December 19th, 2003

Dr. Andrew Rawicz and Mr. Steve Whitmore
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 305/340 Project Wrap-up Report for a Personalized Medical Emergency and Distress System

Dear Dr. Rawicz and Mr. Whitmore,

The attached document, *Project Wrap-up Report for a Personalized Medical Emergency and Distress System*, lists and describes the functional requirements for our ENSC 305/340 project.

We have currently finished development of the proof-of-concept device for a personalized medical system that will monitor and analyse a person's vital signals and contact certain medical parties if a life-threatening situation is detected.

The purpose of this project wrap-up report is to describe our project, our development process, the issues we encountered during development and our group dynamics, the lessons we learned, and the future work and direction for this project.

If you have any questions or concerns about our project or group, please feel free to e-mail us at en-Focus@sfu.ca.

Project Wrap-up Report for a

Personalized Medical Emergency and Distress System

Submitted to:

Steve Whitmore – ENSC 305
Dr. Andrew Rawicz – ENSC 340
School of Engineering Science, SFU

Version number:	1.0	
Draft/Final as of:	December 19th, 2003	
Team Contact:	**Paulman Chan (pkchan@sfu.ca)**	
Authors:	Paulman Chan (pkchan@sfu.ca)	20006-2629
	Mirela Cunjalo (mcunjalo@sfu.ca)	20006-1286
	Brian McKenzie (bdmckenz@sfu.ca)	20006-0636
	Ryan Monsurate (rmonsura@sfu.ca)	20006-1870
	Scott Nelson (snelsona@sfu.ca)	20005-2959

Table of Contents

List of Figures and Tables

1 Introduction

For persons living in the home, sudden life-threatening medical emergencies can easily become fatal if they are not given access to immediate medical attention. Cardiovascular disease and strokes, which are the 1st and 3rd causes of death in both men and women, can often strike suddenly and leave their victims incapacitated. Those who live alone at home are in danger if they suffer an emergency and are unable to call for help.

Those who require constant monitoring, whether for medical reasons or research purposes, are usually burdened with restrictive and/or expensive equipment. For high-risk patients whose health must be constantly monitored, restrictive equipment may confine them to their bed and lessen their freedom and quality of life. Also, monitoring equipment for athletes or test subjects are often wired or bulky, and are not suitable for truly rigorous activities, such as playing various sports.

The Personalized Medical Emergency System (PMEDS) is a wearable, low-profile system that will monitor and analyse a person's vital signals and can detect and take action upon any life-threatening situations. The sensors and circuitry will be embedded in the shirt so as to minimize the intrusion to the user and allow for every day and more rigorous activities.

The en-Focus! group has already completed development of the proof-of-concept device, and this document describes our project, our development process, the issues we encountered during development and our group dynamics, the lessons we learned, and the future work and direction for this project.

2 PMEDS Overview and Development Problems

The Personalized Medical Emergency and Distress System (PMEDS) project consists of several vital sign monitors, which can be embedded into a shirt in the future, a base station, and an RF communications link between the two. The sensors measure three major vital signs, i.e. heart rate, breathing and temperature. The important sensor data is wirelessly transmitted to the base station where it is analyzed via a computer. Currently, the vital sign data and the average heart rate, breathing rate and temperature are displayed on computer screen through the GUI as shown as follows in Figure 1.

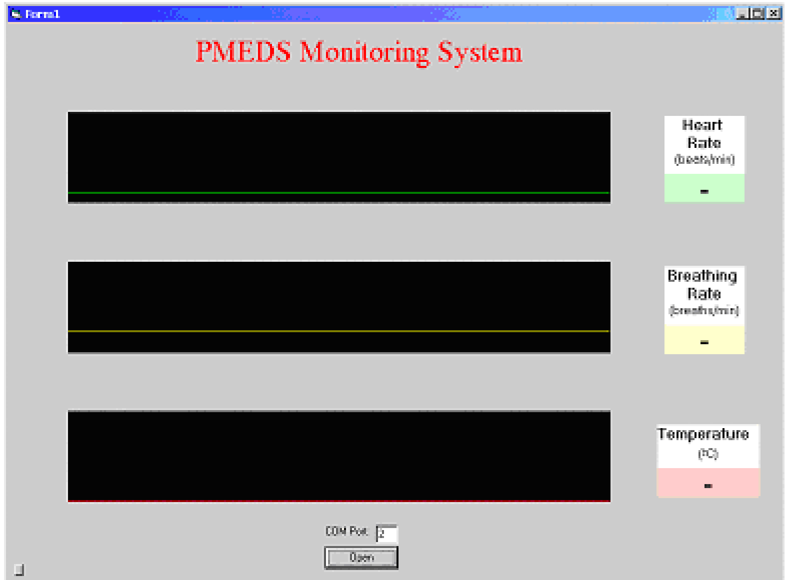

Figure 1: PMEDS GUI screen capture of the vital signals readouts.

This can be expanded such that in case of a crisis, including abnormally high or low heart rate, breathing rate and temperature, the base station contacts the Security Center, which in turn will contact the appropriate medical authorities.

A flowchart giving an overview of the PMEDS is shown below in Figure 2.

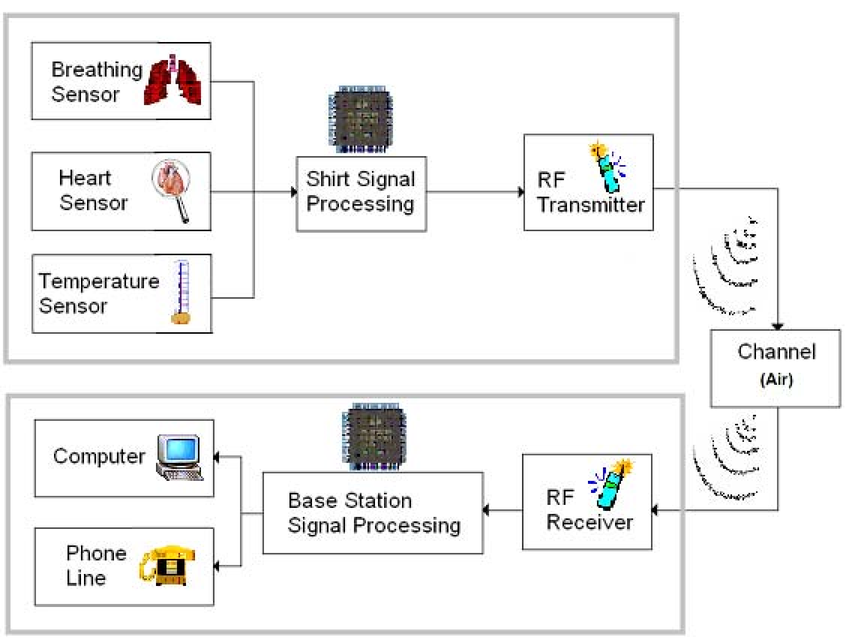

Figure 2: Flowchart overview of the PMEDS.

2.1 ECG sensing circuitry

We have obtained the general ECG design from a reliable Internet source. In order to fine-tune the initial design to our specifications, firstly we needed to remove noise and DC offset using filters. Furthermore, we decided to use the ECG to determine the heart rate only. The initial idea of detecting other abnormalities, besides heart rate problems, such as an abnormal QRS wave, proved possible, since we were able to see the QRS wave in every measured heart beat, but not reliable enough for an accurate crisis diagnosis. The inaccuracies are in part due to the low-precision op-amps and high tolerances of other components, such as the resistors, capacitors and diodes. Moreover, the pennies used as electrodes proved our concept and decreased our cost but added to the inaccuracies, which would have been partially resolved with more conductive, hence more expensive electrodes.

Furthermore, throughout the entire project design one of our major goals was to decrease power consumption. One example to decrease power consumption is to sleep the microcontroller as much as we can and to minimize the analysis performed on the shirt. Hence, knowing that we only require the heart rate we minimized the power consumption by using a comparator at the output of the ECG to simplify the QRS wave into a square wave. This way the microcontroller will only wake up at the interrupt, which is the rising/falling edge of the square wave.

Finally, the goal to minimize the cost has been achieved here since the entire ECG has cost us 3 cents, which were used as the electrodes. All the other components were samples from companies or from ENSC 340 $50 fund.

2.2 Temperature sensing circuitry

One problem encountered during temperature sensor design is to deal with a very small current range. Since 1uA per °K of current passes through the circuit, the range required to detect human body temperature is around 37 °C meaning 310 uA for 310 °K. Furthermore, for reliable crisis detection we need to be able to be precise up to 1°C. But, as mentioned above, a false current change of 1uA is equivalent to a result with 1°C error. The error in current can be caused by the components with high tolerances as well as low precision op-amp.

Moreover, since we have a 5 V supply and a 4 V drop across the temperature IC is required for correct results, only 1 V drop is allowed across the circuit with 310uA. Before using the temperature IC it needed to be calibrated for 5V supply and room temperature deviation.

2.3 Breathing sensing circuitry

In order to detect breathing we have used six strain gages with the basic idea that breathing will change their resistance by stretching or bending them. There were several problems encountered while designing the breathing monitor.

First of all, since each strain gage changes only by 1 ohm at best, it was very important to find the best place on the torso, where the strain gages will stretch maximally while breathing, for the maximum resistance change. The maximum stretch is obtained on the sides of the torso where the diaphragm is. Hence, placing three strain gages one side and three on the other we have obtained the maximum change in resistance with the six strain gages available.

Furthermore, in order for a strain gage to give reliable results it should not slide while the surface, that the strain gage is attached on is bending. Hence, the strain gage must stick to the surface and the surface must be able to bend and be comfortable to the wearer. The cheapest and lightest solution was an aluminum coke can surface.

Moreover, in order to allow the aluminum surfaces, with the strain gages, to bend, an elastic band from old stretch pants was placed between the two aluminum surfaces, hence allowing for the required flexibility.

Furthermore, we must be able to take on and off the breathing monitor as well as adjust to different body sizes. A flexible, light, soft and adjustable belt was attached to the aluminum surfaces to add this functionality.

Finally, the resulting change in signal obtained from the changing resistances while breathing was extremely small. In order to be able to detect the signal reliably, a circuit was designed to amplify the difference between the breathing and not breathing. The resulting signal peak to peak value was dependent on how deep or shallow the breath taken was. This way we added the possibility to detect and differentiate between sleeping, shallow or deep breathing and so on.

But, as mentioned above, in order to save power consumption and simplify the analysis required we have once again used a comparator to convert every breath into a square wave. Then, the square wave rising/falling edges were used as interrupts to the microcontroller. The resulting amplification circuit is shown in Figure 3.

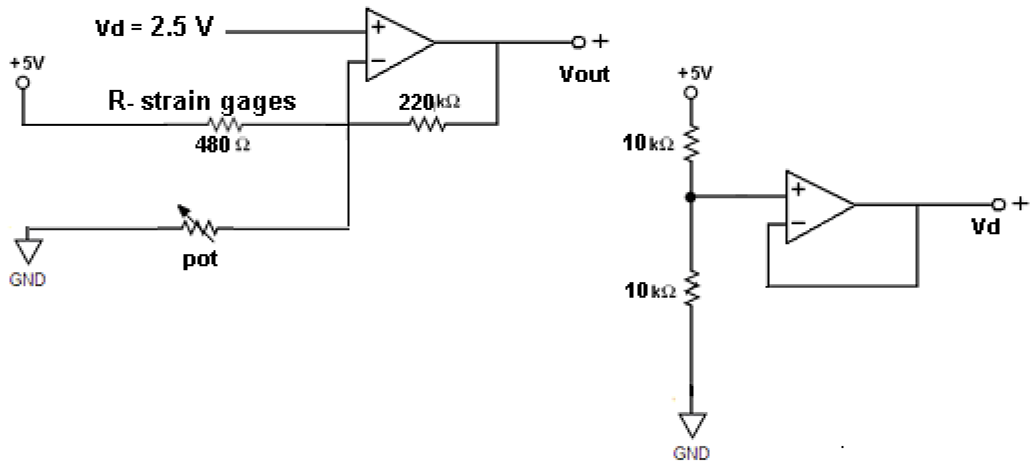

Figure 3: Breathing Amplification

2.4 Base station

2.4.1 RF design

The largest problem encountered during RF design was that we expected to use the RF kit from Andrew Rawicz. Unfortunately, another group had borrowed the kit. Hence, we had to buy the RF transmitter and receiver modules from Lynx later in the semester, which was fairly expensive and did not allow us to begin full development or any testing of the RF communications until they arrived. Once the plug-and-play RF modules arrived, it was a relatively straightforward process to establish RF communications between the shirt and the base station.

2.4.2 PIC programming

The programming of the PIC microcontroller was a large task, as it needed to be programmed to monitor the three different signals and send this data serially to the base station. The first thing developed was the RS-232 transmitting code. Initially we intended to send at a speed of 56,000 baud, but due to speed limitations of the PIC, we settled for 9600. This is still more than sufficient for our purposes though, as the amount of data is quite small.

Next came the reading of sensor data. Temperature was read using the A/D, and this was straightforward to set up. Pulse and breathing were measured by triggering when the voltage output increases to a specified value, using two built-in comparators. It was found that the incoming signal needed to change by at least 100 mV in order for the comparators to accurately detect the change, which at the time wasn't being generated by the breathing or ECG circuits. Because of this, we had to amplify the signals before they were sent to the PIC.

We initially planned to have a PIC at the base station as well, which would receive data from the RF module and then transmit it to the computer. There were difficulties in getting the PIC to receive data using RS-232, so finally it was decided not to use a base station PIC, and to send the RF output directly to the computer.

2.4.3 GUI

The GUI was programmed using Visual Basic. Initially Visual C++ was looked into, but there were troubles in programming the RS-232 code. Visual Basic was chosen because it has a built-in RS-232 control, though this took time to configure correctly. Visual Basic is also much better for making simple GUI's, so it turned out to be a better choice. Overall, there were no major problems encountered, and the GUI did everything we intended for it to do.

3 Comparison of Estimated and Actual Project Plans

3.1 Comparison of Estimated and Actual Project Schedule

Figure 4 shows the Gantt chart of our original project schedule.

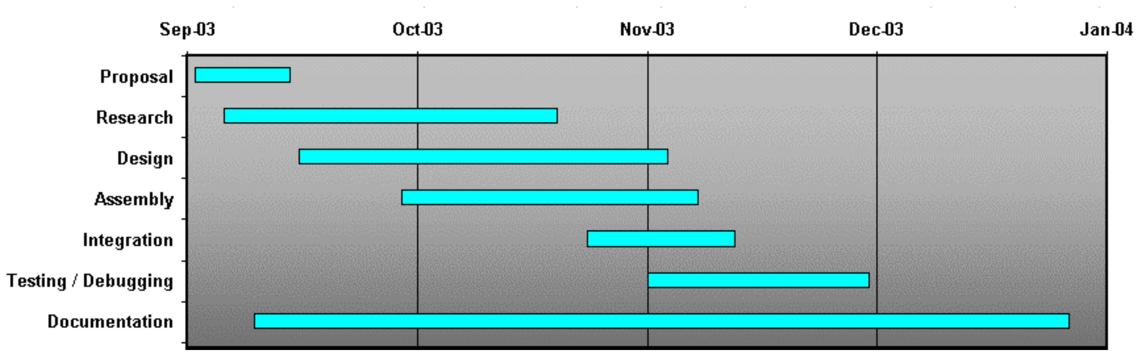

Figure 4: Gantt chart for proposed project schedule

We intended to finish the mock-up by the end of November, and demo in mid-December.

Our actual timeline is outlined below in the Gantt chart of Figure 5.

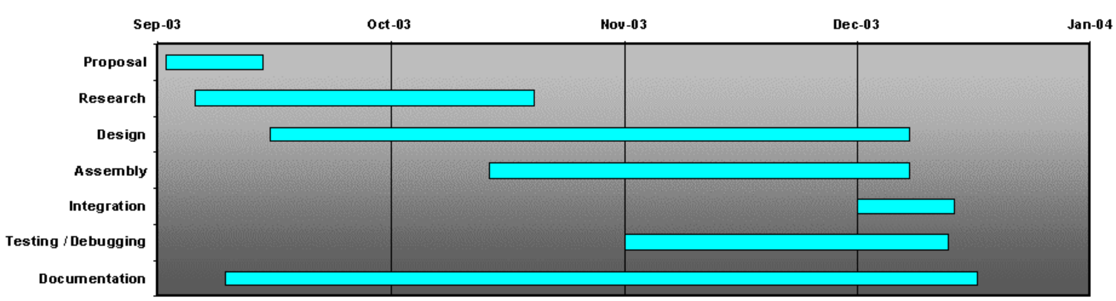

Figure 5: Gantt chart for actual project schedule

As shown above by Figure 4 and Figure 5, most sections took longer than originally planned. Design and assembly of sub-components lasted until near project completion, as constant modifications had to be made to almost everything. Because of this, integration of these parts was not possible until early December. Testing and debugging time increased as well, due to the increased assembly and integration time.

3.2 Comparison of Estimated and Actual Project Budget

3.2.1 Estimated Project Budget

When we first presented our project proposal we decided to be generous with our budget estimate as more often than not projects tend to take longer than usual to complete and go over budget. Therefore we multiplied the perceived price of most parts by 1.5, unless their cost was already quite large. We came up with an initial estimate of $300 after doing a detailed cost analysis. In our original estimate of the products cost, a significant portion was allocated to the RF component of the device. We originally estimated RF to cost $170 US, because we were going to purchase an entire RF development kit, but later found a way to reduce costs.

3.2.2 Actual Project Budget

The first area where we were able to achieve significant cost savings was RF. After some research we came to the conclusion that by purchasing one $30 US receiver module and one $50 US transmitter module, we would be able to design the circuit ourselves resulting in a savings of almost $100 US. In the future it would be feasible to half this again by designing the RF modules ourselves.

The second major savings in cost came from “donations” (sample requests) of IC chips and other circuit components from major corporations. Add to this the lack of an actual “shirt” platform and we saw a combined savings of $50 here. The total project costs came to approximately $150 of which $125 CAD was for the RF modules and antennas. For large scale production, the cost including estimated manufacturing costs should be in the region of $200 after taking into account both mass production savings and unaccounted for expenses.

4 Project Group Dynamics

4.1 Organization of the group

Our group functioned as an informal interactive/web organization in which there was no formal leadership and we made decisions as a group. However, some individuals informally took the leadership role during the project in motivating the group and starting work on the project tasks for the group. Work assignments were largely self-chosen and were completed on the person’s own initiative. We often met to discuss the particular group task first, and broke off individually to work on our tasks.

4.2 Problems encountered

During the course of this project, few inter-personal problems or conflicts were encountered. Specifically, the tendencies that a particular group member had to antagonize or exasperate another particular group member were successfully suppressed and held to a minimum throughout the course of the project.

Another problem that we did experience in this group was that, due to our loose and informal structure, individual group members often did not work on or complete their tasks soon enough as to leave a safe margin of time before the particular deadline.

5 Lessons Learned

While working on our PMEDS project we learnt a lot about time management, group dynamics and of course hardware design do's and don'ts. We first learned that no matter how many times, or how forcefully it is stated, we will never understand in our first week that we're really behind schedule. We also learnt that if you stated working on design during your first week, you're already behind (as we were told at the time).

An important issue, when it came to project documents, was getting everyone to digitally hand in their respective sections on time. The first time we collaborated on a document we decided that the day before was a good enough deadline for our group members to adhere to but found that humans are exactly that and are prone to delays no matter what precautions are taken. From then on we decided to try and get documents done at least two days before they were due, except for this one ☺.
In the area of team cohesion working together we learnt some valuable lessons. It is important to treat each other with respect, learn from each others errors and be open to ideas no matter how opposed your viewpoint on the subject is. Lastly, it's nice to show appreciation for even the smallest accomplishment so that everyone in the team knows that the work that they are doing is appreciated.

As far as the project implementation, even though we planned for a couple weeks of integration time we had to get the working components to work together in only three days. Thankfully, by pulling together as a group with one of us pulling an all-nighter we were able to get everything to work together in time for our demonstration.

6 Personal Project Experiences

6.1 Paulman Chan

Over the course of this project, I learned much about the planning, organization, and tasks required to successfully manage and plan a project. I learned that early design and ordering of parts is necessary if you want to get a head start on the development of the project.

I have also learned that, especially in informally structured groups, it is important to make sure that all group members are actively completing their tasks as early as is appropriate, and also that the work load is being shared equally between group members. I have realized that if these or other problems are occurring in the group, it is important for myself or someone else to take the initiative and address the issue as soon as possible within the group so that the problem does not continue on and affect the project.

My main contributions to this project were: designing and implementing the temperature sensing circuitry, helping to devise and design the breathing sensing circuitry, and managing and editing the project documents and deliverables. In designing the temperature sensing circuitry, I learned much about how to amplify (steady state) sensor readings from small signals when high accuracy is required. I also gained experience with finding and choosing an accurate, cheap, and non-obstructive temperature-sensing device for the circuit. From my experience with the design processes of the temperature and breathing sensor subsystems, I have learned that creativity is important when you are trying to solve a difficult technical problem.

Overall, I have had a good experience in working on this project with my group. I value the friendships amongst the group members. I have realized that mutual respect and immediate openness among group members is essential to keep the group functioning efficiently and without any repressed resentment. Finally, I've also learnt that you can get a lot of free and cool stuff shipped to you really quickly as samples from large companies.

6.2 Mirela Cunjalo

By forming our 340 group and working as a team we have put five talents together and allowed each one to grow further in their respective expertise as well as other fields, and at the same time became friends.

As for most relationships, the beginning of ours was an adjustment period between different personalities, ideas, preferences and goals. But, as the semester progressed, the respect and understanding for each other grew and we leaned to deal with our differences in a respectful way.

We have worked as a team with individual self-chosen tasks not as a hierarchy, because we were all fully committed and tried to give our best throughout the semester.

I have leaned that diversity in expertise and personalities is very important when working in a team. This way a huge project can be subdivided into simpler, more manageable sections, but still keeping in mind the big picture.

Furthermore, I have learned that working in a group, misunderstandings between members are bound to happen. But the best way to deal with a problem is to approach it head–on, meaning always sharing any problems or difficulties one might be having with another member.

I have worked on the ECG and breathing sensors for this project. Since I am in Systems Engineering and always wanted to work in a biomedical application project, the sensor subpart was an excellent choice for me, especially since I was taking a sensors and actuators course during the same semester. I have enjoyed working on these parts and I find that when you like something enough, working on it does not seem like work anymore.

Dealing with biological signals means dealing with very small and noisy signals. While working on the ECG and breathing sensors I learned how to remove the noise as well as be able to amplify the small signals appropriately and most efficiently.

Furthermore, I have leaned how to write professional project documents such as Functional and Design Specifications, as well as how and where to obtain financial help for projects.

The most important fact that I learned during this project is that whenever and wherever we, as future engineers, work on projects we will always be financially limited. This means that we need to be highly creative, not only knowledgeable, and use everyday things to build extraordinary projects. For instance, while I was designing the breathing monitor we could have bought a microphone for acoustic breathing detection or used many other more expensive methods, but instead I used six, very inexpensive strain gages, a coke can, an old elastic band, and an old belt to build a mock-up working and reliable monitor to prove the breathing monitor concept.

I have truly enjoyed being a part of this team. Even though it has been stressful at times, we have had many fun moments, which have made the stressful times worthwhile.

6.3 Brian McKenzie

I found that our group worked quite well together, largely due to our diversity in technical experience. We had no major conflicts, and managed to resolve any differences in opinion in ways satisfactory to everyone.

I learned that it is important to start such large-scale projects early on, even when busy with other projects and assignments. I also learned that division into sub-teams is an effective way of accomplishing tasks, as each group needs only to remain focused on their own part.

My two major tasks were programming of the PIC microcontroller and creation of the base station GUI. I learned very much about development with a PIC, as I have never used one prior to this. I now know how to develop in the PIC's assembly language, which is RISC-based as opposed to the CISC-based microcontrollers that I have had experience with. I learned how the RS-232 serial communications protocol works, as that is the method of communication between the PIC and the base station computer. In creating the GUI, I added to my experience with Visual Basic, which included receiving data over RS-232 and plotting this data for easy examination.

My overall experience with this project was a positive one, although at times stressful and exhausting. I am especially grateful to have worked with the group members that I did. We all managed to remain friends, and were able to create a mock-up on time that did almost everything that we were aiming for.

6.4 Ryan Monsurate

I found the experience of working within this team of students to be the most enjoyable part of the project. At first it took a little getting used to everyone's vastly different personalities but it seemed that as the months went by we learnt to co-operate better and respect each other as well as have productive and interesting group discussions.

The great thing about this group was that everyone had expertise in a different area of the project and so there was very little arguing about who would work on what in the beginning of the project. Nobody was told what to do. Rather group members would tell the rest of the group what they were doing and therefore enjoyed their part of the work more (although we've all had some pretty frustrating experiences when it comes to getting hardware and software to work correctly).

In this project I tried to be the glue that held everything together, and stay invisible while doing my job. I was mainly responsible for the high level project design, and leading most of our early brainstorming sessions for project ideas. During the course of the project I worked on radio frequency communications between the shirt and base station. I enjoyed working on the RF component of the project as well as helping other group members out with their respective parts if they needed or asked for it.

On the whole I found the project to be a very rewarding experience and am thankful for the opportunity I had to work with four talented people who I'm glad to call my friends now that the dust has settled. If I had to do this project over again, I'd tell Brian to get some sleep early on and be a little more cautious when it comes to group member interactions early on in order to get a better feel for how different people react to what I may consider harmless joking.

6.5 Scott Nelson

I found that our group worked very well together, and though sometimes our individual visions of our project differed slightly during our semi-weekly meeting we were able to unify our groups vision of our project. Our different backgrounds and interest were essential in our development of different ideas for our designs, we were all confident enough to present our ideas when we had then and none of us were so arrogant as to believe that our way was simply the best or only way to do something.

After working with the people in this group I found that each person found their own role in the group, not just as an influence upon the direction of the project but also as a go to person for a certain aspect of the project. Also, after a time I could tell that our group member became much more comfortable around each other as we got to know each other and our mutual respect for one and other grew.

In this project I overlook the development of most of the hardware and developed much of the hardware that would be used to communicate between the different modules of our project. I overlooked almost all of the hardware designs and made suggestions on how to improve them or corrected small mistakes that were made, such as trying to use and inverting amplifier configured op-amp while using a single voltage supply.

I developed much of the hardware for the go betweens such as the signal conditioning between the EKG circuitry and the microcontroller, and configuring the RS232 driver for the microcontroller to PC communication. Mostly I was the person who took a step back from each little part of the project and looked at how they should come together in one complete unit.

I had a great experience working with the team of people I had with me on this project, and with working on the challenges of a medical project with little knowledge of medicine or even biology. I must also give a nod to my co-op experiences without which I would not have been able to make the contributions to this project that I did. It was a great project with great people and I had a great time.

7 Conclusion and Future Work

Looking back to all that en-Focus! has accomplished during this project, we can state that the project has been a success. We successfully completed development on the proof-of-concept device for the PMEDS, and we believe that it clearly demonstrates the potential and viability of what we originally set out to accomplish via the PMEDS. We also managed to complete the project significantly under-budget and managed to meet all deliverable deadlines, along with the final project deadline.

Each and every member of the en-Focus! group has learned much about the designing, planning, and developing that goes into an engineering system/product. We have also gained valuable experience in starting a project from scratch and seeing it through to the finish as a somewhat large 5-member group. We've also learned that respect among group members, along with honest and direct communication, is essential to keep the group well motivated and getting along well. Overall, this project has equipped us to become better engineers and team members in the future.

7.1 Future Work

The development of our prototype device demonstrates that our PMEDS is an effective device for monitoring the vital signs of a person and recognizing when a medical emergency is occurring. There are however several improvements that could be made to the systems functionality, to it's electrical specifications, and to it's performance that would be desirable in the systems transition from prototype to production unit. These improvements will be outlined below.

7.1.1 Functional Improvements

- Add a Distress Button

  The addition of a distress button would allow the user of PMEDS to instruct PMEDS to contact emergency services in case of an injury or condition that would not be detected by PMEDS as the person breathing rate, temperature, and heat beat would not be sufficiently altered (i.e. a fall).

- Implement a Base Station

  Due to the time constraints upon the design and construction of the prototype unit, the planned base station was never designed. The design of the base station would allow PMEDS to operate without the need for a PC to do the final signal interpretation.

- Implement a Battery Charger into the Base Station

  In order to reduce the cost of operating the PMEDS the base station would allow the end user to recharge the batteries being used in the PMEDS system without any extra expense.

7.1.2 Electronic Specification Improvements

- Decrease the Operating Voltage

  To allow the PMEDS to operate for as long as possible without a change of batteries is would be helpful to redesign the circuitry such that it would be capable of operating with a voltage supply of 2.4 volts instead of 5 volts to reduce the operating power.

- Decrease the Current Drawn

  To allow the PMEDS to operate for as long as possible without a change of batteries is would be helpful to redesign the circuitry such that it would draw the minimum amount of current possible. This redesign would include looking at the values of resistors used for amplifiers, and voltage dividers, as well as a detailed look at the current drawn be specific integrated circuits that may be replaced with low-power integrated circuits.

- Increase the RF range

  It would be beneficial to increase the effective range of the RF subsystem in the PMEDS to allow for more freedom of movement of the users.

7.1.3 Other Considerations

- Cost Reduction

  To increase the profit margin of our product a cost reduction stage of design should be undertaken to reduce the cost per unit of our device as much as possible. Some possible area where the cost could be reduced include: designing our own RF, replacing the micro-controller with a less expensive one, and reducing the number of unique components.

- Additional Aesthetics

  Our prototype was design with little to no look as the aesthetics of the device thus in order to make the PMEDS more marketable an attractive and effective way of integrating it into a shirt will need to be developed.