SURGICAL ELECTRONIC SOLUTIONS

April 14, 2016

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6
Re: ENSC 440W/305W Post-Mortem for the MYOperator MK 1.0

Dear Dr. Rawicz,

The attached document is the post-mortem for a biomedical device, the MYOperator MK 1.0. The document outlines the design and implementation for our ENSC 305W/440W Capstone project. The wireless MYOperator MK 1.0 is a replacement for the current activating pedal that is used in all operating rooms. We have created a unique solution for the existing mobility restriction problem that surgeons face.

This post-mortem document will describe the state that our device is currently in, as well as overview future plans. Additionally, the document will state any technical challenges that arose throughout development and how they were solved. The scheduling and budget constraints will be covered along with individual written reflections of the project made by each team member

Surgical Electronic Solutions is comprised of five founding partners, Michael Wilkerson, Thomas Newton, Gabrijela Mijatovic, Darren Zwack and Jonathan Feng. You can contact us at mww3@sfu.ca or 604-992-9667 for any questions or concerns.

Sincerely,

Michael Wilkerson
CEO
Surgical Electronic Solutions
Enclosed: *Post-Mortem for MYOperator MK 1.0*

SURGICAL ELECTRONIC SOLUTIONS

ENSC 305W/440W
CAPSTONE PROJECT

Group 11

Post-Mortem

MYOperator MK 1.0

Project Team: **Darren Zwack**
Gabrijela Mijatovic
Jonathan Feng
Michael Wilkerson
Thomas Newton

Issue Date: **April 14th, 2016**

Contact: **Michael Wilkerson, CEO**
mww3@sfu.ca

Revision Number: **1.0**

SURGICAL ELECTRONIC SOLUTIONS

EXECUTIVE SUMMARY

The flawless care and attention that a surgeon needs to take while in an operating room is essential to the successful completion of a patient's surgery. Surgeries often require electro-biomedical devices which include hand tools that the surgeon controls. The controlling of some of these tools is currently achieved through the use of a wired pedal that is located underneath the operating table. These foot controlled wired pedals are often considered to be tripping hazards and inconvenient, making them non-ideal hardware to have in the operating room. Surgical Electronic Solutions has created a better foot pedal, by removing the pedal all together. It is a wireless, wearable device, the MYOperator MK 1.0.

The system of the MYOperator MK 1.0 device can be broken down into three its components, the Calf Sleeve, the Hip Station and the Base Station. The three components communicate with each other wirelessly over Bluetooth using the standard Firmata protocol and the Windows Remote Arduino library. The Calf Sleeve, using EMG, contains our main sensing component responsible for collecting data from the surgeon's muscle movement. This component includes electrodes which sense muscle signals generated when the user flexes their tibialis anterior. The EMG data is then processed and amplified by an analog signal processing circuit connected to an Arduino Uno. The Arduino Uno communicates with a Raspberry Pi 2 B+, which acts as the Base Station. Using digital signal processing, the Base Station then interprets the EMG data and determines if the surgeon's tool should be on or off. The Hip Station, consisting of another Arduino Uno and a simple switching circuit, will enable the user to adjust the sensitivity and turn the device on and off remotely.

This document is a post-mortem of the MYOperator MK 1.0, analyzing the design and implementation from an end review standpoint. The post-mortem is organized by the following: first, an introduction to the problem and motivation for the project, then a system overview of the current state of the device. Following the high level design is a business/market analysis for the MYOperator and an outline of our budget and schedule constraints. Problems and challenges the team at Surgical Electronic Solutions faced while making the device, the team's dynamics and workload distribution are also outlined.

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GLOSSARY

Base Station - The component of the MYOperator located at the wired footswitch input port

Calf Sleeve - The component of the MYOperator around the user's calf

Device - The entire MYOperator

Electromyography - The electrical recording of muscle action potentials [1]

Tool - the cauterizer or whatever we are controlling

ACRONYMS

EMG - Electromyography

ENT - Ear Nose and Throat

HMI - Human Machine Interface

ISO - International Organization for Standardization

PCBs - Printed Circuit Boards

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1. INTRODUCTION

An operating room is where a surgeon needs to feel perfectly comfortable and it is of utmost importance that they can perform their job without error. The basic workplace needs of surgeons are similar to almost all other occupations - they must be able to work safely and effectively. The motivation for our product, the MYOperator MK 1.0, came from the fact that all of a surgeon's attention should be given to the patient's care, and not on the usability of their tools.

The MYOperator MK 1.0 is a wireless and wearable biomedical device that acts as a power activator for surgical tools. The MYOperator MK 1.0 was created in order to completely replace the current activators. Under operating room tables there are activating pedals that a surgeon uses to control whether a tool he is handling with his hands is on or off. The pedal design has a few problems with it, one of which is that this wired pedal creates a tripping hazard. Another common problem with the current design is the wired pedal often gets misplaced; more particular background on the issues of the current design can be found in our project proposal. These safety issues were brought to Surgical Electronic Solutions by a local surgeon and we have created an innovative design to solve these problems. How our team of five brought this design into a functioning prototype will be examined in this document and furthermore what we have each gained from our experiences in creating the MYOperator MK 1.0 will also be covered.

2. CURRENT STATE OF THE DEVICE

The MYOperator MK 1.0 can be broken down into three main components: the Calf Sleeve, the Hip Station and the Base Station. The Calf Sleeve has electrodes which sense small electrical potential signals from the muscle that are generated when the user performs a muscle engaging gesture with their foot. The EMG data is then processed and amplified by an analog signal processing circuit connected to an Arduino Uno. The Arduino Uno communicates, via Bluetooth, with a Raspberry Pi 2, which does our data processing and acts as the Base Station.

The Base Station interprets the EMG data sent from the Calf Sleeve and determines if the surgeon's tool should be on or off. The Base Station also takes in information from the Hip Station which enables the user to adjust the sensitivity and to turn the device on and off remotely. Surgical Electronic Solutions has integrated these components into one cohesive device and

created a wireless solution for a currently wired pedal problem in operating rooms everywhere. The following figures are the Solidworks representations of the current state of the device, separated into its three components.

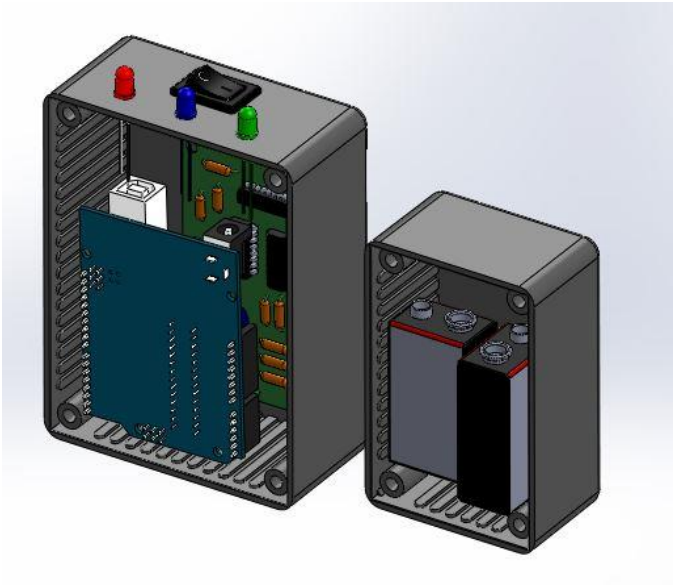

Figure 1: Solidworks Design of the Calf Sleeve

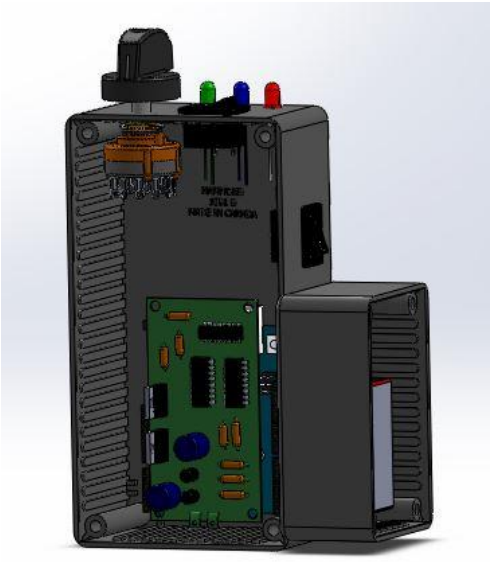

Figure 2: Solidworks Design of the Hip Station

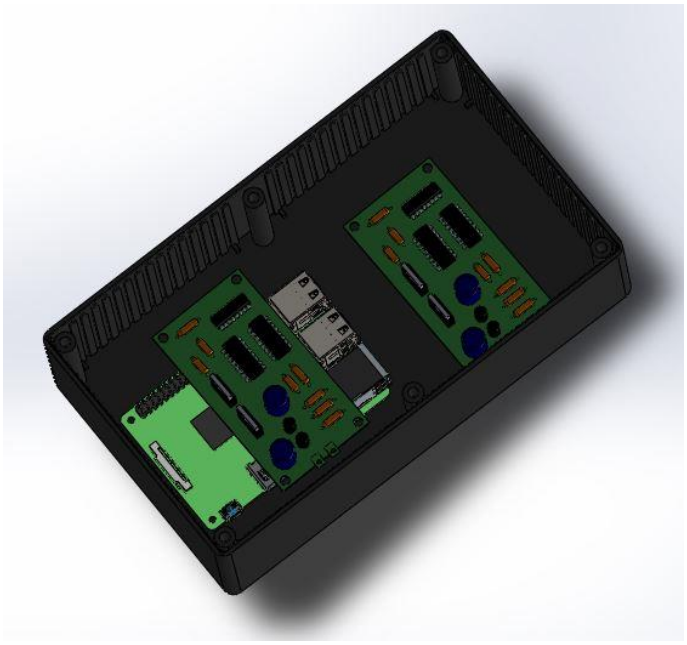

Figure 3: Solidworks Design of the Base Station

2.1 The Calf Sleeve

The Calf Sleeve is the main wearable component of the MYOperator and is comprised of a neoprene sleeve that contains a polystyrene enclosure with an EMG signal processing board, EMG electrodes, a battery, circuitry for a power switch and lights as well as the Arduino and its Bluetooth mate. The job of the Calf Sleeve is to acquire and send EMG data from the muscle activated by a foot gesture of the user. The user flexes their calf muscle when they desire their tool to be on, and the Calf Sleeve ensures their flex gets acquired as a signal. The enclosure attached to the outer portion of the sleeve contains everything except the electrodes, which are embedded into the sleeve itself so they can adhere to the user's skin for proper signal detection. There are three indicator lights on the enclosure, the green LED indicates when power is on, the blue LED indicates when a Bluetooth connection is established and the red LED indicates that the EMG data is being processed by the Base Station. The EMG signal processing board circuit has three stages to convert the EMG sensor output from its low voltage (50mV) AC signal to a DC voltage that the Arduino reads. The first stage contains a 2nd order high-pass Sallen-Key filter circuit which attenuates the 2V DC offset that comes from the raw EMG data collection, and then a non-

inverting amplifier and peak detector. The EMG Signal Processing Board is currently on a prototype board with the circuitry for the power switches and indicator lights. The EMG Signal Processing Board sends EMG data to an Arduino as a stream of DC voltages between 0-5V which are then sent via Bluetooth to the Base Station for signal processing.

2.2 The Base Station

The Base Station is a polystyrene box enclosure that includes our signal processor, a Raspberry Pi 2, as well as circuitry for indicator lights and a relay for interfacing with a DC motor which simulates a tool that the surgeon would use. The Base Station acquires data from the other two components of the MYOperator and computes whether to activate the tool or not. This component of the MYOperator can be placed anywhere within the operating room which is convenient for tool cord length (because the tool is directly connected to the Base Station) as well as a connection to an electrical outlet. The Base Station, needed to be able to directly communicate with the surgeon's tool and therefore we required the Raspberry Pi to not be a part of the wearable portions of the device. There are three indicator lights on the Base Station, a green LED indicating power on, a blue LED indicating a Bluetooth connection has been established between all of the components and a red LED that indicates the tool enable is on.

The wireless control of the Arduino Unos over Bluetooth by the Raspberry Pi 2 is possible by using the Windows Remote Arduino libraries. The Windows Remote Arduino library is built on a Firmata protocol and this allows the Raspberry Pi to issue commands and access information on the Arduino's GPIO pins. The software interprets incoming EMG data, disabling the tool based on the Hip Station On/Off button state and turning the tool off if the Bluetooth connection to either Arduino is lost. There is also an adjustable EMG interpretation based on the analog rotary sensitivity dial on the Hip Station.

2.3 The Hip Station

The Hip Station is another wearable component of our device. It is composed of circuitry for a sensitivity knob, power switch, tool enable switch, indicator lights, battery, Arduino and Bluetooth mate. All of these components are in polystyrene box enclosures and are worn at the user's hip by being attached by a clip to their scrubs. The Hip Station has a sensitivity knob on it that will

adjust the voltage level required for an activating signal to be read. This sensitivity knob has three positions which the surgeon can choose to his preference. There is a main power switch that will turn the Hip Station off, and if the power is on then there is a green LED illuminated. The other switch on the Hip Station is the tool enable switch. The tool enable switch controls the red LEDs on all of the components. When the switch is off, the red LEDs are off, and this indicates that the device will no longer be processing data that could enable the tool to be on. This allows the user to move freely around the room when he does not want to use it, without taking the device off. Similar to the other components there is a blue LED on the Hip Station to indicate when a Bluetooth pairing has been made successfully with the Base Station.

3. MARKET

Electrosurgical devices are a growing industry with worldwide sales expected to grow at Compound Annual Growth Rate (CAGR) of 5.9% to a total of $4 billion (USD) by 2019 [1]. As analyzed in our project proposal, the expected revenue from electrosurgery accessories, which is the category the MYOperator falls into, globally is approximately $160 million (USD) by 2019. The electrosurgery accessory category contains many different products and therefore it is hard to estimate an exact amount for the revenue of foot switches themselves, but it can be approximated to 10% of the $160 million (USD). This 10% is where Surgical Electronic Solutions will carve itself a place in the market.

The current leader in the foot switch market is Linemaster who claim “more than 90% of the world’s largest original equipment manufacturers turn to Linemaster for their medical grade foot controls [2].” Surgical Electronic Solutions has made a product that will theoretically outperform any product offered by Linemaster, and therefore we can cut into their sales and generate contracts with major electrosurgical device manufacturers so they use our product instead of Linemaster’s. Linemaster currently does not sell any type of wearable switch whereas what we have created is wearable, as well as wireless. Linemaster makes wireless foot switches, but since the MYOperator is also wireless, what was once an advantage for Linemaster over the competition will not be an advantage over the MYOperator.

4. MATERIALS & COST

The table below shows the materials and costs that go into the MYOperator. In the beginning of the term, we were awarded $626 by the ESSEF. The high cost of some parts come from needing only a few components, but is only available in ten or more at once. We have also made some mistakes in purchasing components and had to repurchase ones to fit our needs. The following is a table of our cost breakdown.

Table 1: Cost Breakdown

Component	Cost
Arduino Uno	$33.00
Bluetooth Hardware	$165.00
Raspberry Pi	$62.00
Grove EMG Kit	$55.00
Enclosures	$34.56
EMG Signal Processing Circuit	$105.57
Prototype Boards	$35.30
Miscellaneous components (batteries, electronics, switches etc.)	$198.77
Total	**$689.20**

As the table shows, the total amount spent for the MYOperator is about $689.20. We will be looking to the Wighton Fund for reimbursement of the amount over what ESSEF awarded. If the Wighton Fund does not fully cover the overage, the partners of SES have agreed to evenly split the remaining cost.

5. SCHEDULE

At the beginning of the semester our team sat down and created a Gantt chart which estimated the timing of our product development schedule. We broke down documentation as well as hardware and software deadlines. The majority of our original schedule was kept, and most milestones were made. One of the portions that is different from estimated to actual is “buy parts”. Originally we had planned to be done buying parts by the sixth week, when actually we ended up getting parts until the final week, whether it be new batteries because the old ones had insufficient power, or we killed some LEDs. The hardware portion for the Hip Station also ended up taking longer than the original two weeks that were allocated. The potentiometer knob on the Hip Station was what took longer to find, and getting started on the Hip Station was later in general because we were busy getting the other parts working. The following Figure is the original Gantt chart in blue and green bars, with red bars added for what was not kept on schedule.

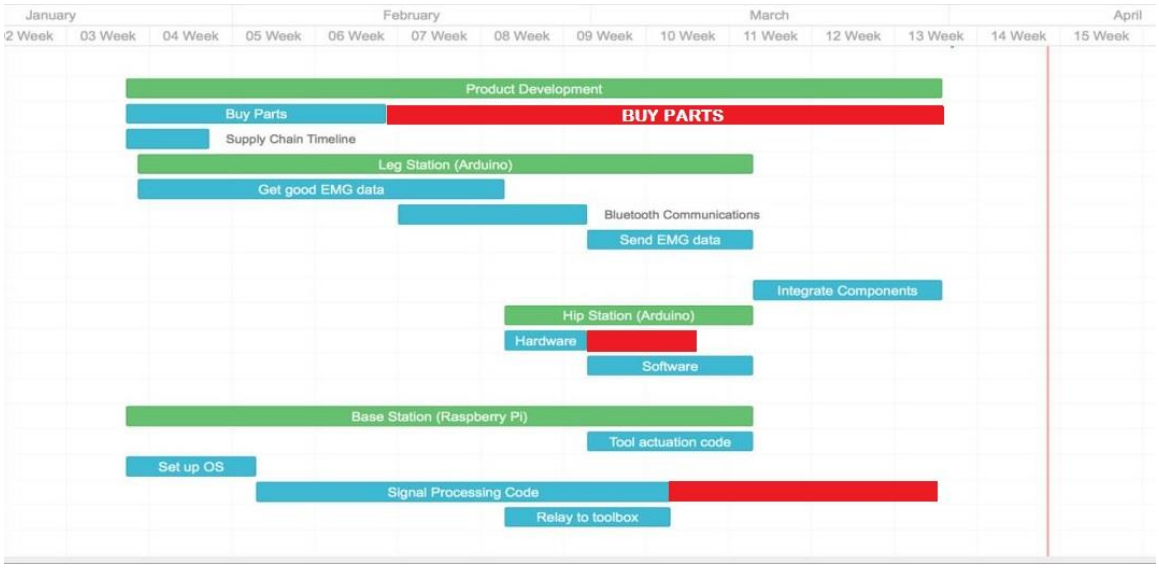

Figure 4: Updated Gantt Chart

6. PROBLEMS AND CHALLENGES

The design of the project is just as we envisioned from our proposal stage. There was one discrepancy from the original scope of the project. One function we hoped the final product would have was an accelerometer on the Calf Sleeve that could identify when the user was walking around and then shut off the software. This accelerometer idea ended up being discarded

because its implementation was not realized early enough in the project and would have meant too many changes in the rest of the design. The rest of our problems and challenges are broken down below.

6.1 Purchasing Parts

A lack of experience and research led us to buy a few unnecessary parts. To start we had issues with getting a proper Bluetooth mate for our needs. The original Bluetooth mate for the Arduino was not able to work with Windows IoT as well as it had low energy issues. The relay component of our project also posed as a challenge because of the power it requires. We had not considered the power output of the Raspberry Pi and so we purchased a relay with a 12V coil rating instead of 5V. When testing the relay circuit, it did not behave as we had expected it to, that is when we realized we had purchased the wrong relay. Another issue where power was the main problem came from when we were looking for switches for our product. The original switches had colored LEDs in them which was what we wanted for usability and aesthetics, but as it turned out the amount of power needed for those LEDs did not work with the rest of our circuitry and therefore we scrapped that idea and used regular, no LED switches. These issues were resolved as they came up, by testing and checking and then buying, and testing again.

6.2 Scheduling

One of the challenges we faced this semester was trying to get the group together often enough so that everything could be integrated and work could be done such that everyone was kept in the loop. One of our members was on full time co-op and was therefore not available during the day, and the remaining four were all taking full time class schedules along with having part time jobs and sports commitments. This challenge was overcome by all of us being flexible about our spare time and being fully committed to the project, and available via other means when we could not be physically present (ie. work on documentation if you are out of town, or be available via phone/text).

6.3 Manufacturing

After we got all of the breadboard circuits working properly we ran into problems with turning those into smaller, working circuits on prototype

boards. Configuring our circuits on the boards along with trying to keep design specification constraints proved to be a challenge. Loose connections after soldering and trying to keep all of the wiring contained without wrecking any connections was also a problem. These problems were resolved after making a few different prototype board designs and purchasing the enclosures after those boards were done.

7. GROUP DYNAMICS AND WORKLOAD DISTRIBUTION

The team at Surgical Electronic Solutions is a group of very dedicated individuals that have been working towards a common goal for the last 13 weeks. The five of us spent countless hours working together as well as individually or in smaller teams. Not a day went by that we were not communicating on the project, whether in person or otherwise. We maintained weekly meetings at the very least throughout the semester to keep everyone informed on each other’s progress.

Early in the semester, during the project proposal stage, we had a discussion on how each of us would contribute to the project based on our individual skillset. In practicality the broken down tasks were done on a volunteer basis and we tried to make sure they were done in at least teams of two and that we all completely understood what happened once the tasks were complete. Michael Wilkerson took a natural leader position as the CEO of Surgical Electronic Solutions and spearheaded the software development. Thomas Newton is the main hardware designer, and CQO. Darren Zwack is the CTO and took care of hardware development as well as a major role in the manufacturing of the end product. Gabrijela Mijatovic, as COO, participated in both software and hardware development while taking care of documentation and administrative tasks. Jonathan Feng is the CFO at Surgical Electronic Solutions and his main responsibilities were the finances, and enclosure design during manufacturing. The group dynamics overall were productive and polite, and if there was a difference of opinion in design or documentation aspects, they were talked through calmly and we made sure everyone's opinions were respected and heard.

The following is a breakdown of the workload distribution.

Table 2: Workload Distribution Chart

High-Level Task	Michael	Thomas	Darren	Gaby	Jonathan
Documentation Planning	X	X	X	XX	X
Documentation Writing	X	X	X	XX	X
Documentation Editing	X	XX	X	X	X
Administrative Tasks	X	X	X	XX	XX
Parts Sourcing	X	X	XX	X	X
Hip Station Circuit Design	X	X	XX	X	X
Base Station Circuit Design	XX	X	X	X	X
Calf Sleeve Circuit Design	X	XX	X	X	X
Circuit Testing	XX	XX	X	X	X
Soldering	XX	XX	X	X	X
Mechanical Design/Enclosures	X	X	XX	X	XX
Software Design	XX	X	X	X	X
Software Implementation	XX	X	X	X	X
Software Testing	XX	X	X	XX	X

Where XX = primary responsibility ; X = some or equal responsibility

8. CONCLUSION

Surgical Electronic Solutions has successfully created a wireless, wearable biomedical device for use as a power activator for surgical tools. Currently, the MYOperator can acquire EMG data and determine the strength of the signal. The EMG data is analyzed to rule whether the user intends to turn their tool on or off, and then the Base Station will activate the tool

accordingly. The current MYOperator takes in data the user inputs from the Hip Station on what level of sensitivity they want to be detected by the Base Station for when they flex their muscle. In order to avoid "false on" detection, the MYOperator MK 1.0 has a tool enable switch on the Hip Station that when turned off the processor will not be computing any EMG data that could activate the tool. In future plans to improve the MYOperator, Surgical Electronic Solutions will implement an accelerometer on the Calf Sleeve which will interpret when the user is walking around, or making undesirable movements. More followup for the project would be increased controllability of some of the code libraries, and potentially a full restructuring of the software. Additionally the Arduinos would be replaced by smaller, and more power efficient microcomputers that have built in Bluetooth capabilities.

REFERENCES

[1] Electrosurgery Market by Product - Generator, Electrosurgical Instruments (Vessel Sealing, Bipolar Forceps, Electrode, Suction Coagulator), Accessories, Surgery (General, Gynecology, Orthopedic, Cardiovascular, Cosmetic) - Global Forecasts to 2019. (2014, April). Retrieved April 12, 2016, from http://www.marketsandmarkets.com/Market-Reports/electrosurgery-market-142006761.html

[2] Linemaster Switch Corporation. "Linemaster Expertise," Linemaster Switch Corporation. Woodstock, CT. 2015. Retrieved April 12, 2016, http://cdn.thomasnet.com/ccp/00469908/52374.pdf

APPENDIX A: INDIVIDUAL REFLECTIONS

Michael Wilkerson's Reflection

I've always heard the horror stories of Capstone. The long nights of project work coupled with the ever lingering stress of documentation deadlines are things of legend in SFU Engineering, and for the most part, these things are true. What people forget to mention however, is just how rewarding an experience Capstone can be. I have learned so much over the four month progression of the MYOperator, gaining skills and building bonds that will stay with me forever.

It was a great experience getting to apply the skills I learned in the classroom to a project with such a wide scope. I was often surprised by the classes I would need to draw from to complete each required task, referring back to old textbooks and notes which had become an overflowing fountain of knowledge over my near decade of attendance at SFU. In terms of personal projects, these resources had lay dormant since their respective classes. Having always wanted to apply these skills to my own home projects, I was thrilled that working on Capstone had taught me where to acquire the appropriate parts for projects around the city and how to tailor my own protoboards and enclosures for specialised use. I also greatly appreciated that I was able to become an expert in something being that no one knows our product better than me and my group. As I mostly dealt with the software in C++ on the Raspberry Pi, I became the team expert on our code base and it was gratifying being able to answer any questions on the subject. These expertise were hard won, as they required hours and hours of work, but through this crucible, I gained an appreciation for how one can become so passionate about a product and how working long hours night after night on something one loves becomes less of a hardship.

These long hours would not have been nearly as survivable had it not been for the rest of the Surgical Electronic Solution team, who time and again exemplified high team synergy and standards. From spending our evenings communally writing documentation, to giving up our weekends to build our product, we have each of us given it our all. It was such a relief knowing I could count on my teammates to fulfill the promise of excellence we envisioned when we began SES, demonstrated continually by the exquisite

circuit work, robust code base and thorough documentation delivered by the team.

Darren Zwack's Reflection

The capstone course has been a challenging and rewarding experience. Throughout the 2015 Fall semester we got our 5 person team together and in the 2016 Spring semester began major development work on the MYOperator MK 1.0. Our group worked together very well overall as we were able to reach decisions based on a majority vote. During this project I used knowledge from a plethora of classes and gained valuable experience in regards to software development, hardware design, documentation, scheduling, team communication, and overcoming problems.

The most rewarding aspect of this project was to be able to use skills and knowledge developed throughout my degree and put it towards making a single product. I was able to expand upon my software skills by learning more about how the Arduino and the Raspberry Pi can be programmed to communicate over Bluetooth. My electrical knowledge was broadened through designing circuitry for the LED's and the switches, as well as the many times that Thomas explained to me the EMG filtering/amplifying circuit he made. The manufacturing stage was an area of work that took a lot longer than I expected. It required a lot of minute modifying of the enclosures to make sure all parts fit inside of them. The documentation was a big challenge in regards to the amount of time dedicated to the documents and my inexperience writing technical documents. As a result I believe that I have increased my writing abilities. In addition to the technical skills I developed, I also learned more about team dynamics when working on a technical project. Clear communication and a full effort from all group members is essential to a successful project.

Overall, Capstone, as frustrating and challenging as it was at times, was an amazing experience I will never forget. I am so proud of all my group members to be able to come together and develop a new product.

Gabrijela Mijatovic's Reflection

Creating the MYOperator MK 1.0 with my team has been a rewarding, and sometimes maddening experience. We maintained an interactive organization

between us throughout the semester, making most important decisions together through democracy. This was particularly valuable to me as most of my previous projects were structured for me already as they were assigned, and there was little room for creativity. Michael, Thomas, Darren and Jonathan are great teammates and I learned many things from each of them.

During this experience I strengthened my time management, task management, interpersonal communication, documentation/writing, and technical collaboration skills vastly. The documentation often felt never-ending and I found it unfortunate that this was the first time I had ever had to do so much. I also learned many new skills through the project, such as coding through Windows IoT. Using a Raspberry Pi and Arduino was also new to me, and finding the Windows Remote Arduino libraries online was a valuable learning experience. On the hardware side the practice soldering was valuable, as well as determining housing for our components.

One of the major lessons I learned was how to communicate with a team on the critical aspects of a long term project. We were all very good at telling each other our needs and schedules and did not take on any responsibilities that could not be accomplished. I learned how important it was to be comfortable enough within the group to ask for help when I needed it. My team was very supportive in this and I was able to go to them when I was struggling with any parts of the project, in particular with the software. Scheduling was another important skill I strengthened through this experience. Previously in my courses most deadlines were spread out and no one project involved so much attention to detail and time. The past 13 weeks I was taking two other ENSC courses besides 440W/305W and I found it challenging to keep up with those classes as well as give my all to documentation and the project. This resulted in an unexpected apathy towards my grades and a complete life overtaking by the Capstone project. The MYOperator was always on my mind, as I am sure it was on my teammates as well. Overall, this was a great experience and I only wish there could have been more like it throughout my degree.

Jonathan Feng's Reflection

Working with Michael, Tommy, Darren, and Gaby has been a wonderful experience. These past four months together has taught me a lot about my partners and also about what it is like to start a small business of our own. I

have witnessed the knowledge we have gathered throughout our university careers all being used in this project. Classes from CMPT 225 to ENSC 304 to ENSC 425 are all being used in some way during the planning to implementation phase. There were still a few things that weren't taught in our classes and we had to do our own trial and error to make it work. I'm sure we've all learned a lot throughout the course of the term.

I have had very little software development experience and was only limited to the knowledge I have from CMPT 128 and 225. However, through Michael's guidance, I learned a lot about the Windows IoT and coding on the Raspberry Pi as well as the Arduino. Since I did not have a lot of software knowledge, I spent most of my focus on the mechanical design as well as the circuitry of the three components of our device. Michael naturally took the lead on the Base Station since he had to be coding extensively with the Raspberry Pi. I put my focus into helping with the Base Station circuitry since we needed a way to activate a tool that requires much more current than what a Raspberry Pi can provide. From there I had to learn about relays and design a circuit that fits our needs. I did my research online and found that the Raspberry Pi had a 5V output pin, which means the relay had to have a coil rating of 5V. This is the knowledge I have acquired in ENSC 225 and a little bit of ENSC 489. Once the relay circuit is complete, the tool is ready to be activated by the Raspberry Pi. I did make some mistakes along the way because I purchased the wrong components, which delayed the completion time of the relay circuit by about a week. However, I finally managed to get the right components and build a proper circuit that works. I learned that I should do a bit more research on each component of the circuit instead of impulse buying the parts because it may lead to false hope and can become expensive. Luckily the components I purchased did not damage the Raspberry Pi or affect the overall outcome of the MYOperator.

Our group is in constant contact with each other through our phones and our messaging app, which I think is a very key point to our success. We also hold weekly meetings to meet in person and catch up on each other's progress with respect to the project. I'm fortunate enough to have such understanding partners if I needed to take some time to finish homework from another class and get back to finishing the MYOperator once I have the time. Communication is very important in any group and I saw it work amazingly within our group.

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Thomas Newton's Reflection

The proudest moments in my life have come from times when I have overcome massive challenges and now completing our MYOperator device for Capstone can definitely be added to that list. Capstone has been every bit as challenging and demanding as I expected, but also very rewarding. Even though it took over my life I will always remember Capstone as a very positive experience because the end result made up for all the time spent.

This is the last semester of my degree and it has been great to utilize so many things I've learned over the years for one project. For the first three years of my degree I felt like I didn't have the electronics knowledge or skills to make any projects even though it was what I had been studying. Co-op and Capstone have provided me with excellent opportunities over the last few years to develop my electronics abilities and I now feel like I can design and build new products. I look forward to doing so once I start my career. It is a very cool feeling to set out with a goal of making something you have no idea how to make, and then four months later have a working prototype.

My Capstone teammates were phenomenal all semester. We had several challenging times when we could have gotten angry with one another or turned on each other, but we always remained calm and worked through our problems logically. In one weekend we took our prototype from having nothing working, to everything working, and we hit about 10 problems in between. It was one of the best examples of teamwork I have ever been a part of. I am truly proud to call my teammates my friends and I look forward to working with them on future hobby projects.

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APPENDIX B: MEETING AGENDAS & MINUTES

Surgical Electronic Solutions

AGENDA

January 23, 2016
2:00pm-3:00pm
THE SUNNY ROOM - SFU

Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Items for Discussion:

- Various hardware solutions
- Software Design

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Surgical Electronic Solutions
MINUTES

January 23, 2016
2:00pm-3:00pm
THE SUNNY ROOM - SFU

In attendance: All group members

Purpose of Meeting: To discuss the project planning portion of our proposal

Problems to be solved

- Reading EMG Data
- Bluetooth communication between microcontrollers
- Send signal to tool
- Buy Parts
- PI Software work packages
    - ON/OFF
    - Sensitivity
    - Signal
    - Main Function
    - Designing and Testing
- Supply Chain
- Hip Switch Board Design
- Arduino Software
    - ON/OFF
    - Sensitivity
    - Send Signal

SURGICAL ELECTRONIC SOLUTIONS

Surgical Electronic Solutions
AGENDA

January 27, 2016
6:30pm-8:00pm
LAB 1

Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Items for Discussion:
- Review Proposal Document
- Talk about next document
- New Technical Tasks

Surgical Electronic Solutions
MINUTES

January 27, 2016
6:30pm-8:00pm
LAB 1

Present: Whole team
Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Minutes:

A. Updates

Thoughts on Design Proposal:
- Lesson learned: start earlier on the document. Give ourselves about a week for documents - Darren
- More milestones for what we are done and when in documentation
- Meet up after going over the rubric to discuss what each section should include
- Reviewing documents needs work. Do content live as a group in Drive. Do formatting on one computer with one person doing it so it is consistent. One person does the formatting and then sends out a formatted copy. Everyone reviews it and gives feedback to the

person who made the document and they make any changes necessary to the document. They are the sole editor of the word document.

B. What is next?

New Business:

- Next tasks
  - Functional Specifications, February 15th, the Monday after reading break.
    - February 3rd will be kickoff meeting for that document
    - everyone needs to review previous documents and the rubric
    - have an idea of what you want to work on
    - split up the document at kickoff meeting so everyone can do a section.
  - Technical
    - Windows IoT onto the PI
      - bluetooth connection with arduino. arduino acts as the slave.
      - getting PI and arduino talking over bluetooth.
      - Michael has already bought the parts to do this
      - Windows IoT is free.
      - Watch the video michael posted
    - Getting the EMG sensing
      - need to figure out how to get a good measurement from our EMG sensor
    - Version control for our code. Tortoise SVN. Michael will look into getting it.
    - Everyone needs to get Windows that wants to do software development
    - Someone set up an environment in Visual studio for our project, then everyone will use the exact same environment.
    - Get newest version of visual studio 2015.
    - need universal windows app
    - Darren will make sure we can get the parts we need when we need them
      - priority is checking we can get another bluetooth shield.

C. Next Meeting Date

The next meeting was arranged for February 3, 2016 at 6:30pm-7:30pm in Lab 1.

SURGICAL ELECTRONIC SOLUTIONS

Surgical Electronic Solutions
AGENDA

February 3, 2016
6:30pm-7:30pm
LAB 1

Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Items for Discussion:

- Software Progress
- Other Technical Progress
- EMG Hardware
- Functional Specification Responsibility Breakdown
- Parts to be bought

Surgical Electronic Solutions
MINUTES

February 3, 2016
6:30pm-7:30pm
LAB 1

Present: Whole team
Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Minutes:

A. Updates

Michael on software - It needs to be broken up. Too much research involved for all different components.

- Michael wants to handle overarching software
- Someone else do data processing and arduino communication - Gaby and Darren
- We are using Tortoise SVN for code

Want to work in groups of two for software.

- Might need second raspberry pi to make this more functional.
- Michael wants to fix his old one

Technical Progress

Need to start reading good EMG data and send to Arduino and figure out how to process the raw data on Pi

- another layer of digital signal processing ie Matlab, export C code
- best way to package the data ie header function, dll, executable so that Michael has a way to deal with it in his overall code & will add sensitivity
- GPIO stuff on IoT

Jono Darren and Gaby

- sending acquired analog data from Arduino to Pi - code on Pi
    - research
    - could just be get function
- processing digital emg data on Pi
    - read

Tom to work on EMG hardware
Software person can make assumptions on that to deal with the Arduino

Michael working on overarching software

- Bluetooth functions - Pi
- Getting data from Arduinos

B. What is next?

Breaking up Functional Specification Responsibilities

Gaby would like to do Sustainability & Letter of transmittal & Intro

- Research into what will be the end product and where it fits into the world

Need to break down the system into parts which all have separate specifications

- Hip clip
- calf sleeve
- EMG

- etc

Each will have its own section
- physical section
- electronic section
- applicable standards section

Also have overarching ones that apply to all
- Medical Standards
- Wireless communication standards

Versioning our product

Tom wants to do the overlying section of function specs
Michael want to do base station
Darren will do calf sleeve
Jono will do hip clip

Tom will be go-to for consistent language as he has experience doing functional specs

Parts

What should we buy
- Extra Raspberry Pi 2
- Bluetooth Shield
- Look into Base Shield

C. Next Meeting Date

The next meeting was arranged for February 10, 2016 at 7:30pm-8:30pm in Lab 1.

SURGICAL ELECTRONIC SOLUTIONS

Surgical Electronic Solutions
AGENDA

February 11, 2016
7:30pm-8:00pm
LAB 1

Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Items for Discussion:

- Signal Conditioning Circuit
- Code options
- Functional Specifications

Surgical Electronic Solutions
MINUTES

February 11, 2016
7:30pm-8:00pm
LAB 1

Present: Thomas, Darren, Michael, Gaby
Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Minutes:

A. Updates

- Thomas working on signal conditioning circuit
- Michael, Gaby and Darren researching different code options for software
- Reading over Jamal's comments for Functional Specification document

B. What is next?

- Teamwork inventory
- Functional Spec Document

C. Next Meeting Date

The next meeting was arranged for February 17, 2016 at 6:30pm-7:30pm in Lab 1.

SURGICAL ELECTRONIC SOLUTIONS

Surgical Electronic Solutions
AGENDA

February 17, 2016
8:30pm-9:00pm
LAB 1

Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Items for Discussion:
- Bluetooth
- Signal Conditioning
- Data processing
- Documentation

Surgical Electronic Solutions
MINUTES
February 17, 2016
8:30pm-9:30pm
LAB 1

Present: Whole team
Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Minutes:

A. Updates

Michael shows test circuit he has made for the bluetooth testing
- IoT libraries are communicating (Firmata open source library for arduino)
- Michael's goal for the weekend: Press button on Arduino and turn LED on in RPI circuit

Tommy is getting stuff for EMG hardware tomorrow
- Working on signal conditioning circuit
- Tommy gone this weekend

B. What is next?

Processing

- Darren: Average of last 10 samples => 100(some number) then send that to Pi which will decide to turn on
- Tom: Look into error checking bits
- Michael: Program on Arduino makes all its pins accessible by Pi
- Arduino side reads info from EMG (write class that takes data argument for true false)
- Speed Arduino reads in , plus amount of time it takes to process the class
- Go through libraries this weekend (sample data examples)
- make class that gets called by main etc.

Talking about how Functional Specs went

- Reviewing the way we did this time was better

Next Document: Due March 7, Presentation March 4

- Design Specs (15-20 pages)
- Our Review session is on March 4th (slideshow)

D. Next Meeting Date

Jonathan Gaby and Darren meeting on Friday the 19th to deal with the processing.
The next meeting was arranged for February 24, 2016 at 7:30pm-8:30pm in Lab 1.

SURGICAL ELECTRONIC SOLUTIONS

Surgical Electronic Solutions
AGENDA

February 24, 2016
6:30pm-7:30pm
LAB 1

Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Items for Discussion:
- Software
- Signal Conditioning Circuit
- Hip Station

Surgical Electronic Solutions
MINUTES
February 24, 2016
6:30pm-7:30pm
LAB 1

Present: Whole team
Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Minutes:

A. Updates

Michael goes over what he has been through
- Sunday he worked on getting the Pi to send a Bluetooth signal
- Using remote bluetooth libraries from Microsoft
- Working in C# but more complicated in C++
- "Newget" gets libraries and incorporates them automatically - fine for C#
- C++ doesn't use "Newget" so he pulled things out manually from C# libraries
- Will turn on light at this point
- Automatic pairing via Bluetooth - perfect for us
- Will be getting caught up on background stuff and then will decide which to use (C# or C++)

Darren

- Researched code. Made function for our data.
- What will the data look like? How many values? How fast is it coming in?
- Buffering for bit stream solution
- Gesture question: Flew on and hold to keep on? Yes.
- Michael suggests testing our code with a DC voltage supply. Current limit it and read it into an Arduino. (values of 1-1024 digital, referenced voltages between 0-5V)

Tommy

- Has videos
- Shows peak detection and all readings
- Unexpected sensor problems - not what he wanted to see - but is working with it

Gaby

- Hip Station update
- Researching code and worked with Darren on above

Jonathan

- Block diagram/Fritzing for Hip Station

B. What is next?

- Hardware for Hip Station
- Software
- Acquiring useful data from EMG

C. Next Meeting Date

The next meeting was arranged for March 2, 2016 at 7:30pm-8:30pm in Lab 1.

SURGICAL ELECTRONIC SOLUTIONS

Surgical Electronic Solutions
AGENDA

March 2, 2016
6:30pm-8:30pm
LAB 1

Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Items for Discussion:

- Individual Updates
- Planning for tool integration
- Plan for integration of software and hardware

Surgical Electronic Solutions
MINUTES

March 2, 2016
6:30pm-8:30pm
LAB 1

Present: Whole team
Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Minutes:

A. Updates

Michael: He worked on the Pi. Broke up all the devices into different classes instead of one big main function

- Researched code - not using much Arduino library stuff
- Windows task manager deals with event handling.
- Showed Darren and Gaby on Monday and talked about code
- Furthermore : Will implement a second thread for analog stuff. Wants to check stuff with a light sensor he has.
- Design documentation

Tommy: Met up with Darren and Gaby last Thursday

- Signal conditioning circuit with amplification etc
- Plugged this into Arduino analog input and had that sense our EMG data
- Both boards had to be grounded to same reference
- Tested on Darrens calf - higher range when lifting toes ie front calf muscles
- Furthermore: Calf 0-40 values therefore will change amplification stage to be relative to what we saw on the calf as opposed to what we saw on the bicep. (Maximize range)
- Bring calf sleeve, get more sticky pad things

Worlds collide on Sunday!

Darren: Did things with Tommy, Michael and Gaby
Jono: Did fritzing for Hip Station

- Needs to figure out Bovie interface. Between RPi and tool.
- Figure out relay things (Rpi turns thing on via relay)

Gaby: Did things with Tommy, Michael and Darren

- Started presentation and document

B. What is next?

System Integration

C. Next Meeting Date

The next meeting was arranged for March 16, 2016 at 6:30pm-7:30pm in Lab 1.

SURGICAL ELECTRONIC SOLUTIONS

Surgical Electronic Solutions
AGENDA

March 16, 2016
6:30pm-8:00pm
LAB 1

Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Items for Discussion:
- Individual Updates
- Remediation on scope of project

Surgical Electronic Solutions
MINUTES

March 16, 2016
6:30pm-8:00pm
LAB 1

Present: Whole team
Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Minutes:

A. Updates

Thomas - Making the signal condition circuit on a proto board aka as small as possible
Jono - working on relay, needs to work on solenoid to turn on switch (finish by weekend)
Michael - Must get both Arduinos going on the Bluetooth
Darren - Proto boarding the hip station
- Get a potentiometer knob that clicks in place

Gaby - Code improvements: Exception handling, stability, create threading (threadpool)
- proto board relay

B. What is next?

Scrapping accelerometer business - no time

Meeting Saturday 10:30 - 3

- Goals
- All proto boarding started - all base things
- Look into enclosures
- Tool → hoop up DC motor

C. Next Meeting Date

The next meeting was arranged for March 23, 2016 at 6:30pm-7:30pm in Lab 1.

SURGICAL ELECTRONIC SOLUTIONS

Surgical Electronic Solutions
AGENDA

March 23, 2016
6:30pm-7:30pm
LAB 1

Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Items for Discussion:
- Update on progress
- Plans for upcoming
- Written progress report

Surgical Electronic Solutions
MINUTES

March 23, 2016
6:30pm-7:30pm
LAB 1

Present: Whole team
Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Minutes:

A. Updates

Michael explains code problems Gaby and him were trying to solve last night.
Goals for the weekend - everything needs to be protoboarded and then we can get working on enclosures

Tommy - protoboarded signal conditioning circuit, has unwanted DC offset, will put in a better filter (2nd order) in first stage
- Will be ready for the weekend to put into calf sleeve

Written progress report and group evaluations - 8pm Thursday

Design thing - Darren wants to know how many sensitivity positions we want

- All decided 3 is good

B. What is next?

- Jono working on relay
- Darren working on sensitivity
- Michael working on sensitivity and code
- Gaby working on soldering hip station etc

C. Next Meeting Date

The next meeting was arranged for March 30, 2016 at 6:30pm-7:30pm in Lab 1.

SURGICAL ELECTRONIC SOLUTIONS

Surgical Electronic Solutions
AGENDA

March 30, 2016
8:30pm-9:30pm
LAB 1

Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Items for Discussion:
- Remaining Tasks and Anticipated Completion Dates
- Updates
- Plans for upcoming days

Surgical Electronic Solutions

MINUTES

March 30, 2016
8:30pm-9:30pm
LAB 1

Present: Whole team
Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Minutes:

A. Remaining Tasks and Anticipated Completion Dates

- Get enclosures and fit circuits in them, April 2nd
- Finalize Soldering, April 3rd
- Sew Onto Calf Sleeve,
- Post-Mortem, April 14th

- Minutes, April 14th
- Schedule Interview with Dr. Tom, April 14th
- Powerpoint presentation, April 14th
- Organize catering, April 14th
- Film/Edit Video, April 14th
- Take nice pictures, April 14th
- Pre-semester notes, April 14th

B. Updates

- All pre-enclosure soldering done other than emg signal processing circuit
- Need to buy enclosures
- Once they're bought we need to solder the LEDs and switches to them
- Software
    - Pretty good on bugs
        - Bluetooth may never connect on start-up. When it doesn't connect we just restart it and try again
    - Need to set sensitivity thresholds
- Need to get final placements for sensors so michael's mom can sew it on

C. What is next?

- Buy enclosures: @ rp electronics 3:30 PM Friday, Darren and Tommy and Jono, Gaby scouted one out.

D. Next Meeting Date

The next meeting was arranged for April 4, 2016 at 7:30pm-8:30pm in Lab 1.

SURGICAL ELECTRONIC SOLUTIONS

Surgical Electronic Solutions
AGENDA

April 4, 2016
7:30pm-8:00pm
LAB 1

Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Items for Discussion:

- Soldering
- Enclosures
- Design Specification meeting

Surgical Electronic Solutions
MINUTES

April 4, 2016
7:30pm-8:00pm
LAB 1

Present: Whole team
Purpose of Meeting: To discuss the latest progress as well as what needs to be done still

Minutes:

A. Updates

- Pre-enclosure soldering done
- Enclosures purchased and components in process of being fitted
- Discuss Design Spec re-write and Tom's meeting with Professor Whitmore
- Will be doing a re-write

B. What is next?

- Still need to get final placements for sensors so Michael's mom can sew them in
- Testing

C. Next Meeting Date

The next meeting was arranged for April 6, 2016 at 6:30pm-7:30pm in Lab 1.