Team Four: Final Assembly

Final Report

Calvin College Engineering Dept.
ENGR 340: Senior Design
Advisor: Professor Ned Nielsen

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Team Members:
Monika Gunnar (ME)
Kingsley Kanu Jr. (ME)
Peter Malefyt (ME)
Freeland Shaw (EE)
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Executive Summary

Machine automation has played an instrumental role in production efficiency throughout history and as engineers we are constantly using our resources to maximize this efficiency. Knoll Incorporated, a furniture manufacturer in Muskegon, Michigan has proposed to improve the manufacturing process of one of their office products through the implementation of automated machinery. As a senior design team, we have worked in conjunction with Knoll to develop and build a machine that will adequately meet their production requirements and increase the efficiency of their assembly process.
1 Introduction

Knoll Incorporated is a furniture manufacturer located in Muskegon, Michigan which specializes in the production of office furniture. One of their primary products is an office pedestal, which is essentially a filing cabinet. Each pedestal 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. The final assembly step in the production of the pedestals is to attach the glides to the bottom of the pedestals. Currently this step is done manually. Tim Holwerda and Kevin Bentz, representatives from Knoll Inc., contacted Professor Ned Nielsen of the Calvin College Engineering Department suggesting this process be automated by a current senior design team.

From the beginning, we were sure of some tools that we would most likely use in order to make the prototype function. After visiting Knoll, the engineers there gave us an idea of even more tools that they often use in their manufacturing processes. Knoll outlined the problem and gave us a starting point to begin design of a prototype. Knoll uses mostly pneumatic devices rather than electrically powered components. Because we wanted our prototype to fit into Knoll’s environment, we knew that we would have to use pneumatically powered components. This meant that we would need air hoses and some type of air valves to control the air to our components. Knoll was also able to provide our team with some of the key components of our prototype. A PLC was needed to control what moved, when it moved, and for how long. A user interface was required so that the operator could control the different components with an easy setting. Screw guns were needed to perform the screwing aspect of our design. Linear actuators were also needed to provide vertical motion to the screw guns, and Knoll paid for these as well. Finally, Knoll also provided us with the glides they use on the bottom of their pedestals, and they provided us with 4 pedestals to give us an idea of the products they make.

Without the support of Knoll, our prototype would not have come together because many of the tools that Knoll supplied us cost much more than the Calvin budget of $300 allotted. Other tools that we used in the design of the prototype included sockets to fit the glides to the screw guns, adapters for the air hoses and also for the screw guns, and finally a steel frame to support our different components.
### Table 1: List of Terms and Abbreviations

<table>
<thead>
<tr>
<th>Term</th>
<th>Abbreviations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Programmable Logic Controller</td>
<td>PLC</td>
</tr>
<tr>
<td>Printed Circuit Board</td>
<td>PCB</td>
</tr>
<tr>
<td>Volts</td>
<td>V</td>
</tr>
<tr>
<td>Alternating Current</td>
<td>AC</td>
</tr>
<tr>
<td>Ryskamp Contraptions</td>
<td>RC’s</td>
</tr>
</tbody>
</table>

## 2 Problem Specification

As stated earlier, the crux of the problem was to automatically screw in four glides to the bottom of a pedestal. The current process at Knoll is described in the pictures below labeled 1 through 6 in Figure 1. First, the pedestal must be lifted off the assembly line and flipped over as shown in pictures 1 through 3. Pictures 4 and 5 show the individual glides being screwed in. The final assembly step is the screwing in of the glides using a pneumatic screw gun as shown in picture 6.

![Figure 1: Current Process at Knoll Inc. described in sequence](image)

### 2.1 Description of the Challenge and Design Norms

The challenge in this project was to find a solution that would implement some form of automation that would be feasibly designed and constructed within the constraints of the school year while maintaining the operator’s job. The design norms played an important role in our decision to take on this project. The first design norm considered was that of caring. We knew...
that we were performing a service of care to the workers at Knoll Inc. Reports of Carpal Tunnel resulting from the repeated screwing in of glides had been lodged with the management.

Secondly, there was the question of stewardship. In most cases, this design norm is related to environmental or economical considerations in design. However, we focused on the stewardship of our talents. As a team, we had decided earlier that we should pick a project that reflected our collective passions. Automation turned out to be that unifying factor and we felt it was a stewardly use of our talents to solve a problem that was presented to us. The next design norm considered was cultural appropriateness. It was apparent early on in the project, that our final product would have to successfully integrate into the manufacturing environment at Knoll. Whatever we designed had to be commensurate with industrial machine conditions and operator behaviors. Finally, the design norm of transparency reminded us that we weren’t designing for our eyes alone but for subsequent users and would-be improvers of our project. We understood that documentation and a description of each of the constituent parts would be necessary.

2.2 Project Requirements

2.2.1 Mechanical

Several different issues had to be considered when designing a prototype for Knoll. The project requirements are a combination of customer and self imposed requirements. Knoll had expectations of us, and we had expectations of ourselves. From the beginning, Knoll required that our prototype would eliminate the need to flip the pedestal. When the engineers gave this requirement, it came with the suggestion that our prototype be installed in line with the conveyor system so that an operator could move the pedestal into position on our prototype but not have to flip it over.

Knoll uses two different styles of glides with their office pedestals. When asked why they do this, the engineers explained that customers often specify which they would like. One of the glides has a hexagonal head and fits into a 1” socket. The second type of glide has a circular head with a diameter of 1.25”. Also, the circular glide is taller than the hexagonal glide. Each glide has the same threads so that they can be interchangeable in the pedestals. The requirement for our prototype was to design a system that would not require significant cycle time increase for different glides. This meant that any tooling changes to accommodate the different glides styles was out of the question.
Knoll makes several different styles of pedestals. Each pedestal is slightly different. There are three different lengths of pedestals: 18”, 24” and 30”. Each one of those pedestals has a differing edge to hole distance and hole to hole distance. Our prototype needs to be adjustable to accommodate the different styles of pedestal. All of the pedestals have the same overall width but the prototype needed to be adjustable in two different directions to accommodate the differing pedestal lengths and hole locations.

Knoll’s approximation for the cycle time was sixty seconds. We would like to improve upon that cycle time if at all possible. This would mean that our prototype would eliminate most of the health risks associated with performing the final assembly step manually, but would also increase the efficiency of the final assembly step.

Safety was a primary concern for us. We wanted to keep the job of the operator and that meant that our prototype needed to be safe to use. It doesn’t make any sense to eliminate the risks associated with a process and then introduce all new risks.

Knoll required that our prototype be adjustable in height. Currently, their assembly line is at 31”. They assigned the task of making the prototype adjustable to ± 3”. Because the prototype is height adjustable, it ensures that the operator would be transferring the pedestal to the same height as the assembly line and does not have to lift it higher or lower than it already is.

The overall prototype is complex, yet we wanted it to be easy to use. The operator should not have to understand all the workings of the electrical and mechanical systems in order to be able to operate the prototype. In order for this to be achieved, the user interface had to be simple with clear instructions on how to operate it.

Finally, we wanted the final prototype that was produced to be able to be improved upon by Knoll if they so desired. From our prototype, they can see some of the different issues involved with making a machine to automatically screw in the glides into the pedestals. Our prototype provided a base allowing for improvements if more time and money were invested. Therefore, if they had an idea that would improve the process, they could implement it on our prototype and not have to start again from scratch.
2.2.2 Electrical

In regards to the control system that would be necessary to fulfill the needs of our customer, the main consideration was if we wanted our design to be fully or semi-automated. This decision was governed by many variables, but the most important were cost, project scope, and customer specifications. These three major design factors ultimately led to a semi-automated system, and following is a discussion of how each factor affected the overall design decision from a controls standpoint.

As with any design, cost played a major role in governing most of our decisions. Since one design specification required us to accommodate for three different pedestal lengths, an automatic system would need to realize the size of the pedestal and then move the components into their proper position. This system would consist of various photo electric detectors as well as a horizontal linear actuator to move the components into position. The conflict arose when we compared the cost of the horizontal actuator to the option of having an operator manually move the components into position after identifying the pedestal configuration. The extra actuator would be about $2,000 more, an unviable option.

Since Knoll Inc. contacted the department with an explicit need, it was important that we addressed this need as specifically as possible. The health issue of Carpal Tunnel was of great concern for the customer and we believed that in addressing this issue we would make the job easier and more comfortable for the worker without eliminating their job altogether. When considering the automation of our process we determined that it would be in the customers best interest to provide them with a machine that would fit their current operations as well as possible. In touring the manufacturing facility it was brought to our attention that workers were present at every stage in their production process for quality management and we believed that providing Knoll with a machine which required human interaction would integrate well with their existing system.

Although there was a considerable amount of time given to the designing and prototyping of our machine, we realized that some design options would not be easily accomplished in the amount of time we were given. In order to fully automate the process given to us by Knoll there were many issues that we determined could not be easily resolved and would be outside of the scope of our project. The most problematic issue concerned the loading of the glides into the
screw guns. Without human interaction we concluded that loading the glides would be too complicated and it was an unnecessary hindrance to pursue a solution to this problem.

By deciding to propose a semi-automated approach to the problem, the control system required was considerably simplified. We were also provided with all of the necessary components making it a very cost effective decision and it allowed us to focus on fulfilling more of the customer needs. This decision also made integration with the mechanical aspects of the machine easier resulting in an overall effective design that we can be confident in.

2.3 Prior Work

From the research conducted we found that similar operations could be accomplished using table mounted slides and actuators such as XYZ table mounts sometimes referred to as positioning stages. However, we decided against following this solution firstly because of the increased cost and secondly because of its heavy electrical bent. This solution would have resulted in less work for the mechanics with the largest focus being on programming and sensor configuration.

3 Proposed Solution

The extensive problem specifications determined our solutions. We spent quite a bit of time researching and thinking about the problem specifications and the ways to meet those specifications with the resources that we had.

3.1 Project Management

Project management turned out to be an integral part of the success of our team. We were very organized and followed a schedule as closely as possible. As new situations arose, we set aside times that we could dedicate to that specific issue.

3.1.1 Team Organization

Kingsley Kanu Jr. is a senior mechanical engineering student from Jos, Nigeria. He intends to pursue graduate studies in alternative energy development. Junior Kanu brought excellent computer skills to the team. Specifically, he was good with designing and prototyping on the CAD software. He also developed and updated our website. He was an organized and
talented young man who brought organization and motivation to the team. He also helped develop and build the prototype.

Peter Malefyt is a senior mechanical engineering student from Lansing, MI. He plans to pursue full time employment after graduation. Peter Malefyt brought excellent skills and a sense of humor to the team. He was especially good with the CAD software and was always ready to get his hands dirty in the metal shop. He was cooperative in working as a team. He went to Youngblood several times and secured the air devices. Finally, he helped develop and build the prototype.

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. Freeland Shaw brought his exceptional and unmatched electrical skills into the team. He was the sole source of all electrical solutions and was highly skilled in this field. He brought good cooperation and leadership into the group. He was also in charge of the final integration of the mechanical and electrical components.

Monika Gunnar is a senior mechanical engineering student from Lucknow, India. She intends to pursue graduate studies in Engineering Management and Marketing. Monika Gunnar brought excellent computer and organizational skills to the team. She is cooperative, motivated and dedicated to the work of the team. She was especially good with details of the jobs required and communication within and outside the group. She handled most of the paperwork and presentation development toward the end of the semester.

3.1.2 Work Breakdown

Altogether each person in the group was dedicated to spending about 12 hours a week toward getting the final prototype in working order and taking care of the miscellaneous work that needed to be accomplished as well.

3.1.3 Schedule

Our schedule made in Microsoft projects is given in Appendix ___. We followed the schedule as closely as possible and made changes along the way as necessary. The schedule helped us to be on task with all our goals for this design project.
3.1.4 Contingency Plan

We had planned to finish the prototype two weeks before the final presentation date. This plan allowed us some testing and tweaking time for what didn’t function as we had planned. We arrived at our goal and began testing what we thought was a working prototype two weeks before the final presentation date. However there were some major issues with alignment of the glides and the screw holes. This, along with the horizontal positioning of the system ended up taking most of our time during the final couple weeks of the semester. More information about how we solved these issues is in the “Design” section for “The Proposed Solution.”

3.2 Project Budget

The budget allotted to our senior design team by Calvin was $300. It became apparent that this budget was too small considering the components we would need to implement. Knoll stepped in and took on most of the financial responsibility for the final prototype.

3.2.1 Prototype

Our prototype costs $4785.96 according to Table 2 given below. This is the cost of our machine when it is built from scratch excluding the price of the components that we got for free from the Calvin College machine shop (listed as 0).

<table>
<thead>
<tr>
<th>Parts List</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubber Insert</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1 1/4” sockets</td>
<td>4</td>
<td>2.25</td>
<td>9</td>
</tr>
<tr>
<td>1/4” hex to 1/2” square adapter</td>
<td>4</td>
<td>1.75</td>
<td>7</td>
</tr>
<tr>
<td>1500 rpm inline screw guns</td>
<td>4</td>
<td>1000</td>
<td>4000</td>
</tr>
<tr>
<td>SH 075–Linear actuator (glide)</td>
<td>2</td>
<td>350</td>
<td>700</td>
</tr>
<tr>
<td>SCHS screws</td>
<td>16</td>
<td>0.6</td>
<td>9.6</td>
</tr>
<tr>
<td>Aluminum</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Steel</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Shoulder Bolts</td>
<td>4</td>
<td>3.65</td>
<td>14.6</td>
</tr>
<tr>
<td>Flow Controls</td>
<td>2</td>
<td>11.86</td>
<td>23.72</td>
</tr>
<tr>
<td>Porous Muffler (1/8”)</td>
<td>2</td>
<td>1.4</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Table 2: Complete List of Components and Costs
Another point to note in our budget is the fact that most of the components used were either donated by Knoll Inc. or obtained from the machine shop, in either case the components were free for us and the only purchases from the Calvin budget can be seen in Table 3. Our design is a one time prototype and will not be mass produced or manufactured again.

Table 3: List of Parts Purchased with Costs

<table>
<thead>
<tr>
<th>Part</th>
<th>Source</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 - 1/2&quot; to 1/4&quot; air adapters</td>
<td>FCI Automation</td>
<td>4.75</td>
</tr>
<tr>
<td>4 - 1 1/4&quot; sockets</td>
<td>Lowes</td>
<td>10</td>
</tr>
<tr>
<td>4 - 1/4&quot; hex to 1/2&quot; square adapters</td>
<td>FCI Automation</td>
<td>6</td>
</tr>
<tr>
<td>4 shoulder bolts, 4 SCHS finely threaded</td>
<td>Godwin Plumbing</td>
<td>18.02</td>
</tr>
<tr>
<td>Super Glue</td>
<td>NAPA</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>60.77</td>
</tr>
</tbody>
</table>

3.3 Preliminary Research

Most of the beginning stages of our work began with research. The project requirements would lead us to consider machines and materials that we were not familiar with. The first of these was linear actuators. We each did web-based and library research to understand how electric and pneumatic linear actuators worked. We were also able to locate manufacturers on Globalspec.com as well as ask Knoll who supplied its equipment. It was during this time that we learned of the importance of manufacturer-supplier reliance. Knoll Inc. primarily ordered its
components from Youngblood Air Systems and we were encouraged to funnel all purchase needs to that supplier.

The second leg of our research involved understanding possible electrical components. The first set of electrical components researched was Programmable Logic Controllers (PLCs). The library proved to be a helpful resource for books on ladder logic and use of PLCs. The next group of electrical components researched was stepper motors. It was also important to learn about the control of the Flexiblok air valves as well as all the air adapters that would be required to connect our pneumatic equipment and air hoses to the air valves.

3.4 Design

3.4.1 Design Alternatives

There were several design decisions to be made and alternatives to consider as can be seen in the decision matrix given in the Appendix.

3.4.2 Design Decisions

This section of the report will focus on three main topics. First, we’ll briefly restate the project requirements; then, we will present an overview of our final prototype. We will then conclude with an in-depth look at each of the components which comprise the final machine.

The mechanical and electrical requirements for our final prototype have been summarized below:

Mechanical

1. Designing for two types of glides
2. Designing for three pedestal lengths
3. Designing for different hole to hole distances along the width
4. Designing for different edge to hole distances
5. Aligning the glides to match up with the holes

Electrical

6. Provide a user-friendly interface
7. Design a pneumatic-powered machine
3.4.3 Final Design

The final AutoDesk Inventor rendering and actual finished prototype are shown below in Figures 2 and 3. In our design, before the pedestal arrives, the operator moves the adjustable assembly into the grooves corresponding to the length of the pedestal. The glides are dropped into the socket and the pedestal is placed onto the machine. After the RC’s have been placed on the glides, the operator, via the Panel View interface, controls the machine. The following section goes through a detailed review of each component of the machine and the process by which the final decisions were made.

Figure 2: Simplified AutoDesk rendering of our design

In reviewing the overall design, we will first discuss the mechanical components and then proceed to discuss the electrical components. The mechanical components consist basically of the frame and the Linear Actuator-Screw Gun assembly while the electrical components consist of the Panel View user interface, the PLC, and the Flexiblok air valves.

3.4.4 The Frame and its components
The frame is made up of a top section which holds the pedestal during operation; a handle for moving the screw guns into the corresponding pedestal lengths; shoulder bolts which slide on the track and fit in the grooves mounted on the track. The frame was also built to accommodate for different machine heights. A finite element analysis (FEA) was performed to determine the integrity of a steel frame.

**Frame Analysis:**

The result of the FEA impact analysis is shown in Figure 4 below. The analysis was performed by simulating a pedestal being dropped onto the frame. From the results shown below, we knew that a material that could sustain a load of about 240 psi was needed. Prior to performing the impact analysis, a search was done to find what materials could be used in the building of the prototype. Calvin’s machine shop had plenty of steel and we knew that steel would be strong enough to support the different components of the prototype and support the load of a pedestal.
**Handle:** The handle design was first such that the handle was outside the frame so that it would be easily accessible. However, this changed when Knoll raised concerns about safety and accessibility of the sockets. The handle design was changed to be accommodated into the frame space as can be seen in Figure 5 below.

**Spacers:** Later in our design we realized that the distance from the holes to the end of the pedestal were not standard for all pedestals. This distance is referred to as the “edge to hole distance” and is described by Figure 6 below. There are two edge to hole distances of 1.94 and
2.5 inches. In order to accommodate for these different distances, we used spacers. A diagram of the spacers in use is given in Figure 7.

**Figure 6: Edge to hole distance**

**Figure 7: Spacers and Implementation**

**Grooves:** There are three pedestal lengths, 18”, 24” and 30”. Initially, we had considered using an electric linear actuator to move the screw guns horizontally to the positions for the corresponding pedestals. However, we decided against this for two reasons. The first reason was the fact that these positions were only six inches apart, which is a small distance. The second
reason is that an electric linear actuator would have greatly increased the cost of our machine by about $2000. The solution that we settled on was to implement an adjustable assembly sliding along the track on shoulder bolts and grooves along the track of the frame corresponding to the desired lengths of the pedestals. A pair of grooves was installed at the 18, 24 and 30 inch positions. The grooves feature a slope to allow for easy access of the shoulder bolts on the adjustable assembly. The design and implementation of the grooves is given in Figure 8 below.

Figure 8: Design and Implementation of Grooves

3.4.5 Linear Actuator Screw Gun Assembly

We used two linear actuator and screw guns assemblies in our design. One assembly was fixed to the frame where as the other was variable to move along the tracks of the frame. The assembly is illustrated in Figure 9 below.
ERROR: stackunderflow
OFFENDING COMMAND: ~

STACK:
Appendix A

A. Design Components and Final Design
A.1 Bottom Bracket
A.2 Top Bracket
A.3 Grooves

A.4 Linear Actuator Bracket
A.5 Socket Insert

Isometric

Top

1.25

1.00
A.6 Adjustable legs
A.7 Frame
A.8 Assembled Prototype
Appendix B

B. Electrical
B.1 Overall Flow Chart
B.2 Flow Chart – Automatic Control
Flow Explanation

- When the pedestal arrives, the size of the pedestal will be determined by the operator. The operator will indicate the size of the pedestal and then move the linear actuators into place.
- The PLC will assure the unit is in the proper configuration.
  - Photo eyes will determine whether the linear actuator is in the proper position
  - An error check will ensure all four glides are in place
- If the unit is not in the proper position the system will wait until the operator configures the unit properly
- Once the unit is in the proper position the linear actuators will move the screw guns into place
  - Photo eyes will check to see if the actuator and screw guns are aligned properly
  - The screw guns will screw the glides into the pedestal
  - After screwing, the screw guns and linear actuators will be deactivated
- The operator will wait for the arrival of a new pedestal
B.3 Flow Chart – Manual Control
B.4 Flow Chart – Debug Operation

B.5 Controls Operation

The controls of our machine prototype allowed the operator to perform the necessary functions without full interaction, increasing efficiency and making their job easier and more
comfortable. The following will serve as a detailed explanation of the functions of our prototype and how to operate our system.

**Interface Screens**

**Main:** The main screen is the initial screen seen by the user upon startup of the system. This screen also allows the user to navigate to the various screens and functions of the system.

- The current system configuration is pictured at the top of the screen. There are three pedestal sizes and two different glide configurations the operation should account for.
- Directly below the configuration is the mode indicator; this allows the user to know if they are in normal mode or debug mode.
- Setup F1 – Allows the user to enter the system setup screen.
- Operate F2 – Operates the machine while running in automatic operating mode.
- Counter F3 – Allows the user to enter the counter screen.
- Manual Op F6 – Allows the user to enter the manual operations screen.
- F7 – Toggles between manual and automatic operating modes.
- Debug F8 – Allows the user to enter the debug screen.
- Power F10 – Main system power; all air valves are on when the power is activated.

**Setup:** The setup screen allows the user to choose the configuration of the pedestal they are operating.
- A list indicator allows the user to choose between the three pedestal sizes (18”, 24”, and 30”)
- A list indicator allows the user to choose between two glide configurations (Circular and Hexagonal)
- Main F10 – Returns user to the main screen

**Manual Operation:** As specified by the customer, our system is able to operate automatically as well as manually. The manual operation screen allows the operator to control each component manually.
The current configuration is located at the top right corner of the screen; this notifies the user if they are in manual mode.

- Actuator Up F1 – Operates the front linear actuator
- Left Gun On F2 – Operates the left screw gun on the front linear actuator
- Right Gun On F3 – Operates the right screw gun on the front linear actuator
- Actuator Up F4 – Operates the rear linear actuator
- Left Gun On F5 – Operates the left screw gun on the rear linear actuator
- Right Gun On F6 – Operates the right screw gun on the rear linear actuator
- Main F10 – Returns user to the main screen

**Counter:** As specified by the customer, our system is able to monitor the frequency of each operation. The counter screen displays the count of each operation and allows the user to reset the system. The counter keeps track of total pedestals, number of circular glides, number of hexagonal glides, and number of each size.
- Reset F1 – Allows user to reset system count
- Main F10 – Returns user to the main screen

**Debug:** In order to have full control of the system, a debug mode was incorporated to allow the user to override the main system power. The debug screen allows the user to control which components are powered at any given time when the main power is off.
The top right corner gives the status of debugging; it also displays an error message when debugging is not possible

- Debug On F5 – Toggles between debug and normal mode
- Actuator 1 On F1 – Turns the front linear actuator on
- Actuator 2 On F6 – Turns the rear linear actuator on
- Gun 1 On F2 – Turns the left screw gun on the front linear actuator on
- Gun 2 On F7 – Turns the right screw gun on the front linear actuator on
- Valve On F4 – Turns the air valve located in slot 6 on
- Gun 3 On F3 – Turns the left screw gun on the rear linear actuator on
- Gun 4 On F8 – Turns the right screw gun on the rear linear actuator on
- Main F10 – Returns user to the main screen

B.6 Operating Modes

There are three main operation modes: normal, manual, and debug. Following is a description of each mode and the user’s capabilities within each.

**Normal:** Normal mode allows the user to operate the machine in its automatic setting. In order to do so the main power must be on (power on is indicated by the power button being highlighted) and user must press the F7 key on the main screen to activate the automatic operation (auto operation is indicated by the F7 key being highlighted) and then press F2 whenever they are ready to operate the assembly process.

**Manual:** Manual mode allows the user to manually operate each component separately. First, the main power must be activated and the F7 must indicate that the system is operating in manual mode. The user must then press F6 on the main screen to enter the manual operations screen. From this screen the operator can choose which tools they would like to operate and also the length of time they are activated.

**Debug:** Debug mode is very useful when trying to debug the air valves or a specific pneumatic component. In order to operate in debug mode the main power must be off and the user must
press F8 on the main screen to enter the debug screen. Once inside the debug session the user must press F5 to activate the debug mode, from there each component can be powered individually and also operated in the manual mode. If the user exits the debug screen and activates the main power an error message will be displayed on the debug screen and the debug session will be exited. In order to reset the system to operate in the debug mode again the user must turn off the main power and reactivate the debug session.
Appendix C

C. PLC Programming
LAD 2 - POWER --- Total Rungs in File = 22

0006
Power

ON_OFF
B3:0
1

DEBUG_MODE
N7:14
6

Screw Gun 4
GUN_4
O:4
11
1746-OA16

0007
Power

ON_OFF
B3:0
1

DEBUG_MODE
N7:14
6

DEBUG_STATUS
CLR
Clear
Dest
B3:3
000000000000000<

0008
Power

ON_OFF
B3:0
1

DEBUG_MODE
N7:14
6

Linear Actuator 1
ACTUATOR_1
O:4
2
1746-OA16

0009
Power

ON_OFF
B3:0
1

DEBUG_MODE
N7:14
6

Screw Gun 3
GUN_3
O:4
4
1746-OA16

0010
Power

ON_OFF
B3:0
1

DEBUG_MODE
N7:14
6

Linear actuator 2
ACTUATOR_2
O:4
9
1746-OA16

0011
Power

ON_OFF
B3:0
1

DEBUG_MODE
N7:14
6

BROKEN_VALVE
O:4
10
1746-OA16

Screw Gun 4
GUN_4
O:4
11
1746-OA16
0012

Power
ON_OFF
B3:0
N7:14

DEBUG_MODE

0013

Power
ON_OFF
B3:0
N7:14

DEBUG_MODE

0014

Power
ON_OFF
B3:0
N7:14

DEBUG_MODE

0015

Power
ON_OFF
B3:0
N7:14

DEBUG_MODE

0016

Resets the count to 0
CNT_RST
N7:0
N7:15

Linear actuator 1
manual operation
MAN_LA1
N7:0

Linear actuator 2
manual operation
MAN_LA2
N7:0

Manual operation for
screw gun 1
MAN_SCREW_GUN1
N7:0

Manual operation for
screw gun 2
MAN_SCREW_GUN2
N7:0

Manual operation for
screw gun 3
MAN_SCREW_GUN3
N7:0

Manual operation for
screw gun 4
MAN_SCREW_GUN4
N7:0

Operate input
OP_INPUT
N7:0

CNT_RST
Clear Dest
N7:1
0<

CIRC_CNT
Clear Dest
N7:4
0<
Resets the count to 0
CNT_RST
N7:0 15

HEX_CNT
CLR Clear Dest N7:6 0<

18" pedestal count
18_CNT
CLR Clear Dest N7:8 0<

Resets the count to 0
CNT_RST
N7:0 15

CLR Clear Dest N7:6 0<

18" pedestal count
18_CNT
CLR Clear Dest N7:8 0<

24" Pedestal count
24_CNT
CLR Clear Dest N7:10 0<

30" Pedestal count
30_CNT
CLR Clear Dest N7:12 0<

True if operation is automatic, false is manual
AUTO_MAN_OP
N7:0 6

Automatic Operation routine
AUTO_OP
JSR Jump To Subroutine SBR File Number U:3

True if operation is automatic, false is manual
AUTO_MAN_OP
N7:0 6

Manual Operation routine
MAN_Op
JSR Jump To Subroutine SBR File Number U:4

( END )
Begin Circular

True if glides are circular, false if hex
CIR_HEX_INPUT

Operate input
OP_INPUT

0005

Controls for hex glide configuration
HEX_GLIDE

Q3:1

JMP

Linear Actuator 1
ACTUATOR_1

0:4

U

1746-OA16

Operate input
OP_INPUT

0006

Off timer for linear actuator 1
LA1_OFF_CIRC

TON

Timer On Delay
Timer
T4:0

Time Base 1.0
Preset 3<
Accum 0<

Operate input
OP_INPUT

0007

Time for second LA to come on
LA2_ON_CIRC

TON

Timer On Delay
Timer
T4:1

Time Base 1.0
Preset 3<
Accum 0<

Operate input
OP_INPUT

0008

Time for first screw guns to come on after linear actuators
SCREW_GUN1_ON_CIRC

TON

Timer On Delay
Timer
T4:2

Time Base 1.0
Presets 1<
Accum 0<

Circ glide control time
SCREW_GUN1_OFF_CIRC

TON

Timer On Delay
Timer
T4:3

Time Base 1.0
Presets 2<
Accum 0<
Time for first screw guns to come on after linear actuators

Circ glide control time

Screw Gun Timer
Screw Gun Timer
LA2 ON CIRC/DN

0013

LA2 Time Off
LA2 OFF CIRC

T4:1

DN

Timer On Delay
Timer T4:4
Time Base 1.0
Preset 3<
Accum 0<

Time for second screw guns to come on
Screw Gun Timer
LA2 ON CIRC/DN

0014

SCREW_GUN2 ON CIRC

T4:5

DN

Timer On Delay
Timer T4:6
Time Base 1.0
Preset 2<
Accum 0<

Time for second screw guns to go off
SCREW_GUN2 OFF CIRC

0015

Time for second screw guns to come on
Screw Gun Timer
LA2 ON CIRC/DN

0016

SCREW_GUN2 OFF CIRC

T4:6

DN

Time for second screw guns to go off
Screw Gun Timer
LA2 ON CIRC/DN

0017

0018
Controls for hex glide configuration

<table>
<thead>
<tr>
<th>Q3:1</th>
<th>HEX_GLIDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>LBL</td>
<td>OP_INPUT</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Operate input

<table>
<thead>
<tr>
<th>N7:0</th>
<th>OP_INPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Linear Actuator 1

<table>
<thead>
<tr>
<th>O:4</th>
<th>ACTUATOR_1</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1746-OA16</td>
</tr>
</tbody>
</table>

Time for first linear actuator to go off with hex glides

<table>
<thead>
<tr>
<th>TON</th>
<th>LA1_OFF_HEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timer On Delay</td>
<td>T4:7</td>
</tr>
<tr>
<td>Timer</td>
<td>1.0</td>
</tr>
<tr>
<td>Preset</td>
<td>3&lt;</td>
</tr>
<tr>
<td>Accum</td>
<td>0&lt;</td>
</tr>
</tbody>
</table>

Time for second linear actuator to come on for hex glides

<table>
<thead>
<tr>
<th>TON</th>
<th>LA2_ON_HEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timer On Delay</td>
<td>T4:8</td>
</tr>
<tr>
<td>Timer</td>
<td>1.0</td>
</tr>
<tr>
<td>Preset</td>
<td>3&lt;</td>
</tr>
<tr>
<td>Accum</td>
<td>0&lt;</td>
</tr>
</tbody>
</table>

Time for first screw guns to come on with hex glides

<table>
<thead>
<tr>
<th>TON</th>
<th>SCREW_GUN1_ON_HEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timer On Delay</td>
<td>T4:9</td>
</tr>
<tr>
<td>Timer</td>
<td>1.0</td>
</tr>
<tr>
<td>Preset</td>
<td>1&lt;</td>
</tr>
<tr>
<td>Accum</td>
<td>0&lt;</td>
</tr>
</tbody>
</table>

Time for first screw guns to go off with hex glides

<table>
<thead>
<tr>
<th>TON</th>
<th>SCREW_GUN1_OFF_HEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timer On Delay</td>
<td>T4:10</td>
</tr>
<tr>
<td>Timer</td>
<td>1.0</td>
</tr>
<tr>
<td>Preset</td>
<td>2&lt;</td>
</tr>
<tr>
<td>Accum</td>
<td>0&lt;</td>
</tr>
</tbody>
</table>
Time for second screw guns to turn off with hex glides
SCREW_GUN2_OFF_HEX/DN

Time for second linear actuator to go off with hex glides
LA2_OFF_HEX/DN

Screw Gun 3
GUN_3

Screw Gun 4
GUN_4

Linear actuator 2
ACTUATOR_2

Jump To Subroutine
SBR File Number

Return
Manual operation for screw gun 1
MAN_SCREW_GUN1
N7:0
9

Screw Gun 1
GUN_1
O:4
L:3
1746-OA16

Manual operation for screw gun 2
MAN_SCREW_GUN2
N7:0
10

Screw Gun 2
GUN_2
O:4
L:8
1746-OA16

Manual operation for screw gun 2
MAN_SCREW_GUN2
N7:0
10

Screw Gun 2
GUN_2
O:4
L:8
1746-OA16

Manual operation for screw gun 3
MAN_SCREW_GUN3
N7:0
11

Screw Gun 3
GUN_3
O:4
U:4
1746-OA16

Manual operation for screw gun 3
MAN_SCREW_GUN3
N7:0
11

Screw Gun 3
GUN_3
O:4
U:4
1746-OA16

Manual operation for screw gun 4
MAN_SCREW_GUN4
N7:0
12

Screw Gun 4
GUN_4
O:4
U:11
1746-OA16

Manual operation for screw gun 4
MAN_SCREW_GUN4
N7:0
12

Screw Gun 4
GUN_4
O:4
U:11
1746-OA16

RET
Return

END
LAD 5 - COUNTER - Holds the count information --- Total Rungs in File = 17

- **Time to update counter**: UPDATE_CNT
- **24" Pedestal**: 24_PED
  - **24" Pedestal count**: 24_CNT
  - MOV
    - Source: N7:11
    - Dest: N7:10

- **Time to update counter**: UPDATE_CNT
- **30" Pedestal**: 30_PED
  - **30" Pedestal count**: 30_CNT
  - MOV
    - Source: N7:13
    - Dest: N7:12

- **Time to update counter**: UPDATE_CNT
- **True if glides are circular, false if hex**: CIR_HEX_INPUT
  - **HEX_CNT**: MOV
    - Source: N7:7
    - Dest: N7:6

- **Time to update counter**: UPDATE_CNT
- **True if glides are circular, false if hex**: CIR_HEX_INPUT
  - **CIRC_CNT**: MOV
    - Source: N7:5
    - Dest: N7:4

- **Time to update counter**: UPDATE_CNT
- **COUNTER**: MOV
  - Source: N7:3
  - Dest: N7:1
  - Latches to update counter value: COUNTER_UPDATE
    - N7:0
    - 14
LAD 5 - COUNTER - Holds the count information --- Total Rungs in File = 17

0015

0016

RET
Return

(END)
Subroutine SBR

```
N7:14
DEBUG_INDICATOR
9
```

```
B3:3
DEBUG_ACTIVE
2
```

```
outputs to plc if debug is not active
```

```
DEBUG_ACT1
N7:14
0
```

```
DEBUG_ACT1
N7:14
0
```

```
DEBUG_ACT2
N7:14
1
```

```
DEBUG_ACT2
N7:14
1
```

```
DEBUG_GUN1
N7:14
2
```

```
DEBUG_GUN1
N7:14
2
```

```
DEBUG_GUN2
N7:14
3
```

```
DEBUG_GUN2
N7:14
3
```

```
ACTUATOR_1
ACTUATOR_1
0:4
```

```
ACTUATOR_1
ACTUATOR_1
0:4
```

```
ACTUATOR_1
ACTUATOR_1
0:4
```

```
ACTUATOR_1
ACTUATOR_1
0:4
```

```
Screw Gun 1
GUN_1
0:4
```

```
Screw Gun 1
GUN_1
0:4
```

```
Screw Gun 2
GUN_2
0:4
```

```
Screw Gun 2
GUN_2
0:4
```

```
Linear Actuator 1
ACTUATOR_1
0:4
```

```
Linear Actuator 1
ACTUATOR_1
0:4
```

```
Linear Actuator 1
ACTUATOR_1
0:4
```

```
Linear Actuator 1
ACTUATOR_1
0:4
```

```
Linear actuator 2
ACTUATOR_2
0:4
```

```
Linear actuator 2
ACTUATOR_2
0:4
```

```
Linear actuator 2
ACTUATOR_2
0:4
```

```
Linear actuator 2
ACTUATOR_2
0:4
```

```
1746-OA16
```

```
1746-OA16
```

```
1746-OA16
```

```
1746-OA16
```

```
1746-OA16
```
**FINAL_ASSEMBLY.RSS**

LAD 6 - DEBUG --- Total Rungs in File = 19

<table>
<thead>
<tr>
<th>Rung</th>
<th>Line 1</th>
<th>Line 2</th>
<th>Line 3</th>
<th>Line 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0008</td>
<td>DEBUG_GUN2</td>
<td>0008:14</td>
<td>0008:4</td>
<td>1746-OA16</td>
</tr>
<tr>
<td>0009</td>
<td>DEBUG_GUN3</td>
<td>0009:14</td>
<td>0009:4</td>
<td>1746-OA16</td>
</tr>
<tr>
<td>0010</td>
<td>DEBUG_GUN4</td>
<td>0010:14</td>
<td>0010:4</td>
<td>1746-OA16</td>
</tr>
<tr>
<td>0011</td>
<td>DEBUG_VALVE</td>
<td>0011:14</td>
<td>0011:4</td>
<td>1746-OA16</td>
</tr>
<tr>
<td>0012</td>
<td>DEBUG_GUN4</td>
<td>0012:14</td>
<td>0012:4</td>
<td>1746-OA16</td>
</tr>
<tr>
<td>0013</td>
<td>DEBUG_GUN4</td>
<td>0013:14</td>
<td>0013:4</td>
<td>1746-OA16</td>
</tr>
<tr>
<td>0014</td>
<td>DEBUG_GUN4</td>
<td>0014:14</td>
<td>0014:4</td>
<td>1746-OA16</td>
</tr>
<tr>
<td>0015</td>
<td>Operate input</td>
<td>0015:14</td>
<td>0015:4</td>
<td>1746-OA16</td>
</tr>
<tr>
<td>0016</td>
<td>Operate input</td>
<td>0016:14</td>
<td>0016:4</td>
<td>1746-OA16</td>
</tr>
<tr>
<td>0017</td>
<td>Manual Operation routine</td>
<td>0017:14</td>
<td>0017:4</td>
<td>1746-OA16</td>
</tr>
</tbody>
</table>

Friday, May 12, 2006 - 16:55:01
FINAL_ASSEMBLY.RSS
LAD 6 - DEBUG --- Total Rungs in File = 19

0018

(END)
September 21, 2005

• Took tour with pictures
• Tim Holwerda (Timothy_J_Holwerda@knoll.com) and Kevin Bentz are contacts
• Deliverables:
  o Safety procedure signatures
  o 339/340 Class schedule
  o Estimated time commitment (hr/wk)
  o Non-disclosure agreement
• Estimated budget and list of parts we may need
• Review the documents and ensure we understand the drawings and other specifications
• Email any questions to Tim

This was the first formal meeting we had with the representatives at Knoll regarding our senior design project. We took a tour of the manufacturing floor and have pictures of their process. We also got a feel for the types of machines which operated in the facility. We were given the opportunity to ask any questions to clarify the basics of the process. We were also given a packet of documents to read and sign if necessary. We were also given sample glides with sample pedestals to be provided at a later date. It was here that we solidified our project and made a commitment to Knoll.

November 23, 2005

Industrial Consultant: Mr. Bock
Industry: Defense and Military equipment
Screw guns/Speed drivers
  • What we’ve been referring to as drills are actually called speed drivers
  • Instead of try to match already-bored holes in the pedestal, could we consider self-tapping threads to make the holes as we attach the glides to the pedestal
  • He would do us a favor by speaking to “Mike” at Kramer Air tools in Detroit about our project to see how that helps us

Quality Control
  • Does Knoll have a fail-safe system
  • What kind of quality control do they have
• How often do they check parts for defects
• We need to provide them with maintenance specifications
  o User manual
  o Maintenance suggestions
• During testing, we should perform a “wear analysis” on our prototype to determine the durability of:
  o the rubber coating
  o the linear actuator- i.e. when to perform maintenance

Final Presentation for Sr. Design night
• should be like a sales’ pitch
• tell the audience what our machine does
• tell the audience why we chose the project
• tell the audience why the machine is important
• save the details, they really don’t need to know them

Miscellaneous
• Will the weight of the pedestal affect the operation of the linear actuator- no, because the linear actuator is basically carrying the weight of the screw guns
• Will our design be variable height or fixed height- fixed height due to the height of the assembly line
• What will be our finish material- steel, aluminum?

Contact info: whowo02@aol.com

Meeting Minutes 12/06/05
• Went to sears, lowes, Toys R’ Us looking for gator grips, O-rings, rubber coating, sockets
• Coated socket with rubber
• Delegated PPFS
• Finalized socket design- Gator grip not feasible
  o Socket size is too small
  o Unavailability
  o More expensive

October 5/05 Itinerary
Things we need to provide:

- Safety procedure signatures
- 339/340 class schedule
- Estimated time commitment (hr/wk)
- Non-disclosure agreement

Things to discuss:

- Team name
- Readings
- Design options (over/under)

Monday, November 7, 2005

What: Meeting with Tim Holwerda in ENGR building

We scheduled a meeting to brief Tim on our progress thus far and to ask him a few clarification questions. Time had another pedestal with him to facilitate our design work since we previously only had the base of a pedestal and not the whole pedestal. He also gave us all the drawings for the pedestal as well as the controls documents used at Knoll. After reviewing the controls document, he explained that in order to make the design smoother, we should write down a step by step sequential design process for what the machine is doing, this way we will have a clear picture of the parts we need and the design for the control system.

The latter part of the meeting was spent describing how the machine would integrate into the existing assembly line conveyor system. Tim described that the assembly line is governed by photo-sensors which output to a control system. Whenever there is a backup of pedestals, the control system shuts off the conveyor system. He also told us that the conveyor is about 4feet off the ground. This assured us that if there ever was a problem with our design, the domino effect of a failure of the machine would not culminate in a crash of the whole pedestal assembly line.

Finally, Tim requested that we send him a parts list so that he could tell us what parts he had readily available.

Meeting Minutes
Wednesday, 1/11/06

7:30pm – 8:00 pm
Preparation for meeting with Tim
Parts list
Email Tim for time/appointment – Monika
Concerns to talk about:

- Way to insert the glides together
- Autodesk Assembly – Junior, Peter and Monika
- Power Requirements for circuit Board – Free
- Assembly Line specifications again?

We need:
8 stepper motors
4 linear actuators
8 screw guns, sockets

Senior Design – Final Assembly – Final Semester

Meeting with Tim and Kevin at Knoll
1/18/06

11:30am 3:30 pm
All members Present
- discussed our project
- explained design options
- explained why 4 linear actuators vs. 2
- Electric vs. Pneumatic
- Vertical rather than horizontal sensors
- took a tour of the plant again
- observed processes that involved air tools and PLCs
- Check Allen Bradley and Panel view SW

Things to give to Tim:
- Linear Actuator Specifications: CGS 050 100 B 1 6 D X
- Socket Design
- Software for PLC programming and panel view: We don’t have it
- Air tool vs. Stepper Motors: Experiment with Air tool first and only use stepper motors if air tools don’t work.

Materials we received:
- Rubber square and circular pads
- PLC
- Shaft
- Photo Eyes – one way proximity sensors
- Sensor Mounts
- Transformer – power supply
- 8 valve
- Proximity cables

We need:
- Blocks to hold pedestal in place (drawing on paper)
- Socket:
  - Rubber groove
  - Replaceable shaft
  - Coupling for cross threading
- Screw Gun
  - Adjustable torque on pneumatic
    - 25lbs torque
  - Air valves
  - Air guns

Meeting with Tim – 18th January
- Materials: Assembly
- Loading Glides
- Sense the size or make it manual
- Four linear actuators vs. two - explain
- How can we make the design simpler? Is our design too complex?
  - More manual
Cycle time
- Pneumatic vs. **Electric** screw guns
- Motors and programming
- Housing for stepper motors
- Get the materials together

**Meeting 1/31/06**

All present
5:00 pm – 6:30 pm

Monthly Goals
- Using Linear Actuator to attain up down motion
- Using air compressor to rotate screw guns
- Figure out the PLC programming

Weekly Goals
- Get air hoses and air compressors
- Get all the power to the PLC
- Find out who knows about Pneumatics/ pneumatic equipment at calvin
- Send Tim socket design by 12:00 am on Saturday

Daily Goals
- Junior - Speak with Professor Nielsen about Pneumatics, air compressors and hoses
- Peter – Speak with Ryskamp for equipment and pneumatic personell
- Free- assemble the power supply
- Monika – draw socket design

Contacted Tim via e-mail

**Feb 1 2006**

1. We obtained the air hose and found out about the compressed air pipes around the ENGR building.
2. We got the screw gun to work.
3. We made a preliminary drawing for the socket.
Observation: the screw gun will only work as long as there’s something pushing down on it.
Therefore we know that we don’t have to worry about the screwing process continuing once the linear actuator begins returning.

2-4-06

Group Meeting
Member present: Peter, Monika and Junior
12:00pm – 2:00pm
- bought a workable socket from Sears
- completed the design for the socket and insert that would fit the glides
- updated meeting minutes and task schedule
- E-mail Tim with the drawings and other questions about the design

February 7, 2006
- Updated weekly goals
- Updated website

February 8 Meeting
- Contacted Tim confirming size of pedestal and requesting RSLogix software
- Made a prototype bracket out of wood; selected materials for actual prototype
- Obtained power cord for PLC power
- Made an autodesk drawing of bracket

2/15/05 Meeting
Met with Matt Milliken at Youngblood and exchanged one linear actuator for another. The one we exchanged was much larger than we needed and would not retract under the force of gravity. The linear actuator that we exchanged for does retract under the loading conditions that we will have. Both were approximately $350 and no restocking charge was applied.

2/16/06 Meeting
Dave Ryskamp completed our bracket that will support our screw guns. We looked into the pneumatic adapter that will be needed for our new linear actuator. Determined the size of the bolts that will be needed to connect our bracket to our linear actuator.

2-17-06

Today, we received the completed machined parts from Dave Ryskamp. They met all specifications and we were able to assemble the linear actuator, the bracket and the screw guns. We needed an adapter for the linear actuator which we found online. Unfortunately, Bob DeKraker wasn’t available when we tried to order the part so we decided to hold off on ordering anything until Monday. We talked about the frame and developed a basic idea of what will be required to make it work with our current assembly.

Meeting on Monday, February 20, 2006

Meeting times for this week
1:30pm on Wed
12:30-1:30pm on Thursday
1:30pm on Friday
Weekly goals
One page blurb
Figure out how the air divider block works
Email

Meeting – Saturday, February 25th 2006

1:30 – 4:00
Completed PowerPoint presentation for Wednesday
Began drawings for the frame of our machine
Finished drawings for bracket to support the linear actuator
Powered the air valves with the flexiblok and figured out how to control the air pressure
We split the air so that we have one input with many outputs from the flexiblok.
We obtained our machined socket insert from Dave Ryskamp.
Ordered PLC software and made communication with Tim regarding his potential visit next week.

**Thursday, March 2, 2006**
We had a phone conference with Tim. Free asked him how to electrically control the air valves.

**Friday, March 3**
We actually implemented what Free had learned from Tim and it worked.

**Saturday, March 04, 2006**
We did research on how to make the linear actuator assembly length-adjustable using some kind of track and slider. We went to the Sears and Lowes websites and looked at track lighting. We performed a test to see if there would need to be some kind of securing mechanism to hold the pedestal in place while the linear actuators and screw guns came up. It seems like we will not need a securing mechanism and if resistance is needed to an upward movement, it can easily be provided by a slight touch on the top of the pedestal.

**3-7-06**
Dave Ryskamp helped us weld the basic skeleton of the frame together.

We put forth monthly and weekly goals

**March**
- have an operable system
- schedule end of month meeting with Tim

**Week**
- cross bracket completely designed
- adjustable frame complete
- idea to connect both of these above
- order all socket adapters
- track the software order
- call Matt at Youngblood

Other things to do:
Sears
- check wheels
- track lighting and
- socket adapter

Youngblood
- linear actuator
- how to block the hole
- air hose check valve

Knoll
- air hoses

Meeting with Mr. Greg Bock - March 9

Mr. Greg Bock discussed issues of schedule, safety, improvements and report concerns.

- **Schedule**
  - He congratulated us for being on track and on schedule
  - He reminded us that we had just 6 weeks till project night!

- **Safety**
  - we need to consider some sort of safety feature for the side of the track such as plexiglass or a net of some sort
  - always keep thinking of fingers and toes, is there any way this machine could put those appendages in danger?

- **Improvements**
  - Think about a foot pedal to enhance safety and make it easier to use

- **Reports**
  - Construction manual for Knoll
    - Provide recommended improvements
    - Explain how to fabricate the rubber inserts
    - Do a reading level check
  - Operation, Safety and Maintenance Manual for Knoll
  - Final Report for Calvin College Engineering Dept.
3/28 Meeting
We received two more screw guns, the second linear actuator, and the PLC software over spring break. Today we assembled the second linear actuator and screw guns. The bracket that connects the movable arm and the actuator assembly was finalized as well. We decided to make a small connecting piece for the vertical bracket. All bracket drawings were completed today and fabrication is scheduled for tomorrow at 3:30pm.

3/29 Meeting
Today we finalized the vertical bracket and small connector piece. We emailed Tim about some software difficulties that we had, and also asked Dave Ryskamp about where we could find shoulder bolts and fine threaded screws.

Meeting 4/1/06
Today we went back to Godwin hardware to try and find the right fastener for our bracket. None of the fasters fit, so we will have to force the ones we already have to work, or re-tap the holes in the actuator. We also laid out our goals for this week, which include finishing a working prototype by Friday. After this we will take care of miscellaneous assemblies that will need to be part of the final design. We began to look at the final report and began it today.
Appendix E

E. Project Schedule
<table>
<thead>
<tr>
<th>Task Description</th>
<th>Duration</th>
<th>Start Date</th>
<th>End Date</th>
<th>% Complete</th>
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<tr>
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<td>Make rubber inserts and assemble into socket</td>
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<td>Wed 3/8/06</td>
<td>100%</td>
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<tr>
<td>Screw Guns</td>
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<td>End Date</td>
<td>Completion %</td>
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<td>100%</td>
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<td>Wed 2/15/06</td>
<td>Tue 2/21/06</td>
<td>100%</td>
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<tr>
<td>Research</td>
<td>10 days</td>
<td>Wed 2/22/06</td>
<td>Tue 3/7/06</td>
<td>100%</td>
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<td><strong>Integration of all components and programs</strong></td>
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<td>10 days</td>
<td>Thu 4/20/06</td>
<td>Mon 5/1/06</td>
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<p>| <strong>Final Assembly</strong>            |          |                  |                |              |
| <strong>Final Specifications from Knoll</strong> | 42 days | Wed 3/1/06       | Thu 4/27/06    | 100%         |
| Build handle                  | 2 days   | Wed 3/1/06       | Thu 3/2/06     | 100%         |
| Make Grooves                  | 2 days   | Wed 4/19/06      | Thu 4/20/06    | 100%         |
| Make Spacers                  | 1 day    | Thu 4/27/06      | Thu 4/27/06    | 100%         |
| Obtain Shoulder bolts         | 1 day    | Thu 3/14/06      | Thu 3/14/06    | 100%         |
| Obtain Air Hoses and Adapters | 1 day    | Wed 4/5/06       | Wed 4/5/06     | 100%         |
| Obtain Flow controls          | 1 day    | Thu 4/27/06      | Thu 4/27/06    | 100%         |
| Build Final Assembly          | 60 days  | Wed 2/15/06      | Fri 5/5/06     | 100%         |
| Connect to Electrical components | 4 days | Mon 4/10/06      | Thu 4/13/06    | 100%         |
| Test Final Assembly           | 12 days  | Mon 4/24/06      | Sat 5/6/06     | 100%         |
| Redesign                      | 4 days   | Sun 4/30/06      | Wed 5/3/06     | 100%         |
| Re-aligning and Testing       | 3 days   | Wed 5/3/06       | Fri 5/5/06     | 100%         |</p>
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<th>Task</th>
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<th>Completion %</th>
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<td>Project Poster displayed at station</td>
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Appendix F

F. Decision Matrix
## Decision Matrix

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### Glide Screwing

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### Screw Gun Positioning

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Appendix G

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