Lukas DiBeneditto
Professor Tim Cooley
MET 436 Pneumatic Motion Control Systems
Purdue University, Purdue Polytechnic New Albany
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Project 2 PusherBot

Risk Analysis Summary (Before/After)

Executive Summary

This document details the Risk Analysis Summary (Before/After) for Project 2 for MET 436 Pneumatic Motion Control Systems. Our customer The Really Cool Engineering Co. tasked us with the design, build, test, and iteration of a pneumatically actuated robot to push a 1 kg (~2.2 lb) weight 18 inches in 10 seconds, with the main limitation that the robot footprint as seen from above must be no larger than 16 in^2, and designed specifically to be mass-produced utilizing a laser manufacturing process.

All other teams were not able to meet the objectives, only our team met and exceeded all objectives almost 2 weeks early.

Requirements	**Our Team**	**Four Other Teams**
pneumatically actuated robot	pneumatically actuated robot	pneumatically actuated robot
push a 1 kg (~2.2 lb) weight	2 kg*	1kg weight
18 inches	18+ inches	~4 inches
10 seconds	8.5 ± .25 seconds	10+ seconds
16 in^2	13.77 ± .5 in^2	No Data
<$10	$1.07 (for rubber balls)	No Data

*Our Pusherbot was able to push 3 kg 18 inches in about 10 ± .25 seconds.

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Risk Assessment (Before)

Risk Matrix (Before)

Severity	Symptoms	Triggers	Responses
5 Severe	System loses air/leaks	Leaks, pressure drop	Find leak and fix, use multiple tests to confirm until confidence interval reached.
5 Severe	System loses electricity/wiring issues	Indicator lights.	Find leak and wiring, use multiple tests to confirm until confidence interval reached.
2 Minor	Arduino Code does allow the robot to work as intended	Piscont cylinders do not function as intended, rapid firing	Use multiple tests to confirm until confidence interval reached.
5 Severe	Robot does not move	No movement of robot	Use multiple tests to confirm until confidence interval reached.
5 Severe	Robot cannot move the weight, pistons are not strong enough to move the 1kg weight	Design iteration	Unlikely considering robust pneumatic design. Design iteration.
3 Moderate	Robot does move the weight fast enough	Testing does not show that the robot can move 18 inches in 10 seconds or less.	Decrease the interval between pneumatic firings in Arduino Code Spreadsheet, to increase firing time and ultimately the speed at which the robot moves and/or increase the pressure.
2 Minor	Robot does not travel in a relatively straight	Robot veers off course during testing.	Adjust metal wiring to straighten the robot

	line		on course. Iteration if necessary. Use multiple tests to confirm until confidence interval reached.
4 Major	Pneumatic Hoses get tangled and prevent movement	Hose tangled.	Pneumatic hose mitigation strategy.
2 Minor	Financial costs exceed allowable financial budget.	80% of budget used.	Unlikely, already built with existing materials found in the shop, just needs testing.
2 Minor	Materials are unavailable and cannot be procured.	Lack of materials.	Unlikely, already built, just needs testing. Alternative materials selected that meet or exceed need.
2 Minor	Time exceeds allowable time budget.	Time record keeping indicates 4 hours remaining per person.	Unlikely, already built, just needs testing.

Severity Risk Matrix (Before)

Symptom	Severity	Likelihood	Likelihood/Severity Rating
System loses air/leaks	5 Severe	4 Likely	20
System loses electricity/wiring issues	5 Severe	2 Unlikely	10
Arduino Code does allow the robot to work as intended	2 Minor	3 Possible	6
Robot does not move	5 Severe	4 Likely	20

Robot cannot move the weight, pistons are not strong enough to move the 1kg weight	5 Severe	3 Possible	15
Robot does move the weight fast enough	3 Moderate	5 Almost Certain	15
Robot does not travel in a relatively straight line	2 Minor	4 Likely	8
Pneumatic Hoses get tangled and prevent movement	4 Major	4 Likely	16
Financial costs exceed allowable financial budget.	2 Minor	1 Rare	2
Materials are unavailable and cannot be procured.	2 Minor	1 Rare	2
Time exceeds allowable time budget.	2 Minor	4 Likely	8

Risk Assessment (After)

Risk Matrix (After). Note that ***bold*** *indicates changes.*

Severity	Symptoms	Triggers	Responses
5 Severe	System loses air/leaks	Leaks, pressure drop	Find leak and fix, use multiple tests to confirm until confidence interval reached.
5 Severe	System loses electricity/wiring issues	Indicator lights.	Find leak and wiring, use multiple tests to confirm until confidence interval reached.
2 Minor	Arduino Code does allow the robot to work as intended	Piscont cylinders do not function as intended, rapid firing	Use multiple tests to confirm until confidence interval reached.
5 Severe	**Robot does not move due to rubber balls not getting enough grip**	No movement of robot	Use multiple tests to confirm until confidence interval reached.
5 Severe	Robot cannot move the weight, pistons are not strong enough to move the 1kg weight	Design iteration	Unlikely considering robust pneumatic design. Design iteration.
5 Severe	**Robot does move the weight fast enough caused by timing issue**	Testing does not show that the robot can move 18 inches in 10 seconds or less.	**Decrease the interval between pneumatic firings in Arduino Code. Optimal setting of 175 ms.**
5 Severe	**Robot does move the weight fast enough caused by to much or too little air pressure**	Testing does not show that the robot can move 18 inches in 10 seconds or less.	**Determine optimal air pressure of 25 ± 2 psi.**
5 Severe	**Robot does move the**	**Testing does not**	**Testing found 40 ±**

	weight fast enough due to suboptimal cycle sequence	**show that the robot can move 18 inches in 10 seconds or less.**	**10 ms delay between each piston cylinder firing. Firing cylinder 14, 23 caused timing issues. Firing sequence 12, 34 allowed for less deviation in desired robot behavior.**
4 Major	Area larger than 16 in^2	Prototype 2 area calculation estimate exceeded 16 in^2	Used solidworks and design review to decrease area, and caused acrylic to be recut on the laser.
2 Minor	Robot does not travel in a relatively straight line	Robot veers off course during testing.	Adjust metal wiring to straighten the robot on course. Iteration if necessary. Use multiple tests to confirm until confidence interval reached.
5 Severe	Pneumatic Hoses get tangled and prevent movement	**Hose tangled, slowed movement of robot**	**Pneumatic hose mitigation strategy. Straightening the hose out in front of the robot and tape worked well.**
2 Minor	Financial costs exceed allowable financial budget.	80% of budget used.	Unlikely, already built with existing materials found in the shop, just needs testing.
2 Minor	Materials are unavailable and cannot be procured.	Lack of materials.	Unlikely, already built, just needs testing. Alternative materials selected that meet or exceed need.
2 Minor	Time exceeds allowable time	Time record keeping indicates 4 hours	Unlikely, already built, just needs

	budget.	remaining per person.	testing.

*Severity Risk Matrix (After). Note that **bold** indicates changes.*

Symptom	Severity	Likelihood	Likelihood/Severity Rating
System loses air/leaks	5 Severe	4 Likely	20
System loses electricity/wiring issues	5 Severe	2 Unlikely	10
Arduino Code does allow the robot to work as intended	2 Minor	3 Possible	6
Robot does not move due to rubber balls not getting enough grip	5 Severe	**5 Almost Certain**	**25**
Robot cannot move the weight, pistons are not strong enough to move the 1kg weight	5 Severe	3 Possible	15
Robot does move the weight fast enough caused by timing issue	**5 Severe**	5 Almost Certain	**25**
Robot does move the weight fast enough caused by to much or too little air pressure	**5 Severe**	**5 Almost Certain**	**25**
Robot does move the weight fast enough due to suboptimal cycle sequence	**5 Severe**	**5 Almost Certain**	**25**

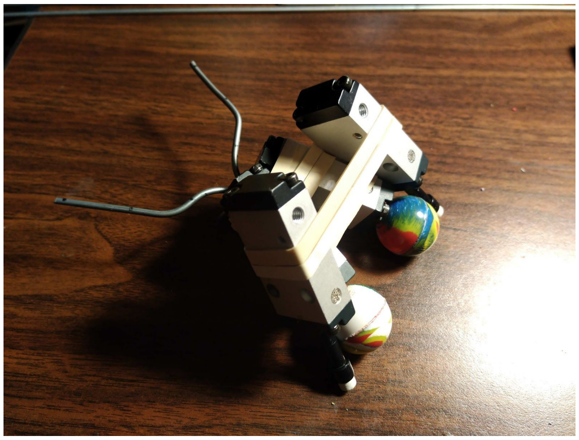
Area larger than 16 in^2	**5 Severe**	**4 Likely**	**20**
Robot does not travel in a relatively straight line	2 Minor	4 Likely	8
Pneumatic Hoses get tangled and prevent movement	4 Major	**5 Almost Certain**	20
Financial costs exceed allowable financial budget.	2 Minor	1 Rare	2
Materials are unavailable and cannot be procured.	2 Minor	1 Rare	2
Time exceeds allowable time budget.	2 Minor	4 Likely	8

Explanation

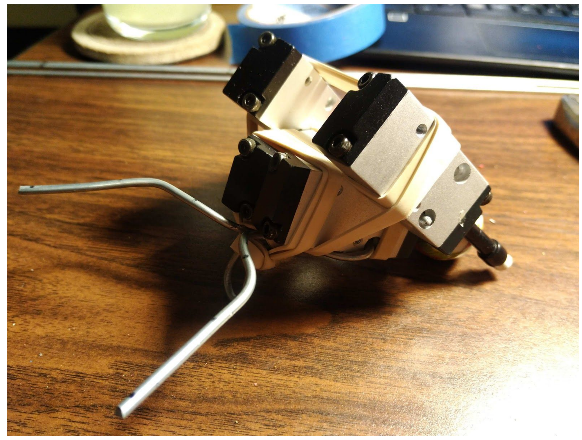
What follows is an explanation of how this researcher's perception and response to the risks our team encountered changed (became better) as the project progressed, including a discussion of the "technical engineering, teamwork, schedule, communication, and design aspects that may not have been apparent when the project started."

Technical Engineering

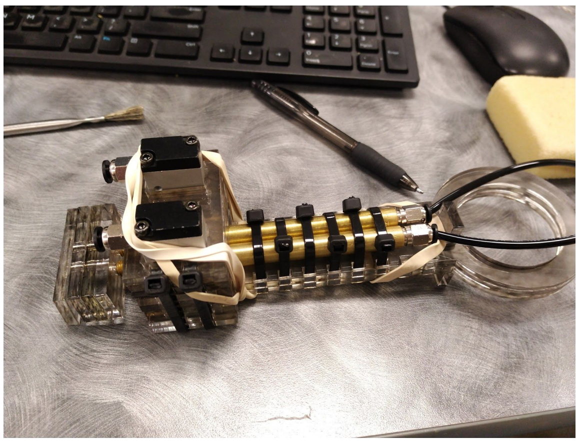
We had 4 main design iterations, photos are on the next pages with significant detail considerations.



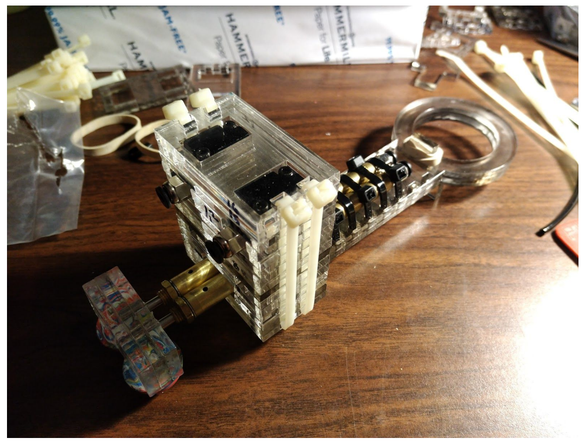
Prototype 1. Wire allowed rapid testing of various angles of robot pneumatic-cylinders.



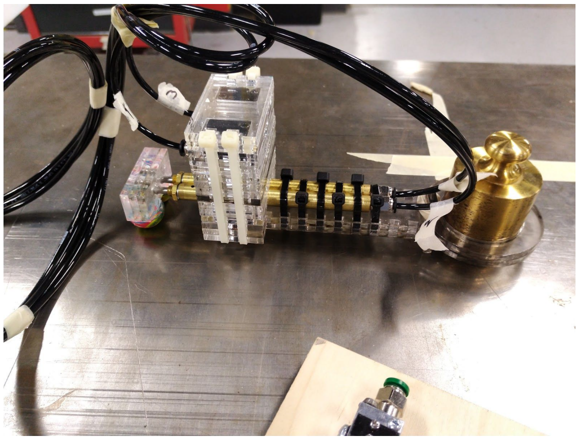
Prototype 1. This robot actually moved fairly well, and allowed me to realize that we needed a longer stroke length.



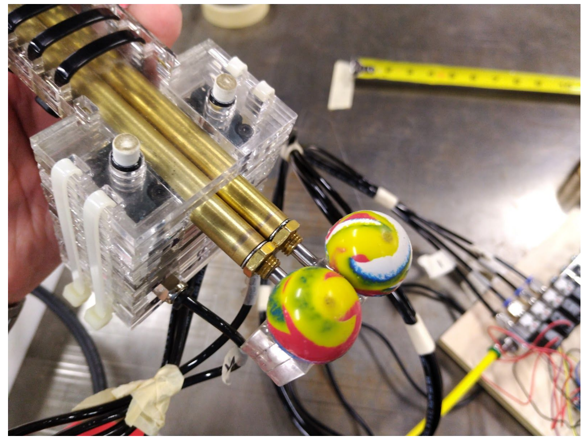
Prototype 2. Testing found that rubber bands were not rigid enough and caused the robot to sway because of a 40 ms timing issue.



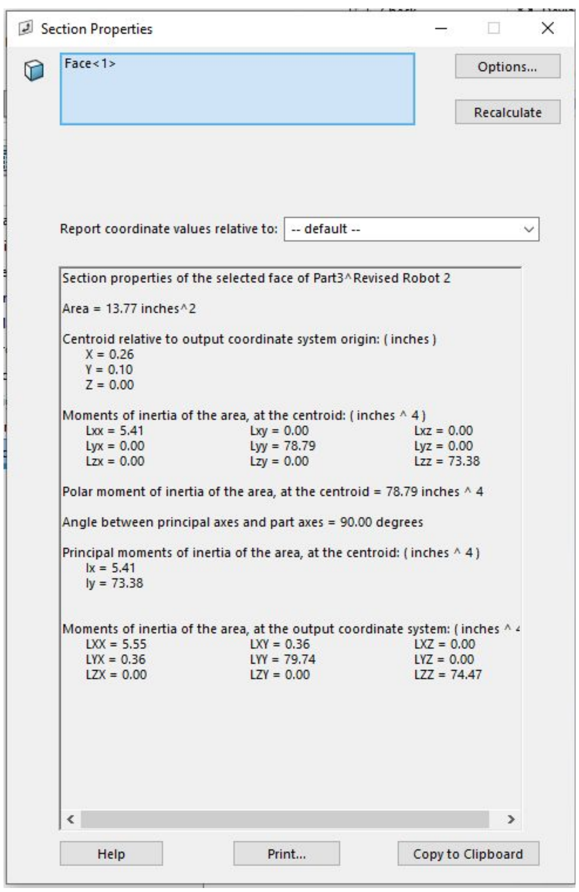
Prototype 3. Additional layers on top and vertical piston cylinders are raised up from an additional layer below them so they do not drag.



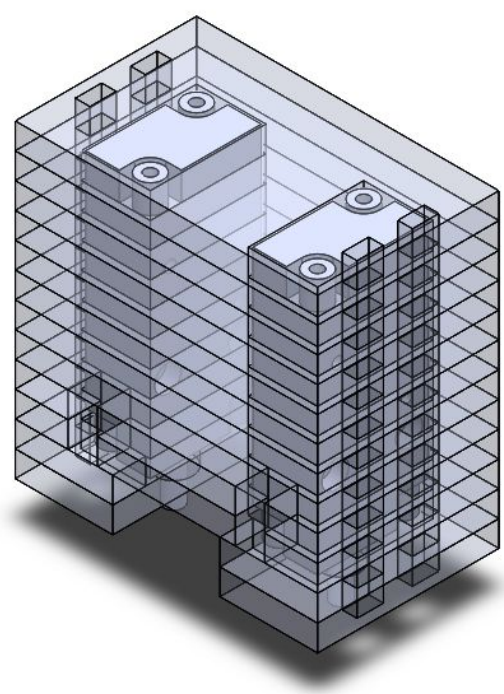
Prototype 3. This robot was able to push a 1kg weight 18 inches in about 6 seconds.



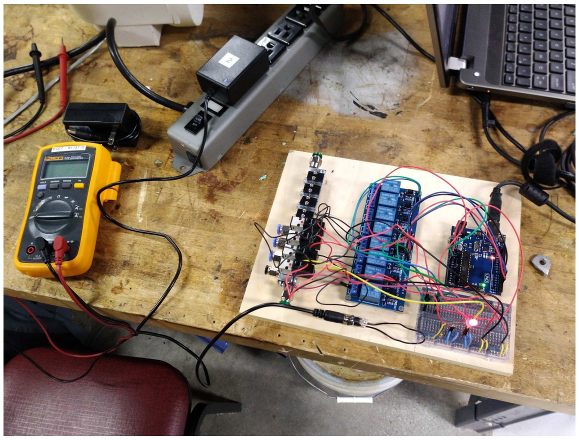
Prototype 3. Note the critical rubber balls. Testing determined that after each run some of the rubber was removed (charred) from "friction burn". So could we say our robot was so fast that it was burning rubber?



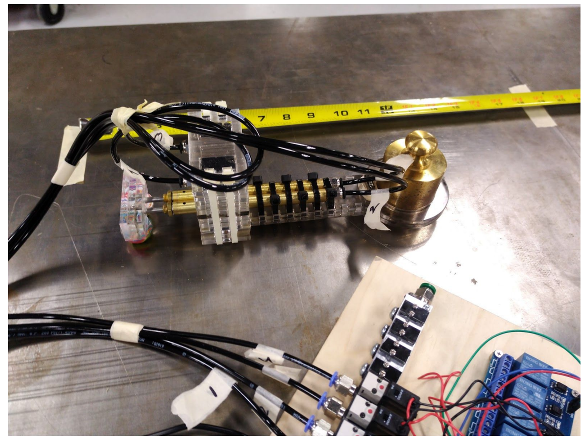
Prototype 4. Area calculation.



Prototype 4. Detail of the layers.



First Wiring.



Testing with Prototype 3.

Teamwork

I designed, built, and tested prototypes 1,2,3. Testing only 4. I also built the electronics board, and wired it 80%. I also found the leakage issue caused by rubber gaskets turned 90 degrees incorrectly with assistance from Paul Haggmann, which took 3 hours of troubleshooting, which then Paul was able to help other teams with. Sutton built prototype 4 based on my instructions to test the assembly instructions. I also did about 90% of the SolidWorks design work. Sutton did the assembly and final exploded view drawing, and the process flow diagram. I tweaked the final, assembly, and process flow diagram. I found the correct pressure, timing, and cycle sequence, through lots of trial and error. I have videos which I may post. Sutton solved the hose issue, and cut off half of the circle to get the robot under the area calculation. I found how to do the area calculation in SolidWorks and showed Sutton how to do it. Sutton did the area calculation.

Schedule

I completed Prototype 1, in 1 day. Getting the timing, pressure, and cycle correct took about 7 hours total, over the course of a couple of days.

Communication

I could have done better in communicating that I was going to build the prototype 1, 2, and 3. But I did ask if he wanted to help, but due to timing conflicts he was not available, so I just designed, built, and tested it myself.

Design Aspects

The key to the robot moving is the higher coefficient of friction for the rubber close to 2.00 where as the weight has a coefficient of friction of 0.2, along with correct timing, cycle sequence, and pressure.

Works Cited

[email-20200227-cooley] Cooley, Timothy R. "Spring-2020-MET-43600-02T: Project 2 Closure Document". Received by Lukas W. DiBeneditto. 28 Jan. 2020. Email.

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