TeleKinetics Unlimited
Simon Fraser University
Burnaby, BC
V5A 1S6
tele-kinetics@sfu.ca

April 15th, 1998

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

Re: ENSC 370 Project BrainWASH Process Report

Dear Dr. Rawicz,

The attached document, *BrainWASH Process Report*, outlines the process our team went through when designing and implementing our system for ENSC 370. Our project was to design an assistive device that would allow the physically disadvantaged to control their environment through the use of brain waves.

This document details the current state of the device, deviations from our original plans, and our future plans for the device. In addition, we outline some of the budgetary and time constraints we encountered and explain the inter-personal and technical experience gained from working on the project.

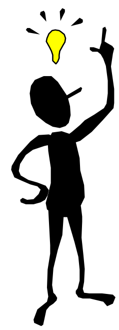
TeleKinetics Unlimited consists of four motivated, innovative, and talented third-year engineering students: Iris Lin, Sunny Wan, Roanna Chiu, and Greg Hall. If you have any questions or require further information, please contact me by phone at 899-0270 or by e-mail at iylin@sfu.ca.

Sincerely,

Iris Lin, President
TeleKinetics Unlimited

Enclosure: *ENSC 370 BrainWASH Process Report*

TeleKinetics Unlimited
Brain Wave Actuated Switch



Process Report

Submitted by TeleKinetics Unlimited
Greg Hall, Iris Lin, Roanna Chiu, Sunny Wan
tele-kinetics@sfu.ca

Contact Iris Lin
School of Engineering Science
Simon Fraser University
iylin@sfu.ca

Submitted to Andrew Rawicz
School of Engineering Science
Simon Fraser University

Steve Whitmore
School of Engineering Science
Simon Fraser University

Date April 15, 1998

Table of Contents

Introduction 1

Current State of the Device 1

Deviation of the Device 3

Overall System 3

Signal Acquisition 3

Signal Conditioning 3

Signal Processing 3

Actuator Interface 4

Future plans 6

Overall System 6

Signal Acquisition 6

Signal Conditioning 7

Signal Processing 7

Actuator Interface 7

Budgetary and Time Constraints 8

Budget 8

Time 9

Inter-Personal and Technical Experiences 10

Iris Lin 10

Greg Hall 11

Roanna Chiu 12

Sunny Wan 13

Introduction

For the past thirteen weeks, the idea of a Brain Wave-Actuated Switch (BrainWASH) has drawn together 4 outstanding individuals -- Iris Lin, Greg Hall, Roanna Chiu, and Sunny Wan -- who have worked tirelessly towards the realization of BrainWASH. This report re-examines the process that took this dream from concept to reality and documents the earth shattering experiences of each of the four members.

Current State of the Device

As described in the project proposal, BrainWASH detects alpha wave, a particular type of brain wave ranging from 8 to 13 Hz, and determines whether to toggle a switch according to a predefined threshold value. A system overview block diagram in Figure 1 illustrates the process mentioned above.

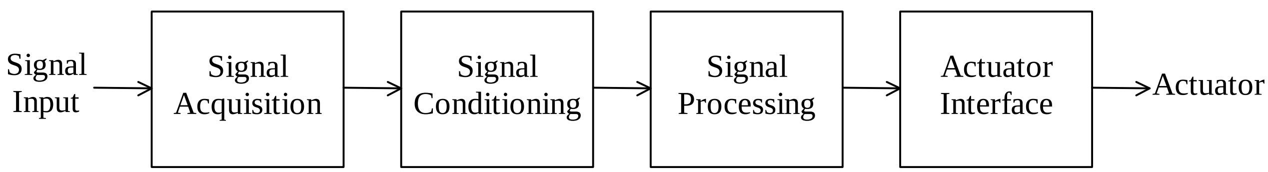


Figure 1: System Overview

As illustrated by Figure 1, BrainWASH contains several sub-units. The current state of the device will be explained by reviewing each of the stages in Figure 1.

In the signal acquisition stage, three permanent electrodes, a reference, a ground, and a signal, are attached to the user to acquire and pass the brain waves to the signal conditioning stage.

The signal conditioning stage is comprised of an instrumentation amplifier, a fourth-order Chebyshev filter, a high-pass filter, and two non-inverting voltage amplifiers. The instrumentation amplifier acquires the signals from the signal and reference electrodes, and amplifies the differential voltage. The resulting signal is filtered by the fourth-order Chebyshev filter to remove any noise outside the 6 to 19 Hz range. It is also further amplified using non-inverting voltage amplifiers to a range of about +/- 4 V. Finally, the high-pass filter removes any remaining DC signals and the resulting signal is transmitted to the signal processing stage.

The signal processing stage is achieved by a Texas Instrument (TI) Digital signal processing Starter Kit (DSK). The DSK includes the Digital Signal Processing (DSP) chip, an Analog Interface Circuit (AIC) for analog/digital conversion, and supplementary circuitry. The conditioned signals are first digitized by the AIC and stored in the data memory space of the DSP chip. Next, the DSP chip processes the data and generates the appropriate output. The software for the signal processing stage includes various modules as illustrated in Figure 2.

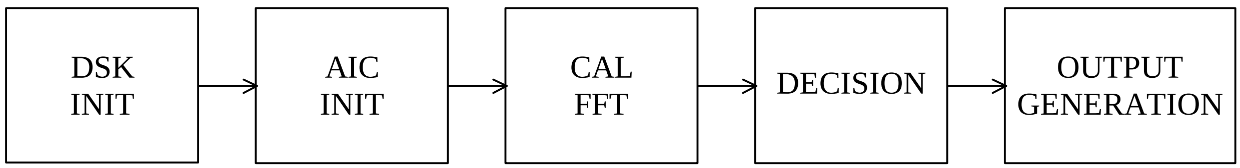


Figure 2: A Flowchart Diagram for the DSP Modules

After many long hours of modifying Fast Fourier Transform (FFT) sample codes from TI, we were able to implement a 32-point radix-2 FFT on the signals, and to compare one of the 32 calculated values, which contains the information from 7.5 to 12.5 Hz, to the predefined threshold. Whenever the signal has a FFT result above the threshold value, the DSP chip outputs logic high to a JK flip-flop, which toggles between high and low. An output high at the flip-flop turns the actuator on, while a low turns it off.

The actuator interface is a universal wall plug adapter which allows most home appliances to be plugged in and thus controlled by BrainWASH. The actuator interface uses an opto-isolated triac circuit to control power to the various devices plugged into it. When the DSP sends a signal commanding the actuator interface to turn on or off the actuator, the signal is fed into an opto-isolator which uses a Light Emitting Diode (LED) to activate a triac. The triac then allows the circuit from the wall socket to be connected to the actuator.

From our tests with two subjects (Greg Hall and Steve Wong), we noted that a person can be trained in less than 5 minutes to generate an adequate amount of alpha waves by opening and closing their eyes.

Deviation of the Device

Overall System

In terms of functionality, we achieved what we planned. Due to time constraints, we were unable to finish packaging the device, to implement the status Light Emitting Diode (LED), to power the device using batteries, and to make the device portable as described in the functional specifications.

Currently, our prototype consists of three separate circuit boards. The actuator interface is properly enclosed while the signal processing and signal conditioning stages are mounted on a plexiglass. Leaving the boards exposed allows us easy access to debug the circuits.

The reasons that the device is not portable and is not powered by batteries will be discussed in the following sections.

Signal Acquisition

The signal acquisition stage has not deviated very much from our original plans. The only difference is that we have yet to test BrainWASH using disposable electrodes. Originally, we planned to use permanent electrodes until the system was functional and stable before testing the disposable electrodes, which are relatively expensive. However, due to time constraints, we will not get an opportunity to test them until our preparation for Solutions 98'.

Signal Conditioning

The implementation of the signal conditioning stage has not deviated at all from the functional and design specifications. The signal conditioning circuitry behaves as the simulation circuitry; therefore, modifications to this stage were not required.

Signal Processing

The implementation of the signal processing stage is somewhat different from the one described in the functional specification. The reason is mainly time constraints. Considering the constraints required to develop our own board, it was less desirable than using a commercially available development platform. As a result, we utilized a TI DSK, which included the DSP chip, an AIC for analog/digital conversion, and supplementary circuitry. The advantage is that we focused our efforts on the software development which were rather time consuming and frustrating because of our unfamiliarity with the particular assembler.

Because we are using the DSK, which has to be powered by a 9V ac through an adapter to a wall socket, we could not power the whole device using batteries.

Actuator Interface

Wireless control was not implemented in the actuator interface. Given more time, the implementation of wireless control is possible with commercially available remote control packages.

The input current control circuitry for the actuator interface was changed from the schematic shown in Figure 3 to the schematic shown in Figure 4. The main reason for this change was that the original design acted as a current amplifier instead of a simple switch circuitry. After modification, the circuitry worked as a simple switch.

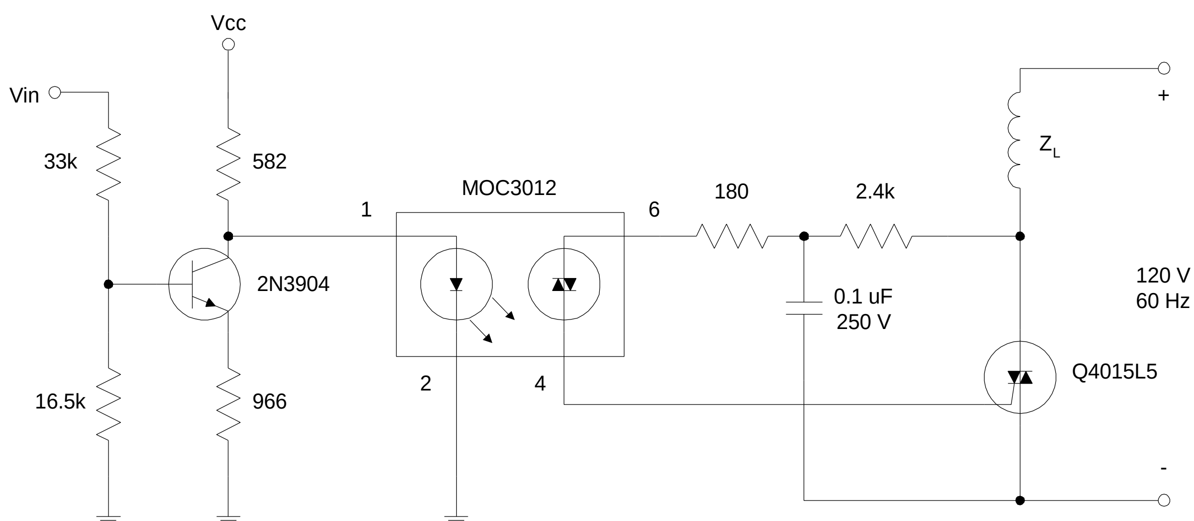


Figure 3: Original Actuator Interface Schematic

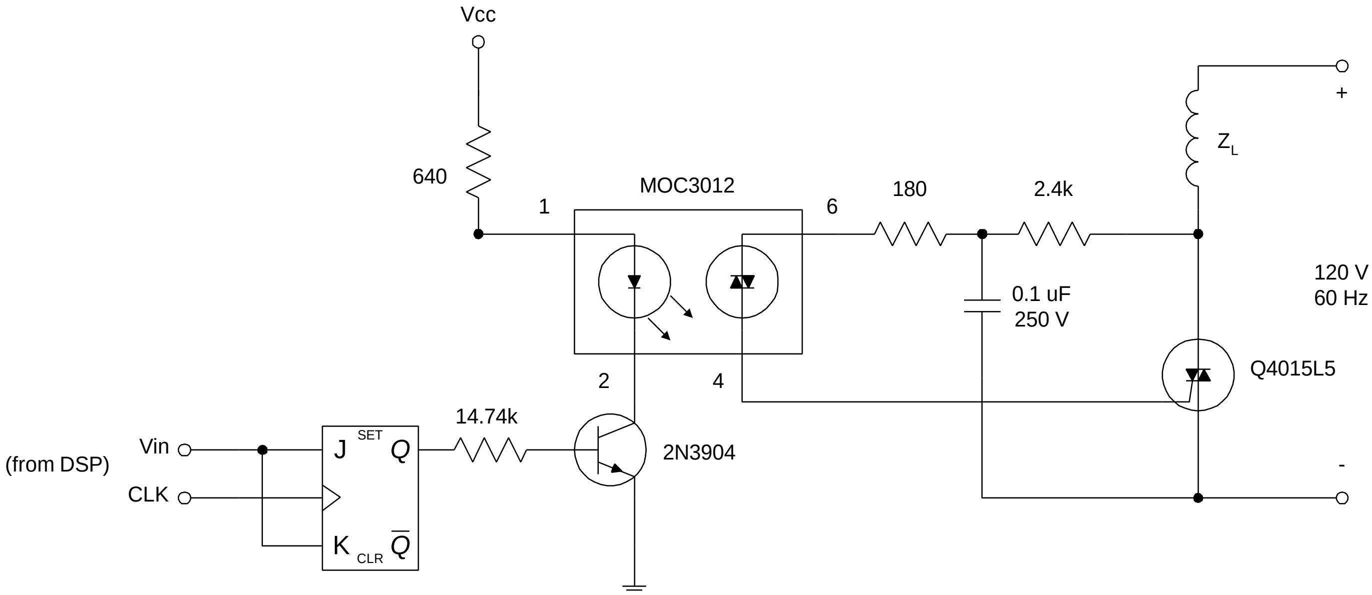


Figure 4: Modified Actuator Interface Schematic

In addition to the change in the input circuitry, we have also added a JK flip flop to the circuit board. Whenever a high signal is sent to the flip flop from the DSP chip, the flip flop output will toggle between a constant high or low signal. This output signal is then continuously applied to the base of the transistor in the input circuit. If the signal is high, the opto-isolator turns on and drives the triac which closes the circuit from the wall to the actuator. If the signal is low, the circuit to the actuator remains open. Also, originally we had planned to power the actuator interface from the batteries on the signal conditioning board. As we were experimenting with this we found that it was too draining for the batteries. So, for the moment, we have chosen to power the actuator interface including the JK flip flop using a 5 V DC signal from the DSK.

Future plans

BrainWASH has great potential for further research and improvement. As we re-examine the development of the device, we have the following suggestions for future development.

Overall System

- *Package the device.*

  As a prototype to prove the concept, the device in its current state is not portable. One solution is to power the entire device by batteries and to enclose the device in a plastic case.

- *Determine and Optimize power consumption.*

  We hope to determine and optimize the power consumption of the entire system when we develop our own signal processing board.

- *Minimal disturbance to the user.*

  One solution is to reduce the size of the device by making it more compact.

- *Develop two-dimensional control using other brain waves.*

  As a one-dimensional control device, the applications are limited. A different approach is to use the mu rhythm, another type of alpha wave, to develop a two-dimensional control device. However, the drawback of the mu rhythm is that it requires intensive training for the user to control it. Unlike the mu rhythm, visual alpha rhythm acquired for our control purpose requires minimal training of the user to control a one-dimensional switch by opening and closing his or her eyes.

Signal Acquisition

- *Develop a user friendly acquisition platform.*

  For example, the signal acquisition stage can be modified such that the electrodes are hidden in a cap or a wig. Also, looking for an easy-to-use electrolyte paste or even eliminating the use of such paste to improve usability. Use the ear as the reference instead of the forehead.

Signal Conditioning

- *Combine the signal conditioning stage with the signal acquisition stage.*

  Use of surface mount components will reduce the dimension of the signal conditioning stage for integration with the signal acquisition stage, namely the electrodes allowing us to reduce EMI interference with the input signal.

Signal Processing

- *Use AIC for output.*

  The current design of the output is digital which requires external circuitry. It will be interesting to explore the possibility of using the analog output for our control purpose.

- *Implement different algorithms to interpret the signal.*

  The implementation of signal processing utilizes an algorithm that has a predefined threshold value which differs from person to person and from time to time. Therefore, usability is reduced since calibration is required. A relative comparison algorithm or a neural network may overcome such a problem.

- *Use a different DSP chip.*

  Our experience with the TI C50 chip was not exactly pleasant. Therefore, more efforts will be focused on finding a more user-friendly DSP development platform or other micro-controllers.

Actuator Interface

- *Development of Remote Control.*

  The use either Infrared or Radio Frequency (RF) for control of appliances will improve the mobility of the user and versatility of control.

- *Control of multiple devices.*

In the future, we will need to invite our target users, physically disabled people, to test the device and obtain their feedback.

Budgetary and Time Constraints

Budget

Table 1 contains the estimated cost and the cost of the project up to April 14th, 1998.

Table 1: Estimated Cost vs. Actual Cost

Required Materials	Estimated Cost	Actual Cost
Sensors (EEG electrodes)	$500	Borrowed
Microprocessor(s) & evaluation board(s)	$200	$173.29
Discrete components	$100	$58.42
actuators	$100	Borrowed
Power supplies	$100	Borrowed
Prototype board(s)	$100	$14.28
Cables / wiring	$50	$10.00
Miscellaneous	$50	$61.64
Total	**$1200**	**$317.63**

Because the project will be continued to prepare for the student design competition, Solutions 98', the cost listed above does not indicate the total cost of the project. As one can see, our estimated cost was more than 3 times the actual cost of the project as of now. One of the major reasons is that we were able to borrow certain items, such as the EEG electrodes from Dr. Weinberg in Kinesiology and the actuator and power supply from the group members, so that the cost of the project is significantly reduced. The budget estimated for the miscellaneous category was less because we neglected the cost of components, such as pin sockets, connectors and batteries, which are also important to the completion of the project.

Time

A Gantt chart is attached to the document in which the expected time to completion are indicated in black and the slippage are the addition in gray.

It is interesting to note that the actual implementation of most stages requires about twice as much time as we anticipated. One reason is that we had underestimated the complexity of certain stages, such as the signal algorithm development.

Despite certain slippage, we began integration of the entire system as we planned and had the first successful trial on March 27, one week ahead of our scheduled deadline. Since than, more modifications have been taking place to ensure safety and robustness of the device.

Due to exam conflicts, we could not demo our system immediately after the completion of the project. However, our group was the first ENSC 370 group to demo on Tuesday, April 14th, 1998.

We all felt that it was very important that we tried our best to follow our project schedule and complete the project as we planned. By adhering to the schedule, we were able to distribute the frustration and pressure throughout the entire semester.

Inter-Personal and Technical Experiences

Iris Lin

For the past 13 weeks, I felt that I have learned to analyze seemingly meaningless data and to extract from it what I needed to accomplish my tasks.

In addition, I have become familiar with the digital signal processor used for the project. I learned Texas Instrument C50 assembler and gained better understanding of Fast Fourier Transform algorithms. Despite many sleepless nights attempting to understand what and how I was supposed to do, I grew to enjoy low level programming and I am awed by what digital signal processing can achieve. Even though the digital signal processing (DSP) algorithms we implemented were relatively simple compared to the hard-core DSP algorithms used by other applications, I am pleased to have the opportunity to be exposed to basic DSP algorithms. I hope to work on projects that have DSP components in the future to experiment in depth with DSP techniques.

I have also found that sufficient research will help set the direction for the project. What I learned is that no matter how innovative one thinks one's ideas are, someone out there must have thought about it, possibly researched and published some papers on their research result. I got in touch with Dr. Wolpaw who has done similar research to what we wanted to accomplish. It was very encouraging to contact him and sent us his research papers. Personally, I felt that it was important knowing that a similar project has been progressed over the past 8 years and shown signs of success because some people around us suspected the possibility. Knowing that it is possible to accomplish our goal encouraged us to be focused and dedicated to our project.

Our group has developed an excellent way of reviewing our documents. We first brainstormed for ideas together, and then everyone wrote some sections. Then, we gathered again to review each other's write-up, to suggest ideas, and to correct grammatical errors. Finally, one person took it home to format it and to double check that everything is done.

Interpersonally, I have learned to be understanding. Working in a group means compromise at times because everyone is entitled to his or her opinion and will feel more involved if and when their ideas are incorporated in to the design of the system. It was also important to be patient when others express their ideas. Communication is a two-way street. If I can not respect what my group members have to say, I will not be listened to when I want to express myself.

Personally I feel extremely lucky to have worked with four very hard-working, dedicated, and fun individuals, including myself ☺. We all learned to listen to each other and expressed our ideas, thoughts, and concerns when necessary at our weekly meetings and other occasions when we discussed our progress and technical difficulties we encountered. If I were forced to repeat the experience, I would not do anything differently because what we had really worked well for us.

Greg Hall

From a technical perspective, I increased my knowledge of transistor circuitry, learned about the use of triacs and opto-couplers in power electronics. I also learned about filter design. From an overall perspective, I learned that the design process is very much an iterative process. I found that we made several changes to our first design as we learned more and were able to make better decisions on what we needed. Also, it is very important to fully characterize your device or circuitry so that you have a full understanding of how the device works. This understanding will allow you to troubleshoot your device much more effectively. A lot of time was wasted simply because we didn't have a full understanding of the device. Once we did characterize the device, we found it much easier to troubleshoot any problems.

One of the most important attributes I learned that you need to have while working in a group is patience and understanding. We need to be patient with one another as we try to understand and integrate each other's ideas. Listening skills are vital. Talking over top of one another gets nowhere. We need to really strive to understand each others ideas before we start commenting on them.

Once we do understand one another, we need to learn not to take any criticism personally and not to give any personal criticism unless it is really affecting the project. It's important to keep the group goals in mind while criticizing and being criticized.

I learned that planning ahead is vital in succeeding in any project. Deadlines must be set and stuck to. I found that deadlines helped me to plan the work out over the required time without having to rush everything at the end. Along with deadlines, meetings are essential to success. Meetings allow us to communicate on project progress and eventually work together to easily integrate the final project. One very important thing that must be done in meetings is to stick to the agenda and not get caught up in problems or other topics that pop up. If we end up talking about all these problems that appear, the meeting will never finish and nothing will get accomplished because we end up identifying all these problems without solving any of them. It is important to focus on one problem at a time until it is solved then move on.

I also learned that if you don't know something, ask. There are many knowledgeable people that are willing to help and teach us about what we need to know. Also, we must not be afraid of making mistakes. It helps in the learning process to make mistakes and learn from them.

Finally, it is important to push yourself and allow yourself to be pushed by your group. Reminders and encouragement from members of the group are very helpful in completing all that is needed. It is also important to be considerate and respectful of group members. The group should have the same goals and objectives for the project but also be aware that the members have different lives and other things to be done at different times. The group must support and trust each other. I found that when group members believe in and encourage one another great things can happen.

Roanna Chiu

Since the formation of the group, we have been having weekly meetings, when we take turns to be the chairperson and scribe. Each member also reports the weekly progress to the whole group either at the meeting or via email. Although we divided up the tasks, we were able to learn about each detail in different sub-tasks as well as contribute our ideas. The group has been very good at helping each other out as well as fulfilling the duties of each individual.

I guess one possible improvement in terms of group dynamics is to shorten some of the meetings when we discuss the documentation. For all our proposal and specifications, each of us was responsible for different sections, then we met and edited each other’s work. This routine has proved very useful in producing good documents, but maybe we should have better planning in terms of the length of meetings.

For the time being, although our device is basically working, it is still not a very stable system. More research and testing on the signals should enable us to generalize a typical alpha waveform.

This project has exposed me to an area, which I have never dreamed about before, and that area was brain wave activities. Since my major task was software programming, I have gained more experience on microprocessor programming and DSP, especially in real-time. From the report of my group members who worked on the signal conditioning circuit and actuator interface, I learnt a lot about analog circuits and power consideration.

In terms of interpersonal skills, our weekly meetings and progress reports have given me the chance to present myself and listen to others. Because each stage of the system relies heavily on the other, we had to communicate well to each other so that at the time of system integration, the system could be put together successfully. It has been a very precious experience and I enjoyed working very much working with my group. ☺

Sunny Wan

I really enjoyed participating in this group because the people in it are dedicated, determined, and considerate. I got the impression during our first meeting that we would work very well as a group because of these characteristics and also because our group consists of people with different strengths and interests. For example, certain people used their leadership abilities to direct the project along and set goals and deadlines that were both challenging and necessary but also realizable. At the same time, other members used their strengths to contribute effectively to the group in other ways.

In retrospect, we as a group spent a lot of time on the project in our respective responsibilities. However, at no time did anyone need to be prodded along to complete his or her assigned tasks. While all of us have full workloads, we all found the time to work on the project, whether to meet the mini-deadlines that were set or to complete other duties that were assigned. All the work that was done was always of high quality, which I feel demonstrates the effort within the group to succeed. At different times, different people took the initiative to be responsible for different things. Whether a specific document was due or a certain problem that needed addressing, often someone could be expected to volunteer to be responsible for it.

I think all the small factors added up throughout the semester and are one reason why our project is near completion. Our project has not seriously fallen behind schedule at any point in the semester, and perhaps the main reason is that deadlines were set and people were willing to work harder if that were the only way to meet them. The group effectively split into two smaller groups of two, one working on the hardware and one on the software, but the communication between the two subgroups remained excellent, in part due to the weekly meetings. I think we all spent a lot of time during the semester doing all the small things, but right now we are being rewarded with a near-completed project while many other groups are having to spend more time on theirs now.

Given my feelings for our group dynamics, if I were to repeat the experience I would not have a lot to change. Perhaps my biggest regret is taking 20 credits this semester and therefore having to spend a lot of time on other work. ENSC 370 is obviously very time consuming but I needed to schedule time for other subjects. As a result, I have not had the opportunity to participate in all aspects of the project as I would have liked.

"Everything I needed to know, I learned in ENSC 370" --- Greg Hall