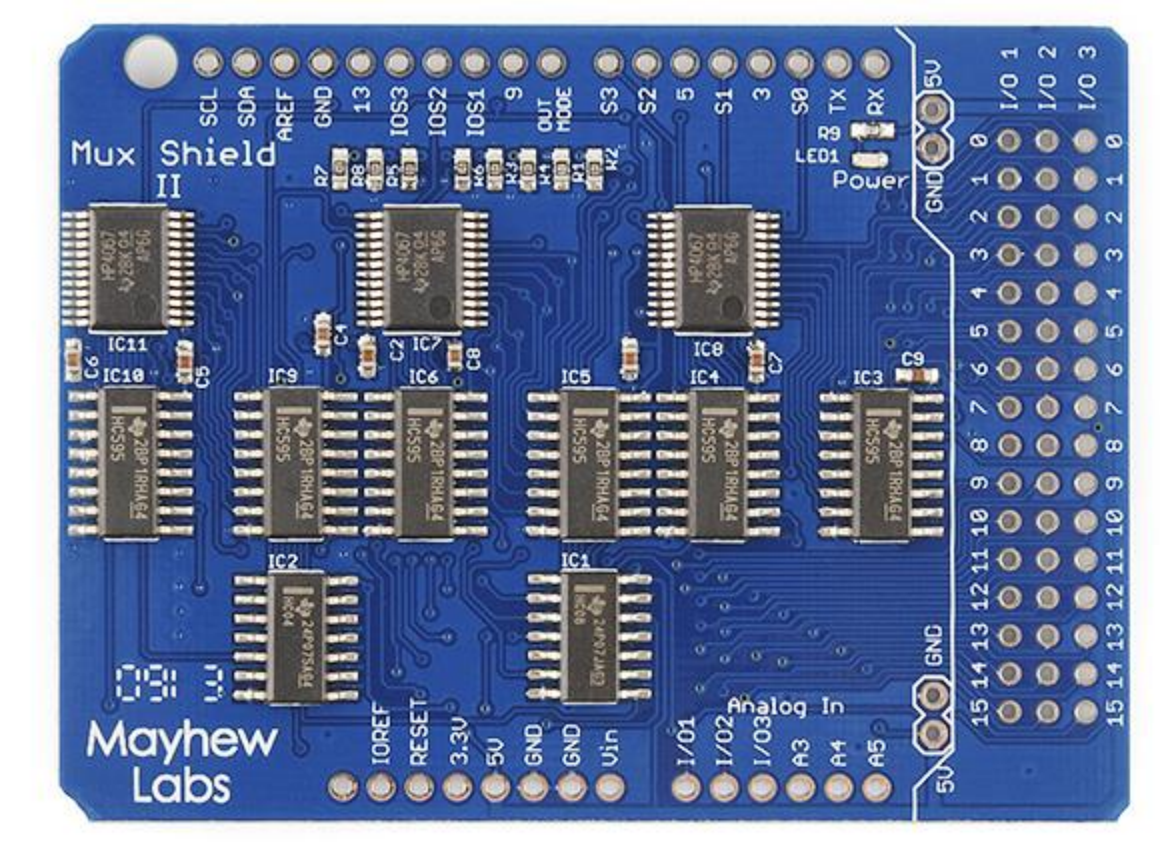
# SENSOR ARRAY



# CONTROL HARDWARE

- UPDATES
  - Two 7.4V 1000mAh LiPo batteries (and charger) ordered
  - Possible multiplexer shield identified
- CONCERNS
  - Fixed number of pins on the MUX shield will only be adequate to handle enough sensors for half socket coverage (at a good sensor resolution)
    - How could this be expanded to full coverage? Would likely require a complete redesign
- ACTION ITEMS
  - Finalize MUX design
  - Order parts/modules and expedite shipping

# MUX SHIELD ?




- 48 I/O total
- Uses minimum of 4 digital pins
- Uses 3 Analog pins

# AXOLO METRICS PROSTHETISENSE PROJECT

CAPSTONE MEETING OUTLINE

MAR 3RD, 2016

# MEETING ATTENDANCE

All members present

# MEETING SCHEDULE

- Present updates
- Mention any concerns
- Identify action items for following week/weeks
- Review Design Specifications draft

# UPDATES

- All sensors and components have been ordered and will arrive before next Thursday
  - 60 FSRs total, 30 Flex total, MUX, wiring, connectors
- MUX configurations analyzed, problems solved, optimal design config confirmed
- Characterized FSRs and developed a model to get the force based on the sensor resistance
- Implemented pinch-to-zoom and touch-to-rotate for 3D modelling, as well as integrated the iOS shell and web-based core
- Demo booked April 12$^{th}$ 10:00 -11:30

# CONCERNS

- Immediate concern: Completing the Design Specification document
  - Document under construction from 12 noon to 12 midnight. Will complete a high quality document
- No specific concerns at the moment, besides random roadblocks that come up in the next few weeks

# ACTION ITEMS

- Lay out sensor array on fabric, solder necessary wiring to sensors and begin fabrication
- Design shield in EAGLE to support MUX breakout, ADC Voltage divider resistors, and sensor array connection
  - Manufacture PCB shield on ProtoMat and assemble
- Implement code that modifies the FSR readings appropriately once received by the App
- Develop more general GUI elements on the App
- Once we have hardware completed, make sure spacing and sizes in 3D model are correct, as well as set the correct amount of rows and columns.

# AXOLO METRICS PROSTHETISENSE PROJECT

CAPSTONE MEETING OUTLINE

MAR 17TH, 2016

# MEETING ATTENDANCE

All members present

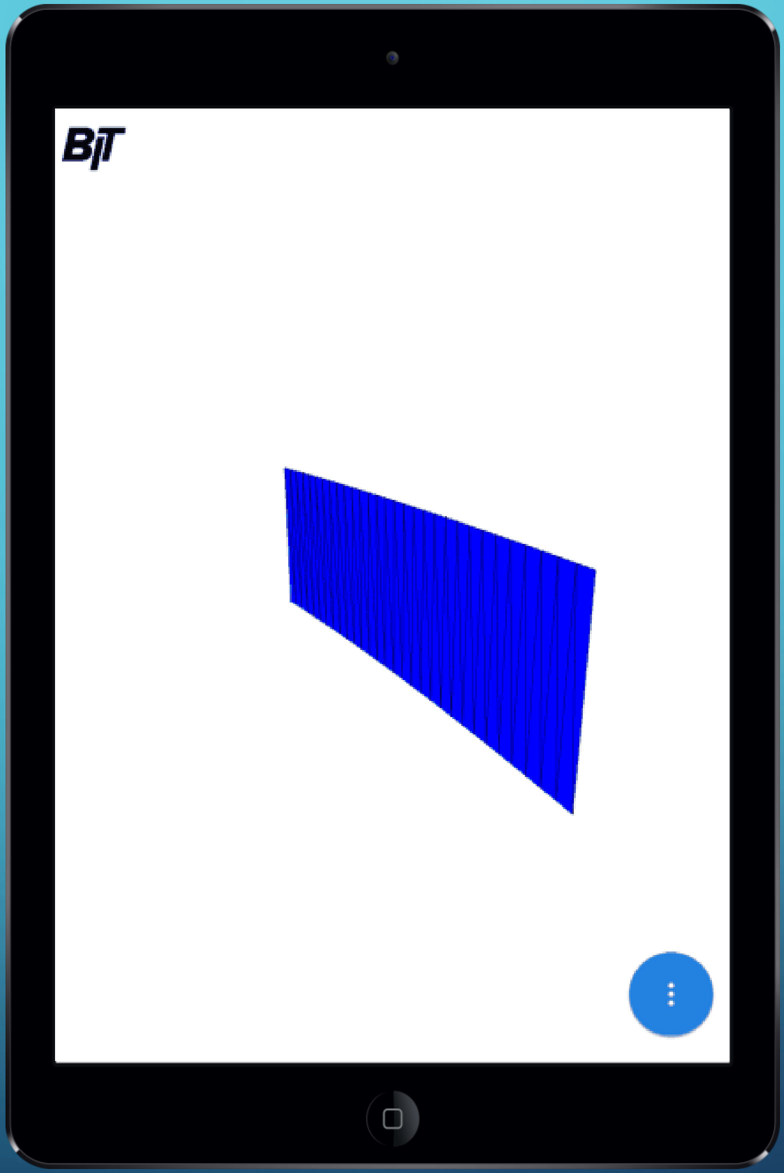
# FIRMWARE

- UPDATES
  - Code written to read data from the flex sensor and send to iOS app (see animation of result in 3D modelling section
  - Code written to calibrate the flex sensor to find the curvature vs. resistance characteristic for each sensor
- CONCERNS
  - The consistency of values read by the flex sensor
- ACTION ITEMS
  - Determine what is the bottleneck of the system: Sensor reading or Bluetooth sending
  - Write code to read FSRs and classify the pressure ranges for a heat map

# 3D MODELLING

- UPDATES
  - Performed 3D modelling in real time with test sensor array, only partially successful
  - Identified the possible issues and fixed them
  - Improved the 3D model centering algorithm (both translational and rotational centering)
  - Created UI similar to the native mobile experience
- CONCERNS
  - Problem with inputting calibration radius on iOS
  - Unexplained test array 3D modelling problem that occurred on iOS, but not on Windows
- ACTION ITEMS
  - Test device calibration and real time 3D modelling for the test sensor array
  - Identify the cause of inputting issue on iOS and create a solution
  - Improve UI design: add header, and other menus

# 3D MODELLING



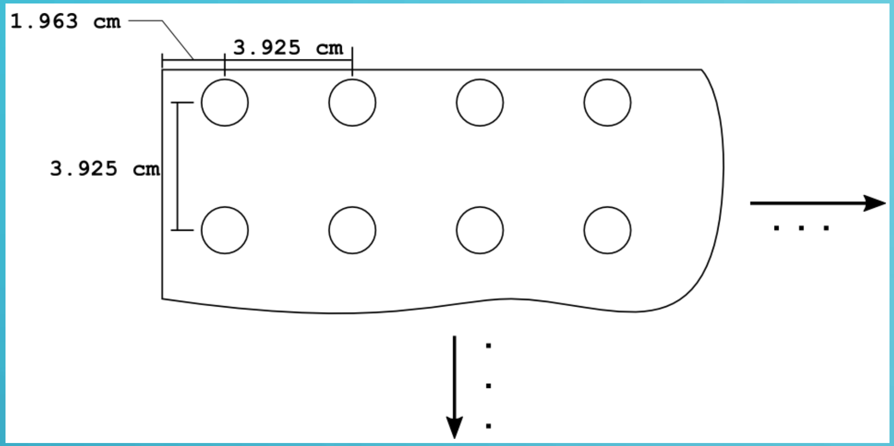
# SOFTWARE

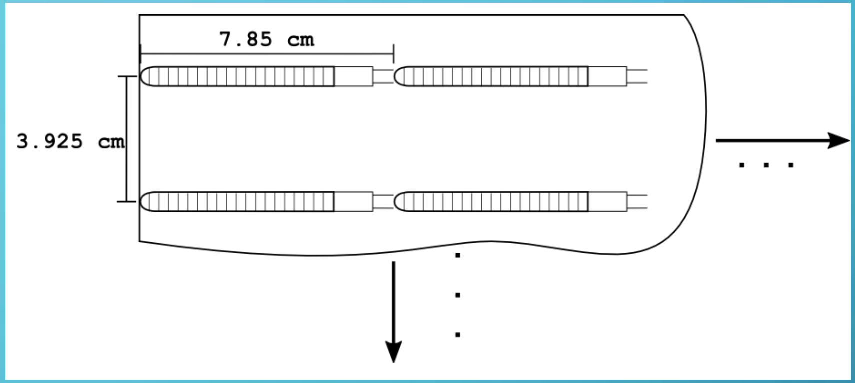
- UPDATES
  - Analog sensor data is being received and decoded from the Genuino
  - WebView with JavaScript page is working
  - Analog data is being passed to the JS webview
- ACTION ITEMS
  - Polish up the application for better visual appeal
  - Optimize BLE transmission

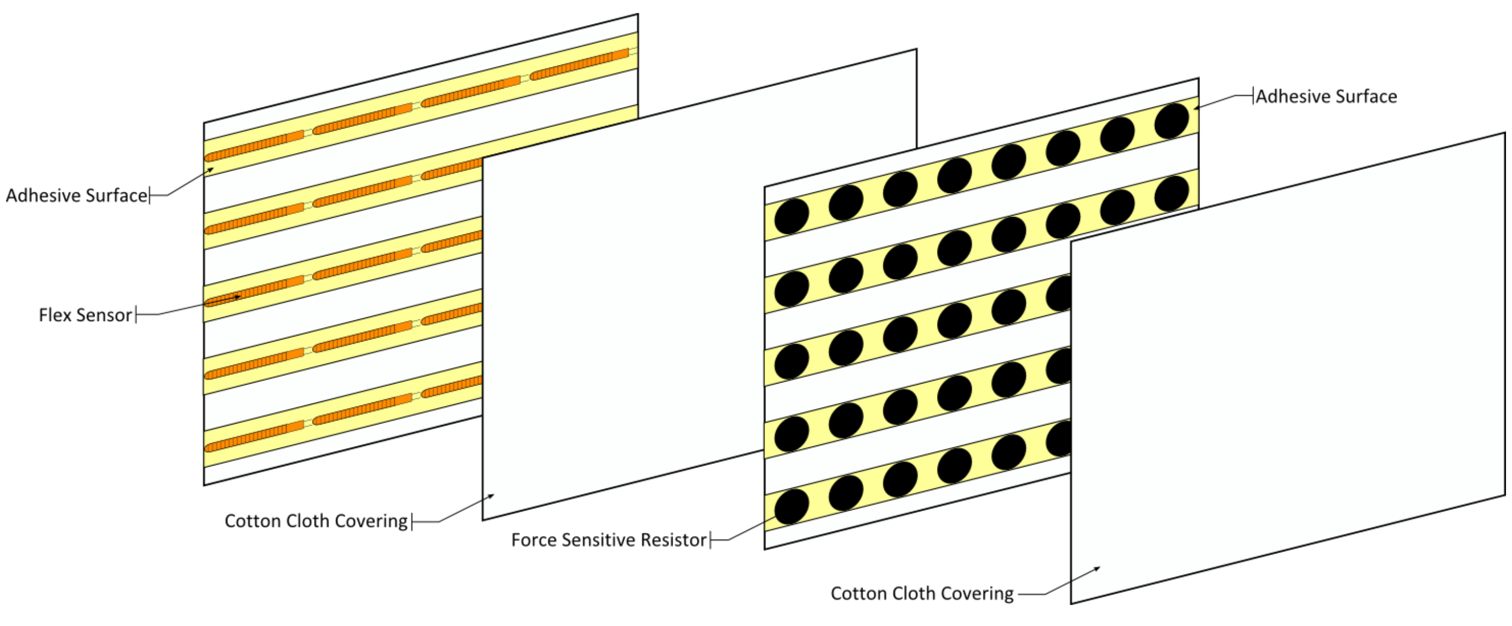
# SENSOR ARRAY

- UPDATES
  - Created a 'sample' sensor array, 8 FSRs and 4 flex sensors. This is so the software team can finalise/calibrate/correct the software to use actual data collected from sensors.
  - Spacing between FSRs is 3.92 cm, vertical and horizontal (figure on next page).
  - All orders for sensors have now arrived.
- CONCERNS
  - Positioning of wires to not interfere with FSR sensing. We need to have an 'elegant' wiring solution, after seeing the mess only 12 sensors creates. Prototype for presentation will have way more sensors and wires.
- ACTION ITEMS
  - Work on a floorplan for the wiring in the sensor array.
  - Solder the wires to the rest of the sensors and implement the floorplan.

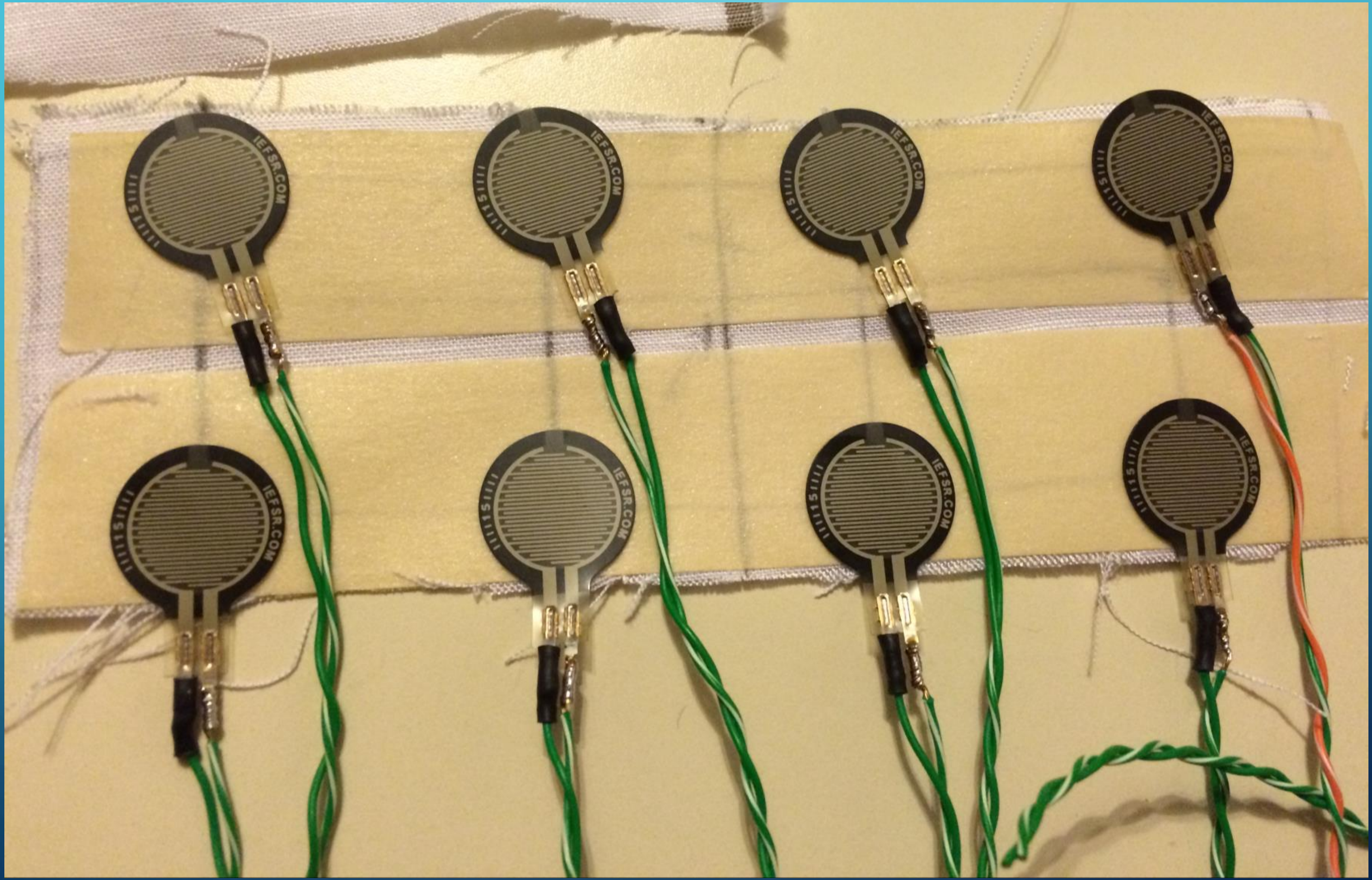
# SENSOR ARRAY

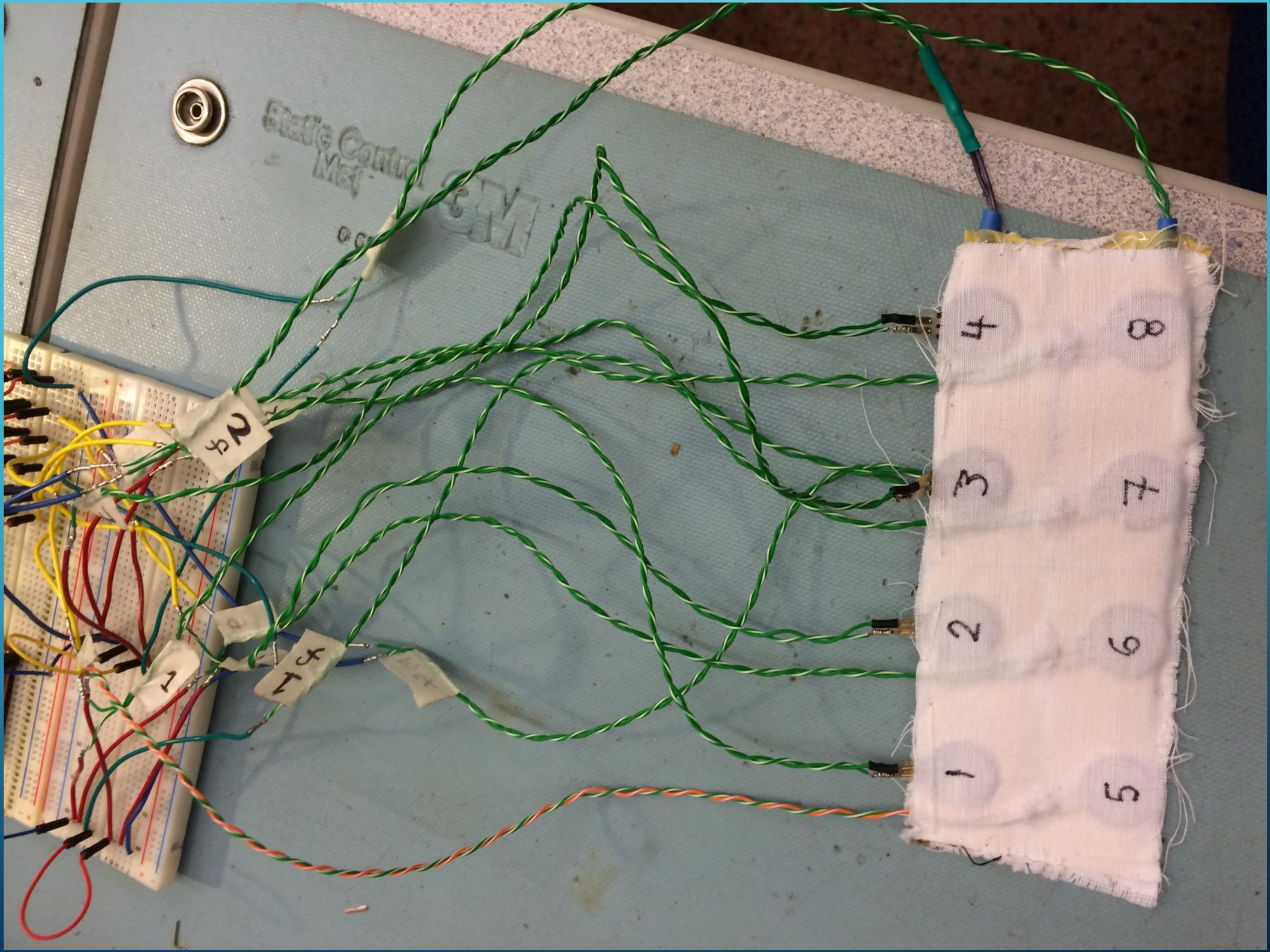


# SENSOR ARRAY

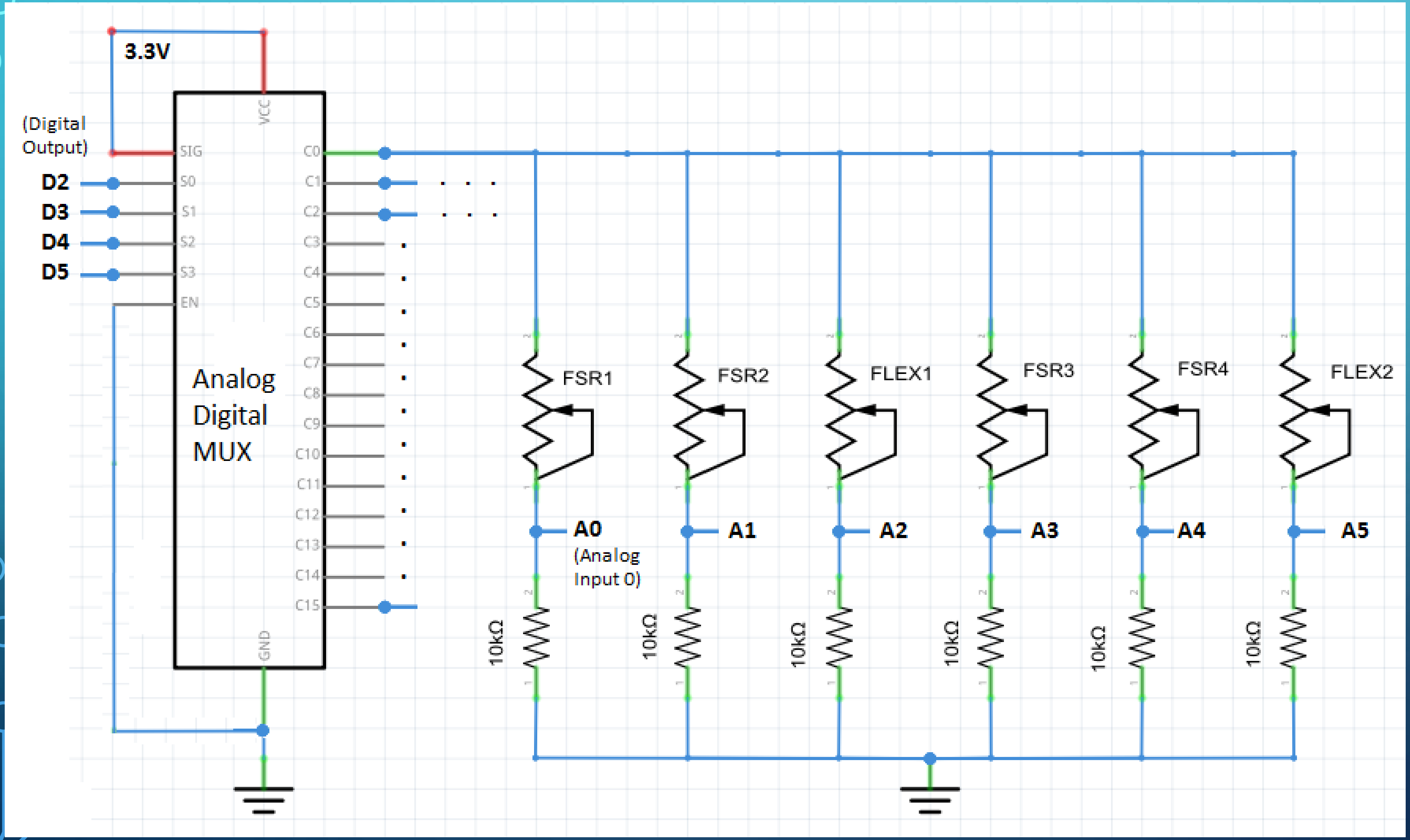



Static Control Mat
3M

# CONTROL HARDWARE

- UPDATES
  - Batteries and barrel jacks power switches have arrived
  - Multiplexer configuration design confirmed.
  - Multiplexer breakouts arrived
- CONCERNS
  - Protomat machine maintenance/operability
- ACTION ITEMS
  - Complete MUX shield design
  - Print and solder to the shield
  - Test system with the battery (instead of USB power).
  - (Lower Priority) Test for current draw with battery and battery life.

# MUX CIRCUIT DESIGN




- Proposal: One time measurement of the shape, then stop reading from flex sensors, due to shakiness of the 3D model.
- This would change how the MUX is wired, to ensure maximum efficiency (e.g. pin usage, etc.)

# AXOLO METRICS PROSTHETISENSE PROJECT

CAPSTONE MEETING OUTLINE

MAR 23RD, 2016

# MEETING ATTENDANCE

All members present

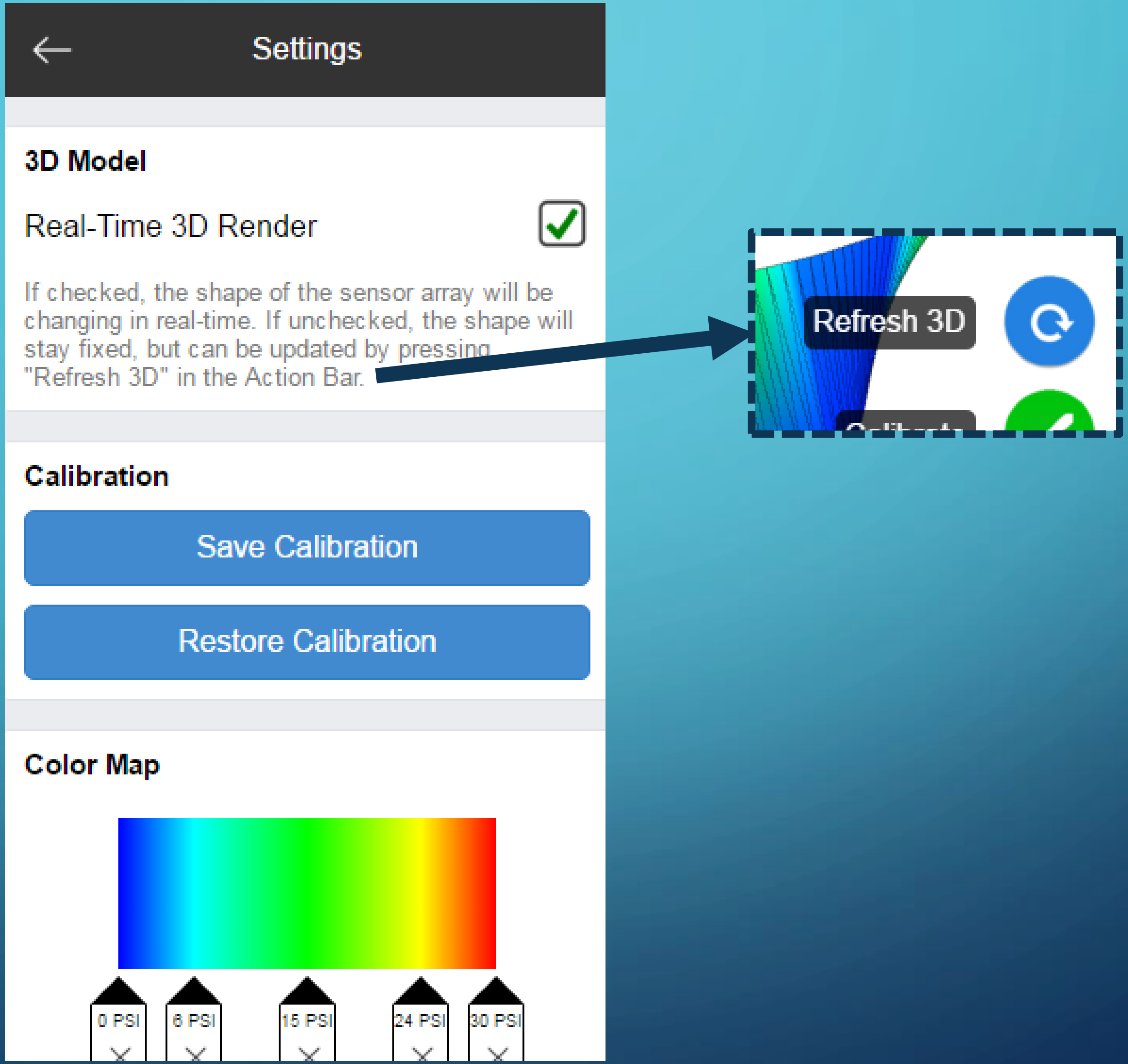
# FIRMWARE

- UPDATES
  - Code written to read data from the flex sensor and send to iOS app (see animation of result in 3D modelling section
  - Code written to calibrate the flex sensor to find the curvature vs. resistance characteristic for each sensor
- CONCERNS
  - The consistency of values read by the flex sensor
- ACTION ITEMS
  - Determine what is the bottleneck of the system: Sensor reading or Bluetooth sending
  - Write code to read FSRs and classify the pressure ranges for a heat map

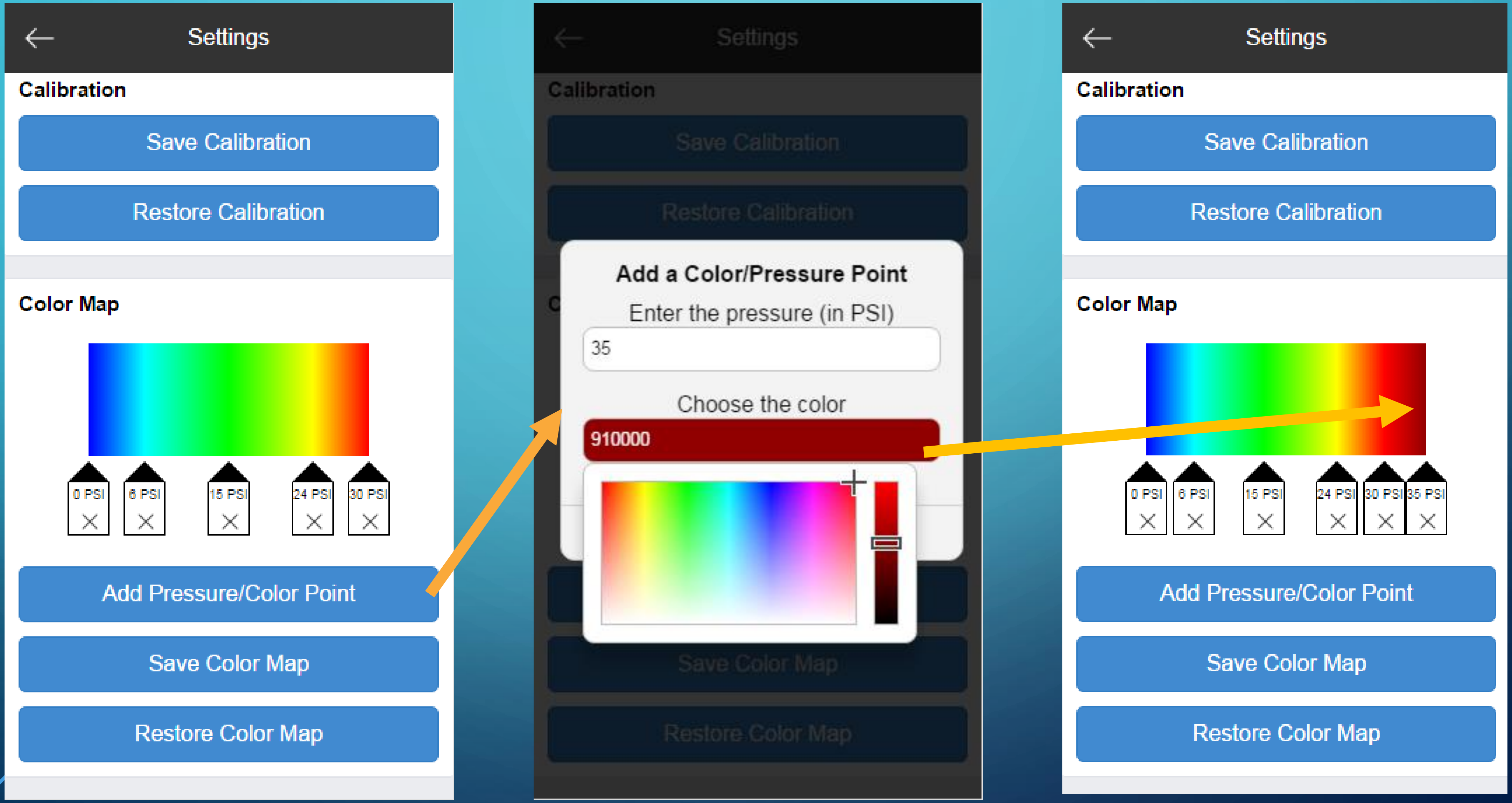
# 3D MODELLING

- UPDATES
  - Fixed the calibration issue, and improved the calibration algorithm (added averaging of 5 readings for each calibration step)
  - Updated Settings:
    - Added “Real Time 3D Render” option
    - Added the ability to change the color map
- CONCERNS
  - What other options have to be added to Settings without unnecessarily complicating things?
- ACTION ITEMS
  - Integrate Shell and Core and add the ability to save / reset calibration and color map data

# 3D MODELLING



# 3D MODELLING



# SOFTWARE

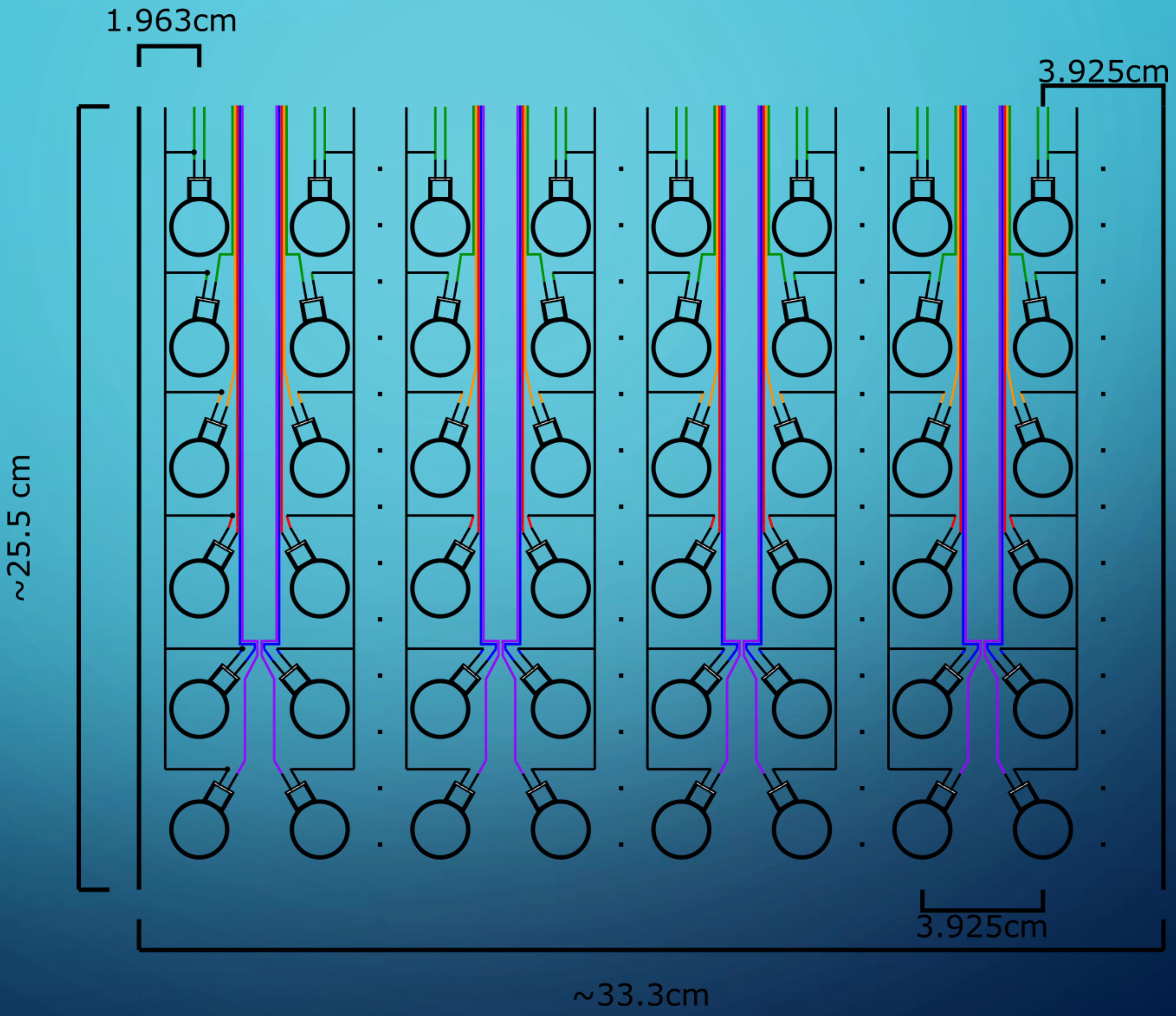
- UPDATES
  - Analog sensor data is being received and decoded from the Genuino
  - WebView with JavaScript page is working
  - Analog data is being passed to the JS webview
- ACTION ITEMS
  - Polish up the application for better visual appeal
  - Optimize BLE transmission

# SENSOR ARRAY

- UPDATES
  - Soldered wires to the 48 FSRs in preparation to assembling the sensor array
  - Designed a layout for the wiring of flex sensors and FSRs. (see next page).
- CONCERNS
  - Individual sensor testing should likely be done prior to assembly of the full array
- ACTION ITEMS
  - Solder the wires to the rest of the sensors.
  - Attach all sensors according to the floorplan.

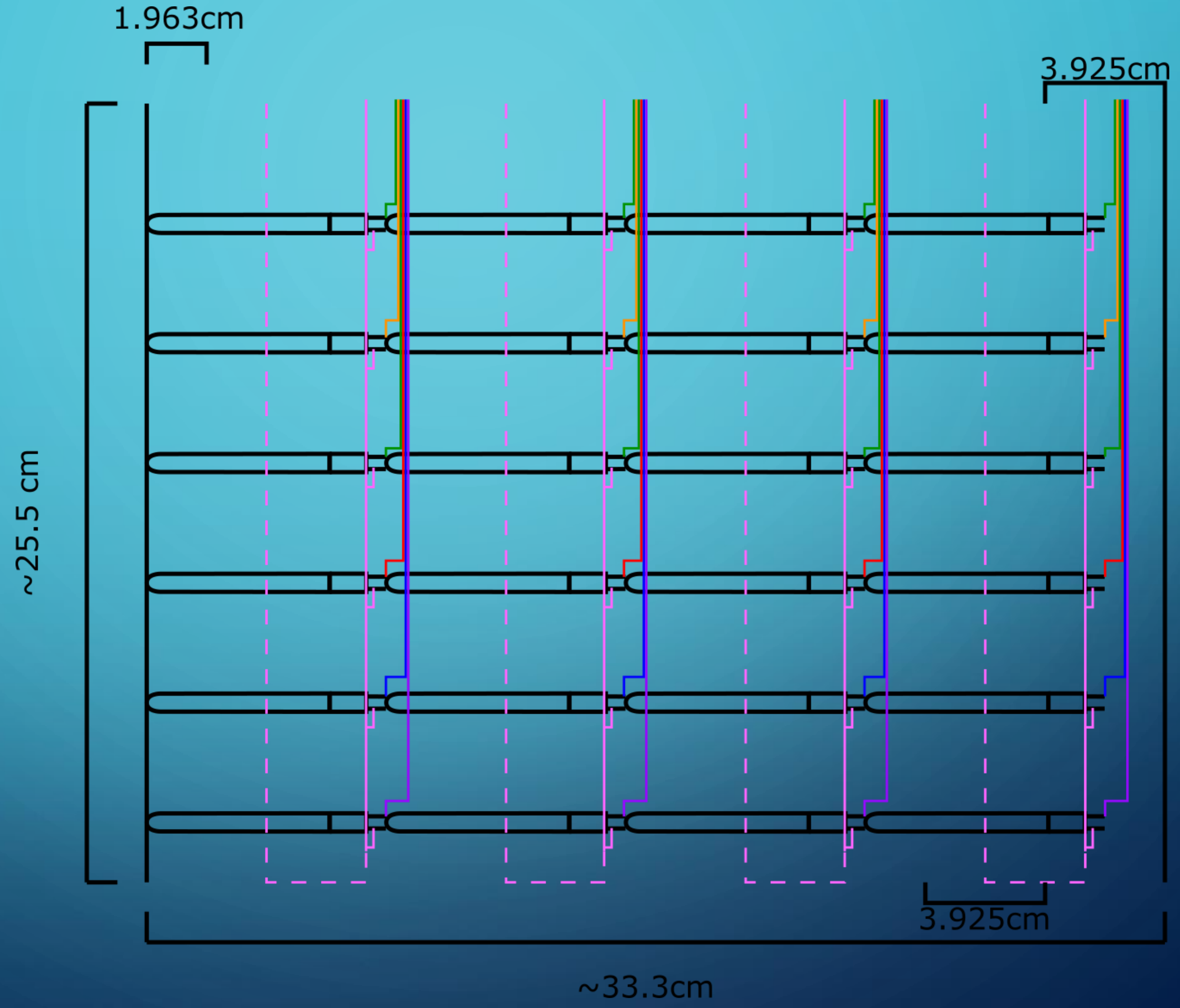
# SENSOR ARRAY (FSRS)

- Wiring floor plan for the FSRs
- 24 Flex Sensors, 48 FSRs



# SENSOR ARRAY (FLEX SENSORS)

- Wiring floor plan for the Flex sensors

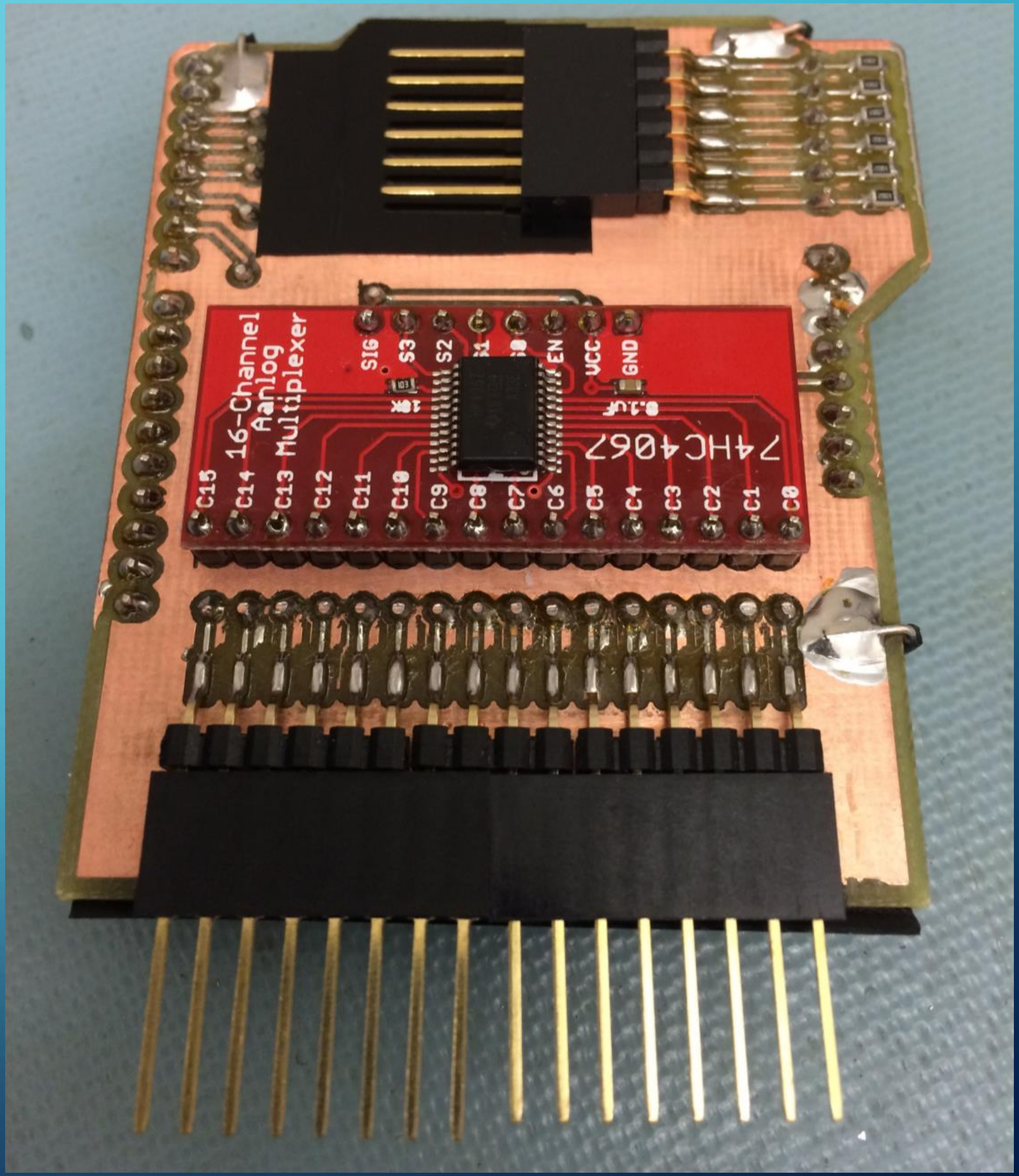


# CONTROL HARDWARE

- UPDATES
  - Custom MUX shield manufactured and assembled on ProtoMat
- CONCERNS
  - N/A
- ACTION ITEMS
  - Solder the stranded wire to the MUX and Analog header connectors on the board
  - Create some sort of enclosure for the controller, and choose a method to attach it to the outside of the socket

# PROTOMAT ASSEMBLED SHIELD

- Continuity testing completed
- Connector for 6 analog pin bus wires
- Connector for 16 power branches for clusters of up to 6 sensors



# AXOLO METRICS PROSTHETISENSE PROJECT

CAPSTONE MEETING OUTLINE

MAR 31ST, 2016

# MEETING ATTENDANCE

All members present

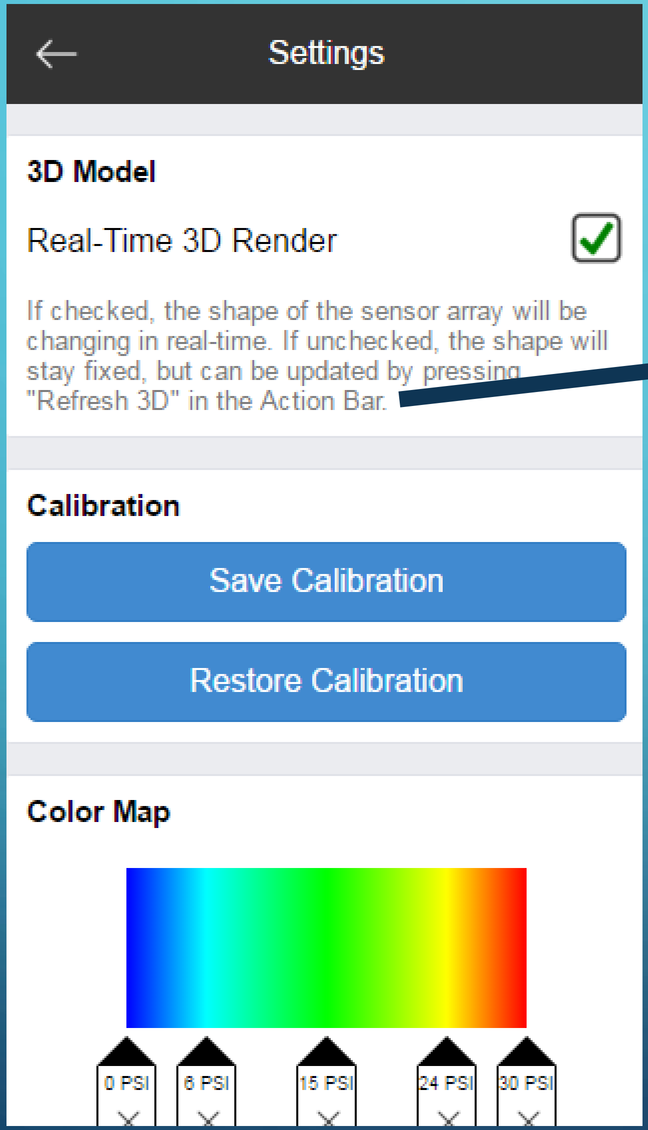
# FIRMWARE

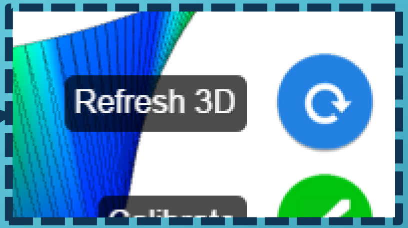
- UPDATES
  - Changed BLE buffers from 8 byte to 20 byte, meaning 10 sensors can be transmitted at one time (vs 4). Transmission time reduced by over 50%
  - Refactored code to be more efficient
- CONCERNS
  - Waiting to debug with full sensor array
- ACTION ITEMS
  - Debug with full sensor array when ready

# 3D MODELLING

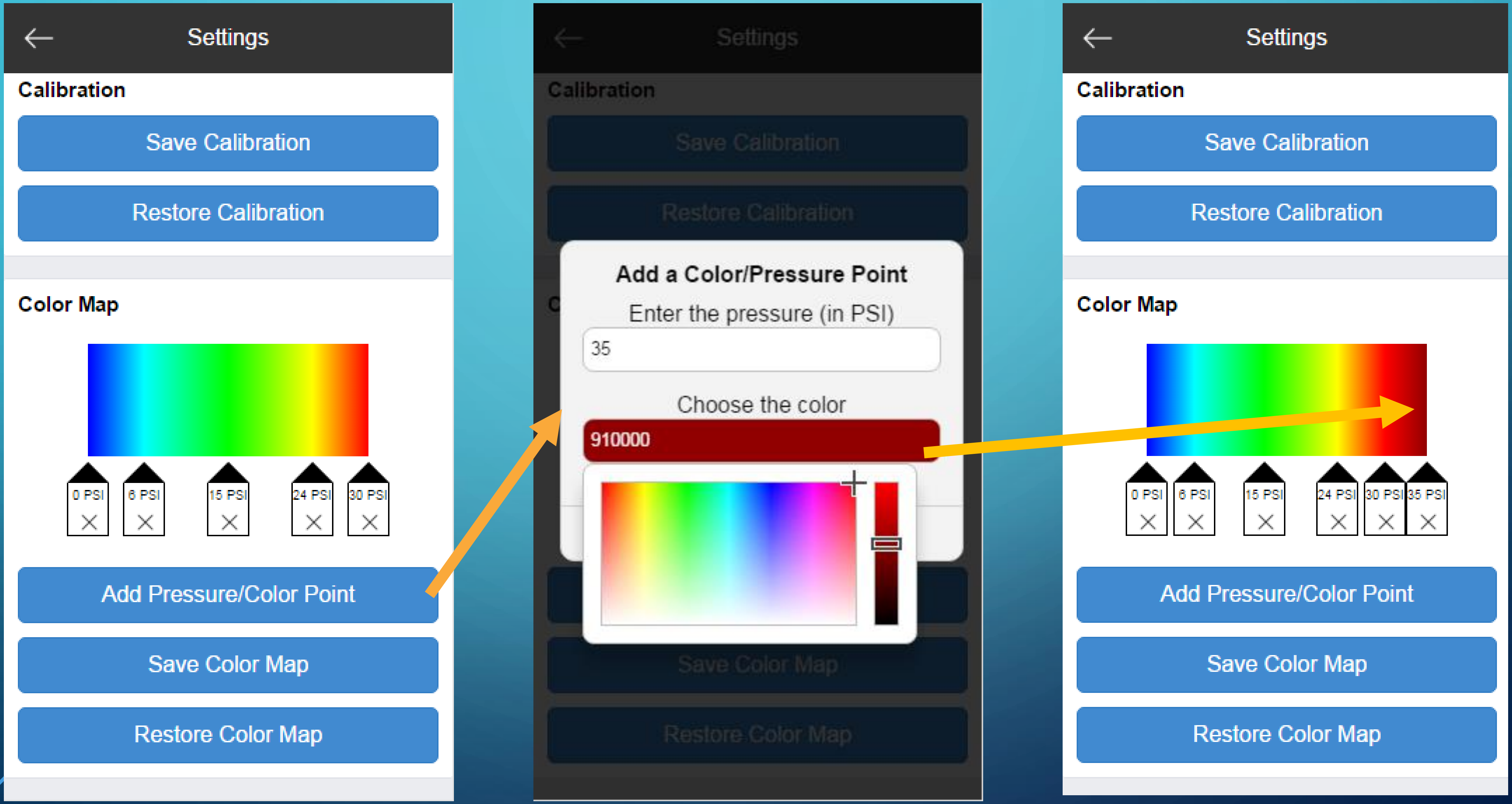
- UPDATES
  - Added the support for starting/stopping the Real Time 3D shape in firmware
  - Added the ability to save and restore the settings (Color map, Calibration, etc)
  - Added the support for all 72 sensors
  - Fixed a few other issues, made the code less likely to break if data is incorrect
- CONCERNS
  - Speed of rendering reduced slightly with more sensors, yet is unlikely to be a bottleneck
- ACTION ITEMS
  - Wait on the completion of the final sensor array, test, fix bugs

# 3D MODELLING (LAST WEEK)



# 3D MODELLING (LAST WEEK)



# SOFTWARE

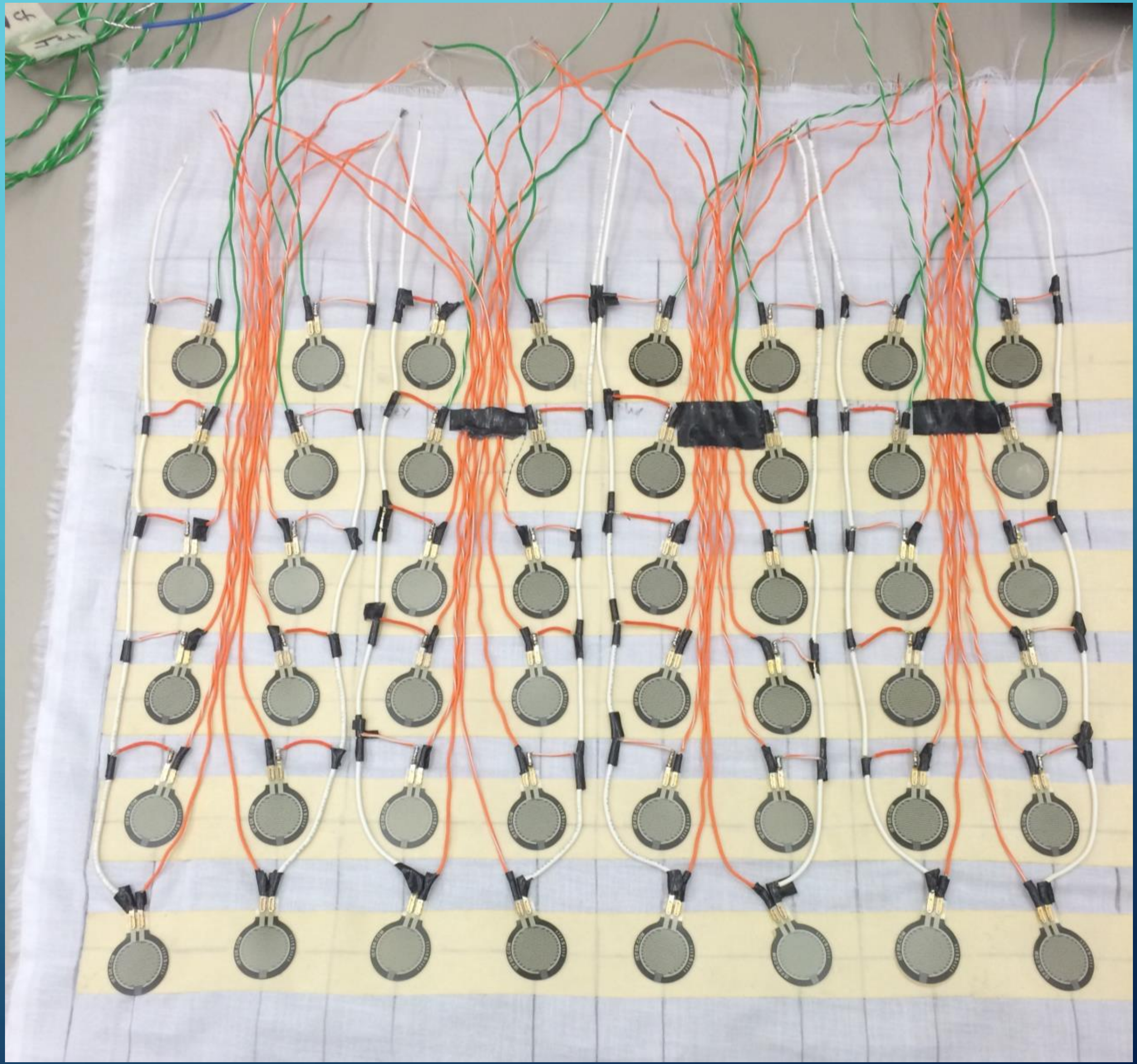
- UPDATES
  - Analog sensor data is being received and decoded from the Genuino
  - WebView with JavaScript page is working
  - Analog data is being passed to the JS webview
- ACTION ITEMS
  - Polish up the application for better visual appeal
  - Optimize BLE transmission

# SENSOR ARRAY

- UPDATES
  - Completed the soldering of all sensors and power bus lines
  - Tested all sensors and placed them onto the double sided adhesive on the cloth
- CONCERNS
  - Some of the FSRs have wiring running underneath them despite our best efforts to avoid this, thin layer of foam may need to be added between the sensor layers
- ACTION ITEMS
  - Finish soldering the connector wires to the sensor array
  - Test the entire system

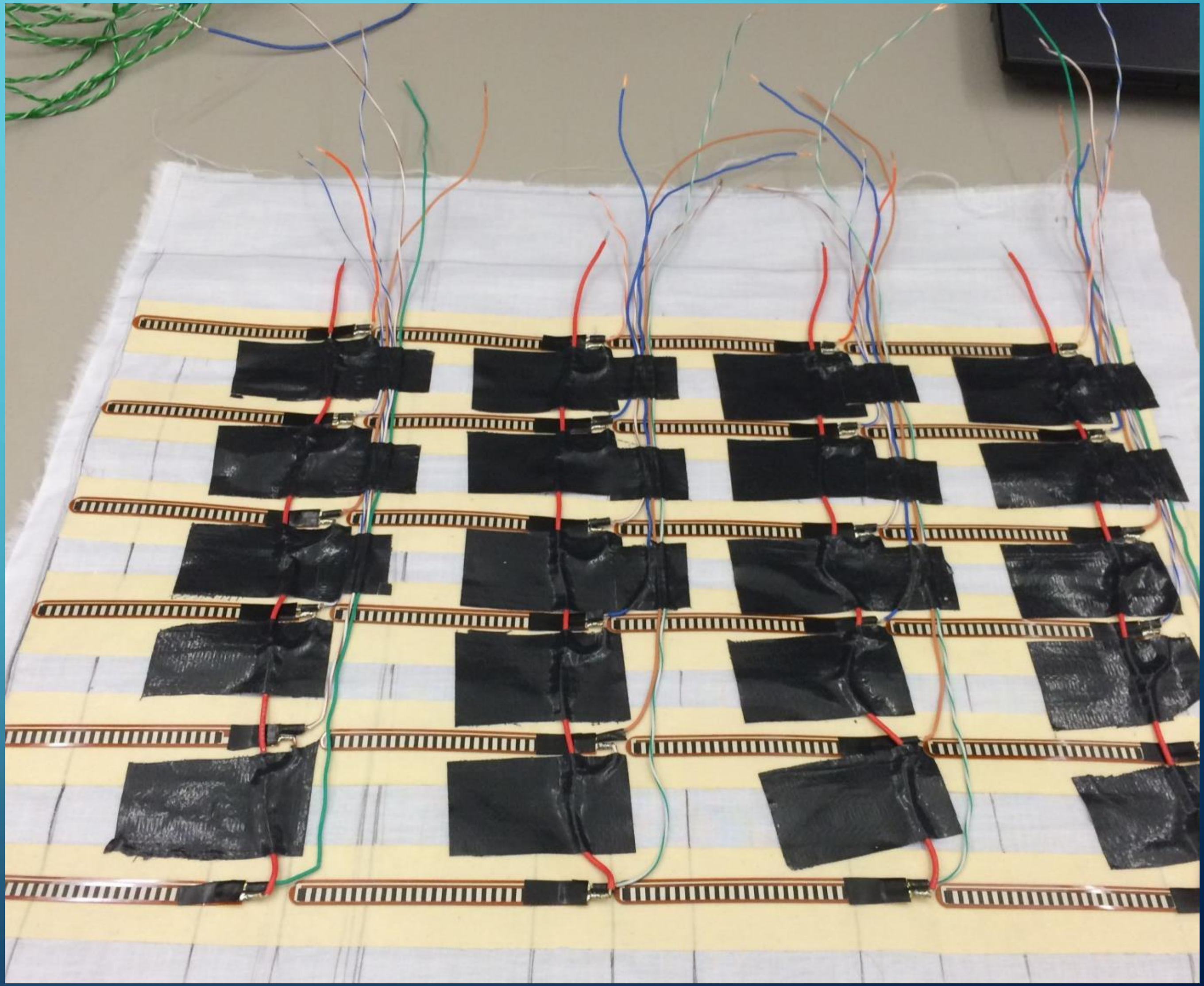
# SENSOR ARRAY (FSRS)

- Wiring floor plan executed for the FSRs
- 48 FSRs, 8 power bus lines that power 6 sensors each



# SENSOR ARRAY (FLEX SENSORS)

- Wiring floor plan for the Flex sensors executed
- 24 Flex sensors, 4 power bus lines that power 6 sensors each



# CONTROL HARDWARE

- UPDATES
  - Sensor array connectors for the shield assembled (pictures on next slide)
- CONCERNS
  - N/A
- ACTION ITEMS
  - Create some sort of enclosure for the controller, and choose a method to attach it to the outside of the socket

# CONNECTORS TO THE MUX SHIELD

- Connector for 6 analog pin bus wires (WHITE wires)
- Connector for 16 power branches split into two 8 wire connectors