Personal Fire Escape System

December 8, 2020

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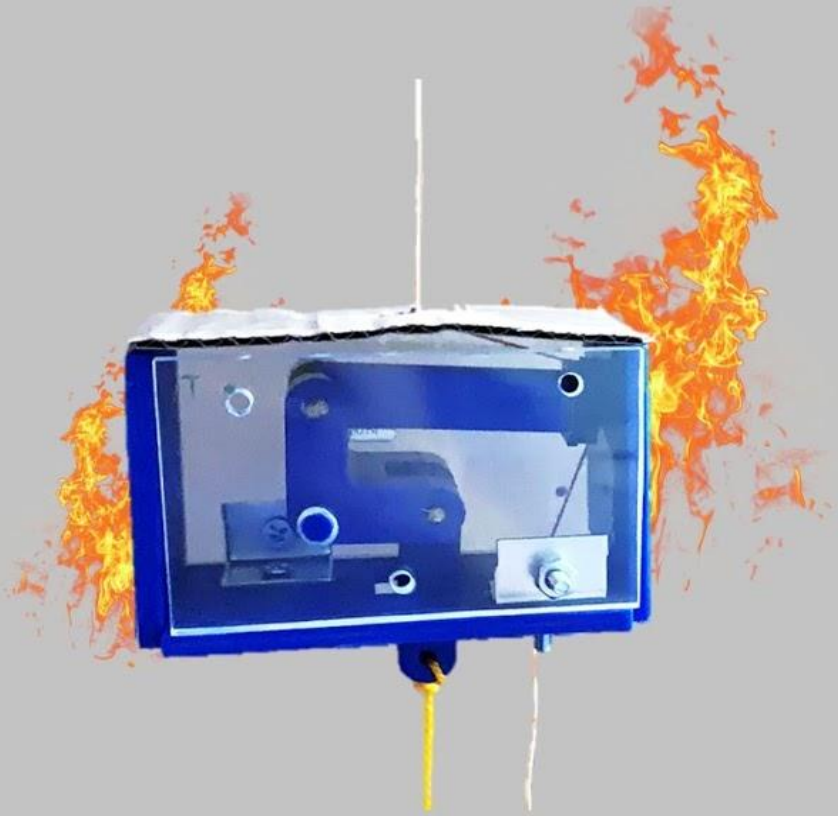
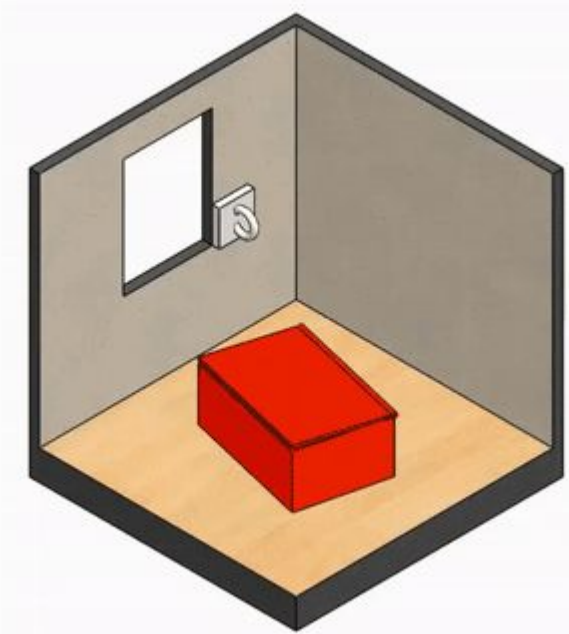


Agenda

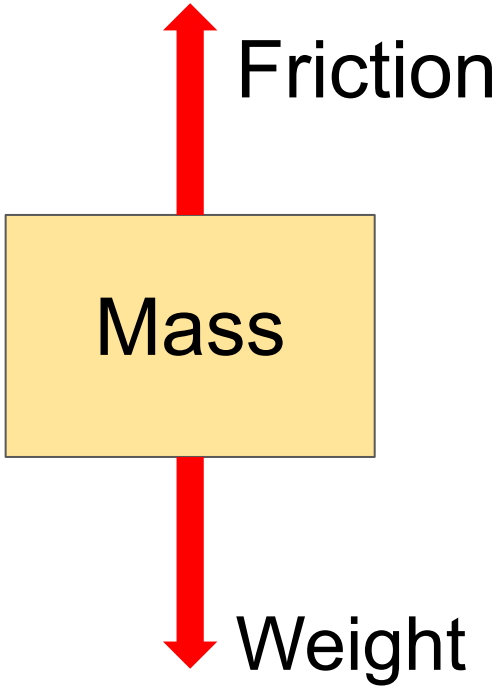
1. Problem description
2. Design modification
3. Trade studies
4. Manufacturing
5. Testing
6. Next steps

Problem Description



Quick, portable fire escape system through a window

Free body diagram



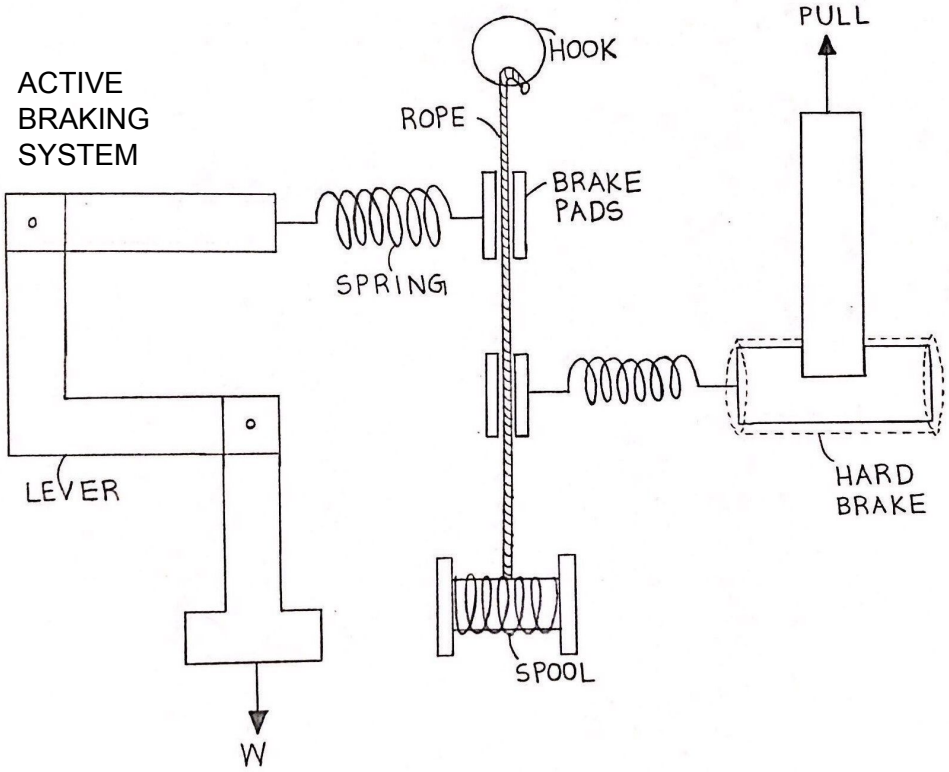
Newton's Second Law:

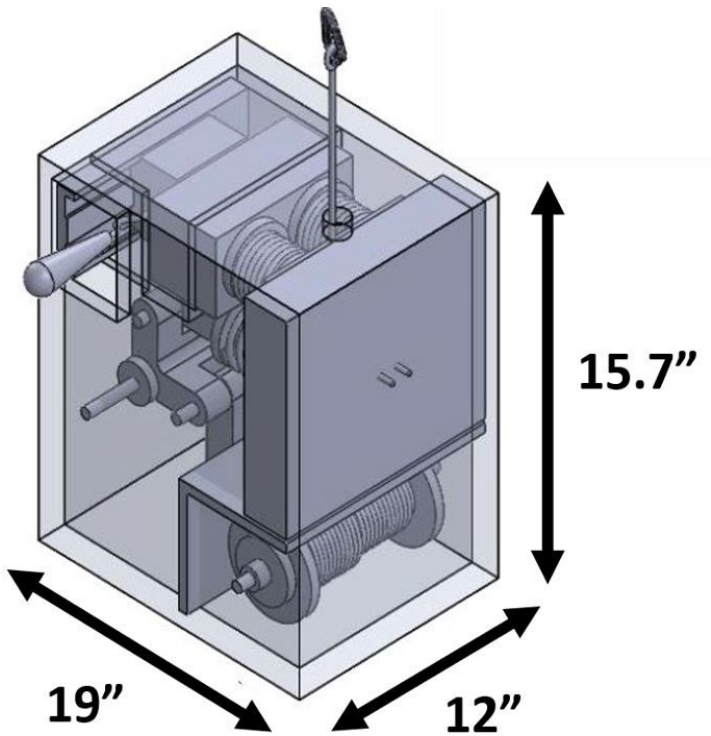
$F_{NET} = ma = 0$ (for constant speed)

Weight - Friction = 0

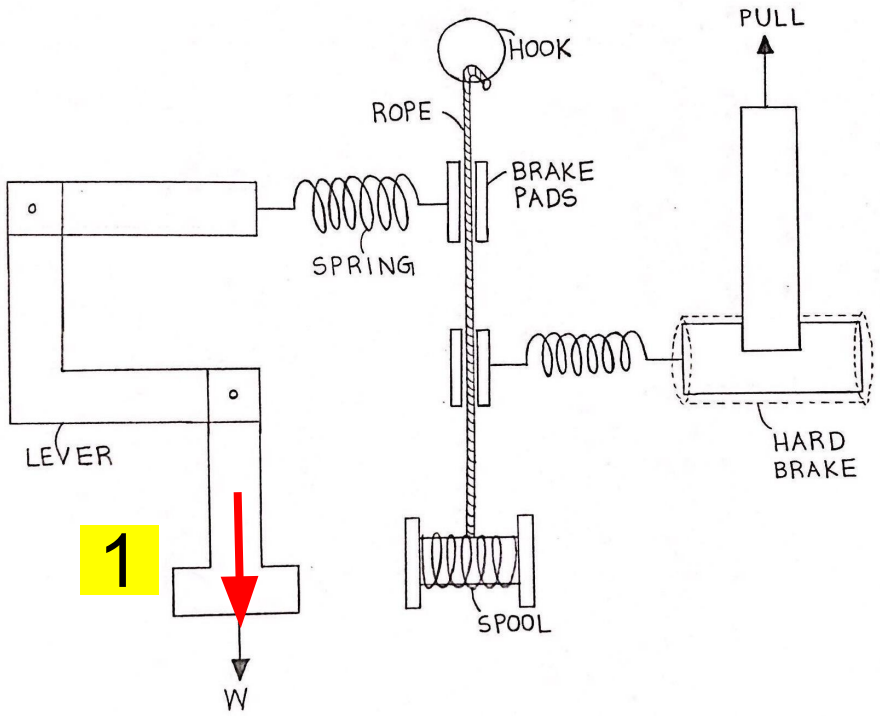
Weight = Friction

Semester 1 Design Summary

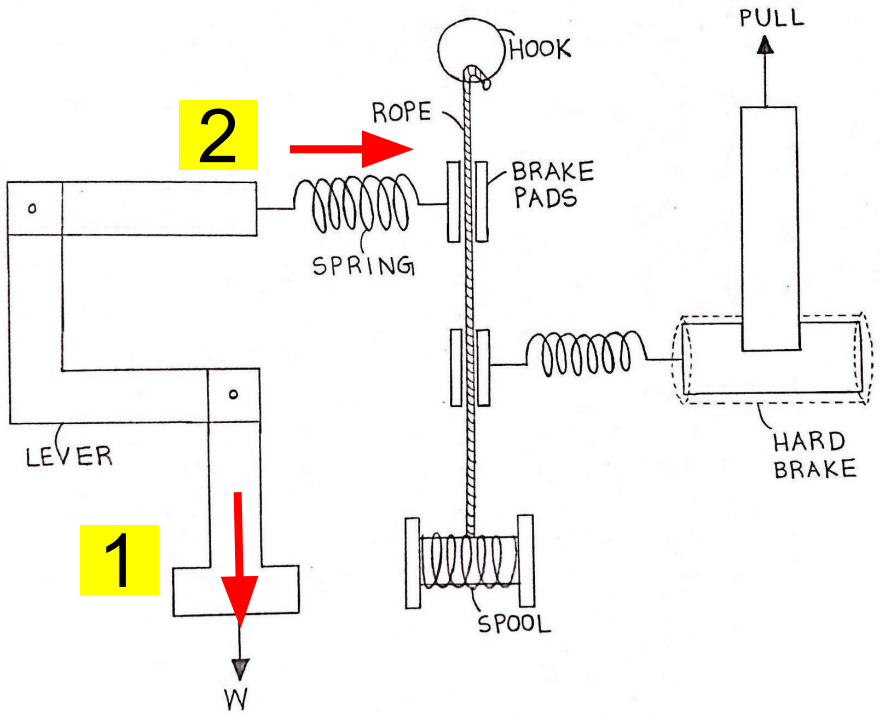




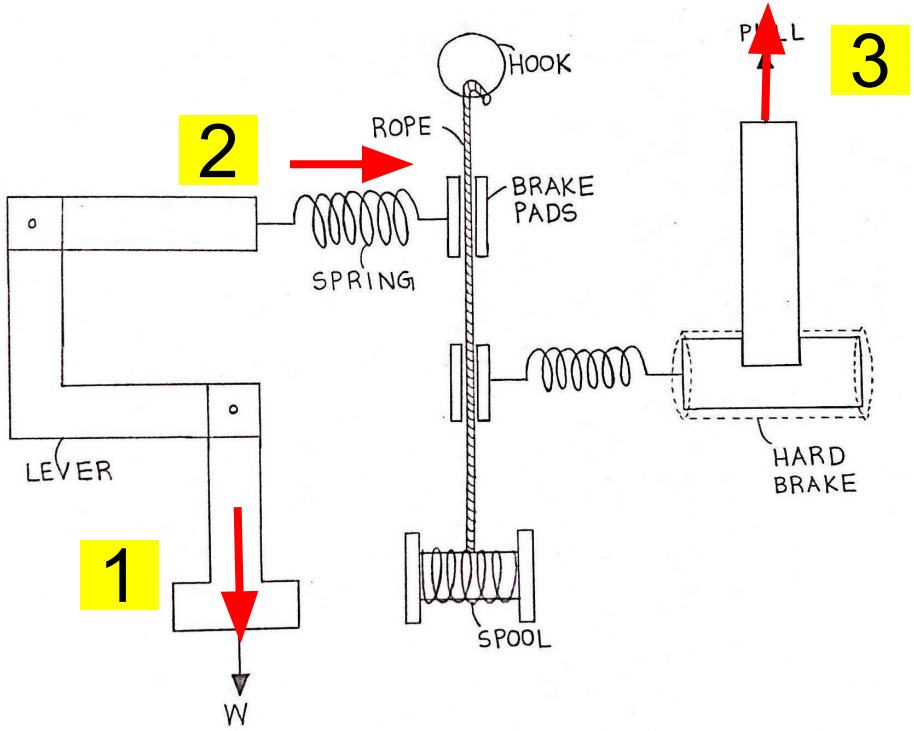
Semester 1 Design Summary



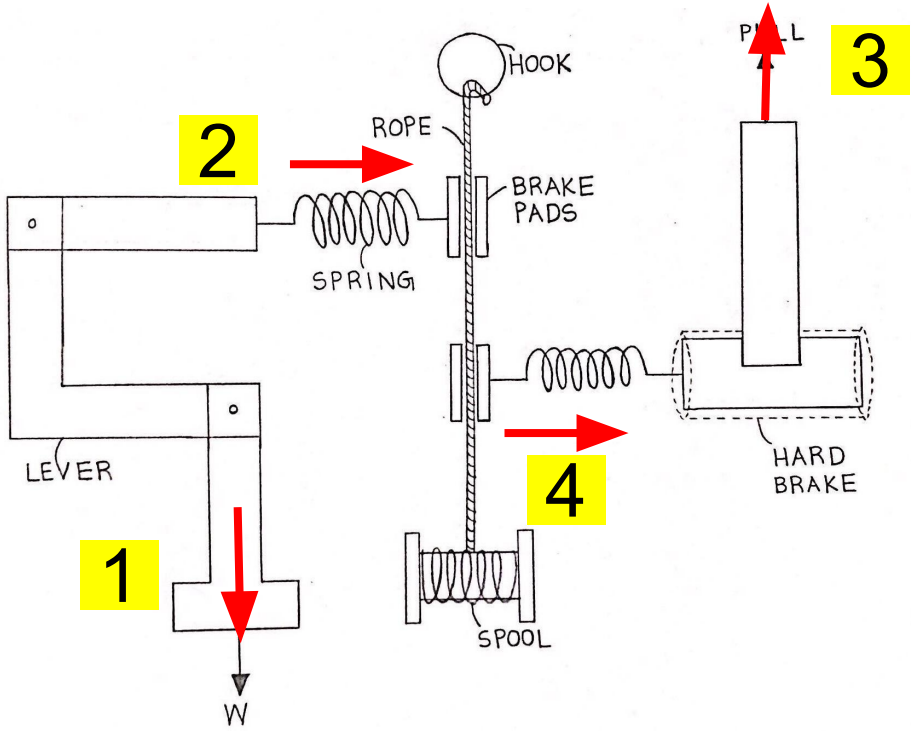
Semester 1 Design Summary



Semester 1 Design Summary

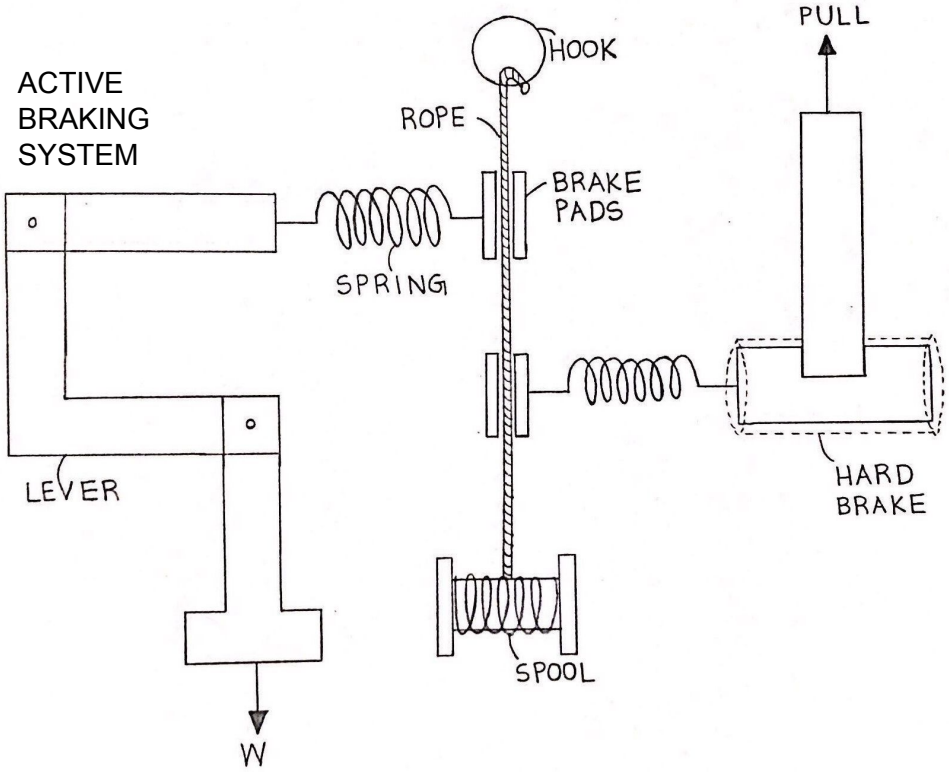


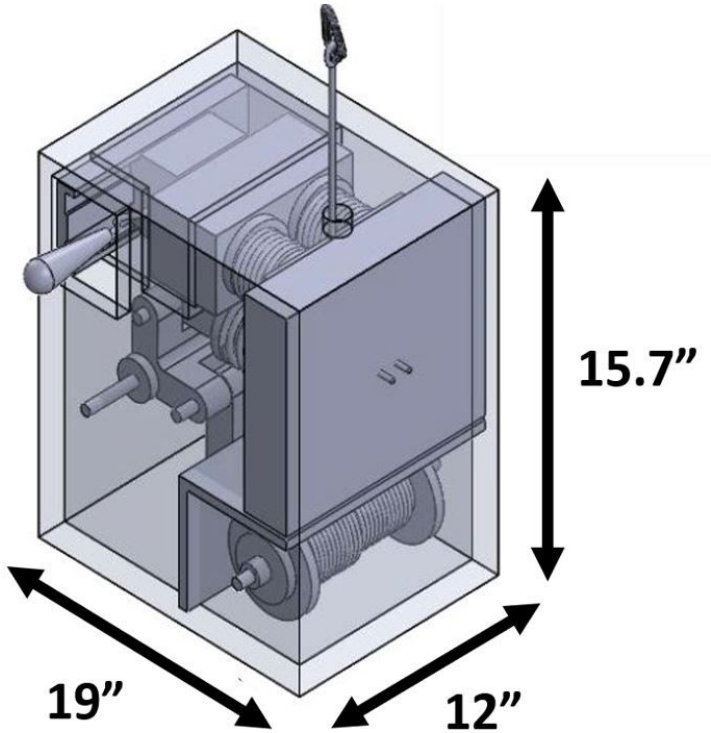
Semester 1 Design Summary



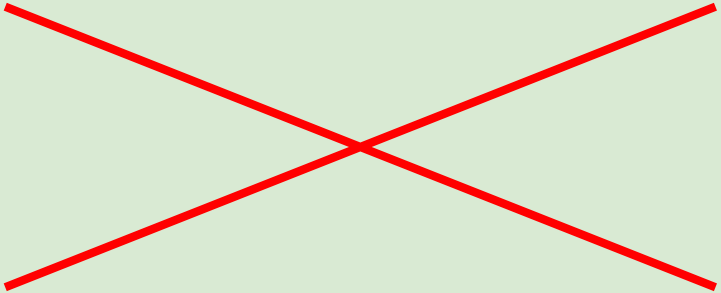
Design Modification due to COVID-19

Semester 1 Design Summary





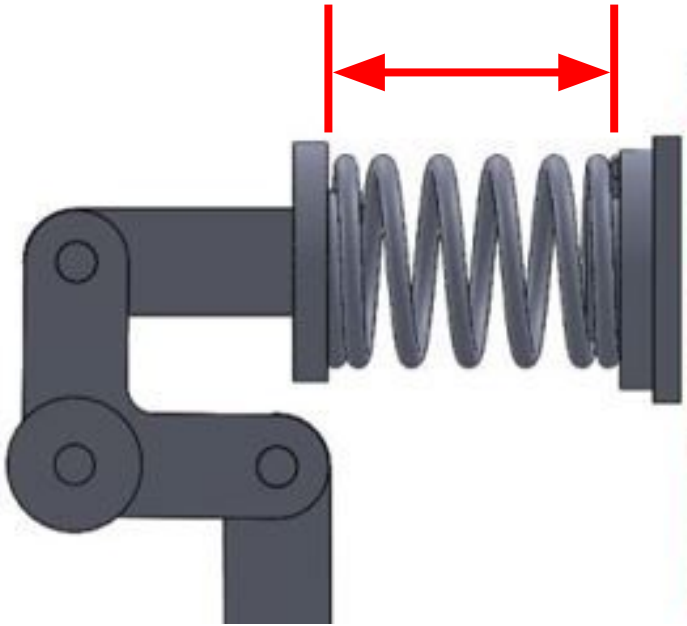
Design Revision Process

Previous Requirements	Current Requirements
• Can handle up to **250 lbs** • Maximum drop height of **100 feet** (equivalent to a building with 10 stories) • Rope must be flexible and can withstand a certain amount of dynamic load • Descent rate of 3 feet/s • Clear markings on pre-installed hook and box • Portable and lightweight • Clear instructions • Pre-installed hook and sturdy clasp • Adjustable to different body sizes • Must be slow enough to avoid obstructions during descent • Fire Proof System	• Can handle up to **2 lbs** • Maximum drop height of **10 feet** (equivalent to a building with 1 story) • Rope must be flexible and can withstand a certain amount of dynamic load • Descent rate of 3 feet/s 

Design Revision Process

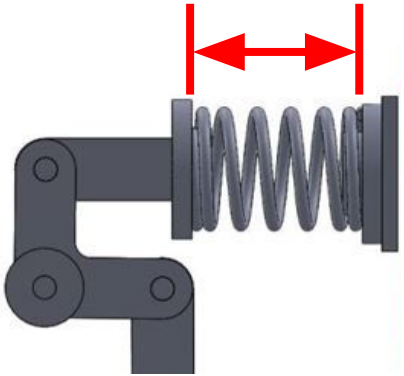
Force = 50 ~ 250 lbs

Free length = 110 mm



Force = 1 ~ 10 lbs

Free length = 40 mm



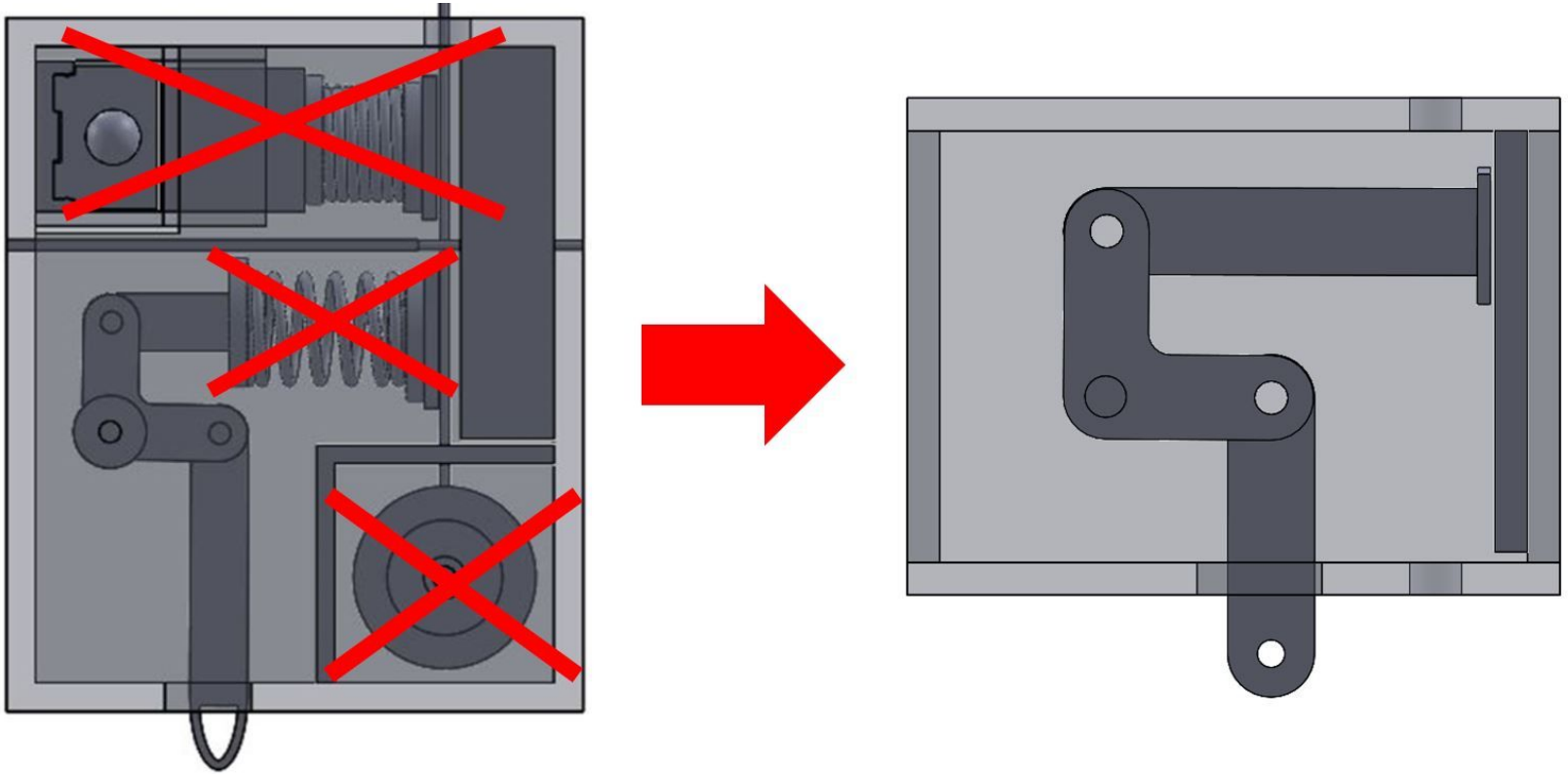
Design Revision Process

Using proportions, the downscaled case size can be determined:

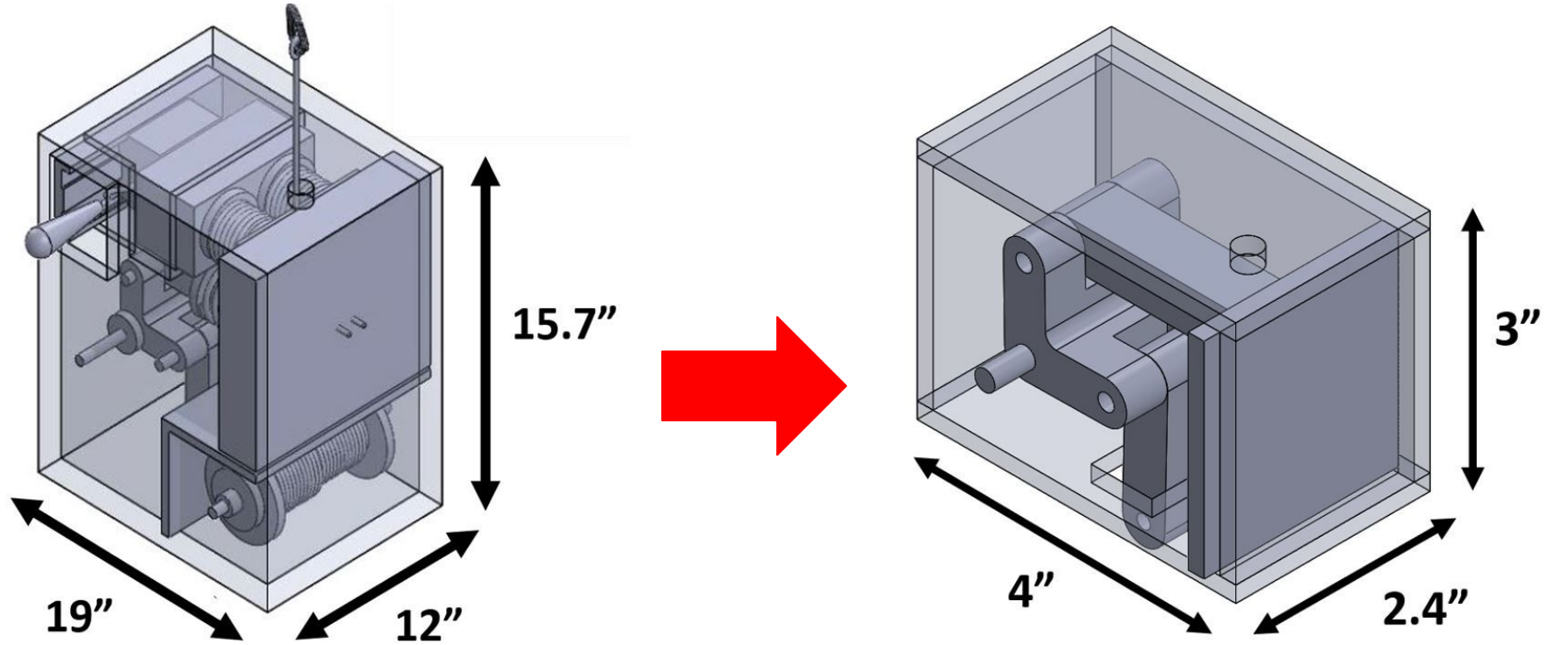
$$\frac{\text{Old size of system case}}{\text{Old free length of spring}} = \frac{\text{New size of system case}}{\text{New free length of spring}}$$

19” x 12” x 15.7” → 6.9” x 4.36” x 5.71”

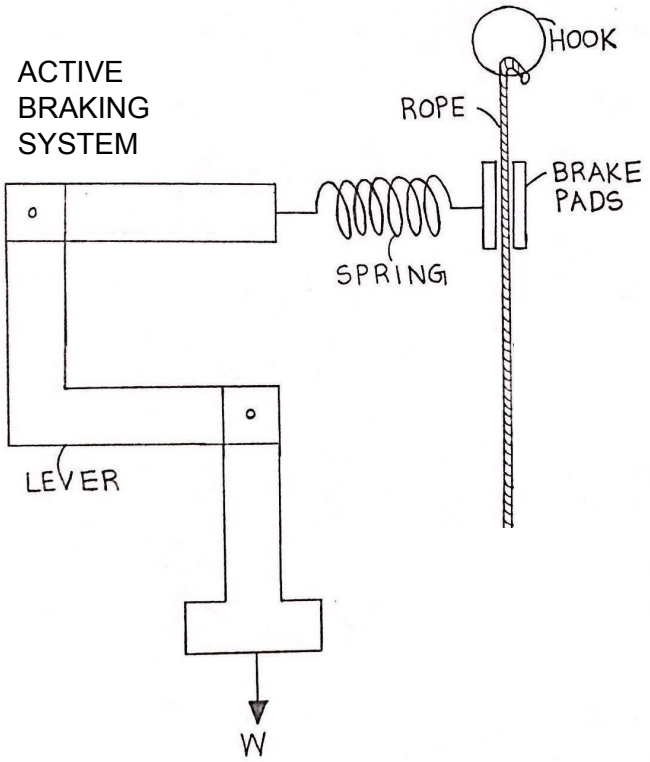
Design Revision Process

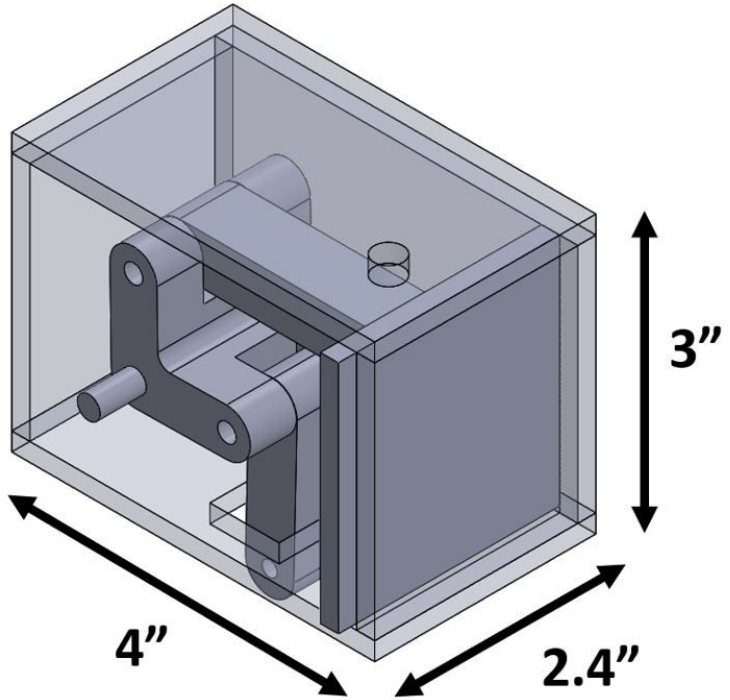


Design Revision Process



Semester 2 Modified Design Summary





Trade Studies

Trade Studies - Rope

Nylon

Technora

Galvanized Steel

¼ ” Diameter:	Nylon	Technora	Galv. Steel
Availability 1 = hard to find, 3 = easy to find	3	1	2
Elastic Modulus 1 = weak, 3 = strong	2	1	3
Cost 1 = expensive, 3 = cheap	3	1	2
Weight 1 = heavy, 3 = light	3	2	1
Heat Resistance 1 = low , 3 = high resistance	2	3	1
Ease of Attachment 1 = hard , 3 = easy	3	2	1
Total /18	16	10	10

Trade Studies - 3D Printing Materials

PLA (Polylactic Acid)

ABS (Acrylonitrile Butadiene Styrene)

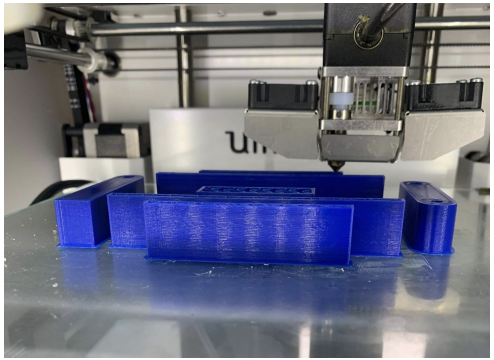
Nylon

	PLA	ABS	Nylon
Availability 1 = hard to find, 3 = easy to find	3	2	1
Durability 1 = flimsy, 3 = durable	1	2	3
Cost 1 = expensive, 3 = cheap	3	2	1
Ease of Printing 1 = difficult, 3 = easy	3	2	1
Heat Resistance 1 = low , 3 = high resistance	1	2	3
Strength 1 = weak , 3 = strong	3	2	1
Total /18	14	12	10

Manufacturing

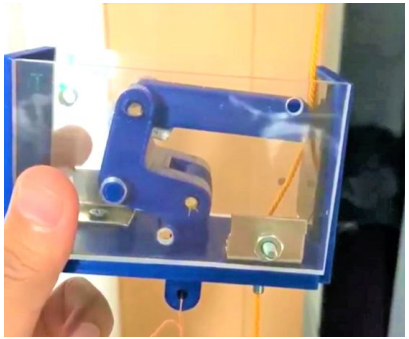
Manufacturing Process

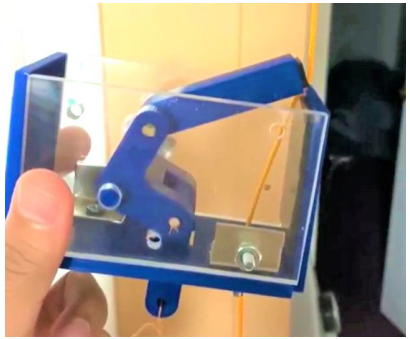
*done safely masked and outside



Testing

Initial Tests & Troubleshooting





Problem

The arm moved up and down with the rope

Solution

The top arm was fixed to the lever by adding padding to fill the gap and gluing

Initial Tests & Troubleshooting

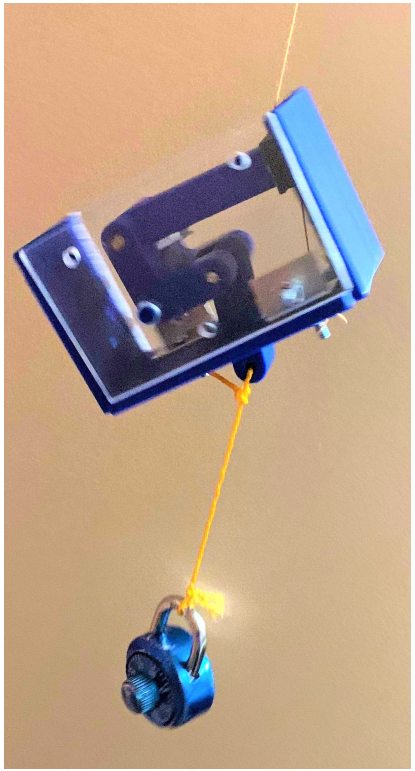
Problem

The object sometimes floats when the system is released, causing the top arm friction to lessen and the whole system to free fall

Solution

A lock was added to keep the bottom arm in place

Initial Tests & Troubleshooting



Problem

The system tilted

Solution

A top cover with a centered hole was placed to fix the tilt

Initial Tests & Troubleshooting

Problem

The rope shifted out of the brake pads, causing the system to fall free-fall

Solution

The rope was guided from the rope entrance to the brake pads to ensure little room for shifting

Final Tests & Results

0.35 lbs
(combination lock)

The system did not go down with the weight of a single combination lock

→ This suggests the system has a minimum weight requirement in order for it to work

Final Tests & Results

1.10 lbs
(combination lock, stapler)

1.20 lbs
(water bottle)

1.95 lbs
(stapler, water bottle)

2.94 lbs
(combination lock, stapler, water bottle, umbrella)

Final Tests & Results

Objects	Weight (lbs.)	Speed [7 ft / time] (ft/s)	Free Fall Speed (ft/s)
Combination lock	0.35	0	21.223
Combination lock, stapler	1.1	0.0583	21.223
Water bottle	1.2	0.0583	21.223
Stapler, water bottle	1.95	0.0778	21.223
Combination lock, stapler, water bottle, umbrella	2.94	0.0583	21.223

Very slow!

Final Tests & Results

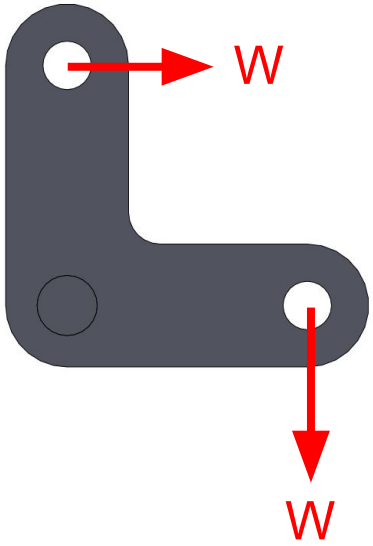
Relatively constant descent speed across all weights

→ System is weight-independent as designed

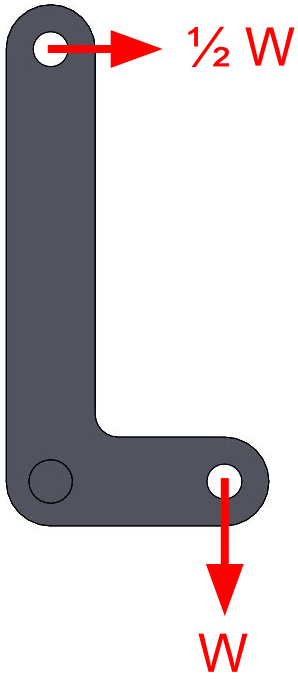
Next Steps & Conclusion

Next Steps - Decreasing Friction

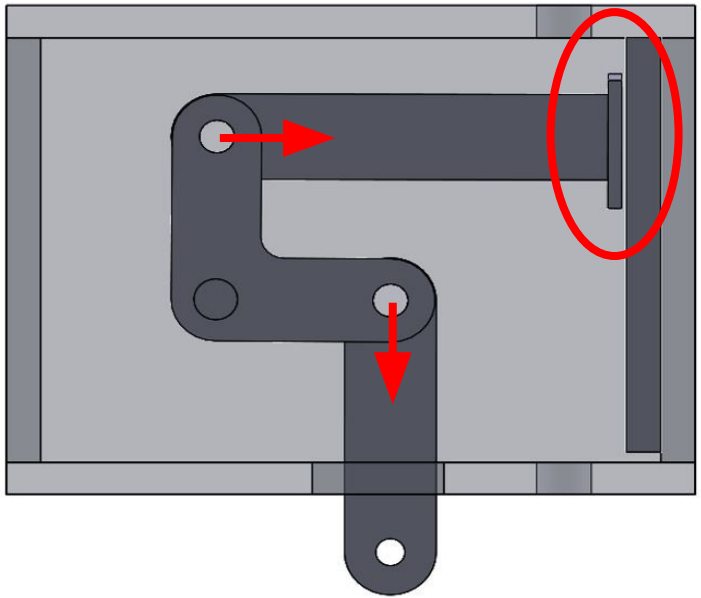
Current Design



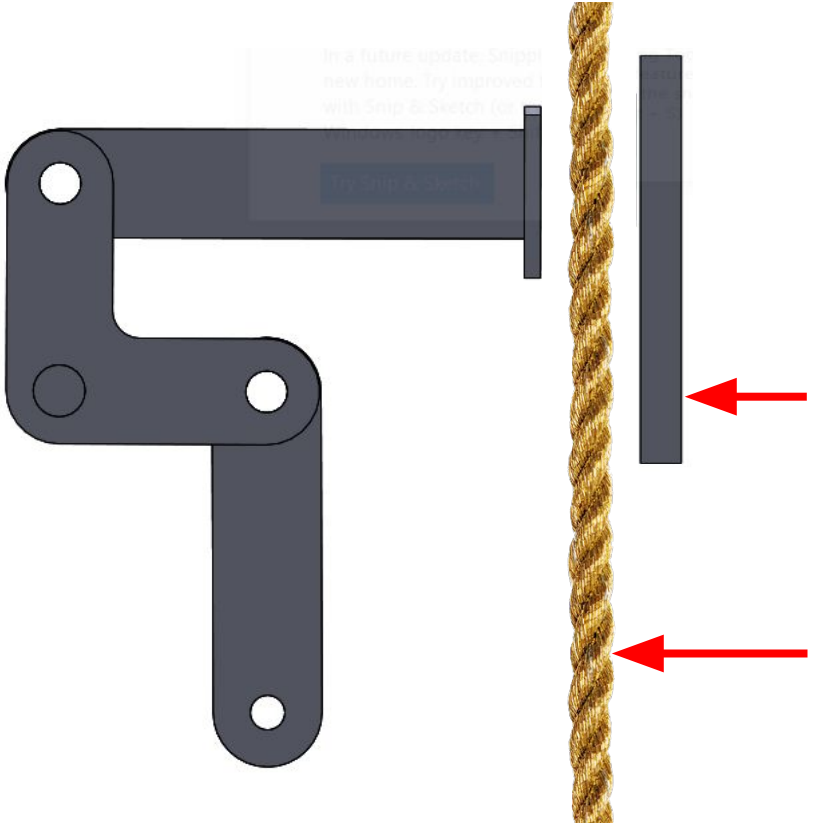
Proposed Design



Decreases friction!

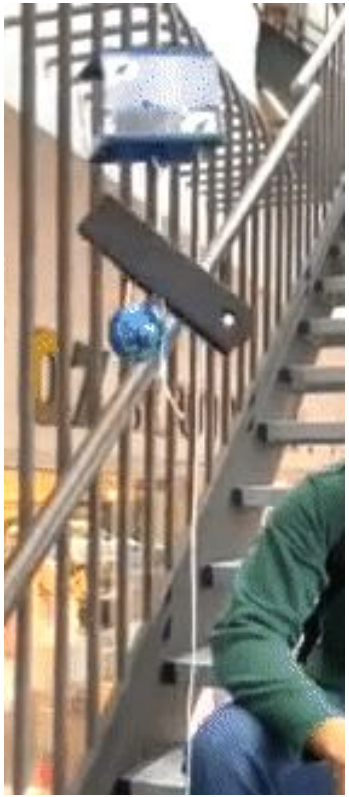


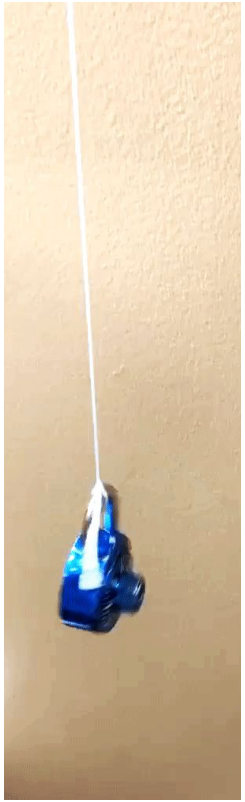
Next Steps - Decreasing Friction

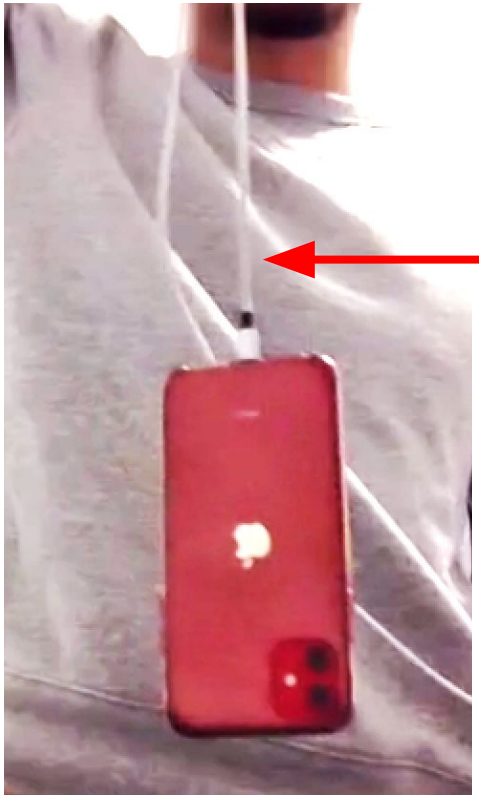


- Add lubricant
- Use a different rope
- Change the brake pad material

Next Steps - Prevent Rotation





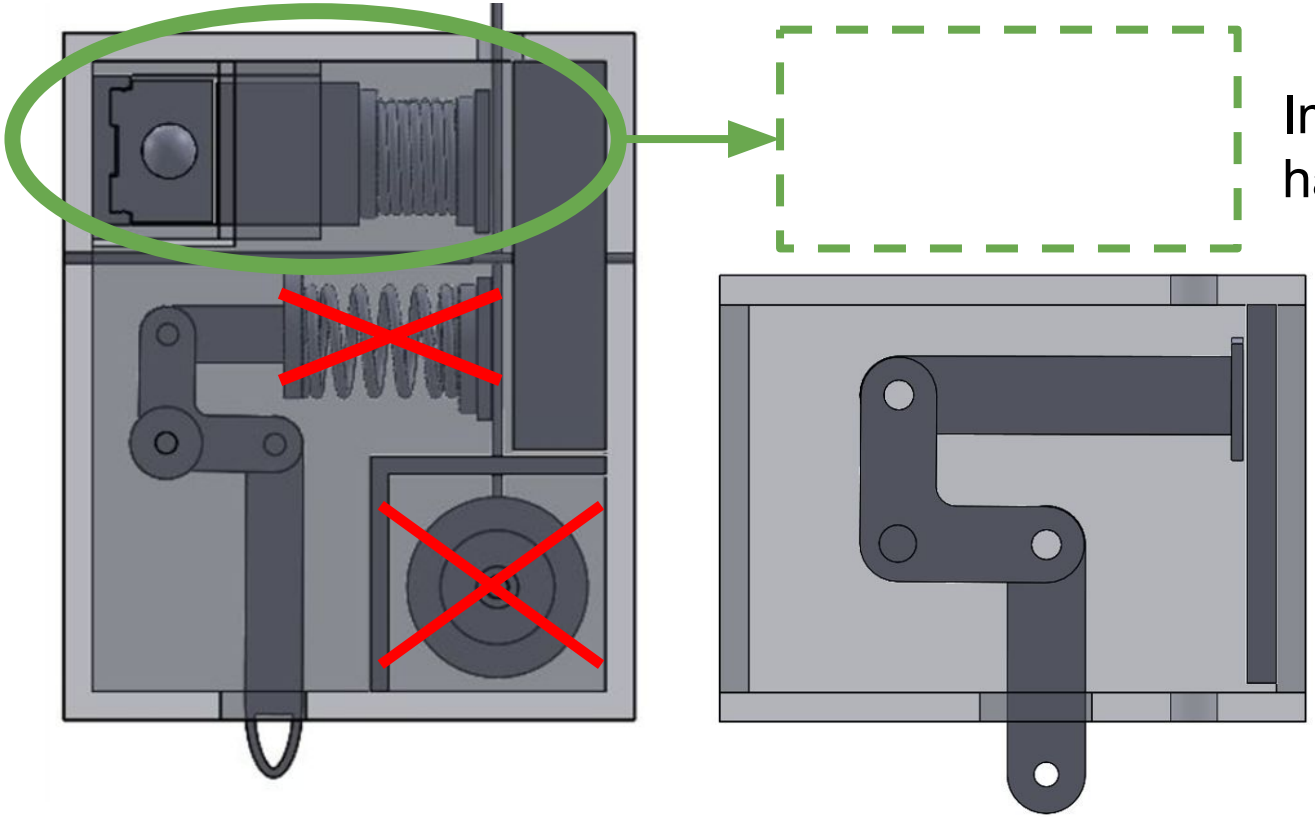


Use a stiffer rope to prevent rotation

Next Steps - Hard Brake System

- Holding the model serves as the hard brake system
- Holding the model allows the water bottle to register its weight

Next Steps - Hard Brake System

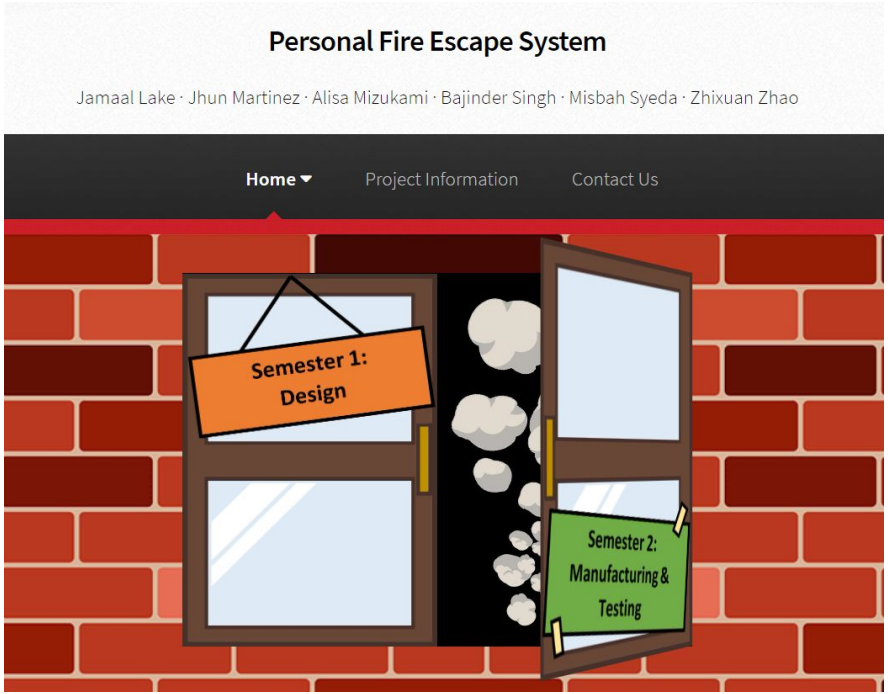


Implement the
hard brake system

Conclusions

- The system is weight independent however the descent speed is very slow
- Further improvements need to be made in order to speed up the descent speed
- Hard brake system will be added and a stiffer rope will be used in future testing

Thank you!



https://amizuka000.github.io/fireescape/