Beyond the Horizon

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December 18, 2000

Dr. Andrew Rawicz

School of Engineering Science
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Re: ENSC 340 Process Report for StairCraft – a Stair-Climbing Mechanism

Dear Dr. Rawicz:

The attached document, Process Report discusses the development of Beyond the Horizon's StairCraft.

The Process Report discusses the evolution of the StairCraft system from its conceptual model to its current state. The future of the project is then discussed, detailing the enhancements we at Beyond the Horizon wish to pursue. The document also examines the time line and budget deviations.

Should you have any questions or concerns, please feel free to contact me via e-mail at kchengc@sfu.ca or our team at staircraft-340@sfu.ca.

Sincerely,

Kenneth Cheng
Team Manager
Beyond the Horizon

Enclosure: Process Report for StairCraft – a Stair-Climbing Mechanism

Beyond the Horizon

presents

STAIRCRAFT™

a Stair-Climbing Mechanism

Process Report

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Submitted to:
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December 18, 2000

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1 Introduction

Injured, handicapped and elderly people traveling with their wheelchairs all face a common problem – they cannot go to their desired destinations as convenient as the rest of the population. Not all buildings provide ramps, elevators, escalators, or other assistive devices that transport wheelchairs to higher or lower altitudes. In addition, lifting heavy objects up and down stairs has resulted in numerous injuries. Thus, Beyond the Horizon aims to address all these problems by creating a device that can travel along staircases smoothly, reliably and most importantly – safely.

Beyond the Horizon's StairCraft is a low cost, reliable and safe stair-climbing mechanism. The special feature that separates our system from most other stair-climbing mechanism is that StairCraft keeps the platform horizontal during the stair-climbing process. As a result, our product can be incorporated into wheelchairs, robots, or cargo-transporters.

Beyond the Horizon was formed for the ENSC340 engineering project course. Our mission was to create the climbing-up-stairs portion of the final product due to our limited time and budget. After approximately thirteen weeks of continuous hard work, we are about to finish a working prototype. This document, the process report, will explain the various aspect of the project that includes: an overview of the project, the technical implementation of solution, problems encountered, things we would do differently, things we learned, and recommendations for future work. Our engineers have also included a discussion of Beyond the Horizon's team dynamic, and individual reports from the team members outlining what they have gained from the project.

2 Overview of project

The final version of StairCraft should transports users or other goods up/down stairs. Based on user inputs and statuses of the sensors, the central processing unit analyzes the input signals and StairCraft reacts by driving its motors. Figure 1 illustrates the relationship between the users, StarCraft, and the stairs.

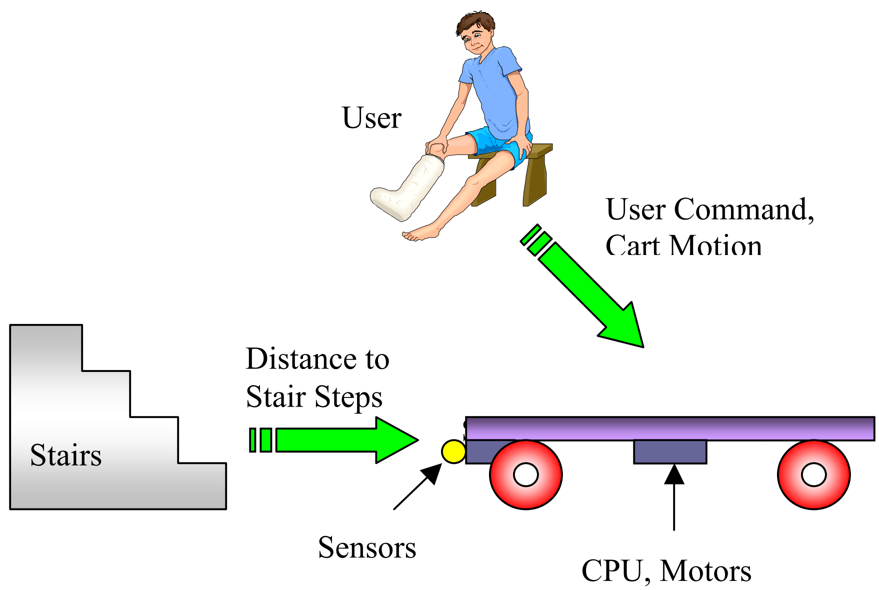

Figure 1: System Overview

However due to limited time and budget, we are planning to finish the climbing-up-stairs portion of the final product. Our primary goal is to explore the usability and reliability of our mechanism. Thus, we are going to build a smaller prototype instead of constructing the intended final version's size. Consequently, we can cut down the cost of building such system. Our prototype's design is shown below in Figure 2.

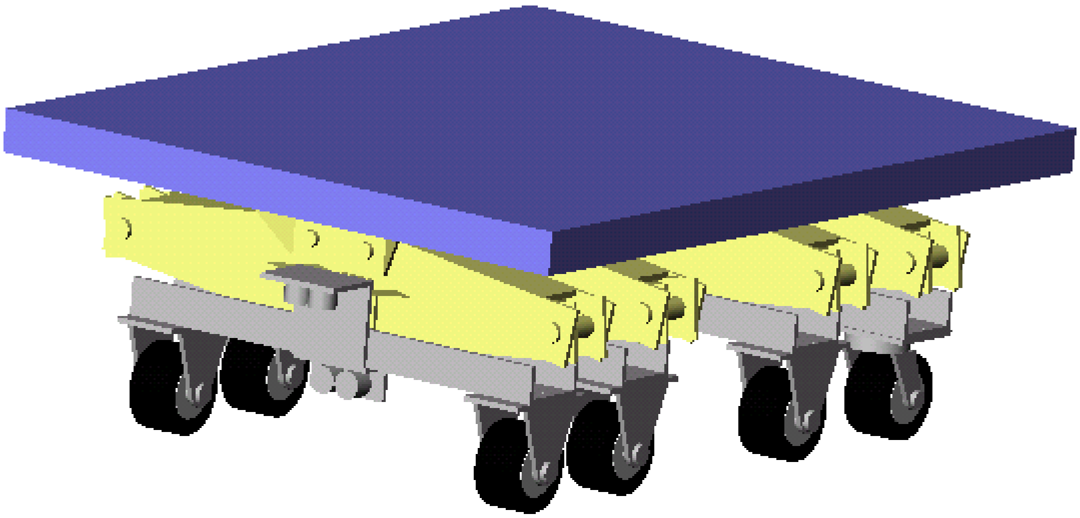

Figure 2: Mechanical Design of our prototype

The detailed technical implementation of solution is discussed in the following sections.

3 Technical implementation of solution

The prototype shown in Figure 2 is capable of climbing up stairs only. Here we are going to discuss the 3 main portions of our project – Mechanics, Electronics, and Software.

3.1 Mechanics

In this version of StairCraft prototype, we only require 3 wheel-sets that have extend/shorten ability. In addition, we need to have motors to drive the car forward.

3.1.1 Overall Structure

The following table includes the required mechanical components.

Table 1: Table of required mechanical components

Components	Number Used	Description
Rigid Casters	6	2 in diameter, 90 lb capacity, soft rubber wheel
Swivel Casters	2	2 in diameter, 90 lb capacity, soft rubber wheel rotating in 360°
Jacks	4	1320 lb capacity, height range from 3 ½ to 12 ¾ in
Platform	1	20 in by 15 in acrylic plastic
Plates	N/A	¾ in by ¾ in aluminum plate, thickness 1/8 in
Motors	5	Variable speeds from 325 to 650 rpm

As shown in Figure 2, the prototype we built only has climbing-up capability and lacks any steering system. This version of StairCraft is basically a platform with 4 sets of wheels underneath it.

3.1.2 Lifting mechanism

We have considered several existing lifting mechanisms such as hydraulic actuators and z-shaped car jacks that may be applicable to our project. Because of the geometry and cost-effective reasons, we have decided to choose and slightly modify the scissors car jacks as the actuators of our device. The existing symmetrical scissors jacks are capable of lifting a load of about 1320 lbs to 1 ft high. Therefore, the jacks suit our testing purpose of the prototype. Furthermore, the scaled down factor from the real case with the use of these jacks is approximately 1:2 because the height requirement is also halved. As the sizes of the casters decrease, the maximum load capacity of each caster reduces too. The diminished operative load reduced the motor requirements accordingly since the motors do not need to produce as high torque as before in order to drive the heavier load. Therefore, the expenses of this project were greatly reduced and we could locate motors that meet the scaled down requirements for our prototype testing.

In terms of driving motor, we have to use some high torque motor that could produce 1~2Nm. This requirement is obtained by a simple experiment with the car jack with about 50lb of weight on top. We used the lever arm system to measure the maximum require torque to lift the StairCraft up and down. There were two options when we chose the driving motor. The first option was to use a high quality high torque servomotor and the second option was to use some normal heavy-duty motor with a step down gearbox. We chose the second option base on the cost factor because the cheapest servomotor that fits out purpose cost around $200US each. Therefore, we modified some rechargeable hand drills and adapt them to our StairCraft. We could further cut down our project cost since the batteries and the gearbox cases were included with the hand drill package.

3.1.3 Forward mechanism

The forward mechanism is also driven by the hand drill motors that we have mounted on the jack for up/down motion. We used pulleys and bearings to connect the motor and the caster shaft. This combination requires less precise measurement and mounting technique since the major requirements for the belt are tension and alignment.

3.2 Electronics

There are 2 sets of sensors on each wheel-set: a top set and a bottom set (those cylinders shown in Figure 2). We want to minimize cost and avoid any physical contact with the staircase so we can reduce wearing if we were to use contact switches. Thus, we decided to use ultrasonic sensor to detect the presence of steps ahead of our StairCraft. The following is a simple block diagram showing our sensory circuit.

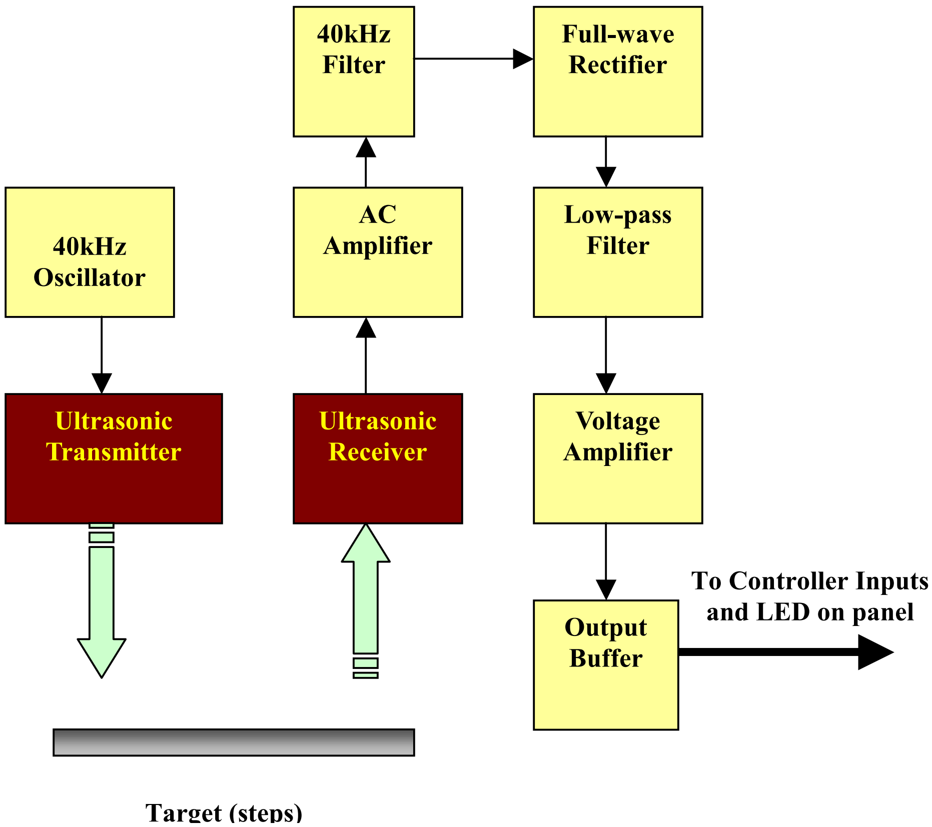

Figure 3: Block Diagram for the Sensory Circuit

Overall, the sensor should give a DC voltage of 5V when an obstacle is present about 4-5 inches away, and 0V when no object is present. The conditioned sensor input will be fed to the microcontroller circuit and the LED output on the user panel. There will be one sensor input conditioning circuit for each set of sensors.

The sensory circuit design was completed by mid-November. We have made a few simplifications and enhancements to our original proposed design. We have removed the low pass filter since it slows down the sensor signal response quite a bit. We have added a voltage comparator and a diode to make the output signal cleaner. We have included a variable resistor at the voltage supply of the oscillator (which is used to drive the ultrasonic transmitter). The user can tune the variable resistor to control the strength of the transmitted ultrasonic wave, and therefore control the sensing range.

After we have sourced all the electronic components required, we started soldering and assembling the sensory circuit boards. We decided to fit the whole sensory circuit into one 3" by 2" general-purpose PCB due to restricted mounting space on StairCraft. We used sockets for all IC's so that if the chips are burned, they can be replaced easily. We also used coloured wires for all the power and I/O cables. The cables were arranged in groups so that they can be interfaced more easily. Since we needed to fit so many electronic components onto such a small PCB, we have spent tremendous time and efforts on soldering and connecting the wires. By December 10, 2000, I have finished soldering all 8 sensor boards, and by December 11, we have finished testing all these sensor boards and they all worked as required.

SoftwareFigure 4 illustrates the locations of all sensors and motors in StairCraft.

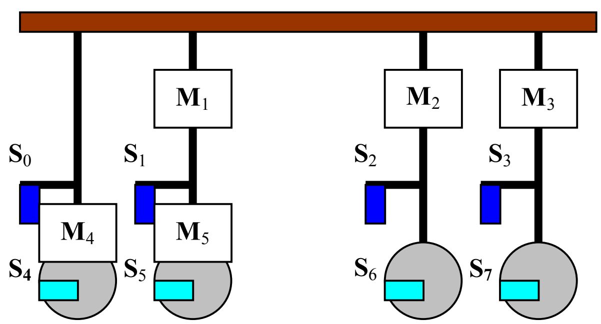

Figure 4: Sensor and Motor Locations in StairCraft

We have decided to use microcontroller to control the climbing sequence of StairCraft over the micro-controller. Sensors S_0, S_1, S_2, S_3 are mounted on legs 1, 2, 3, and 4 respectively. Sensors S_4, S_5, S_6, S_7, on the other hands, are mounted on wheels 1, 2, 3, and 4 respectively (as close to ground as possible). Motors M_1, M_2, M_3 will be mounted on legs 2, 3, and 4 to extend and shorten the legs respectively. Motors M_4 and M_5 will be mounted on leg 1 and 2 to drive the StairCraft forward. The control logic of the climbing sequence is as follows:

1) If our microcontroller senses the S_0's rising edge, M_1, M_2, and M_3 drives to extend the 2nd, 3rd, and 4th legs. They will continue to extend until our microcontroller senses S_4's falling edge (the first wheel has cleared the step). The StairCraft will then move forward until S_0, S_1, S_2 or S_3 senses again.

2) If our microcontroller senses S_1's (or S_2 or S_3) rising edge, M_1 (or M_2 or M_3) drives to shorten the 2^{nd} (or 3^{rd} or 4^{th}) leg until our microcontroller senses S_5's (or S_6 or S_7) falling edge. The StairCraft will then move forward until one of S_0, S_1, S_2 or S_3 senses again.

3) If multiple sensors sense a step is in front of it (as long as not S_0), the respective legs will shortens as described in (2) above. However, if S_0 and one of S_2 or S_3 sense a step, we first extend leg 2, 3 and 4 until leg 1 has cleared the step (as in (1)) before leg 3 or 4 shortens to clear its own obstacle (2).

4) If S_0 and S_1 (or S_2 and S_3) give rising edge at the same time, this is an error state where the steps is too shallow and thus StairCraft cannot climb this type of stair. With this prototype, our StairCraft will just stop. However, in future, our StairCraft will climb back down stairs.

The microcontroller has to take inputs from ultrasonic sensors and potentiometers to determine which motor to turn on and off and at what speed to drive the motor. The control logic is implemented by programming the microcontroller using assembly code.

There are 31 instructions available with the microcontroller PIC16F877 20/P we chose to use. Since our control logic is pretty much straight forward, we only needed to use less than half of the instructions.

The control process can be divided into three main stages. The first stage is defining input and output pins and taking inputs. We have two user interface inputs, eight ultrasonic inputs, and three potentiometer inputs. The ultrasonic inputs are taken from normal digital inputs because we only need to know if the inputs are on or off. On the other hand, the potentiometer are taken with the input pins that can do analog to digital conversion, making use of the A/D converter provided by our microcontroller. A one-bit digital high or low is not enough because we want to keep track of the voltage variation of the potentiometer outputs.

The second stage is doing control logic. Based on the inputs, the code has to decide which motor to turn on at what time. Then it has to determine which motor to turn off at what time. This is the most complex part of the code. Moreover, our jacks do not rise linearly. Therefore, we have to turn the different motors at different speed in order to keep the platform flat. We need to use the feedback from the potentiometers to adjust the speed of the motors according to which stage the jack is in by outputting pulse width modulation to a motor-controller. There are two pulse width modulation outputs available on our microcontroller.

Finally, the microcontroller output control signals to the motor controllers. The microcontroller would set or clear its digital output pins according to the decisions made. In case of the pulse width modulation outputs, the code would tell the microcontroller how long the duty cycles should be and output a square wave.

4 Problems encountered

4.1 Technical issues

4.1.1 Mechanical

4.1.1.1 Modification of the car jack

The car jack that we use is 6lb each. With 4 of them, our StairCraft weights over 25lbs already. As a result, we need more power to lift up the StairCraft so we need to cut down weight as much as possible.

4.1.1.2 Modification of hand drill

The hardest part of modifying a hand drill is to break the drill apart. We need lots of manpower and time to break down the drill to the size and shape that we want. We need to cut out the drill head in order to save weight and space. We also need to unscrew some very tight screws since the manufacturer applied some screw glues inside. For those screw that we cannot unscrew, we used a drill to break the whole screw in two parts.

4.1.1.3 Driving unit design

There were two major problems when we constructed the driving unit. The first one was to embed a pulley in the middle of the shaft. We had to drill some small holes in the middle of a 3/16" aluminum rod as a slot to lock the freely rotating pulley with the caster shaft. Since the holes were too small, we finally broke 4 drill bits after drilling 4 rods. The second problem was the connection between the hand drill unit and the pulley on the shaft. In order to do so, we have to use belt with enough tension. We bought those pulleys and belts in hobby shop; however, the belts are either too long or too short. As a result, we had to design the mounting distance between the motor and the shaft very careful to achieve the best tension on the belt. We also used cable tires to further reinforce the hand drill casing to provide more belt tension.

4.1.2 Electrical

The following are the technical problems we have encountered in designing and assembling the sensor boards. Our solutions to each of the problems are also included.

- When the sensor circuit is first powered up, it needs 20~30 seconds for its capacitors to fully discharge. The solution is to implement the AC amplifier using the common-collector common-emitter cascade configuration (2 transistors) instead of op-amps.

- The output signal is not stable. The solution is to increase the capacitance value used in the peak detector (full-wave rectifier) circuit.

- There is certain delay time associated with the turning on/off of the output signal. The solution is to remove the low pass filter stage (where there is a big capacitor) and to make the capacitance in the peak detector stage just big enough to get a stable output signal.

- The output goes below zero when the sensor is not sensing anything. The solution is to put a diode at the output buffer stage.

- The output contains signals with intermediate voltage values (between 0 and 5). The solution is to use a voltage comparator (implemented using an op-amp). Unless the signal has a voltage higher than the set threshold (3.5V), the output voltage should always stay low.

- The input oscillator frequency is wrong. The problem turns out to be the capacitors that are used to tune the operating frequency of the oscillator. Initially we used ceramic type of capacitors but their capacitance changed as we applied voltage. Thus, we replaced these capacitors with the film type and the capacitance values became more stable.

4.1.3 Software

The biggest problem in choosing the microcontroller is to find the microcontroller with enough I/O ports to satisfy our needs. We need a relatively large number of inputs from the user interface, sensor and potentiometers and so more outputs to control the motors via motor controllers. We do not want to find out that we do not have enough number of I/O's several days before the demo.

In terms of writing code, the biggest problem is that I have to understand how the microcontroller is structured before I could write any code because I've never worked with a PIC microcontroller before. Although the instructions are pretty clear and easy to learn and there are some sample codes available for me to refer to, I still needed to spend a couple of hours flipping through the thick datasheet in order to figure out what a couple of lines in the sample code are actually doing and how can I use them. In short, I had to spend lots of time studying the datasheet before I could write some useful code.

4.2 Financial issues

4.2.1 Budget

Table 2 provides a comparison between our estimated and actual (up to December 18, 2000) budget of our project.

Table 2: StairCraft Budget

Required Materials	Estimated Costs (CDN $)	Actual Costs (CDN $)
Bearings / PVC Tubes (Self Made)	40	*Did not use*
Ultrasonic Sensors	120	82.08
DC Motors (Electric Hand Drill Kit)	500	170.83
Springs / Elastic Bands	20	*Did not use*
Casters (Wheels)	100	32.04
Twin Lead Screws (Self Made)	100	*Did not use*
Miscellaneous Mechanical Parts	200	274.65
Microprocessor	10	45.71
User Interface	80	73.31
Miscellaneous Electronic Parts	50	80.34
Battery Supply	100	*Part of the Drill Kit*
Domain name (www.staircraft.org) Cost	20	Sponsored
Staircase Model for Demo (lumber)	*New*	20.62
Total Estimation	**1340**	*N /A*
15% Mark Up	200	*N /A*
Grand Total of our Budget	**1540**	**779.58**

As of December 18, 2000, our group had spent a total of $779.58. Comparing our total actual costs with our estimated costs of $1540, we have saved $760.42. The main reason was because we decided to build a smaller version of StairCraft. Hence, some of the expenses were decreased. Also, items such as bearings, springs and the twin lead screws were not used in our final design because they were either too expensive or we came up with better alternative designs. On the other hand, we overestimated the costs for our dc motors and casters. The main reason behind the overestimation was our inexperience about motors. We could not grasp the exact price for the types of motors that we wanted. Hence, we utilized our motor research results from the Internet and came up with an estimate. Unfortunately, those prices were too expensive. In the end, we asked different people for their ideas and they helped us decide on which motors to use.

Eventually, we chose the dc motors used in the electric hand drill kits because they can provide the torque we need. Furthermore, we reused the batteries that came with the drill kits as our power supply for our motors plus our circuit boards. Hence, we did not have to spend more money in buying batteries. As for the casters, the overestimation as mentioned above was due to our change in project plans of building a smaller prototype. Finally, we underestimated the costs for the miscellaneous mechanical and electronic parts. The miscellaneous mechanical parts cost a lot because we used a number of expensive pulleys and gear belts made for model cars sold in hobby shops. The remaining money was used to buy aluminum frames and screws. Similarly, the underestimation of the expense for the miscellaneous electronic parts was due to a lack of supplies in the laboratory. We were able to take advantage of items such as resistors and wires in the lab. Hence aside from buying the printed circuit boards, potentiometers, diodes, sockets, and opamps, we had to buy capacitors and LED's as well. The cost of the microcontrollers was underestimated as well because we did not know the price and we have burned one already. Therefore, we had to buy a second microcontroller plus a third piece in case our second one burns out.

4.2.2 Funding

In the end, we were successful at acquiring funding from the EUSS and the Wighton Fund. We tried to look for several other places such as APEGBC, various associations dealing with physically disabled people, and various levels of government for financial assistance. We had time at applying only for some of the places. Either they rejected our proposal because our project did not fit their funding requirements or we did not have time to type a proper funding proposal for application. Fortunately, Steve Whitmore and Jason Rothe gave us valuable comments in creating a proper funding proposal.

4.3 Scheduling issues

Due to the busy life of being a SFU Engineering student, allocating time to do project is often a big problem. Every week each of us had to hand in various assignments and labs, study midterms or final exams and take care of other personal businesses. As a result, our project milestones, as outlined in the project proposal, were not always met on time. We had handed in our design specification later than expected because there were too many difficult technical decisions. In addition, because of our lack of experience in assembling mechanical devices, it took us extra time to build our prototype. Since we do not have a physical system ready, we cannot finish our testing and integration. The research portion of the project extended over the length of the term because we were continuously searching for ways to improve the project. The process report was finished late because we needed to have a more concrete idea of our project before writing this document. Shown in Figure 5 is a Gantt chart displaying the original project milestones and timeline along with extended time factors and additional milestones we felt better reflected the progress of the project throughout the term. Note that the original times to completion are shown as blue bars while the extended times are shown as red bars.

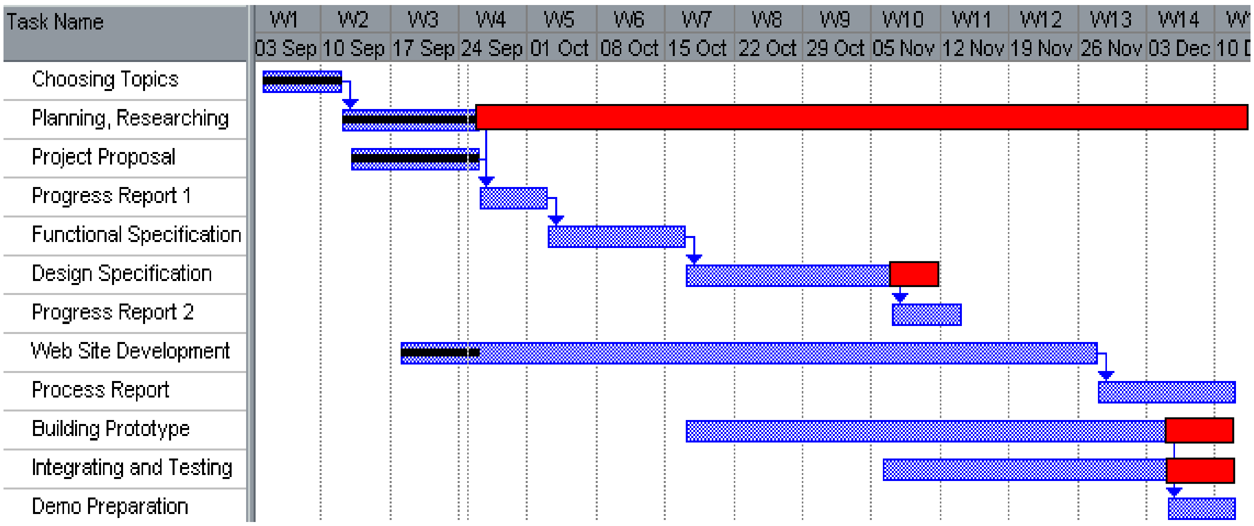

Figure 5: Revised Gantt Chart

4.4 Group dynamics issues

As our group worked together as a team most of the time, the workload was distributed quite evenly and fairly. We were quite happy with our work arrangement through working together as a team. If we have to do another project again, we would have split the work up the pretty much the same way again. Basically we have Kenneth as the Team Manager to organize and coordinate the 3 subgroups (Mechanical, Electrical and Software). He communicated with individual member regarding their progress and dealt with their concerns. In order to combine our talent so that we can work together efficiently, we had assigned everybody with a role that they felt most comfortable in so that they could maximize their contribution to this challenging project. Gordon and Andy mainly concerned with the Mechanical aspect of our StairCraft project and they worked well with each other. Wayne and Michael, on the other hand, worked really hard together on the sensors and the corresponding circuits. In addition, Michael was also responsible on applying for financial assistance and other funding sources. Jeff, with his programming experiences, was assigned to write the assembly code for our microcontroller. With our frequent team meetings and weekly status emails system, no one in our team had felt left out and everybody shared the same vision.

5 What you would do differently (i.e., solutions)

5.1 Mechanics

The main purpose of this project is to show that the StairCraft climbing sequence and logic work the way we expected. The mechanical solution need not be the best looking and space efficient. Also, cost is another important factor without mass production of mechanical parts. Most of the parts in this project have been heavily custom-modified. We have modified some car jacks and mounted some hand drills on it. We built the whole StairCraft platform and we also constructed the forward/backward mechanism using pulley-and-belt system with the hand drills. However, the parts that we used in this project might not be the best combination based on the time given and budget constrain. The following list can be considered as possible upgrades or improvement if the StairCraft were to be mass-produced.

- The lifting mechanism is definitely not the best solution for lifting a person or even heavy cargo. There is a design problem with the car jack because there is only one support pivot point in the middle. Which means if we apply force on either side of the jack, the jack might flip over. If we were to lift human using StairCraft, the lifting mechanism cannot guarantee the stability of the StairCraft if the center of mass were not in the middle of the cart. In order to improve the lifting design, we should consider those mechanisms with at least two support points on both sides to increase stability. We have consider using those X cross mechanisms in the design stage of the StairCraft, but base on the time and budget we have and limited access to specialized machinery, we decided to go for a faster and cheaper lifting method.

- The lifting motors that we use in the StairCraft are from some rechargeable hand drills. The problem of using those low-end motor is the noise and lost in efficient. When the drill is being turned on, the noise is very loud compare to those high cost servomotor. We realize that the noise is actually coming from the gearbox. Therefore, we think that in the production version of the StairCraft, we should use those high torque servomotors without gearbox. Also, hydraulic is another good option to lift up the jack. The major problem with hydraulic lift is the slow response time of the lifting motion.

5.2 Electronics

In this project, we have found solutions to all of the technical problems encountered and we have successfully finished building all of the sensor boards on time. Our success here is largely due to our familiarity with electronic circuit design (covered in lots of courses), good time management (start as early as we could), good resources (Patrick and Lucky), and good communication with other teams within our group. If we are to do any project again, we will do exactly the same thing as we did in this project. However, we did feel a bit stressed with the heavy course load and we will definitely take less courses if we are doing a project course concurrently.

5.3 Software

I would get a C compiler or a program called PICBasic, which would make the coding and debugging much simpler and efficient. In addition, there are many sample codes available on the Internet, but almost all of them are in PICBasic format. Therefore, buying a PICBasic compiler will not only make coding and debugging much simpler and efficient, it will shorten the time we need to spend struggling with the code by a lot because we can make use of the proven and running sample codes available on the net.

5.4 Team Organization

If we can do this project again, we will try to take fewer courses concurrently with Ensc340 so that we can have more time on this project. We would also like to have one more member specialized in software writing to assist Jeff with coding. Beside those, we would organize our team pretty much the same way we did because we all felt comfortable working in the current position.

6 What we have learned

6.1 Kenneth Cheng (Team Manager)

I feel that this ENSC340 course was an extremely valuable experience, as I was able to develop several engineering skills I already had and learn new ones. Being the team's manger, I have to work with all of the sub-groups and thus, working on this project taught me about analog and mechanical design. In addition, I will learn more on microcontroller programming in the soon future because after I finish this process report, I will help Jeff on programming the microcontroller. Through this project, I have also improved my soldering skill dramatically. More importantly, I have learned the importance of imagination and observation in problem solving.

In addition to engineering skills, I have also learned the process of developing something out of nothing. The longer time we spent on preparation, the better quality our final product becomes. Communication skill and teamwork are vital to the success of any engineering project because it is impossible to finish a project in this scale by 1 or 2 people. As a result, we really need talent from different fields so that each of us can contribute in a different way. However, with larger team size, we need better coordination between each sub-group so nobody will be left out. Distributing work equally is also very important to the success of the project. Last but not least is that I learned we should have started working earlier in the semester so that we can avoid spending all these time after our final exams to finish our project. Anyway, I really enjoyed working with the rest of the team and would like to work with them again in future.

6.2 Michael Tam (VP Finance)

First, I learned how to create a proper funding proposal. Investors not only want to look at the general picture of the project plus they want to find out what they can gain in return for their investments. Hence, it is very hard to fit all the appropriate information into 1 to 2 pages. With the help from Steve and Jason Rothe, I learned how to write a suitable funding proposal.

The second thing I learned was how a ultrasonic sensor worked. In particular, the conditioning circuit that the signal travels through from the receiver to the microcontroller. During the process, I was also successful at improving on my soldering skills. We have 8 sensors therefore we had to solder 8 sensor circuit boards.

The last thing I learned was where we can buy specific items such as our ultrasonic sensors, the bearings, odd sized screws, casters, and old motors. Originally, we did not know how expensive the bearings cost. As a result, we planned on using that in our first design. Fortunately, we discovered the cost problem early and changed our design.

Ensc 340 is a really tough course especially when we had to take it along with other hard courses. However, I benefited a lot from this course. Also, I gained lots of valuable skills plus experience that will be helpful for me in my future engineering career.

6.3 Andy Ma (VP Engineering)

Throughout this semester I have contributed my creativity, knowledge, and skills to mostly the mechanical design, hardware assembling and also many other parts of the project. I have learned and even further realized that one really has to be interested in a project or a subject in order to spend his/her time and devote him/herself to the subject. Especially like a project of this size, gradual and accumulative development is very important. I have also learned and acquired the skills to thinking, designing and engineering a project during my leisure time, eating time, and the time lying on my bed before falling to sleep, as this is how sometimes ideas suddenly come into mind during a day, such as the ideas of the design of a wheelchair able to walk stairs, the use of existing car jacks to simulate the elevation mechanism, the resource of the cheap (currently still on sale at Home Depot) and efficient power hand drill motors to drive the jacks and the cart, etc. Engineering is all about creativity. On the other hand, sometimes the materials required to implement a proposed design or a particular solution might be difficult to resource.

Some other specific things I have learned including the further mastering of a CAD program (i.e. SolidWorks) to generate the layout of the device with designed dimensions and put into simulation of the problem before manufacturing. Also, I have obtained more experiences in some manufacturing skills for the metal and wood works. As Gordon and I assisted each other throughout the manufacturing process, we customized many parts of our device such as modifying the secure hand drills that should have been designed as quite unbreakable (i.e. not to be opened by customers as stated in the manual), and turning the drills into our own nicely working specialized gearboxes. At last but not least, I enjoy working with all the members, and if I would start this project again, I would also contribute to the project the same way, working with Gordon for the mechanics of the device because it was so interesting to break the unbreakable, testing out our ideas, hunting around the machine shop, and creating a drivable cart from zero, while slightly contributed to some soldering and testing of the circuit boards, debugging assembly codes learning the configurations of the PIC microcontroller, and overall the integration of all the components in order to assemble the device as a working unit.

6.4 Gordon Yip (Chief Mechanical Engineer)

As the chief of mechanical engineer, I am responsible for the hardware team management and the final design of the StairCraft. This is a valuable course for me in my engineering career. My duty is not only limited to electronic and processing unit; I can extend my knowledge in hardware and mechanical design. The problem solving skills is even more demanding in mechanical design because we always have many different ways to design the solution for a single problem. We have to choose the best option that benefits the project.

Although I have some mechanical working experiences before, I still learn some new technique in designing the mechanical solution of the StairCraft. I learned that the design has to be really creative. We can just modify anything around and apply on the StairCraft if we are creative. One good example is that we used the car jack and hand drill combination to cut down cost and shorten the production time. Sometimes, existing solutions might work better than the custom solution because the existing solution should be built to work efficiently.

6.5 Wayne Chen (Chief Electronic Engineer)

Through this project, and as the Chief Electronic Engineer, I have the chance to apply what I have learned from all my electrical and electronic engineering courses to real-world situations. I have gained familiarity with the operations of ultrasonic sensors, the principles of “block by block” circuit design method, the implementations of signal conditioning circuits, and circuit board testing and trouble-shooting. I have also improved some of my practical engineering skills such as soldering, laying out circuit board, wiring, electronic component purchasing, and operating the basic lab bench testing instruments (scopes, DMM, duel power supplies, function generator).

As for the non-engineering related aspects, I have learned the importance of time management and group dynamics, and understood that cooperation and communication is the key to success. I have learned and experienced the entire cycle of the project development process. I have also gained exposures to technical documentations that are required during the project development.

It has been a pleasure working with my team members. Everybody is willing to help each other out and sacrifice time and health to complete the project in time. In conclusion, this project course is valuable not only because of the practical experiences I have acquired, but also because of all the memorable moment with my team members that has made my life in engineering brighter.

6.6 Jeff Hsu (Chief Software Engineer)

The first and the most important skill I learned is the skill to read and look for useful information in a datasheet about three hundred pages thick. Since I had to understand the structure of the microcontroller before I could write any useful code, I flip through the datasheet countless times. Now I know what section I need to go to find the information I need quickly.

The second thing I learned is how to connect the hardware around the microcontroller and test them. In the previous courses I have taken, all the boards are connected, tested and ready to run. In the process of developing our StairCraft, I had to connect the circuit from scratch and test the microcontroller. By doing so, I really gained a more in depth understanding of how microcontrollers work and how we can apply them to real world applications.

The last thing I learned is that we really were far behind schedule when we started the project!

7 Conclusions/Recommendations/Future work

In future, if we have more time and budget, we would like to build the final version of StairCraft, as discuss in the project proposal. The final version of StairCraft can lift heavy objects up and down stairs safely and smoothly. Such a device can be very useful in assisting handicaps on a wheelchair to move up and down the stairs when situations apply. Also, with our device installed on transporters, heavy cargo lifting in offices, warehouses, and household can be accomplished automatically. Thus, the chances of injuries for people can be reduced.

The StairCraft can move forward, backward, turn left, and turn right electronically with the control buttons or joystick on the control pad. However, the user has to leave StairCraft to climb the stairs on its own for safety reason. If the StairCraft senses the stair is too dangerous to climb (for example: slanted, shallow or narrow steps), it will not continue and backup to the starting location.

Currently we are only focusing on the climbing-up portion of the final design. Given more money and time, we would like to finish the rest of the project so that physically challenged people can be benefited.

