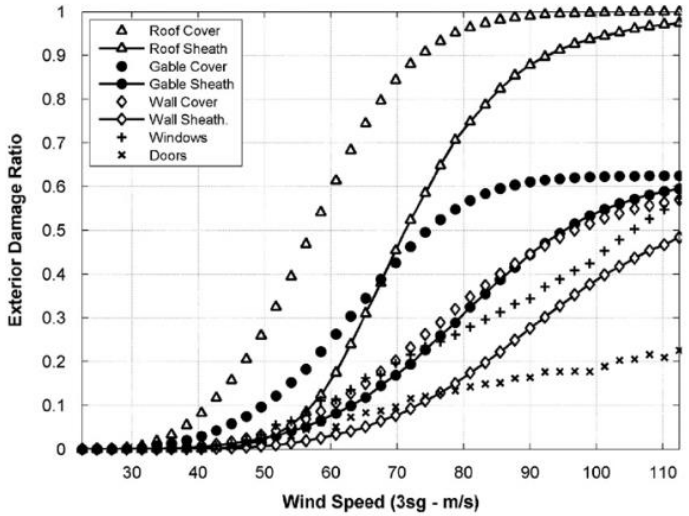
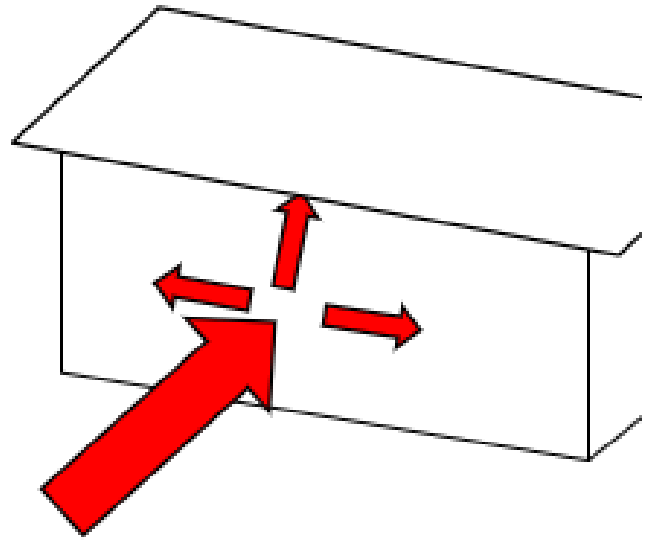
Engineering Problem

- Hurricane force winds cause major damage to parts of buildings every year, specifically roofs, resulting in billions of dollars in damages.
- Hurricanes are costly
  - Government: $28 billion
  - High winds
- Roofs
  - 150 mph – 90% damage
- Overhangs



Pita, G. (24AD). Retrieved from https://www.sciencedirect.com/science/article/pii/S0167610512000803



Engineering Goals

- This project will develop a new design for roofs of buildings that is optimized to counter the effects of hurricanes and this will be accomplished by creating models and also test said models using low powered fans or adult-supervised leaf blowers to compare them to current designs.
- See how wind interacts with roofs
- Build a design that is more resistant to wind
- Use a decision matrix to find the optimal design

Purpose

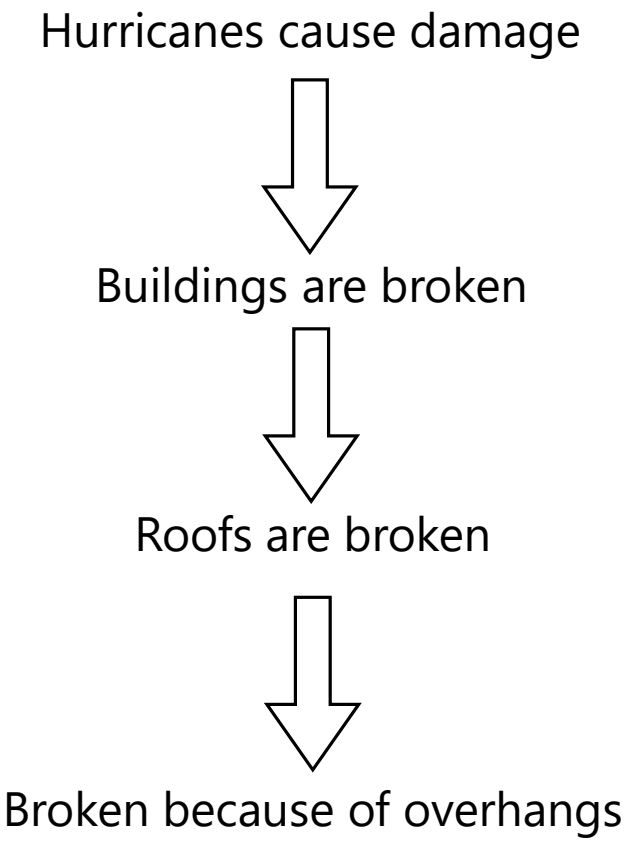
- The aim of this project is to research the effects of hurricane force winds, roof designs, and improve upon current roofs; success would mean creating models of roofs and simulating low force winds on the models to create a sturdier roof design.

Other components considered

- Foundation
  - Foundations are components of a building in the ground.
  - Depending on the building, they may be shallow or deep.
    - Residential buildings often use isolated footing or combined footing, where the foundation base is small.
    - Large buildings often use deep foundation, where metal piles are driven into the ground.
  - Because they are buried in the ground, they are not subject to wind, and thus are not a concern.
- Framing
  - The framing of a building is its skeleton.
  - It is often made out of steel, reinforced concrete, or wood.
  - Since each building varies greatly, it is hard to find an optimal design to compare to.

Background

- Hurricanes > 74 mph (119 kph)
- Very costly
- Most components are stable
  - Ex. Foundation is underground
  - However, roofs are exposed
- Roofs – many components
  - Rafters and purlins: main structure of roof
  - Gable: vertical side of roof
  - Eaves and overhangs: parts that hang off the side
- **Main failure: Overhangs on roofs**
- Alternatives
  - Metal roofing (Aluminum)
    - Although effective, very expensive
  - Curved walls
    - Diverts wind, unconventional
  - No overhangs
    - Water damage



Decision Matrix

Design matrix for testing:

Criteria	Weight (importance)	Wind tunnel (WPI)	Wind tunnel (custom)
Versatility	10	3	10
Usability	9	2	10
Precision	7	10	6
Accuracy	5	10	9
Cost	4	10	4
Time	2	5	3
Total		**218**	**299**

Procedure

- Weigh the model in grams.
- Place the leaf blower at the start of the wind tunnel where the funnel is on the edge of the tunnel.
  - Turn on the leaf blower.
- Measure with an anemometer the wind speed of each of the hatches.
  - This is to calibrate all of the measurements.
- Open the hatch and place a single model perpendicular to the direction of the wind tunnel in the hatch.
  - Close the hatch.
- Turn on the leaf blower on high for 1 minute.
- Open the hatch and take the model out of the tunnel.
- Rip off any damaged, but attached pieces.
- Weigh the model in grams.
- Weigh the damaged pieces in grams.
- Collect the completely destroyed pieces and weigh those in grams.

Materials

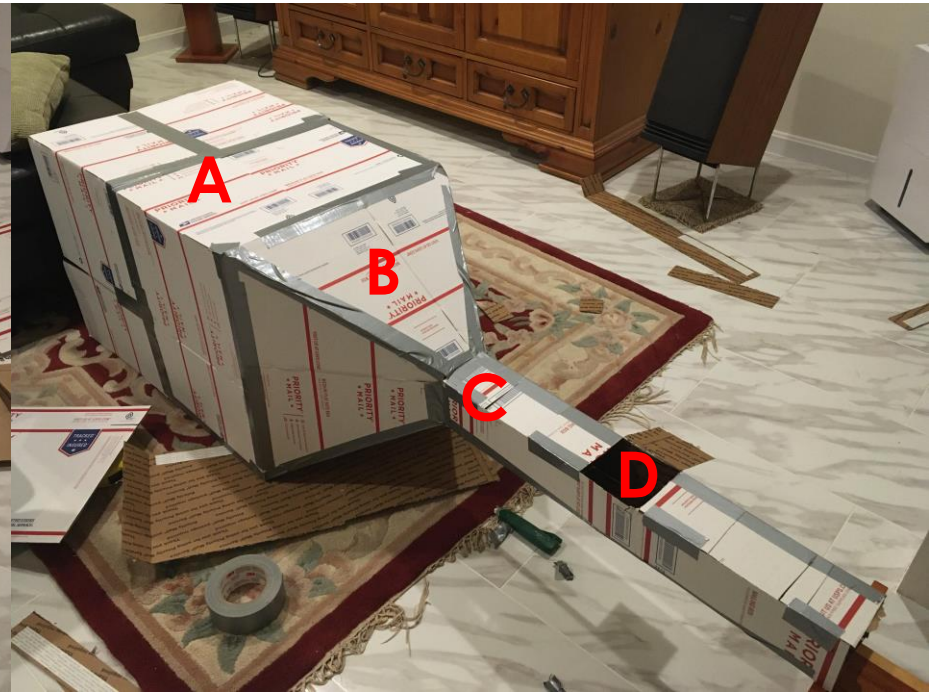
- Wind tunnel prototype
  - Cardboard
  - Duct tape
  - Leaf blower
- Final wind tunnel
  - (Plexiglass)
  - Polyfoam
  - Glue
  - Leaf blower
- Model prototypes v1
  - Toothpicks
  - Popsicle sticks
- Model prototypes v2
  - ABS plastic (3d printing)

Results

- There will be a function to determine the sturdiness of each model:

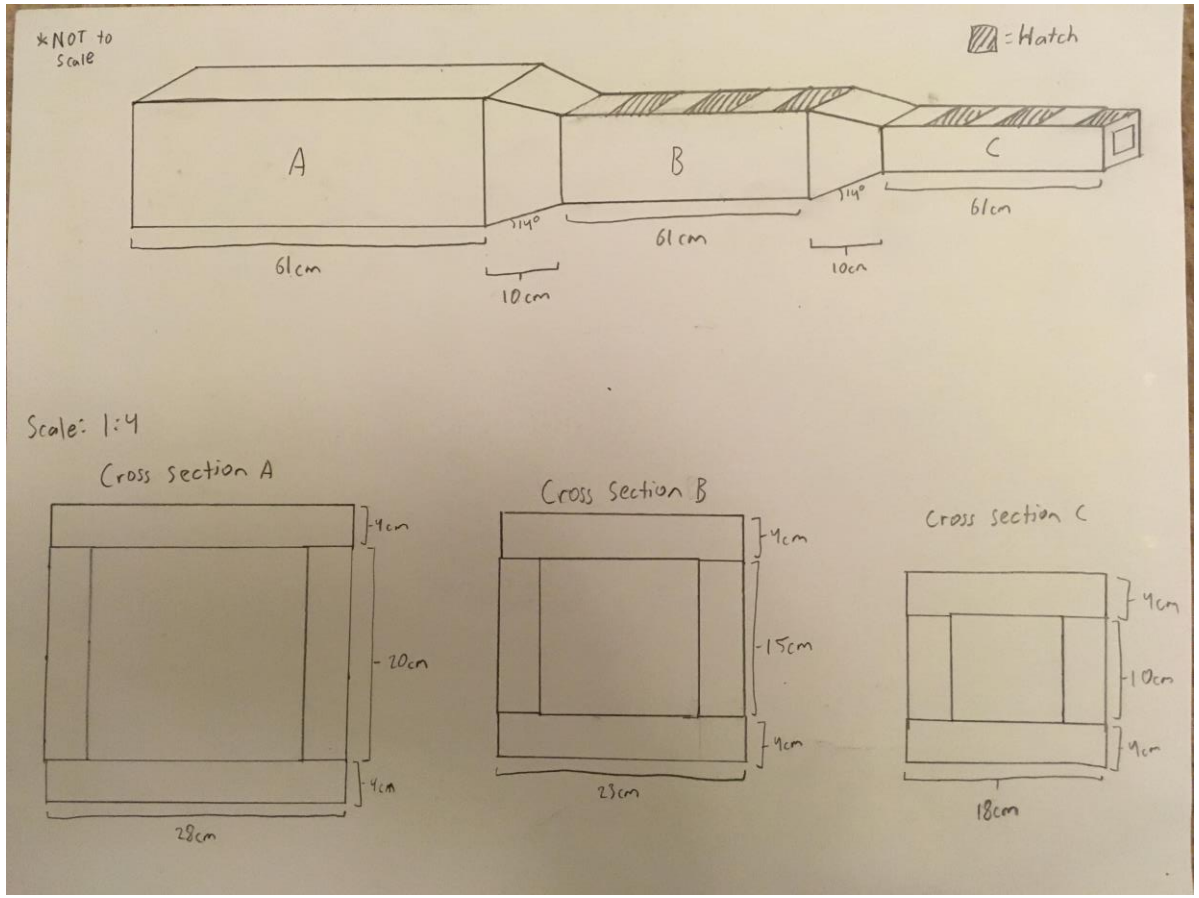
- $Score = \frac{a+0.5b}{c}$
- $a = mass\ in\ grams\ of\ pieces\ that\ remained$
- $b = mass\ in\ grams\ of\ pieces\ that\ are\ broken, but\ still\ attatched$
- $c = total\ mass\ of\ structure\ in\ grams$

Prototype of wind tunnel



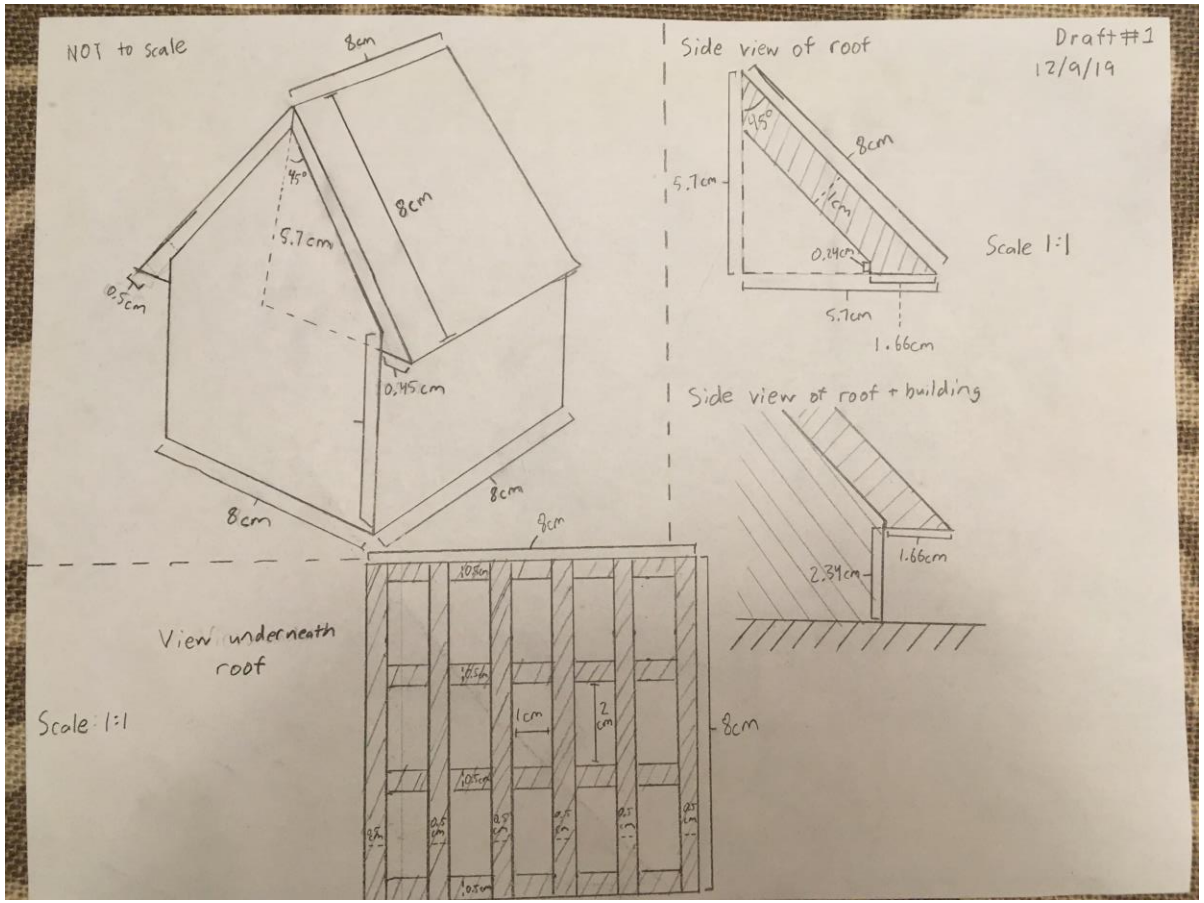
Very basic, just a proof of concept.
A - Where the leaf blower is located.
B - Funnel directs air flow to central location.
C - Tunnel facilitates air flow.
D - Openable hatches to put models. Can be used to measure wind speed.

Drawing of planned wind tunnel



Planned wind tunnel made out of polyfoam and plexiglass. The hatches are where one can put the models into the wind tunnel.

Drawing of Model Prototype v1



Planned model of roof and building. To be built possibly by CAD. This is the first version of the prototype, and will likely be changed in the future.

Drawing of CAD design

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Drawing of functionality of wind tunnel

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Data analysis

- $Score = \frac{a+0.5b}{c}$
- $a = mass\ in\ grams\ of\ pieces\ that\ remained$
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- Each score will be graphed along side its wind speed
- Each line of each model on the graph will receive a further score that will be used in the decision matrix

Design Criteria /Criteria Matrix

- Sturdiness
  - Determined from the equation from Data Analysis
  - The main objective is to design a strong roof
- Cost
  - Determined from weight of structure and expert opinion
  - Strong designs already exist, but they are expensive. Find a cheaper alternative
- Feasibility
  - Determined from complexity of design and expert opinion
  - Complex designs are possible, but more difficult
- Weight
  - Determined from weight of model
  - A heavy roof is not ideal for residential roof

Criteria	Weight (importance)
Sturdiness	10
Cost	7
Feasibility	6
Weight	4

Timeline

12/10 – 12/21 (weekdays): Sketch possible designs of models to test
12/10 – 12/21 (weekends): Finish building the final wind tunnel with smoke machine

12/21 – 1/5: Test various models and gather data

1/5 – 1/12: Analyze and graph data to notice trends

1/12 – 1/26: Iteration #2: Sketch designs and consult with experts

1/26 – 2/2: Test various models and gather data

2/2 – February fair: Analyze and graph data, notice trends, finalize project