Design of a Personal Fire Escape System

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Agenda

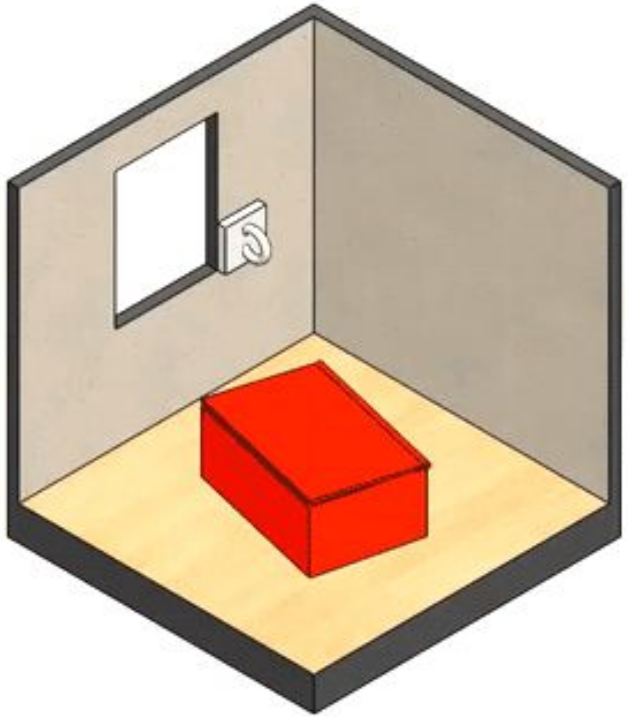
1. Personal Fire Escape System
2. Conceptual Design: How will it work?
3. The Braking System
   (Lever, Hard brake, FEM…etc)
4. Spring, spring cups and brake pads
5. Rope, Carabiner and Harness
6. Manufacturing Plans
7. Testing Plans
8. Conclusion

What is the problem?

- After 9/11, engineers realized that buildings need better evacuation systems

- Although modern evacuation systems are efficient, they still take a long time to get people out

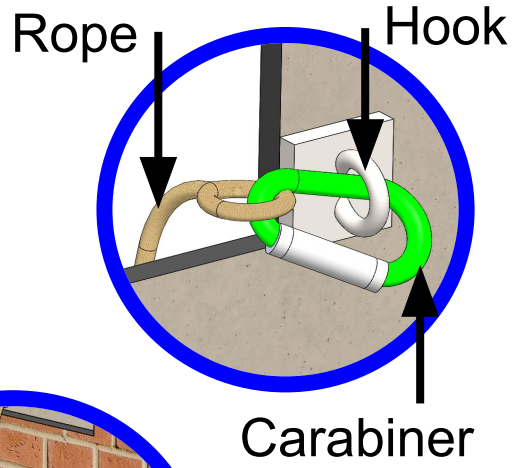
Our solution: Personal Fire Escape System

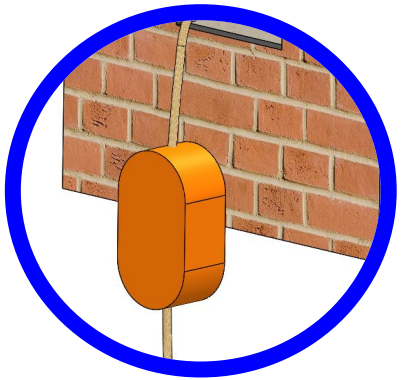


Quick, portable fire escape system through a window

What is in the box?

1. Braking system
2. Carabiners
3. Hook: needs to be installed by user
4. Harness
5. Instruction guide





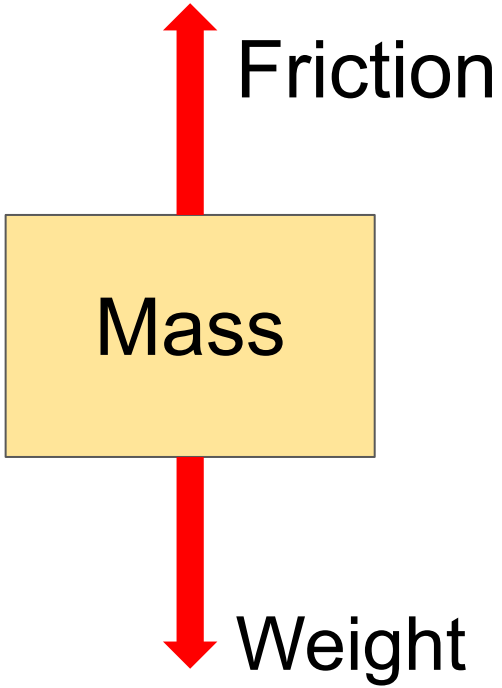
Major Requirements

- Maximum weight limit is 250 lbs
- Maximum descent height is 100 ft (10 stories)
- Maximum descent speed of 3 ft/s

  (at ground in 33 seconds)
- Very easy to read instruction on the hermetic box

  → No more than 4 sentences to read

Free body diagram



Newton's Second Law:

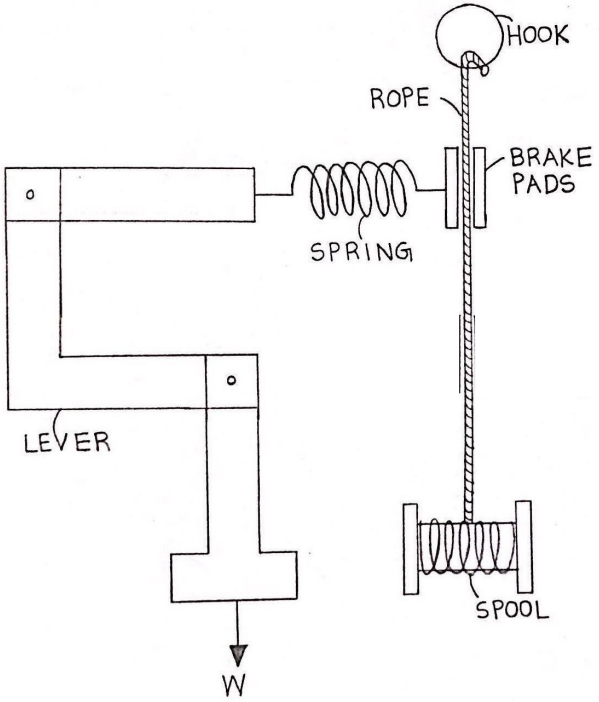
$F_{NET} = ma = 0$ (for constant speed)

Weight - Friction = 0

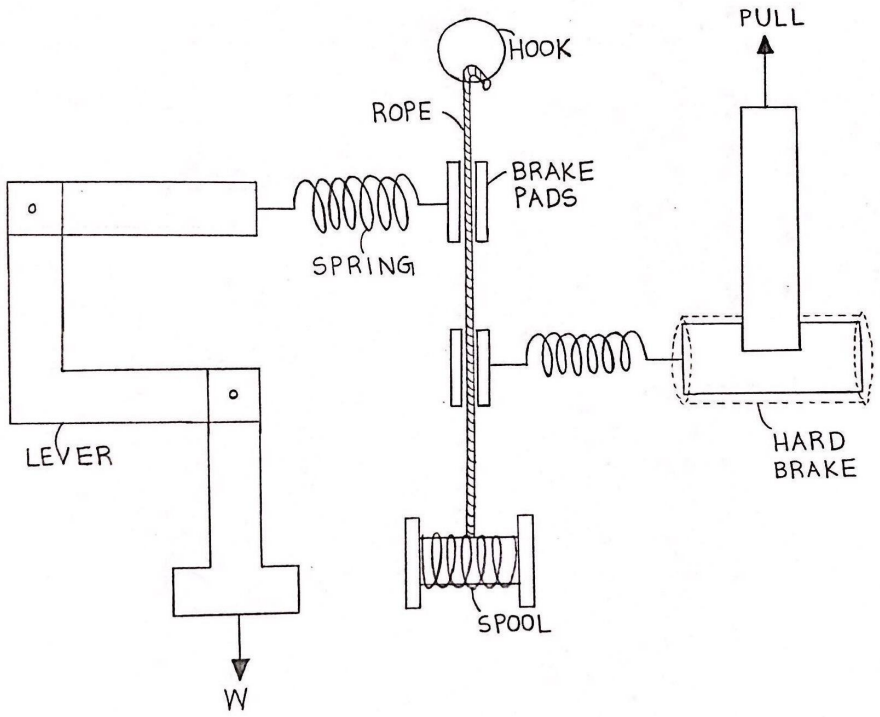
Weight = Friction

What is our solution?

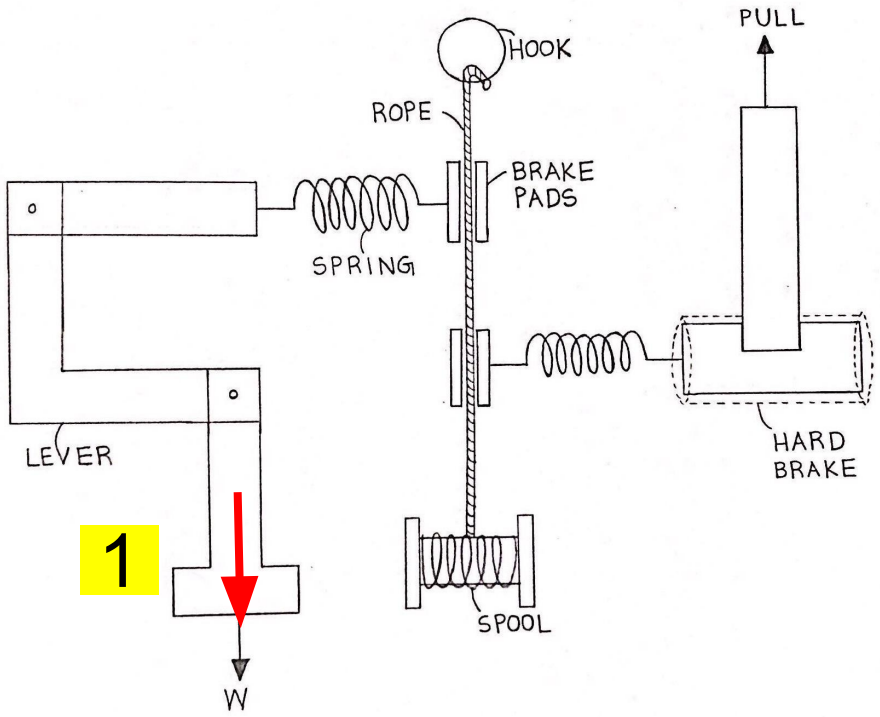
Active Braking System



What is our solution?



How does it work…?



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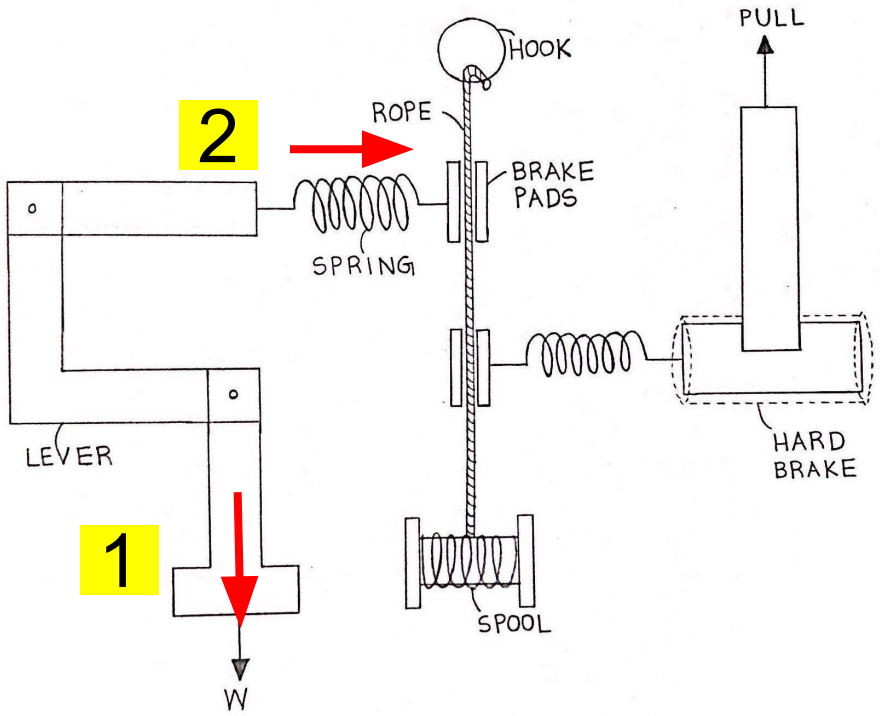

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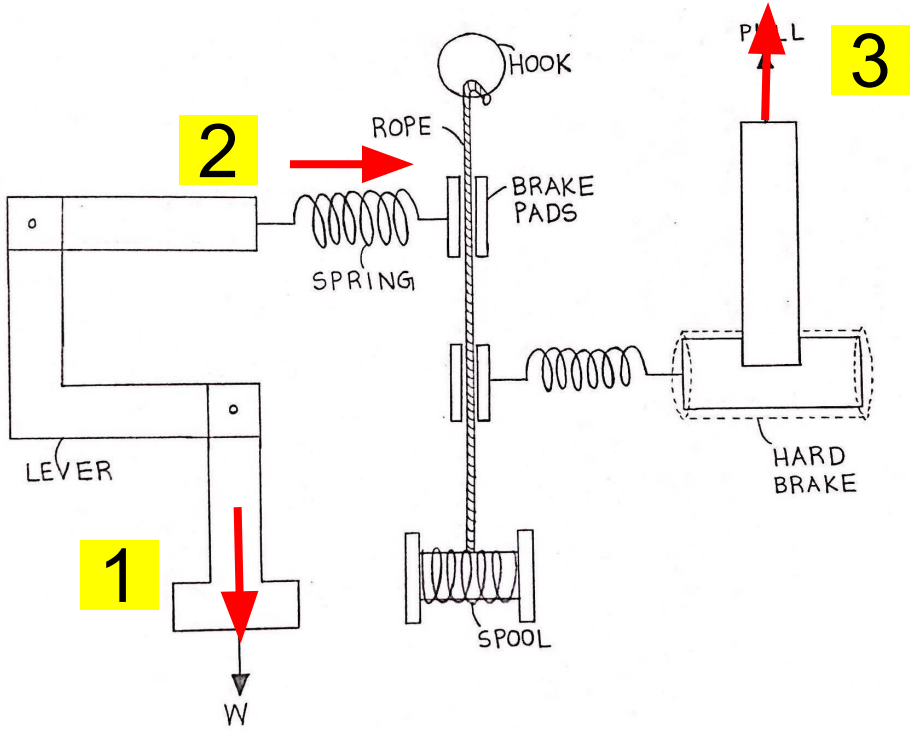

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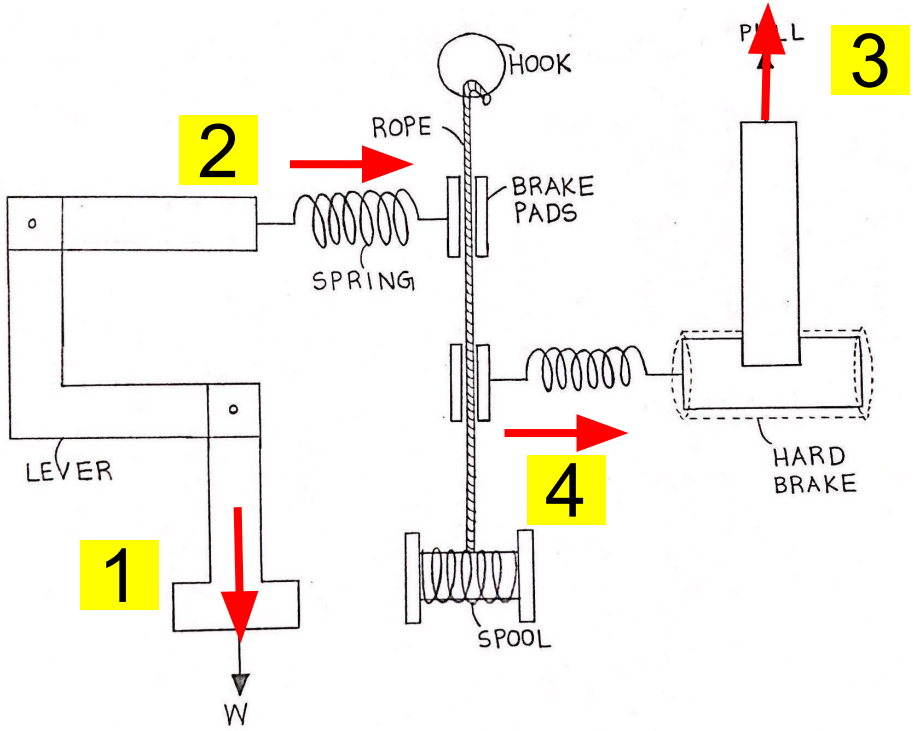

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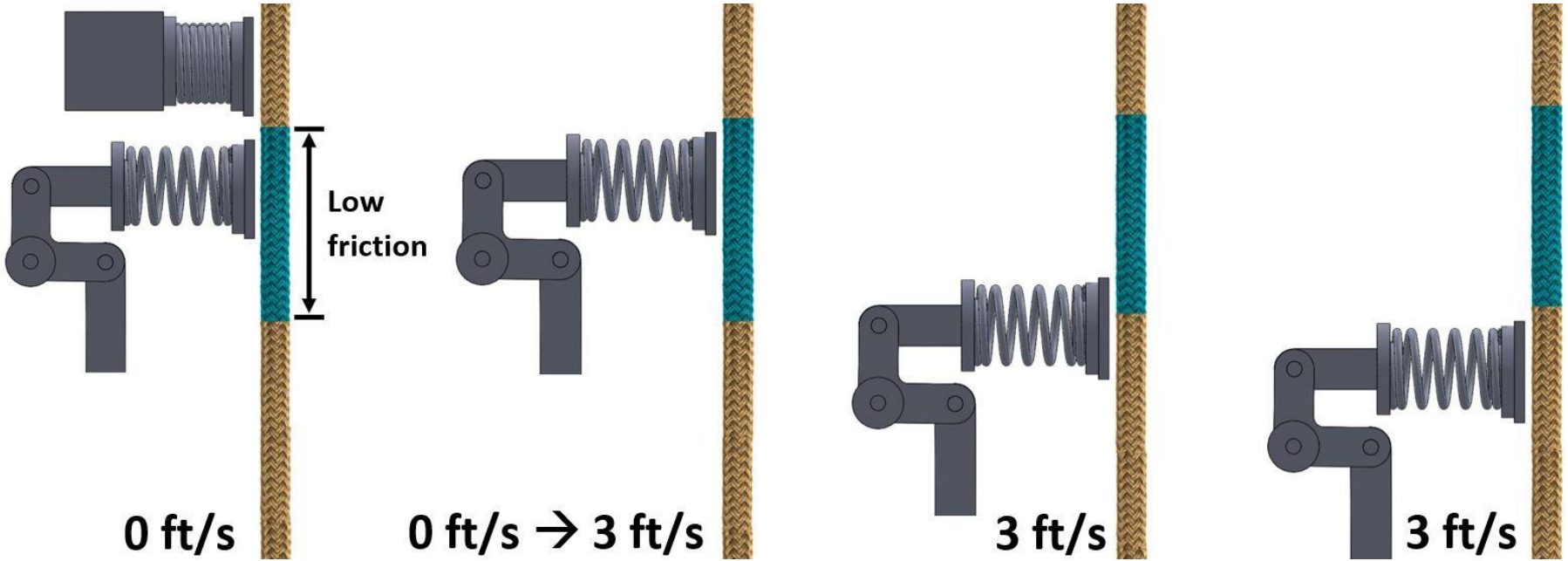
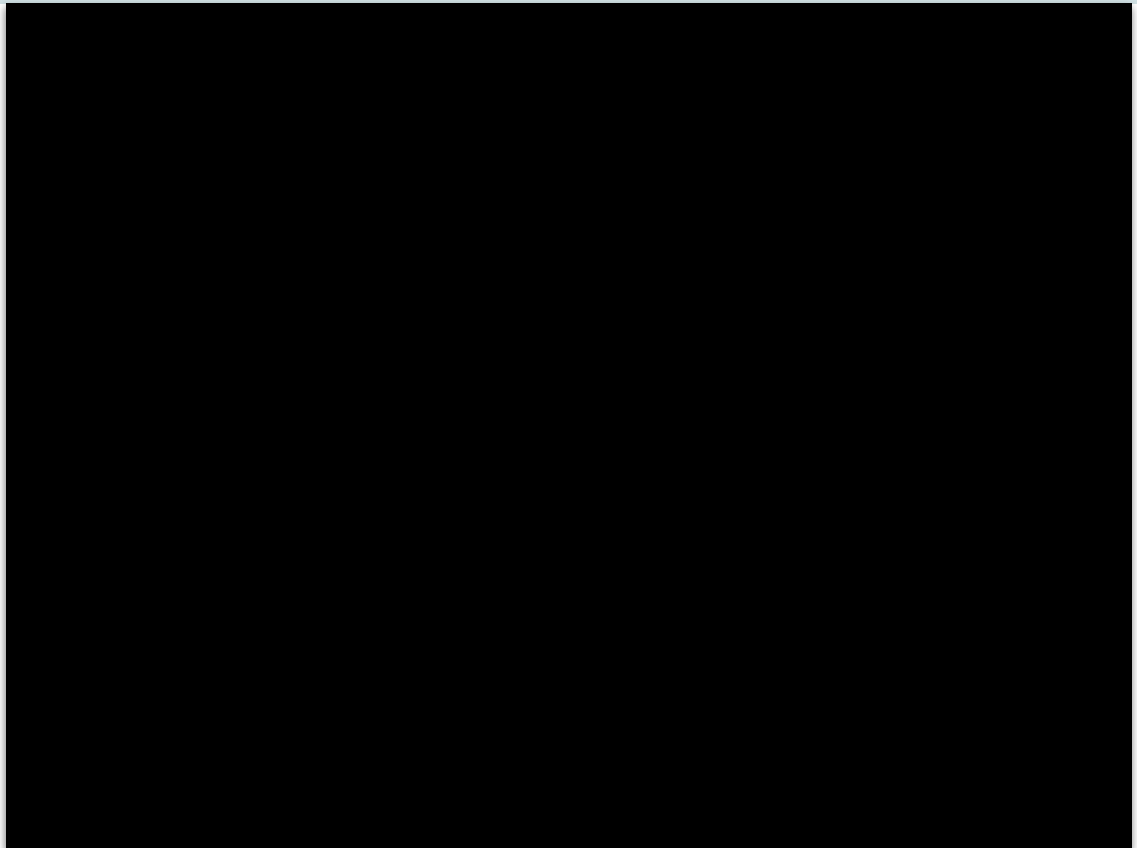
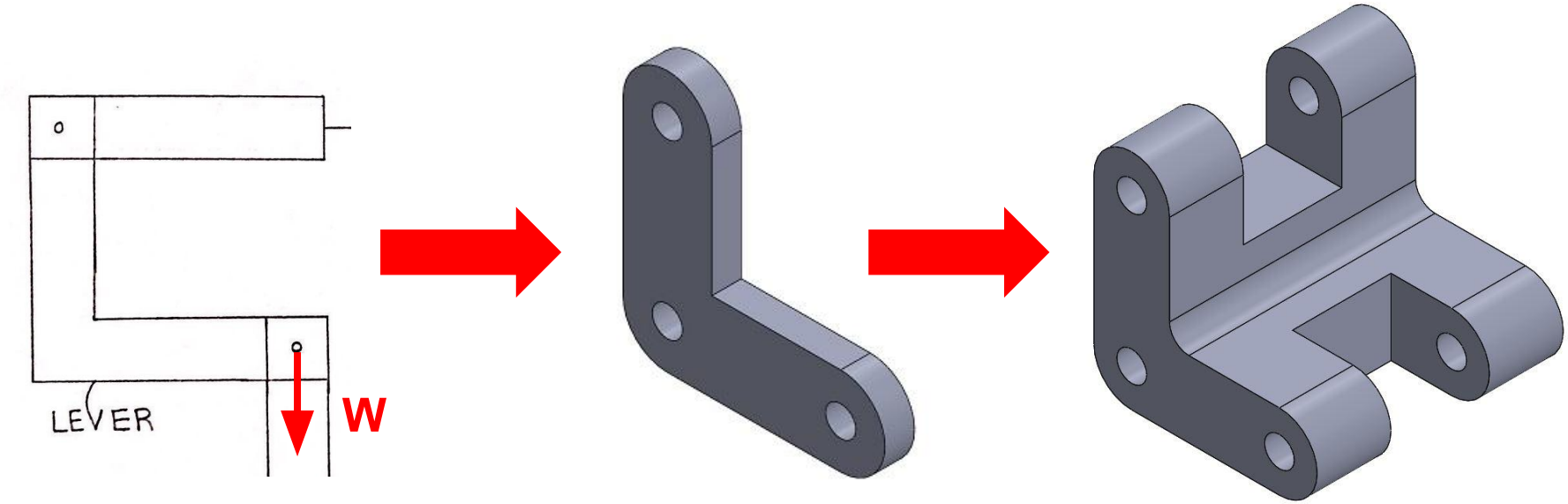


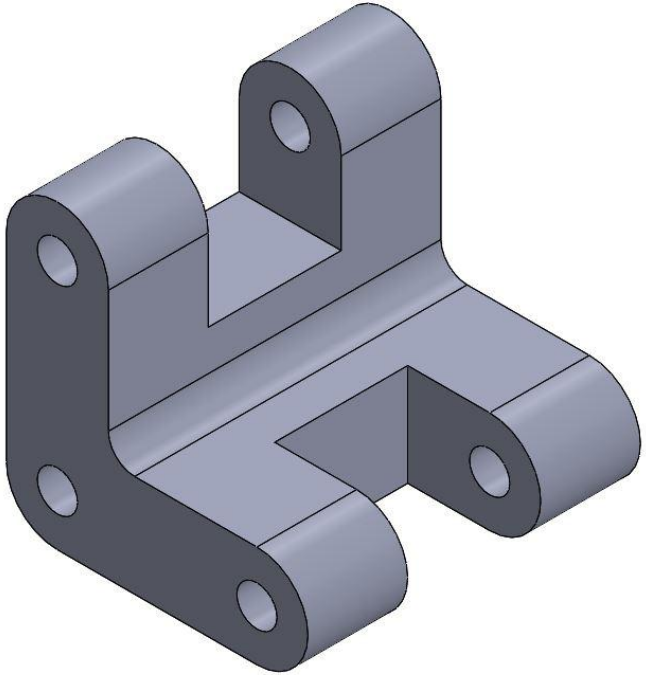
Lever Animation



Design of Lever (3D Model)



Lever Material



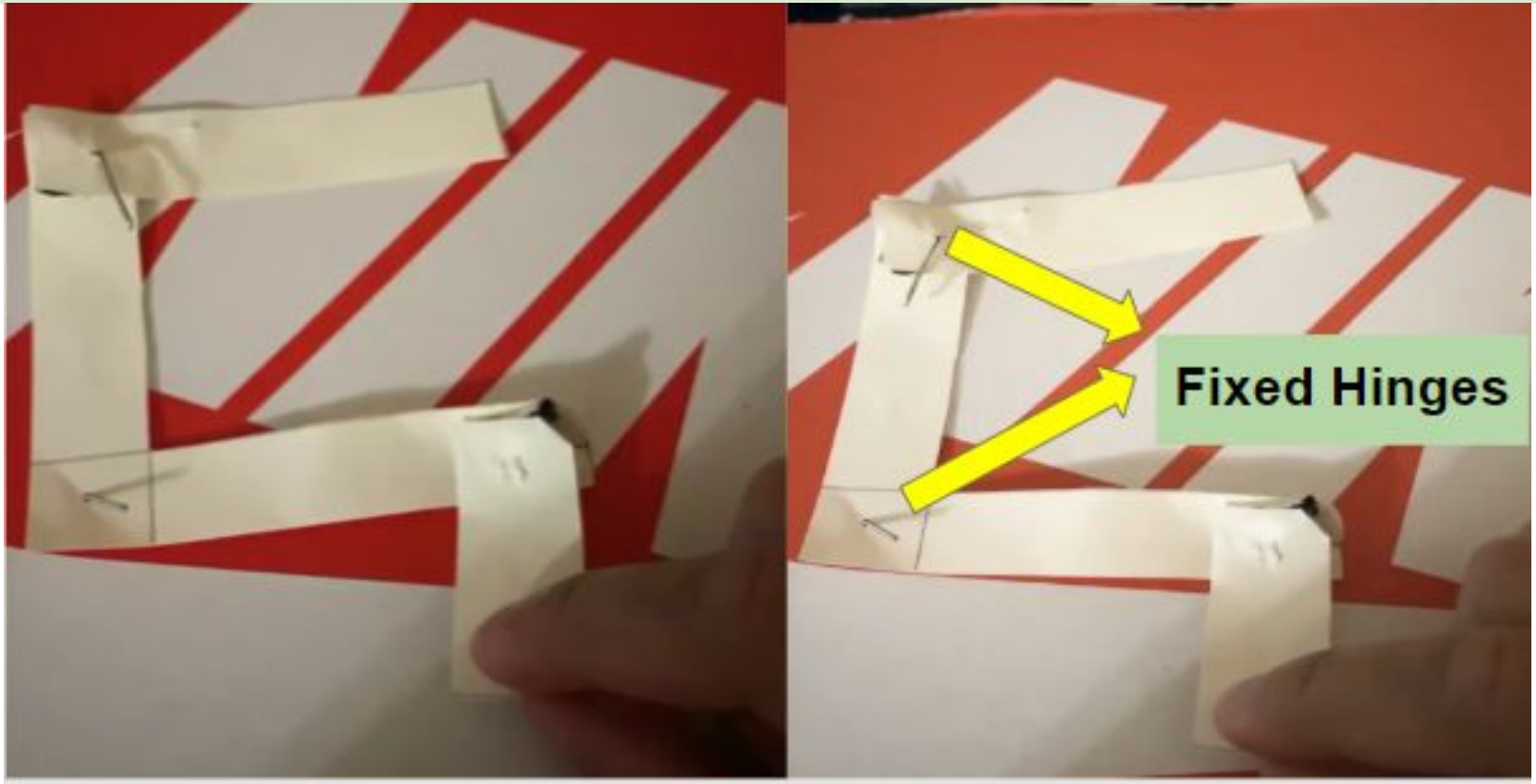
Aluminum 6061-T6, T651

- Cheaper than steel
- Lighter than steel
- Corrosion-resistant

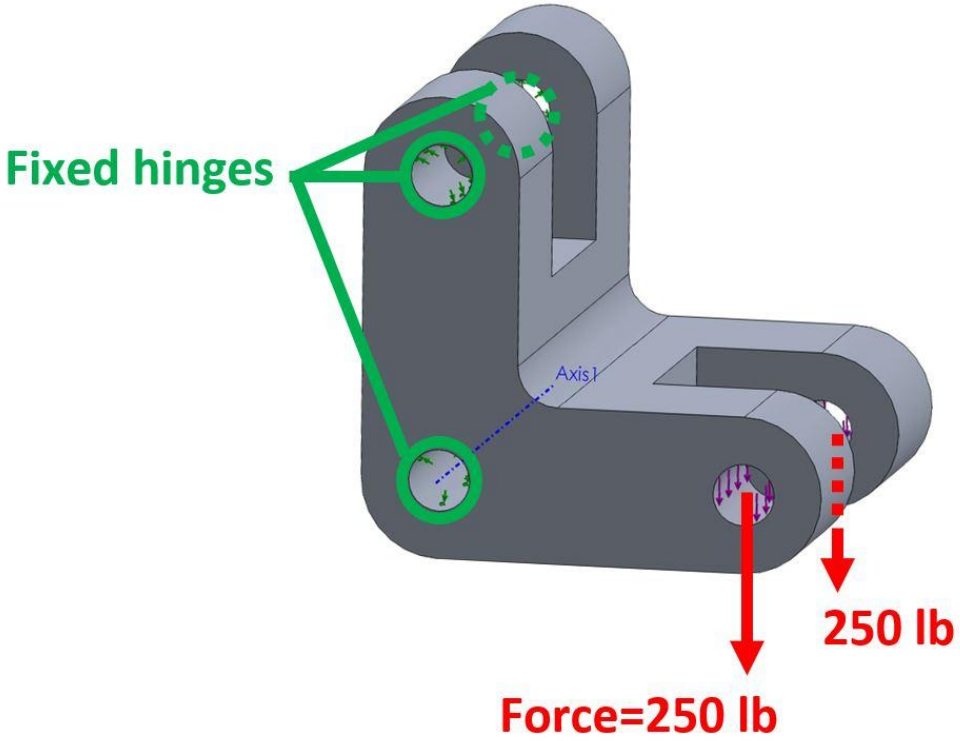
Finite Element Analysis on Lever: But Why?

The purpose of FEA is to conduct a virtual test

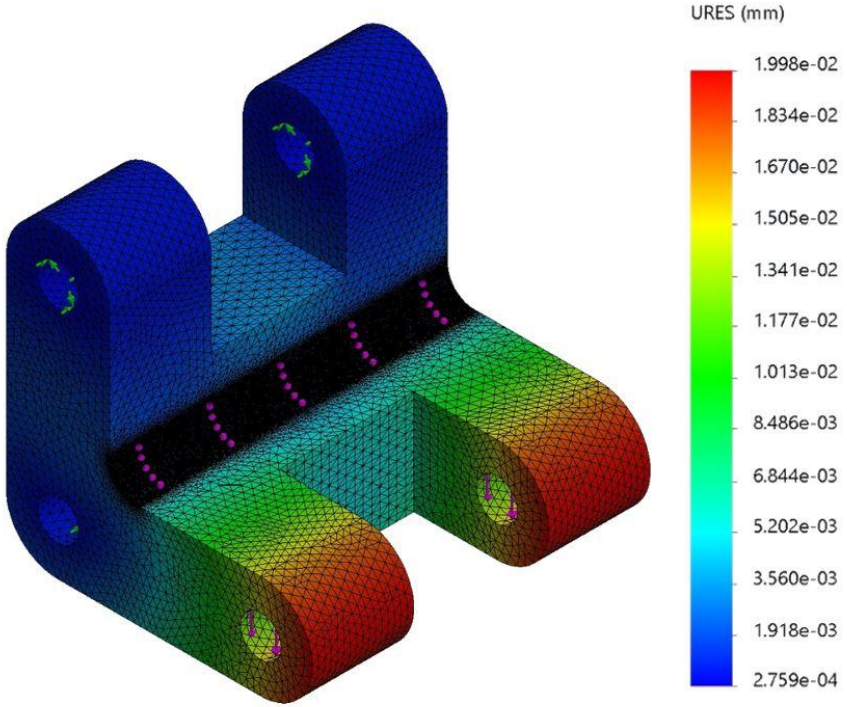
FEA on Lever: Boundary Conditions?



FEA on Lever: Boundary Conditions?

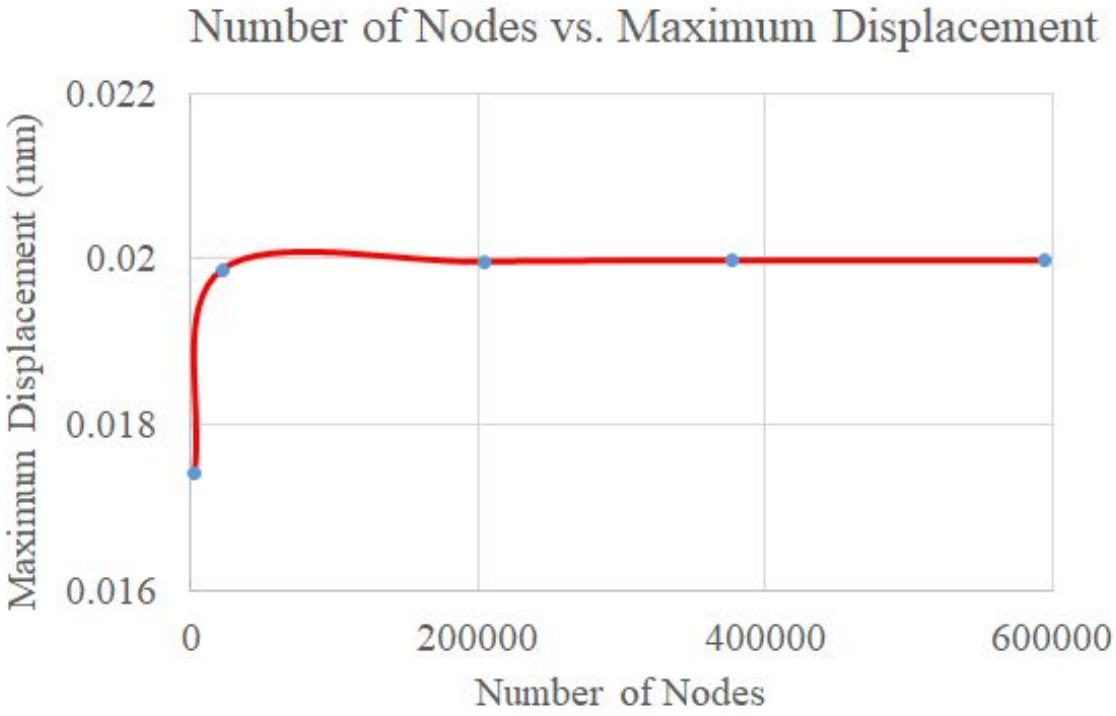


FEA on Lever: Displacement Test

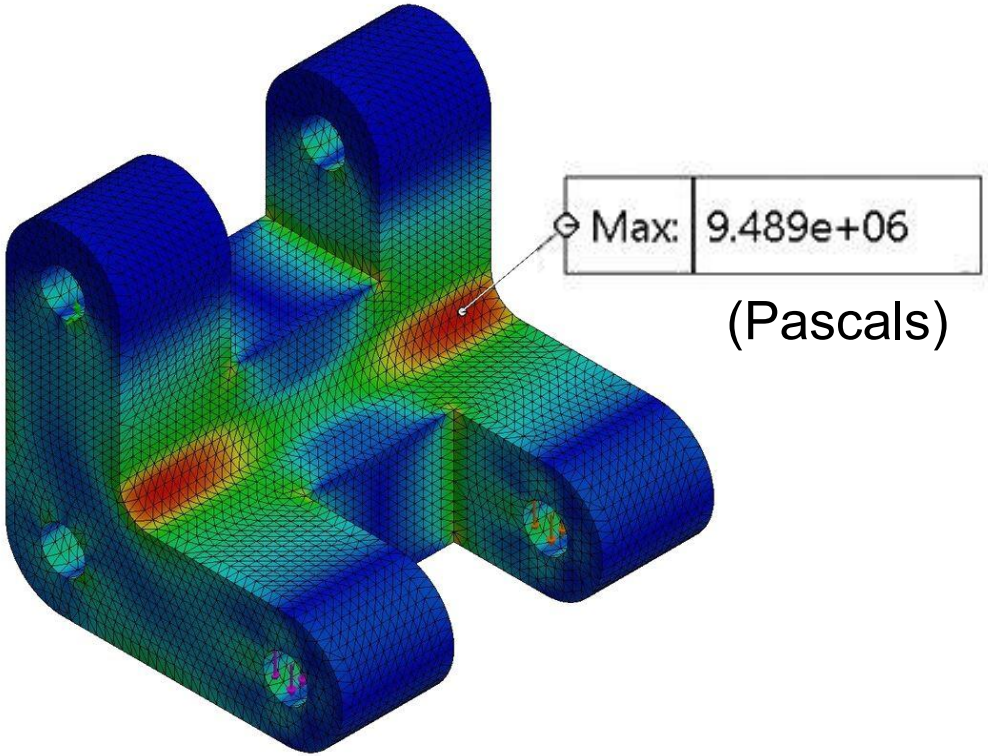


As expected!

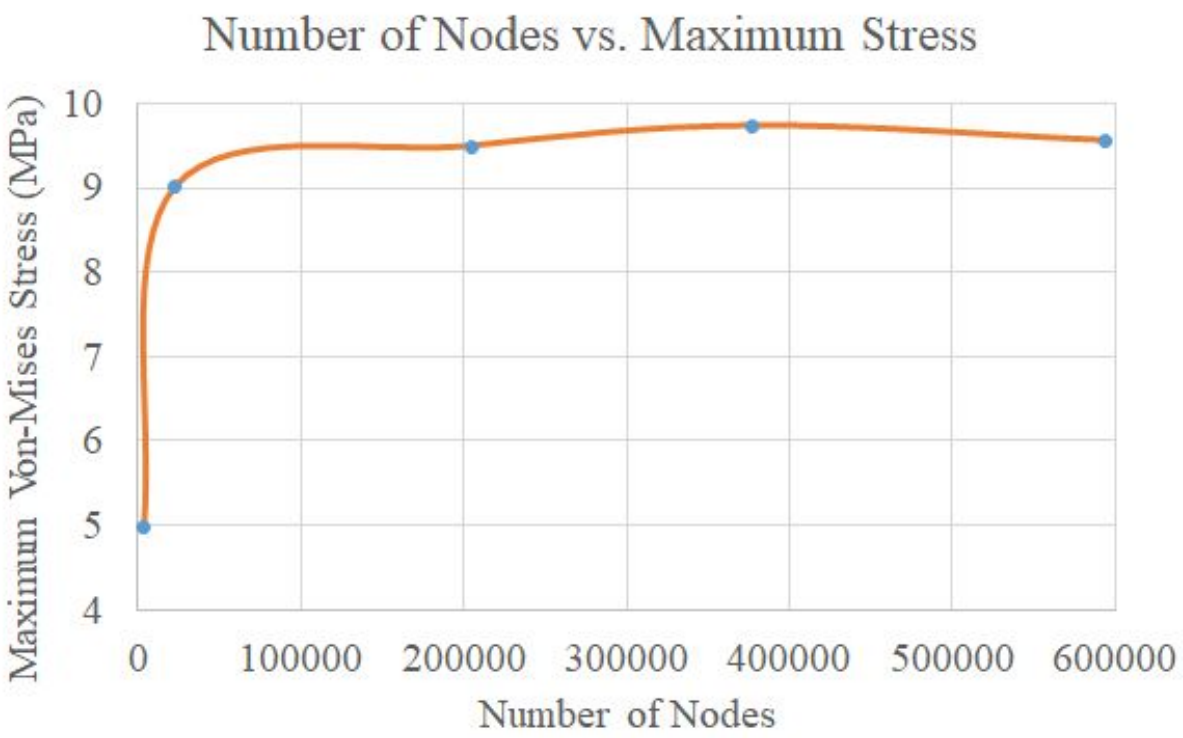
FEA on Lever: Displacement Test



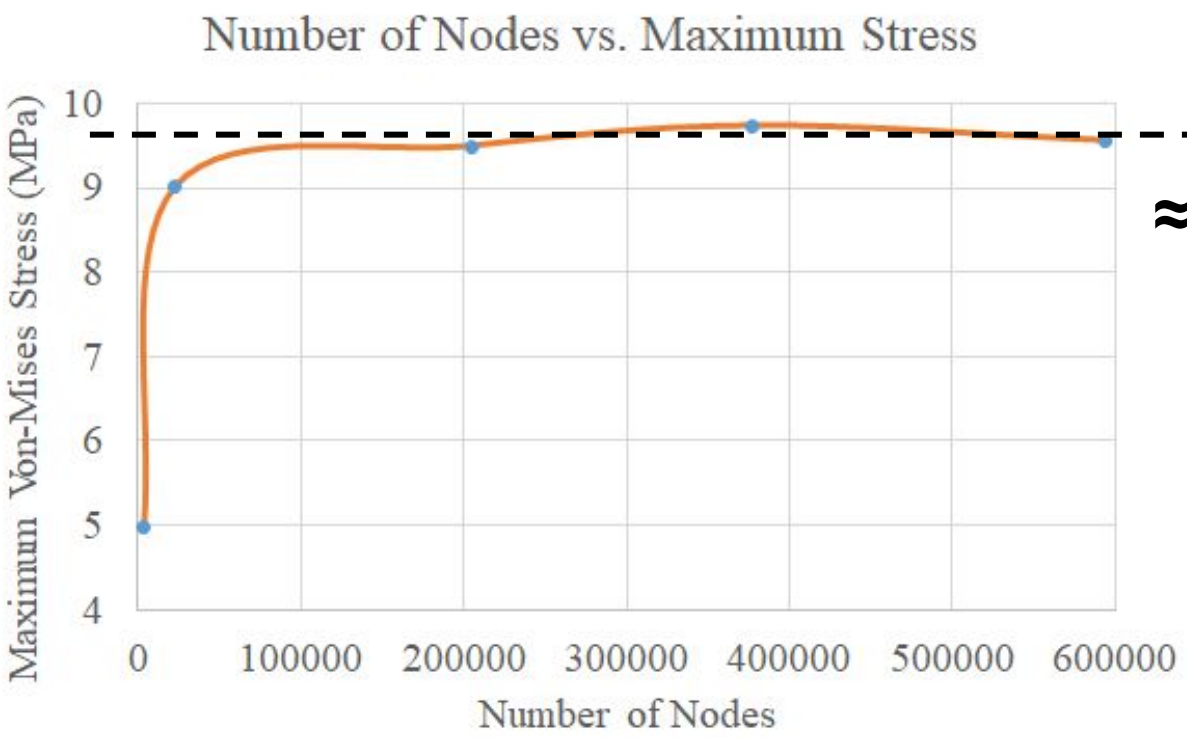
FEA on Lever: Stress Test



FEA on Lever: Stress Convergence



FEA on Lever: Stress Convergence



≈ 9.5 MPa

FEA on Lever: Failure Criterion

- Yield Strength of Aluminum 6061 = 255 MPa
- Chosen factor of safety = 5
- Therefore, the allowable stress is 255 MPa / 5 =

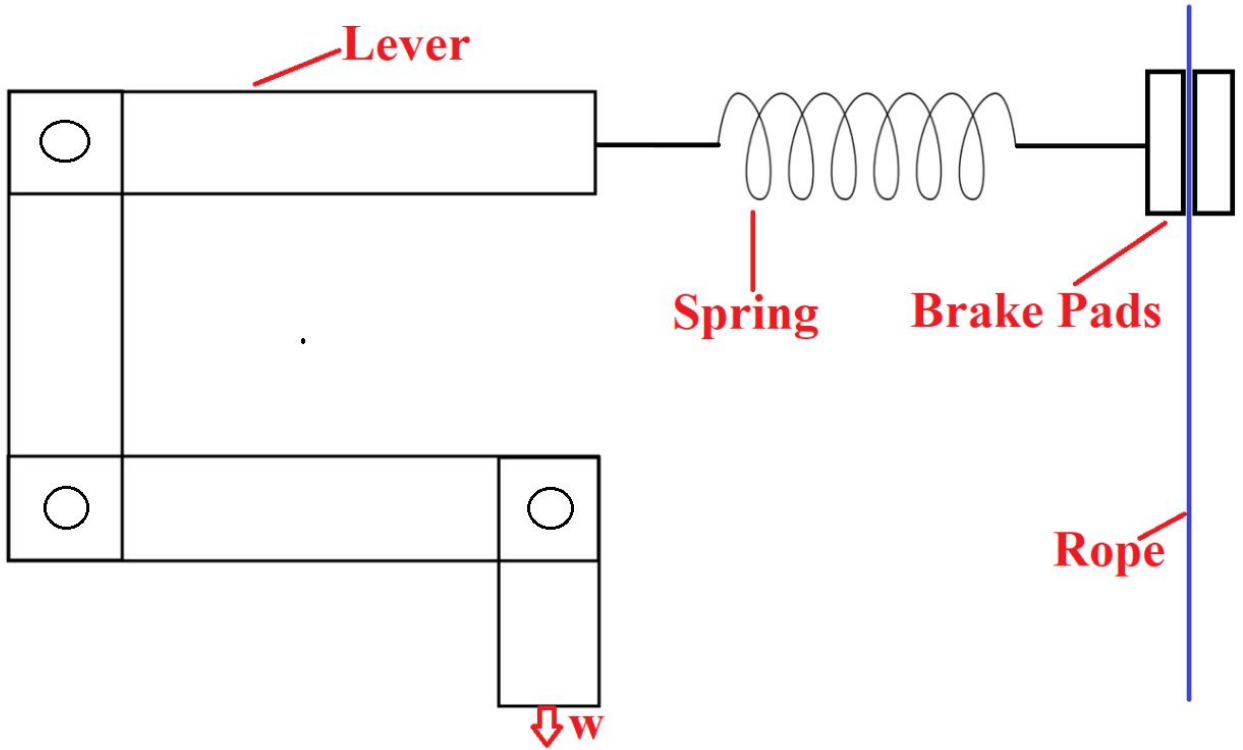
51 MPa

FEA on Lever: Failure Criterion

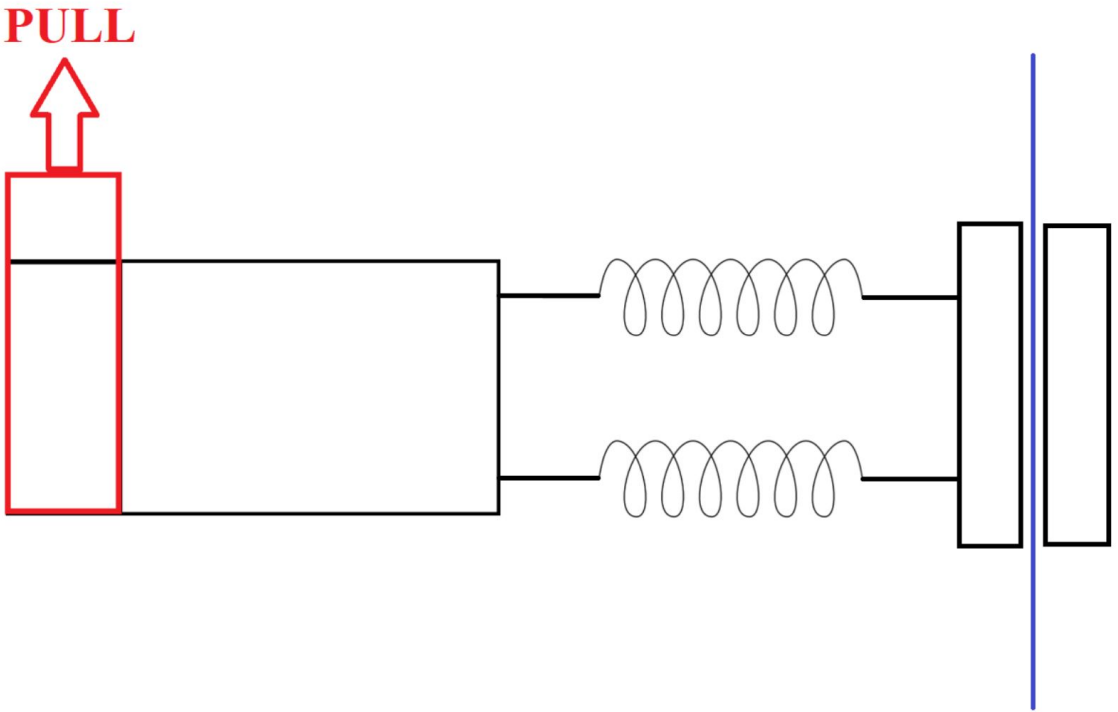
- FEM Maximum Stress = 9.5 MPa
- Allowable stress = 51 MPa
- Therefore,

maximum stress < allowable stress

Design of Spring for Lever



Modified Design of Springs for Hard-brake

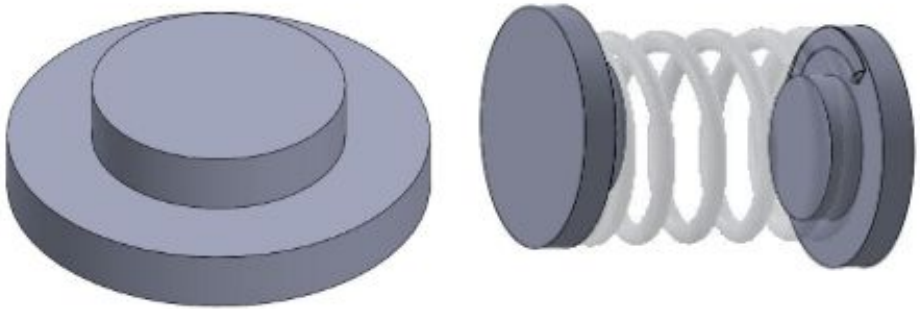


Spring specifications for lever and hard-brake

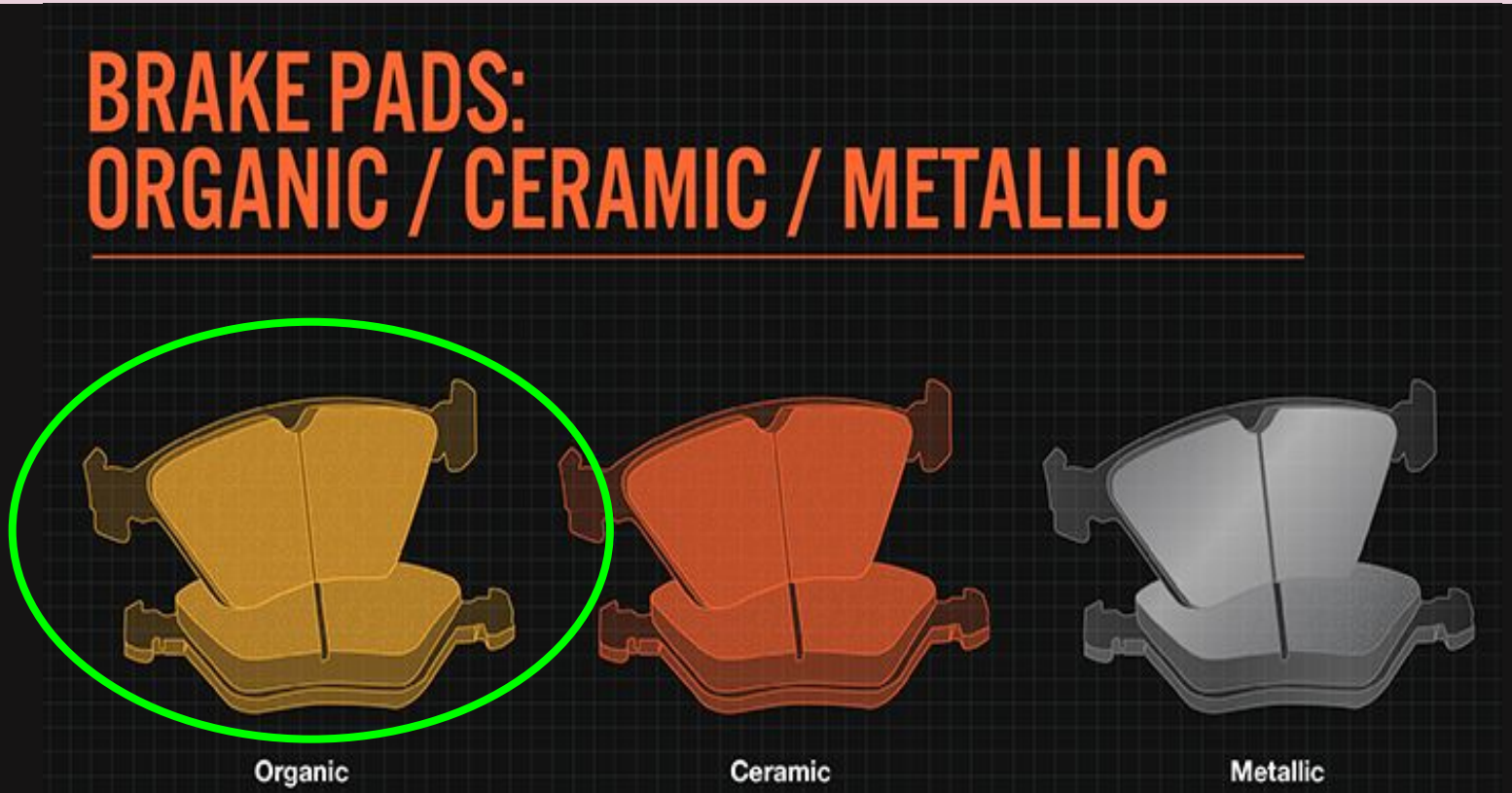
MATERIAL	OIL-TEMPERED A229
SPRING CONSTANT	27.2 N/MM
END TYPE	CLOSED AND GROUND
WIRE DIAMETER	8 MM
OUTER DIAMETER	80 MM
INNER DIAMETER	64 MM
FREE LENGTH	110 MM
SOLID LENGTH	48 MM
ACTIVE COILS	4
TURNS	6

How do we hold the springs in place?

Using spring cups!



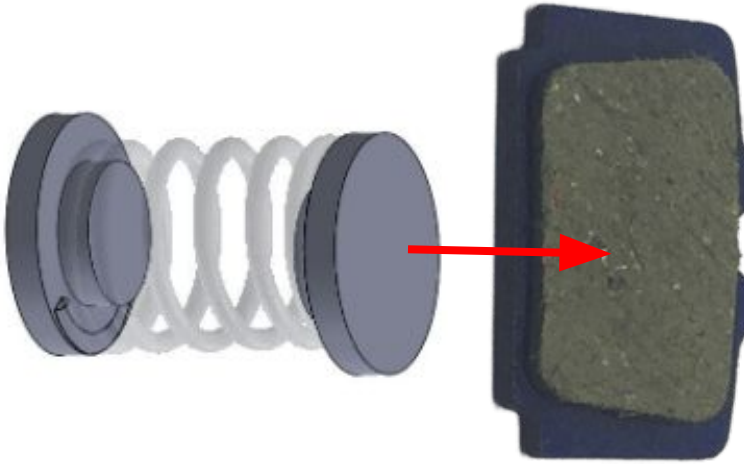
Brake Pads


BRAKE PADS:
ORGANIC / CERAMIC / METALLIC
Organic
Ceramic
Metallic

Brake Pads

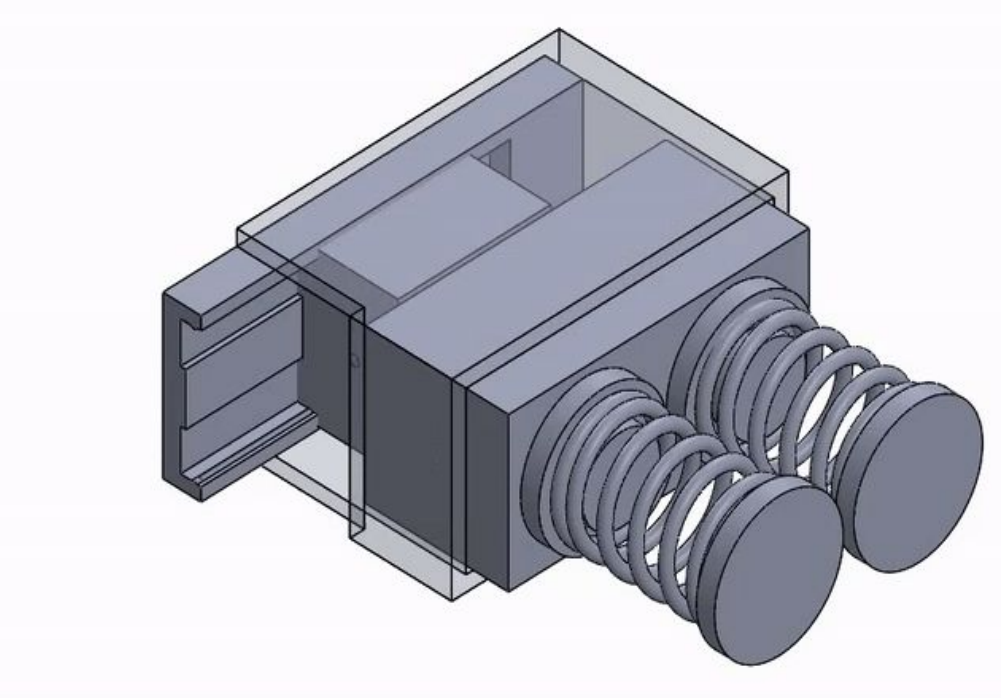
Organic brake pads:

- Widely available: made of materials such as rubber and fiber
- Relatively inexpensive
- Reasonable wear and tear life cycle



	Ceramic	Organic	Semi Metallic	Non Metallic
Availability 1 = hard, 4 = easy to find	3	4	2	1
Cost 1 = expensive, 4 = cheap	1	4	3	2
Loudness 1 = Loud, 4 = Quiet	4	3	1	2
Fatigue 1 = wears down fast, 4 = hard to wear down	4	3	2	1
Fireproof 1 = bad performance 4 = good performance	2	3	4	1
Total /20	14	17	12	7

Design of Hard Brake System



Designed to keep the system stationary

Rope

Rope

Nylon

Technora

Galvanized Steel

¼ ” Diameter:	Nylon 6	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

Rope Diameter

Rope Diameter		Minimum Breaking Strength	
(in)	*(mm)*	*(lb_f)*	*(kN)*
3/16	5	880	3.91
1/4	6	1486	6.61
5/16	8	2295	10.2

Rope Summary

- Nylon
- ¼ inch diameter and 100 feet long
- Able to absorb dynamic load of 1000 lbf

Pre-installed hook

- Easy to install
- Able to withstand a dynamic load of 1000 lbf

Carabiner

Carabiner: Shapes

Oval

D-Shape

Modified D-Shape

Pear

	Oval	D	Modified D	Pear
Availability 1 = hard to find, 4 = easy to find	4	2	3	1
Cost 1 = expensive, 4 = cheap	4	2	3	1
Strength 1 = weak, 4 = strong	1	4	3	2
Weight 1 = heavy, 4 = light	3	1	4	2
Ease of clipping 1 = hard to clip, 4 = easy to clip	2	1	3	4
Total /20	14	10	16	10

Carabiner Gates

Straight

Wire

Screw lock

Auto-lock

	Straight	Wire	Screw	Auto-lock
Availability 1 = hard to find, 4 = easy to find	1	2	4	3
Cost 1 = expensive, 4 = cheap	2	3	4	1
Safety (x3 weight) 1 = not safe, 4 = safe	2 x 3	1 x 3	3 x 3	4 x 3
Ease of opening 1 = hard to open, 4 = easy to open	4	3	1	2
Ease of locking 1 = hard to lock, 4 = easy to lock	N/A	N/A	3	4
Total /28	13	11	21	22

Carabiner Summary

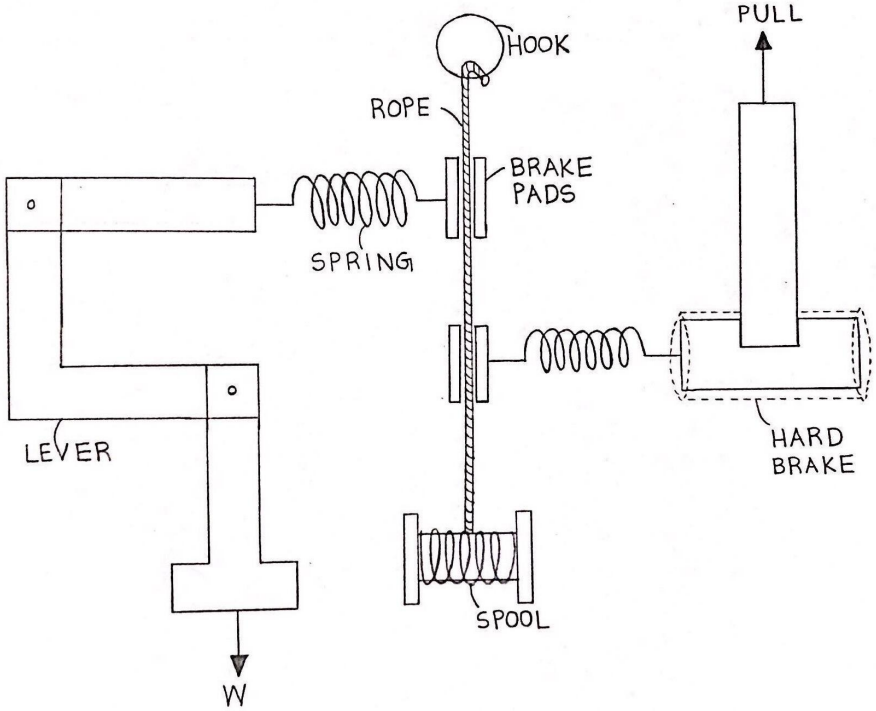
- Modified D-Shape
- Auto-lock

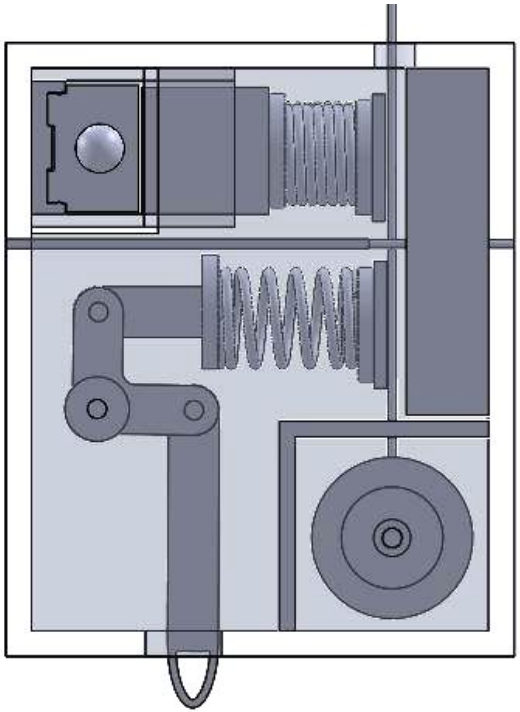
Harness

- Easy to put on
- Able to withstand 1000 lbf

Summary of Braking System

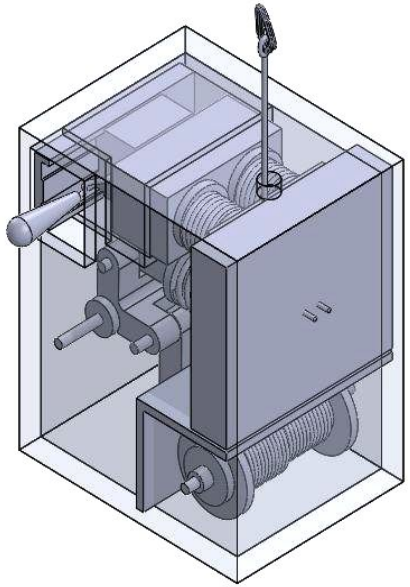
Personal Fire Escape System CAD Model



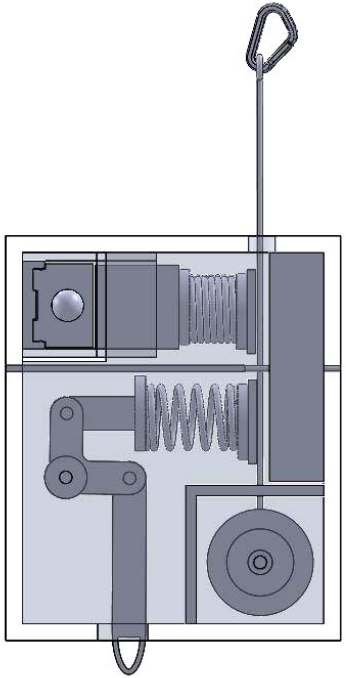


Personal Fire Escape System CAD Model

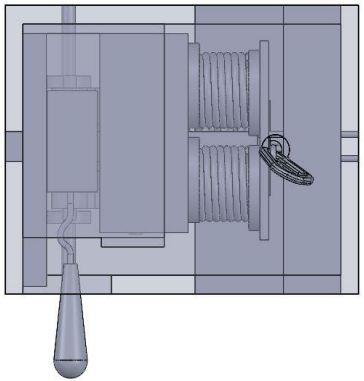
Isometric View



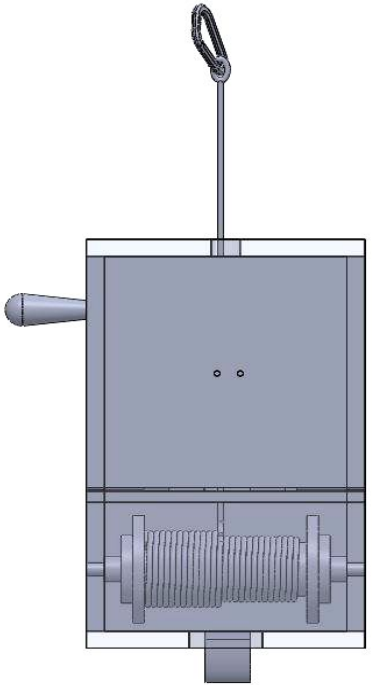
Front View



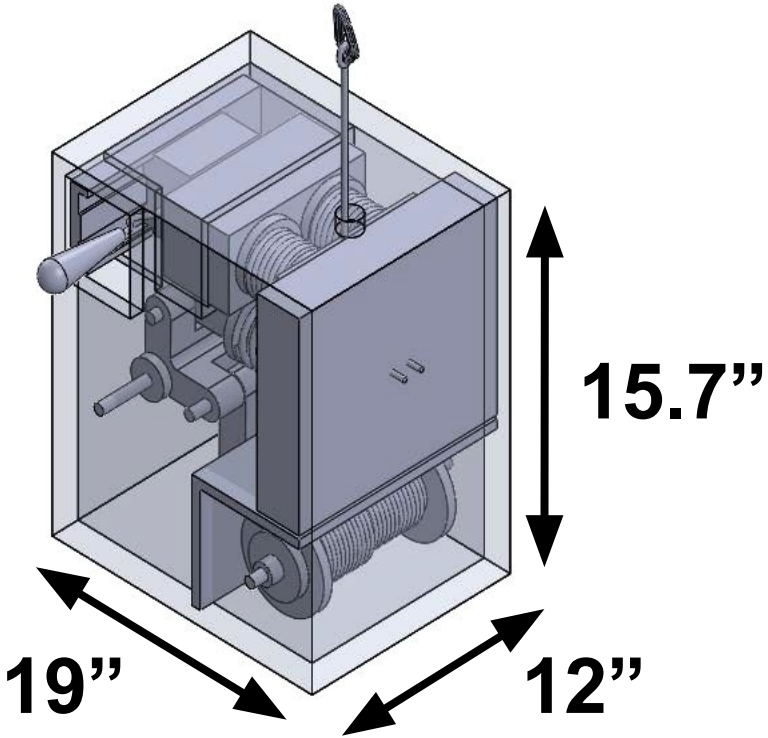
Top View



Right View



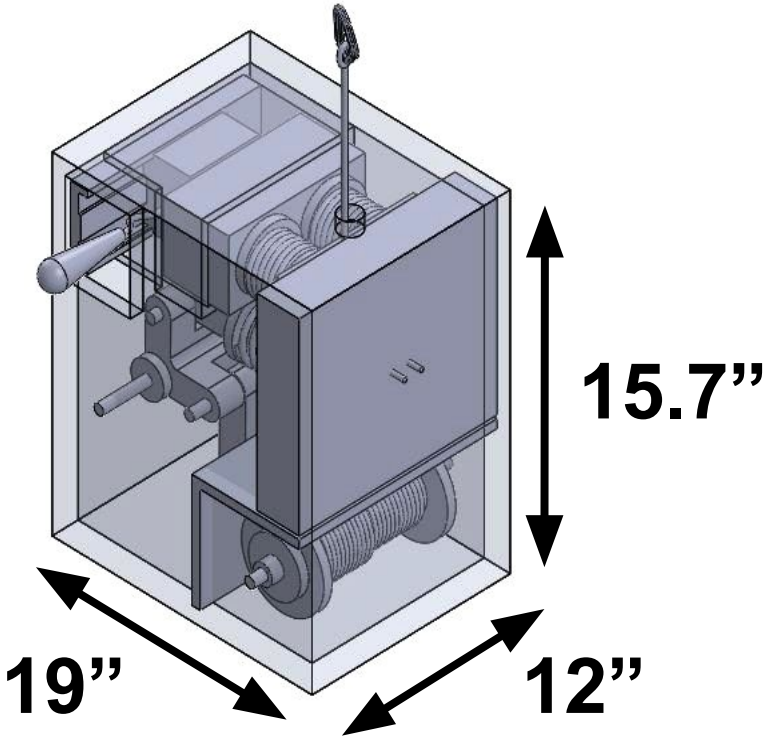
Overall Dimensions



Overall size:

19” x 15.7” x 12”

Overall Dimensions

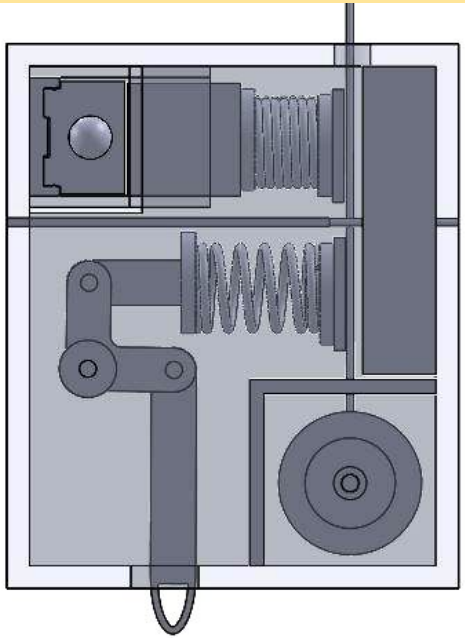


Overall size:

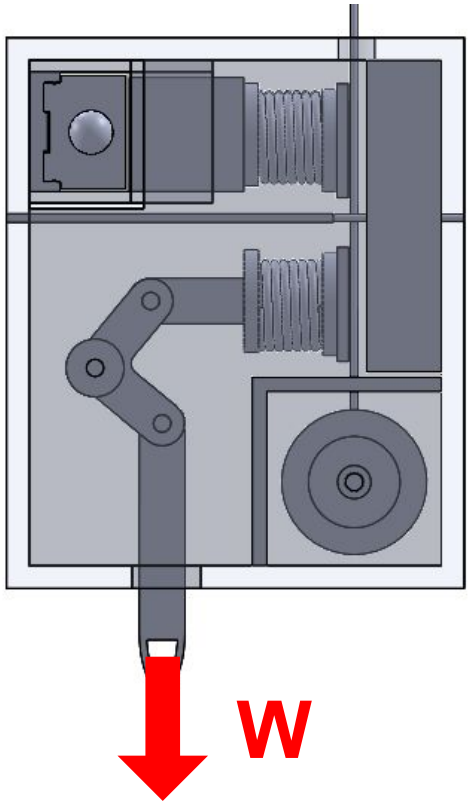
19” x 15.7” x 12”

Large backpack size

Summary: How will it work?



NO WEIGHT APPLIED



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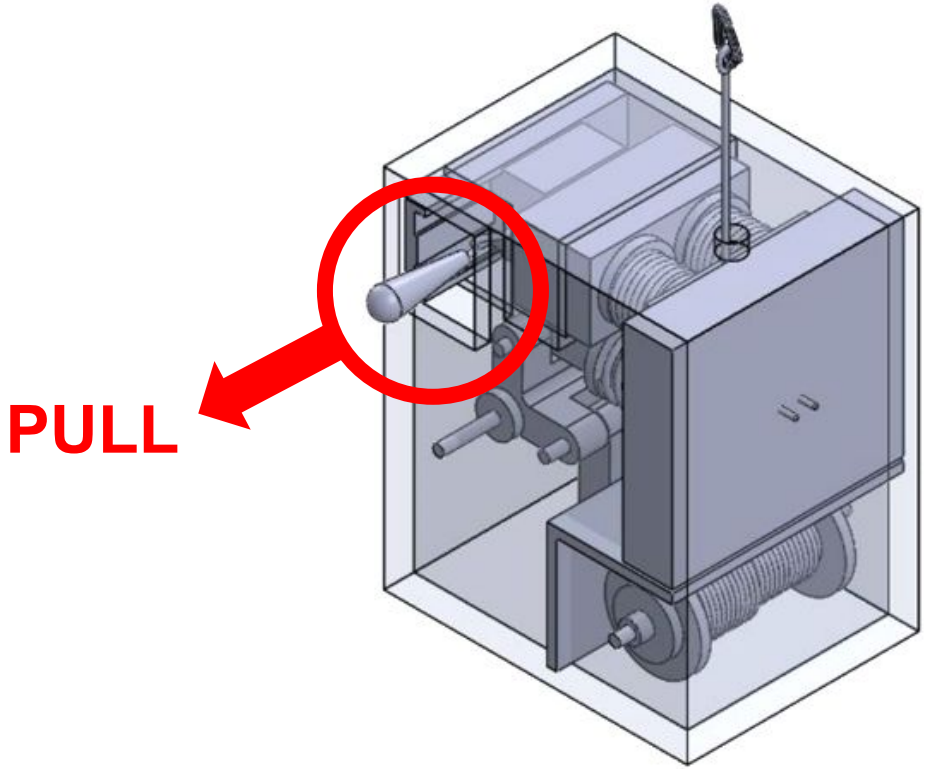
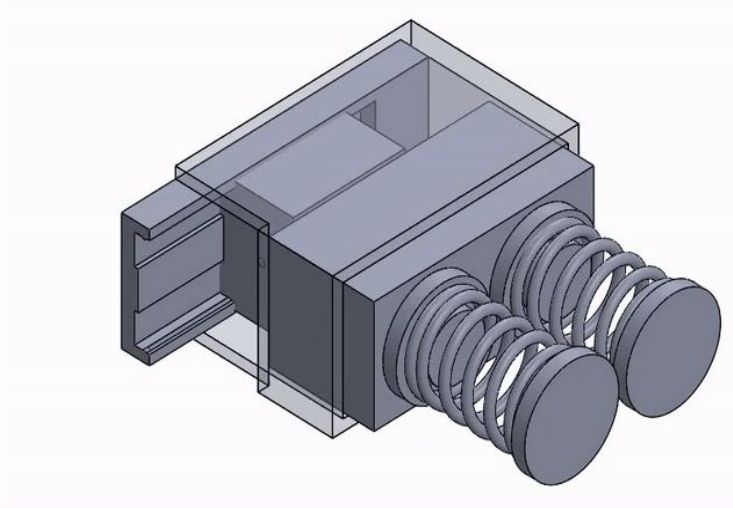
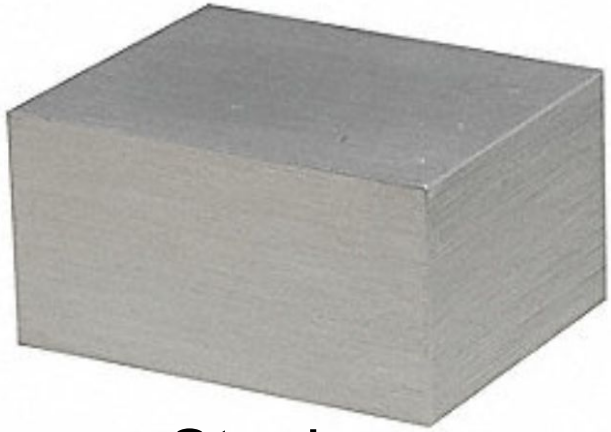




Manufacturing

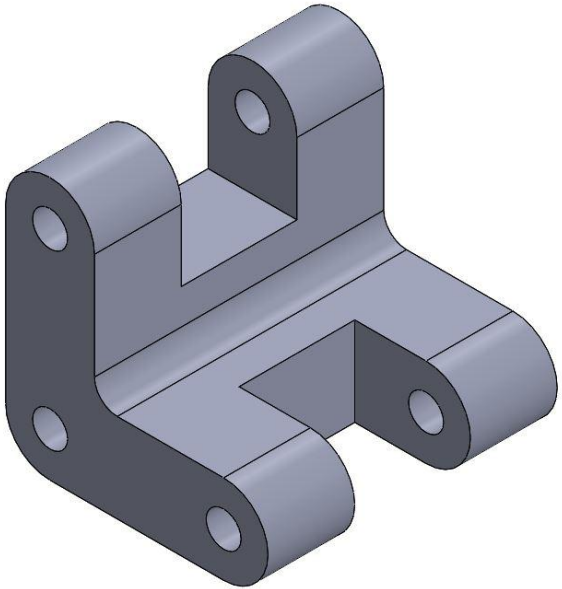
Manufacturing Plans

CNC milling machine the bell crank lever



Stock

CNC



Manufacturing Plans

- Welding machine (housing)
- Purchasing parts online

Product Name	Product Cost	Manufacturing	Purchasing
Lever	$94.65	Yes	No
Pins for Lever	$27.74	No	Yes
3 Springs	3 X $28.49 = $85.47	No	Yes
Brake Pads	$50.00	No	Yes
Rope and Spool	$39.00	No	Yes
SpeedClock App	$1.99	No	Yes
Harness	$86.90	No	Yes
Carabiners (2)	$0.00	No	Yes
Hook	$4.30	No	Yes
Coating	$12.57	No	Yes
Spring Cups	$20.00	Yes	No
Rail	$60.00	Yes	No

Cost Analysis

TOTAL:

$482.62 < $500 Budget

Manufacturing Summary

Total manufacturing time: 8 weeks

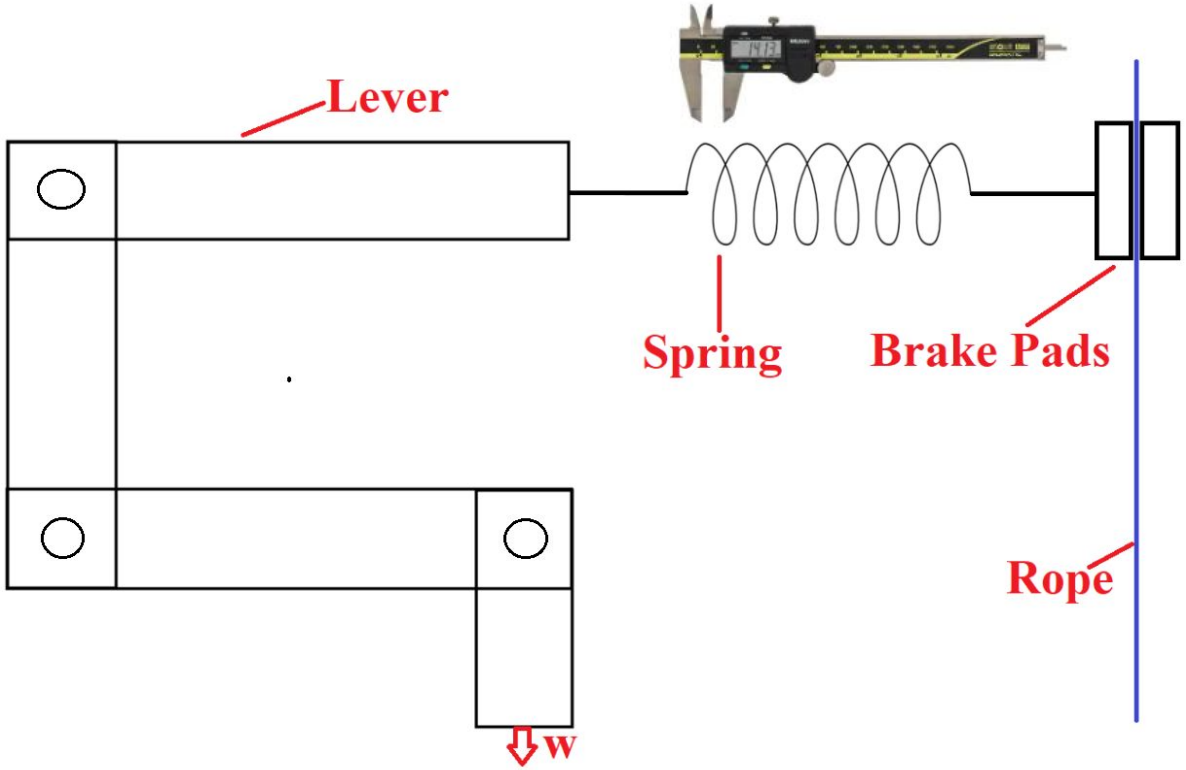
Total manufacturing cost: $482.62

How do we test our product?

Testing Plans

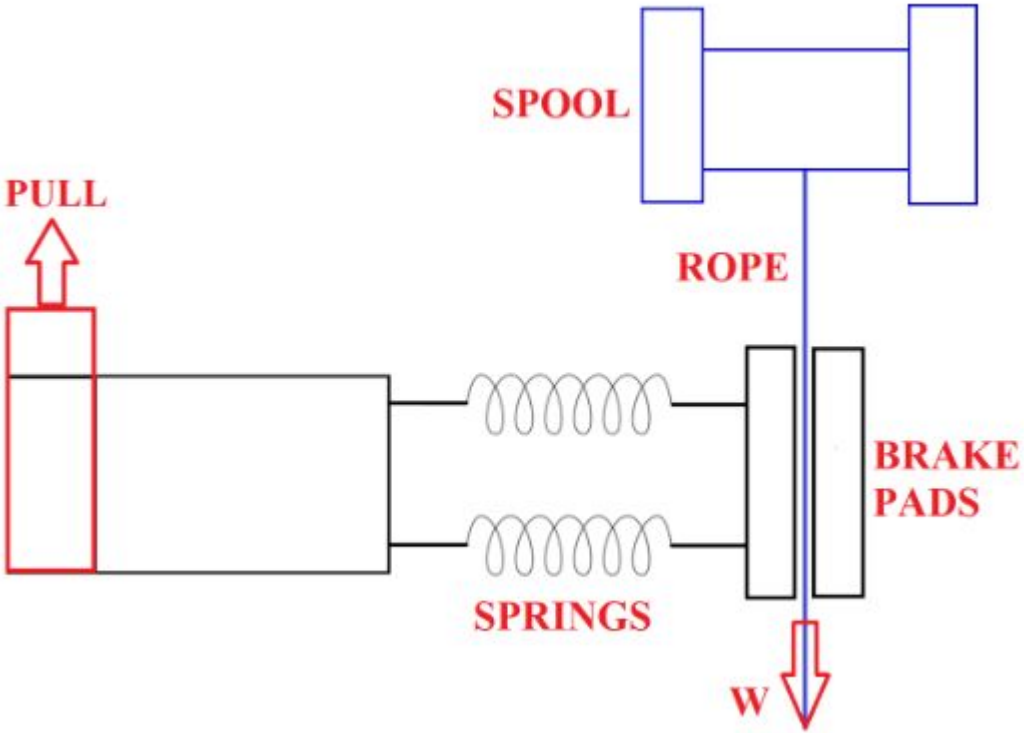
1. Lever and Spring Testing
2. Hard-brake System Testing
3. Pre-Installed Hook and Rope Testing
4. Final Product Testing

Lever and Spring Testing



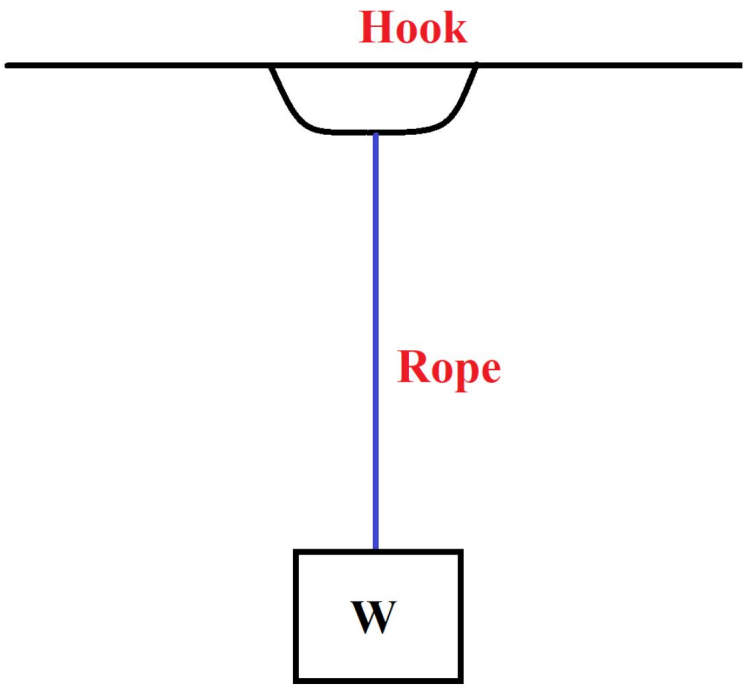
Weight (lbs)	Did the lever fail?	Spring Displacement (mm)	Reached Solid Length?
25			
50			
150			
200			
250			

Hard-brake System Testing



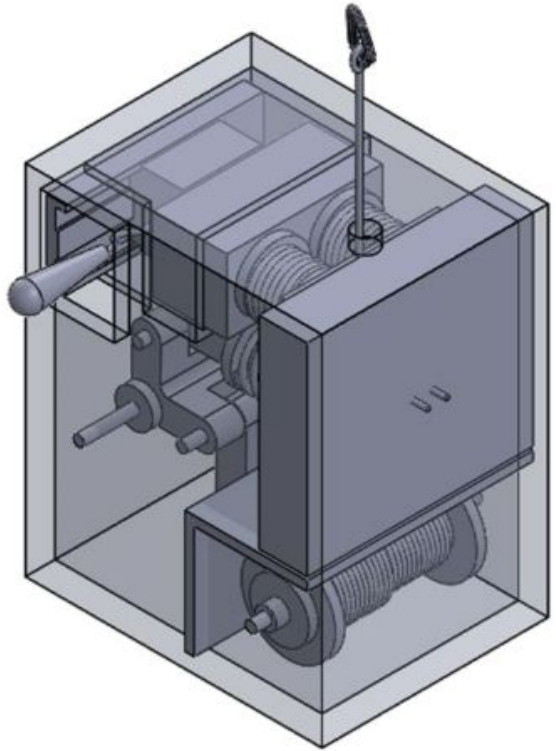
Weight (lbs)	Does the weight descend or stay at rest?	Was it easy to deactivate the brake?
50		
100		
150		
200		
250		

Pre-installed Hook and Rope Testing



Weight (lbs)	Did the hook fail?	Did the rope fail?
50		
100		
150		
200		
250		

Final Product Testing



How do we track speed?

SpeedClock App

- Cheap ($1.99)
- Easy to use
- Simply follow the object to measure its speed

Height (Building Stories)	Object speed (ft/s)
1st	
2nd	
3rd	
4th	
5th	
6th	
7th	
8th	
9th	
10th	

Testing Summary

Total testing time: 2 weeks

Total testing cost: $1.99

Problems & Concerns

Brake Pads:

- Will the brake pads burn out due to a constant brake being applied by the user?

Ventilation System

- How much heat is being dissipated in the housing due to friction?

- Do we need to add more ventilation to the system if the brake pads are inadequately affected by a constant brake?

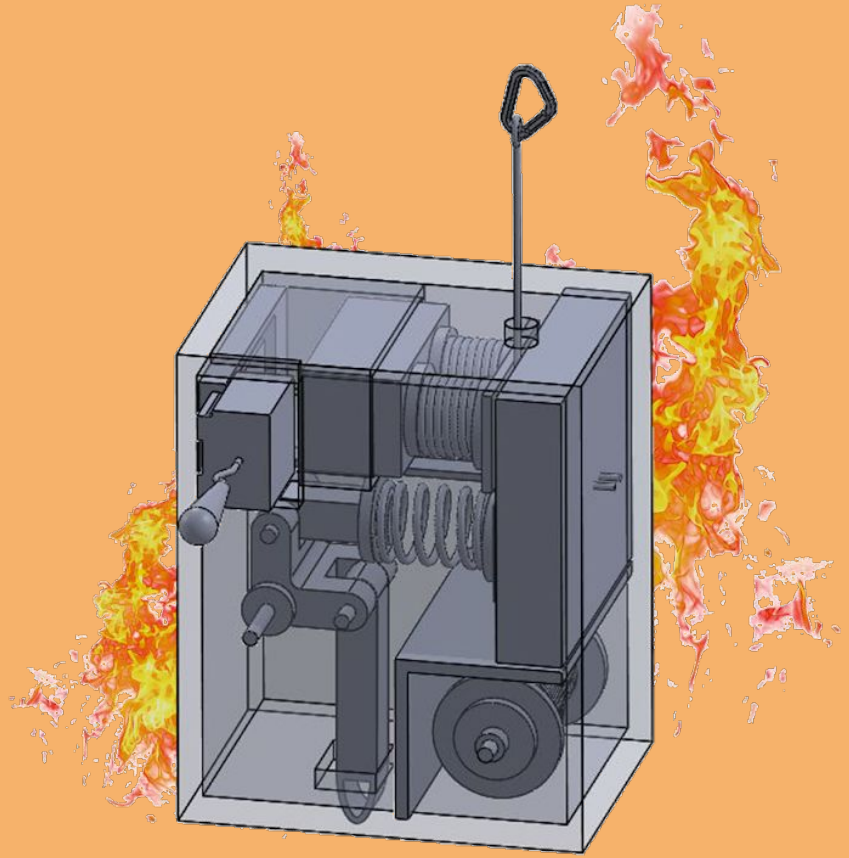
What’s next?

- Think of ways to reduce the number of springs used
- Work on reducing the overall dimensions of the system
- Automatic deactivation of the hard-brake system

Website Link

For more detailed information about our Personal Fire Escape System, check out our website at:

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



Thank you to:

Professor La Grotta

Questions?

References

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