Cross Disciplinary Project Management

A Major Qualifying Project Report:

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WORCESTER POLYTECHNIC INSTITUTE

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by

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Abbreviations

CRS Compression/Release Stabilized

DAPS Dynamic Adjustable Prosthetic Socket

MQP Major Qualifying Project

PCB Printed Circuit Board

SVG Smart Variable Socket

WPI Worcester Polytechnic Institute

Abstract

The overall objective for this project was to learn how to be an effective manager through managing an MQP in another field. The state of the art revealed many different techniques and advice on managing teams that was incorporated into the management process. In order to effectively manage the MQP team, a management plan was created utilizing principles from Industrial and Management Engineering and axiomatic design. Methods used included creating a value proposition, axiomatic design decomposition, Gantt and PERT charts, and risk and failure analysis. The results show that a student can effectively and successfully manage an MQP in another field. Future MQPs may benefit from a similar position being added to their group. In conclusion, valuable management skills can be developed at a university that are applicable to work immediately after graduation.

1 Introduction and Problem Statement

Management Engineering students studying at WPI are required to take the business core which involves classes in time-line management, organization behavior and change, marketing, project management, and leadership. These classes gave me a background in different techniques and tools used in industry. To gain knowledge and experience in the fields of project and product management I joined another Major Qualifying Project (MQP) as their project manager. As their project manager I gained experience working as a project lead of a team and they received benefits from some of the knowledge I had learned in the business core curriculum.

This project focused on managing an interdisciplinary team of engineers at Worcester Polytechnic Institute (WPI). The main objective of this project was to effectively and successfully manage an MQP in another field. To accomplish this objective I hoped to aid them in accomplishing all of the goals they designed upon conception of the project and to ensure that the entire learning experience of MQP was utilized. Key methods I utilized to successfully manage the team were: axiomatic design, effective communication techniques, risk analysis, logistical planning, and identifying and managing bottlenecks throughout the process. These methods helped the team move toward completing their goal of designing and prototyping a dynamically adjusting prosthetic socket for trans-femoral amputees.

Limb loss is a growing problem in the United States with 1.6 million reported in 2005 with expectations to hit 3.6 million by 2050 [Ziegler-Graham et al., 2008]. Prosthesis offers regained mobility to some of these amputees and the field is constantly changing to help patients regain more functionality and comfort as the technology becomes available. The aspect that has been identified as the most important in a socket is its fit [Legro et al., 1999]. However, with changing limb sizes of up to 10% daily [Greenwald, 2003] a perfect fit is hard to obtain. These improper fits can lead to instability of the limb and health risks such as restricted blood flow, sores, and skin damage [Mak et al., 2001].

Current socket technologies range in techniques and methodologies with the Dynamic Adjusting Prosthesis group focusing on a combination of a Smart Variable Geometry (SVG) socket and

a Compression Release Stabilizing (CRS) socket designs. The CRS socket design compresses the residual limb to reduce the amount of energy put into movement of the prosthetic. However, this constant pressure can sometimes cause unintended harm from reduced blood flow, limb deformation, and nerve damage. The Dynamic Adjusting Prosthetic Socket (DAPS) team attempted to recreate the high pressure of a CRS socket but limit the time the limb was compressed through controllable hydraulic bladders. The bladders also allowed for a proper and consistent fit throughout the day, compared to a manual socket.

2 Materials and Methods

This section briefly introduces the different methods used throughout the MQP.

2.1 Initial and Revised Client Statements

The focus of my project was on managing an interdisciplinary team of engineers to aid them in accomplishing all of the goals they designed upon conception of the project and ensuring that the entire learning experience of MQP is utilized. Initially, I thought that would mean primarily scheduling and taking meeting minutes, but through research and my axiomatic design process, I realized that the problem was larger than that. In order to meet the team's goals and fully utilize the MQP experience, I had to lead the team, promote team growth, resolve team problems, as well as all of the managerial tasks I had initially conceived.

2.2 Axiomatic Design Decomposition

A key element of discovering my role in the project was the Axiomatic Design Decomposition in A term of the project. Axiomatic design is an analytic tool, which utilizes rules or axioms to break down anything into the smallest possible elements [Suh, 1990]. The axiomatic design process can be broken down into axioms, domains, hierarchies, and zigzagging.

Axioms are the rules that bind the process together and there are two main axioms to apply to

any design. The first is the Independence Axiom, which says all functional requirements should be independent. The second axiom is the Information Axiom, which maintains that the creator should minimize the information content of the design. The Independence Axiom helps reduce coupling, when two or more design features are interdependent, which can tie together tasks in an unwanted way. The Information Axiom helps to increase efficiency by decreasing unnecessary information thereby reducing waste through reducing unnecessary time wasted [Brown, 2012].

Domains define how to break down the problem. There are four main domains for any design activity: customer, functional, physical, and process. The customer domain is considered anything that the customer seeks. This is, generally, high-level part of the breakdown such as defining the original goal and answering what are we trying to achieve. The functional domain breaks down the functional requirements of the design solution. Functional requirements are the minimum set of independent requirements that completely characterize the functional needs of the design solution. To brainstorm functional requirements, one question we can ask is how do we propose to achieve our goal? From the functional domain we move to the Physical domain, which deals with design parameters and design solutions. Design parameters are elements of the design solution in the physical domain that satisfy the functional requirements. The process domain deals with process variables, which are the elements in the process domain that characterize the process that satisfies design parameters. In order to visually represent this process, we use a design matrix where the functional requirements are on one matrix axis and design parameters are on the other. An X or O in a column helps us represent whether a Design parameter affects a functional requirement, where X represents that the functional requirement is affected.

Hierarchies represent the design architecture of axiomatic design. Starting at the highest level or goal the designer decomposes the higher-level functional requirements into lower level requirements. The process used to decompose the problem into hierarchies is known as zigzagging because before one can break down a functional requirement one must decide its design parameter. In this way the process zigzags between the two domains [El-Haik, 2005].

Through axiomatic design I was able to decompose the problem down into the smallest parts

and identify potential bottlenecks. It also aided me in identifying what areas I needed to research further. I also received feedback from a WPI graduate class, MFE 520 - Axiomatic Design of Manufacturing Processes, on my axiomatic design and process. The class gave me insight on how to restructure my axiomatic design more effectively. One thing that was difficult when designing the axiomatic design was that I was decomposing the process that my group was going through where some variables were already fixed (for example the group was required to use bladders). The DAPS MQP was difficult to break down in the same way that one would decompose a mechanical processes. It was difficult to specify ways to solve every problem because many human problems depend directly on the people (Appendix A).

2.3 Literature Review Overview

One thing that became apparent after my first meetings with my adviser, my group, and the beginning of my design decomposition was that I needed to do research into common problems in teams and what role good managers play in leading their teams. To do this I researched three main areas, namely the role of management in groups, common group problems, and developing productive teams of knowledge workers. Drucker first coined the term ”knowledge worker” as a ”man or woman who applies productive work ideas, concepts and information rather than manual skill or brawn” [Drucker, 2000]. This term has since been used and adapted to mean, ”systematic activity that traffics data, manipulates information and develops knowledge. The work may be theoretical and directed at no immediate practical purpose, or pragmatic and aimed at devising new applications, devices, products or processes” [Despres and Hiltrop, 1995].It was important to research knowledge workers and how to make them more productive because managing knowledge workers is different from how one would manage an assembly line or process (Section 4).

2.4 Project Approach

The project approach was be divided into two main parts, namely research on current management techniques and problems, and the design or method of management. The design of man-

agement can be broken down into risk identification and analysis (Section 2.4.1), time-line management (Section 2.4.2), communication management (Section 2.4.3), and conflict and problem management (Section 2.4.4).

2.4.1 Risk Identification and Analysis

The first step to developing a comprehensive management plan was to brainstorm all of the potential problems and how to mitigate them. After the initial brainstorming was complete, the entire project process had to be examined for the critical path and potential bottleneck. Tools such as PERT charts and axiomatic design were used to identify the critical path from which a time-line was developed with the aid of the DAPS team. Halfway through the project time-line, a risk assessment was conducted to determine the likelihood of the project extending an extra seven weeks or not being completed at all.

In order to effectively brainstorm ideas on potential project failures, research was conducted on common team problems (Section 4.1.4). Problems were then put into a modified risk management table (Figure 1). Methods of prevention were chosen using information from previous classes and experiences, as well as techniques that were discussed in the research conducted on common team problems. These tools were then discussed with the DAPS team to explain potential benefits and insure the tool was properly integrated with their project.

After completing the failure analysis the Axiomatic Design was completed providing isolated project variables, such as the mechanical design. These variables were translated into PERT and Gantt charts with the help of the DAPS. The PERT chart was invaluable because it provided background necessary to calculate potential bottlenecks through calculation of the critical path (Appendices E and F). A critical path is a tool that is used to identify potential bottle necks to the project and also looks at the slack time of each item. The slack time is the amount of extra time that a single variable can take without affecting the project's total time. Slack time was critical to the management plan as it clearly defined what events could be delayed without affecting the rest of the project. The critical path was then used to help calculate the risk of going into D term or not

Identification	Description	Effects	Prevention
Unassigned Tasks	Tasks were assigned but forgotten or not assigned to a spcific person	Task is not accomplished timeline has to be adjusted	Trello, Check ins, Action Items
Lost Email	Email is lost or misplaced with important information	Information is lost, time is wasted looking for the email	Slack
Poor Time Management	Time is use ineffectively due to poor prioritization	MQP is unfinished or goes into D term	Gantt Charts, Weekly planning meetings
Defensive management	Micromanage the team, ensuring everything goes through me for a first inspection	Create a bottleneck around the manager	Trust the DAPS team, limit checkins, Trello
Burnout	Team members take on too many tasks and therefore diminsh the quality of work they are doing	Work quality is diminished and reduced	Identify and assign less work, Talk with the team about setting realisitc expectations for themselves
Feel Untrusted	Team members feel untrusted to produce work	Members get defensive and the quality of work is diminished	Treat all members equally
Feel Undervauled/ Useless	Members feel like their work is undervalued or that they do not know enough to complete work	Members reduce the amount of work they do and their quality of work drops	Open Communication, Reiterating that it is okay if you are not an expert
False Deadlines	Daedlines are to tight and restricitve	The team ignores deadlines set as they know they will be moved as a result the timeline has to be adjusted	Deadlines are set as a group
Group Conflict	Becasue of one of the above identifications or something else conflict in the group arises	The team becomes unjelled, team members interact poorly, the group as a whole becomes less productive	Open communicaiton, Talking one on one with involved parties

Figure 1: Failure Analysis for the DAPS MQP

finishing the project before the end of the year (Appendix F). The Gantt chart in Figure 2 is the final Gantt chart of the project.

2.4.2 Time-line Management

Most of the time-line management was left up to the DAPS team. This decision was made after doing research into time-line management and finding that restrictive time lines are more detrimental to teams and that time-lines are more likely to be restrictive if made by the manager alone [DeMarco and Lister, 1999]. My main role in time line management was to enforce the time line set out by the DAPS team at the beginning of the project. This initial time-line can be seen as the purple in the Gantt Chart in Figure 2 or in the initial Gantt Chart (Appendix D). The slippage can be seen by the orange bars in Figure 2.

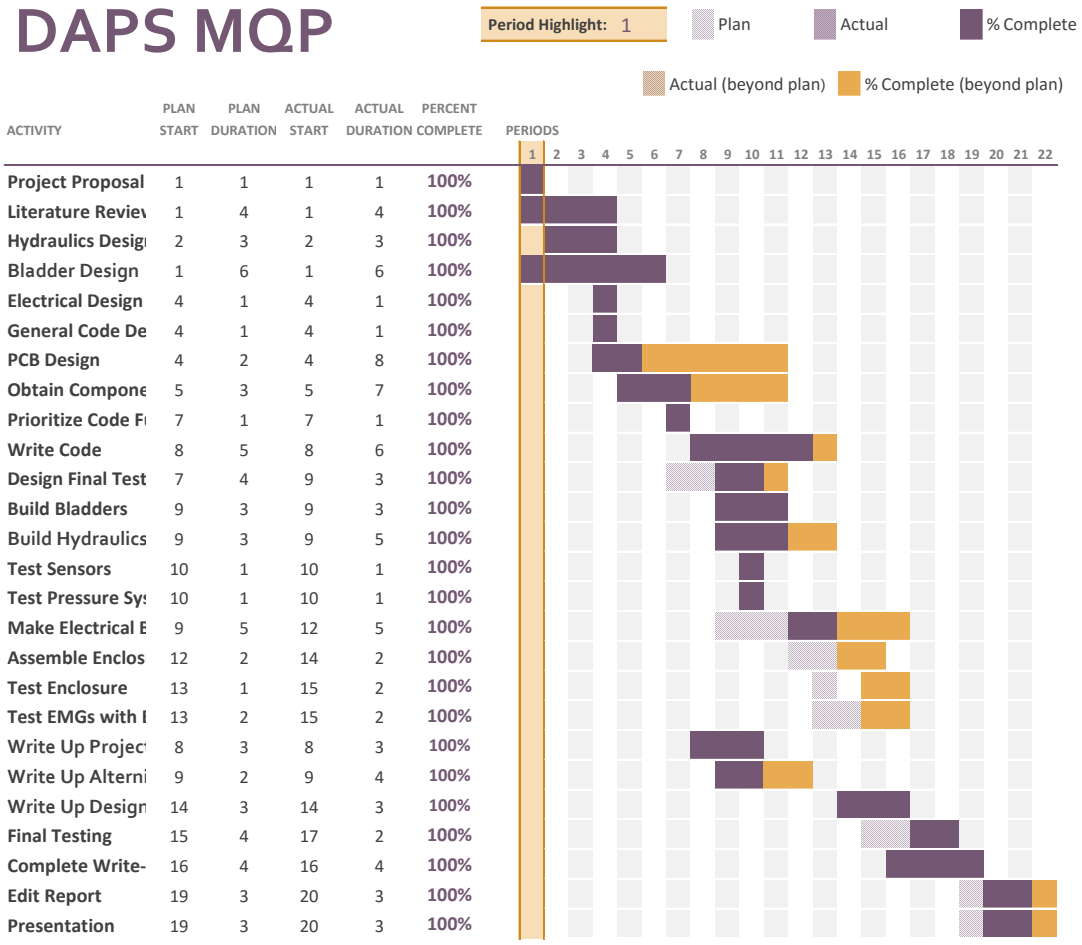

Figure 2: Final Gantt chart of DAPS MQP

2.4.3 Communication Management

Using the failure analysis in Figure 1, main tools and plans were chosen to help with the different communication techniques the team would need. These tools can be broken down into Slack, Trello, Email, Face to Face Meetings, and Google Drive.

2.4.3.1 Slack

Slack is a team messaging application that is meant to help replace email, an example of our team's Slack messaging tool can be found in Figure 3. Groups establish a Slack team and various channels within the team that can be used to discuss specific topics. While everyone on the team

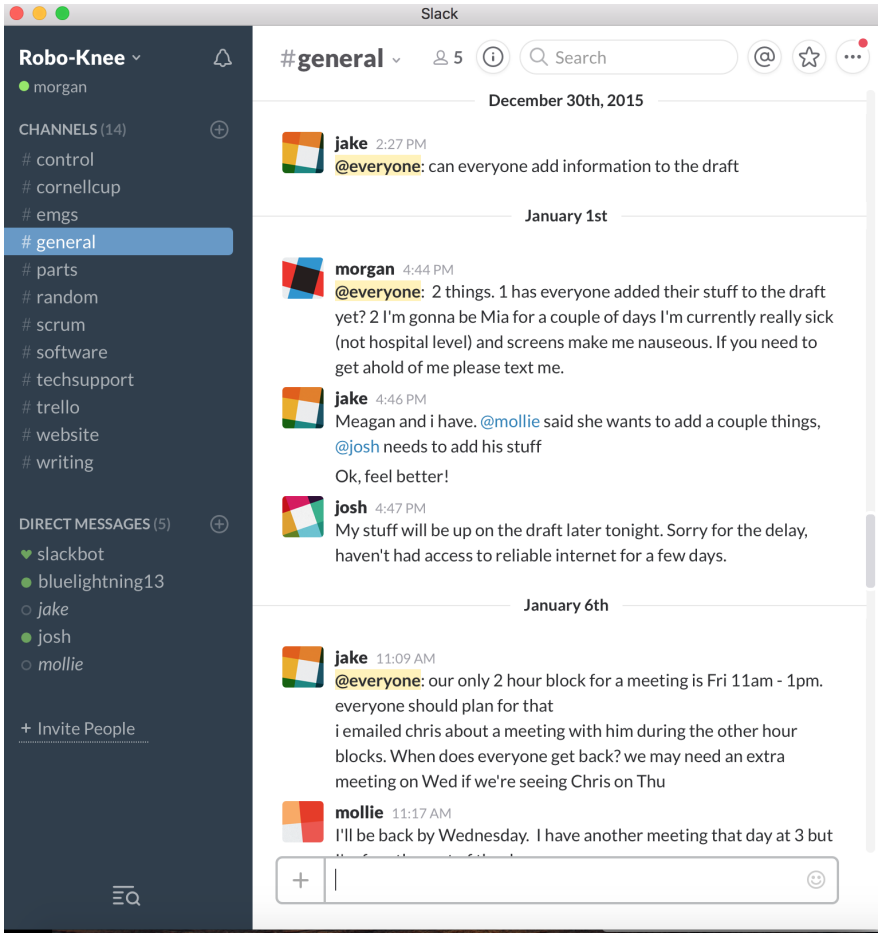

Figure 3: An example of the DAPS Slack Application

is on the general channel one can limit which members are on other channels. This allowed us to create channels for parts of the project such as EMGS and share that channel with only the team members working on that aspect of the project. If another member were curious about that topic he/she could browse through the channel's chats, creating a transparent communication method. By updating a channel, one immediately updates all parties who needed to be informed. One can also tag a person in a message so that they are sent notification even if they are not in a channel. Slack also has push notifications for all mobile devices allowing the team to be immediately updated when something happens. Aside from channels Slack also allows for private communication between two users which allowed team members to ask each other questions not pertinent to channels or for me to connect with the team members one-on-one about specific tasks or actions.

Another benefit of Slack was that videos, pictures, and documents were easily uploaded to the

group and if we felt that a specific message was important we could 'pin it' to save it for later. Slack also allowed us to search for previous messages and keeps a running document library of all of the documents that have been uploaded to any channel. This library can be sorted by which member uploaded it or what file type it was. The main benefit of slack was that within our group it allowed us to almost completely eliminate inter-team email. This allowed the DAPS team to not worry that someone was being left out of the loop and reduced the possibility of losing emails that could potentially have valuable information in them.

2.4.3.2 Trello

Trello is an online kanban board, which was used to track the project's process. On Trello different categories or bins such as to-do, work in progress, and done were created. After team meetings I was charge of updating the Trello board to reflect the work the team was trying to accomplish in the next week. It was then up to the DAPS team to move the cards as they worked on them, for example from to-do to work in progress. Utilizing Trello allowed the team to stay up to date on what other teammates were working on without having to use email or Slack. An example of our Trello board is shown in Figure 4.

2.4.3.3 Email

By using Slack for internal communication, email became mostly used for external communication with advisers and others interested in the DAPS project. To ensure that communication went to the entire team I created several email aliases. Our informal email alias, robo-knee@wpi.edu, was used mostly for external communication where a team member wanted to copy the rest of the group on. Our more formal email alias, DAPS@wpi.edu, was created for emails with our advisers and all communication with the Intel-Cornell Cup. By primarily using aliases instead of individually emailing group members, the group helped eliminate problems of disproportional knowledge among the group members.

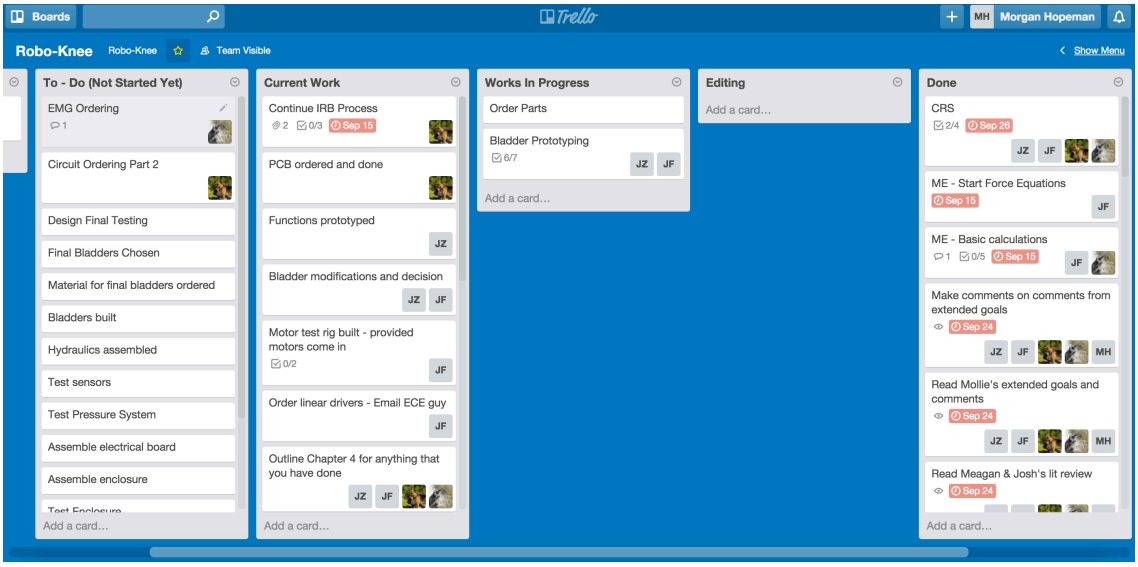

Figure 4: An example of the DAPS Trello Board

2.4.3.4 Google Drive and Google Docs

Google Drive was used as the team's main location for documents, pictures, and videos. While Slack has a section for team documents, it was decided Google Drive was better because of the organizational benefits of folders. The team also decided to use Google Documents as our main location for writing, as it would allow team members the ability to easily edit and share among the team in real time. Using Google Docs made Google Drive an easy storage location. By keeping all of the documents in a central location the team limited the amount of time spent waiting for a group member to share a document or edit a document.

2.4.3.5 Meeting Schedule

Based on research conducted for the literature review I learned that knowledge workers work best if they can work in uninterrupted time periods. As all of the members of the DAPS project were full time students, I realized that the best way for them to not have to spend time adjusting

from different subjects was to schedule one longer meeting, instead of multiple shorter meetings. By having a once a week meeting, the team could spend two hours brainstorming, planning, and addressing conflicts uninterrupted by other work.

I also learned from the research conducted that knowledge workers value where they work and the environment they work in. To provide the best environment during team meetings I booked a library tech-suite so that the team would have a location that would promote work. The tech-suites provide a secluded quite area with helpful tools like the large TV to allow us to project our agenda so that everyone could easily follow along. By limiting the meetings to once a week I also attempted to give the team freedom in when and where they worked the rest of the week. I encouraged meeting as a team or in smaller groups outside of our regular meeting. This allowed the team to plan smaller meetings that were at times that I would think inconvenient, such as at ten at night, but it was when they had the time and energy to be productive.

2.4.4 Conflict and Problem Management

Much of my plan for conflict and problem management came from the idea that every person is different and needs to be treated as such. Therefore, there were some group members that I identified that I would need to talk more regularly with than others. When the team did run into a group conflict I tried to identify the problem and address it quickly. I also attempted to utilize tools like Slack's private chat to chat with members of the group when I was unable to get an in-person one on one meeting. One topic that I stressed at multiple meetings was my willingness to talk or meet with members of the group if they felt anything was ever going awry.

3 Results

One of the most difficult parts of managing an MQP or any knowledge work is the lack of measurable data. Due to the subjective nature of the project, I have shown the results of the project from three different perspectives, a professor grading the DAPS MQP (Section 3.1), the DAPS

team (Section 3.2), and someone outside of the project and WPI (Section 3.3).

3.1 Goals Assessment

I looked at the goals that the team laid out at the beginning of the project, the initial conversations with the professor about the goals for the project, and a time-line assessment for the amount achieved by the team.

3.1.1 DAPS Project Goal Analysis

The DAPS project goal analysis can be broken down into two parts, initial discussions with the professor (project client) and the project goals the team established in D term of 2015.

One of the initial goals established by the adviser was perusing FDA approval. The team quickly realized this goal was unattainable in the short time period of the project. FDA approval requires in-depth IRB testing and IRB medical testing. IRB stands for Institutional Review Board and they are a type of committee used in medical research to approve and monitor testing on animals and humans to make sure that it is ethically sound. IRB testing for the project would have required a finished design and prototype as well as an application to each hospital or facility that the team hoped to test the prosthesis. These requirements meant that the process could not be started until the team had a completed prototype which was expected to be finished by mid C term. As the team planned the completion of the project for the end of C term it was determined that there was not enough time to pursue IRB applications. The team hopes that the design that was created by this project can be taken by another group which could immediately begin the process for IRB approval completing the adviser's long-term goals.

The goals set in D term for our project were broken into three categories, namely main project goals, additional project goals, and reach project goals.

The main project goals were:

1. Develop demand driven design

   (a) Utilize interviews and surveys with doctors and amputee patients (with IRB approval).

2. Improve the design for a more efficient and longer lasting use-time, either with compressed air or a mechanical model if compressed air cannot be improved enough.

3. Evaluate and implement predictive sensors, such as an Surface EMG, and compare to responsive sensors, such as accelerometers.

4. Create a working model of our design which demonstrates the functionality of our project.

   (a) Ensure proper pressure, through rigged testing, so that the leg will not slip out and injuries (e.g. bruising) will not occur.

The additional project goals were:

1. Optimize the system to have a fast, but accurate, response to the user's movements.

2. Running and Stairs

   (a) Identify the motions and forces for running and stair climbing movements.

   (b) Testing for running and stairs.

The reach project goals were:

1. Begin testing on real amputees (with IRB approval).

2. Develop the structure for further demand-driven features

   (a) Incorporate a data-collection system into the prosthetic's software to gather relevant medical information

   (b) Integrate manual settings for user interactions

Based on conversations with the team members I believe that we met three of our four main goals, all of additional goals, and none of our reach goals (Section 4). Therefore we accomplished five out of six of the goals of the project.

3.1.2 Time-line Assessment

The team successfully completed the project in three terms, despite having some project tasks slip in time (Figure 2). In the three terms the team successfully completed: background research, initial design reviews, multiple prototype designs, testing of design aspects, system integration, and the creation and testing of a final prototype. All of the members of the team are also on track to graduate on time.

When I conducted a risk assessment during B term the DAPS team had 5 weeks of slack time remaining at the end of A term and four weeks of slack time remaining at the end of B term.The critical path sum had a total of 24 weeks which showed that there was a high risk of going into D term but a much lower risk of not finishing the project. When I revisited the risk analysis at the end of the project the team had used all of the Slack time but had not gone over.

3.2 Group Outcomes

In order to understand how the team felt about my management of the project, after we had completed final testing, I distributed a survey and scheduled one-on-one meetings with each team member. The survey provided me with quantitative data as well as subjective data on how the team felt I had performed as a manager and how they had performed as a team (Appendix C). I then followed up on some responses and questions in the one-on-one meetings.

3.2.1 Group Conflicts

One way of measuring how successful the project was was to analyze the amount of unresolved conflict in the group. The smaller the amount of unresolved conflict the more successful I was. When discussing conflict with the group members, the team agreed that there was only one major group conflict, which will be discussed more in section 4, which was resolved. After analyzing and explaining the problem and talking with each group member, the entire team understands why the problem happened and know how it would have been prevented if the team were recreating the

project. Additionally, while the conflict was a hindrance to production, it did not prevent us from completing the project and did not delay the project at all, specific features just used more of their lag time. At no point during the project did the DAPS team not know how to progress or have a group conflict that completely stalled the progress of the project.

3.2.2 DAPS Group Satisfaction

I broke down the group satisfaction in my survey into two sections. The first section asked about satisfaction with the project and satisfaction with meeting our initial goals while the second asked about satisfaction with the management of the project and how likely the team would be to recommend a management major to work with other MQP projects.

3.2.2.1 DAPS Project Satisfaction

All of the members of the team said that they were satisfied with the amount of work that was completed on the project although two mentioned that they wished we could have scaled the scope of the project to focus on a fewer components. The DAPS group was also divided on how well they met the initial project goals. Half of the team said that they were satisfied with the goals the team set and the result of those goals, while half said that they felt that the team did not meet the initial goals. The half that said the team did not meet the project goals thought that it was partially due to knowledge that the team had assumed at the beginning of the project based on last year's project. For this reason those team members wished that the goals had been remade at the end of A-term when all of the background research was complete.

3.2.2.2 DAPS Management Satisfaction Along with their satisfaction in the DAPS project I asked the members of the group to rank their satisfaction in the management of the group. The scale was from one to ten where one was detrimental to the project and ten was perfect management of the project(Appendix B). The average of the scores received was 8.5. I also asked how likely the DAPS team would be to recommend student managers for other MQPs. The average response was an 8 out of 10, meaning that the team would recommend a student manager to other teams.

3.3 Intel Cornell Cup

The Intel Cornell Cup is a ”college-level embedded design competition” [Intel, 2015] meant to ”empower student teams” to be come inventors of embedded technology. Previous WPI teams have entered the Cornell Cup and placed in the finals with a WPI team coming in second in 2013. DAPS applied to the Cornell Cup at the recommendation of JZ, one of the group members, and made it through the initial screening into the semi-final round. DAPS then gave a video presentation on their project and recently proceeded to the final round of the competition, which will be held in early May. This shows interest in the project from other institutions and people in industry outside of the project.

4 Discussion

This chapter discusses my literature review (Section 4.1), the members of the DAPS team (Section 4.2), my role in meetings (Section 4.3), project challenges (Section 4.4), the project goals (Section 4.5), and student interest in my project (Section 4.6).

4.1 Literature Review

It was necessary to research topics that directly impacted the management process such as the role of managers (Section 4.1.2), management of knowledge workers (Section 4.1.3), and common team problems (Section 4.1.4). However, it was also necessary to research the DAPS project topics (Section 4.1.1) in order to make meaningful contributions to their discussion and successfully manage their MQP Process.

4.1.1 Brief Summary of DAPS Literature

In order to appreciate the significance of this project, one must first understand why Dynamic Adjusting Prosthetic Socket (DAPS) is important. Despite improvements in lower limb sockets over the past years, the current sockets on the market still have many problems facing them. A

residual lower limb can fluctuate about 10% in size over the course of one day and even small weight gains of 5 to 10 pounds can cause changes in the fit of a socket [Legro et al., 1999][Maguire and Boldt, 201 These shifts in socket fit can lead to health problems such as pressure sores, and back and hip problems as well as users of the sockets having to replace the socket as frequently as every two years [Mak et al., 2001].The current market for lower limb prosthetic sockets can be grouped into three main categories that describe the method by which the limb is suspended in the socket. These categories are vacuum sockets, mechanical sockets, and inflatable bladder sockets.

Vacuum suspension sockets utilize a prosthetic sock that forms an airtight seal inside the socket. A pump is then used to remove the air from between the limb and the socket providing either positive pressure when standing and negative pressure when the limb is in motion or a constant negative pressure on the limb [Beil, 2002]. This process has the benefit of helping to control residual limb volume aiding in maintaining a better fit and reducing general discomfort and pain [Street, 2007]. Common problems with the vacuum socket are poor initialization causing potential fit problems, additional adjustments in the forms of additional socks or bladders for larger limb volume changes, and sweat accumulation and allergic reactions to sock materials [Legro et al., 1999].

Mechanical sockets can be divided further into two classes of sockets, adjustable and static systems. Adjustable sockets are manually adjustable systems that provide pressure on the limb. The benefit to this system is that the socket is adjustable by the user and can account for fluctuation not only across a day but also across months or years. The method of tightening varies depending on the brand with such systems as straps and dials used by LIM Infinite and Revolimb. Two problems with mechanically adjustable sockets are over tightening by the user, potentially cutting off blood flow, and constant manual input, which may be tedious or difficult in some situations. Additionally, manually adjustable sockets require the user to constantly manually modify the socket fit. This process can be time consuming and tedious for users.

Static sockets utilize a fixed socket design so that no adjustment is needed. One type of static socket is the Compression/Release Stabilized (CRS) socket, which applies continuous pressure to the residual limb. The CRS socket divides the leg into areas of compression and release where the

release sections provide relief for the compressed tissue. One benefit from this design is that it allows little to no delay between moving the residual limb and moving the prosthetic; this allows the user to expend less energy while moving and have greater mobility of the limb [Alley et al., 2011]. The problem with static mechanical sockets such as the CRS socket is that the constant compression can lead to problems such as limb deformation and blood circulation problems. Static sockets can also become problematic if the residual limb shrinks or grows due to situations such as weight loss or gain.

Bladder controlled sockets use pneumatic or fluid systems to help suspend the residual limb inside the socket. Most bladder systems are inserts into other existing sockets to aid in filling reduced limb volume. Some designs incorporate the pumps into the socket design itself such as *Pump It Up!*. In both cases users manually pump up the bladders to the desired level or deflate them if the pressure is too high. Air bladders have distinct problems because of the compressibility of air. Due to the compressibility the bladders have to be filled to a higher pressure than actually needed to retain stability. This increase in pressure can cut off blood flow or cause tissue damage similar to the CRS socket [Sanders, 2001]. Fluid bladders provide better support as they can operate at a wider range of volumes so as to provide a more comfortable fit. Problems with a bladder system can include not being able to adjust one bladder individually, and the delay in the system when moving from sitting to standing or walking to running.

To combat the problems facing the different sockets, the DAPS team looked to combine the CRS and bladder sockets to gain the benefit from the CRS socket while mitigating the potential health problems provided by having constant applied pressure. The bladders allowed the team to control the amount of pressure on the residual limb and adjust that pressure throughout the day to minimize sores or other potential blood flow problems. Additionally, by utilizing bladders the team introduced a socket that adjusts to the fluctuation of residual limb loss or gain over time. For further information on the DAPS Project please see Appendix A for their paper.

4.1.2 The Role of Managers

One of the first topics I researched was the role managers play in organizations. I needed to define for myself what my responsibilities were as the manager of the DAPS Project. When someone first says ”manager”, the first thoughts that some people have are about check in meetings that waste time, the barrage of ”when2meets” or ”outlook invites”, or the constant stream of emails asking what one has accomplished. It was with these thoughts that I first began my MQP. The first person to inform me of my lack of understanding was my adviser. When Professor Towner first informed me that I was the CEO of the DAPS teams project, I mutely nodded my head in agreement pretending to understand. After three terms or research and practice I believe I now better understand the role of a product manager.

To better define my position after the discussion with my adviser, I researched many different types of managers. After completing initial research I narrowed it down my position to either a product manager or a project manager. The line between product and project manager can often be blurred as sometimes product managers can be asked to perform jobs that would usually be run by a product manager. The best description of the difference between the two positions was that the product manager deals with the why and what of a product, why it should be made and what it should do, while the project manager deals with how to accomplish those goals on time and under budget [Haaff,]. I have summarized in a table below some of the different roles and responsibilities each position is responsible for.

Project Manager	Product Manager
Budget	Strategy
Delivery	Releases
Resources	Ideation
Capacity	Features
Cross-Team Organization	Organizational Training
Problem Resolution	Profit and Loss
Status Updates	

Figure 5: Comparison of Responsibilities of a Project and Product Manager

Through my research, I realized that I had to be both the project and product manager for the

DAPS team with a higher focus on the project manager role. To come to this conclusion I created a list of my duties (seen below) as the DAPS manager and compared them to Figure 5. Once I had clearly defined the role, I researched many management techniques and pitfalls to better understand the impact that I could have on my team. The quotes that most clearly defined my role and helped me shape my position were, ”The managers function is not to make people work, but to make it possible for people to work” [DeMarco and Lister, 1999] and ”to articulate the common policy and to organize our shared goals” [Edgar et al., 2015]. Utilizing these definitions I tried to establish a management plan that would allow me to facilitate rather than hinder the DAPS group.

Primary Duties as the Manager of the DAPS MQP

- Product strategy Prioritization of different parts
- Team organization Scheduling, running meetings, sending out reminders, etc
- Budget Make sure one is not exceeding the given budget
- Deadline Delivery
- Problem resolution
- ”Customer approval Assure that the group meets their Professors Requirements
- Continuously look at overall vision Including the physical project as well as writing

4.1.3 Management of Knowledge Workers

The next aspect of the project that I wanted to research was what kind of workers the DAPS team was. I came to the conclusion that the best term for the DAPS team of engineers was ”knowledge workers”. A knowledge worker are defined as any worker whose job involves a significant amount of gathering, creating, and dissemination of knowledge [Edgar et al., 2015]. It is also estimated that knowledge workers make up more than 40% of the US workforce [Matson and Prusak, 2010] I felt that this best fit my team because the primary goal of the MQP is to research, collect, and

transform knowledge into a new, previously unthought-of form. While the DAPS MQP did aim to have a prototype, the primary goal of any MQP is learning and thus if, due to time, budget, or other constraints, DAPS was not able to finish the prototype it would still be able to achieve an acceptable grade. Because the focus of the DAPS MQP was the design of the project, the team was chosen for its knowledge of different fields that would allow it to design the best system possible. Things such as their ability to use the machine shop were not deciding factors on the group.

As more of the work force moves into knowledge work, more research is being done into the field. Unfortunately, no one has had a major break through that can drastically increase knowledge worker productivity. However, there are key values that have been identified to help boost productivity among knowledge workers. These values are autonomy, value as a teammate, trust, respect, motivation, and support [Edgar et al., 2015]. Autonomy means that knowledge workers like to be able to choose where, when, how, and on what they work. The more control they are given over their work the better they perform. Knowledge workers need to feel valued as teammates. If a knowledge worker feels that his/her work is under appreciated he/she is more likely to leave or care less about a project, making the performance suffer. Trust and respect go hand in hand and are important both to give and receive from knowledge workers. If knowledge workers do not trust each other, they are not likely to share knowledge as easily thus making collaboration hard. One important value knowledge workers hold is self-motivation [Mohanta and Thooyamani, 2010]. Self-motivation is how much the individual cares about the project and can prove difficult to identify. Similar to value, if knowledge workers do not feel supported by their team or company they are less likely to perform as highly because they feel that their contribution is not as important.

To adapt to this I tried to establish that there would be minimal team meetings (Section 2.4 Project Approach) provided that the work assigned at those meetings was being accomplished. This meeting method is also how I chose to establish trust and respect. As we got later into the project and deadlines started slipping, I talked with the team and we decided that on top of having the items of each member on the Trello board (Section 2.4 Project Approach) I would add a check-in via our messaging application half way though the work week. Value as a team member

and support was harder to establish in a group of our size and resources. What I attempted to do was make sure that the entire DAPS group knew that they could come to me with any problems and I tried to make sure it was established that they could also go to each other if they needed help outside of their field. I also attempted to check in on each individual group member. As for establishing value of group members, most members felt comfortable with the group initially. There was one exception to this where a group member felt that her value was less than that of the rest of the group. This group member later had problems committing the amount of time/effort to the group, which I believe may have partially stemmed from that feeling of less value and knowledge.

One of the most difficult problems of managing knowledge is a unit of measurement. If I were managing factory line workers, each worker's skills could be measured by the speed or rate at which they produce the manufactured item. But how do you measure thought? This lack of measurement is a problem not only in small groups but also in industry (The mysterious art and science). If I were in Human Resources, how would I choose to evaluate the DAPS group and how much each of them contributed. Much of what knowledge workers do is think, and how does one measure how much one has thought about something and if the thinking were in a serious manner. One of the theories of knowledge work management is hire smart people and leave them alone [Davenport et al., 2002]. This technique is actually used frequently in industry [Davenport et al., 2002] due to the importance of the workers and the seemingly black box around what they do [Davenport, 2013].

For the most part "hire smart people and leave them alone" (The mysterious art and science) worked well with the management theory I stated earlier, "The manager's function is not to make people work, but to make it possible for people to work" [DeMarco and Lister, 1999]. As I had the opportunity of helping to recruit two of the four members of the group and was confident in the ability of the initial two from previous project experience, I was satisfied that I had a good team to base the project on. For the most part I judged how well the project was going based on the satisfaction of the DAPS group with the work being done and the relative adherence to the time-line I worked to create with them. The one time I did encounter a problem with this method was when

one of the DAPS group mates was singled out for not doing as much work. While there were a few warnings that I missed, the main reason I failed to spot the growing tension was that the work was mostly theoretical in nature and it was hard to judge how much had been accomplished. While I had given the benefit of the doubt to the teammate and believed the work was in progress, the rest of the team began to feel otherwise. This tension eventually led to a confrontation in which the teammate admitted to having done very little work on the item and it was taken over by other members of the team.

4.1.4 Identification of Common Team Problems

The final key piece of research I conducted before I felt ready to begin the project was on what common problems plague teams and I concluded there were three main areas of potential problems time management, communication, and faulty management.

4.1.4.1 Time Management

Time management is a common problem for teams regardless of the field. I found that it could generally be broken down into two problems 'workaholics' and Parkinson's Law. Workaholics are people who put overtime into a project, they stay up late to make sure something gets done and just because someone has a bout of workaholism does not mean that most of the time they can not fall into the category of procrastinators [DeMarco and Lister, 1999]. Initially, workaholics may seem like a great member to have on the team, they are willing to put in the long hours to get things done, meaning they are not going to be the people who will sit around and not do anything on the project. However a constant workaholic can create more damage than someone who is unwilling to put any effort into the project at all. In college overtime may seem like a nonexistent problem, the students do not get paid for specific hours so how could they work overtime. What I mean by overtime is time spent outside of regular work hours. I would say this is around 10AM to 11PM with variance depending on the person, or working to the detriment of other activities you do. There are two main problems with putting in overtime. The first is that it can negatively affect

sleep and, thus, productivity [Dahlgren et al., 2006]. The second is that overtime can negatively affect group dynamics and willingness to work over a period of time. I have seen many examples of overtime at my time at WPI. The most frequent are when students are sleeping in a lab to spend more time to finish a project. While at the time this may seem like a good idea to get things accomplished. However, it becomes detrimental to the students productivity and mental health. This can also create burnout, an acute stress disorder or reaction characterized by exhaustion resulting from overwork, with anxiety, fatigue, insomnia, depression, and impairment in work performance [Andrew M. Colman, 2015], which is a surefire way of not accomplishing one's project goals.

One of the trickiest parts about overtime is not the risk to the individual; it is the imbalance it can create in the group. If group members have to go because of a prior commitment while the rest of them stay to accomplish work the first time, everyone will say they understand and let it go. But if it happens multiple times, the team will become more and more estranged from the members because the member is 'doing less work' [DeMarco and Lister, 1999]. The person or people who are not pulling the long hours will slowly become estranged from the group and will cause the group to be less productive, less trusting, and to value less the member who can't commit to the overtime [DeMarco and Lister, 1999]. As trust and group value are aspects that are highly valued by knowledge workers, [Edgar et al., 2015] this could have a drastic negative impact on their future performance as part of the group.

The second main problem of time management is Parkinson's Law. Parkinson's Law says work expands to fill the time available in which to do it [par, 2009]. This is a common problem with MQPs even though it shouldn't be. It has even been recognize so that there is no charge for taking MQP as an extra class in D term your senior year. Parkinson's Law is not based on any actual evidence. The biggest problems with Parkinson's Law arise when managers use it as an excuse or treat their workers as though they are only going to follow the law, as though everyone will wait until the last possible second to do anything [DeMarco and Lister, 1999]. One common response to Parkinson's Law is to set tight deadlines thus moving the scramble to finish earlier. However, "when the schedule for a project is totally unreasonable and unrealistic ... morale drops" [Jones, 1986].

Studies have shown that not scheduling can actually create the most productive environment in comparison to environments where the engineers set deadlines, managers set deadlines, or they worked together to set the deadlines [DeMarco and Lister, 1999]. Unfortunately, as most MQP advisers would not be happy with the response of ”it will get done” with no clear deadlines I tried to leverage the fact that workers are more productive when they set the deadlines instead of when a manager sets them (Section 2.4 Project Approach).

4.1.4.2 Communication

Communication is a common problem in groups regardless of size, location, or industry. Communication is such a large problem because it covers everything from how one conducts meetings, to the tools one uses, to how one treats co-workers. Communication is also what allows groups to take calculated risks, create more fluid job roles, and facilitate conversations that enhance the learning of individuals and the group as a whole. One of the hardest parts of managing knowledge workers is getting them to disseminate their knowledge or research to others.

Workers who face contextual barriers may struggle because of difficulty assessing colleagues' level of expertise or apply recommendations because they do not feel that the fields are compatible [Matson and Prusak, 2010]. This can lead to dismissal of ideas or colleagues and can create tensions within or across teams. The best ways to break down this lack of communication are a combination of facilitating fluid jobs roles and conversation [Matson and Prusak, 2010]. These conversations can help with another known problem among knowledge workers, which is that they want to experience continuous learning [Drucker, 1999]. By having more fluid job roles and promoting communication one allows an opportunity for the members of the team to learn something about another field or about their own work. The difficulty with having role rotation is if one puts someone in a situation that is out of his or her depth, it could cause the member to shut down performing worse than assigning it to someone who knew more about the project. As a manager is it my job to asses the strengths and weaknesses of each member and arrange tasks that allowed them opportunity to grow without putting them out of their depth

4.1.4.3 Growing Productive Teams

One aspect that is difficult for managers of groups is not killing your groups' productiveness. Now all of the common problems I have mentioned to this point can be mitigated or made worse by a manager, but this section is on ways that a manager or managers management style could kill a groups productivity, Peopleware calls this "teamicide". To become really productive teams have to jell, they have to get through all of Tuckerman's steps before performing (Form, Norm, and Storm see figure 6 for more details) [Tuckman, 2001]. Unfortunately groups rarely get to the performing stage or can reach and leave the performing stage quickly if mismanaged.

Table 1: Stages of Group Development

	Group Structure The pattern of interpersonal relationships; the way members act and relate to one another.	**Task Activity** The content of interaction as related to the task at hand.
Forming: orientation, testing and dependence	Testing and dependence	Orientation to the task
Storming: resistance to group influence and task requirements	Intragroup conflict	Emotional response to task demands
Norming: openness to other group members	Ingroup feeling and cohesiveness develop; new standards evolve and new roles are adopted	Open exchange of relevant interpretations; intimate, personal opinions are expressed
Performing: constructive action	Roles become flexible and functional; structural issues have been resolved; structure can support task performance	Interpersonal structure becomes the tool of task activities; group energy is channeled into the task; solutions can emerge
Adjourning: disengagement	Anxiety about separation and termination; sadness; feelings toward leader and group members	Self-evaluation

Figure 6: Tuckerman's Stages of Group Development

Part of the problem with getting to perform is that you can not guarantee it will ever happen for a group. There is no simple formula that works on all groups, or even most groups. Sometimes it comes down to pure luck that the team does not clash in ways that can be managed and mitigated. I wanted to look at some of the ways that bad management can kill teams. Peopleware mentions a list of but many of them, such as physical separation, fragmentation of time, and bureaucracy

I have little to no control over because we are all students taking at least two other classes while working on MQP not to mention the number of clubs the DAPS team itself was in. So I focused my research on two areas that I felt that I could affect and make a difference in ”defensive management” and ”phony deadlines” [DeMarco and Lister, 1999].

Defensive management has multiple names but the basic concept behind defensive management is that one does not trust those who work under them. Another term for defensive management is micromanagement or ”when influence, involvement, and interaction begin to subtract value from people and processes” [Chambers, 2004]. This kind of management style can lead to many problems. As previously mentioned, knowledge workers highly value trust in them [Edgar et al., 2015]. So when one takes away that trust, team members will understandably lose trust in both the manager and can also cause them to lose trust in their teammates. Additionally, this loss of trust creates a cycle where one has to define tasks in more and more detail. It can also cause the manager to become overwhelmed with the work of checking things off such that the manager becomes the bottleneck of the process [DeMarco and Lister, 1999]. With the manager signing off on everything, the team also becomes more risk adverse, which can lead to projects becoming less successful than they could have been.

As I mentioned in time management, false deadlines can be detrimental to a group. More so than tight deadlines, false deadlines can promote distrust in groups [DeMarco and Lister, 1999]. The biggest problem with false deadlines is that everyone knows they are false and everyone knows that when the deadline is not made it will be pushed back again. This creates a damaging cycle when, if some of the deadlines are false, how does the group distinguish between those and deadlines that actually have a hard stop date, for example a release of software will go out that day. False deadlines also promote the idea that the manager believes the team will not do work unless under pressure and, therefore, does not care about the team as people. One of the ways I tried to avoid creating false deadlines was by trying to not set deadlines without the consultation of the group. That way when a deadline was a hard stop date they all knew why and knew that it couldnt be moved without repercussions to the team.

4.2 About the DAPS Team

One of the things that struck me when conducting research on management and knowledge workers was that the two aspects that seemed to be repeated over and over again were ”find good people and treat your team like people with brains in their heads”. It doesn't seem surprising to me that team members would want to be treated as people and it also doesn't surprise me that it would have to be stated and restated to new managers. Managers are often brought into the company in one of two ways, they can be hired from outside the company or promoted from within. The managers who are hired from outside the company should have some kind of management experience, either through previous work or schooling, such as an MBA or business degree. These people often enjoy management and tend to understand the way people work because they have studied them in some manner previously. This by no means make them better than someone promoted from within. The key difference is that someone promoted from within may not have that experience interacting with people which could explain the reiteration that you must treat team members like people. Below is my further background and analysis of each team member and the role each played in the project. In order to make it anonymous I have omitted their names.

4.2.1 JF

JF is a senior double major in mechanical and robotics engineering. He is also a member of Alpha Phi Omega, a service organization, and was inducted into Rho Beta Epsilon, the robotics honors society on campus, during the final term of the MQP. JF was one of the two members, the other member being JZ, already on the MQP team before I joined. JF had worked with JZ on previous projects and so had a working relationship. One of JF's largest problems was starting any of the work assigned to him. JZ provided a good partner for this because he would drive JF to work by planning times they were going to go work. Unfortunately, this often led to JZ being more responsible for JF's work than JF himself.

One of the hardest elements I had with JF was convincing him to do the work or that the work he was doing was important because it could create a bottleneck for someone else. When JF did

focus on the work that he needed to accomplish, it often was accomplished well and needed only minimal editing or fixing. JF is the group member who would have benefited the most from the consequences about slipping deadlines. If I had had a clearer understanding of how to appropriately motivate JF I feel that he would have been a more productive team member. Of all of the group members, JF had the least burnout at the end of the project which made him valuable in designing a list of final testing materials. While JF was less motivated to start work than others he was not adverse to working and regularly made himself available if other members wanted to work or needed help. He also volunteered to take on more work several times when he could have suggested other team members.

4.2.2 MH

MH is a senior double major in robotics and electrical computer engineering, minoring in Chinese, who is planning to complete a masters in robotics next year at WPI. She is an active member in SOMA, one of the martial arts groups on campus, and WIRE, women in robotics engineering, as well as a tutor in the robotics and electrical departments. MH constantly took on new challenges and was never afraid to speak her mind to me which made her an invaluable member of the team. MH gave me insightful feedback any time I inquired as to how I could improve and was not afraid to tell me when she thought I had done something incorrect as a manager.

MH's two challenges were her other courses and not having enough time. As she is pursuing her masters at WPI she was often taking graduate level courses while working on MQP. Because the graduate level courses often took more energy than undergraduate level courses and would occasionally cause her to lose focus on the MQP, especially near the end of B term when the grad course projects were finishing. This also caused MH to have a high level of burnout at the end of B term, though she was able to recover by the beginning of C term. MH would have preferred to limit the scope of our project and do more design than design and prototyping. This is because it would have allowed much more time for research and prototyping of specific parts, such as prototyping

the printed circuit board (PCB) as a bread board beforehand, which she feels like would have made the project better than some of the rushing of parts that we had to do. MH took on many of the hardest aspects of the project, EMG signal analysis and designing/creating the PCB, and did them without complaint always providing high quality work.

4.2.3 MM

MM is a senior bio-medical engineering major with a bio-mechanics focus, pre-med, with a minor in international studies. She was also on the Executive board of her sorority Alpha Gamma Delta, in the ”Skull” honors society, and also an active member in four other clubs on campus. During MQP she took eight classes and a PE class every term. Due to MM’s plethora of other activities, including applying to graduate school, she was one of the less proactive group members. While wanting to contribute her part to the project, MM often fell behind in the work she took, due to her lack of time and other commitments. MM also got a concussion at the end of A term which put her behind on work and made it hard for her to be motivated when coming back to the project.

MM was underutilized during the project, at least in part, because I misunderstood her skill set. MM’s concentration in bio-mechanics would have proved useful to more of the bladder analysis and creation than to the EMGs, which is more of a bio-medical instrumentation focus. MM’s biggest problems arose from lack of self confidence and lack of communication. At the beginning of the project MM approached me, concerned that she did not know enough to be useful to the MQP group, and while I reassured her that she was valuable member, and carried that concern with her throughout the project. This fear of not being useful, coupled with her lack of time, made MM self conscious about not completing tasks which lead to poor communication about tasks. Her self consciousness, also led to her occasionally taking on more than she could handle resulting in her pulling late nights to try to get her work done. These late nights coupled with the amount of work from other classes and clubs resulted in faster burn out than other group members.

MM is the group member who would have benefited most from one-on-one meetings (Section 5). With one on ones I would have been able to identify MM’s strengths earlier in the project,

caught her habit of taking on too much work sooner, and been able to provide her with more targeted help in the areas she struggled with. Despite all of the problems that MM had and facing burnout, she consistently put effort into the project and did not ever stop working completely.

4.2.4 JZ

JZ would easily have filled the role of team manager if I had not been present on this project. JZ is a senior robotics major with a minor in computer science. During the MQP Process he took six classes, one of which was required for his minor and five of which were requirements to graduate. He is also a member of Rho Beta Epsilon, the robotics honors society on campus, a Crimson Key tour guide for the school, and an undergraduate teaching assistant for three robotics classes, robotics courses 2001, 3001, and 3002. He was the most enthusiastic team member and cared the most about the project and its success. He drove the DAPS team entry into the Intel-Cornell Cup and led the management for the deadlines for the competition.

JZ was an invaluable team member because of his desire to drive the project to success. There were multiple times where, because of illness or conflicts, JZ stood in for me to lead meetings. JZ had an incredible work ethic that coupled with his drive inspired other team members to also be productive. However, it was also his drive that led to smaller problems with the group. JZ would often take things upon himself if he felt that they were not getting done or done in the time frame that he felt was necessary for the good of the project. By taking on extra work, either voluntarily or from another team member, he would overtax himself. This also led to conflict with other team members when something that they were working on affected his ability to work on the code or a task assigned to him. JZ almost never missed deadlines and, thus, when others fell behind he would get irritated at the them. This led to the major conflict that happened within the group (to be discussed later). Overall, JZ was the most productive group member and a fantastic teammate. JZ is hoping to continuing robotics somewhere in industry next year.

4.3 Meeting Management Synopsis

In order to breakdown my role during our weekly meetings I divided the work that I did into different topics that I did during each meeting/week.

4.3.1 Scheduling

Before a meeting could happen I needed to schedule a time and location. To do this at the beginning of each term, I sent out a when to meet to our team to find general availability. We met for three scheduled hours a week, two hours once a week as a group and another hour with our advisers. To ensure that the group could consistently meet I reserved the times of our meeting with everyone at the beginning of the term. I then booked rooms and distribute the location of our meetings every week. I was also responsible for finding a time and location if we needed any additional one-hour meeting times to cover something that we do not have time to go over in our weekly two hour meeting.

4.3.2 Meeting Agendas and Minutes

Before each meeting started I distributed an agenda that I later took minutes on. I tried to distribute the agenda the day before so that other group members could add items that I might not have thought of. The agenda I initially sent out had topics that I knew need to be covered such as a review of action items from last week and planning work for next week. Action items were a device to tell meeting members what the team was working on right away. They allowed anyone who missed a meeting or forgot what they needed to do from the meeting to quickly look at the minutes and know what they needed to accomplish. The action items always referred to things that need to be accomplished by the next meeting.

In order to successfully plan the next week of work I would bring up the topic of planning and facilitate the discussion, but rarely specifically assign tasks to members. Because I allowed members to determine what they needed to get done in the next week they felt more motivated to accomplish the tasks and only assigned themselves a workload that they felt they could accomplish.

One way I facilitated the discussion was by bringing up topics that were on our Gantt chart that may have been forgotten.

In addition to sending out the agenda I took minutes for each meeting and ensured that meeting minutes were placed in the correct folder on the Google drive. This allowed any group member to find and easily access the minutes to review what we had talked about (Appendix B).

4.3.3 Facilitate Discussion

One of my most important contributions to the team was facilitating team meetings. Facilitating meant that I started the meeting, decided the order the team covered the agenda, decided when to move on to the next topic, and brought us back on topic if we start wandering into the weeds. As the facilitator I made sure that action items were covered first, because that informed the whole group of what has been accomplished in the last week, and that planning next week was talked about last. By planning the next week at the end of the meeting the team did not need to add anything to our to do list later in the conversation. This also let all of the group members leave with what they need to do fresh in their minds.

4.3.4 Facilitate Paper Writing

Each of the engineers on the team was often focused on the work that needed to get done within the next week. This meant that I was often the one to define writing deadlines and goals to make sure that they were talked about at the appropriate meetings. In the final survey (Appendix C) multiple team members mentioned that they thought I drove much of the paper writing.

4.3.5 Transfer Meeting Information to Trello

As mentioned in Section 2 it was my job to update the Trello board after every meeting. This meant creating cards, putting them in the appropriate bin (to do, work in progress, etc), assigning the appropriate people, and setting due dates on the cards. We also used our Trello board as a scrum-ban board for the most part. Scrum-ban is an Agile combination of scrum an kanban that

pulls from to-do until done. I also used Trello to help me protect against defensive management, mentioned in section 4.1.4. By making the team update the tasks, I could keep track of our goals for the week instead of having to constantly check in to see if a task had been done. This allowed me to be more hands off and less likely to slip into micromanagement.

4.3.6 Scrum Meetings

In C-Term, the last term of our project, the team felt that they needed more regular check-ins to keep everyone on the same page and to ensure that no one was falling behind on the work as we reached the end of the project. JZ suggested Scrum meetings to help fill this gap as mentioned previously. Scrum is an Agile framework based on the idea that things happen, customers regularly change their mind or things get in the way, and the best way to deal with that is to plan for it happening. Scrum uses daily stand-up meetings where each team member explains what they have accomplished since the last scrum to promote the sprint goal, what they plan to accomplish before the next scrum to promote the sprint goal, and any problems they have encountered. The sprint goal is a longer term goal, such as add a feature, and is determined at a sprint meeting. There are three main roles in scrum the product owner, the scrum master, and the team. The product owner would be the product or project manager and is in charge of the bigger picture of making sure that the goals everyone is working toward are valuable. The Scrum Master is in charge of running the scrum stand-ups. The stand up meetings are time boxed to 15 minutes and the job of the scrum master is to ensure that the meeting starts and ends on time and to facilitate the conversation so that it stays on task. The scrum master is also in charge of removing impediments to the team to make them more productive. As the project manager of the group, I took on the role of both the scrum master and the product owner. If there was a larger group of management students interested in doing a project like mine I would suggest dividing the roles of scrum master and product owner. Scrum was fairly successful in that we accomplished many goals relatively quickly. One thing that was difficult about using scrum was there were days where team members reported that they were not going to do any work due to tests or other projects. While this was useful to know, it sometimes

made group members more anxious about reporting doing nothing, or sometimes miss report how much they could accomplish before the next sprint. This was one of the reasons I had not chosen to use scrums at the beginning of the project along with the worry of burning out my team too quickly.

4.4 Project Challenges

I have already mentioned the individual challenges I had with the members of the DAPS team but I wanted to briefly acknowledge and explain the one conflict that the group had in more detail. There was only one main team conflict and it had to do with work not being accomplished. At the end of B term, JZ and the team confronted MM about EMG signals processing algorithm which was assigned fairly early in B term and had not had any movement during the term. When confronted, MM admitted that she had not understood the research behind the algorithm and, thus, had none of the algorithm done. At this point the team decided that JZ and MH should complete the algorithm and take away from MM. When this had been decided JZ also said that he wasn't sure what MM's contribution to the project would be in C term as the algorithm was meant to be one of her main contributions. This made MM upset and feel like she was not a valuable team member and that her contributions to the project had been negligible. This confrontation also made MM defensive going into C term whenever someone would question something that she said. I talked with her about being defensive and why it happened as well as about her value to the group. I also talked with JZ about the confrontation, as to why he had not alerted me to the confrontation beforehand, and about the whole problem. These discussions diffused later conflict between the team and illuminated why the conflict had happened and ways that it could have been avoided.

4.4.1 The Problem

The problem could be dissected into two main parts the first was knowledge of the topic and the second was communication of difficulty. When we began looking into EMG signal algorithms, the method we would use to detect if a person was moving or not moving, we believed that it would

be a fairly simple algorithm. I knew that MM had some background in code for her major and felt that she could produce an algorithm either from previous knowledge or through research. What we did not know was how complicated the EMG signal analysis was and how much of it required a working knowledge of electrical signal analysis, which MM did not have. Looking at the material we have since discovered MH and JZ believe that MM should not have been initially given the research.

The biggest problem with the task was not who it was assigned to but that MM did not reach out for help. When asked about why she did not reach out she explained that she felt that she should be able to come up with the algorithm on her own and, when she could not, she felt unintelligent. When she went to look at the literature she only became more lost in the talk of signal analysis. By the time that she reached the conclusion that she was in over her head much of the time had passed and she did not want to admit her failure at part of the project that she felt she should understand. This lead her to not reaching out to me or any of the other group members for help. Additionally while all of this was happening MM began communicating less internally to the group. The combination of the algorithm holding up part of the code that JZ was working on and lack of communication worried JZ and prompted the confrontation.

4.4.2 The Confrontation

The worst part of the conflict was not the problem itself but the confrontation of the problem. JZ decided to confront MM shortly before one of the final group meeting of B term and, thus, gave me no warning. Because I had no warning, I was not able to diffuse the problem before the confrontation happened. The biggest thing JZ did incorrectly in the confrontation was make MM feel attacked. By blaming MM for not getting things done, instead of talking about why things were happening, JZ made MM immediately shut down. What MM understood from that meeting was that her fear was true and that she was not a valuable member of the group, that she had contributed nothing of significance, and that she had nothing of significance to contribute to the rest of the project. JZ also made it sound as though MM was the reason the team was being held up

and the only member slipping on deadlines. She was not, in fact, holding the team up and almost every member of the group had had major slips in deadlines in B term. I tried to mediate JZ's accusations with notes that the team had had slip ups and tried to get MM to tell us what she had found and why she was struggling to make it more of a conversation. By the time I had managed to say that, MM had shut down.

After the confrontation was over I had a series of texts with MM where she apologized for being a horrible team member and I attempted to assure her that she was a valuable team member and that there would be plenty of opportunities for her to work in C term. I also had a discussion with JZ about the problems that led up to the confrontation and told him to consult me if he ever felt like a confrontation needed to happen again with any group member. After the confrontation there was also a clear division between MM and the rest of the team for the rest of B term and for the first weeks of C term.

4.4.3 Potential Prevention Method

From talking with all of the group members the solution that the entire team agreed would have helped was individual one-on-one meetings between me and the members of the DAPS team. One-on-One meetings would have let me hone in on MM's problems with the algorithm earlier. I then could have figured out how to get her the help she needed or re-assigned the task to JZ and MH earlier and had MM move to a different part of the project, such as helping JF with the mechanical system, or looking at how to attach the EMGs to the user of the socket. If I still had not caught MM's discomfort with the algorithm, it would have let me talk to JZ and catch the confrontation earlier, allowing me to better prepare and lead the confrontation instead of JZ. If I had led the meeting in which the confrontation had happened, I could have tried to have a more productive discussion.

4.5 Discussion of Project Goals

4.5.1 Initial Project Goals

In this section I broke down the project goals individually and accounted for how we met it or why we did not meet the goal.

4.5.1.1 Main Project Goals

1. Develop demand driven design

    (a) Utilize interviews and surveys with doctors and amputee patients (with IRB approval).

The goal of creating a demand driven design by utilizing interviews with doctors and patients was unsuccessful. When we began the project, the team believed that the background research done by the previous year's team was correct. Using this assumption, the team felt they could develop accurate questions to go out in a survey quickly. When reviewing the previous literature review the team discovered that much of the previous research was faulty. Some of the previous research used few references and multiple choices were made because one option was harder than the other. This lack of adequate research meant that the team had to conduct completely new research before a questionnaire could be made. Additionally, the IRB process to get surveys to the amputees was discovered to be much more time consuming than initially expected. In addition to going through IRB training, which the DAPS team completed in less than a week, the team would need to submit an individual IRB to every potential hospital or clinic where the team wished to survey patients. Each hospital or clinic would also have its own individual IRB process with differing time lines and the team may not have gotten approval on the first attempt at the IRB. The combination of extra time to research as well as the time consuming process to obtain multiple IRBs would have put major strain on the time line because if the team were using demand driven design they would have had to wait to receive the returned surveys before they could generate a design. Therefore, as a team it was decided that it was more important for the education of the students involved to go through the full product design process than to create a survey. To help supplement the lack

of surveys the DAPS team also did further research in their literature review and found multiple surveys that support the decisions they made in the project.

2. Improve the design for a more efficient and longer lasting use-time, either with compressed air or a mechanical model if compressed air cannot be improved enough.

The team completed this goal by switching to hydraulics. After researching why the previous team used pneumatics the DAPS team wanted to conduct more research on why pneumatics would provide the best support for the design. The result was finding the pneumatics was a suboptimal option to hydraulics due to the compressibility of air. Hydraulics uses an incompressible fluid such as water which allows greater actuation of pressure. Hydraulics were also more efficient than pneumatics as the fluid could be reused multiple times and was smaller and provided a more compact design than pneumatics.

3. Evaluate and implement predictive sensors, such as an Surface EMG, and compare to responsive sensors, such as accelerometers.

The team completed this goal by evaluating multiple sensors and choosing EMGs. They decided on EMGs because EMGs provide predictive signals as opposed to accelerometers or pressure sensors which would be reactive and only be able to start actuation after the amputee had already started moving.

4. Create a working model of our design which demonstrates the functionality of our project.

    (a) Ensure proper pressure, through rigged testing, so that the leg will not slip out and injuries (e.g. bruising) will not occur.

The team completed these goals by assembling a final prototype and completing final testing. Final testing on the project consisted of nine tests designed to test accurate response of the system, the EMG detection algorithm, the response time of the system, support (whether the leg has the potential to slip), weight, duration, the system fail safes, and potential failure points (such as

where the system might leak). To learn more about the final testing, see the DAPS MQP report. To account for potential injuries, the team made the system so that the maximum pressure was adjustable, which could be calibrated by a trained professional.

4.5.1.2 Additional Project Goals

1. Optimize the system to have a fast, but accurate, response to the user's movements.

The team completed this goal by researching current EMG algorithms and developing an algorithm that was predictive in nature so that the socket would begin adjusting before the user was moving.

2. Running and Stairs

    (a) Identify the motions and forces for running and stair climbing movements.

    (b) Testing for running and stairs.

The initial goal of running was completed in multiple parts. It was decided by the DAPS team to change the user interface from multiple modes of sitting, standing, walking, running, or stairs, to a passive and active mode. In passive mode the detection algorithm determines whether one if you are moving or sitting and adjust the pressure accordingly. Active mode keeps the bladders inflated and could be used whenever one is are actively moving about for a longer period of time. By simplifying it to moving or sitting the team took into account running. MM and JF conducted force plate testing and analyzed the data to look at the pressures on the leg for running. The DAPS team then tested the system to see if it could withstand the force of someone running in their final testing. To learn more about the user interface system or the testing that was conducted please see the DAPS final report.

4.5.1.3 Reach Project Goals

1. Begin testing on real amputees (with IRB approval).

Similar to why no IRB was obtained at the beginning of the project obtaining testing IRBs had two main problems and, thus, was not accomplished. The first problem was that in order to submit a testing IRB one needs a final product design and working prototype. As the DAPS team wanted to test their new socket design it would not have been possible to submit for an IRB before the end of C term. This lead to the second main problem of the amount of time it would take to get IRB approval. The team felt that the IRB process might take over seven weeks and thus would not be finished until after the project could be due at its latest. The team now has a function design and design specifications so that a team taking over the project would be able to apply for IRB testing before the summer and potentially have testing in A term.

2. Develop the structure for further demand-driven features

    (a) Incorporate a data-collection system to the socket to gather relevant medical information

    (b) Integrate manual settings for user interactions

The team did not have time to create a structure for how to implement further demand driven design features. As this was a reach goal, it was not a high priority and we had no data that either of the ideas were actually wanted in the industry. The team believed that it would not be difficult for a future team to modify the user interface or code to provide these features if they were desired in future settings.

4.5.2 Intel Cornell Cup System Goals

In addition to the main project goals the team came up with system goals for the Intel Cornell Cup. These goals were created much later than the initial project goals and helped to define the final testing for the prototype. The goals for the system were accurate response of the system (the bladders inflated when they were supposed to), the EMG detection algorithm accurately detected muscle movement before it happened, the response time of the system was fast enough to begin actuation before the amputee wanted to move, that the leg was supported (the socket did not slip

off the limb), the weight was less than 7.25 lbs, the system lasted longer than 58 minute, the system fail safes worked reliably, and potential failure points (such as where the system might leak) did not fail (See the DAPS MQP).

4.5.3 Discussion of Final Survey Results

Overall, the final survey results were very positive. The DAPS group members were satisfied with the result of the project. The team noted how well we did at combining four different fields of study and project backgrounds into one MQP. The biggest change the DAPS team would have made to the project would be to have limited the scope more so that they could spend more time researching and testing individual components than rushing something so that the prototype could be assembled and tested as a whole. They also would have liked to revise the project goals at the beginning of B term to better evaluate the project instead of goals made before the project had begun.

4.6 Student Interest

Many times over the course of my MQP, while explaining my project to friends or acquaintances at the school other seniors commented that their project could 'use someone like me'. When inquiring into these comments I found that the groups that were struggling, had no team leader, or too many team leaders among the group. Lack of leadership or diffuse leadership could lead to conflicts with professors, not meeting internal or external deadlines, and conflict within the group itself. Too many team leaders also caused friction when ideas did not align. The groups that were succeeding all seemed to have, formally or informally, declared a singular team leader. This team leader helped push deadlines, set goals, and did many of the tasks shown under project manager in Figure 5.

One of the benefits of being 'outside' the group I was managing is that I was a more neutral party to the DAPS team. This means that when there was difference of ideas they could weigh my opinion knowing that it had little bias. Another benefit was that since i had been declared the

manager, the entire team agreed to my management at the beginning of the project, I got little internal push back when making decisions. These benefits would not be given to an informal or even a declared internal leader of a group. This let me say things with authority during one on one meetings with my teammates that helped to diffuse some problems before they began. One of the roles that I think the team gained from having me was as a mediator for team conflict. As an outside representative, I was given neutrality that let me mediate without biases and look at it as part of the bigger project as a whole.

I would personally recommend that any professor who wants high team independence and accountability to consider having an independent project manager. A benefit to 'hiring' the project manager would be the added knowledge that someone with a management or management engineering background would bring to the project. As an engineering student, one is not required to take business or specific classes that would expose them to management tools, such as Gantt charts, or planning methodologies. And while some students may be exposed to some of these ideas in other project classes, such as ME 2300 or IQP, others have not. While it would be useful for some students to learn these methodologies before they go into industry it would be more useful to require them to take a class than apply them to an MQP. By making student add research on management tools to their long list of other things to research, build, and compile, professors could degrade the level of research they are able to put into both the management tools and the MQP topic. As the primary goal of the MQP for students to "gain real-world design or research experience within their major field" (WPI MQP Homepage), it does not make sense to make students do research outside of their field when one could have a manager explain the tools to them in less time and show them how to utilize the tools more effectively.

5 Conclusions

Management of the DAPS MQP demonstrated that a student can successfully and effectively manage an MQP team.

The were six key findings:

1. I was able to simulate real business management challenges while still a university student by being a 'CEO' of an MQP in another department.
2. A value proposition was defined in terms of learning outcomes for a manager and an MQP group.
3. The MQP was decomposed using Axiomatic design and potential failure analysis to break-down potential failure points and bottlenecks that could inhibit the MQP process.
4. Utilizing the Axiomatic design process and potential failure analysis led to the creation of a management plan for the MQP.
5. The management plan was implemented and measured in effectiveness using risk and time-line analysis.
6. At the end of the MQP conflicts/management failures were analyzed and recommendations were given to improve the management plan.

5.1 Future MQP Management Recommendations

My recommendations are observations as to how future project managers could make a more successful project and how I could apply what I have learned.

5.1.1 Learn From Your Mistakes

Everyone makes mistakes; the only way to be a successful manager is to learn from one's mistakes instead of trying to hide them. The main purpose of this section is not just to help other management majors who hope to do a similar project, but to write down all of the things I could have done better or did well to get my thoughts down and to help me learn from my mistakes. This section highlights some of my biggest failures on the project and has ideas about how someone could learn how to avoid them.

5.1.2 Have Background in the Project Topic

One aspect that all of the DAPS team agreed on was that the manager of the project must have some background in the area of the project. I had previously taken robotics, computer science, mechanical, and electrical engineering classes before managing the DAPS project and I still felt that I could have done more research or taken specific classes to better understand some topics. I believe that having a better understanding of bio-medical engineering would have aided me in identifying the best ways for MM to contribute to the project. If the manager does not understand what is happening on the project there is no way for him/her to effectively manage the team. Additionally, if the manager has no background in the topic, the team will be more inclined to disregard the manager.

5.1.3 Present Status Updates

Presenting status updates would have been more beneficial to me than to anyone else on the team. In order to give a good succinct status update, one must be completely up to date with all of the team members and their smaller aspects of the project. Arrange to update the professor and then the professor can ask the team any further questions he or she might have. This will ensure that you constantly know what is happening with every aspect of the team and that you do not fall behind.

5.1.4 Set Consequences Early On

This is one of the aspects that I regret not clearly defining at the beginning of our project process. One of the hardest things I had to deal with was that in A term there were almost no late deadlines. The team was eager to contribute and put in the work to making the project great. As we moved into B term and the amount of work increased, deadlines, started falling behind. As the work started to slip, initially, I was not worried as I knew that when making the schedule in A term the entire team knew that we had built some slack into the schedule. By the middle of B term the slipping had gotten to the point where we sat down as a group and said that we needed to be better

about the deadlines we set, be realistic, as well as adhering to the deadlines we had already set. What we didn't come up with was some kind of repercussion. This meant that when I got feedback from my team saying that I should be stricter on deadlines, I was at a loss. I was not an adviser and did not control their grades, I was not their mother and couldn't tell them that until their work was done they were not allowed to go out. And even if I could, many of the times I approached a team member who fell behind on work, their justification was homework for other classes, exams, or projects that lasted until 3 am. I struggled to fight the line between pushing my members into burnout, a state that many of them had reached by the end of B term and C term regardless, and letting deadlines continue to slip.

As a note, consequences do not have to be negative. The consequence of missing a writing deadline could be that I schedule an hour meeting for anyone who missed a writing deadline and during that hour the members who had not completed the writing would work on it. By defining the consequence early on in the project I believe the manager could be more effective than I was when deadlines slipped.

5.1.5 Meet with the Professor(s) of the Project Alone

The manager of a project should know the real intentions behind what the professor(s) of the project they are managing want. Some professors may want students to go through the design process, some may want the full product life-cycle, and some may be looking for potential grant money. If the manager can understand the professor(s) motivations for the the project he/she can better understand what the main goal of the project should be.

The biggest advantage sitting down with the professors of the DAPS project would have given me was an understanding of how much of the project we could limit in scope. If I had found out that the DAPS team main adviser just wanted a more detailed design and more potential future improvements, we could have limited the scope to not include assembling a prototype. This would have let the DAPS team focus in more on some of the problems that they found interesting while designing the prototype.

5.1.6 Schedule Non-MQP Group Bonding Time

Go to a movie, out to dinner, or just hang out. It will help you form a more coherent team and it is important that you all have something in common besides your project. The DAPS team did this twice and each time team tensions seemed to be lower immediately following. Doing things that are not your project can help you jell as a team because it makes you see your MQP partners as humans instead of people only associated with your project.

5.1.7 Weekly One-on-Ones

I mentioned this in the section of the conflict our team had but I want to reiterate it here because I think that it would have made the project much smoother. Weekly one-on-ones allow group-mates to tell you important information, vent about the project or other aspects that are being stressful in their life, or warn you of potential disasters. And even if someone comes to your one-on-one meeting and talks about something completely unrelated for half of the meeting, you may have discovered something while they were talking, whether it is that you need to watch them for potential disaster, that you need to schedule less work for them, or just learned a little more about them as a person. It also provides a great way to diffuse arguments before they begin by bringing up something you might have heard during someone else's one-on-one.

5.1.8 Question the Project Goals

Within reason it is okay and even encouraged to question your project goals. For instance as soon as we discovered that hydraulics are much better for bladder actuation than pneumatics I should have brought up to the group that we should change the project goal that is focused on pneumatics. In industry it is rare for a customer to only talk to developers once. There should be constant communication with both sides. Project goals should be the same way, consulting the group and advisers when a goal changes.

5.1.9 Break Project Goals into Terms

I believe that one of the reasons the team was so successful in A term was that there was a very clear goal for what we wanted accomplished. We wanted to finish background research and conduct a PDR so that we could start work on building the prototype in B term. When we came back from the break between A and B term we had a larger goal of building the prototype but fewer smaller goals to get us there. This made it difficult to motivate the team when deadlines slipped as the goal of finishing the project became less immediately attainable than building the hydraulic system and designing and printing a PCB.

5.1.10 Watch out for Cliques

This piece of advice was mentioned in one of the management books that I read at the beginning of the project. I thought that there was probably minimal risk with a project team of 4-5, depending on if you are counting me, and thought that the team had jelled well as a unit in A term. However, after the conflict at the end of B term and, even beginning before, that I noticed that JZ, JF, and MH had jelled more with each other and less with MM. This was partially due to the fact that they shared many of the same classes and saw each other much more outside of MQP but it became problematic when they would schedule work and not invite MM. MM was slowly left out of more things and, thus, felt more and more separated from the group. AS cliques are easier to disband when they are forming instead of after they have formed I would recommend watching out for potential cliques within MQP groups, especially of larger sizes.

5.1.11 Be Careful of What You Say and Do

This piece of advice came to me in the initial management survey I sent out in B term (Appendix C). It was made about a comment I had made going into Thanksgiving break. I could see the team burning out faster than I could reconcile and so told them to take the time to rest and not work on the project for a couple of days. A few of the team members took this to mean that they should do none of their work over the break rather than what I had meant which was give yourself

two days of not thinking about the project and then finish up the work assigned before we get back.

As the manager you have more sway with the group than you might realize and with that comes the responsibility not to abuse it. While going into breaks, such as between terms, it is tempting to say things like ”I know no one is going to work over break”. While this may be the truth and may be what happens over the break by explicitly saying that you are giving your team an excuse to not do work and some team members will take advantage of that. Try to be clear and professional about what you say and how you say it. For example, do not tell your team you will add another meeting ”if you have to”. If you stop paying attention to a group member it tells the rest of the team it’s okay for them to ignore that person as well. It is your job to be the best group member all the time, even when it is hard.

5.2 Closing Remarks

Management of the DAPS MQP has taught me many aspects of managing a project team that I did not previously realize went into management. When I first began the project I thought that my job would be mostly ”when2meets”, ”outlook invites”, and check-in meetings. This project has shown me that there is much more to project management and that I have more to learn before I would be ready to lead a team in an industry environment. The MQP has also shown me what some of my personal strengths and weaknesses are and what I need to develop more fully to become a better leader. I would like to thank both of my advisers on this project Professor Towner and Professor Vassallo for all of their support and guidance throughout the entire process. They have been invaluable guides on this learning experience.

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Appendices

A Axiomatic Design

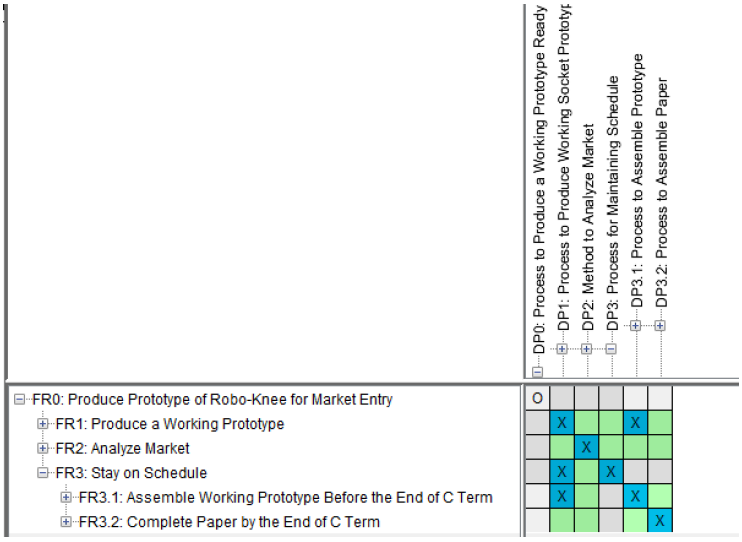


Figure 7: Top Level FRs

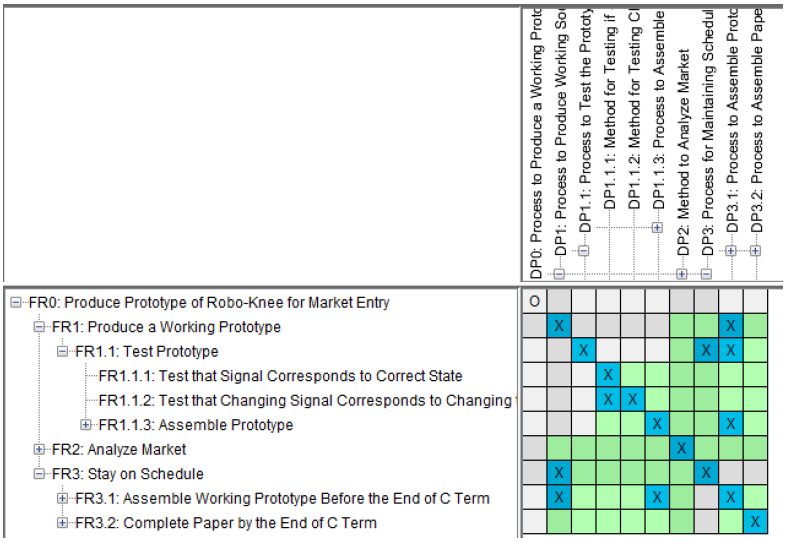


Figure 8: Expanded FRs One Level

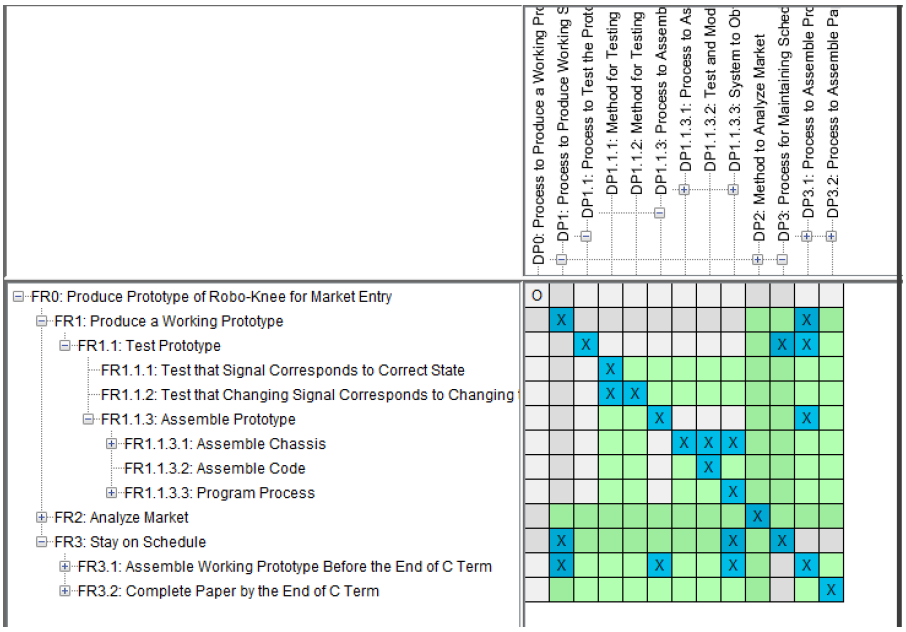


Figure 9: Expansion of FR 1.1 Test Prototype

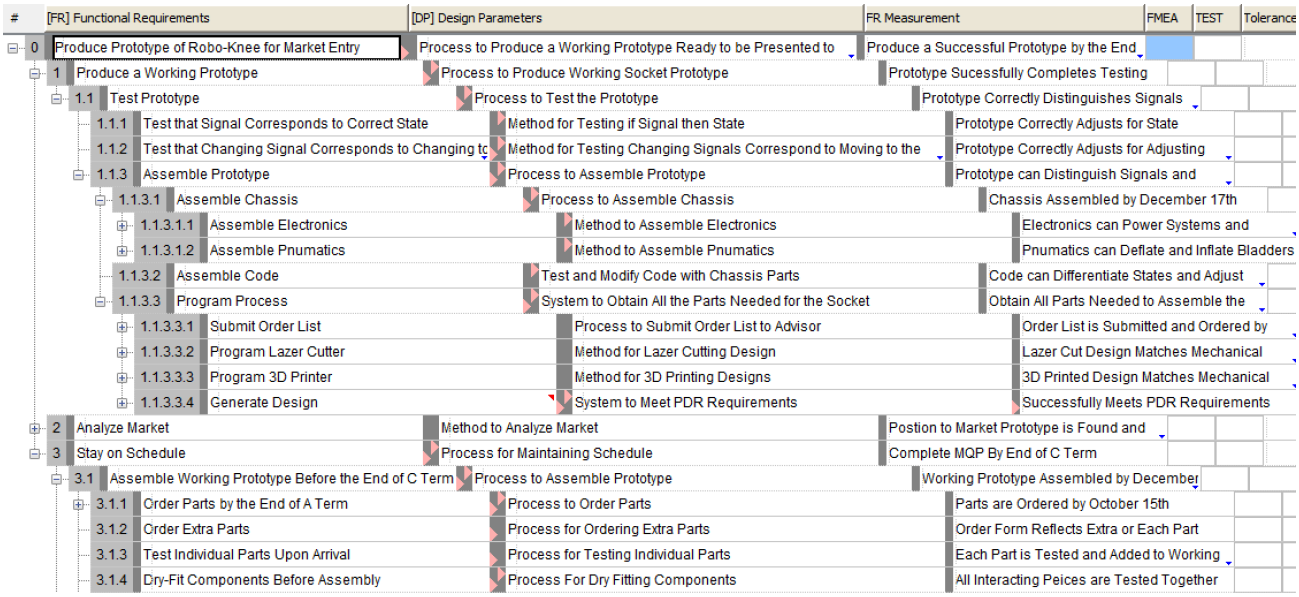


Figure 10: Side by Side View of FRs and DPs

B Example Meeting Minutes

Action Items

- AI - Josh - Order linear drivers
    - Email ECE guy
- AI - Everyone - Check on where we need to present for MQP - meeting with fischer
- AI - Mollie and Josh - Write bios add to drive
- AI - Jake & Josh - Bladder Testing
    - Bike tube - have currently
    - PUL - Need to get
    - Compare results and choose
- AI - Meagan - Add orders/ receipts to drive
- AI - Mollie - See if you get any bio money - BME department office (Ambady)
- AI - Mollie - Copy Overleaf over to Google doc
- AI - Morgan - On agenda for tomorrow - Feedback on submitted paper
- AI - Mollie - Assign ports in excel sheet
    - http://www.nxp.com/documents/data_sheet/LPC1769_68_67_66_65_64_63.pdf
    - Symbol, LQFP100, Description in 1 cell
- AI - Everyone - Look at goals for next week

Parts of the syringe: http://i00.i.aliimg.com/img/pb/365/057/939/939057365_982.jpg

Meeting Minutes

- Review Action Items
    - AI - Everyone - Check on where we need to present for MQP - meeting with fischer
    - ~~AI - Mollie - ask Lisa Wall if EMG machine in BME lab had filtering on it~~
    - AI - Mollie - Email Delph that the 1 page summary thing he wanted is on the drive - link it for him
    - ~~AI - Josh - Email Delph Equations~~
    - ~~AI - Meagan - Eventually order parts~~
    - ~~AI - Mollie and Josh - Write bios add to drive~~
    - ~~AI - Meagan - Add bio to drive~~
    - ~~AI - Mollie - write chapter 3~~
    - ~~AI - Everyone - briefly research knee joint~~s
        - We don’t need to do anything YAY
        - Keep components on the socket
        - Can move down if needed
    - AI - Jake - Continue Bladder Testing
- Updates from break
    - Josh CADed a plunger stopper
        - Working on attachment for motor body to syringe body (small faceplate)
        - Updated receipts
    - Jake
        - Bladders - have a potential valve design
            - ~$4 a valve

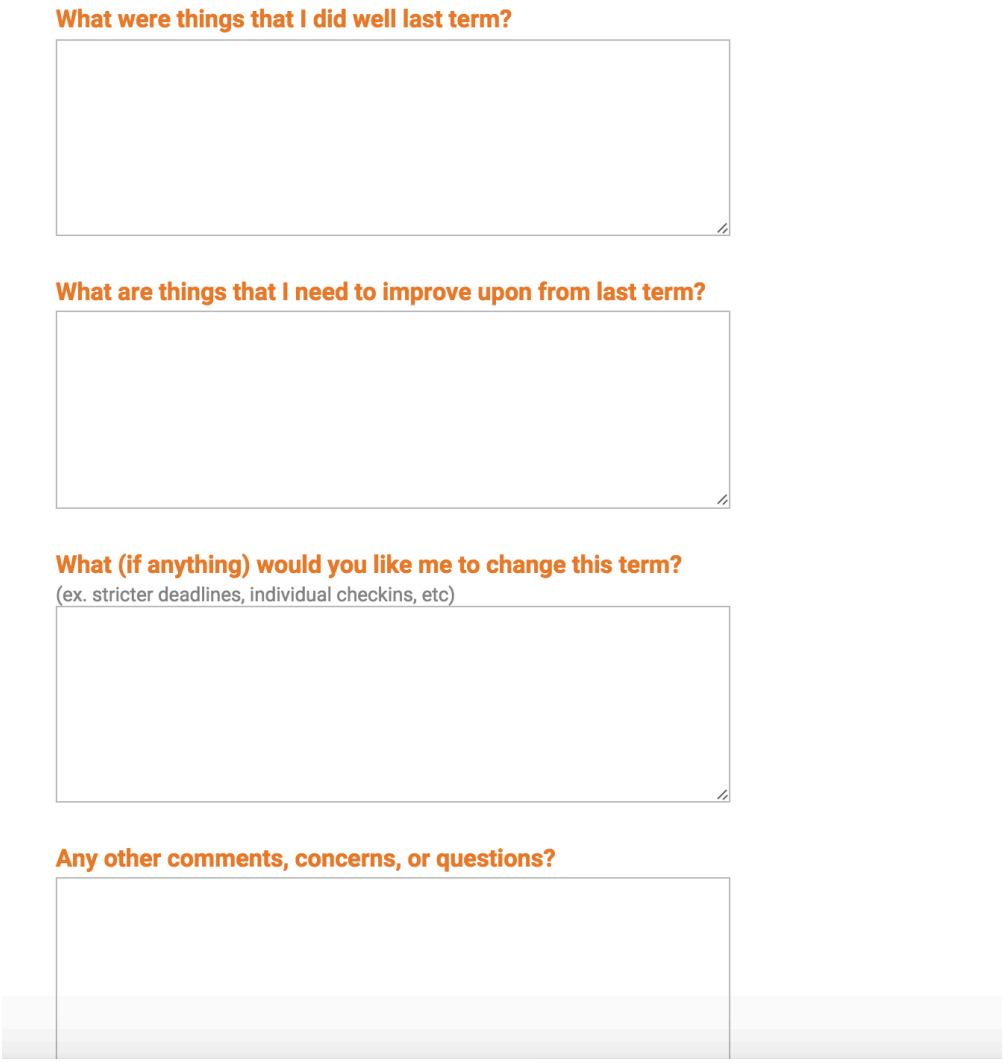
        - Set up Eclipse
        - Set up Doxygen
        - Set up Stash and sourcetree
        - Guide in software on slack
        - Started making function headers
            - Some function definitions
            - All have doxygen comments
    - Meagan
        - Made all the schematics
        - All resistor and capacitor values
- Ordering Motors
    - Go through RBE or ECE
    - Josh Email ECE guy
- Cornell Cup
    - Make sure everyone is on the same page
        - What the competition is
            - Competition run by Cornell and intel - for engineering
            - Must involve embedded controls (for intel)
        - What we've done so far
            - Sent in application
            - Should be getting back to us this Friday
        - What we'll do for the competition
            - If we make it to next round write more
            - Then there's another round then we get an Intel Atom Processor and we have to incorporate into project
            - Virtual Presentation is final round
                - Talk about project and how we incorporated the intel atom chip
        - Timeline
- Software
    - JIRA - Bug tracking
        - Bug reporting
    - Stash
        - Github - don't have to download
    - Source Tree
        - Github manager/gui
    - clone repo into sourcetree
    - all eclipse programs should compile
    - show branching for testing and reference purposes
- Review of timeline of B term
    - Extend Make electrical board to the 14th
    - fix Hydraulic/ alternative spelling on Gantt
    - Prioritize code 7-8
    - For next week
        - PCB ordered and done

        - Functions prototyped
        - Bladder modifications and decision
        - Motor test rig built - provided motors come in
            - At minimum designed
            - Pieces 3d printed
        - How to attach EMGs to someone
        - Outline Chapter 4 for anything that you have done chapter 4 should include (see guidelines) - Chapter 4. Alternative Designs - Needs Analysis - Functions (Specifications) - Conceptual Designs - Preliminary/ Alternative Designs - Feasibility Study/ Experiments - Modeling - Preliminary Data
- MQP Writing guidelines
    - https://www.wpi.edu/Images/CMS/Biomedical/MQP_Project_Guide_December_6_2010.pdf
- Deadlines

C Management Surveys

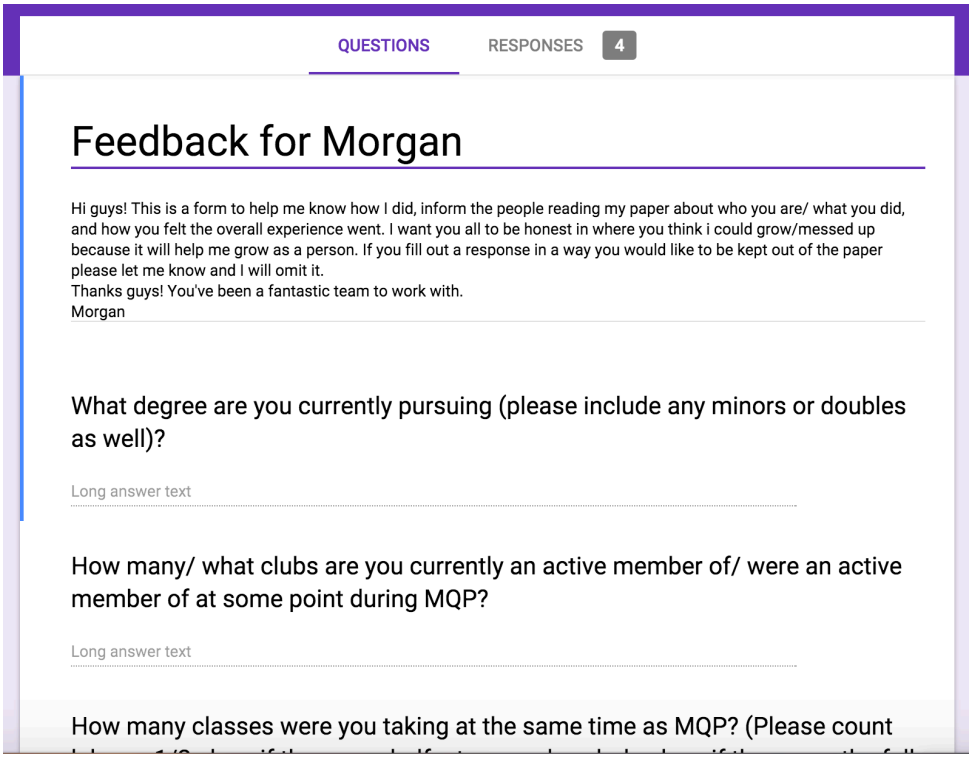
This survey was distributed half way through b term at the halfway point of the project. This survey was to get an overall feel for how the project was progressing as well as to get feedback that I could implement before the end of the project.

The following survey was distributed at the end of C term 2016 at the conclusion of the project. The survey was to see about the team's satisfaction with their project as well as with my management of their project and to receive feedback from the group.



D Iterations of Gantt Charts

Below is a series of Gantt charts made at different points along our MQP process. Each Gantt chart is labeled with the term and year it was made and is put in chronological order so that you can easily see the progression over time.



QUESTIONS RESPONSES 4

Feedback for Morgan

Hi guys! This is a form to help me know how I did, inform the people reading my paper about who you are/ what you did, and how you felt the overall experience went. I want you all to be honest in where you think i could grow/messed up because it will help me grow as a person. If you fill out a response in a way you would like to be kept out of the paper please let me know and I will omit it.
Thanks guys! You've been a fantastic team to work with.
Morgan

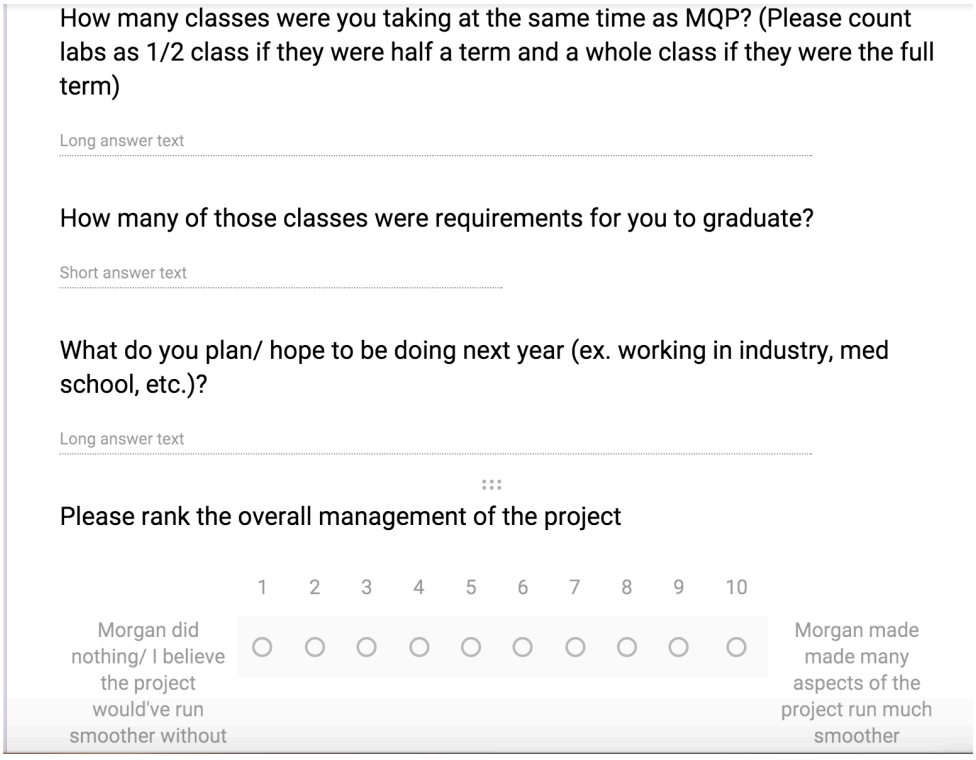
What degree are you currently pursuing (please include any minors or doubles as well)?

Long answer text

How many/ what clubs are you currently an active member of/ were an active member of at some point during MQP?

Long answer text

How many classes were you taking at the same time as MQP? (Please count



How many classes were you taking at the same time as MQP? (Please count labs as 1/2 class if they were half a term and a whole class if they were the full term)

Long answer text

How many of those classes were requirements for you to graduate?

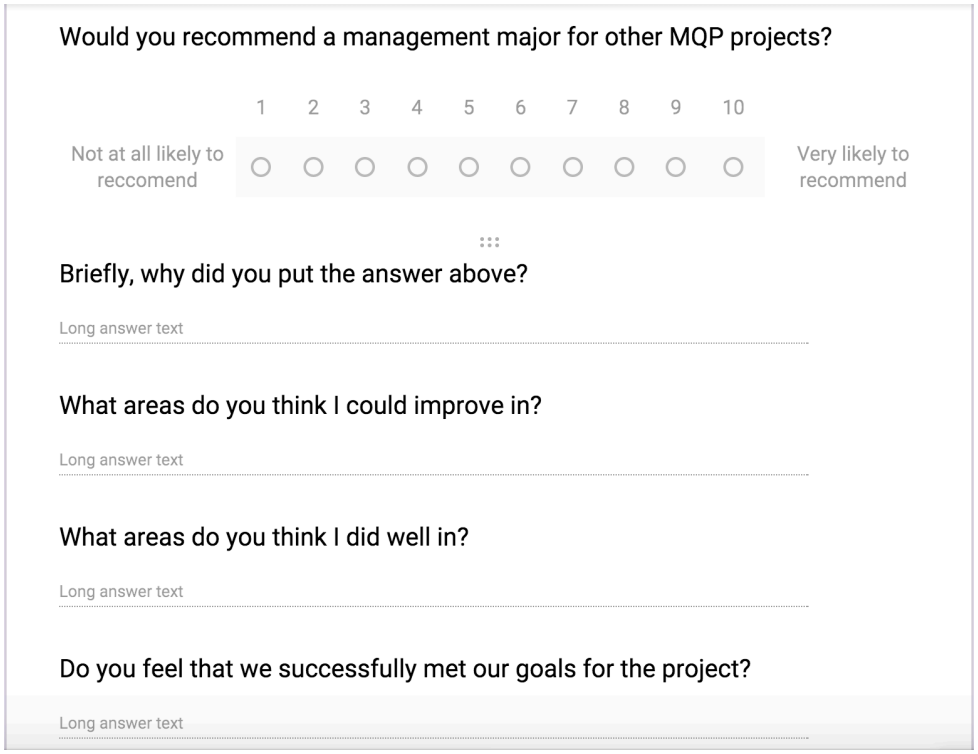
Short answer text

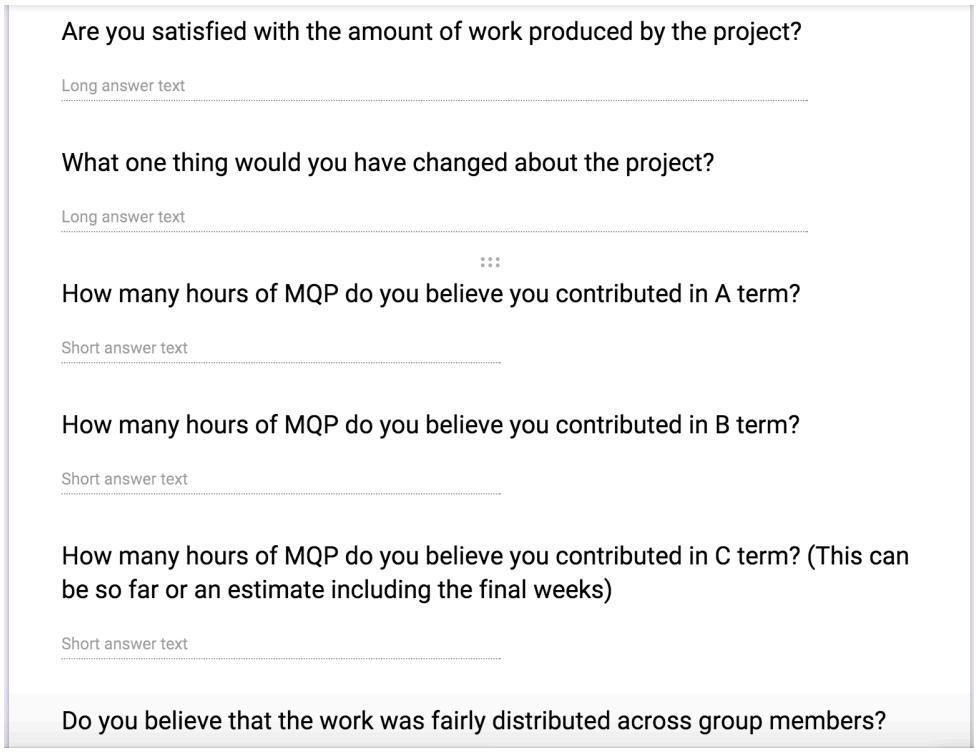
What do you plan/ hope to be doing next year (ex. working in industry, med school, etc.)?

Long answer text

Please rank the overall management of the project

	1	2	3	4	5	6	7	8	9	10	
Morgan did nothing/ I believe the project would've run smoother without	○	○	○	○	○	○	○	○	○	○	Morgan made made many aspects of the project run much smoother


Would you recommend a management major for other MQP projects?
1 2 3 4 5 6 7 8 9 10
Not at all likely to reccomend
Very likely to recommend
Briefly, why did you put the answer above?
Long answer text
What areas do you think I could improve in?
Long answer text
What areas do you think I did well in?
Long answer text
Do you feel that we successfully met our goals for the project?
Long answer text


Are you satisfied with the amount of work produced by the project?
Long answer text
What one thing would you have changed about the project?
Long answer text
How many hours of MQP do you believe you contributed in A term?
Short answer text
How many hours of MQP do you believe you contributed in B term?
Short answer text
How many hours of MQP do you believe you contributed in C term? (This can be so far or an estimate including the final weeks)
Short answer text
Do you believe that the work was fairly distributed across group members?

Do you believe that the work was fairly distributed across group members?

Long answer text

Did you feel like you could talk to Morgan/other group mates about problems?

Long answer text

Do you have any other feedback you would like to give me (I appreciate any and all feedback)?

Long answer text

Is there anything that you would like the reader's of Morgan's MQP to know about you, the team, the project or anything else?

Long answer text

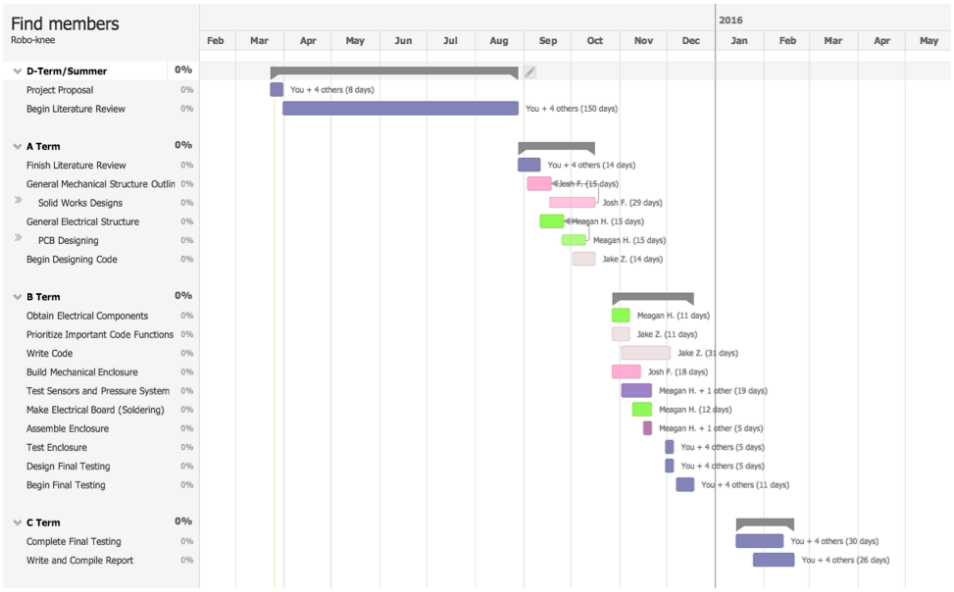


Figure 11: The first Gantt Chart for the DAPS Project Created in D-Term 2015

To see the final Gantt chart you can refer to figure 2 on page 7 of the report.

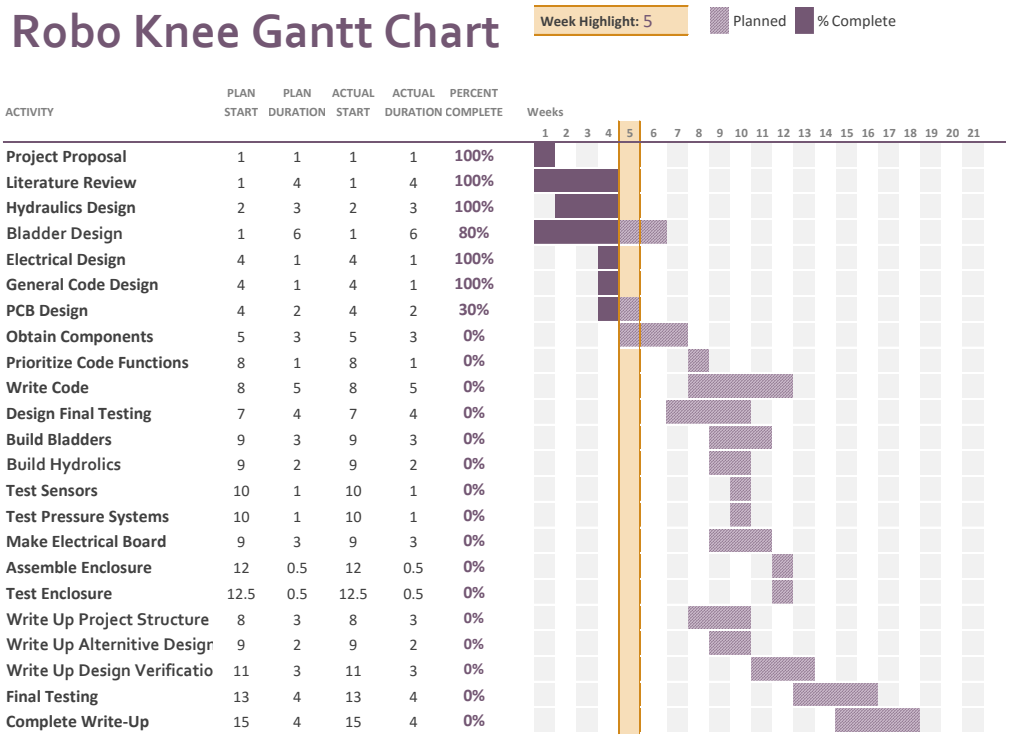


Figure 12: Updated Gantt chart from A Term 2015

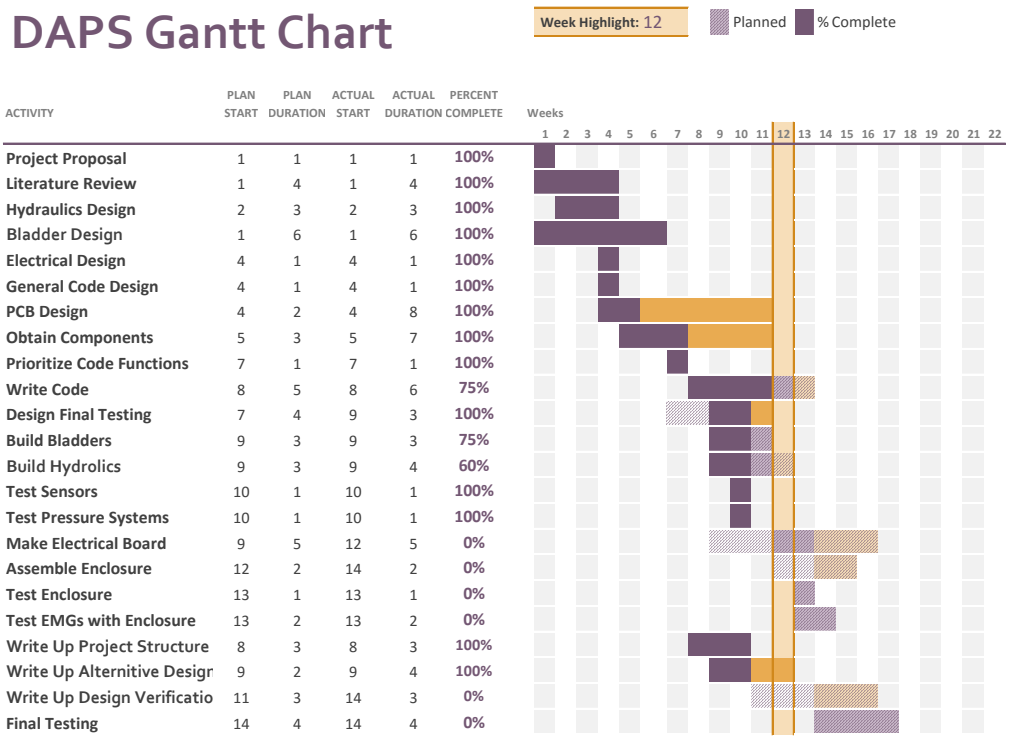


Figure 13: Updated Gantt chart from week 12, B term 2015, half way through the project

E PERT Chart

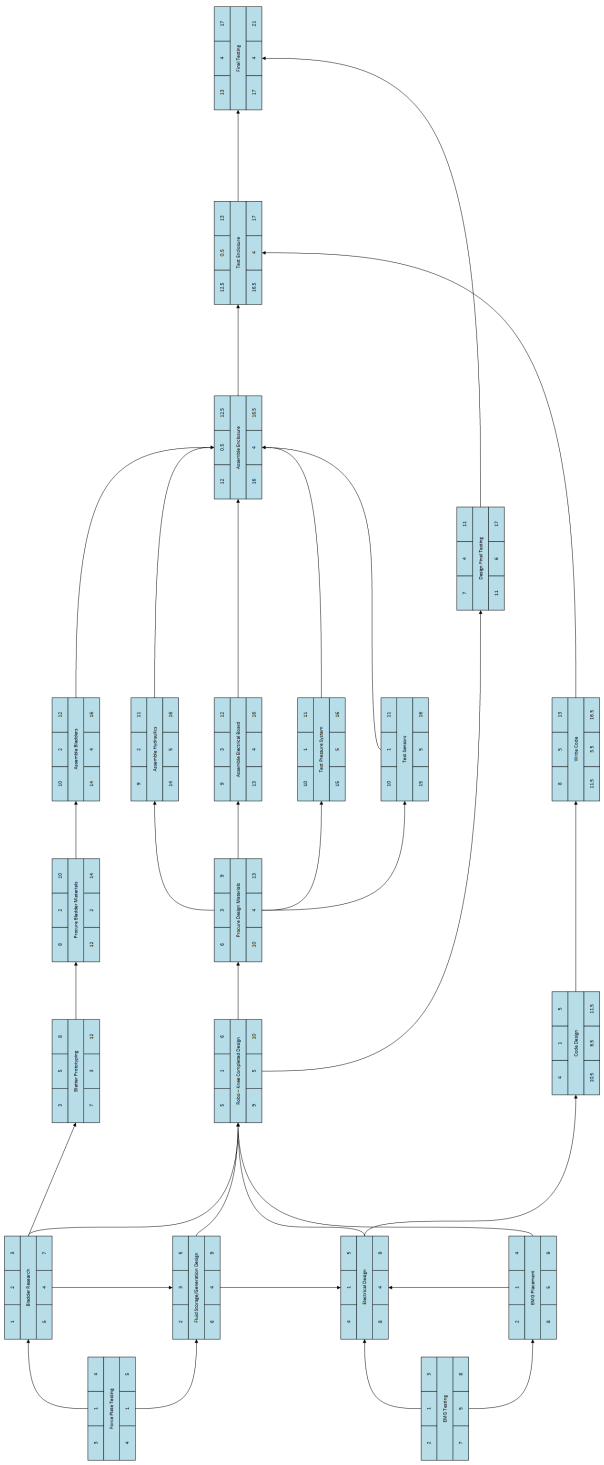


Figure 14: PERT chart for Dynamic Adjusting Prosthetic Socket

F Risk Calculations

Below is the excel sheet I used to calculate the risk of going over. The initial values were the values placed in the pert chart in appendix E but these were update to reflect more the actual times as I moved into B term to give me a better estimate of expected time. the Cells in Yellow represent the critical path with other potential critical path sums (the sum of all of the expected time values in the critical path) shown at the bottom with the actual critical path also highlighted.
The formula I used for the expected time was:

$$(a + 4m + b)/6 \tag{1}$$

The formula I used for the activity variances was:

$$((b - a)/6)^2 \tag{2}$$

The slack times were calculated using the pert chart and the assumption of finishing in 21 weeks. Slack time is equal to the late start minus the early start (b-a).

Activity Letter	Activity	Immediate Prediscesor	Time Esitmates a (optimistic)	m (actual)	b (pessimistic)	Expected Time	Activity Variences	Slack Time	Actual Time	Slack Time Used
A	Force Plate Testing	-	1	1	2	1.167	0.028	2	1	0
B	EMG Testing	-	1	1	2	1.167	0.028	6	1	0
C	Bladder Research	A	2	2	4	2.333	0.111	5	2	0
D	Fluid Storage/ Generation Des	A, C	3	3	4	3.167	0.028	5	3	0
E	Electrical Design	B, C , F	1	1	2	1.167	0.028	5	1	0
F	EMG Placement Design	B	1	1	2	1.167	0.028	6	1	0
G	Bladder Prototyping	C	4	4	6	4.333	0.111	4	4	-1
H	Robo-knee Completed Design	C, D, E, F	1	1	3	1.333	0.111	6	1	0
I	Code Design	E	1	1	2	1.167	0.028	7.5	1	0
J	Procure Bladder Material	G	2	3	4	3.000	0.111	3	3	1
K	Procure Design Material	H	3	3	7	3.667	0.444	5	3	1
L	Assemble Bladders	J	2	3	4	3.000	0.111	5	3	1
M	Assemble Hydraulics	K	2	4	5	3.833	0.25	6	4	2
N	Assemble Electrical Board	K	3	6	7	5.667	0.444	5	8	5
O	Test Pressure Systems	K	1	1	2	1.167	0.028	6	1	0
P	Test Sensors	K	1	1	2	1.167	0.028	6	1	0
Q	Write Code	I	5	6	7	6.000	0.111	4.5	6	1
R	Design Final Testing	H	2	2	4	2.333	0.111	5	2	0
S	Assemble Enclosure	M, N, O, P, L	0.5	2	3	1.917	0.174	6	0.5	
T	Test Enclosure	Q, S	0.5	2	4	2.083	0.340	5	0.5	
U	Final Testing	T	4	5	6	5.000	0.111	5	2	
								Actual Total	19	

		Crit Path Sum
Critical Path	A, C, G, J, L, S, T, U	22.833
	A, D, H, K, N, S, T, U	24
	A, C, E, I, Q, T, U	18.917

Risk Asssment	
	End of A Term
	5 Weeks of slack remaining
	0 Weeks of slack used
	All goals for A Term Accomplished
	Half way though B term
	4 Weeks of slack remaining
	1 Week of slack used

Figure 15: Risk Analysis of DAPS MQP

G DAPS MQP Report

To learn more about the DAPS project you can see their MQP report under the name ”Dynamic Adjustable Prosthetic Socket” through the WPI library website. Their MQP should be cross listed under Robotics, Electrical Computer Engineering, Mechanical Engineering, and Biomedical Engineering Departments.