Adjustable Aircraft Brake Simulator

Preliminary Detailed Design Review

Team P18371 - ‘Spring Brakers’

MEGGITT

MULTIDISCIPLINARY SENIOR DESIGN

Kate Gleason College of Engineering

Agenda

1. Objective
2. Starting Status
3. Preliminary Design
4. Calculations
5. Proof of Concept Design
6. BOM
7. Budget
8. POC Fabrication
9. POC Construction and Assembly
10. Test Plans
11. Risk Assessment
12. Scheduling and Future Plans

Objective

The goal of this phase is to fully flesh out our design concept and begin working on calculations and models.

To accomplish this, we:

1. Started calculations to determine spring constants
2. Designed and developed a scaled down prototype
3. Created CAD models for the preliminary design

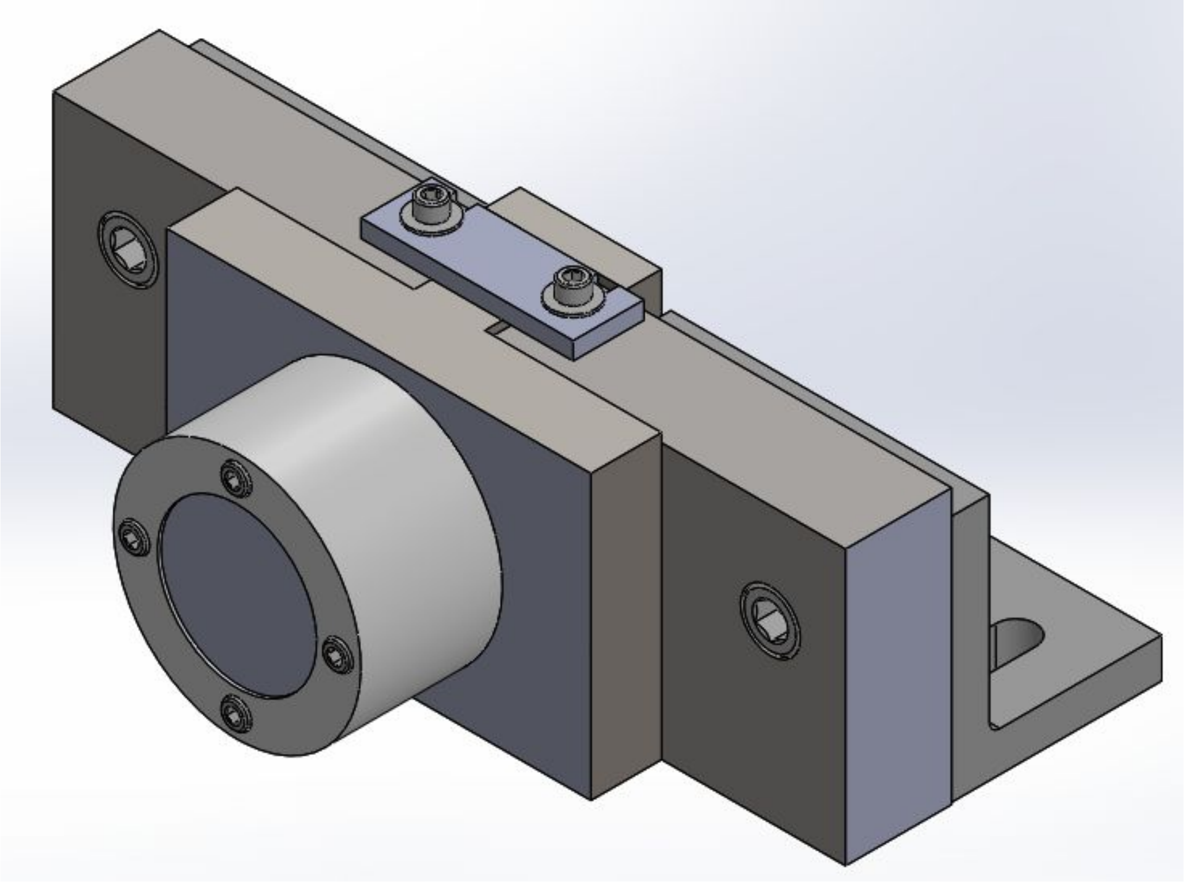
Starting Status

- Narrowed down our design concepts
- Removed spring wheel from possible concepts
- Selected the Cartridge System with Digital and Analog Data Acquisition

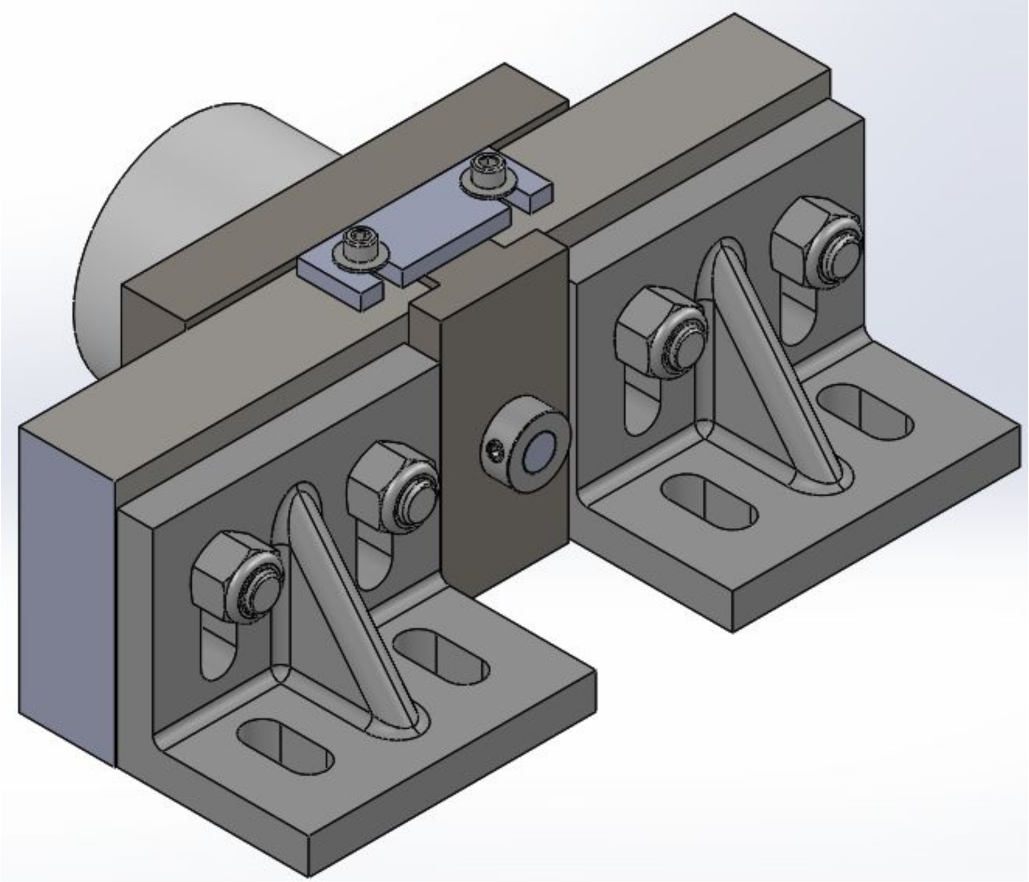
This design consisted of a hydraulic piston pushing against a set of springs which are held in a cartridge that could be switched out to select springs for different aircrafts.

Preliminary Design

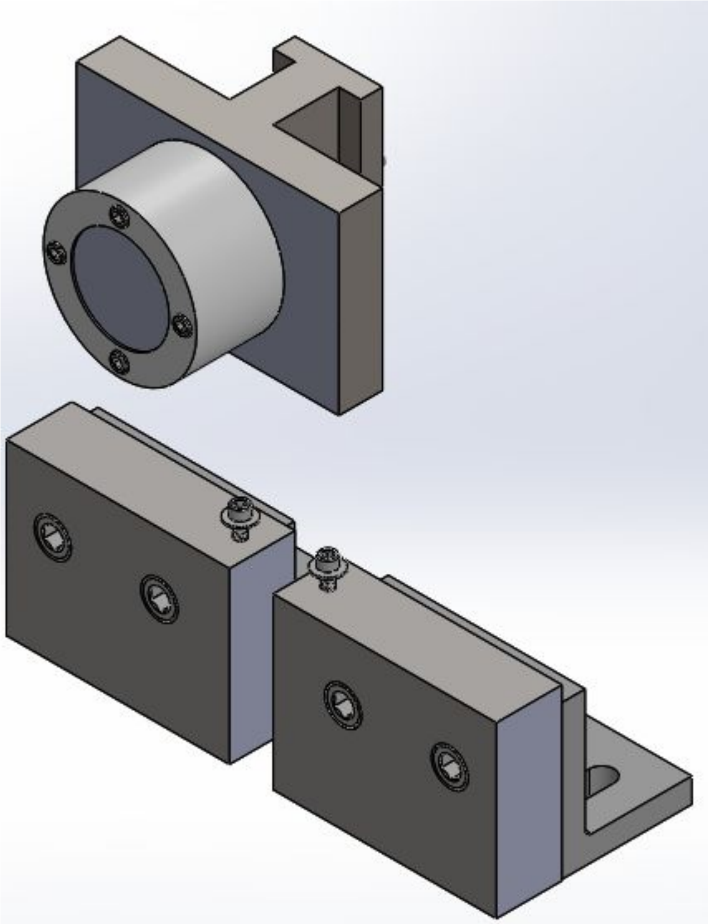
Cartridge Design



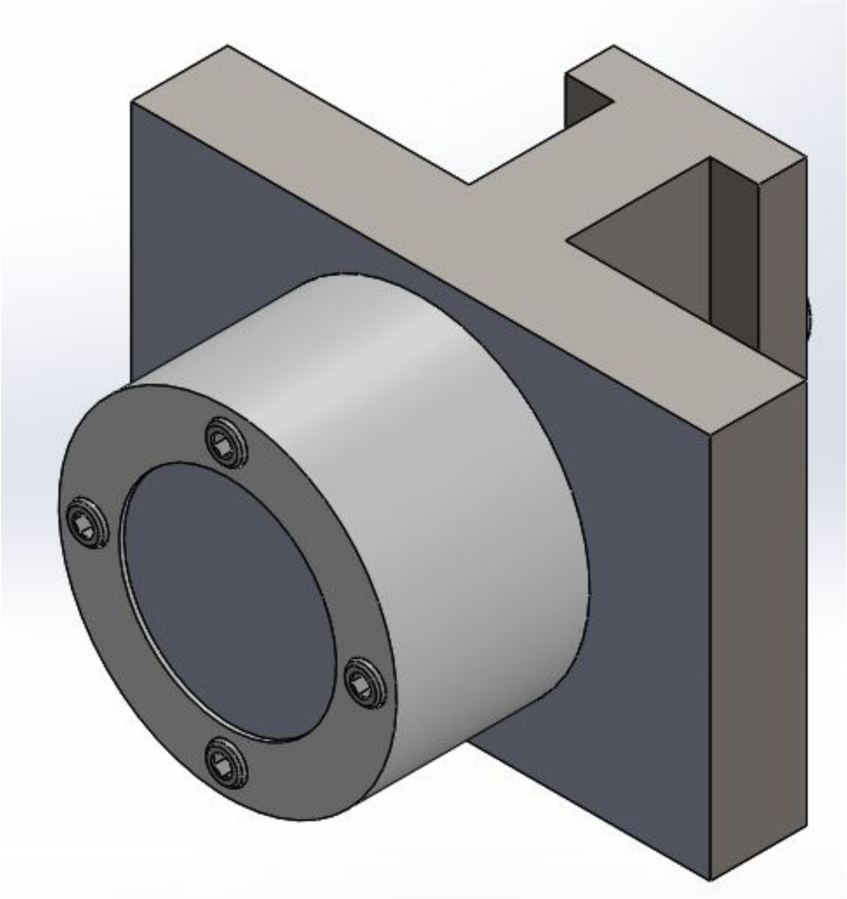
Cartridge Design



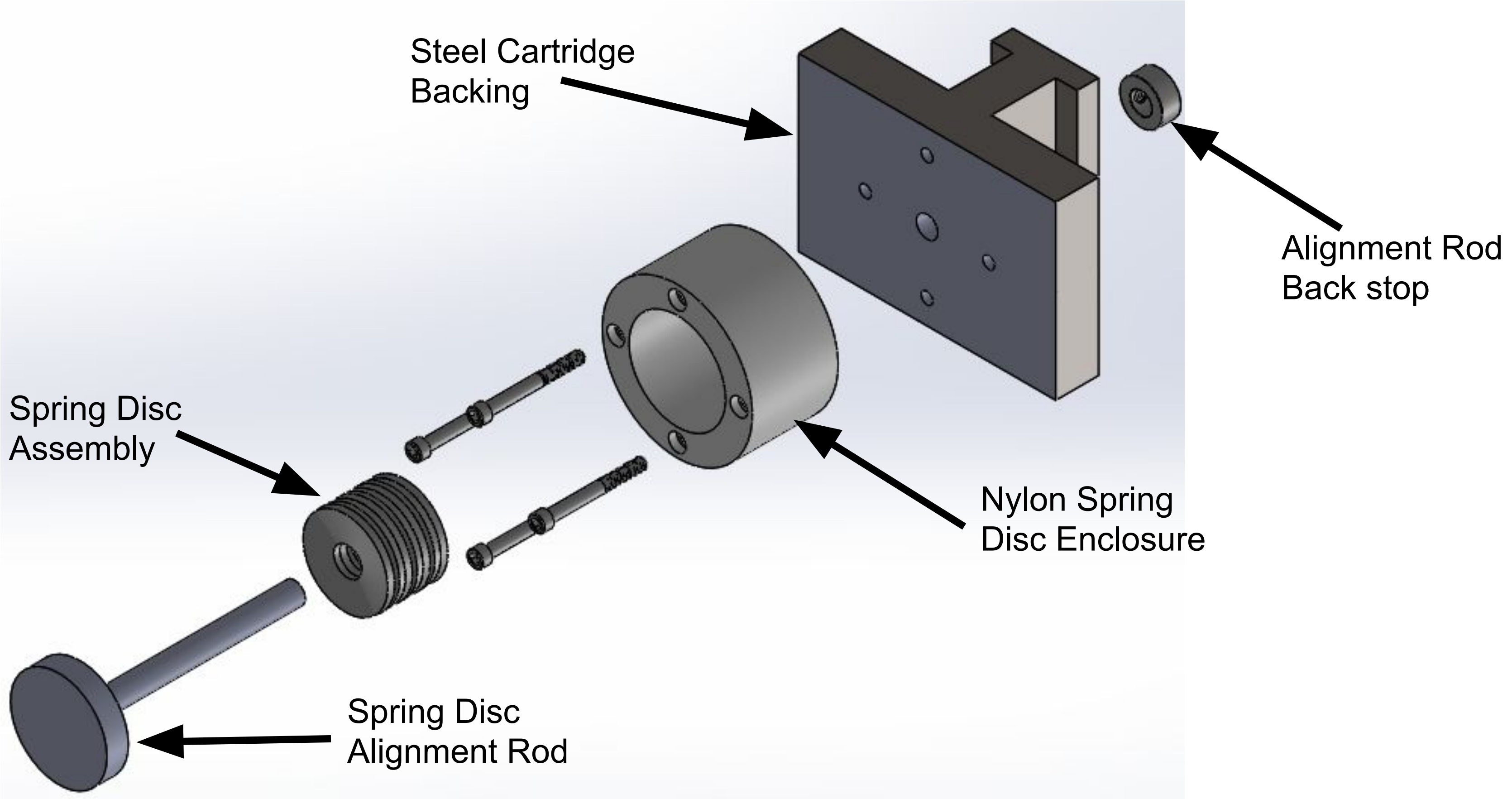
Cartridge and Housing



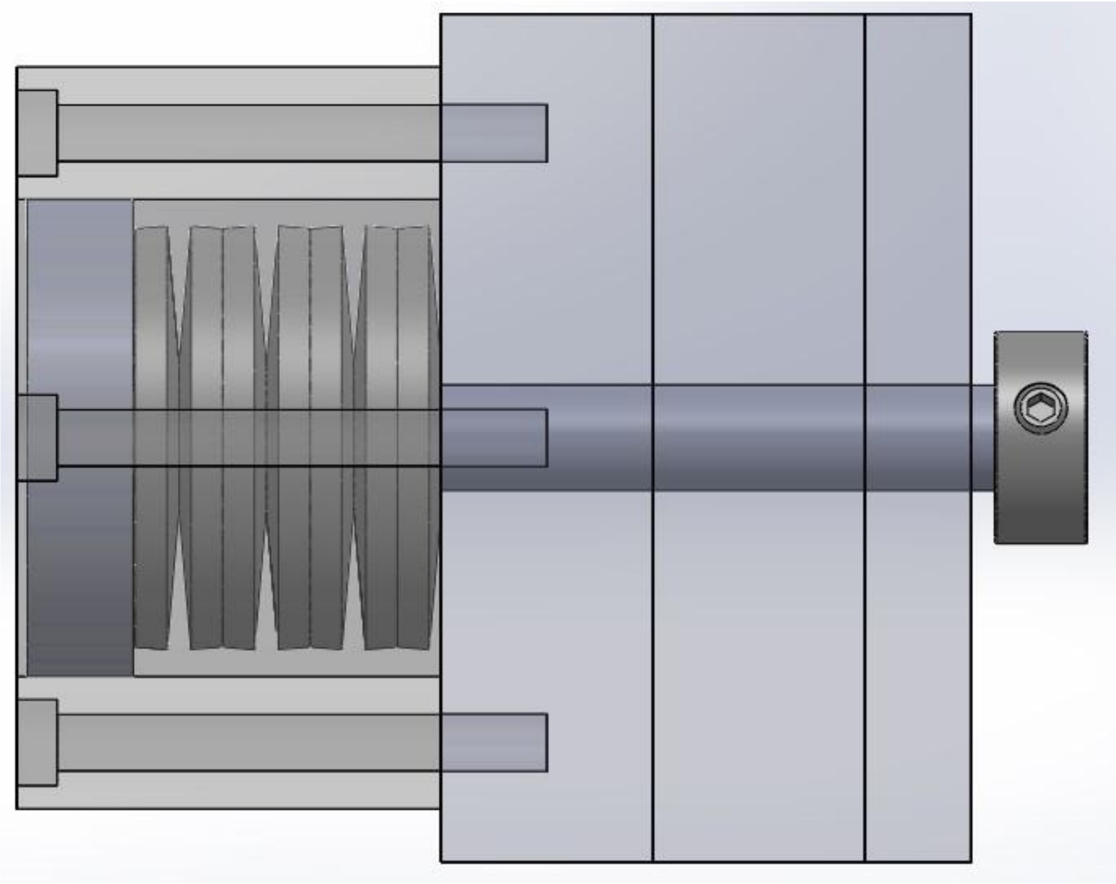
Brake Cartridge



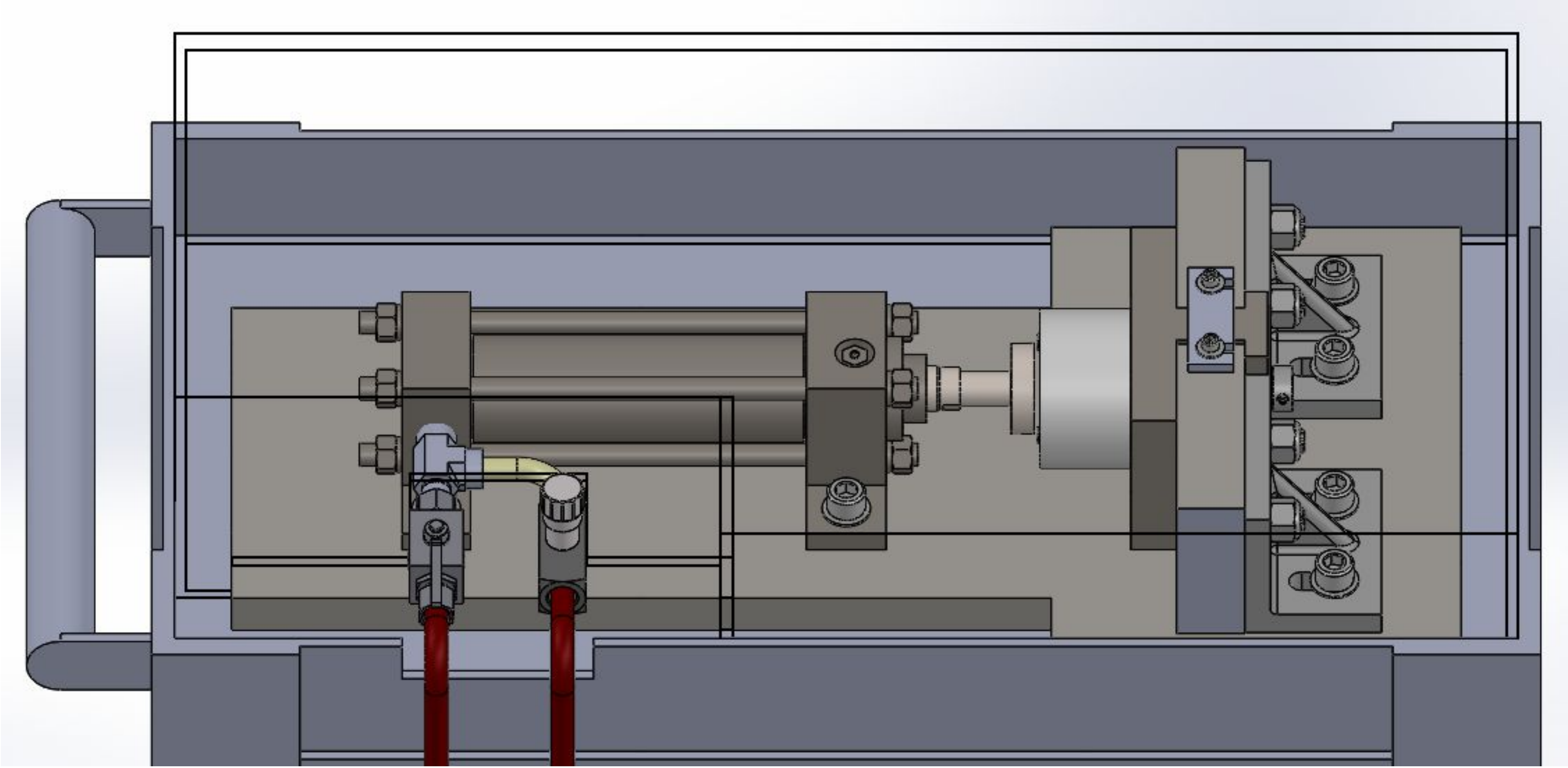
Cartridge Exploded View



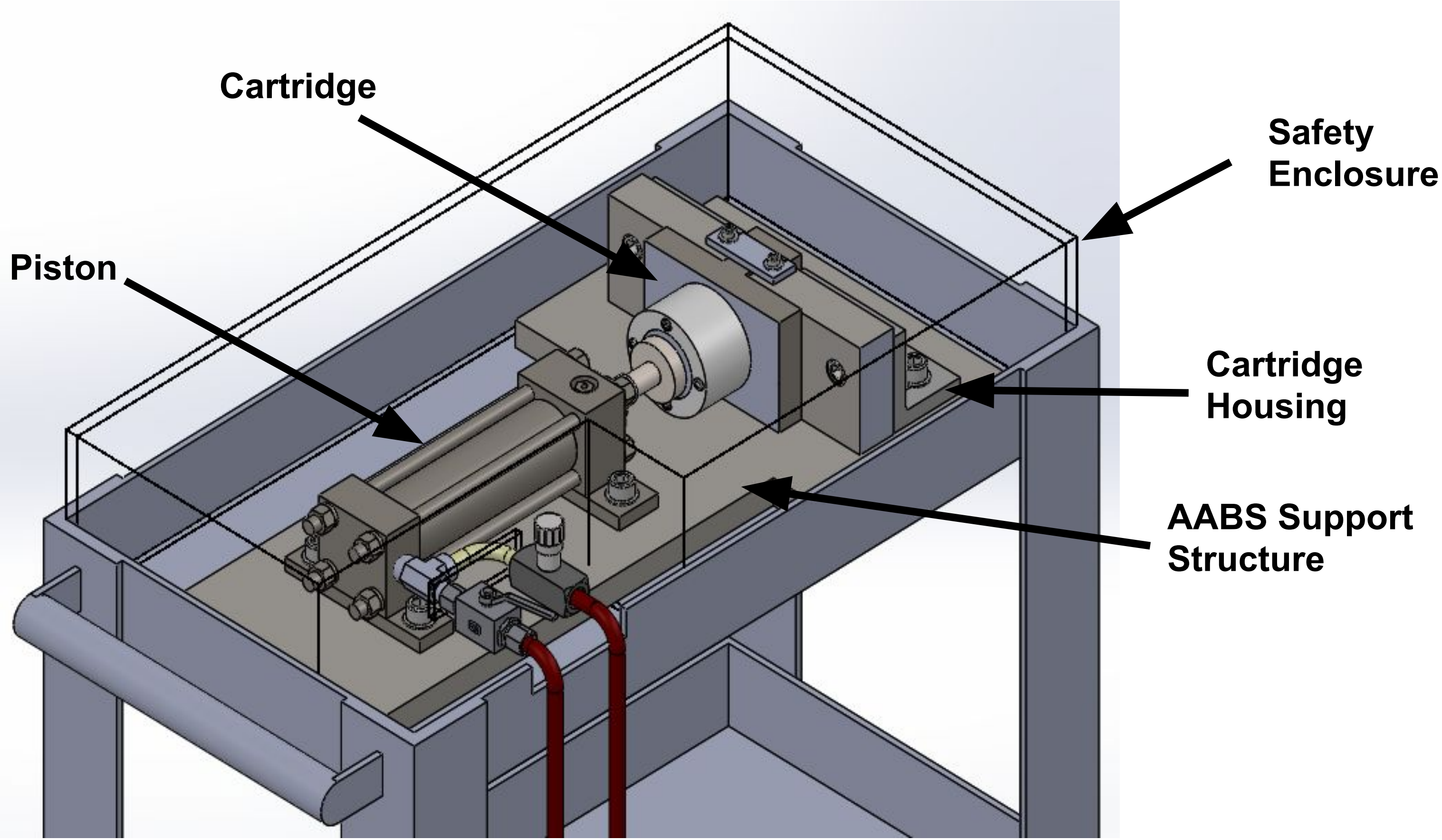
Cartridge Hidden View



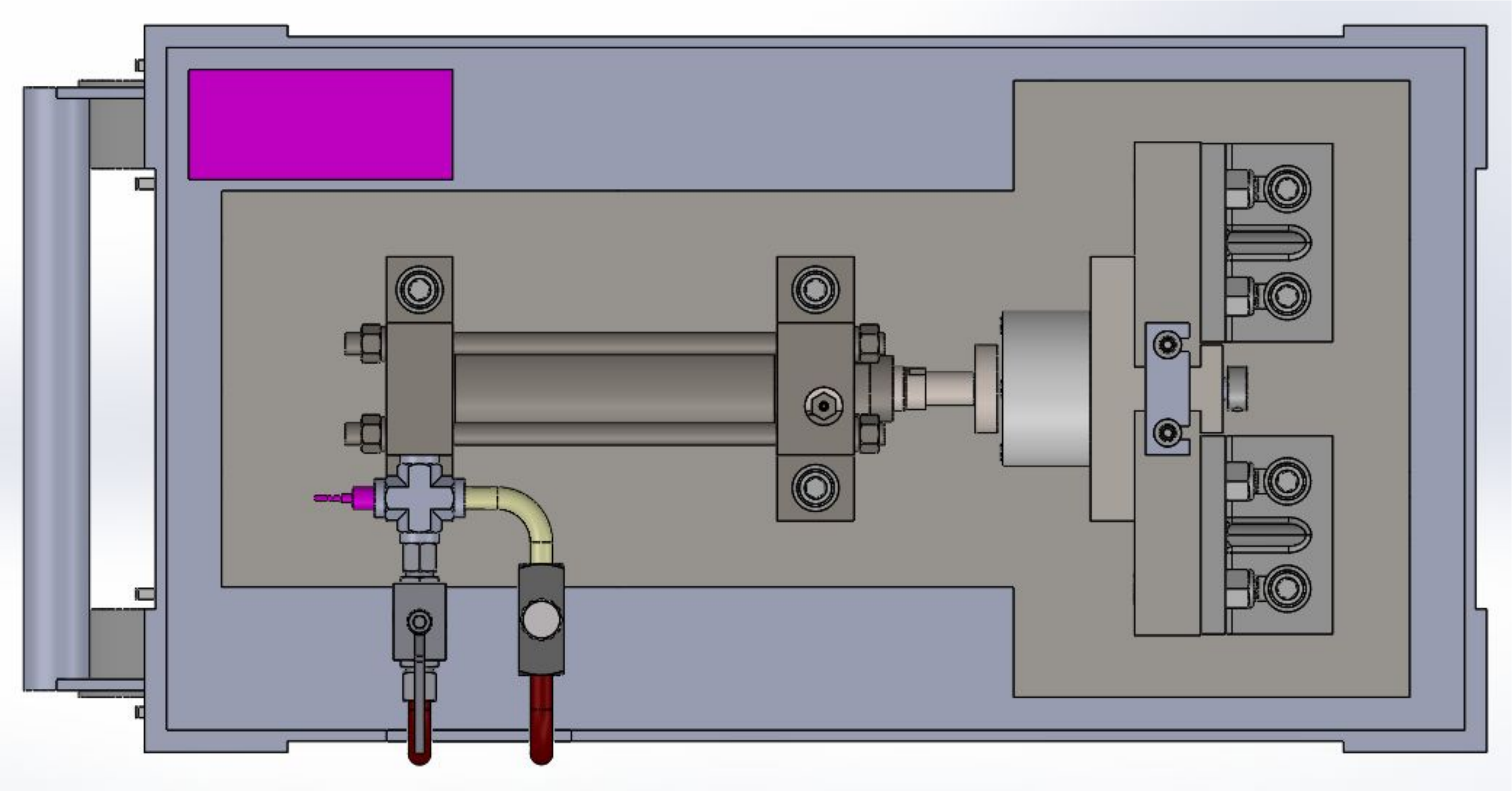
Cartridge and Piston



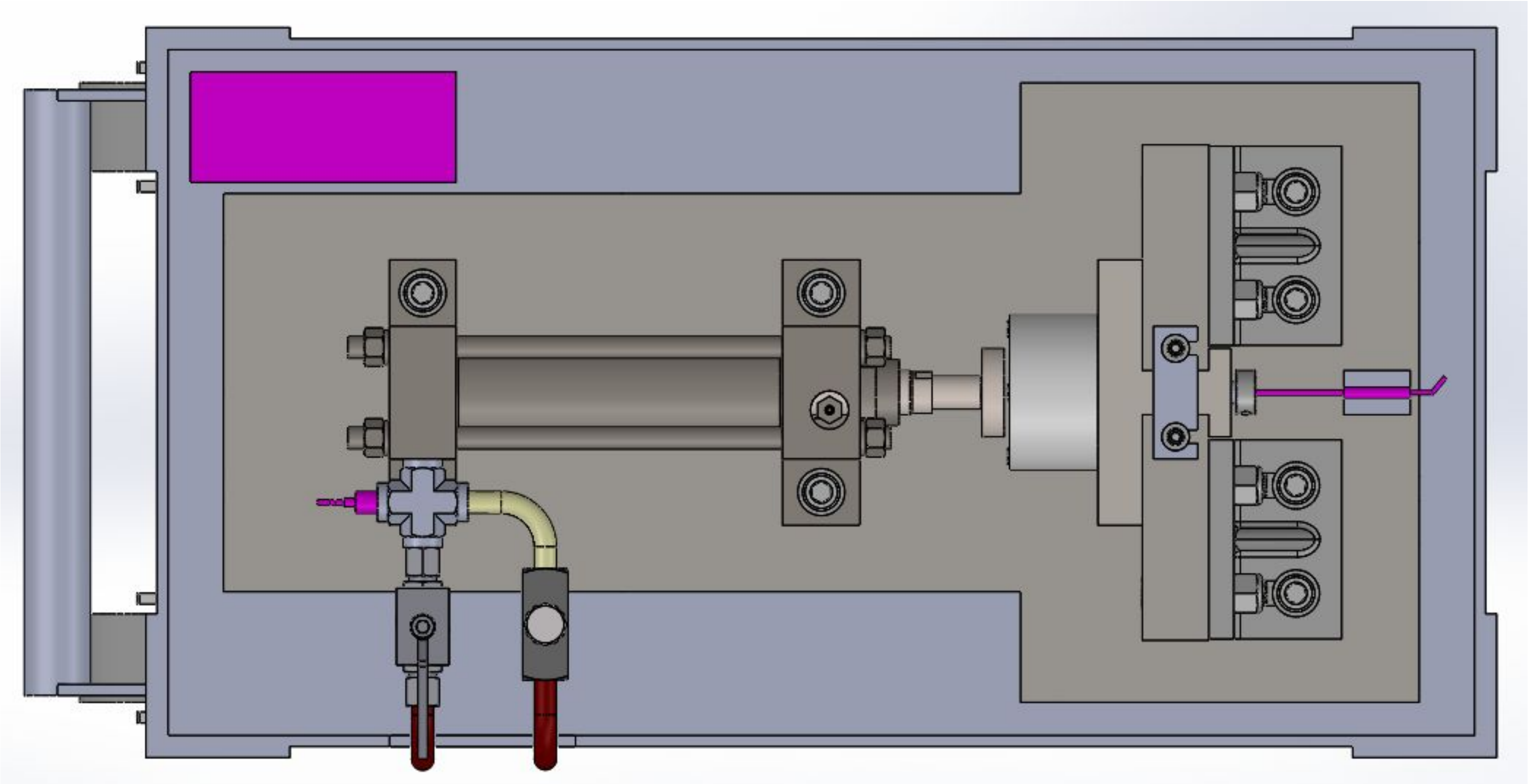
Isometric View



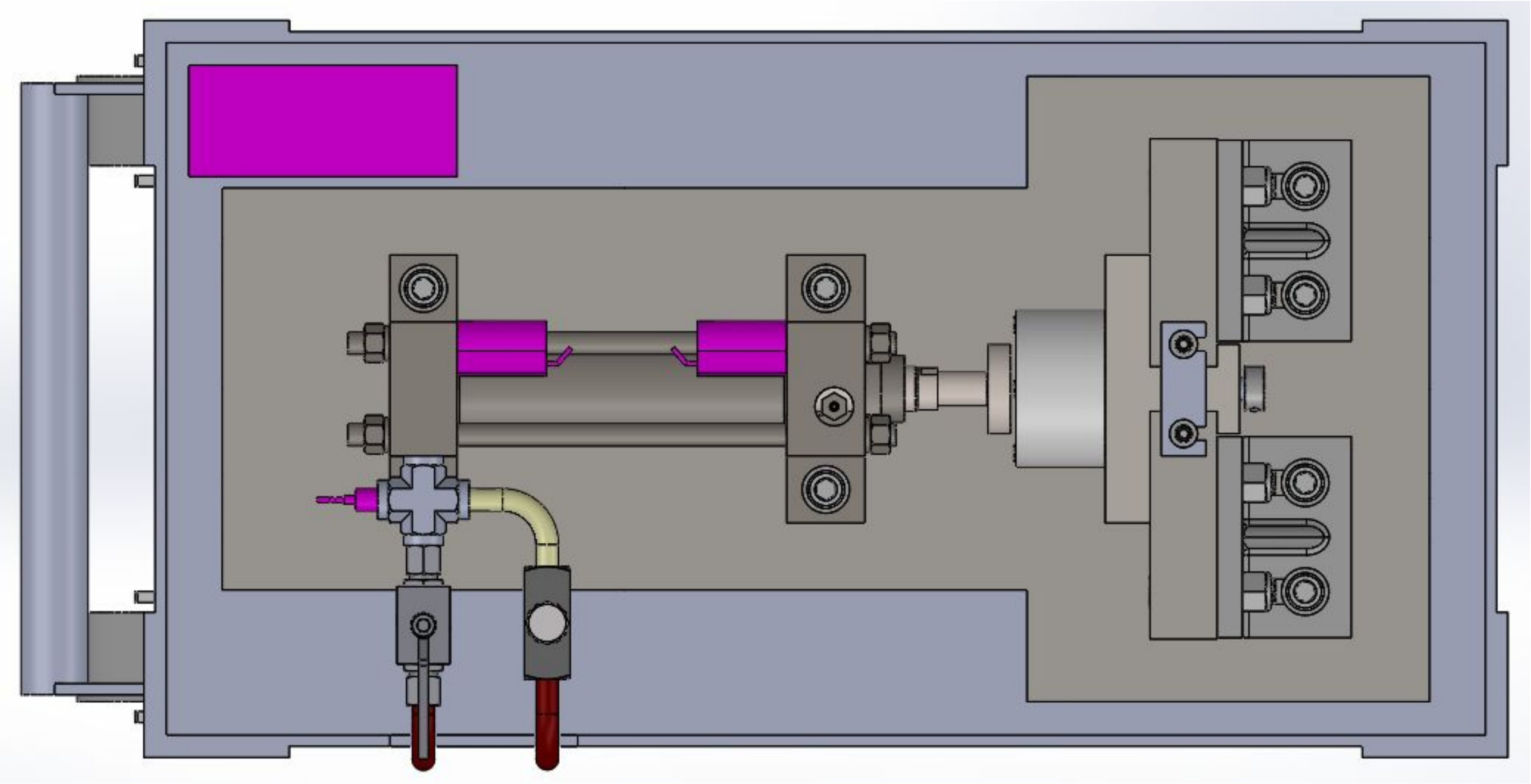
Pressure Transducer



Linear Potentiometer



Magnetic Position Sensor



Graduated Reservoir

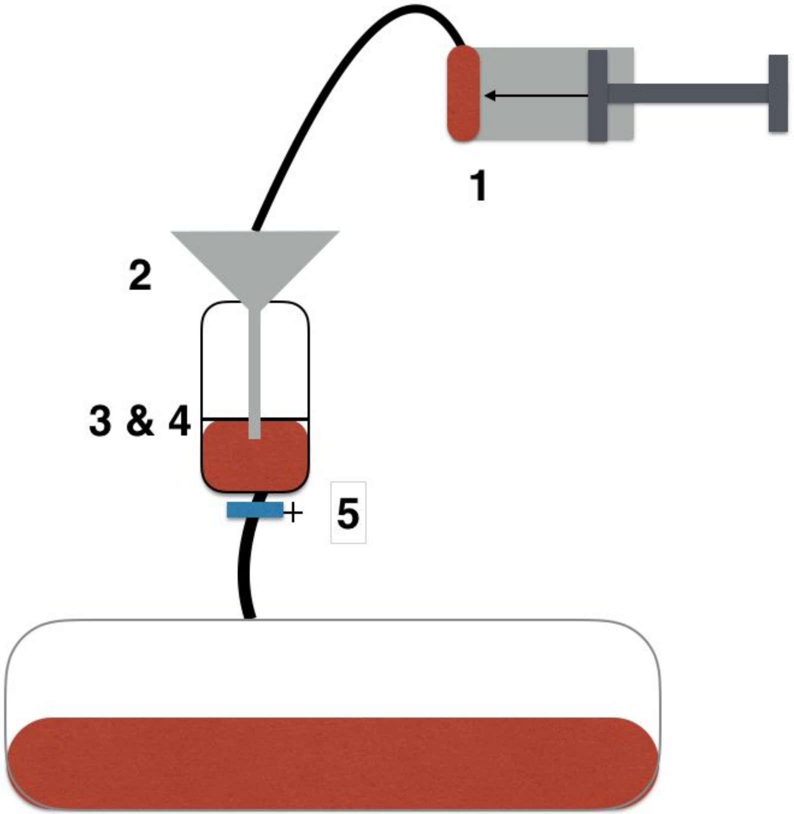
1. The piston will displace the fluid by creating pressure. This is the pressure inlet.

2. The fluid will run into a tub that siphons into the graduated cylinder and underneath a plate in the cylinder.

3. The lightweight plate will float up and the cylinder will have measurements.

4. The operator will read and record the measurement.

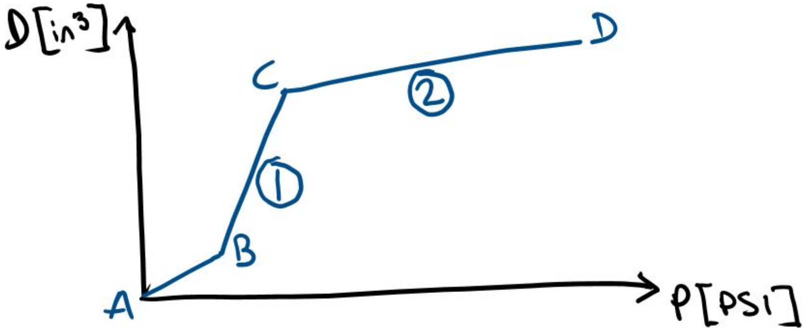
5. The operator will then open a pressure outlet valve and drain the fluid.



Calculations

Analysis

Given Information:



	P[psi]	D[in^3]
A	0	0
B	100	0.3051180502
C	225	4.271652702
D	3000	6.407479-54

Max pressure for POC model = 100 psi ; scale $P_{POC} = \frac{P_{actual}}{30}$

	P[psi]	D[in^3]	F(lbf) = A*P
A	0	0	0
B	3.333	0.172661	5.8905
C	7.5	2.41726	18.1295
D	100	3.62589	176.716

Where $A = \frac{\pi D^2}{4} = \frac{\pi(1.5in)^2}{4} = 1.76715\ in^2$.

Calculating spring constants required to mimic graph:

$$k = \frac{F}{X}$$

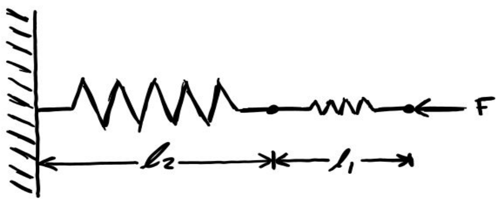
$$Spring\ (1): C - B = \frac{[18.1295 - 5.8905]lbf}{[2.41726 - 0.172661]in} = 5.45262\ lbf/in$$

$$Spring\ (2): D - C = \frac{[176.715 - 18.1295]lbf}{[3.62589 - 2.41726]in} = 131.171\ lbf/in$$

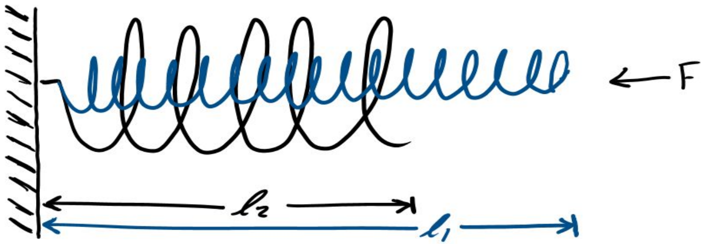
Analysis

Finding spring lengths for proposed POCs:

Case A – Schematic



Case B – Schematic



Analysis:

Using knowledge of spring combinations (series and parallel), the following values were obtained:

Case A

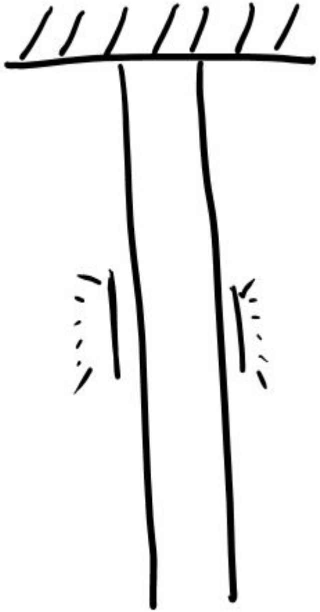
$$Spring\ 1: k = 5.5\frac{lbf}{in}$$
$$l = 2.42in = l_{total} - l_{compressed}$$
$$Spring\ 2: k = 135\frac{lbf}{in}$$
$$l = l_{total} - l_{compressed} = 1.21\ in$$

Case B

$$Spring\ 1: k = 5.5\frac{lbf}{in}$$
$$l = l_2 + 2.42$$
$$Spring\ 2: k = 129\frac{lbf}{in}$$
$$l = l_{total} - l_{compressed} = 1.21inch$$

Analysis

K=2, defines by boundary conditions E=69 GPa, modulus of elasticity



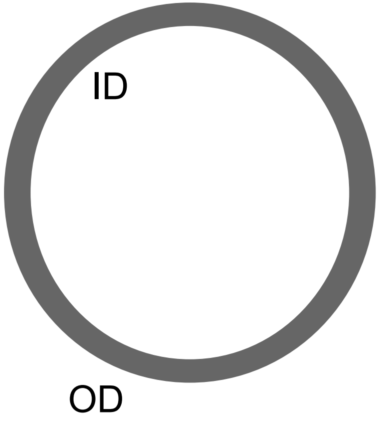
$$I = moment\ of\ inertia\ of\ cross - section$$

$$I_{circle} = \left[\left(\frac{OD}{2}\right)^4 - \left(\frac{ID}{2}\right)^4\right]\frac{\pi}{4}$$

$$P_{critical} = \frac{\pi^2 EI}{(KL)^2}$$

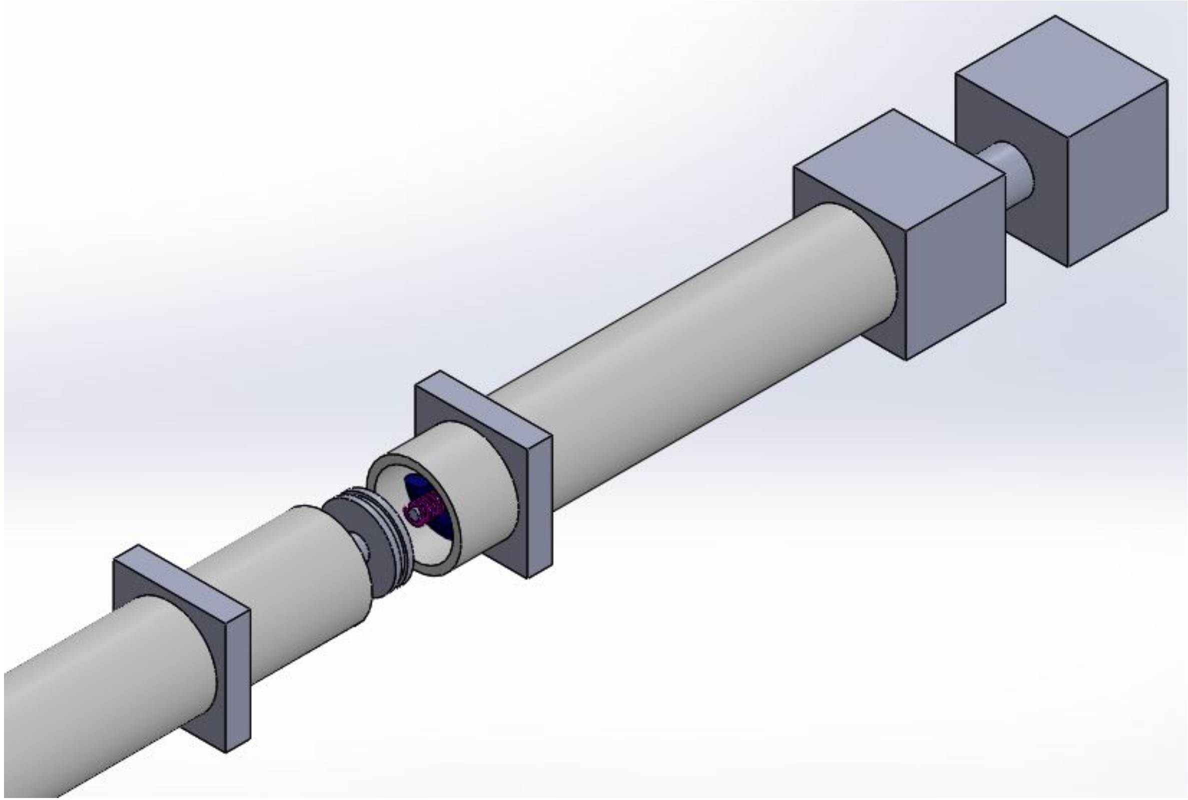
$$* \ as\ K = 2$$

$$* \ P_{critical} = \frac{4\pi^2 EI}{L^2}$$

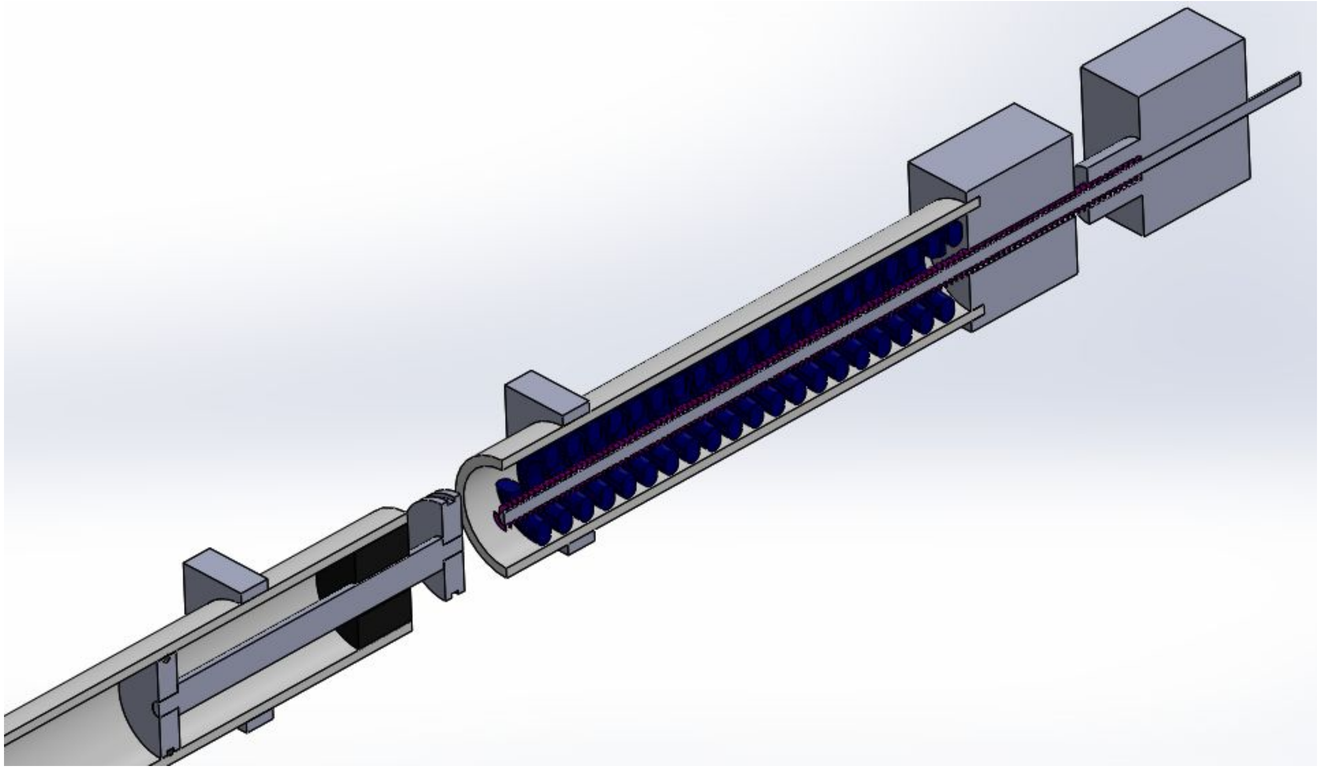


Proof of Concept Design

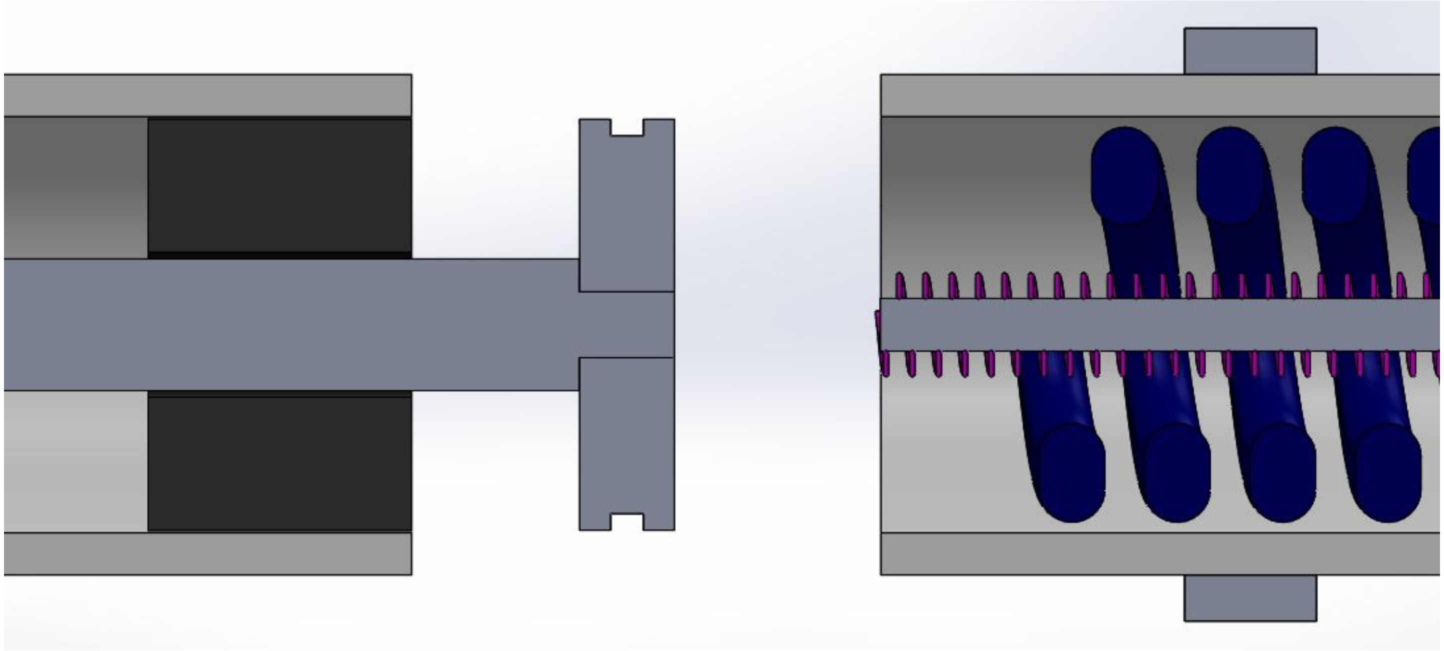
Prototype



Cross-Sectional View



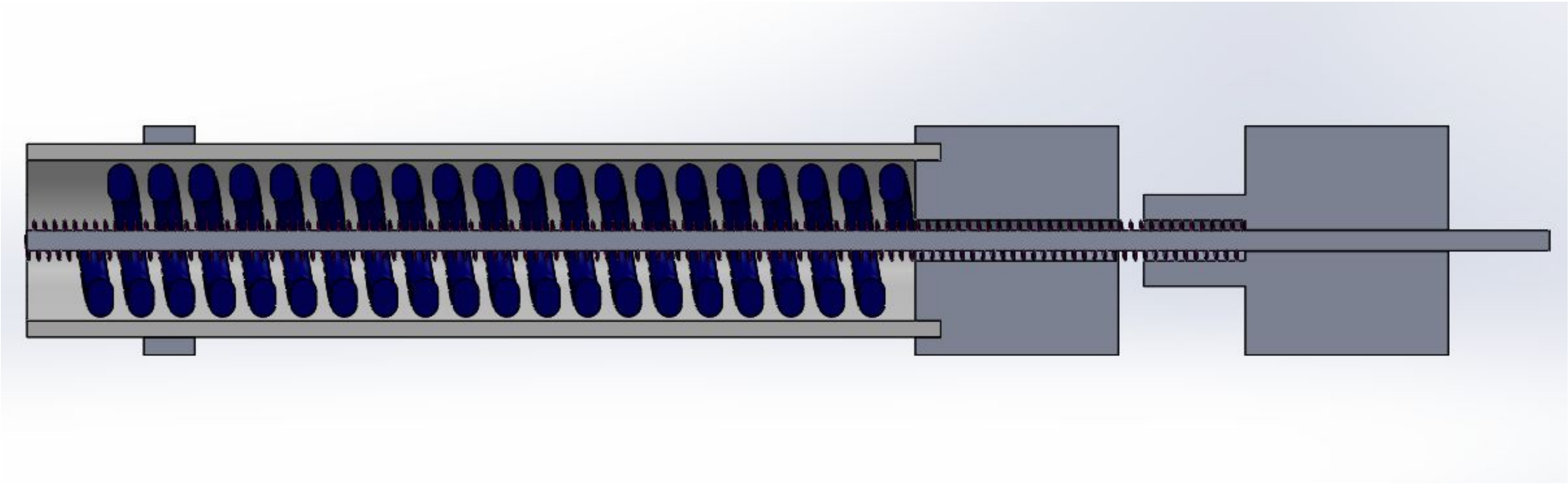
Piston and Springs



Piston Housing

Spring Housing

Spring Setup



Bill of Materials and Budget

Preliminary BOM

Assembly	Name	Price	Quantity	Total Price	Vendor	Prod. No.	Comments
Cartridge	3.5" OD 2" ID Nylon Tube	$52.25	2	$104.50	McMaster Carr	85005K282	Cartridge Housing
	1"x4"x6" 17-4 PH Stainless Steel Plate	$92.51	6	$555.06	McMaster Carr	88775K87	Cartridge Base
	1"x4"x6" 6061 Aluminum Plate	$19.64	6	$117.84	McMaster Carr	8975K242	Cartridge Base
	0.5" OD x 3' 4041 Steel Rod	$11.70	1	$11.70	McMaster Carr	8935K359	Cartridge Alignment Rod Shaft
	3" OD x 0.5" 4140 Steel Disc	$11.03	6	$66.18	McMaster Carr	8960K51	Cartridge Alignment Rod Cap
	1.5"x4"x1' 17-4 PH Stainless Steel Plate	$212.97	1	$212.97	McMaster Carr	88775K89	Cartidge Acceptor Plate
	3"x4.5"x3.5"- 4 Slots, Iron	$75.21	2	$150.42	McMaster Carr	2353A66	Angle Plate
	1'x1'x1" 6061 Aluminum Plate	$189.36	2	$378.72	McMaster Carr	7255K8	Base Plate
Cart	30"x16" Medium Duty Steel Cart	$125.73	1	$125.73	McMaster Carr	4633T41	Cart
Enclosure	24"x28"x.25" Polypropylene Sheet	$58.78	1	$58.78	McMaster Carr	8742K635	Safety Shield
Sensors	OMEGA PX309 Pressure Transducer	$198.00	1	$198.00	Omega	PX309-100GV	Sensor
	OMEGA .38" OD x 6" Travel Linear Potentiometer	$330.00	1	$330.00	Omega	LP804-01	Sensor
	4000hz 10Vmax Magnetic Position Sensor	$65.00	2	$130.00	IFM	MK5104	Sensor
Piston	Hydraulic Cylinder	$650.00	1	$650.00	Parker	TBD	Range from 300 to 1000
Springs	Large K Bellville Spring Discs	$19.32	3	$57.96	McMaster Carr	9712K89 or eqv.	(12 per pack)
	Small K Bellville Spring Discs	$9.39	3	$28.17	McMaster Carr	9712K443 or eqv	(12 per pack)
Pump	10,000PSI Hand Pump w/ Gauge	$74.99	1	$74.99	Northern Tool	46278	For testing at RIT only
Hydraulics	Hydraulic Hose - 12ft, 5000PSI	$78.15	1	$78.15	McMaster Carr	8646T23	Hydraulic Hose
	Hydraulic Restrictor	$20	1	$20	Lee Company	VDCA1415565D	14 Series Lee Visco Restrictor 0.055"
	Hydraulic Shutoff Valve, 3/8"	$41.75	1	$41.75	McMaster Carr	4715K43	Valve
	Hydraulic Needle Valve, 3/8"	$67.45	1	$67.45	Parker Hannifin	N600S	Needle Flow Control Valve
	Hydraulic Adapters, 3/8" , Steel, SAE	$200.00	1	$200.00	Parker Hannifin	TBD	Hydraulic Fittings and Adapters
	Hydraulic Oil	$26.00	1	$26.00	Phillips	TBD	Red Oil for testing
	Total			**$3,390.92**			

Proof of Concept BOM

Name	Price	Quantity	Vendor	Prod. No.
128 lbf/in K-Const. Spring	$28.72	1	MSC Direct	7661150
6 lbf/in K-Const. Spring	$14.88	1	MSC Direct	67898361
3/16" 3 ft. Steel Rod (Cut to 16 in.)	$3.68	1	The Home Depot	801577
9 in. PVC Pipe (Cartridge)	$0	1	-	-
12 in. PVC Pipe (Piston)	$0	1	-	-
12 in. 1.5" OD 1.35" ID Al-6061 Tube	$0	1	RIT Machine Shop	-
PVC End Cap	$0	1	-	-
140 psi. Bike Pump	$0	1	-	-
Bike Tire Air Valve	$0	1	-	-
Small Spring 3D-Printed Housing	$1.43	1	RIT Construct	-
Cartridge PVC 3D Printed-Housing	$1.40	1	RIT Construct	-
1.5" OD 3D Printed Static Busing	$0.43	1	RIT Construct	-
1/2" Thick PVC 3D Printed Support	$0.29	3	RIT Construct	-
6061-Al 1.5" OD Piston Head	$0	1	RIT Machine Shop	-
3/8-16 UNC Thread 6061-Aluminum Rod	$0		RIT Machine Shop	
1/8" Gland Diameter O-Rings (Pack)	$4.99	1	Pep Boys	-
3/8-16 UNC Steel Lug nut	$0	1	RIT Machine Shop	-
Total:	**$55.82**			

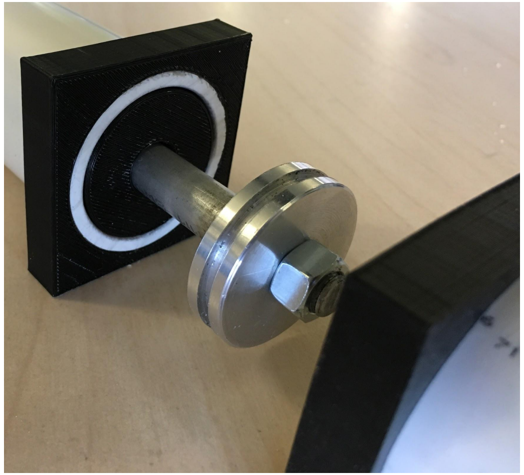
Summarized Budget

Budget			
Customer: Meggitt		*Prepared by: P18371 Spring Brakers*	
Product: Adjustable Aircraft Brake Simulator		*Date: 04/05/2018*	
Order/Expense	**Date**	**Cost**	**Available Budget**
Meggitt Visit	February 16, 2018	287.00	**6251.46**
POC	April 02, 2018	70.62	
Preliminary Design	April 4, 2018	3390.92	
	Total	3748.54	

POC Fabrication

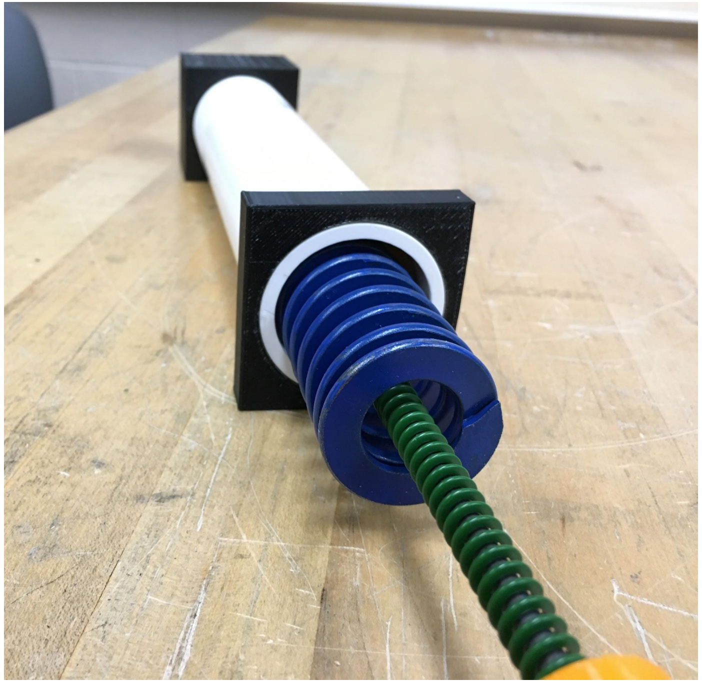
Piston

1. Lathe round 6061-Al stock to 1.56 in. OD
2. ⅛ in. wide parting tool used to produce O-ring groove 0.15 in. deep
3. Both piston heads cut to 0.36 in. long using parting tool
4. 5/16 in. hole threaded with ⅜-16 UNC thread for piston shaft
5. ½ in. 0.1 in deep hole bored to allow for press fit of 0.5 in OD. centering tube
    a. Tube allow for smooth travel through 3D printed static bushing
6. Both Piston heads are press fit into position and rod is threaded through
7. O-ring placed in air-side piston head
8. Mounting fixtures are 3D printed for clamping to testing surface



Cartridge

1. PVC pipe length cut to 9 in. to allow for proper piston travel
2. Cap is drilled for bike pump air valve, epoxy applied to secure
3. 3D printed base and mounting fixtures comprise base structure
4. Spring housing is 3D printed to rest behind main assembly
5. 3/16 in. shaft sits in assembly to retain longer spring’s rigidity



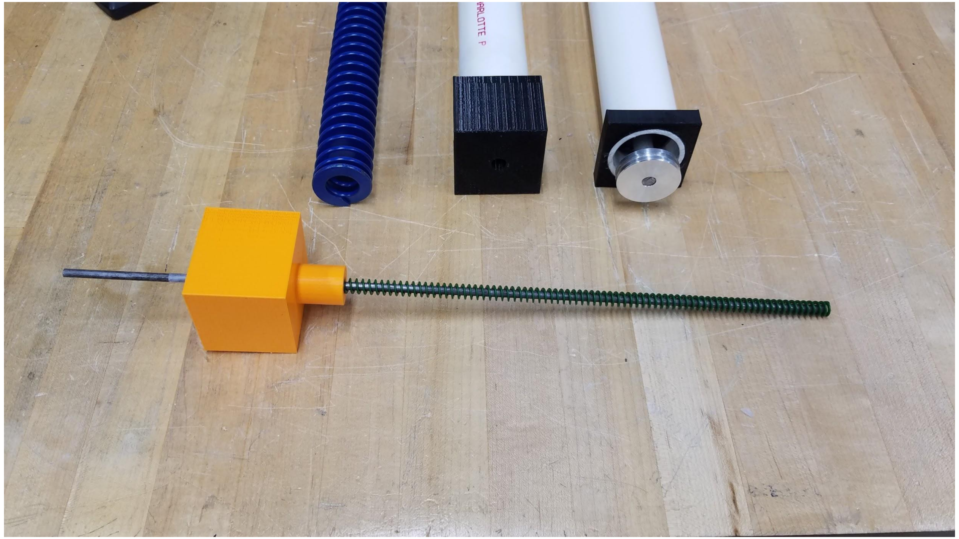
POC Construction

Construction of Prototype

Materials:

1. Bike Pump (up to 140 psi)
2. Small Spring Base (orange)
3. Green die spring
4. Rod to prevent buckling
5. Blue die spring
6. Spring housing
7. Piston and Piston housing
8. O-ring

Construction of Prototype

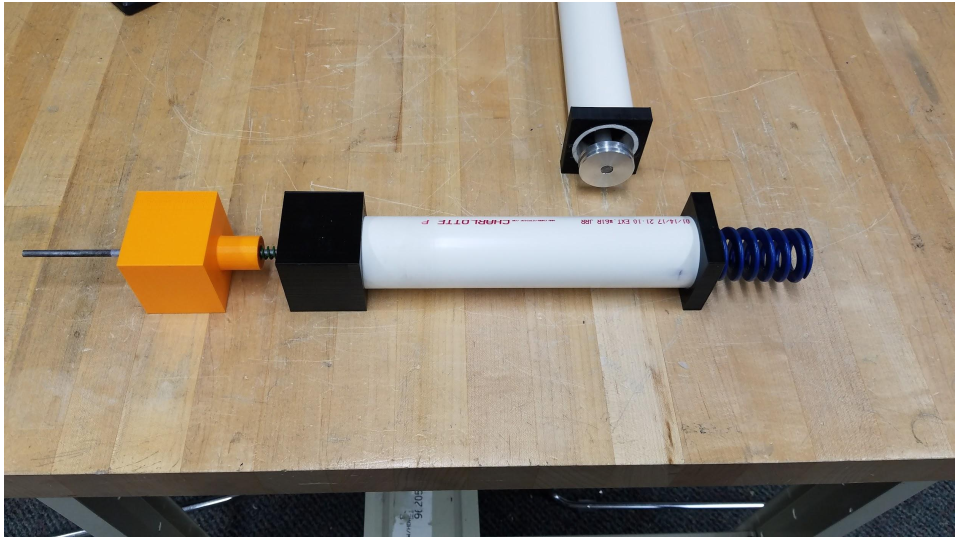


Step 1:

Put the green spring inside the small spring base.

Slide rod through the base and green spring.

Construction of Prototype



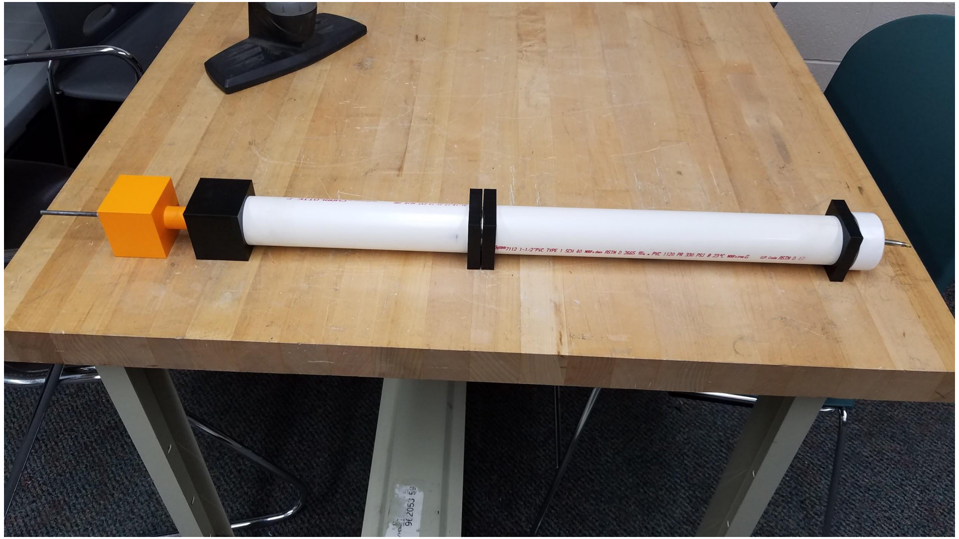
Step 2:

Slide rod and green spring through hole in the spring housing block.

Push small spring base flush against the black block.

Slide blue spring inside the spring housing.

Construction of Prototype



Step 3:

Place the piston and the piston housing flush against the spring housing.

Clamp the blocks to the table to prevent movement and separation (not shown).

Construction of Prototype

Step 4:

Attach bike pump to valve.

At this point, the prototype is complete and testing can begin, once proper safety measures are taken.

Results

TBD

During testing the team was made aware of the limitations of PVC usage with respect to containing compressed gases

Therefore, the piston housing is now composed of an aluminum-6061 tube (1.5” OD, 1.35” ID)

Testing will be conducted at the beginning of Phase 4

Test Plans

Test Plan Steps

Once the Proof of Concept is completed, the following test plan will be performed.

1. Position the blocks as specified by spring lengths as noted.
2. Pressurize the tank to approximately maximum pressure ~90-100 psi.
3. Record pressure measurement off bike pump gauge as well as displacement with dial caliper.
4. Using valve, decrease the pressure with small increments. Record pressure and displacement measurements.
5. Repeat until piston is no longer pressurized.

Risk Assessment

Added Risks

ID	Category	Risk Item	Effect	Cause	Likelihood	Severity	Importance	Action to Minimize Risk	Owner
21	Prototype	Explosion of piston housing	Danger to team members, damaged equipment	Using air, which is compressable	3	9	27	Wear safety goggles and stand clear when testing. Pressurize slowly	Team
22	Prototype	Leakage	Prototype won't work properly	The seals on the piston and bike pump hose aren't tight enough, the 3D printed parts have gaps for air to escape from	3	6	18	Make sure seals are tight. 3D print the blocks thick enough. Check for leakeage will testing	Team
23	Prototype	Doesn't give us a curve	We need to rethink our entire design	Inaccurate assumptions about the designs/calculations	3	9	27	None - this is why we're making the prototype	Team
24	Technical	Can't use springs due to K value and displacement being inversely proportional	We'll have to switch to spring disks	Natural effect of the numbers and our design	6	3	18	Check expected values of springs and see if they're feasible	Team
25	Technical	Can't measure spring disks displacement	Won't be able to get accurate displacement data	Spring disks are very small	3	3	9	Use the graduated reservoir idea to measure volumetric displacement	Team

Updated Risks

ID	Category	Risk Item	Effect	Cause	Likelihood	Severity	Importance	Action to Minimize Risk	Owner	Reason for change
5	Technical	Spring wheel doesn't "lock" in place	Actuator won't hit springs directly, which could cause more deformation	Poor design	1	3	3	Design wheel so it must "lock" in certain positions	Team	
5	Technical	Spring wheel doesn't "lock" in place	Actuator won't hit springs directly, which could cause more deformation	Poor design	0	0	0	Design wheel so it must "lock" in certain positions	Team	No longer using a spring wheel
18	Misc	Simulator is too large	Simulator is hard to move around, use, and hook up to the hydraulic rig	Poor design	1	3	3	Consider the size of the simulator early in the design phase	Team	
18	Misc	Simulator is too large	Simulator is hard to move around, use, and hook up to the hydraulic rig	Poor design	3	3	9	Consider the size of the simulator early in the design phase	Team	One of the springs for the prototype is a foot long. The sizes for the real version look longer
21	Prototype	Explosion of piston housing	Danger to team members, damaged equipment	Using air, which is compressable	3	9	27	Wear safety goggles and stand clear when testing. Pressurize slowly	Team	
21	Prototype	Explosion of piston housing	Danger to team members, damaged equipment	Using air, which is compressable	6	9	54	Wear safety goggles and stand clear when testing. Pressurize slowly	Team	Testing showed that our initial seal was not as strong as we had hoped. We have added epoxy to increase the strength

Schedule and Future Plans

Phase 3 Plan

Task Name	Duration	Start	Finish	% Complete	March 4 - 10	March 11 - 17	March 18 - 24	March 25-31	April 1 - 7
Proof of Concept	**17 days**	**Tue 3/6/18**	**Tue 3/27/18**	93					
Discuss verification technique	1 day	Tue 3/6/18	Wed 3/7/18	100					
Hardware Design	17 days	Tue 3/6/18	Tue 3/27/18	80					
Calculations - dimensions and forces for fun	2 days	Tue 3/6/18	Thu 3/8/18	100					
Schematics of electrical components	2 days	Tue 3/6/18	Thu 3/22/18	N/A					
Request Meggitt resistance values	3 days	Tue 3/6/18	Fri 3/9/18	100					
Research and Benchmark components	12 days	Thu 3/8/18	Tue 3/20/18	100					
BOM and budget analysis	12 days	Thu 3/8/18	Tue 3/20/18	100					
Test/Analyze subsystems	3 days	Tue 3/20/18	Thu 3/22/18	0					
Refine design	1 day	Thu 3/22/18	Fri 3/23/18	N/A					
Software Design	3 days	Tue 3/6/18	Fri 3/9/18	100					
Determine is software is necessary	1 day	Tue 3/6/18	Wed 3/7/18	100					
Select programming language	2 days	Tue 3/6/18	Thu 3/8/18	N/A					
High level software design	2 days	Tue 3/6/18	Thu 3/8/18	N/A					
User interface brainstorm	1 day	Thu 3/8/18	Fri 3/9/18	N/A					
Detailed Design of System from POC	**6 days**	**Tue 3/27/18**	**Thu 3/29/18**	100					
Redefine systems architecture	2 days	Fri 2/23/18	Tue 3/27/18	100					
BOM and budget analysis for prelim. Design	2 days	Fri 2/23/18	Tue 3/27/18	100					
Develop a detailed design	6 days	Fri 2/23/18	Thu 3/29/18	100					
Risk Assessment and troubleshooting plans	**5 days**	**Thu 3/29/18**	**Tue 4/3/18**	100					
Develop assessment of risk according to detaile	2 days	Thu 3/29/18	Tue 4/3/18	100					
Generate plans for all possible failure points	3 days	Thu 3/29/18	Tue 4/3/18	100					
Phase 3 Review	**1 day**	**Tue 4/3/18**	**Thu 4/5/18**	75					

Phase 4 Plan

Task Name	Duration	Start	Finish	% Complete	Resources	Predecessors	April 8 - 14	April 15 - 21	April 22 - 28
Redefined POC model and Testing	**7 days**	**Fri 4/6/18**	Thu 4/12/18	50	Team				
Complete Detailed Design	**12 days**	**Tue 4/10/18**	**Sat 4/21/18**	0					
Redifine Preliminary Design	12 days	Tue 4/10/18	Sat 4/21/18	0	Team				
Evaluate preliminary design	3 days	Tue 4/10/18	Thu 4/12/18	0	Team				
Determine modification of prelim. Design	3 days	Tue 4/10/18	Thu 4/12/18	0	Team	4			
Update design	5 days	Thu 4/12/18	Tue 4/17/18	0	Team	5			
Benchmark and select specific components	8 days	Thu 4/12/18	Thu 4/19/18	0	Team	5			
Modify CAD drawings	3 days	Tue 4/17/18	Thu 4/19/18	0	Evan,Mike,Lily	6			
Check if design meets all requirements	12 days	Tue 4/17/18	Thu 4/19/18	0	Team				
Redefine Design (if necessary)	3 days	Thu 4/19/18	Sat 4/21/18	0	Team	9			
Planning and Scheduling	**7 days**	**Tue 4/17/18**	**Mon 4/23/18**	0					
Generate plans for building design	4 days	Tue 4/17/18	Fri 4/20/18	0	Team				
Generate test plans	7 days	Tue 4/17/18	Mon 4/23/18	0	MEs				
Create MSDII Plans	4 days	Fri 4/20/18	Mon 4/23/18	0	Elias	13			
Budgeting	**7 days**	**Tue 4/17/18**	**Mon 4/23/18**	0					
Detail BOM	4 days	Tue 4/17/18	Fri 4/20/18	0	Tony				
Update/Analyze budget	4 days	Tue 4/17/18	Fri 4/20/18	0	Tony				
Purchase all hardware for MSDII	3 days	Sat 4/21/18	Mon 4/23/18	0	Tony	7			
Risk Assessment	**8 days**	**Thu 4/12/18**	**Thu 4/19/18**	0					
Revisit Risk Assessment	8 days	Thu 4/12/18	Thu 4/19/18	0	Sabrina,Lori				
Develop troubleshooting plans	8 days	Thu 4/12/18	Thu 4/19/18	0	Sabrina,Elias				
Document on EDGE	**6 days**	**Thu 4/19/18**	**Tue 4/24/18**	0	Garrett				
Phase 4 Review	**3 days**	**Tue 4/24/18**	**Thu 4/26/18**	0	Team	2,11,15,19			

Complete Detailed Design

2 Weeks

Redefine Detailed Design

- Evaluate Preliminary Design
- Determine modifications of Prelim. Design
- Benchmark and select specific components
- Update Design
- Modify CAD Drawings
- Check if design meets all requirements
- Redefine Design (if necessary)

Planning & Scheduling

Budgeting

Risk Assessment

Complete Detailed Design

Planning & Scheduling

- Generate plans for building prototype
- Generate test plans
- Create MSDII Plans

Budgeting

- Detail BOM
- Update/ Analyze budget
- Purchase all hardware (MSDII)

Risk Assessment

- Revisit Risk Assessment
- Develop troubleshooting plans

Lessons Learned

- **Team size:** For concrete solutions we can break into smaller groups. For brainstorming we need the whole team
- **Calculating spring constants:** They are higher than expected. We should scale the pressure, not displacement
- **Lead time:** It takes time for MSD to process orders
- **Testing:** Plan for the worst case scenario, always
- **PVC pipe:** PVC can not be pressurized with air in POC- replace with Al-6061
- **Before summer break:** Create a report that summarizes where we are

Questions?