Team Four: Final Assembly
Project Proposal Feasibility Study

Calvin College Engineering Dept.
ENGR 339: Senior Design
Advisor: Professor Ned Nielsen

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Abstract

Industrial Automation is largely responsible for the increased productivity and efficiency of manufacturing plants today. Although automation has been condemned as a factor resulting in the loss of jobs, it is largely neglected that automation is beneficial to making the work of an assembly-line worker more bearable. Workers with repetitive jobs which make intensive use of the same muscles and joints are at high risk for health problems.

Team 4, Final Assembly, is working with Knoll Inc., a furniture manufacturer, to design and build a machine which completes the uncomfortable final assembly step of an office product. A machine was designed to improve the working conditions of an assembly-line operator by replacing harmful repetitive tasks with a machine which facilitates the process.

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Table 1: List of Terms and Abbreviations

Term	Abbreviations
PLC	PLC
Printed Circuit Board	PCB
Electric Screw Gun	ESG

1 Introduction

1.1 Description of Team

Peter Malefyt is a senior mechanical engineering student from Lansing, MI. Currently, he is employed at Pipp Mobile Storage Systems and plans to pursue full time employment after graduation.
Freeland Shaw is from Dayton, Ohio and is majoring in Electrical/Computer Engineering at Calvin. Currently he is an intern at Smiths Aerospace and plans to pursue full time employment after graduation.
Monika Gunnar is a senior mechanical engineering student from Lucknow, India. She intends to pursue graduate studies in Engineering Management and Marketing.
Kingsley Kanu Jr. is a senior mechanical engineering student from Jos, Nigeria. He intends to pursue graduate studies in alternative energy development.

1.2 Project Background

Knoll Incorporated is a furniture manufacturer located in Muskegon, Michigan which specializes in the production of office furniture. Currently the final assembly step of an office pedestal, which is a primary component of their product line, requires extensive manual labor. The pedestal, which is essentially a filing cabinet, has four adjustable “feet” on the bottom; we will refer to these feet as glides as this is the nomenclature used by Knoll and its associates. Tim Holwerda and Kevin Bentz, representatives from Knoll Inc., contacted Professor Ned Nielsen of the Calvin College Engineering Department suggesting this design problem be addressed by a current senior design team.

2 Problem Statement

The final assembly step in the production process of a pedestal at Knoll Incorporated involves the attachment of four glides to the bottom of the product. When the product arrives on the conveyor system, the operator must flip over the box to access the bottom. Then, the glides must be seated manually before they are secured using an electric screw gun. This is a tedious and inefficient process which increases production time as well as the risk of Carpal Tunnel Syndrome among the employees. In an effort to reduce employee discomfort and increase production efficiency for Knoll Inc., we have accepted the challenge to automate this final assembly step in pedestal manufacturing.

3 Project Objectives

The final goal of our project is to present Knoll Incorporated with a working prototype capable of automatically attaching glides to the bottom of office pedestals. In order to accomplish this goal within the constraints of our senior design class we have defined several objectives to keep us on schedule and focused on our ultimate goal.

3.1 Understand the Problem

Before we began the design process for our project we gained a full understanding of the problem that we are addressing. First we became familiar with Knoll Incorporated through a visit to their Muskegon location in which we observed their facilities and established contact with the project engineers we are working with. During the tour of the operating floor we were given a demonstration of their current design process and shown how our design should be implemented in their process. As we met with the Knoll representatives we are working with we were able to have our preliminary questions answered and were also provided with their design process specifications as well as product samples.

3.2 Brainstorm Possible Solutions

After understanding the project requirements, we began considering different approaches to the design. Several aspects of the design were taken into account and alternative solutions were proposed, which are presented in the design section.

3.3 Perform a Feasibility Study

After presenting possible design solutions it was necessary to conduct a study in order to determine the feasibility of our alternative designs. This study, which included such considerations as cost, time scope, and part availability, enabled us determine the most appropriate design. A detailed look at the feasibility study is located in the design section.

3.4 Present a Prototype

This final step in our design process will require us to maintain a schedule as well as communicate regularly with Knoll Inc. in order to perform the necessary tasks to construct a working prototype.

4 The Design Process

4.1 Method of Approach

The method of approach involved four basic steps. The first step that was completed was listing a step by step task breakdown that our prototype would need to accomplish. This breakdown gave us an understanding as to what components we would need. The next step was to determine a preliminary parts list that included as many of the prototype components as possible. This helped us get a grasp on how much integration of parts would be required as well as determining much of the preliminary budget. The third step in our design process was to research the different components found on the parts list. Research was done on different manufacturers as well as how well the components would work with each other. This research provided our group with many options on how to perform the sequential design. These options are outlined in Alternative Solutions, section 5.3. Finally, a decision matrix was performed based on five factors. This decision matrix determined our preliminary design which can be found in the following sections.

4.2 Sequential Model

Below is the sequential model of what our prototype is to accomplish:

1. Manually load the sockets with glides
2. Pedestal arrives on the conveyor system
3. Sensors and Operator ensures right pedestal configuration
4. Photo sensors sense the size of the pedestal
5. Photo sensor input to the PLC
6. Output from PLC becomes input to the device controlling the linear actuator
7. Linear actuator extends vertically, extending ESG
8. A switch is triggered to activate ESG's
9. Glides are inserted into pedestal
10. Screw guns retract
11. Linear actuators retract to base position
12. Operator removes pedestal manually

4.3 Preliminary Parts List

The following is a preliminary list of parts:

1. Four Linear Actuators
2. Four Pairs of Photo Sensors
3. Eight ESGs with Stepper Motors
4. Eight Screw Gun Sockets
5. DC Power supply
6. Electric Power On/Off Switch
7. PLC
8. PCB
9. Base frame
10. Circuit box
11. Miscellaneous wires and air hoses

4.4 Alternative Solutions

The design solutions presented in this section were evaluated using the criterion found in the decision matrices located in the appendix. A brief summary of the chosen design alternatives can be found in the alternative design analysis (5.6.2).

4.4.1 Machine Position

4.4.1.1 Overhead

The current process at Knoll Inc. requires workers to flip the pedestal over before inserting the glides therefore we considered the idea of having an overhead machine which would be based on the current design concept of inverting the pedestals before installation.

4.4.1.2 Below Pedestal

Our clients at Knoll Inc. would prefer a system which would allow the glides to be inserted without the need to invert the pedestal before loading. This recommendation required us to consider a system which would incorporate into the existing assembly line and insert the glides from below the pedestal without need for manual flipping.

4.4.2 Mobility

4.4.2.1 Fixed Position

The machine would be installed in a fixed position and would remain in that position for the duration of its operating life.

4.4.2.2 Unfixed Position

The machine would be mobile, allowing it to be easily moved from one application to the next.

4.4.3 Process Automation

4.4.3.1 Fully Automatic

There would be no need for an operator; the machine would seamlessly be integrated as part of the assembly line on the conveyor system.

4.4.3.2 Semi-Automatic

Some parts of the machine would be automated, however, the machine would still require an operator to perform one or more tasks.

4.4.4 Glide screwing

4.4.4.1 Pneumatic Screw Guns

Screw gun powered by compressed air.

4.4.4.2 ESGs

Screw gun powered by electricity.

4.4.5 Screw Gun Socket Design

Due to the fact there are two glide head sizes we must determine how we are going to accommodate for this design variable.

4.4.5.1 Gator Grip

Using the Gator Grip technology we could have a socket automatically adjust for the size of the glide head.

4.4.5.2 Customized Socket

This would require us to fabricate our own socket design that would accommodate both glide configurations.

4.4.5.3 Rubberized Socket

Using rubber “o” rings or a rubberizing solution, we could coat the screw sockets with rubber, allowing the socket to grip the glide as it is inserting it into the pedestal.

4.4.6 Screw Gun Positioning

Knoll produces three different pedestal sizes which have different bottom lengths. The installation process must consider these lengths in order to position the glides properly.

4.4.6.1 Fixed Position

By fixing the position of 8 screw guns, a control device could select which guns would be activated based on the size of the pedestal.

4.4.6.2 Variable Position

Instead of using 8 screw guns, 4 could be used with 2 being fixed on a track controlled by a linear actuator. A control device could then drive the linear actuators allowing them to move the screw guns into the correct position.

4.4.7 Vertical Screw Gun Motion

4.4.7.1 Hydraulic

Hydraulic piston used to move the screw guns linearly.

4.4.7.2 Motorized Gear

Mount the screw guns on a gear and track system.

4.4.7.3 Vertical Linear Actuators

Mount the screw guns on a platform controlled by linear actuators.

4.4.7.4 Spring Loading

Lower the pedestal down to the screw gun level instead of moving the screw guns into their respective positions.

4.4.8 Pedestal Loading

4.4.8.1 Manual

This would require an operator to manually load the pedestal into the glide loading position.

4.4.8.2 Conveyor System

In this system the pedestal would arrive at the glide loading station by means of a conveyor system.

4.5 Project Feasibility Analysis

In this section, each technical component essential to the progress of our project is discussed to investigate the feasibility of achieving our desired final product.

4.5.1 Glide Loading

We have considered various ways to adapt a steel socket. At this point, we are testing an idea of coating the socket with layers of liquid rubber. If coating the socket does not sufficiently grip both glides, we will need to order a custom-made socket as described in the alternative solutions.

4.5.2 Length Sensing

Since the pedestals are of variable sizes – 18 inches, 24 inches and 36 inches, we must be able to recognize the specific size of the pedestal to install the glides in the proper position. We have performed tests on a pair of thru-beam photocells from IFMefector Inc. and are confident these photo sensors will perform the desired length sensing function. The photocells operate by having the transmitter emit a light beam to the receiver to determine the presence or absence of an object. We will be configuring the cells to function in the light operating manner, which means that as long as the receiver is receiving transmitted light it will produce no output but when there is an obstruction to this light beam, the photocell transmits an output to a controller unit. Each photocell output can then be read by a unit or fed directly into the input of a motion controlling unit to place the screw guns in the proper position. When the 18-inch pedestal is present, only one pair of the sensors will be obstructed. The first and second pneumatic linear actuators will be activated. Two pairs of sensors will be obstructed when the pedestal is 24 inches and thereby activating the first and third pairs of linear actuators. All three pairs of sensors will be obstructed when the pedestal is 36 inches and this will activate the first and fourth pair of linear actuators.

4.5.3 Motion Control

We have checked to ensure that electrically activating the pneumatic linear actuators is possible. The air supply valve to each linear actuator can be opened and closed based on electric input. We will be working with Knoll's technicians to coordinate this process.

4.5.4 Glide Screwing

We are confident that all four glides will be screwed in simultaneously. All four screw guns will be activated by the same signal from the photo sensor and this will eliminate the possibility of lag time between each screw gun.

4.5.5 Overall Design

While we have determined that the individual components of our design are feasible, we can only make educated guesses as to how they will integrate to form a complete and functioning machine. Currently, we do not anticipate any problems with integrating each component of the machine onto one PCB and PLC. As long as the individual parts are working as desired, we do not anticipate any trouble integrating these parts to produce a coherent and functional final product.

4.6 Preliminary Design

4.6.1 Design Specifications

The final product needs to meet the following specifications:

1. total cycle time of one minute or less
2. total screwing time of approximately one second
3. all four screw guns must be running concurrently
4. automatically detect pedestal length
5. vertical motion and screwing process occur simultaneously
6. the machine must be no more than four feet to integrate well with the conveyor system
7. there needs to be an emergency stop switch

4.6.2 Alternative Design Analysis

Considering the design specifications along with our design criterion, we were able to select the most appropriate design components.

4.6.2.1 Machine Position

For machine positioning the major factor in the design decision was the client. Since Knoll preferred a system which allowed the glides to be installed without manual movement of the pedestal, we decided to design a system which will screw the glides in from the bottom of the pedestal.

4.6.2.2 Mobility

We determined that creating a system which is easily moved from one area to the next will result in greater flexibility and easier implementation. It will also be more cost effective because it would not require mass production of our product.

4.6.2.3 Process Automation

Our design will be semi-automatic due to the fact that glide automatic glide loading will be a problem outside of the scope of our current class. We also considered our design norm of caring in that we do not want to replace any jobs, rather make the current jobs easier and more enjoyable.

4.6.2.4 Glide Screwing

Currently we have decided on electrical screw guns due to our familiarity with them and their ease of implementation into our current design.

4.6.2.5 Screw Gun Positioning

We have decided that linear actuators will be more expensive and difficult than having 8 screw guns. The multiple screw gun approach will not only fit better into the budget, but also eliminate the need for additional components necessary for the linear actuators.

4.6.2.6 Vertical Screw Gun Motion

Having the screw guns moved into the proper vertical position is the most practical application for their positioning. Although having a motorized system is also practical, the peripherals involved would cause for a more complicated and less reliable design.

4.6.2.7 Pedestal Loading

In conjunction with the design for less manual labor, we have decided to incorporate our design into the existing conveyor system, eliminating the need for manual pedestal loading. This should also increase efficiency as it allows the operator to perform other tasks while the pedestals are reaching their necessary position.

4.6.3 Photo sensor Programming and Simulation

In order to verify the functionality of thru-beam photo sensors for our design needs, 6 photo sensor samples were received from IFMefector in order to gain familiarity. The test setup utilized the following materials:

- Motorolla 68HC11 Evaluation Board
- Tektronix 2 Channel Digital Oscilloscope
- PSpice
- Keithly DC Power Supply
- Digital Multimeter

The photo sensors require 36 volt supply voltage which was supplied by the DC power supply; this 36 volts also represent the output voltage given by the sensors. Since the 6811 microprocessor operates on TTL logic levels the 36 volts was scaled to 5V using two resistors as voltage dividers. The determination of these resistor values was made using a PSpice simulation found in the Appendix A. A simple assembly program was written allowing the output of the photo sensors to be sent to the microprocessor and having the microprocessor produce an output which was able to be read by an oscilloscope. The photo sensors were configured in the dark operating mode which means as the transmitted light between them was obstructed the output was triggered. This was tested by holding breaking the transmitted light by an opaque object and observing the output. Since the desired and expected output was obtained we were convinced the photo sensors would be adequate for our design.

5 Project Management

In this section, the individual tasks needed to be performed are broken down by concentration and then delegated to each member of the group. This enabled each member to focus on a specific aspect of the design project. As part of project management, we developed a project schedule and budget to enable us to effectively make use of time as well as project the expenses which we anticipate during the course of this project.

5.1 Project Schedule

In the schedule below, each task is broken down and identified by concentration (electrical or mechanical). The schedule shows the time assigned per task and the projected date of completion for each task. So far, we have remained on time and hope to continue in this fashion until the end of next semester.

Table 2: Project Schedule

⊟ System Design	**3 days**	**Mon 9/19/05**	**Wed 9/21/05**
Determine overall goals	2 hrs	Mon 9/19/05	Mon 9/19/05
Determine complications	1 hr	Mon 9/19/05	Mon 9/19/05
Develop Basic Design Specifications	3 days	Mon 9/19/05	Wed 9/21/05
⊟ Basic Machine Assembly	**103 days**	**Mon 11/14/05**	**Fri 3/31/06**
⊟ Frame/ Base (Mechanical)	**39 days**	**Fri 1/6/06**	**Tue 2/28/06**
Basic design of Base	2 days	Fri 1/6/06	Sat 1/7/06
Build/Buy Base	2 days	Sat 1/7/06	Mon 1/9/06
Modify for weight and size	2 days	Mon 1/9/06	Tue 1/10/06
Documentation	20 days	Wed 2/1/06	Tue 2/28/06
⊟ Actuators (Mechanical)	**80 days**	**Mon 11/14/05**	**Tue 2/28/06**
Calculate load and size specifications	38 days	Mon 11/14/05	Mon 1/2/06
Research different actuators	39 days	Tue 11/15/05	Wed 1/4/06
Decide on and verify choice of acutator	1 day	Wed 1/4/06	Wed 1/4/06
Obtain Actuators	2 days	Wed 1/4/06	Thu 1/5/06
Test Actuators	5 days	Thu 1/5/06	Tue 1/10/06
Mount on Base/Frame	1 day	Wed 2/1/06	Wed 2/1/06
Documentation	20 days	Wed 2/1/06	Tue 2/28/06
⊟ Photoelectric Sensors (Electrical)	**78 days**	**Wed 11/16/05**	**Tue 2/28/06**
Research and Obtain Sensors	1 day	Wed 11/16/05	Wed 11/16/05
Tested with 6811 Micro-controller	1 day	Mon 11/28/05	Mon 11/28/05
Mount on Frame	3 days	Wed 2/1/06	Fri 2/3/06
Build circuit board	5 days	Mon 1/16/06	Fri 1/20/06
Connect sensors to circuit board	7 days	Mon 1/23/06	Tue 1/31/06
Documentation	20 days	Wed 2/1/06	Tue 2/28/06
⊟ Screw Guns (Mechanical)	**38 days**	**Sat 1/7/06**	**Tue 2/28/06**
Research	6 days	Sat 1/7/06	Fri 1/13/06
Obtain (Buy or Free from Knoll)	1 day	Wed 1/11/06	Wed 1/11/06
Verify Choice	1 day	Wed 1/11/06	Wed 1/11/06
Test workability	5 days	Thu 1/12/06	Wed 1/18/06
Mount on Frame/Base	9 days	Wed 2/1/06	Mon 2/13/06
Documentation	20 days	Wed 2/1/06	Tue 2/28/06
⊟ Sockets (Mechanical)	**65 days**	**Mon 12/5/05**	**Tue 2/28/06**
Research	2 days	Mon 12/5/05	Tue 12/6/05
Obtain	1 day	Tue 12/6/05	Tue 12/6/05
Coat with rubber layer	4 days	Tue 12/6/05	Fri 12/9/05
verify choice	1 day	Fri 12/9/05	Fri 12/9/05
Test workability	3 days	Mon 1/9/06	Wed 1/11/06
Mount on Screw gun	3 days	Wed 1/11/06	Fri 1/13/06
Test workability	6 days	Fri 1/13/06	Fri 1/20/06
Mount on Frame/Base	13 days	Wed 2/1/06	Fri 2/17/06
Documentation	20 days	Wed 2/1/06	Tue 2/28/06
Test Basic Machine Assembly	24 days	Tue 2/28/06	Fri 3/31/06
⊟ Emergency Stop and Control (Electrica	**24 days**	**Fri 2/17/06**	**Wed 3/22/06**
Research and devise a plan	6 days	Fri 2/17/06	Fri 2/24/06
Implement switch	11 days	Fri 2/24/06	Fri 3/10/06
Test workability	6 days	Fri 3/10/06	Fri 3/17/06
Documentation	4 days	Fri 3/17/06	Wed 3/22/06

⊟ **Documentation/Presentations/Administrati**	**65 days**	**Mon 9/19/05**	**Mon 12/12/05**
Projects Defined	3 days	Mon 9/19/05	Wed 9/21/05
Project Objectives defined	3 days	Mon 9/26/05	Wed 9/28/05
Project Poster displayed at station	3 days	Wed 9/28/05	Fri 9/30/05
Project slide to M. Krul	3 days	Mon 10/3/05	Wed 10/5/05
Alternative Solutions	5 days	Mon 10/3/05	Fri 10/7/05
Oral Presentation 1	2 days	Sat 10/8/05	Mon 10/10/05
Project website LIVE	2 days	Thu 10/13/05	Fri 10/14/05
Preliminary Task Specifications	2 days	Sat 10/15/05	Mon 10/17/05
Preliminary evaluation of feasibility	5 days	Mon 10/24/05	Fri 10/28/05
Preliminary Budget	1 day	Mon 10/31/05	Mon 10/31/05
Refined Task Specs	3 days	Wed 11/2/05	Fri 11/4/05
Preliminary Project schedule	1 day	Mon 11/7/05	Mon 11/7/05
Monthly Budget Report	1 day	Wed 11/30/05	Wed 11/30/05
PPFS draft due	2 days	Sun 11/6/05	Mon 11/7/05
Oral Presentation 2	2 days	Fri 12/2/05	Mon 12/5/05
⊟ **PPFS DUE**	**4 days**	**Tue 12/6/05**	**Fri 12/9/05**
Abstract	1 day	Wed 12/7/05	Wed 12/7/05
Intro	1 day	Wed 12/7/05	Wed 12/7/05
Project Background	2 days	Tue 12/6/05	Wed 12/7/05
Problem Statement/Scope	2 days	Tue 12/6/05	Wed 12/7/05
Project objectives	2 days	Tue 12/6/05	Wed 12/7/05
The Design Process	2 days	Tue 12/6/05	Wed 12/7/05
Alternative Solutions	2 days	Tue 12/6/05	Wed 12/7/05
Feasibility Study	2 days	Tue 12/6/05	Wed 12/7/05
Detailed Task Specifications	2 days	Tue 12/6/05	Wed 12/7/05
Prelimianry Design with components	2 days	Tue 12/6/05	Wed 12/7/05
Method of Approach	2 days	Tue 12/6/05	Wed 12/7/05
Christian Perspective	2 days	Tue 12/6/05	Wed 12/7/05
Christian Perspective	2 days	Tue 12/6/05	Wed 12/7/05
Tast Breakdown and Time Schedule	2 days	Tue 12/6/05	Wed 12/7/05
Cost Estimates	1 day	Wed 12/7/05	Wed 12/7/05
compilation of Final Report	2 days	Thu 12/8/05	Fri 12/9/05
Prepare Notebook	3 days	Fri 12/9/05	Mon 12/12/05
⊟ **Contacts and Meetings**	**70 days**	**Mon 9/12/05**	**Mon 12/12/05**
Meeting with Tim Holwerda from Knoll Inc.	1 day	Wed 9/21/05	Wed 9/21/05
Meeting with Tim Holwerda from Knoll Inc.	1 day	Mon 11/7/05	Mon 11/7/05
Consulting with Young Blood	1 day	Tue 11/15/05	Tue 11/15/05
Meet to research and work on PPFS and Project	69 days	Mon 9/12/05	Mon 12/12/05
Project brief for industrial consultant	1 day	Wed 11/23/05	Wed 11/23/05
⊟ **Interim and Second Semester**	**84 days**	**Thu 1/5/06**	**Sun 4/30/06**
Finalize components	5 days	Thu 1/5/06	Tue 1/10/06
Building a prototype	36 days	Tue 1/10/06	Tue 2/28/06
Testing and finalizing the prototype	24 days	Tue 2/28/06	Fri 3/31/06
Writing the product manual	21 days	Mon 4/3/06	Sun 4/30/06
Writing the safety manual	21 days	Mon 4/3/06	Sun 4/30/06

The core mechanical components required for this machine are the linear actuators, screw guns and screw gun sockets. We have submitted a parts list to Knoll Inc. and have received feedback indicating the availability of pneumatic linear actuators and motor starters for the screw guns. The motor starters will substitute the need for stepper motors. However, we are still responsible for designing a socket which will effectively hold both glides.

This project requires the integration of electrical components with its mechanical counterparts. The main electrical components required include thru-beam photo sensors, a PLC, a circuit board, and various integrated circuit parts. Now that we have a feasible design in which we know the necessary components and how to integrate them, we will move toward our ultimate goal of constructing a prototype. In doing this, we must acquire the necessary parts and assemble our proposed design. Once this is completed much of our effort will be focused on testing this design and making adjustments as stated in the schedule above.

5.2 Individual Task Delegation

Each member of the team contributed significantly to the success of our project so far. Since the team is made up of three Mechanical Engineers and one Electrical Engineer, the tasks were divided among these two categories- Mechanical and Electrical. As the electrical engineer, Freeland has been in charge of the electrical aspect of the design. He acquired free photo sensors from IFMefector and configured to work as desired. He will also be responsible for the PLC, Circuit Board and other electrical needs as the project progresses.

The Mechanical aspect of our design was divided among the mechanical engineers. Everyone participated in doing research on linear actuators and screw guns. Peter has been primarily responsible for AutoCAD drawings. Junior facilitated meetings with Youngblood, and team members. Monika kept minutes of meetings along with Freeland and has been the team mediator between Youngblood and Knoll.

Apart from the individual tasks, the entire team worked together on deliverables, attending meetings with representatives from Knoll and Youngblood and getting feedback from the industrial consultant and Professor Nielsen.

5.3 Budget Analysis

In order to ensure the financial feasibility of our project we performed a budget analysis which required us to research the appropriate product prices of the manufacturers Knoll recommends. In addition to the $300 grant from Calvin College, Knoll has offered a stipend of $1000 to assist us in our project. They have also notified us of the products which they will be able to provide us with at no cost to us. Taking these things into consideration we have concluded that we will still need to account for about $350 in order to complete our project. A detailed cost analysis can be found in the appendix.

6 Christian Perspective

A Christian perspective is used in our project and design process. As a group, we considered how God would want us to approach this project. We have realized that our design will result in increased productivity and have a domino effect on other aspects of the workers' life. For instance, our product will increase the workers' productivity because less time will be spent flipping the box over, manually installing four glides, and using a screw gun to finish the process. Not only is the job done faster and more efficiently, it is done easier. With the increased productivity and added value which this product will bring to the company, it is our hope this will result in better benefits for the workers. From a Christian perspective, we are doing what is ethical with the resources that we have been given- education and natural talents. We are being good stewards of our education and using this education to better the lives of the workers and ensuring the company's ability to viably remain in business. This idea is summed up in the design norm of stewardship. As Christian engineers, we are concerned with being good stewards of time and resources and we are convinced that our design embodies stewardship.

Furthermore, we are concerned with life after work. It is one thing to increase productivity at work, however, we are also eliminating a health hazard. Carpal tunnel has been a problem for people who have had this job. After spending eight hours at work, a worker has been returning home tired and injured. This adversely affects life at home such as lifting and doing household chores as well as family activities.

We are exercising a caring attitude by implementing a design which will ensure that health Carpal Tunnel and other possible health hazards are eliminated. This is a representation of the design norm of caring.

Finally, we will be sure to clearly document our design. We have constantly maintained open lines of communication with our client. We are putting together an operating manual which will detail how the machine is put together and how it functions. Quality is another important component of our final design. We are taking steps to ensure that our product is the best we can provide. We are putting considerable amounts of time and energy into this project. We believe the best way to achieve our final design is to continually think of ways to better out current design and challenge former ideas. This principle signifies the design norm of transparency. As Christian engineers, we know that withholding knowledge from those who use our product stifles their effectiveness as users and their total enjoyment of the product. Furthermore, we want to establish a relationship of trust with our client where the client knows and trusts that our product is high quality. We are determined to deliver on our promise by meeting all the specifications for our project. This idea symbolizes the design norms of transparency and trust.

References

Allen Bradley, Milwaukee, WI

GlobalSpec.com

IFMefector Inc., Exton, PA

Knoll Inc., Muskegon, MI

Ned Nielsen, Calvin College Engineering Dept.

Numatics Inc., Highland, MI

Robohand Inc., Monroe, CT

Youngblood Air Systems, Grand Rapids, MI

7 Appendices

7.1 Appendix A: PSpice Simulation

7.2 Appendix B: Cost Analysis

7.3 Appendix C: Mechanical Aspects of the prototype

7.3.1 Screw Guns and Linear Actuator System

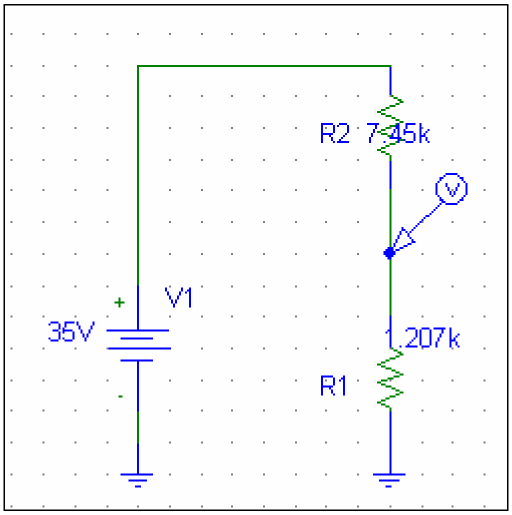
7.3.2 The Full design/ prototype

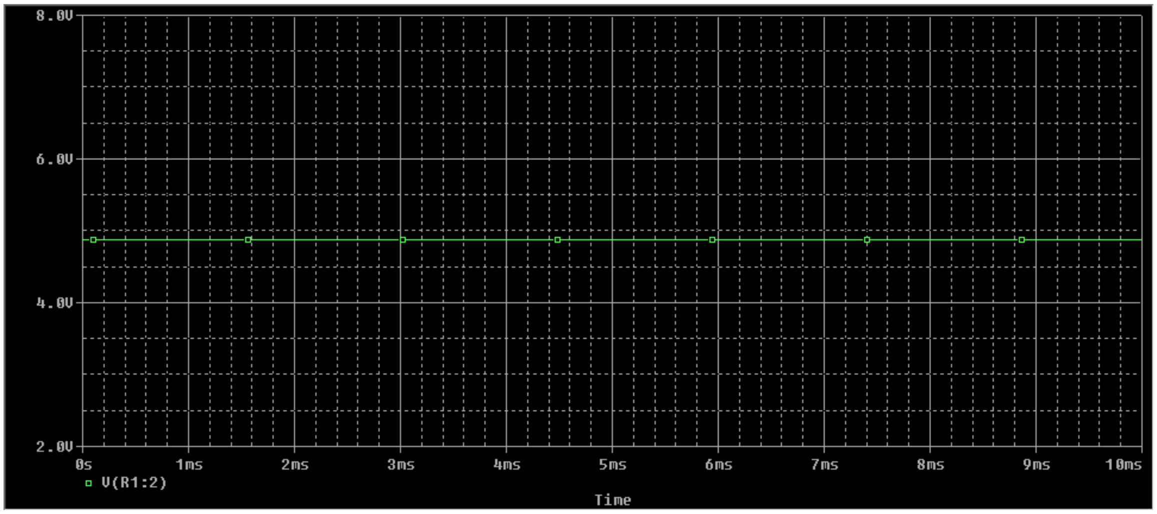
7.3.3 Socket Design

7.4 Appendix D: Decision Matrix for Alternative Solutions

Appendix A

PSpice simulation





Appendix B

Cost Analysis

Assuming Full Financial Responsibility					
Part Number	**Part Description**	**Manufacturer**	**Cost/Unit**	**Quantity**	**Total Cost**
OG5096	Through-beam sensor	Efector	$77.00	6	$462.00
SLC500	Programmable Logic Controller	Allen-Bradley	$400.00	1	$400.00
CGS Series	Pneumatic Linear Actuator	Numatics	$200.00	4	$800.00
SDN 4-24-100P	DC Power Supply	Sola	$291.81	1	$291.81
	Emergency On/Off Switch		$48.84	1	$48.84
	Screw Gun				
					$2,002.65

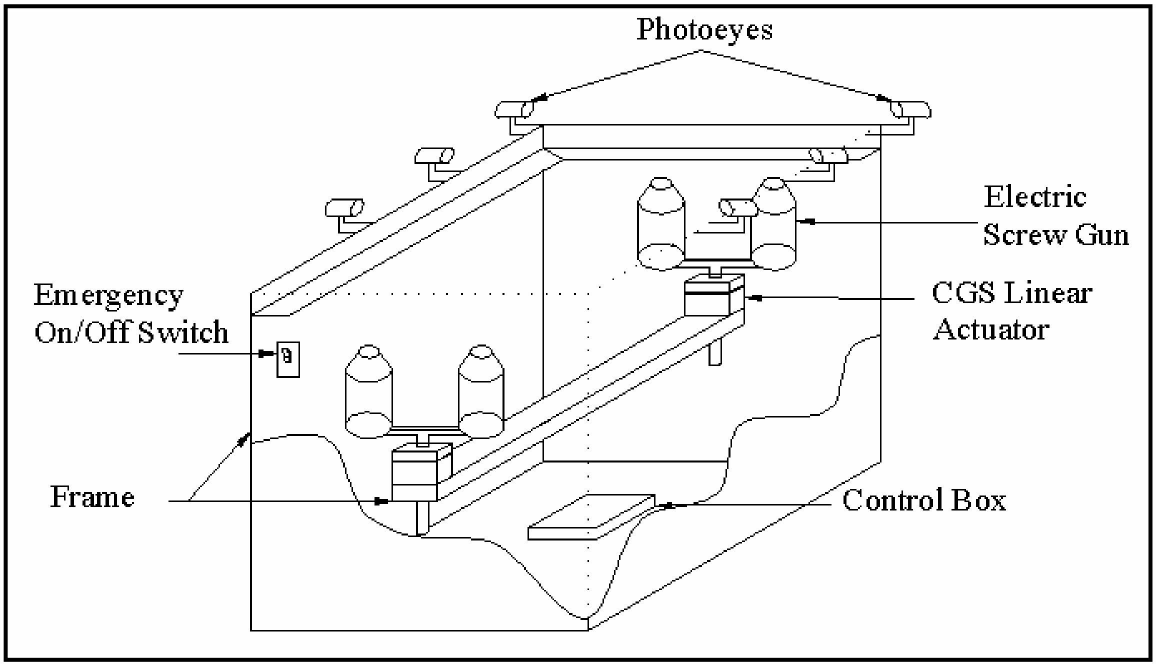
Projected Budget					
Part Number	**Part Description**	**Manufacturer**	**Cost/Unit**	**Quantity**	**Total Cost**
OG5096	Through-beam sensor	Efector	$0.00	6	$0.00
SLC500	Programmable Logic Controller	Allen-Bradley	$400.00	1	$400.00
CGS Series	Pneumatic Linear Actuator	Numatics	$200.00	4	$800.00
SDN 4-24-100P	DC Power Supply	Sola	$0.00	1	$0.00
	Emergency On/Off Switch		$48.84	1	$48.84
	Screw Gun				
					$1,248.84

Appendix C

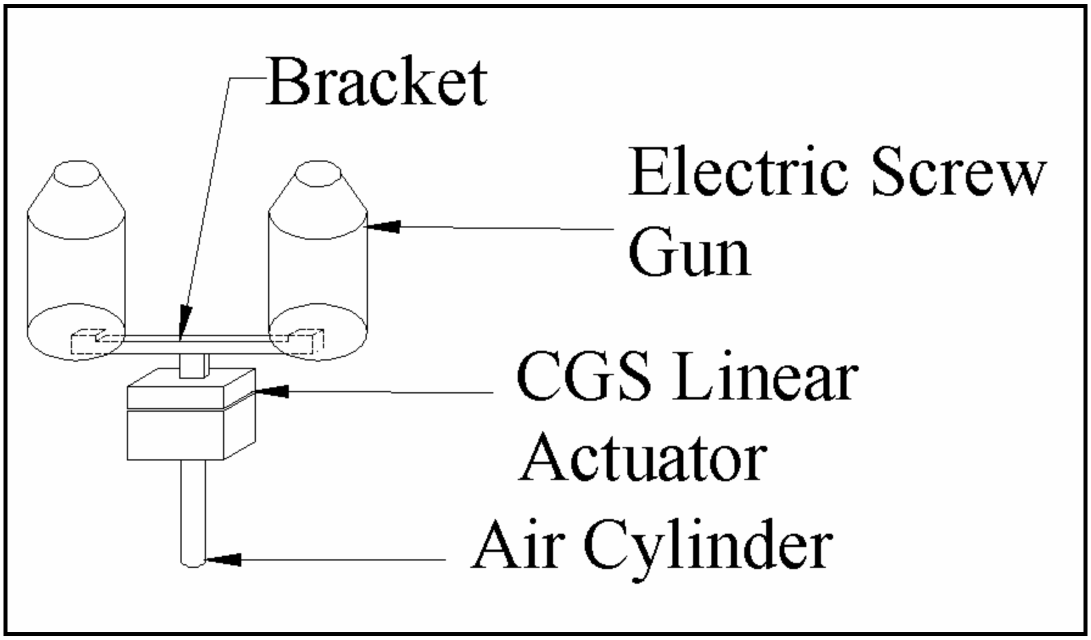
Preliminary Design

The Full design/ prototype

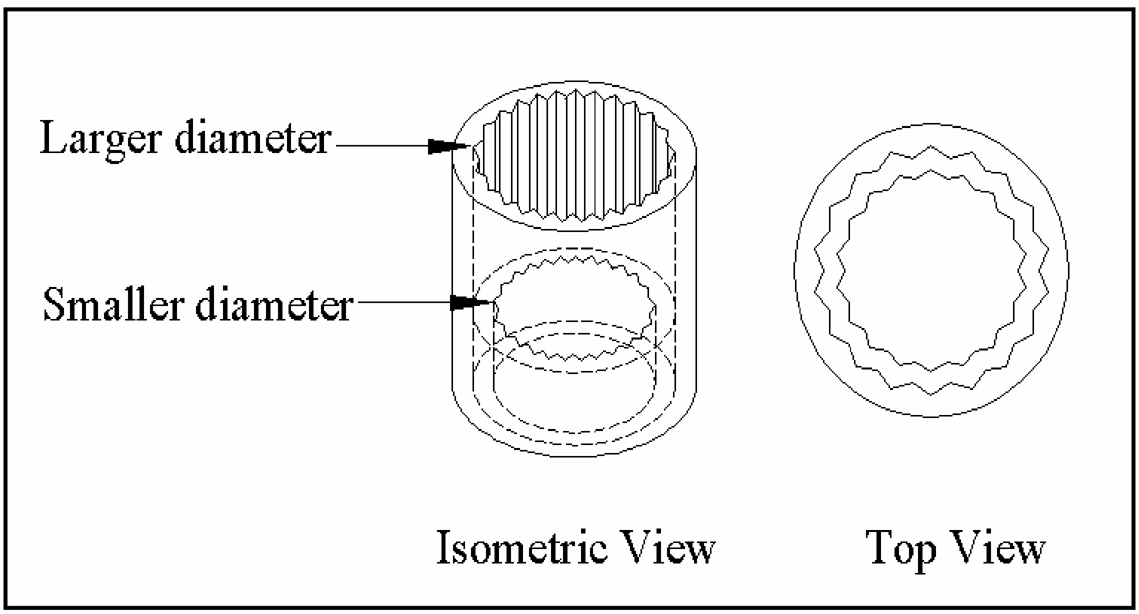
Note: The prototype will be built with four linear actuators and eight ESG's. Only two linear actuators and four ESG's are shown here for picture clarity.



Screw Guns and Linear Actuator System



Socket Design



Appendix D

Decision Matrix for Alternative Solutions

Design Criterion	Weight	Alternative Solutions
Cost	10	
Familiarity/Difficulty	2	
Time	6	
Availability	4	
Practicality	8	
Total		

Glide Screwing		**Alternative Solutions**	
Design Criterion	**Weight**	**Pneumatic Screw Guns**	**Electric Screw Guns**
Cost	10	2	1
Practicality	8	1	1
Time	6	1	1
Availability	4	1	1
Familiarity/Difficulty	2	2	1
Total		**42**	**30**

Screw Gun Positioning		**Alternative Solutions**	
Design Criterion	**Weight**	**Eight Screw Guns (Fixed)**	**Linear Actuator (Variable)**
Cost	10	2	1
Practicality	8	2	1
Time	6	2	1
Availability	4	1	1
Familiarity/Difficulty	2	2	1
Total		**56**	**30**

Vertical Screw Gun Control		Alternative Solutions		
Design Criterion	**Weight**	**Pneumatic Linear Actuator**	**Motorized Linear Gear**	**Spring Loading**
Cost	10	1	2	3
Practicality	8	2	2	1
Time	6	2	2	1
Availability	4	3	2	1
Familiarity/Difficulty	2	1	1	1
Total		**50**	**56**	**48**

Pedestal Loading		Alternative Solutions	
Design Criterion	**Weight**	**Manual**	**Conveyor System**
Cost	10	2	2
Practicality	8	1	2
Time	6	2	2
Availability	4	2	2
Familiarity/Difficulty	2	2	1
Total		**48**	**56**

Glide Loading		Alternative Solutions	
Design Criterion	**Weight**	**Manual**	**Automatic**
Cost	10	2	1
Practicality	8	2	1
Time	6	2	1
Availability	4	2	1
Familiarity/Difficulty	2	2	1
Total		**56**	**28**