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April 28, 2010

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

Re: Post-Mortem Process Report for DispensAlert™

Dear Dr. Rawicz:

Please find attached the Post-Mortem report for the product DispensAlert™ by Xypnios Innovations Inc. We have designed and implemented a device that reminds individuals to take their medication and to dispense the correct combination of medicine at a given time. DispensAlert™ will increases the probability of maintaining a healthy lifestyle.

Our Post-Mortem details the current state of the system, changes from our initial plans, and possible future plans for the device. The design and prototyping process is viewed from a reflective standpoint. We will examine what our goals were and how our team went about achieving these goals throughout the semester. We also delve into team dynamics as well as giving individual accounts of the way the group performed.

I will be more than happy to discuss any additional questions or comments you may have regarding the Post-Mortem report. Please do not hesitate to contact me via email at rdl2@sfu.ca or by phone at 604-613-1611.

Sincerely,

Ryan Laing

Ryan Laing
President and CEO
Xypnios Innovations Inc.

Enclosure: *Post-Mortem Report for DispensAlert™—Medicine Dispensing Alert System*

DispensAlert

POST-MORTEM

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GLOSSARY

CSO	Chief Science Officer
CMO	Chief Marketing Officer
MCU	Microcontroller Unit
UI	User Interface
GUI	Graphical User Interface
LCD	Liquid Crystal Display
USB	Universal Serial Bus
I^2C	Inter-Integrated Circuit
SPI	System Packet Interface
GPIO	General Purpose Input Output
TFT	Thin Film Transistor
ROM	Read Only Memory
UART	Universal Asynchronous Receiver Transmitter

1.0 INTRODUCTION

For the past thirteen weeks, the concept of a medicine dispensing alert system (DispensAlert™) has occupied the time of our six team members – Ryan Laing, Joseph Liu, Mohammad Abu-Laila, Trevor McCauley, Steven Horita, and Gary Chiang – who have worked tirelessly towards the realization of DispensAlert™. This report examines the process that took our project from concept to reality and the issues we encountered along the way.

2.0 CURRENT STATE OF THE DEVICE

DispensAlert™ is a medicine dispensing alarm system. That is, it alarms the user when it's time to take their medication and also dispenses the correct combination of medicine for that time. The basic block diagram of the system is given in Figure 1.

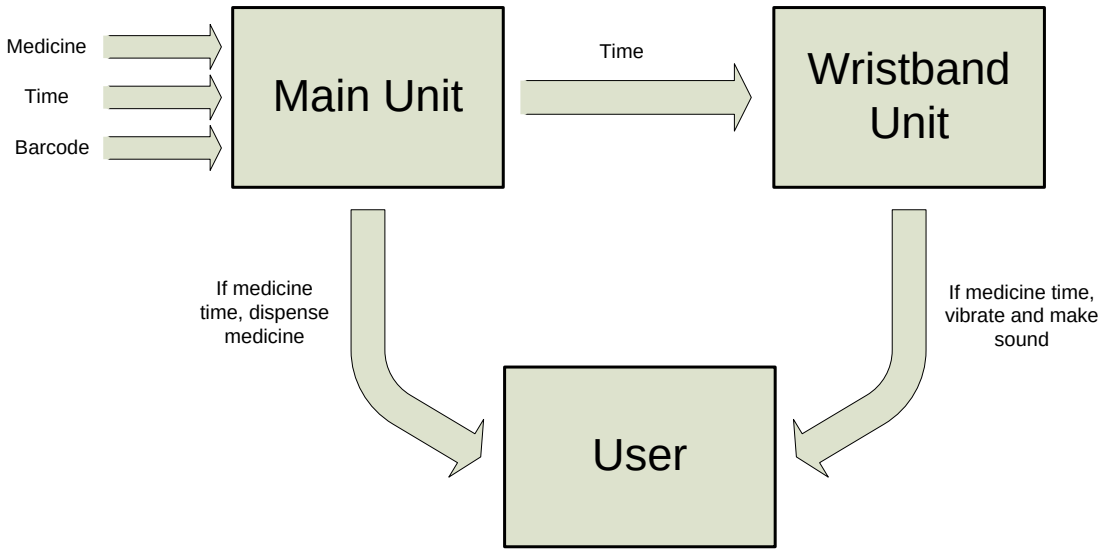

Figure 1: Basic Block Diagram of DispensAlert™ system

For the main unit, an easy to use GUI has been implemented. Using this GUI, the user is able change the system settings, add a medication, delete a medication, review entered data and view next alarm time.

The GUI for the main unit has been implemented using C/C++, Adobe Photoshop, the ezLCD touch screen display and the LPC2148 MCU. The graphics are professional looking which will draw positive attention from the target users. Serial commands from the LPC2148 MCU are sent to the touch screen in order to display the appropriate graphic bitmaps. In addition, serial

data from the touch screen is received by the MCU and processed in order to find out what icon the user has pressed.

There are only two things that can be changed in the settings menu of the main unit GUI. Those are the system time and date. When adding a medication, the user is able to choose between the manual method and the barcode method of entering information. In this prototype, the user is only able to enter the information required for one medication at a time. If the user chooses the manual method, then they are prompted to choose the: reservoir to store the medicine at, times per day to take medication, hours in between dispense times of medication, number of pills every dispense time, and first time of the day to take medication. The main unit has only two reservoirs (one per medication). Also the times per day to take medication, hours in between dispense times of medication and the pills every dispense time have a maximum value of nine. However, there are no restrictions to when the user chooses to take their medication for the first time of the day. The system works on a daily basis; hence medicine is dispensed every day at the same chosen time.

If the user chooses the barcode method of entering information, they simply scan special barcodes made for our system. This barcode will contain information regarding: times per day to take medication, hours in between dispense time of medication and the number of pills every dispense time. However, after scanning the barcode the user has to choose which reservoir to store the medicine at and the first time of the day they wish to take at. The barcode is controlled by serial commands sent by the MCU. When the correct type of barcode has been scanned, serial data is sent from the barcode to the MCU for processing. But if an incorrect type of barcode has been scanned, the GUI will show an error message and allow the user to rescan if they wish to do so.

In addition the user is able to delete a medication from the system. All they have to do is press the delete icon and choose which reservoir (medication) to delete. The user is also able to review what information they have entered for a particular medication and review what the next alarm time is by pressing the review or alarm icons respectively.

When it's time for the user to take their medication, a screen prompting to dispense or dismiss the medication at that particular time is shown. If the user presses the dismiss icon, the system goes back to normal operation. However, when the user chooses to dispense the medication, signals are sent to the stepper motors from the MCU which causes them to rotate, hence causing pills to be dispensed.

Since the MCU of the main unit has only two UARTs and three are needed for the touch screen display, the barcode scanner and the wireless transmitter, a special switching circuit has been designed and implemented in order to allow the barcode scanner and wireless transmitter to share the same UART. The drivers for the MCU and this switching circuit have been built on a prototype board. Also, the entire main unit runs using a signal 5V power supply which includes a switch for turning the system on/off. The enclosure for the main unit has also been made which contains special compartments for all of the components such as the MCU and the touch screen display. This will ensure its robustness and easy placements of the components. All the components are currently placed in the enclosure.

When the user adds or deletes a medication or modifies the system time, there is a change of data saved in the main unit. When this happens, new data is processed by the MCU and sent wirelessly via the Xbee wireless transmitter to the wristband unit, which receives this data via an Xbee wireless receiver. The data is then processed and saved using the AVR Butterfly MCU board.

When it's time for the user to take their medication, the wristband unit will make sounds and vibrate in order to alert the user. The user can simply turn off the alarm by the press of a button. Other features of this unit include displaying the current time and displaying a countdown till the next alarm time. Such information can be displayed using the built in LCD display of the AVR Butterfly board.

Circuitry needed for the wristband unit which includes voltage regulators and a TTL/RS-232 converter has been built on a small prototype board. All of the circuitry runs using a 9V battery which includes a switch for turning the wristband on/off. A small enclosure, which can be easily placed on a person's wrist, currently houses all of the wristband unit's components.

The main unit and the wristband unit are able to effectively communicate with each other. Rigorous testing has been done to ensure the operation of the DispensAlert™ system. Several people outside of the group have tested the GUI for the main unit and concluded that it's easy to use.

3.0 DEVIATIONS FROM INITIAL PLANS

As is expected with any project of this magnitude, we did experience some deviation from our original plans once we had completed our part sourcing research. Below we discuss these deviations, how they came about, and what impact they have had on our final product.

3.1 Overall System

Overall, our system meets the basic functionality we set out to accomplish as outlined in our functional specification. There is a main unit and a wristband unit. The main unit holds the medication, dispenses it at the correct time, and sends the alarm times to the wristband unit. The wristband unit, in turn, alerts the user when it is time to go to the main unit and get their medication. So from this holistic standpoint, there are no deviations from what we set out to do. Deviations, however, have arisen during the implementation of our collective vision for DispensAlert™.

3.2 Main Unit

The main difference between the original design proposition of the main unit and our final model was the mechanical design of DispensAlert™.

The original dispensing mechanism consisted of a reservoir that controlled the number of pills to be dropped onto a sweeping mechanism. The sweeping mechanism would then sweep the pills towards the outer perimeter of the round flat platform, and force one pill out at the small opening on the side. However, after further testing, we realized that the design encounters difficulties upon different sized pills, and therefore we moved onto a different design.

The dispensing mechanism of our final model consists of round cartridges that already have pills separated into different compartments. The cartridges were designed with a rotatable opening at the bottom. Using the stepper motor, we can control the rotating movement of the opening, and thus control the number of pills being dispensed. After being released from the cartridge, the pill would travel through a funnel to the exterior of the main unit.

Another change we implemented was the wireless communication protocols between the main unit and the wristband unit. This modification is discussed in the next section.

3.3 Wristband Unit

The wristband unit has one principal change in hardware, and a couple changes in software functionality which deviate from our original plans for our prototype.

The hardware change we implemented is a change in wireless modules. We had planned on using a MO-RX3400/MO-SAWR Receiver/Transmitter pair but when we tried sending serial data across the lines it became apparent that we had made an error in choosing these modules. It turned out that they were only mean for on/off functions and weren't suitable for serial communication. So we went back to the drawing board and ended up choosing a pair of Xbee modules using the ZigBee protocol. The Xbee pair has an added benefit of both modules being transceivers (meaning we can now have two way data communication).

In our software, we both added functionality and removed/did not implement functionality in our final prototype. We originally intended to only have a simple buzzer and vibration alert go off when the alarm expires; thanks to the butterfly's LCD screen, we now are able to differentiate between the two alarms and show that difference to the end user via the screen.

The only functionality that we lack in our current iteration is the battery level functionality. We had intended to show when the battery is low so that the user may change the batteries; unfortunately, we did not have enough time at the end of the semester to implement this function.

4.0 FUTURE WORK

DispensAlert™ has excellent potential for further research and development. As we look back at the process that brought us to this point, we have some suggestions for future work on our system.

4.1 Overall System

There are several future developments that can help make DispensAlert™ more robust, practical, and more user-friendly. Specifics of these upgrades are outlined in their respective sections.

The overall system turned out slightly bulkier than anticipated. It is definitely worth trying to look into ways of shrinking the size of both the main unit and wristband unit. Reducing the form factor of the two units will involve sourcing new surface mount components instead of through-hole components. Also, smaller stepper motors can be used since we are not using them for high-torque applications.

Lastly, future development can be used to make both units aesthetically pleasing. This may entail things such as graphics, different material, and matching colours. For example, we should have matching GUI interfaces for both the main unit and wristband unit.

4.2 Main Unit

There were a couple of future development that we had in mind, but never had the opportunity to implement due to budgetary and time constraints. Currently, the stepper motors are instructed to move in fine increments of 1.8 degrees to properly dispense the correct amount of pills. However, it is important to design an optical feedback located at the mouth of the dispensing cartridge. Designing DispensAlert™ with an optical sensor would eliminate the chances of dispensing more or less pills than it was programmed to dispense. In addition, we can use the optical sensor to count the number of medicines dispensed and notify the user than the reservoir is low in quantity.

Secondly, it would be preferable to integrate a larger touch-screen display such that icons are more easily spread out and reduces the chances of pressing the wrong button. Also, increasing the size of the touch-screen increases the visibility of buttons for individuals with impaired vision. Since increasing the size of the touch-screen will definitely increase the cost, we can consider sourcing a larger display without color. A monochrome display is sufficient for displaying pertinent information for adults and the elderly while color is more contemporary.

Lastly, the redesigning of the mechanical mechanism used for dispensing medicine can be revisited again. Having a new form of dispensing medicine may greatly reduce the size of the current prototype and may also reduce the overall weight of the main unit.

4.3 Wristband Unit

If we were to continue working on the wristband unit, we would have a couple of areas that we would like to improve upon in the design and functionality of the wristband.

Firstly, we could implement a battery voltage level indicator to notify the user when the battery pack on the wristband is low and needs to be changed. There is an ADC in the butterfly meant for voltage measurement so this could be easily coded to function.

Second, we would take some time to refine the wireless protocol our device uses to ensure the security and reliability of our solution. Since our Xbee modules are transceivers, we can implement better handshaking and error checking, guaranteeing a much higher level of usability.

Lastly, our prototype is bulky. If we were to market this product, we would take the components that we are using on the butterfly and print a custom PCB so that our solution could be incorporated into a small more stylish and comfortable wristband. It could even be incorporated into something like a wristwatch.

5.0 BUDGETARY AND TIME CONSTRAINTS

Perhaps two of the most important factors which determine the success of our project, the financial and time constraints that our team faced greatly shaped the outcome of the project. This section briefly discusses the financial situation as of the end of the project as well as our time schedule and how closely our goals were met time wise.

5.1 Budget

Table 1: Projected Cost vs. Actual Cost contains the projected and actual cost of the project as of April 28th, 2010:

Table 1: Projected Cost vs. Actual Cost

COMPONENT	PROJECTED COST	ACTUAL COST
LCD / Touch Screen Panel	$125	$280
Microcontrollers	$100	$120
Enclosures	$100	$25
Motors	$100	$30
Miscellaneous Parts / Connectors	Not Budgeted	$130
Power Supply	$100	$50
Barcode Scanner	$80	$30
Wireless Transmitter / Receiver	$95	$130
Force Feedback Device	$50	$25
Contingency	$100	N/A
Grand Total	**$850**	**$820**

Although we grossly underestimated the costs of the LCD / Touch Screen and the MCU's, this is compensated by the fact that we over budgeted on every other item. We were granted $600 from the Engineering Science Student Endowment Fund (ESSEF) which helped us offset our realized costs. We hope to apply for additional funding from alternate sources to recover the outstanding costs associated with our project.

5.2 Time Constraints

A Gantt chart outlining our projected and realized time schedule is in Figure 2:

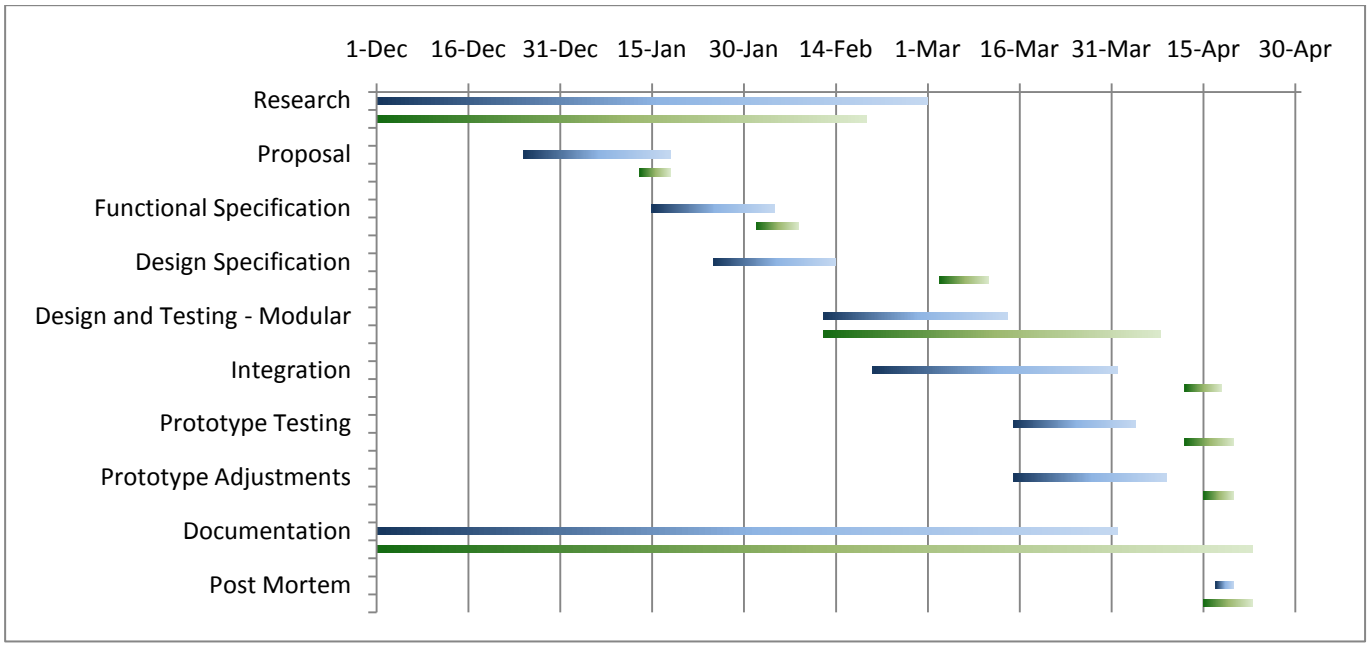

Figure 2: Gantt Chart - Projected (Blue) vs. Actual (Green)

As can be seen, we tended to spend less time on each document than we had originally projected, using about a quarter of the time we allocated for each of the Proposal, Functional Specification, and Design Specification. Modular design and testing took about twice the amount of time that we had budgeted for and as a result, tasks such as integration and prototype testing happened much later and were afforded much less time than we had originally allocated to them.

Simply by having these milestones to strive for, we were able to get through all stages of development of DispensAlert™ in an overall timely manner. Milestones are an important driving force behind production and became the invisible hand pushing us to achieve our goals.

6.0 INTER-PERSONAL AND TECHNICAL EXPIERENCES

This section outlines, for each member, their personal experiences during the semester. We will discuss the goals, challenges; knowledge gained, inter-personal, technical issues we each dealt with personally.

6.1 Ryan Laing

As CEO, I was in charge of the overall direction of the group in terms of goals and deadlines in addition to the day to operations so to speak of the team. As akin to the organizational requirements as CEO, I also took on a large chunk of the composition and layout for each document required for the various milestones.

On a development level, I was involved with the research and development of the wristband unit. This included sourcing parts, reading all the accompanying documentation on our parts, and working with my partner to design and implement the wristband subsystem. The wristband was coded with the C programming language and presented a set of unique challenges to be overcome. We first had to worry about the portability of the unit, which mainly means weight and power consumption. The advantage of this constraint is that it made looking for parts a little easier because we had something to go on.

Before ENSC 440, I had very little experience designing my own circuits and systems as in class you usually just follow whatever design is given to you in a particular lab. This class has given me the hands on design and debugging experience I had been lacking from the other components of my program here at SFU.

My C programming skills are greatly improved, I can now solder much more effectively, and I have now had experiences with programming another microcontroller (other than the HC12). Interfacing our components with the MCU was both educational and rewarding when the finished product was realized.

This project has not been an easy process, while I gained a lot of knowledge from ENSC 440, I feel that if I had not taken such a heavy course load I could have spent even more time on the project and learned that much more. The added time would have also given me the chance to implement some of our future work mentioned in the above sections.

If I had to go back and do it again, I would insist we adhere to deadline much more strongly. We also needed to get a jump on the design and prototyping process earlier than what we did – lessons learned – essentially the point of ENSC 440 though isn't it?

6.2 Joseph Liu

My initial role for this project was to facilitate in hardware design and to help bridge the gap between software and hardware. As the project progressed, my role became broader and I took on programming the microcontroller development board to interface with other peripherals such as the barcode scanner, touch-screen display, stepper motors, and wireless transmitter.

Before venturing into this project, I came in with very little experience programming in C/C++ to work with hardware. Thankfully, after taking this course and getting the chance to play with the hardware available, I was able to fulfill this technical requirement that I was missing from past courses.

In addition, I gained experience in designing and building circuits for interfacing different RS232 serial communication voltage levels. Also, valuable experience and insight was gained through working with stepper motors, motor driver circuits, solid-state relays, and an ARM7 LPC2148 microcontroller.

The project did not come easy at any point. The most significant problem we ran into during preliminary design and testing was bad connectivity. The most valuable lesson that will reduce the amount of time troubleshooting is purchasing the right type of cable and mating connectors. Secondly, labeling the loose wires/connections also quickly identifies whether something is plugged in correctly.

I had doubts in the beginning that I did not have enough experience to complete the task proposed. In the end, I was surprised that I used knowledge that I have learnt in the past and put them to practical use. The next most important tool besides past experience is the ability to research online for clarification on particular subjects.

I have enjoyed the chance and freedom that we have been given in the course to design something that we proposed. This course is unique in its own ways because it gives students the chance to engage in a self-motivating project that they can see from start to finish.

With the diverse experience that we have in our team, many problems were solved internally. It is amazing how much one can learn from another. Everyone has their own special skills and when the team is able to combine them, it makes for a very valuable contribution towards the team's success.

6.3 Mohammad Abu-Laila

As the CSO, I was involved with both the hardware and software portions for the main and wristband units. However, special focus was directed by me towards the main unit, which is the heart of the DispensAlert™ system.

I was involved in researching the required criteria of the components that we are to use for our system as well as sourcing already made components that meet those criteria. The components I sourced include the touch screen display, the stepper motors/drivers, the LPC2148 MCU board, the barcode scanner and the Xbee wireless modules. Finding components that are compatible with each other proved to be a difficult task and special attention was paid when it came to the MCU board as it needed more than one UART in order to communicate with the touch screen display, the barcode scanner and the wireless transmitter.

I was also involved in the creation of the GUI. Much time was spent creating our GUI and many revisions of it were made as we progressed in making our system in order to ensure ease of use for our target users of which a majority is senior citizens. Everyone working on the main unit had some input towards how to make the GUI as easy as possible to use.

Prior to ENSC 440, I had no experience with the C/C++ programming languages geared towards embedded software. I was involved in programming the GUI and control of the different peripherals which consisted of the touch screen display, barcode scanner and the Xbee wireless transmitter using C/C++ and the LPC2148 MCU. Controlling the different peripherals proved to be a difficult but doable task. Much time was spent reading the datasheets of the different peripherals in order to understand their principle of operation and hence control them. My C/C++ programming skills have significantly improved and I can now say that I am exceptional at creating embedded software.

However, since the LPC2148 had only two UARTs and three were needed (one for the touch screen, one for the barcode scanner and one for the wireless transmitter), a special switching circuit was designed and implemented by me which made it possible for the barcode scanner and the wireless transmitter to share the same UART. This involved using knowledge I have learned in first year university. This also helped improve my circuit design and soldering skills.

I was also involved with the Xbee wireless receiver which is on the wristband unit's side. Making the wireless transmitter and receiver communicate was an easy task even though there were some minor glitches along the way due to our lack of attention.

From my experience in ENSC 440, I found that critical thinking is important. Much research must be done prior to starting a project in order to ensure the feasibility of the project, and ensure the compatibility and functionality of the different components. This is especially true when it came to our original wireless transmitter and receiver which apparently were intended for switching (on/off) functions only. Having to research and buy a wireless transmitter and receivers which are compatible with our components towards the end of the semester was frustrating.

Writing down what I intended to do in my journal proved to be an excellent way to reduce errors in our project. Making flowcharts in my journal made it much easier to write code. I always found myself referring back to my journal. If the journal wasn't there, time would have been wasted trying to recall what I have done.

I have also reaffirmed by belief that communication between group members is an essential part for a successful group. That way, less time would be wasted as everyone knows what the others are doing and integration of the different units would be easier since everyone knows the standards that are being used. Communication between the main unit and wristband unit groups were good but if I was given the chance to redo ENSC 440, I would ensure there was more communication. That way, integrating the main and wristband units would have been easier. I would have also more strictly adhered to deadlines.

Overall, my experience in ESNC 440 was excellent. Taking an idea and implementing it to an actual prototype was an enriching experience. My group consisted of a dynamic range of individuals where each has a special set of skills. My group members came together and through their hard work and efforts, we managed to create a working prototype of the DispensAlert^{TM} system. I had high expectations from the very beginning and I knew that our system could be finished in time, although, at times, glitches brought my expectations down. But through hard work and dedication our project was completed.

6.4 Trevor McCauley

As CMO, my duty was to complete the necessary general market research for our product. In addition to my officer duty, in a smaller team of two, my partner and I were tasked with designing and creating the wristband unit. In developing the wristband, I was involved with component research and judgment calls as well as implementing the units systems. Using a compiler provided by the manufacturer, we programmed the unit with C programming language. As our portion of the product was meant to be small and portable, we were presented with a set of challenges to work past. We had to meet a series of criteria consisting of lightweight, low power consumption, and compactness.

Before this course, my experience with circuit design and general systems was limited to the number of circuit labs I have had over the years. In hind sight, those labs still had a schematic to design from where as here we designed things from the bottom up. This is the first time I have ever had to implement a number of different systems (i.e. supplying sufficient power for the hardware operations and the software alike). This course improved my debugging proficiency as well as my tolerance for larger scale design (i.e. designing smaller components of a larger whole to be later integrated).

My understanding of the C programming language has improved as well as my general coding technique and competency. In addition, I have improved my soldering and circuit building skills. I think that the most beneficial task from this course was integrating our components together and then integrating the two units together. Being able to create a fully functional prototype has been a very rewarding and enlightening experience.

Over the past four months, this project has presented us with a series of tasks and problems to overcome at each pivotal moment in the design. The most important lesson I can take away from this would be time management and communication. It is so easy to work alone but to work in a group is a project all on its own that requires effort and practice to perfect. If we as a group had been more endowed in those areas we could have avoided many trials and tribulations but now we have come out better because of it.

If I could go back in time and redo this course I would get working from the get go because time goes by really fast when you don't keep yourself in check. The biggest mistake I made was not adhering to deadlines strictly. Now that the dust has settled from the commotion that is 440, I am more the wiser and eagerly look forward to my next challenge to overcome.

6.5 Steven Horita

In my role as Chief Technical Officer on this project, my duty was to oversee the technical issues and find solutions to any problems which may arise. During development, I focused mostly on the challenges related to programming and digital communications. Whenever a major, seemingly impossible problem arose in the programming of the main unit, as well as one time in the wristband, I would get a phone call or email requesting a solution to the problem.

These problems came in many forms and there are a couple of them that stand out in my mind. The first was when we were starting to program the GUI and we were doing it using nested while loops. As soon as we started getting up to ten or fifteen nested while loops the code was becoming unmanageable. This meant a major restructuring of the code as a whole. Another problem we ran into that caused issues for quite a while were the functions we were using that ended up being blocking functions when we needed non-blocking functions. But throughout all of these, I was able to find the problem, find the solution and implement it in the code.

While I have been working on this project, my understanding of microcontroller units has improved significantly. This understanding is related to several things including, but not limited to the problems related to uploading new code, the limits of memory size, the connection and communication with external components and knowledge of the subset of C++ that will compile and run on current microcontrollers.

As for the group dynamics, there were issues. The members, myself included, had busy schedules and were at times unable to be in the lab working on the project when they were needed. With our group being the size that it is and with the number and difficulty of classes that each of was taking, it became impossible for the whole group to meet at once and work all together. That being said, there were very few days that I didn't receive an email or ten updating the group on what work had been completed that day. At times, I felt that other members of the group were too high strung, pushing a little too hard early on in the design process. Now, that we are at the end of the semester I am somewhat pleased that they pushed as hard as they did.

Now that this is coming to an end, I feel a strange sense of relief even knowing that the project is not complete and we still have a major presentation to give. I believe this relief comes from knowledge that our project is well done and when we present our final product no one will doubt our skill and engineering prowess.

6.6 Gary Chiang

My role as the Chief Financial Officer of Xypnios Innovations was to overlook the financial planning and potential marketing risks of our products. Throughout the course of this project, I've monitored our budget closely and facilitated the decisions of purchasing components and materials. In addition, since one of the main criteria for this project course is the ability to develop a marketable product, I devised potential marketing strategies to propel our company forward.

Besides the financial planning responsibilities, I was also involved in the development of DispensAlert^{TM}'s GUI. With my team members, we went through all types of possible scenarios to make the user interface as simple yet effective as possible. On top of the overall GUI, I also designed the graphic images displayed on the LCD touch screen to improve the aesthetics of our product.

My main task for this project was designing the mechanical mechanism and the enclosure for the main unit. We ran into numerous problems when designing the mechanical portion of dispensing of medication. After various designs and consulting other peers, we reached an agreement that it was impracticable to design a pill sorting/dispensing mechanism within the financial capability and affordability of this product. In addition, it did not make sense financially to add an expensive and complex robotic arm to a household appliance to potentially solve our problem.

When designing the enclosure, I encountered problems mainly due to the parallel design timeframe of the enclosure and the product itself. Due to the timing issue, I had to constantly make changes to accustom the new features and hardware components. In addition, fitting everything into the smallest possible area with enough freedom to make adjustments also took a lot of trial and errors in addition to the prolonged design time.

Before this semester, I had little experience with integrating hardware components and software programming. This opportunity allowed me to gain valuable experiences in soldering, testing hardware components, designing mechanical systems and further knowledge in C++ programming and various hardware circuits.

At the start of the semester, this project seemed overwhelming considering the lack of experiences of our group members. However, through hard work and contribution from everyone's expertise, we were able to stay relatively close to our proposed schedule and complete the project with our proposed functionalities. Overall, I have enjoyed these thirteen weeks and am grateful for the plentiful opportunities this course offered.