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April 05, 2012

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC V5A 1S6

Re: ENSC 305/440 Post-Mortem for Multifunction Intelligent Headphone System

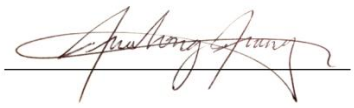
Dear Dr. Rawicz,

Enclosed is a document entitled *Post-Mortem for a Multifunction Intelligent Headphone System*. This document describes the process our team undertakes to design and implement the MIHS we are prototyping. Multifunction Intelligent Headphone System is to design a system that is capable of detecting the voice and noise in the surrounding environment in real time and processing this information for the user.

This post mortem summarizes our project, current state of the device, deviations from proposed system, and future improvement of this product. It includes a budget and time constraints we went through, as well as a description of our learning experiences through this project.

Our company, Sound Tec Inc. is comprised of five senior students from the School of Engineering Science at Simon Fraser University: Afrin Chowdhury, Frank Zhu, Leo Jiang, Simranjit Sidu and Xiao Peng He. If you have any questions about our design specification, please do not hesitate to contact us via phone at 778-855-4037 or email at jhj1@sfu.ca.

Sincerely,



Leo Jiang
Chief Executive Officer
Sound Tech Inc.

Enclosure: *Post-Mortem for Sound Tech Inc. Multifunction Intelligent Headphone System*

Post-Mortem:

Multifunction Intelligent Headphone System

PROJECT TEAM

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Dr. Andrew Rawicz – ENSC 440
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School of Engineering Science
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ISSUED DATE

April 05, 2012

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1 Introduction

The headphones in the market nowadays provide great comfort and offer high-quality sound, and the technology has made the “high-end” headphones completely noise proof. Having the noise cancelling headphone is great, however it also brings a range of issues: often it is very inconvenient to use when communicating with other people, and it brings danger to users when using the headphone outside. There were some studies showed that the number of injuries and deaths related to people using headphone on the street has been increasing.

In order to improve these defects, SoundTechInc is dedicated to design the multifunction intelligent headphone system that continues to provide users the comfort, and great sound quality, as well as safety. MIHS, the Multifunction Intelligent Headphone System which has three modes: word, sound, and voice recognition modes that has been successfully invented from the drawing on scratch papers over the past twelve weeks. This past semester is definitely exciting learning experience; each member of the Sound Tech Inc. developed their technical skills, problem solving skills, and also the practiced team cooperation and self-contribution.

In this post-mortem, we will describe the current state of the devices and a few modifications from the functionand design specifications. Then the future work and potential improvements will be discussed, as well as the analysis of how we follow the proposed budget and timeline. Lastly, a personal the reflection of the learning experience will be shared from each group member.

2 Current State of Device

The Multifunction Intelligent Headphone System (MIHS) consists of 4 main components, the micro-controller, the voice recognition module, the volume controller and headphone.

The Multifunction Intelligent Headphone System has a power switch, a reset button and five LEDs to show the mode selection: a red LED indicate there is an "ERROR"; a green LED indicate the MIHS is "ON", and three green LEDs indicate the mode selection of MIHS. The three different modes are "WORD", "SOUND" and "VOICE". The device requires a standard 9V battery to power up. Once the device is on, the device will capture any three speaker dependent trained words: "WORD CONTROL", "SOUND CONTROL", and "VOICE CONTROL" as input signal and process to determine which modes to select. Each of the different modes interrupt the headphone system and adjust the volume automatically when any trained words detected. The three models are listed below:

- **Word Mode:** MIHS selects "WORD" mode after detecting speaker dependent trained word "WORD CONTROL". In this active mode, the user can control volume by using trained word such as "VOLUME UP" or "VOLUME DOWN" or "MUTE VOLUME". In addition, the user can also move to other modes by using trained word "SOUND CONTROL" or "VOICE CONTROL".

- **Sound Mode:** MIHS selects "SOUND" mode after detecting speaker dependent trained word "SOUND CONTROL". In this active mode, the device detects any emergency sound such as police or ambulance that matches the database, then it will automatically tune the volume down to alert the user. The user can return to his/her task by using trained word "RESUME" and the device will automatically volume up to the desired. In addition, the user can also move to other modes by using trained word "WORD CONTROL" or "VOICE CONTROL".

- **Voice Mode:** MIHS selects "VOICE" mode after detecting speaker dependent trained word "VOICE CONTROL". In this active mode, the device detects pre-trained voice of trainer that identifying the voice in the database. The user can return to his/her task by using trained word "RESUME" and the device will automatically volume up to the desired. In addition, the user can also move to other modes by using trained word "WORD CONTROL" or "SOUND CONTROL".

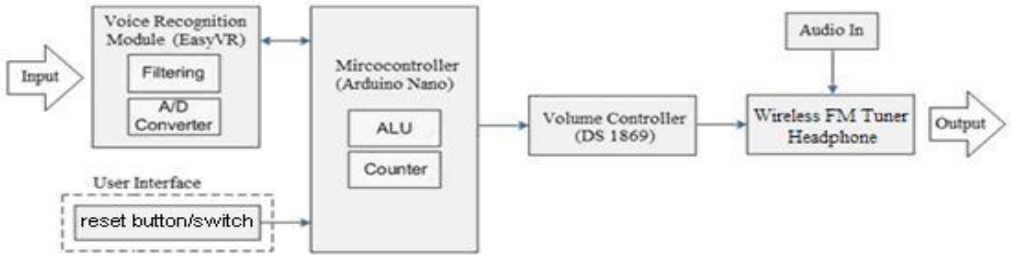

Figure 2.1: High Level Block diagram of MIHS – current device

2.2 Software

The software consists of programming the microcontroller in accordance with the voice recognition module and the volume controller. The voice recognition module will communicate with the Arduino Nano microcontroller, which then controls the volume controller by the C code developed by the software team. The module is trained to recognize sounds, words, and noises provided by the user. The program can be divided in three main parts: structure, values, and functions. The central system is programmed in the microcontroller and contains a main process which calls functions for completion of tasks.

In the integration stage, we wrote a program which controls all the recognition process and sends the appropriate signal to the microprocessor to perform the action. The voice recognition module will capture the noise, and the programs will call its special functions to determine if the noise matches the one that is trained. In our main process, an infinite loop will be run to detect any input noise signals. When a signal is detected, it will store the data then call the mode function to be set up mode of operation by the system.

2.3 Hardware

2.3.1 Arduino Nano - Microcontroller

The Micro-controller we are using in this project is Arduino Nano. The three main operations of the microcontroller are: checks the mode of operation, performs arithmetic operations, and sends pulse signals. Once the microcontroller determined the mode of operation, it then performs arithmetic operation on the signal received from the EasyVR. It compares the data in the sound table that is stored in the EasyVR. If the signal matches those in the sound table it sends the number of pulse signals to the volume controller, the DS1869. The number of signals to send is controlled by the counter in the microcontroller.

2.3.2 EasyVR - Voice Recognition module

The Voice Recognition module we are using in this project is EasyVR. Its excellent price, small size and specific functionality inspire us to use it for this project. The main task of EasyVR is that it captures ambient sounds by the microphone, filters the noise, converts the signal to digital signal and finally sends it to the microcontroller.

2.3.3 Volume Controller – DS 1869

The volume controller as DS1869 is a digital potentiometer. The pulse signal from the microcontroller adjusts the resistance of the potentiometer. The variable resistance of the potentiometer results in higher or lower intensity of audio provided to the headphone.

2.3.4 Wireless FM Tuner Headphone

Because of the budget cut down, we used portable wireless FM tuner headphone instead of noise cancelling headphone in our prototype. This headphone provides good quality of sound with super bass function.

The main features of this headphone include:

- High quality
- Excellent choice for mobile video when used with a wireless FM transmitter
- Works as standalone FM headphones for private FM listening
- Features a volume control, power switch and FM frequency tuner from 88 to 108Mhz

2.4 User Interface

The user interface hardware consists mainly two buttons: Power, Reset. The buttons are located on the side of the ear piece of the headphone. Each button is associated with a unique function. The following table is shown as their functions.

Button	Function
Power	Turns the MIHS On/Off
Reset	Reset after Word, Sound, or Voice Detected and Action Performed

Table 2.1: User Interface Button Specifications

The software part allows users to customize the word, sound, and voice used. This is done through the EasyVR commander. After the installation of the software, user can connect MIHS directly to their PC using the mini USB and start the EasyVR Commander.

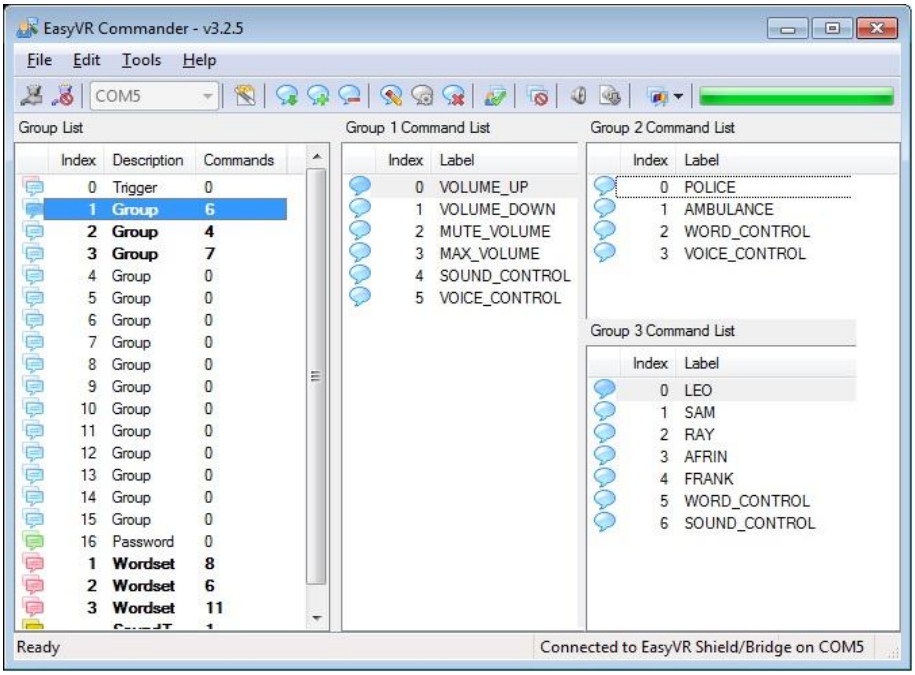

Figure 2.2: User Interface Software – EasyVR Commander

MIHS comes with pre-trained word and sound sets, simple word as VOLUME_ UP and VOLUME_DOWN will trigger the MIHS to tune the volume up and down. It also comes with pre-trained sounds such as ambulance and police siren sounds. User can train special words such as 'one' and 'two' to tune the volume up and down, or add train more sounds. Using the EasyVR Commander, user can also train the special voice such as themselves or their parent's voice to trigger the MIHS.

3 Deviation from Proposed System

As described from the last section, current state of device, there are still some deficiencies that we need to improve. The following figure 3.1 displays the high level block diagram of original proposed design specifications. By comparing figure 3.1 with figure 2.1, the input buttons which perform the model selection between voice recognition, speech recognition and voice recognition has been changed to an external system reset button and a power switch button. This section will talk about the deviations of MIHS from both software and hardware perspectives.

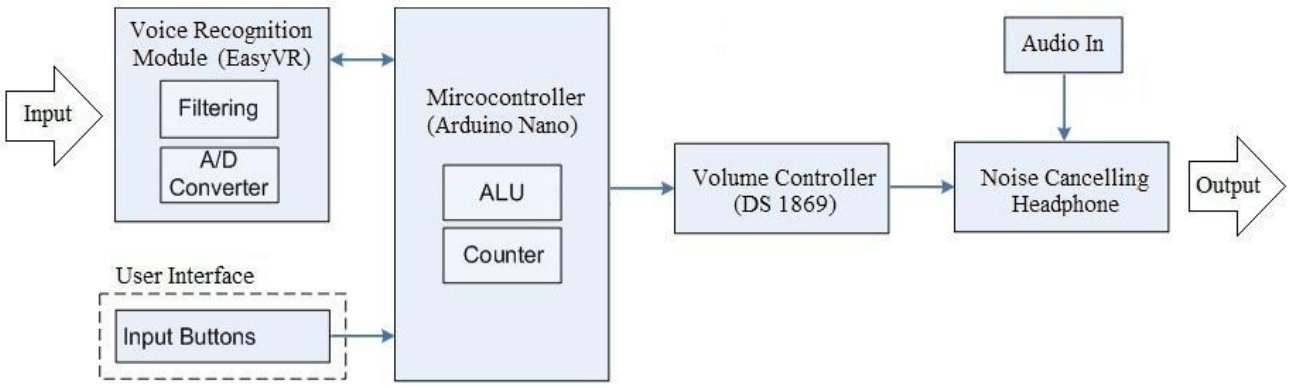

Figure 3.1: High Level Block Diagram of MIHS – original planned

3.1 Software

According to our design specification, we want the software to support three different modules i.e. Sound, voice and word. In our final software we have three different modules. The user can configure the chip to operate in one of the three modules at a time. We had built robust software which has met all the requirements except some small deviations.

As per our initial plan, we have the Arduino microcontroller software to configure, control the EasyVR chip. In our initial plan, we also wanted Arduino microcontroller software to train word, sound and voice commands in EasyVR. However, our current Arduino software is not able to train word, sound and voice commands. This training is done by separate EasyVR commander software. This little work around had not impacted the overall performance at all.

We also want to control the digital potentiometer with the digital wire library in the Arduino example software. This would have made the integration between microcontroller and the digital potentiometer much easier. However, we find out that our digital potentiometer is not compatible with the digital wire library. The current software is not dependent on the digital wire library, but has its own module to effectively communicate with the potentiometer using digital pulses. In fact, this workaround gives us more flexibility in terms of the communication. Moreover, current software can configure any pin of the Arduino chip to control digital the potentiometer instead of using the digital wire pin specified by the digital wire library.

3.2 Hardware

3.2.1 EasyVR - Voice and Speech Recognition Module

The SmartVR also known as VoiceGP module is definitely a powerful development board from that can easily perform the voice and speech recognition. As mentioned in the proposal and function design specification, SmartVR is our initial choice. It is the backorder that delays the whole team's work more than two weeks; we have to switch to EasyVR which is an excellent board as well that integrates all the necessary components for performing the voice and speech recognition.

There was one difficulty we had to mention was that we got stuck when we tried to integrate the microcontroller and voice module. The communication between microcontroller and EasyVR could not be constructed in the first week when we got all the components back. It took our one week hard working to realize that the circuit on the EasyVR got burnt during the process of integration.

3.2.2 Noise Cancelling Headphone

We planned in our proposal that a noise cancelling headphone would be used in MIHS to provide a high quality audio output and to avoid the external noise. The actual headphone we used in our prototype is just a normal headphone that can be easily modified and adjusted. One reason is a normal headphone is much cheaper that we take a lower risk of damage. On the other hand, we switched to a much cheaper headphone for most people do not want to spend more than $100 on headphone in our market survey. That is no doubt that noise cancelling headphone has a higher price but most people do not need it.

4 Future Improvement of the System

The Multifunction Intelligent Headphone System developed by Sound Tech Inc. is to provide users great comfort, high sound quality, as well as safety. In our prototype, the function's behaviors proposed in the proposal are working as expected. During the initial proposal we are not too familiar with the compatibilities and the interaction of the components, so there are few concerns that are not addressed. Through the development stage these concerns have arisen, these concerns will be explained in detail in the following section.

4.1 Microphones

The prototype MIHS currently has only one microphone, this is located just above one the ear piece of the headphone. We would like to add 3 more microphones to MIHS in the future, so there will be two microphones on each of the ear pieces, one above and one below. Having more microphones can cover a larger range of sound that is coming to the user, so the user is more aware of their surroundings. Also, we would like to upgrade the microphones, microphones that have noise filtering, the microphone we are using in the developing stage does not filter noise that well so sometimes it cannot pick up the command.

4.2 Audio Amplification

One thing we did not put into consideration in the development of MIHS is the total resistance the microcontroller and the voice recognition module outputs. The resistances coming from these components play a major role in MIHS; it limited the level of sound delivered to the headphone. There is a big difference in the sound level when using normal headphones and using the MIHS, the volume from MIHS is around half the normal headphones. There needs to be a sound amplification for the system, this amplification should give user better sound quality.

4.3 Digital Potentiometer

During the development stage, we found that the digital potentiometer cannot be accurately controlled by the microcontroller. The digital potentiometer requires a 1µs HIGH and 250 µs LOW between pulses, the pulse signal from the microcontroller was found to last for approximately 10 µs. This created an issue as there is a limited and inaccurate control of the volume of the MIHS. After doing further research, we found there is a digital potentiometer that can be accurately controlled by the microcontroller and its built-in libraries. We hope to test this digital potentiometer in the future so we can have a more accurate volume control on our MIHS.

4.4 Power Supply

Currently MIHS can be powered by a 9V battery or through a USB. In the future, we would like to make the power source rechargeable, the recharging will either through a USB or through a power outlet. There are many advantages of using a rechargeable battery, the main advantages are: it saves the user money in the long term and it is good for the environment. We would also like to implement a power indicator, the power indicator will indicate to user if MIHS is fully charged or not. Because MIHS is designed to provide user safety when using the headphone, it is important that MIHS can be functioned for the period when users are using it, so the power indicator really important and it is a must have.

5 Budgetary and Time Constraints

Our initial fund from the Engineering Science Student Endowment Fund (ESSEF) for this project was $500 and the actual amount spent for the project is $572. The actual cost includes one wireless FM Tuner Headphone, two microcontrollers, three voice recognition modules, multiple digital potentiometers, debugging chips and various electrical components. Having these duplicate components allowed Sound Tech Inc. to divide into two teams to work in parallel and also for backup in case of emergency.

5.1 Actual and Estimated Budget

Table 5.1: Proposed and Actual Final Budget (Prototype, Module, Testing showed separately)

PROPOSED COMPONENT	PROPOSED PRICE	ACTUAL PRICE	DEVIATION	PROTO-TYPE	MODULE	TESTING / EXTRA
Micro-controller	$150	$97	$53	$49	$48	$1
Voice Recognition Module	$150	$218	-$68	$49	$67	$102
Headphone	$150	$100 (Donated)	$50	$100 (Donated)	$0	$0
Debugging Chip	$100	$103	-$3	$13	$14	$77
Miscellaneous Electrical Components	$50	$51	-$1	$19	$15	$19
Power Supply and Batteries	$50	$3	$47	$3	$0	$0
	$650	**$572**	**$78**	**$233**	**$144**	**$199**

Our estimated budget at the beginning of the project differed slightly from the actual budget. But we went over the estimated cost at the beginning, but also we tried our best to cut the costs as much as possible. For instance for some parts instead of buying new equipments, we modified some of old components that we already had. However, This Actual amount shown in table 5.1 does not include Noise Cancelling Headphone. The Noise Cancelling Headphone itself cost around $300. For the prototype, the members of Sound Tech Inc. contributed the cost of Wireless FM Tuner Headphone.

5.2 Actual and Estimated Project Timeline

We have completed our project in time for the presentation, and have demonstrated the effective use of the time allotted. We also met all the deadlines for the documentations and even had our presentation and demo in early April. However, the time used for component selection took longer than expected and this is due to some of the parts that are mis-ordered and some are defective. Furthermore, the component has been tested separately to reduce any more delay.

Below a Gantt chart shows the comparison between the actual and proposed project timeline.

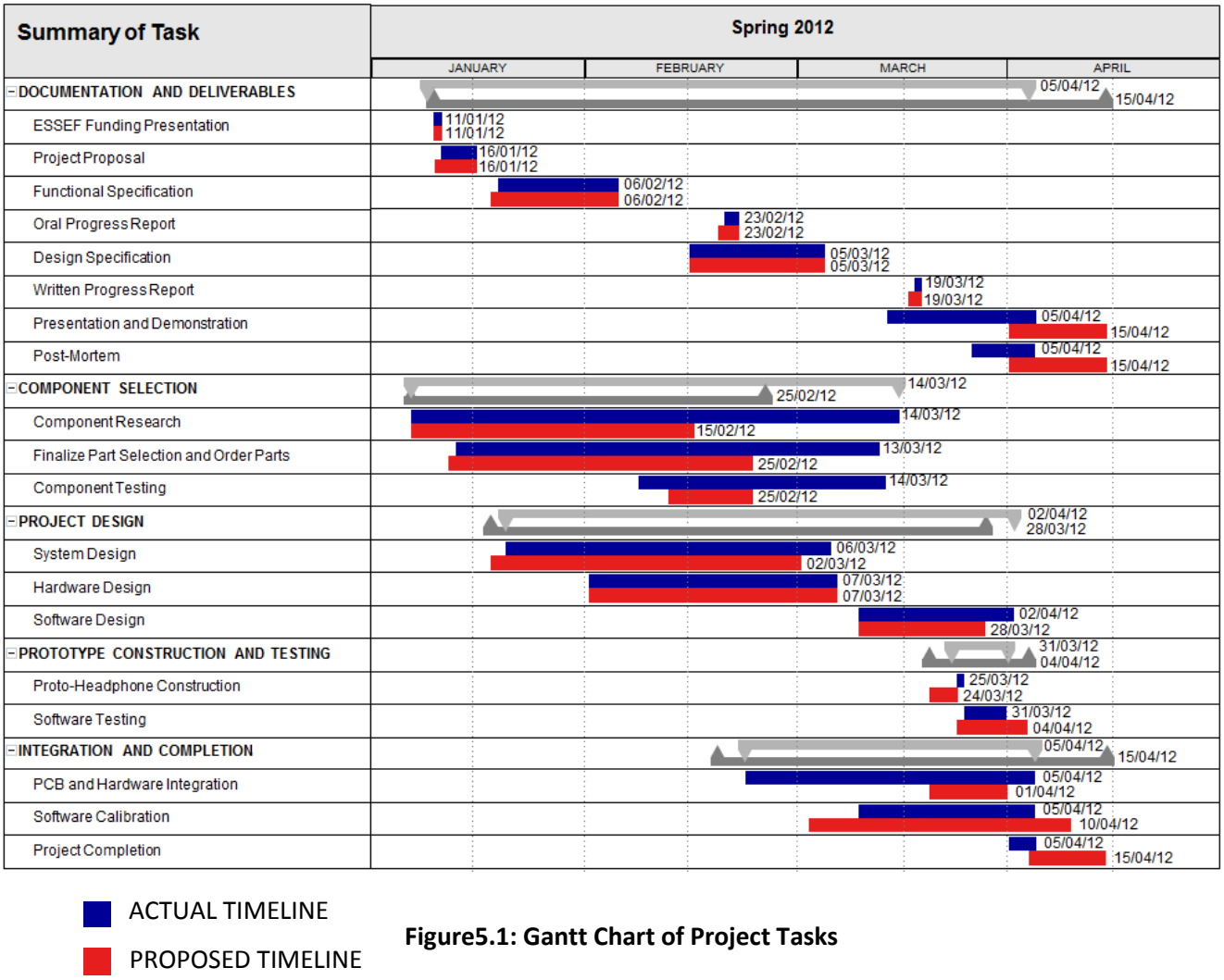

Figure5.1: Gantt Chart of Project Tasks

6 Interpersonal Technical Experiences

6.1 Afrin Chowdhury – Chief Finacial Officer

First of all, I would like to thank Dr. Andrew Rawicz and Steve Whitmore for sharing many valuable information during the lecture hours of ENSC 305 and 440. I believe these are the most important and interesting courses I have ever taken at SFU. I have learnt many valuable lessons throughout this course. My previous co-op experience at HSBC Canada as "Data Analysis And Reporting Support" helped me in this project to a great extent.

My role as Chief Financial Officer of Sound Tech Inc. was to look after the financial planning and potential marketing risks of our products. Throughout the course of this project, I've monitored our budget closely and facilitated the decisions of purchasing components and materials. I ensured that the project remains within the allocated budget.

Besides the financial planning responsibilities, I was also involved in the hardware research such as microcontroller, voice recognition module etc. I had the opportunity to work with microcontroller and voice recognition module which are the main components of our project.

This project helped me to improve my project management skill, time management skill, communication skill, and various technical knowledge. I have also learnt that there are a lot of things which can turn the financial books in the wrong direction. Before this project, I had little experience with integrating hardware components and software programming. This opportunity allowed me to gain valuable experiences in testing hardware components, designing electronics systems, and practical knowledge in C programming.

Finally, I would like to thank my group members. With the diverse experience that we have in our team, many problems were solved internally. It is amazing how much one can learn from another. Everyone has their own special skills and when the team is able to combine them, it makes for a very valuable contribution towards the team's success. So through hard work and dedication our project was successful.

6.2 Frank Zhu – Chief Information Officer

As the CIO of the company, I was responsible for information technology and computer systems. I would be managing the implementation of the useful technology to increase information accessibility and integrated systems management. Working on this capstone project throughout three months has been an exciting, rewarding and work intensive experience. I have acquired not only valuable skills from product development in engineering, but also interpersonal teamwork skills that are essential for functions of team in working.

From a technical point of view, I have developed my several important knowledge while of working on our project. Firstly, I have strengthened my fundamentals in electronic circuit and component operating characteristics. Arudino Nano as our microcontroller and EasyVR as our voice recognition module are the core parts of our project, so I paid special attention to them in order to realize how they normally work. Therefore, I have also learnt how to use new circuit components that I have never seen before.

For the software aspect of the project, I had an opportunity to work with Simranjit Sidhu, further developed my programming skill in C language and other software. We programmed the Arduino Nano microcontroller in order to perform arithmetic operation on the signal received from the EasyVR, and let it compare the data in the sound table that is stored in the EasyVR. Hence, I have developed my skills of embedded system programming.

Overall, we have achieved our goal, and our prototype looks like a professional headphone. To be honest, I have improved my communication skills, appreciated all group members' work, and knowing that without any of my partners, I wouldn't be able to achieve our goal. Thank you my team members! I would absolutely like to work with you guys again in the future.

6.2 Leo Jia Hong Jiang – Chief Executive Officer

ENSC 305 and ENSC 440 are by far two of the most important courses I enrolled in Simon Fraser University. These two courses are like a continuous test for me, it tested me on everything I learned in the past 5 years: hardware design, software programming, communication, and writing reports. From these two courses, I have improved my academic knowledge and my management skills, also I proved to myself that I am up for any challenges.

My role at Sound Tech Inc. is the CEO; I was largely responsible for three main things: making high-level decisions, distributing work tasks, and ensuring all group members are up-to-date at all times. The biggest challenges for me being a CEO is making the high-level decisions, every decision made has a huge effect on all different stages of our design. The first decision I have to make was if we should wait for the component or get a different one. In the early stage of our design, one of the components was backorder twice; this created a huge setback for members of Sound Tech Inc. My final decision was to order a different component, and I was glad that everything turned out great. The decisions not only bring the team back on schedule, but also saved us some money. The next challenge I had was distributing work tasks; first off, I have fair amount of knowledge on different aspect of the project so I am capable to handle any part of it. However because some group members have limited knowledge and many tend to share the same, it was difficult to assign tasks from time to time. To be fair, if certain task was difficult there will be more than one person working on it, and since I have knowledge on different aspects I will also assign difficult tasks to myself.

Through working on different tasks of the project, I have gained many valuable experiences and a great deal of knowledge. Research: I realized how important researches are, the detail of the research is very important and we should never rely on just one resource. Programming in Arduino: I wrote number of codes to test different components; this coding has strengthened my knowledge on coding and how easily I can adapt to different programming languages. Documentation: Through a series of documentation that is required for the project, I have improved my written skills as well as professionalism in writing.

Overall the experience with the group members are remarkable, we did have some trouble communicating and during some task assignments but it was resolved very quickly. Final note I want to add is "When in doubt, talk it out!" All problems can be solved with a peaceful mind.

6.4 Simranjit Sidu – Chief Technical Officer

This course gave me the best opportunity to work in a small start-up company in a group of five intelligent and talented engineers. By making a working model of our headphone system, I have learnt, applied and improved my creative thinking, communication, documentation, management, research and technical skills.

My position at Sound Tech was CTO. I was largely responsible for providing technical vision in terms of the hardware and software required to meet the design idea of the headphone system. I have done extensive research in the beginning to find out six different design solutions for the problem. We have discussed the pros and cons of each design solution including the time and complexity involved in each solution. Finally, we came up with the design solution to best meet the requirements of the product keeping our budget and time in the mind. We have decided to use Arduino Nano, EasyVR and digital potentiometer. This helped me to improve my research, discussion and brainstorming skills.

The integration of Arduino Nano, EasyVR and digital potentiometer hardware pieces together into one system, strengthened my hardware skills. I successfully created a software module for arduino nano to control and communicate with the EasyVR in bridge mode. This enhanced my software skills. Furthermore, I provided support to whole team by explaining them the software module and the communication command set used by Arduino with EasyVR. Hence, I improved my communication skills.

I was responsible for combining the design solution report for the prototype. There was a strict deadline for the report. Completing the report and meeting the strict deadlines improved my documentation and time management skills.

Overall I can say that this project is one of the biggest milestones completed by me in my Biomedical engineering career. The skills gained by working on the project will help me in my professional career.

6.5 XiaoPeng He – Chief Operating Officer

Over the past 4 months, I have had a great opportunity and honour to work with my highly skilled teammate, Afrin, Frank, Leo, and Sam. I learned a great deal of technical skills in software and hardware through this embedded system design. Also it's a truly pleasure that not only successfully completing multifunction intelligent headphone system as our ENSC 440 capstone project but also benefits our society that the MIHS has great potential to prevent injuries.

As a team member of Sound Tech Inc, my main responsibility is to focus on the daily operation of the whole company and to offer the technical support in software programming. First of all, my primary duties included scheduling weekly meetings, coordinating workflows, as well as involved in all facets of project development from hardware research. In order to follow our timeline that I strengthened my fundamental sills in time management and coordinating team work. Secondly, with the help of Leo, we decided all the hardware we need to use in this project and made adjustment time when there was a backorder from our initial purchase. With my previous coop experience, the other technique I acquired progress is embedded system design, PCB design and electronic hardware debugging. Also I got chances to test the Arduino microcontroller and EasyVR voice recognition module.

The most challenging part during this project was integrating the whole system. We got stuck when we tried to integrate the microcontroller and voice module. The truth was that we knew next to nothing about the EasyVR voice recognition module and testing the communication between microcontroller and voice module was needed as soon as possible. We realized the one capacitor on EasyVR board got burnt after spending almost the whole week working on the particular section. Even though it was a big challenge, it was a great opportunity to learn knowledge of the electronics hardware test.

ENSC 440 is definitely one of the most important courses in my SFU career. The experience of completing this capstone project is absolutely necessary to become an engineer. It was so hard to describe my appreciation to my teammate who gave me support, help and motivation. All the time we experienced, no matter the pleasure or the stressful and harsh time will be my stepping stones to my further career.