

# **Bio-Inspired Design for Energy Efficiency**

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### Background

- Northern Arizona University (NAU) is inefficient with its energy
- Carbon neutral campus by 2020 [1]
  - Not on track to achieve goal
- Social Behavioral Science West (SBS West)
  - Heating, Ventilation, and Air
    Conditioning (HVAC) is out of date
  - Ventilation codes are not met



Figure 1: SBS West

#### Project Description: Analytical Approach

- Design a ventilation system that increases energy efficiency
- Bio-inspired
- Bring building up to proper ventilation code
- Implemented into current HVAC system

**Importance:** SBS West is inefficient with its energy use and does not meet current standards for ventilation

#### **Project Description: Design Experimentation**

- Focus on venting excess pressure
- Innovating vents in SBS West
- Bio-Inspired vent designs
- Design of Experiments (DoE)
- Generate a scaled final design

**Importance:** Design system to relieve pressure



#### **Customer Requirements**

- Weights scale of 1-5
  - 5: Most important
  - 1: Least important

Table 1: Customer Requirements

Customer Needs	Weights
Bio-Inspired	5
Bring Building Up to Ventilation Code	5
Exhaust Excess Air/Relieve Plenum Pressure	5
Increase Energy Efficiency	4
Safe	3
Maintain Temperature of Building	1

#### **SBS West Original Ventilation**



Figure 3: Current Ridge of SBS West



Figure 4: Aerial View of SBS West

#### **Theoretical Ridge Design**



Figure 5: CAD Model of Proposed Design

#### **Theoretical Ridge Design**



Figure 6: Ridge Implementation



Figure 7: Structural Analysis of Ridge Design



#### Vent Design

- Four bio-inspired vents with a standardized area of relief (~10 in<sup>2</sup>)
  - Fibonacci
  - Termite Mound
  - $\circ$  Pinecone
  - $\circ$  Flower
- 3D printed vents
- Design of Experiments (DoE) for pressure release



#### Fibonacci Vent Design



Figure 8: Fibonacci Vent Shell



Figure 9: Fibonacci Vent Shell



Figure 10: Fibonacci Fan Blade [3]



#### **Termite Mound Vent Design**



Figure 11: Termite Mound Vent Design



Figure 12: Termite Mound [4]

#### **Pinecone Vent Design**



#### Figure 13: Pinecone Vent Design



#### **Flower Vent Design**

Movement of Pedals



Figure 15: Flower Vent



Figure 16: Flower Blossoming [5]

#### Manufacturing: Pressure Chamber



Figure 17: Pressure Chamber



Figure 18: Pressure Release Trap Door

#### Manufacturing: Arduino



Figure 19: Arduino Wiring



Figure 20: Arduino Setup

#### **Design of Experiments Assumptions**

- Outlet vent surface area: 10 in<sup>2</sup>
- Constant volume of air: 1 ft<sup>3</sup>
- Standard measuring device
- Constant Pressure
- Constant temperature



Figure 21: DoE Testing Setup

#### **Design of Experiments Procedure**



#### **Design of Experiments Testing Results**



Figure 22: Results, Fibonacci Design

Figure 23: Results, Pinecone Design

#### **Design of Experiments Testing Results**



Figure 24: Results, Termite Design

Figure 25: Results, Flower Design

#### **Final Scaled Design**



Figure 26: CAD of Final Vent Design, Section View



Figure 27: 3D Printed Final Vent Design



Figure 28: CAD of Final Proposed System

#### **Conclusions/Takeaways**

- Final design
  - Provides proper ventilation
  - Increases energy efficiency
- Budget: \$350 / \$700 used thanks to 3D Systems for 3D printing
- HVAC is handled by teams of specialized engineers
- Understanding blueprints of buildings and current HVAC systems
- Pressure is hard to control and manipulate with limited resources
- Experimentation to evaluate designs



#### **Special Thanks**

NAU Facility Services: Jon Heitzinger

3D Systems Inc.: Moria Tuffs

Mechanical Engineering Department Faculty:

- Dr. Sarah Oman
- Dr. Jennifer Wade
- Dr. David Trevas

#### References

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## **Questions?**