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RUSH

April 16, 2008

Dr. Patrick Leung
School of Engineering Science
Simon Fraser University
Burnaby, BC
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Re: ENSC 440 Post Mortem for a Helmet-Embedded Communications System

Dear Dr. Leung,

Our team has completed work on a proof-of-concept prototype that provides an innovative solution to the growing and diverse communication needs of snow-sports enthusiasts. By integrating a communication and location tracking system into a snow-sports helmet, our product will deliver a new level of safety and convenience to winter sport enthusiasts.

The attached document, *Post Mortem for a Helmet-Embedded Communications System*, describes the current state of our device, the problems we encountered during implementation, and how we had to adjust the design to produce a functional prototype. A comparison of our expected budget and schedule are also included, along with a personal description of each team members experience during the project.

The success of our project is a result of the collective effort of a team of five enthusiastic and talented individuals from the School of Engineering Science: Mathew Bond, Daniel Hessels, Robert Hueber, Darren Jang, and Rob Tyson. You are welcome to contact us by phone at 604-783-9650 or email at ensc440-rush@sfu.ca if you have any questions regarding our project.

Sincerely,

MBond

Mathew Bond, CEO RUSH

Enclosure: Post Mortem for a Helmet-Embedded Communications System

cc: Mr. Steve Whitmore, Mr. Brad Oldham, Mr. Jason Lee

RUSH

Raven

Post Mortem for a Helmet-Embedded Communications System

Management Team:	Mathew Bond Daniel Hessels Robert Hueber Darren Jang Rob Tyson
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Submitted to:	Dr. Patrick Leung Mr. Steve Whitmore Mr. Brad Oldham Mr. Jason Lee
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Glossary

FRS Family Radio Service

GPS Global Positioning System

GGA Global Positioning System Fix Data

RMC Recommended Minimum Specific GPS Data

PTT Push-to-talk

TSSOP Thin Shrink Small Outline Package

NMEA National Marine Electronics Association

SD Secure Digital

1. Introduction

The current adoption of personal communication technologies continues to deeply penetrate our social networks. As an indicator of this, we are expected to see in 2008, the global number of cellular telephone users surpass the number of those without cell phones [1]. Clearly our dependence on convenient wireless communications has pervaded our consciousness so thoroughly that we constantly rely upon them at home, at work, and on the go.

With the recent increase in the availability of portable media services, outdoor enthusiasts have readily adopted music players, GPS receivers, and FRS radios to enhance their recreational experience. While these technologies have so far existed independently, RUSH now innovatively integrates them together into our fully featured snow-sports helmet that offers users wireless control and uncompromised protection.

Our device, the RUSH Raven, is a helmet-embedded communications system that brings together the functionality of handheld GPS units and common two way radios in the form of an ergonomic and easy to use snow-sports helmet.

Protecting its users against potential head injury is the paramount function of the RUSH Raven. Our design team has taken helmet design to the next level by integrating electronic and mechanical components together to provide enhanced features to the user without compromising safety. With the RUSH Raven, snow-sports enthusiasts can now:

- communicate to others via FRS radio
- log GPS performance data and transfer it to a PC
- listen to external audio without the need for clumsy headphones

Most importantly, all of the enhanced features of the RUSH Raven can be effortlessly accessed and controlled through our ergonomically designed user interface. Users are now able to transmit radio messages and adjust volume without having to stop and remove their gloves.

2. Current State of the Device

2.1. Overview

The RUSH Raven is currently in its initial prototype stage. This means that all the prototype functional and design specifications have been met including functions for radio communication, audio reception, wireless PTT, and GPS data reception.

The following block diagram, Figure 1, shows how each module depends on the microcontroller to regulate input from the user and direct the actions of the appropriate module.

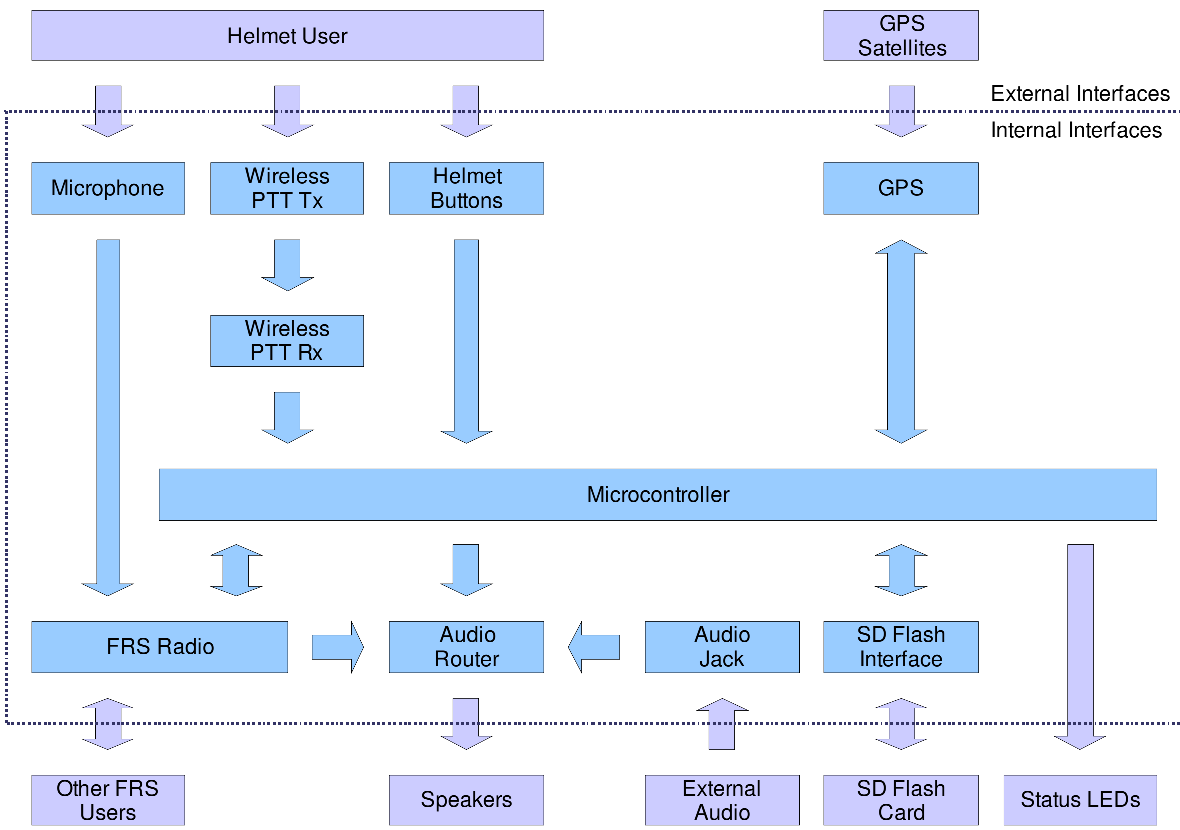

Figure 1 – Overview of Hardware Modules

These conceptual modules are integrated into the helmet through six distinct physical modules labeled in Figure 2 and Figure 3 below.

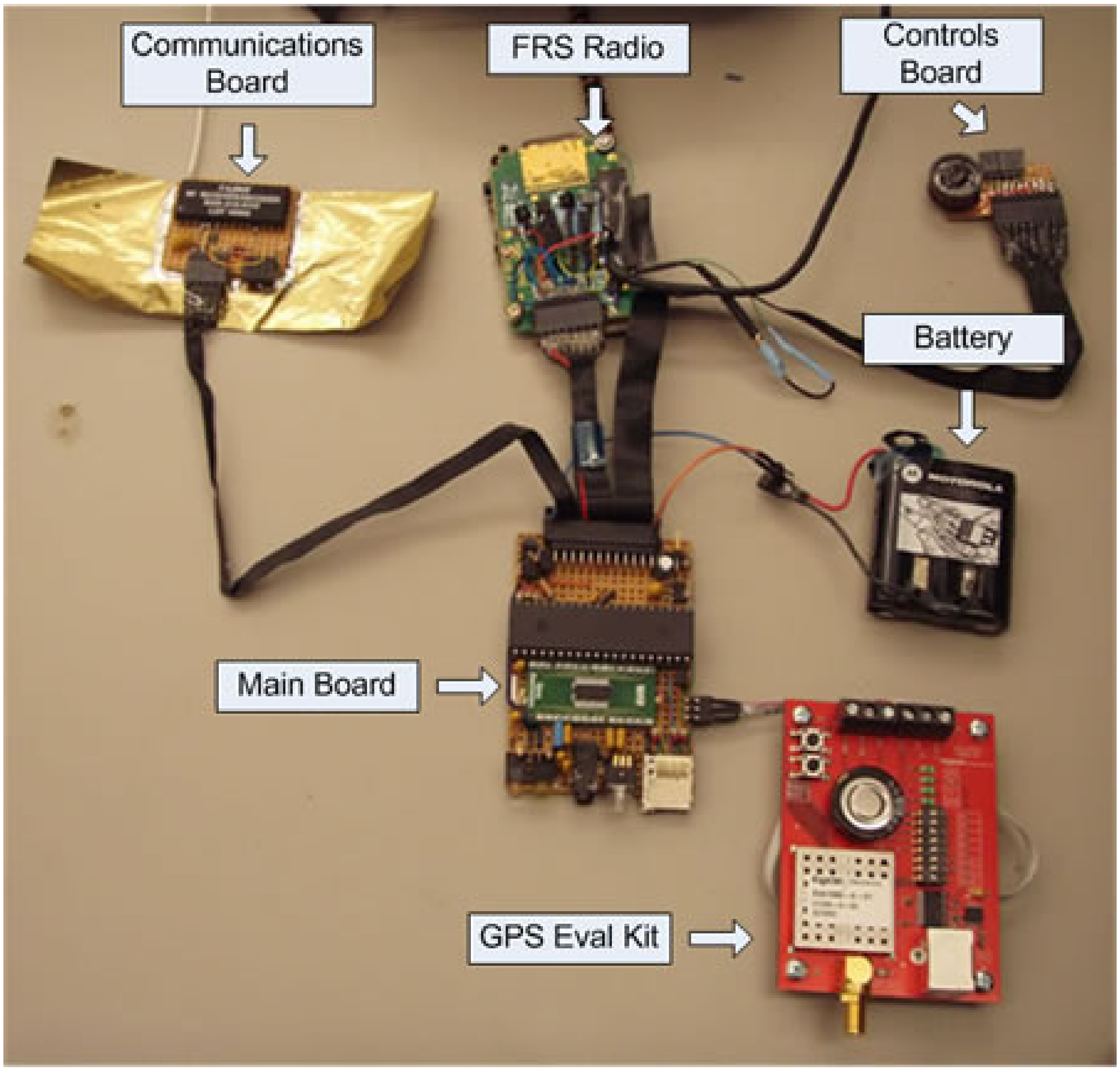

Figure 2 – Physical Modules of the RUSH Raven

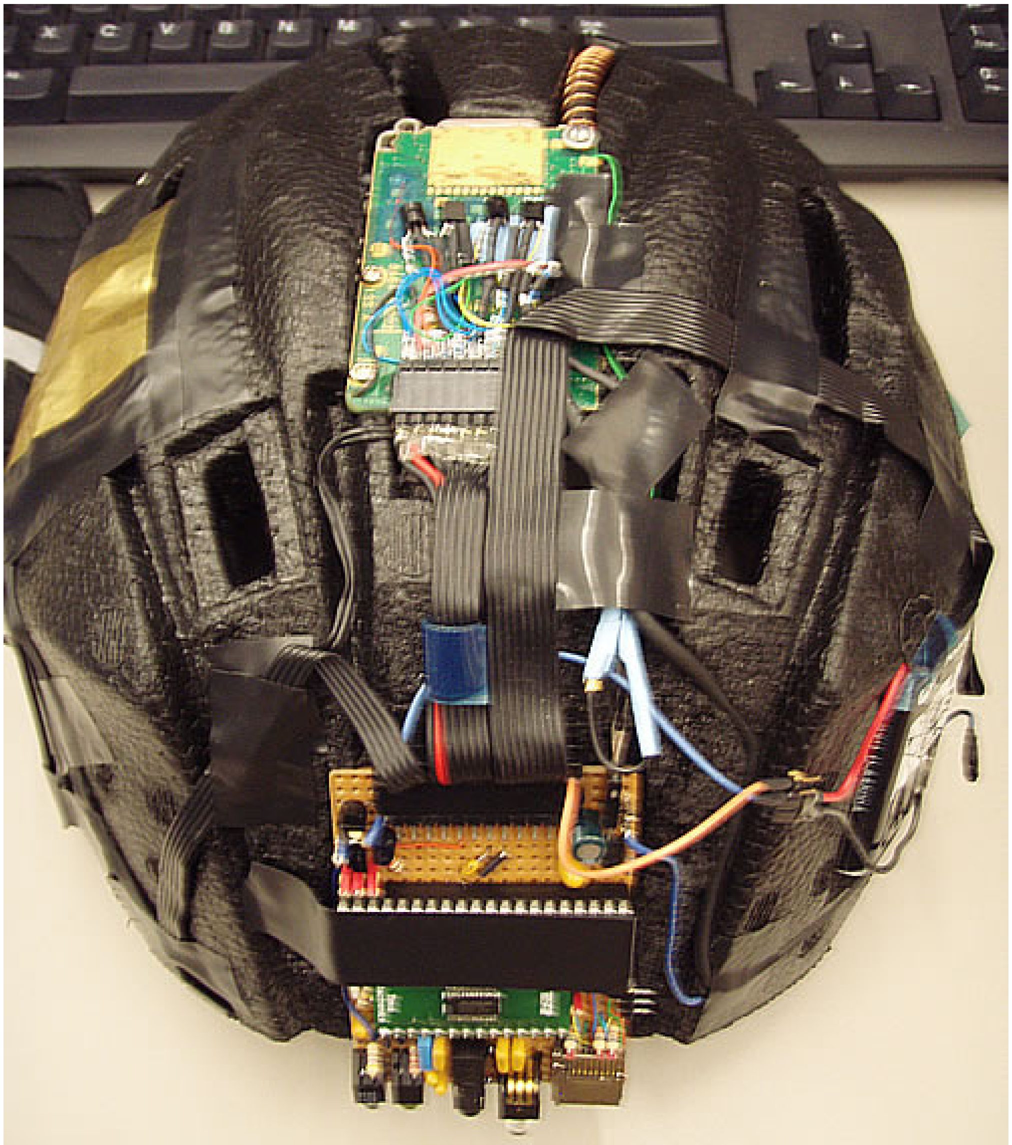

Figure 3 – The Physical Modules Embedded in the RUSH Raven

2.2. FRS Radio

As written in the design specifications, the FRS radio, excluding its external case, LCD display, and speaker, is installed in its entirety in order to preserve the integrity of the transmitter. This also ensures that all of the functionality of the radio remains available for our use. Shown below in Figure 4 is a picture of the FRS radio and the connections made to it from the microcontroller.

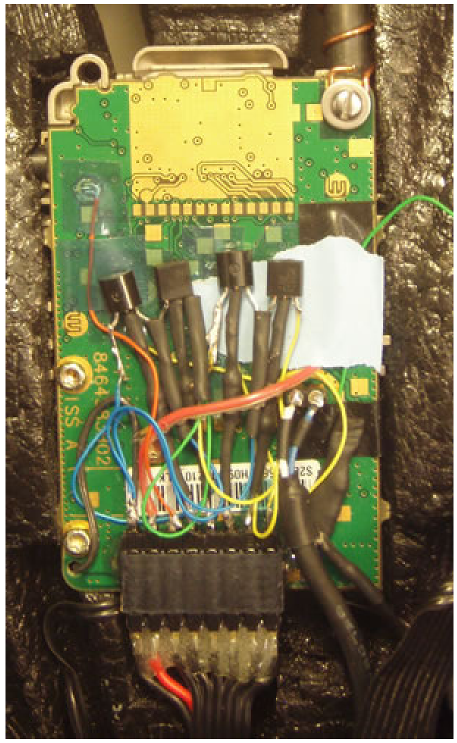

Figure 4 – Modified FRS T6210 Radio

Whenever the user activates the PTT, the volume rocker, or the channel wheel, the microcontroller receives these inputs and makes the necessary adjustments to the radio. Note that the issue of connecting through the button pads of the FRS radio was far more complex than anticipated, as described in Section 3. As you can see in Figure 3 on the previous page, the FRS radio is mounted on the top of the helmet to minimize any negative effects caused by the user's body on the range of the radio.

2.3. Audio Control

The MAX9770 performed wonderfully and fulfills our needs in terms of audio multiplexing and interconnection. The conditioned signal from the FRS radio speaker connections and the external stereo signal are its audio inputs. The microcontroller employs the selection logic exactly as outlined in both the functional and design specifications through the selection inputs of the MAX9770. The selected audio source plays through the speakers attached in the ear coverings on each side of the helmet. The MAX9770 audio chip can be seen on the main board in Figure 5.

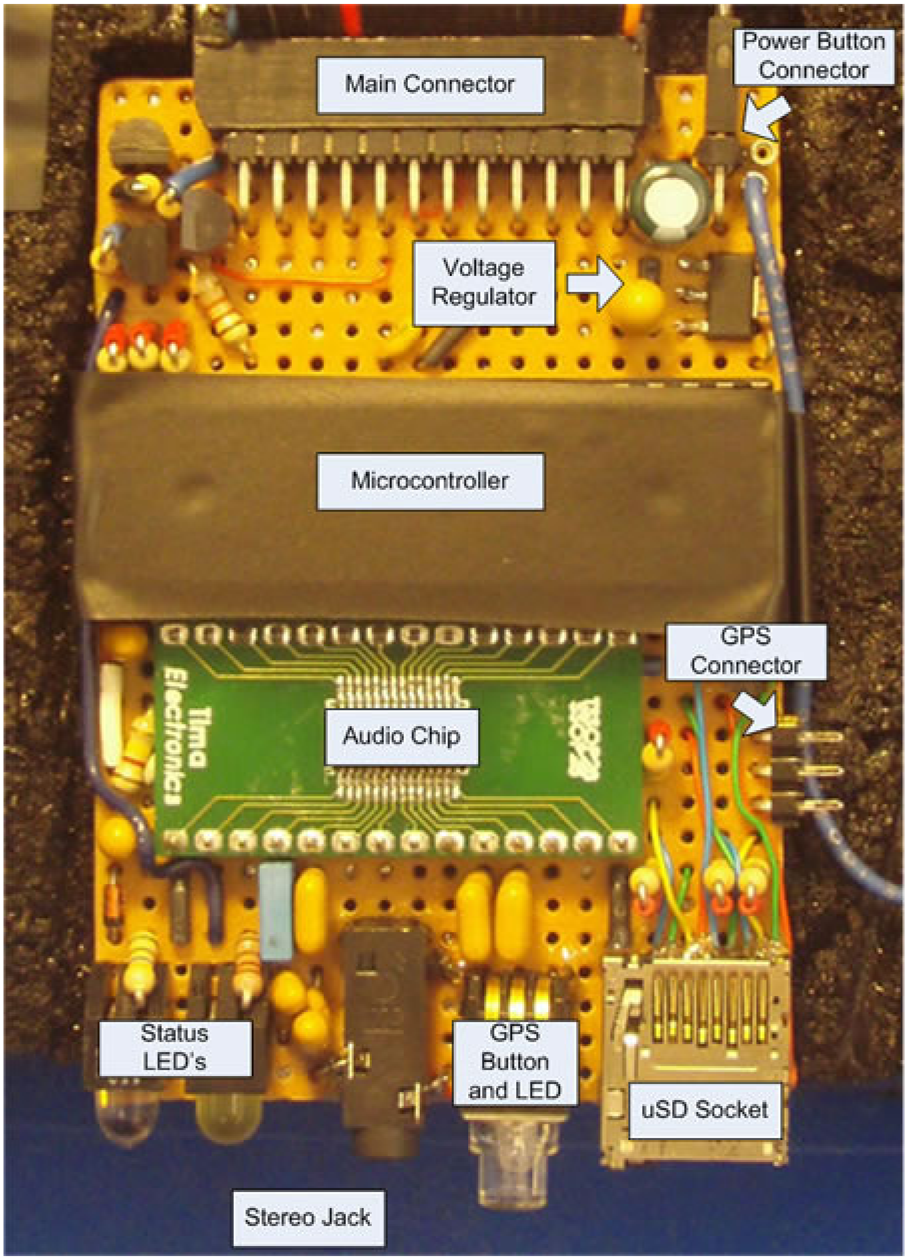

Figure 5 – RUSH Raven Main Board Circuit

The controlling logic is built around the fact that the radio is interactive while the external audio is most often passive, thus the radio must have higher priority. Therefore the external audio is interrupted whenever the user needs to interact with the radio by transmitting, receiving, or adjusting settings. The controls for the external audio stream remain a function of the playback device for reasons outlined in Section 3.3.1 of the design specifications.

2.4. GPS Module

The prototyped Raven uses the A1080 Evaluation Kit purchased from Tyco Electronics and uses the active antenna supplied in the kit to receive GPS signals. The GPS module was configured to send all the necessary data to the microcontroller, once every five seconds, over the NMEA out serial line at the rate of 9600 baud.

When writing the data to a comma separated file both the GGA and RMC data needed to be active, but when writing to a KML file for use in Google Earth only the RMC data needed to be active. This is because the Google Earth program assumes ground level, unless otherwise specified, rendering the altitude data in the GGA sentence unnecessary. Since the KML output is preferred, and users are not expected to be either underground, or in flight, this setting was deemed appropriate.

Only three connections to the GPS module were necessary, serial data, power, and ground. Note that the GPS ground connection is under gated control of the microcontroller to implement the functional case wherein the user wished to turn off the module.

2.5. PTT Subsystem

The wireless PTT system was implemented with a Linx transmitter and receiver pair as described in Section 3.5 of the design specifications. The receiver (with extended ground plane) was embedded into the left side of the helmet shown in Figure 6 and the transmitter was enclosed into an attractive housing depicted in Figure 7.

Figure 6 – Wireless PTT receiver

Figure 7 – Wireless PTT Transmitter

The wireless PTT reliably activates FRS transmission when used in realistic situations. There are some positions such as behind the body and low down by the right hip (on the opposite side of the body from the receiver) where reception is intermittent. Note that the addressing functionality of the wireless chips is not employed for use in the prototype.

The successful implementation of this system is due in large part to the thoughtful selection of antenna types and considerations made in packaging the transmitter such that as little metal as possible could interfere with the signal.

2.6. Buttons and User Interface

Buttons and switches were chosen for their differing tactile properties and sufficient activation forces, in order to make the user interface as glove friendly as possible. As you can tell by Figure 8 below, every button has a different shape and mechanism of operation allowing easy differentiation between controls.

The left speaker and wired PTT are connected to the communications board from where they are routed to the main board. The volume rocker, channel wheel, and right speaker are connected to the controls board from where the signals are routed to the main board.

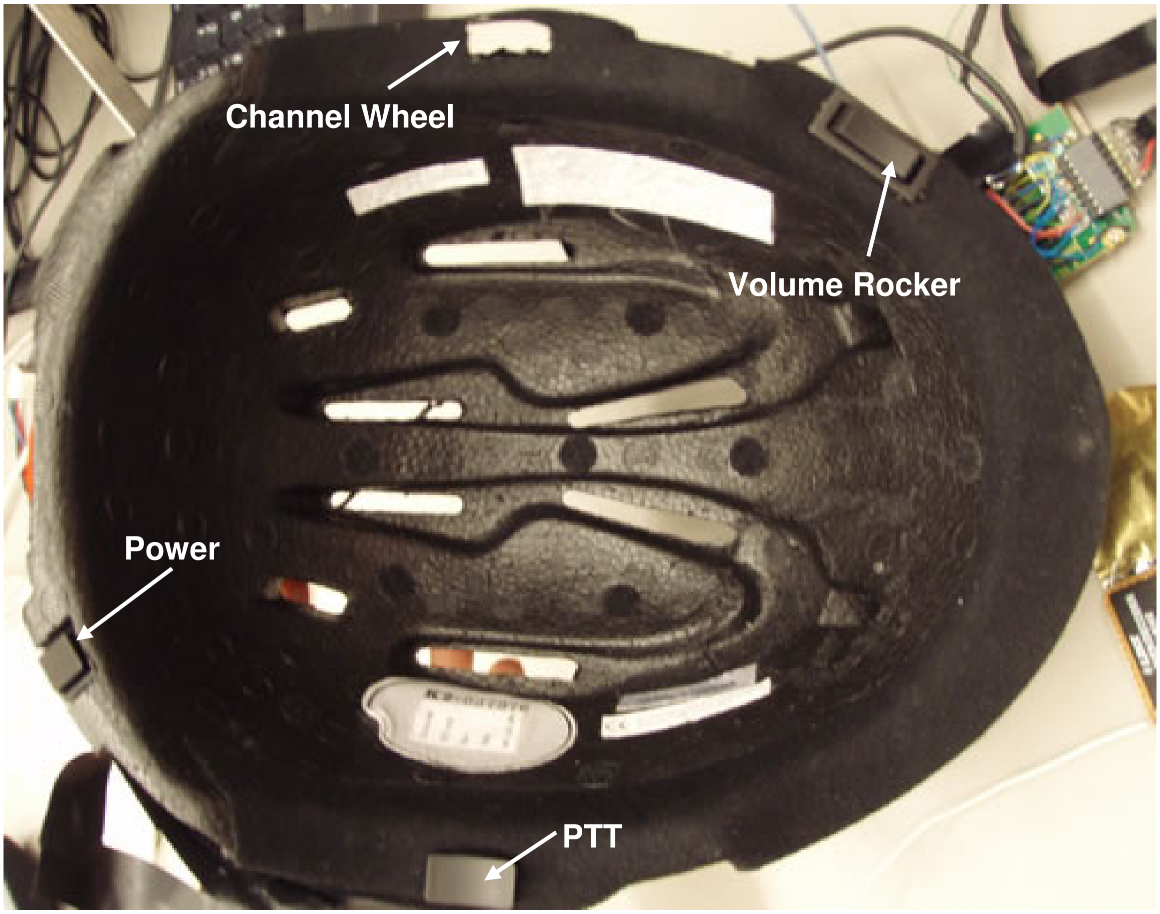

Figure 8 – Helmet Buttons

2.7. MicroSD Memory

The microSD flash memory stores all the files created by the microcontroller's firmware and is easy for the user to remove and replace. The card dock is located at the bottom of the main board so that the card can be accessed without having to dissemble the product. The type of dock is a "push-push" loading mechanism which locks the card into the dock so that the card will not accidentally fall out.

Connectors for use with desktop computers are commonplace and available at many electronics and computer supply stores, making it easy for the user to access the KML files on the microSD card. The user then can download and install the free Google Earth program and open the files to view the data displayed onto a map.

2.8. Microcontroller

As the brains of the Raven the PIC18LF4620 acted as the puppeteer of the helmet in order to orchestrate all the functions and modules. The interconnections between each module and the main board simplify the organization of the many inputs and outputs, and also made it easy to program the controller in circuit during the testing and debugging phases. Finally, the microcontroller's resources are well utilized; few of the I/O ports are left unused and those that are leave room for future additions to the project.

2.9. Power Supply

The RUSH Raven is powered by a pack of three AA batteries. This power source is regulated as documented in Section 3.9 of the design specifications, at 3.3V. The microcontroller is always connected to power, and when the user presses the power button the controller then powers up all of the hardware modules. This central control of the power supply allowed the implementation of power saving techniques and error avoidance due to lost data when the device is shut down.

Power saving is implemented through the use of the two extra positions of the channel wheel, and the GPS power button. In one of these special positions the FRS radio, which is a large contributor to power consumption, is shut down while the external audio continues to function. The other position mutes all audio sources by disconnecting power from both the FRS radio and the MAX9770. The GPS power button allows the user to turn off the GPS module, which is useful if you don't have a microSD card or don't need its abilities. In this way the user can customize the functionality of the helmet and extend the life of their batteries.

3. Technical Innovations and Lessons Learned

Throughout the implementation phase of the project, we generally followed the guidelines from our Design Specifications. However, there were a number of unforeseen challenges that we stumbled upon throughout the semester. For each of these roadblocks we were able to engineer solutions, which were not always ideal, but allowed us to create a functional product. A brief synopsis of our challenges and lessons learned is listed below. If you are planning to take ENSC 440, or a currently in a team, taking these lessons into account could save you a lot of time, money, and grey hair.

RF design is not to be taken for granted

A major component of our product is the wireless PTT controller. Since the school has limited support for RF design and testing, we opted for a packaged transmitter/encoder and receiver/decoder chipset from Linx. While the concept was simple, the actual implementation took far longer than expected. Prototyping was complicated by the fact that these chips do not function reliably on a breadboard, and after numerous iterations on protoboard and fine-tuning of the antenna, the final product just barely met our functional specifications.

The difficulties of interfacing with off-the-shelf systems

To avoid any additional RF design, we decided to purchase two Motorola FRS radios. However, difficulty arose when we attempted to interface the FRS radio with our microcontroller. Since the design of the FRS was proprietary, we had no documentation to work from. With the FRS circuitry designed to accept input from a human, we had to design our microcontroller firmware to act like a human. This involved accepting inputs from the buttons on our helmet, and conditioning and coordinating them in a fashion that the FRS radio circuitry would understand. Functions such as channel control, which we implemented with a rotary switch, required multiple button presses on the FRS board. In the end, after many frustrating weeks, we were able to reliably control the functionality of the FRS.

Use of copyrighted and trademarked technology

In the planning stages of our project, our team had long debates as to how we would store the GPS data captured by our product. Due to its growing industry acceptance, we decided SD memory would be the ideal choice for our product. It wasn't until later into the term that we realized the SD memory standard is trademarked, and that you must pay a substantial license fee in order to access the documentation. Thankfully, we were fortunate enough to have purchased a microcontroller from

Microchip, who is the only company we found to have specific drivers for their chips to interface with SD memory!

Modular design makes life ten times easier

Not everything that we learned during the project came about from headaches and failures. Starting with our functional specs, we decided to make our product as modular as possible. Initially, this was intended to benefit the end user, allowing them to easily replace broken components that might be damaged due to the physical nature of sports, such as skiing or snowboarding. What we didn't expect were the added benefits a modular design would have during integration and testing. Instead of centralizing all our circuitry onto a single board, we decided to use a number of small and simple circuit boards. These boards are situated throughout the helmet, with connectors running to a main board where the decision making takes place. Not only did this allow us to actually fit everything inside the shell of an existing snowboard helmet, but it also allowed us to prototype, test, debug, and refine each subsystem before trying to integrate them all together. If you decide to use this technique, make sure to use a consistent colour coding scheme for all your connectors to avoid any mishaps with cross-connections.

Make sure all team members are on the same page

When everyone in a team has access to the same information, the team will work effectively together. Inequity in access to information will lead to misunderstandings and resentment between team members. All of our team members were diligent with record keeping and ensuring that proper documentation was available to the group through our online repository, lab binder, and personal journals.

We believe the most important lesson learned by our team is that design and implementation is an iterative process. When designing and prototyping, make sure to be diligent in referring to product datasheets, because they actually do contain a wealth of useful information. When testing, ensure that you have a plan and follow a scientific process to reach test results. When documenting the results of your tests, the designs you've completed, or the latest firmware you've written, ensure that there is a clear and easy to use system in place to keep track of all the versions.

4. Future Plans for the Device

There are two stages to our future plans for the RUSH Helmet. First the prototype needs to be developed into a finished product. Second, due to its modular nature, the product can support a variety of other functionalities that can be integrated into future product models.

4.1. Final Production Model

For the helmet to go to market we must design a version to meet the rest of the 'F' specifications in the Functional and Design Specifications documents. The specific tasks that need to be completed to meet these requirements follow.

4.1.1. Miniaturization

The prototype's current state is not suitable for actual use because the GPS module is part of the GPS evaluation kit which doesn't fit into the helmet. The solution to this is to design a PCB for the main board module, with a properly laid trace for the antenna, and to purchase a standard passive antenna to embed in the helmet as well.

Creating a PCB will also allow for miniaturization of the audio routing circuit by eliminating the need for the TSSOP adapter, as well as allowing us to use a smaller package style for the microcontroller and passive components.

Once these subsystems have been integrated onto a PCB module it is estimated that the area will be the same size as, if not smaller than, the current main board module and will also be slimmer.

Finally, the FRS radio could be made smaller by designing a model specifically for working with our main board's functionality. This will eliminate the need for many of the user considerations built into the radio currently used in the prototype. This could be done in a partnership with a manufacturer and/or designer of handheld FRS radio products.

4.1.2. Helmet Design

For the product to meet the safety requirements outlined in our specifications we will need a specially designed helmet to contain the electronics without creating any increased risk to the customer. It remains possible for this to be done in partnership with an existing snow-sport helmet manufacturer.

The buttons currently in use on the helmet would also need to be improved. Because of the huge variety of input devices available it takes some time to select the ideal type, so our current prototype only employs functional equivalents. In the future it will be necessary to find the most ideal buttons available in terms of first usability, second functional characteristics (i.e. bounce time), and finally cost.

4.1.3. Waterproofing

Currently the prototype has no waterproofing and is prone to damage from snow, rain, and even condensation. To meet the performance expected from the product, it must be completely waterproof. This means that each module must be self-contained, most likely done by potting the modules.

It will also be necessary to employ waterproof buttons and caps for unused ports.

4.1.4. PTT Enhancement

Addresses must be assigned to each helmet/PTT pair to allow multiple users to operate near each other without interfering with the other's system. To do this the PTT components will be built onto a PCB along with a DIP switch to control the address of the transmitter. The address of the receiver will be static and set by hard-wiring the appropriate address lines.

A hard-wired battery switch will also be added to make accidental activation when the device is in storage impossible, saving the life of the battery.

4.1.5. Avalanche Safety

As a responsible company we should make our product as safe as possible. To help rescuers find users should they be trapped in an avalanche we will include a RECCO RF reflector [2].

4.1.6. GPS Feedback

The final product will utilize the GPS module better by providing real-time voice feedback to the user. This will be achieved by using a voice chip with saved audio samples.

4.1.7. Modularity

Every component of the RUSH Raven system needs to be easily removed and replaced by the user. This means each module will have to be contained in a neat package and be compatible with future versions of hardware and software. The helmet will also have to be designed such that the modules are easy to access.

4.1.8. Radio Upgrade

Currently the most advanced FRS radios feature 38 encoded sub-channels per standard FRS base channel. To fully utilize the radio's capabilities it is desirable to add this functionality.

4.1.9. Industry Regulations

Before we can sell the product to customers we will have to test the helmet to ensure that it meets all FCC regulations.

Additionally, we are required to purchase a license to use SD memory technology before a product can be brought to market.

4.2. Future Production Models

As with any product on the market, newer and better versions are dreamed up to adapt to market conditions and customer's needs. The following are ideas for future versions of the RUSH Raven.

4.2.1. Technology

Although FRS radios are still in common use at ski resorts today, it is becoming increasingly common for companies to install cell phone towers on the mountain, especially for the larger resorts. Because of this, users are slowly abandoning radios and more often relying upon their cell phones.

Accordingly, future versions of the RUSH Raven will include Bluetooth technology to enable hands-free cell phone use. Besides being able to use your phone remotely, this model will also have much lower power consumption because the FRS radio requires a lot of power to transmit compared to short range Bluetooth.

Therefore, the helmet may be able to use only 2 AA or AAA batteries by redesigning the module to run at lower voltages than before. A more suitable battery pack design than the current trio of AA batteries can also be created to reduce the weight of the system.

4.2.2. PTT Enhancement

The PTT antenna will be properly designed for application in the helmet to achieve the reliable performance expected by the user.

4.2.3. User Feedback

A visual display, such as a LCD or PDA via Bluetooth, will improve the ability for the user to set and adjust the settings of the RUSH Raven. It will also allow them to access GPS information in real time.

Finally, to reduce power consumption, smaller LEDs will be selected to replace the large type currently used.

5. Timeline

Although we technically finished the project ahead of time because we have not only fulfilled all of our prototype specifications, but have met a few of the final specifications as well, there were some incidences that forced us to work late hours in the last few weeks.

Figure 9 below depicts the planned timeline for the project in blue, and the areas that went overtime in red. The schedule began to run into the red during the prototyping when some Linx chips were destroyed and we were forced to wait for replacements in order to finish. Thankfully, no further such mishaps occurred and we were able to complete the project with a spare set of transmitter and receiver.

Further delay was created while we waited for the MAX9770 audio chip and the first microcontrollers to arrive. The audio chip was only a few days later than we expected, but the microcontrollers were at least a week and a half later than indicated by our suppliers. Rather than wait that long we chose to purchase them from DigiKey so that we could begin building right away.

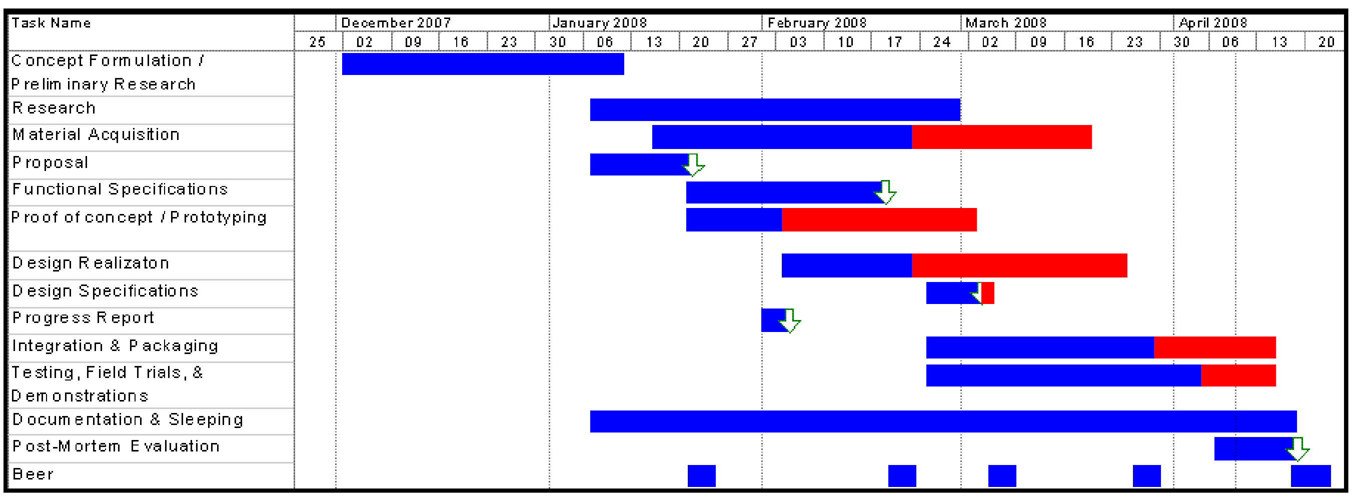

Figure 9 – Timeline for Completion of the RUSH Raven

Finally, when all the parts had arrived we ran into the problems mentioned in Section 3. These delays snowballed through the schedule and forced us to run a (very large for some) sleep debt near the end of the semester in order to catch up. The reason we were able to save our bacon in the end is the original forethought before and during the beginning of the semester that facilitated good communication and a clear plan to the finish line.

6. Budget

A comparison between our budget and the actual costs we incurred over the course of our project is shown in Table 1 below. Despite significant differences between the actual costs incurred from what we expected, overall we were able to stay on budget.

Table 1: Comparison of Budgeted and Actual Costs

Item	Expected Cost	Actual Cost	Explanation
GPS Evaluation Kit	$250.00	$154.81	Found a cheaper, compatible model
Memory Card	$5.99	$0.00	Provided by team member
Memory Dock	$6.50	$2.46	
Microcontroller Programmer	$162.50	$188.13	
Microcontroller	$0.00	$32.45	Free samples slow to ship, needed more memory
Helmet	$37.50	$0.00	Provided by team member
Speakers	$14.99	$0.00	Provided by team member
FRS Radios	$25.00	$20.00	
Linx Chipset	$19.25	$80.00	Ordered numerous replacements
Miscellaneous	$50.00	$83.19	Ordered an audio chip and TSSOP adapter
Total	***$571.73***	***$561.04***	

As you can see from Table 1 above, we were able to save significant funds on our GPS Evaluation kit by sourcing our parts from a different supplier. The donation of a used snowboard helmet and set of headphones from team members also brought about major savings. However, a number of unexpected purchases were needed over the course of the project. The most significant of these was the purchase of three pairs of Linx transmitter/receiver chipsets for our wireless PTT sub-system, when we originally expected one pair would be sufficient. Throughout our hardware development process, we had difficulties securing an antenna to the surface-mount chip and two of the chips were rendered useless. The other unexpected expenses were an upgraded microcontroller when the free samples failed to arrive on time, and an audio chip and TSSOP adapter to control our multiple audio inputs.

Finally, we would like to thank the ESSEF and its contributors for the $516 that was provided to help fund our project so that we did not have to dip too deep into our own pockets. In return, as agreed, we will be donating the GPS evaluation kit to the ESSS for future student's use in ENSC 440 projects.

7. Team Dynamics and Personal Experiences

7.1 Mathew Bond

Some people follow the philosophy that you should leave the best for last, a category of people which I would definitely place myself into. With a failed attempt at following through with a group (OnBoard Technologies) in the spring of 2006 and the horror stories I'd heard from some of my friends (Accomodarsi Solutions), ENSC 440 has been a nemesis of mine for a number of semesters. I started preparing for this project long in advance, making sure all my other courses would be complete, so that I would have more than enough time to make ENSC 440 a priority.

Early last fall I contacted Dan, who is a friend I've know for a couple years, to sow the seeds of forming a group. I was working with Darren last semester on a grueling ENSC 488 project, and knew we worked well together and that he would be an excellent team member. Rob Tyson, whom I knew for the fact that he was the only person that had started this program before me and still hadn't graduated (is that legal?), was contacted and our team of four was formed in early October. It wasn't until the middle of November, after many brainstorming sessions and team meetings, that Rob Heuber was introduced to the group and we really started to get down to business.

At the beginning of the project I was concerned about my relative lack of technical hardware experience compared to my team members. It had been almost four years since I had taken any courses on low-level circuit design, and concepts like the properties of BJT's or the implementation of a simple inverter seemed foreign to me. This is one of the main reasons, along with Darren's encouragement, that I decided to take on a leadership role in the group. If I wasn't able to contribute as much to the technical design and implementation of our project, I was confident that I could ensure that the team was communicating effectively, well directed, on-task and on schedule. One of my primary accomplishments during the project was to ensure that our group kept rigorous documentation of our activities. I believe our well organized and up-to-date online file repository, Gmail logging account, personal and team journals, and quick but effective meetings really eased the strain of implementing such an ambitious project.

It also turned out that I wasn't as incompetent in the lab as I thought. I took a very meticulous approach to all the tasks I completed and surprisingly, didn't blow anything up! I took on an assistant's role in the lab, helping each team member with their tasks by soldering, testing circuits, or working through and analyzing problems. When group communication problems arose, I also took on the role of mediator to ensure that each group members concerns were heard and addressed, allowing the group to move forward with our work.

I was really impressed, and thankful for, the diverse range of experiences and talents that all of my team members brought to the table. I appreciate all of their patience in answering my numerous technical questions throughout the semester. Originally I was a bit apprehensive about Rob Hueber joining our group, as I thought our differing personalities and styles of communication would cause group tension. This apprehension was completely unfounded, and as we worked together throughout the term I found Rob to be a very intelligent, capable, and practical team member. I've know Dan to be an excellent student and hard-worker, and I was disappointed when he was absent from our team for most of March, the time when we needed him most. I know our group could have greatly benefited from Dan's knowledge, technical skills and enthusiasm during this time. As group leader and CEO, I can't help feeling partly responsible for Dan's motivational failings, as it is my task to ensure all of the group members feel involved in the project. I really appreciated Dan's honesty and efforts he made at the end of the term to contribute as much as possible to our documentation, presentation, and post-mortem.

Coming into the project I knew that I would have no problems working with Darren, as I think we have very similar work/life philosophies. I was not disappointed, and Darren carried more than his share of the workload, ensuring that discussion did not carry on at the expense of implementation. Rob Tyson was the workhorse of our team and completed task after task tirelessly/sleeplessly to ensure our project was on schedule. While working with Rob, I found him to be both knowledgeable and confident in his technical abilities. I'd say he epitomizes the image of a hardworking, technically adept, caffeine-addicted engineer!

Overall I feel that ENSC 440 solidified my undergraduate experience; it really was the "capstone project."

7.2 Daniel Hessels

The RUSH Raven presented me with an opportunity to experience a facet of engineering that my previous work in development and manufacturing had not provided. That is, to form a bright and industrious group in order to envision the creation of a brand new and unique innovation. Our team was sociable from the outset, and although there was a bump or two in the beginning, I was glad to see how we worked together as professionals and friends despite differences of opinion. As with any project there were numerous decisions to make, with input from all sides, and the team was able to adapt methods from previous experience and to devise our own, to organize and plan the work on the Raven. The soft skills of mediation, negotiation, and consideration are a big part of the experience that I will be able to take with me from this project. The most impressive achievement was how we were able to keep records of our work so that others could access it and smoothly integrate their work together. In the future, whenever I work with other individuals, I will look for the skills, personalities, and talents that made our team successful.

At the beginning of the project I thought I would have sufficient work acting as meeting minute's taker, acquisitions manager, and the financial officer, along with the configuration and characterization of the GPS module and a heavy hand in the design of the hardware circuitry, as electronics is my academic focus and personal interest. As the project progressed and some parts didn't arrive on time, the main board's design was done mostly by the tireless zombie that is Rob Tyson, and Darren Jang who sought tasks to use his time wisely. I had thought at first that Rob Tyson was just really gung-ho and I didn't want to ruin his enjoyment of the work, but I failed to pursue other avenues of work to fill the void, and allowed myself to become distracted by extra-curricular activities. Later on I learned that Rob Tyson was concerned over the project's pace, and as I got to know him better I realized that I had let him, and the team, down through my lack of self-discipline. There were a few times where I legitimately wasn't capable of making it to the lab to meet the team, as is the case for anyone. However, there were also times when I could have gone, but chose to spend my time elsewhere.

Near the end of the project I felt this couldn't continue, and also I had learned how my attitude had affected my teammates, and especially Rob Tyson who took on so much extra work (half the time without anyone knowing until it was already done) and Darren who already had a packed and challenging semester besides this project. I tried to pull up my socks near the end of March, but by then the work in the areas of my expertise was mostly complete, and I didn't know how to approach my team about this issue. The consequence is that I have increased my focus on documentation, and stayed in the lab with team members to be able to help, support, and troubleshoot with them, even if I wasn't sure what I was going to do. The only positive result, in this respect, is that I have learned to go out and forcefully ask people to let me help, rather than waiting for a desperate plea or saying I would like to help and waiting for a teammate to come to me.

7.3. Robert Hueber

Throughout the project, I was responsible for several areas. Initially, I was responsible for the PTT subsystem, and as the project progressed, I also took on the integration of file I/O into the firmware. The PTT subsystem was considerably more difficult to get working than I expected, as both the transmitter and receiver circuit required about 4 re-implementations due to RF issues. In fact, one of the primary lessons I learned is that RF signal transmission is extremely sensitive to small variations, and that minimizing the amount of RF design needed is extremely important. While I was previously somewhat aware that RF design is difficult, I had no idea just how bizarre and counterintuitive it can be in practice. I will not necessarily be avoiding RF design in future work, but I will certainly approach it with caution.

Something I found surprising was the effectiveness of organized meetings. Initially, I was skeptical that having agendas and minutes would be worth the hassle, however, after a few meetings, it had become clear to me that an organized approach is far more efficient. However, even this organization cannot prevent people from talking over each other, which is a problem I occasionally caused.

Overall, I think that I gained an appreciation for all of the complexities involved in the integration of hardware, as well as the need for planning and organization when taking on a large project with a large group. While nothing is perfect, I think our group worked together relatively well and created an ambitious and innovative product.

7.4. Darren Jang

I was pleased to start this project a few weeks early with an eager, organized, and confidence-inspiring group of individuals. From the outset I had concerns about the organizational structure of our team. Knowing that an impartial, focused, balanced, and *designated* leader would likely serve the team best, I was happy that Mathew seemed to accept my unsolicited endorsement for him to step up to the role. He did an excellent job serving the best interests of the team while also sharing leadership responsibilities when we occasionally assumed them.

I felt it was important to decide on a project that would interest the team sufficiently that they'd be willing to lose sleep over. The best efforts and results are only achieved when members are challenged, motivated, and committed to the success of a project. I regret that we could not decide upon or think of a more noble, socially beneficial project of suitable scope, and thank Rob H. for his dedication despite being the only non-active skier/snowboarder (I've got my fingers crossed for you).

Our team's diverse skill and experience set was a significant advantage. We effectively managed our expertise and were able to cooperatively work in areas of overlap. This included diligently playing devil's advocate roles and offering constructive criticism. It was sometimes challenging to keep this mix appropriately proportioned, especially when benefiting from personal experience, but ceding control or responsibility for other's benefit is teamwork. I strove to inspire creative solutions to the challenging technical problems while also to maintain a realistic and defined project scope.

We all made efforts to accommodate each other's varied working styles and habits. I also tried to lead by example by committing my efforts to the project as my first priority while simultaneously having fun with it. Despite a 16-credit course load in my final term, I made every attempt to serve in the team's best interests, and in the fullest capacity possible. For me, this had to be balanced with the play-harder dynamic that saw frequent and spontaneous humour and BEvERage appreciation. I (hope and) feel this balanced approach helped strengthen the team by providing non-technical avenues for us to relate and relationship-build over.

Several procedural practices were also key to our success. Our commitment to the documentation process ensured we shared a common understanding of our project, its scope, specifications, and state. We could have improved on having independent double-checking of our hardware implementations, and with having a secondary member familiar with enough of the firmware so as to be a more effective consultant and debugger. Our file storage scheme was efficient and well maintained. Conventions were used for hardware interfaces and they were diligently documented and version-controlled.

Rob T. proved to be more of an ally than I had ever originally anticipated. His dedication and schedule-conscious development discipline was both commendable and prerequisite for our success. I suspect that our firmware development process would have been much more efficient had we been more involved during the very early stages, when we could have incrementally tested base-functionality while programming in the lab.

Rob H. also played an important role in several key areas of the project. He consistently worked towards the goal of a realistic prototype, took initiative, and was productive when working with any member of the team. While Dan did not contribute equitably due to personal challenges of his own, his administrating efforts throughout the project, and the improvement at the end are recognized. I feel the delay in the parts acquisition and GPS proficiency were the largest detriments to the project. A more responsible and professional attitude would have self-identified a discrepancy in contribution and commitment, and corrective actions could have been taken sooner. Mathew's strengths are well articulated by Rob T. below, and as I alluded to above, he is also largely responsible for the success of the project.

I'm glad to have enjoyed the opportunity to work with this group for our capstone project. Numerous lessons and experiences resulted and I leave proud of our accomplishments. I'd like to also thank Eric Lee, Ighodalo Iyayi, and Bryan Schurko for sharing their 440/305 experiences and advice before and during this term.

7.5. Rob Tyson

The formation of our ENSC440 team during the fall semester was partly a chance occurrence. During that semester I had become part of a project team with Dan and Rob, I'd never met Darren, and I vaguely remembered Mat from earlier in my degree. In a chance conversation between Darren and Dan in the lab, it came to light that we were all in need of an ENSC440 team for the following semester. Ambition and anticipation led to an official meeting quickly thereafter, wherein we would have our first brainstorming session on candidate problems we could strive to solve. This was the official beginnings of the RUSH development team - and one of the more rewarding experiences of my university career.

Idea generation was quite a process and, given that our individual interests were diverse, these ideas jumped between a couple different areas of electrical/electronic engineering. We even met with a local power electronics company to see if they had any active projects that we would be willing to develop for them. Eventually, however, the various power engineering ideas we had been considering were scrapped, and Darren suggested something related more to consumer electronics: a high-tech snowboarding helmet. It's worth noting that many of the soft details related to our project - such as our company and product names - were arrived at during the most productive type of brainstorming session in existence - the kind that involves beer.

According to our original plans, the other four members of our team would be tackling the various hardware sub-systems of our project, while I would be entirely responsible for the firmware that would coordinate everything and bring the helmet to life. For a couple different reasons, by mid-February, my gut feeling told me that we were falling behind schedule in order for me to have a fair chance at writing firmware to integrate GPS and flash memory functionality. At this point, I started taking on hardware development tasks to help speed things up. I ended up pulling several all-nighters during this stage of the project and, even then, it feels like we just barely completed our project on time. If we hadn't discovered that our microchip vendor had a set of SD and FAT16 drivers available online, we may never have finished. Credit must also be given to Rob Hueber for agreeing to take that portion of firmware development off my hands - given his own experience level with file systems and flash memory.

In terms of team dynamics, I think our group held together relatively well for most of the semester. At our first team meeting, it became apparently to me that there were a couple leaders in our ranks, and I wondered if too many cooks would spoil the broth. Owing, perhaps, to the differences in our respective technical backgrounds, this ended up being one of our team's strengths, instead of a weakness. Naturally, however, even the strongest of groups will experience problems - and ours was no exception. On personal level, I would maintain that friendships were forged between all our group members. On a professional level though, honesty drives me to admit I would not partner up again with all members of our team.

If I might comment on my teammates I would start by saying that - considering his course load - Darren was one of our most dedicated and invaluable members. He and I got a lot of good work done together and I can't recall a single dispute between us more significant than spilling beer. Mat was also a pivotal member of our team, and although, technically, he nominated himself to be our CEO, in the end I think he really fit the position. Mat served as an excellent coordinator, mediator, and whip-cracker - all when it counted most - and it was obvious he took his leadership position to heart. With regards to Rob and myself, it became obvious that he and I have drastically different communication styles and work habits. We may have disagreed often on technical results, but I don't think either of us ever doubted each other's dedication and enthusiasm towards the project. Finally, while Dan and I get along well on a personal level, I think that he struggled in making an appropriate contribution to the project. As the semester progressed, different mechanisms were implemented - such as mandatory group progress reports and lab times - to help Dan get productive without making him feel singled out. Despite my best efforts, these all showed limited success. In the spirit of fairness, Dan tried to show dedication towards our project closer to the start of April, but there was a period of almost a month wherein we could have benefited from his help. Unfortunately, by the start of April, most of the hardware he could have helped with had already been finished.

8. Conclusion

The RUSH team is proud to have completed a fully functional prototype that not only meets, but exceeds, our original expectations. We're relieved to have completed on-time and under budget, and be free to pursue our careers and lives once again. Over the course of the semester, we've learned to work effectively as a team and forged strong personal relationships and memories. We'd like to wish all members of our team the best of luck in their future endeavors, but we'll probably see each other next week at the pub.

9. Acknowledgements

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