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April 20, 2011

Dr. Andrew Rawicz
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Re: ENSC 440 Post-Mortem Report: Auto Secure Binding - An Automated Snowboard Binding System by JAC Innovations Ltd.

Dear Dr. Rawicz,

Please find enclosed the post-mortem report for the Auto-Secure Bindings (ASB) from JAC Innovations. The prototype version of the ASB has been completed in its design and implementation stages. The ASB advances snowboarding binding technology by completely automating snowboard binding process. The ASB is the first product of its kind to enter the snowboarding market.

The post-mortem report documents the current state of our system, deviations from the original design, and future aspirations for the ASB. The system will be examined in a retrospective viewpoint. We hope that this document reveals the stages of development of the ASB. Team dynamics and individual reflections are documented as well.

JAC Innovations consists of five motivated and knowledgeable fifth-year engineering students: Clara Luo, Andrew Ng, Jackie Ng, Jeffrey Sun, and Jacky Wong. These five individuals bring their experience in software engineering, hardware fabrication, and telecommunications to the team.

If you have any inquiries or comments regarding our project, please feel free to contact our team via e-mail at jac-ensc440@sfu.ca. Alternatively, you may contact me directly by e-mail at chiw@sfu.ca or by telephone at 604-751-5556.

Sincerely,

Jacky Wong
Chief Executive Officer
JAC Innovations Ltd.

Enclosed: *Post-Mortem Report for Auto-Secure Bindings - An Automated Snowboard Binding System*

JAC INNOVATIONS

Post Mortem

for an automated snowboard binding securing system

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Submitted to: Dr. Andrew Rawicz
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Table of Contents

List of Figures and Tables ii
List of Tables iii
Glossary iv
1.0 Introduction 1
2.0 Current State of the Device 2
  2.1 Overall System 2
  2.2 Remote Control Unit 2
  2.3 Binding Unit 5
3.0 Deviations from Initial Plans 8
  3.1 Overall System 8
  3.2 Locking Mechanism 8
  3.3 Binding Plate Design 8
4.0 Future Work 9
  4.1 Overall System 9
  4.2 Binding Unit 9
  4.3 Controller Unit 10
5.0 Budget and Time Constraints 11
  5.1 Budget 11
  5.2 Time Constraints 12
6.0 Team Dynamics and Individual Reflections 13
  6.1 Jacky Wong – CEO 14
  6.2 Jeffrey Sun – CFO 15
  6.3 Clara Luo – COO 16
  6.4 Andrew Ng – CTO 17
  6.5 Jackie Ng – CMO 18
7.0 Conclusion 19

List of Figures and Tables

Figure 1 – ASB - Auto Secure Bindings 1
Figure 2 – System Overview of the ASB 2
Figure 3 – Remote Control Unit 3
Figure 4 – Flowchart of Remote Operation 4
Figure 5 – ASB Binding Unit 5
Figure 6 – Flowchart of Binding Operation 6
Figure 7 – Gantt Chart 12
Figure 8 – ASB Binding Unit with Boot 19

List of Tables

Table 1 – Projected Cost vs. Actual Cost 11

Glossary

ASB	Auto Secure Bindings
CEO	Chief Executive Officer
CFO	Chief Financial Officer
CMO	Chief Marketing Officer
COO	Chief Operating Officer
CTO	Chief Technology Officer
DC	Direct Current
ENSC	Engineering Science
LED	Light Emitting Diode
MCU	Microcontroller
MIG	Metal Inert Gas
RF	Radio Frequency
SFU	Simon Fraser University
V	Voltage

1.0 Introduction

The Auto Secure Bindings (ASB) is a system which contains a wireless controller and a pair of motorized bindings to be mounted on a snowboard. Signals will be transmitted by the wireless control unit via RF communication so that the binding unit will secure or release upon receiving the command. The goal of this concept is to create a comfortable and convenient way for snowboarders to release and lock their bindings. This aids in maximizing their time on snowboarding rather than fumbling with their bindings. Members of JAC innovations have been working closely on developing this fully automated binding system for the past 4 months. This document will provide the most current state and the deviation in design of ASB prototype, as well as the issues encountered along the development process. Possible future developments for the ASB will also be discussed.

Figure 1 – ASB - Auto Secure Bindings

2.0 Current State of the Device

2.1 Overall System

The ASB is an automatic snowboard system. It automates the snowboard binding process with minimal physical human actuation. There are two units which come with the ASB system: the remote control unit and the binding unit. These two units work in conjunction with the user to facilitate the ASB snowboard binding system with ease.

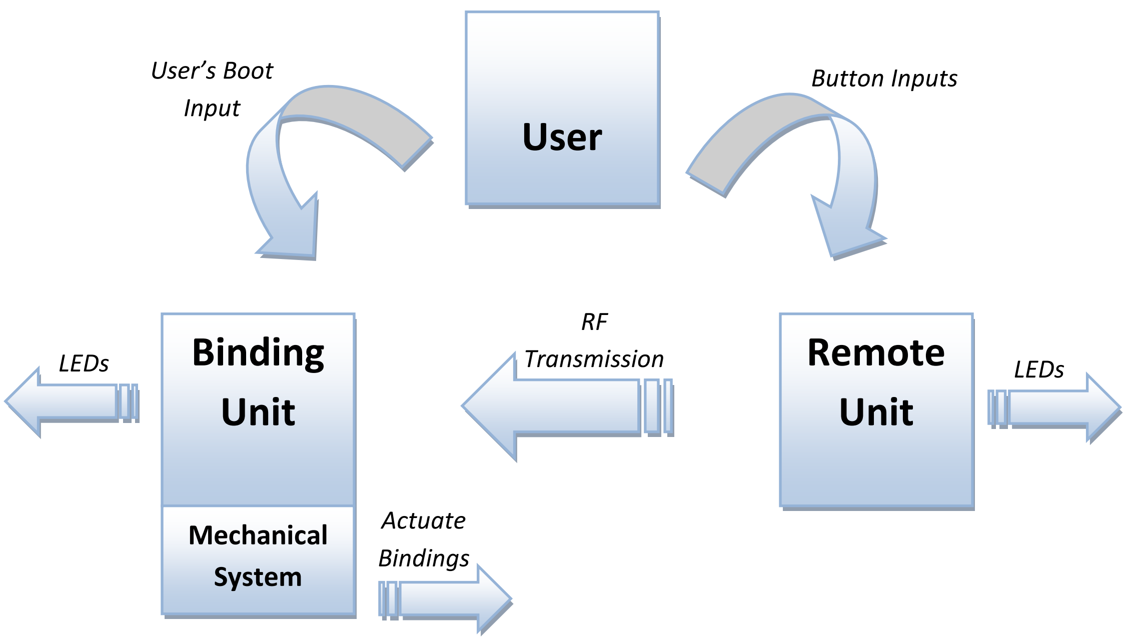

Figure 2 – System Overview of the ASB

2.2 Remote Control Unit

The remote control unit is a simple handheld device with 5 buttons and LEDs indicators. The components for the remote are an Arduino Duemilanove development board with an ATMega328 MCU, a 2.4GHz XBee RF transceiver, 2 LEDs, and 5 momentary switches. The remote controller is powered by a single 9V battery.

On the left side of the controller, there is a single momentary switch. This is the switch which closes the circuit to the battery. To turn on this unit, this button must be pressed and held during the operation of the remote. On the right side on the remote, there are 4 buttons which are used to send commands to the binding unit. From the top down, the commands are as follows: release left binding, release right binding, release both bindings, and tighten bindings.

Figure 3 – Remote Control Unit

By utilizing the digital pins on the Arduino Duemilanove, a button-array circuit was constructed to detect the 4 different button presses. This consisted of connecting one terminal of a switch to the 5V source on the Arduino and on the other terminal, in parallel, a wire connected to a digital pin on the Arduino and a pull-down resistor to ground. The pull-down resistor of 10kΩ was used to ensure that the digital pin was detecting a low when the switch was open, as the Arduino pins were configured to be active high.

The XBee transceiver was conveniently powered by a 3.3V port provided by the Arduino. By sending serial messages from the transmit pin of the Arduino to the data in pin of the XBee, we were able to achieve wireless communcation.

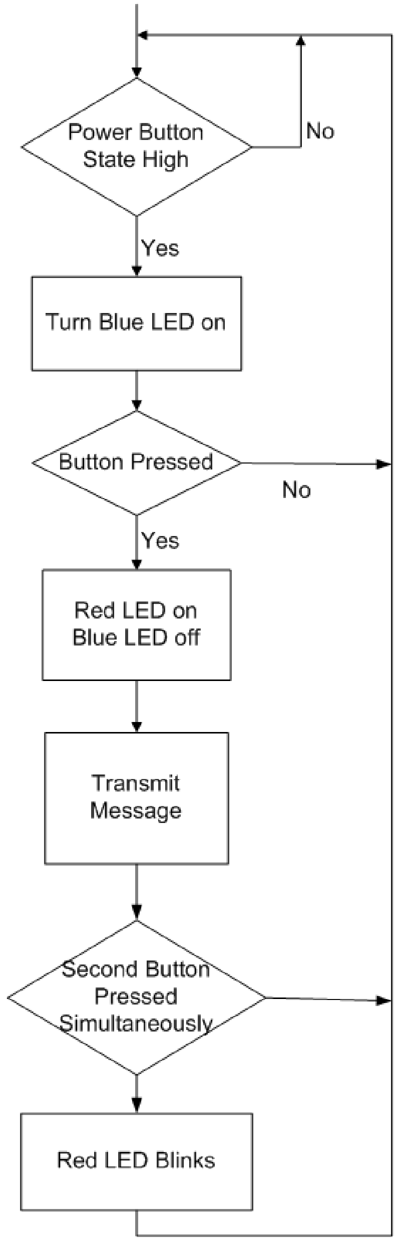

Figure 4 – Flowchart of Remote Operation

When the power switch is held on, a blue LED illuminates indicating that the remote is now turned on. By closing the battery switch, the Arduino receives power and the code executes. The code was written in the Processing language which is very much like C/C++ however with much less standard library instructions. The code was structured to poll for button presses and distinguish which button was pressed and send the respective message by the means of switch statements. If a button is pressed, the blue LED toggles to the red LED as visual stimuli to tell the user that a button has been pressed. If multiple buttons are held down, a flag in the code will make the LED flash red signifying an invalid operation.

2.3 Binding Unit

The binding unit comes in a set of two, left and right bindings. The base frame of the binding was fabricated from steel metal sheets. Oxy-acetylene and MIG welding was employed to create the desired angles at which the hinges were to be mounted. The purchased hinges possessed a 220 degree range of movement, a maximum 450lb-inch torque limit, and it is constructed from industrial-grade plastic. It also possessed a resolution of 10 degrees rotation at each locking pin. The rear bracket for the user's snowboarding boot was made from sheet-metal conformed to fit the contours of the heel of the boot. The front bracket was made of Plexiglas. The remaining structural parts of the bindings were made from custom cut pieces of Plexiglas. Packing foam was used to provide padding for the user.

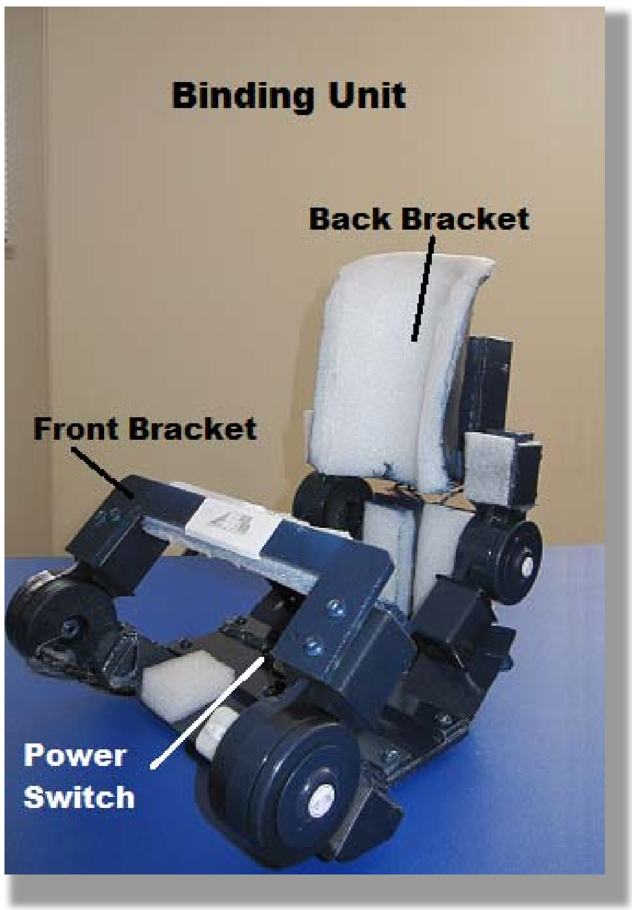

Figure 5 – ASB Binding Unit

The front bracket is driven by a motor with a 90 degree gear-train. This motor features a clutch which will slip out if the maximum torque is reached, thus protecting the motor from over-cranking of the bracket. The rear bracket is driven by a large spur and a pinion gear attached to a gear-motor linearly. This gear-motor does not have a clutch, therefore can be damaged by over-tightening. The release mechanism for the hinges uses the same clutch-less motors. A spool is attached to the motor head and it pulls a heavy-gauge fishing wire which will depress the release caps on the hinge allowing it to rotate freely.

Onto the electrical components, the binding utilizes the same Arduino Duemilanove and XBee components. In addition, a motor shield module capable of driving up to four DC motors is included. The binding unit is powered by two 9V batteries, one for the Arduino and one for driving the motors via the motor shield. The DC motors used occupy 3 sets of motor pin connectors. Two white LEDs were attached to the Arduino to light up as a power indicator and also for aesthetic appeal.

The XBee receives the wireless messages from the remote control unit because the XBee's data out sends whatever data is received to the receive pin on the Arduino. The receive pin on the Arduino sees these serial messages and stores them into a temporary character array. This temporary character array is flushed out before every read to ensure clean messages are received. The code utilizes a character-by-character matching algorithm to a library of messages stored on the binding. Then, a checksum verifies the wireless communication for a pass or failure. The command received then actuates the bindings.

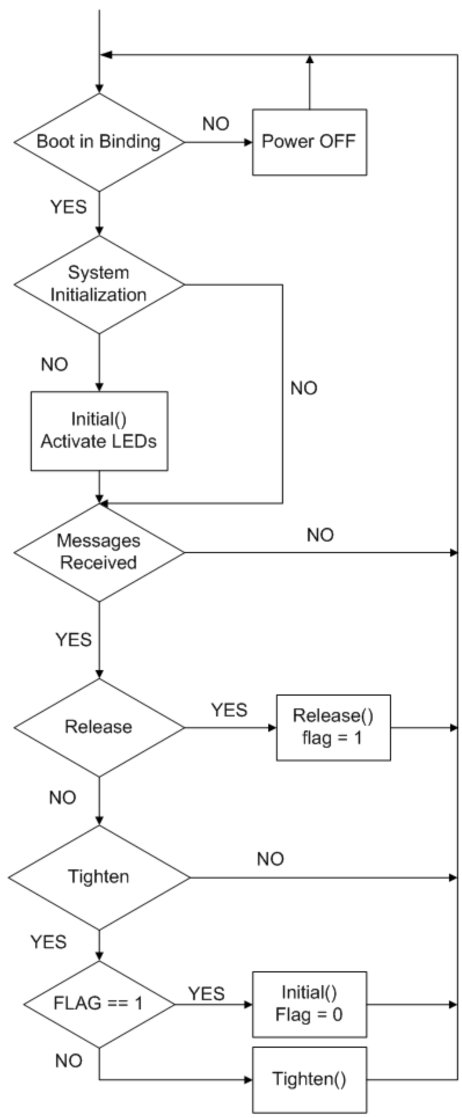

Figure 6 – Flowchart of Binding Operation

There is a center momentary switch attached at the sole-plate of the bindings. This switch closes the battery circuit. Once the user places their snowboarding boot onto the sole-plate, the initial tightening code sequence is executed and the front and rear brackets tighten around the user's boot. It should be noted that the bindings so not react to the remote control unit with there is not boot present in the binding as the microcontroller would not be on. However, the operation logic never requires a bootless binding to be actuated. Also, in case of electrical failure, the brackets can be manually adjusted be simply pressing the release caps on the hinges and rotating the bracket to the desired positions.

3.0 Deviations from Initial Plans

3.1 Overall System

The ASB achieved all of the basic functionality mentioned in our design specifications. The remote and binding unit successfully communicate with each other. The bindings tighten and release when commanded and do so automatically. Size restrictions were exceeded in both units, however we hope future iterations will diminish the dimensions of the ASB. The majority of the deviations arise in the implementation from the original designs.

3.2 Locking Mechanism

In our design specifications, we proposed an unlocking process of the hinges that is achieved by a cable release mechanism attached to a motor. The motor spools the inner wire of a bicycle brake cable which would depress the unlocking button on a pair of hinges. However, we have underestimated the amount of force required for the springs in the unlocking button of the hinges, and the motor was unable to depress the button. So, we decided to eliminate most of the springs in the hinges. The locking feature was not implemented due to different design, alignment errors, and poor hinge choice.

3.3 Binding Plate Design

In our design specifications, we proposed to use sheet-metal to construct the binding frame, front, and rear brackets. However, when we reached the implementation phase, we realized that the sheet-metal was too heavy and very hard to work with. We decided to substitute materials with Plexiglas, which is a much lighter material. Secondly, we have altered the front plate design to compromise for the front motor swap, because the original motor cannot be aligned properly and occupied too much space.

4.0 Future Work

4.1 Overall System

Despite the potential of ASB, there are several developments needed in order for the whole system to be a competition in the competitive snowboard binding market. Specific upgrades to each unit of the system will be listed in their own section.

The overall bindings' strength is lower than what we have anticipated at the start of the project. This problem can definitely be improved on by upgrading certain factors. For example, the quality of the gears we used for our binding can definitely be improved by ordering custom made parts from specific manufacturers. By ordering custom made gears, it will be able to increase the strength and durability of the hinges yet reduce the size of the gears. This will allow the gear to be enclosed in water proof casing easier. Also, a new type of hinges of a smaller size can be applied to our system. With smaller hinges, the overall binding size can be further reduced, and the power required for releasing the locking mechanism will be lowered.

Finally, the aesthetic design of the binding can be increased. Since snowboard equipments are luxurious items, its looks can greatly affect its sale. With higher quality materials and a better paint job, a new inspiring outlook will be a perfect for this revolutionary product. Thus, the ASB's marketing prowess can greatly increase.

4.2 Binding Unit

In order for the ASB to be a compatible candidate in the future market, the binding unit requires a few major tune ups. One of the major concerns for the binding unit is the motors and locking mechanism cannot withstand the pressure sustained during a normal snowboarding trip. In order to strengthen the bindings, stronger hinges and motors with higher torque must be used in order to sustain the shock and vibrations from snowboarding. Furthermore, pressure sensors should be added to the front and back plates such that the users will be able to know the tightness and condition of their bindings by reading off the controller unit. This will ensure the user's safety when using the bindings and avoid the chances of accidental release during usage.

Another improvement necessary to the binding unit is to increase the protection of our mechanical and electronic components. Mechanical components, such as the hinges, motors, and gears needed to be secured in a shock, pressure, and moisture proof casing to ensure the parts will not crack or damage due to the material's fatigue. This will increase the lifetime of the binding, and ensure that the replacement cost will be low for JAC Innovations. Additionally, the security of the wireless communication between the bindings and the controller can be further improved. By adding encryption to the wireless radio frequency communications, the binding unit will have a much lower chance of being hacked and used by malicious means. With these improvements, the overall binding unit will be much more durable and secure, and these will increase the user's confidence in our product.

4.3 Controller Unit

Two major future developments to the controller unit are required in order for it to be successful in the future. The first major development required in order for the controller unit to be user friendly, is by decreasing its size to an easily pocketed machine. By decreasing its size, the user will be able to keep the controller inside their jackets. This will significantly lower the chances of the user losing the remote. Additionally, programmers will be able to lower the active range of the controller in order to avoid interference with other bindings and other radio frequency equipments.

In addition to size adjustments, more feedback to user can increase the controller's functionality. By adding a LCD monitor to the controller unit, it is possible for the user's to receive feedbacks and information from the bindings such as pressure, temperature, and the battery levels. This will allow the users to have a clearer understanding of the condition of the bindings; thus, it will reduce the amount of uncertainty the user has on the ASB. If enough funding is given, it is possible to minimize the controller unit into the size of a wristwatch.

5.0 Budget and Time Constraints

5.1 Budget

Table 1 compares the projected cost and actual cost of the project as of April 17th, 2011.

Component	Projected Cost	Actual Cost
Automatic Snowboard Bindings:		
Binding Material	$20	$50
Padding Material	$10	$10
Ratchet Joints	$120	$108
Motors	$100	$162.80
Microcontroller	$60	$51.00
RF Receiver	$30	$52.00
Electroluminescent Wire/LEDs	$20	$2.00
Battery	$20	$9.00
Wireless Remote Controller:		
Microcontroller	$30	$25.50
RF Transmitter	$20	$26.00
LCD Display	$20	N/A
Battery	$10	$2.25
Miscellaneous:		
Tax and Shipping	$70	$153.00
Contingency	$50	N/A
Total	**$680**	**$651.55**

Table 1 – Projected Cost vs. Actual Cost

Although the final actual costs of the ASB are lower than the projected cost, various important components are over budgeted. In addition, the tax and shipping cost for the components are twice than what we have envisioned at the start of the semester. With help from the Engineering Science Student Endowment Fund (ESSEF), we were able to cover all of the costs of the prototype. We hope to be able to reduce the shipping costs in the future so that the costs of the bindings will drop significantly.

5.2 Time Constraints

Figure 7 illustrates the Gantt chart for the project. The team followed the timeline proposed in the early stages of the development, shown in blue/green bars. We spent more time on the research, functional specification, and hardware fabrication stages due to the complexity of the development process of the project. The design specifications, modular design, and testing took about twice the amount of time as what was expected. This is because the team was not able to find correctly-sized gears for the hinges on the bindings. However, the team worked seamlessly and was able to find the suitable gears and complete the tasks on hand. Due to the delay with the design specifications, and modular design, the integration, prototype testing, prototype adjustment, and validation took place at a later scheduled time.

Despite the difference between expected time and the actual time spent for each of the development stages, the team strived to adhere to the proposed schedule and was able to finish our prototype on time.

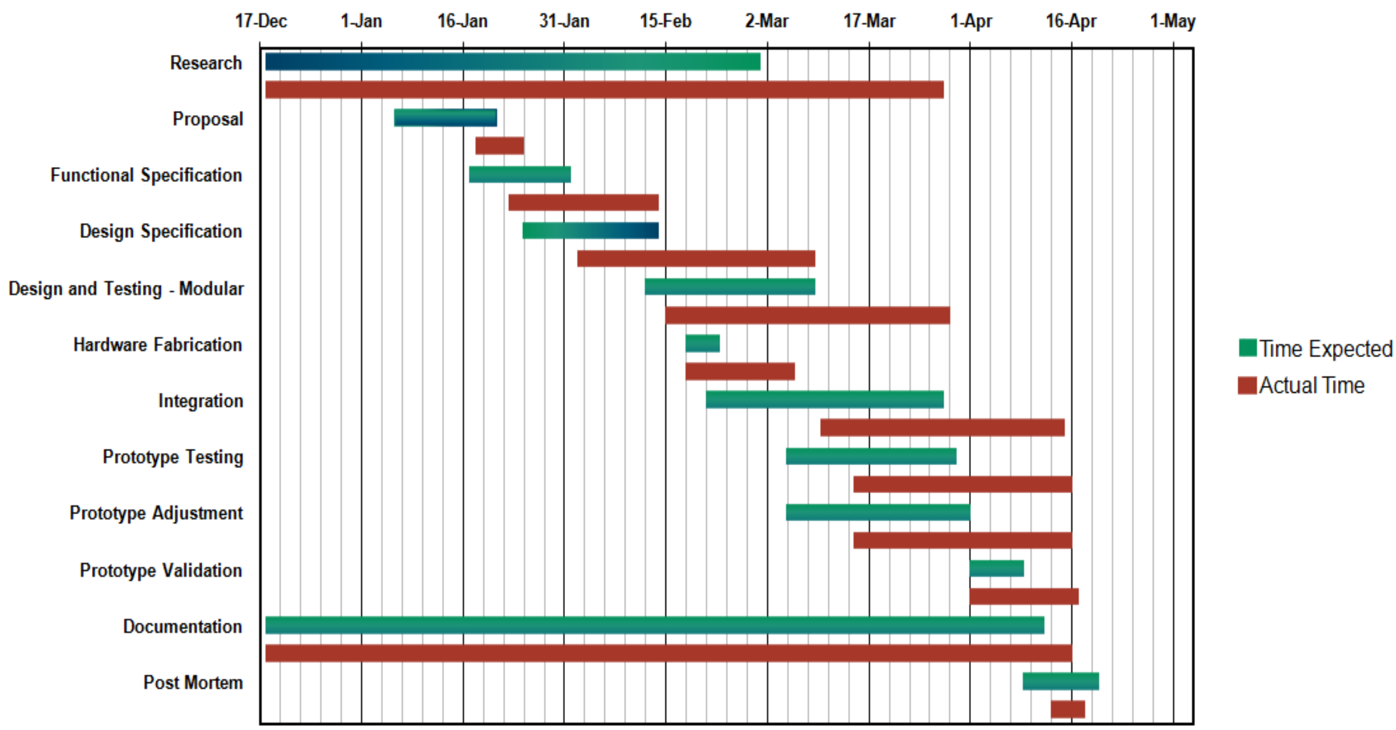

Figure 7 – Gantt Chart

6.0 Team Dynamics and Individual Reflections

The team members of JAC Innovations were comfortable working together during the development of this project. Having worked with each other in group settings numerous times throughout our undergraduate academic career, we recognized each member's area of strengths and weaknesses. This team is full of dynamic individuals and everyone each possesses a unique skill set. Because of this, the project roles were distributed appropriately which leads to increases in team efficiency throughout the entire project.

We held regularly scheduled meetings during the entire semester to make sure that the whole team was on the same page with respect to how the project was progressing. There was not any moment we let individual member to take on a task on his/her own. We always worked together as a group and never hesitated to offer help whenever necessary.

There always seems to be a point in any group where the group experiences stressful times and frustration boils over. Luckily, our group experienced such a moment without severe repercussions. All members were able to complement each other on every task and the group became stronger as the project progressed.

6.1 Jacky Wong – CEO

My initial role in ENSC 305/440 project was to be in charge of the daily progress of the project. I was also responsible for researching and developing the mechanical design of the binding unit. This project was a unique experience for me. The amount of time and effort required was immense and sometimes a little overwhelming, but the end result was rewarding and priceless.

Although I have previous experience working on hardware fabrication, I never realized how difficult it was to integrate all the hardware components together as a unit. I was very fortunate to work with a group of enthusiastic and passionate engineering students who do not back down from challenges. It was rewarding to see our project progress day by day from a simple idea to a fully functional device within short period of less than four months. Every group member had carefully made the right decision to maintain a minimal course load for the semester, allowing our schedule to be more flexible, which I strongly believe played a major role in our team's success.

My most notable contributions to the project were focused on hardware design, fabrication and assembly. As a student majoring in electronic engineering, I do not have a strong background in mechanical design. Therefore, I came across a lot of challenges and also experienced many failures with my designs. However, these defeats gave me more energy and motivation to work even harder until I got the perfect design. I have always enjoyed practical work and this project has provided me with plenty of opportunity to refine various aspects of my skills including both technical and non-technical skills.

An important lesson I learned from this course is how to be an independent learner, especially during research and development stage on our project. The knowledge on how to apply CAD design or interprets datasheet of components into an actual product does not come from studying but from repetitive action or actual hands on experience.

Another great thing I gained from this project is the confidence that with the right individuals and hard work, I can conquer any challenge. Although we took on a very ambitious idea/project, there was never a moment that we thought that we would fail. This is because we had planned and done our research well. We emphasized the importance of contingency plans to deal with setbacks such as parts failure or design failure. Therefore, we only lost a very short amount of time when we came across a setback.

Once again, I am happy to be surrounded by a group of passionate and friendly individuals. We worked very well together and the chemistry among us was unbelievably well. I strongly believe that we did an absolute fantastic job by achieving this much within this short period of time.

6.2 Jeffrey Sun – CFO

My initial role was to determine the parts required for the project. I was also in charge of acquiring the list of components that I created. I had to order and communicate with the suppliers to get more information on the components required. Much research and thinking was done since I have never before designed a system from scratch before. After the parts were obtained, I explored the Arduino Duemilanove to program the ATmega328 MCU. The Processing language is very similar to C/C++ so I had little difficulty switching between the languages.

Afterwards, I investigated the XBee wireless modules to implement the bare-bone code to allow two XBees to communicate with each other. This allowed me to gain experience in reading schematics and datasheets to know. After that, I completely designed and implemented the remote controller unit, from the electrical circuits to the physical enclosure. This exercised my circuitry building skills to determine which pins require active loads, pull-down resistors, and maximum current loads.

Jacky Wong was the main designer of the physical binding while I handled the software portions of both the binding and remote controller. I aided in the physical build of the bindings and this was not a simple task. I do not possess much mechanical design knowledge and even less in fabrication using materials such as metal and Plexiglas. However, I managed to learn along the way and further develop skills in the machine shop.

The circuitry required for the binding unit was similar to the controller design, with the addition of a motor shield to drive the DC motors. Since the XBee communication was figured out beforehand and the controller was completed already, communication between the binding and remote was hassle-free. This demonstrated good scheduling and foresight to reduce the workload congestion near the end of the term.

Several systemic errors occurred along the way. Several components on the original parts list ended up being not required. For example, the regulated XBee break-out board turn out to be useless. The board converts a 5V power input to the XBee required 3.3V. However, this will make the data output from the XBee to be too low in voltage amplitude for the MCU to detect. Also, the Arduino has a higher current 3.3V pin that can be used, thus rendering the break-out board unnecessary. Other components such 74HC595N logic chip mysteriously burnt out and the button shield was easier to build a custom array of buttons instead.

This project has employed all of my undergraduate engineering knowledge. Getting a feel of the project lifetime from design to implementation gives a nice glimpse to real-world applications. The most important aspect to a successful project is to keep motivated and promote morale within the group.

6.3 Clara Luo – COO

As the COO, I was in charge of organizing meetings, ensuring that the project is on schedule, and that all tasks are on track. One of my roles was to document the minutes and agendas for every meeting and to distribute them to each member of the group to provide them with a summary of the discussions.

On the development level, I have focused on research and the implementation of motors on the Arduino board controlled by the motor shield. I was also involved in hardware components fabrication and the mechanical design of the bindings. During the development process of the ASB, I was dedicated to take part of the technical drawings for the system.

The technical skills I learnt and gained from school and my co-op terms definitely benefitted me in this project, as I have been exposed to different microcontrollers, different levels of software and hardware design. Through this project, I was able to refine my programming and soldering skills. I also gained new skills and experiences in designing and working with motors, gears, and hinges.

One of the most challenging parts of the project was to complete different tasks and stages on time as proposed in the Gantt chart in the beginning of the development process. When we set up deadlines in the beginning, we didn't include the delivery time and possible delays, thus many of our development stages happened much later than what was proposed originally. Another issue we ran into was when we were doing modular designing and testing. We were unable to find the suitable and the right sized gears for the motors and the hinges. However, the team was unstoppable, and eventually found a shop that sells all sizes of gears, and we were able to buy the gears we need for the motors and hinges. Once we reached the integration process, we ran into another obstacle. That is, the motors and the hinges for tightening and releasing front and back plates were not functioning as what we were expecting. Nevertheless, the team discovered an alternative way to solve that problem and eventually, the prototype was completed on time.

Overall, JAC innovation members were enthusiastic about the development of ASB. All members stayed on tasks. Each member came together and with their skills and efforts, we have successfully created and completed the prototype of ASB. JAC innovation enjoys the feeling of accomplishing a project with a great level of complexity and it definitely pushes us to new concepts and future developments.

6.4 Andrew Ng – CTO

As the CTO of the company my role was to focus on the technical and scientific issues within the company. My duties included the conceptual design of the product, troubleshoot the issues we had, and to monitor the overall development of the product.

I aided Jeffrey Sun in the research of electronics to use for the device. I provided advice as to which products could be used as an alternative and help select the desired components.

While working on this project I have learned many skills. Skills in hardware and software design, as well as implementation. During the entire build I aided both Jacky Wong and Jeffery Sun in the development of both the software and hardware aspects of the project.

For the software aspect of the project, I developed the algorithm for both the bindings and the wireless controller. As we developed the product I discovered more and more functionality that could be added to the device which would make the product easier for the user to use. Functions such as checking if the bindings were released so that the next time you press tighten, it would tighten all the way. I also aided Jeffrey Sun in the coding of the bindings. While working on the software aspect of the product I learned how to implement algorithms I have learned from programming courses in a different language, since the language itself is very close to C/C++.

For the hardware portion of the project, I created the initial design which was later improved by Jacky Wong. During the build we were faced with many issues related to the implementation of multiple hardware parts. Parts such as the hinges, motors, and cable release mechanisms. I aided in the troubleshooting and changes in the design to make the bindings more effective. Since this product required a vast amount of work on the physical bindings I also aided in its construction. I aided in the wiring and construction of the binding itself. I have never worked with Plexiglas or metal, this experience will be very beneficial to me in the future when I attempt to develop prototypes of my own.

I had a very good experience working with the group members. When I needed help they would gladly come to help me and vice versa. We kept in constant contact so that we would know what to do and when to do it. Overall, I wish that my teammates in the future would be just as helpful and supportive as this group.

To conclude, this project has given me a vast amount of experience both in applying learned skills from SFU's engineering program and in newly learned skills such as fabrication. This project has let me see what is like to develop a product from a concept and to me it seems really fun. I hope that engineering will implement more courses like this in the future.

6.5 Jackie Ng – CMO

As my role as the CMO in this project, my duty was to complete the necessary marketing research for our product. My duties required me to look into similar products in the market and analyze their successes and failures. This information allowed me to interpret the market's demand for our product and allowed us to set the pricing of our product in order to stay competitive in the market.

In addition to the marketing duties, I was required to design the binding so that it is aesthetically pleasing to attract customers. During the development stages, numerous changes to the design of the binding are required to adjust its functionality. In order to keep up with the design changes of the bindings, I work closely with CFO, Jeffery Sun, to ensure that the budget allow smaller yet durable parts to be purchased. This will ensure the bindings look more pleasant and be easier to promote in the market.

Besides the previously stated responsibilities, I am also responsible for finding the necessary parts and creating customized parts for the ASB. Since the budget for the project is low, it is not smart to purchase customized parts from specialized manufacturers. Instead, we have to buy existing parts from various stores and customize the parts by ourselves. When customizing the parts for the bindings, I encountered many problems related to parts sizes. Due to the limitations of the motors, both hinges have to be parallel with each other in order for the frame to not twist due to the rotational pressure. Since it is very hard to perfectly reproduce identical parts, this process is time consuming and requires a lot of fine-tuning in order for the final product to be smoothly functional and also aesthetically pleasing.

Before this semester, I had very little experience with mechanical designs. Most of the laboratory experiences I have to date are mainly related to electronic circuitry in the past few years. This new challenge of building a mechanical design allowed me to gain valuable experience in designing hardware and allowed me to learn more about how to efficiently connect various hardware components.

At the start of the semester, the project seemed like an impossible task to build as we are very unsure of what to do. However, after various encouragement and advice from our group members, all members were able to overcome the seemingly endless obstacles and successfully complete the project. Throughout this project, I have learned to know my weakness as an individual and how important it is to co-operate with others in order to achieve success. Overall, I believe these past months were a very helpful experience and it created valuable memories to my future career. I am also very grateful of what all my partners have done to support me when I needed help the most.

7.0 Conclusion

Figure 8 – ASB Binding Unit with Boot

The ASB prototype has been successfully completed. The goals JAC Innovations set out 4 months ago have been accomplished. By going through all the project phases, design, implementation, and testing, the team has gained much technical and non-technical experience.

We at JAC Innovations would like to recognize Dr. Rawicz and Mr. Sjoerdma for giving us the opportunity to execute this project for the past 13 weeks. Special thanks to Gary Chiang, an engineering undergraduate of SFU, whom shared his ENSC 440 experience with the team. We would also like to give acknowledgment to the Applied Science Building (ASB) at SFU which the team has spent countless hours in and in giving us the inspiration for our product name.