



ENVIRONMENTAL 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

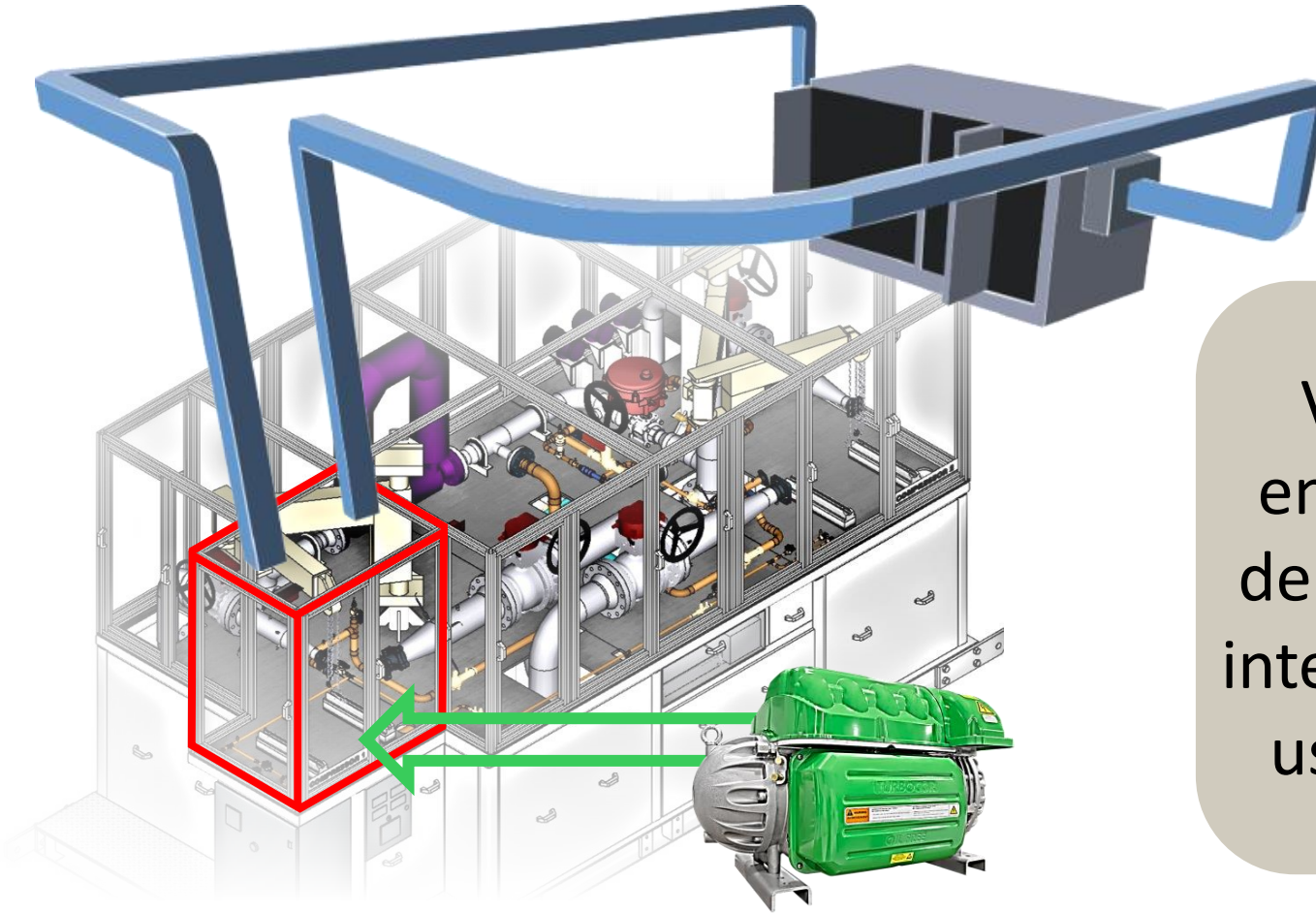


Keith Larson

*FAMU-FSU College of
Engineering*

Nicholas Blenker

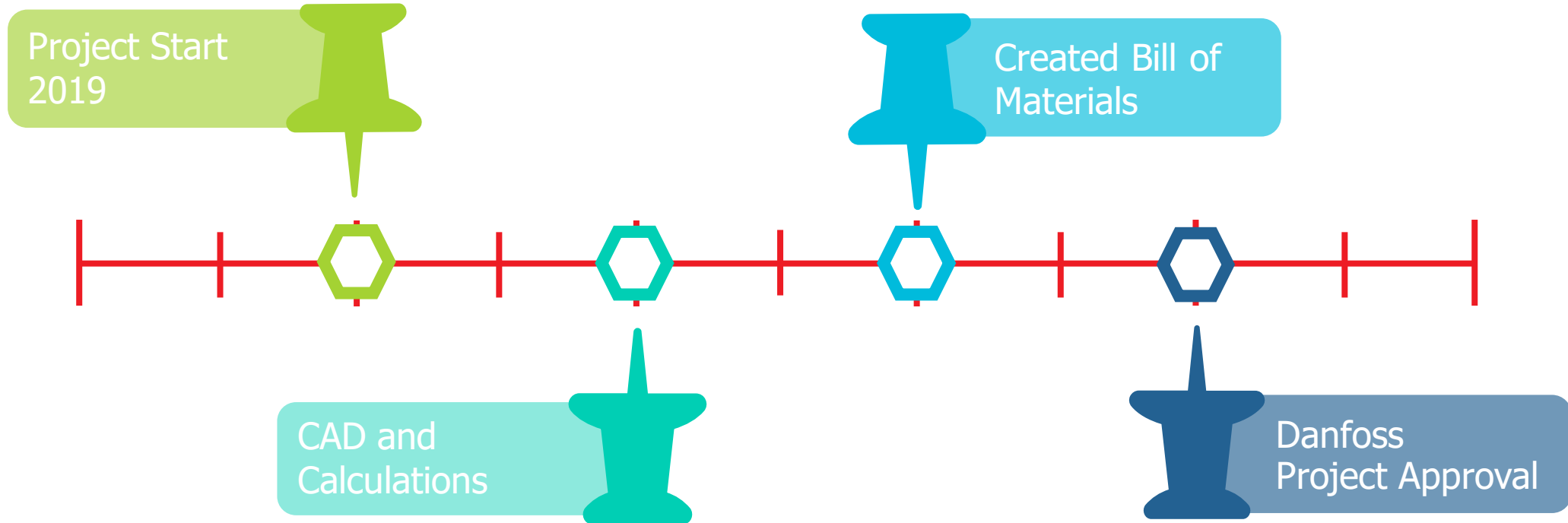
Project Objective



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.

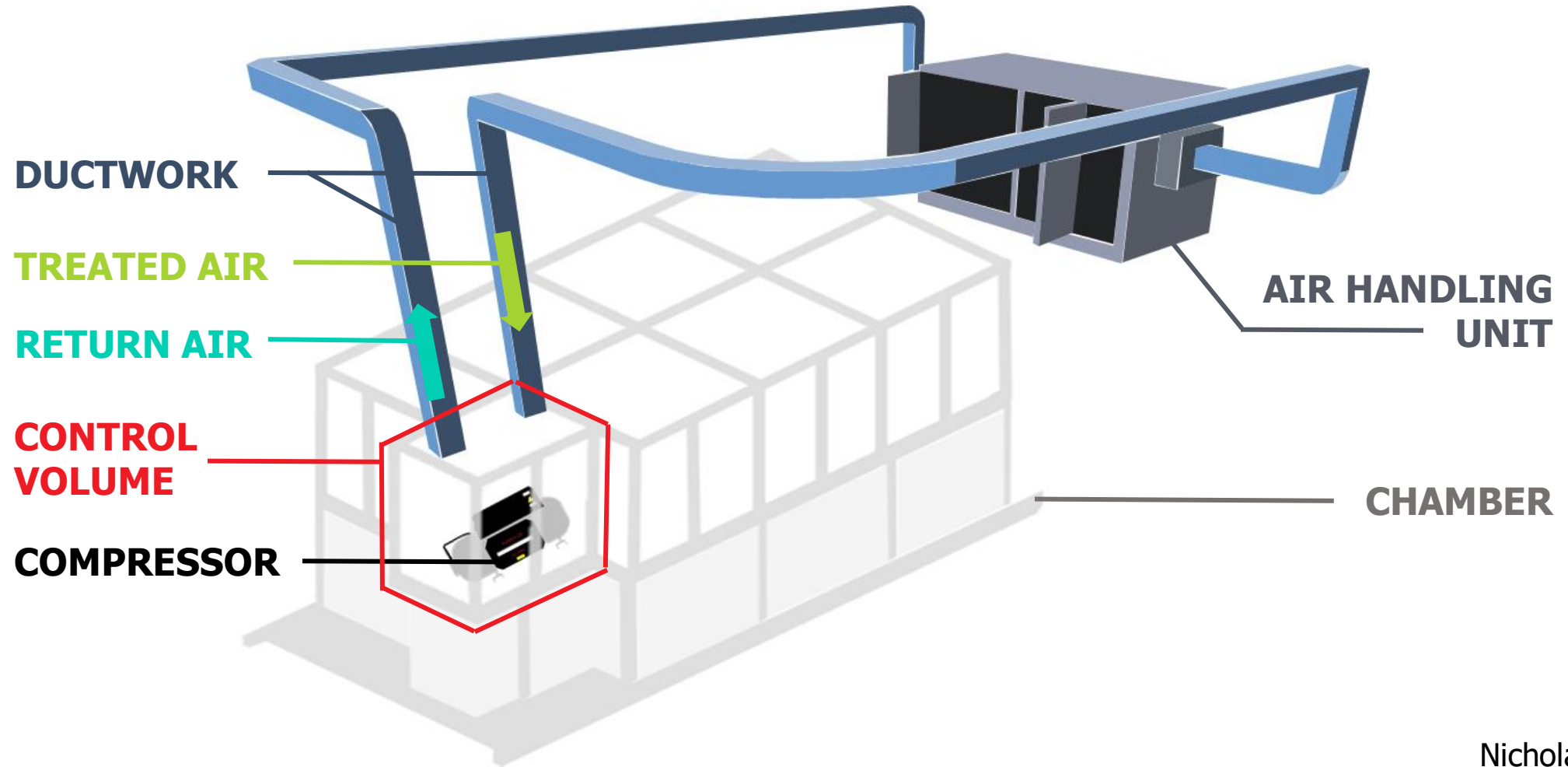
Nicholas Blenker

Project Background



Nicholas Blenker

Motivation



Nicholas Blenker

Assumptions



The test rig will rest on a flat and level surface



Conductive heat from the compressor is negligible



Danfoss Turbocor Compressor will be used



The existing support has adequate load capacity

Nicholas Blenker

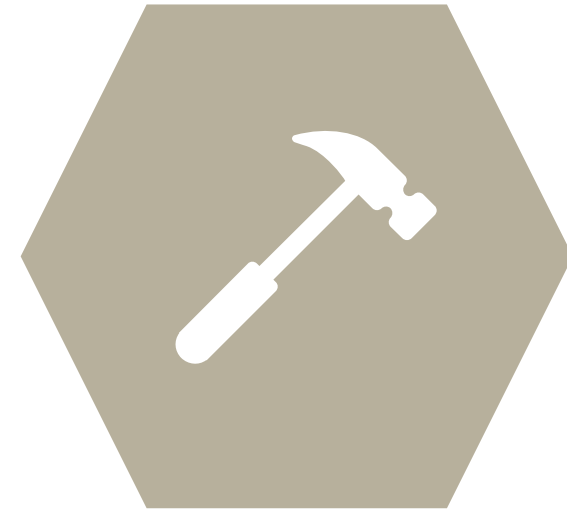
Key Goals



Validate



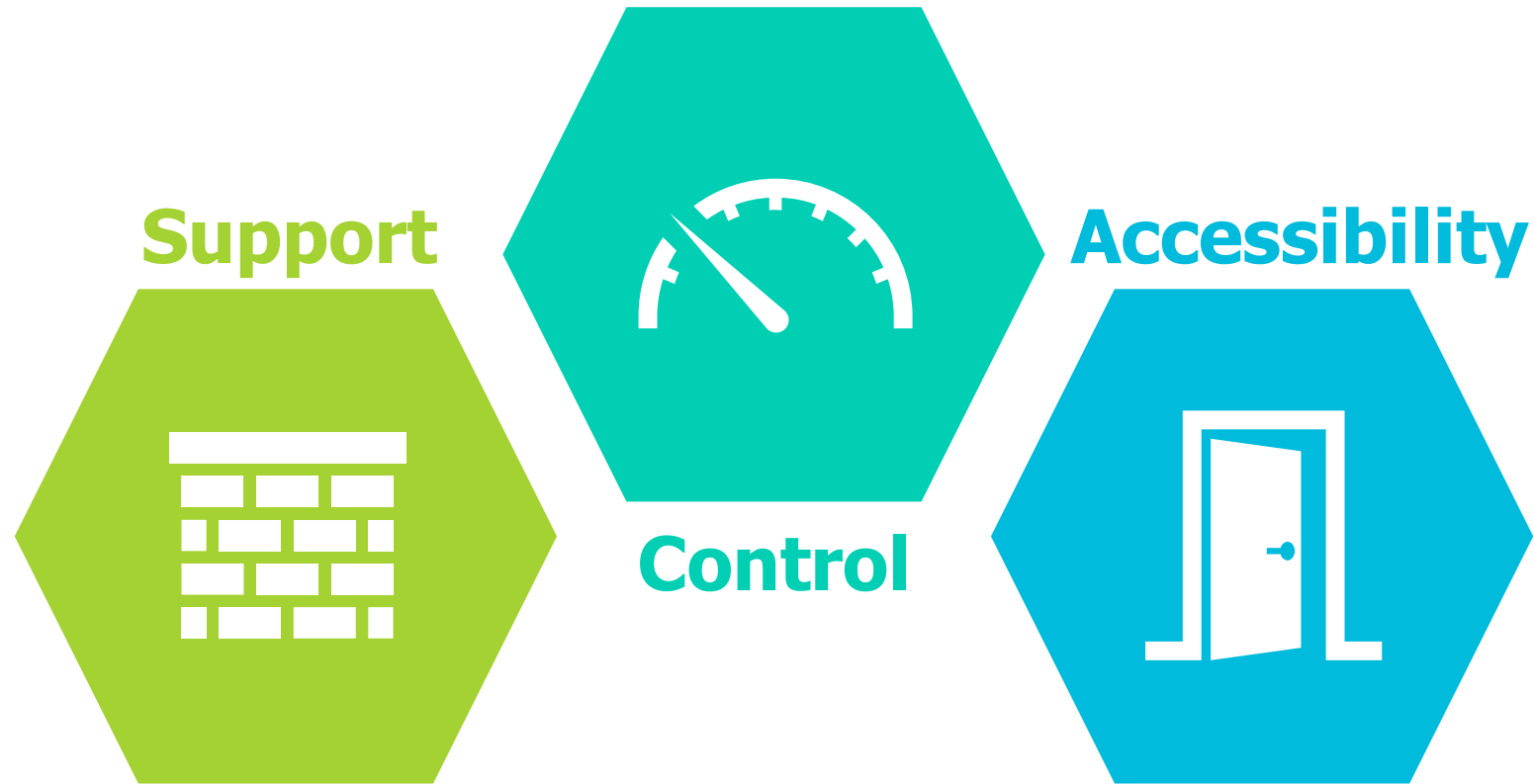
Finalize



Implement

Nicholas Blenker

Targets & Metrics

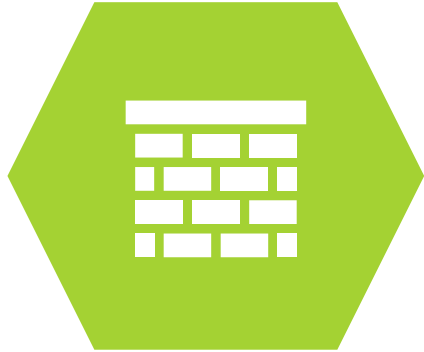


Nicholas Blenker

Key Targets & Metrics

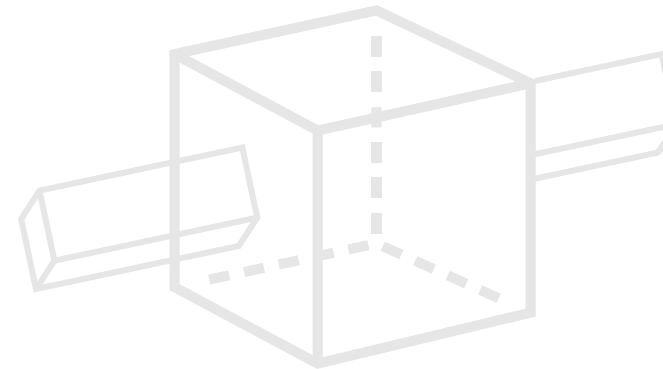
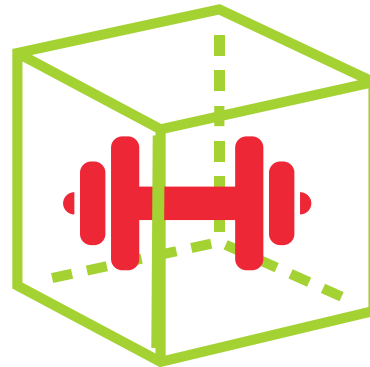


Support



Support

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

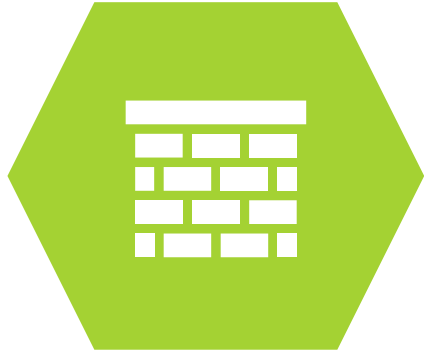


Nicholas Blenker

Key Targets & Metrics

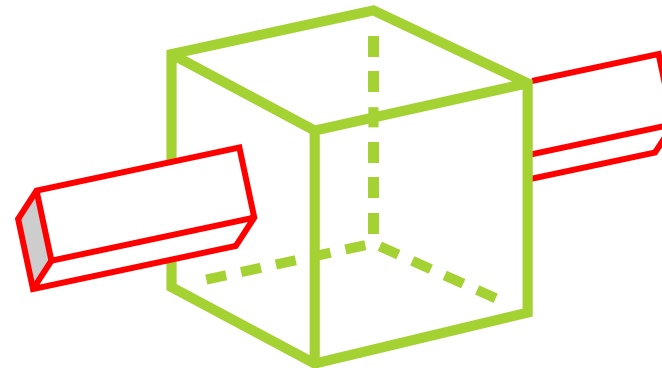
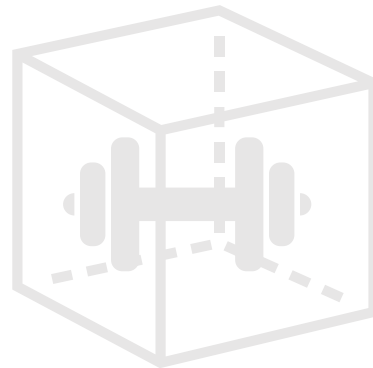


Support



Support

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



Nicholas Blenker

Key Targets & Metrics

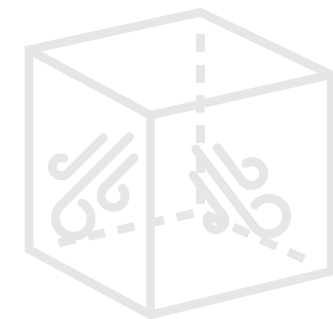
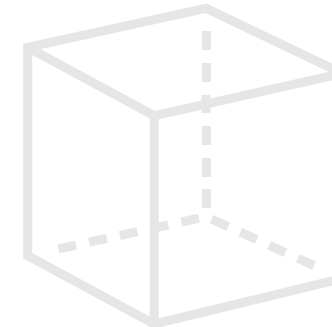
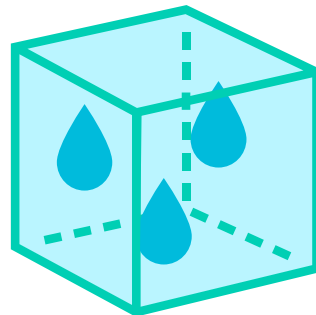


Control



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



Nicholas Blenker

Key Targets & Metrics

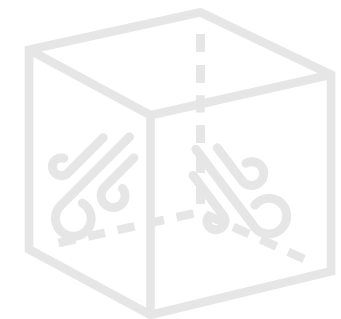
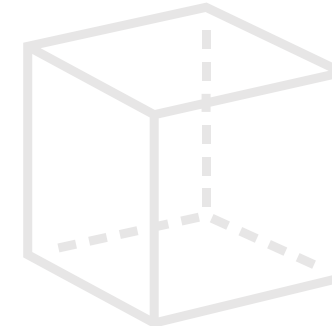
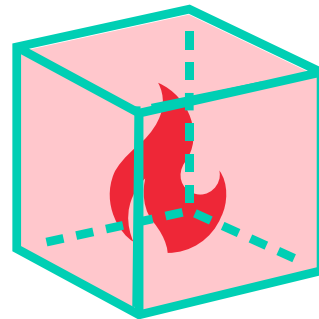
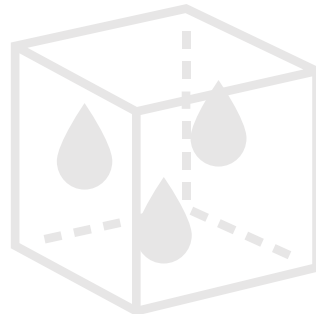


Control



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



Nicholas Blenker

Key Targets & Metrics

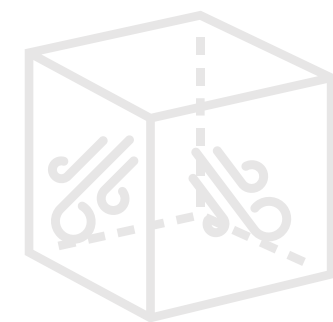
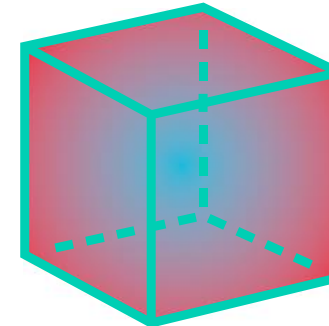
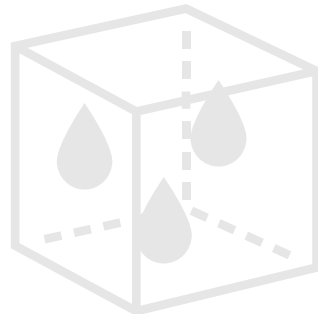


Control



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



Nicholas Blenker

Key Targets & Metrics

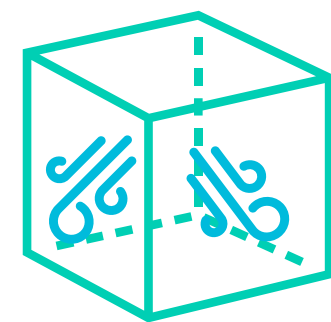
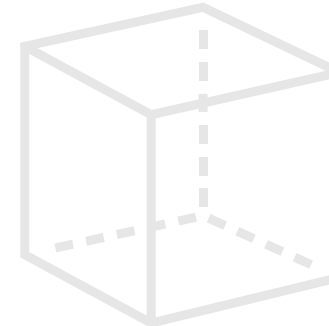
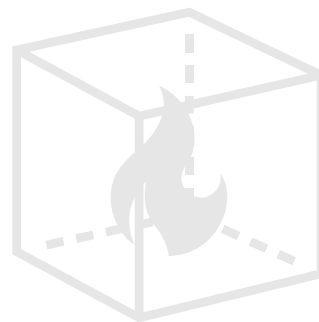
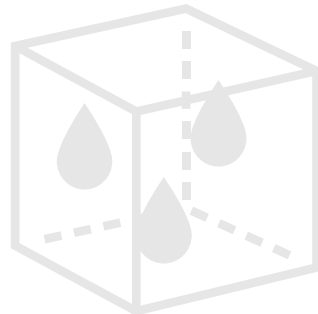


Control



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

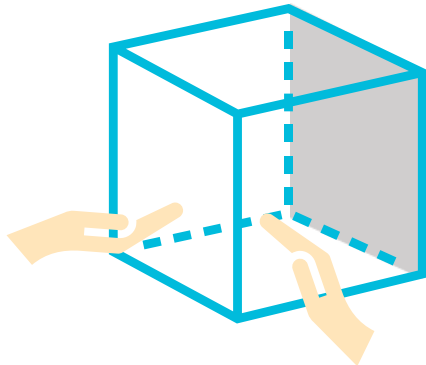


Nicholas Blenker

Key Targets & Metrics



Accessibility



Accessibility

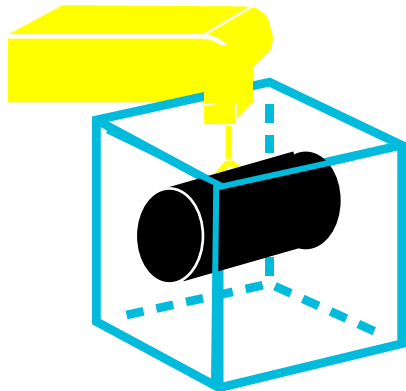
Function	Target	Metric
Allow Access from All Sides	3 Sides	Accessible Sides
Enable Efficient Exchange of Compressor(s)	15 minutes	Time
Provide Clear View of Compressor	360° Visibility	Degrees of visibility
Adjust Temperature and Humidity	No Human Interaction	Human Interaction

Nicholas Blenker

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

Nicholas Blenker

Key Targets & Metrics

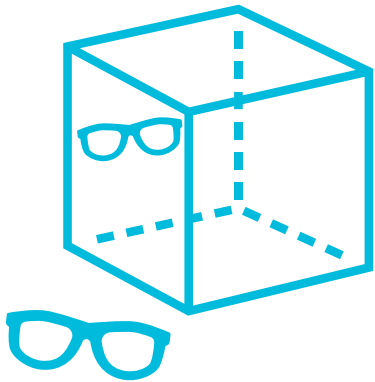


Accessibility



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



Nicholas Blenker

Key Targets & Metrics

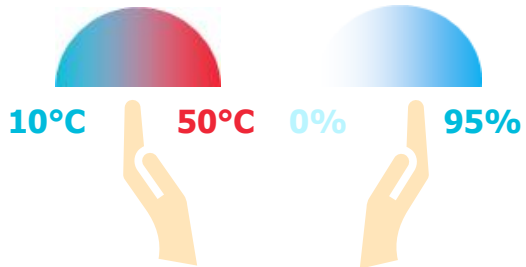


Accessibility



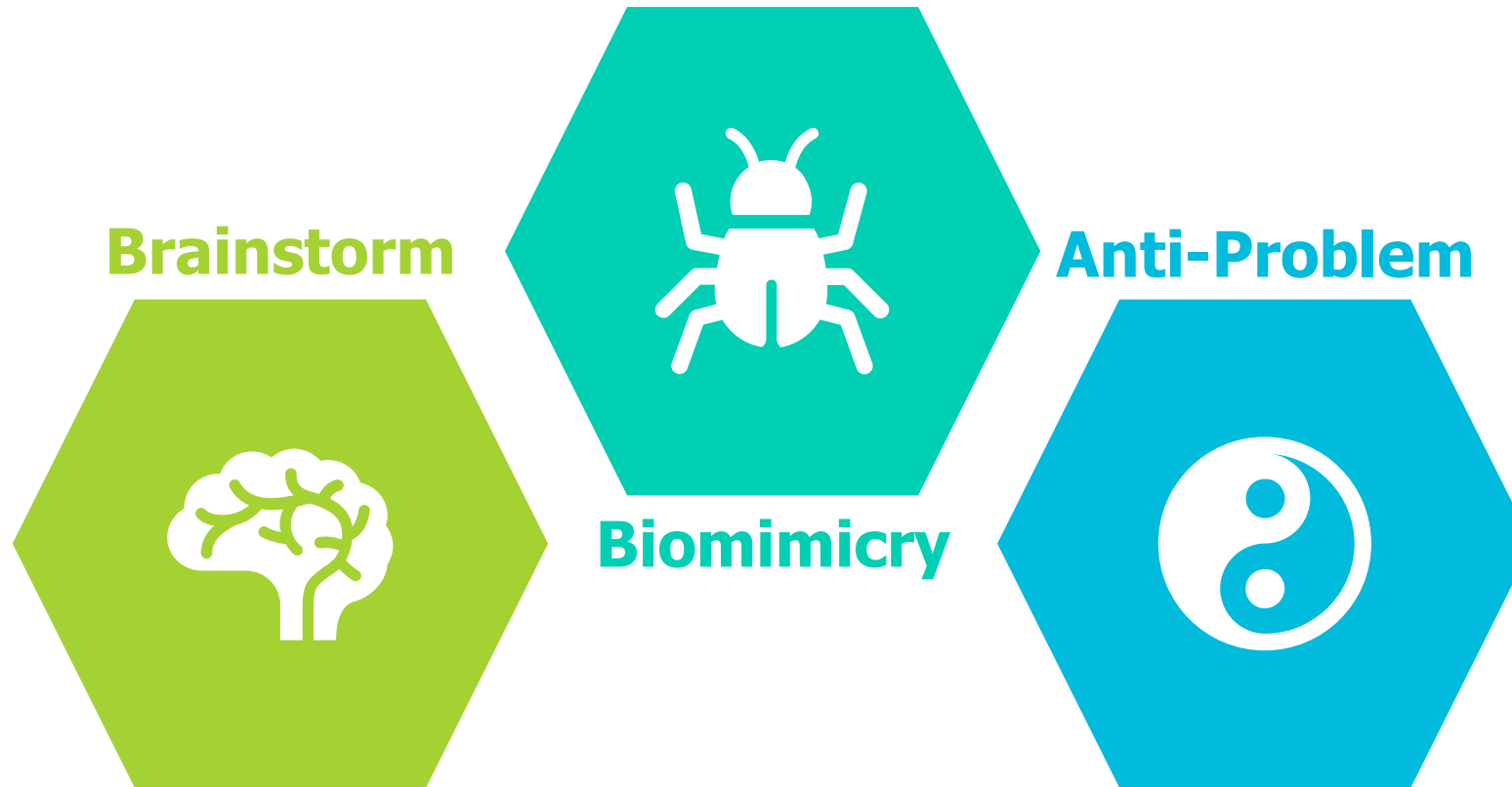
Accessibility

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



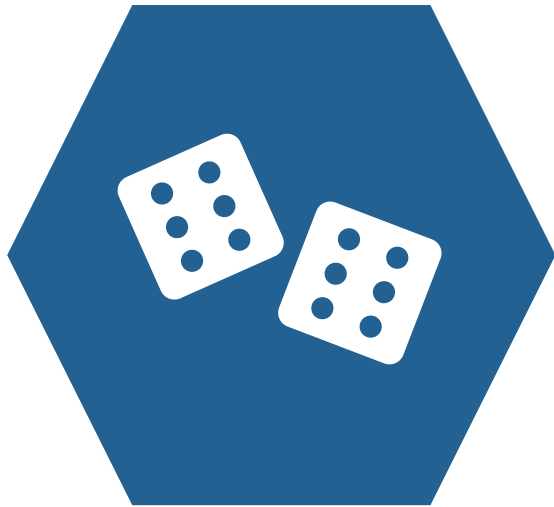
Nicholas Blenker

Concept Generation



Nicholas Blenker

Concept Generation



**Morphological
Chart**

AHU Placement	Duct Attachment	Infiltration Seals	Other Features
Floor-Mounted	Fixed Overhead Ducts	Putty	Duct Dips with Valves
Wall-Mounted	Detachable Side Ducts	Rubber Inserts	Duct Close-Off

Nicholas Blenker

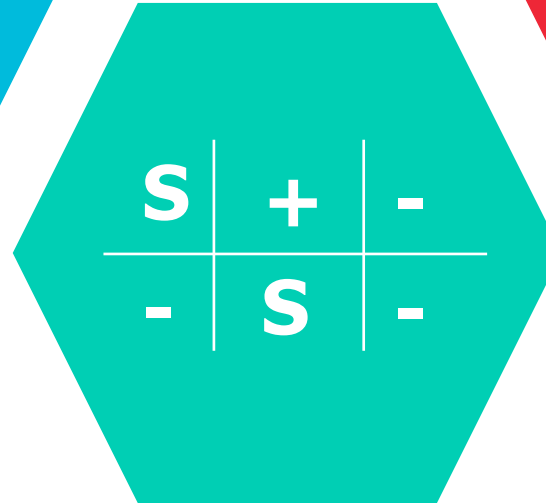
Concept Selection

**Pairwise
Comparison**



**House
of Quality**

**Pugh
Chart**



**Analytical
Hierarchy Chart**

Nicholas Blenker

Concept Selection

Results



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



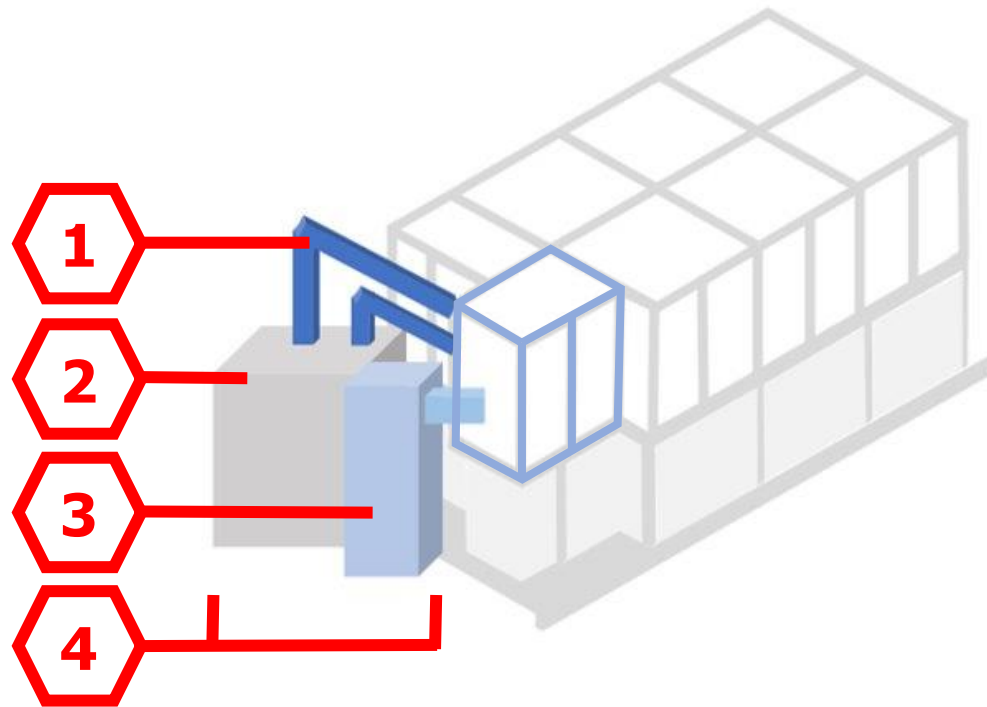
Wall-Mounted AHU with Detachable Overhead Ducts, Puddy Seals, and Dips Inside Ductwork



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

Nicholas Blenker

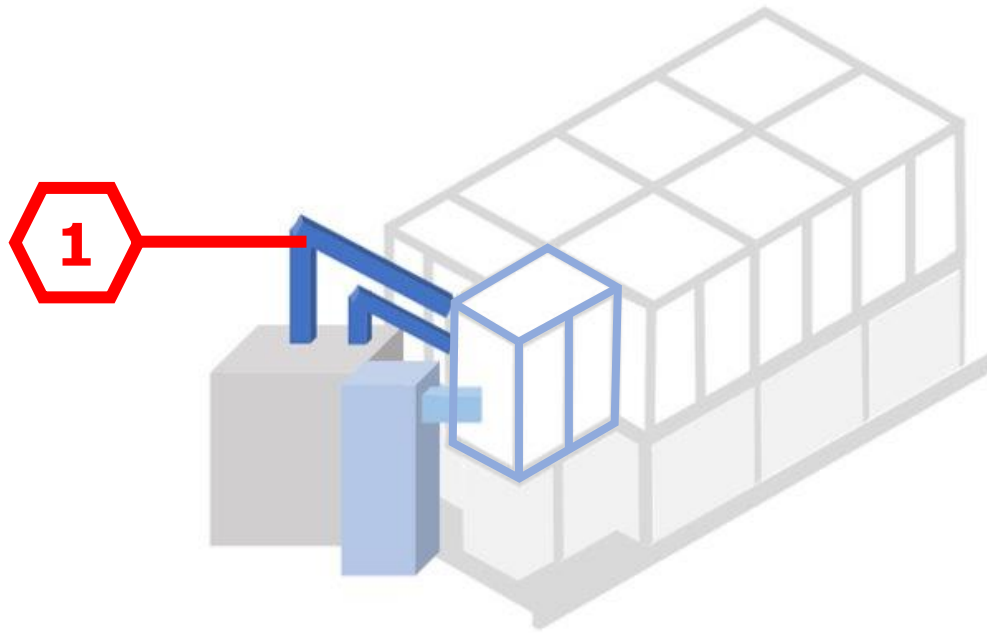
Key Changes



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

Tucker Hall

Key Changes



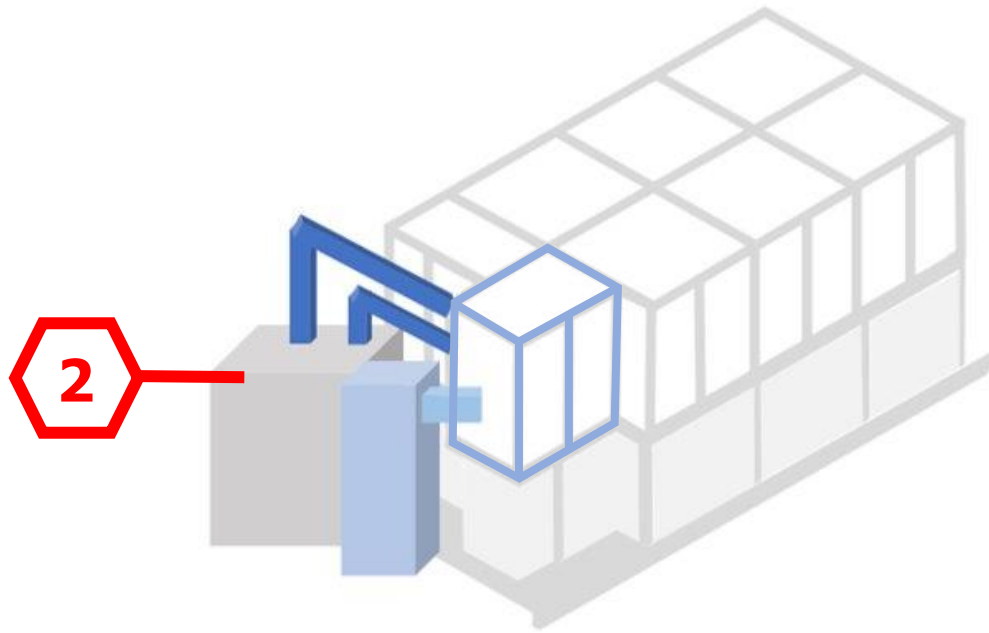
1

Screw-On Side Ducts

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

Tucker Hall

Key Changes



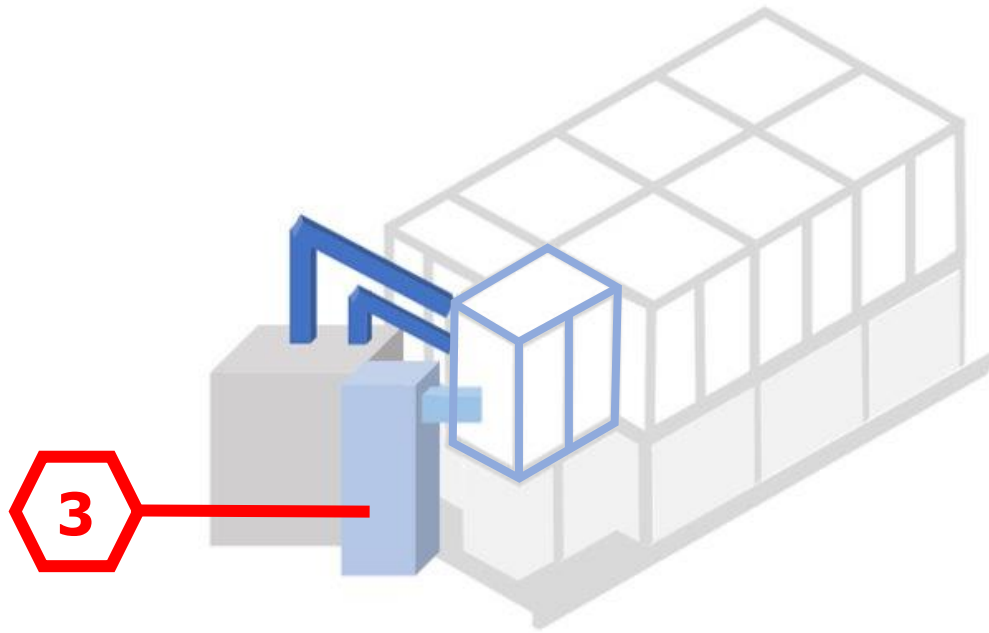
2

29,000 BTU A/C

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

Tucker Hall

Key Changes



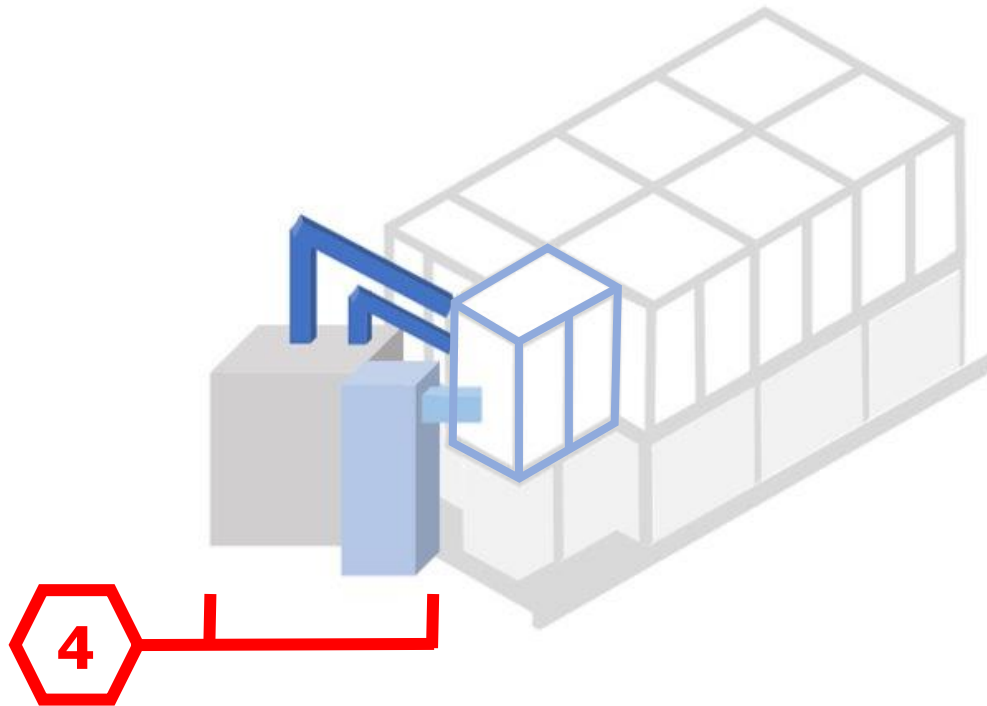
3

Industrial Humidifier

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

Tucker Hall

Key Changes



4

Floor-Mounted AHU

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

Tucker Hall

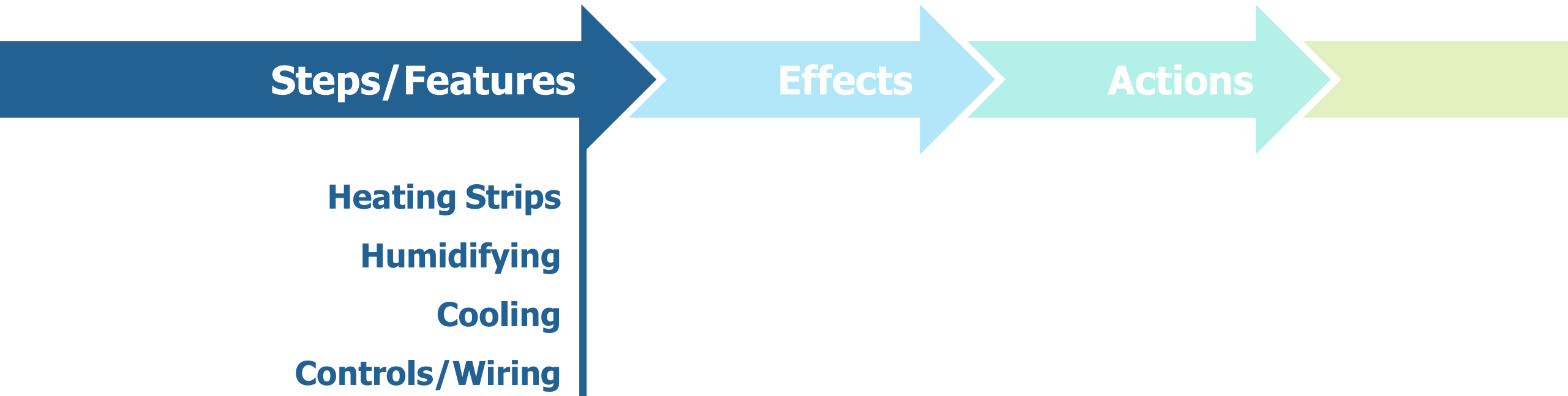
Initial Proposed Materials



- 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 Strip**
- 1 x Foam Sealing Strips
- 1 x Ambient Air Adapter**
- 1 x Pack of Wires
- 1 x Fiberglass Insulation

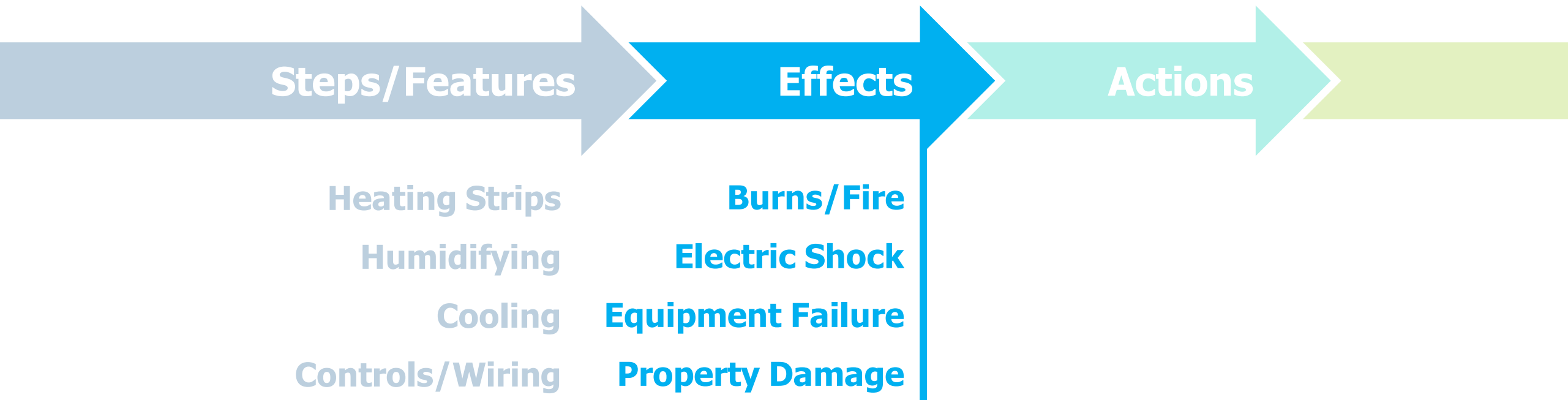
Tucker Hall

Risk Analysis



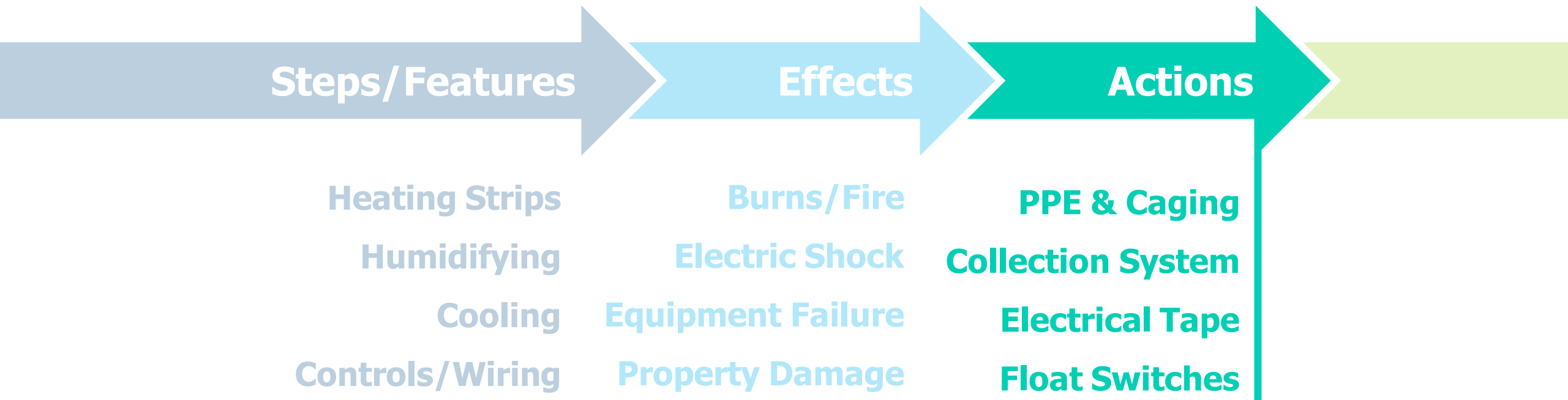
Tucker Hall

Risk Analysis



Tucker Hall

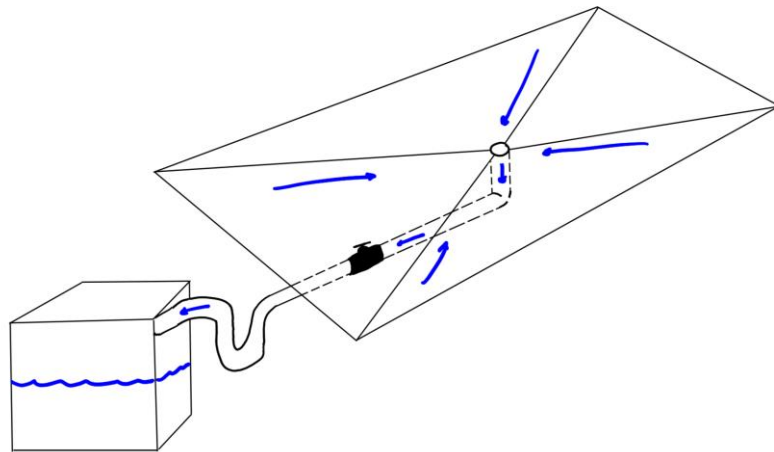
Risk Analysis



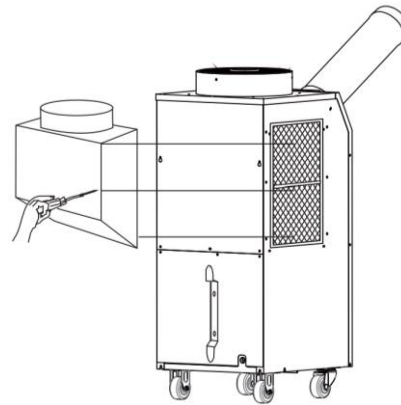
Tucker Hall

Design Changes

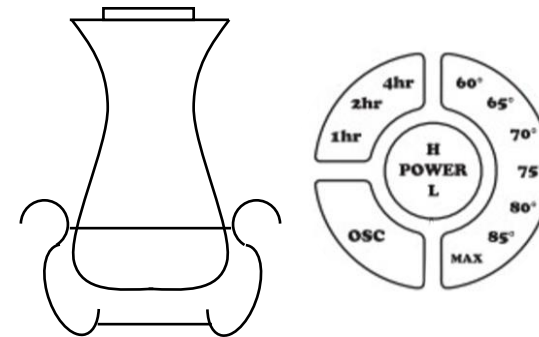
Condensation
Collection System



Air Adapter for
Humidifier



Electric Space
Heater



Control Changes
Over 110°F

A/C is Turned Off

Heat Vented to Cool

Tucker Hall

Updated Materials

- 1 x Arduino Mega
- 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 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
- 1 x Electric Space Heater
- 1 x Plastic Tote
- 1 x Circulation Pump
- 3 x Float Switches
- 1 x Tubing
- 8 x Button Pushers
- 1 x Duct Reducer

Tucker Hall

Current Materials

Expensive Items

- ✓ A/C Unit - \$2,942.55
- ✓ Ambient Air Adapter - \$424.00
- ✓ Humidifier - \$307.38

Total Cost	\$ 4,512.08	= 90%
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%

Tucker Hall

Projected Totals

Final Install Items

- Circulation Pump
- Float Switches
- Rubber Gaskets

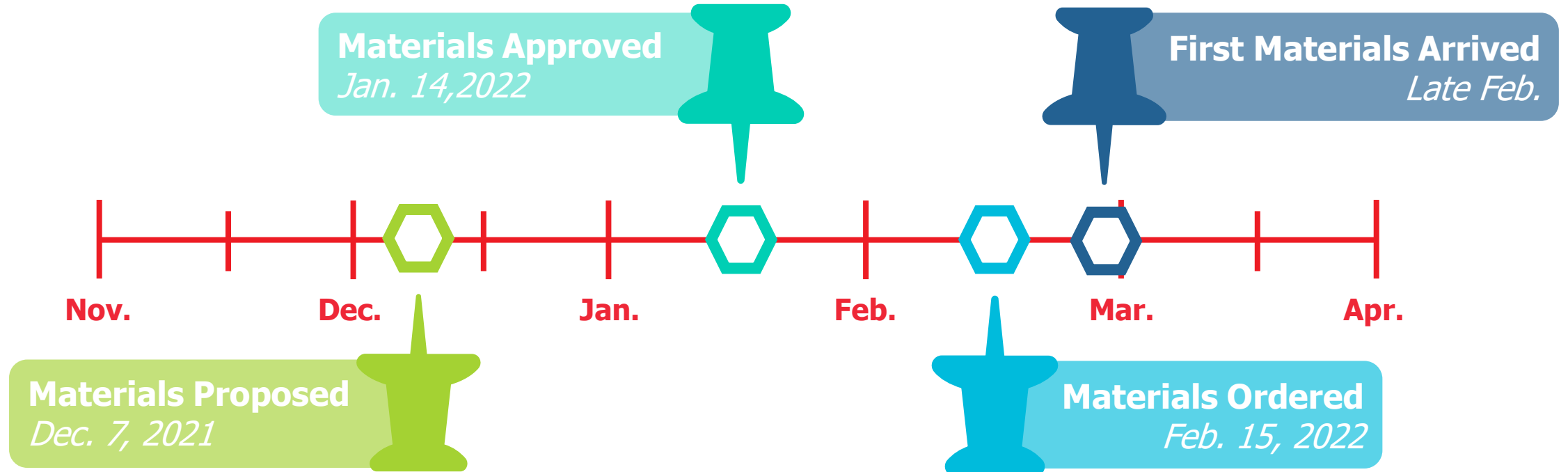
- Group Assembled Prototype
- COE Machine Shop
- 3D Printed Custom Parts

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%

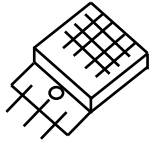
Tucker Hall

Key Dates



David Wilson

Component Testing



Temperature Sensors

VS

Thermometer



<1°C Error



Humidity Sensors

VS

Hygrometer



<2% Error

A/C Unit

+

Thermometer



Down to 12°C

Heater

+

Thermometer



Up to 55°C

Humidifier

+

Hygrometer

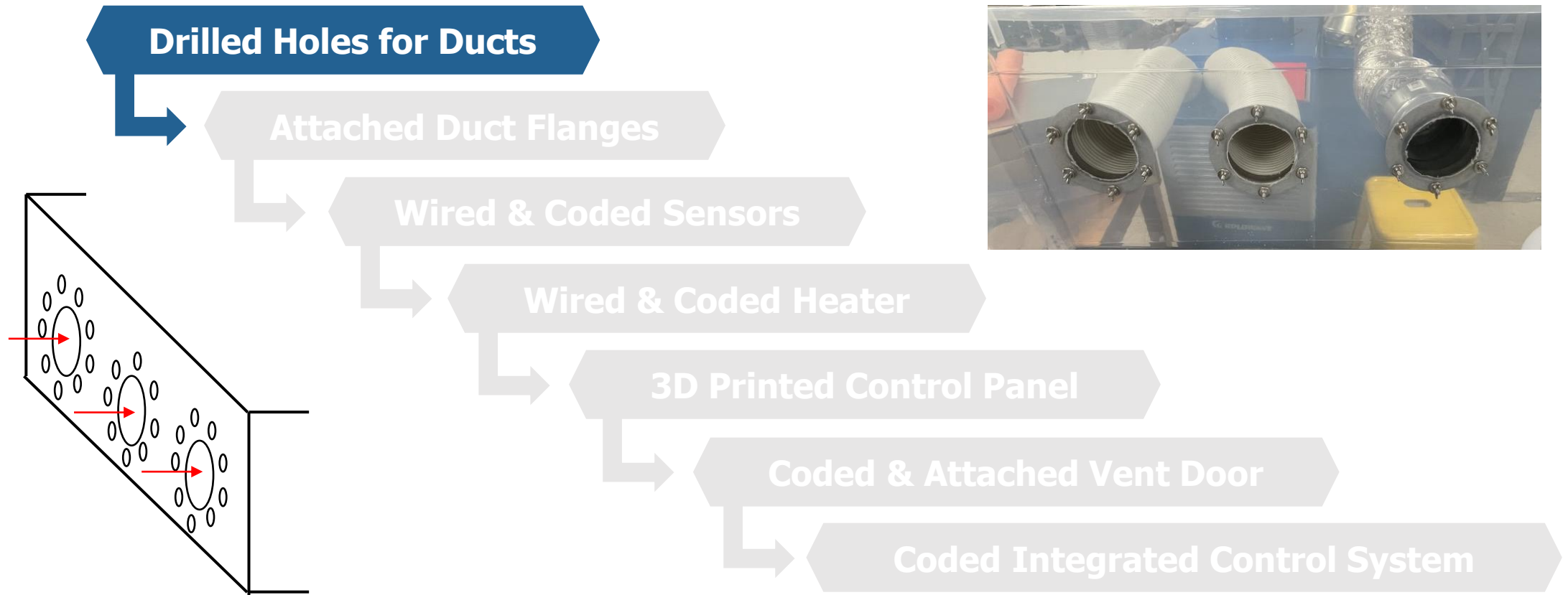


Up to 98% RH



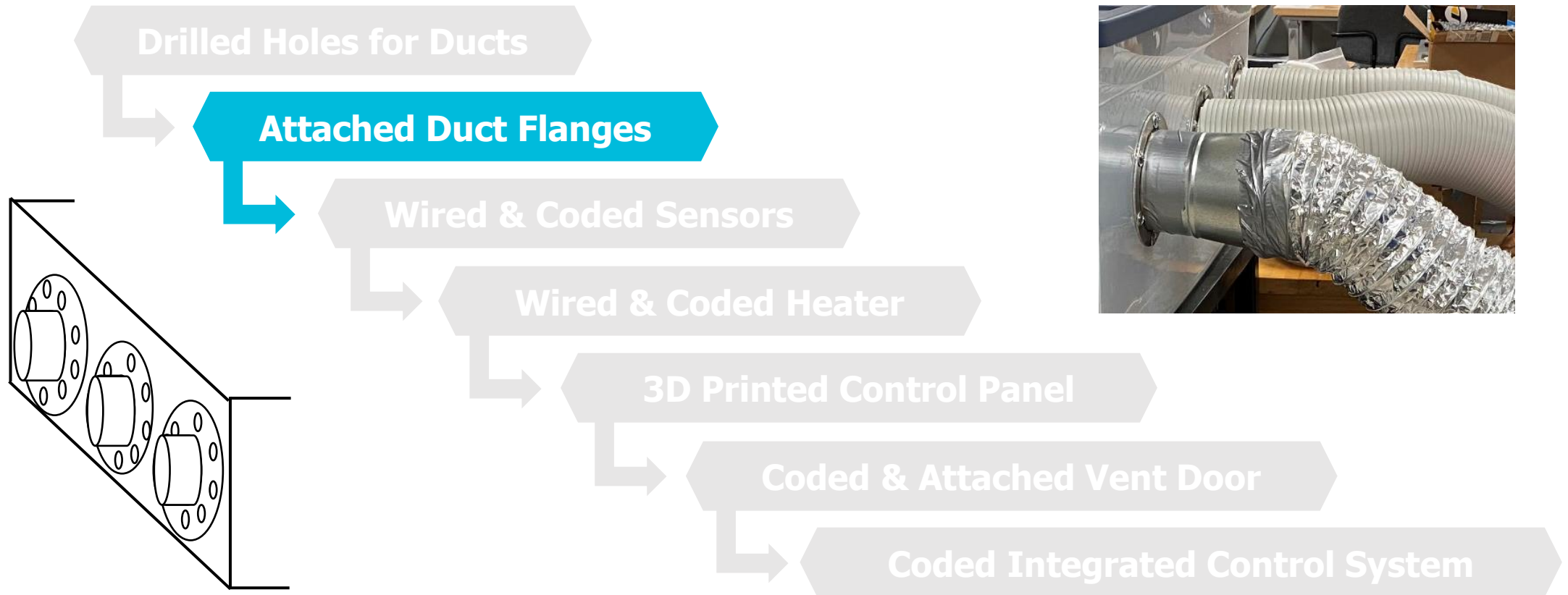
David Wilson

Assembly



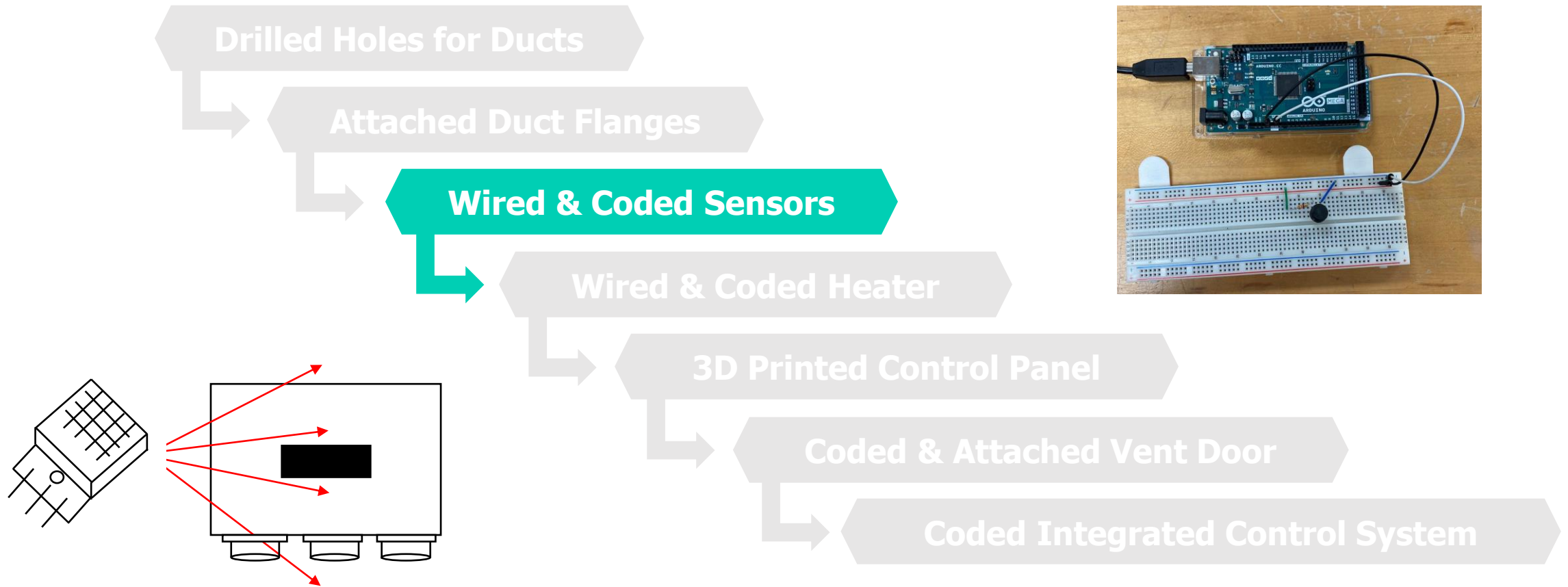
David Wilson

Assembly



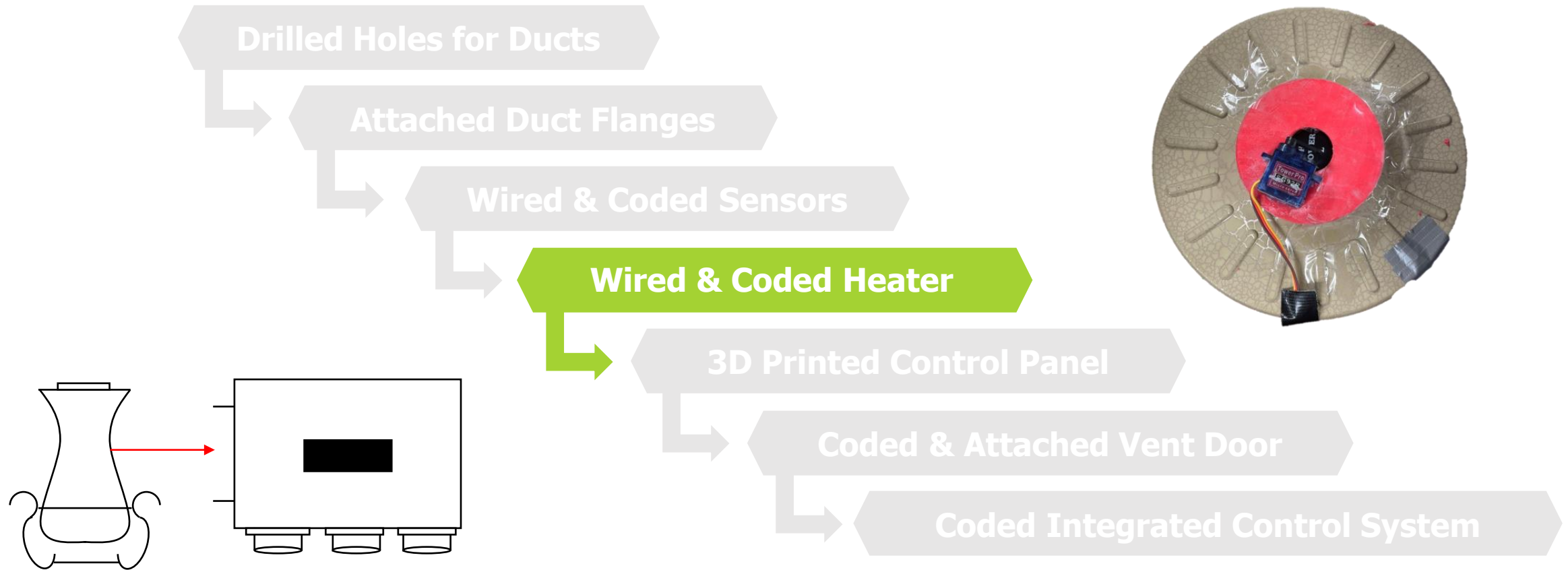
David Wilson

Assembly



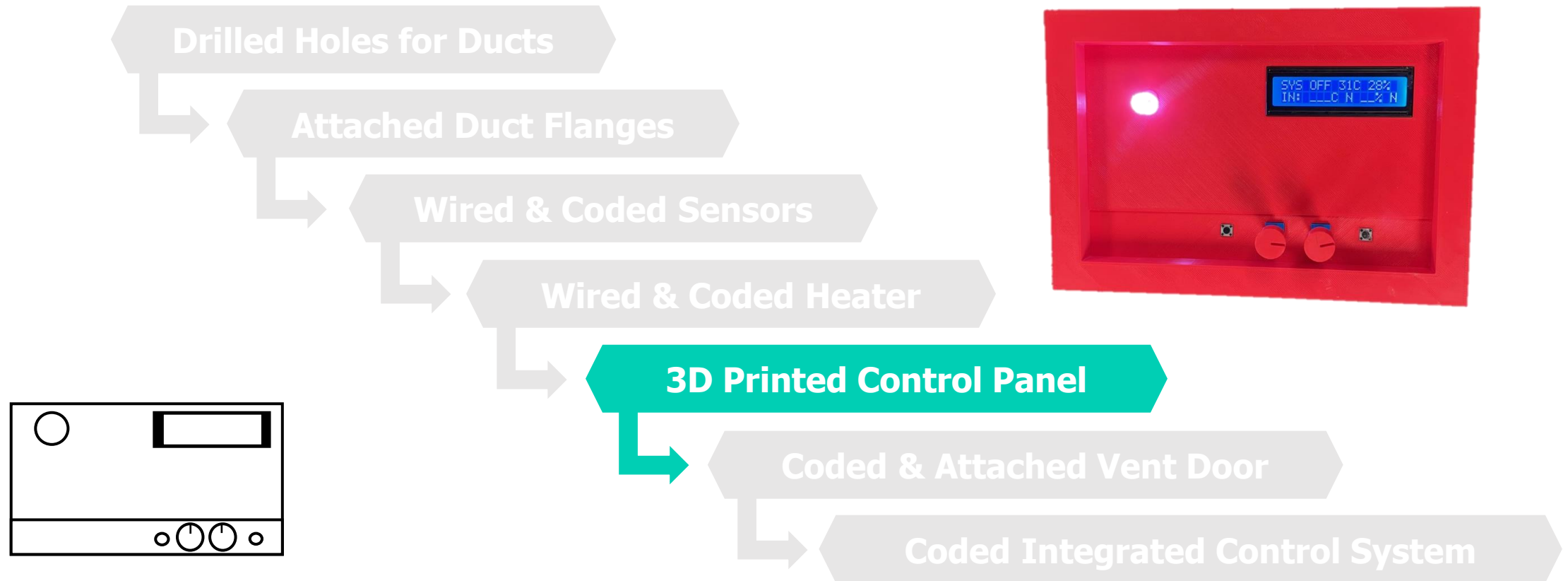
David Wilson

Assembly



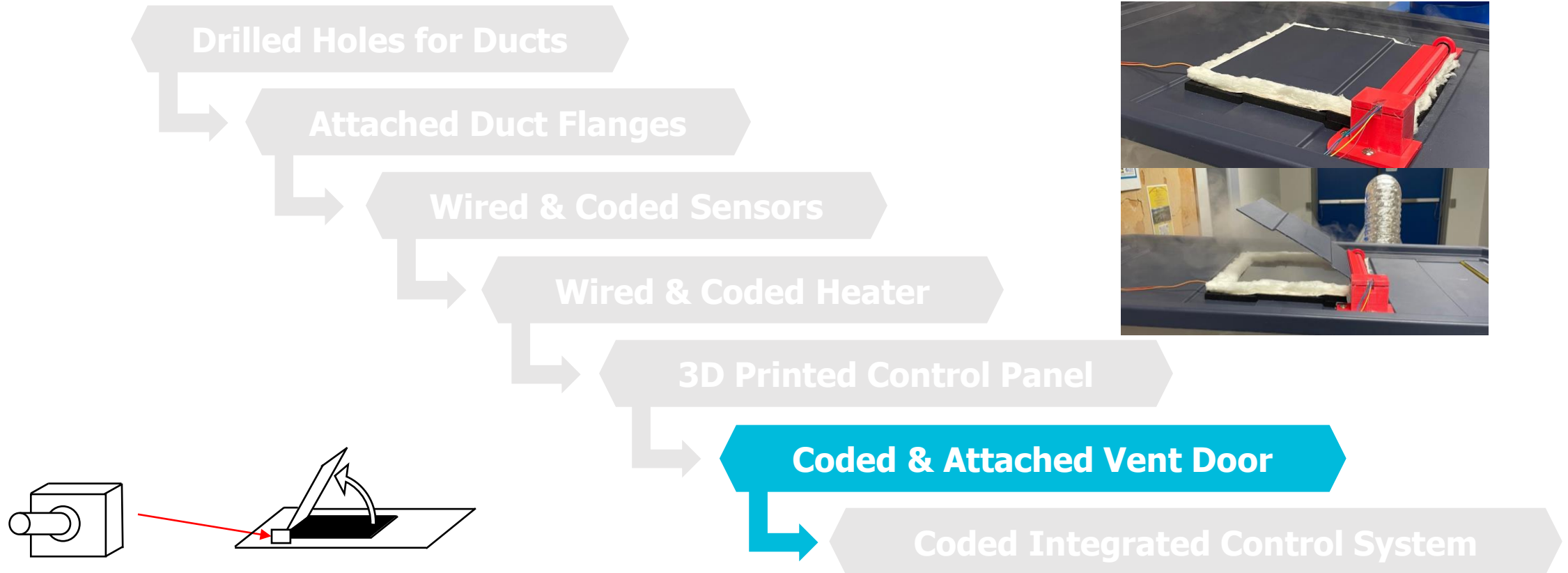
David Wilson

Assembly



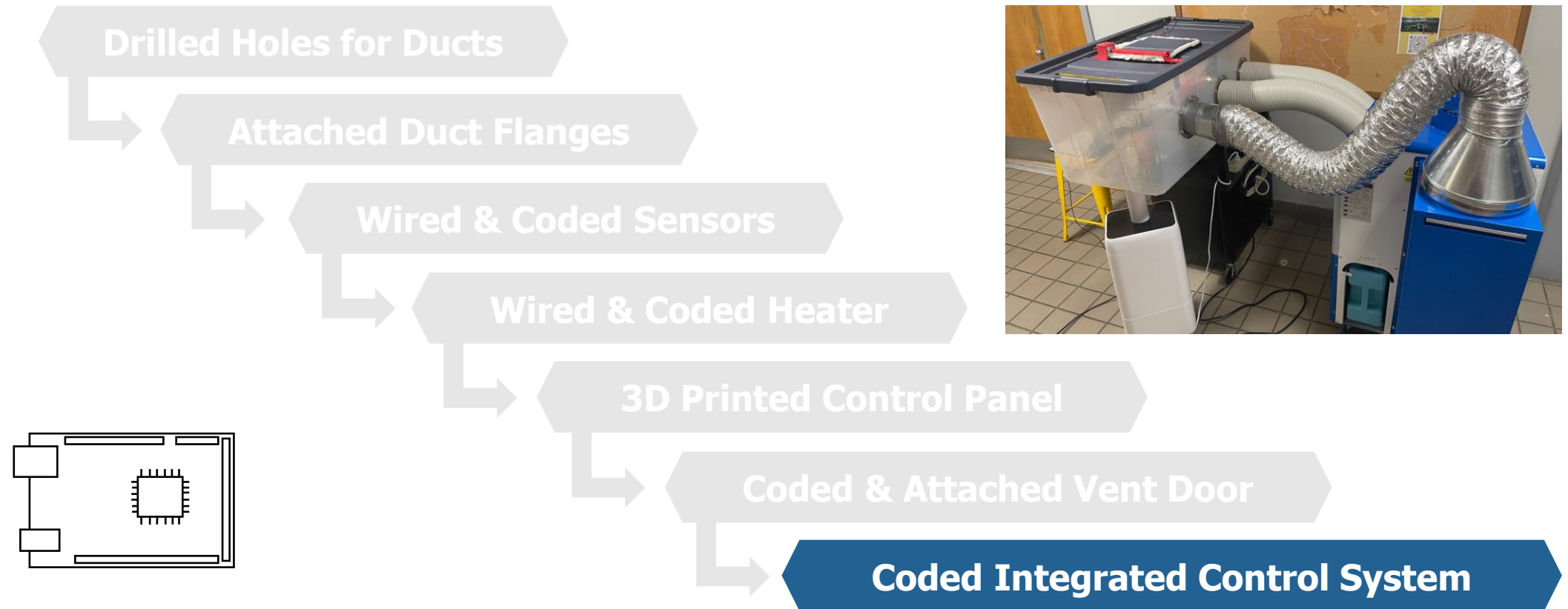
David Wilson

Assembly



David Wilson

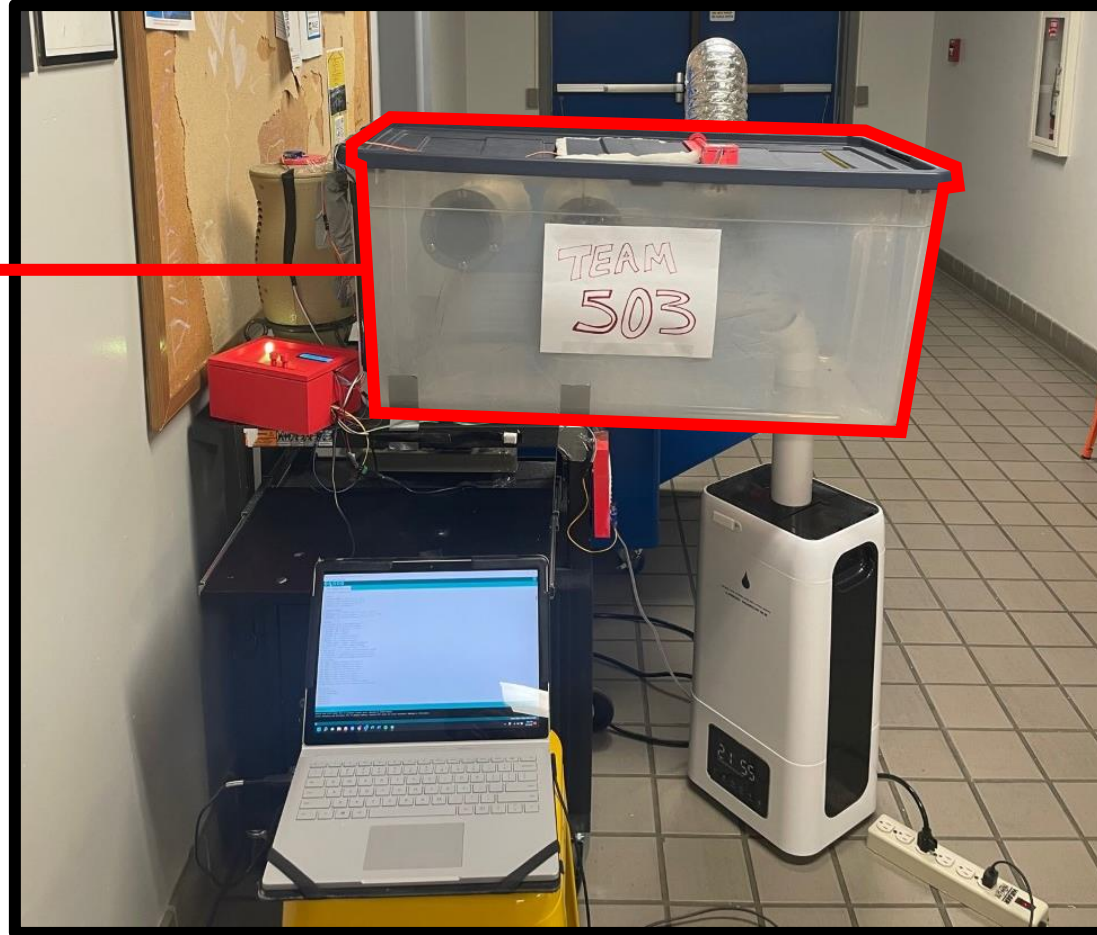
Assembly



David Wilson

Integrated System

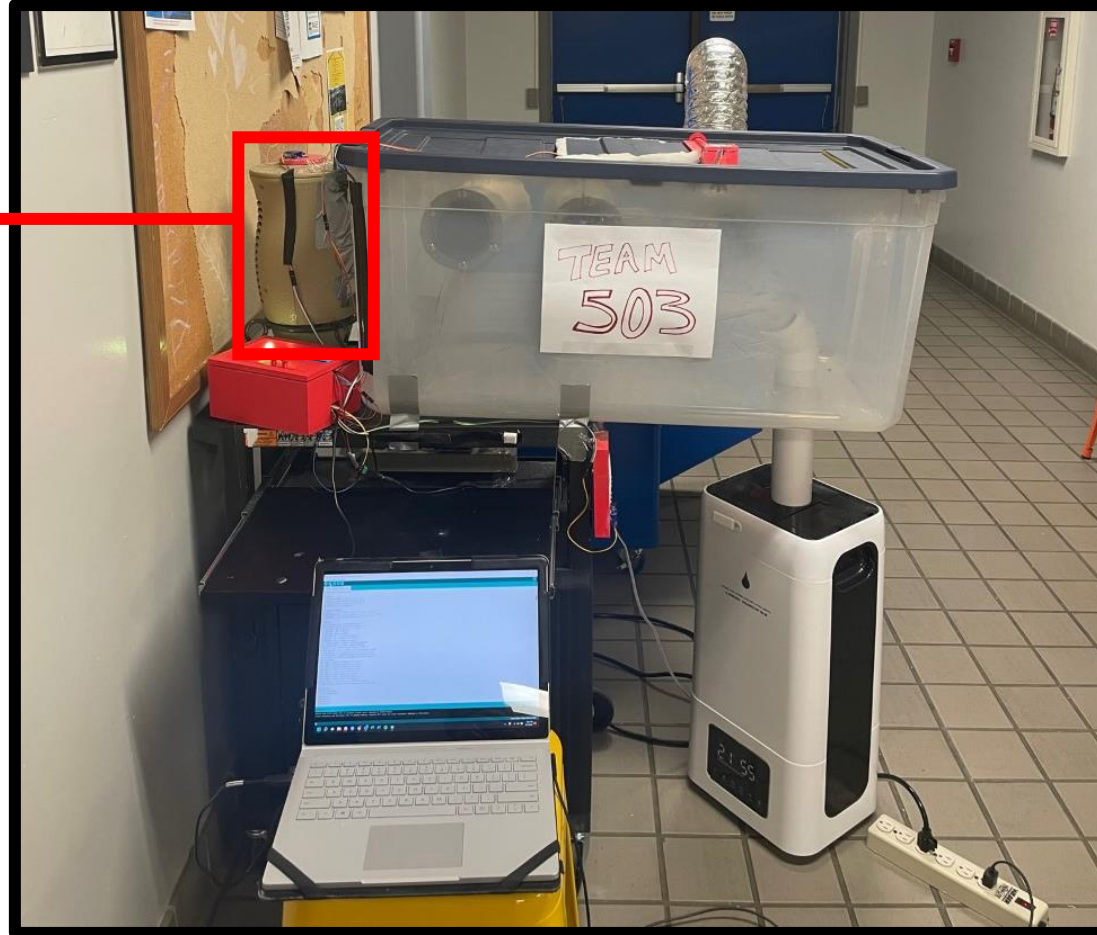
Control Volume



David Wilson

Integrated System

Heater



David Wilson

Integrated System



Humidifier

David Wilson

Integrated System

**Mechanical
Vent Door**



David Wilson

Integrated System



Air Conditioner

David Wilson

Integrated System



Ambient Air Adapter

David Wilson

Integrated System



Condensate Tank

David Wilson

Control Panel



Status Indicator

White – System Off

Blue – Input Required

Yellow – In Progress

Green – Successful

Red – System Error

David Wilson

Control Panel

SYSTEM | ON/OFF | Current Temperature (°C) | Current Humidity (%RH)



INPUT | Temperature (°C) | Match? (Y/N) | Humidity (%RH) | Match? (Y/N)

David Wilson

Validation

Key Target	Result	Error
Maintain Structural Stability (10 lbs)	Success	-
Support Airducts & Equipment (5 lbs)	Success	-
Monitor Temperature ($\pm 1^{\circ}\text{C}$)	Success	-
Monitor Humidity ($\pm 1\%$)	Failure	1%
Provide Heat (50°C)	Success	-
Provide Cooling (10°C)	Failure	2%
Regulate Air Circulation ($1\text{m}^3/\text{min}$)	Success	-
Increase Humidity (95% RH)	Success	-
Decrease Humidity (0% RH)	Failure	15%
Provide Clear View (3 Sides)	Success	-
Adjust Conditions (No human interaction)	Success	-

David Wilson

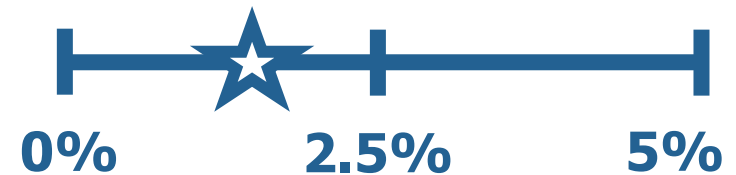


Validation

Targets Met



Average Error



David Wilson

Application

Test Rig 12 in the Danfoss Lab Facility

Drill Holes in Replacement Plexiglass

Install Condensation Collection System

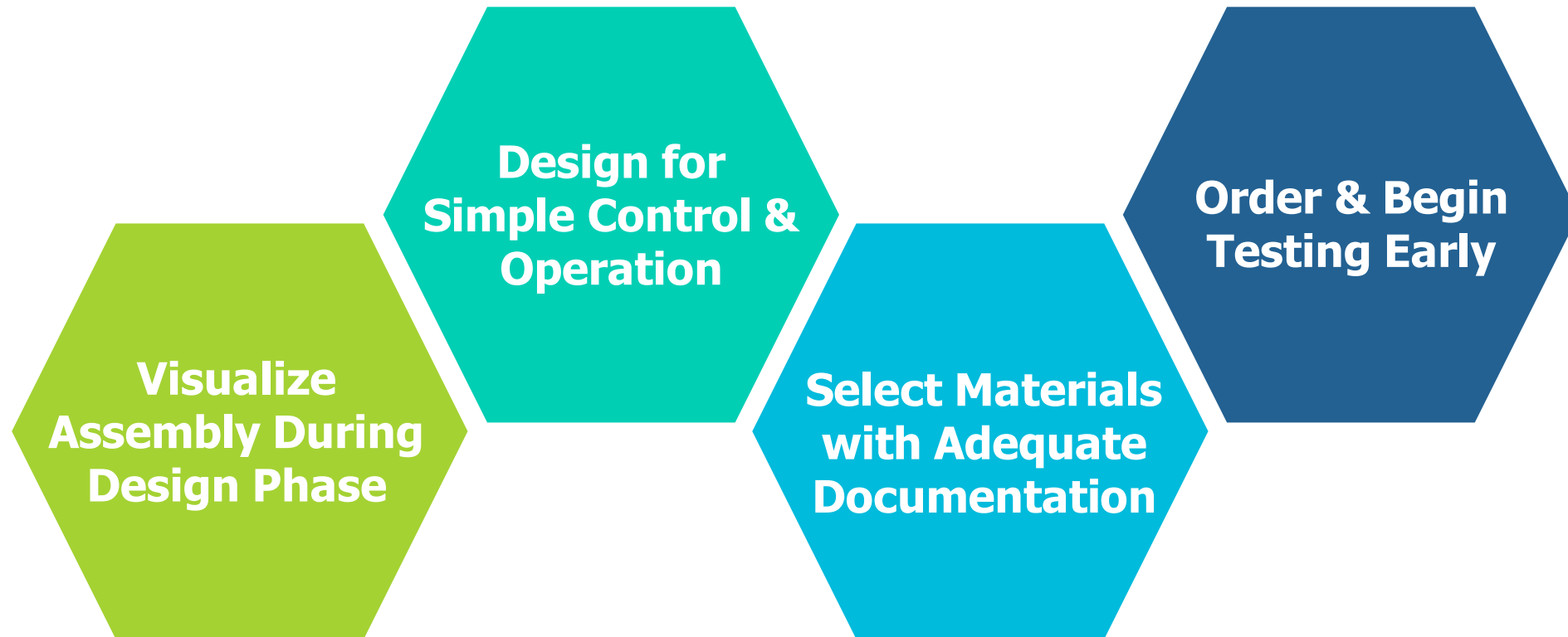
Testing Electronic Components

Industrial Equipment Stress Testing

Different Material Properties

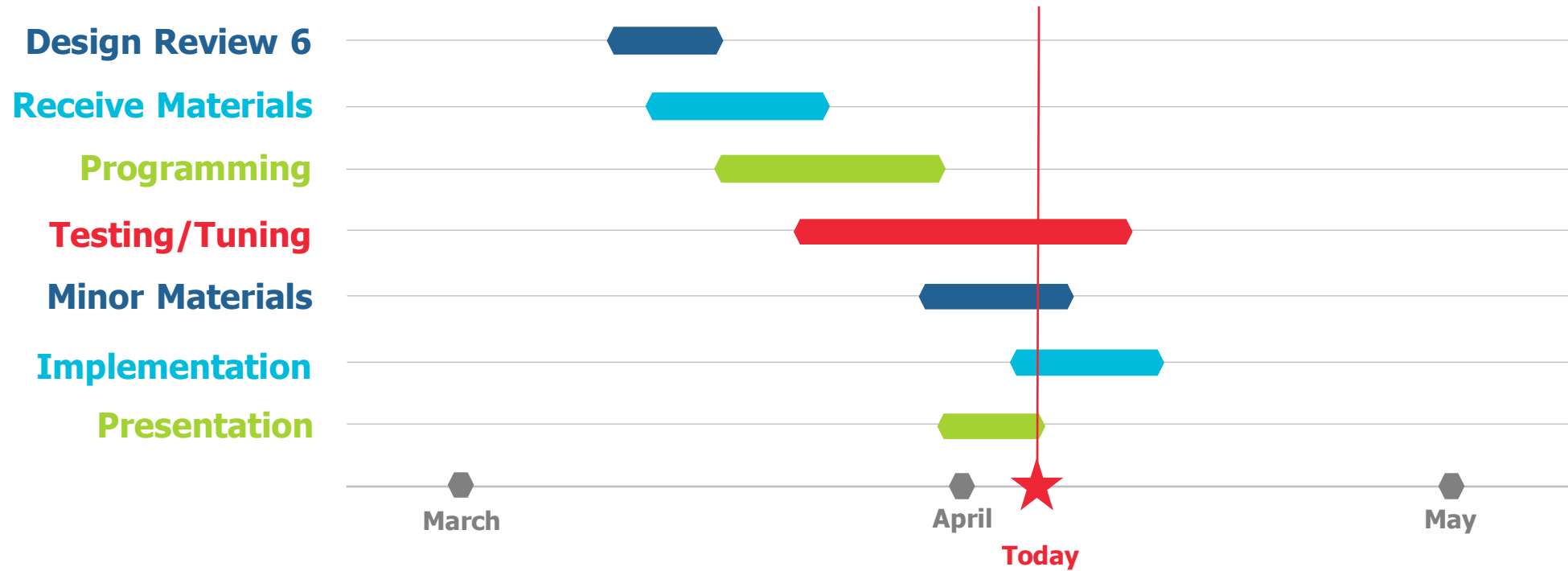
David Wilson

Lessons Learned

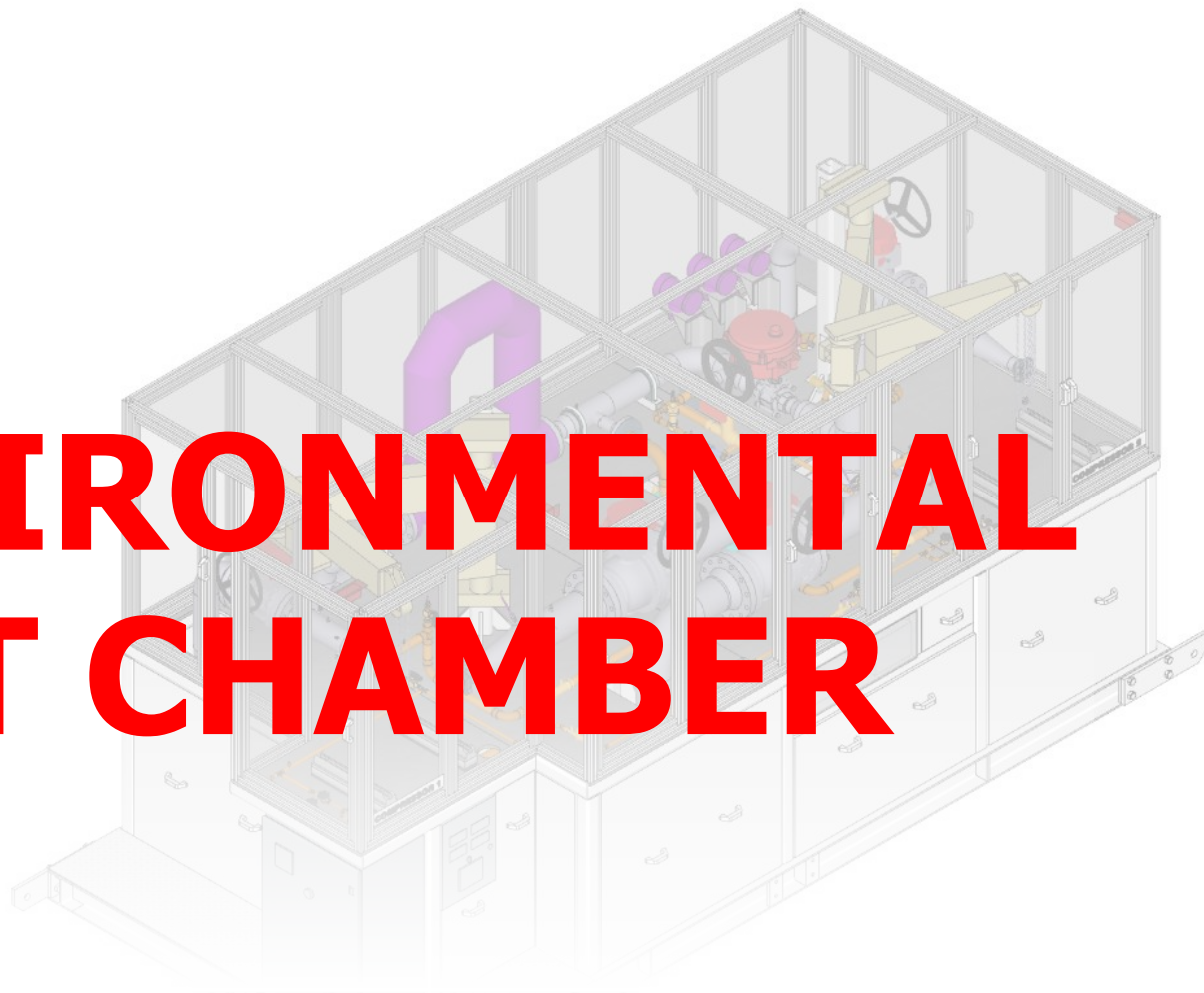


David Wilson

Timeline



David Wilson



ENVIRONMENTAL TEST CHAMBER

TEAM 503

Nicholas Blenker
njb17@my.fsu.edu



Tucker Hall
tdh16c@my.fsu.edu



David Wilson
dhw18@my.fsu.edu

