



# **ENVIRONMENTALLY CONTROLLED TEST CHAMBER**

Nicholas Blenker | Tucker Hall | David Wilson

# Meet Team 503



Nicholas Blenker

*Design Engineer*



Tucker Hall

*Systems Engineer*



David Wilson

*Controls Engineer*

Nicholas Blenker

# Sponsor & Advisor



William Bilbow

*Danfoss*

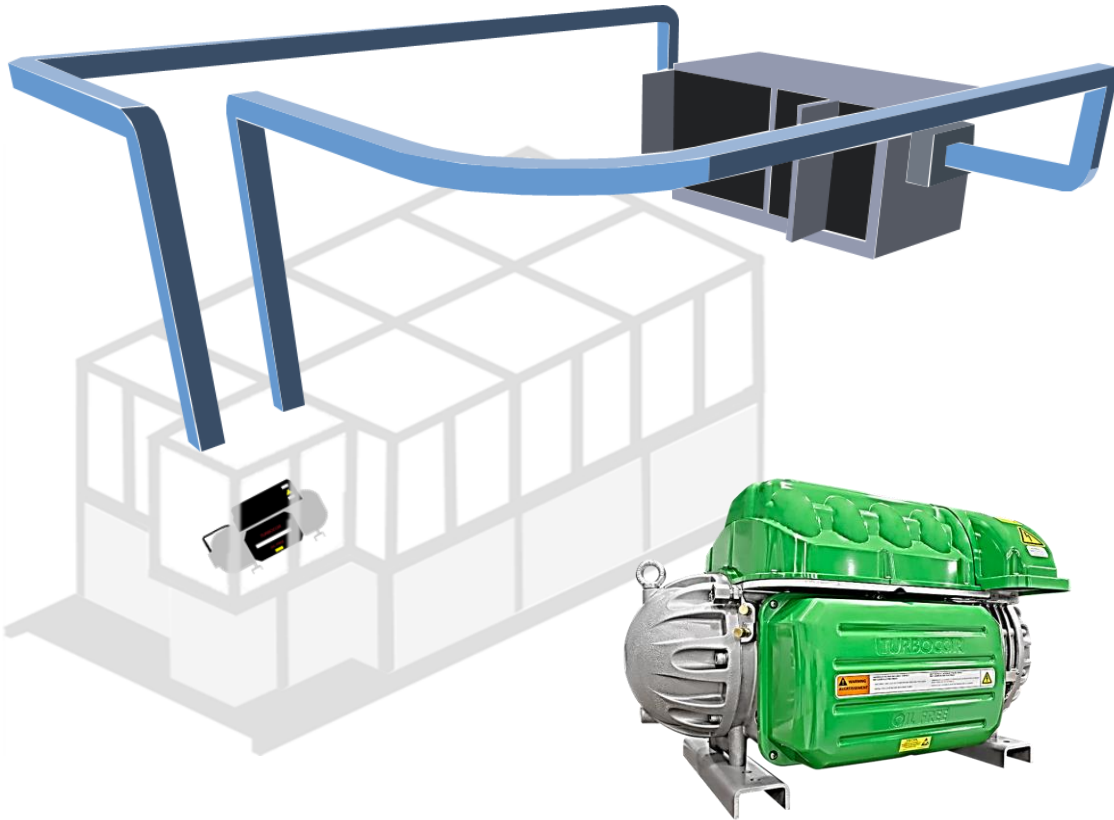


Keith Larson

*FAMU-FSU College of  
Engineering*

Nicholas Blenker

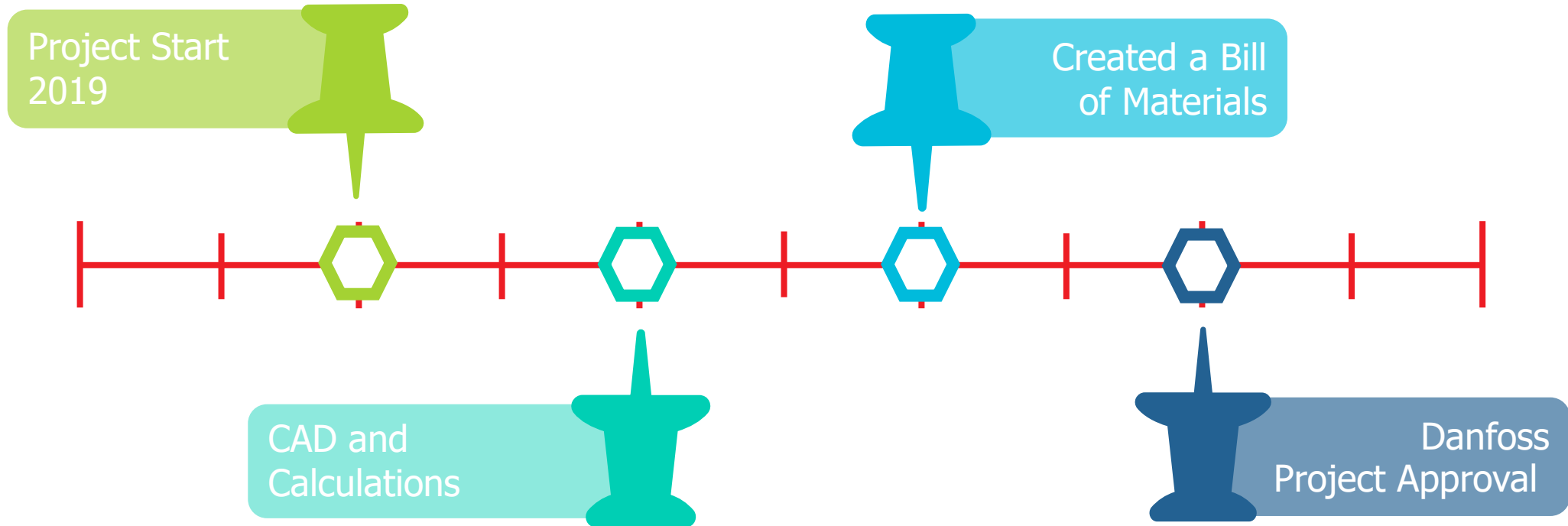
# Project Objective



Validate the existing design of an environmental testing chamber and deliver an assembly that regulates its internal **temperature** and **humidity** for use in a laboratory environment.

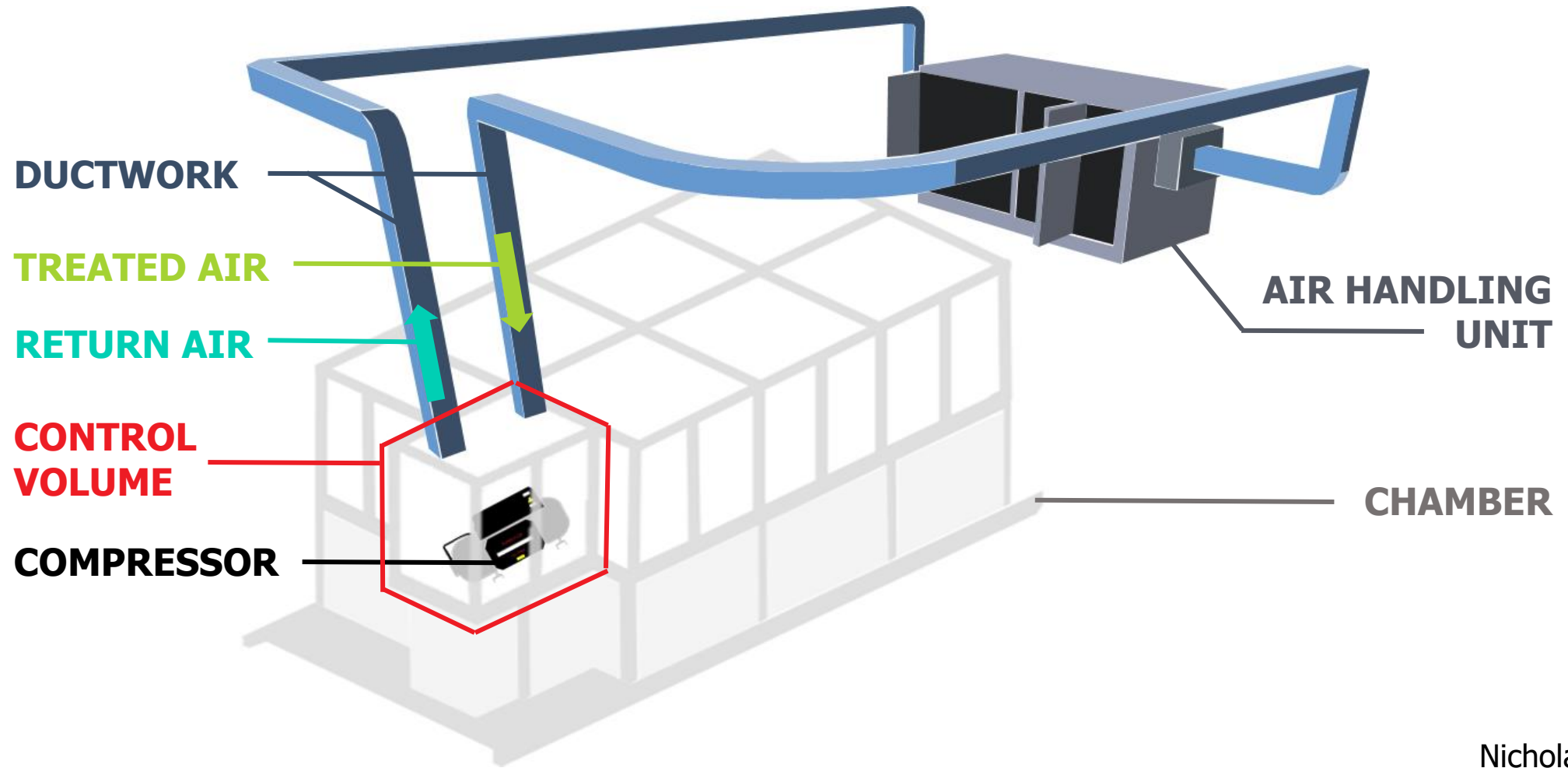
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# Project Background



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# Motivation



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# Assumptions



The test rig will rest on a flat and level surface



Conductive heat from the compressor is negligible



Danfoss Turboacor Compressor will be used



The existing support has adequate load capacity

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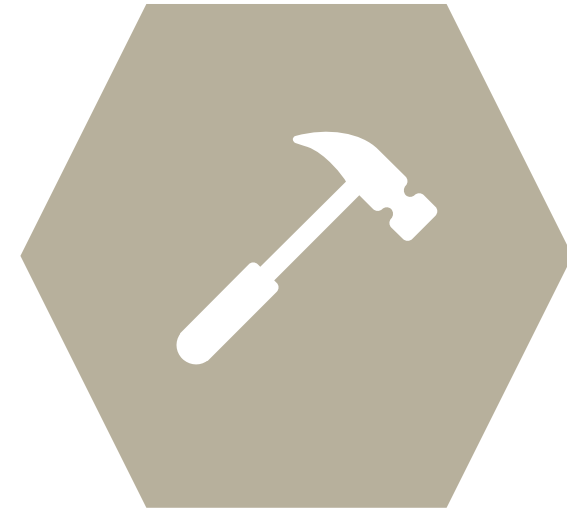
# Key Goals



Validate



Finalize

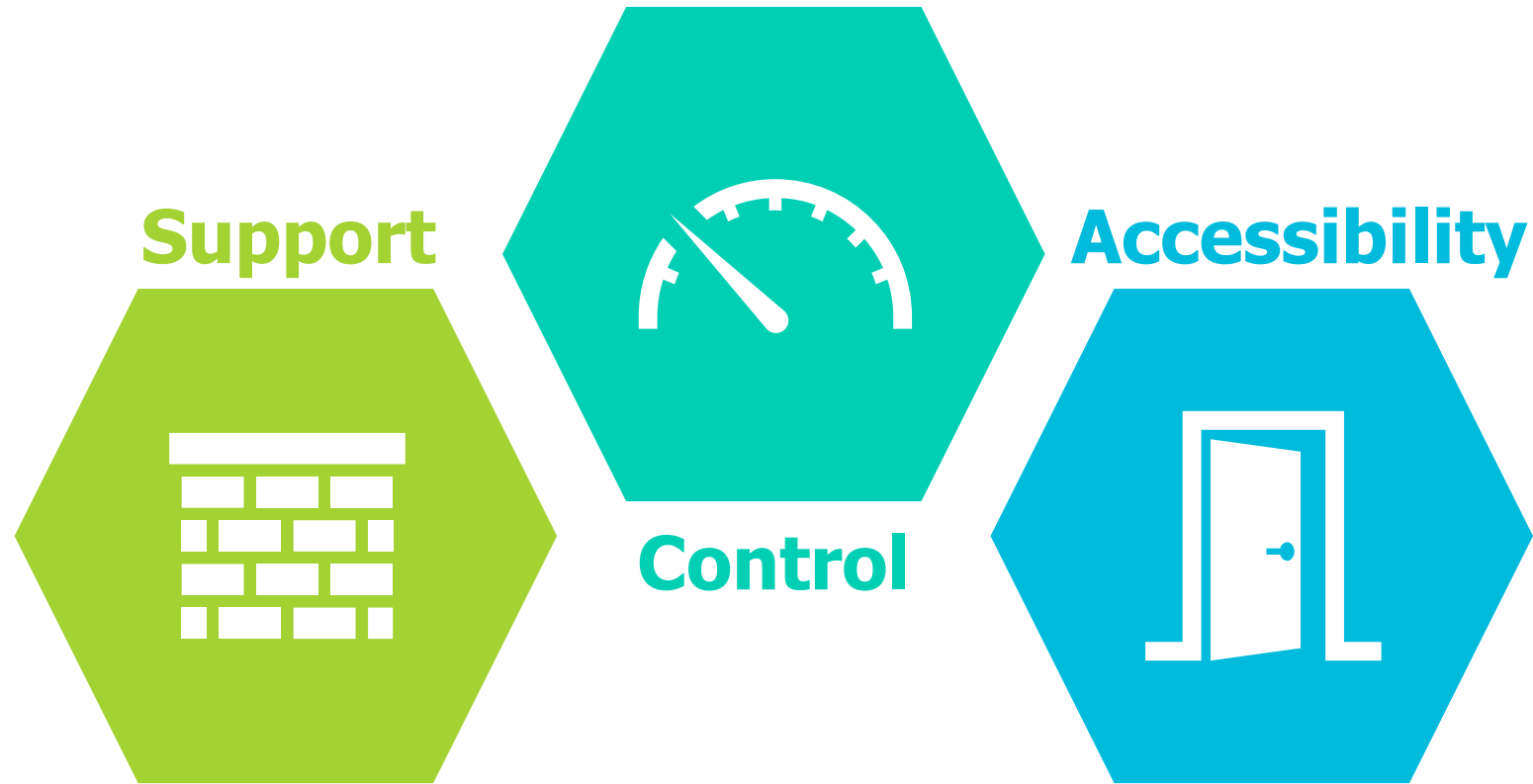


Implement

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# Targets & Metrics

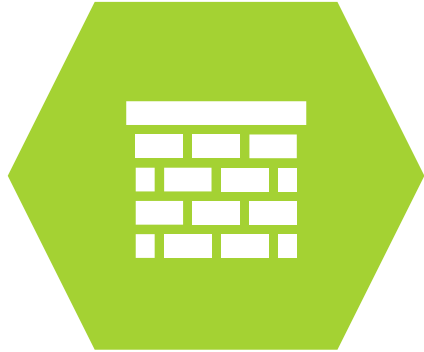


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# Key Targets & Metrics

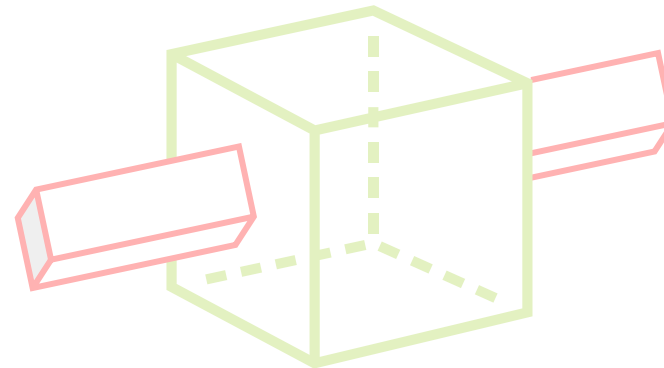
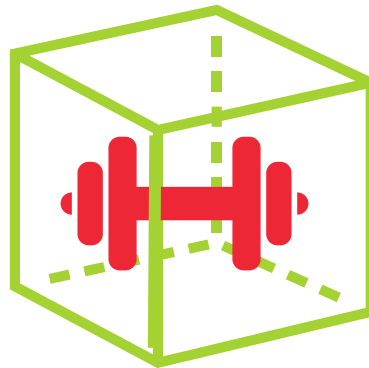


Support



Support

| Function                       | Target | Metric |
|--------------------------------|--------|--------|
| Maintain Structural Stability  | 10 lbs | Weight |
| Support Airducts and Equipment | 5 lbs  | Weight |

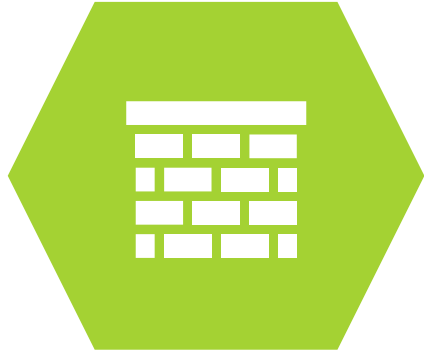


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# Key Targets & Metrics

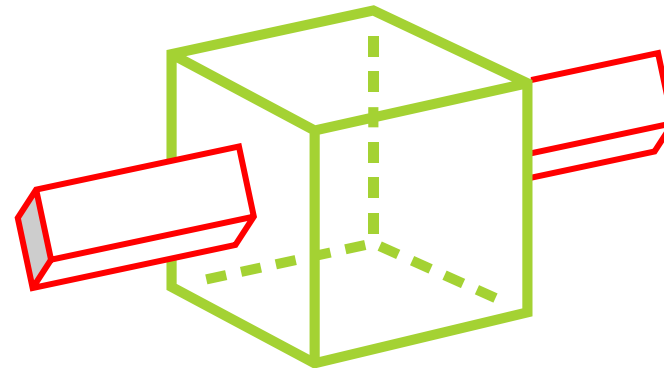
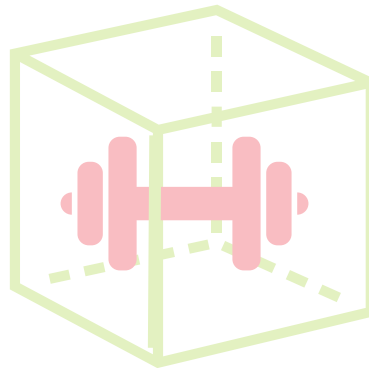


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# Key Targets & Metrics

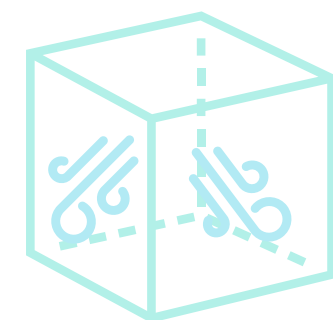
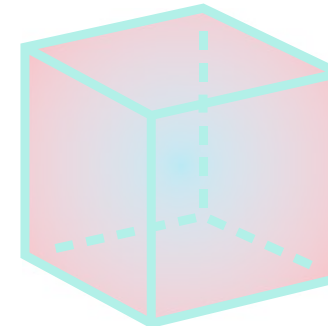
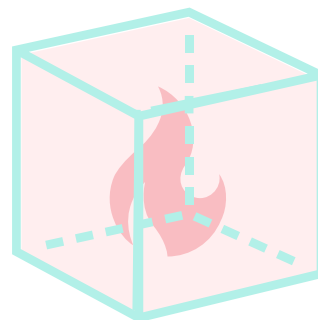
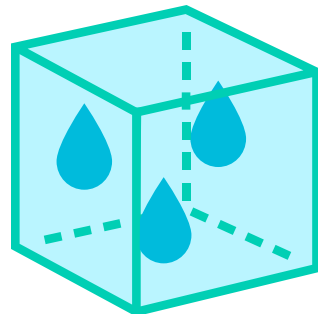


Control



Control

| Function                         | Target  | Metric               |
|----------------------------------|---|----------------------|
| Monitor Temperature and Humidity | 1%  | Temp/RH              |
| Add & Remove Heat                | $10^{\circ}\text{C} \leq T \leq 50^{\circ}\text{C}$ | Temperature          |
| Increase & Decrease Humidity     | 0-95% RH  | Relative Humidity    |
| Regulate Air Circulation         | $1\text{m}^3/\text{min}$                            | Volumetric Flow Rate |



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# Key Targets & Metrics

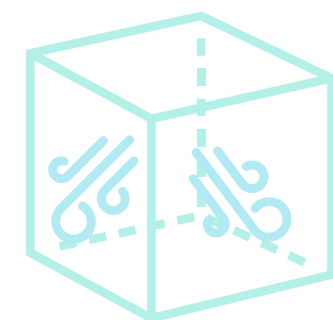
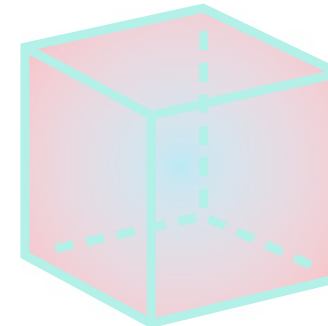
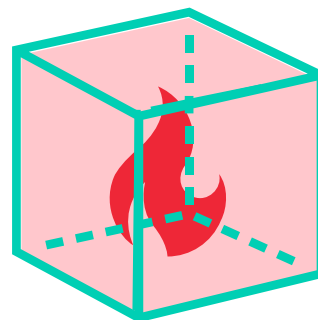
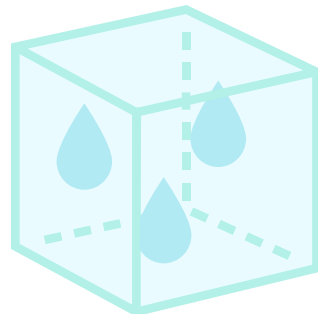


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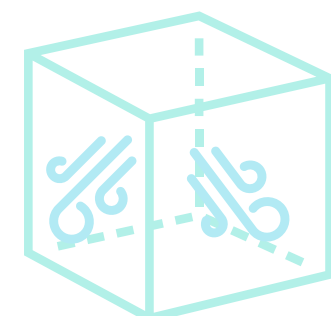
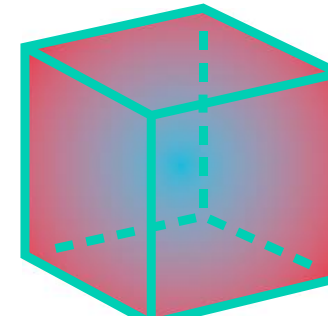
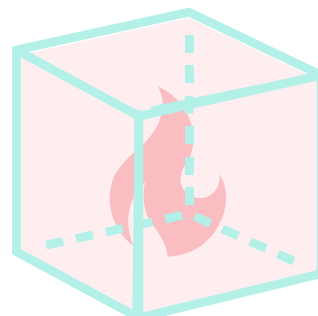
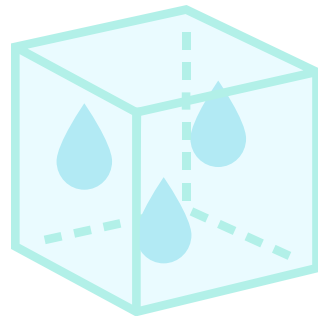


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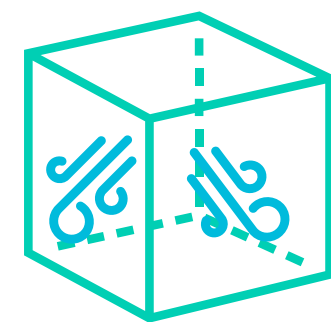
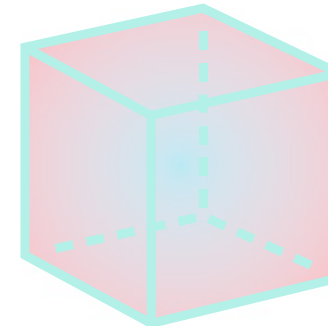
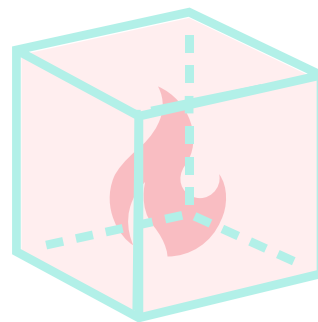
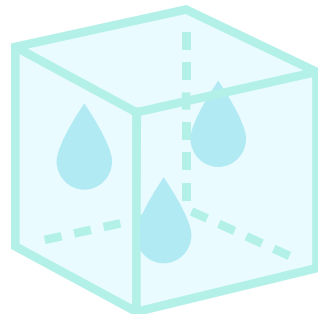


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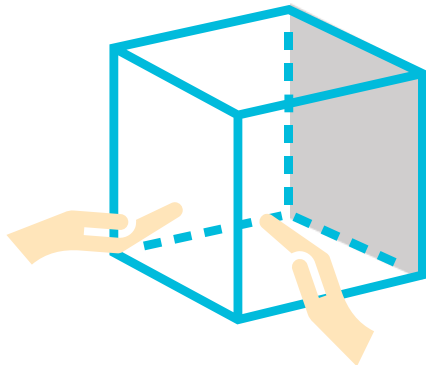


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# Key Targets & Metrics



## Accessibility



## Accessibility

| Function                                   | Target               | Metric                |
|--|----------------------|-----------------------|
| Allow Access from All Sides                | 3 Sides              | Accessible Sides      |
| Enable Efficient Exchange of Compressor(s) | 15 minutes           | Time                  |
| Provide Clear View of Compressor           | 360° Visibility      | Degrees of visibility |
| Adjust Temperature and Humidity            | No Human Interaction | Human Interaction     |

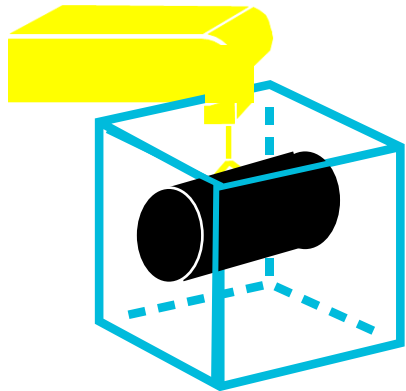
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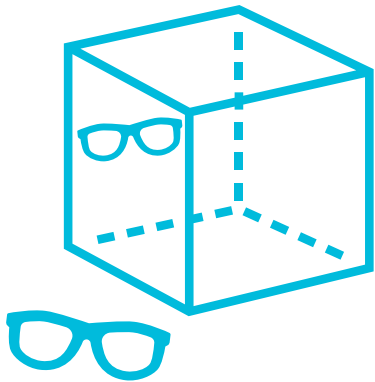


## Accessibility



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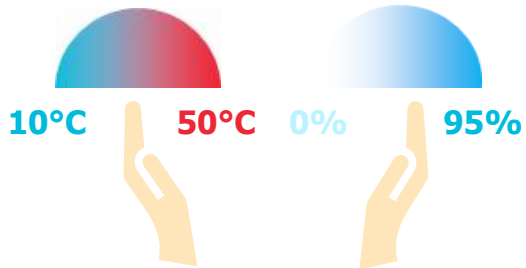


## Accessibility



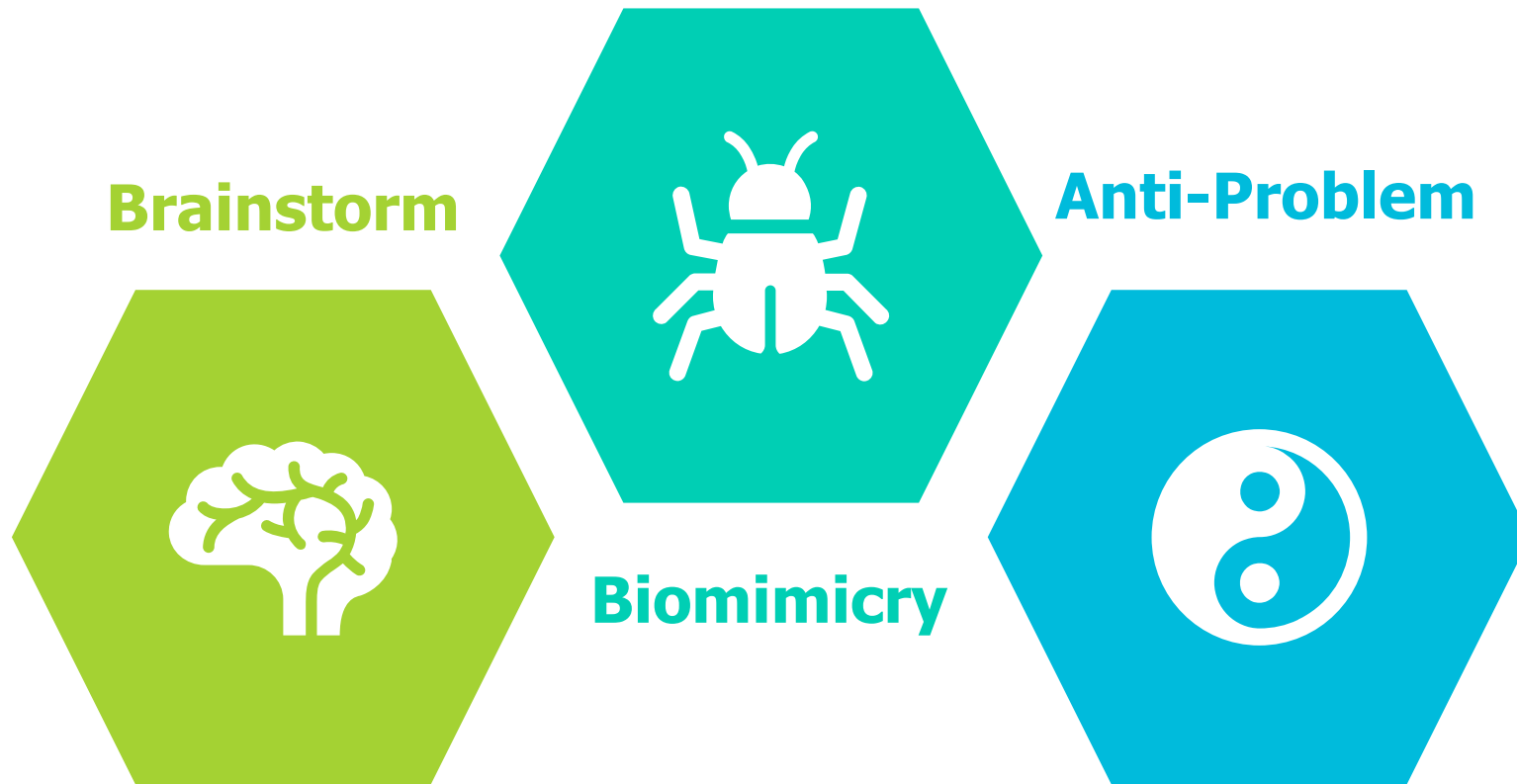
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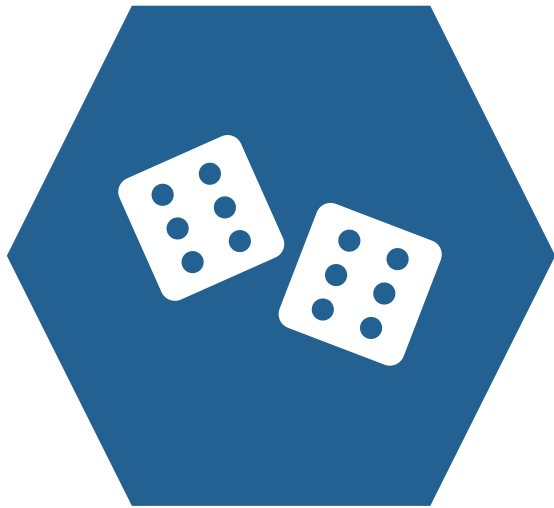
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# Concept Generation



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# Concept Generation



**Morphological  
Chart**

| <b>AHU Placement</b> | <b>Duct Attachment</b> | <b>Infiltration Seals</b> | <b>Other Features</b> |
|----------------------|------------------------|---------------------------|-----------------------|
| Floor-Mounted        | Fixed Overhead Ducts   | Puddy                     | Duct Dips with Valves |
| Wall-Mounted         | Detachable Side Ducts  | Rubber Inserts            | Duct Close-Off        |

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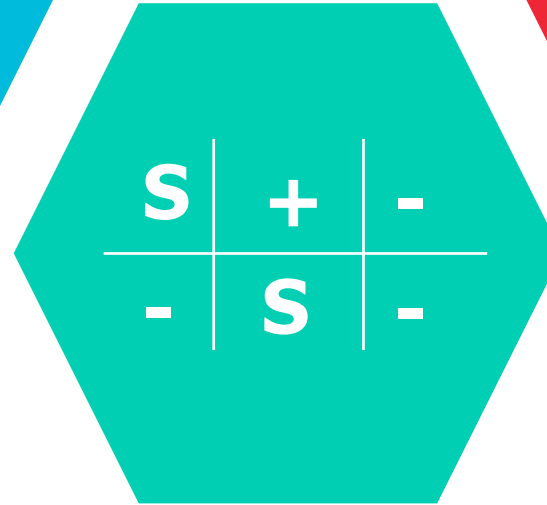
# Concept Selection

**Pairwise  
Comparison**



**House  
of Quality**

**Pugh  
Chart**



**Analytical  
Hierarchy Chart**

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# Concept Selection

## Results



**Floor-Mounted AHU with Detachable Side Ducts, Rubber Inserts, and Dips Inside Ductwork**



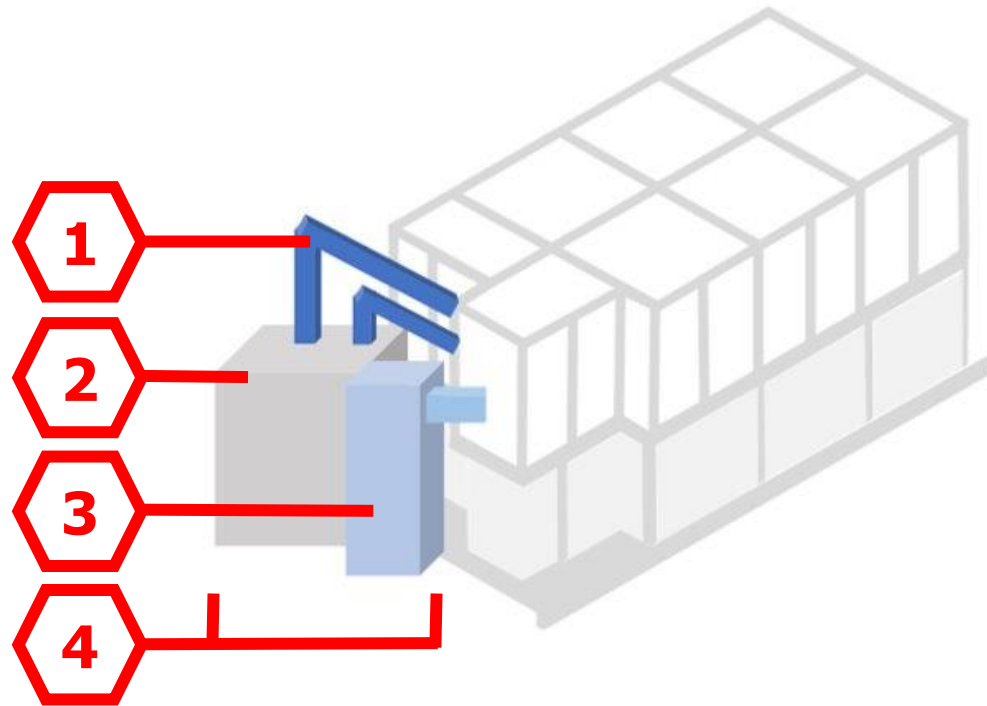
**Wall-Mounted AHU with Detachable Overhead Ducts, Puddy Seals, and Dips Inside Ductwork**



**Floor-Mounted AHU with Detachable Overhead Ducts, Rubber Inserts, and Close-Off Inside Ductwork**

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# Key Changes

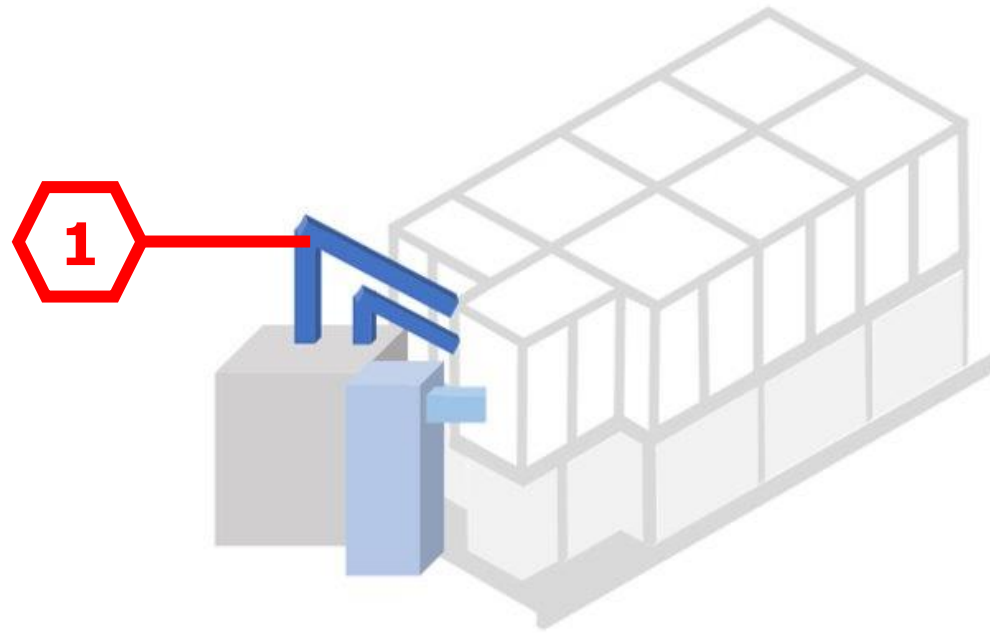


- 1 Screw-On Side Ducts**
- 2 29,000 BTU Chiller**
- 3 Industrial Humidifier**
- 4 Floor-Mounted AHU**

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# Key Changes



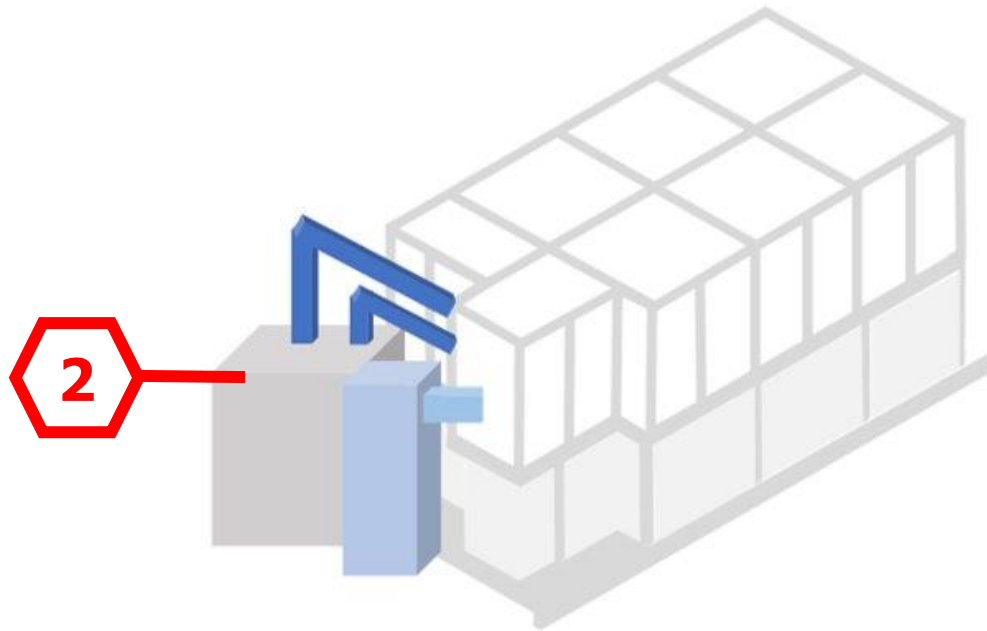
1

## Screw-On Side Ducts

- Easily removable
- More accessible
- Reduced length of ductwork
- Increased portability

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# Key Changes



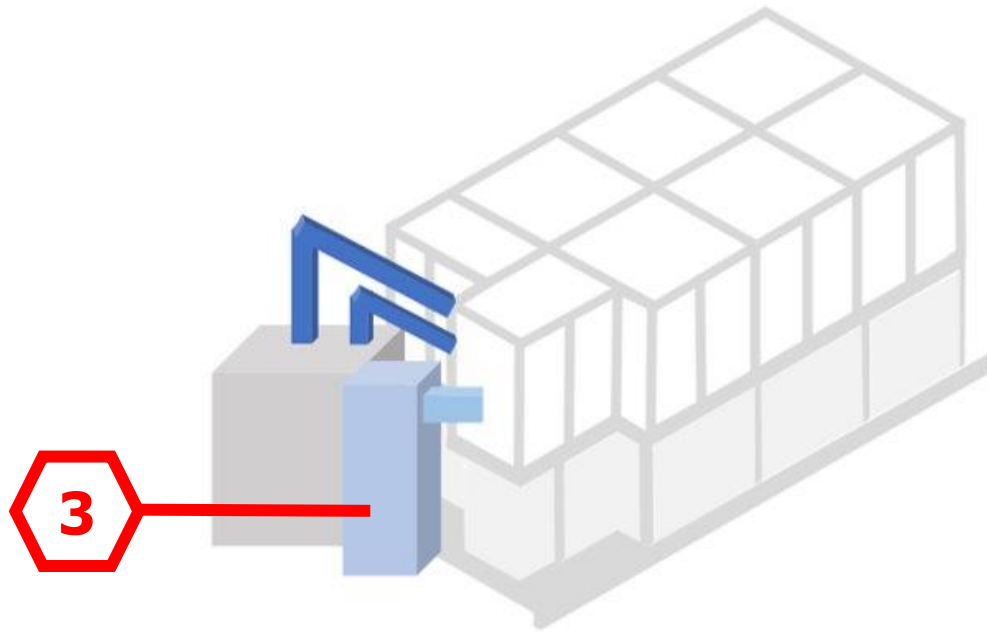
2

**29,000 BTU A/C**

- More versatile
- Most value (power vs cost)
- Compensates for leaks & infiltration
- Decreases time response
- Built-in ductwork

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# Key Changes



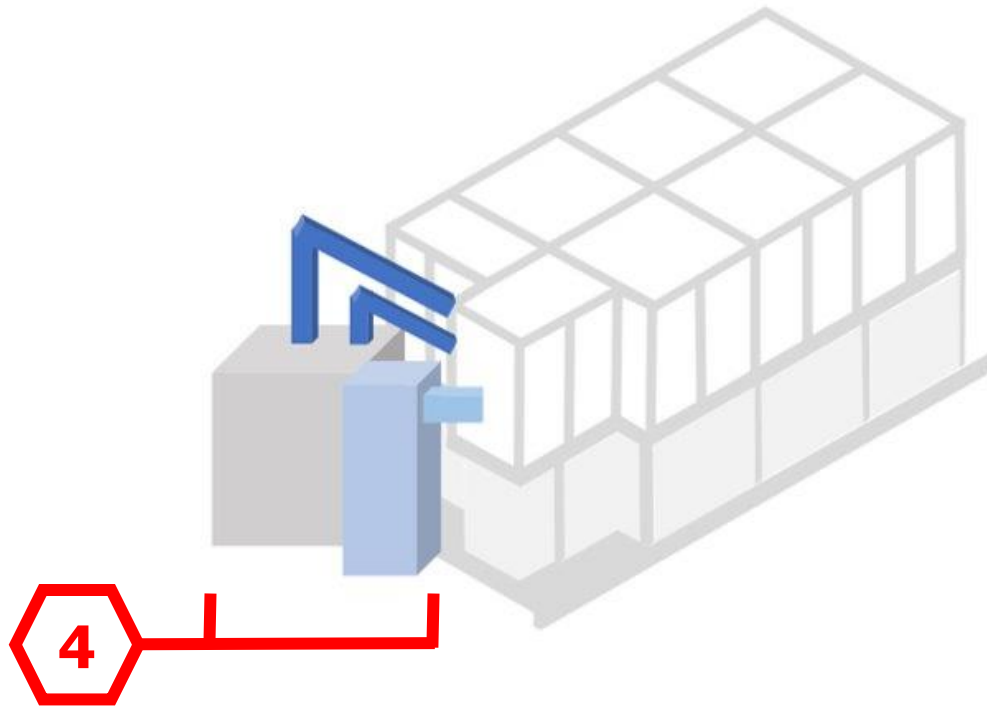
3

## Industrial Humidifier

- Full range from 0-100% RH
- Large tank
- Decreases time response
- Automated control system

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# Key Changes



4

## Floor-Mounted AHU

- Limited wall space
- Suggested by lab staff
- Reduced length of ductwork
- Increased portability

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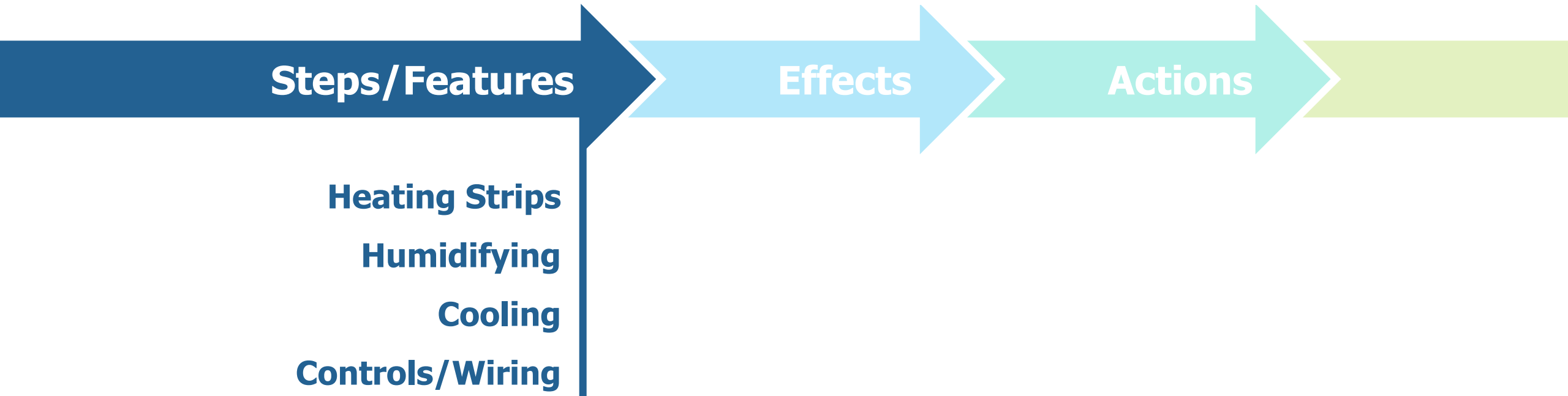
# Initial Proposed Materials



- 1 x 29,000 BTU Portable A/C**
- 3 x Electric Strip Heaters**
- 1 x Industrial Humidifier**
- 4 x Humidity Sensors
- 4 x Temperature Sensors
- 1 x Arduino Mega**
- 1 x Duct Sealant
- 1 x Duct Take-Off
- 1 x Clear Vinyl
- 1 x Rubber Sealing Strips**
- 1 x Foam Sealing Strips
- 1 x Ambient Air Adapter**
- 1 x Pack of Wires
- 1 x Fiberglass Insulation

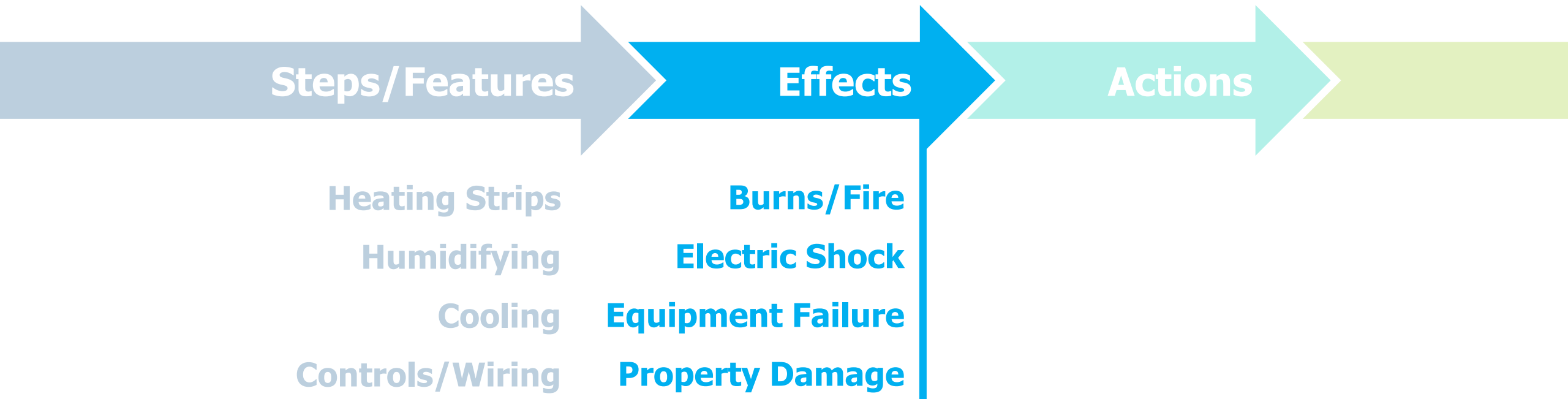
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# Risk Analysis



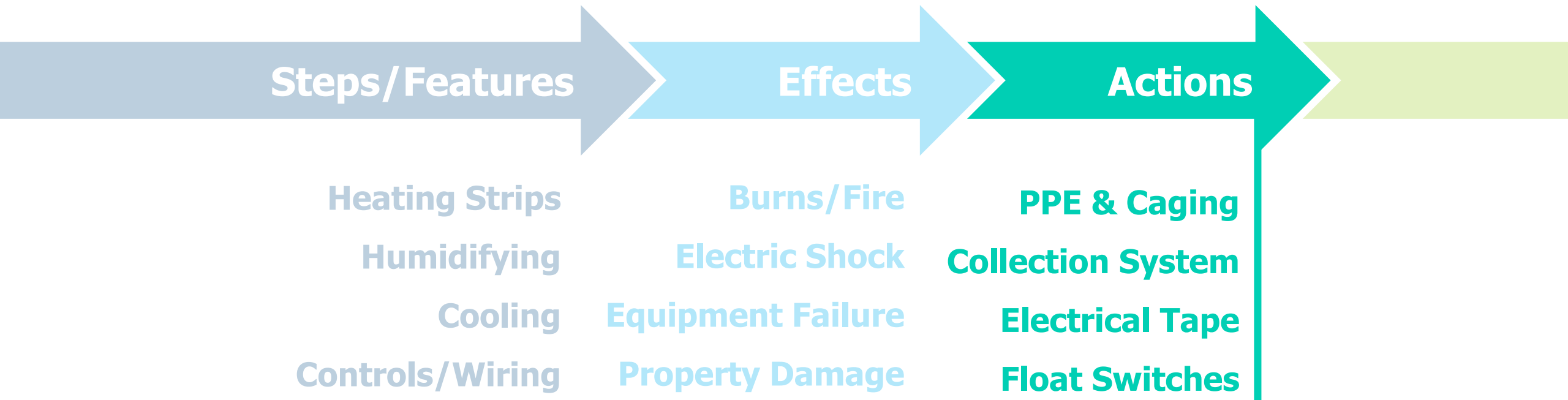
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# Risk Analysis



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# Risk Analysis



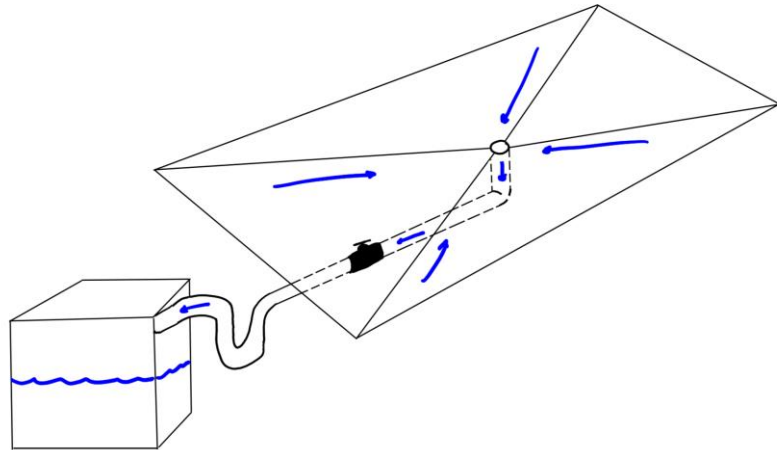
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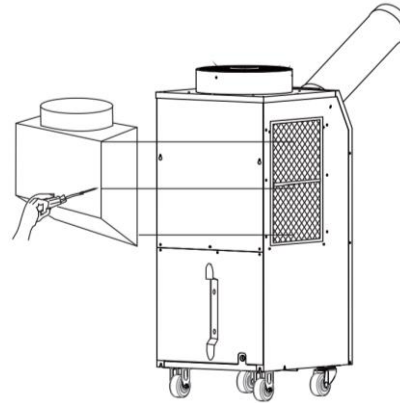


# Design Changes

Condensation  
Collection System



Air Adapter for  
Humidifier



Waterproof Electric  
Heaters



Control Changes  
Over 110°F

A/C is Turned Off

Heat Vented to Cool

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# Updated Materials

- 1 x Industrial Humidifier
- ~~4 x~~ → 2 x Humidity Sensors
- ~~4 x~~ → 2 x Temperature Sensors
- 1 x 29,000 BTU Portable A/C →
- 3 x Electric Strip Heaters →
- 1 x Arduino Mega
- 1 x Duct Sealant
- 6 x Duct Take-Offs
- 1 x Clear Vinyl
- 1 x Rubber Sealing Strips
- 1 x Foam Sealing Strips
- 1 x Foil Duct
- 18 x Screws & Wing Nuts
- 1 x Ambient Air Adapter
- 1 x Pack of Wires
- 1 x Fiberglass Insulation
- 1 x 16,800 BTU Portable A/C
- 2 x Waterproof Electric Strip Heaters
- 1 x Plastic Tote
- 1 x Circulation Pump
- 3 x Float Switches
- 1 x Tubing
- 8 x Button Pushers
- 1 x Duct Reducer

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# Current Materials

## Expensive Items

- ✓ A/C Unit - \$2,942.55
- ✓ Ambient Air Adapter - \$424
- ✓ Humidifier - \$307.38

|            |             |              |
|------------|-------------|--------------|
| Total Cost | \$ 4,512.08 | = <b>90%</b> |
| Budget     | \$ 5,000.00 |              |

## Approved BOM

|                     |             |
|---------------------|-------------|
| Total Part Cost     | \$ 4,156.97 |
| Total Shipping Cost | \$ 97.84    |
| Total Labor Cost    | \$ 0.00     |
| Total Taxes         | \$ 276.13   |
| Total Cost          | \$ 4,512.08 |
| Cost Budget Ratio   | 90%         |

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# Projected Totals

## Final Install Items

- Circulation Pump
- Float Switches
- Rubber Gaskets

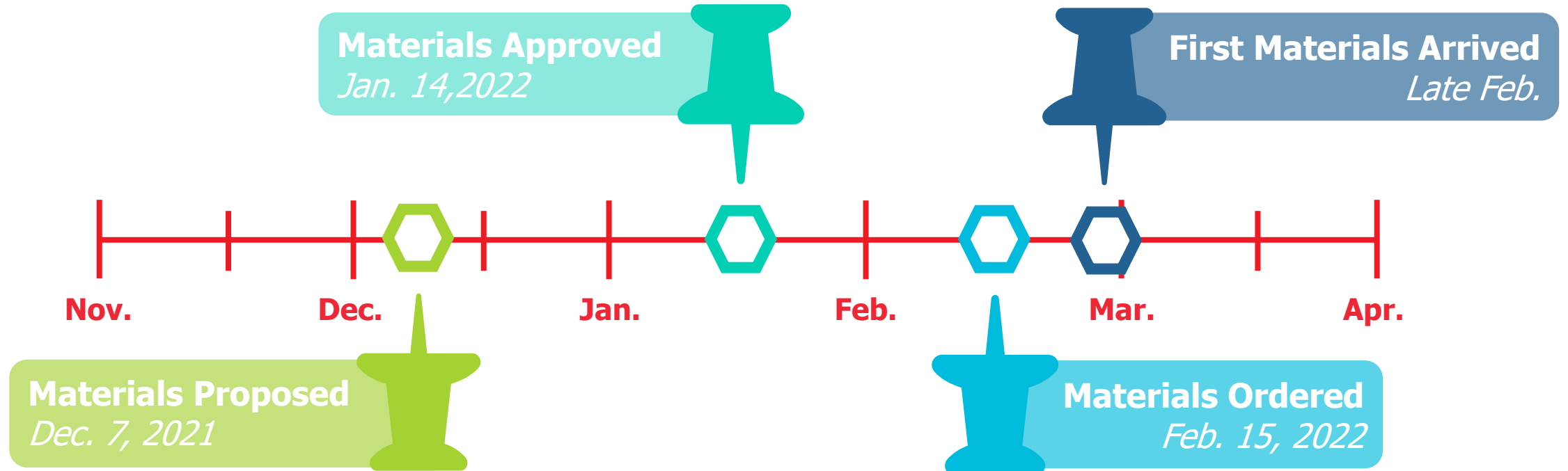
- Group Assembled Prototype
- COE Machine Shop
- 3D Printed Custom Parts

## Complete BOM

|                     |             |
|---------------------|-------------|
| Total Part Cost     | \$ 4,638.10 |
| Total Shipping Cost | \$ 104.73   |
| Total Labor Cost    | \$ 0.00     |
| Total Taxes         | \$ 304.22   |
| Total Cost          | \$ 4,638.10 |
| Cost Budget Ratio   | 93%         |





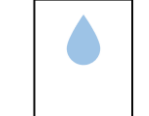
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# Key Dates



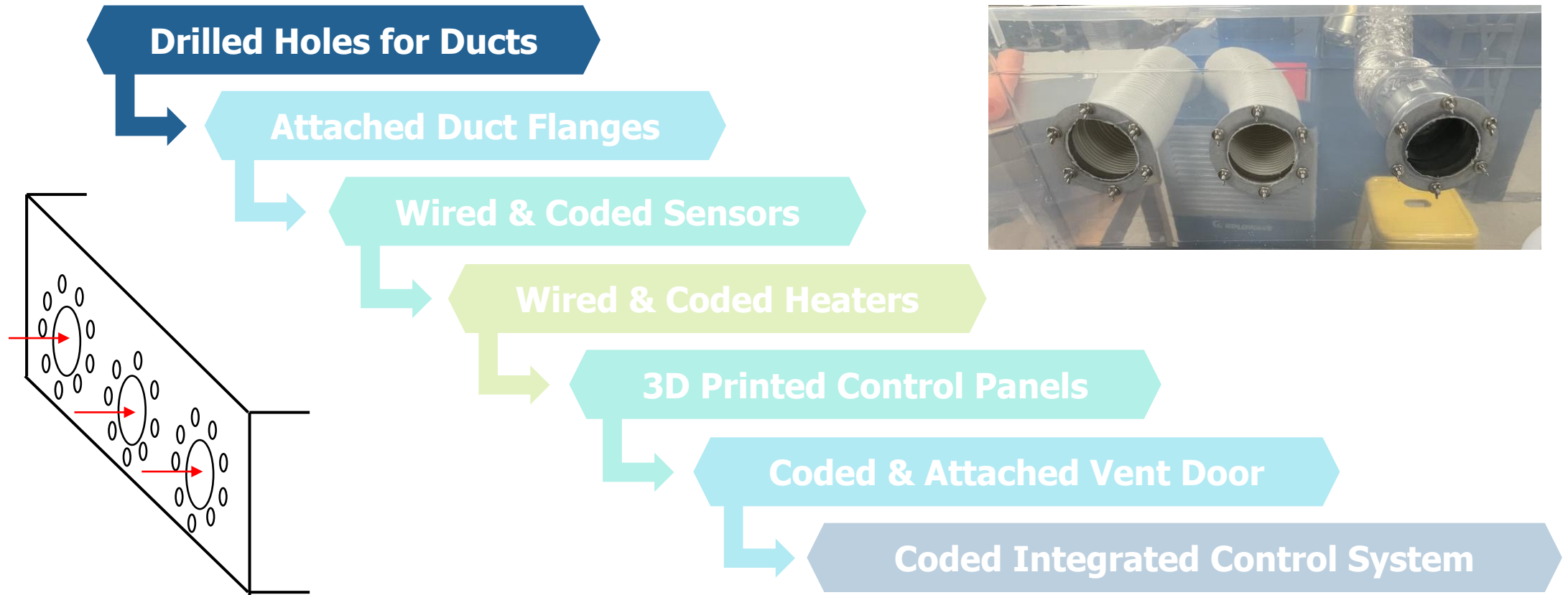
David Wilson

# Component Testing

|   |                            |    |                    |   |                      |
|---|----------------------------|----|--------------------|---|----------------------|
|   | <b>Temperature Sensors</b> | vs | <b>Thermometer</b> | → | <b>&lt;1°C Error</b> |
|   | <b>Humidity Sensors</b>    | vs | <b>Hydrometer</b>  | → | <b>&lt;2% Error</b>  |
|   | <b>A/C Unit</b>            | +  | <b>Thermometer</b> | → | <b>Down to 5°C</b>   |
|   | <b>Heaters</b>             | +  | <b>Thermometer</b> | → | <b>Up to 38°C</b>    |
|  | <b>Humidifier</b>          | +  | <b>Hydrometer</b>  | → | <b>Up to 98% RH</b>  |

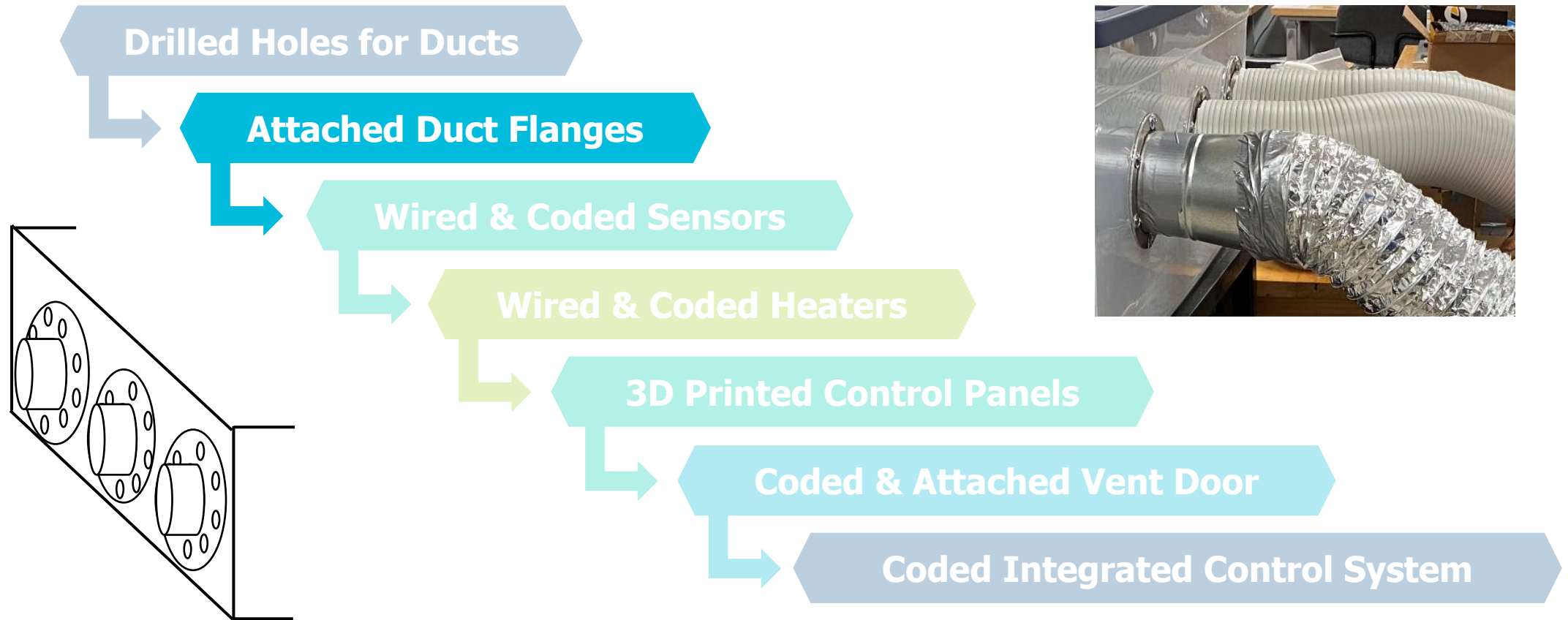
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# Assembly



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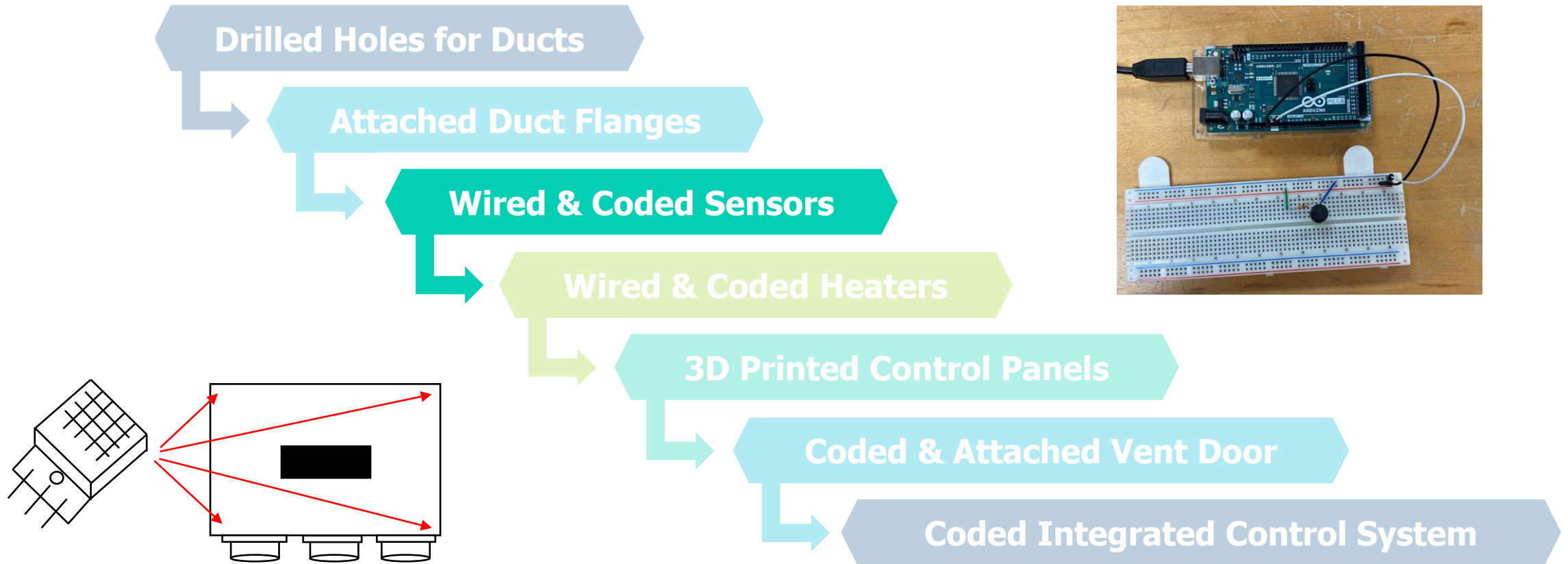
# Assembly



David Wilson



# Assembly



David Wilson

# Assembly

Drilled Holes for Ducts

Attached Duct Flanges

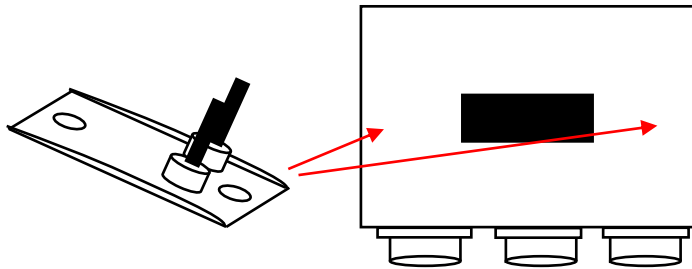
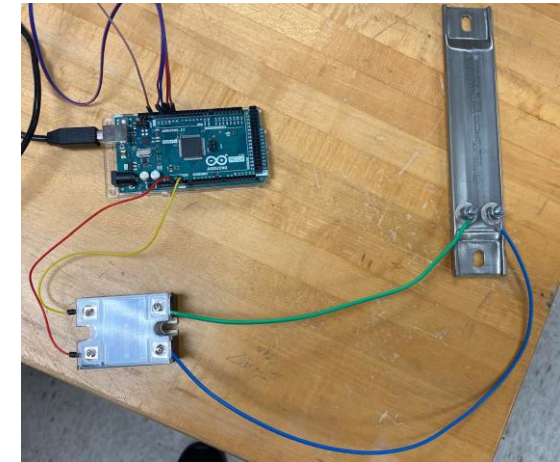
Wired & Coded Sensors

Wired & Coded Heaters

3D Printed Control Panels

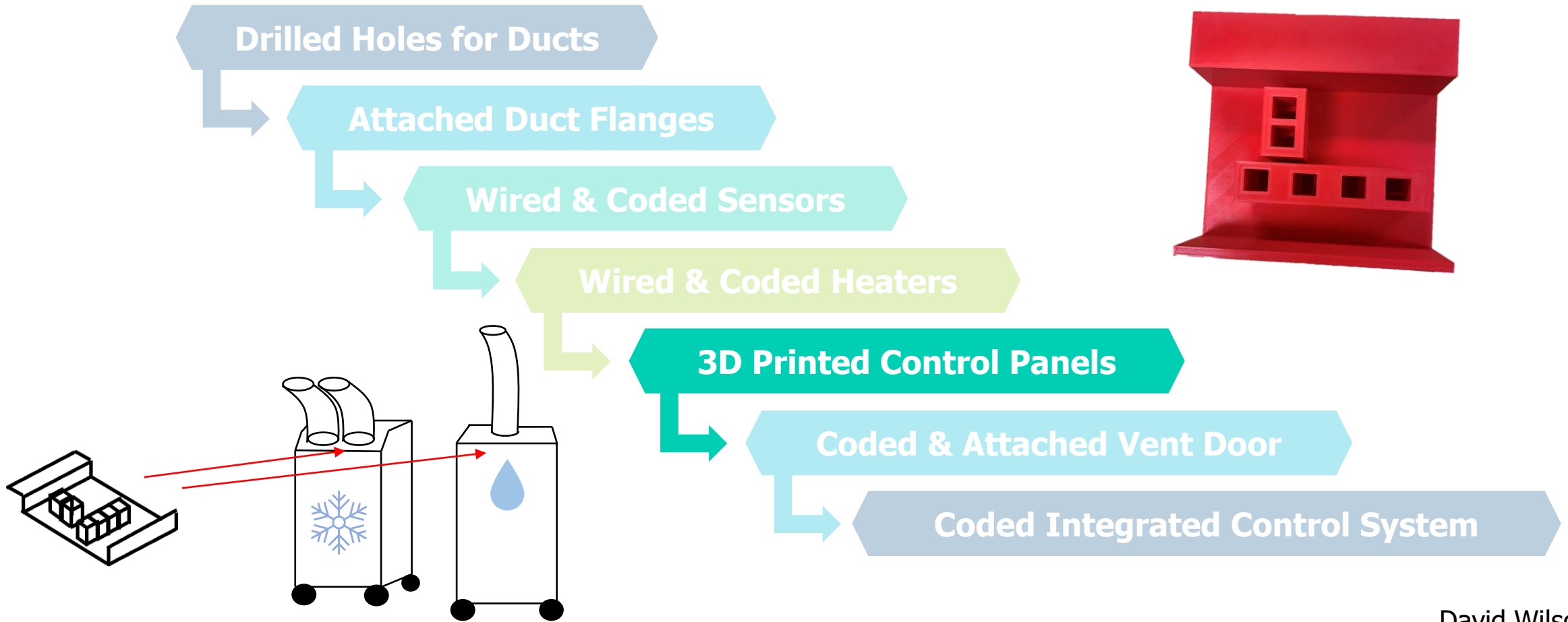
Coded & Attached Vent Door

Coded Integrated Control System



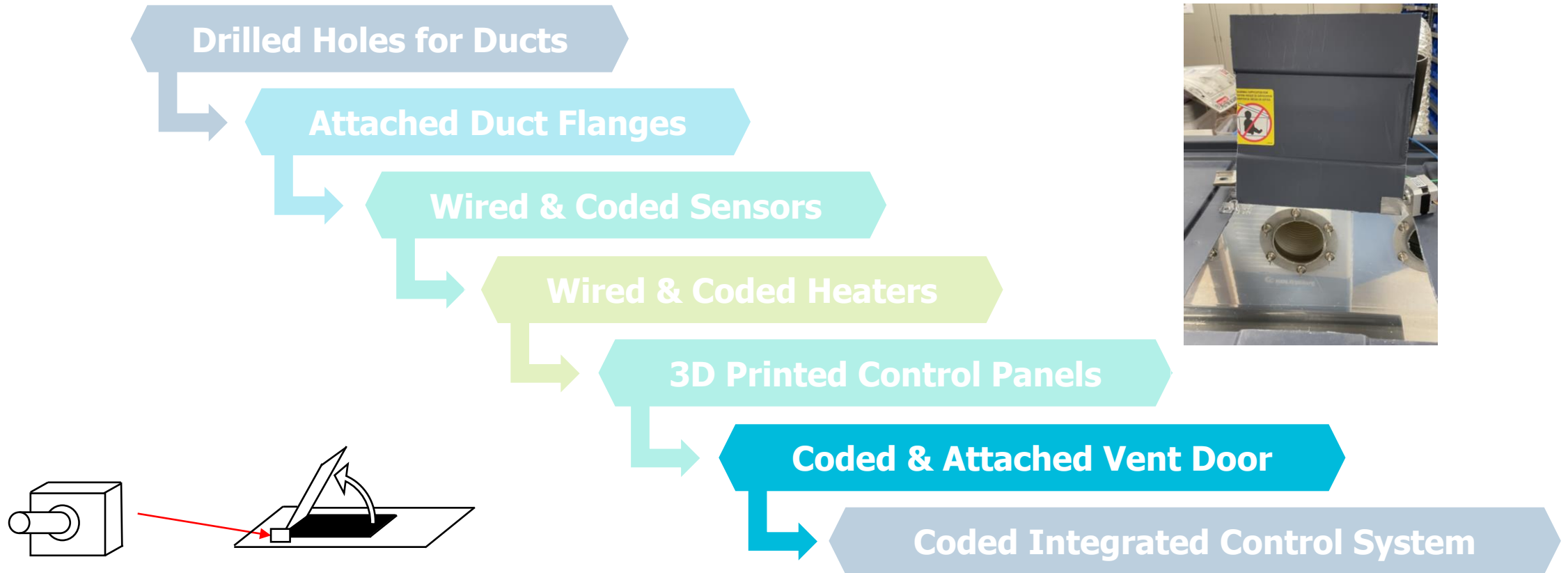
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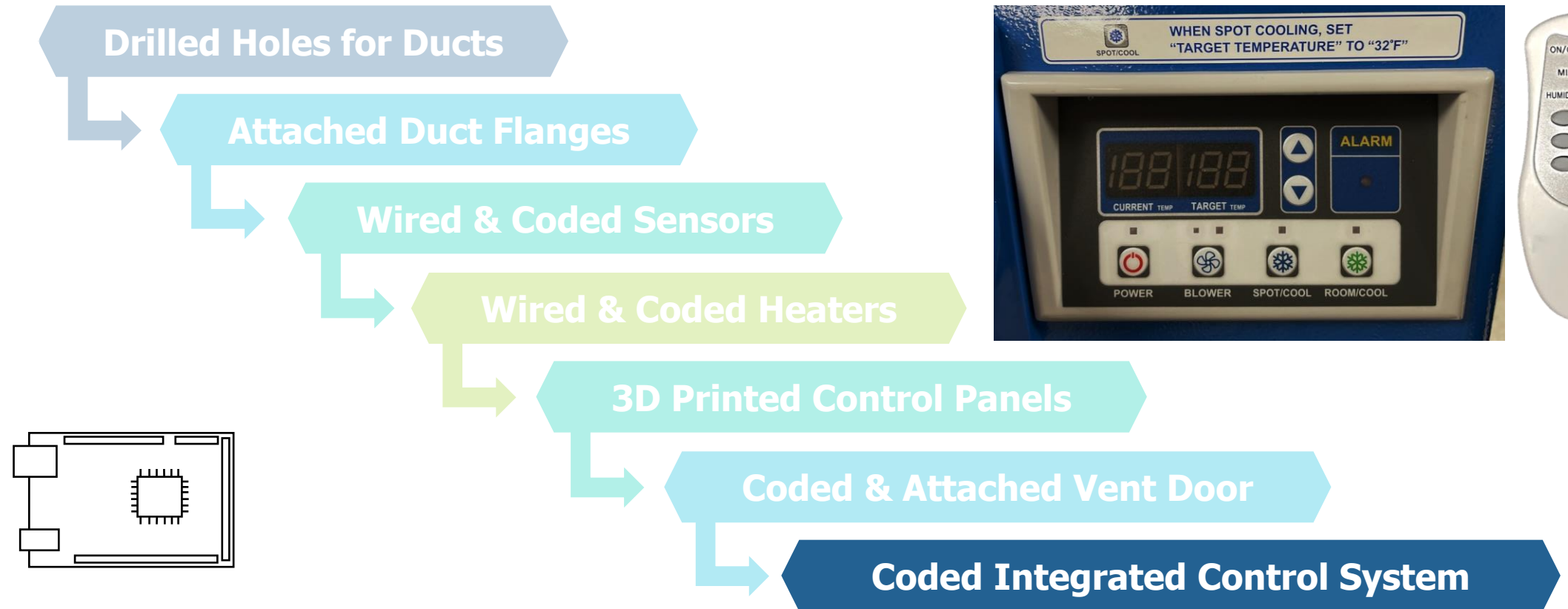
David Wilson

# Assembly



David Wilson

# Assembly



David Wilson

# Integrated System

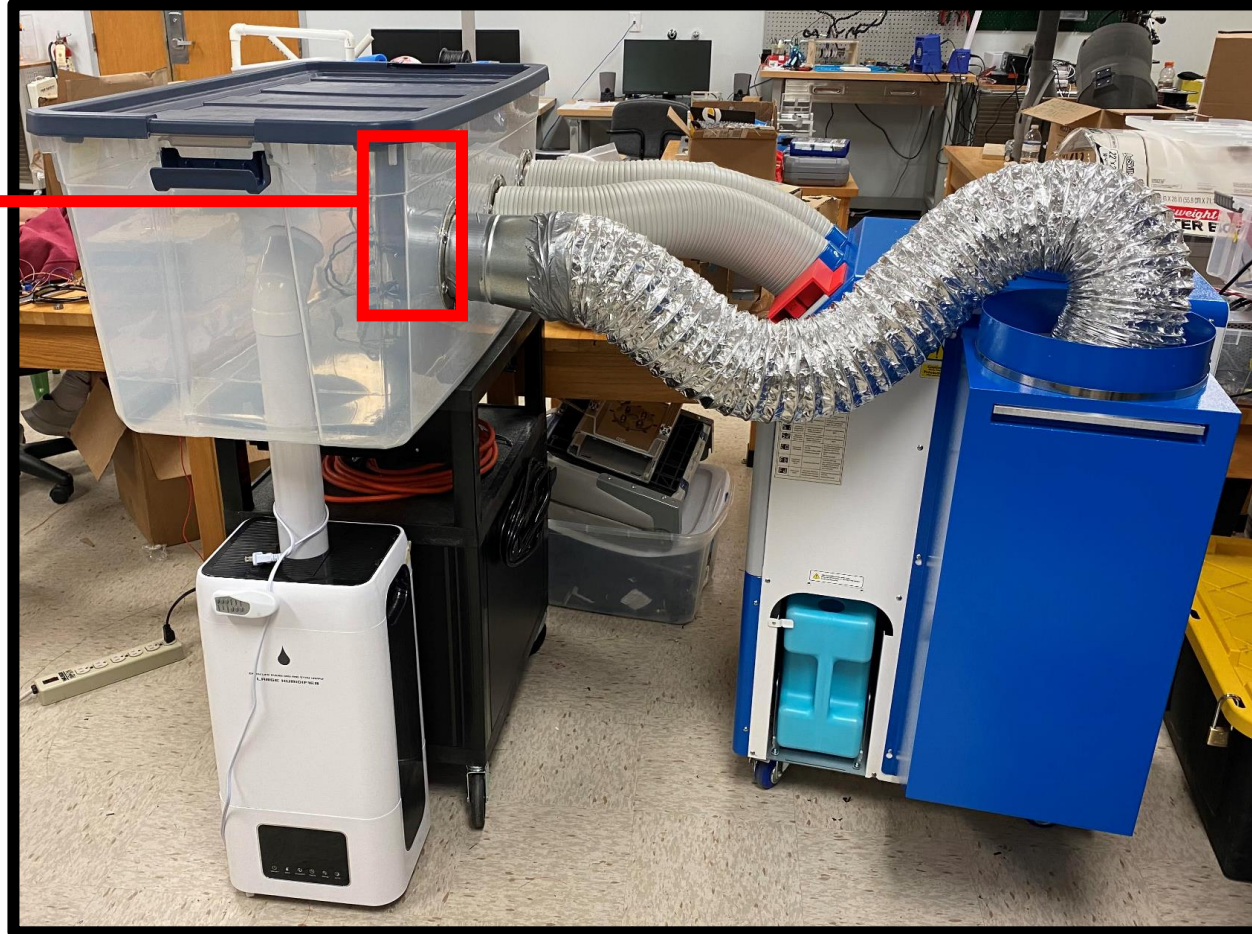
Control Volume



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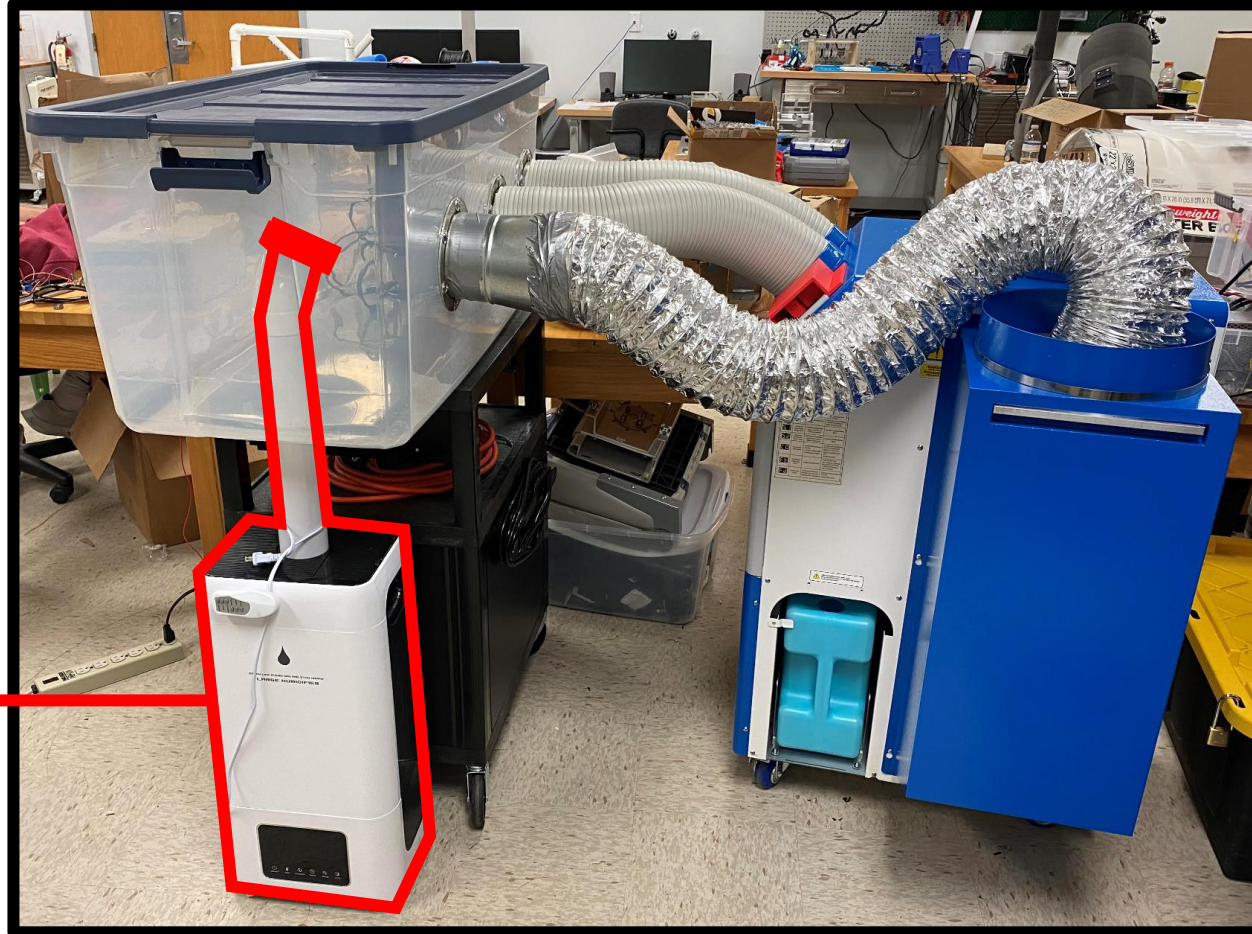
# Integrated System

Heater



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# Integrated System

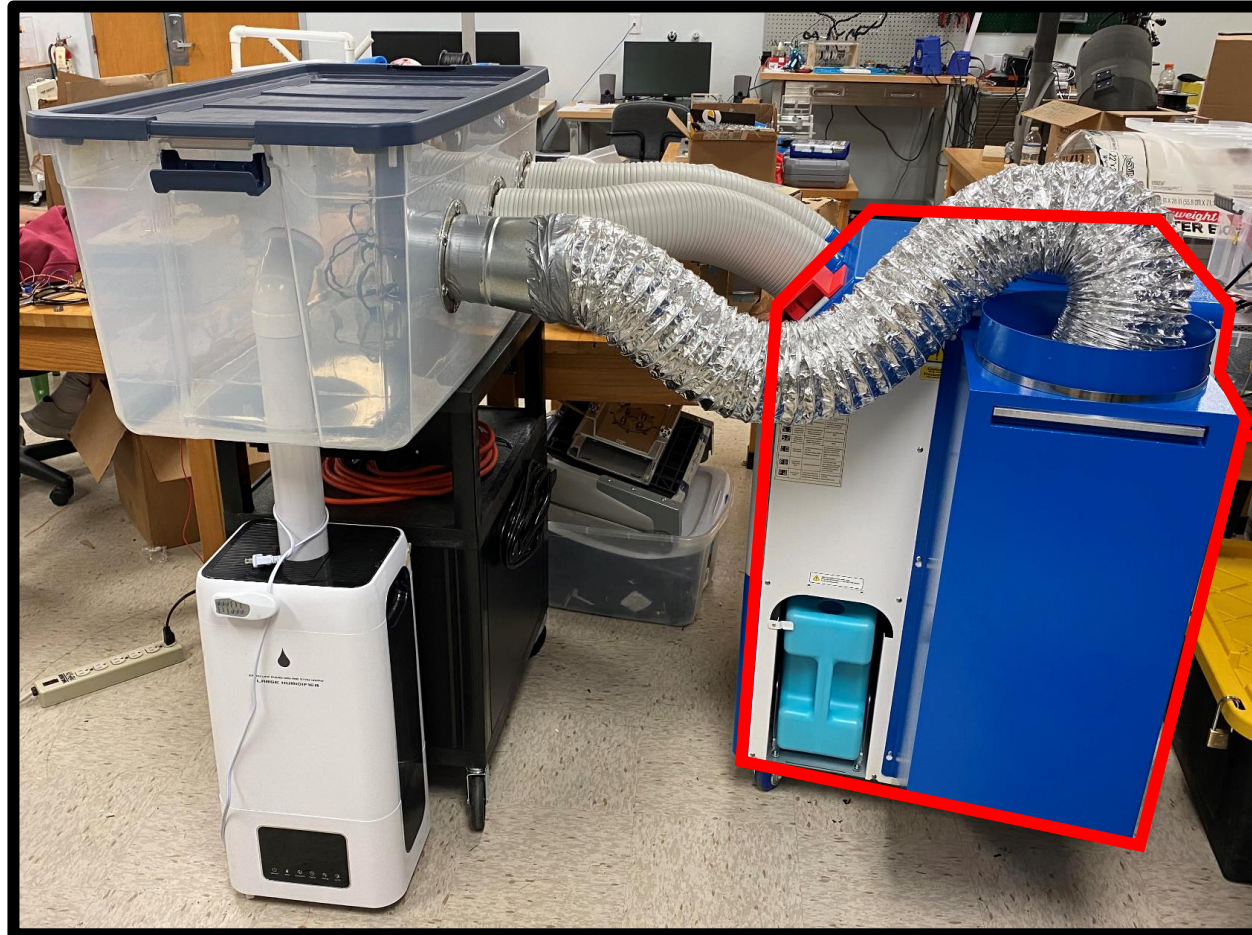


**Humidifier**

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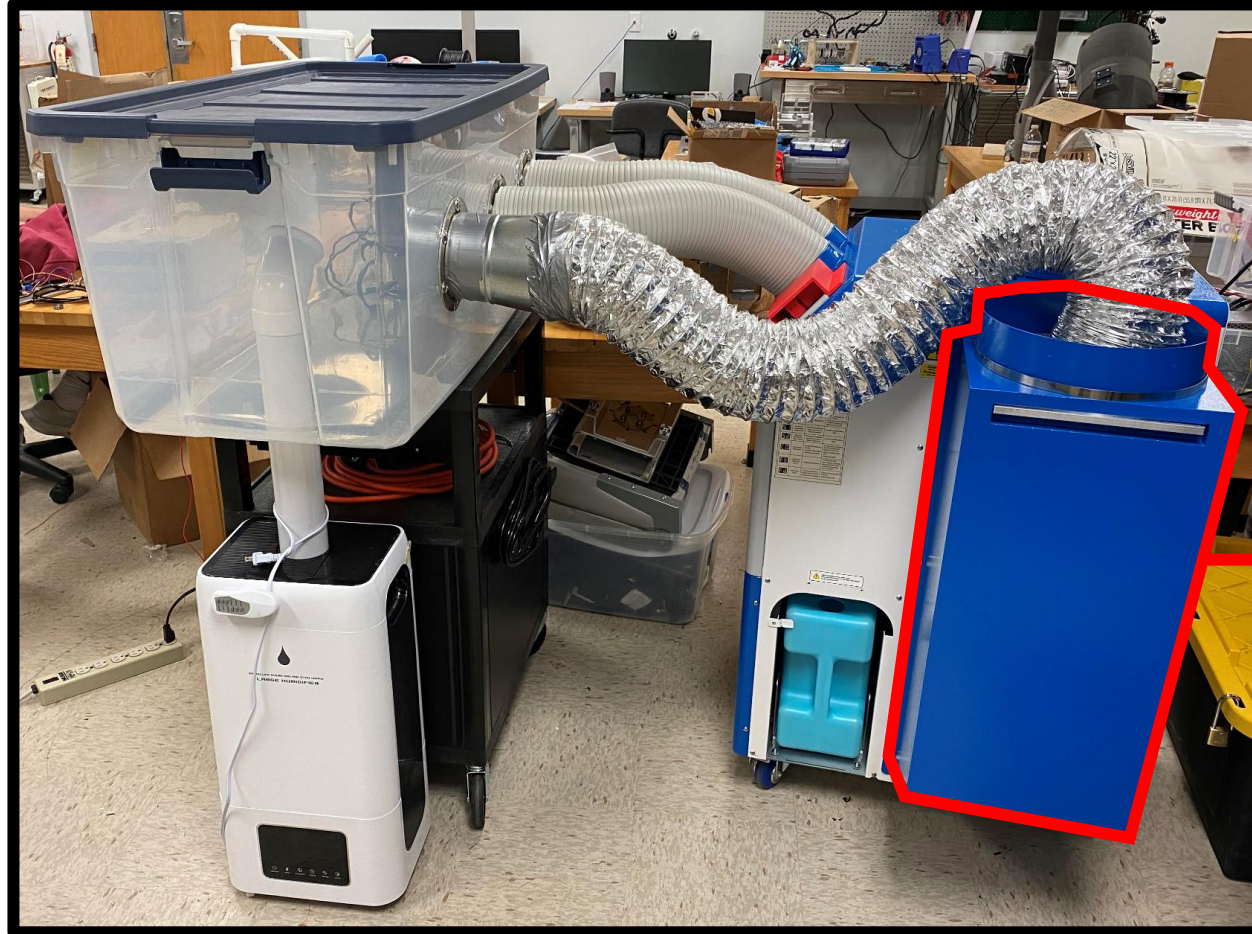
# Integrated System



**Air Conditioner**

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# Integrated System



**Ambient Air Adapter**

David Wilson

# Integrated System



**Control Panel**

David Wilson

# Integrated System



**Condensate Tank**

David Wilson

# Validation

| Key Target   | Result  | Error |
|--|---------|-------|
| Maintain Structural Stability<br>(10 lbs)          | Success | -     |
| Support Airducts & Equipment<br>(5 lbs)            | Success | -     |
| Monitor Temperature & Humidity<br>(Within 1%)      | Failure | 1%    |
| Add & Remove Heat<br>(10-50°C)                     | Failure | 5%    |
| Regulate Air Circulation<br>(1m <sup>3</sup> /min) | Success | -     |
| Increase & Decrease Humidity<br>(0-95% RH)         | Success | -     |
| Provide Clear View<br>(3 Sides)                    | Success | -     |

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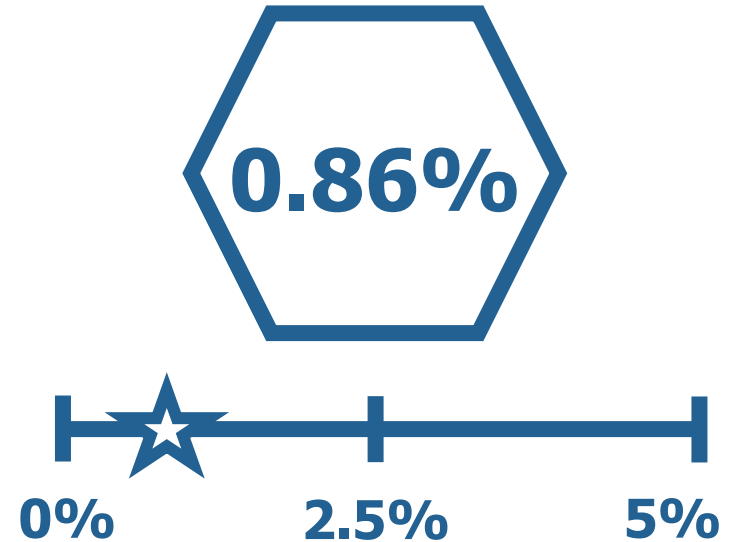
# Validation



Targets Met



Average Error



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# Application

**Implement System at Test Rig 12 in the Danfoss Lab**

**Drill Holes in Replacement Plexiglass**

**Install Condensation Collection System**

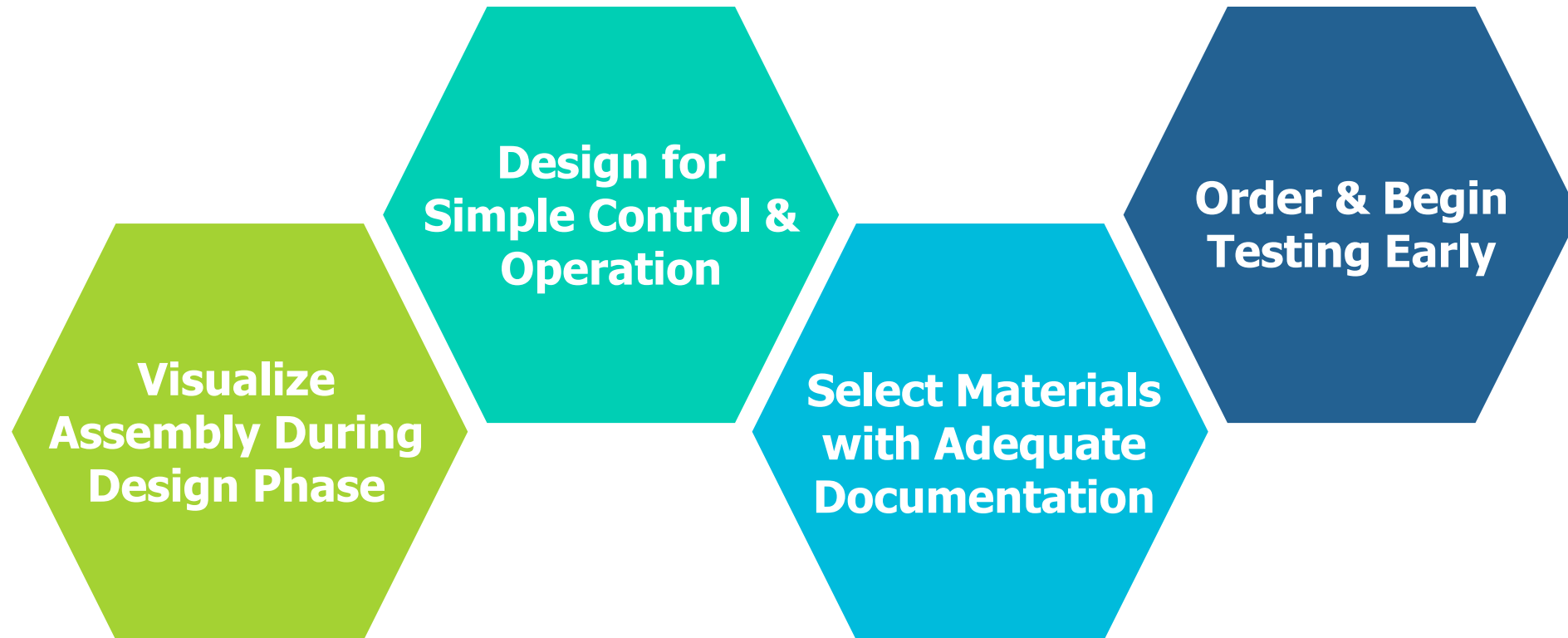
**Testing Electronic Components**

**Industrial Equipment Stress Testing**

**Different Material Properties**

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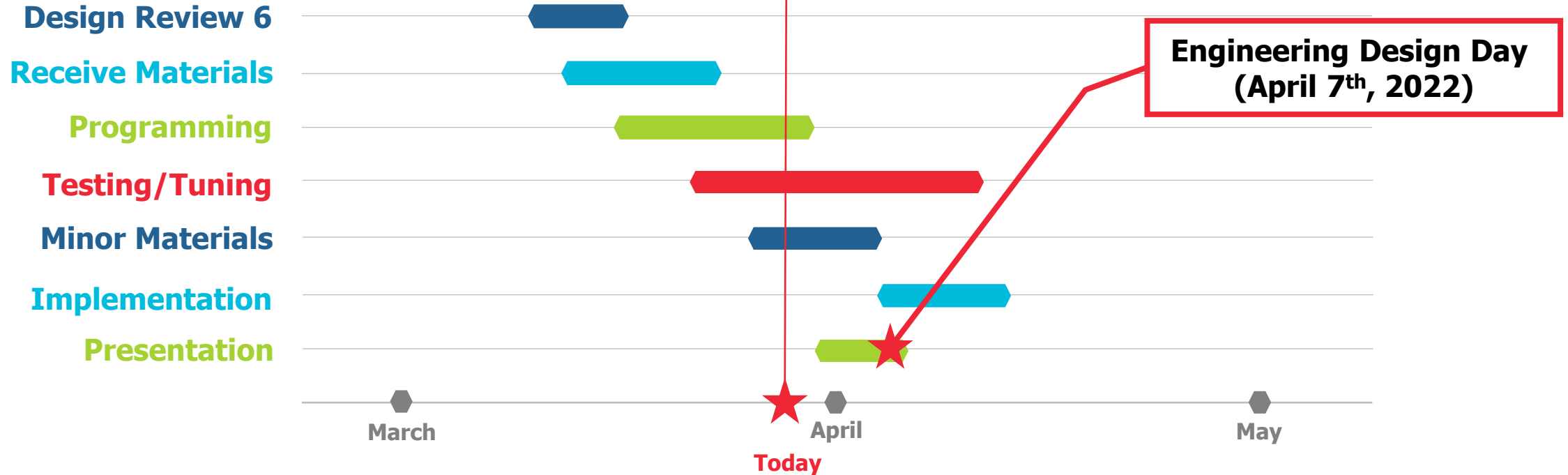
# Lessons Learned



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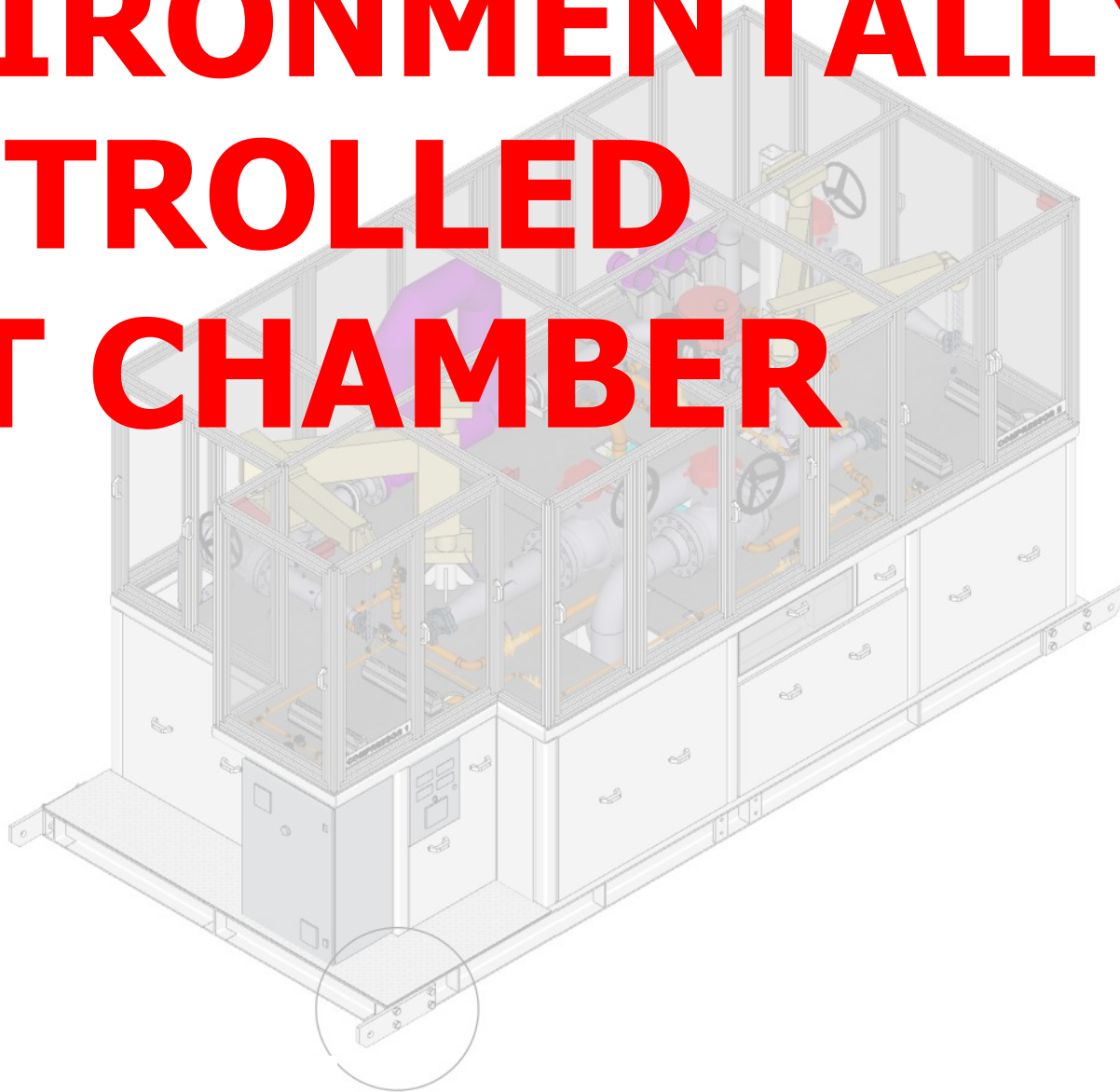


# Timeline



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# ENVIRONMENTALLY CONTROLLED TEST CHAMBER



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