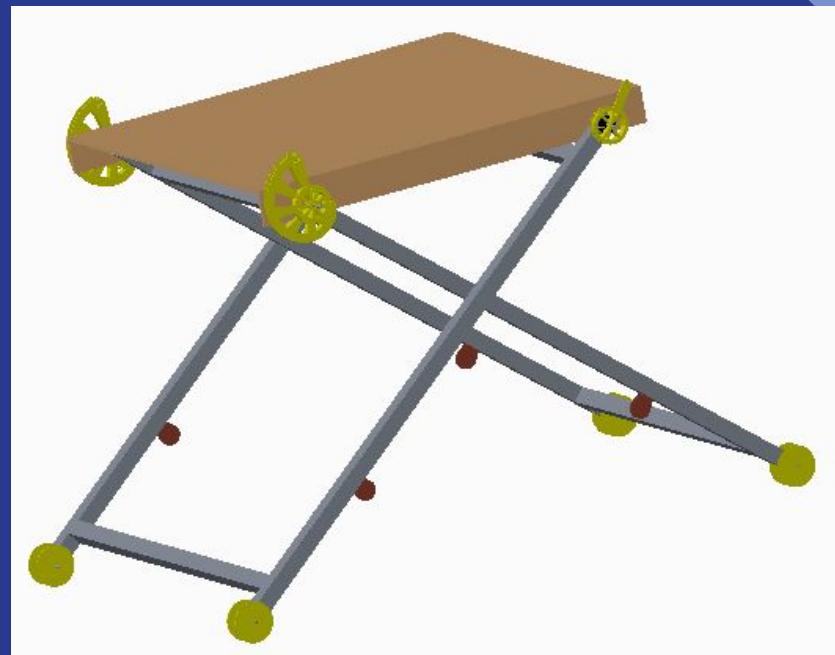


# The Able Table

ME 270 - Final Presentation  
Team ABD - 1



# Problem



# History



# Demonstration

The Able Table would do the following in order.

- Effortlessly carry a weight of 10 pounds between the heights 14"-25".
- Fall to the ground when extra weight is added.
- Rise up to max. height when all weight is removed.
- Lock at some height, change spring extension to balance a different weight.

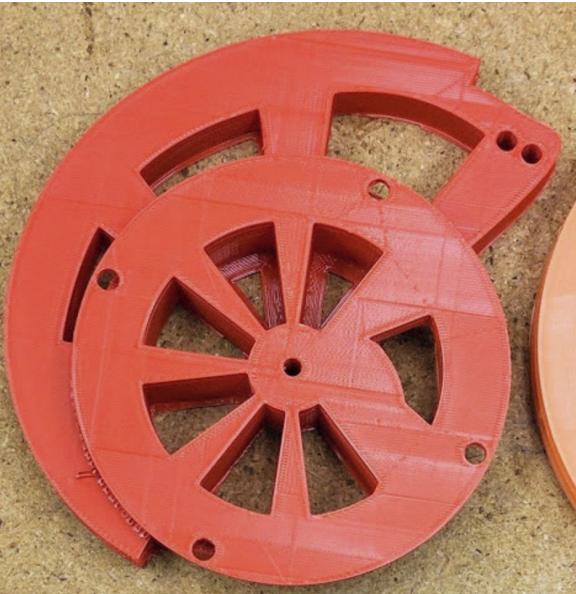
Video: [https://www.youtube.com/watch?v=v3yi1W1\\_UEg](https://www.youtube.com/watch?v=v3yi1W1_UEg)

# Critical Aspects - Cam

Our ‘cams’ are rotating objects that are maintained in equilibrium.

## HOW?

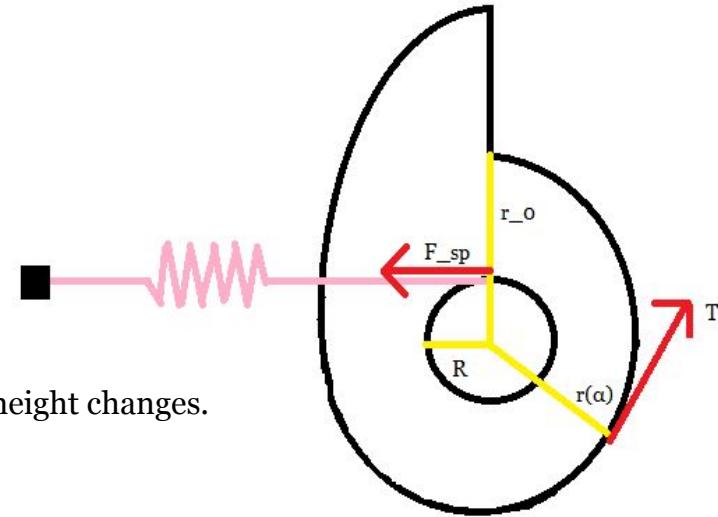
Apply force → tension adjusts → cams rotate to equilibrium → cable adjusts →height changes.



## Governing Equation

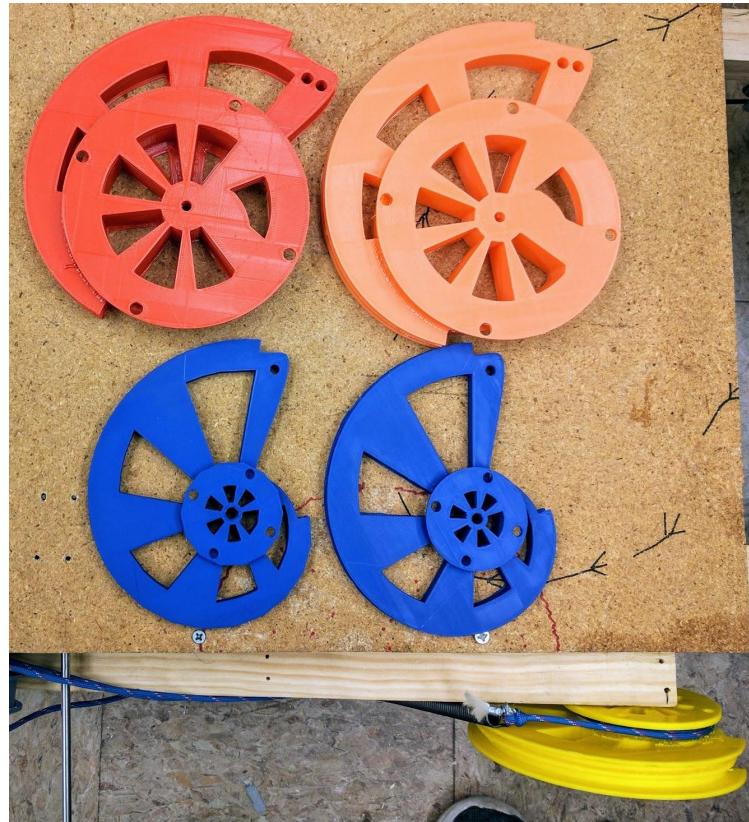
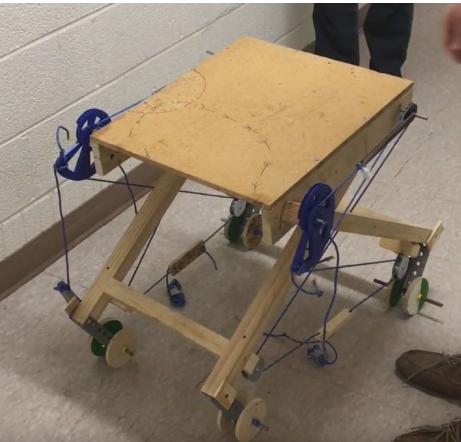
$$r(\alpha) = r_0 + \frac{R^2 k}{T} \alpha \quad \alpha \in [0, 2\pi]$$

**Tension (T)** turns out to be highly non-linear, cannot be easily measured.  
Performed multiple trials, varying **R** and spring constant **k** to find the arrangement that maximizes range (**DOE**).



# DOE

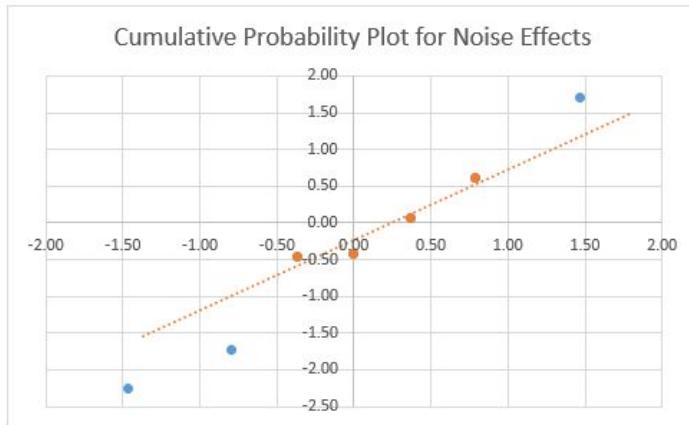
- Optimizing the range at which the table travels
  - Secondary output of weight necessary for movement
- Variables
  - Cam Size, (Spring connection radius): 0.8 in, 1.5 in, 2.5 in
  - Spring Constant: 4.8 lb/in, 10 lb/in, 25 lb/in
  - Pre-torque, (Stretching of spring): zero in,  $\frac{3}{4}$  in,  $2\frac{1}{4}$  in



# DOE- Noise

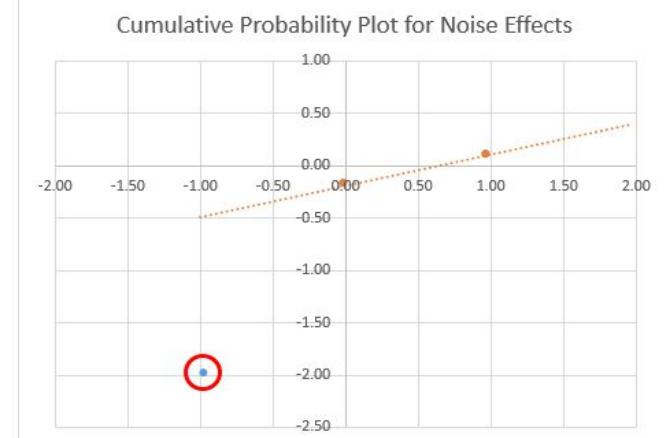
- 3 Variables - Cam - 0.8 in & 1.5 in  
- Spring - 4.8 lb/in & 10 lb/in  
- Pre-torque - 0 in & 2 1/4 in

Noise:	E1	E2	E3	E12	E13	E23	E123
	0.60	0.06	1.71	-1.74	-0.41	-0.45	-2.25



- 2 Variables - Cam - 0.8 in & 1.5 in  
- Spring - 4.8 lb/in & 10 lb/in

Noise:	E1	E2	E12
	0.10	-0.19	-1.99

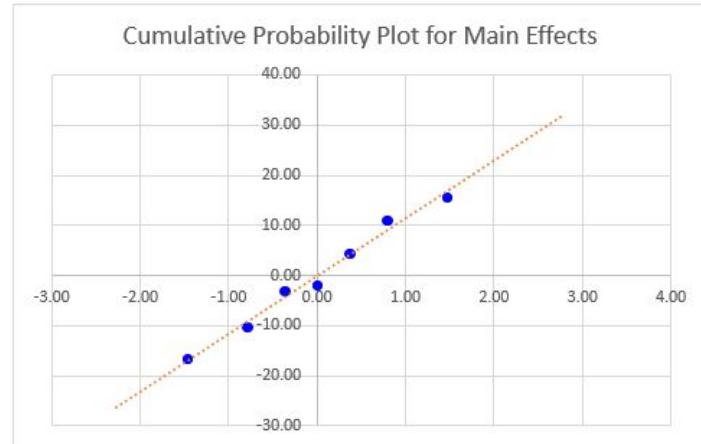


# DOE- Main Effects

- 3 Variables - Cam - 0.8 in & 1.5 in  
- Spring - 4.8 lb/in & 10 lb/in  
- Pre-torque - 0 in & 2 1/4 in

System Standard Deviation: 0.58

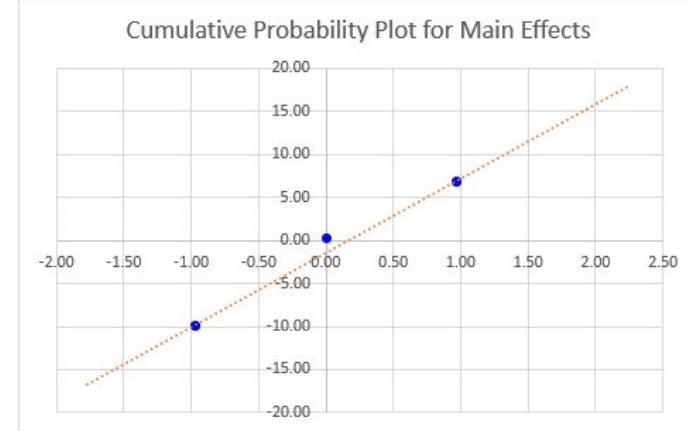
Main:	E1	E2	E3	E12	E13	E23	E123
	15.66	-3.04	4.34	-10.34	-1.96	-16.66	11.04



- 2 Variables - Cam - 0.8 in & 1.5 in  
- Spring - 4.8 lb/in & 10 lb/in

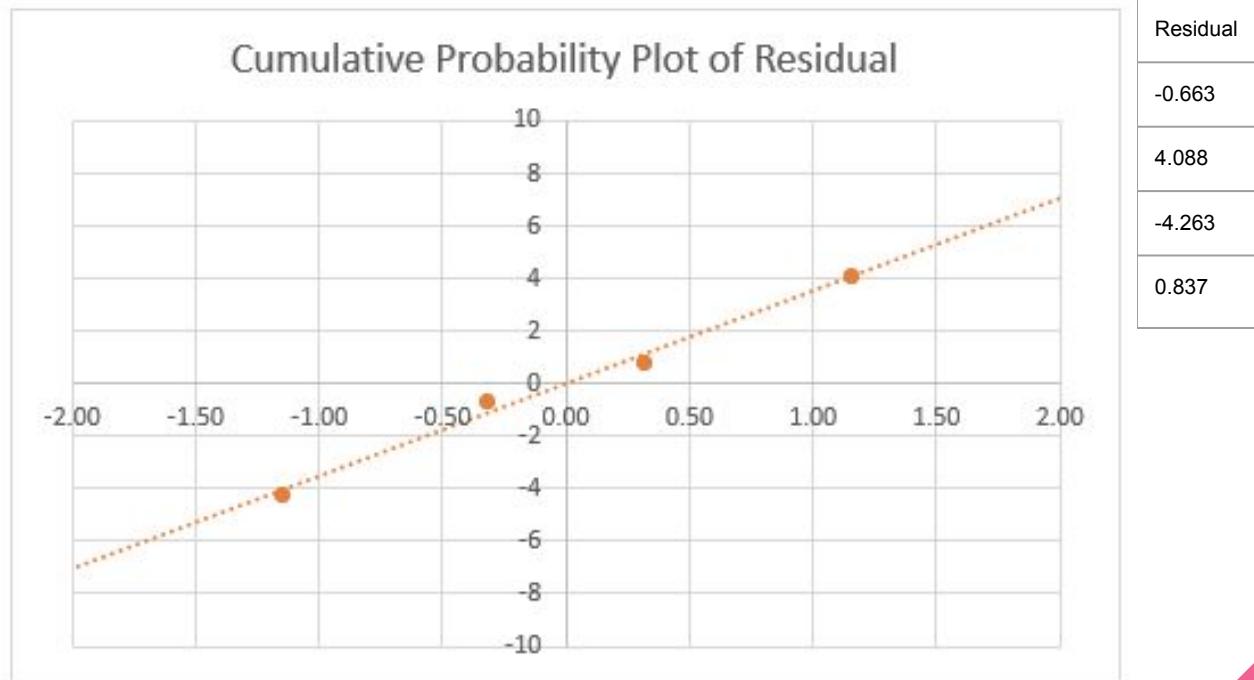
System Standard Deviation: 0.74

Main:	E1	E2	E12
	6.85	-9.85	0.35



# DOE- Analyzation

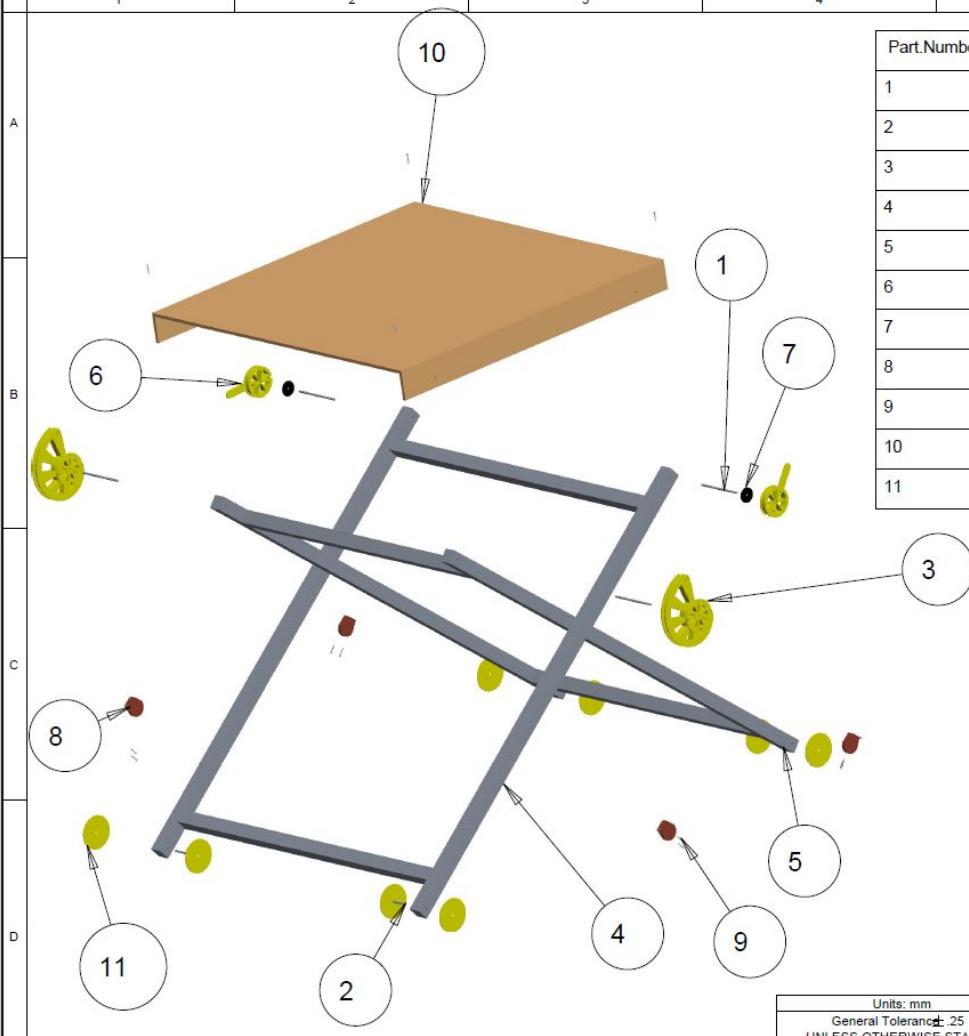
2 Variable Characteristic Equation:  $y = \bar{y} + \frac{E_1}{2}x_1 + \frac{E_2}{2}x_2 = 7.66 + 3.43x_1 - 4.93x_2$



# DFA - Efficiency of 21.31%

Step	Part	$\alpha$ Symmetry	$\beta$ Symmetry	Handling and Alignment		Insert and Secure		Number of Parts	Total Time (s)
				Time (s)	Total	Time (s)	Total		
1	Table Top	180	180	0.5 (fetch) + 1.0 (symmetry) + 0.3 (large) + 0.3 (aspect ratio)	2.6	0	0	1	2.6
2	Table Side	180	180	0.5 (fetch) + 1.0 (symmetry) + 0.3 (large) + 0.3 (aspect ratio)	2.1	0.5 (placement)	0.5	2	5.2
3	Screw	360	0	0.5 (fetch) + 1.0 (symmetry) + 0.1 (aspect ratio)	1.6	0.5 (placement) + 1.0 (turning insertion) + 2.0 (tightening)	3.5	4	20.4
4	Table Leg	360	360	0.5 (fetch) + 2.0 (symmetry) + 0.3 (large) + 0.1 (aspect ratio)	2.9	0.5 (placement) + 0.3 (align to hole) + 0.4 (hold)	1.2	2	8.2
5	Fixed Pulley - on bottom of legs	360	180	0.5(fetch) +1.5(symmetry)	2	0.5 (placement) + 0.6 (align to hole)	1.1	4	12.4
6	Screw	360	0	0.5 (fetch) + 1.0 (symmetry) + 0.1 (aspect ratio)	1.6	0.5 (placement) + 1.0 (turning insertion) + 2.0 (tightening)	3.5	8	40.8
7	Pin	180	0	0.5 (fetch) + 0.5 (symmetry) + 0.1 (aspect ratio)	1.1	0.5 (placement) + 0.2 (align to hole) + 0.4(tight tolerance) + 7 (two sided tightening)	8.1	8	73.6
8	Wheel	180	0	0.5 (fetch) + 0.5 (symmetry)	1	0.5 (placement) + 0.1 (align to pin) + 0.4 (hold)	0.6	8	12.8
9	Fixed Pulley - on table sides	180	0	0.5(fetch) +0.5(symmetry)	1	0.5 (placement) + 0.1 (align to pin)	0.6	2	3.2
10	Cams	360	360	0.5(fetch) +2(symmetry)	2.5	0.5 (placement) + 0.1 (align to pin)	0.6	2	6.2
11	Pre-torque Cylinder	180	0	0.5(fetch) +0.5(symmetry)	1	0.5 (placement) + 0.1 (align to pin)	0.6	2	3.2
12	Spring - on table sides	180	0	0.5(fetch) +0.5(symmetry)	1.4	0.5 (placement) + 0.1 (align to pin)+0.4 (insertion difficulty)	1	2	4.8
13	Rope				30		30	1	60
								<b>Total Time:</b>	253.4

1 2 3 4 5 6

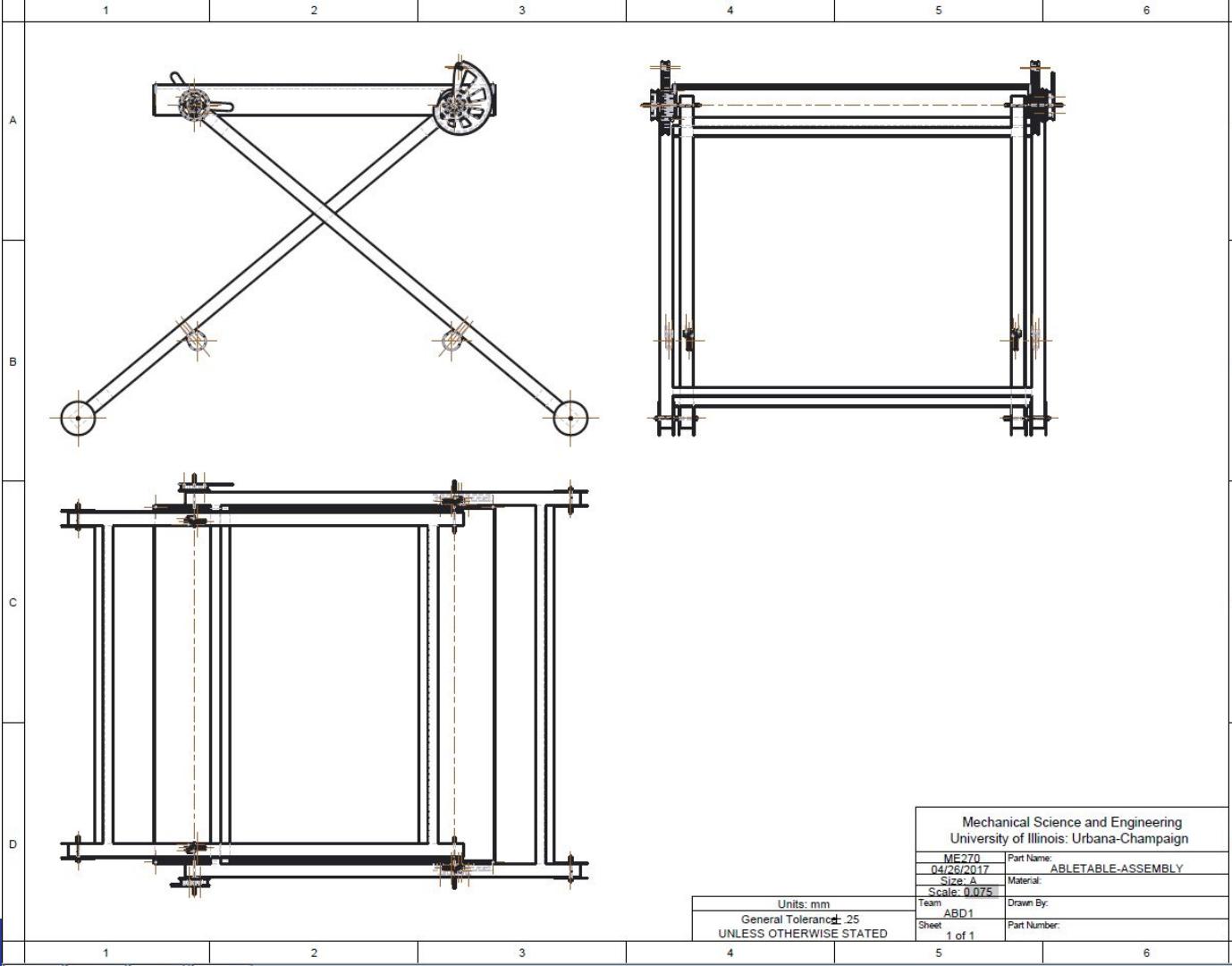


Part.Number	Quantity	Part Name
1	4	1327K650SHAFT
2	4	3SHAFT
3	2	CAM_M
4	1	LEG_B
5	1	LEG_S
6	2	PRETORQ-CYLINDER
7	2	PULLEY
8	4	PULLEY1
9	12	SCREWS
10	1	TABLE
11	8	WHEEL

ME270	Part Name:	ABLETABLE-ASSEMBLY
04/26/2017	Material:	
Size: A	Scale: 0.070	
Team: ABD1	Drawn By:	
Sheet: 1 of 1	Part Number:	

General Tolerance: ± .25  
UNLESS OTHERWISE STATED

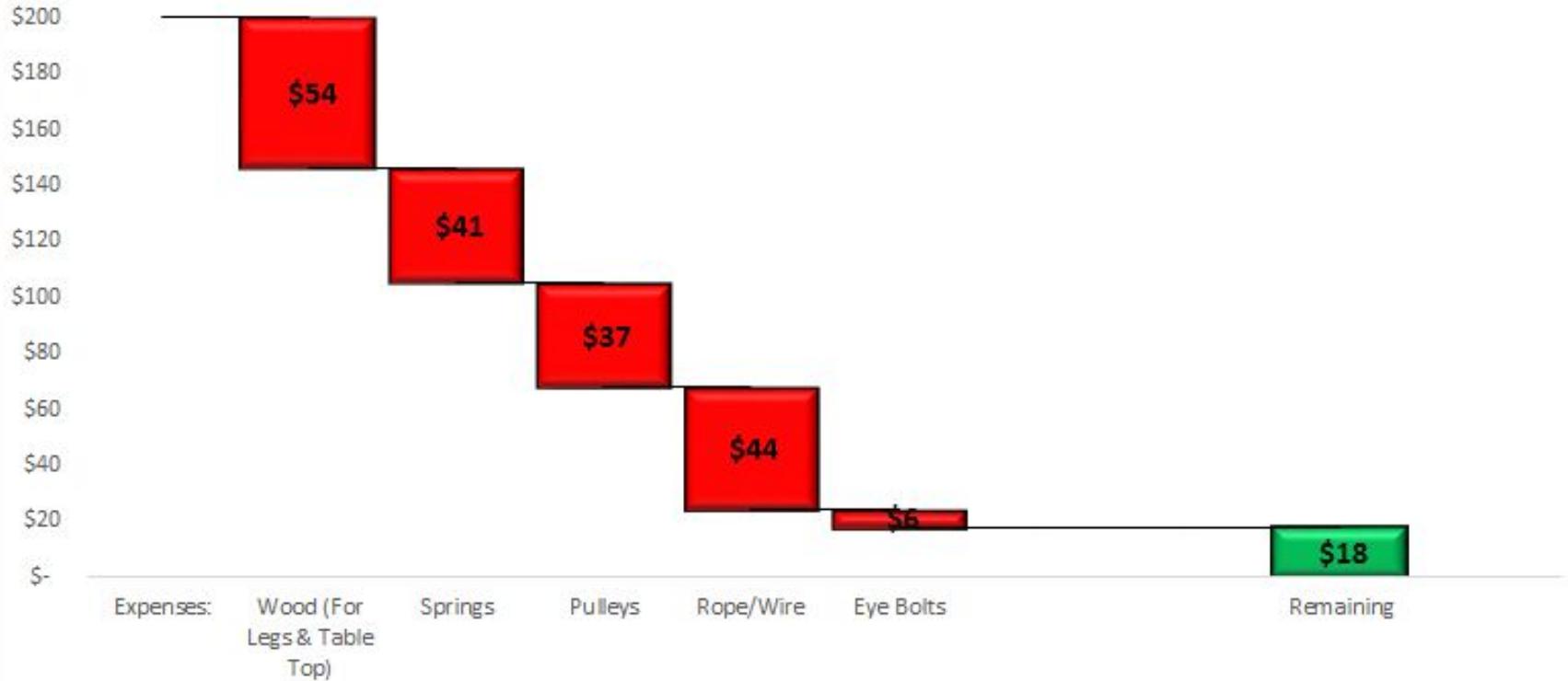
Units: mm



# Apriori Cost Analysis

Parts	Material	Production	Material Cost	Piece Part Cost	Fully Burdened Cost	Total Capital Investments	Quantity	Total Fully Burdened Cost
Wheel	ABS	Plastic Molding	\$0.05	\$0.13	\$0.23	\$5,354.82	8	\$1.84
Cams	ABS	Plastic Molding	\$1.22	\$4.55	\$4.74	\$9,574.01	2	\$9.48
Pre-torque Cylinder	ABS	Plastic Molding	\$0.20	\$1.02	\$1.36	\$16,950.45	2	\$2.72
Miscellaneous	Material	Company	Catalog number	Quantity			Cost per part	Total cost
Pin	12L14 Carbon Steel(36")	MC Master	<a href="#">1327K71</a>	1.5	7*6"(upper shaft)+4*3"(wheels)	54	\$20	\$30
Fixed Pulley - on bottom of legs	Steel	MC Master	<a href="#">3099T34</a>	2			\$7.02	\$14.04
Fixed Pulley - on table sides	Acetal Plastic	MC Master	<a href="#">3434T37</a>	2			\$2.25	\$4.50
Screw	Zinc-Plated Steel(pack of 100)	MC Master	<a href="#">90190A125</a>	12	\$3.57	100	\$0.04	\$0.43
Spring - on table sides	4.80lb/in (pack of 3)	MC Master	<a href="#">9044K383</a>	2	\$8.18	3	\$2.73	\$5.45
Table Top/Sides	1/2 in. x 4 ft. x 4 ft. PureBond Prefinished Maple Project Panel	The Home Depot	<a href="#">3127</a>	1			\$38.80	\$38.80
Table Leg	Square Tubing	Speedy Metals	1.5" width. 0.065"wall 60"length	7	4*59"(length)+2 *42"(width1)+2*37.5"(width2)	395	\$10.66	\$70.18
Rope	Rope 50ft x 1/8"	The Home Depot	<a href="#">498533</a>	1			\$2.97	\$2.97
Assembly								
Labor Assenby								\$1.06
							<b>Total cost:</b>	\$180.41

## The Able Table ME 270 Waterfall Budget



# Gantt Chart



# Final Message

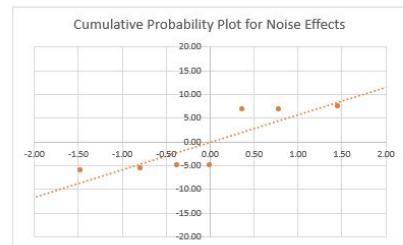
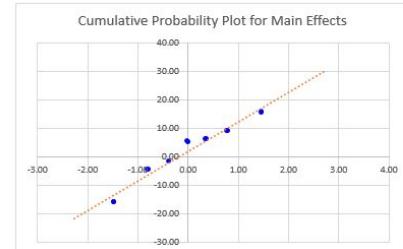
“Success comes from hard work,  
dedication, and learning from  
failures”



# Appendix

Variables	low	high																	
1. Spring Connection Radius	0.8 in	1.5 in																	
2. Spring Constant	4.8 lbs/in	10 lbs/in																	
3. Pre-torque	0 Rope Unit	1 Rope Units																	
Test	x1	x2	x3	x1x2	x1x3	x2x3	x1x2x3	Max (in)	Min (in)	Range1	Max (in)1	Min (in)2	Range2	Weight	Average Range	Std Dev.	Variance	Expected	Residual
1	-1	-1	-1	1	1	1	-1	13.75	13.75	0.0	13.75	13.75	0.0	0.0	0.0	0.00	0.00	-21.06	-21.063
2	-1	-1	1	1	-1	-1	1	23.4	20.7	2.7	23.75	17.50	6.3	0.0	4.5	2.51	6.30	-5.09	9.570
3	-1	1	-1	-1	1	-1	1	22.75	14	8.8	23.25	14.50	8.8	0.0	8.8	0.00	0.00	13.94	-5.187
4	-1	1	1	-1	-1	1	-1	23.7	15.2	8.5	23.70	15.60	8.1	0.0	8.3	0.28	0.08	10.21	-1.905
5	1	-1	-1	-1	-1	1	1	25	15	10.0	24.75	15.25	9.5	0.0	9.8	0.35	0.13	16.01	-6.255
6	1	-1	1	-1	1	-1	-1	25.375	14.75	10.6	25.25	14.63	10.6	0.0	10.6	0.00	0.00	21.44	-10.812
7	1	1	-1	1	-1	-1	-1	25.5	17.25	8.3	25.00	17.63	7.4	10.0	7.8	0.62	0.38	8.26	-0.443
8	1	1	1	1	1	1	1	27.3125	17.625	9.7	26.63	18.25	8.4	12.0	9.0	0.93	0.86	15.06	-6.030
<b>Main:</b>	<b>E1</b>	<b>E2</b>	<b>E3</b>	<b>E12</b>	<b>E13</b>	<b>E23</b>	<b>E123</b>												
	15.69	9.04	6.12	-0.01	-1.93	-0.58	5.27												
	1.00	1.00	1.00	1.00	0.00	1.00	1.00												
<b>Noise:</b>	<b>E1</b>	<b>E2</b>	<b>E3</b>	<b>E12</b>	<b>E13</b>	<b>E23</b>	<b>E123</b>												
	-5.01	-5.10	6.73	7.34	-6.03	-5.62	6.82												
								System Yave								Sig Std Dev.	Ave. Var.		
								7.34								0.98	0.97		
																2 Sigma			
																1.969			

Data collected when using all three variables with a smaller pre-torque.



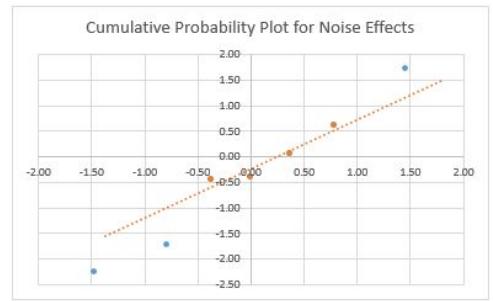
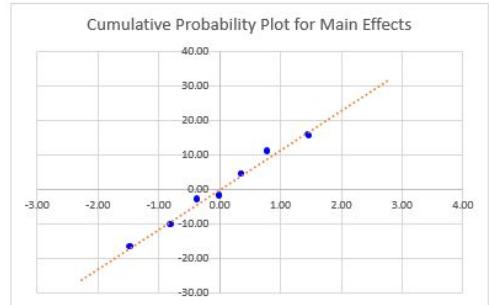
# Appendix

Variables		low	high																
Test	x1	x2	x3	x1x2	x1x3	x2x3	x1x2x3	Max (in)	Min (in)	Range1	Max2 (in)	Min2 (in)	Range2	Weight	Average Range	Std Dev.	Variance	Expected	Residual
1	-1	-1	-1	1	1	-1	-1	12.75	13.75	0.0	13.75	13.75	0.0	0.0	0.0	0.00	0.00	-21.36	21.361
2	-1	-1	1	1	-1	-1	1	23.8	15.5	8.3	24.50	15.80	8.7	0.0	8.5	0.28	0.08	12.64	4.133
3	-1	1	-1	-1	-1	1	-1	22.75	14	8.8	23.25	14.50	8.8	0.0	8.8	0.00	0.00	13.64	-4.989
4	-1	1	1	-1	-1	1	-1	21.6	18.9	2.7	22.00	17.90	4.1	10.0	3.4	0.99	0.98	-7.76	11.161
5	1	-1	-1	-1	-1	1	1	25	15	10.0	24.75	15.25	9.5	0.0	9.8	0.35	0.13	17.64	-7.989
6	1	-1	1	-1	1	-1	-1	25.75	13.25	12.5	25.00	14.00	11.0	2.0	11.8	1.06	1.13	25.64	-13.889
7	1	1	-1	1	-1	-1	-1	25.5	17.25	8.3	25.00	17.63	7.4	10.0	7.8	0.62	0.38	9.89	-2.077
8	1	1	1	1	1	1	1	25.375	18.5	6.9	25.25	18.13	7.1	12.0	7.0	0.18	0.03	6.64	0.361

Main:	E1	E2	E3	E12	E13	E23	E123	System Yave				Sys Std Dev.	Ave. Var.				
	15.66	-0.04	4.34	-10.34	-1.98	-10.99	11.04	7.12				0.58	0.34				
	100	100	100	100	100	100	100					2 Sigma	1.167060945				
Noise:	E1	E2	E3	E12	E13	E23	E123										
	0.60	0.06	1.71	-1.74	-0.41	-0.45	-2.25										

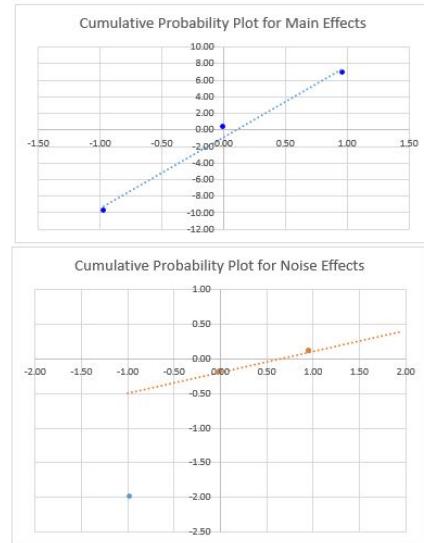
Data collected when using all three variables at best pre-torque.



# Appendix

Variables		low	high												
1. Spring Connection Radius		0.8 in	1.5 in												
2. Spring Constant		4.8 lbs/in	10 lbs/in												
Pretorqued to 2 1/4 in		2 1/4													
Test	x1	x2	x1x2	Max (in)	Min (in)	Range1	Max2 (in)	Min2 (in)	Range2	Weight	Average Range	Std Dev.	Variance	Expected	Residual
1	-1	-1	1	23.8	15.5	8.3	24.50	15.80	8.7	0.0	8.5	0.28	0.08	9.34	-0.837
2	-1	1	-1	21.6	18.9	2.7	22.00	17.90	4.1	10.0	3.4	0.99	0.98	-0.86	4.263
3	1	-1	-1	25.75	13.25	12.5	25.00	14.00	11.0	0.0	11.8	1.06	1.13	15.84	-4.088
4	1	1	1	25.375	18.5	6.9	25.25	18.13	7.1	12.0	7.0	0.18	0.03	6.34	0.663
Main:	E1	E2	E12	System Yave				Sys Std Dev. Ave. Var.							
	6.85	-9.85	0.35	7.66				0.74 0.55							
	1.00	1.00	0.00												
Noise:	E1	E2	E12					2 Sigma 1.488707493							
	0.10	-0.19	-1.99												

Simplified data using only spring constant and spring connection radius.



# Appendix

Variables		low	high														
Test	x1	x2	x3	x1x2	x1x3	x2x3	x1x2x3	Max (in)	Min (in)	Range1	Max (in)1	Min (in)2	Range2	Weight	Average Range	Std Dev.	Variance
1	-1	-1	-1	1	1	1	-1			0.0			0.0	0.0	0.00	0.00	
2	-1	-1	1	1	-1	-1	1			0.0			0.0	0.0	0.00	0.00	
3	-1	1	-1	-1	1	-1	1			0.0			0.0	0.0	0.00	0.00	
4	-1	1	1	-1	-1	1	-1			0.0			0.0	0.0	0.00	0.00	
5	1	-1	-1	-1	-1	1	1	23.375	12.375	11.0	22.13	15.56	6.6	15.0	8.8	3.14	9.85
6	1	-1	1	-1	1	-1	-1	25.375	14.1875	11.2	25.44	13.60	11.8	17.0	11.5	0.46	0.21
7	1	1	-1	1	-1	-1	-1			0.0			0.0	0.0	0.00	0.00	
8	1	1	1	1	1	1	1			0.0			0.0	0.0	0.00	0.00	

Tests 5 and 6 in the table above show the only two successful tests with the large cam, and the required weight for the table to move successfully.