Creating Interactive Training Mock-Ups

La Academia Nacional de Bomberos
and
Worcester Polytechnic Institute

Our Team

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Objectives & Methodology

OUR GOAL:

Design physical, affordable, and reusable mock-ups that the Costa Rican Bomberos can implement into their fire protection and emergency response training curriculum.

Objectives

Structural Reinforcement

- Design a mockup that can test the integrity of structural reinforcements

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Ventilation

- Design a mockup that can replicate different ventilation techniques and fire phenomena

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Ventilation

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Budget and Reusability

- Draft a cost outline for each mockup
- Keep mockups reusable and sustainable

Methodology

Gaining Insight

BOMBEROS INTERVIEW

ANB TOUR AND VISIT TO NORTH METROPOLITAN FIRE STATION

BACKGROUND RESEARCH

Key Principles

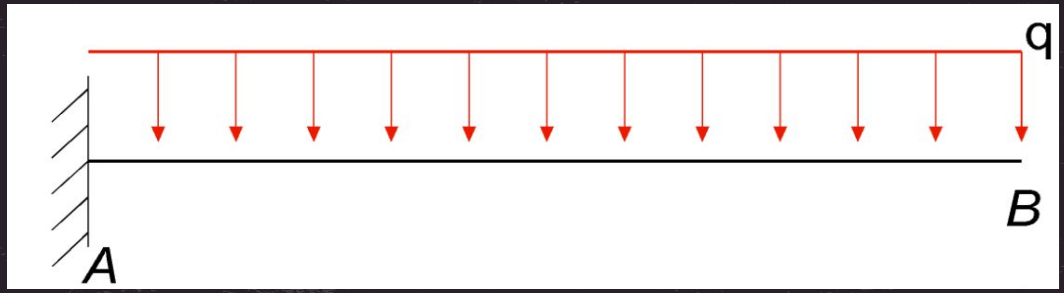
Types of Forces Acting on the Reinforcements

Smoke Flow, Ventilation Mechanisms, and Fire Phenomena

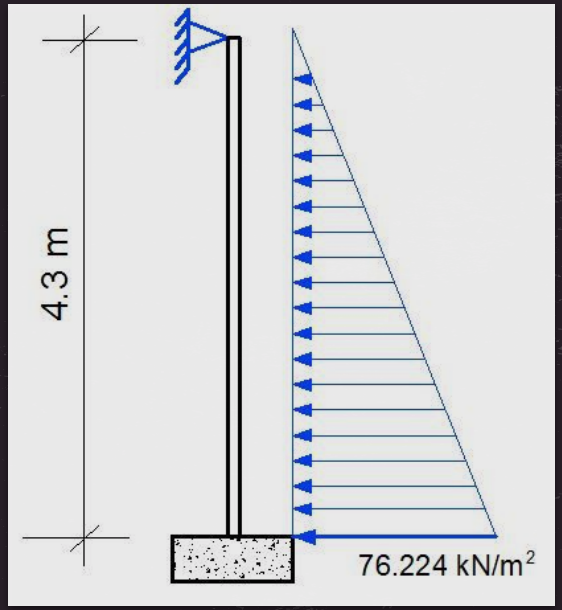
Our Findings

Non-Uniform Distributed Load

Added a challenge to our design process



Uniform Distributed Load



Non-Uniform Distributed Load

Our Findings

Fire Phenomena:

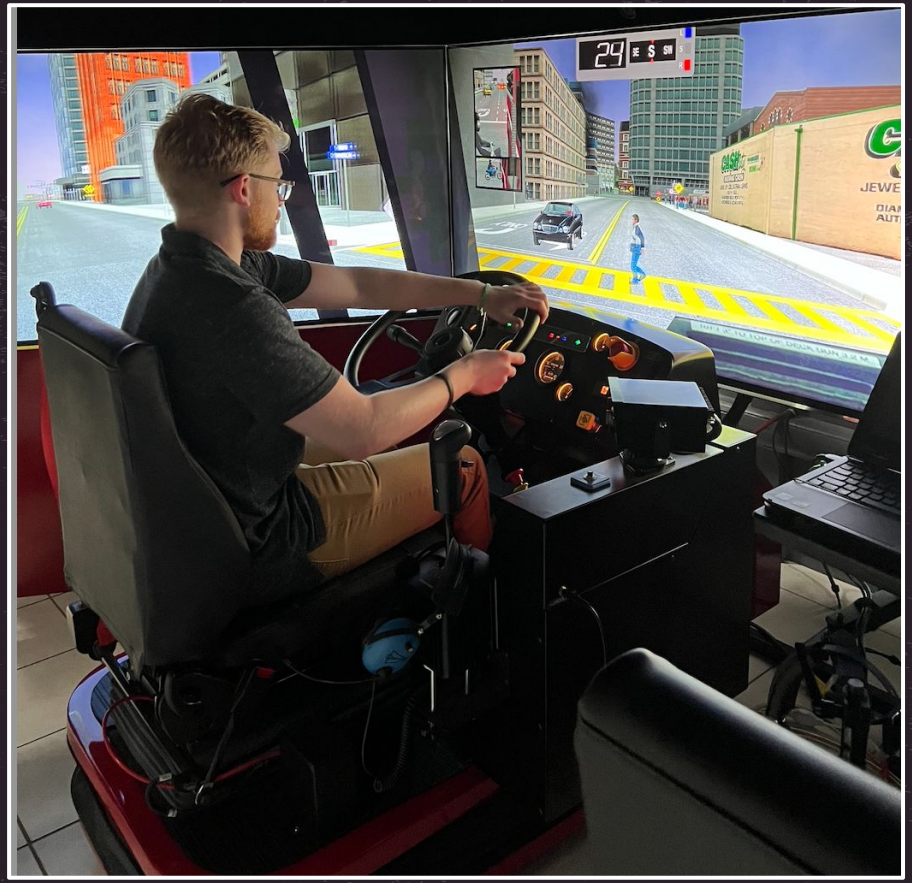
- **Backdraft**
- **Flashover**
- **Rollover**

Ventilation Techniques:

- Horizontal
- Vertical
- Positive Pressure
- Hydraulic

TOUR OF ANB AND NORTH METROPOLITAN FIRE STATION

BOMBEROS COSTA RICA




BOMBEROS
COSTA RICA


COSTA RICA
2
5

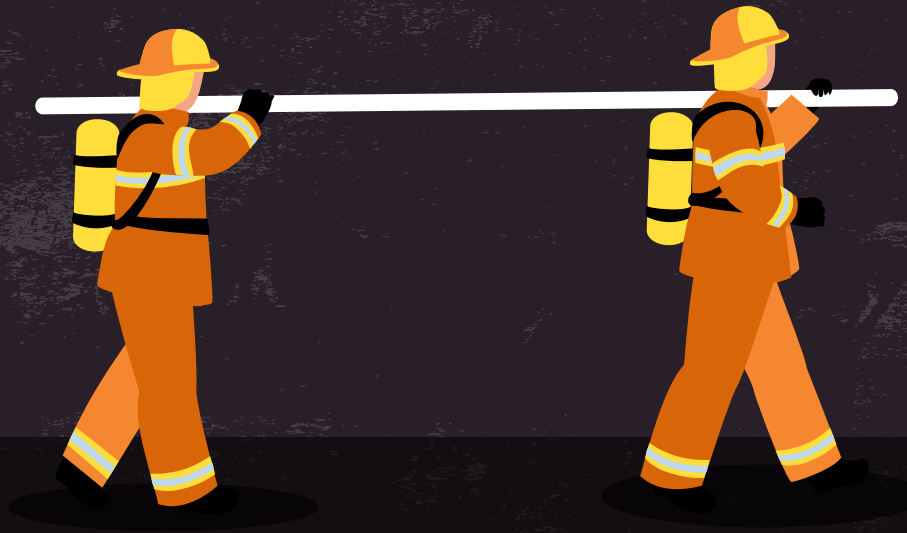

M-32


M-32
BOMBEROS CR

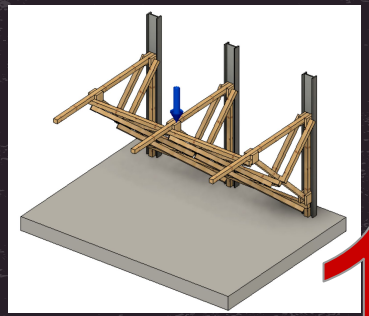

COSTA RICA
mos lo que hacemos,
nos lo que usted ama.


COSTA RICA
BOMBEROS CR
COSTA RICA
341-590
CENTROAMERICA

DESIGNING MOCK-UPS



Structural Reinforcement Design Iterations



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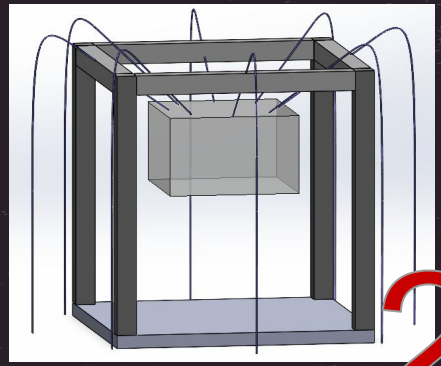

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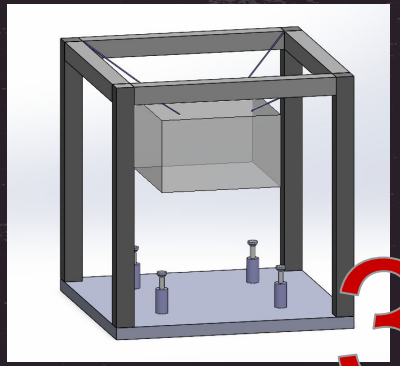
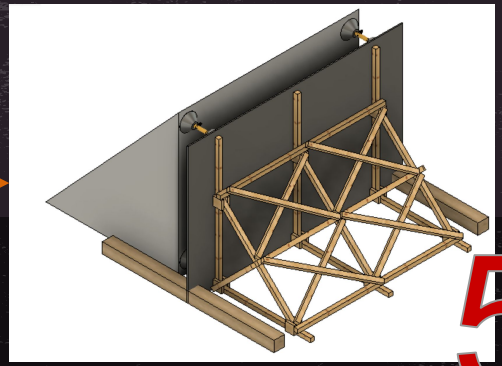


3

4



5

Structural Reinforcements

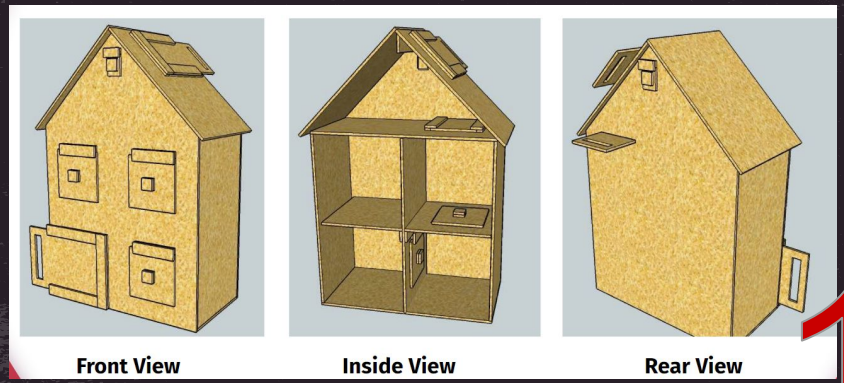
Top-Loading Simulator

- Lower cement block onto the shores and trusses
- Maximum load of 40 tons

Hydraulic Based Simulator

- Hydraulic cylinders apply force
- Shores and trusses are laid on their sides

Ventilation Design Iterations



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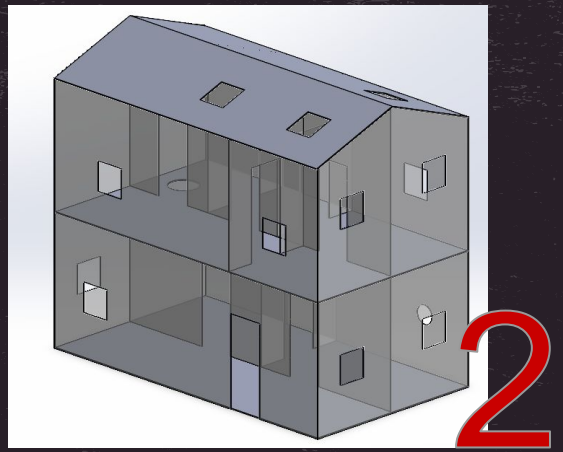

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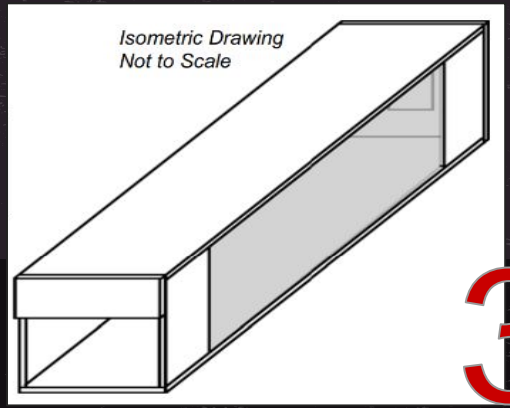

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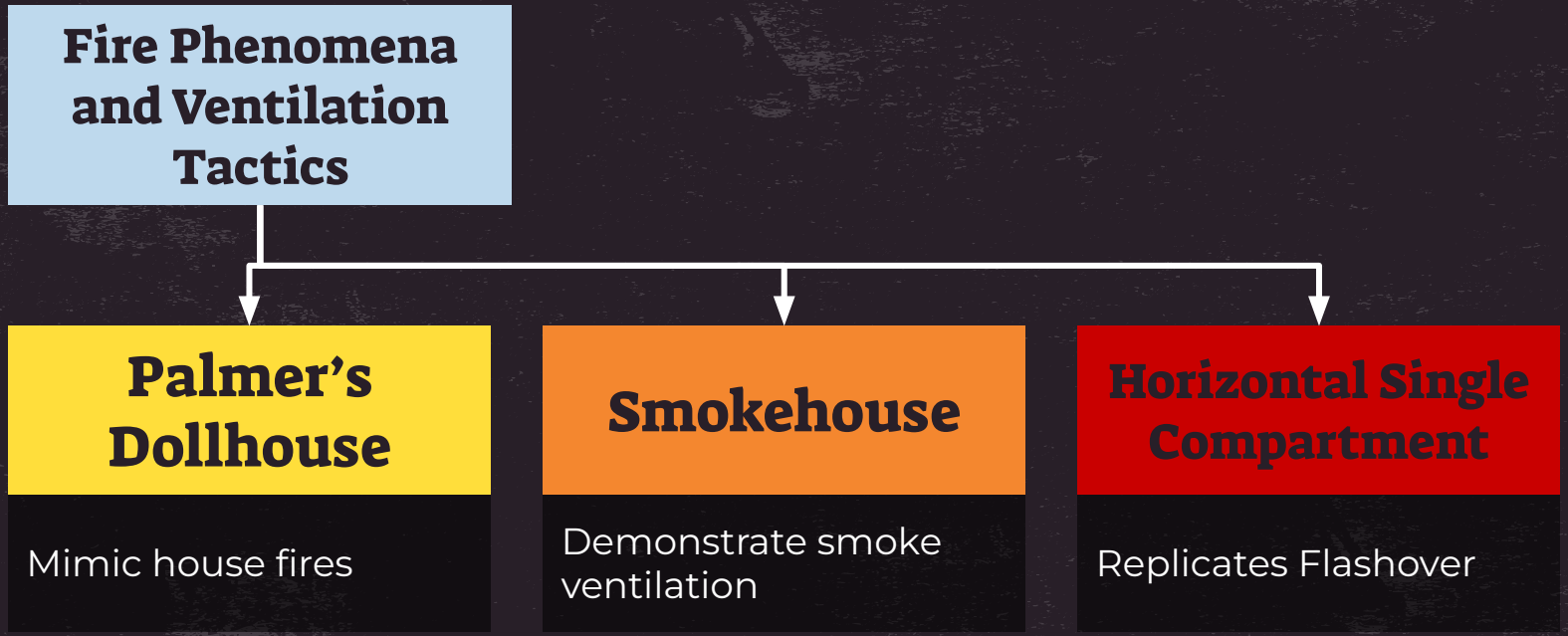
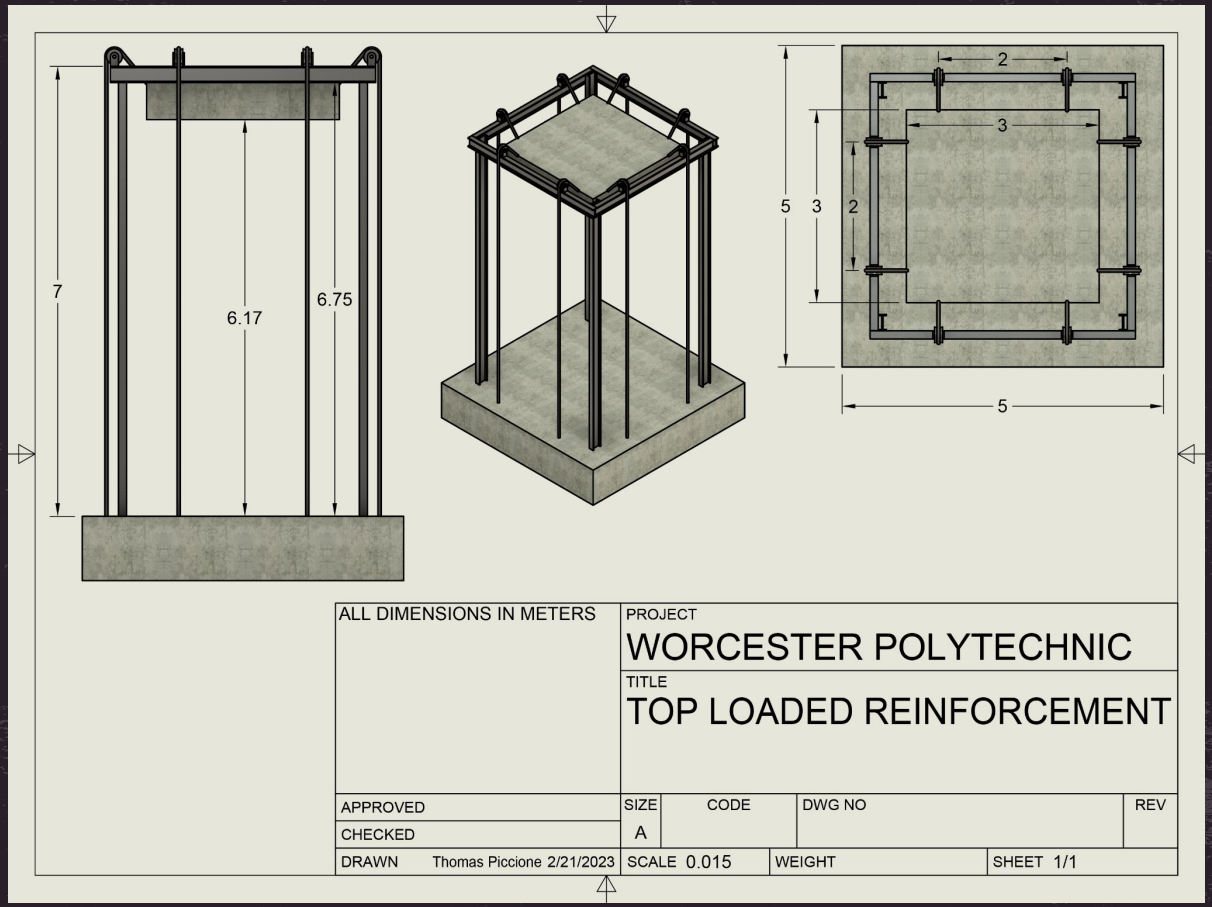
Ventilation Design

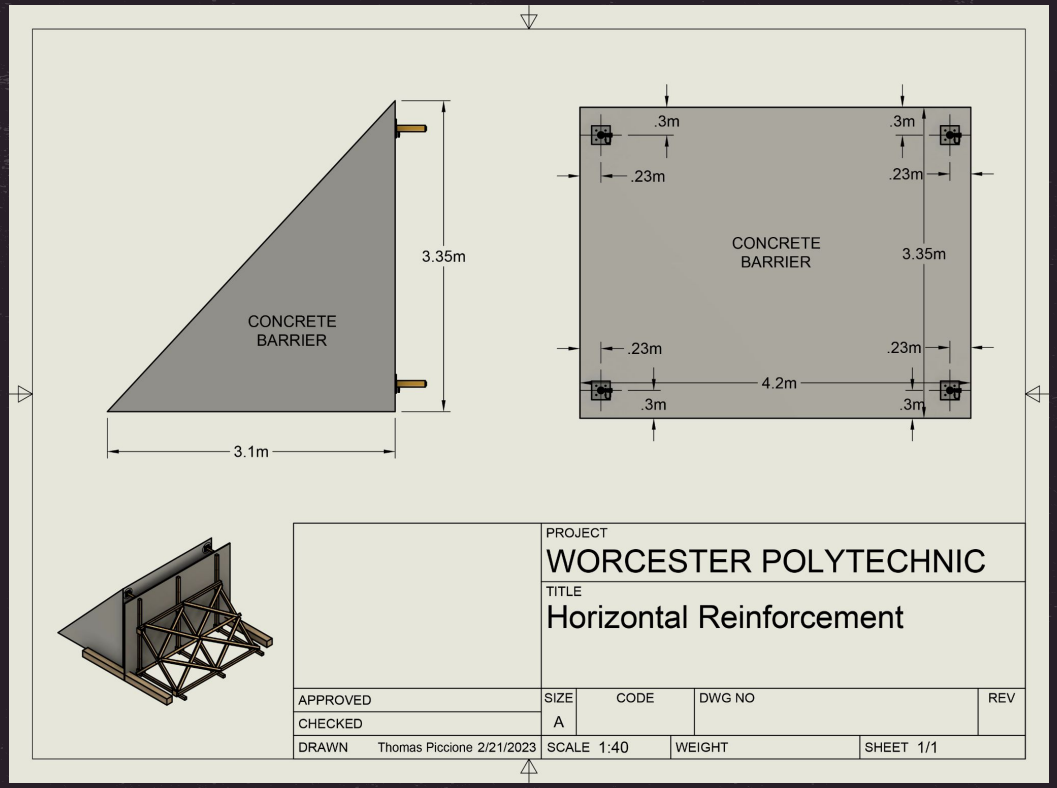


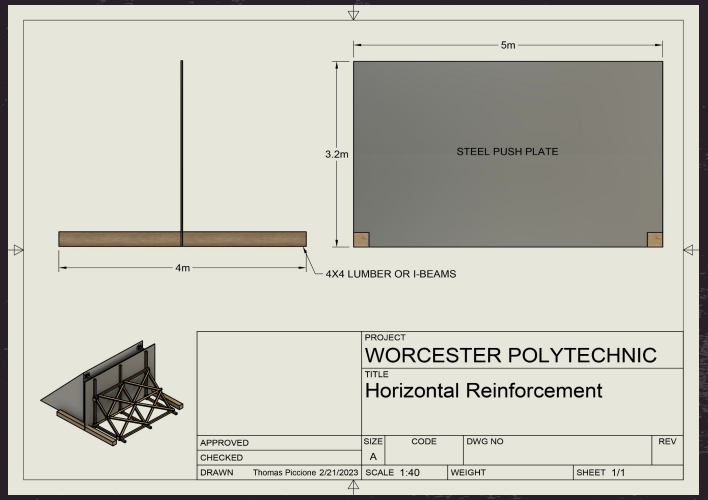
02
Final Mockup Designs

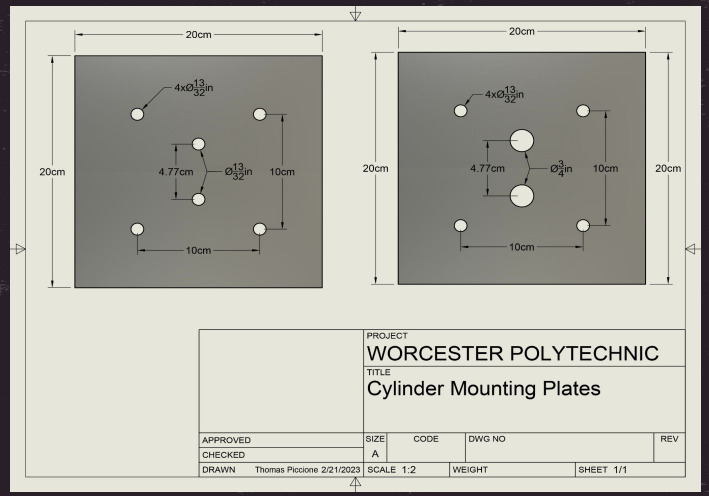
Top-Loaded Structural Reinforcement



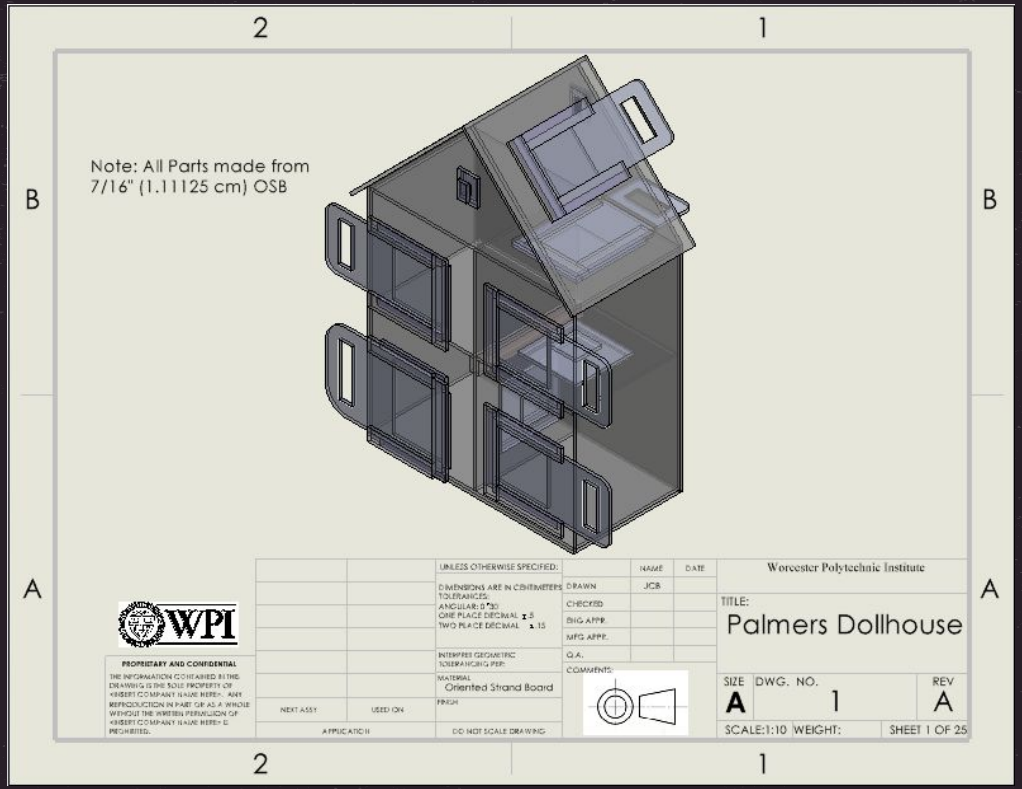
Hydraulic Side Press





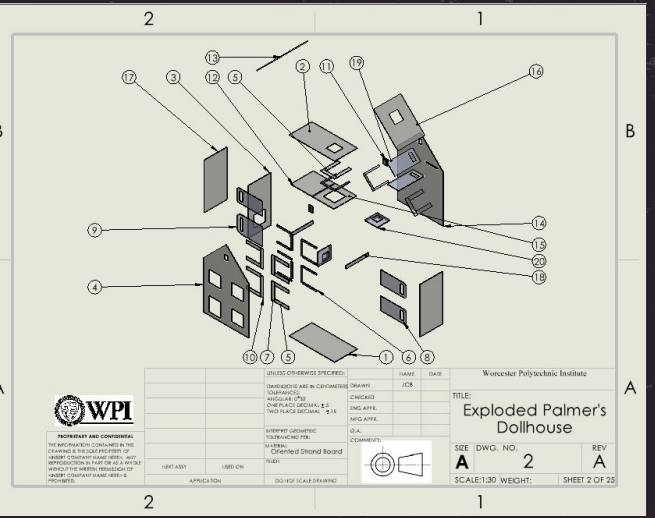


Palmer's Dollhouse

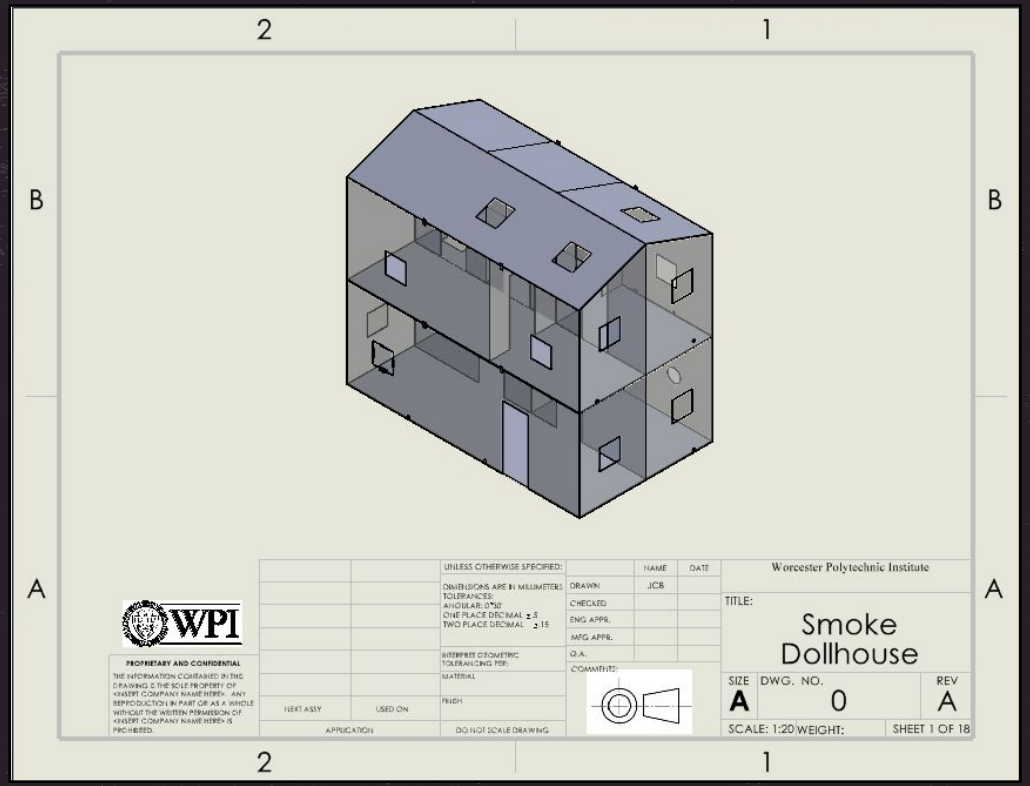


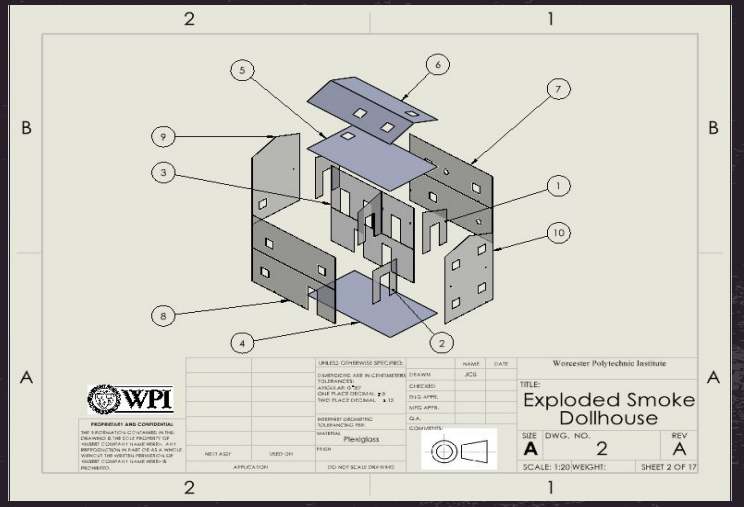
ITEM NO.	PART NUMBER	DESCRIPTION	MATERIAL	QTY.
1	Base		Oriented Strand Board	1
2	Ceiling		Oriented Strand Board	1
3	Central Panel		Oriented Strand Board	1
4	Front Panel		Oriented Strand Board	1
5	2 inch cap 2		Oriented Strand Board	14
6	1 inch cap		Oriented Strand Board	18
7	2 inch cap 1		Oriented Strand Board	3
8	Window Cover Slide		Oriented Strand Board	3
9	Door Cover Slide		Oriented Strand Board	1
10	2 inch cap 3		Oriented Strand Board	1
11	Gable Vent Cover		Oriented Strand Board	2
12	Left Floor Panel		Oriented Strand Board	1
13	Left Side Panel		Oriented Strand Board	1
14	Rear Panel		Oriented Strand Board	1
15	Right Floor Panel		Oriented Strand Board	1
16	Right Side Panel		Oriented Strand Board	1
17	Side		Oriented Strand Board	2
18	2nd floor supports		Oriented Strand Board	2
19	Roof Deck Slide		Oriented Strand Board	2
20	Inner Vent Cover		Oriented Strand Board	2

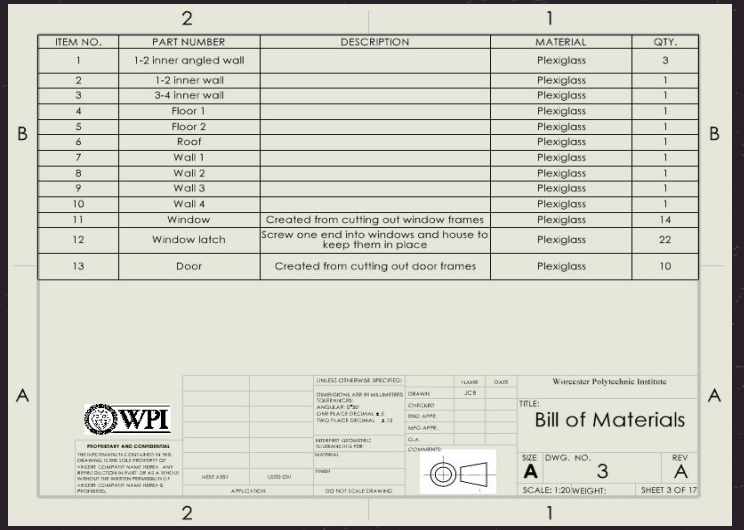
Worcester Polytechnic Institute
Bill of Materials
SIZE A | DWG. NO. 3 | REV A
SCALE: 1:20 WEIGHT: SHEET 3 OF 25



Smokehouse

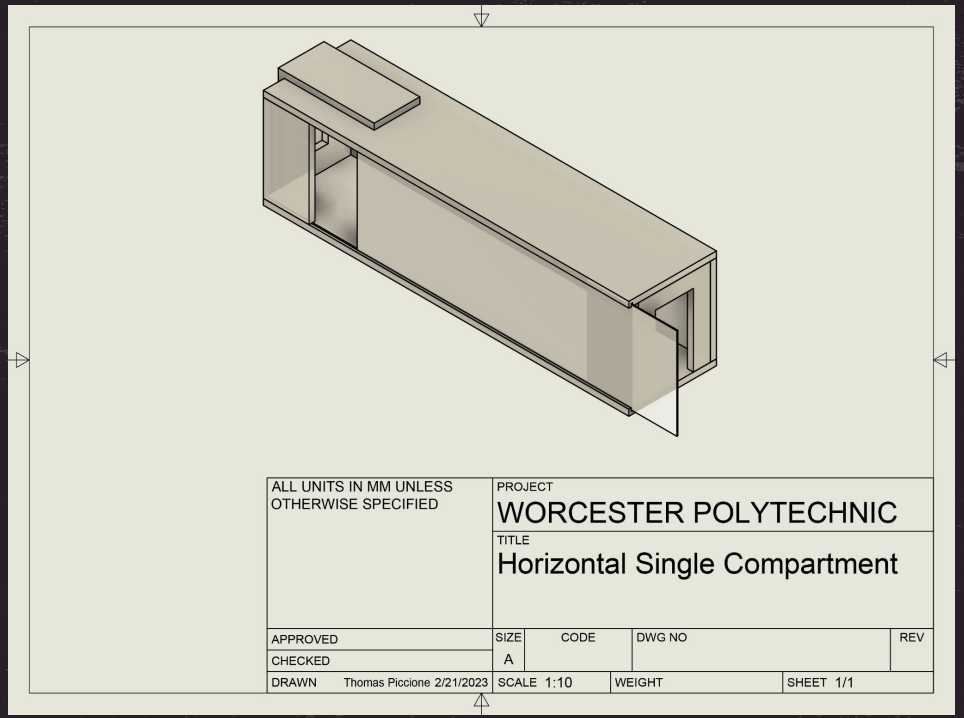


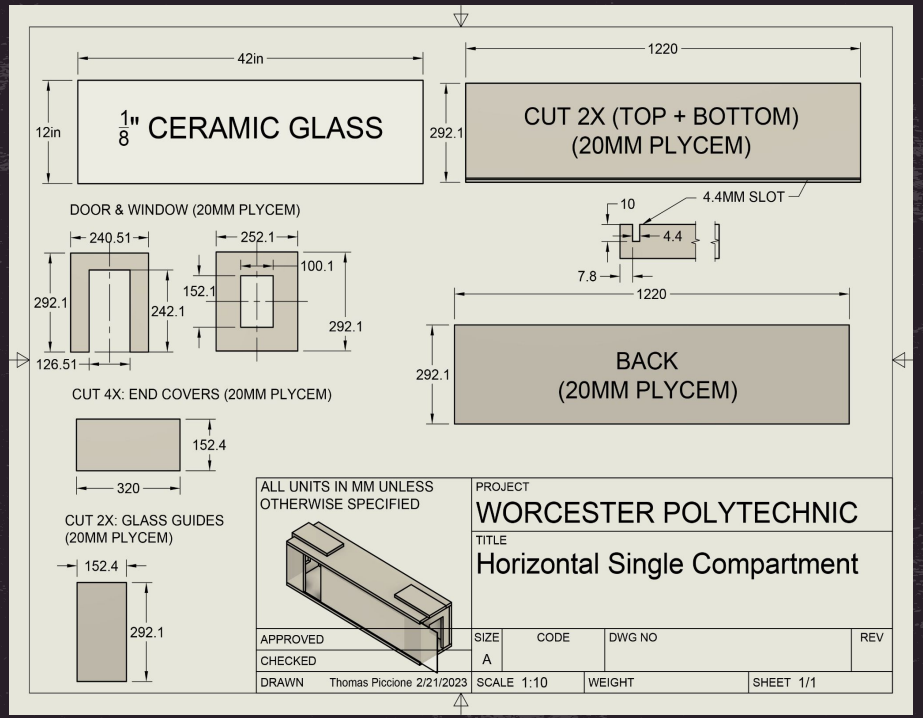




ITEM NO.	PART NUMBER	DESCRIPTION	MATERIAL	QTY.
1	1-2 inner angled wall		Plexiglass	3
2	1-2 inner wall		Plexiglass	1
3	3-4 inner wall		Plexiglass	1
4	Floor 1		Plexiglass	1
5	Floor 2		Plexiglass	1
6	Roof		Plexiglass	1
7	Wall 1		Plexiglass	1
8	Wall 2		Plexiglass	1
9	Wall 3		Plexiglass	1
10	Wall 4		Plexiglass	1
11	Window	Created from cutting out window frames	Plexiglass	14
12	Window latch	Screw one end into windows and house to keep them in place	Plexiglass	22
13	Door	Created from cutting out door frames	Plexiglass	10

Horizontal Single Compartment





03

Instruction Manuals, Cost Outline & Reusability

Instruction Manuals

- Supplies/Materials
- Assembly Guides
- Cut Sheets
- Classroom Instructions

WPI

2023 Training Mock-up Instruction Manual and User Guide

Our team from Worcester Polytechnic Institute in conjunction with the Costa Rican Bomberos have developed the following instruction manuals for five proposed training mock-ups. Due to the high risk factor associated with the structural reinforcements it is strongly recommended a Civil Engineering Firm or licensed contractors approve before use. This document serves as a guide for these mockups' intended use. The ventilation mockups have been widely used in other parts of the world and therefore should be safe for use based on our instructions as follows.

Top-Loaded Structural Reinforcement Tester:

Supplies/Materials:

- Approximately 1.513 bags of Concrete (50 kg Bags)
- 4 7-Meter Steel I Beams
- 4 5-Meter Steel I Beams
- 8 3-Ton Chain Motors
- 8 Chain Pulleys
- 32 20-mm diameter U-shaped Rebar

Assembly Instructions:

1. Dig out an 5x5 meter hole, at a depth of 1 meter
2. Using about 1.150 bags of concrete, create a 5x5x1 meter concrete pad
3. Anchor and/or bolt the 4 7-meter I beams vertically into the concrete pad, arranged in a square smaller than 5x5 meters by a width of 1 I beam on each side
4. Attach and/or bolt the 4 5-meter I beams horizontally to the top of the vertical I beams
5. Arrange and attach the 8 3-ton chain motors around the concrete pad, so that there are two on each side of the square
6. Attach all 8 of the chain pulleys on top of the horizontal I beams, aligning each with their respective motor located below
7. To create the concrete blocks, construct a 3 x 3 m box out of wood, and cover the inner sides with trash bags, located in the center of
8. Pour concrete into the constructed mold at various heights (47.1126 cm, 6.5738 cm, 12.0520 cm, and 4.3825 cm)
9. While the first block is setting, insert 8 of the U shaped rebar into each block, 2 on each side, and distance the same as the motors and pulleys. Insert as much as possible while the chain motors' hooks are still able to attach to the rebar
10. After the first block has set, deconstruct the mold and reconstruct it on top of the new concrete block
11. Repeat steps 8-10 with all heights listed in step 8

Palmer's Dollhouse:

This Palmer Dollhouse design and instruction manual has been adapted, with permission from Capt. Matthew Palmer of the Stamford, Connecticut Fire Department and StopBelievingStopKnowing.com.

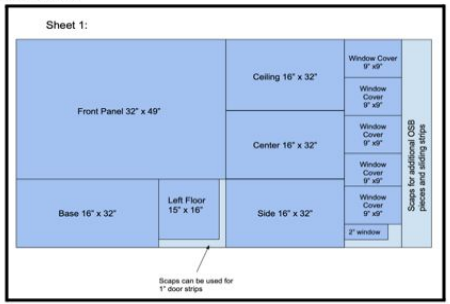
Materials:

- 6 wooden palettes (used as platform)
- 2 sheets of 4' x 8' 7/16" Oriented Strand Board (OSB)
- Dry straw/pine strips (initial fuel)
- Styrofoam (additional fuel source)
- Torch (to light fire)
- Spray bottle (used to wet the exterior of the dollhouse to increase OSB longevity)
- Fire extinguisher
- Caulk or construction adhesive
- 1" staples for use with a pneumatic staple gun
- Sand paper

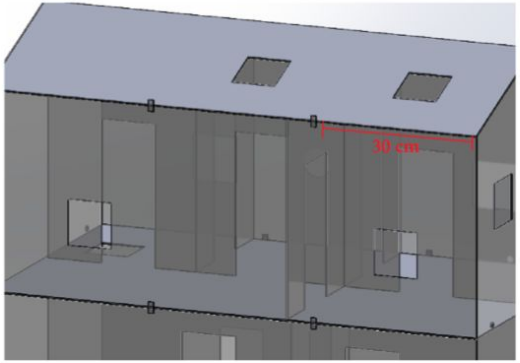
Tools:

- Table saw or worm drive saw
- Miter saw
- Jigsaw or multi-tool oscillating saw
- Pneumatic stapler with compression gun
- Cordless drill with spade-style wood drill bit

Cut Sheet:



28. Once the first floor, second floor, and roof all finish drying the entire smokehouse can be assembled.
29. To hold the second floor and roof in place, screw in 2 latches per intersection between the two separate floor compartments with the screws being located on the lower compartment, located 30 cm from their respective sides. Rotate the latches vertically to hold the different compartments in place (see below)



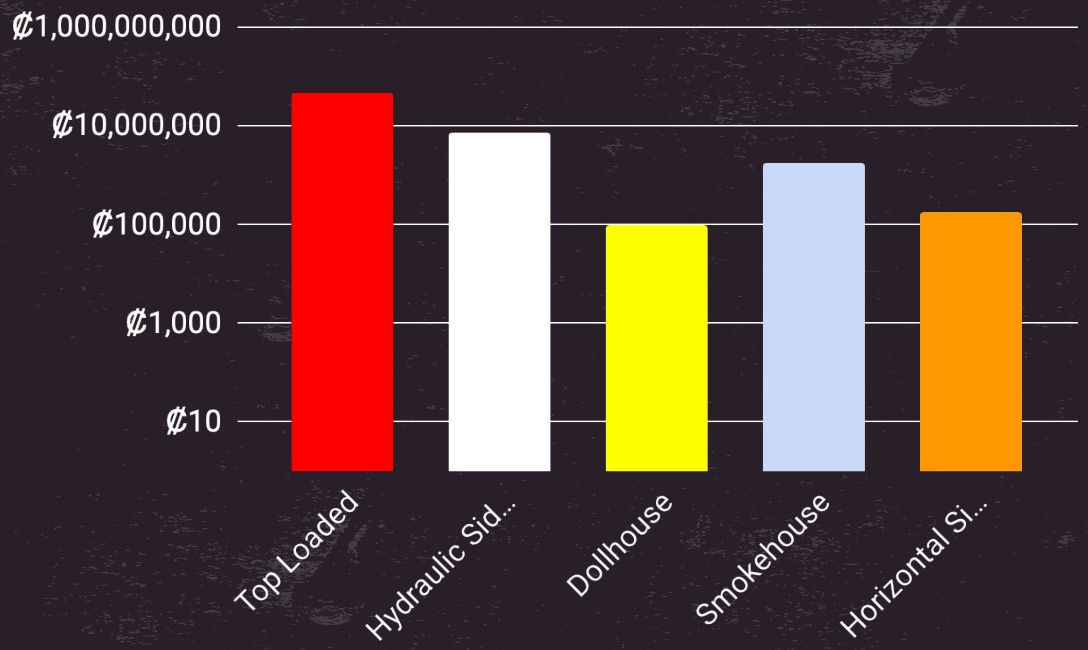
How to construct windows:

1. First, construct the window piece according to the blueprints, aligning the smaller 4 rectangles onto the back of the previously cut out squares
2. Orientate the window so that the larger of the 4 rectangles is on the bottom
3. Screw in the window latch into the window and through the larger of the 4 rectangles, ensuring that the latch is still able to rotate, although tightly

How to use:

1. Load the smoke machine with fuel and fasten the nozzle into the designated hole for the smoke source
2. In order to open the windows turn the latch until it is horizontal, then pull the window piece out

Cost Outline



Top-Loaded

₡ 48.887.189

Hydraulic Side Press

₡ 7.459.290

Dollhouse

₡ 100.707

Smokehouse

₡ 1.738.681

Horizontal

₡ 181.758

WPI

2023 Training Mock-Up Budget Presented to La Academia Nacional De Bomberos

Our team from Worcester Polytechnic Institute in conjunction with the Costa Rican Bomberos have developed the following budget for five proposed training mock-ups. Some distributors are located in other countries, but based on our research there should be private vendors in Costa Rica as well.

Top-Loaded Structural Reinforcement:

ITEM	MATERIAL	DISTRIBUTOR	QTY	PRICE (₡)	TOTAL (₡)
Weighted Blocks	Concrete (50 kg bags)	EPA (CR)	363 bags	6.950 per 50kg bag	2.522.850
I-Beams	Steel	Need a consultation from construction company	48 m	84.181.42 per meter	Estimated to be 4.040.708
Concrete Pad	Concrete (50 kg bags)	EPA (CR)	1.150 bags	6.950 per 50 kg bag	7.992.500
3 Ton Chain Motor	N/A	ACE Industries (USA)	8	3.931.648,93 per motor	31.453.191
Chain Pulleys	Iron	McMaster-Carr (USA)	8	337.104.78 per pulley	2.696.3
U-Shaped Rebar	Steel	Reinforcement Products Online (UK)	32	5.659,45	181.102
				Total (₡)	**48.887.189**

**Additional costs that need to be factored into the budget for Top-Loaded Structural Reinforcement include consultations from engineering firms and construction companies. It is expected that increasing the safety factors, which our team has deemed necessary, will be extremely costly. It is also important to note that the labor for building this mock-up has also not been budgeted for.

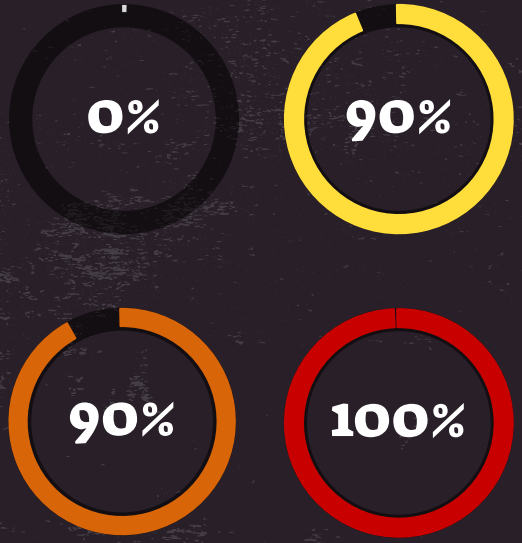
Palmer's Dollhouse:

ITEM	DISTRIBUTOR:	QTY	PRICE (₡)	TOTAL (₡)
4'x8' 7/16" Oriented Strand Board (OSB)	EPA (CR)	2	21.950	43.900
Wood Caulk	UBuy (CR)	2	5.902	11.804
½" Industrial staples w/ pneumatic staple gun	UBuy (CR)	1	36.304	36.304
600 Grit sandpaper	UBuy (CR)	1 pack	8.699	8.699
			Total (₡)	**100.707**

Horizontal Single-Compartment:

ITEM	DISTRIBUTOR:	QTY/DIMENSIONS	PRICE (₡)	TOTAL (₡)
Ceramic Glass	One Day Glass	42" x 12" X ⅛" piece	145.805,22	145.805,22
Plycem	Construplaza (CR)	20mm x 1.22mm x 2.44 m	23.500	23.500
FibaTape Alkali-Resistant Self-Adhesive Cement Board Tape	HomeDepot (USA)	2in. x 150ft.	5.084,66	5.084,66
1-¼ in. Phillips Flat-Head Fiber Cement Board Screw	HomeDepot (USA)	1 lb. pack	7.376,74	7.367,74
			Total (₡)	**1.713.071,60**

Reusability



DollHouse

Must be built each time

Smokehouse

Everything is reusable except smoke fluid

Horizontal

Everything is reusable except for fuel source

Structural Reinforcements

Both top-loaded and hydraulic side press designs are reusable

WPI

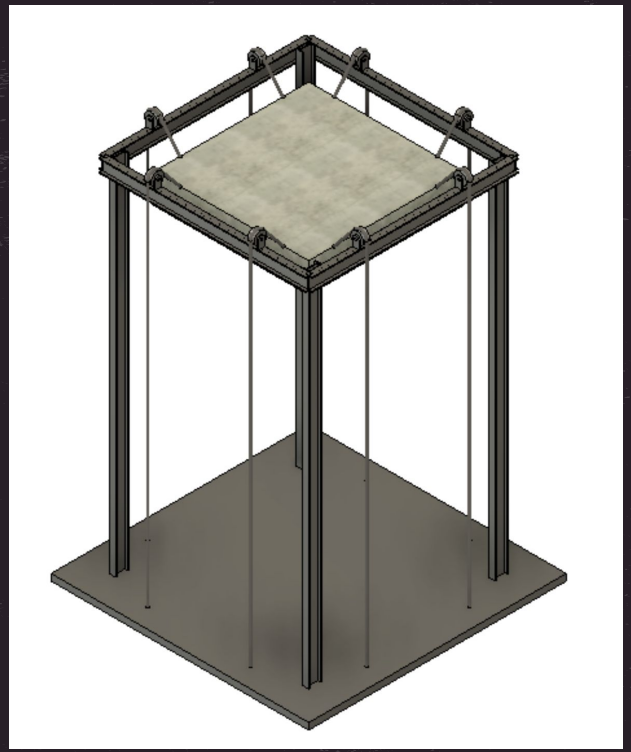
2023 Training Mock-Up Reusability Guide

Our team from Worcester Polytechnic Institute in conjunction with the Costa Rican Bomberos have developed the following reusability guide for the five mock-ups. In the table below our team lists which materials will need to be reused and how to care for each mock-up to ensure its longevity.

Mock-Up	Non-Reusable Materials	Maintenance	Reusability Summary
Top-Loaded Structural Reinforcement	N/A	Due to the high risk factor associated with this mock-up routine maintenance and inspections should be completed from engineering firms. Engineering firms will have more insight on necessary safety factors to consider but most importantly the chain motors should be inspected each year and concrete should be inspected for damage. Due to its size, the mock-up will most likely be exposed to the elements, keeping this in mind the simulator should	In theory, the device is reusable and with proper maintenance would work for years to come. However, the high safety issues associated with this simulator makes the mock-up unreliable and thus reusable. It is very likely that chains could snap, concrete could crack, or an I-Beam could bend in the likely event of a single-point failure. Thus the mock-up is not considered reusable at this time.

04
Recommendations

Safety Considerations



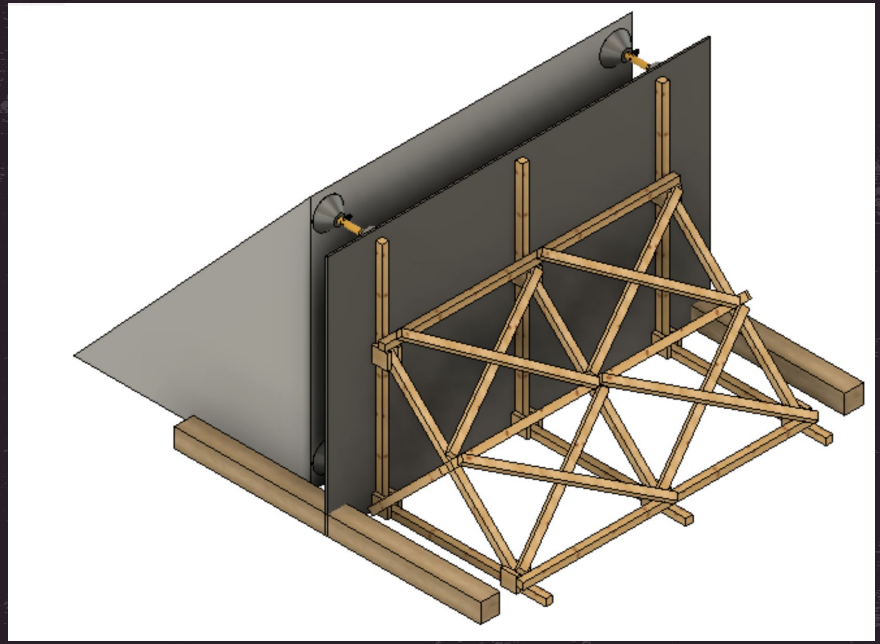
Design is extremely dangerous

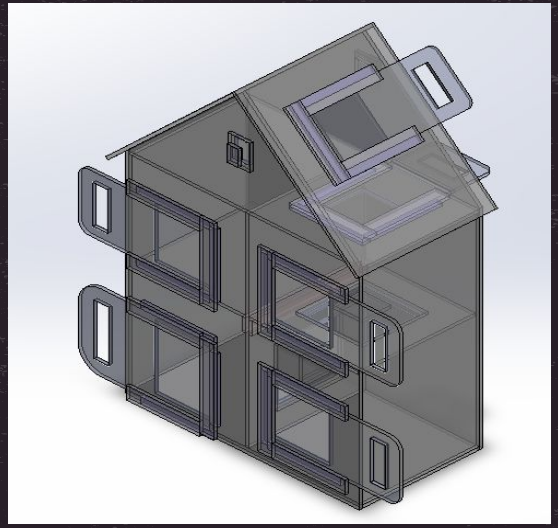
Several single point failures due to size of simulator

Should ***NOT*** be constructed without additional safety features from a licensed engineering firm

Safer of the two structural reinforcement designs

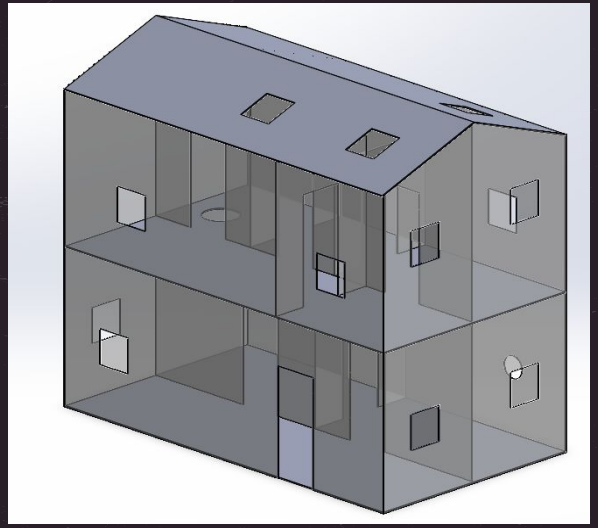
There is a small chance of leaking hydraulic oil, do not touch it. Potential to crush anyone in its path, avoid standing in the crush zone





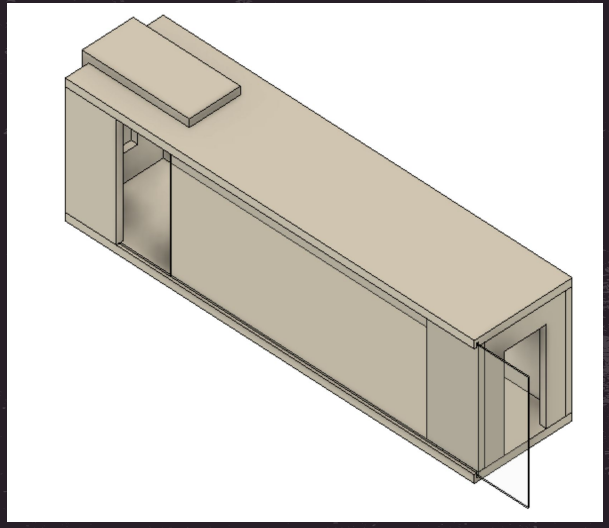
Palmer’s Dollhouse

Burning OSB and glue, due to toxic fumes and fire, you should wear full firefighting gear and SCBA



Smoke House

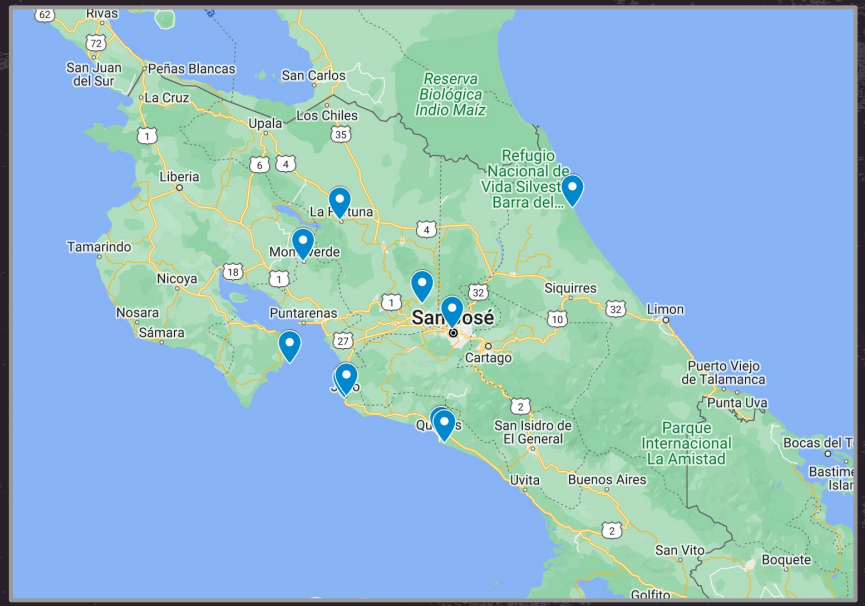
Does not pose any threat, however it is recommended to do it in a well vented area/outdoors. Do not inhale the smoke



Horizontal Single Compartment

Due to high intensity flames, it is recommended to wear full firefighting gear and SCBA

Our Time In Costa Rica!



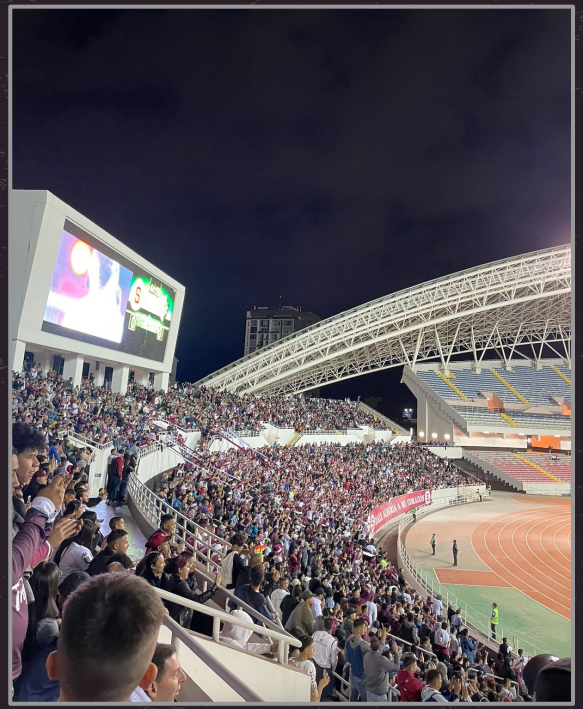
Map of everywhere we traveled to!

Food

Our “Office”

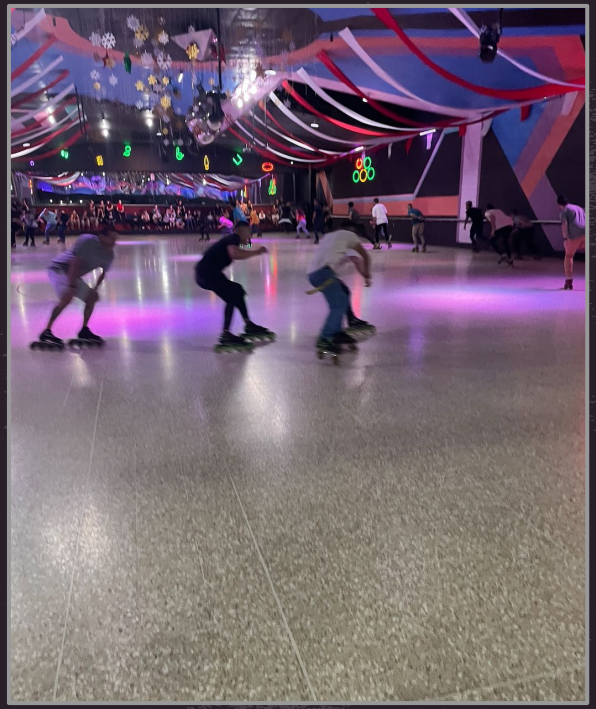
Our friend Maurice!

Things in San José



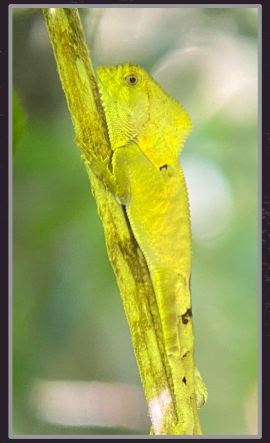
Soccer Games

Museums

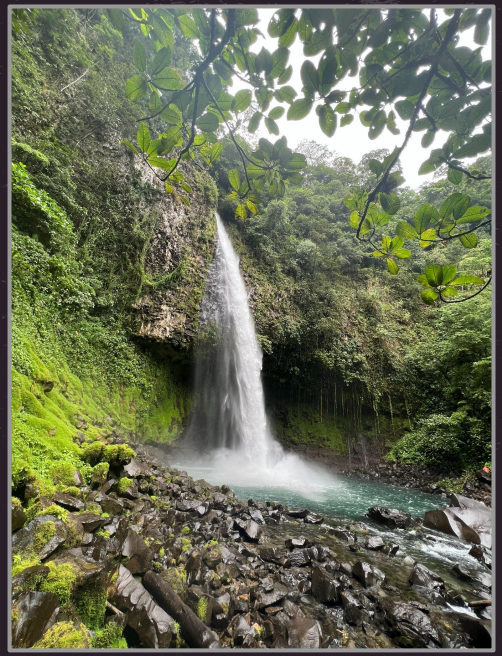


Roller-skating

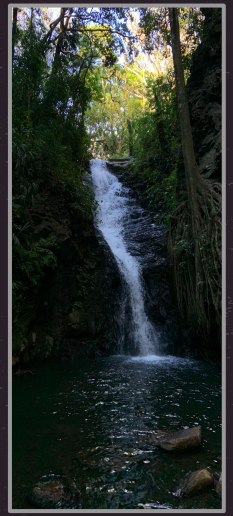
Manuel Antonio



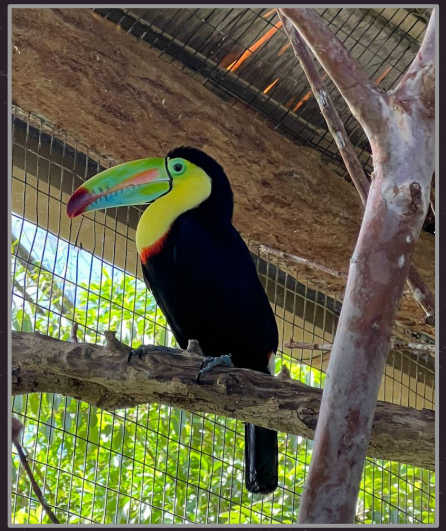
La Fortuna

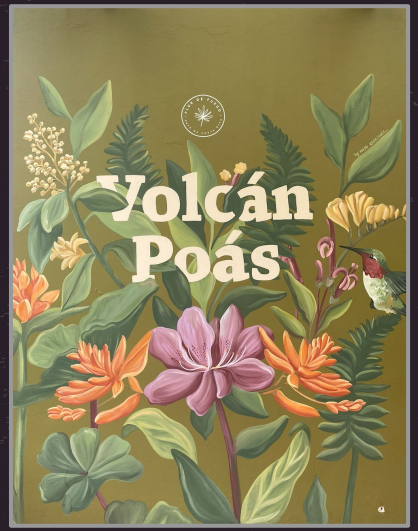


Monteverde

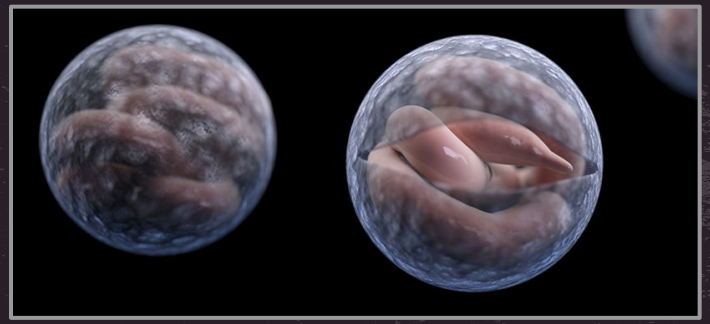


La Paz, Volcán Poás, & Doka Coffee Plantation

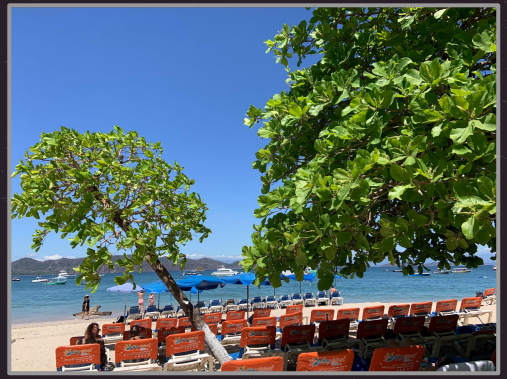




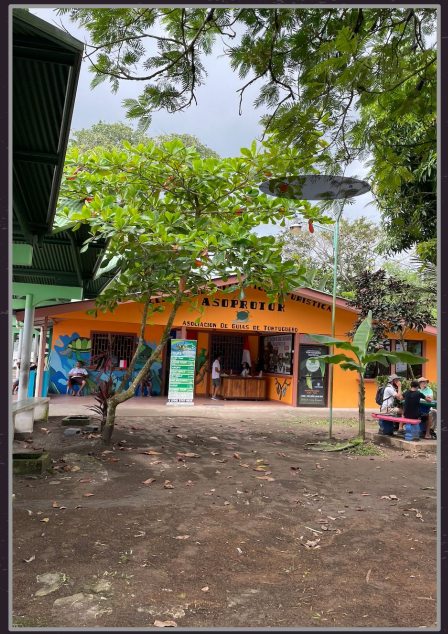
Playa Jaco and Isla Tortuga



Sam tuvo un parásito :(



Tortuguero



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WPI for granting us this once in a lifetime experience.

Thank you!
Any questions?