UNIVERSITY OF WISCONSIN – STOUT
CAPSTONE
VIRACON - TILT TABLE

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BRANDON HAAG, JORDAN OTT, AND ALEX SUELFLOW

INTRODUCTION

Who is Viracon

VIRACON®

Located in Owatonna, MN

Architectural glass fabricator that adds coating to glass panels for exterior use

Name comes from “Environmental Control”

Create glass panes of different varieties, including laminated and insulated glass

Also applies coatings to modify thermal insulation capabilities.

Projects are all custom ordered so the sizes of the pieces and packaging vary.

Box Enters Workspace

Box is centered on the Tilt Table

Shelf is raised up

Box bottom is pulled flush with shelf

Table Tilts from 0 degrees (Horizontal) up to 84 degrees

Box is moved from Tilt Table to Cart

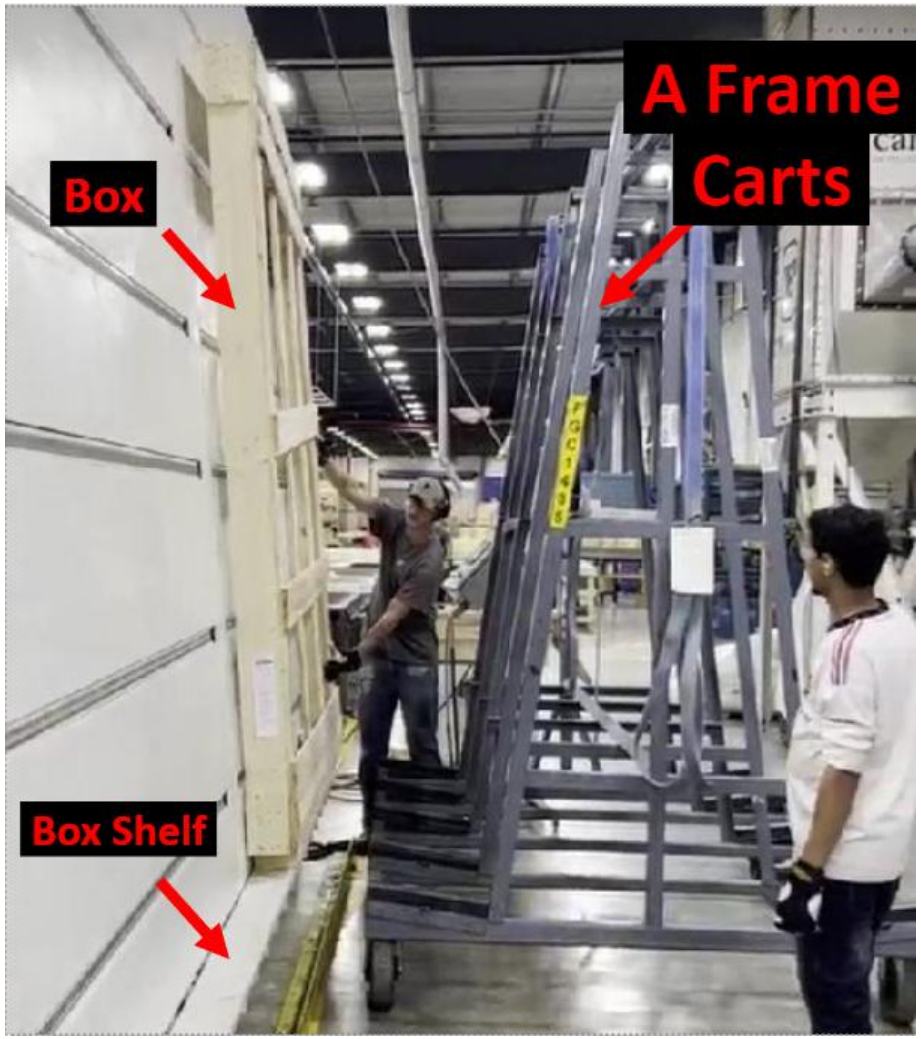
Table Lowers from 84 degrees back down to 0 degrees

Table is in starting position

Tilt Table Process Flow

This Process Flow covers the step by step that a box undergoes from entering the Tilt Table workspace from the build table to leaving the cart loading zone on a cart.

The Problem



- Wooden frames where glass is packaged and shipped are called “Boxes” and weigh up to 400lbs.
- Current transition of boxes from tilt table to A frame carts is by lifting boxes by 2 people, which poses many ergonomic issues.
- Boxes tend to tip off Box Shelf when Table is fully vertical due to boxes center of gravity being beyond the Shelf.
- Our goal is to re-design this table to make transitioning the Boxes safer and more reliable.

PROJECT SCOPE

Creating Scope of Work

Due to the importance of the scope of work there are multiple steps to the process

- Seeing Process in Person
- Speaking with Sponsors to Understand Project
- Presenting Draft of Scope of Work to Professors

Scope of Work

The scope of work is to prototype a 1/3 scale alteration to the tilt table that serves as a proof of concept for loading boxes onto the cart with an automated system.

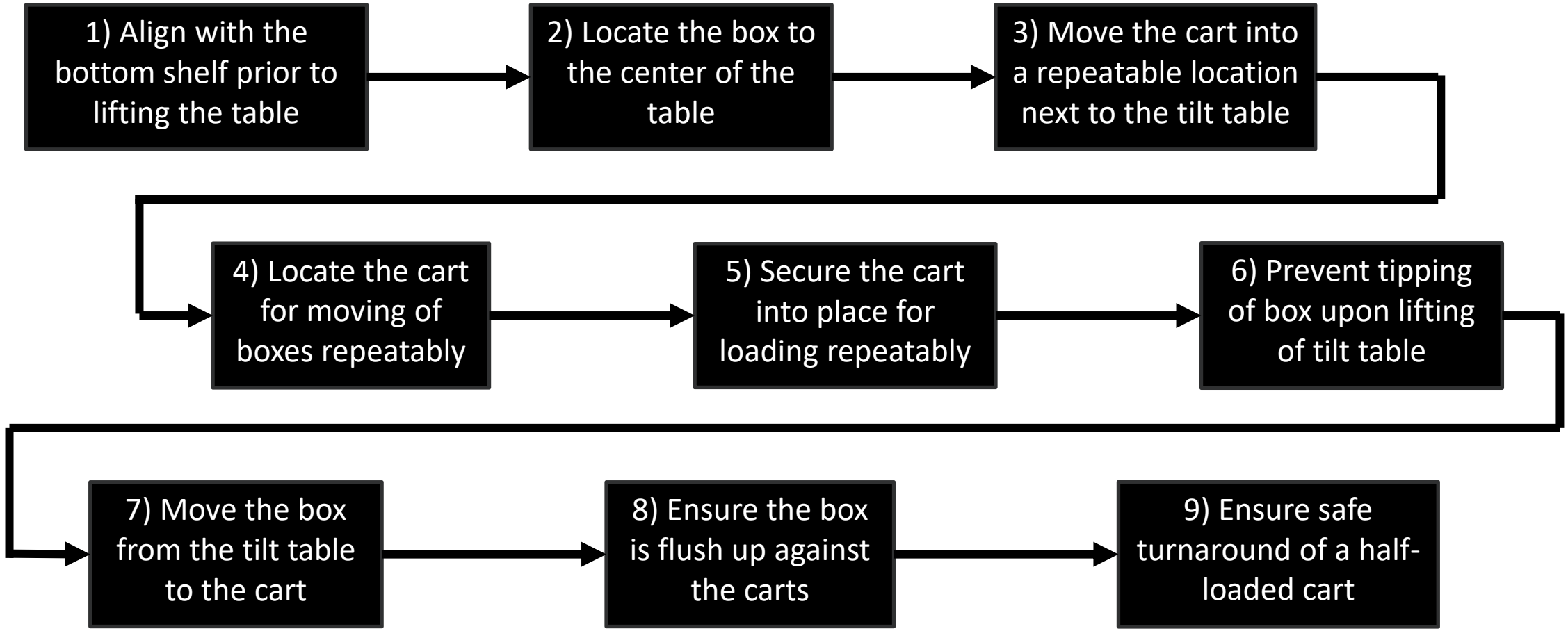
DESIGN CONCEPTS

Determining Functional Needs

Before beginning the design, we needed to determine the functional needs for our prototype. This is done by:

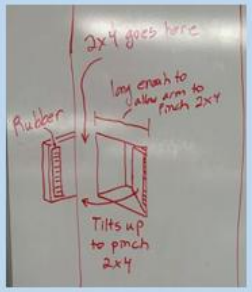
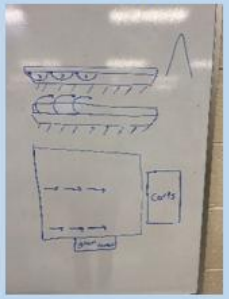
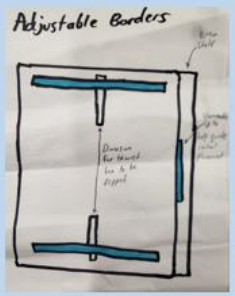
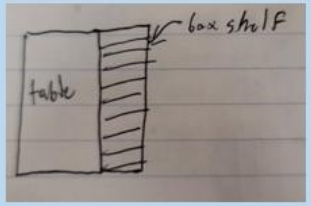
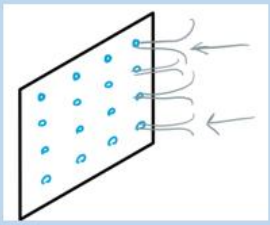
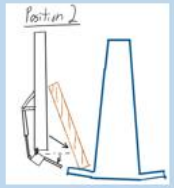
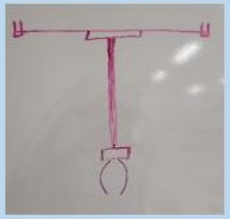
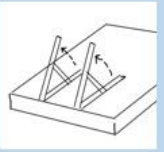
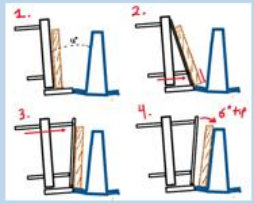
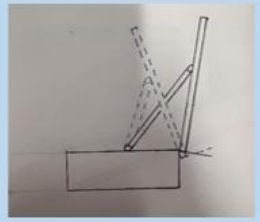
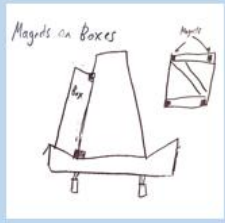
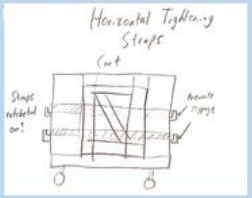
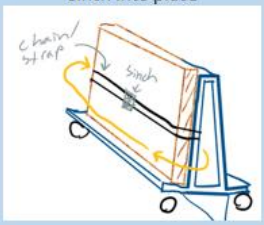
- Discussing with our sponsors what their expectations were for the solution.
- Developing the process flow to understand the steps currently taking place.

Functional Need Process Map

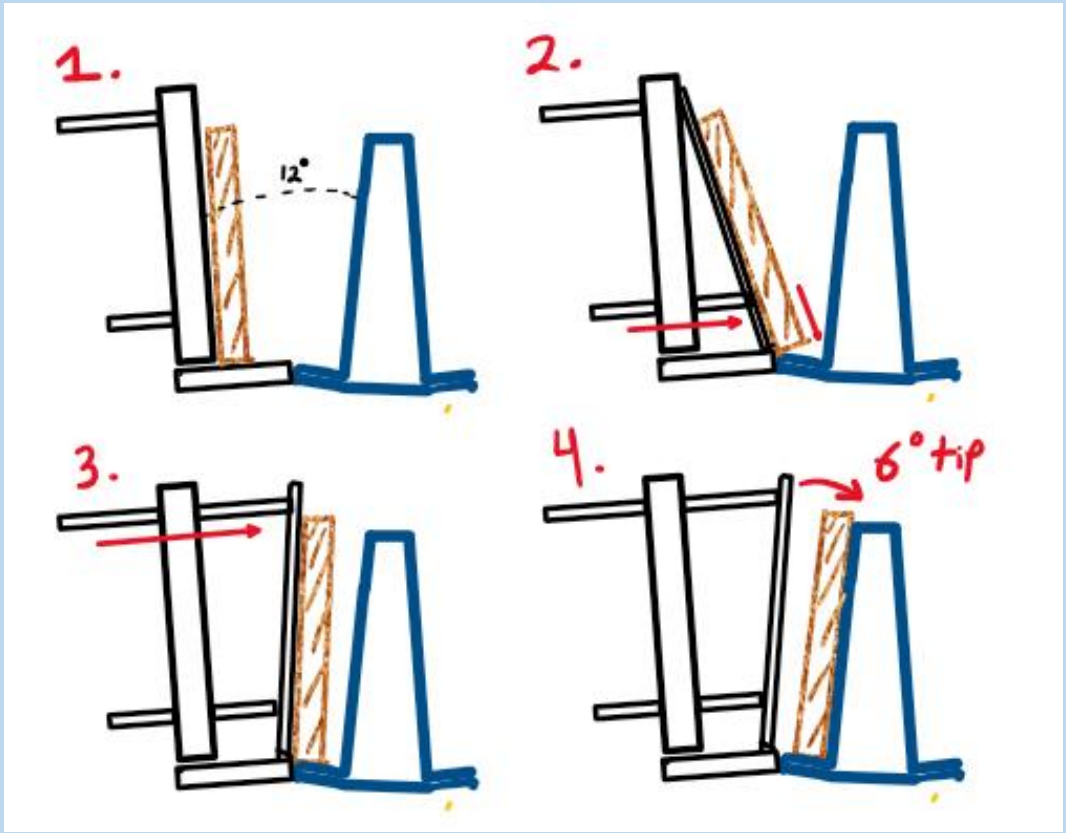


Concept Generation

Morphological Matrix

Functional Need	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5
Prevent tipping of box upon lifting of tilt table	clamping bar 	Brace bar 	Pinch bars 	Lengthen box shelf 	Suctioning feature to hold it in place 
The box is moved from the tilt table to the cart	Slide Box onto cart 	Lower box with pistons 	Roll onto cart 	Crane 	Push bar Pistons, when table turned 90 degrees 
Ensuring the box is flush up against the carts	Extending pistons to push into place 	Push table angle past 90 degrees to line up the angles 	Magnets on cart connect with magnets on box 	Horizontal tightening straps, add brackets to side of cart to prevent slippage 	straps or chains across the box to sinch into place 

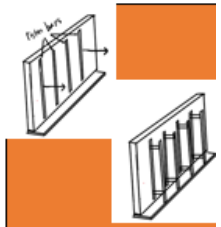
Concept Generation

Ensuring the box is flush up against the carts	Extending pistons to push into place 

Concept Evaluation

CRITERIA	WEIGHTAGE
Cost to Implement (1 - 10) 1 being very expensive, 10 being cheap)	15%
Necessary Manpower (<5 requires more input, >5 less human input)	12%
Cycle Time (<5 Time loss, >5 time improvement)	15%
Predicted Accuracy (1-10 as 50%-100%)	20%
Safety of function (1-10)	23%
Complexity to impliment (1-10) 1 being very difficult, 10 being simple	15%

Concept Evaluation



varying sized 2 step Push bar pistons when side loading

Description (Optional): Using tall vertical bars actuated by pistons to push the box frame out from the table onto the cart

CRITERIA	WEIGHTAGE	Brandon	Sophie	Nate	Alex	RATING	TOTAL
Cost to Implement (1 - 10) 1 being very expensive, 10 being cheap)	15%	3	4	2	2	2.75	4.13%
Necessary Manpower (<5 requires more input, >5 less human input)	12%	10	10	10	9	9.75	11.70%
Cycle Time (<5 Time loss, >5 time improvement)	15%	9	6	7	6	7	10.50%
Predicted Accuracy (1-10 as 50%-100%)	20%	9	8	7	7	7.75	15.50%
Safety of function (1-10)	23%	8	8	9	8	8.25	18.98%
Complexity to impliment (1-10) 1 being very difficult, 10 being simple	15%	8	9	8	7	8	12.00%

TOTAL

72.80%

Concept Evaluation

Tilt Table to The Cart
Decision Matrix

CRITERIA	WEIGHTAGE	Slide Box onto cart		Lower box with pistons		Roll onto cart		Crane		Push bar Pistons, when table turned 90 degrees		varying sized 2 step Push bar pistons when side	
		RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL
		AVERAGE		AVERAGE		AVERAGE							
Cost to Implement (1 - 10) 1 being very expensive, 10 being cheap)	15%	4.5	6.75%	4	6.00%	6.25	9.38%	2	3.00%	6	9.00%	2.75	4.13%
Necessary Manpower (<5 requires more input, >5 less human input)	12%	7.5	9.00%	8.75	10.50%	8.75	10.50%	3.5	4.20%	6.75	8.10%	9.75	11.70%
Cycle Time (<5 Time loss, >5 time improvement)	15%	4.25	6.38%	4.75	7.13%	5.5	8.25%	2.5	3.75%	5.5	8.25%	7	10.50%
Predicted Accuracy (1-10 as 50%-100%)	20%	5.75	11.50%	6.25	12.50%	7.25	14.50%	4	8.00%	6.5	13.00%	7.75	15.50%
Safety of function (1-10)	23%	5.25	12.08%	7.5	17.25%	3.25	7.48%	3.25	7.48%	4.25	9.78%	8.25	18.98%
Complexity to impliment (1-10) 1 being very difficult, 10 being simple	15%	6.25	9.38%	4.75	7.13%	6.75	10.13%	4.75	7.13%	6.75	10.13%	8	12.00%
			TOTAL		TOTAL		TOTAL		TOTAL		TOTAL		TOTAL
	max												
	100%		55.08%		60.50%		60.23%		33.55%		58.25%		72.80%

PREDICTIVE ANALYSIS

Defining Predictive Analysis Process:

Ask questions that justify concepts we just evaluated:

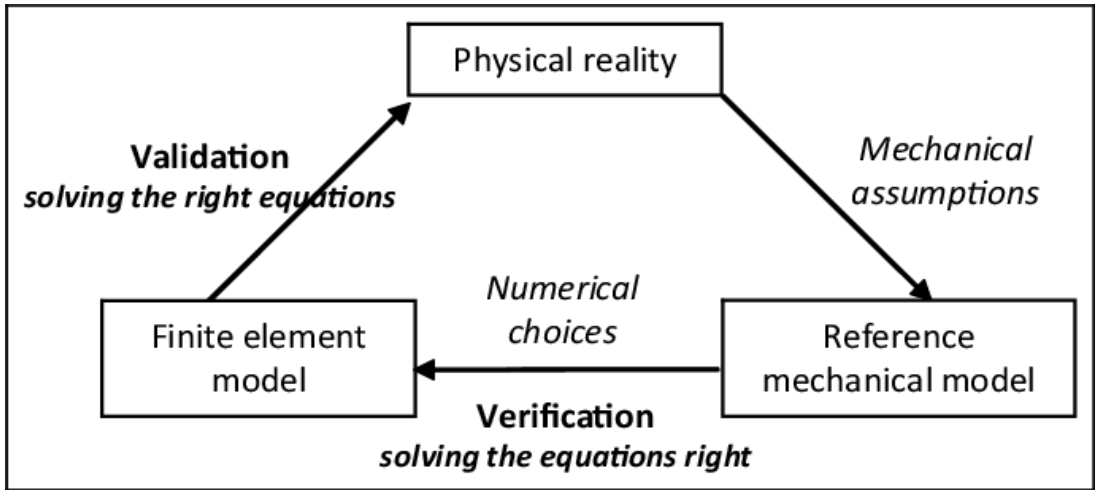
- The justification will prove that the concept works and how we designed using engineering analysis methods

The questions must be answered with at least 2 analysis methods:

1. Experiment
2. Hand calculations
3. Finite element analysis

Once Done, ensure data is both:

- Verified: Is the math done correctly?
- Validated: Do the results make sense?

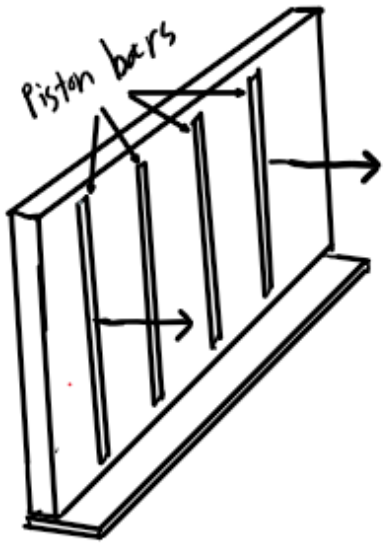


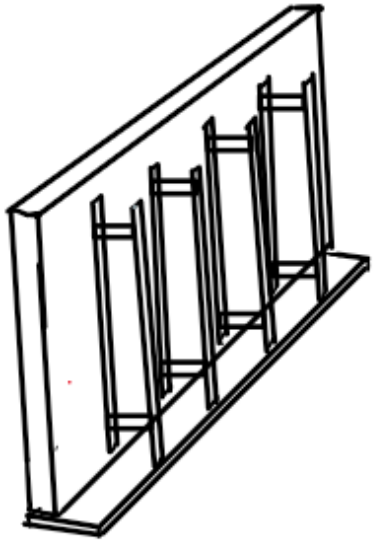
https://www.researchgate.net/figure/Principle-of-the-verification-and-validation-methodology_fig1_258186808

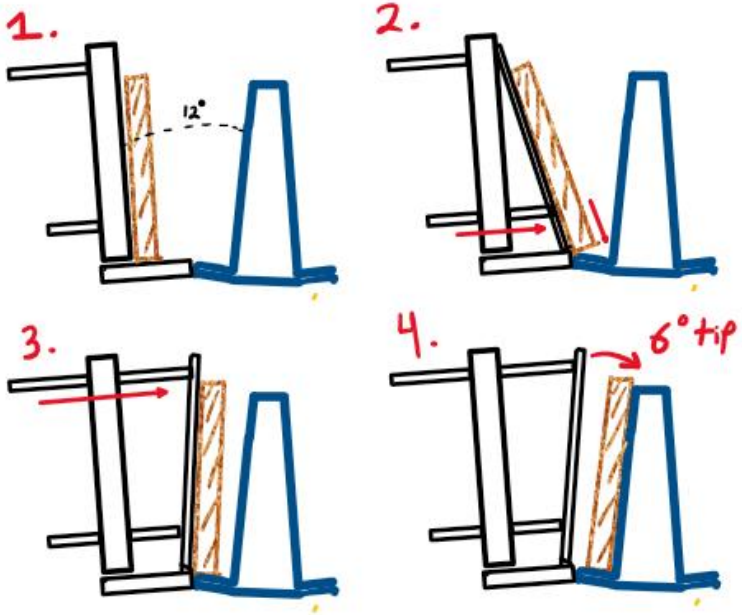
https://www.digitalengineering247.com/article/verification-vs-validation/

Predictive Analysis Question Example

Engineering Questions	Method to Solve	Resources Needed for Method	Method to Benchmark	Resources Needed for Method	How Results Will Further Design	Functional Need
How far do the top/bottom pistons need to each extend to push the box flush to the back of the cart?	Experiment	Sizes of the cart, table, and box.	Physical experimentation	Wooden blocks matching scaled down sized of box, table, and cart	This will help us determine the furthest distance necessary that pistons need to extend and piston size.	Box flush up against the carts

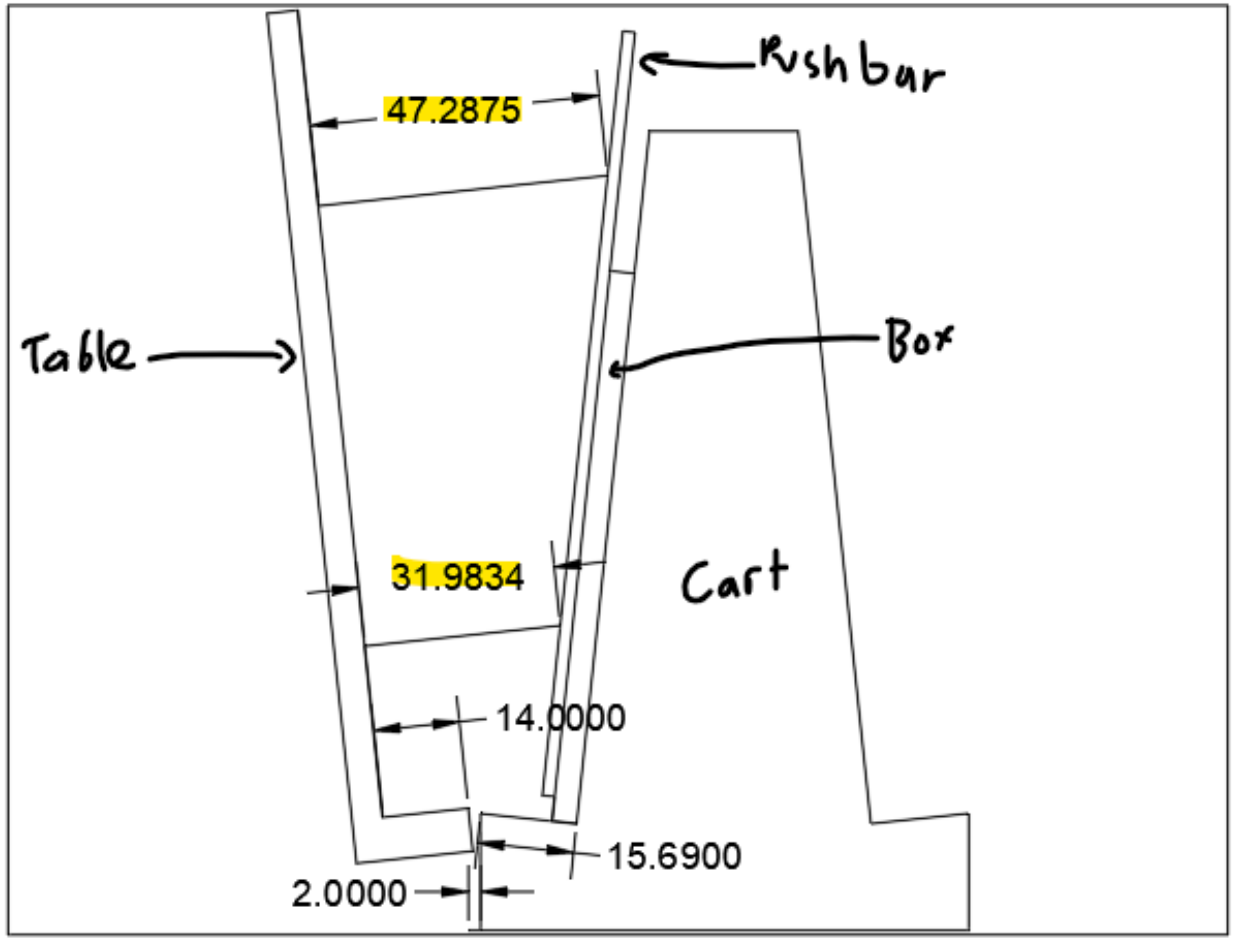






Hand Calculations – Push Piston Concept Ex.

- Knowns:
  - Angle of box shelf and cart shelf: 6 deg
  - Angle of tilted table and cart: 6 deg
  - Position of bar vertically on the table: 4in up, 8in down
  - Length of box shelf: 14in
  - Depth of deepest cart: 15.69in
  - Depth of shallowest box: 4in
  - Height of tilt table: 137in
- Assumed values:
  - Distance between shelf and cart: 2in
  - Vertical positions of pistons: 24in in from edges
  - Depth of push bar = 2in
- Solved Values with AutoCAD:
  - Max extension for bottom piston: 31.984in
  - Max extension for top piston: 47.2875in



Prototype – Push Piston Concept Ex.

Functional Lego model as a physical proof of concept display

video-20231116-172629-8ebf69fa.mov

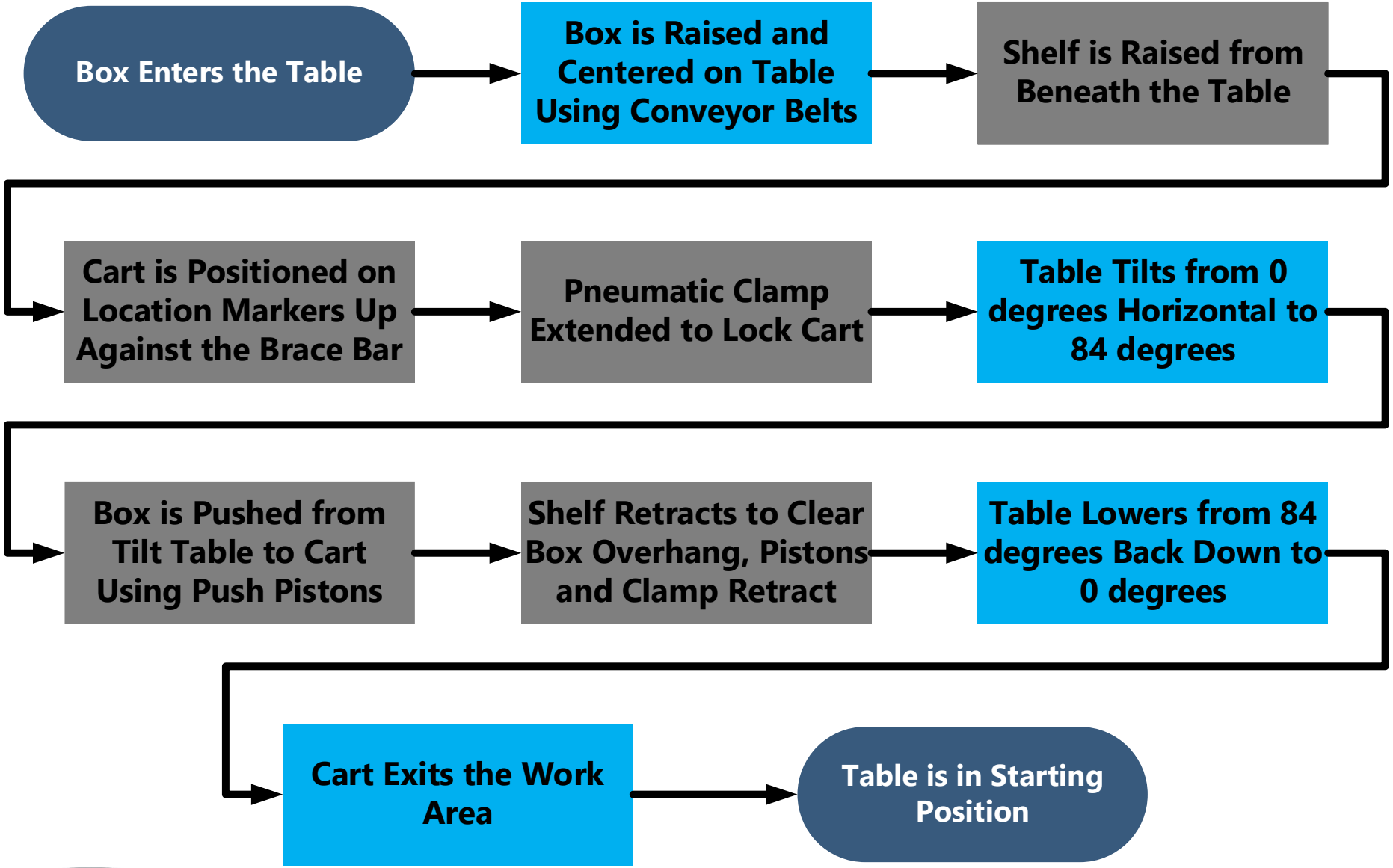
COMPLETE DESIGN REVIEW – PART 1

Complete Design Review

During this time, we

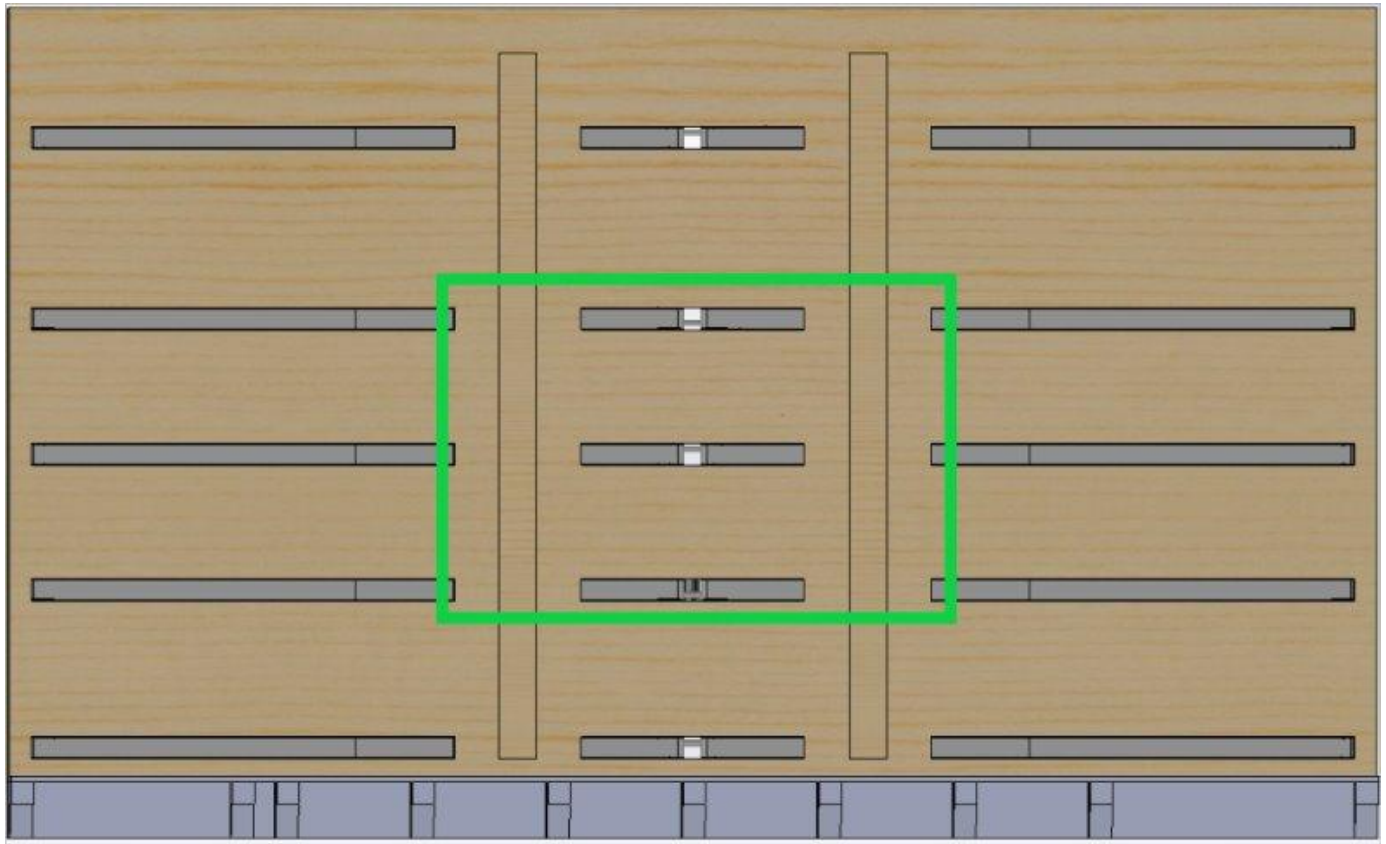
- Cleaned up documentation
- Finished the initial 3D model
- Created justification for all processes

Redesign Process Flow



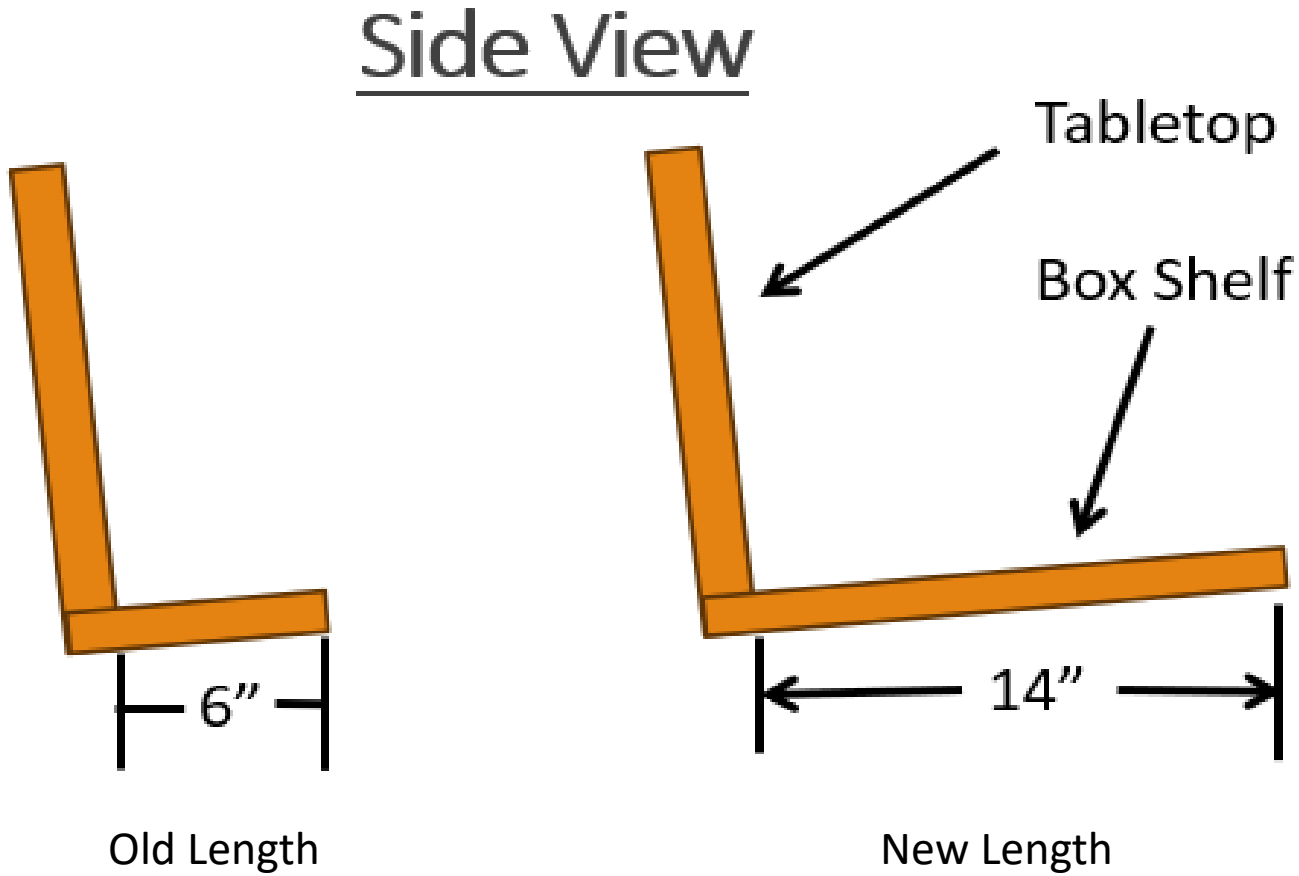
Note: Gray indicates processes that changed in Semester 2

Box Enters the Table → **Box is Raised and Centered on Table Using Conveyor Belts** →



Painted green square indicates where box should be to be centered.

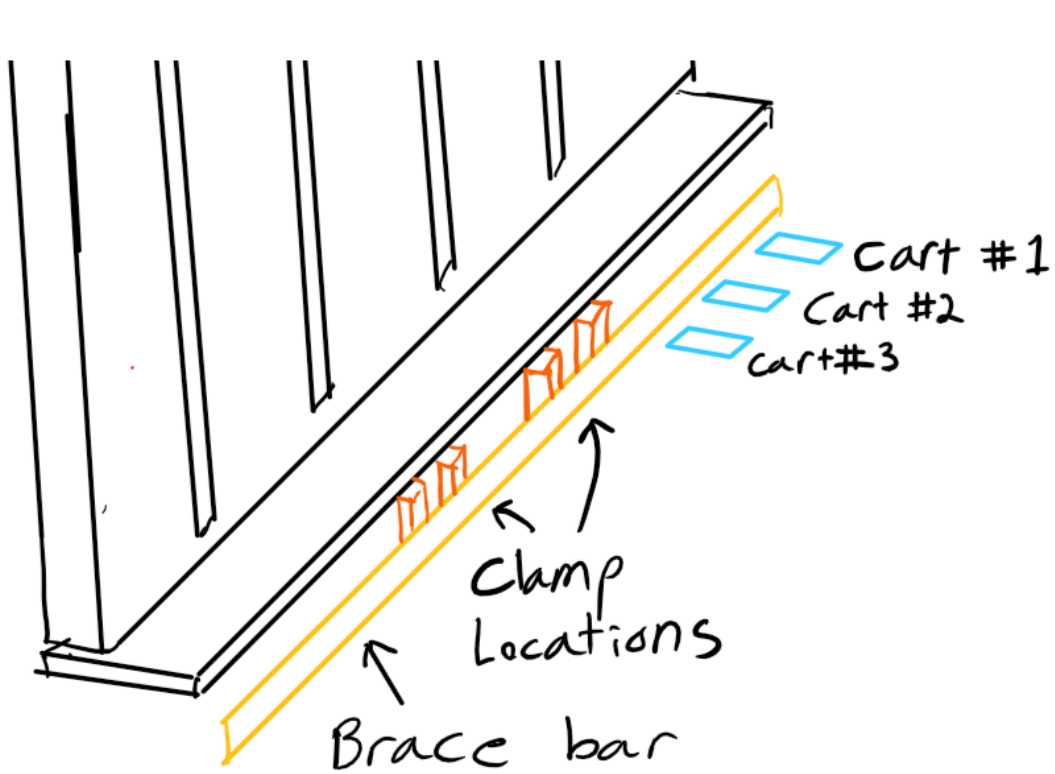
Shelf is Raised from Beneath the Table

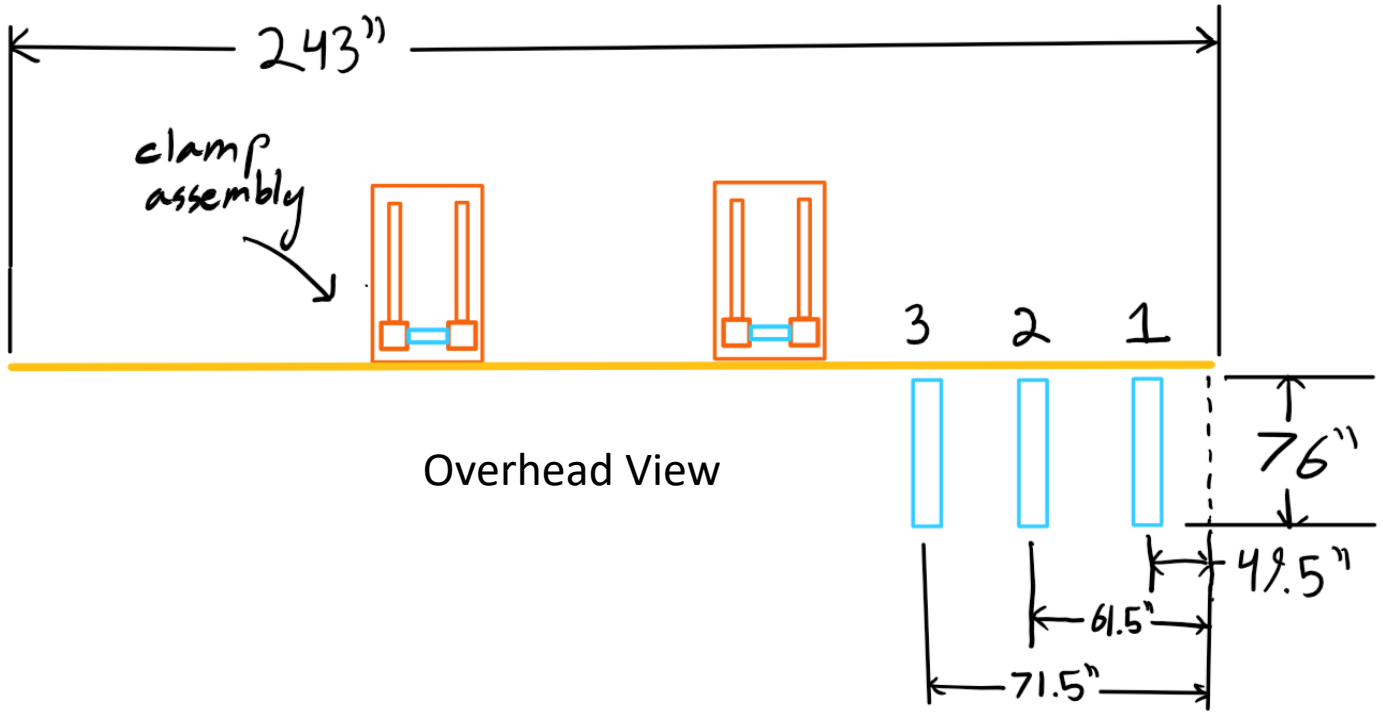


Old Length

New Length

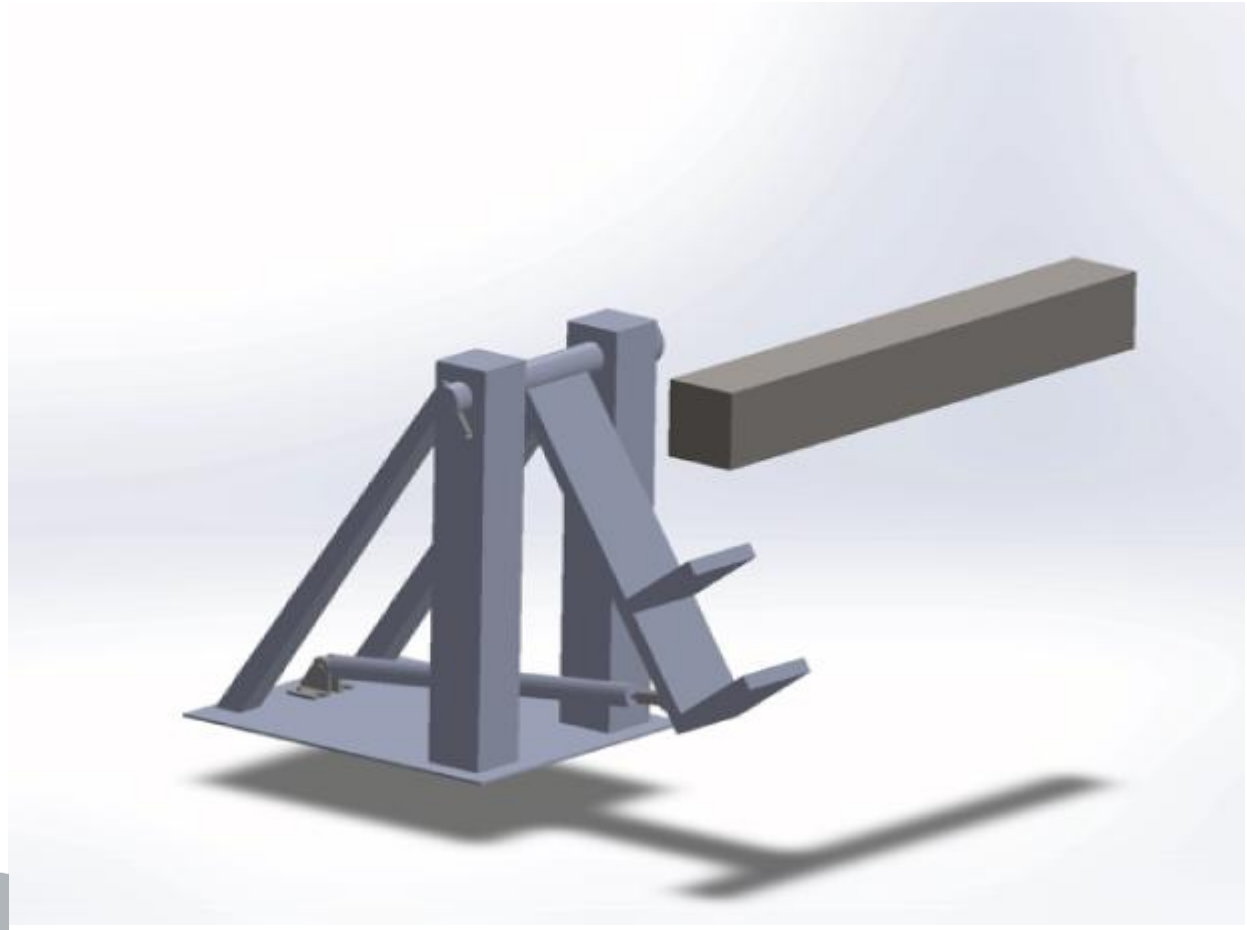
Cart is Positioned on Location Markers Up Against the Brace Bar





Overhead View

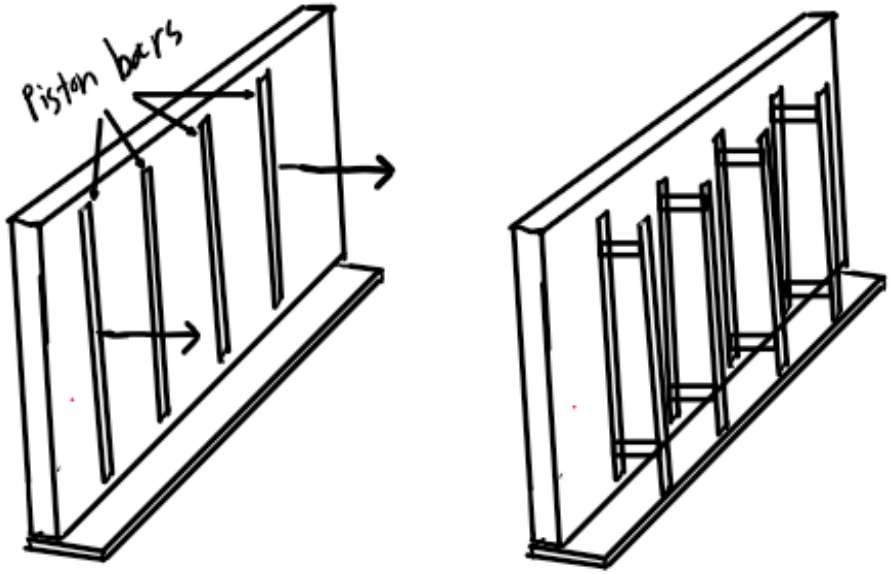
Pneumatic Clamp Extended to Lock Cart

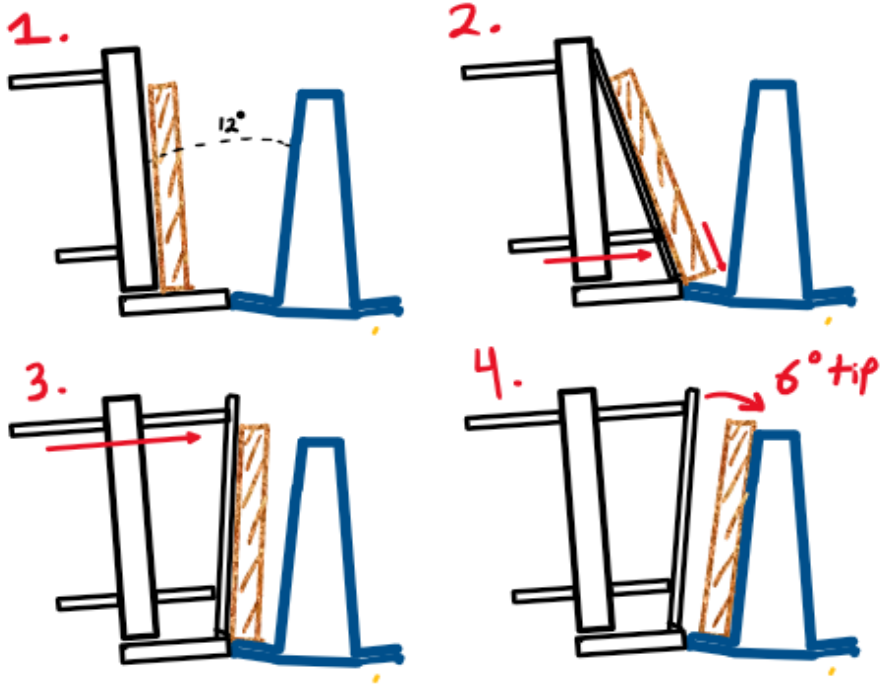


Clamp lifts to attach to bar on cart, securing it in place.

Table Tilts from 0 degrees Horizontal to 84 degrees

Box is Pushed from Tilt Table to Cart Using Push Pistons





Shelf Retracts to Clear Box Overhang, Pistons and Clamp Retract

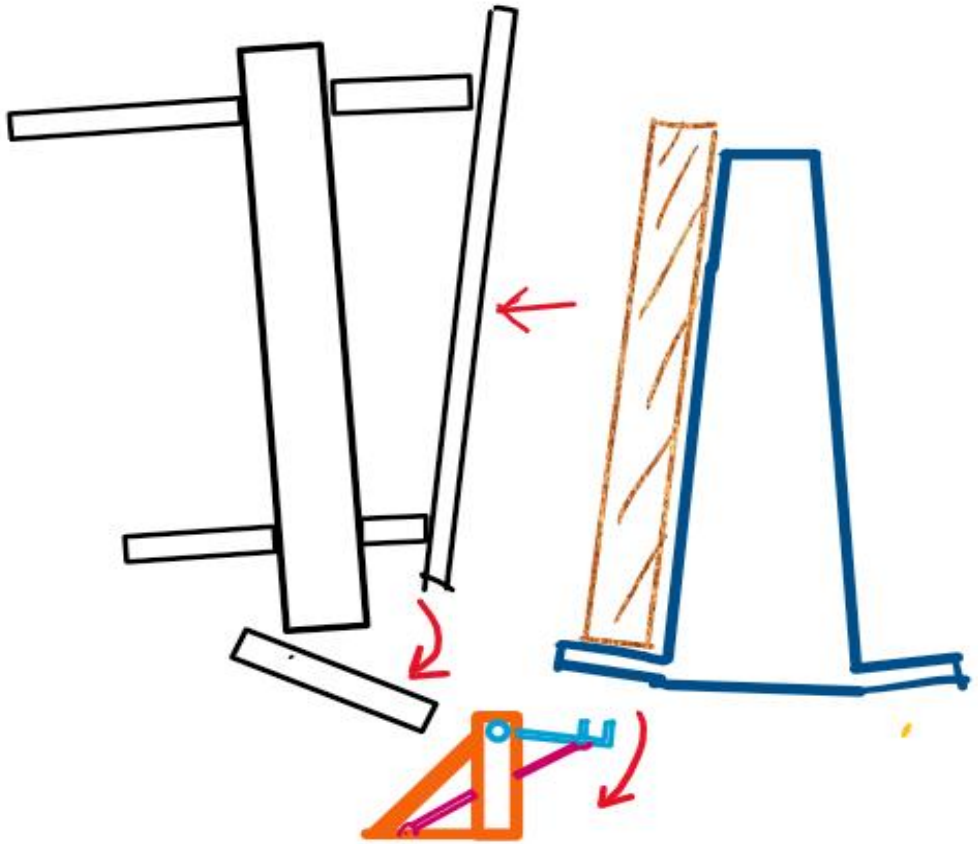
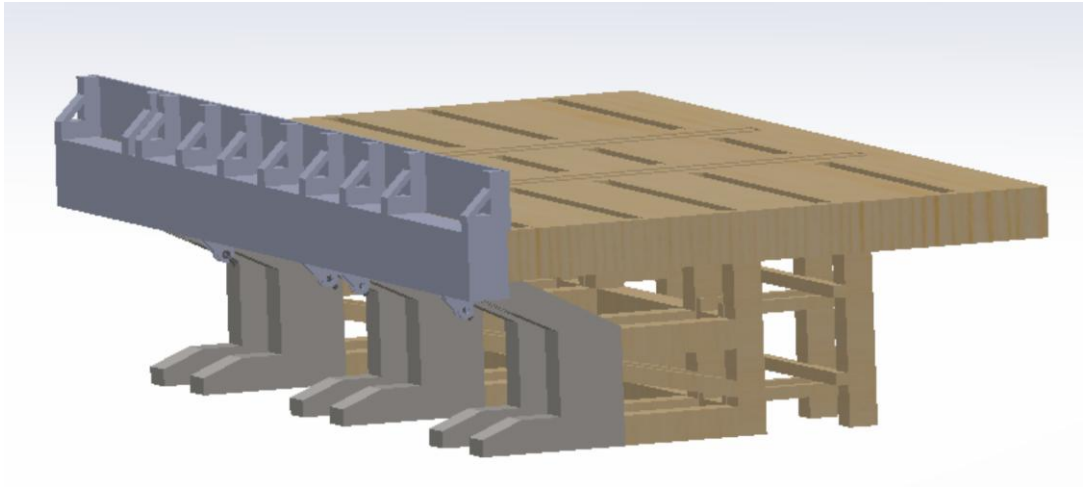
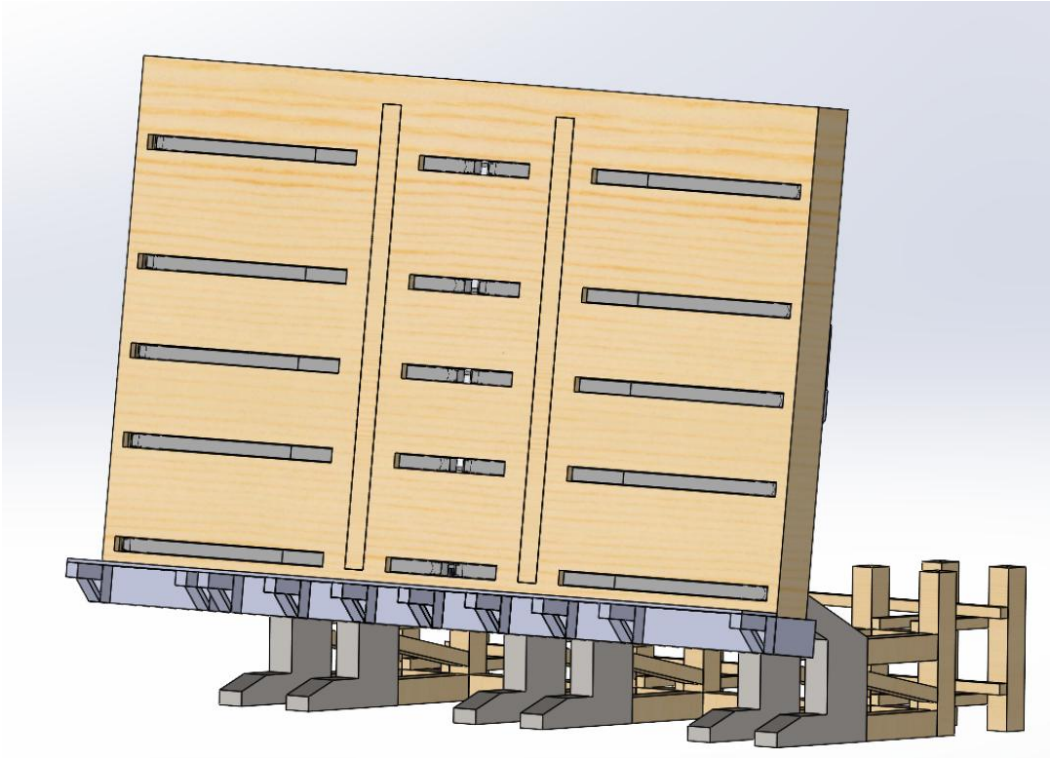


Table Lowers from 84 degrees Back Down to 0 degrees

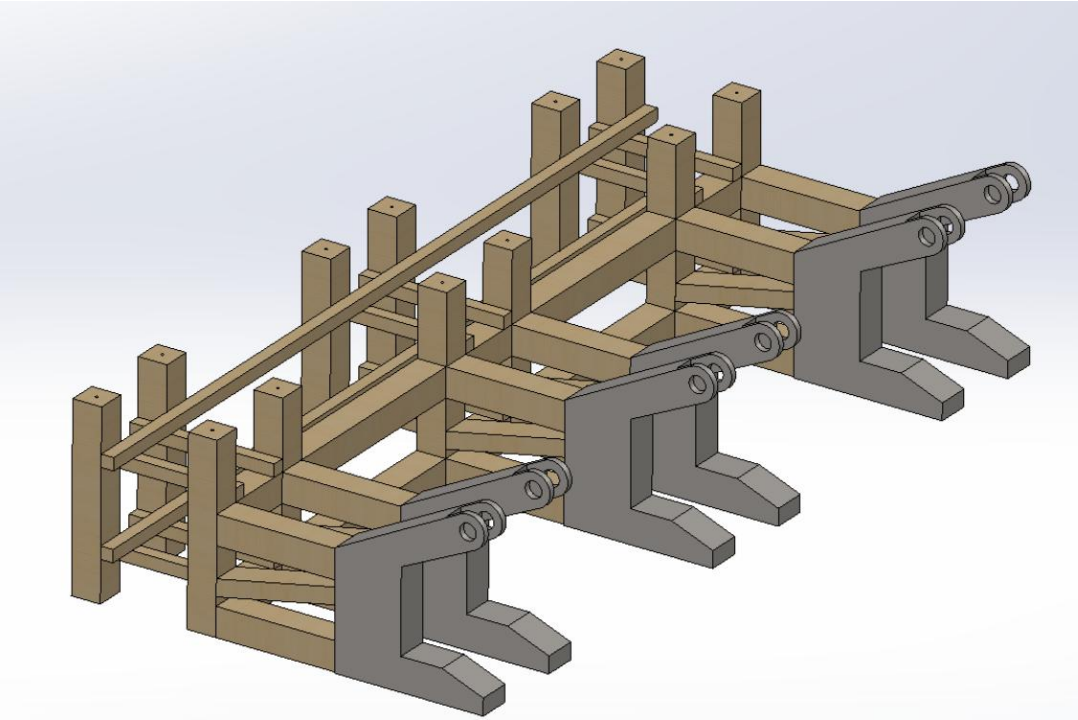
Cart Exits the Work Area

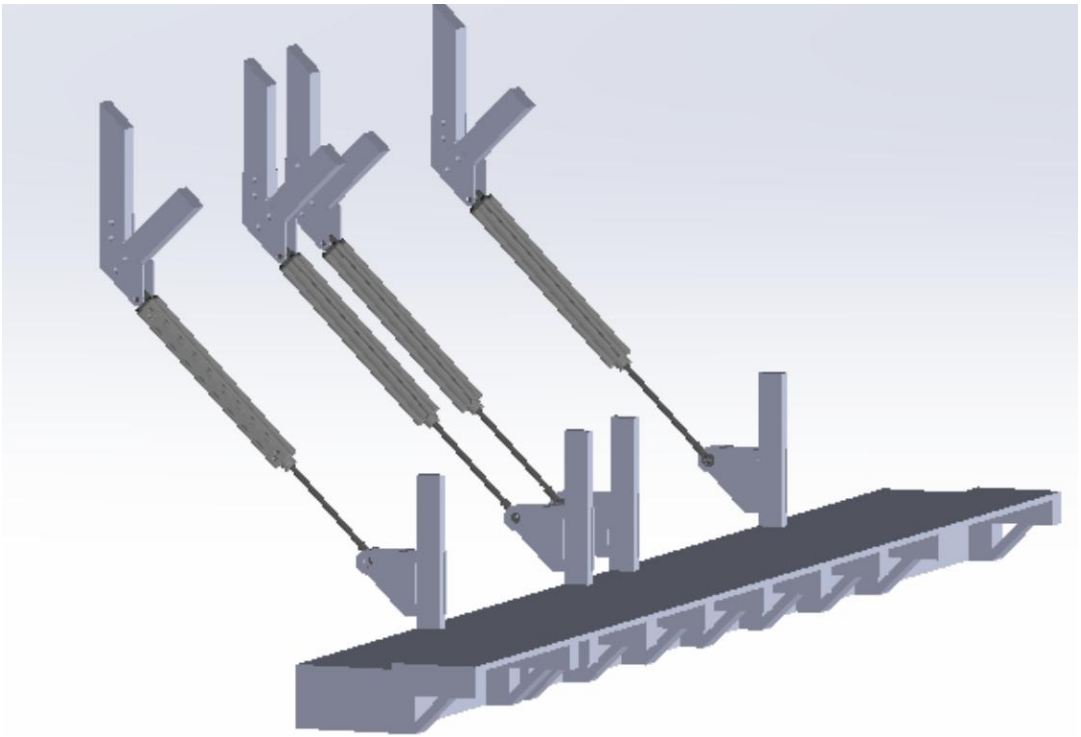
Table is in Starting Position





FULL MODEL





FULL MODEL

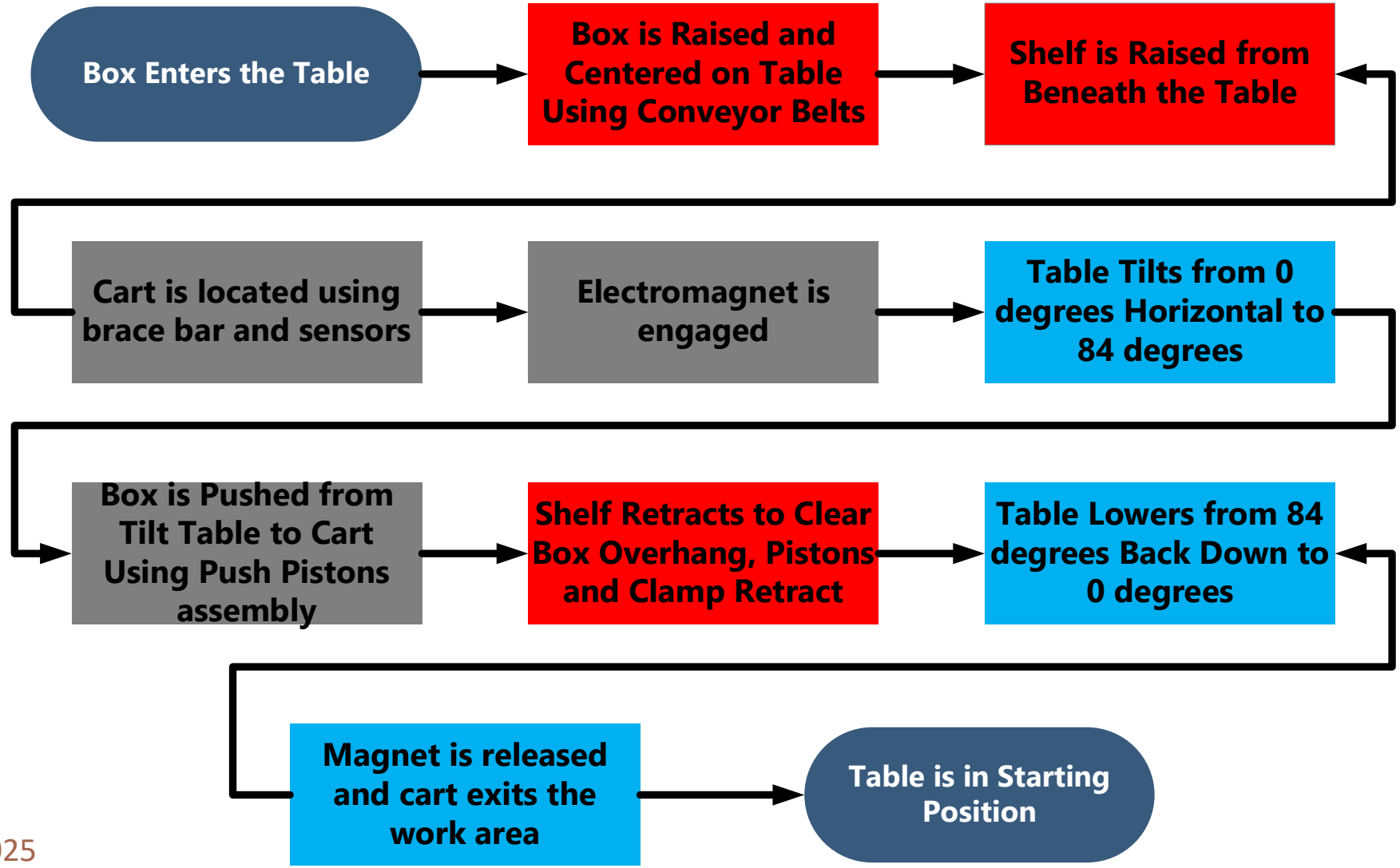
COMPLETE DESIGN REVIEW – PART 2

Re-defining Scope

- Through comments from professors in previous presentations
- Another site visit with Viracon
- New team member perspective

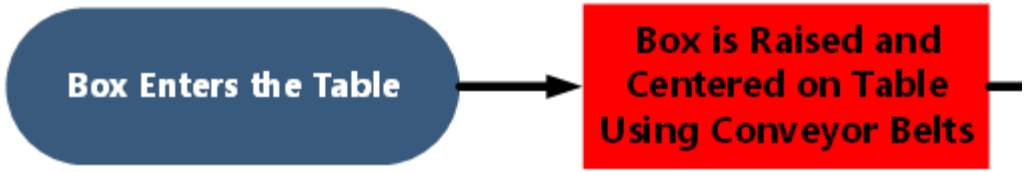
We realized we were doing a lot of work outside the project goals. So, we modified our scope to better reflect those goals

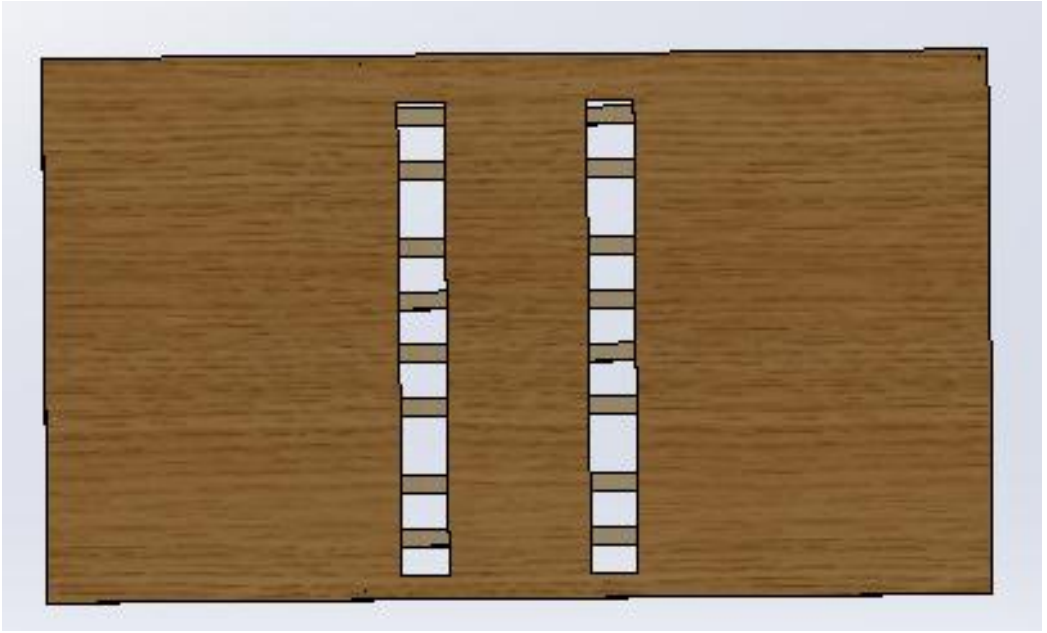
Process Flow



Note: Red indicates processes that were removed from our system in semester 2

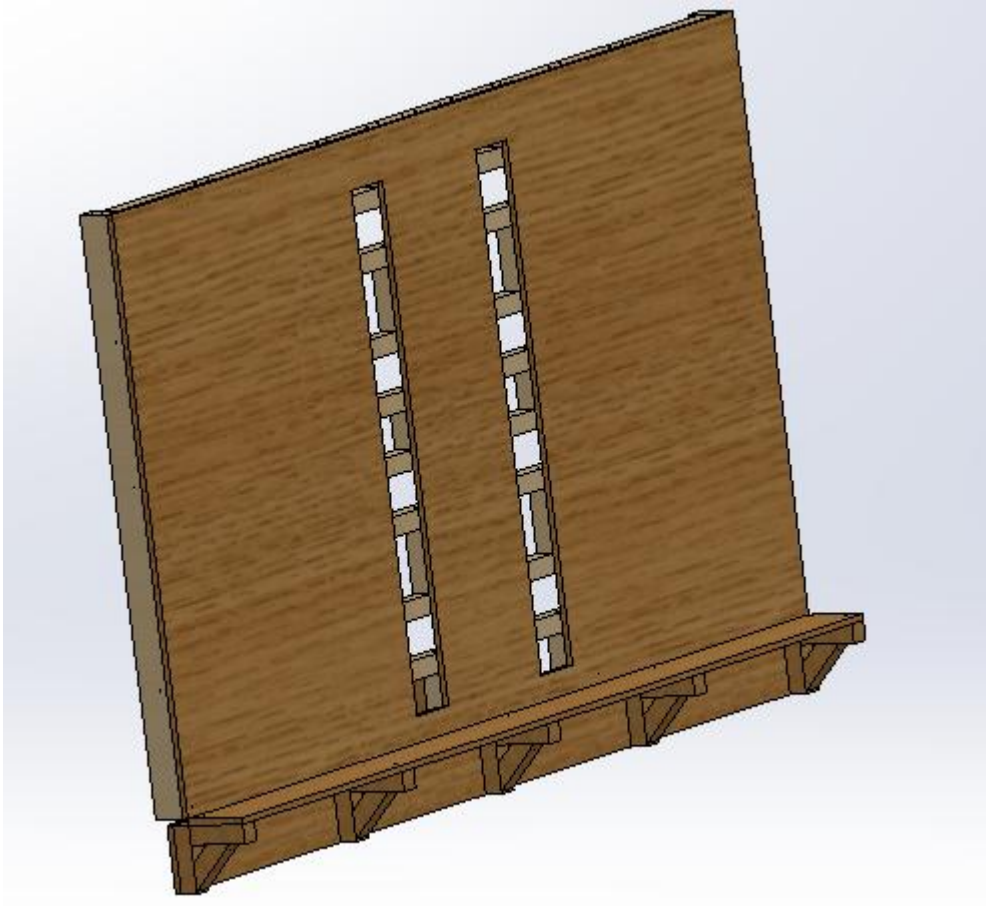
Process Flow Explained





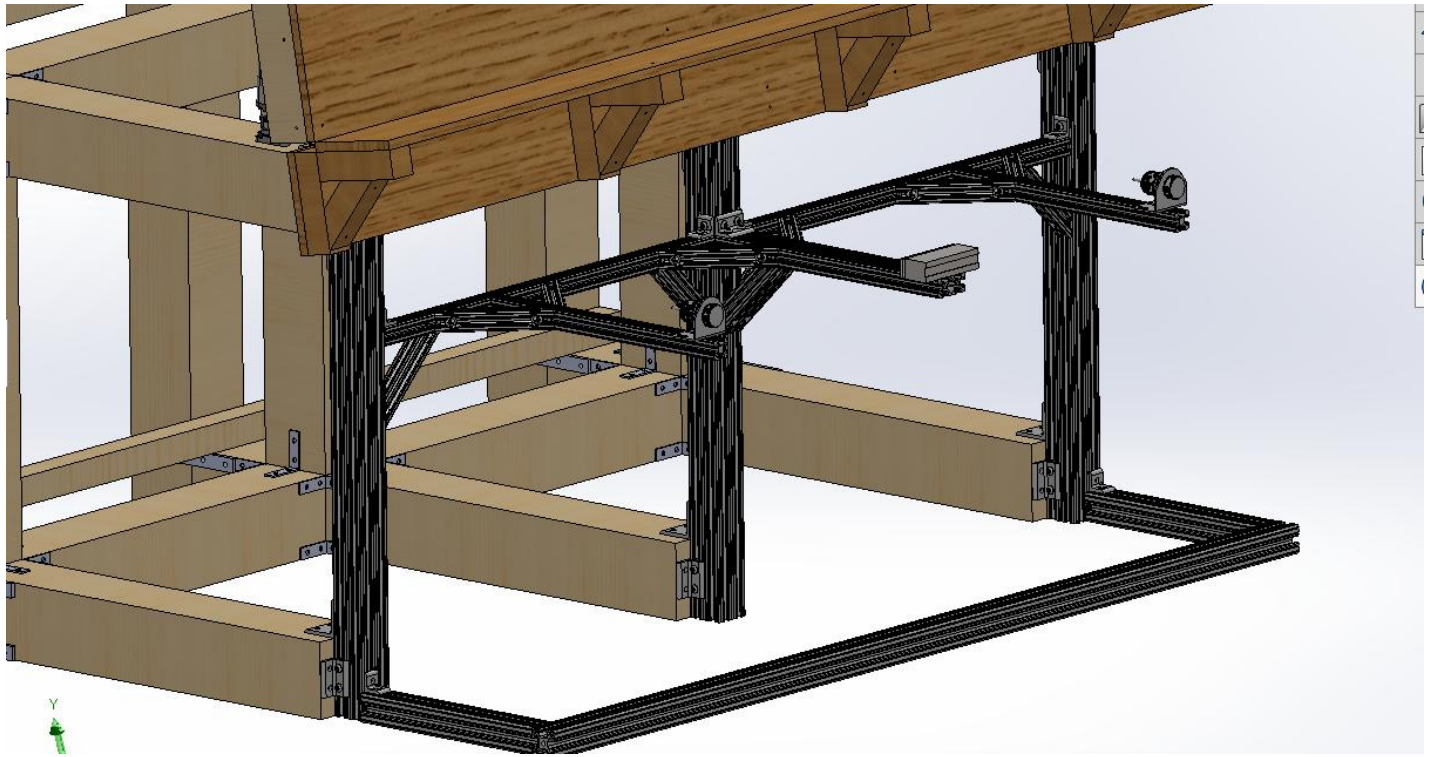
Process Flow Explained

Shelf is Raised from Beneath the Table



Process Flow Explained

Cart is located using brace bar and sensors



Process Flow Explained

Electromagnet is engaged

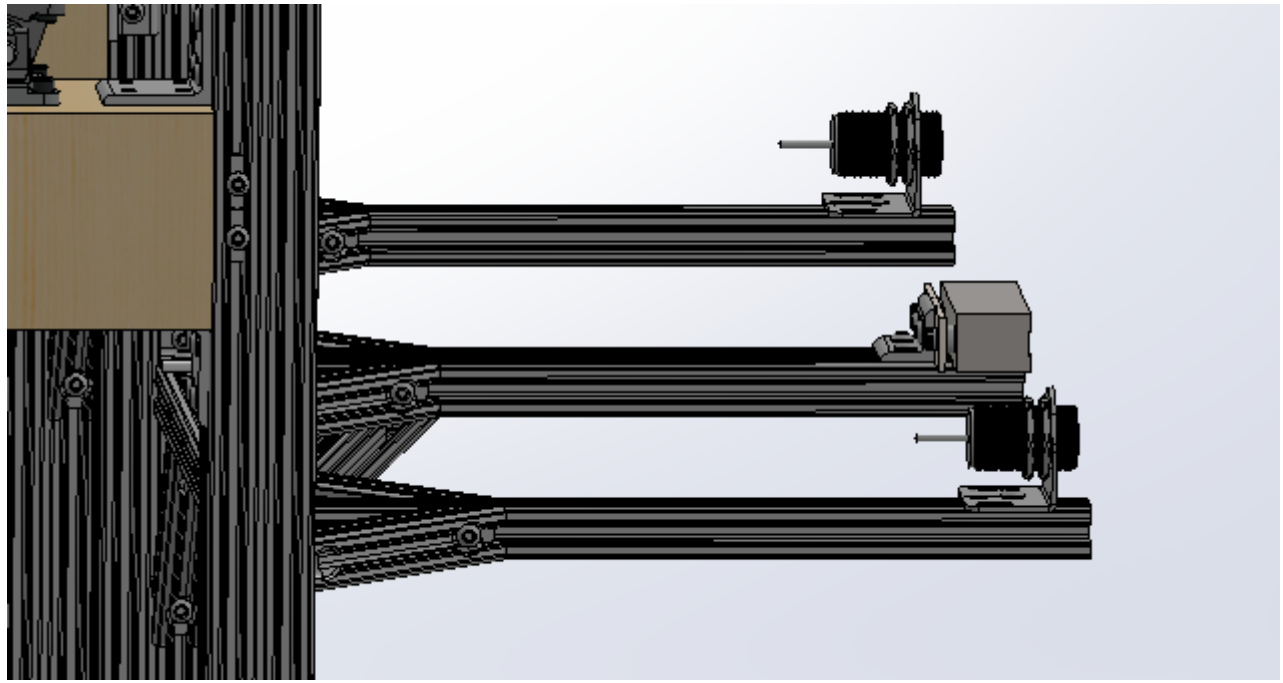
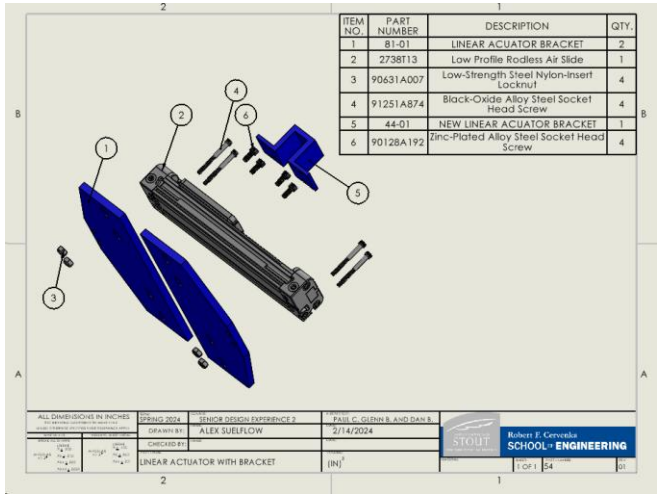
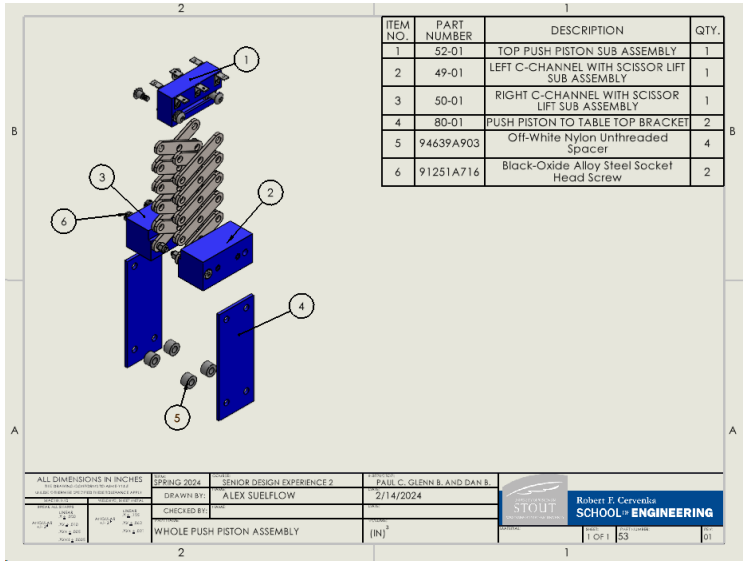


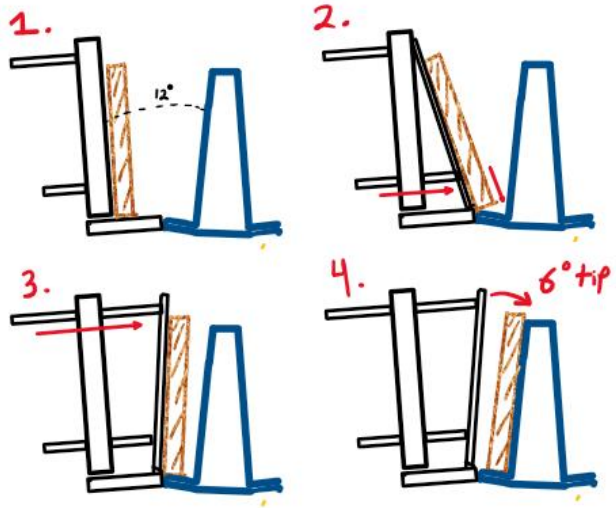
Table Tilts from 0 degrees Horizontal to 84 degrees

Process Flow Explained

Box is Pushed from Tilt Table to Cart Using Push Pistons assembly







Process Flow Explained

Shelf Retracts to Clear Box Overhang, Pistons and Clamp Retract

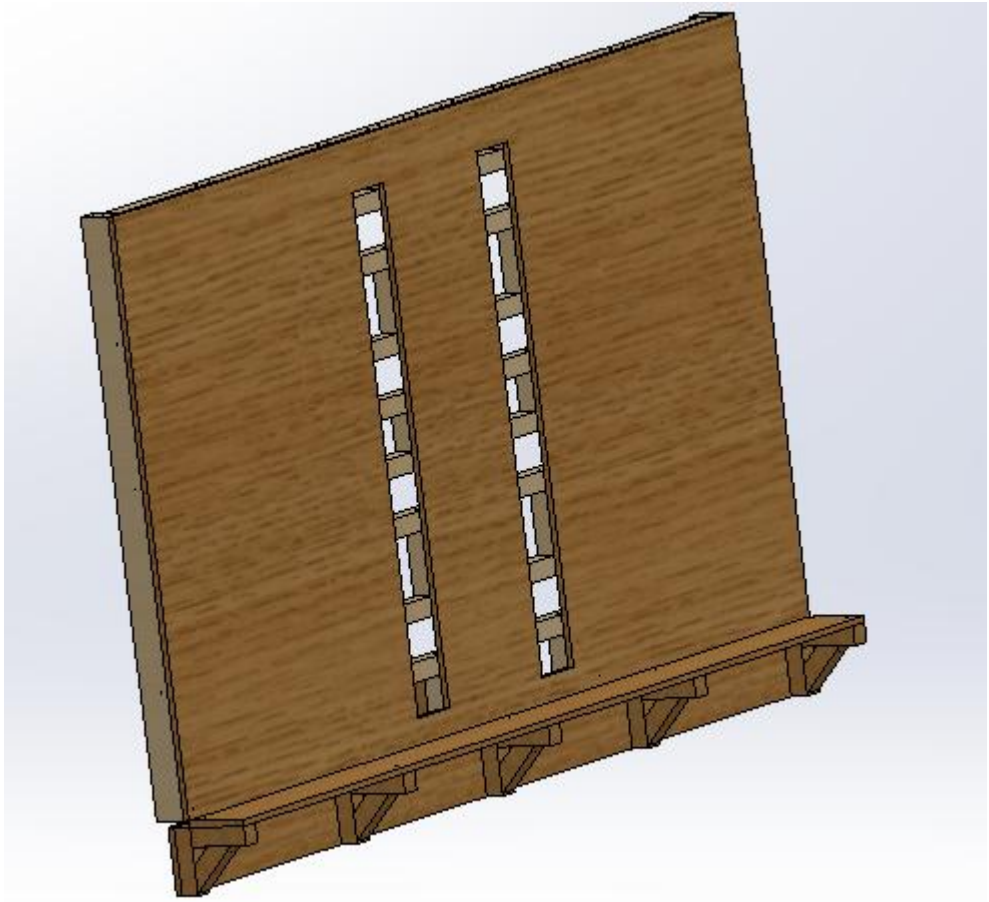
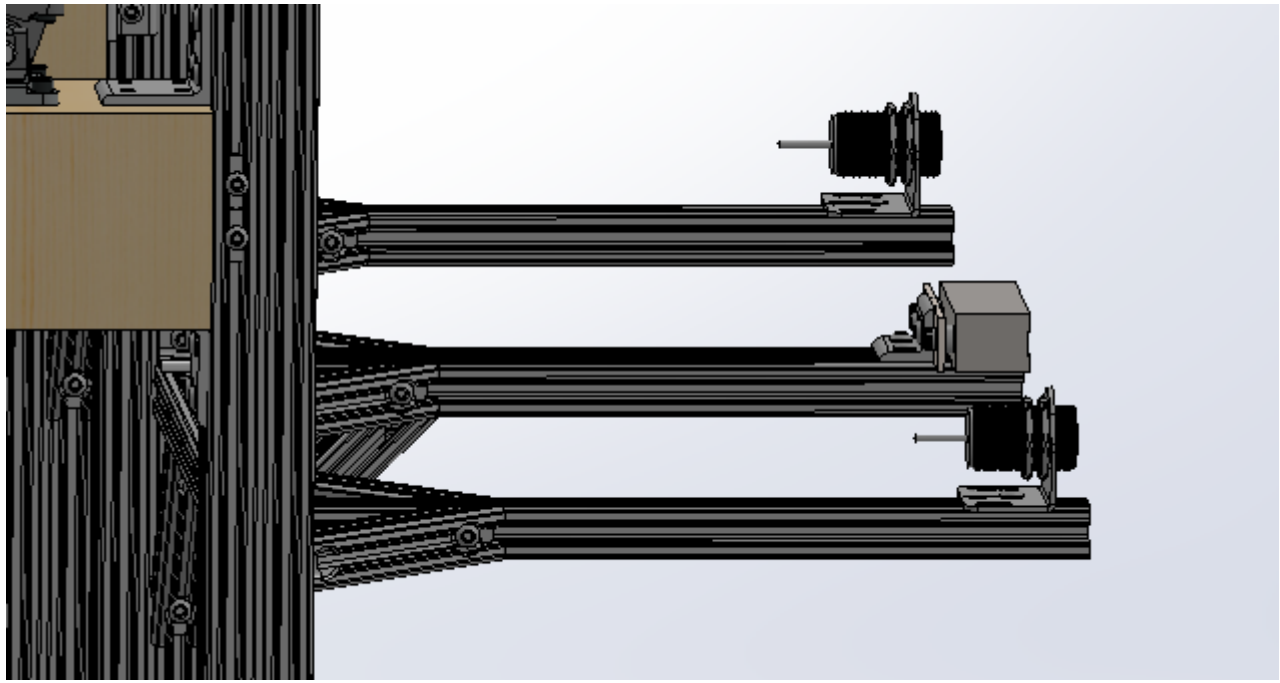


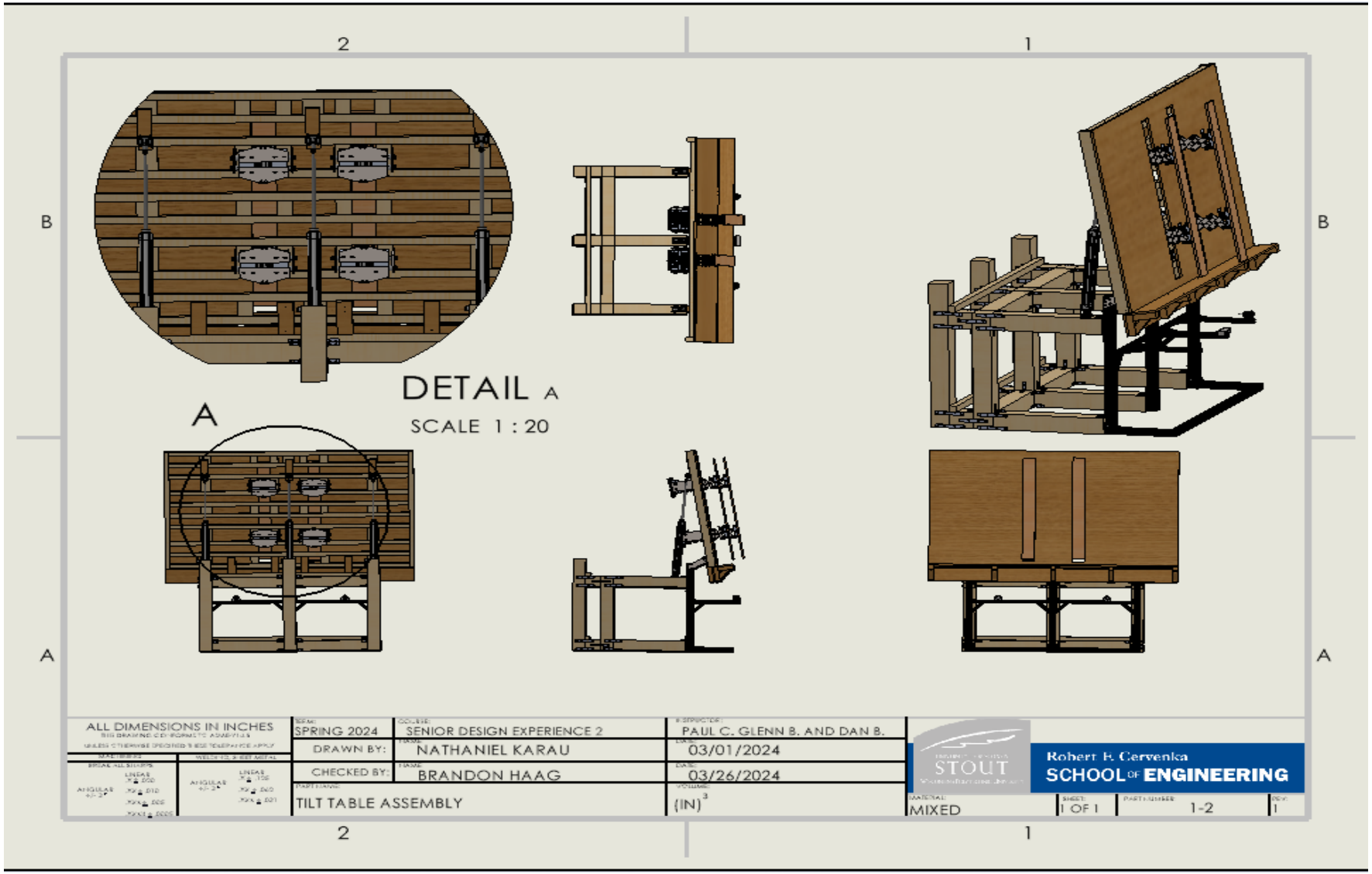
Table Lowers from 84 degrees Back Down to 0 degrees

Process Flow Explained

Magnet is released and cart exits the work area



Updated Model Part 2



CONTROLS

Complete Design Review: Controls

INPUTS

HMI PB1 – Table Extend

HMI PB2 – Table Retract

HMI PB3 – Bottom Push Pistons Extend

HMI PB4 – Top Push Pistons Retract

HMI PB5 – Push Pistons Retract

HMI PB6 – Rest

HMI PB7 Magnet

PB8 – E-Stop

PROX 1

PROX 2

OUTPUTS

Sol1 – Extend Bottom Push Piston

Sol2 – Retract Bottom Push Piston

Sol3 – Extend Top Push Piston

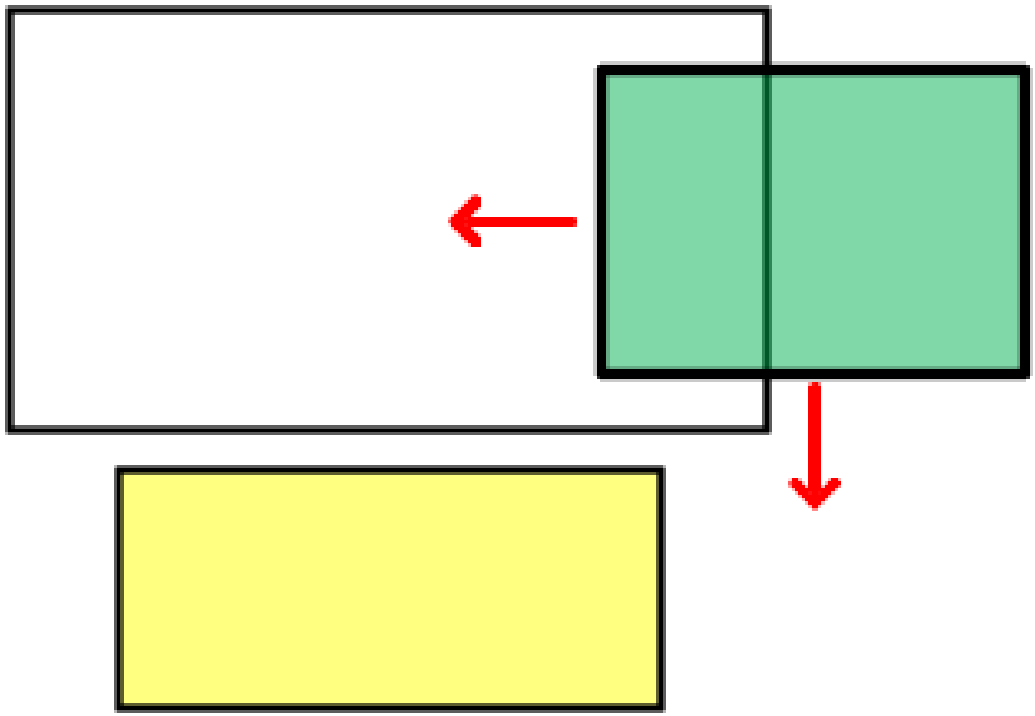
Sol4 – Retract Top Push Piston

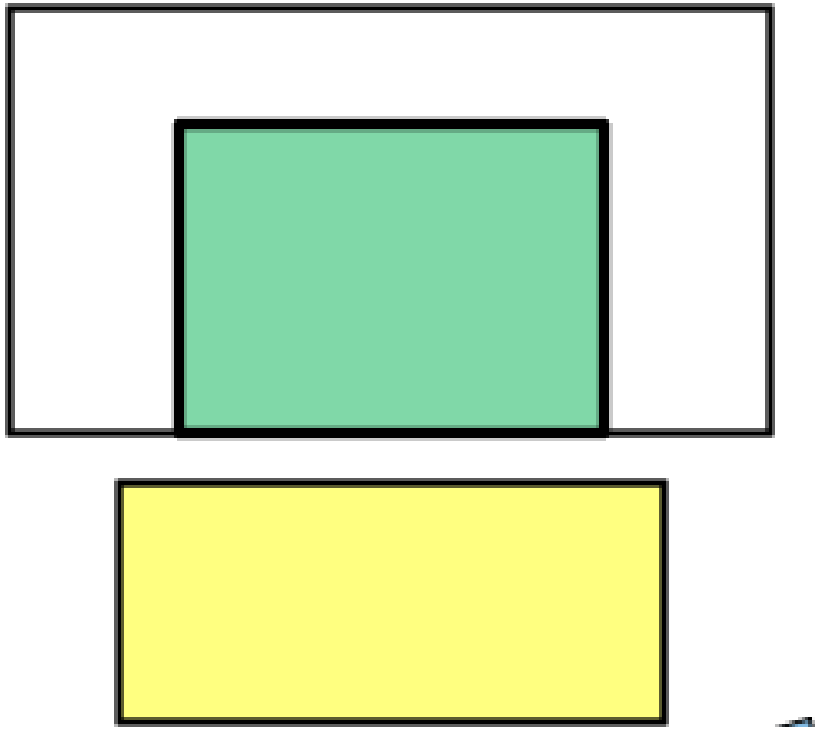
Sol5 – Extend Tilt Table

Sol6 – Retract Tilt Table

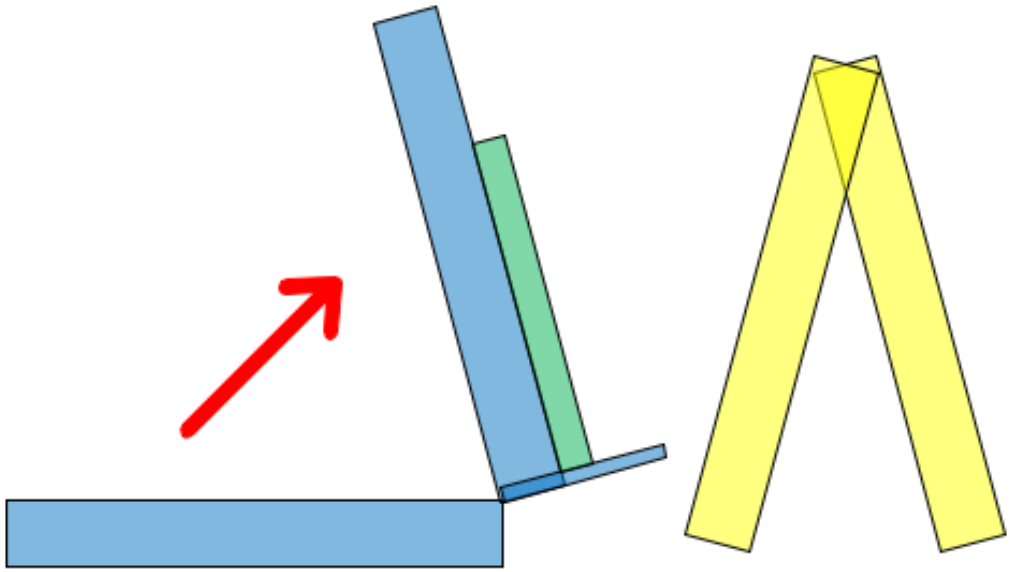
Magnet

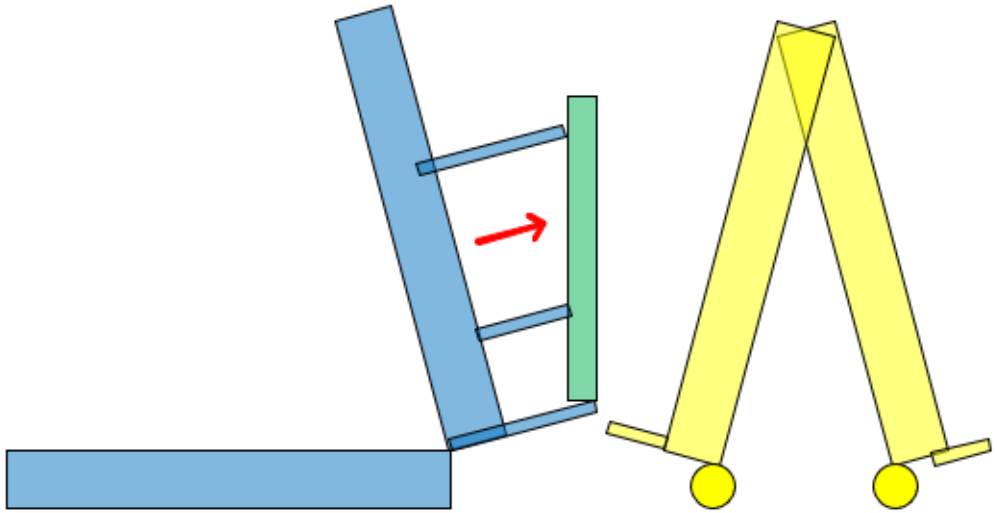
Controls: Part Flow

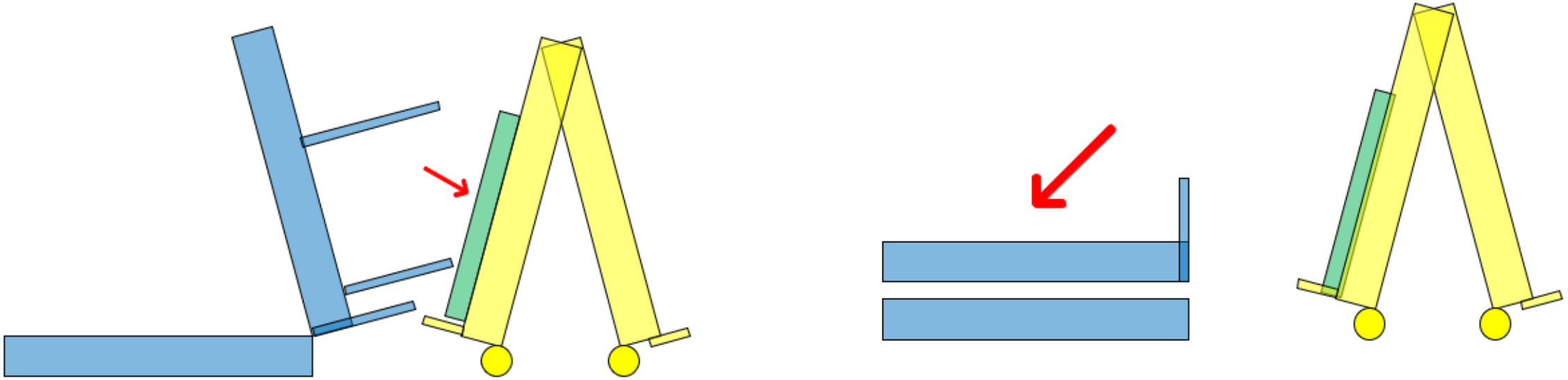




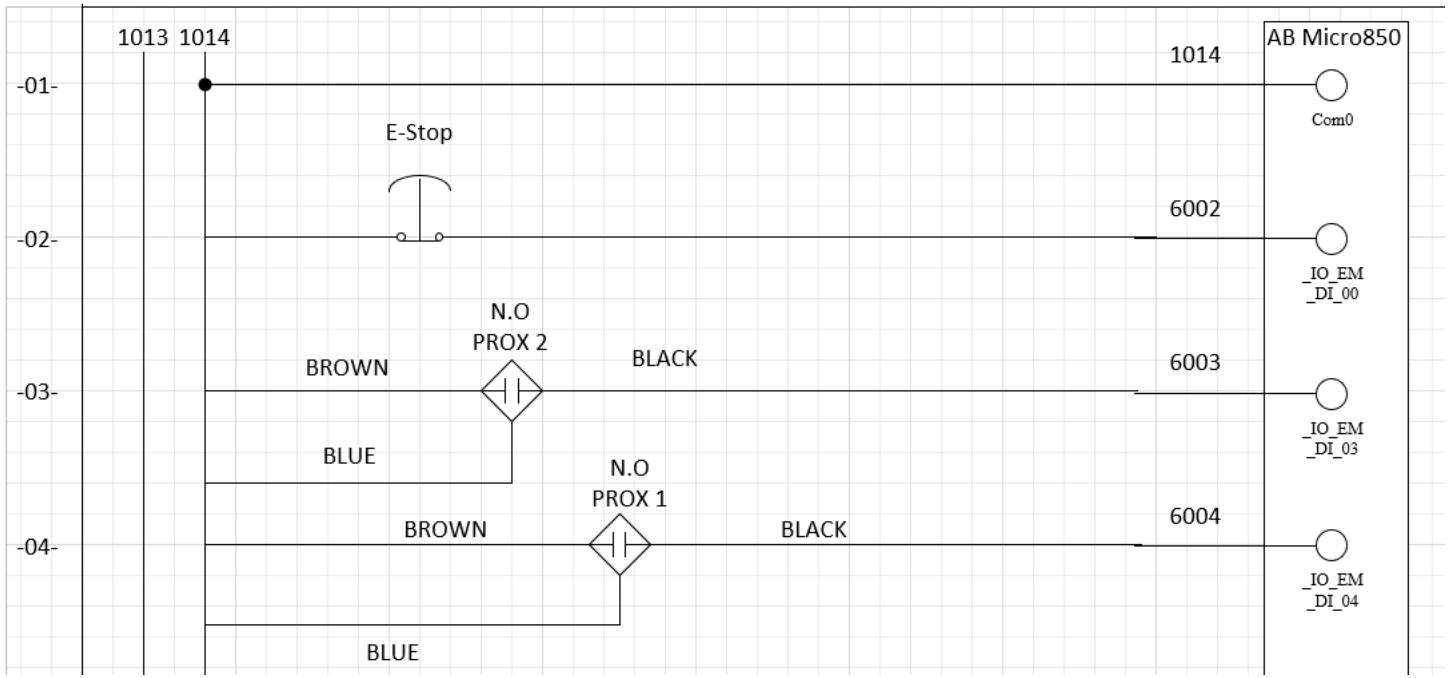
Controls: Part Flow



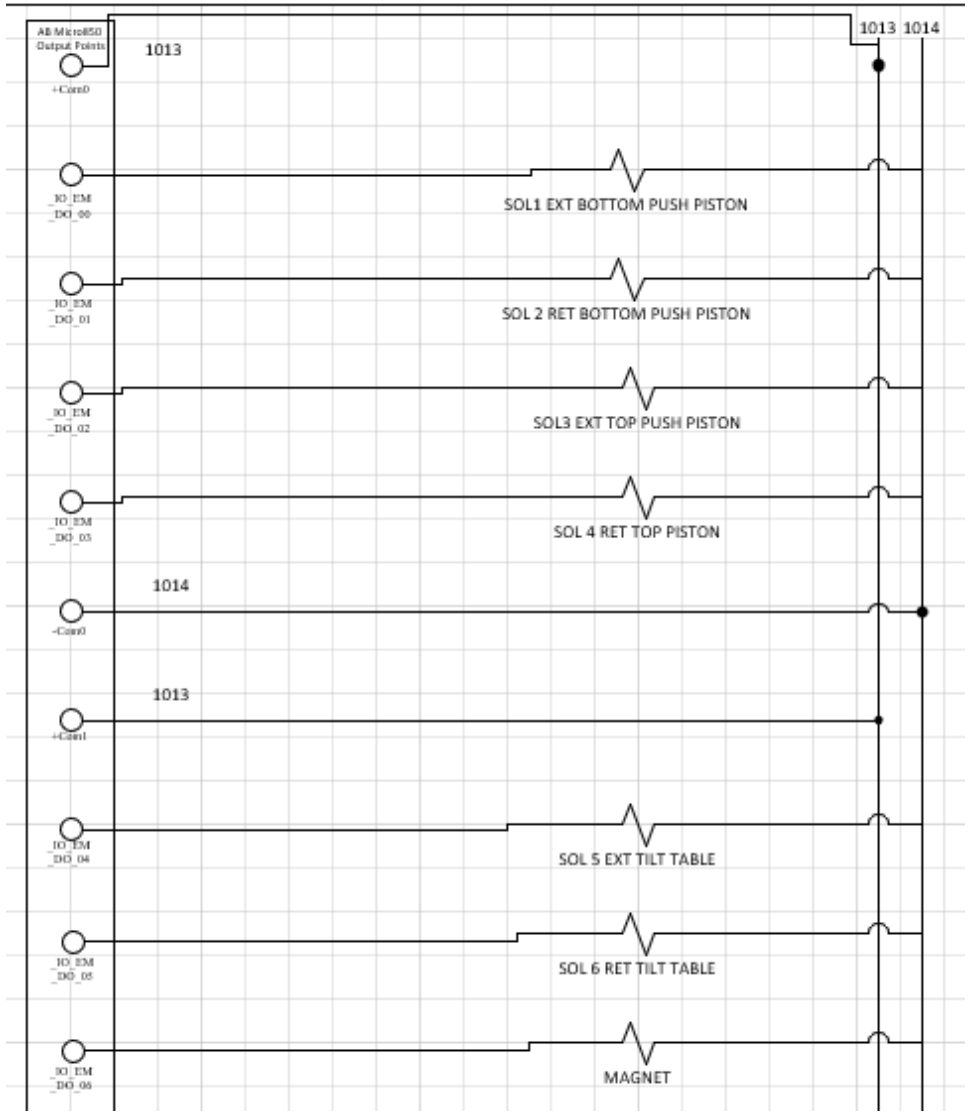




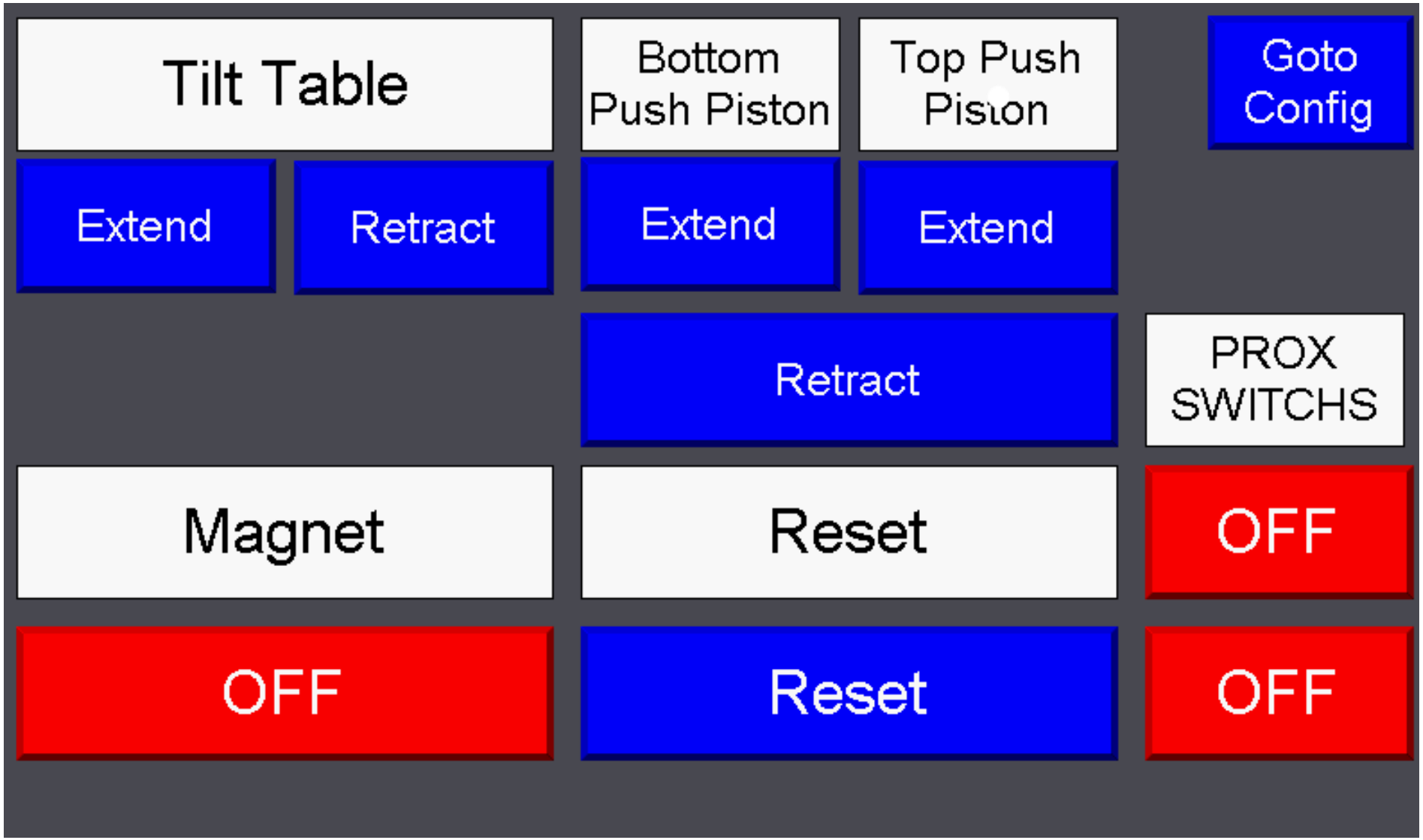
INPUTS


1013 1014
AB Micro850
-01-
1014
Com0
E-Stop
-02-
6002
_IO_EM
_DI_00
N.O
PROX 2
BROWN
BLACK
-03-
6003
_IO_EM
_DI_03
BLUE
N.O
PROX 1
BROWN
BLACK
-04-
6004
_IO_EM
_DI_04
BLUE

OUTPUTS


1013
1013 1014
SOL1 EXT BOTTOM PUSH PISTON
SOL 2 RET BOTTOM PUSH PISTON
SOL3 EXT TOP PUSH PISTON
SOL 4 RET TOP PISTON
1014
1013
SOL 5 EXT TILT TABLE
SOL 6 RET TILT TABLE
MAGNET

HMI


Tilt Table
Bottom Push Piston
Top Push Piston
Goto Config
Extend
Retract
Extend
Extend
Retract
PROX SWITCHS
Magnet
Reset
OFF
OFF
Reset
OFF

FINAL BUILD

Parts list

We organized the parts in this excel

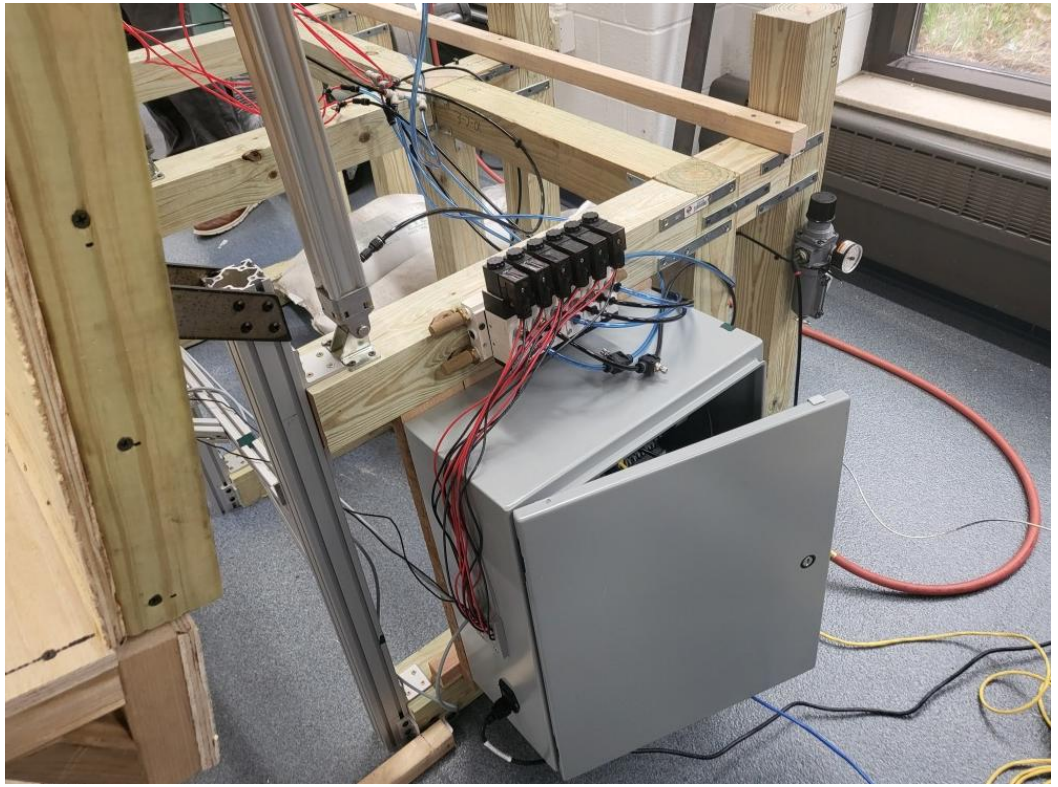
Assem. #	Part #	Rev.	Name	CAD Drawing	QTY for Build	Dimension (LxHxW) INCH	Vendor	Cost	PKG QTY	Total Cost	Leftover Material	Total Leftover Material	SKU#
2252186			Mending Brace	Menards	36	N/A	Menards	$0.98	1	$35.28	N/A	N/A	2252186
2250128			Corner Brace	Menards	58	N/A	Menards	$0.89	1	$51.62	N/A	N/A	2250128
4	**1**	**1**	**Box Shelf**										
4	2	1	Box Shelf Assembly/BOM	X	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Assembly
4	3	1	Back Support	X	4	10.25 x 2.5 x 1.5	Menards	$3.91	1	$3.91	7x3x2	32x3x2	1110777
4	4	1	Back Board Support	X	1	80 x 5.25 x .50	Menards	$17.79	1	$17.79	80x18.75x.5	80x20.75x.5	1231456
4	5	1	Support Frame Bottom	X	5	5.25 x 1.5 x 1.5	Menards	$3.37	1	$3.37	9.75x2x2	151.75x2x2	1072416
4	6	1	Support Frame Top	X	5	5 x 1.5 x 1.5	Menards	$0.00	0	$0.00	-25x2x2	126.75x2x2	(Used from other wood)
4	7	1	Support Frame 45	X	5	5 x 1.5 x 1.5	Menards	$3.37	1	$3.37	11x2x2	137.75x2x2	1072416
4	8	1	Box Shelf Board	X	1	80 x 5 x .5	Menards	$0.00	0	$0.00	-80x5x.5	80x15.75x.5	(Used from other wood)
5	**1**	**1**	**Push Piston Assembly**										
5	2	1	Push Piston	X	2	40 x 4 x .5	Menards	$0.00	0	$0.00	2 (40 x 4 x .5)	0	1231456 (extra from box shelf)
5	3	1	Left Side C-Channel	X	4	3 x 3 x 6	In house	N/A	N/A	N/A	N/A	N/A	(We have it)
5	4	1	Scissor Lift Bracket	X	40	5 x 1 x .25	In house	N/A	N/A	N/A	N/A	N/A	(We have it)
5	5	1	right side c-channel	X	4	3 x 3 x 6	In house	N/A	N/A	N/A	N/A	N/A	(We have it)
5	6	1	new linear acuator bracket	X	4	2.5 x 1 x 1.125	In house	N/A	N/A	N/A	N/A	N/A	(We have it)
5	7	1	top push piston slider	X	4	5 x 2.5 x 1.5	In house	N/A	N/A	N/A	N/A	N/A	(We have it)
5	8	1	push piston to table top bracket	X	8	9.25 x 3.5 x .25	In house	N/A	N/A	N/A	N/A	N/A	(We have it)
5	9	1	linear acuator mountng bracket	X	8	8 x 3 x .25	In house	N/A	N/A	N/A	N/A	N/A	(We have it)
5	10	1	push piston slider	X	8	2.94 x 1.13	Mc-Master	N/A	N/A	N/A	N/A	N/A	Assembly

Final Build Successes

- Assemblies
  - Tabletop
  - Base
  - Magnet & Sensors

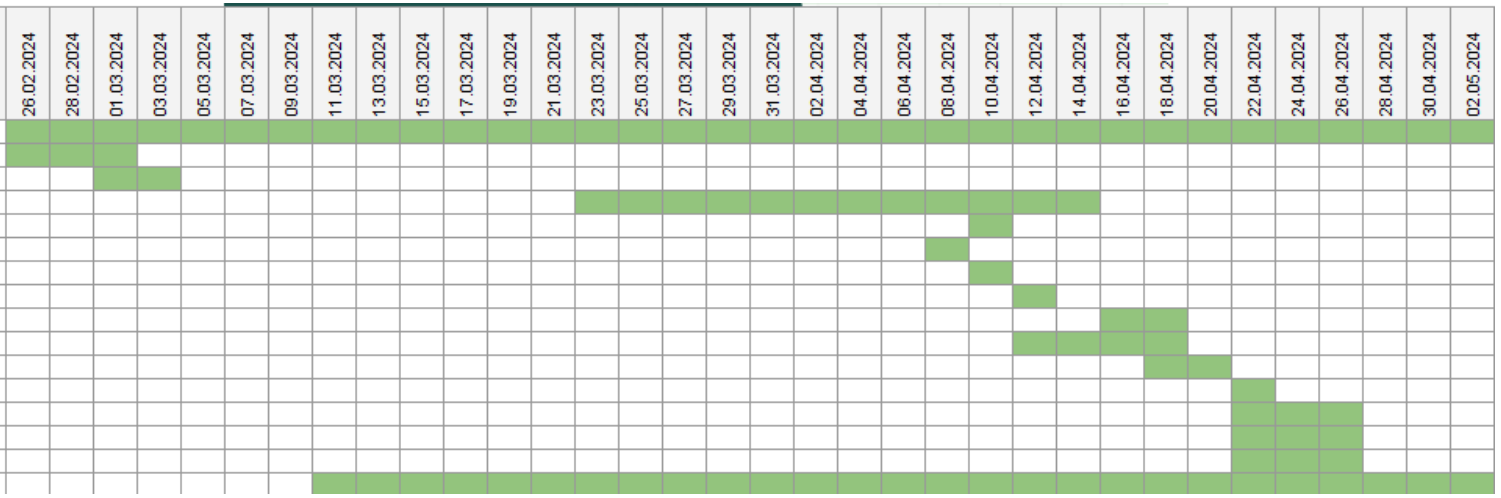
Final Build Complications

- Linear actuator operation troubles
- High machining hours required for manufactured parts
- Miss-ordered parts



Final Build Gantt Chart

Task name	Start date	End date	Assigned	Status
Viracron Tilt Table	21.02.2024	03.05.2024	Jordan,Alex,Nate,Brandon,Sophie	In process
Collect Skews from Vendors	26.02.2024	01.03.2024	Jordan,Alex,Nate,Brandon	Closed
Complete Order Forms	01.03.2024	04.03.2024	Jordan,Alex,Nate,Brandon	Closed
Machine in house materials	22.03.2024	15.04.2024	Alex,Nate,Brandon	Closed
Laser cut material	09.04.2024	11.04.2024	Sophie	Closed
Assemble table base	08.04.2024	09.04.2024	Jordan,Alex,Brandon	Closed
Assemble tabletop	09.04.2024	10.04.2024	Jordan,Alex	Closed
Assemble Cart	11.04.2024	12.04.2024	Alex	Closed
Assemble Push Pistions	15.04.2024	18.04.2024	Jordan,Alex,Nate	Closed
Combine Assemblies	11.04.2024	18.04.2024	Alex,Nate	Closed
Create electrical box	18.04.2024	21.04.2024	Alex,Nate	Closed
Finalize controls	21.04.2024	22.04.2024	Alex,Nate	Closed
Trouble shoot controls	22.04.2024	26.04.2024	Alex,Nate	Closed
Demo Run	22.04.2024	26.04.2024	Alex,Nate	Closed
Create presentation	22.04.2024	26.04.2024	Jordan,Sophie,Brandon	Closed
Finish Binder	11.03.2024	03.05.2024	Jordan,Alex,Nate,Brandon,Sophie	In process



QUESTIONS?

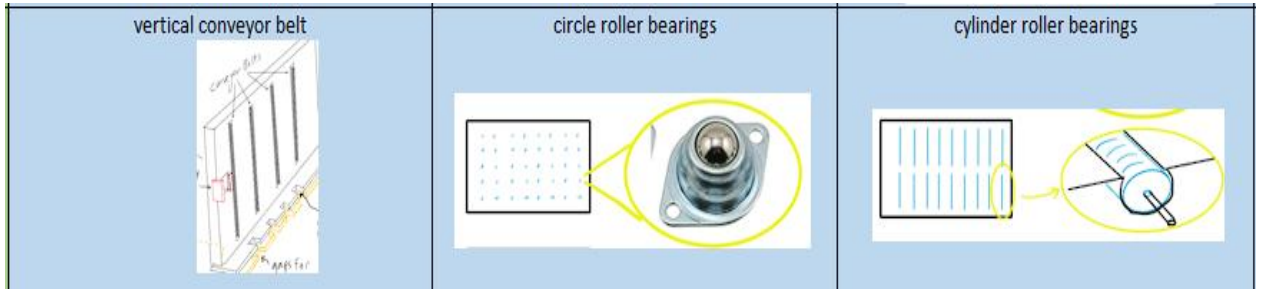
APPENDIX

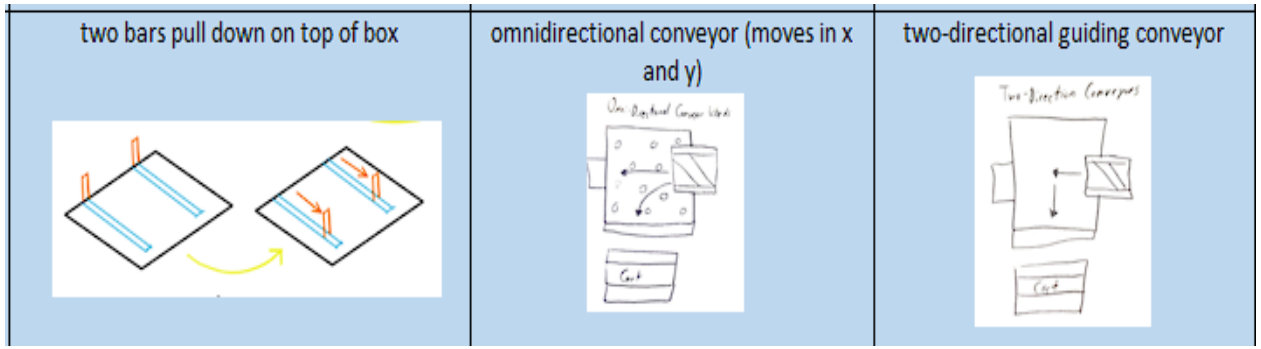
Appendix Links

- A1 – Design Concepts Semester 1
- A2 – Predictive Analysis Semester 1
- A3 – Controls Information Semester 1

A1: DESIGN CONCEPTS SEMESTER 1

Functional Need – Align with The Bottom Shelf Prior to Lifting the Table

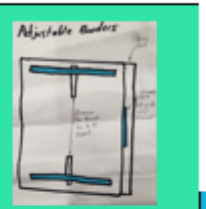


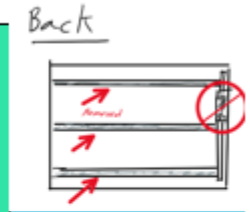


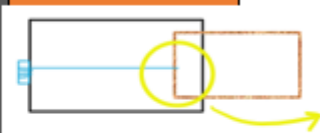
- Multiple designs were considered (Left).
  - Vertical conveyor belts
  - Roller bearings
  - Conveyor/pull bar contraptions
- A compromise was proposed by Viracon.
- Viracon will create a work instruction in place of a design solution.
  - Workers will orient box in line with the table's loading side before centering

Locating Box in the Center

Decision Matrix



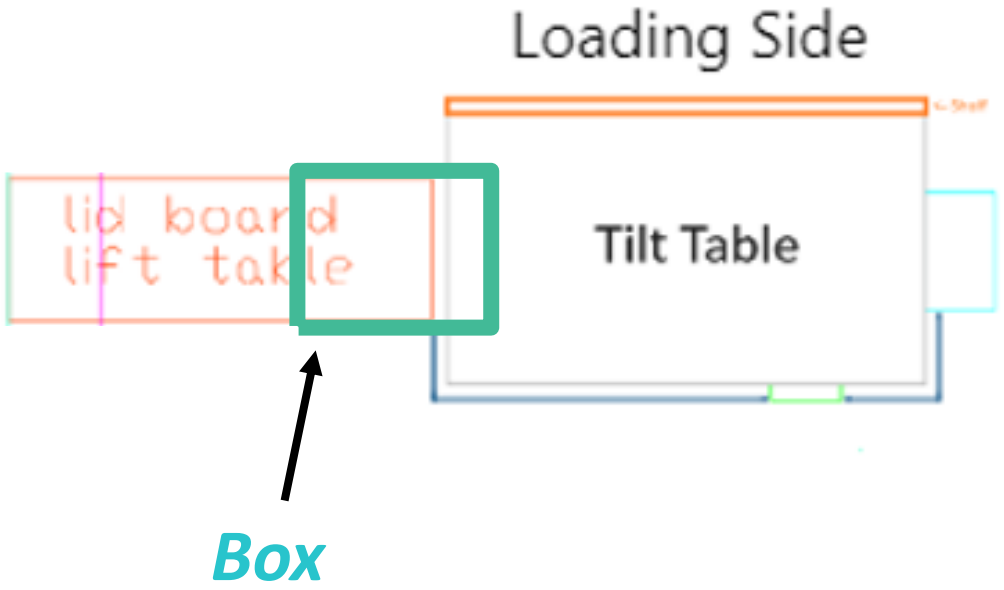




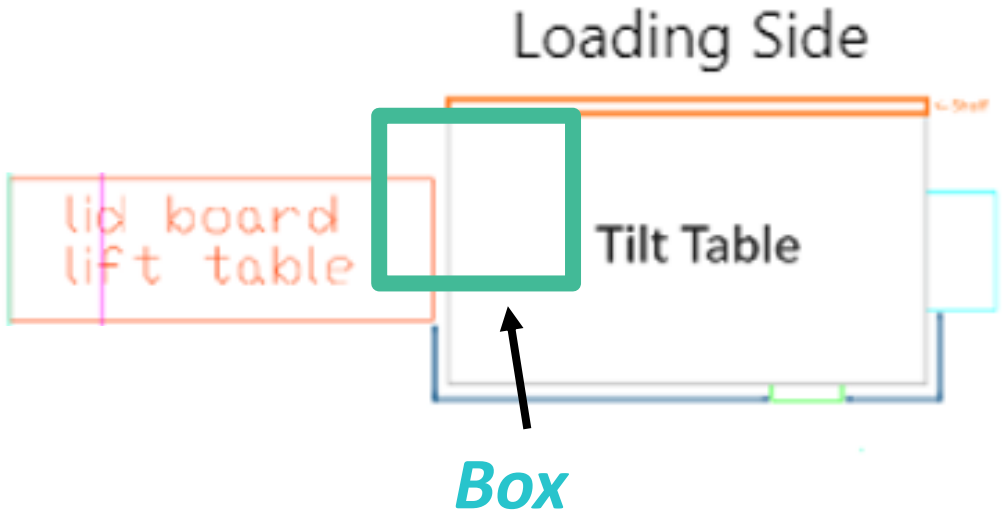
CRITERIA	WEIGHTAGE	converging bars to locate box		maintain Conveyor belts		Using tape or paint on the table		omnidirectional conveyor wheels		two-directional guiding conveyor		Hook to pull in frame	
		RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL
		AVERAGE		AVERAGE		AVERAGE		AVERAGE		AVERAGE		AVERAGE	
Cost to Implement (1 - 10) 1 being very expensive, 10 being cheap)	15%	6	9.00%	8.75	13.13%	8.5	12.75%	4	6.00%	3.25	4.88%	4.25	6.38%
Necessary Manpower (<5 requires more input, >5 less human input)	12%	8.5	10.20%	5.25	6.30%	5.5	6.60%	9.75	11.70%	8.25	9.90%	8	9.60%
Cycle Time (<5 Time loss, >5 time improvement)	15%	6	9.00%	6.5	9.75%	7	10.50%	6.5	9.75%	7.75	11.63%	8.25	12.38%
Predicted Accuracy (1-10 as 50%-100%)	20%	8.75	17.50%	8.875	17.75%	8.175	16.35%	8.5	17.00%	8	16.00%	7.75	15.50%
Safety of function (1-10)	23%	8.625	19.84%	9.25	21.28%	7.75	17.83%	8	18.40%	8	18.40%	7.75	17.83%
Complexity to impliment (1-10) 1 being very difficult, 10 being simple	15%	7	10.50%	9.5	14.25%	8.5	12.75%	5	7.50%	4.25	6.38%	4	6.00%
			TOTAL		TOTAL		TOTAL		TOTAL		TOTAL		TOTAL
	max												
	100%		76.04%		82.45%		76.78%		70.35%		67.18%		67.68%

Demonstration Diagram

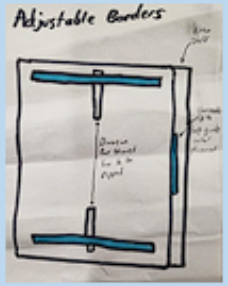
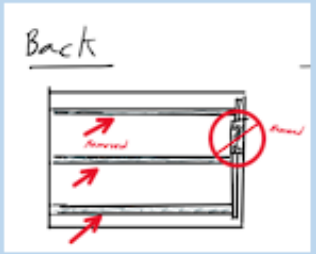
- Box enters workspace on Lid table

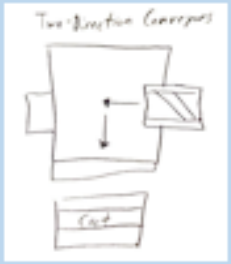
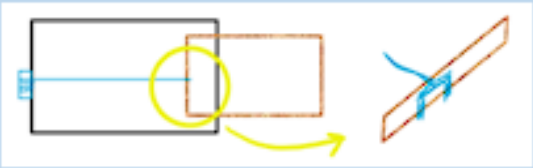


- Box is oriented to have bottom edge in line with the tables loading side.



Functional Need - Locate the box to the center of the table

converging bars to locate box	maintain Conveyor belts	Using tape or paint on the table
		

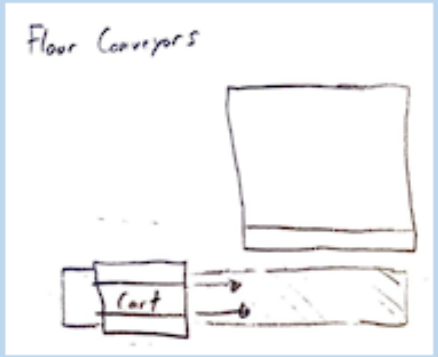
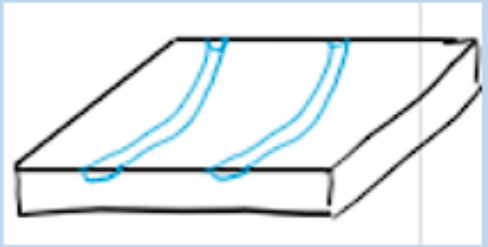
omnidirectional conveyor wheels	two-directional guiding conveyor	Hook to pull in frame
 		

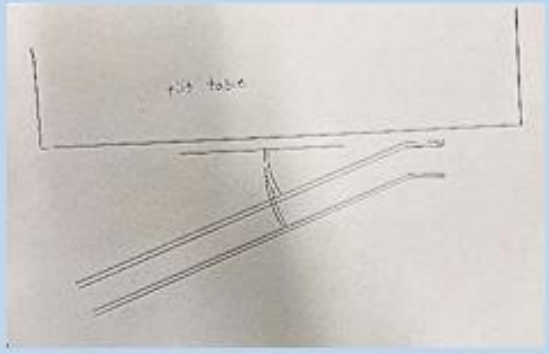
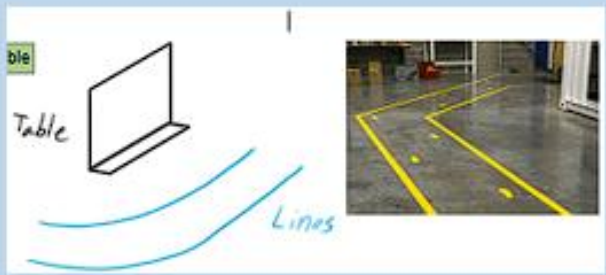
Locating Box in the Center

Decision Matrix

CRITERIA	WEIGHTAGE	converging bars to locate box		maintain Conveyor belts		Using tape or paint on the table		omnidirectional conveyor wheels		two-directional guiding conveyor		Hook to pull in frame	
		RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL
		AVERAGE		AVERAGE		AVERAGE		AVERAGE		AVERAGE		AVERAGE	
Cost to Implement (1 – 10) 1 being very expensive, 10 being cheap)	15%	6	9.00%	8.75	13.13%	8.5	12.75%	4	6.00%	3.25	4.88%	4.25	6.38%
Necessary Manpower (<5 requires more input, >5 less human input)	12%	8.5	10.20%	5.25	6.30%	5.5	6.60%	9.75	11.70%	8.25	9.90%	8	9.60%
Cycle Time (<5 Time loss, >5 time improvement)	15%	6	9.00%	6.5	9.75%	7	10.50%	6.5	9.75%	7.75	11.63%	8.25	12.38%
Predicted Accuracy (1-10 as 50%-100%)	20%	8.75	17.50%	8.875	17.75%	8.175	16.35%	8.5	17.00%	8	16.00%	7.75	15.50%
Safety of function (1-10)	23%	8.625	19.84%	9.25	21.28%	7.75	17.83%	8	18.40%	8	18.40%	7.75	17.83%
Complexity to impliment (1-10) 1 being very difficult, 10 being simple	15%	7	10.50%	9.5	14.25%	8.5	12.75%	5	7.50%	4.25	6.38%	4	6.00%
			TOTAL		TOTAL		TOTAL		TOTAL		TOTAL		TOTAL
	max												
	100%		76.04%		82.45%		76.78%		70.35%		67.18%		67.68%

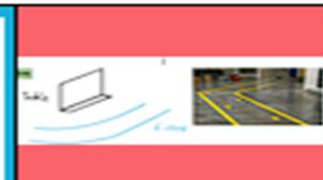
Functional Need – Move Cart into Repeatable Location Next to Tilt Table

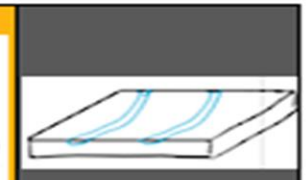
conveyors on floor	grooves in the floor
	

track guides on the floor	sensors to guide cart	painted lines to guide cart into place
		

Move Cart Into Location

Decision Matrix

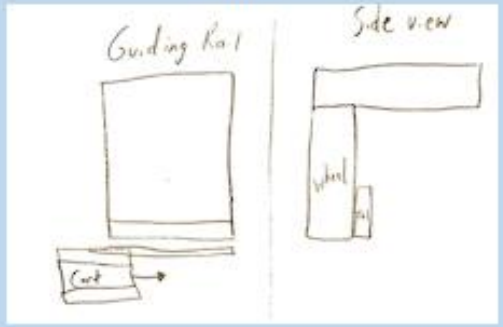
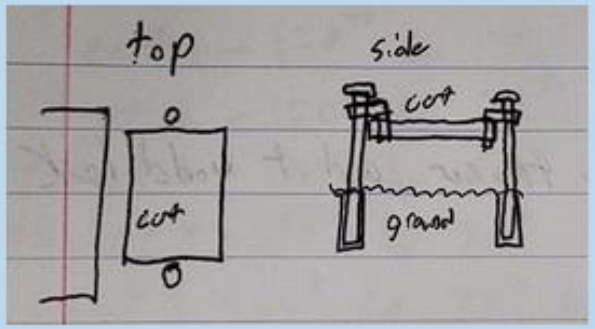




CRITERIA	WEIGHTAGE	track guides on the floor		sensors to guide cart		painted lines to guide cart into place		conveyors on floor		grooves in the floor	
		RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL
		AVERAGE		AVERAGE							
Cost to Implement (1 – 10) 1 being very expensive, 10 being cheap)	15%	7.5	11.25%	7.25	10.88%	6.75	10.13%	1.75	2.63%	7.75	11.63%
Necessary Manpower (<5 requires more input, >5 less human input)	12%	5.5	6.60%	5	6.00%	4.75	5.70%	5	6.00%	5	6.00%
Cycle Time (<5 Time loss, >5 time improvement)	15%	5.25	7.88%	4.75	7.13%	5.75	8.63%	6.25	9.38%	5	7.50%
Predicted Accuracy (1-10 as 50%-100%)	20%	9.75	19.50%	8	16.00%	5.75	11.50%	6	12.00%	8.75	17.50%
Safety of function (1-10)	23%	4	9.20%	8.25	18.98%	6.5	14.95%	2.75	6.33%	4.25	9.78%
Complexity to impliment (1-10) 1 being very difficult, 10 being simple	15%	5.5	8.25%	7.5	11.25%	8.5	12.75%	4.75	7.13%	6	9.00%
			TOTAL		TOTAL		TOTAL		TOTAL		TOTAL
	max										
	100%		62.68%		70.23%		63.65%		43.45%		61.40%

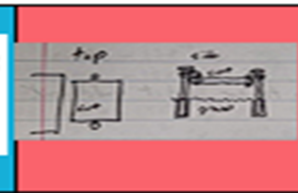
Functional Need – Repeatable Location of Cart for Loading Boxes

Painted lines to guide into place	Sensors to guide
	

push fixed end into physical bracket, then pivot swivel end into place	Rail on the ground to guide the wheels closest to table	Locating using pin and bracket system
		

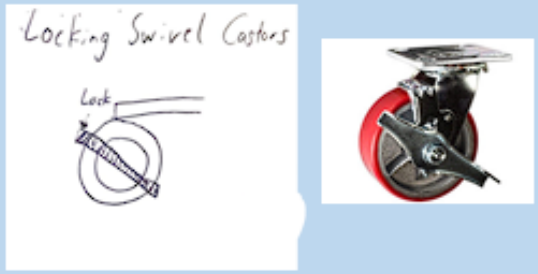
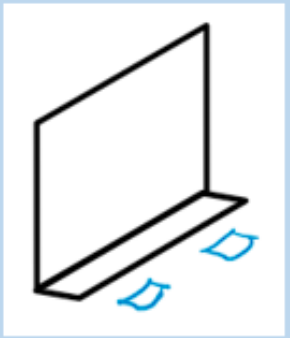
Location of Cart For Loading

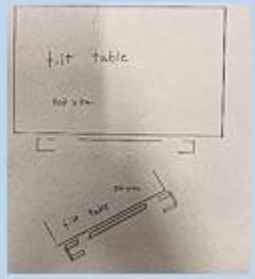
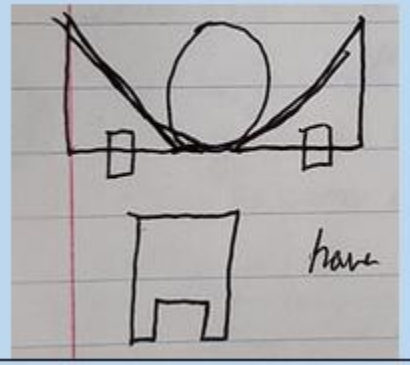
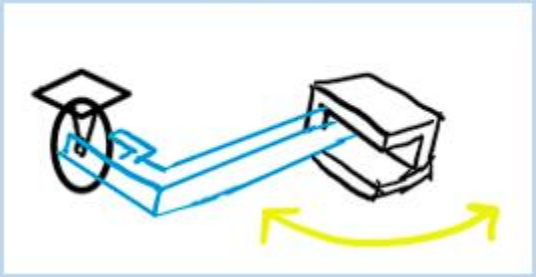
Decision Matrix



CRITERIA	WEIGHTAGE	push fixed end into physical bracket, then pivot swivel end into place		Rail on the ground to guide the wheels closest to table		Locating using pin and bracket system		Painted lines to guide into place		Sensors to guide	
		RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL
		AVERAGE		AVERAGE		AVERAGE					
Cost to Implement (1 - 10) 1 being very expensive, 10 being cheap)	15%	6	9.00%	7.5	11.25%	5.5	8.25%	9.25	13.88%	8	12.00%
Necessary Manpower (<5 requires more input, >5 less human input)	12%	5.75	6.90%	5.5	6.60%	4.5	5.40%	5.25	6.30%	5.5	6.60%
Cycle Time (<5 Time loss, >5 time improvement)	15%	7.75	11.63%	6.5	9.75%	4	6.00%	5.75	8.63%	5.25	7.88%
Predicted Accuracy (1-10 as 50%-100%)	20%	9.25	18.50%	7	14.00%	8.25	16.50%	6.25	12.50%	8.5	17.00%
Safety of function (1-10)	23%	7.75	17.83%	6.5	14.95%	6.5	14.95%	6.75	15.53%	8.5	19.55%
Complexity to impliment (1-10) 1 being very difficult, 10 being simple	15%	8.5	12.75%	8	12.00%	6.25	9.38%	8.5	12.75%	6.5	9.75%
			TOTAL		TOTAL		TOTAL		TOTAL		TOTAL
	max										
	100%		76.60%		68.55%		60.48%		69.58%		72.78%

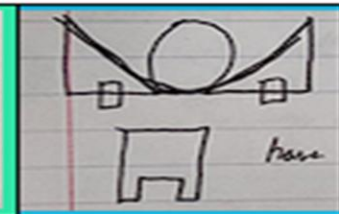
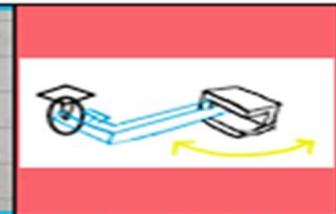
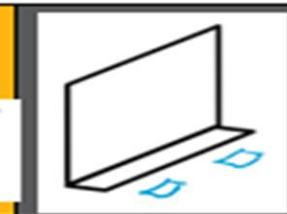
Functional Need – Repeatable Securing of Cart in Place

Add locks on the swivel castors	Grooves to slide the wheel into place
	

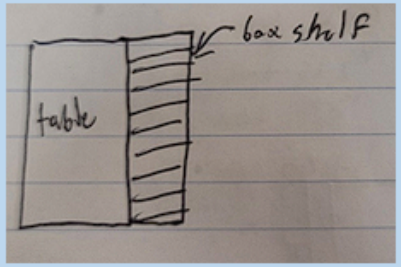
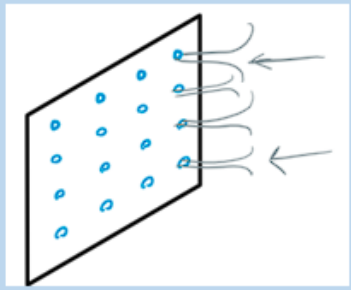
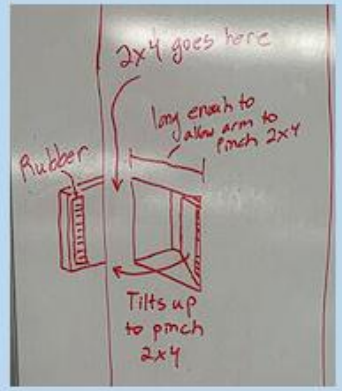
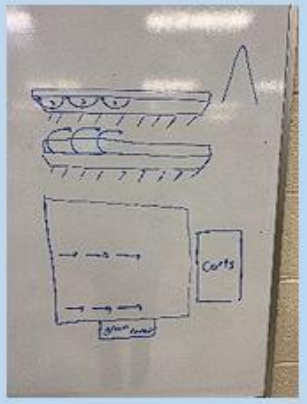
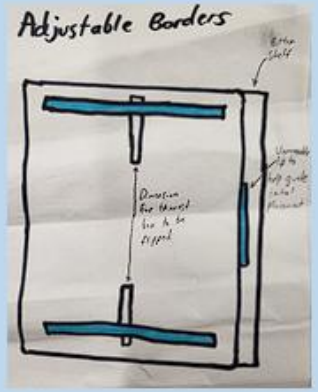
Using bracket slots at two points on table, pull swivel castors into them to lock in place	Use removable wheel chock blocks	Mechanical Arm could swing out and clamp the wheel/cart
		

Securing of Cart In Place

Decision Matrix

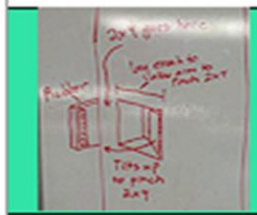
CRITERIA	WEIGHTAGE	 Using bracket slots		 Use removable wheel chock blocks		 Mechanical Arm could swing out and clamp the wheel/cart		 Add locks on the swivel castors		 Grooves to slide the wheel into place	
		RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL
		AVERAGE		AVERAGE		AVERAGE					
Cost to Implement (1 – 10) 1 being very expensive, 10 being cheap)	15%	6.5	9.75%	7	10.50%	4.75	7.13%	7	10.50%	8	12.00%
Necessary Manpower (<5 requires more input, >5 less human input)	12%	6	7.20%	4.5	5.40%	5.75	6.90%	6	7.20%	4.75	5.70%
Cycle Time (<5 Time loss, >5 time improvement)	15%	7.75	11.63%	5	7.50%	5.5	8.25%	5.5	8.25%	5.25	7.88%
Predicted Accuracy (1-10 as 50%-100%)	20%	9.5	19.00%	7.5	15.00%	6.5	13.00%	5.75	11.50%	7.5	15.00%
Safety of function (1-10)	23%	8	18.40%	7.5	17.25%	6	13.80%	7.5	17.25%	5	11.50%
Complexity to impliment (1-10) 1 being very difficult, 10 being simple	15%	8.5	12.75%	9	13.50%	4.5	6.75%	8.25	12.38%	6.75	10.13%
	max		TOTAL		TOTAL		TOTAL		TOTAL		TOTAL
	100%		78.73%		69.15%		55.83%		67.08%		62.20%

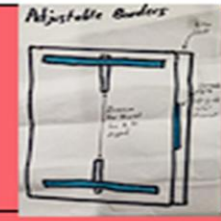
Functional Need – Prevent Tipping of Box upon Lifting of Tilt Table

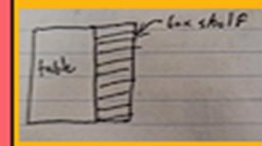
Lengthen box shelf	Suctioning feature to hold it in place	Magnets on box and table to hold in place
		
clamping bar	**Brace bar**	**Pinch bars**
		

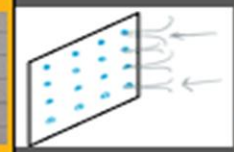
Prevent Tipping of Box

Decision Matrix



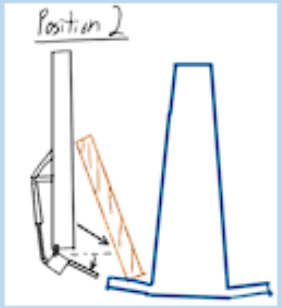
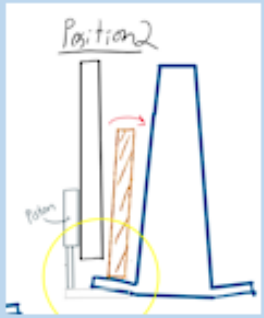


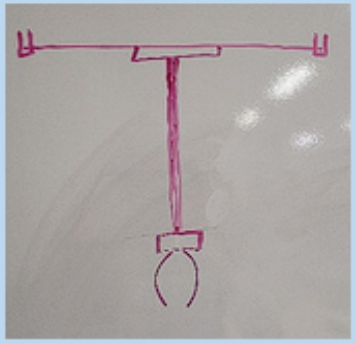
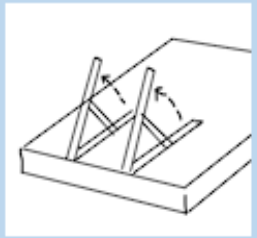
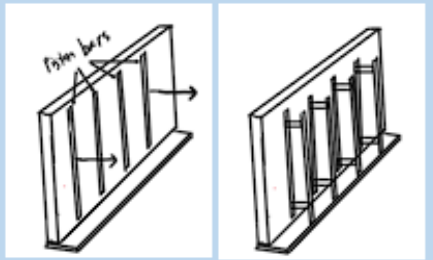




CRITERIA	WEIGHTAGE	Clamping bar		Brace Bar		pinch bars		lengthen box shelf		Suctioning feature to hold boxes in place		Magnets on box and on table to hold in place	
		RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL
		AVERAGE		AVERAGE		AVERAGE							
Cost to Implement (1 – 10) 1 being very expensive, 10 being cheap)	15%	5	7.50%	4.75	7.13%	4.25	6.38%	8.5	12.75%	3.5	5.25%	1.75	2.63%
Necessary Manpower (<5 requires more input, >5 less human input)	12%	10	12.00%	9.25	11.10%	8.75	10.50%	9	10.80%	9.5	11.40%	8.25	9.90%
Cycle Time (<5 Time loss, >5 time improvement)	15%	8.75	13.13%	7.5	11.25%	7.25	10.88%	6.75	10.13%	5	7.50%	7.25	10.88%
Predicted Accuracy (1-10 as 50%-100%)	20%	7.25	14.50%	7.5	15.00%	8.25	16.50%	8.5	17.00%	3.5	7.00%	5.5	11.00%
Safety of function (1-10)	23%	7.25	16.68%	8	18.40%	6.75	15.53%	8.75	20.13%	5.75	13.23%	4.5	10.35%
Complexity to impliment (1-10) 1 being very difficult, 10 being simple	15%	4.25	6.38%	4	6.00%	5.25	7.88%	9.125	13.69%	4.25	6.38%	6.75	10.13%
			TOTAL		TOTAL		TOTAL		TOTAL		TOTAL		TOTAL
	max												
	100%		70.18%		68.88%		67.65%		84.49%		50.75%		54.88%

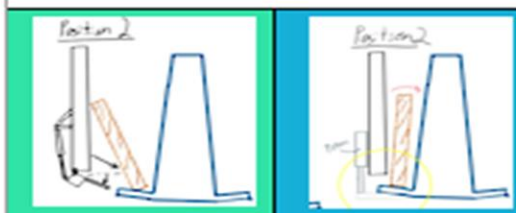
Functional Need – Moving the Box from the Tilt Table to the Cart

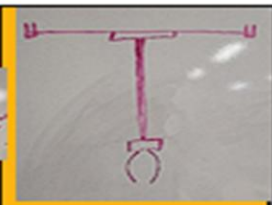
Slide Box onto cart	Lower box with pistons	Roll onto cart
		

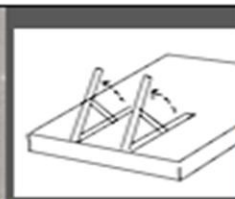
Crane	Push bar Pistons, when table turned 90 degrees	varying sized 2 step Push bar pistons when side loading
		

Tilt Table to The Cart

Decision Matrix

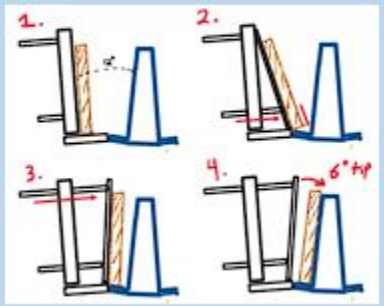
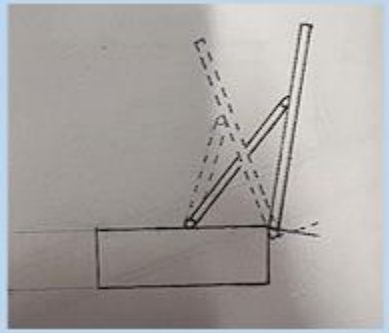
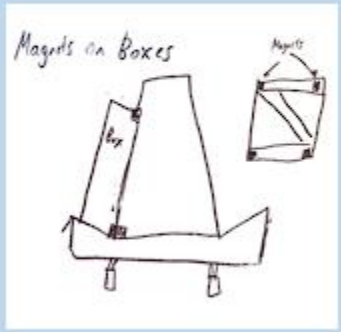


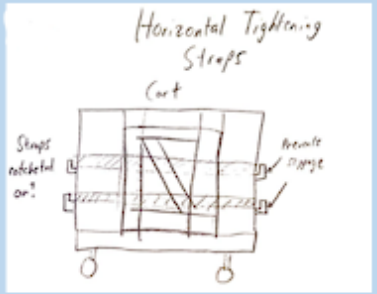
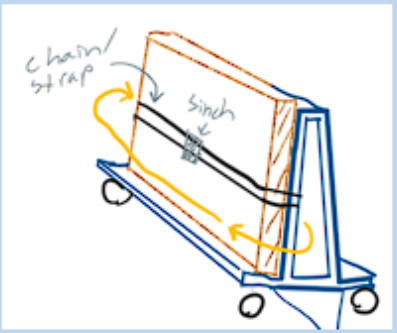




CRITERIA	WEIGHTAGE	Slide Box onto cart		Lower box with pistons		Roll onto cart		Crane		Push bar Pistons, when table turned 90 degrees		varying sized 2 step Push bar pistons when side	
		RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL
		AVERAGE		AVERAGE		AVERAGE							
Cost to Implement (1 - 10) 1 being very expensive, 10 being cheap)	15%	4.5	6.75%	4	6.00%	6.25	9.38%	2	3.00%	6	9.00%	2.75	4.13%
Necessary Manpower (<5 requires more input, >5 less human input)	12%	7.5	9.00%	8.75	10.50%	8.75	10.50%	3.5	4.20%	6.75	8.10%	9.75	11.70%
Cycle Time (<5 Time loss, >5 time improvement)	15%	4.25	6.38%	4.75	7.13%	5.5	8.25%	2.5	3.75%	5.5	8.25%	7	10.50%
Predicted Accuracy (1-10 as 50%-100%)	20%	5.75	11.50%	6.25	12.50%	7.25	14.50%	4	8.00%	6.5	13.00%	7.75	15.50%
Safety of function (1-10)	23%	5.25	12.08%	7.5	17.25%	7	16.10%	3.25	7.48%	6.25	14.38%	8.25	18.98%
Complexity to impliment (1-10) 1 being very difficult, 10 being simple	15%	6.25	9.38%	4.75	7.13%	6.75	10.13%	4.75	7.13%	6.75	10.13%	8	12.00%
			TOTAL		TOTAL		TOTAL		TOTAL		TOTAL		TOTAL
	max												
	100%		55.08%		60.50%		68.85%		33.55%		62.85%		72.80%

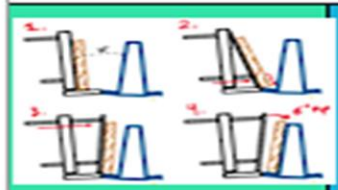
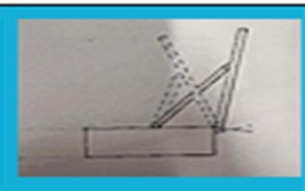
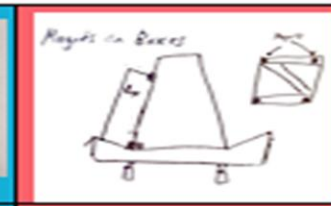
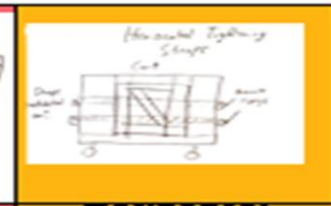
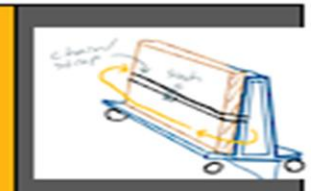
Functional Need – Ensuring the Box is Flush up against the Cart

Extending pistons to push into place	Push table angle past 90 degrees to line up the angles	Magnets on cart connect with magnets on box
		

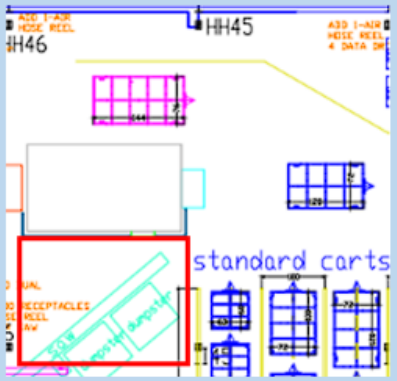
Horizontal tightening straps, add brackets to side of cart to prevent slippage	straps or chains across the box to sinch into place
	

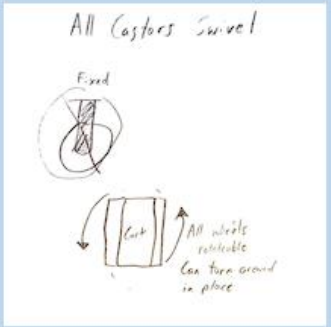
Box Flush Up Against The Carts

Decision Matrix

CRITERIA	WEIGHTAGE	 Extending pistons to push into place		 Push table angle past 90 degrees to line up the angles		 Magnets on cart connect with magnets on box		 Horizontal tightening straps, add brackets to side of cart to prevent		 straps or chains across the box to sinch into place	
		RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL
		AVERAGE		AVERAGE		AVERAGE					
Cost to Implement (1 – 10) 1 being very expensive, 10 being cheap)	15%	3.75	5.63%	9.25	13.88%	3	4.50%	7.5	11.25%	8	12.00%
Necessary Manpower (<5 requires more input, >5 less human input)	12%	9.75	11.70%	6.75	8.10%	5.5	6.60%	4.75	5.70%	4.5	5.40%
Cycle Time (<5 Time loss, >5 time improvement)	15%	5.75	8.63%	6	9.00%	4.75	7.13%	3.5	5.25%	3.5	5.25%
Predicted Accuracy (1-10 as 50%-100%)	20%	8	16.00%	7.875	15.75%	7	14.00%	6.25	12.50%	6.5	13.00%
Safety of function (1–10)	23%	7.5	17.25%	6.5	14.95%	7	16.10%	6.75	15.53%	6.25	14.38%
Complexity to impliment (1–10) 1 being very difficult, 10 being simple	15%	4.25	6.38%	7.25	10.88%	8	12.00%	7.75	11.63%	6.75	10.13%
			TOTAL		TOTAL		TOTAL		TOTAL		TOTAL
	max										
	100%		65.58%		72.55%		60.33%		61.85%		60.15%

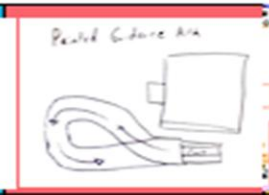
Functional Need – Ensure Safe Turn Around of Loaded Cart

Trailer hitch puller	rotating plate on floor to turn cart around	efficient guidance path painted lines on ground	Rotate the tilt table 180 degrees so you have room to turn the cart around with the tugger
			

Change fixed castors with swivel castors	replace all wheels with optional lockable castors	wheels for the steeple barrier in place of other castors
		

Safe Turn Around of Loaded Cart

Decision Matrix

CRITERIA	WEIGHTAGE	 Trailer hitch puller		 rotating plate on floor to turn cart around		 efficient guidance path painted lines on ground		 Rotate the tilt table 180 degrees so you have room to turn the cart around with the		 Change fixed castors with swivel castors		 replace all wheels with optional lockable castors		 wheels for the steeple barrier in place of other castors	
		RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL
		AVERAGE		AVERAGE		AVERAGE									
Cost to Implement (1 – 10) 1 being very expensive, 10 being cheap)	15%	7.25	10.88%	2.25	3.38%	9	13.50%	7	10.50%	5	7.50%	5.5	8.25%	3.25	4.88%
Necessary Manpower (<5 requires more input, >5 less human input)	12%	7	8.40%	8.25	9.90%	5.25	6.30%	5.5	6.60%	5.75	6.90%	5.25	6.30%	4.75	5.70%
Cycle Time (<5 Time loss, >5 time improvement)	15%	4.5	6.75%	7.5	11.25%	4.75	7.13%	5.5	8.25%	5.5	8.25%	6.25	9.38%	4.75	7.13%
Predicted Accuracy (1-10 as 50%-100%)	20%	5.75	11.50%	7	14.00%	5.5	11.00%	6.5	13.00%	6.5	13.00%	6.5	13.00%	6.75	13.50%
Safety of function (1-10)	23%	7	16.10%	5.75	13.23%	5.75	13.23%	6.75	15.53%	6.25	14.38%	7.25	16.68%	7.25	16.68%
Complexity to impliment (1-10) 1 being very difficult, 10 being simple	15%	7.5	11.25%	5.5	8.25%	7	10.50%	7	10.50%	7.25	10.88%	7.25	10.88%	6.25	9.38%
			TOTAL		TOTAL		TOTAL		TOTAL		TOTAL		TOTAL		TOTAL
	max														
	100%		64.88%		60.00%		61.65%		64.38%		60.90%		64.48%		57.25%

A2: PREDICTIVE ANALYSIS SEMESTER 1

Showstopper #1: Locating Cart in Loading Zone

What is the optimal distance from the cart to the table to accommodate all box depth sizes?	Hand Calculations/ experiment	Sponsor documentation of box shop layout	testing and experiment	modeling and sketch	This will inform us of the appropriate location for the cart that will accommodate all box sizes.

- Max box depth = 24 inches
- Min Box depth = 4 inches

- Main Problem – Center of gravity exceeds edge of box shelf and causes boxes to fall

Calculations and proof

Explanation:

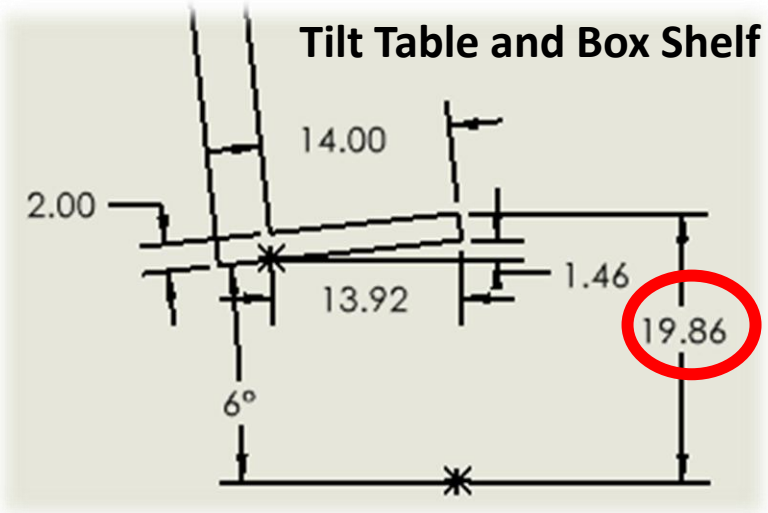
Known

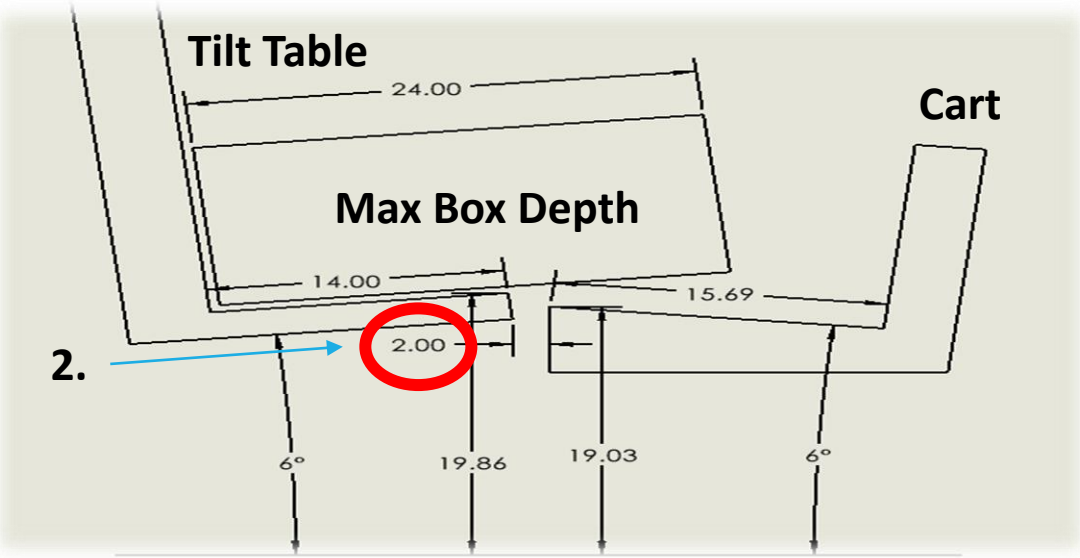
- Cart max height next to table = 19.03”
- Our Box shelf is 14” by 2”

Unknown

- Height to increased shelf length
  - = 18.38+ 2”*sin(6) + 14”*sin(6) = 19.86”
- Shortest Center of Gravity = 4/2 = 2”
  - The Gap can be no greater than 2 inches to avoid the weight shift

- Next steps:
  - If this distance is determined to be too large, it can be shortened easily by moving the brace bar.

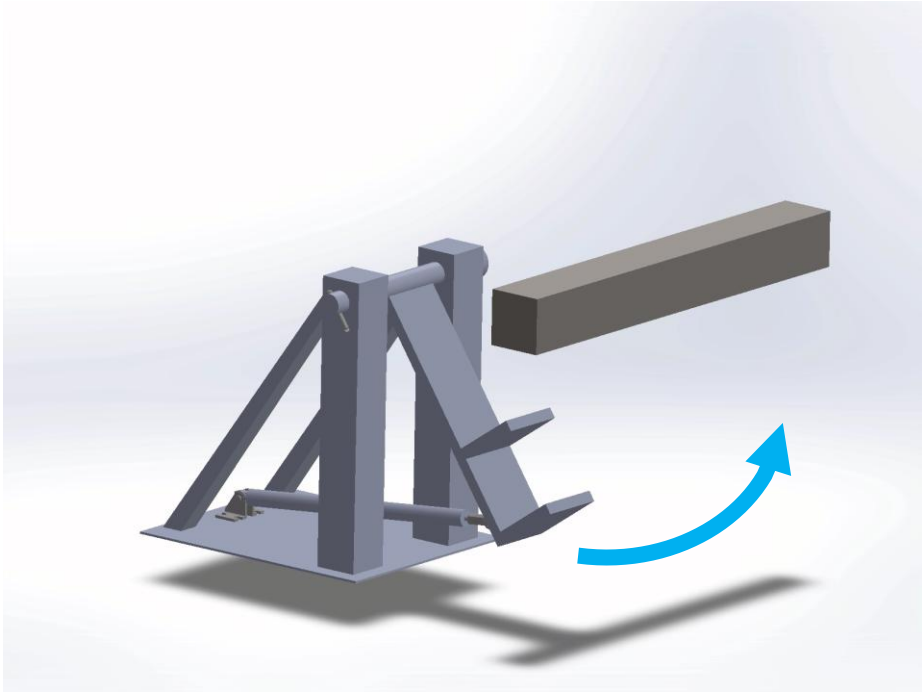




Showstopper #2: Securing Cart for Loading

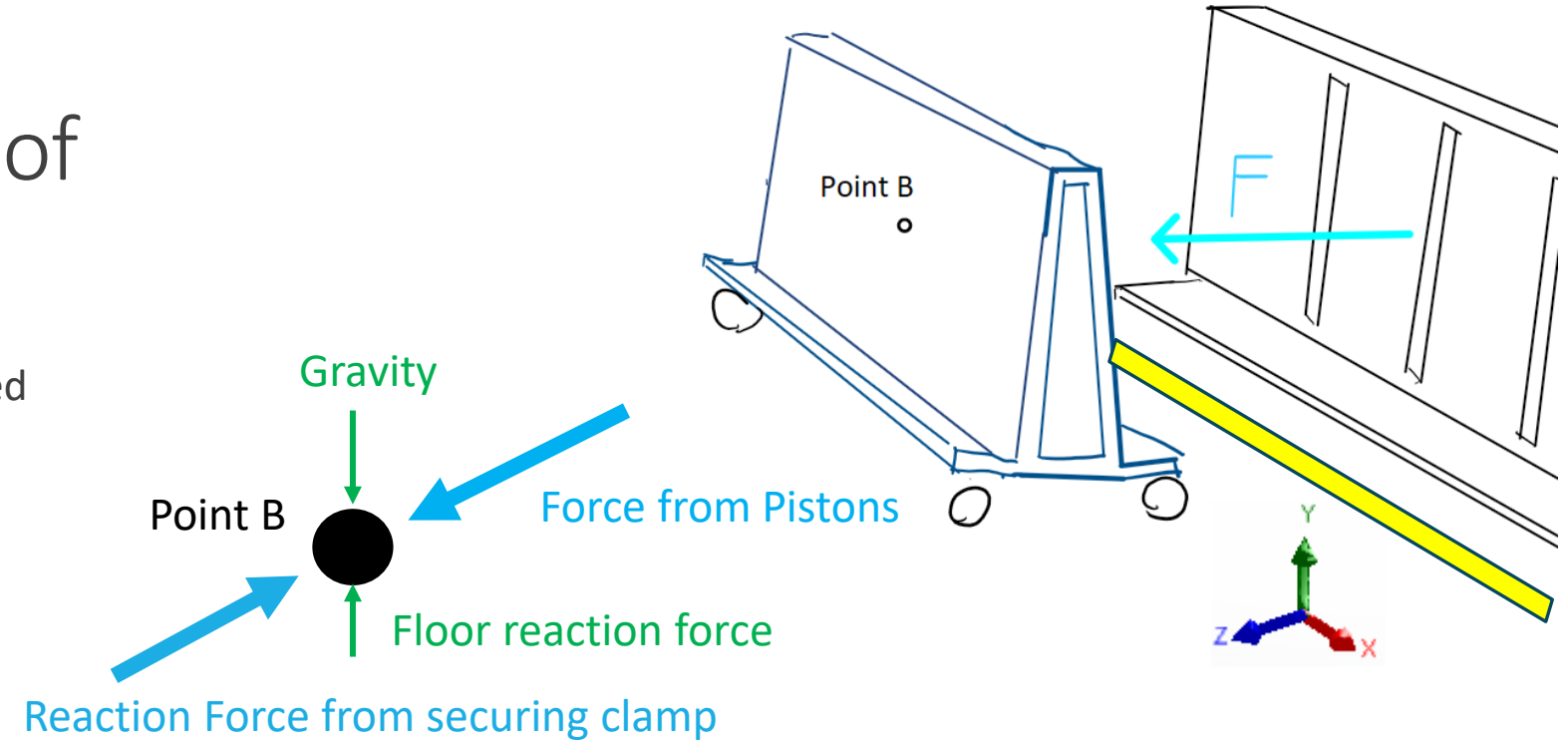
Are all 6 degrees of freedom locked when securing the cart?	Hand Calculations	Jigs and Fixtures Notes and resources	calculations and experiment	sketches	This will inform us if the cart is properly secured.

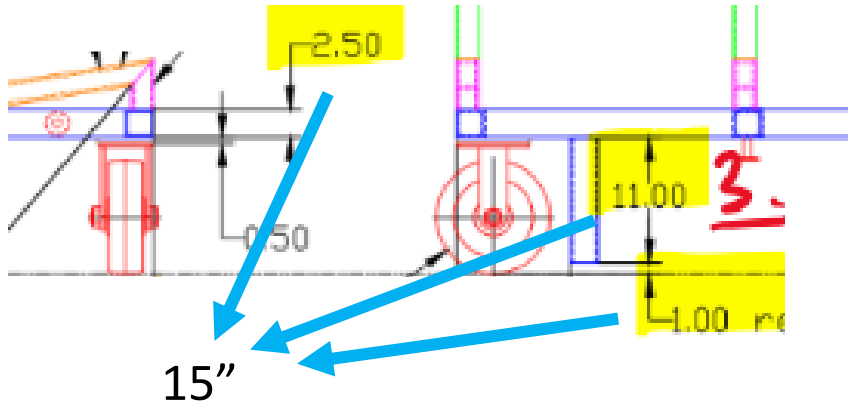
Design: Two pneumatically extending arms to clamp onto the lower portion of the cart frame



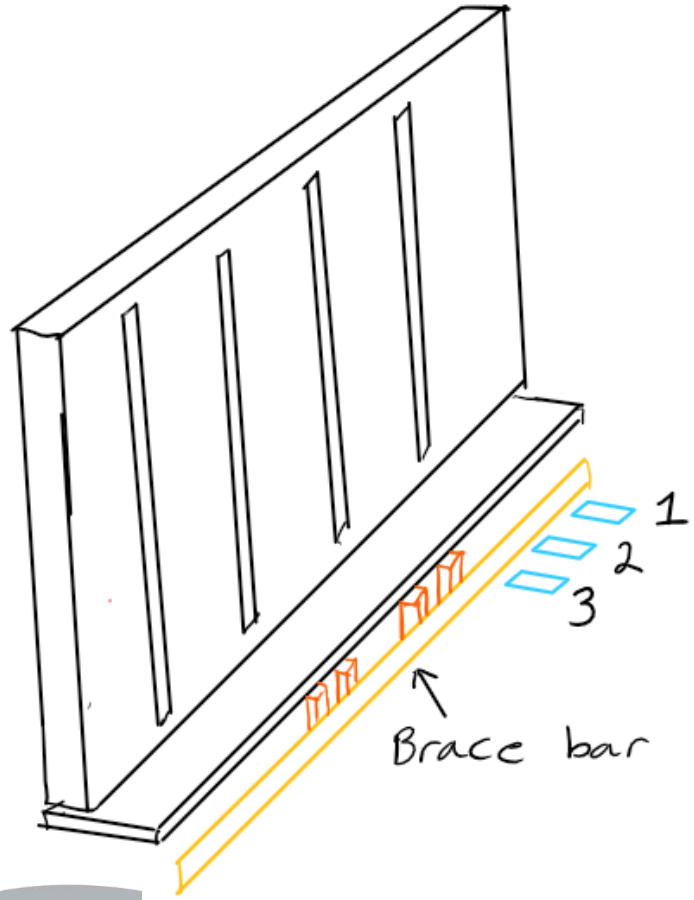
Calculations and proof

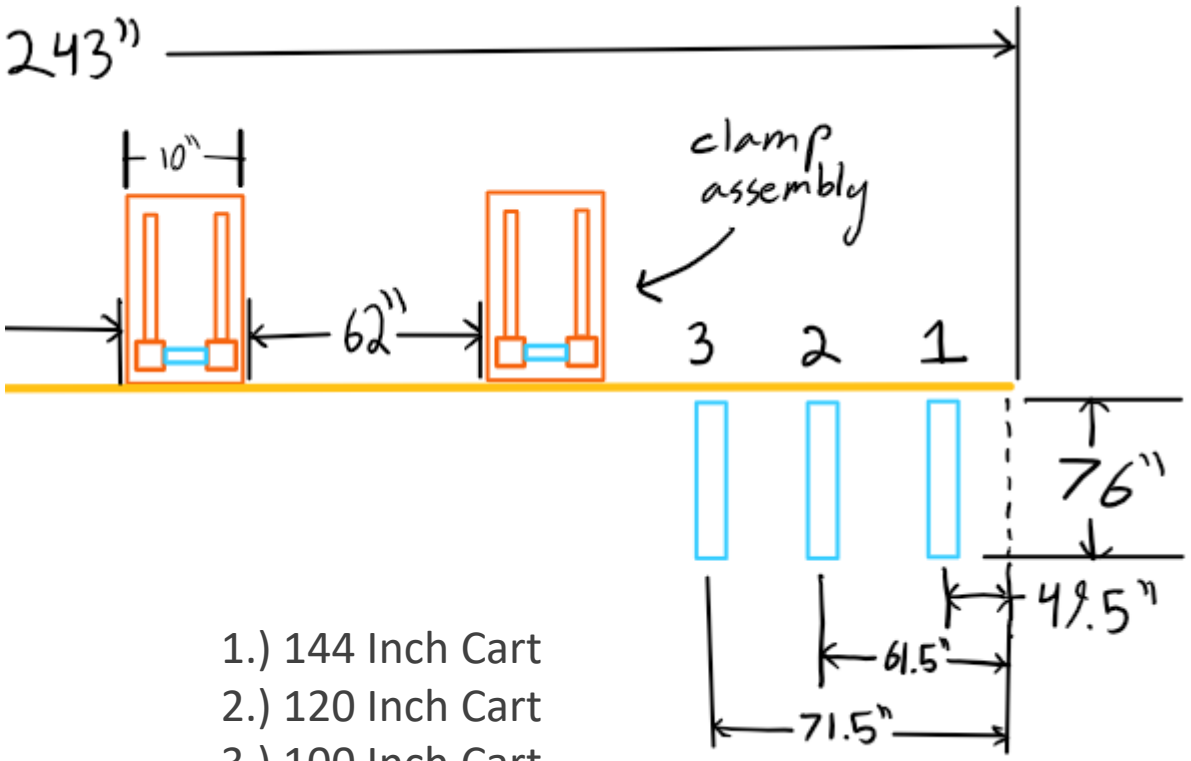
- Explanation:
  - Both the cart and clamp will be positioned directly next to the brace bar
  - Pneumatically operated, triggered manually on the HMI.'
  - Degrees of Freedom:
    - Y Axis: Locked by ground
    - X Axis: Locked by Clamp bar
    - Z Axis: Zero Force acts, so locking is unnecessary
- The total height the clamp would have to reach to is: 2.5+11.0+1.0 = 14.5 inches
  - Model axle is located at this height. (Subject to being lowered if there is collision between this and the box shelf)





Proof Continued…

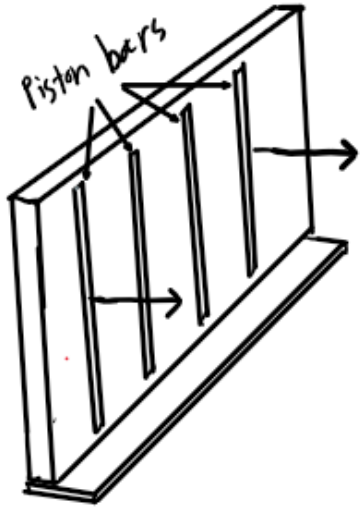


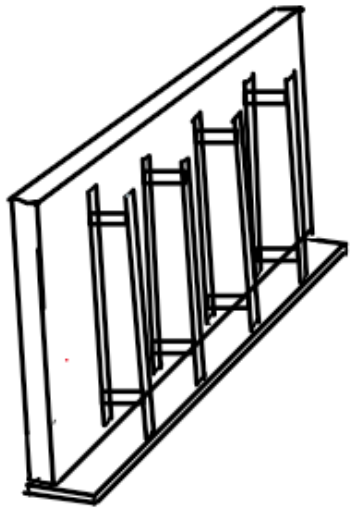


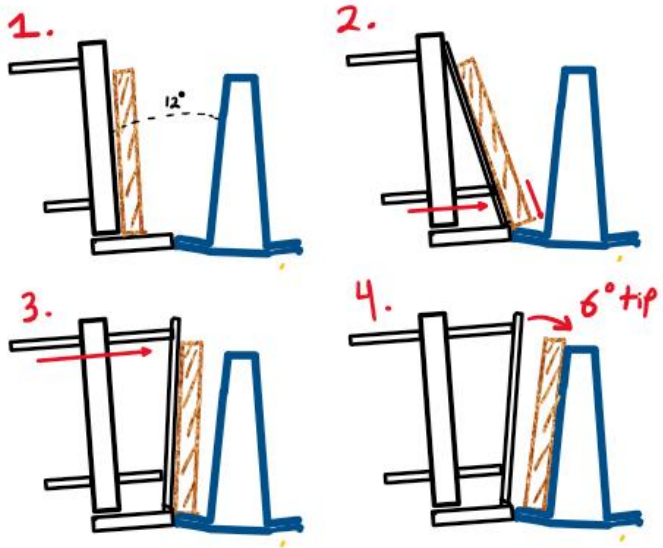
1.) 144 Inch Cart
2.) 120 Inch Cart
3.) 100 Inch Cart

Showstopper #3: Box is Flat against cart

How far do the top/bottom pistons need to each extend to push the box flush to the back of the cart?	Experiment	Sizes of the cart, table, and box.	Physical experimentation	Wooden blocks matching scaled down sized of box, table, and cart	This will help us determine the furthest distance necessary that pistons need to extend and piston size.







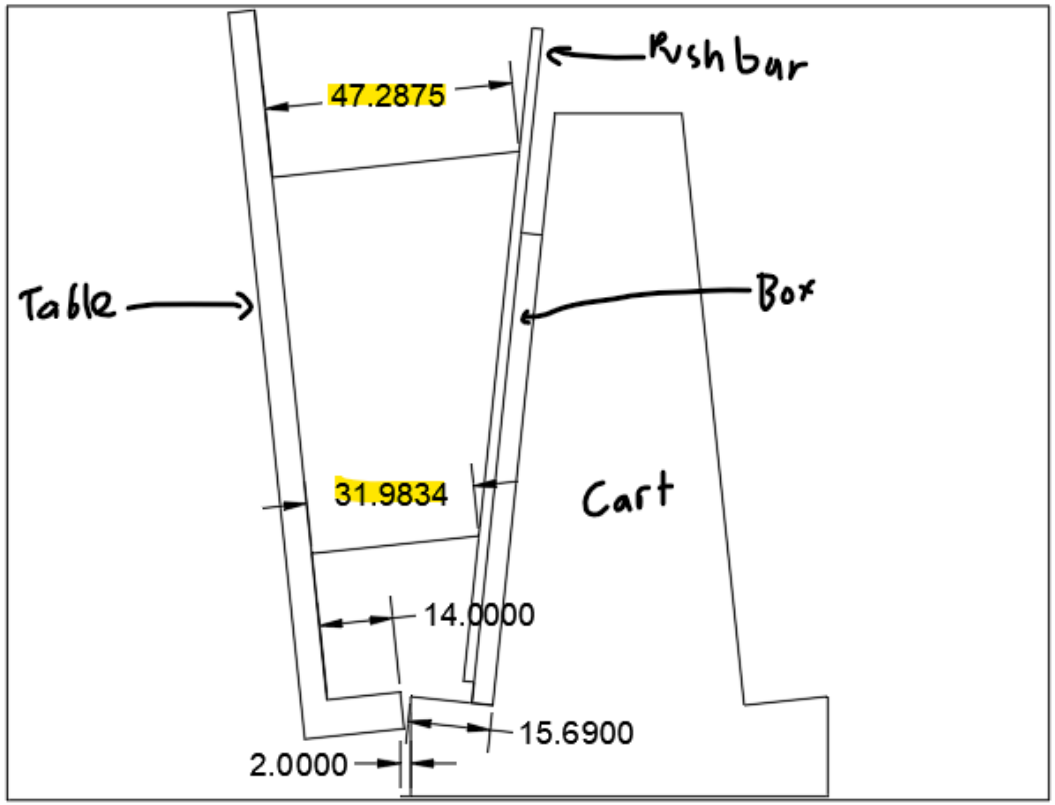
Calculations and proof

Explanation:

- Knowns:
  - Angle difference: 12 degrees
  - Depth of box shelf: 14in
  - Depth of deepest cart: 15.69in
  - Smallest box depth: 4in
- Assumed values:
  - Distance between shelf and cart: 2in
  - Vertical positions of pistons: 24in from top and bottom
- Solved Values with AutoCAD:
  - Max extension for bottom piston: 31.984in
  - Max extension for top piston: 47.2875in

Next steps:

- Complete in-depth comparison matrix for Hydraulic vs Pneumatic Pistons
- Piston lengths may be shorter if testing shows boxes naturally slide into position

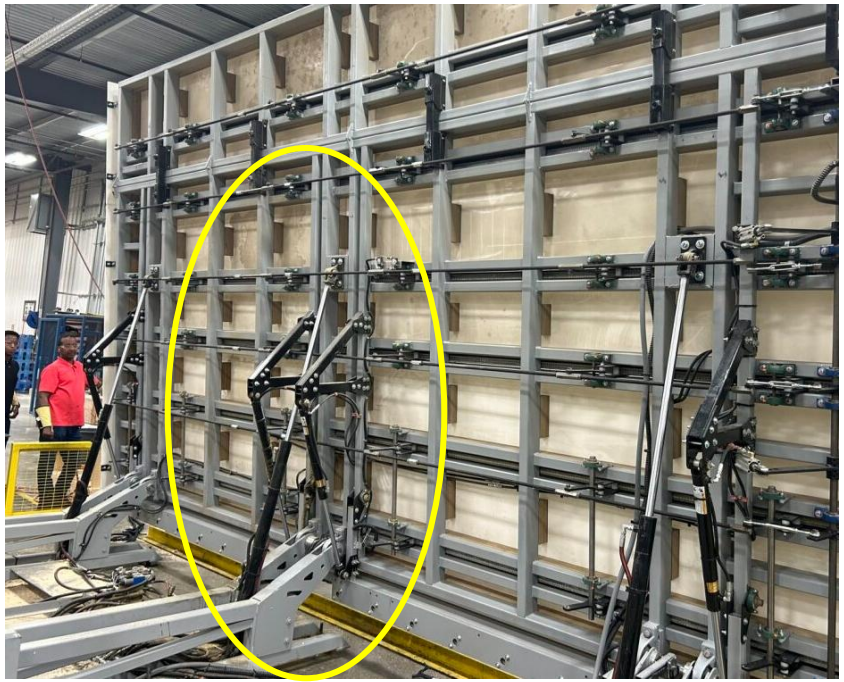


Showstopper #4:Lifting the Table

what is the force and pressure in the hydrulics to raise the table up to 84 degrees?	hand calculations	Specs on pistons used on curretn tilt table	Sponsor infromation of box sizes, center of mass of boxes	Models, solidworks simulation	To inform us the amount of force and pressure is being excerted on the hydrulics.

Explanation:

- Min weight increase: 4x Hydraulic Pistons: 5kg/11lbs each w/connections and hydraulic fluid = 80 lbs increased weight
- Weight of Box shelf change predicted to be negligible.
- Current pistons rated at 500 lb each, table current weight is _____:



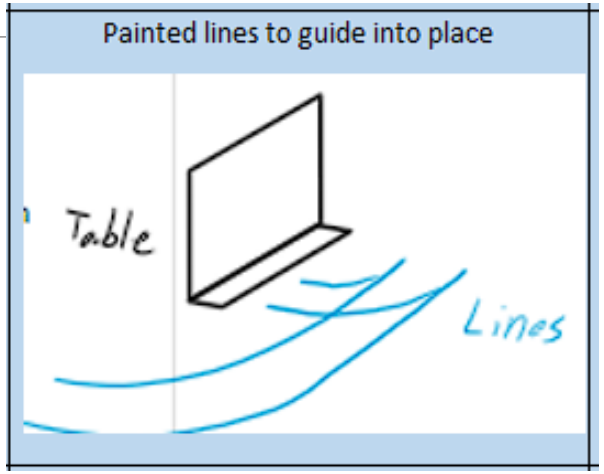
Next steps:

- Continue calculating size requirements and weights of components as research provides.
- Are the current hydraulic pistons strong enough or do we need to order new ones?

Additional Supporting Data

Functional Need:

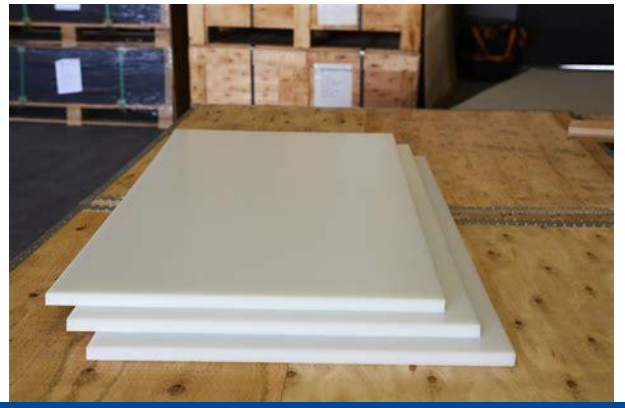
- Painted lines to guide cart into location for loading:
  - Plan: Experiment during prototype phase for what the turn radius of the cart is. This would determine the distance away from the table to locate paint.



- Safe turn around of cart:
  - For boxes causing force to move cart exceeding 100 lbs., dolly must be used to prevent potential injuries
  - Dolley hitch will be adjusted to fit current method of pulling heavier carts.

Material Choice Justifications - Prototype

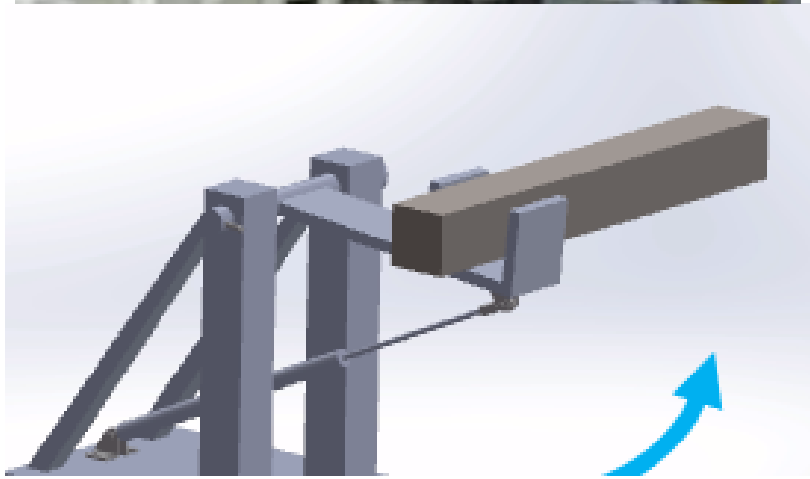
- Tabletop: Plywood – Cheap and easy to manipulate for adjustments.
- Table structure: Combo of 4x4 and 2x4 wood.
- Box Shelf and push piston bar: HDPE – Self lubricating material for low coefficient of friction for good price.
- Shelf structure, ground brace bar and cart clamp structure: 2x4 wood – Strong enough to hold high weight, cheap in cost.
- Small scale cart: Aluminum square stock and miniature castor wheels.
- Small scale Box: plywood and 2x4 wood cut to size w/ extra weight for realism.



Potential Design, Manufacturing or Process Issues

1. The box may shift in a way where the lower end of the push bars pass through the center of the box.
   - This may be solved by requiring boxes to have at least one cross-frame support and to be oriented, so the support is perpendicular to push bars.

2. Will the clamp arms reliably close tightly enough around the cart frame for securing?
   - This could be solved by elevating the brace bar and requiring the cart to be flat against it. This way the clamp arms can be reduced to a shorter length and will be more consistent.



A3: CONTROLS INFORMATION SEMESTER 1

Inputs

PB1- Estop (N.C.)

PB2- Home (N.O.)

PB3- Conveyors Raising (N.O.)

LS1- Box Shelf Fully Extend

LS2- Box Shelf Fully Retracted

LS3- Tilt Table Fully Extended

LS4 – Tilt Table Fully Retracted

LS5 – Bottom Piston Fully Extend

LS6- Bottom Piston Fully Retraced

LS7- Bottom Piston Force Detection

LS8 – Top Piston Fully Extend

LS9- Top Piston Full Retraced

LS10- Top Piston Force Detection

LS11- Secure Cart Fully Extend

LS12- Secure Cart Fully Retraced

Outputs

M1- Hydraulic Pump

M2- Pneumatic Pump

M3 – Conveyor Motor

Sol 1- Conveyors Ext/Ret

Sol 2- Tilt Table Ext/Ret

Sol 3- Box Shelf Ext/ Ret

Sol 4- Secure Clamp Ext/Ret

Sol 5- Top Piton Ext/Ret

Sol 6- Bottom Piston Ext/Ret

(Loading of the 1st and 2nd Box on the A-Frame cart *Tilt Table*)

1. The cart is brought in to loading area by hand.
2. The fixed wheel end will go in first with the Trailer Hitch, then the cart will be manual be pushed so it's lined up with the paint on the ground in center of table for that certain sized cart (3 different sizes)
3. Once the cart is in place the operator will switch **LS7** and will activate **M3 and Sol 4** where it will raise the securing method to lock the cart.
4. Once the box is done loading from the Tilt Table to A-Frame Cart, the operator will then switch **LS7** and deactivate **M3 and Sol 4** to lower the securing method.
5. The cart is then turned around and lined up on the same painted line in center of table.
6. Then repeat Step 3-4
7. The cart is then brought out of loading area by the Buggy.
8. New cart is brought in to loading area and steps 1-7 are repeated.

(Operation of the Box to the Green Ramp)

1. When the box is finished, it will stay in the middle of the table.
2. All Conveyers will go up with the push and hold of **PB3** and it will active **Sol 1** it will grab the box to move towards the Green Ramp
3. All Conveyers will be switched on by **LS4** to start **M1** and begin to go forward to the end of the table.
4. Once at the end switch **LS4** off to stop the **M1**.
5. Then, all conveyors will go down with the release of **PB3** and it will deactivate **Sol 1**.

(Operation of the Box on the Tilt Table)

6. When box is finished, they will have Work Instructions to place down flush to the Box Shelf.
7. Next, all Conveyers will go up with the push and hold of **PB3** and it will active **Sol 1** it will grab the box to move towards center.
8. All Conveyers will be switched on by **LS4** to start the **M1** and begin to go forward to the center of the table.
9. If the box has gone too far from the center, switch off **LS4** and use switch **LS5** to reverse the **M1** on the conveyors.
10. Once centered switch either **LS4 or LS5** off to shut off **M1**
11. Then, all conveyors will go down with the release of **PB3** and it will deactivate **Sol 1**.
12. The box shelf will then come up with switch **LS7** and active **Sol 3**
13. Next, switch **LS6** to active **Sol 2** and the Tilt Table will go up to the 84 degrees.
14. Once at the 84 degrees, the switch **LS2** will active **Sol 6** and the bottom push piston will extend **until a certain pressure is exerted and will stop its motion.**
    a. **We will have the push piston back off 2 inches to allow space from box.**
15. The top push piston will then begin to extend with switch **LS3** and will active **Sol 5** **until a certain pressure is exerted and will stop its motion.**
    a. **Unless the push piston reaches a max length at that point the box should be flush on the cart**
16. As the push pistons are done with the action switch **LS2 and LS3** will be turned off to deactivate **Sol 5 and Sol 6** until they are retracted back into place.
17. As step #16 is going, switch **LS6** and that will deactivate **Sol 2** and the table will be lowered down to the 0-degree angle.
18. Then the switch **LS7** and that will deactivate **Sol 3** that will retract the box shelf to its original position.

Operators Manual

Statement of Operations

(Loading of the 1st and 2nd Box on the A-Frame cart *Tilt Table*)

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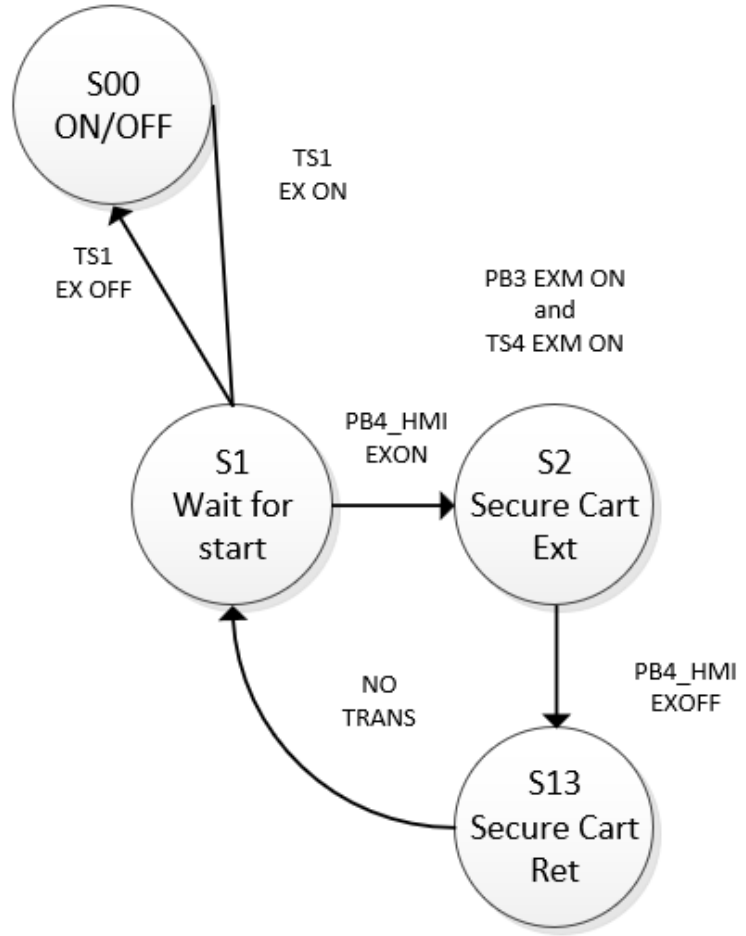

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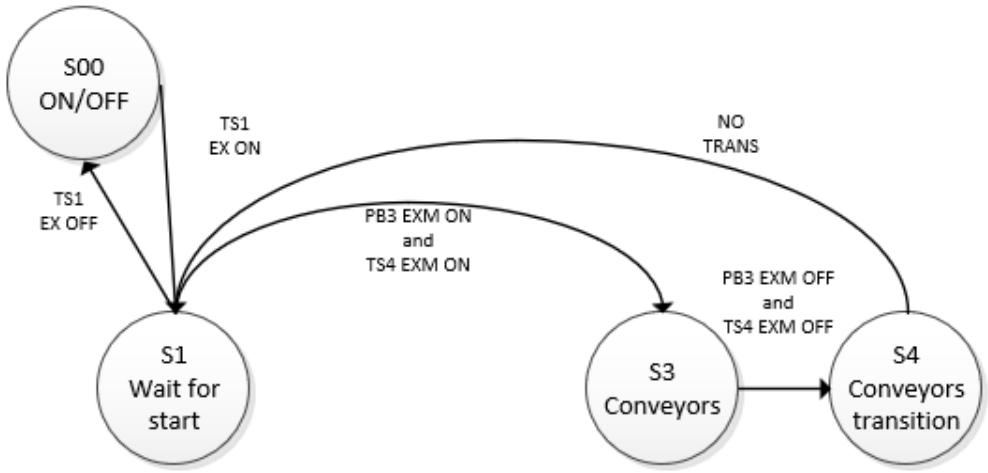

Green Ramp Cycle

(Operation of the Box on the Tilt Table)

6. When box is finished, they will have Work Instructions to place down flush to the Box Shelf.
7. Next, all Conveyers will go up with the push and hold of **PB3** and it will active **Sol 1** it will grab the box to move towards center.
8. All Conveyers will be switched on by **LS4** to start the **M1** and begin to go forward to the center of the table.
9. If the box has gone too far from the center, switch off **LS4** and use switch **LS5** to reverse the **M1** on the conveyors.
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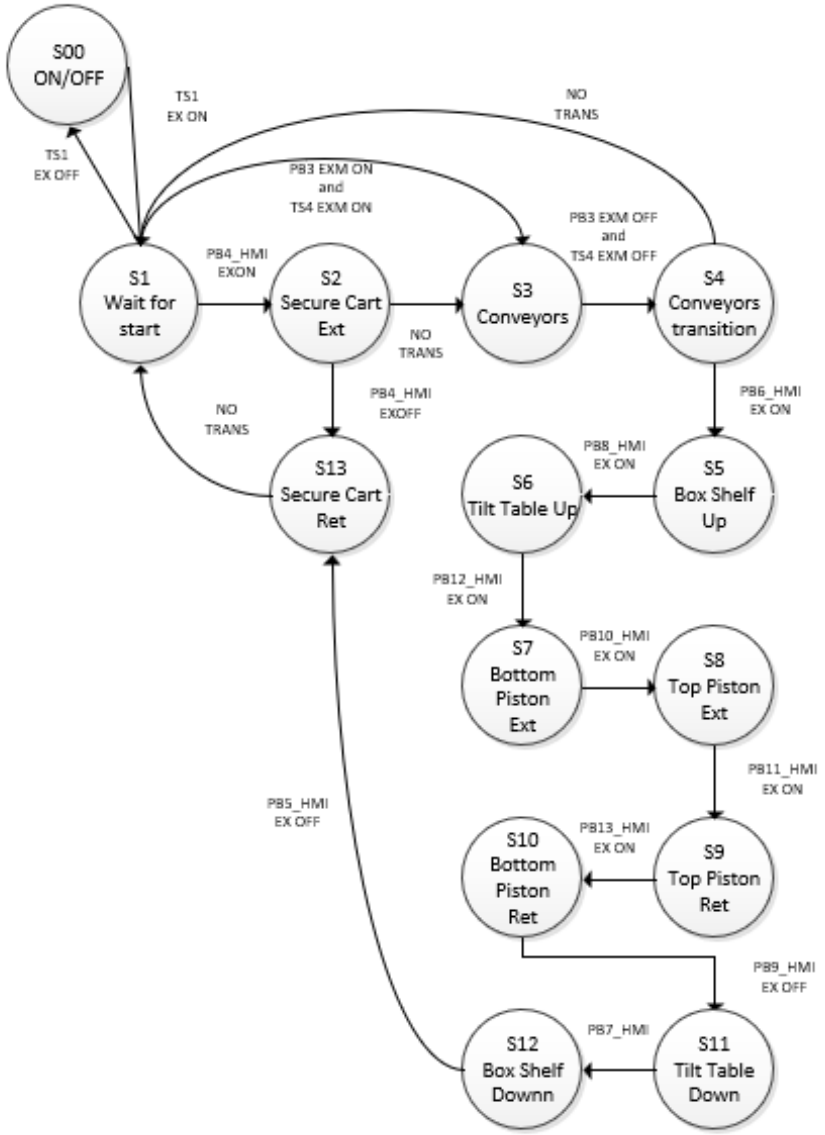
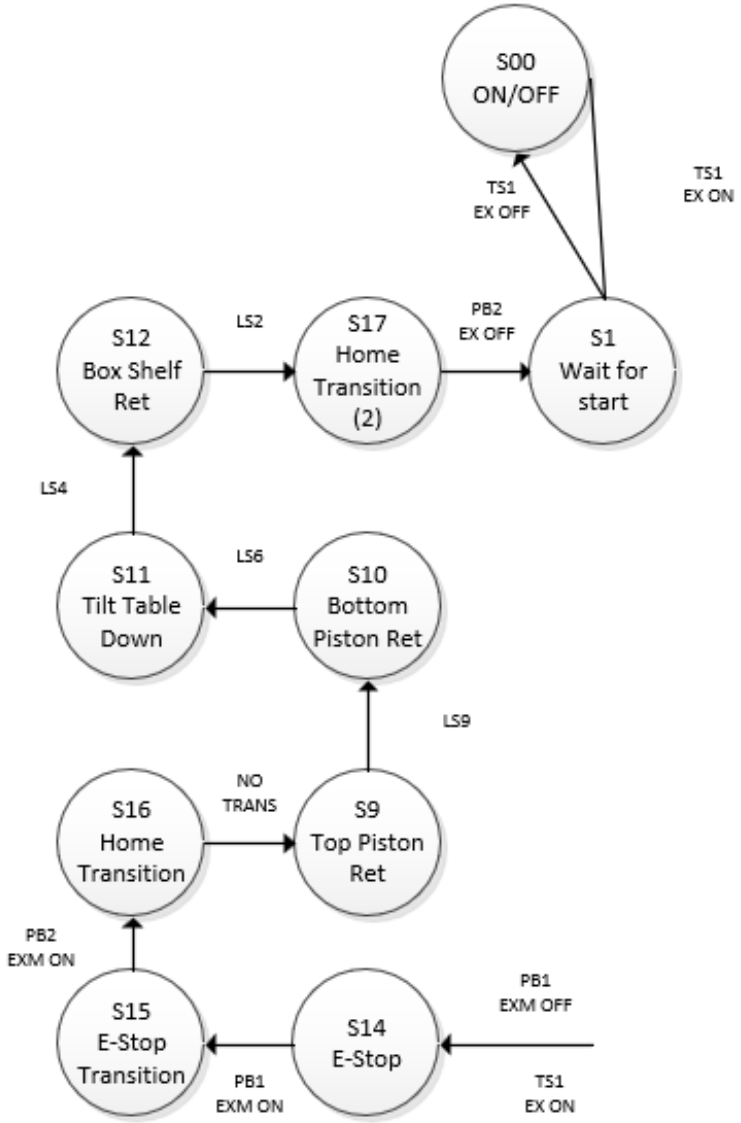
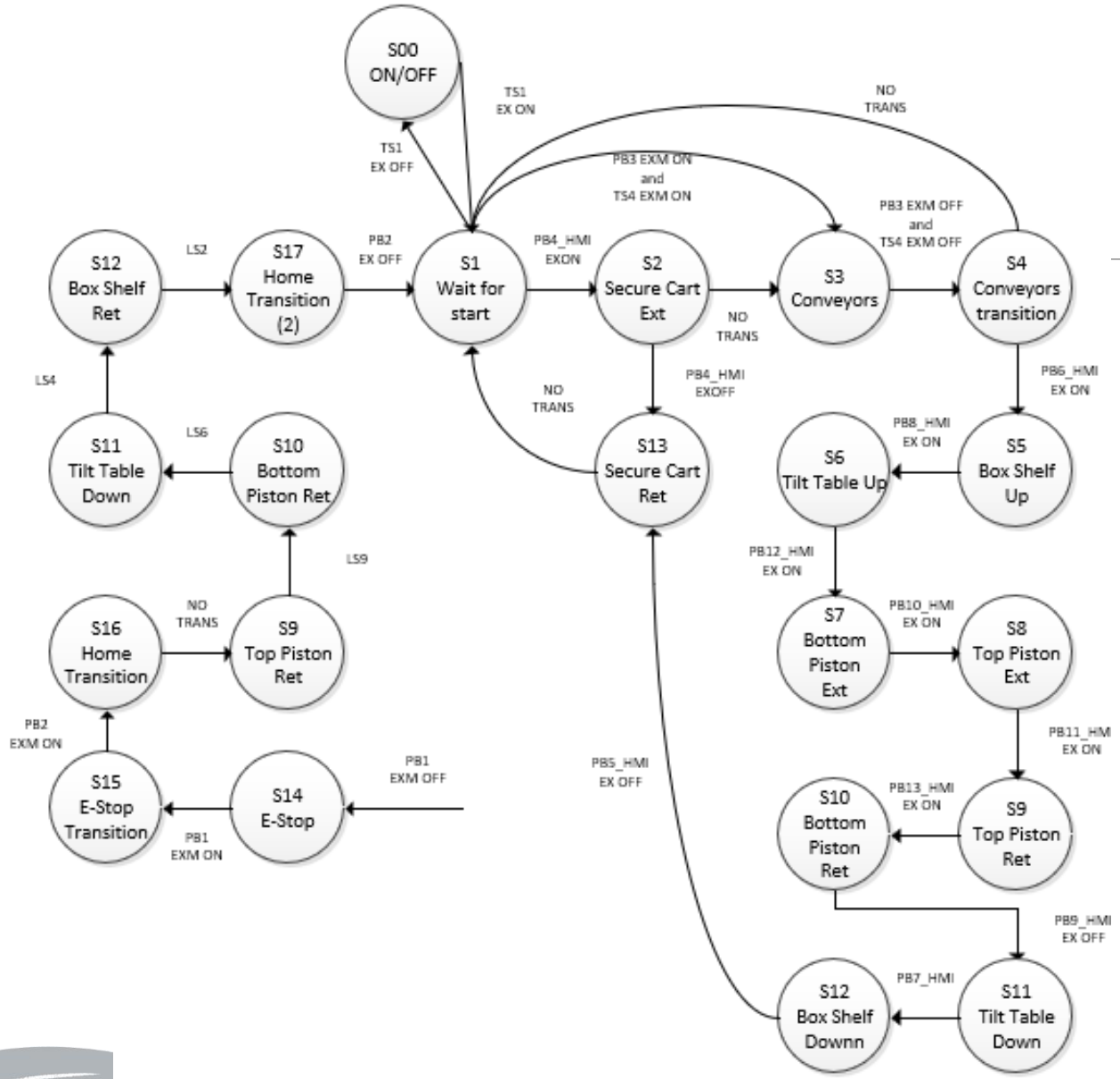


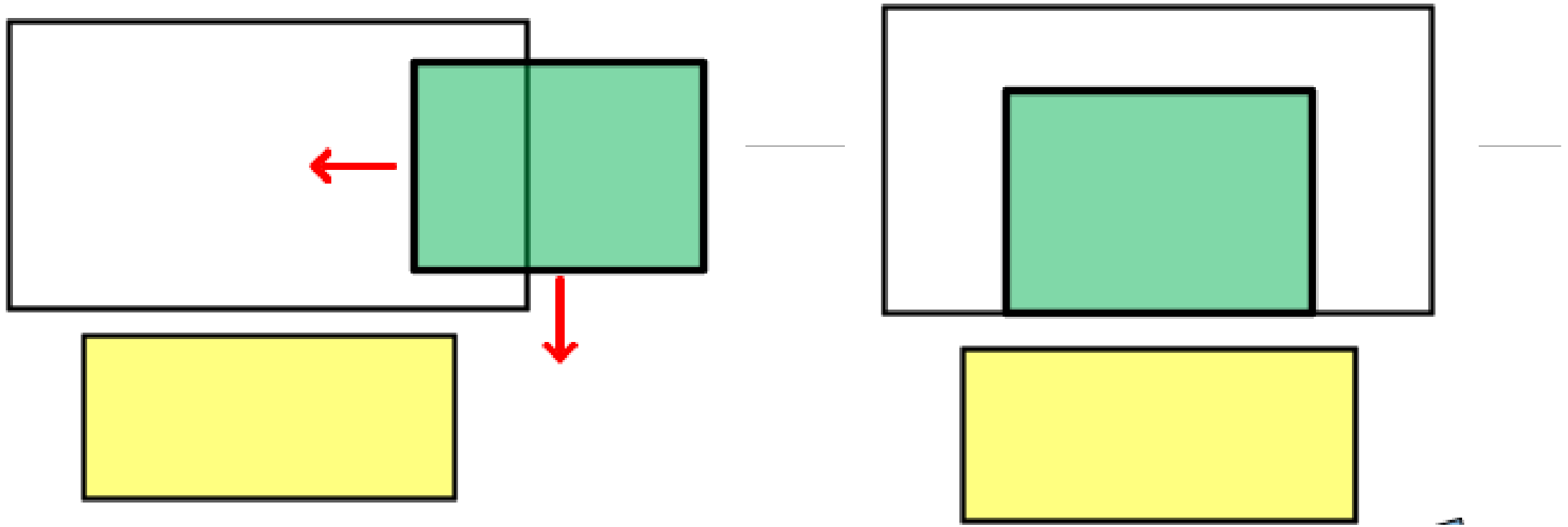
Statement of Operations Cont.



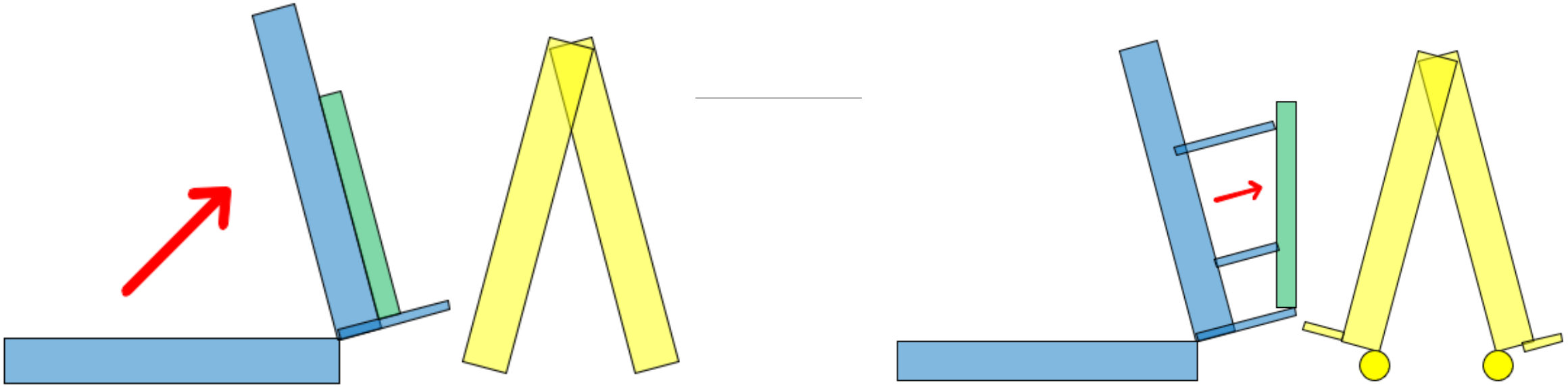
Homing Cycle



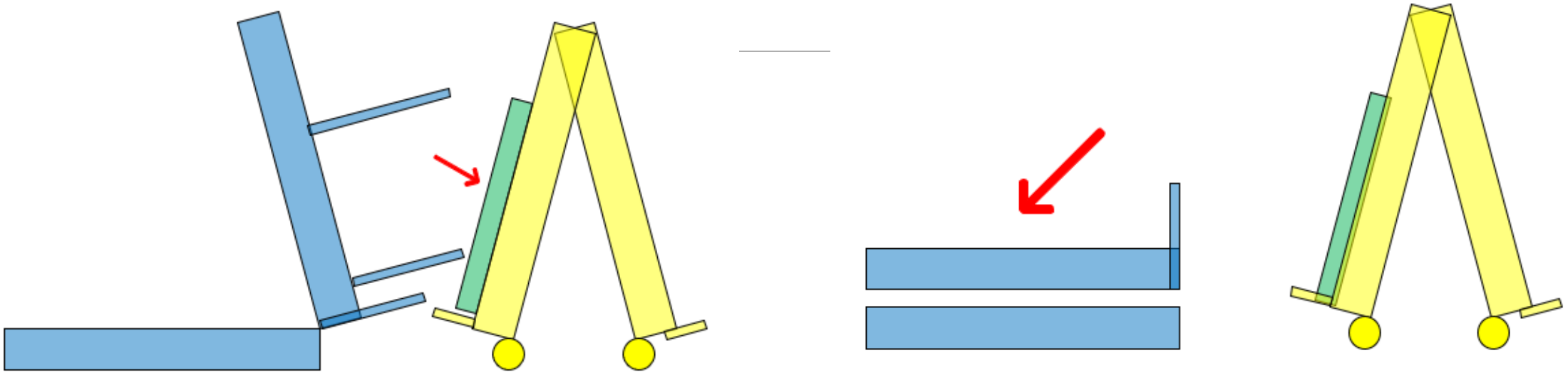
State diagram



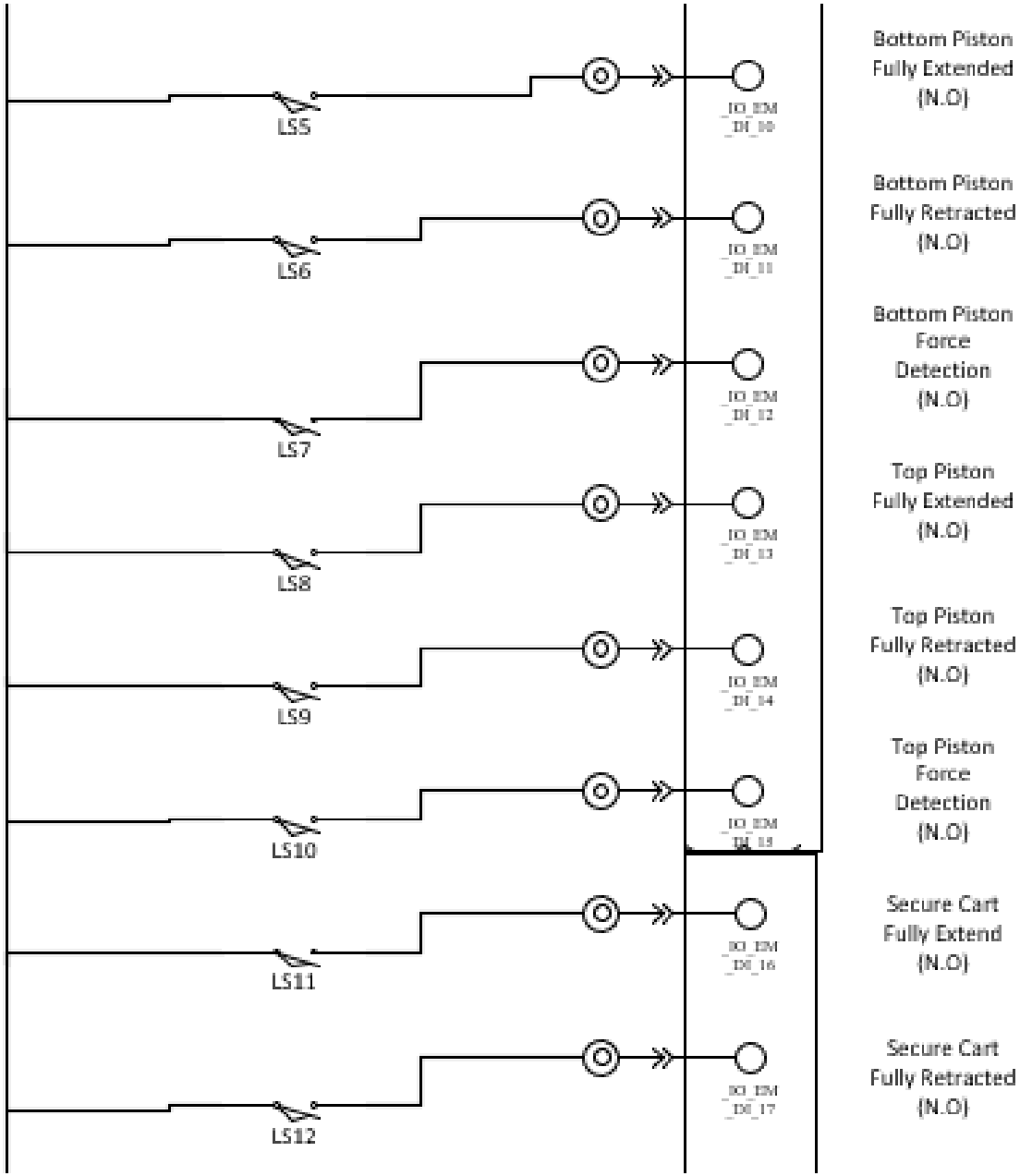
Part Flow



Part Flow



Part Flow


LS5
LS6
LS7
LS8
LS9
LS10
LS11
LS12
IO_EM_DI_10
IO_EM_DI_11
IO_EM_DI_12
IO_EM_DI_13
IO_EM_DI_14
IO_EM_DI_15
IO_EM_DI_16
IO_EM_DI_17
Bottom Piston Fully Extended (N.O)
Bottom Piston Fully Retracted (N.O)
Bottom Piston Force Detection (N.O)
Top Piston Fully Extended (N.O)
Top Piston Fully Retracted (N.O)
Top Piston Force Detection (N.O)
Secure Cart Fully Extend (N.O)
Secure Cart Fully Retracted (N.O)

Short Device Name	CCW Variables	Full Description
PB1	_IO_EM_DI_00	E-Stop (N.C.)
PB2	_IO_EM_DI_01	Home (N.O.)
PB3	_IO_EM_DI_02	Conveyors (N.O.)
TS1	_IO_EM_DI_03	ON/OFF
TS2	_IO_EM_DI_04	Conveyor Forward
TS3	_IO_EM_DI_05	Conveyors reverse
LS1	_IO_EM_DI_06	Box Shelf Fully Extend
LS2	_IO_EM_DI_07	Box Shelf Fully retracted
LS3	_IO_EM_DI_08	Tilt Table Fully Extend
LS4	_IO_EM_DI_09	Tilt Table Fully Retracted
LS5	_IO_EM_DI_10	Bottom Piston Fully Extend
LS6	_IO_EM_DI_11	Bottom Piston Fully Retracted
LS7	_IO_EM_DI_12	Bottom Piston Force Detection Reached
LS8	_IO_EM_DI_13	Top Piston Fully Extend
LS9	_IO_EM_DI_14	Top Piston Fully Retracted
LS10	_IO_EM_DI_15	Top Piston Force Detection Reached
LS11	_IO_EM_DI_16	Secure Cart Fully Extend
LS12	_IO_EM_DI_17	Secure Cart Fully Retracted

Tag Table Inputs

Secure Cart Extend	Secure Cart Extend	
Secure Cart Retract	Secure Cart Retract	Secure Cart Retract
Box Shelf Up	Box Shelf Up	Box Shelf Up
Box Shelf Down	Box Shelf Down	Box Shelf Down
Tilt Table Up	Tilt Table Up	Tilt Table Up
Tilt Table Down	Tilt Table Down	Tilt Table Down
Bottom Piston Extend	Bottom Piston Extend	Bottom Piston Extend
Bottom Piston Retract	Bottom Piston Retract	Bottom Piston Retract
Top Piston Extend	Top Piston Extend	Top Piston Extend
Top Piston Retract	Top Piston Retract	Top Piston Retract
Display to show angle	Display to show angle	Display to show angle
Conveyors Up	Conveyors Up	Conveyors Up
Conveyors Forward/ Reverse	Conveyors Forward/ Reverse	Conveyors Forward/ Reverse
Run Mode	Run Mode	Run Mode
Manual Mode	Manual Mode	Manual Mode
Error Codes	Error Codes	Error Codes

HMI Tags

M1	_IO_EM_DO_00	Hydraulic Pump
M2	_IO_EM_DO_01	Pneumatic Pump
M3	_IO_EM_DO_02	Conveyor Motor
Sol1	_IO_EM_DO_03	Conveyors Ext/Ret
Sol2	_IO_EM_DO_04	Tilt Table Ext/Ret
Sol3	_IO_EM_DO_05	Box Shelf Ext/Ret
Sol4	_IO_EM_DO_06	Secure Clamp Ext/Ret
Sol5	_IO_EM_DO_07	Top Piston Ext/Ret
Sol6	_IO_EM_DO_08	Bottom Piston Ext/Ret

Tag Table Outputs

S00		ON/OFF
S 1		Wait for Start
S 2		Secure Cart into Place
S 3		Conveyors Raise
S4		Conveyors Transition
S 5		Box Shelf Raise
S6		Tilt Table Raise
S7		Bottom Pistons Extend
S8		Top Pistons Extend
S 9		Top Pistons Retract
S 10		Bottom Pistons Retract
S 11		Tilt Table Lower
S 12		Box Shelf Retract
S13		Secure Cart Release
S14		E-Stop
S15		E-Stop Transition
S16		Home Transition
S17		Home Transition (2)

Tag Table States

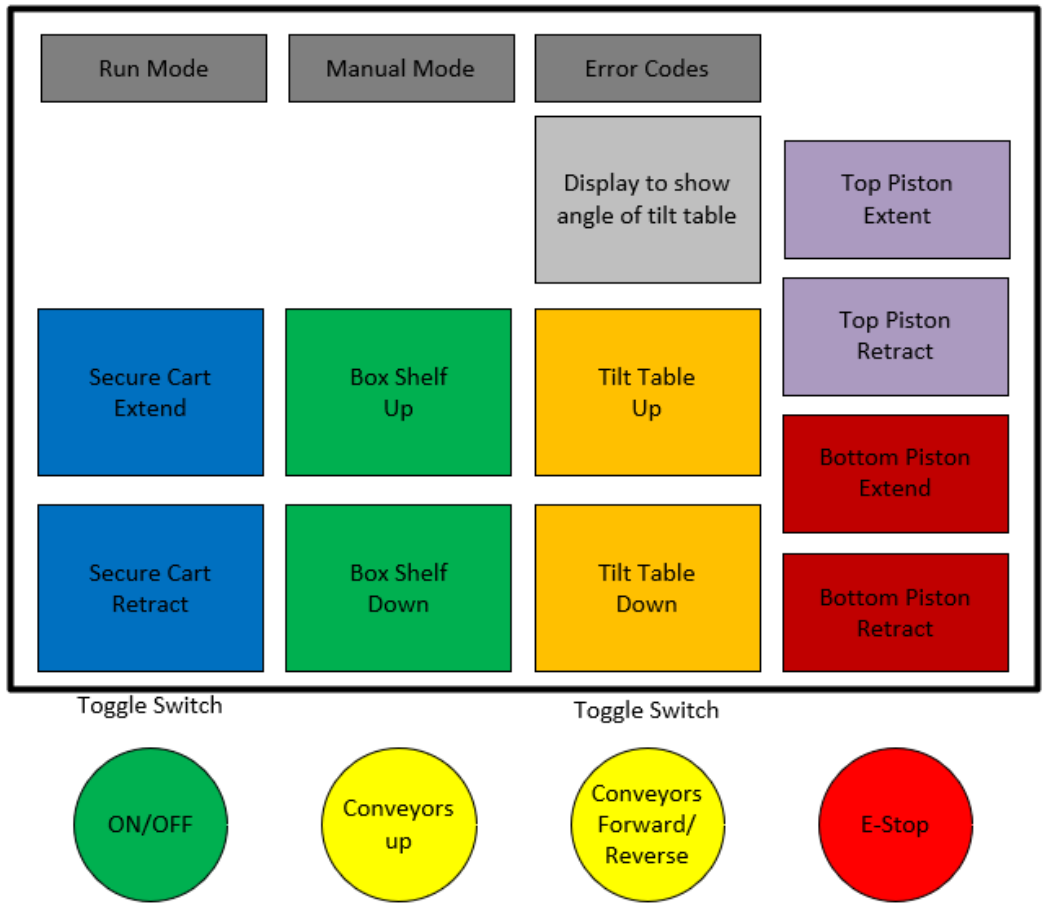
State	SOL 1 Conveyors ext/ret	SOL 2 Tilt table ext/ret	SOL 3 Box shelf ext/ret	SOL 4 Secure Clamp Ext/Ret	SOL 5 Top Piston Ext/Ret	SOL 6 Bottom Piston Ext/Ret	M1 Hydraulic pump	M2 Pneumatic pump	M3 Conveyor Motor4
S1									
S2				X				X	
S3	X			X			X	X	X
S4				X			X	X	
S5			X	X			X	X	
S6		X	X	X			X	X	
S7		X	X	X		X	X	X	
S8		X	X	X	X	X	X	X	
S9		X	X	X		X	X	X	
S10		X	X	X			X	X	
S11			X	X			X	X	
S12				X				X	
S13									
S14									
S15									
S16									
S17									

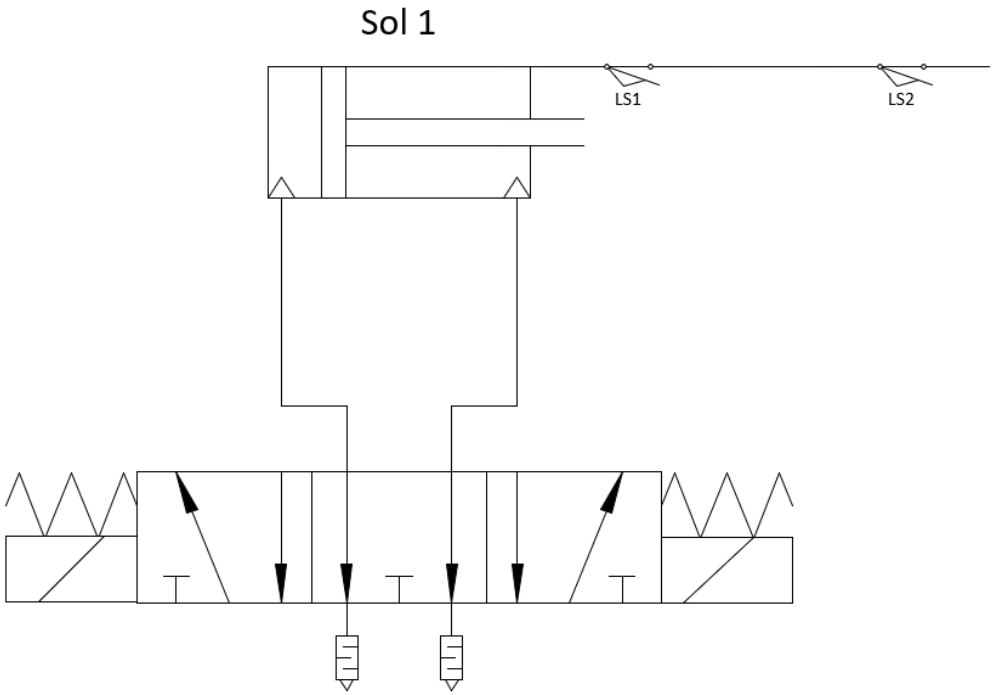
State Output Table

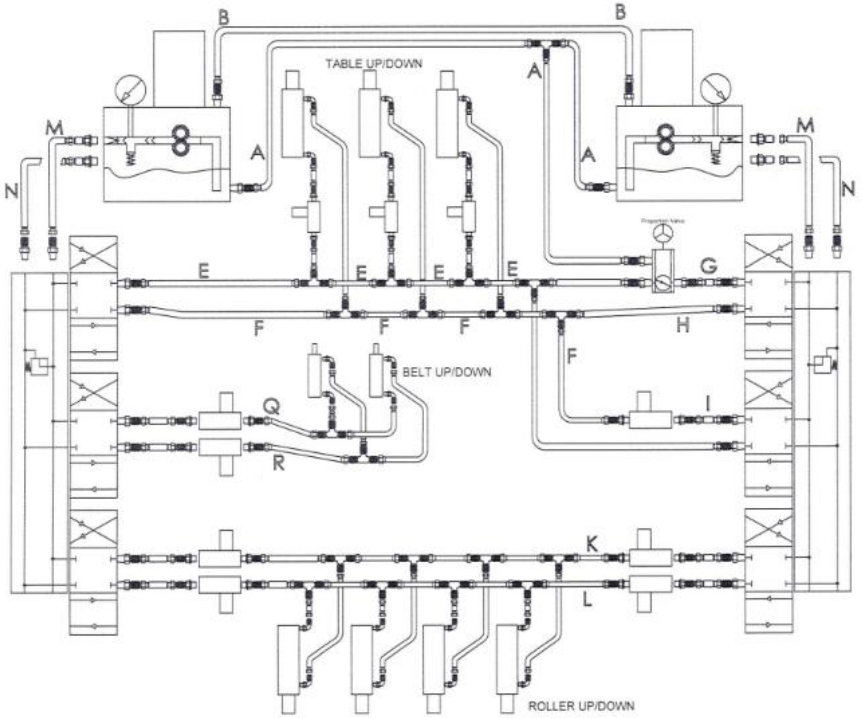

Conveyor
Tilt table
Box stuff
Conveyor Direction
Secure Clamp
Top Piston
Bottom Piston
Hydraulic Pump
Pneumatic pump
Down/Up
Down/Up
Ext/Ret
For/Rev
Ext/Ret
Ext/Ret
Ext/Ret
Sol 1
Sol 2
Sol 3
Sol 4
Sol 5
Sol 6
Sol 7
M1
M2
ON/OFF
Bottom Piston Ext/Ret
Top Piston Ext/Ret
Conveyor direction For/Rev
Tilt Table Down/up
Box stuff Ext/Ret
Secure Clamp Ext/Ret
LS1
LS2
LS3
LS4
LS5
LS6
LS7

HMI


AUTOMATIONDIRECT
TILT UP
ROLLERS UP
TILT DOWN
ROLLERS DOWN
BROMER INC.
OFF ON
RESET
E-STOP


Run Mode
Manual Mode
Error Codes
Display to show angle of tilt table
Top Piston Extent
Top Piston Retract
Secure Cart Extend
Box Shelf Up
Tilt Table Up
Bottom Piston Extend
Secure Cart Retract
Box Shelf Down
Tilt Table Down
Bottom Piston Retract
Toggle Switch
Toggle Switch
ON/OFF
Conveyors up
Conveyors Forward/ Reverse
E-Stop



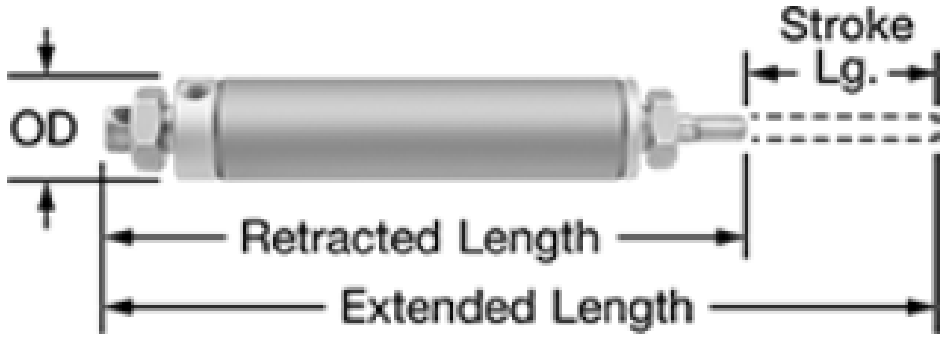


Pneumatic Diagram

Physical Components Required for the System

Pneumatics

- Air Compressor
- 3x for raising up/down tilt table
- 4x extending and retracting box shelf
- 4 pneumatic pistons for push pistons
- 1x for raising and lowing conveyors
- Hoses
- Fittings
- Connectors



Physical Components Required for the System

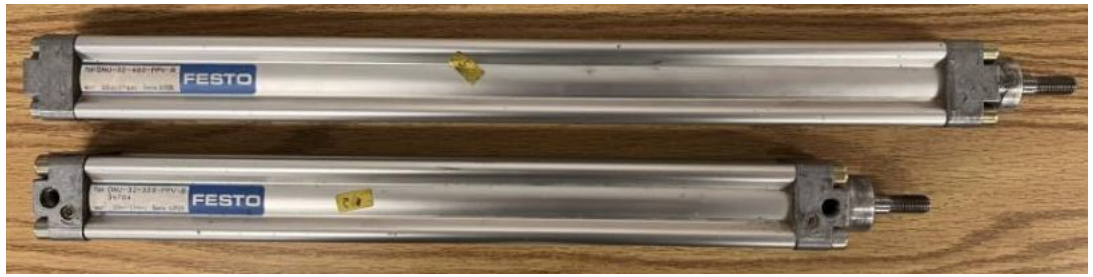
Motors

- 120V AC Motors for conveyors

Parts- Prototype

ITEM NUMBERS

- Festo
  - DNU-32-400-PPV-A
  - DNU-32-320-PPV-A



Prototype Solution Cost - Overview

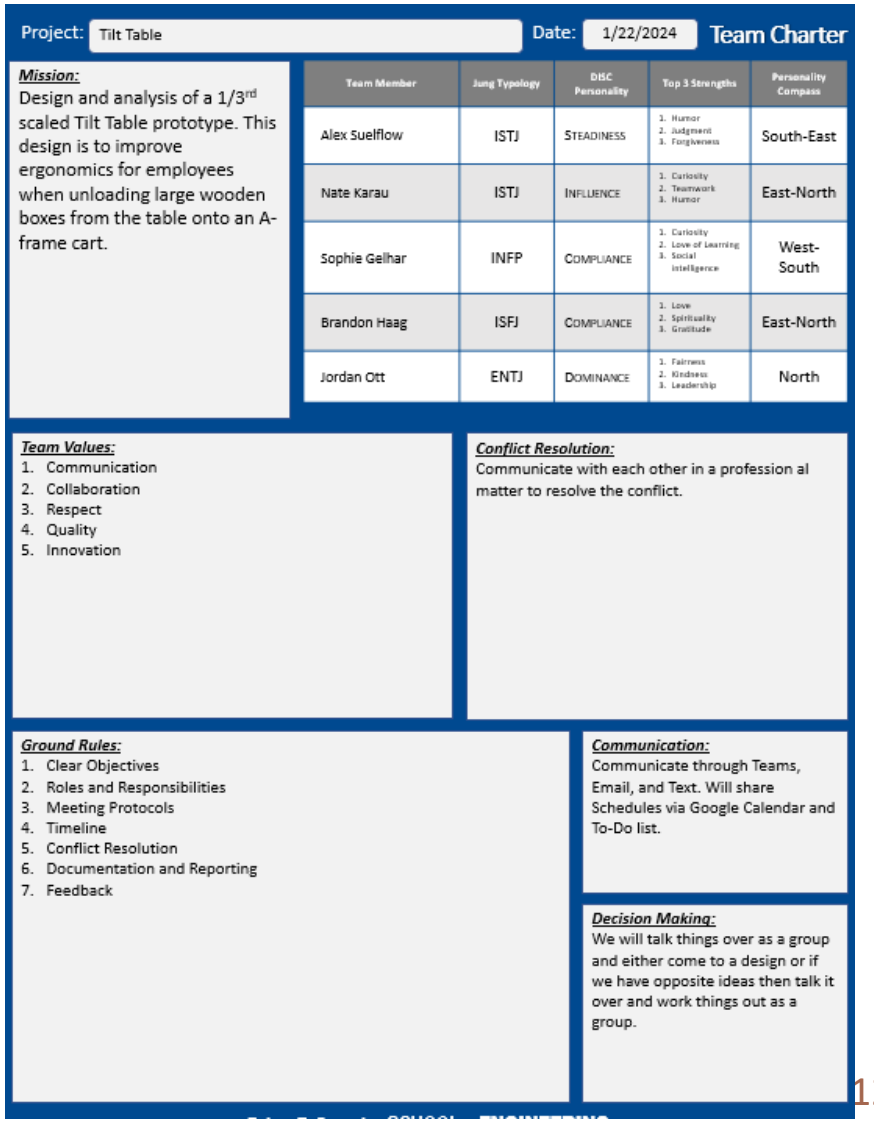
- Tilt Table Assembly ------$1,787.82
- Tabletop ----------$109.10
- Bottom Frame ----------$751.97
- Box Shelf ----------$28.44
- Push Piston Assembly ---$1,655.19
- Cart Connection ----------$926.47
- Cart Model ----------$329.73
- **Total ----------$5,588.71**

TEAMWORK

Teamwork

The first step of the process was establishing the team by establishing:

- The Goal
- Our Values
- Conflict Resolution
- Who We Are
- Ground Rules
- Additionally: Interim and End of Semester Peer Reviews



Project: Tilt Table Date: 1/22/2024 **Team Charter**

Mission:
Design and analysis of a 1/3rd scaled Tilt Table prototype. This design is to improve ergonomics for employees when unloading large wooden boxes from the table onto an A-frame cart.

Team Member	Jung Typology	DISC Personality	Top 3 Strengths	Personality Compass
Alex Suelflow	ISTJ	Steadiness	1. Humor 2. Judgment 3. Forgiveness	South-East
Nate Karau	ISTJ	Influence	1. Curiosity 2. Teamwork 3. Humor	East-North
Sophie Gelhar	INFP	Compliance	1. Curiosity 2. Love of Learning 3. Social Intelligence	West-South
Brandon Haag	ISFJ	Compliance	1. Love 2. Spirituality 3. Gratitude	East-North
Jordan Ott	ENTJ	Dominance	1. Fairness 2. Kindness 3. Leadership	North

Team Values:
1. Communication
2. Collaboration
3. Respect
4. Quality
5. Innovation

Conflict Resolution:
Communicate with each other in a profession al matter to resolve the conflict.

Ground Rules:
1. Clear Objectives
2. Roles and Responsibilities
3. Meeting Protocols
4. Timeline
5. Conflict Resolution
6. Documentation and Reporting
7. Feedback

Communication:
Communicate through Teams, Email, and Text. Will share Schedules via Google Calendar and To-Do list.

Decision Making:
We will talk things over as a group and either come to a design or if we have opposite ideas then talk it over and work things out as a group.