April 15, 2016

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
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Re: Post Mortem for AlarmSense System

Dear Dr. Rawicz

Attached you will find the document 'Post Mortem for AlarmSense System', which outlines the process and results for our ENSC 440W project. Our goal was to design a system protocol to allow workers in noisy industrial settings to remain safe and work efficiently while protecting their hearing.

The Post Mortem includes the original business case, budget, design, problems, and personal reflections on our project. This document serves as the conclusion to four months of development on the AlarmSense System.

Ekho Systems is composed of four fourth year engineering students: Russell McLellan, Taylor Robson, Gordon Ho, and Adrian Tanskanen. If you have any questions or concerns, please contact us by email at rmclella@sfu.ca.

Sincerely,
Russell McLellan
Ekho Systems

Post Mortem for AlarmSense System

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Executive Summary

Workplace safety is becoming one of the biggest, if not the biggest, concern for the men and women working in the trades and resource industries. Ever present are the rules and safety regulations, which while necessary, can be cumbersome and often cause new issues to arise. Ekho Systems seek to make dangerous workplaces safer and more efficient by allowing seamless communication between workers, while ensuring that important emergency signals never go unheard through optimal design of the personal protective equipment (PPE).

The AlarmSense system integrates hearing protection, advanced communication, and modern functionality into a single unit, with the unique benefit that allows for emergency signals to bypass the hearing protection. Active noise cancelling attenuates industrial noise, but certain frequencies corresponding to worksite alarms are passed through. The frequencies of the alarms will be selected by the user of the AlarmSense System to allow for its use across all worksites.

In addition to passing through alarms, the AlarmSense System allows the users to communicate to each other as easily and intuitively as in a quiet environment. A throat microphone will record and send speech from worker to worker, improving the cohesiveness of the worksite. This communication will also allow an injured worker to quickly request help, even if the injury leaves the worker immobile or unable to signal with visual cues.

The trials and tribulations the design team went through are discussed herein. The costs, schedules and workloads are also covered in this document. Each individual design engineer at Ekho Systems will discuss their own personal growth while designing a product that will hopefully benefit others.

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Glossary

Term	Meaning
Alarm	An auditory alert of a specific frequency present in a worksite
AlarmSense System	The complete product, including the unit, briefcase, and app
App	A smartphone program used for managing the AlarmSense System
Foreman	A manager of industrial workers responsible for safety
PPE	Personal protective equipment, including hearing protection
Unit	The part of the AlarmSense system worn by every worker, including headphones, a microphone, and a microcontroller
Worker	An individual using an AlarmSense System unit
Worksite	An area where loud industrial work is carried out

1. Introduction

The AlarmSense System is a system of active noise cancelling headphones to be used as PPE for hearing protection in industrial worksites that will allow workers to hear auditory alarms and communicate with each other despite background noise. The goal of the system is to create safe and efficient worksites.

The system comprises the unit, worn by each worker, and an app for control of the system. The units consist of active noise cancelling headphones, a noise cancelling throat microphone, and a microcontroller for real time audio processing. The app will allow the foreman to check the status of the system and update the frequencies of the alarms. This post mortem document details the business case for the system, the current status of the prototype, the team dynamics, and the future of the project.

A strong business case based on increased safety and efficiency on industrial worksites has been validated by consultations with industry workers. While the system has a high cost per unit, competitive PPE are also expensive and do not provide all of the functionality of the AlarmSense System.

A proof of concept system was developed in the last three months which demonstrates almost all functionality of a complete system. While the development encountered problems, the members of Ekho Systems were able to persevere.

2. Business Case

Catastrophe can strike in loud industrial worksites if workers remain unaware of alarms. The cacophony of noise in these situations makes auditory alarms inadequate, leaving only visual alarms. But safety should not be trusted to visuals. If an employee is deeply immersed in work, a visual alarm may go unnoticed and a serious accident can occur. Worse still – if a worker is injured in a high noise environment, signaling for help could be impossible. In addition to this the use of power tools, the use of hearing protection and the obstructions between employees and the location of the visual alarm can cause alarms to go unnoticed. Missing alarms will lead to a hazardous worksite and time and money spent by both the government and the company running the worksite on injured workers. Clearly, a system is needed for workers to use their sense of hearing to remain safe.

Through equipping the workers of a job site with the AlarmSense System, the benefits of using the system will quickly outweigh the costs. By removing the safety concerns surrounding missed auditory emergency signals and by improving communication in a worksite, there will be less loss due to injured workers and a greater efficiency due to improved communication. Additionally, by integrating the AlarmSense System into a worksite, visual alarms will not need to be installed.

The AlarmSense System can be marketed to a number of sources including: trade schools such as the British Columbia Institute of Technology (BCIT) and Vancouver City College (VCC), government organizations like WorkSafe BC, and individual industrial firms that wish to equip their workers with the most advanced safety technologies available. In particular, it is predicted that trade schools will be interested in using the AlarmSense System. Trade schools like BCIT and VCC train their students first and foremost in safety, with the

idea that companies will hire those who are well versed with modern safety equipment. Additionally, if the system is sold to trade schools, each new generation of tradespeople will be trained and practiced with the AlarmSense System, making them more likely to buy the product when they move onto independent job sites.

The AlarmSense System should not be marketed to individual workers as with passive hearing protection. The system is only practical when all workers are using it on the worksite. A foreman needs to be able to count on the fact that all workers can hear auditory alarms and communicate with each other, which can only happen if all workers are using the AlarmSense System.

The AlarmSense System is projected to cost $500 per unit, which appears to be expensive, but when compared to current standard equipment this price is not unreasonable. This cost compares to $100 for high quality passive hearing protection, $300 for active noise cancelling headphones, and $200 for high quality radios which would total around $600. Workers personal protective equipment can range from $500 to $1500 dollars depending on the industry [1, 2]. These figures were confirmed by two industry workers, a site supervisor on a construction crew and a log home builder [3, 4].

Looking at the economic benefits, the AlarmSense System helps society by reducing time lost to injuries on industrial worksites. According to the Association of Workers' Compensation Boards of Canada, there were approximately 36,000 injuries that resulted in time off work in manufacturing during 2013, 27,000 injuries that resulted in time off work in construction during 2013, and 2,000 injuries that resulted in time of work in mining, quarrying and oil wells [5]. Between these three industries, in 2013 there were an estimated 65,000 injuries and 480 fatalities [5]. Considering the number of injuries and fatalities, improved response and notification systems will drastically reduce the time employees are off work, the number of injured employees, and the number of fatalities. The average cost of an injury is estimated at $40,000 in industrial settings [5]. With the cost of each injury being so high, WorkSafe BC could mandate all industrial workers wear this product. In this case the product would have a guaranteed customer base, and assuming the product is patented there is a very large margin for profit.

3. System Overview

The overall proof of concept system has a primary unit comprised of an Arduino Zero and Arduino Uno working in parallel, a secondary unit comprised of an Arduino Uno, and the mobile application. The primary unit was responsible for alarm detection, receiving wireless communication, and transmitting the sounds through the noise cancelling hearing protection. The secondary unit was responsible for recording and sending a speech signal through the wireless transmitters. The mobile app was responsible for measuring and setting alarm frequencies on the primary unit. The overall system is shown in Figure 1.

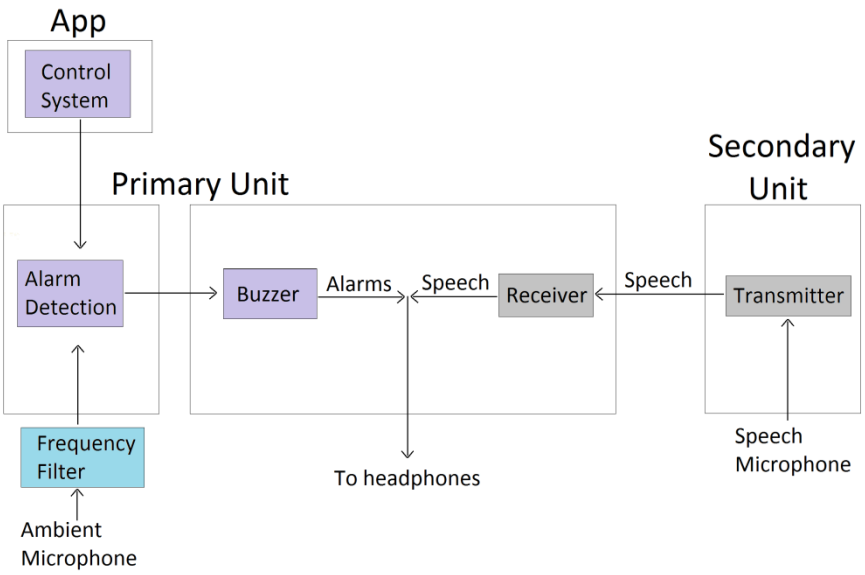

Figure 1 – Block diagram of the proof of concept system

While the system shown in Figure 1 is not a fully integrated AlarmSense System, it demonstrates all of the required functionality.

3.1 Alarm Sensing Headphones

The alarm sensing headphones were successfully built and tested over the 16 week project period. This part of the project incorporates both a hardware and software component. The hardware and the software interact in order to detect alarms and then send warning signals that bypass the hearing protection provided by a pair of noise cancelling headphones. A block diagram of this interaction is shown below in Figure 2.

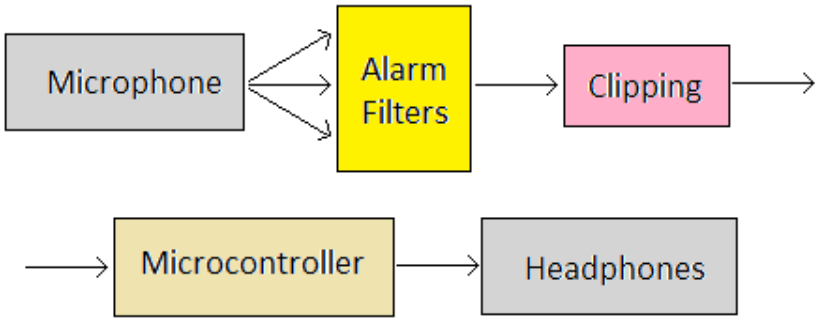

Figure 2 - Alarm sensing process

3.1.1 Hardware Overview

The hardware used for alarm detection picks out the alarm frequencies using an array of narrowband filters connected to a standard microphone. Extensive circuitry was required to convert the small

voltage signal from the microphone to the signal filtered through the array of narrowband filters and into the microcontroller.

The array of narrowband filters currently is set to one of three alarm frequencies. While the proof of concept system only allows for the three alarm frequencies, digital potentiometers will easily allow for a user of a complete system to tune the alarm frequencies to any arbitrary value.

The hardware also involves circuits to ensure that the inputs to the microcontroller are protected from particularly large input voltage signals as well as set to the right DC offset levels. The Arduino Zero used for the alarm detection software requires signals centered at 1.67 V and not exceeding 0 V o 3.3 V.

3.1.2 Software Overview

The software needed to able to detect if certain alarm frequencies were present and that they are indeed an alarm and not just a background sound that happened to be at the alarm frequency for a brief moment. This task was done by first detecting if the frequency was present by checking the slope and amplitude of the incoming noise. An existing Arduino library was used for this purpose. Once the frequency was detected the software had a built in delay of half a second after which it check to ensure that the frequency is still present. This second check avoids intermittent background noises setting off the alarms.

Once an alarm has been detected, its priority is compared to any other alarms that are currently detected. If a higher priority alarm is concurrently detected, only the high priority alarm signal is sent to the Arduino Uno. If only one alarm is detected it sends the corresponding priority signal to the Arduino Uno.

3.2 Proximity Communication

In the proof of concept system, speech signals are recorded through a throat microphone on the secondary unit and sent wirelessly to the primary unit to be played out through the headphones. This system is shown in Figure 3.

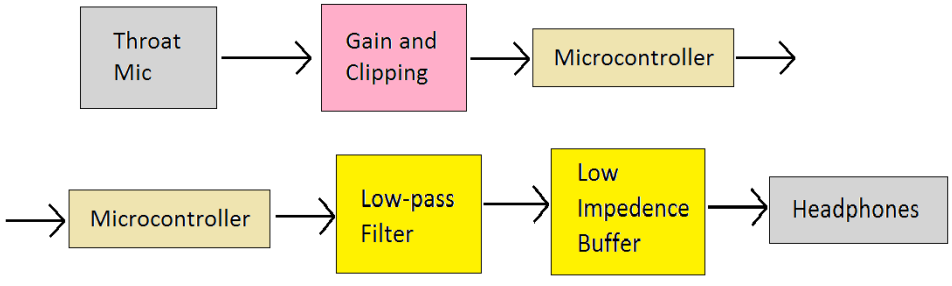

Figure 3 – Wireless communication process

The wireless communication system was intended to have a proximity based attenuation mimicking verbal communication without industrial noise. As the units moved further apart, only loud speech signals would transmit from one unit to the other. This functionality was partially developed, but due to hardware problems and time constraints was not available for presentation.

3.2.1 Software Overview

The software component of the proximity communication was done through a modified version of the TMRh20 RF24Audio open source library. The library handles the audio reception and transmission of the audio signal through interrupts. The transmission half of the library reads in audio signals into a 1-byte value at a rate of 24 kHz. These samples are stored as a 32 byte array and sent at a rate of 750 Hz. The array is read via a capture interrupt by the receiving microcontroller and played out in a differential mode through two pulse-width modulation (PWM) ports.

The software library was altered to allow for a distance-based proximity sensor. As the input samples were read in, the largest value in the array was tracked as a separate variable. Every 100 attempts, the software would wait for the transmitter to determine whether the transmission was received by the paired radio. If the transmission was not received, the next transmission packet would be sent through a longer range radio provided its largest volume was loud enough.

3.2.2 Hardware Overview

As with the input for the alarm sensing portion of the system, the input waveform from the microphone needed to be processed before entering the Arduino Uno. The input needed to be centered at 2.5V and not exceeding 0 V to 5 V. In addition, the microphone needed an input stage, which needed to power the audio jack and give gain to the signal.

The audio was transmitted between the two Arduino Uno modules through matched nRF2401+ transmitters. The nRF2401+ modules communicate with the Arduino through the Serial Peripheral Interface (SPI) pins, which allow transmission and reception of data from different peripherals synchronized with the Arduino clock. The proximity based attenuation was to be a two level filter, with a short range radio broadcasting when the input volume was low. This functionality was not implemented for the demonstration.

3.3 App Overview

The mobile app was written using the latest version of the developer environment Android Studio. There were a few main components for the app: Bluetooth connectivity, frequency detection, alarm prioritization, and layout formatting. A HC-06 Bluetooth module was used. Frequencies were detected through the use of a 3rd party library for the Fast Fourier Transform. The app was designed so that the user can select and connect to any Bluetooth modules that are turned on within the range of the mobile phone. The alarm priorities needed to combine a user textbox with the detected frequency. This was fairly straight forward to implement. And finally, page layouts were developed using XML files. The app

was designed to automatically format to any screen size the user's device may have. The app home screen is shown in Figure 4.

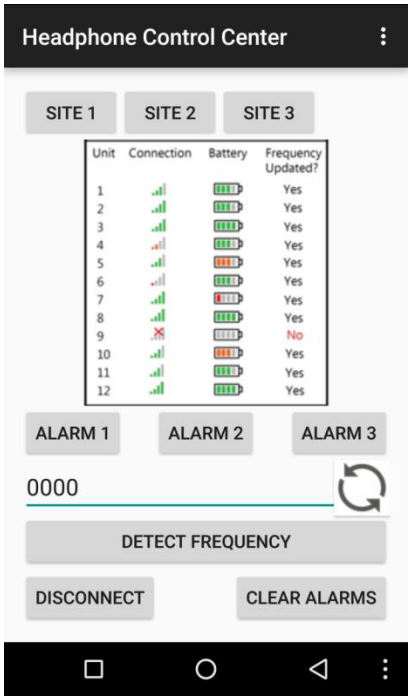

Figure 4 – App home screen

4. Budget

Table 1 – The budget

	Planned		Actual	
Component	**Part**	**Unit Cost**	**Part**	**Unit Cost**
Primary microcontroller	1x Intel Galileo Gen 2	$100	1x Genuino Uno 1x Genuino Zero	$101
Noise cancelling headphones	1x Sony 10RNC Noise Cancelling Headphones	$220	1x Bose QuietComfort 25 Headphones	$300
Noise cancelling microphone	1x Motorola Noise Cancelling Microphone	$200	1x Throat Microphone	$56
Proximity sensor	2x Ultrasonic Transducers	$10		
Secondary microprocessor	1x Genuino Uno	$25	1x Genuino Uno	$32
Receiver/ transmitter pair	1x Wenshing Wireless Receiver/Transmitter	$10	4x nRFL01+ Receiver/Transmitter	$60
Misc.		$200	Protoboards, batteries, Bluetooth module, trimpots	$402
Wasted			Arduino Due, Arduino Zero, Noise cancelling microphone	$214
Total Cost		**$765**		$1165

Comparing the estimated versus the actual costs of developing the AlarmSense System in Table 1 it can be seen that the project was budgeted below the actual amount spent. This is primarily due to underestimations of the cost of miscellaneous components needed to develop the system as well as money wasted. Money wasted includes money spent on shipping unnecessary components back, as well as money spent replacing parts which were accidentally destroyed during testing.

Most of the components planned for integration into the AlarmSense System were replaced during development. In almost all cases, the new component cost the same as the original component. The exceptions are the noise cancelling headphone and microphone. The planned noise cancelling headphones were replaced with slightly more expensive headphone when research showed that the planned headphones would not be sufficient to block out industrial noise. The planned noise cancelling microphone from Motorola was replaced by a throat microphone, or laryngophone, at a much smaller cost. The Motorola microphone had a proprietary audio jack which could not be interfaced with the rest of our project. The cost of shipping the Motorola microphone back to the manufacturer is accounted with the wasted costs.

The main funding source for the project was the ESSEF. Based on the proposed budget, $517 was received.

The other funding source was the personal funds of the members of Ekho Systems. The expected cost of the project to the members of Ekho Systems was $248. Due to going over budget, $648 was spent. The personal expenses of the members of Ekho Systems are being filed with the Whighton Engineering Development Fund for reimbursement.

5. Timeline

Figure 5 shows the planned versus actual schedule.

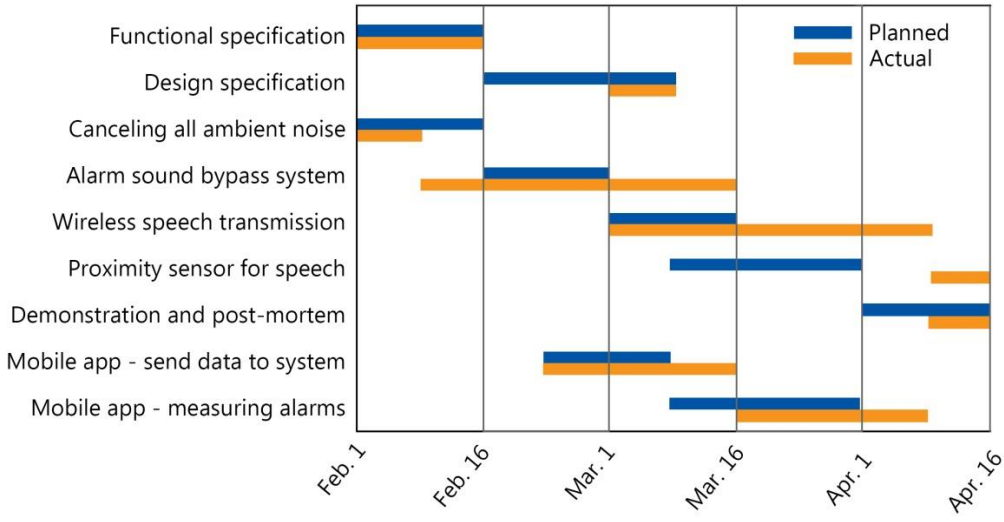

Figure 5 - The planned and actual schedule

Aside from the proximity based attenuation for the wireless communication, all planned functions were developed for the system by the demonstration date. This project was completed despite not strictly adhering to the planned schedule.

Documentation and app development timelines closely aligned with the milestones set out in the design proposal, while the alarm detection and wireless transmission system timelines did not. Both the alarm detection and wireless transmission systems were far more complicated than initially thought, and required far more work than was planned. The planned schedule was overly optimistic on both deadlines, and failing to meet these timelines caused the proximity filter to not be completed for the demonstration.

Missing from Figure 5 is time for system integration. While Ekho Systems worked closely with each other throughout the semester and integration was relatively problem free, the lack of time budgeted could have caused significant problems close to the demonstration date.

6. Problems

6.1 Logistical

When originally determining the parts required for this product, lack of experience was a large hindrance. Insufficient research was done on components prior to purchasing. Once the products were received they did not always work as expected. The first example of this is the Galileo Gen 2 microcontroller initially purchased for the primary unit. The Galileo was advertised as a high powered Arduino with a 400MHz clock, but was actually a Linux system that emulated an Arduino, which was not sufficient for the project. Other purchasing mistakes were getting an Arduino Due rather than another Arduino Uno and buying a Motorola noise cancelling microphone with a proprietary connector. These issues could have been avoided if more research had been done or if the team had more experience with this style of project.

Lack of care when connecting power supplies resulted in the destruction of an Arduino Zero, used for alarm detection, and a radio module. These destructions resulted in delays to their respective parts until replacements were acquired.

6.2 Technical

6.2.1 Alarm Detection

The hardware had significant problems when it was first implemented. Each stage was initially connected directly into the next stage, which caused feedback throughout the circuit. This feedback would cause false positives in the alarm detection at random intervals. To solve this issue, the circuits were redesigned and rebuilt with buffers between each stage to prevent feedback.

6.2.2 Wireless Transmission

The SPI protocol used for communication between the radios and the Arduino Uno is capable of differentiating between multiple devices connected to the same ports. The radio modules used, however, would interfere with each other if two were connected to the same ports. Several possible solutions were attempted, but this problem was not solved in time for the demonstration and proximity attenuation was missing from the proof of concept system.

6.1.3 Mobile App

While no single major problem was encountered during app development, the programming environment was completely new and required quick learning to complete the project on time. Bluetooth connectivity and frequency detection were difficult to implement due to the lack of debugging solutions available. With slow, careful testing, these problems were solved and the application was completed on time.

7. The Team

7.1 Roles

Russell McLellan – *President*
Russell made sure the entire team stayed organized and orchestrated all of the meetings. His main technical task was wireless transmitting, and he helped with other sections when needed. He showed his versatility and proficiency by editing all sections of the documents and making suggestions where he saw fit.

Adrian Tanskanen – *Hardware Engineer*
For this project Adrian took on a versatile role but since he is the best at circuit design he took the lead on all of the circuits. Straying from his comfort zone he also helped with coding and testing of the wireless transmitters and alarm detection algorithms.

Taylor Robson – *Chief Executive Officer*
Taylor showed his business and carpentry roots by making sure there was a viable market and that the product was actually needed. The alarm detection algorithm was his main task, but he also helped with the design and soldering of the circuits, as well as acquiring the needed components.

Gordon Ho – *Software Engineer*
Designing the mobile application was Gordon's primary task. Coding in a different environment then he was used to required perseverance and determination, but these two factors did not limit his success. In addition to app development, Gordon took on support roles as necessary during the development period.

7.2 Work Breakdown

Table 2 – Work breakdown for the project

Task	Russell McLellan	Adrian Tanskanen	Taylor Robson	Gordon Ho
Report Writing	XX	XX	X	X
Microphone Circuits	XX	XX	XX	
Alarm Detection Hardware	X	XX	XX	
Alarm Detection Software		X	XX	X
Wireless Transmission Hardware	XX	XX	X	
3D CAD Modeling				XX
Wireless Transmission Software	XX	X		
Mobile App Design				XX
Material Acquisition			XX	XX
Physical Enclosure				XX

Where xx = major responsibility; x = minor responsibility

In Table 2, the work breakdown for the project is given. Note that Table 2 lays out the amount of work done, not the design responsibility for each component. Design responsibilities are given in Section 7.1.

8. Conclusion

The AlarmSense System is a system of PPE designed for use in noisy industrial workplaces. The system will allow a maximum amount of safety while not compromising worksite efficiency. Consultations with industry workers confirmed the business viability of the finished project.

A full proof of concept system was developed in three months. The proof of concept system demonstrated almost all functionality of the system in two units and a mobile app. The proof of concept was successfully demonstrated in April 2016. While somewhat over budget and off schedule, the project was successful due to the cohesiveness of the Ekho Systems team.

In the coming months, the members of Ekho Systems are taking co-op education terms in various locations. This fact, combined with the lack of external interest in the future of the AlarmSense System, means that this project will not be pursued further despite the successful proof of concept system and business viability.

References

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[3] E. Bikadi, personal communication, Jan 2016.

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Appendix A: Personal Reflections

Russell McLellan

My contribution to the project centered on documentation, project management, and the wireless communication subsystem. While both were necessary for the completion of the project, it was the project management that I learned the most from.

Designing the wireless transmission taught me many low level programming skills. Before this project, my experience with this aspect of programming had been very limited, and I am glad that I learned more about this subject.

I underestimated the amount of work that being the sole document editor would entail. Throughout my four years of engineering school, I have done many group labs requiring reports. For almost all of these labs, I have volunteered to do a large section of the writing and the final editing of the reports. I have taken on these tasks because I believe that while technical skills separate bad engineers from good engineers, communication skills separate good engineers from great engineers. In this course however, the amount of documentation required in the early stages is far, far more than any other course that I have taken. Despite warnings during the 305 lectures, this amount of work took me slightly by surprise and caused me much stress. Having suffered through the editing of all of my team's documents this semester, I have to say that I have noticed myself become a better writer.

I have never had to set a strict schedule or budget for an engineering project. This lack of experience was reflected in the underestimation of miscellaneous costs and the over-optimistic schedule for most of the system components. Part way through the semester, when I realized that the initial targets we had set were not going to be met, I wondered why there was no project management course offered at SFU. Of course, ENSC 305/440 is the project management course that I thought I was missing. Unlike technical skills, management skills must be taught by direct experience in projects such as this one.

Capstone was an extraordinary amount of work for a course. I am very thankful that my team was cohesive and friendly, as it made coordination and integration very easy. Noticing groups in the labs encounter team dynamics problems during the semester has only reinforced my belief that it is not technical skills, but soft skills that make a great engineer.

In ENSC 102 I was given a quote by Aeschylus: "We suffer to learn". After this course, I agree.

Adrian Tanskanen

Before this course, I only really liked coffee. Now after Capstone, I believe I can successfully say that I graduated to a full time caffeine addict.

To reflect on some slightly more technical aspects of this project, I actually find the disparity between my initial predictions for what I would be doing in this class versus what I actually did, to be quite amusing. For instance, I thought that I would finally be required to venture out of my comfort zone and do a project that would inevitably be software based. Instead, I very much found myself in my element designing and building circuits, and implementing hardware solutions to any of the problems that Russel and Taylor brought to me. So, rather than learning new things, I was instead building my previous knowledge up to a new level, which suited me well.

That being said, I did learn one incredibly valuable lesson with regards to my hardware: Murphy's Law rules, and nothing works the first, second, or even third time. And usually not the fourth as well. Most notably this came into effect after spending around 40 hours over 3 days building a solution, with Russell, to a random noise that came from feedback in our circuit. Once this circuit was built we finally connected it, only to find the noise replaced with a sound that can in simple terms be described as a harmonic mix between a cat fight, bagpipes, and a laser gun. It turns out that headphones need a very low input impedance, who knew? I certainly didn't before, however I sure do now.

I found it interesting how we all worked as a group. Being the team problem solver and hardware designer I found myself working closely with both Taylor and Russell. It was often the case that simply having two perspectives on the same problem, would lead to some ingenious ideas that neither of us could have conceived alone. For instance, early in the project when we were still trying to figure out how to detect alarms I remembered simply mentioning to Taylor off hand that it would be "so simple" if we could just program the Microcontrollers to detect a frequency in the time domain. At this comment I watched Taylors eyes light up as he told me that doing so would be a simple matter. This quick conversation lead to the central design of our system, which ended up working as well as we could have possibly hoped.

In conclusion, this class was an insane amount of work. However, it was very rewarding, and I could not have asked for a better group. It was certainly a unique experience to invent a product, design it, and then actually build something that works. In a way I feel it actually makes me more of an engineer than before.

Taylor Robson

During the previous four years I have had the pleasure of working with Russell, Adrian and Gordon. For the last four months we banded together to create Ekho Systems and design a new product that could potentially create safer worksites for industrial workers. During this design I have learned a lot from the value of putting in lots of research before ordering parts to buffering all inputs into an addition circuit.

Since this project had such strict time constraints we did not do a sufficient amount of research into which products would work best, and if the products worked as advertised. At the start we ordered am Arduino Galileo. Upon initial testing we could not get it to perform fast enough. I took it upon myself to take it home and try to write low level code to reduce overhead, hoping this would make the product useable for this project. After coding in a Linux environment for countless hours and sending the code to the Galileo I was able to increase the speed, but not nearly enough. This is when I realized that I was wasting my time and that I should just look into a product that works instead of trying to make a product we have, work. Many times throughout this project we undervalued time and overvalued money, and if we were getting paid hourly we would have been wasting the company's money. I learned that preemptive research is better than post trial effort and that time is money.

My main task for this project was writing the code for detecting alarm frequencies. Since I am not very proficient at coding, I took on this task hoping to increase my understanding of real time processing, priorities, and microcontrollers. Ensc 351 gave me an overview of these concepts which led me to believe I would be able to accomplish this task. The main thing I learned was, don't reinvent the wheel! When struggling to code something, I learned to search on the internet because many times others had already found solutions to the problem I was having. Most of the times the solutions were for different platforms or not exactly what I need but after researching these other solutions, I was usually able to fix the problem I was having.

Hardware circuits, soldering, and testing was another large part of this project. Whenever I needed a circuit designed, I gave Adrian the parameters and he designed circuits that would work for me. After building the circuits we tested them together and found gaps between theory and reality. Working closely with each other we discovered the beauty of buffers. Having two people test circuits also reduced the amount of problems encountered later on.

Through this entire experience I realized the benefits of teamwork and the importance of having a good team. Having a group of competent engineers in training—working together—made it so that seemingly unbeatable obstacles were not only achievable but achievable in a timely fashion. Also, research products thoroughly before purchasing them, it will save time in the long run!

Gordon Ho

Working with a team of friends definitely has its advantages and drawbacks. However, with this capstone group, the drawbacks were close to none. Everyone took on a major role in the group and helped each other out when help was needed. When we divided up the tasks, everyone knows that extra knowledge was required and tha no one knew 100% of their role consists of. Overall this was a great group dividing the main tasks based on their skill.

My main task for this project was the mobile application. We had to make an app from scratch that can connect to our headphone system, set user inputted alarms, and detect incoming alarm frequencies. I had some previous experience in making mobile scripts in the past, but nothing as complex as this. I had to look up quite a few 'how to' guides from the internet before I got up to speed at the most basic functions.

The most difficult part for me was to get the Bluetooth connectivity set up correctly with the arduino with arduino reading the proper values from the app. As discussed in section 6.1.3, there were a lot of problems that were occurring at the same time which made it difficult to pinpoint the origin. Sometimes I wished that there was another group member helping at these difficult areas. But then again, no one else had any app making experience, and they were probably all going through the similar difficulties in their part of the project with their, wireless transmitters, digital circuits, and noise canceling algorithm.

Overall, I think that splitting the work independently was a very effective solution for this project. In retrospect, we should have accounted for more difficulties and have our timeline adjusted to reflect that. We were very pressed for time near the end when we were putting all the modules together, and it would have been a better overall experience if we had taken out a few minor features to have more time at the end to test the entire system.

Appendix B: Meeting Agendas and Minutes

Ekho Systems Inc.

AGENDA

January 15, 2016
10:30-11:20
West Mall Centre

Purpose of Meeting: To discuss the timeline, budget, and proposal for the project

Items for Discussion:

- Equipment needed at what price?
- Milestones for progress?
- Status of ESSEF proposal
- Status of 305 proposal

Ekho Systems Inc.

MINUTES

January 15, 2016
10:30-11:20
West Mall Centre

Present: Russell McLellan, Adrian Tanskanen, Taylor Robson

Absent: Gordon Ho (with regrets)

Purpose of Meeting: To discuss the timeline, budget, and proposal for the project

Topic	Discussion	Action Items	Timeline
Equipment needed and price	-Arduino intel galileo USD$90 board -Extras for board (ie power cable, connectors for audio, possible shield) $25 -shield (arduino protoshield) USD$13 -Arduino Due USD$80 -Noise cancelling headphones – CAD$100 -Total approx. CAD $450 w/o microphone, $700 w/ microphone	-RM - Create a complete parts list for a system	Monday, Jan 18
Timeline	-ESSEF proposal by Sunday -305 proposal by Jan 25 – try to get done by Sunday -parts in by reading break (ie parts ordered within a week) -Another meeting Friday to discuss high level system specs -Alarm filtering first by the end of February -Voice filtering by the second week of March -Proximity sensing by the end of March	None	
Status of ESSEF proposal	-mostly done Needs: -Timeline	RM-finish	By Saturday Jan 16th

	-Budget		
Status of 305 proposal	-Executive summary finished -Introduction mostly done Need: -Current solutions -Proposed design -Team summary (w/pictures)	AT-Current solutions section AT-Proposed design RM-Gantt chart TR-continue working on content ALL-team summary w/ picture	TR/AT finish by Sunday Jan 17th

Ekho Systems Inc.

AGENDA

January 22, 2016
10:30-11:20
West Mall Centre

Purpose of Meeting: To finalize direction of project

Items for Discussion:

- Mobile app
- 305 Proposal
- Review and order parts

Ekho Systems Inc.

MINUTES

January 22, 2016
10:30-11:20
West Mall Centre

Present: Gordon Ho, Russell McLellan, Taylor Robson, Adrian Tanskanen

Absent: None

Purpose of Meeting: To finalize direction of project

Topic	Discussion	Action Items	Timeline
Mobile app	Tuning the alarms is the only functionality needed – don't need an app Frequency selection done in hardware? – not easily tunable	GH – bring basic arduino for filter test	Next Thursday GH, TR, RM work with GH's arduino to figure out audio in/out protocol
305 Proposal	Needs to edit down to Jamal's specs Footers and headers	AT – reformat proposal TR – headers and footers, table of figures RM – final revision Sunday night	Due Monday midnight
Review and order parts	Headphones – bose or sony Microphone – Motorola Arduino – both agreed	TR – compare beats to sony and buy GH – buy microphone, arduino, audio jacks, possibly shield	Order tonight
Proximity sensor	SONAR? Not reliable GPS? Computationally expensive? Developmentally expensive?	Wait until later in the project to order	

Ekho Systems Inc.

AGENDA

January 29, 2016
10:30-11:20
West Mall Centre

Purpose of Meeting: Preliminary results and plan for next week

Items for Discussion:

- PWM to analog converter
- Status of parts
- Functional spec

Ekho Systems Inc.

MINUTES

January 29, 2016
10:30-11:20
West Mall Centre

Present: Adrian, Taylor, Gordon, Russell

Absent:

Purpose of Meeting: Preliminary results and plan for next week

Topic	Discussion	Action Items	Timeline
PWM to analog converter	-Need to convert PWM to analog -Low pass filter with ~16KHz cutoff and -60dB per octave	AT – build a filter on a breadboard GH,AT – test the filter to recover	In a week
Status of parts	-Protoboards in (breadboards) audio jacks in -Headphones are in	None	About a week
Functional spec	-Wait until Jamal marks the proposal to start	None	5 days before Func Spec is due
3D printed enclosures	-GH has a printer available -Hold off until everything works to see if we have time -Enclosure is not a priority	None	
Voltage limiter	-Need to limit the voltage to limit the volume on the headphones		In a week

Ekho Systems Inc.

AGENDA

Feb 4, 2016
3:30-4:30
TASC1

Purpose of Meeting: Results of lab work

Items for Discussion:

- Audio input
- Filter output
- Dividing of the work
- Functional spec

Ekho Systems Inc.

MINUTES

Feb 4, 2016
3:30-4:30
TASC1

Present: Adrian, Taylor, Gordon, Russell

Absent:

Purpose of Meeting: Results of lab work

Topic	Discussion	Action Items	Timeline
Audio input	-Problem with constant sampling -needs to be in discrete chunks -software problem to do this -Hardware needs: high input resistance, low pass filter for noise, DC offset	TR, GH – look into coding for the sampling AT – look into input circuit on GH's breadboard	End of the week
Filter output	-PWM to analog -Low pass filter doesn't work as intended -resistor ladder – problems with matching resistor values -when we get the galileo, we can test a simple low pass filter to see if it works as well as we expect	RM – simulate the different filters discussed -TR, RM test circuits in lab	-RM tonight -TR, RM tomorrow
Division of work	-Want to keep working all together	None	
Functional spec	-Hold off until Wednesday, need Jamal's feedback	None	

Ekho Systems Inc.

AGENDA

February 11, 2016
2:30-3:20
Lab 1

Purpose of Meeting: Results of Arduino Due and functional spec work division

Items for Discussion:

- Next steps for Arduino Due
- Microphone
- Functional Spec
    - Functions
    - Environmental safety (cradle to cradle)
    - Introduction
    - Executive Summary
    - App picture
    - Diagram of device
- Product name

Ekho Systems Inc.

MINUTES

February 11, 2016
2:30-3:20
Lab 1

Present: Adrian, Taylor, Gordon, Russell

Absent:

Purpose of Meeting: Results of Arduino Due and functional spec work division

Topic	Discussion	Action Items	Timeline
Next steps for Arduino Due	Works great Interrupt based coding allow for flexibility True analog out pins Next steps is recognizing input frequencies Circuitry stopped working after soldering	AT, RM, GH, learn the code TR wrote TR – continue working on code, trouble shoot circuitry	After the functional spec
Microphone (including Bluetooth)	Motorola microphone is proprietary TR has lots of microphones on a list Still need a noise cancelling mic Need a headphone splitter to use the Bose headphone mic for the ambient microphone Bluetooth for wireless connection Master/slave connection only – need to have a central hub Some Bluetooth connectors handle their own interfacing Stay away from Bluetooth	GH – order splitter GH – look into Bluetooth connectors	Within a week
Function list	RM half done	RM – complete	Sunday
Environmental safety (cradle to cradle)	Not done yet Need	AT – complete	Sunday
Introduction/Executive summary	Intro partly done	AT - complete	Sunday
Pictures of App and	Need for high level description	RM for app, GH	Friday

single unit	of product	for single unit	
Product name	HearFail EmergeNoise Noisemergency WorkNoise SoundWorks QuietAlarm SafeAlarm Headphones	Going with SafeAlarm Headphones	
App	Not functional yet	GH – continue work on app	This weekend or next week

Ekho Systems Inc.

AGENDA

February 22, 2016
12:30 - 1:30
Physics Corner

Purpose of Meeting: Design review, app, input circuit soldering

Items for Discussion:

- Circuit
- Signal processing
- Transmitters
- App
- Design review

Ekho Systems Inc.

MINUTES

Febraury 22, 2016
12:30 – 1:30
Physics Corner

Present: Adrian, Taylor, Gordon, Russell

Absent:

Purpose of Meeting: Design review, app, input circuit soldering

Topic	Discussion	Action Items	Timeline
Circuit	- Blue out to headphones - Green arduino DAC0 - White -9V - Red (w/white) +9V - Red(w/black) +3V - Black ground - Yellow A_in0 - Orange mic in $1 microphone – does not work	GH – buy microphone RM – test microphone	RM – test tonight
Signal processing	Two processors – one processor feeds output One processor detects alarm frequency with fft and sends it over May have to use analog filter if fft doesn't work	TR, AT – work on fft algorithm AT – build analog circuit as a backup. 5k	Start about Wednesday or so
Transmitters	AT – bought them Two sets – one high range Might use for proximity sensor	RM – set them up on the Due/Uno setup	This week
App	GH looking into most compatible Bluetooth modules Working on data transmission, then aesthetics, then frequency detection	GH – continue working on app	Continuous
Budget	Refunds for Microphone and Galileo. Galileo is %100, microphone		
Design review	Need circuit diagrams, budget information, details on design review	GH, TR – add costs AT – add circuit	Due Friday

		diagrams ALL – work on presentation	

Ekho Systems Inc.

AGENDA

February 26, 2016
10:00 – 11:00
West Mall Centre

Purpose of Meeting: Design Spec, wireless transmission, app, frequency selection

Items for Discussion:

- Design spec
- Wireless transmission
- App
- Frequency selection
- Microphone

Ekho Systems Inc.

MINUTES

Febraury 22, 2016
10:00-11:00
West Mall Centre

Present: Adrian, Taylor, Gordon, Russell

Absent:

Purpose of Meeting: Design Spec, wireless transmission, app, frequency selection

Topic	Discussion	Action Items	Timeline
Design spec		RM – make proximity sensor spec Everyone – write your own section	
Wireless transmission	Tested yesterday Works with sample code and AT long range transmitters Spotty Need to buy FtM connectors	TR – go to Lee's and buy connectors RM – figure out spottiness, interface with code for microphone	Tonight for spottiness, next week for interfacing
App	Going well Waiting on Bluetooth module Will need the Zero	GH – continue work, pick after CEC	Pick up after CEC
Frequency selection	Going well Need a separate alarm buzzer Need analog narrowband filter	AT – adjust narrowband filter to give different cutoff frequencies. Eventually need more circuits TR – work on code next week	
Microphone	Order cheap mic and see how well it works Auditorium mic – pick up based on proximity to mic	GH – research mic	Before Wednesday

CEC	GH going away Wednesday to Monday		
Shopping list		TR – buy – FtM connectors, op amps, d flop flop, possibly a mic, trimpots – 5 10k	

Ekho Systems Inc.

AGENDA

March 7, 2016
12:30-1:30
Physics Corner

Purpose of Meeting: Design Spec, test plan, headphones

Items for Discussion:

- Design spec
- Test plan
- Headphones

Ekho Systems Inc.

MINUTES

March 7, 2016
12:30-1:30
Physics Corner

Present: Adrian, Taylor, Gordon, Russell

Absent:

Purpose of Meeting: Design Spec, test plan, headphones

Topic	Discussion	Action Items	Timeline
Design spec	Almost done Need AT references RM needs to edit GH work	RM edit and submit	Thursday
Test plan	Need to do	GH, TR, AT draft their tests, RM edit and draft his	Tonight
Headphones	Lost and found or buy another pair	RM – lost and found	
New parts	Microphones in Splitters in Both microphones are about the same - GH	Don't lose them AT, TR Test with microphones when doing input circuits from now on	
Transmitters	Synchronization problems Needs TR code locked down to time the code	RM – work on code	

Ekho Systems Inc.

AGENDA

March 14, 2016
12:30-1:30
Physics Corner

Purpose of Meeting: Buy list, Audio transmission library, app, alarm detection

Items for Discussion:

- Buy list
- Audio transmission library
- App
- Alarm detection

Ekho Systems Inc.

MINUTES

March 14, 2016
12:30-1:30
Physics Corner

Present: Adrian, Taylor, Gordon, Russell

Absent:

Purpose of Meeting: Buy list, Audio transmission library, app, alarm detection

Topic	Discussion	Action Items	Timeline
Buy list	9V battery stuff Trimpots – 500k, 1M, 10k Another long range transmitter – RM and AT burnt the last one	AT – contact guy about more transmitters TR – go to Lee's	This week
Audio transmission library	RF24Audio library only for Uno, not Due Needs to be rewritten for the Due if it will be used	RM – look for alternatives, possibly rewrite library	Alternatives tonight, rewriting the library for the rest of the project if necessary
App	Bluetooth connection works. Need to port in the code to interface the Zero	GH – test with the Zero	Tomorrow
Alarm detection	TR computer does not work well with the Arduino Detects the alarms with a given priority Not tested with background noise altogether Hardware filters need soldering	TR, AT – solder the circuit, test the alarms with background noise through the Bose mic	This week
Battery	Two 9V for each board, and one for each arduino		

Ekho Systems Inc.

AGENDA

March 14, 2016
11:30-12:30
Physics Corner

Purpose of Meeting: Progress report, including progress on various parts

Items for Discussion:

- Proximity filter
- Frequency filters
- App
- Progress report

Ekho Systems Inc.

MINUTES

March 14, 2016
11:30-12:30
Physics Corner

Present: Adrian, Taylor, Gordon, Russell

Absent:

Purpose of Meeting: Progress report, including progress on various parts

Topic	Discussion	Action Items	Timeline
Proximity filter	It works in software Radios detect when they are in range and can set a pin high to signal this to hardware	RM – tune the values used for the loudness RM – set up the hardware AT – email to craigslist guy to replace fried transmitter	This week for both people
Frequency filters	They don't work Need to rebuild	AT – rebuild filters on breadboard TR – solder filters	AT – by Thursday morning TR – on Thursday
Combining the alarm with speech	Needs to be done in hardware Adder subtracter using op amps Currently on a breadboard	Eventually solder with filters	
App	Still needs work	GH – need to test code with the Zero GH – need to interrupt the Zero	This week
Progress report	Need: -Budget -Timeline -Next steps App and transmission is on schedule	AT, GH, TR – itemized list of expenditures TR, AT – give progress of filters after Thursday	Due Monday Work on Friday