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December 18, 2009

Dr. John Bird
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Re: ENSC 440 Ecological Monitoring System Post-Mortem

Dear Dr. Bird:

The attached document outlines the undergone design process for our proposed ecological monitoring system, the ECOmonitor. Our project entails the monitoring of environmental conditions ($CO_2$ levels, temperature etc.) in remote areas using a wireless data 'hopping' technology.

This document summarizes the design and development process of the ECOmonitor. We discuss the current state of the device, deviations from the design specifications and future design plans. The budgetary and time constraints are outlined and finally, the ECOmonitoring Team provides their interpersonal technical experiences.

The ECOmonitoring Technologies Inc. team consists of four innovative and passionate engineers: Ryan Cimoszko, Amandeep Grewal, Brian Lee and myself, Harvir Mann. If you have any questions or concerns about our post-mortem, please feel free to contact me by e-mail at eco-mt@sfu.ca.

Sincerely,

Harvir Mann
President and CEO
ECOmonitoring Technologies Inc.

Enclosure: *Ecological Monitoring System Post-Mortem*


# ECOLOGICAL MONITORING SYSTEM

## POST-MORTEM

**Project Team:** Ryan Cimoszko
Amandeep Grewal
Brian Lee
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**Submitted to:** Dr. John Bird – ENSC 440
Steve Whitmore – ENSC 305
School of Engineering Science

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**Revision:** 1.1

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# GLOSSARY

| | |
|---|---|
| **ADC** | Analog-to-Digital Converter |
| **HTML** | Hyper Text Markup Language |
| **LED** | Light-Emitting Diode |
| **PC** | Personal Computer |
| **PHP** | PHP: Hypertext Preprocessor |

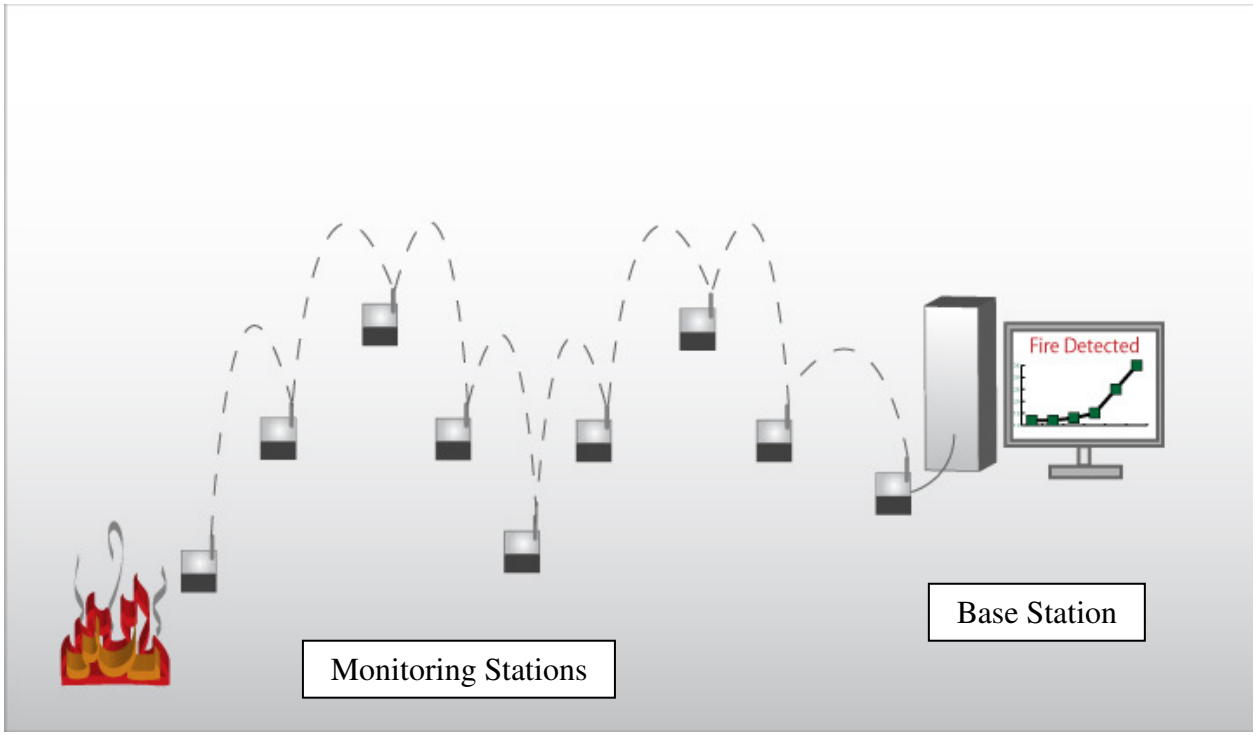
# 1.0 INTRODUCTION

The ECOmonitoring Technologies team: Harvir Mann, Brian Lee, Amandeep Grewal and Ryan Cimoszko have dedicated the past 13 weeks conceptualizing and constructing the ECOmonitor. This document outlines the design process for this device which includes the current state, deviation from the design and future plans. Also, budgetary and time constraints are discussed as well as each member's individual experience recapping the highs and lows during the ECOmonitor development.

# 2.0 CURRENT STATE OF DEVICE

The ECOmonitoring team was able to create the ECOmonitor system which was described in the project proposal. The ECOmonitor is a monitoring system which can be used to for detection and monitoring of environmental conditions in remote areas. A basic system overview is shown in **Figure 1**.

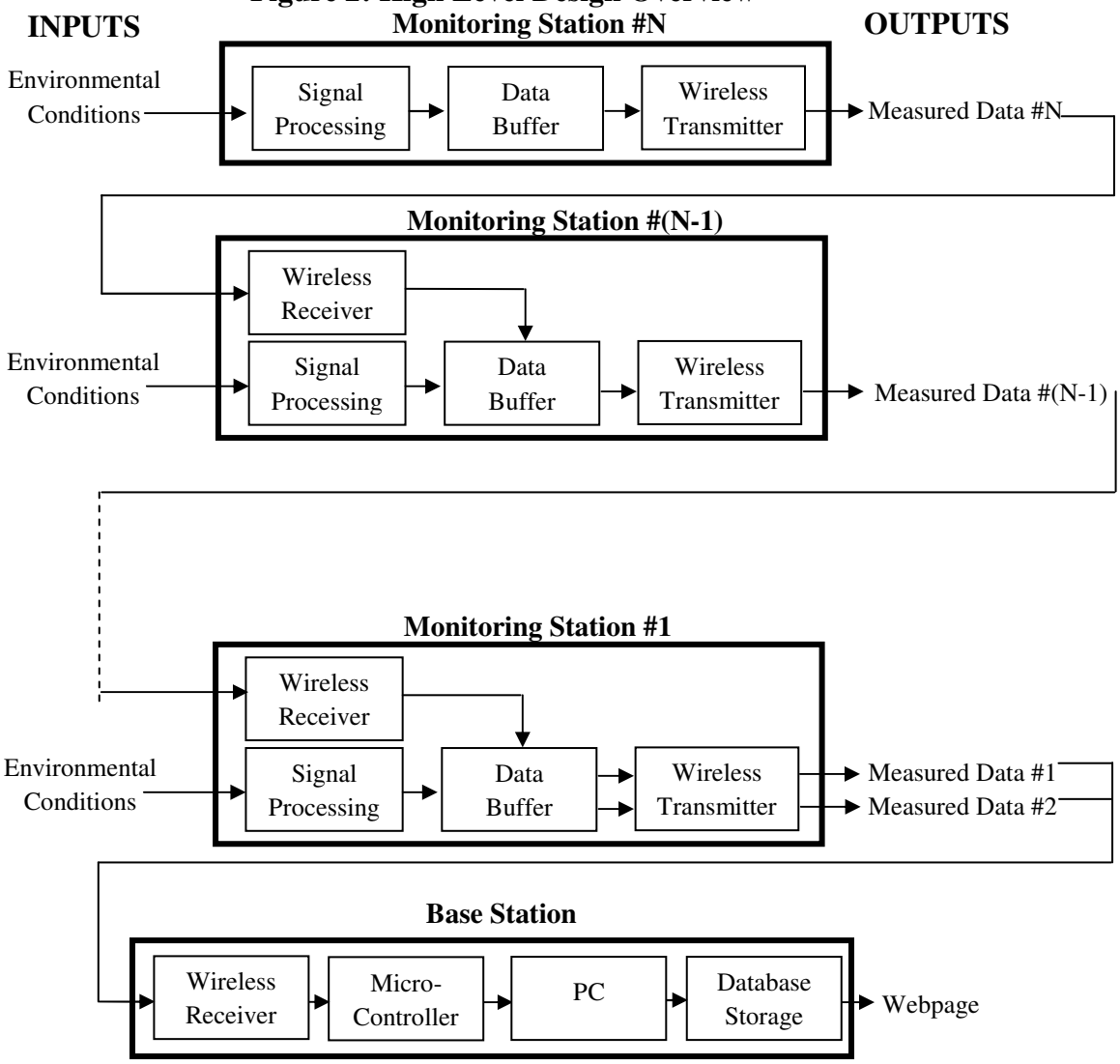
**Figure 1: System Overview**




The system consists of a base station, multiple monitoring stations, database, and a real-time web interface. As long as the user has access to the internet, they can monitor environmental conditions in remote areas.

The high level system design is shown in **Figure 2.**

**Figure 2: High Level Design Overview**




Each monitoring station takes inputs from the environment through the use of a sensor array. The input signals produced from this sensor array are then processed within the micro-controller and placed in a data buffer internal to the microcontroller RAM memory. For the humidity and temperature sensors the data is retrieved via a Two-Wire interface, and for the $CO_2$ sensor an Analog-to-Digital convertor will be used to condition the signal before it is sent to the microcontroller. This data is stored in the microcontroller buffer until a flag is set giving the micro-controller permission to feed the contents of its buffer into the wireless transmitter. The

specifics of how this permission is given to the micro-controller are shown in wireless 'hopping' algorithm figure and microcontroller figure. At the base station the data will be received via the wireless transceiver and relayed through the microcontroller which will then communicate with the host PC. The host PC will receive the data through a python interface and store it onto the database. The database will be tied to the webpage which will display all of the gathered data.

# 3.0 DEVIATION OF DEVICE

## 3.1 OVERALL SYSTEM

Overall, we were able to create the ECOmonitor without much deviation from our initial design specs. There were a few minor changes we had to make to make to our design because of budget constraints and functionality issues.

## 3.2 SENSORS

There weren't any deviations in the sensors used for the ECOmonitor. The $CO_2$, humidity, and temperature sensors all worked fine so we didn't need to make any changes. However, the datasheet for the $CO_2$ sensors were incomplete so it took a bit longer than anticipated to get them functioning properly.

## 3.3 MICROCONTROLLER

The microcontroller we chose to go with was the ATMega32. This is the same one we anticipated using in the start since one of our group members had previously worked with this microcontroller and found it worked well.

## 3.4 WIRELESS TRANSCEIVER

We planned on using the XBee 802.15.4 RF module and it was the one that we ended up using. It had a great range and was easy to work with, making it a perfect fit for our project. The one issue we had with this specific model was that each of wireless units didn't have a unique ID called a PANID. The ones that had the PANDID built in had a cost in excessive of $600 each, which was way out of our budget. So we had to settle for the cheaper module and manually created a PANID for each. The PANID was essential for the proper functioning of our communication algorithm.

We were able to successfully implement adaptive hopping for station two only. Meaning, when station two failed, station one would still be able to send data to the base station. Also when station two was revived, our system was able to continue working as before. However, issues arose when we were implementing adaptive hopping for station one. When station one failed,

station two was still able to send data to the base station, however, when station one was revived, station one was not able to send data.

### 3.5 DATABASE AND SERVER

The database design that we used was the same as we had originally planned to use. We used a MySQL server on a Linux based server. The only deviation we had was that we had to use a Linux O/S based server to be able to connect and transmit data remotely to the server. However the difference in operating systems didn't cause many problems and we were able to run and manage the database as we originally planned.

### 3.6 WEBSITE

The website was designed as originally planned with PHP used for server-side scripting allowing communication from the MySQL server and webpage interface. The web template was designed with HTML and Javascript was used for the graphing capabilities. The user is able to view the recorded data in real-time depending on the selected station, time interval and environmental condition.

## 4.0 FUTURE PLANS

### 4.1 OVERALL SYSTEM

In future designs, the ECOmonitor will be able to support a wide range of sensors based on the specific application. The user will be able to simply swap out the sensors which fit to the application they want to use them for. Very little adjustments will be needed to be made when the sensors are swapped, thus making it very user friendly.

### 4.2 SENSORS

The one thing we would change is the $CO_2$ sensor which we were used in our prototype. Due to budget constraints, we had to settle for less accurate sensors, and it turned out that our sensors were a bit too sensitive. In the future we will use NDIR (Non-Dispersive Infrared) sensors. These sensors work by modulating the IR signal from the source so that thermal background signals can be offset, which results in a much more accurate reading. The price tag for these sensors is $ 150 each.

### 4.3 MICROCONTROLLER

The ATMega32 microcontroller worked great and we will be using it in future implementations of the ECOmonitor.

### 4.4 WIRELESS TRANSCEIVER

In the future we will stick with the XBee-PRO XCS RF multipoint wireless module. Even though we had to create our own PANID for each station, it still worked as we had hoped. The cost factor for the higher model is an issue so we will stick with the module used in the prototype.

### 4.5 DATABASE AND SERVER

The database and server that we used worked well for us so we won't be making any major changes to them in the future. At first we weren't sure about using a Linux O/S based server but it ended working great for us and thus we will use it in the future. The database software MySQL will also be used in future implementations.

### 4.6 WEBSITE

The future development of the website should include log-in capabilities for multiple users, customizable graphs dependent on the sensors used and multiple graphs per page. A system map could be implemented to visually see where the monitoring stations have been placed and determine the status of each station.

## 5.0 BUDGETARY AND TIME CONSTRAINTS

### 5.1 BUDGET

The project was funded mainly through ESSEF and the remaining costs were split among the team members. **Table 1** shows the estimated costs of the required materials as they compare to the actual amount spent.

**Table 1: Estimated and Actual costs incurred for project components**

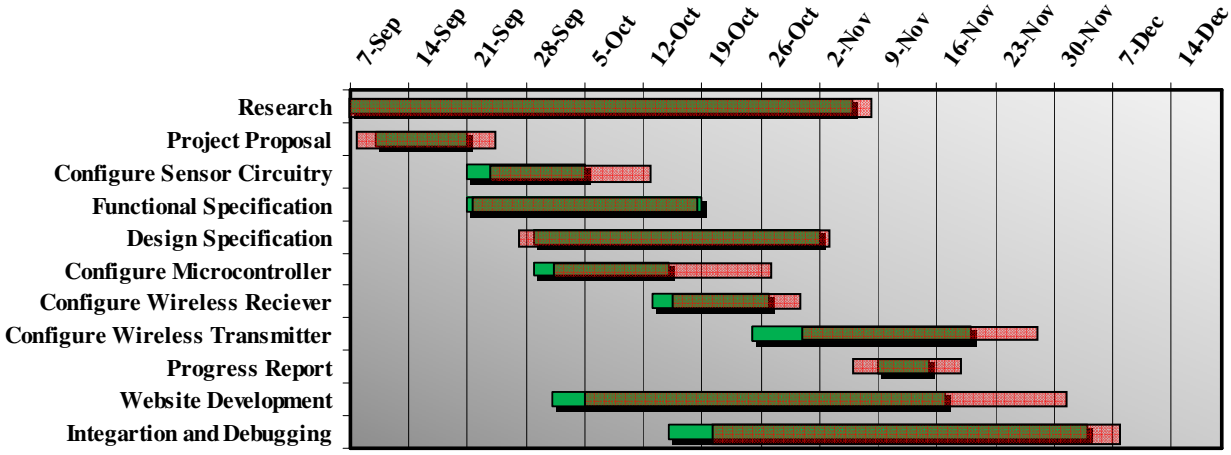
| Required Materials | Estimated Costs | Actual Cost |
|---|---|---|
| Solar Panels | $170 | - (Used 6V battery instead) |
| Wireless Transmitters | $80 | $100 |
| Developmental kit | $200 | $210 |
| Microcontrollers | $300 | $300 |
| CO2 Sensors | $40 | $95 |
| Temperature Sensors | $30 | $20 |
| Humidity Sensors | $80 | $180 |
| Server Space | - | $35 |
| ADC | - | $20 |
| Miscellaneous | $40 | $152 |
| **Total Cost:** | **$940** | **$1112** |

Overall, ECOmonitoring Technologies spent slightly more than the estimated costs but still within a reasonable amount. The main reason for the deviation from the estimated amount was the result of unsuspecting malfunctioning of parts and increased shipping expenses in order to receive parts in a timely fashion. Also, we had to order a couple more humidity sensors since one of ours stopped working, which had a cost of $ 45 associated with it. We also underestimated the cost for the casing that our final product would go into and miscellaneous parts like the casing for each of the stations. In the end we were able to cover the costs by using the $ 800 funded through the ESSEF and each member putting in $ 103.

## 5.2 TIME

The estimated completion of the ECOmonitor was proposed for December 1, 2009. The following Gantt chart illustrates the proposed timeline for the various developmental stages as they compare to our actual amount of time spent. The proposed time for each stage is in green and the actual amount of time spent is in red.

**Figure 3: Gantt Chart**




We were able to finish the final testing and integration by December 14, 2009. We had anticipated that the final testing would be complete by December 01, 2009 but we ran into a few issues. We started off with five group members, but had let one member go because he wasn't willing to contribute to the group. Before releasing him, we gave him one more chance to show us that he is capable of doing work, but he never let us evaluate him. He was supposed to have some work done by a certain date but he never showed up for the meeting which we had schedule with him. We tried contacting him numerous times, via email and telephone, but he never replied or even attempted to contact any of the other group members. We found out later that he had dropped the course so we had to move one member from hardware to the software side of the project. This miscue set our group back a couple of weeks of work since one of the tasks he was supposed to do was required to be completed before the other group members could do their work. He also decided to delete all of the programming that 2 team members had worked hard on. The scripts were saved and backed up on a server space the group member had rented on behalf of the team. Even the server space he rented wasn't right for our application, since it didn't allow remote access to the database. We were using it for testing our code and were going to rent one later that fit our requirements. This set our group back another week since all of the software components were saved and backed up on the server. We managed to

find a server space provider that had exactly what we needed but it took an extra five days to get it all setup and ready to run.

We also had an issue with our $CO_2$ sensors. The order was put in for them in early October but they never arrived until November. The company which we originally ordered them from had run out of sensors but never informed us. We waited a couple of weeks, since they were coming in from overseas, and then contacted the company. They told us that the parts would be in early December so we had to find a new place to buy them from since our projected deadline was December 1. After searching through numerous websites for $CO_2$ sensors, we finally managed to find some that fit within our budget and had them express delivered to allow our team to get back on track. Even through all of this adversity, our team managed to finish the project only five days later than originally anticipated. This was the result of great teamwork and everyone working long days.

# 6.0 INTERPERSONAL AND TECHNICAL EXPERIENCE

## 6.1 HARVIR MANN

During the course of planning, scheduling and ultimately executing the design of the eco-monitoring project I have learned a great deal about the obstacles and work that goes into taking a project from concept to reality. As the CEO I gained knowledge not only from a technical aspect, but gained invaluable experience in dealing with group dynamics and project planning.

From a technical perspective my responsibilities consisted mainly on working on the hardware and firmware aspects of the project. Brian and I worked in conjunction in creating the wireless hopping algorithm and the overall network topology. In working a technical project of this scale with another group member I was able to see new methods of approaching problems as well as able to discuss the feasibility of my ideas. Being able to investigate my ideas in this manner made the learned process much less frustrating. During debugging of the wireless hopping I was able to familiarize myself with using the Atmel series of microcontrollers. During integration of the wireless Xbee module with the database I was also able to learn the Python programming language and implemented a script to receive inputs perform all of the necessary data conversions and store them in the database.

Throughout the semester the group as currently constituted maintained good communication lines in terms of what we were working on and what needed to be completed. We communication issues with a former member of our group, and that ultimately led to his exclusion from further involvement in the ECOmonitoring project. In spite of this failure I found that on a large scale we worked exceptionally well together. One thing I believe I would try to

improve upon if repeating this course is to create the full design specification before order all of the parts. In creating the design specifications many issues that are otherwise overlooked are noticed and as a result a more thorough and precise parts list can be compiled. In addition to this the design specification provided a detailed block diagram of the components that the entire system would be broken down into.

## 6.2 BRIAN LEE

First of all, I would like to say I appreciate the fact that such a great course exists in engineering science faculty on this university. The Capstone project has led me to be involved in the whole product development process: Brainstorming ideas, making proposals, specifying functional requirements, composing design specs, writing out progress reports, and finally the final product launch which would be the final presentation!.

While spending more and more time on engineering designs and troubleshooting problems, I always realize how much experience is important in engineering. During this project, if we were more experienced than what we were, we would have gone through testing some of the most obvious corner cases and we would not have had to spend so much time near the end trying to figure out our design problems that we thought for sure would not be problems in the near beginning of project timeline. I obviously feel like I have still very long ways to go, but this project has definitely taught me a yet higher level of future-problems-anticipating ability.

On the technical side, my duties included working on electrical circuit designs, circuit layouts, writing firmware, sensors, overall wireless hopping network, and designing bridges between each component in our project. Other than my main duties, I was able to use my previous work experience knowledge to help out on Website and Database developments. I was able to take on most of my duties without too much difficulty because I have had work experiences in almost every aspect of this project. The only area I was not so experienced in was the wireless hopping network, which indeed gave me and my group members most of the headaches. However, a team of sophisticated engineers should have no things impossible to do! Harvir and I worked jointly very well together, sharing and discussing our opinions almost every day, to come to solve all of these impossible-looking wireless network problems. We even felt like we could build a wireless router right away!

Throughout the whole project, I was quite satisfied with the team and also every individual member in our group on their work ethics. Although not everyone, including me, was perfect for each other, we were able to understand each other better and moved on to creating a stronger bond to the point that we just enjoyed working with each other a lot! I really look forward to going on a big party after this project ends because these guys are hilarious!

Finally, I do feel sorry for one of the group members who had to be excluded from our team, but at the same time I feel that it would be beneficial for him to not take this course yet since he is technically and mentally not ready for this course yet.

## 6.3 AMANDEEP GREWAL

It was a pleasure working with the four senior level engineering students that remained in the ECOmonitor team. From this experience I was able to learn about group dynamics, in addition to technical skills. Working on this project really allowed us to apply the various knowledge and skills that we have developed through our undergraduate studies to create a coherent product.

Our group met quite regularly to work on our project and to discuss any issues which we might be having with a specific part of the project. Planning and meeting deadlines is extremely important since deviation for either can lead to bad ramifications. I have learned that it is important to leave yourself at least a couple of weeks for integrating and testing the complete system. Many issues can arise during this phase, which weren't apparent before, and they can be very time consuming and frustrating. In addition, communication is fairly important when working in a team. Team communication is not only important for sharing each others designs and concerns, but it can be a good way to get help if you are stuck on a specific task.

Initially I was in charge of working with the sensors for our system, but due to some unforeseen issues with a former team member I was moved to software side of the project. I was in charge of managing the server, database, and communication between our base station and the server/database combo. From working with software I have learned about Python, PHP, and the Putty scripting languages. At first Python was a bit confusing to use since its syntax was slightly different than other languages that I have worked with but after picking up the syntax differences I found it to be a fairly useful and easy to use tool, which I will use in future projects. I have also gained some knowledge about servers and databases. By using the Putty we were able to create a tunnel to our remote server, which allowed us to send seamless data through a secured shell (SSH).

For the most part, our group worked well together and was able to meet most of our deadlines, which were set out in our project proposal. We did run into some issues, as all groups do, but we were able to deal with them without much conflict in a professional manner. In the future I would definitely work with this group again.

## 6.4 RYAN CIMOSZKO

Throughout this semester, I've learned the many aspects of engineering product development: writing proposals, determining functional specifications, designing the product, and finally implementing the design. While working with the group members, I've also learned non-technical skills such as teamwork, dealing with conflict and understanding team dynamics.

My duties for the project consisted mainly of website development, database management, communication between the base station and database, as well as the final editing for the technical documents. My co-op experienced helped be greatly in putting together polished technical reports. On the technical side, prior to ENSC 440 my knowledge of web development consisted of simply basic HTML. After 13 months working on this project, I was able to learn PHP, MySQL and Javascript and feel confident in my web development abilities. I learned how valuable it was to test the functionality prior to fully implementing it, as there were instances where I fully implemented a design that I thought would work seamlessly, but turned out to be flawed due to the communication between server-side and client-side scripting.

As a group we all understood that each individual had other priorities that they would have to attend to. Since there were two individuals working on both the software and hardware sides, as one individual was unable to work, there was always another that was willing to step up. The group as a whole worked well together and was able to meet all the deadlines (except the demo date). A couple areas where we could have improved on were the completion of the design specifications as well the testing of the corner cases where we were pressed for time due to poor time management.

As you know, a group member was let go throughout the project life due to his unwillingness to contribute to the group. Before to our decision, I personally wanted to expel him from the group immediately after his behavior. However, as a group we decided to deal with this situation by giving him a final opportunity to contribute. Through this, I learned how to deal with situations as the aforementioned professionally and rationally.

Overall the group was a pleasure to work and it was interesting to see the different technical skills that each member possessed all work together for one common goal. We came to understand each other better and were able to not only worked well together but also enjoyed to time spent.