January 22, 2007

Dr. Lakshman One
School of Engineering Science
Simon Fraser University
Burnaby, BC V5A 1S6

Re: ENSC 305/440 Laparoscopic Surgery Training System Post Mortem Report

Dear Dr. One,

The attached document encompasses the *Post Mortem* for the Laparoscopic Surgery Training System for the final Capstone project via ENSC 440. The purpose of this document is to explain current state our system and show a comparison between the end result and the planned system. The document will also cover the budget and timeline deviations as well as technical and team work experiences we have gained.

For our project, we designed and implemented a hybrid Laparoscopic Surgery that allows a trainee to perform object moving, cutting, and suturing through a physical environment and then be graded on their work through software. The overall goal of this system is to train more trainees at a faster rate to increase their proficiency and skill thus having a large field of highly skilled laparoscopic surgeons.

MediTronics is a group of three fifth-year engineering students: Alexander Hahn, Mark Jung, and Han-Lim. If there are any questions in regards to the functional specification, please contact us by e-mail at ensc440-group3@sfu.ca or by phone at (604) 828-1276.

Sincerely,

Alexander Hahn
CEO and Software Developer
MediTronics

Enclosure: *Post Mortem for a Laparoscopic Surgery Training System*

Post Mortem for

Laparoscopic Surgery Training System

Team Members: Alexander Hahn
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Contact Person: Alexander Hahn
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Submitted to: Dr. Lakshman One – ENSC 440
Steve Whitmore – ENSC 305
School of Engineering Science
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Issued Date: April 21, 2007

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1 Introduction

Over the past three to four months, the three members of MediTronics Inc. have worked on building a laparoscopic training system which is designed to help surgeons learn how to perform the laparoscopic surgery tasks quicker, and more accurately by providing the trainee's with video playback (to see where they need improvement), as well as computer assigned grade to the trainee to indicate their progress for a certain tasks. The tasks include cutting, suturing and object movement.

This document goes back to the very beginning of the project and examines the project flow from proposals and planning all the way to final execution. The report will cover the technical aspects as well as the financial, timeline, interpersonal aspects of our journey.

2 Current Status

The proposal and functional specification of the Laparoscopic Training System described three phases of the project which were defined as: crucial functions, functions to be attempted given enough time, and functions that should be considered for future plans. In the end we were able to complete all the crucial functions (cutting, object moving, suturing) and added the extra function of wireless capability to transmit sensor data to the computer through a wireless serial connection. The final system overview is shown in Figure 1 below. From Figure 1, we see four modules where each module accomplishes a different task.

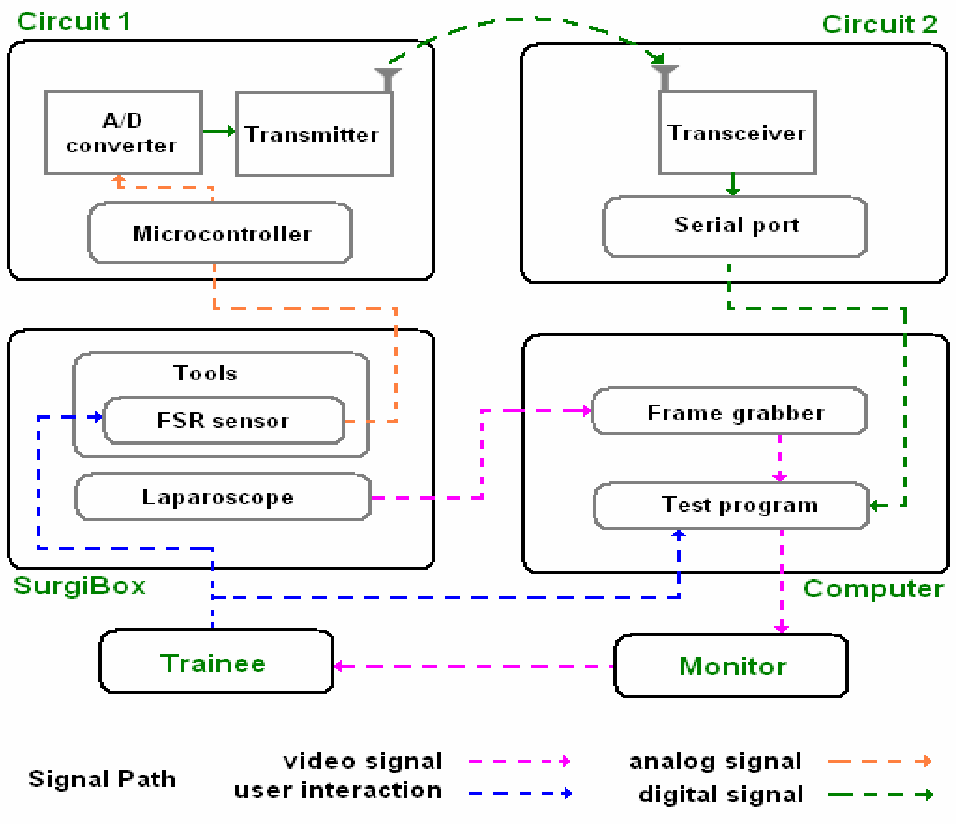

Figure 1: High Level System Overview

The trainee provides the input to the system by first selecting from the test program what kind of task they wish to perform. Once the user selects a task, they are then able to perform the task inside the SurgiBox (Figure 2). Inside the SurgiBox resides the laparoscopic camera and an FSR sensor enabled tool tip. The camera images from the laparoscopic camera is sent directly to the computer (Figure 5) to be captured and processed. The FSR data takes a longer path by first being digitally quantized in Circuit 1 (Figure 3) which is then transmitted to Circuit 2 (Figure 4). Circuit 2 receives the FSR data and sends this data directly to the computer to be sampled and used for grading purposes. Generally, the modules are setup to be a loop which starts with the trainee providing inputs and ends with the trainee receiving a grade from the computer.

In terms of a trainee point of view, the trainee interacts physically with the SurgiBox module and the computer module. The trainee performs tasks inside the SurgiBox, but to view the contents inside the box the trainee must view the computer to watch the live video feed (Figure 8). The computer module also provides a graphical user interface (Figure 6) that allows the trainee to select the type of task they wish to perform (Figure 7) and also a grading summary for the task (Figure 9).

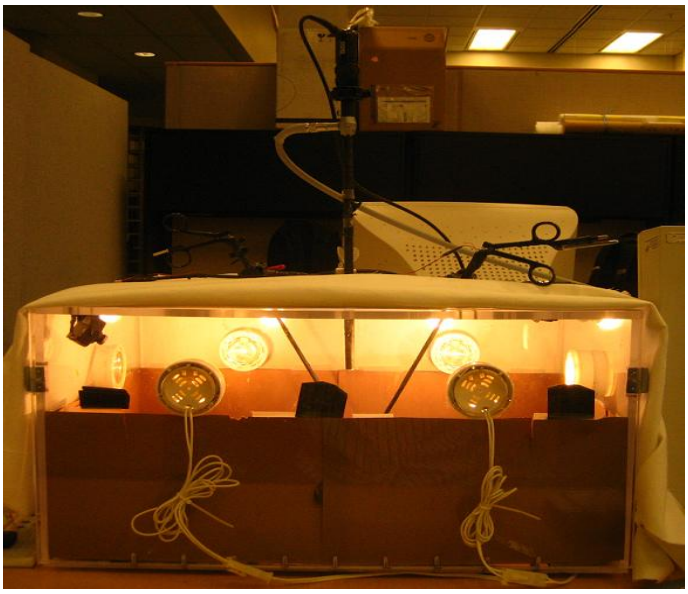

Figure 2: SurgiBox Module

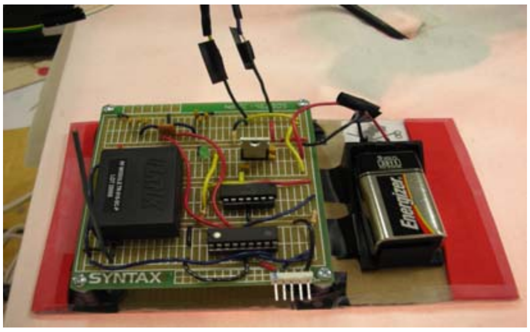

Figure 3: Circuit 1 Module - Transmitter

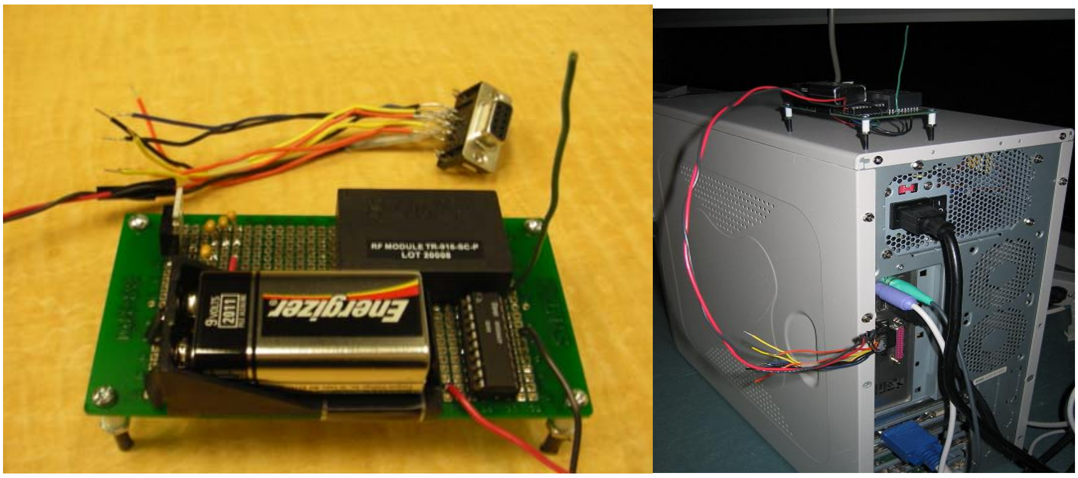

Figure 4: Circuit 2 Module – Receiver

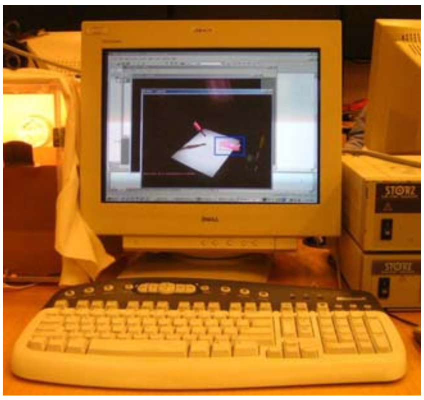

Figure 5: Computer Module

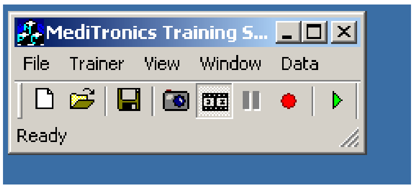

Figure 6: Initial Graphical User Interface

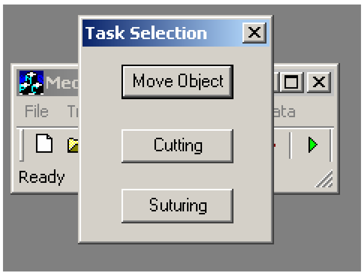

Figure 7: Task Selection Menu

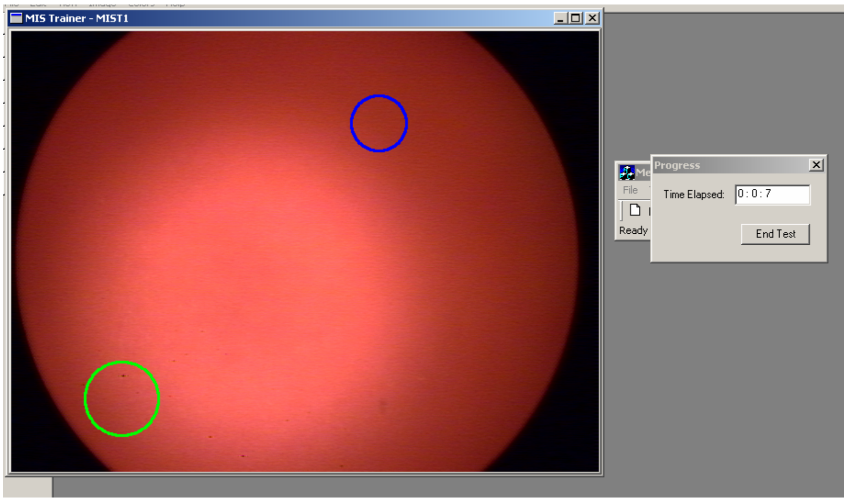

Figure 8: Live Video Feed of SurgiBox and Elapsed Time Counter

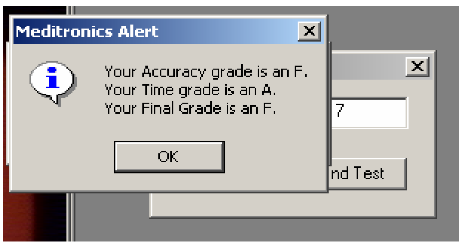

Figure 9: Grading Summary

3 System Deviations

3.1 Overall System

Throughout the project, some details were either compromised or altered heavily but in the grand scheme we were able to achieve all of the crucial functions that we set out to do and even managed to get the extra wireless functionality incorporated into the system. The biggest shortfall we endured, however, was the inability to use a Printed Circuit Board for the circuitry and also the inability to provide proper packaging of the devices or a competent user manual. These shortcomings were caused mainly due to the fact that there just wasn't sufficient time to tackle all those details.

Another area where we are lacking is in the area of providing a lot of concrete statistical evidence for the results we achieved. We were able to collect a fair amount of statistical data on our FSR and image processing experiments but clearly not enough to be considered a guarantee for repeatability or reliability. This problem was also caused by the lack of time available, but also by the fact that our group highly underestimated the amount of statistical analysis required when dealing with medical equipment, especially one that requires as much precision as laparoscopic surgery.

3.2 Hardware

3.2.1 Force Limit Set-Up

As we consulted with CESEI in the beginning, we were promised to be provided a pig tissue to measure the force limit not to damage it. Unfortunately, we lost a contact with the doctor who told us to provide a pig tissue as time went by. Instead, we used beef to measure the force limit.

3.2.2 Multiple FSR and PCB Design

Originally, we tried to use two FSR instead of one. Two FSR's were supposed to be mounted on each gripper so we could measure force on both right-hand sided tool and

left-hand sided tool. However, due to budget issue and the size of tool insertion holes in SurgiBox, we decided to use only one FSR. We have three tool insertion holes for which one is used for FSR mounted-gripper and the others for scissor and thin-gripper.
Additionally, PCB could have been used instead of vector board. However, we experienced a hardship on our budget since PCB required at least $150 to $300 CAN. Thus, we used vector board which cost only $3 CAN per board.

3.3 Software

3.3.1 FSR Data Retrieval / Grading

Our original plan for the FSR data retrieval was to sample the binary data and convert it into a number that would represent the force, in Newtons, and graph the force readings vs. time. Unfortunately we found ourselves in a situation where we were unable to find the correct data field or property to get the proper value. Due to time constraints, our group collectively agreed to compromise with a solution where binary data is sent when 2.0 N of force was applied (which translated to 2.9V in the circuit) on the FSR. Instead of sampling the data from the serial port, we converted the program to treat incoming data as a trigger, or an event. This also affected the grading system where instead of graphing the force and finding a statistical mean, the grade would now depend on the number of events (excessive force on FSR) triggered.

3.3.2 Image Processing

There wasn't very much deviation with the method of image processing discussed in the functional specification, but we did run into some problems with the implementation of it due to the fact that the pre-existing graphics libraries were insufficient for what we needed, so we had to spend extra time finding a better graphics library and incorporating with our existing system with minimal after effects. Luckily, we found a powerful library in GDI+, provided by Microsoft.

A secondary issue occurred during the image matching phase. Initially, the end result of a trainee's task is first photographed and saved as a bitmap file using the openCV graphics library and then this bitmap is read into the program using the GDI+ library where the image is quantized and then compared pixel by pixel to a master image. One factor we didn't consider was the resolution and focus of the camera, so all images captured had blurry edges. Oddly enough, the blurriness was quite consistent, so we created a solution where matching was performed by returning the number of mismatched pixels. This number would then be compared to a scale of numbers to determine its letter grade (A, B, C, D, F) but the number scale took into account for the extra number of mismatched pixels caused by blurriness.

4 Future Developments

4.1 General System

A lot of the future developments follow the ones mentioned in the functional specifications like random cutting areas, movement of multiple objects, and measuring suturing tightness. The new developments we think will add the most benefit to the system is adding knot tying and suction to the task list. These two tasks are quite commonly performed during laparoscopic surgery and require some extra skill as well.

4.2 Software Features

4.2.1 FSR Data Retrieval

For future developments, the FSR data retrieval should be fixed from the current event triggering style into the proper force measurement reading mode to sample the proper values and graph the results.

4.2.2 Grading Features

As mentioned previously, the grading system can be improved upon by upgrading the FSR data retrieval and getting proper values and then calculating a statistical mean to provide proper feedback to the trainee.

Another grading feature that would be helpful is to provide another menu for the supervising doctor to change the time and accuracy scales to their own settings. Grading for this type of surgery is highly subjective in terms of quality and as such the grading scales should be able to be modified by the doctor in charge.

Currently, the test program is built specifically for an easy setting. An ideal upgrade for the system would be to have an easy, medium, difficult setting for each type of task where the tasks become more difficult and require higher accuracy.

4.3 Hardware Features

4.3.1 Force Limit Sensing Mechanism Improvement

Further medical research on the amount of force applied during laparoscopic surgeries is required as well as the experiment on human organ-like object. Having the accurate force limit, we can manage to get feedback from different sources such as combination of FSR and Strain Gauge or combination of multiple FSR's.

Since the size of currently used FSR (FSR400) is little big to be mounted on the laparoscopic surgery tool tip, continuous research on smaller device or FSR to measure applied force is also required.

4.3.2. PCB Design

As mentioned previously, PCB can be used instead of vector board. By using PCB, we can improve the reliability of our circuit and remove all the external wiring. The figure 10 shows the PCB layout drawn by OrCad.

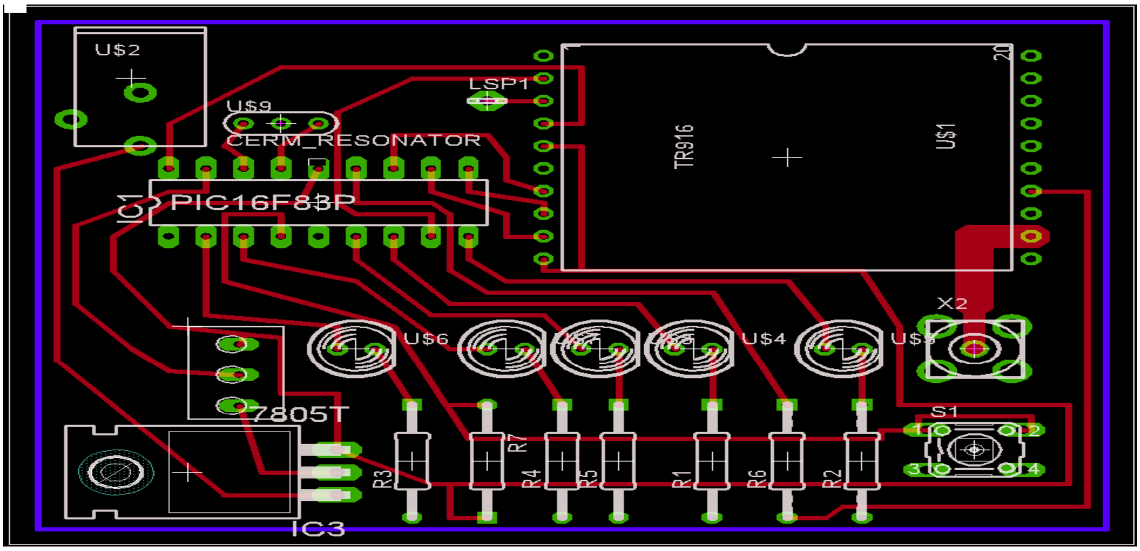

Figure 10: Example PCB Design of Hardware Circuitry

5 Budget and Time Management

5.1 Budget

Table 1 shows a materials list with prices of the total estimated cost and Table 2 shows the total actual cost to build the system as of April 20, 2007.

Required Equipment	Estimated Cost
3 ~5 Breadboards	$30.00
2 Transceivers	$70.00
IC Chips for Various Sensor Circuits	$20.00
Microchip Microcontrollers	$10.00
Parallel Computer Ports/Cables	$30.00
Wires and Foils	$10.00
9V Battery	$20.00
Various IC Chips	$20.00
Required Cost	**$210.00**

Table 1: Estimated Cost

Component	Cost
Vector boards	$24.00
Chip components	$15.00 & SFU Robotics Lab
CCD board camera	$100.00
FSR sensors	$30.59
Batteries and holders	$23.84
Color paper, needle and tapes	$15.00
Total	**$208.43**

Table 2: Real Cost

As per the figures from Table 1, the project came in highly under budget. As the project was progressing, we found some creative ways to perform certain tasks with cheaper parts, or not using the parts at all. We decided to invest our time and efforts in making the software perform most of the workload and error compensating rather than invest our money in better hardware. This resulted in our program becoming more complex and requiring some more development time, but our costs were decreased heavily.

5.2 Time Schedule

A general Gantt time chart was originally conceived during the proposal stage which we tried adhering to throughout the past 13 plus weeks. This Gantt chart is shown in Figure 10 along with a second Gantt chart showing what the real time scheduling that occurred.

Overall, the documentation stages (proposal, function specification, design specification, etc.) were completed well on time according to the predicted Gantt chart. We more or less followed the Gantt chart except we spent a few more weeks on the software and integration phases. We originally allocated a fair amount of time for these specific areas, however, the team learned the hard way that it is nearly impossible to predict what will go wrong, how long it will take, and effort required to fix the problem. Due to the extra time required in developing the system, a lot of time was taken away from testing and debugging. Fortunately, the time remaining was enough to fix the major bugs that were found.

The majority of the time deviations were cause, interestingly enough, from underestimating course loads and exams of our other courses. Sometimes, tests or assignments would change dates and caused major conflicts in time schedule. There were even situations where all 3 members of our group could barely do any project work for a full week due to these time conflicts.

Despite all the conflicts and deviations in the schedule, we were able to get our system working a week later than we had planned, but fortunately we originally scheduled to have a buffer week in case we did fall behind. In the end, our hard work and dedication to following the time schedule allowed us to successfully complete our system on time and perform the demo on April 20, 2007.

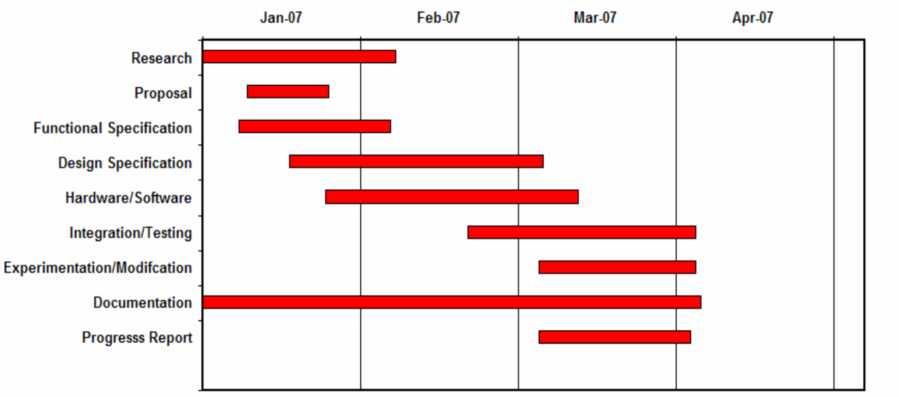

Figure 11: Original Gantt chart (Predicted)

6 Team Dynamics and Experiences

6.1 Alex Hahn

This experience was a very interesting one starting from day one, mainly because I had never even heard of laparoscopic surgery. Having finished the project, I am still no expert on laparoscopic surgery, but I do understand what it is and the huge potential that type of surgery has in the world. This potential of this new kind of surgery offers opportunities for people, like our group for instance, to offer new ideas, tools, and business plans.

From a technical standpoint, I came into the project with a strong background in many different software languages, but I had no experience with MFC (Microsoft Foundation Classes). Visual C++ MFC was the language that was necessary to create a graphical user interface while also being able to use the proper libraries and drivers. I struggled quite a bit with having to learn MFC, but in the end I came out of the project having a good understanding of MFC based C++, as well as the graphic libraries used for image processing.

Prior to forming the group, we were all fairly good friends and were quite well aware what everyone's strength and expertise was, so it was quite easy planning who would tackle what area. One problem that we noticed right from the beginning was that since we were a group of three, we would most likely have to do more work per person compared to a person in a four person group. Due to this perceived idea of an extra work load, we tried to keep our weekly meetings productive, and to stay in constant contact with each other to keep the group up to date on the progress of the project. There was a lot of work that was required from this course and in a short amount of time, but I had a lot of fun doing the project work and I attribute that mostly to having great group members to work with. The biggest reason for our success was that we each trusted one another completely to do the work that was assigned to them.

If there were one life changing lesson I took away from this experience, it is that plans are meant to be guidelines and should be constantly changing. We first started off with a big plan for the entire project, then broke those plans down into a monthly time frame, then broke it down more and more until we wound of up with a daily plan schedule. Any time we changed the day plan, we then took a look at the weekly plan and noticed that that one day already changed the week's plan and in turn this worked all the way up to the very first project plan we came up with first. Throughout the project, this ladder effect of constant plan changes allowed us to quickly adapt to any kind of situation and continue towards our final goal.

6.2 Mark Jung

The laparoscopic surgery system was my research topic during my first co-op in the Robotics Research Lab in fall, 2005. I have researched this area for several months and have tried to come up with a sophisticated training system for the trainees in laparoscopic surgery field. This interesting research is still going on for my special project course and another motion tracking software using image processing technique is now under developing.

I was glad that three dedicated people, who are also very good friends to each other, form a Capstone Project group to develop the laparoscopic surgery training system and actually ended up to bring a good product in both software and hardware sides. I am sure that our product will be one step for further development in the laparoscopic surgery system of the Robotics Research Lab.

For my contribution to our project, I showed the solid guideline to other group members in both software and hardware. Since I was working on this project during my co-op term, I had very clear goals in my mind to achieve throughout this course. I knew exactly what hardware components we have to use for building our electronic circuits and where to order them. I also clearly knew which open library source we have to use for implementing our test program. One of the greatest advantages that I could deliver to our team was abundant help sources from many friends who are working in the Robotics Research Lab, simply because I knew them personally. ☺

From the project, I was able to learn lot of technical knowledge and skills. In particular, I gained how to pick up the data signal from a serial port using C++ program and how to connect the circuitries for data transmitting. I also gained the hands-on experience in calling the key functions for image processing in the test program.

Throughout the project work, I learned most valuable lesson, "Always try to keep the good relationship between team members!". Having a good relationship between team members helps communication between the members and results in good planning and finding most efficient way to solve the problems.

6.3 Han-Lim Lee

I really enjoyed working on the laparoscopic surgery training system, which I had not known that much about to begin with. For now, I can explain what it is, and its advantages and disadvantages to colleagues who have never heard about it.

Despite there being a little concern about the amount of work in the beginning since we had only 3 group members, I am very pleased that we finished the tasks we set out to do. Now, when looking back what we have gone through, working as a member of Meditronics was a great experience from both a technical and interpersonal viewpoint.

For technical contributions, I mainly participated in hardware, thus I mostly gained knowledge related to hardware. I discovered that there were many electronic components that I have never heard of before. For example, I would not have known about the FSR (Force Sensing Resistor) or strain gauge without doing this project. I learned how to design

a circuit using FSR in order to measure force. I also learned about the use of the LINX RF module, the PIC micro-controller, the Sipex line driver, and the RS-232 serial port. By working on the LINX RF module, I vastly increased my knowledge on wireless circuits. When I was studying about PIC micro-controller (the one that I had the most difficulties), I gained the practical understanding of how to use micro-controllers as well as practiced assembly language when programming the PIC chip.

In addition to the technical achievements, I gained more valuable skills on how to work in a team. I have had lots of group work experience previously, such as in electronics labs; however, working in MediTronics was completely different because this required a high level of team work and planning. From this experience, I learned how to schedule, distribute work, and arrange meetings. I also gained a deeper understanding on the responsibilities of a group member. In order to not fall behind and delay the project work, I needed to keep pushing myself in a way to try and keep ahead of the group schedule.

Putting aside what I learned in the group, I really appreciated having hard-working and motivated people to work with.

I realized that I cannot be smart everyday but three people can be smart everyday. One day, I could be struggling with something that my co-workers can solve easily, and on another day it would work vice versa. From now on, I will always remind myself of the fact that the collective intellect of a group is always more powerful than that of a single person.

7 References

[1] Proposal for Laparoscopic Surgery Training System. MediTronics.

[2] Functional Specifications for Laparoscopic Surgery Training System. MediTronics.

[3] Design Specifications for Laparoscopic Surgery Training System. MediTronics.