School of Engineering Science
Simon Fraser University
Burnaby BC V5A 1S6

March 8, 2006

Mr. Steve Whitmore and Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby BC V5A 1S6
Re: ENSC 440 Post Mortem for the Sure-Step® intelligent walking aid

Dear Mr. Whitmore and Dr. Rawicz,

Please find attached a copy of Incedonex's Post Mortem for our Ensc 440 project, the Sure-Step® intelligent walking aid. Our goal was to design and build a technologically advanced walker created to assist elderly users. It is comprised of three subsystems: the M-Brake™ the Sense-Steer™ and the Nav-Pro™. These modules aim to address problems such as abrupt breaking, walker rollback, hazard detection and path planning in order to better assist and protect the user.

This document highlights the development process and outlines the current state of the system, deviations from our original specification and recommendations for future work on this product. It also covers budgetary and time constraints and each team member provides a brief personal reflection on the project.

Incedonex is comprised of: Mr. Daniel Agyar, Mr. Duncan Chan, Mr. Steven Dai, Mr. Yijun Jing, Mr. Victor Tai and Mr. Li Xu. We are six highly skilled and ambitious engineering students at Simon Fraser University with backgrounds in Engineering and Computer Science. If you have any questions or comments please to contact me by e-mail at lxu@sfu.ca. Alternatively, you may contact me directly by telephone at 604-505-9063.

Sincerely,
Li Xu

Li Xu,
Chief Executive Officer
Incedonex
Enclosure: Post Mortem for the Sure-Step® intelligent walking aid**.**

incedonex

SIMPLY MOBILITY, SURELY SAFETY

Post Mortem

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Submitted To
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Engineering Science
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Issued Date June 2, 2006

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1 Introduction

At the start of this project, it was Incedonex's goal to design and build a proof-of-concept intelligent walking aid called the Sure-Step®. The system would be composed of three design modules: the M-Brake™, the Sense-Steer™, and the Nav-Pro™. These modules would serve to address the issue of uncomfortable braking as well as provide assistance such as hazard detection and navigation in an unfamiliar surrounding. This stage would also let us investigate the potential of such a product and help us determine if commercialization would be pursued.

This document assesses the design and development process of the Sure-Step® intelligent walker and highlights deviations from our original plan as well as addresses possible future work for this project.

2 Current State of the System

2.1 M-Brake™

As defined in the design specification, the M-Brake™ system architecture is shown in Figure 1.

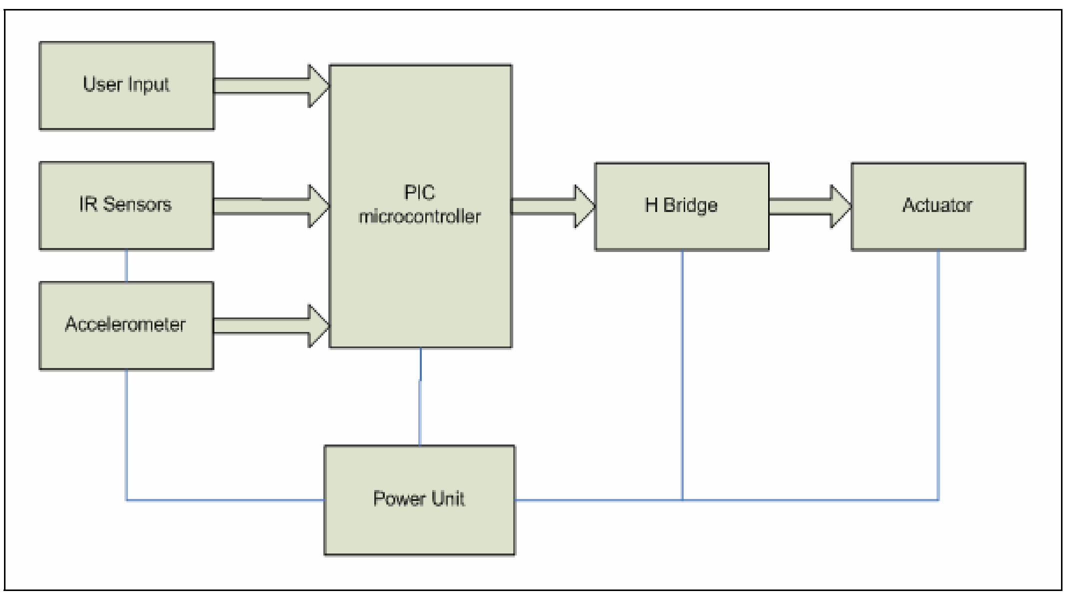

Figure 1: System Architecture Block Diagram

Overall, most of the system implemented was according to the block diagram, with the exception of the main PIC microcontroller and some modification to the power unit. The control system was actually handled by two microcontrollers instead of one. This design deviation will be discussed further in section 3.1. The User Input block consists of a single push button mounted on the left handle for the user to activate the braking mechanism when required. The button is implemented so that the amount of braking is controlled by how long the button is pushed. A limit is set where the brake is at its maximum and the wheels no longer move until the user releases the button, hence releasing the brake. The IR sensors are mounted on each leg at the front of the walker frame. The outputs from these sensors are used to trigger either the right or left brake, depending on control signals supplied by the Sense-Steer algorithm. This will be further discussed in subsequent section 2.3. The accelerometer is read to the secondary microcontroller which in turn calculates and analyzes the slope to determine if predefined thresholds are exceeded and relays control bits to the main MCU in order to activate the brakes. The H-Bridge is composed of two HSI Motors 39105 drivers [1]. We opted for commercially available drivers instead of building our own due to the time involved with design and testing of such circuits. Each driver is capable of controlling one motor and has digital input control bits in order to enable the motors and specify the direction. Each driver also has a +5 V regulated output pin which was used to power the MCU's, IR sensors and accelerometer. In this fashion, the power unit block was only connected to the drivers and, in turn the +5V outputs were used to power other digital components. Currently, the functionality of the modules has been verified with some erratic behaviour of the incline functionality caused due to bad connections. The next step is to carry out precise calibration through field testing and user input.

2.2 Nav-Pro™

The current Nav-Pro system supports up to four beacons with two of the beacons considered to be of the same type. The beacons that are the same type are designed to demonstrate the path finding algorithm. Figure 2 shows a possible arrangement of the beacon system. With Beacon A and Beacon B the same type of destination, a walker going from Beacon C will always proceed to Beacon A because that type of destination is closest.

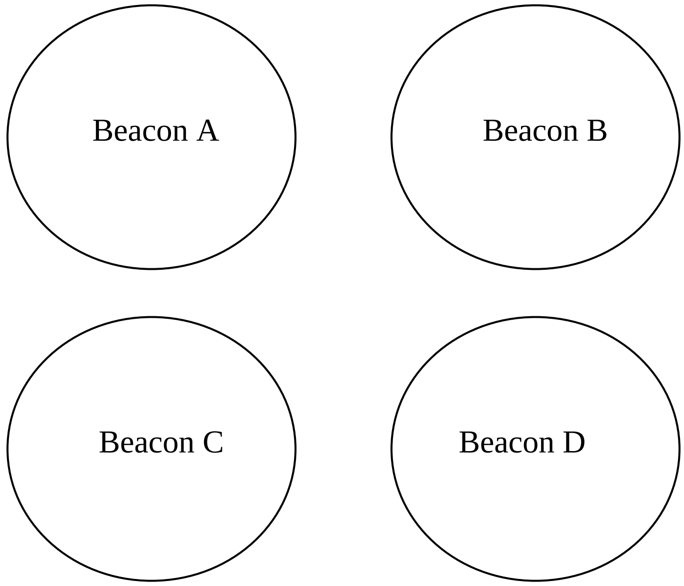

Figure 2: Beacon Locations

The user interface in the current system has a four LED arrangement in a cross that indicates North, East, South, and West. When the destination is selected, the corresponding LED will turn on, indicating the general direction of the next destination.

2.3 Sense-Steer™

We've implemented the majority of functions for the sense-steer component. The walker is able to successfully detect the curb and avoid it for a person walking at an elderly's speed. Unfortunately, the override push button doesn't work yet, which most likely is due to bad wiring connection. The following figure shows the interaction diagram for the module.

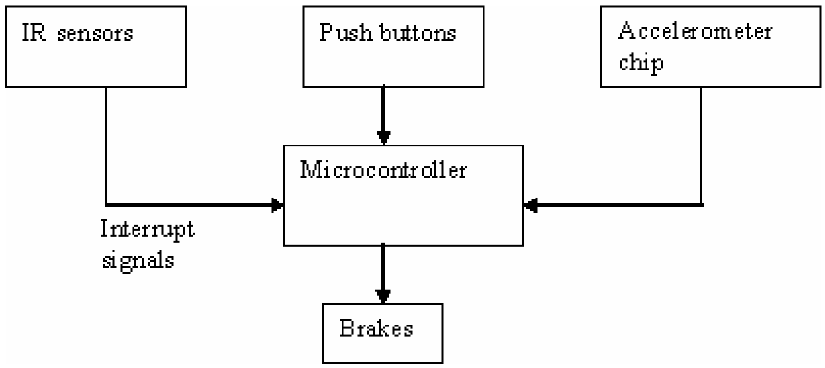

Figure 3: Interaction diagram for sense-steer module

Figure 3 shows that the system is interrupt-driven. Every component talks to the main controller through interrupt. The main controller then tells the brake to act accordingly.

Figure 4 shows the software architecture for the module.

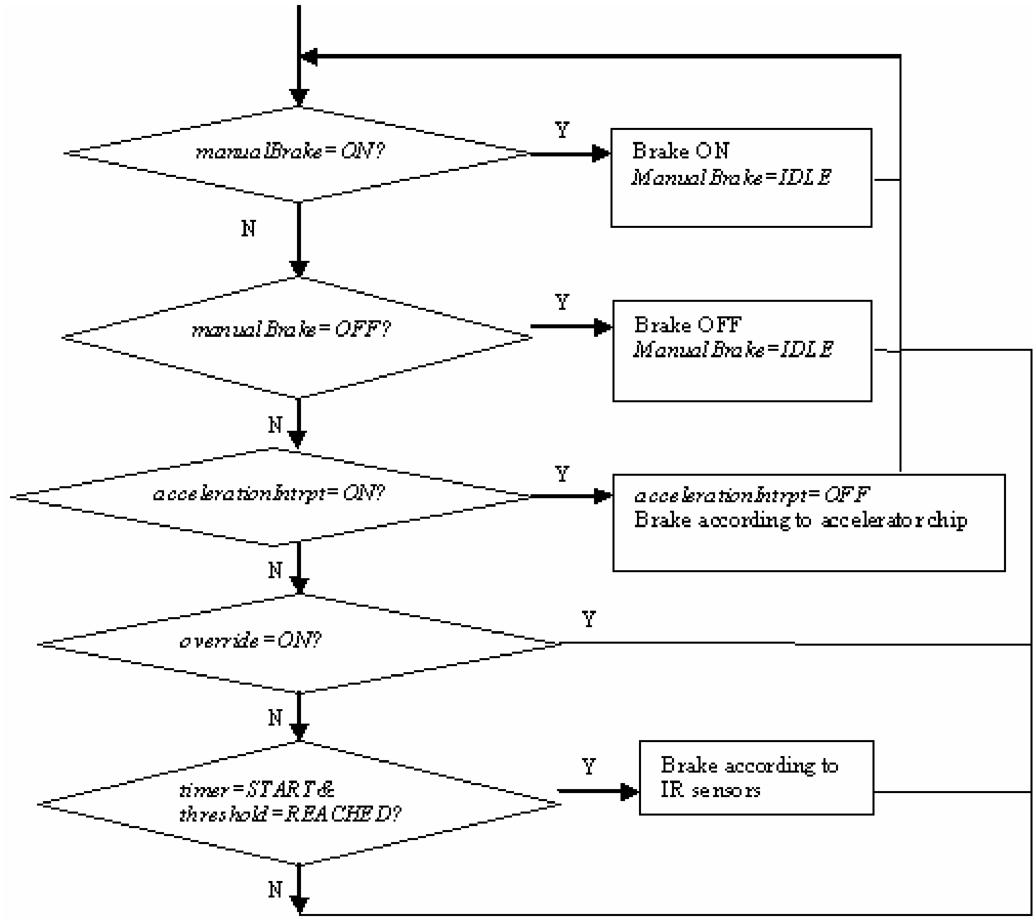

Figure 4: High-level software architecture for sense-steer module

Please refer to section 2.1 on how the microcontroller is interfaced to the brake.

3 Deviation of the System

3.1 M-Brake™

We deviated slightly in the system architecture as shown in Figure 1 by implementing a separate, dedicated micro-controller unit (MCU) to poll the accelerometer and handle the decision making for the decline braking module. This MCU would then trigger an interrupt in the main MCU and pass on control bits which would control the braking for a decline slope. Initially we had planned for braking on both, an incline and decline slope. However, after some preliminary testing, we opted to eliminate the incline braking. This was due to the additional amount of force a user would require to push the walker uphill. Another deviation was the choice of linear actuator. Our initial design incorporated an HSI Motors size 11 linear actuator capable of supplying a maximum of 25 lbs [2] of linear force. However, after initial testing we realized this force was pushing the limit and opted to change to a large size 17 motor, capable of supplying up to 80 lbs of force [3]. This certainly met our needs and also allowed for some flexibility with the speed versus force of the motor. Figure 6 below shows the comparison between the Size 11 and Size 17 Thrust versus Speed graphs for L/R Driver used in our project. This change in design also had an immense impact on our schedule due to the time involved with testing and exchanging the motors.

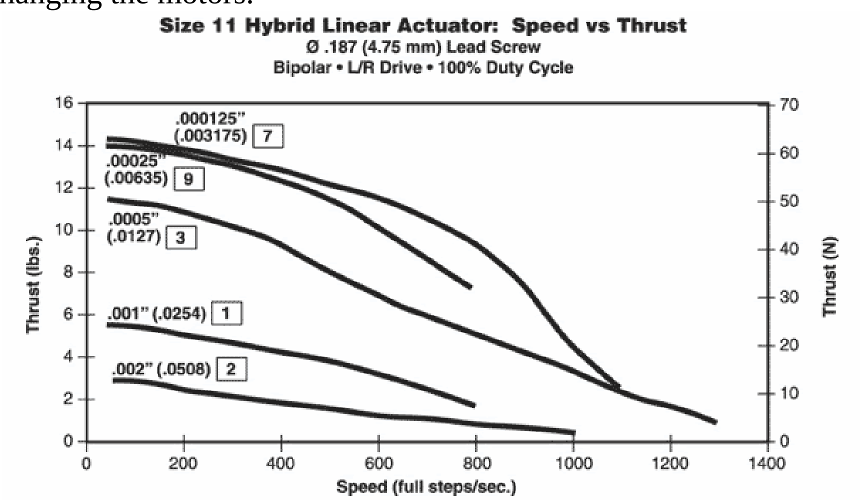

Figure 5: Size 11 Thrust vs. Speed curve

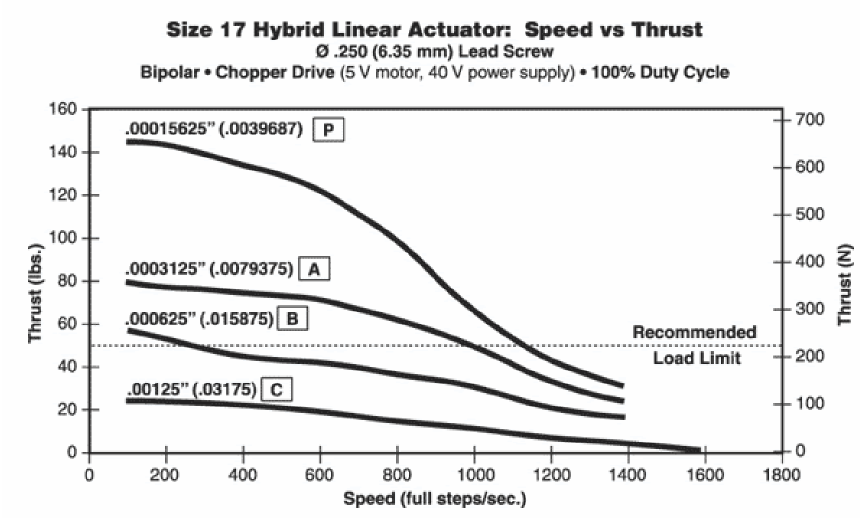

Figure 6: Size 17 Thrust vs. Speed curve

3.2 Nav-Pro™

The current Nav-Pro system performs mostly as planned. The only deviation from the original design is that it does not include the digital compass needed to provide relative direction to the destination. The digital compass that was bought may have been defective as it was not providing any output when powered.

3.3 Sense-Steer™

There are few deviations from the design specification. The IR sensor was originally going to be taped to the walker's legs, but we found a better solution by using a metal connector. One end of connector connects to walker's leg and other to sensor. The mounting offered good stability and flexibility for the sensor.

The software is almost the same from design specification, and the circuit design is almost the same. One difference for the circuit is that a RC low pass filter is added to the push button to filter out the high frequency noise.

4 Assessment of Budget and Schedule

4.1 Budget Assessment

Our estimated cost and actual cost are in Table 1. From Table 1, we can see that we estimated a cost of $700, but we actually spent about $1020. The only item's price that we underestimated is brake system. The reason is that the original brake system was not suitable for our system and we have to reorder another type of brake system to replace it. However, we saved some money from the walker due to buying a used walker for our project. Therefore, our actual cost is not much higher than what we have estimated.

Table 1: Actual and Estimated costs of our project

Actual Cost (CDN)	
Walker	$ 100
Braking System	$ 400
Motors	$ 200
Wireless Modules	$ 90
Accelerometer	$ 80
Battery	$ 30
Digital Compass	$ 60
Unforeseen Costs	$ 60
Totals	$1020

Estimated Costs (CDN)	
Walker	$ 300
Braking System	$ 100
Motors	$ 100
RFID Sensors	$ 20
Display	$ 40
Battery	$ 30
Digital Compass	$ 60
Unforeseen Costs	$ 50
Totals	$ 700

4.2 Schedule Assessment

Our Original schedule is in the Figure 7. We found in the middle of March that we were behind schedule. The main reason is that the time we expected to implement the three modules and the actually debugging time are not enough. Another issue we did not consider is that four members of our group had final exam in beginning of April, which made another week delay for our progress. The system testing and debugging was continuously proceeding just before our final demonstration. The purpose for that is to make sure our system stabilized.

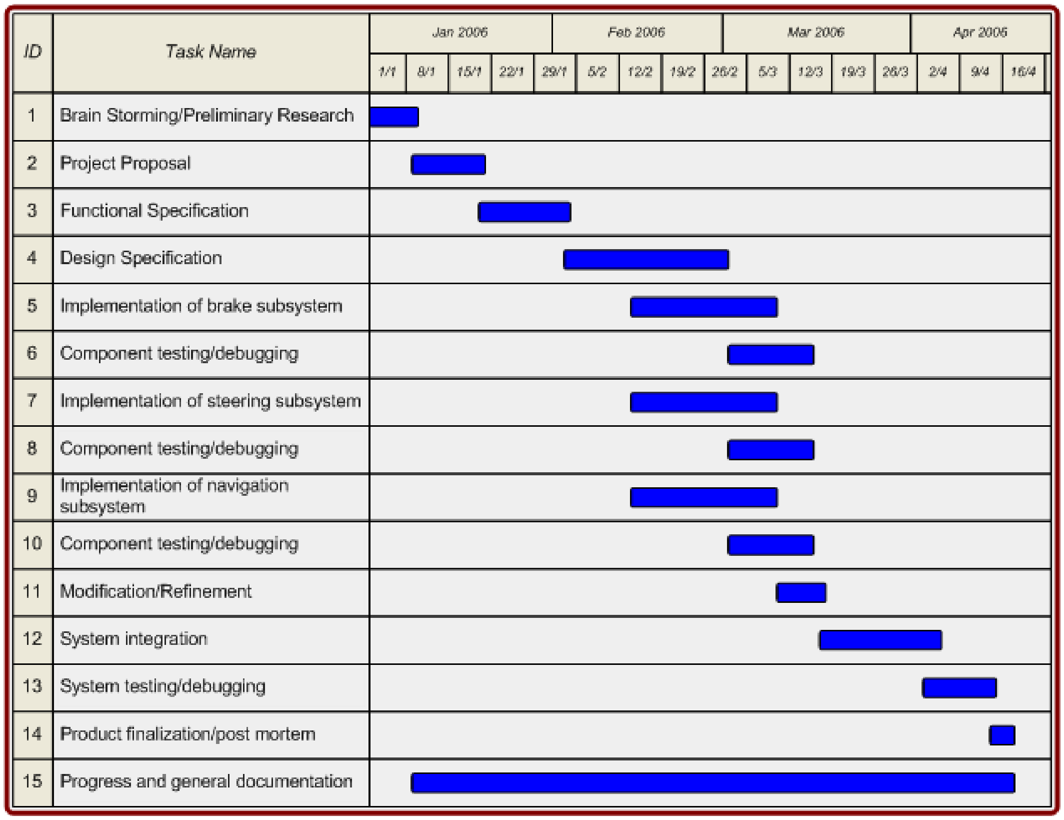

Figure 7: Proposed schedule

5 Future Plans and Recommendations

5.1 M-Brake™

The current prototype M-Brake system is able to perform some degree of smooth braking with a preset linear strength VS time curve. The accelerometer is able to detect some degree of incline, however the result is unstable. In the next stage of prototype design, more calibration is needed to yield better result of braking performance and slope detection accuracy and consistency. In the near future, our company's plan for the M-Brake system is to improve the already effective system with braking rate adjustability. The speed of brake is currently set by the factory. Our plan is to make the speed adjustable by the user. To take it further, we'll make the braking speed controllable by the brake button by pressing it harder when faster braking is desired. A non-linear braking profile will be implemented to improve the smoothness of the system. In the long term road map of the system, our company plans to change the actuator driven system into magnetic brake driven system with feedback control to provide improved smoothness and control. With feedback controlled magnetic brake, we can implement non-linear braking profile with stable transient response. The slope detector would be made to monitor slope continuously instead of discretely. A slope detection bypass button will also be added.

Another plan for the M-Brake system is to explore the potential of using it as an exercise feature by allowing the user to control an intended braking feature as a way to provide resistance for exercise purpose. This feature would be useful for rehabilitation patients.

Acceleration threshold should also be readjusted to better meet a user's needs. Overall, intensive real user testing and calibration is needed and will be carried out in the next stage. Clinical trial is critical for the success of the M-Brake system.

5.2 Nav-Pro™

The Nav-Pro can be improved by incorporating a better user interface and more intuitive directional indications. The current LED system may be confusing to elderly and a simple LCD or LED display with an arrow may serve as a better interface. For the location beacons, they could be improved with the use of RFID to lower the costs and may increase accuracy.

5.3 Sense-Steer™

Although the module successfully detects and avoids curb, sometimes it may erroneously detect a small dent as curb. To solve this problem, more calibration, data filtering or multiple IR sensors may be used to solve the problem.

6 Personal Experiences

6.1 Li Xu, CEO

I worked on the curb detection module for walker. I learned about using IR sensors, writing embedded software and interrupt handling, and circuit building including using a RC filter to filter out high-frequency noise. Specifically, I learned PIC microprocessors, and using ICD 2 development kit to develop my part. I've learned that simulating software is very important to ensure the logic of the algorithm, and for isolating problems. Many hours were spent on finding loose connections, and I learned to avoid such problems, clean bread boarding and good soldering is very important.

Working in a group of 6 is challenging. Several people were on co-op and also taking this course. Thus, the group had to meet on weekends and on evenings. In addition, everyone has different personalities, technical strength, and has different preferred working time and methods. Tolerance, consideration of others, and being flexible are qualities that are important in a group. We encountered many problems during integration, but we were able to solve them.

Overall, our group worked very well together, and even though we weren't able to complete the project within 1 semester, we completed it within reasonable amount of time. I have gained much valuable knowledge from this project experience.

6.2 Steven Dai, CTO

As the CTO of our company, I must say the experience of completing this project is both tiring and rewarding. As the CTO, I had the opportunity to oversee the entire development cycle, from the conceptualization stage to design stage to implementation and testing. This proves to be a great learning experience. I had to face many high-level design decisions. I realized the importance of preliminary study and research. Without a thorough, in depth, solid research and study, we are building castles on the sand. This pre design stage is often neglected or put as low importance. However, this stage has critical impact on the design of the system and consequently the eventual result of the project. Because of our lack of preliminary study, we wasted a lot of time trying to finalize design and we made many fatal mistakes on the design.

In terms of design, we were limited by time and financial strains. Thus we could not experiment with different designs. Testing with alternative design is definitely useful. However, the biggest problem we encountered during the implementation of the system is the electronics hardware assembly. Due to the lack of experience in the electronics hardware assembly process, our company wasted huge amount of time and energy on trying to assemble and debug the hardware. The design was tested logically in simulation with ease. However when actually putting the design down onto circuit boards, we hit walls after walls in wiring and soldering. Personally I had lots of software experience but very little hardware experience. As the CTO, this lack of experience translated to a lack of emphasis on hardware layout and wiring routing. I didn't expect the impact of a sloppy soldering or a tangled wiring would bring fatal result to the system, which we had to spend days to debug. As a result, I simply throw the wiring and soldering job to one member without double-checking and quality assure the output. In conclusion, the biggest lesson I learnt is that bad soldering is fatal, lose connection is fatal, long unsorted wiring is fatal. Those hardware problems are even tougher to debug then software. In the future development, I'll assure the hardware design is error free and the circuit board is stable before integrating software component.

In terms of team working, technically coordinate a large group is challenging. Predefined technical interface of each component module is of paramount importance. With a well-defined interface, integration tusk will be much easier. Team communication is also very important; all members should be kept updated about each module. Dedication from each member is critical to the success of the whole group, as well as the ability to work flexibly. Overall, our team's dynamic is very good and reasonably well coordinated. In the future, we'll continue our energetic team spiritual and hardworking attitude.

6.3 Duncan Chan, CFO

The experience gained from working this project can be related from the quote: why do hot-dog buns come in packages of 12, but hot-dog sausages come in packages of 8? Having been through this course, one would understand that things do not fall into pieces naturally. The best we can do is to make the best out of what we get. Take for example in the Nav-Pro module, the digital compass possessed great complication for our group due to numerous reasons. First, the device arrived later than expected. Second, our group failed to identify reasons why the device did not work after countless attempts to power it. Finally, our group did not come up with a contingency plan in the beginning to deal with unexpected problems caused by this device.

Despite all these complications, our group made a big step forward by conforming to a hard decision, which was to remove that part of the module and proceed along with the project. The consensus was that we should focus on the big picture, and not let one malfunctioning part affect the overall functioning of our product. This example illustrates how our group tried to make the best out of what we have and what we are limited to.

The need for testing has never been more important in other projects than in this course. We found that testing at each stage of the design and integration would save a huge amount of time in the future. The further we delay testing, the more ambiguity is inserted to our product, and ultimately more testing is required in order to deliver a working prototype of our product. This point is best illustrated with the testing of the shortest-path algorithm within the Nav-Pro module. The algorithm was first programmed in C, and using the ICD2 development kit, one could perform simulations for testing the functionalities of the algorithm. Because testing was taken lightly coupled with the fact that the author of the algorithm was over-confident of his ability to write error-free code, testing at this stage was very minimal. The result was that once the algorithm was programmed to the PIC, bugs began to surface. The algorithm did not work as planned, and attempts to resolve the bug was not possible without using the ICD2 simulator. Therefore, time was wasted in transferring the program between the compiler and the PIC.

Aside from the technical difficulties encountered in this project, there also exist minor personal concerns regarding group dynamics. In this group, everyone is treated equally important, which are keys from generating ideas to working on the modules. However, since each member sees himself the boss, punctuality in meetings, deadlines, and work organization were often not met on time. In hindsight, it would have been better if each group member is a sub-ordinate of another group member. This would provide the pressure needed to motivate each group member to complete the tasks assigned for this project in a timely manner.

Overall, the project was very impressive and was a very rewarding experience. Nearing the deadline of this project, the mentality for every group member was similar to that as if everyone is at war, with completion of the project as the goal of the battle. The group grew and became a close-knit group as deadline approaches. As a result, the project was also socially and mentally rewarding for each group member.

6.4 Daniel Agyar, COO

This project has taught me valuable lessons in team and project coordination, and also enlightened me on how much we, as students, have yet to learn. Working on the M-Brake module gave me significant exposure to integrating control software with mechanical components. This also brought to light how much a hands-on, design and manufacturing course within the curriculum would have benefited our team.

Our project suffered a significant delay due to some early design decisions. Realizing components we had based our design on were either too expensive or unsuitable in the grand scheme of things completely derailed our timeline. From this experience, I have come to realize that the key stumbling block was not doing enough research early in the project and considering the smallest level of detail in the design. Having a general overview of the system and what you would like to achieve is simply not enough. It is also extremely important to factor in delivery times for uncommon components as this will also skew a project's timeline (in our case, by as much as three weeks). Finally the most grief was cause when debugging our circuits. It was extremely frustrating finding out how a series of bad connections between components can completely hinder progress when everything else works correctly. We ended up completely re-soldering our vector board because we could not afford to spend any more time debugging bad connections. This decision paid and we could have spared a few days had we opted for this route earlier.

In terms of group dynamics, our group had fantastic chemistry and worked very well together on this challenging project. Apart from some minor conflict of project ideas early on, there were no real disputes between us. Every member was responsible and hard working and was very supportive of their teammates. I believe this can be attributed to the fact that most team members had worked with each other previously and were accustomed to each other's work habits and character. The last three weeks were absolutely exhausting and stressful since three members started new co-ops and another was heading abroad to begin his co-op. Due to this, time was scarce, with only late nights and weekends free for group work. However, the team endured this and no doubt, strong teamwork played a vital role in pushing towards the finish line. I will end by thanking my teammates for their dedication and I hope to have the opportunity to work with them again in the future.

6.5 Victor Tai, CMO

During this project, I have learned several aspects of project planning, research and time management. This project is the first time that I have the chance to explore wireless communications. This has given me much insight into the details of wireless communications. Although the wireless modules weren't used for actual voice communications, it has given me a practical view of the material that I learned in my courses.

One of the most frustrating parts of the project was the debugging of circuits on the board and using the wireless module. While soldering components onto a vector board should minimize the number of connection problems, bad components such as sockets and wires produced a lot of problems that took a lot of time to debug. The wireless module needed serial communications to program and use. With serial communications protocol, it was hard in the beginning to test and determine which part of the control software is at fault. At one point in the project, I found that the serial communications module on the PIC controller was not functioning properly. The controller had an erratum for this bug and this has taught me to read all documentation, including errata and bug reports, before choosing the parts to use.

Throughout the project, there have been many discussions and differences of opinion. However, this did not hinder us in any way, as our team dynamics has been good. I enjoyed working with this team and hope that we can work together again.

6.6 David Jing, Chairman of the Board

This group was the best group I had before. There was a lot of fun when I worked in this group. Not only that, but we actually finalized some really smart design, which exceeded our expectations concerning the project and actual results.

Over the whole course, I did learn the procedure of how to develop prototype from blank paper. And also, I practiced my management skills and ability for motivating our members. I worked on M-Brake module with another two members. I became familiar with how to use integrate the hardware, mount modules in walker and commutate hardware with software we developed. The weekly meetings were significant for the project in my opinion. There were so many smart designs coming from discussion, but unfortunately, we cannot apply all of them on our project due to time issues. This experience actually let me know the gap between school and real industry, and how important teamwork is in real industry.

However, there are still some problems during project implementation. As students, we lack an efficient way to restrict the behavior of our members. Therefore, we cannot predefine the testing procedure and let all of us to follow it. As a result, we had a really hard time during the system level testing and debugging. 90 percent of the time for our system level testing was spent on how to solve problems the previous tester left and this behaviour continued to the end. Personally, I am better at hardware than software. From my coop experience, I did see some hardware boards made by company broken by inexperienced people. I do predict this situation will happen, especially in PCB soldered by several members. However, I failed to restrict times for unpurposed testing.

In term of teamwork, I think our team is good team. After 5-month work, I got five more friends and found that some members in our group can be my potential partners for future.

7 Conclusion

In four and a half months, Incedonex successfully developed a Sure-Step prototype, which is the next generation walking assistant device for the elders. Some parts of the design exceeded what we expected at beginning and have huge value in potential marketing. All of us developed new sets of skills after this project and enjoy working together. We hope we can go further and help all elders with our design in the near future.

8 References

[1] HSI Motors. L/R Driver Manual Model 39105 <http://www.hsi-inc.com/39105.php>

[2] HSI Motors. 28000 Series Size 11 Linear Actuator Product Brochure <http://www.hsi-inc.com/linearactuators/hybrid/28000/28000.pdf >

[3] HSI Motors. 43000 Series Size 17 Linear Actuator Product Brochure <http://www.hsi-inc.com/linearactuators/hybrid/43000/43000.pdf>