Team 510: Indoor Air Quality of Hotspots

February 25th 2021

Eric Grogans, Leon Johnson, Emma Martin,
Razhan Matipano, Whitley Pettis

Team Introductions

Eric Grogans
Electrical Engineer

Leon Johnson
Test Engineer

Emma Martin
Project Engineer

Razhan Matipano
Research Engineer

Whitley Pettis
Manufacturing Engineer

Emma Martin

Sponsor and Advisor

FAMU-FSU College of Engineering

Honeywell

Engineering Mentor
Alfred Guerrero
Honeywell

Engineering Mentor
Danny White
Honeywell

Engineering Mentor
Danny Mims
Honeywell

Academic Advisor
Neda Yaghoobian, Ph.D.
Professor

Senior Design Professor
Dr. McConomy, Ph.D.
Professor

Emma Martin

Objective

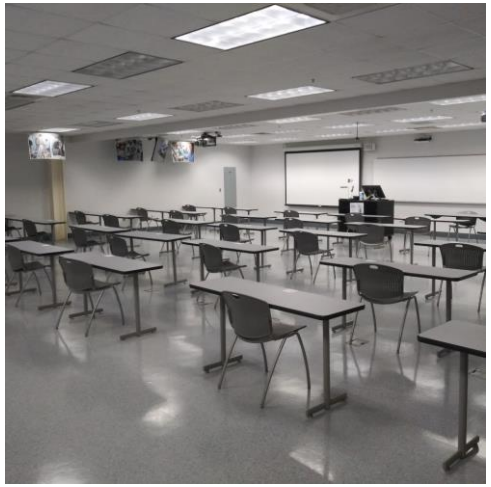
The objective of the project is to measure the air quality in the FAMU-FSU College of Engineering and modify the air based on these findings to promote a healthy building environment.

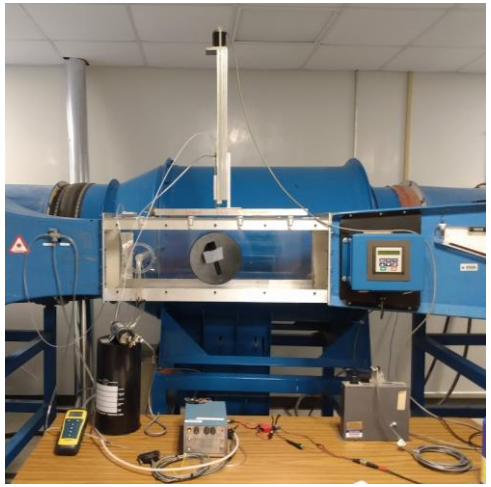
Emma Martin

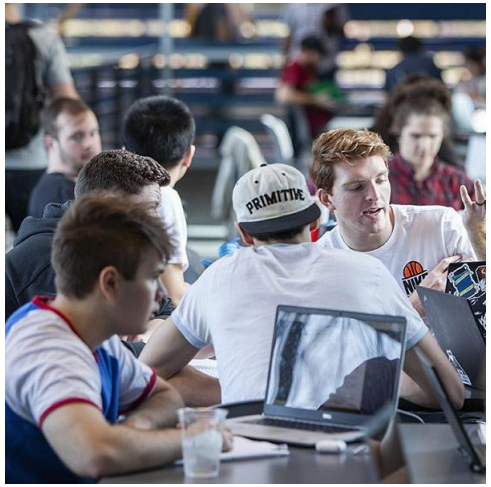
Project Background

Emma Martin

Location







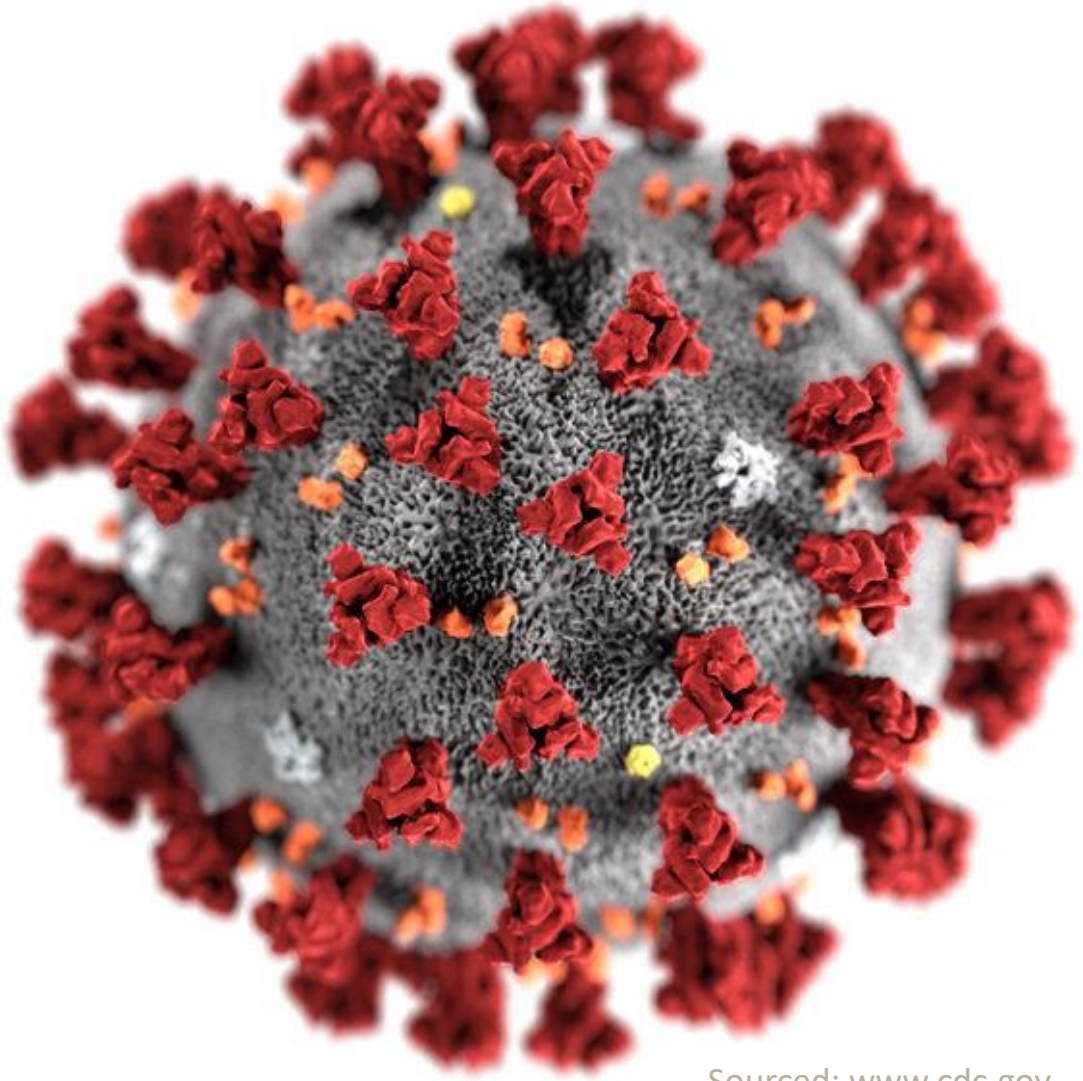
- The FAMU-FSU College of Engineering is used by thousands daily
- There are several types of spaces around the college

Sourced: eng.famu.fsu.edu, www.thebluebook.com

Emma Martin

COVID-19

- Air quality is especially important
- Caused by the pathogen SARS-CoV-2
- Carried by respiratory droplets in air



Sourced: www.cdc.gov

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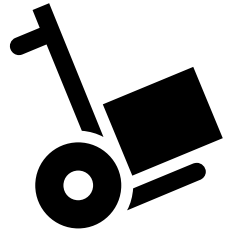
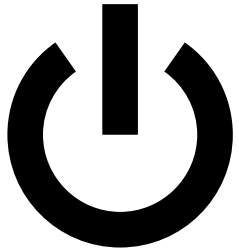
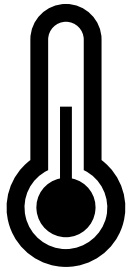
Facilities' Needs



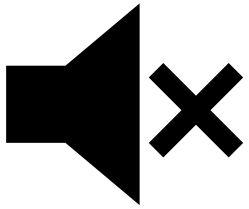
Portable



Internal
Power Source

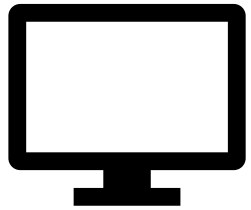


Limited
Heat

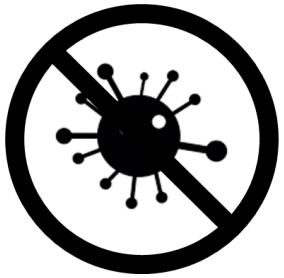


Limited
Volume

Honeywell's Needs



Monitors
Air Quality



Reduces
Contamination

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Functional Decomposition

Control System	Ventilate room	Improve Air Composition

Emma Martin

Functional Decomposition

Control System	Ventilate room	Improve Air Composition
Sense and measure air quality		

Emma Martin

Functional Decomposition

Control System	Ventilate room	Improve Air Composition
Control hardware  Sense and measure air quality		

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Functional Decomposition

Control System	Ventilate room	Improve Air Composition
Control hardware	Propel air through device	
Sense and measure air quality		

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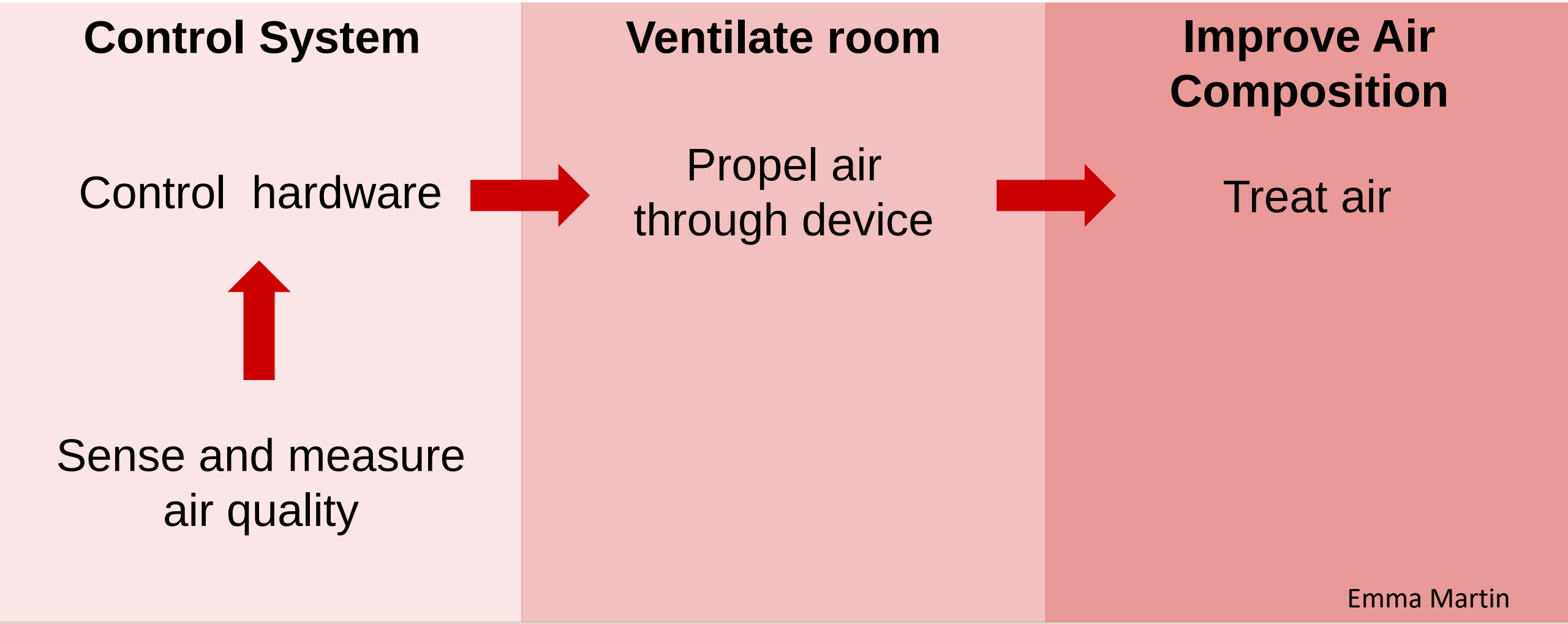
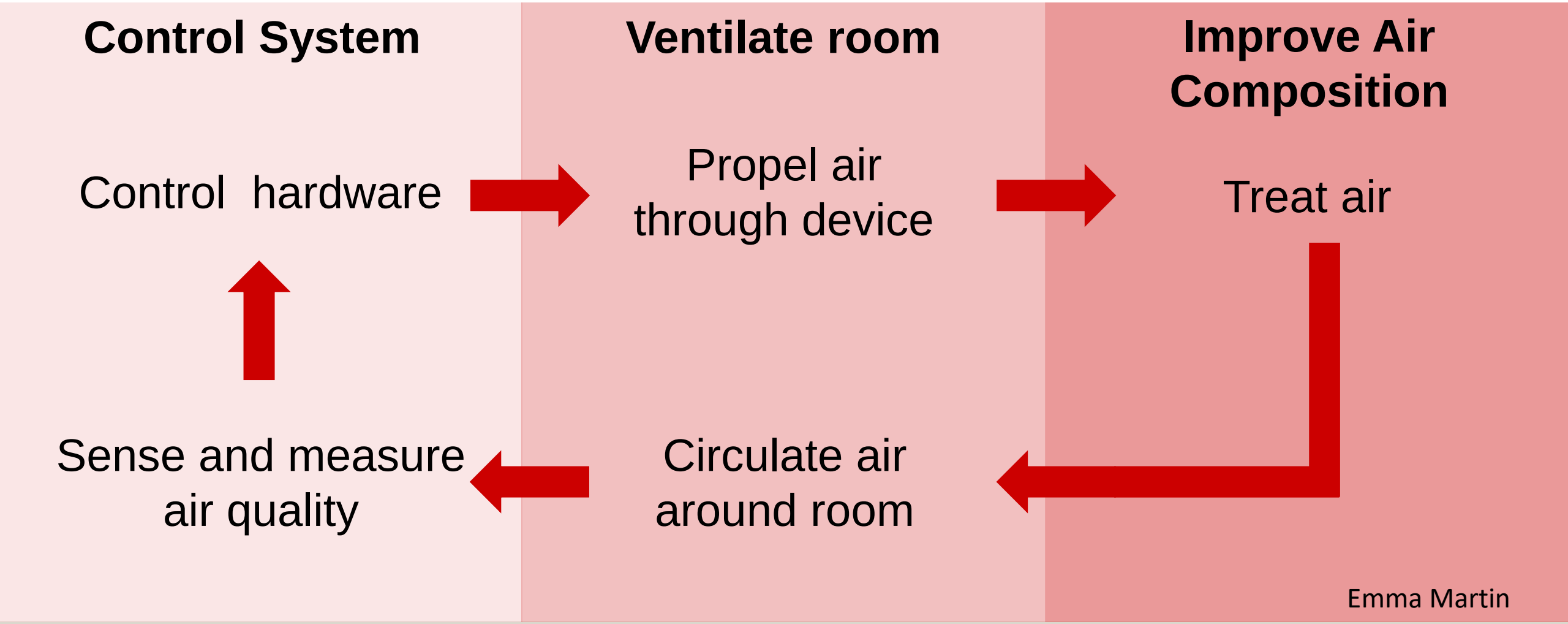
Functional Decomposition



Functional Decomposition



Targets and Metrics

Emma Martin & Eric Grogans

Control System

Sense Air Quality

Concentration range of sensors

- Particulate: 0.1 µg/m^3 and 1000 µg/m^3
- Gas: 0 ppm to 250 ppm

Measure Air Quality

Accuracy of sensors

- Particulate: ±15%
- Gas: ±3%

Control Hardware

Reaction time of hardware

- 6 seconds

Sourced: Honeywell.com

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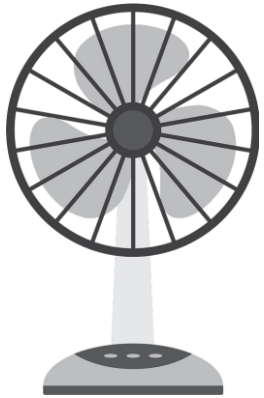
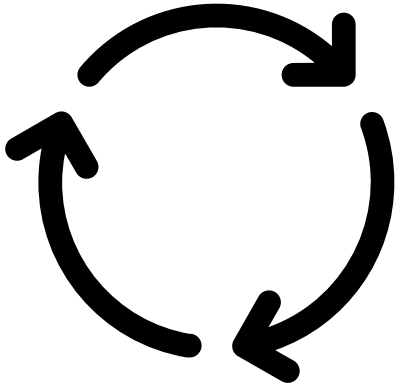
Ventilate Room



Propel Air

Volumetric flowrate per person

- 40 cfm per person



Circulate Air

Number of air changes per hour

- 7

Emma Martin

Improve Air Composition

Treat Air

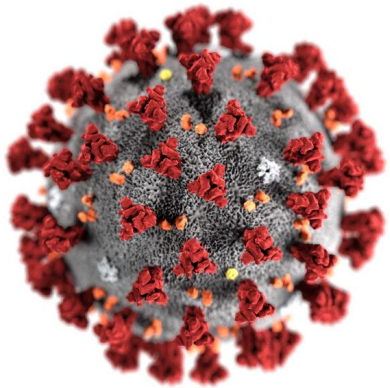
Number of Filters

- 3

Sanitize Contaminants

Particulate removal percentage

- 99%



Control Air Humidity

Humidity range

- 40% to 60%

Filter Particulates

Minimum diameter of filterable particles

- 0.1 µm

Sourced: Honeywell.com, www.cdc.gov

Emma Martin

Improve Air Composition

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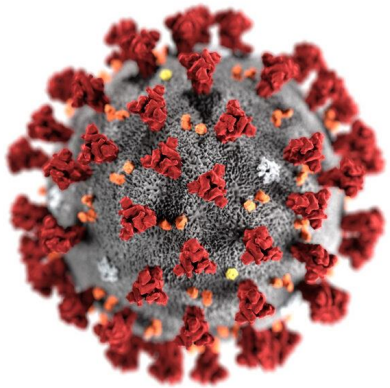

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Eric Grogans

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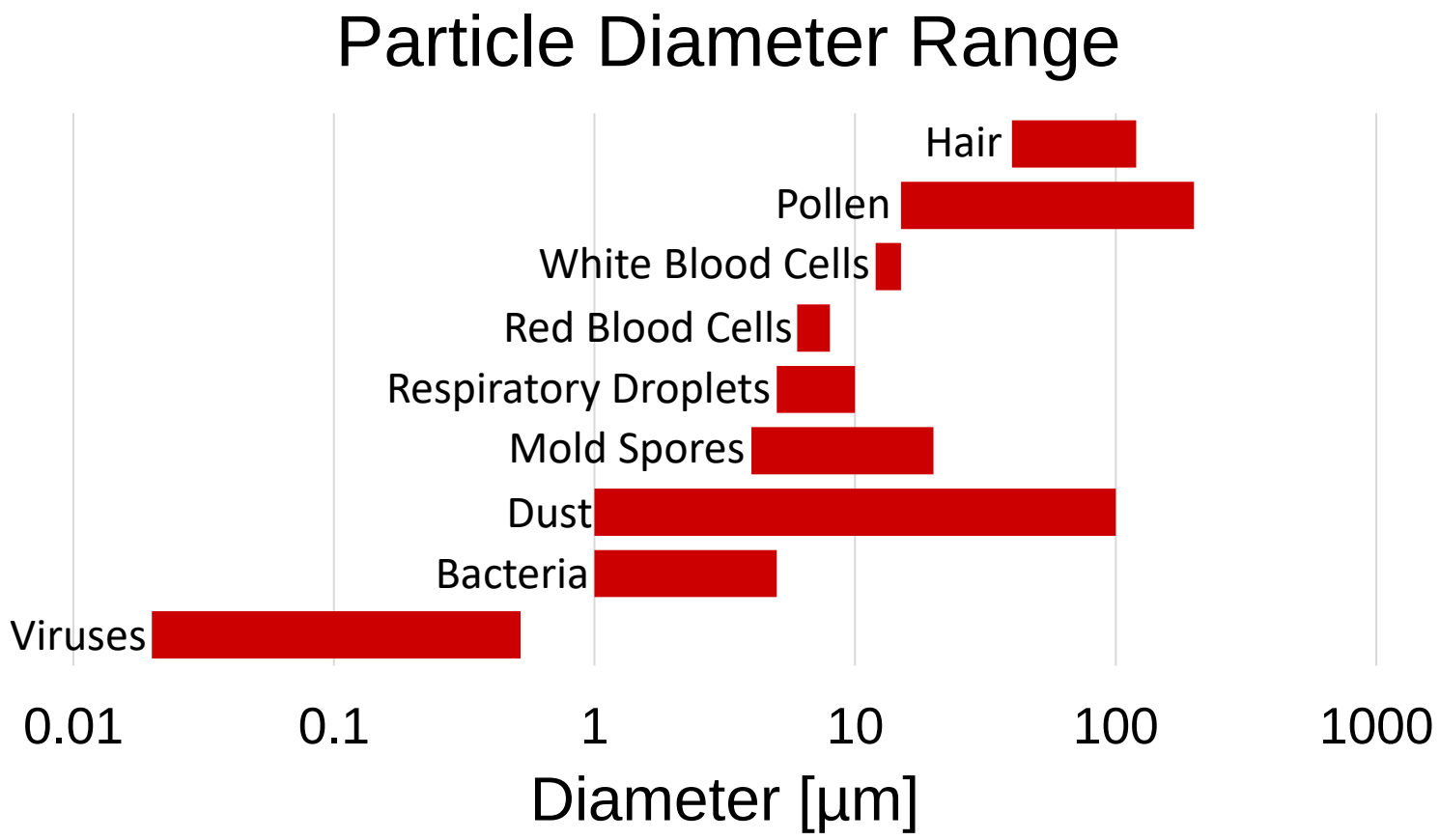

Sourced: Honeywell.com

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Eric Grogans

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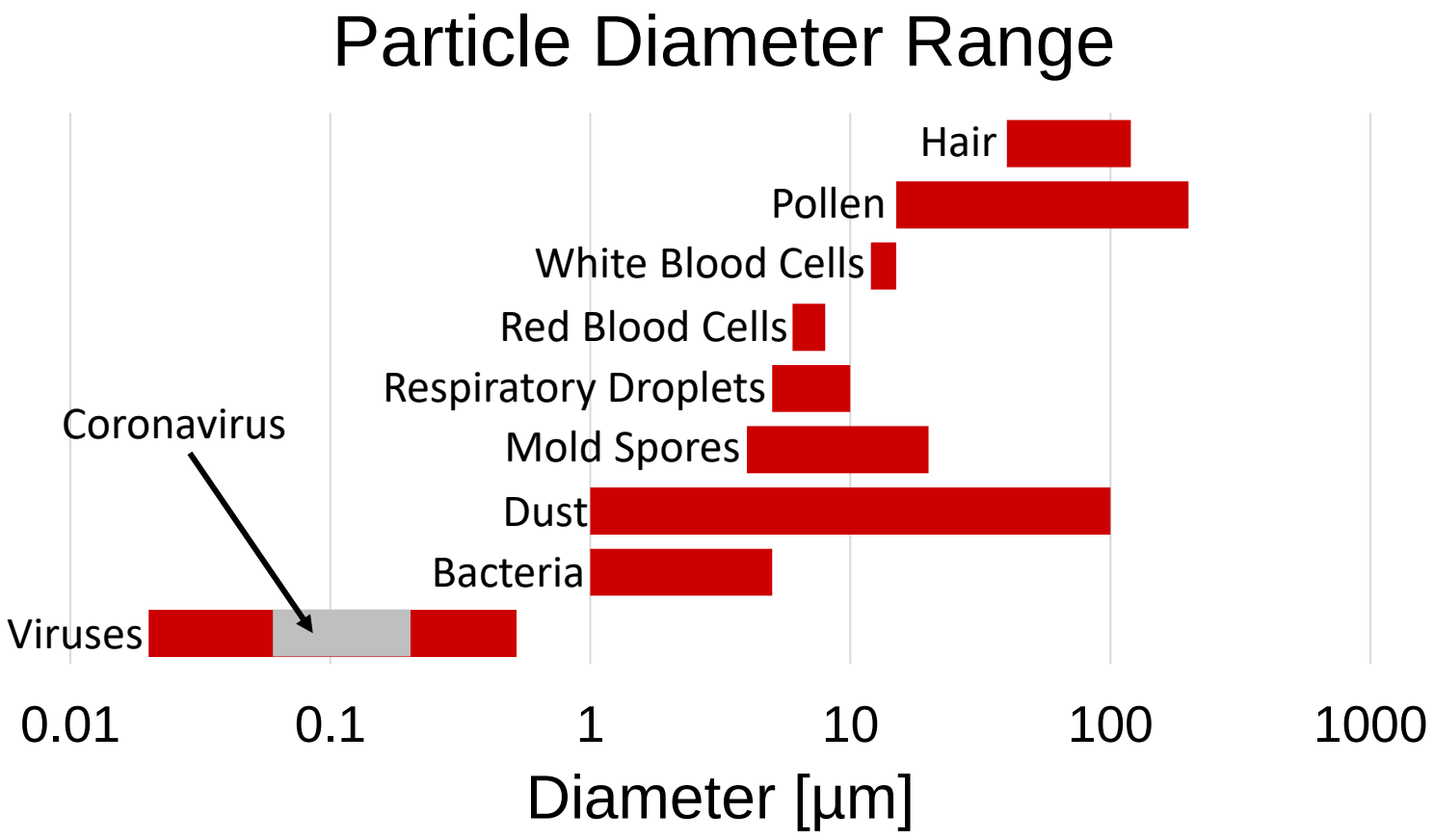

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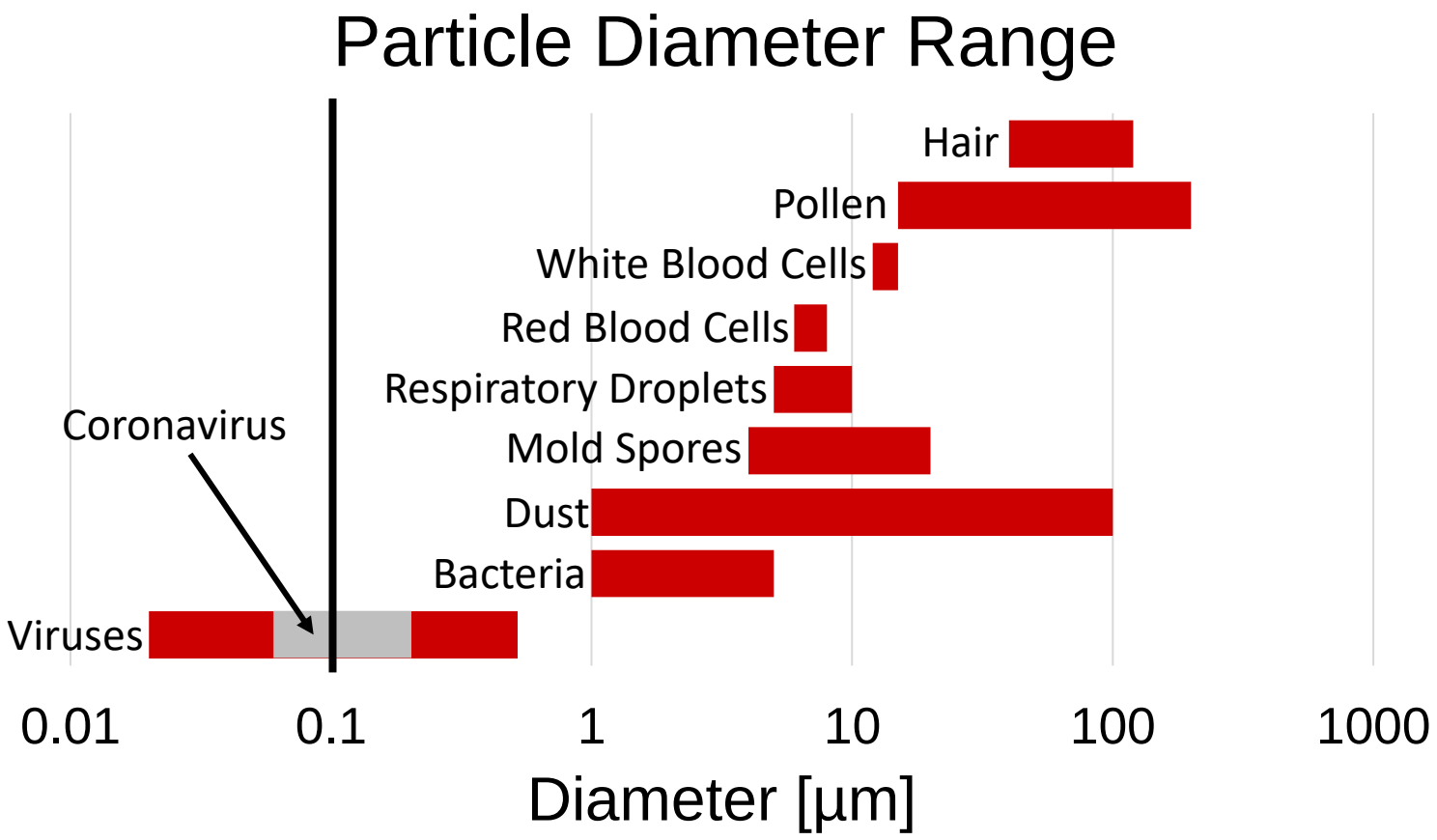
Improve Air Composition



Sourced: Honeywell.com

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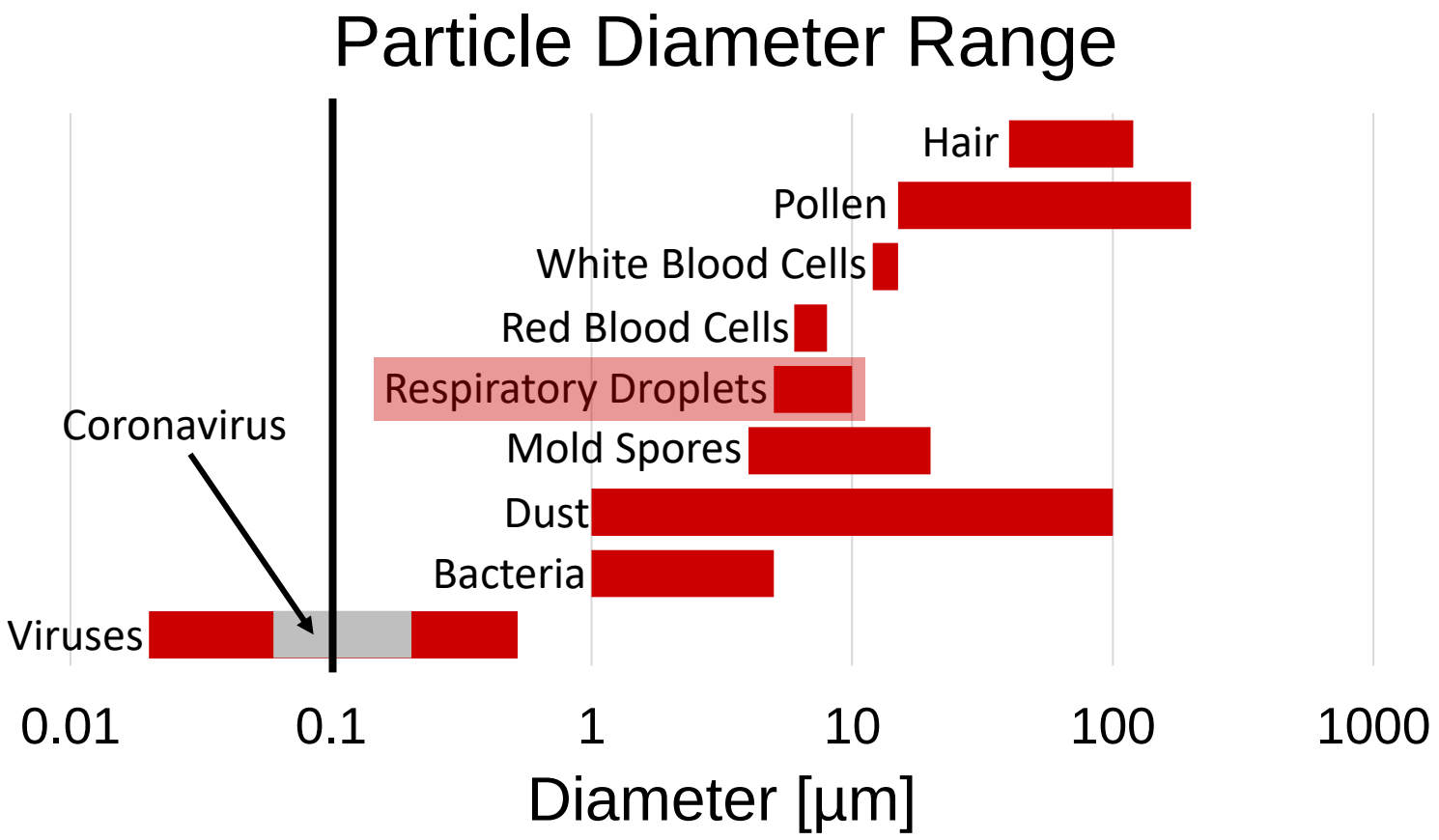
Eric Grogans

Improve Air Composition



Sourced: Honeywell.com

Filter Particulates

Minimum diameter of filterable particles

- 0.1 µm

Eric Grogans

Noise







0 dB	10 dB	20 dB	30 dB	40 dB	50 dB	60 dB	70 dB	80 dB	90 dB	100 dB	110 dB	120 dB	130 dB	140 dB
	Breathing		Whispering		Rainfall		City Traffic		Hairdryer		Tuba		Jet Engine	

Sourced: LetsTalkScience.ca

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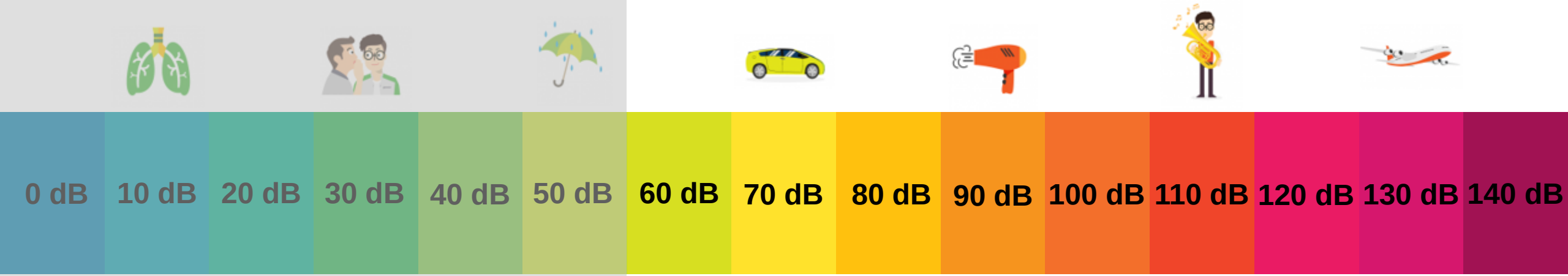
Noise



Device Noise

Maximum noise level

- 50 dB

Sourced: LetsTalkScience.ca

Eric Grogans

Methods of Validation

Inspection

Measure and Calculate

Test Equipment

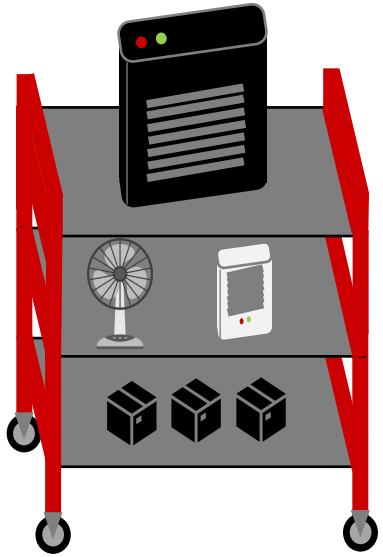
Sourced: Honeywell.com, Walmart.com

Eric Grogans

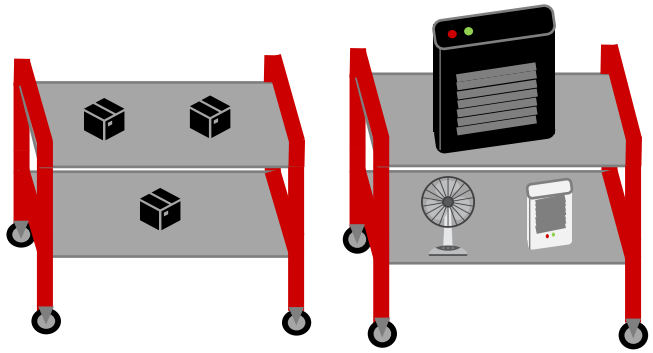
Concept Generation and Selection

Leon Johnson

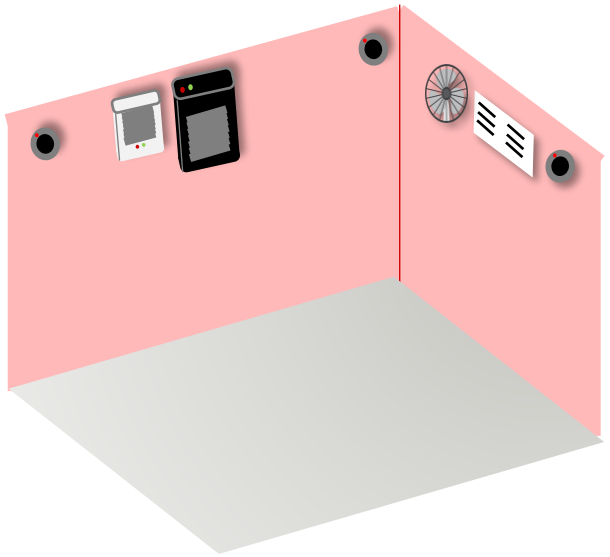
High Fidelity Concepts



Mobile Sensing and Cleaning Station



Dual Sensing and Cleaning Stations

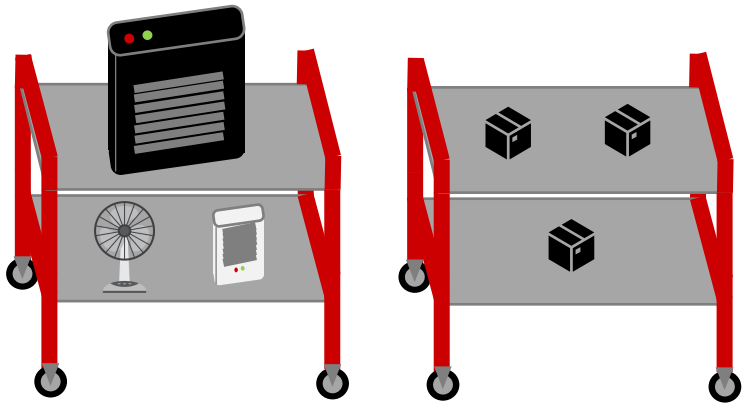


Mounted Sensing and Cleaning Devices

Leon Johnson

Concept Selection

- House of Quality identified most important engineering characteristics:
  - Measure air quality
  - Monitor air quality
- Pugh Chart eliminated mounted sensing and cleaning devices
- Analytic Hierarchy Process used to select dual sensing and cleaning stations as final design



Leon Johnson

Bill of Materials

Eric Grogans

Storage and Power

120 V Power Station

JACE Controller

Utility Cart

Sourced: Honeywell.com, APC.com

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Sensing

HPM Particulate Matter Sensor

Multi-Gas Detector

Humidity Monitor

Sourced: Honeywell.com, Grainger

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Sensing

Anemometer

Intellidox
Docking Station

Mobile
Computer

Sourced: Honeywell.com

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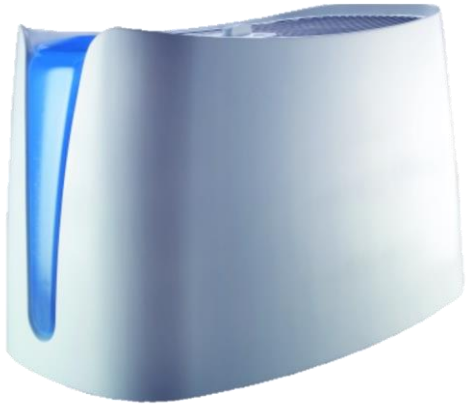
Cleaning

HEPA Air Purifier



Humidifier

Dehumidifier

TurboForce Floor Fan

Sourced: Honeywell.com

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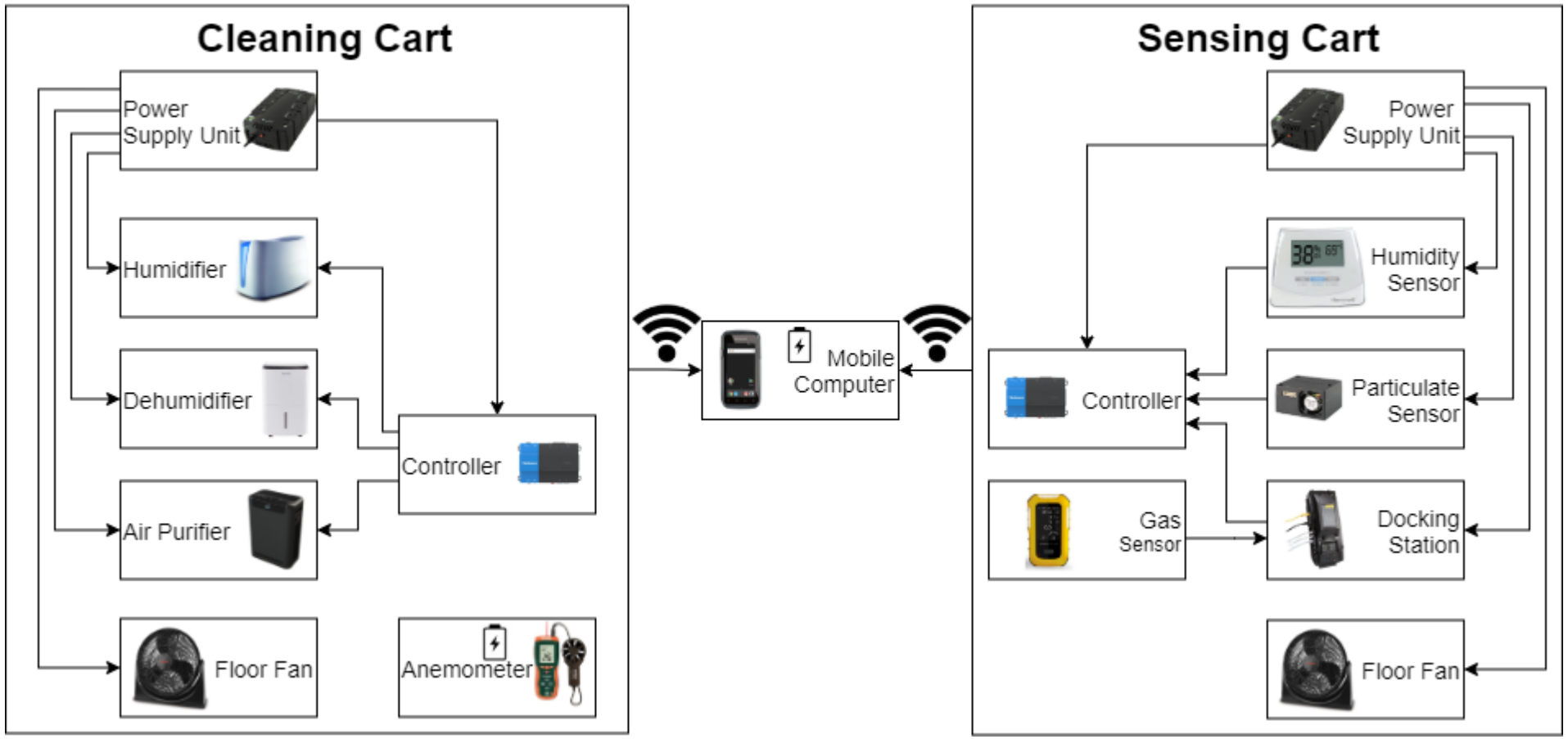
Wiring Diagram



Wireless Connection

Battery Powered

Sourced: Honeywell.com, APC.com, Grainger

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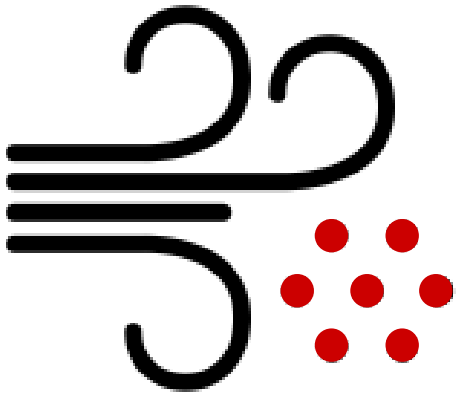
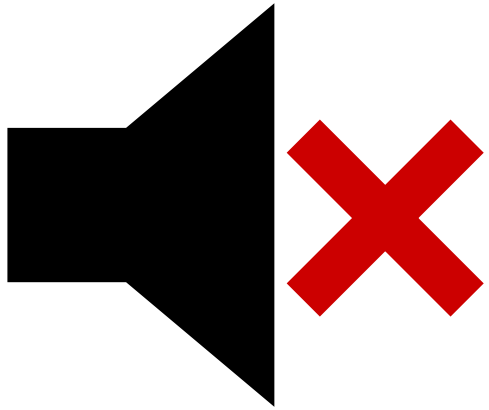
Testing and Simulation

Leon Johnson

Preliminary Tests



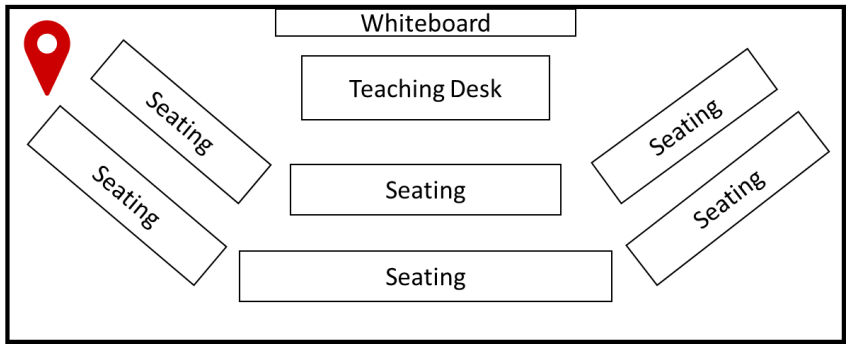
Measure air quality before cleaning



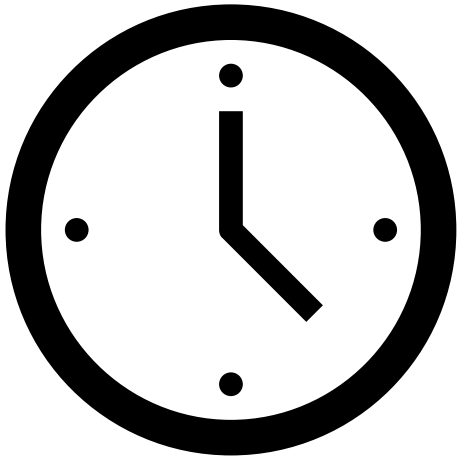
Measure equipment noise levels before placement

Leon Johnson

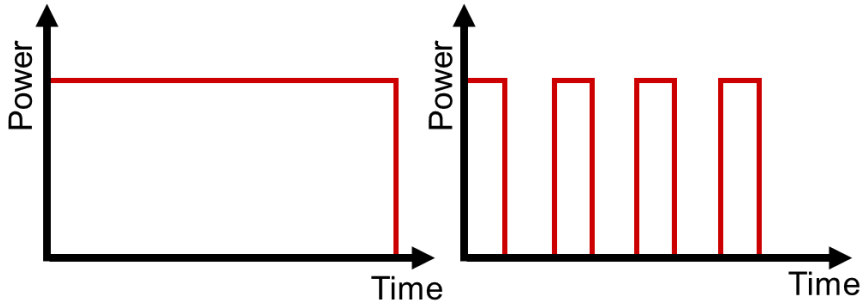
Testing Procedures



Test air quality in different locations within the same room



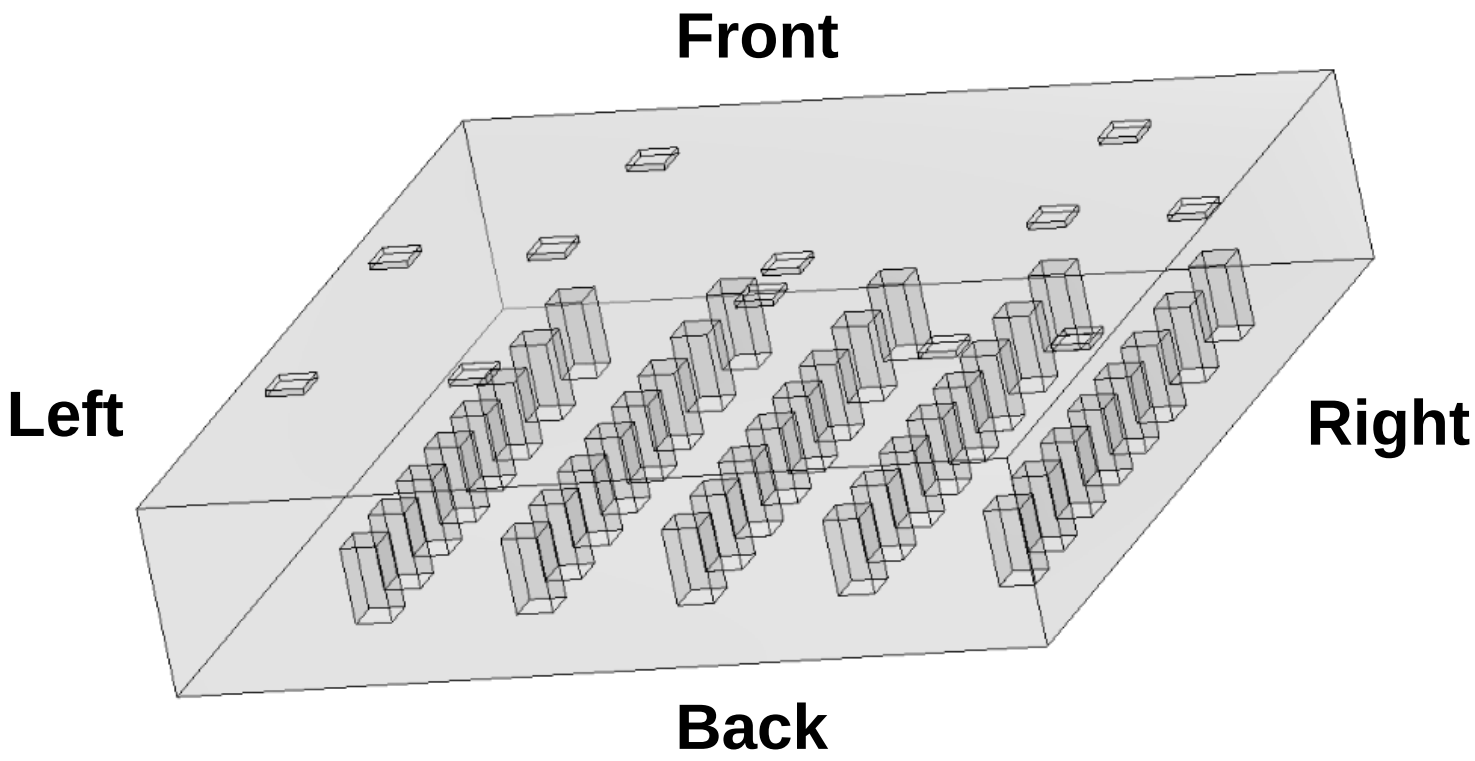
Test air quality at different times of day



Compare air quality when device is run continuously and intermittently

Leon Johnson

B135 Model



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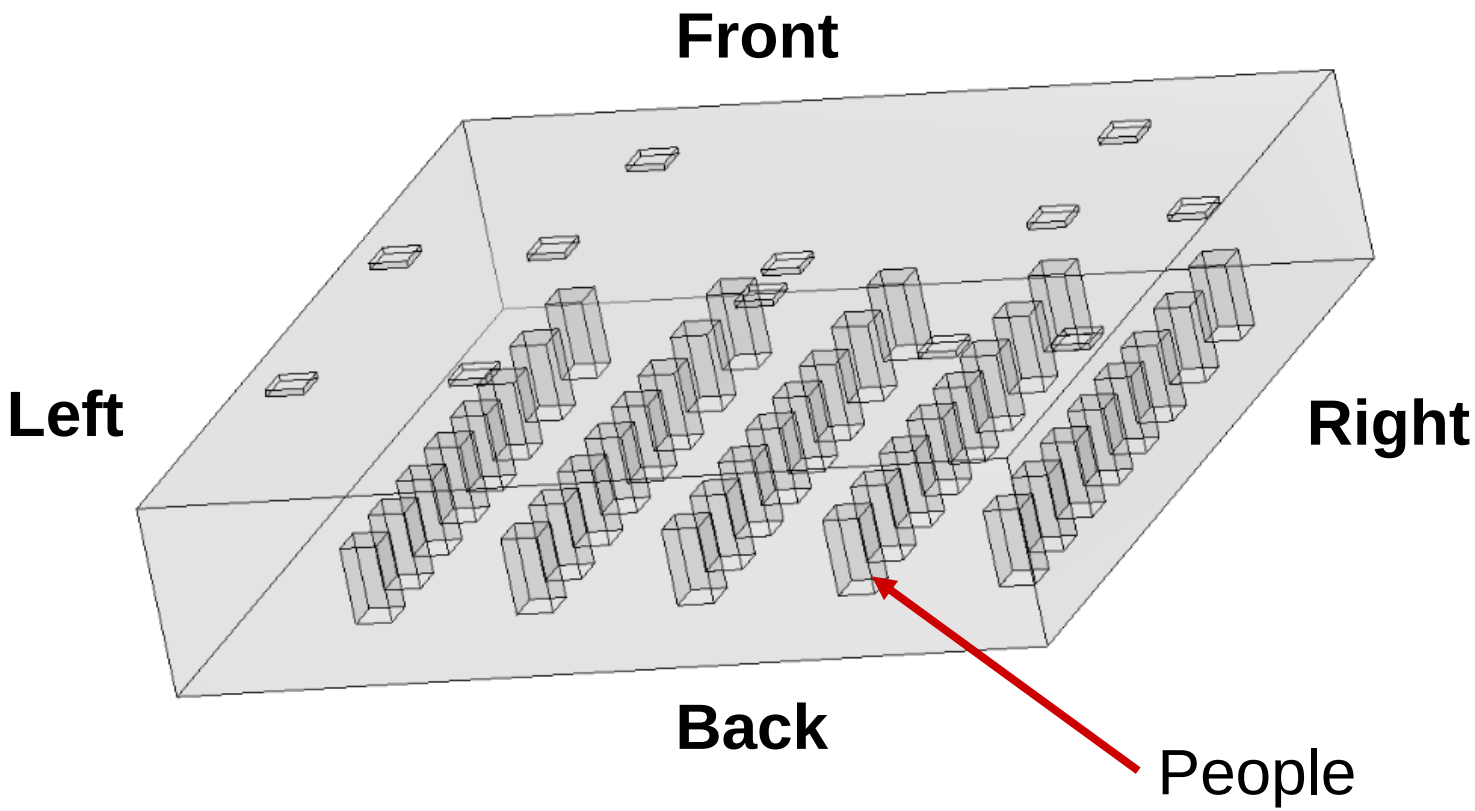
B135 Model



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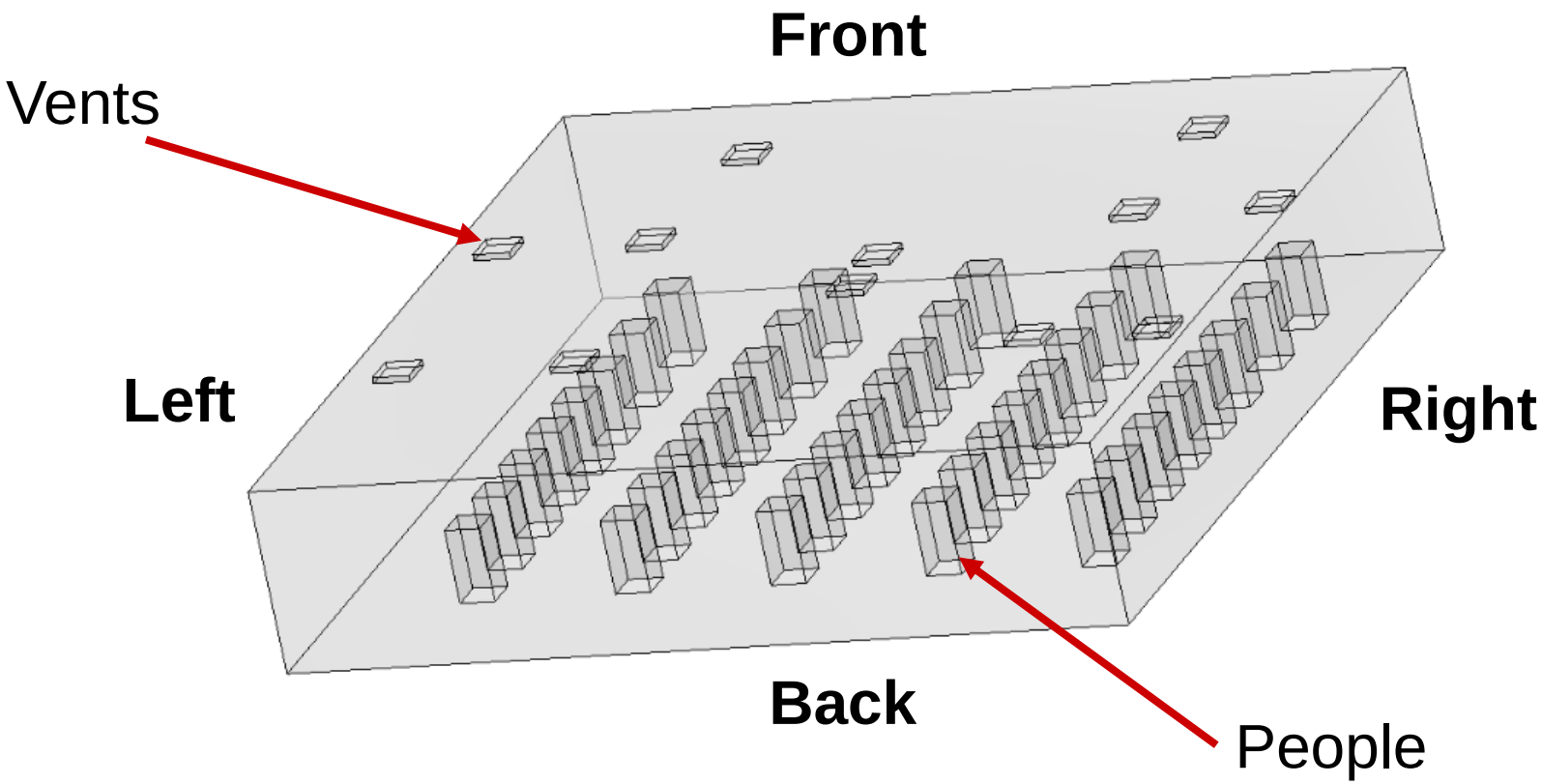
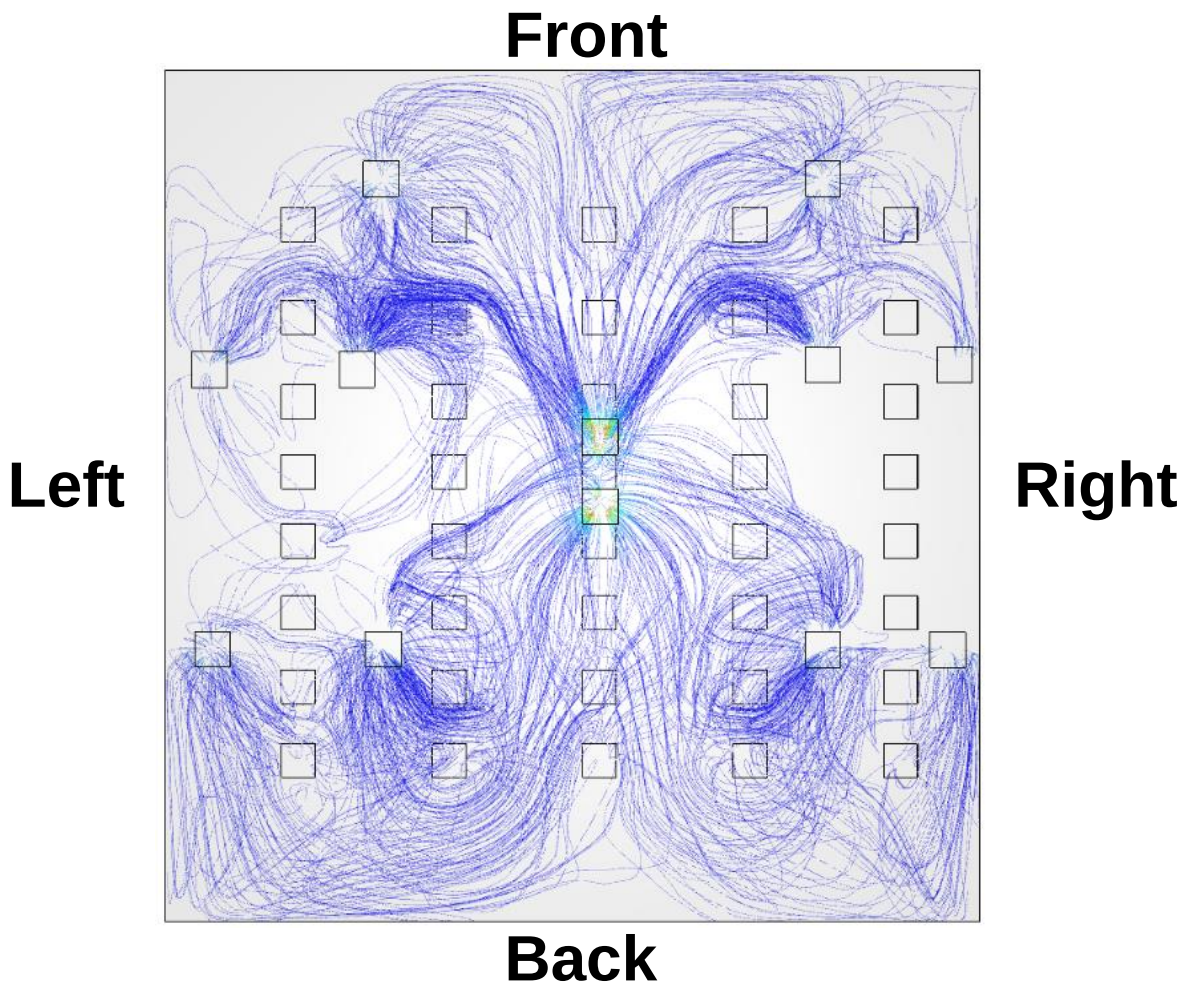


Leon Johnson

Simulation – Top View



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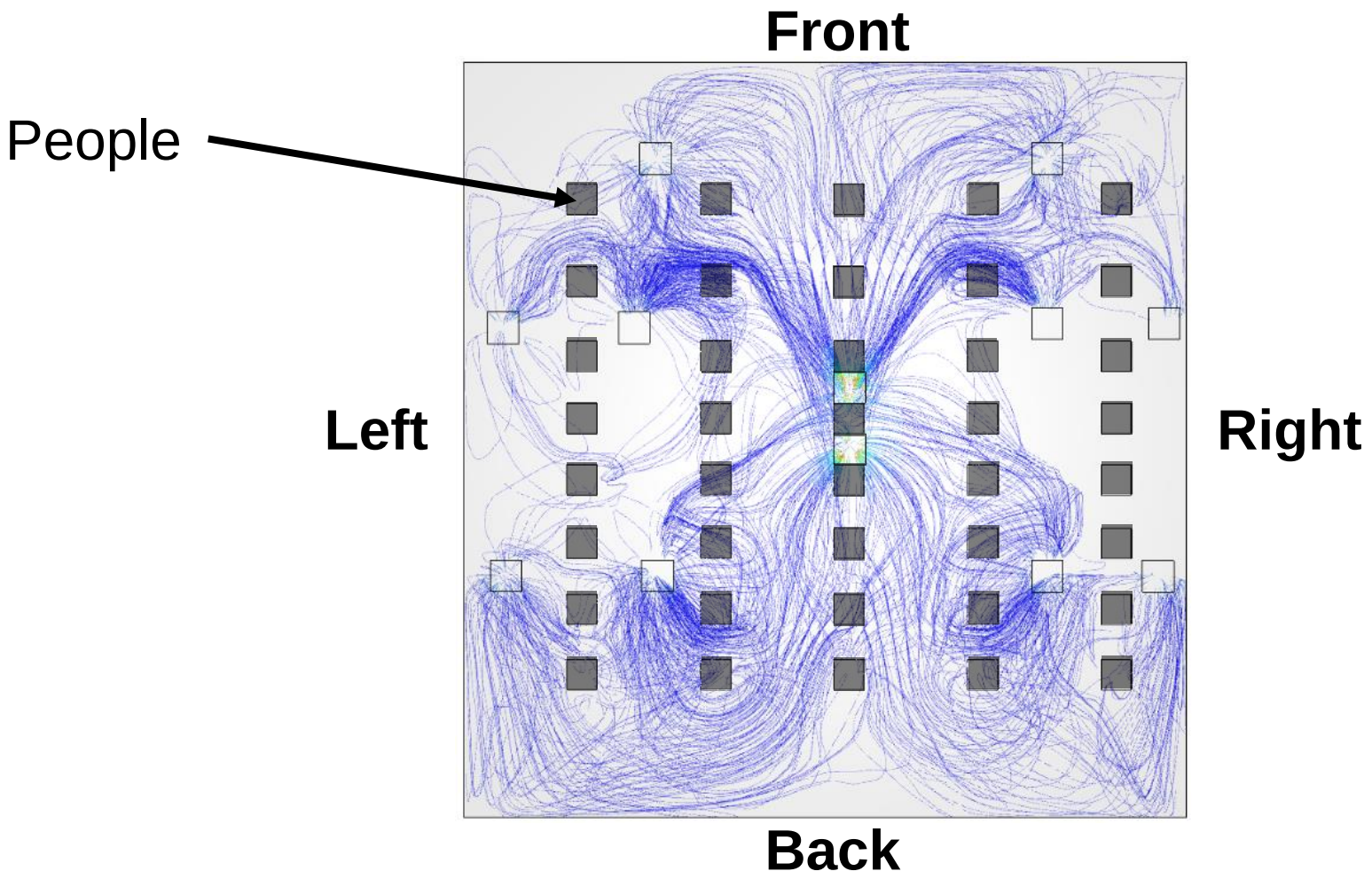

Leon Johnson

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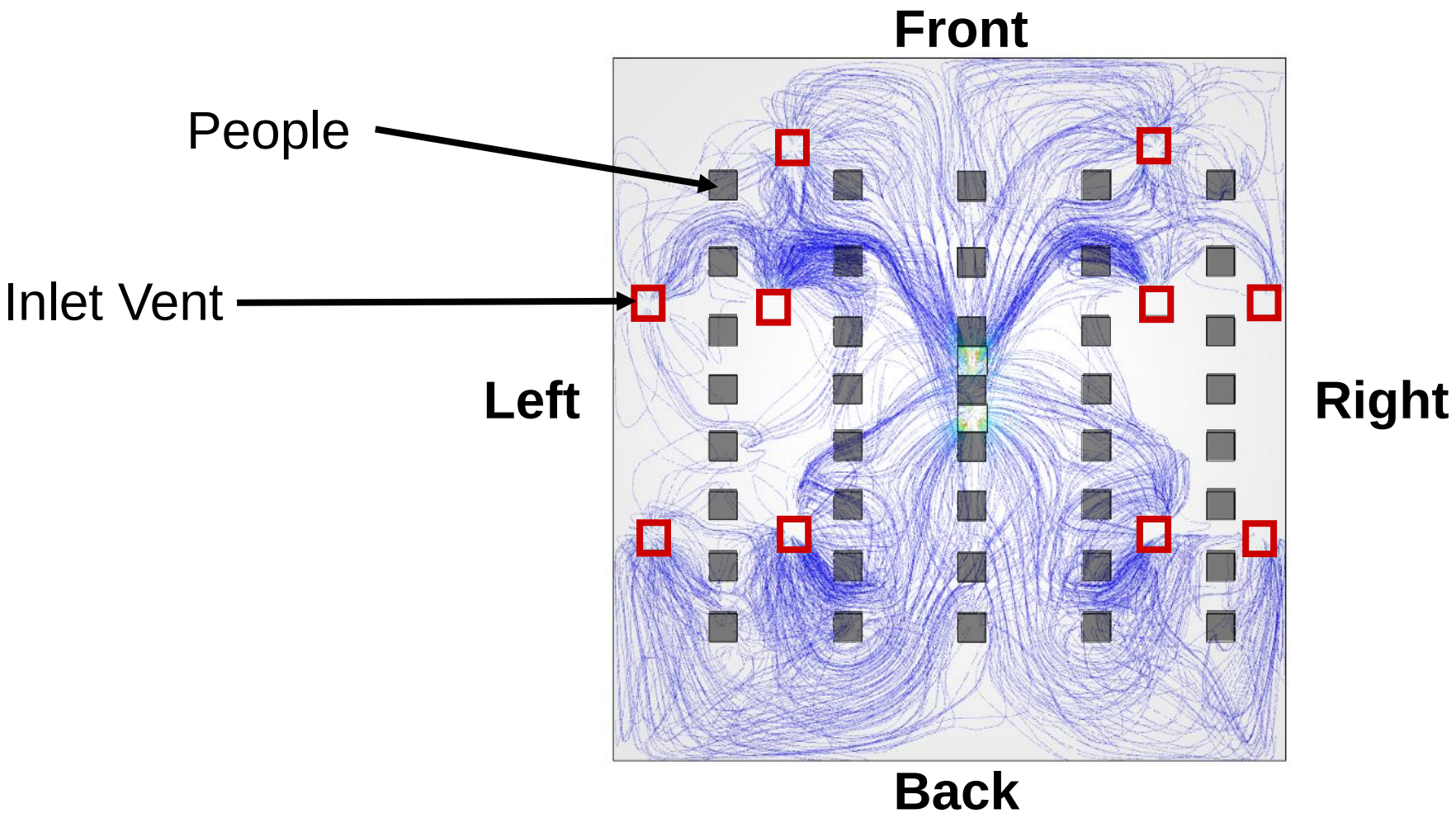

Leon Johnson

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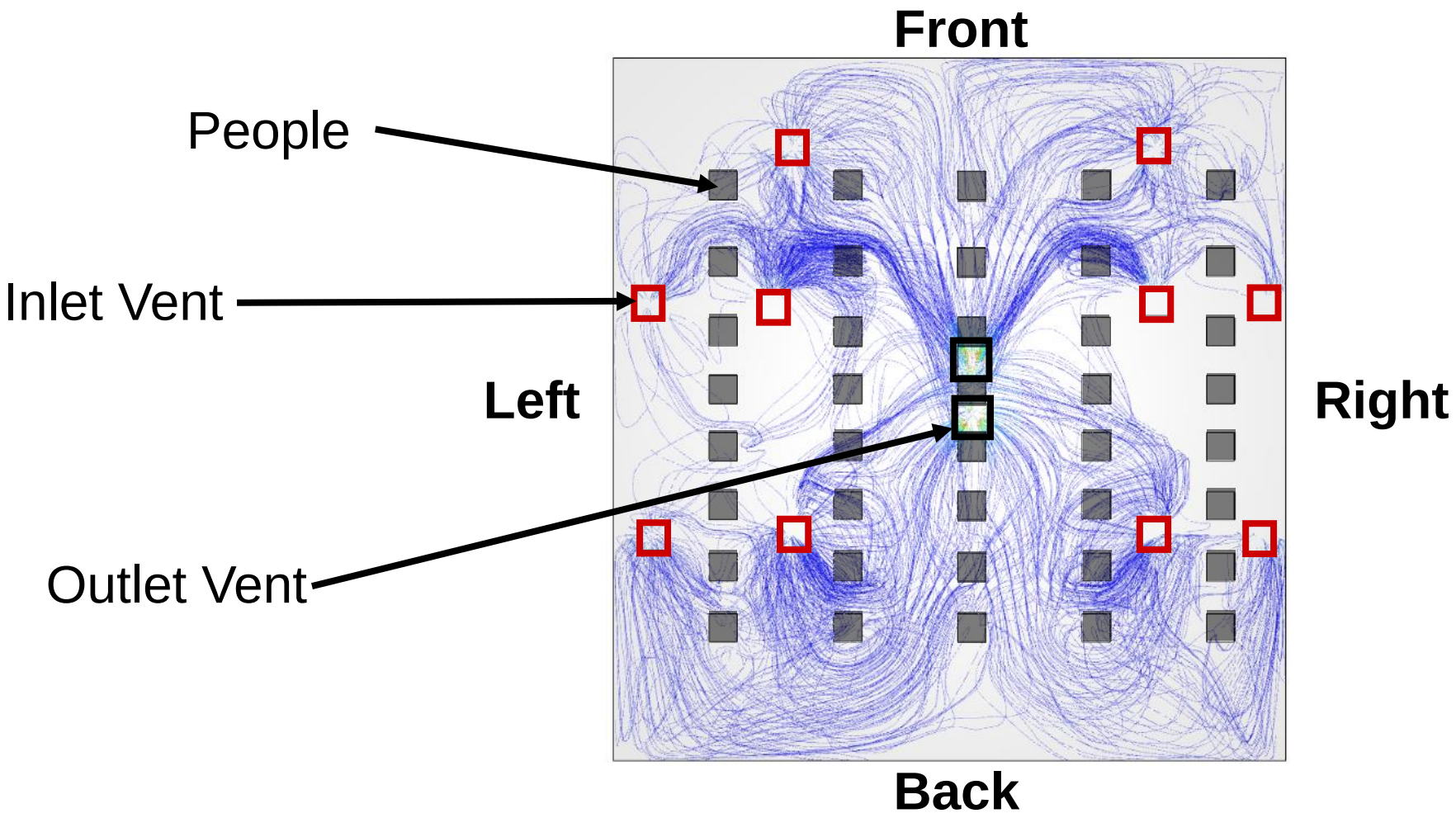

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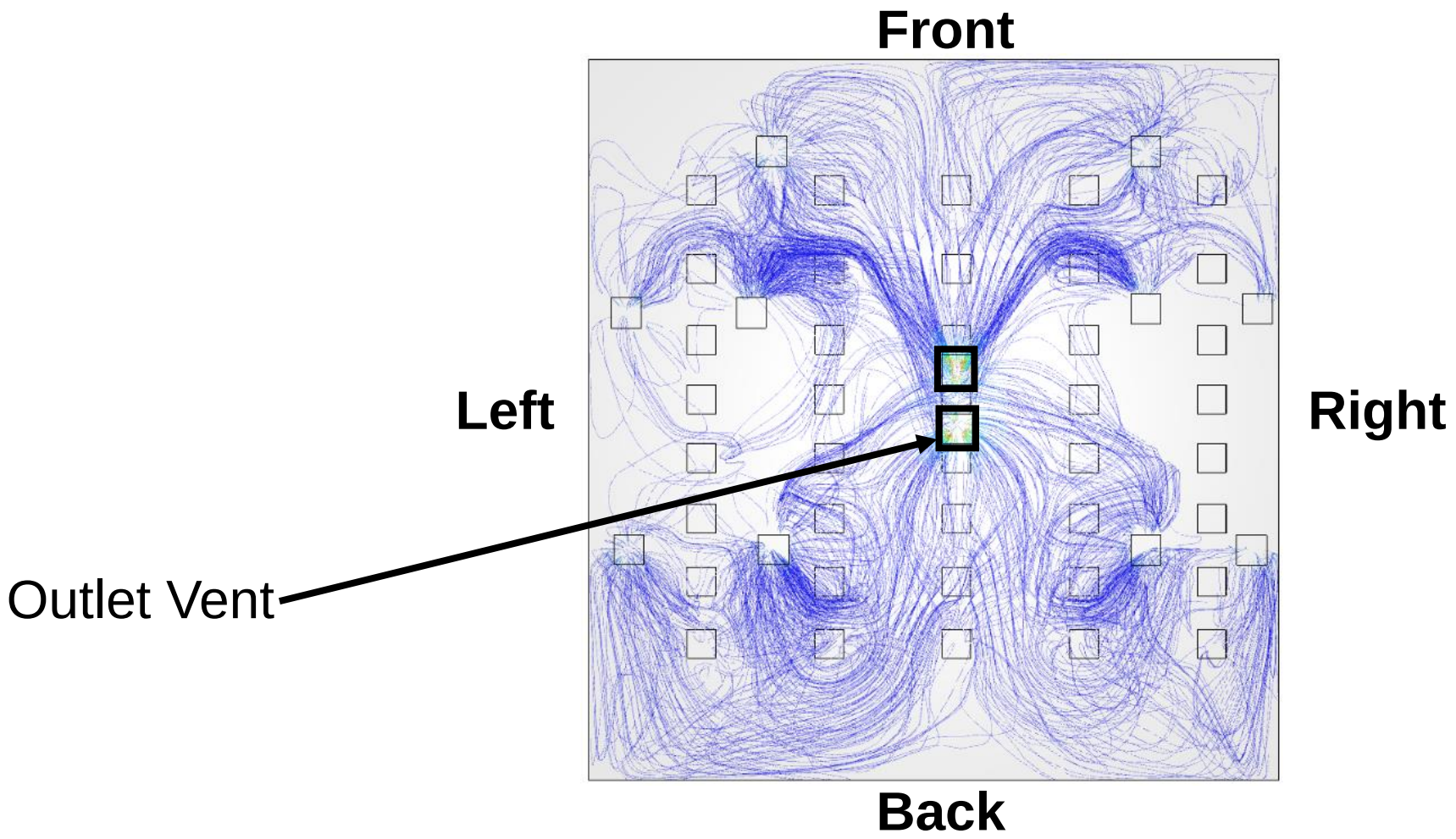
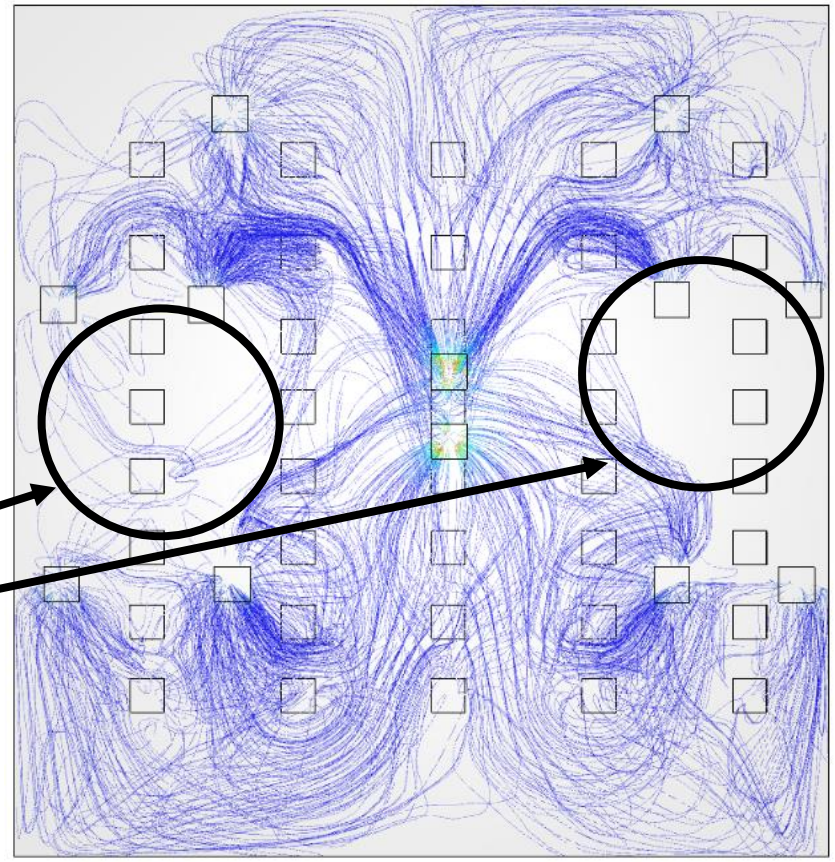
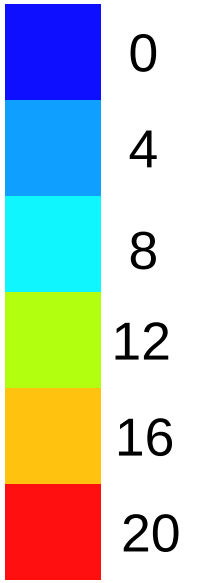


Leon Johnson

Simulation – Top View



Place fans in low airflow areas



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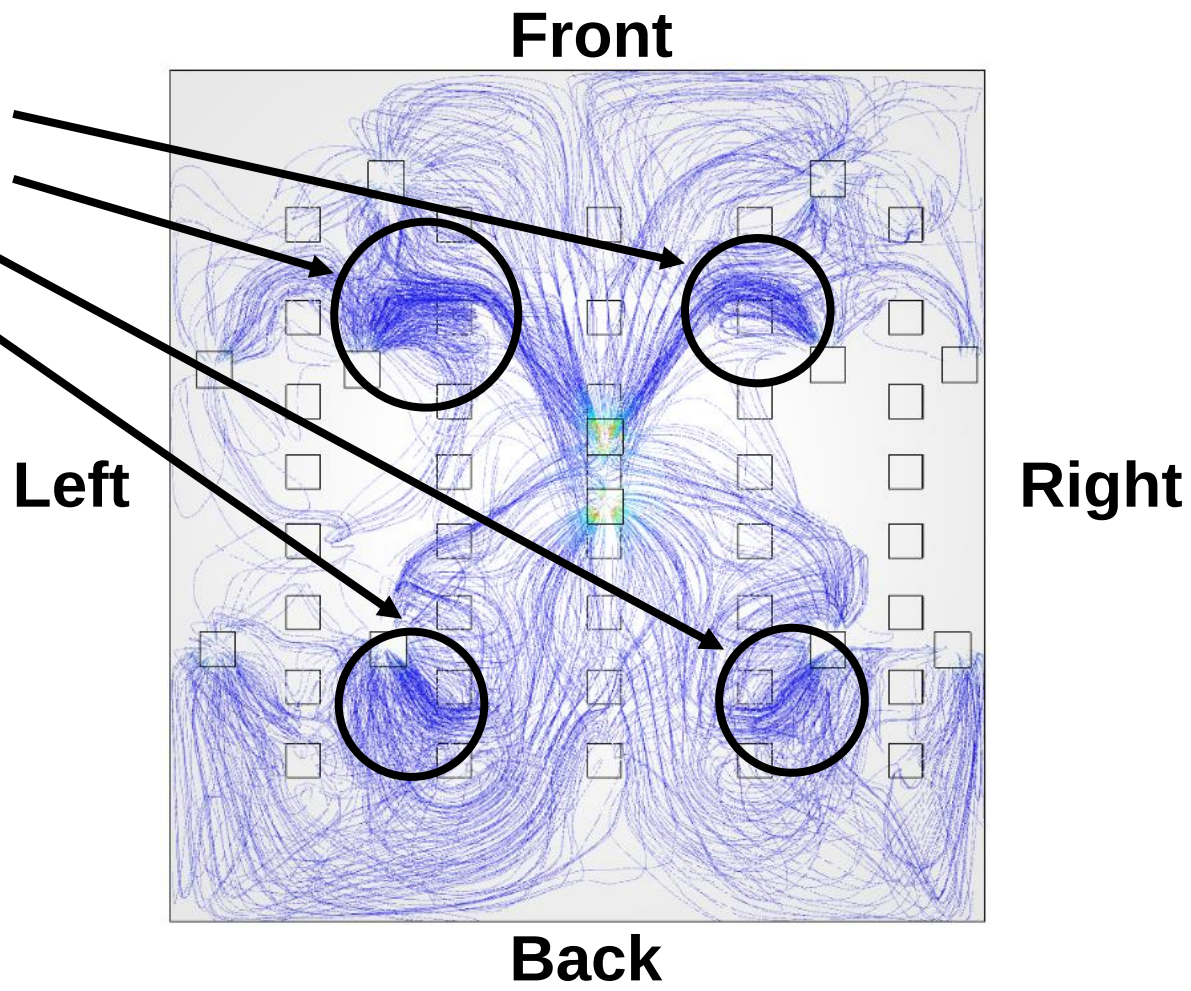
Simulation – Top View

Place air purifiers and other cleaning devices in high airflow areas



Leon Johnson

Future work

Leon Johnson

Key Takeaways

- CFD software is being used to simulate airflow in test locations
- Results of CFD simulations will be used to select the placement of devices in testing locations

Leon Johnson

References

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Backup Slides

	Major functions		
Minor functions	Control System	Ventilate Room	Improve Air Composition
Sense Air Quality	x		
Measure Air Quality	x		
Activate Propeller	x		
Deactivate Propeller	x		
Modulate Propeller	x		
Activate Purifier	x		
Deactivate Purifier	x		
Modulate Purifier	x		
Propel Air		x	
Circulate Air		x	x
Purify Air			x
Treat Air			x
Filter Particulates			x
Dehumidify Air			x
Humidify Air			x
Sanitize Contaminants			x
Total	8	2	7

Questions	Customer Statement	Interpreted Need
Would using the most outside air be efficient enough to clean air?	The best method to clean the air, would be 100% outside air utilization. This would be too expensive	Clean and recycle existing indoor air.
How do healthy buildings affect energy consumption?	Using systems to work more efficiently, increases consumption. Portable and battery powered units with data loggers.	A device that is portable and battery powered would be more appropriate.
Are there any structural or sizing limitations? e.g. volume, height, length, weight, etc.	The device cannot be added to the existing structure of mechanical equipment. Small, and lightweight to be moved on a cart.	A portable device that can be moved easily.
In what environment will the project be used? e.g. home, office, stadium, retail, etc.	The idea is to create a product that can be used at FAMU-FSU COE	The product is designed to work in classrooms, labs, and study spaces.
Should it be geared towards reducing contamination or increasing ventilation?	The device should be geared towards reducing contaminants.	The product reduces contamination and increases ventilation.

Do you have any existing products or previous research that could be used to help this project?	Similar projects are being done at other universities.	The product will resemble other products that have been installed in other universities.
Will our project be used in conjunction with an existing product or will an entirely new system need to be designed?	Since we have products already made, I do not figure that you all will create an entirely new system.	The product will work in conjunction with an existing product.
If it will be used in conjunction with another system, what type of system? Do you have any specific details?	We will donate products for you to work with.	The project will make use of existing Honeywell products.
Does the current COE mechanical system include sensors?	Some rooms have humidity sensors, but there are no Volatile Organic Compounds (VOC) or particulate sensors.	Device will measure the VOC, CO2, humidity, temperature, and particulate levels
Is there a problem with the current purifiers?	Current purifiers would only clean 10% of the air in the room, because of placement.	The device will clean and monitor more of the air in the spaces.
What is the nature of the contamination we are aiming to reduce? e.g. viruses, bacteria, fungi, odor, etc.	Reducing the replication of airborne pathogens	The product reduces viruses that are in the hotspot area.
Does the project need to be an automatic or a manual system?	It would be great for it to be automatic but if it ends up having to be manual that will work.	The product is activated automatically.

	Monitor Air Quality	Portable	No Noise	No Heat	Reduces Contamination	Internal Power Source	Compatiable with Honeywell Products	Doesn't Interfere with Existing Infrastructure	Total
Monitor Air Quality	-	1	1	1	1	1	1	1	**7**
Portable		-	1	1					**2**
No Noise			-	1		1			**2**
No Heat				-					**0**
Reduces Contamination		1	1	1	-	1	1	1	**6**
Internal Power Source		1		1		-			**2**
Compatiable with Honeywell Products		1	1	1		1	-		**4**
Doesn't Interfere with Existing Infrastructure		1	1	1		1	1	-	**5**

		Engineering Characteristics							
Improvement		↑		↑	↓	↓	↓	↓	↓
Units		µg/m3		ft3/min	dBA	Watts	ft3	sec	µm
Customer Requirements	**Importance Weight Factor**	**Concentration Range of Sensors**	**Accuracy of Sensors**	**Volumetric Flowrate**	**Noise Level**	**Daily Energy Consumption**	**Volume of Device**	**Reaction Time of Hardware Components**	**Minimum Diameter of Particles the Device Will Filter**
Monitor Air Quality	**7**	9	9					3	
Portable	**2**					1	9		
No Noise	**2**			1	9				
No Heat	**0**								
Reduces Contamination	**6**	3	9	9				3	9
Internal Power Source	**2**					3	1		
Compatiable with Honeywell Products	**4**	1	1						
Doesn't Interfere with Existing Infrastructure	**5**						1		
Raw Score (406)		85	121	56	18	8	25	39	54
Relative Weight %		20.94	29.80	13.79	4.43	1.97	6.16	9.61	13.30
Rank Order		2	1	3	7	8	6	5	4

Pugh Chart									
Engineering Characterisitcs	Datum: Air Purifier	Concept 13: Single mobile cart	Concept 14: double mobile cart	Concept 34: Air purifier on cart	Concept 36: Stationary air purifier	Concept 38: Air purifier with UV cleaning	Concept 46: rotating air furifier	Concept 47: Light-up air purifier	Concept 48: Wall mounted sensors
ability to circulate air	Datum	+	S	+	+	S	S	-	+
ability to purify air		+	+	S	+	+	+	+	S
ability to filter particulates		+	+	+	+	S	S	+	S
ability to humidify and dehumidify air		+	+	+	+	-	-	-	+
utilizes control systems		+	+	+	-	-	-	S	+
portable		S	+	+	-	-	-	+	-
utilizes proprietary power source		S	S	S	-	-	-	S	+
utilizes multiple sensors		S	S	-	-	-	-	+	S
Plusses		5	5	5	4	1	1	4	4
Minuses		0	0	1	4	5	5	2	1
Satisfactory		3	3	2	0	2	2	2	3

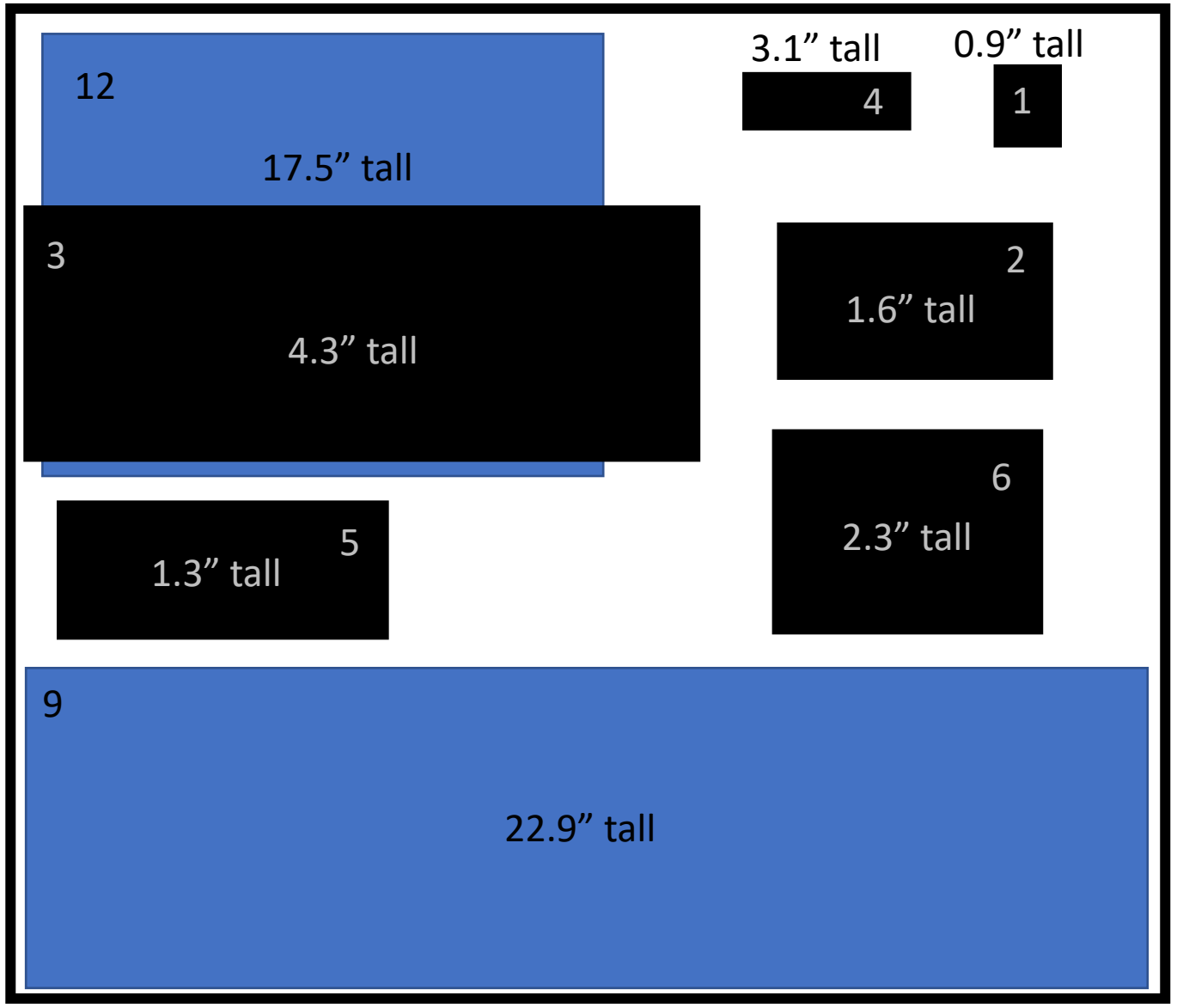
Pugh Chart				
Engineering Characterisitcs	Concept 34: Air purifier on cart	Concept 13: Single mobile cart	Concept 14: double mobile cart	Concept 48: wall mounted sensors
Ability to circulate air	Datum	+	S	S
ability to purify air		+	+	+
ability to filter particulates		+	+	+
ability to humidify and dehumidify air		+	+	+
utilizes control systems		S	S	+
utilizes mobility		S	+	-
utilizes proprietary power source		S	S	-
utilizes multiple sensors		S	S	S
Plusses		4	4	4
Minuses		0	0	2
Satisfactory		4	4	2

Development of Candidate Set of Criteria Weights {W}												
Criteria Comparison Matrix [C]												
Engineering Characteristics	Portability	Sense air Quality	Propeller Activation	Propeller Modulation	Purifier Activation	Purifier Modulation	Air Propulsion	Air Purification	Air Treatment	Filter Particulates	Humidify	Sanitize
Portability	1.00	3.00	0.14	0.14	0.14	0.14	0.20	0.20	0.20	0.20	0.20	3.00
Sense air Quality	0.33	1.00	0.14	0.20	0.20	0.20	0.20	0.14	0.14	0.14	0.33	5.00
Propeller Activation	7.00	5.00	1.00	7.00	1.00	3.00	0.33	0.14	0.14	0.14	0.20	0.14
Propeller Modulation	7.00	5.00	0.14	1.00	0.14	1.00	0.33	0.14	0.14	0.14	0.20	0.14
Purifier Activation	7.00	5.00	1.00	7.00	1.00	5.00	0.33	0.14	0.20	0.20	0.20	0.14
Purifier Modulation	7.00	5.00	0.33	1.00	0.20	1.00	0.33	0.20	0.20	0.20	0.20	0.20
Air Propulsion	5.00	5.00	3.00	3.00	3.00	3.00	1.00	0.33	0.33	0.20	0.20	0.33
Air Purification	5.00	7.00	7.00	7.00	7.00	5.00	3.00	1.00	1.00	0.33	0.20	0.33
Air Treatment	5.00	7.00	7.00	7.00	5.00	5.00	3.00	1.00	1.00	0.33	3.00	3.00
Filter Particulates	5.00	7.00	7.00	7.00	5.00	5.00	5.00	3.00	3.00	1.00	5.00	5.00
Humidify	5.00	3.00	5.00	5.00	5.00	5.00	5.00	5.00	0.33	0.20	1.00	1.00
Sanitize	0.33	0.20	7.00	7.00	7.00	5.00	3.00	3.00	0.33	0.20	1.00	1.00
Sum	54.67	53.20	38.76	52.34	34.69	38.34	21.73	14.30	7.03	3.30	11.73	19.30

Development of Candidate Set of Criteria Weights {W}													
Normalized Criteria Comparison Matrix [NormC]													
Engineering Characteristics	Portability	Sense air Quality	Propeller Activation	Propeller Modulation	Purifier Activation	Purifier Modulation	Air Propulsion	Air Purification	Air Treatment	Filter Particulates	Humidify	Sanitize	Criteria Weight {W}
Portability	0.0183	0.0564	0.0037	0.0027	0.0041	0.0037	0.0092	0.0140	0.0284	0.0606	0.0171	0.1554	0.0311
Sense air Quality	0.0061	0.0188	0.0037	0.0038	0.0058	0.0052	0.0092	0.0100	0.0203	0.0433	0.0284	0.2591	0.0345
Propeller Activation	0.1280	0.0940	0.0258	0.1337	0.0288	0.0782	0.0153	0.0100	0.0203	0.0433	0.0171	0.0074	0.0502
Propeller Modulation	0.1280	0.0940	0.0037	0.0191	0.0041	0.0261	0.0153	0.0100	0.0203	0.0433	0.0171	0.0074	0.0324
Purifier Activation	0.1280	0.0940	0.0258	0.1337	0.0288	0.1304	0.0153	0.0100	0.0284	0.0606	0.0171	0.0074	0.0566
Purifier Modulation	0.1280	0.0940	0.0086	0.0191	0.0058	0.0261	0.0153	0.0140	0.0284	0.0606	0.0171	0.0104	0.0356
Air Propulsion	0.0915	0.0940	0.0774	0.0573	0.0865	0.0782	0.0460	0.0233	0.0474	0.0606	0.0171	0.0173	0.0580
Air Purification	0.0915	0.1316	0.1806	0.1337	0.2018	0.1304	0.1381	0.0699	0.1422	0.1010	0.0171	0.0173	0.1129
Air Treatment	0.0915	0.1316	0.1806	0.1337	0.1441	0.1304	0.1381	0.0699	0.1422	0.1010	0.2558	0.1554	0.1395
Filter Particulates	0.0915	0.1316	0.1806	0.1337	0.1441	0.1304	0.2301	0.2098	0.4267	0.3030	0.4263	0.2591	0.2222
Humidify	0.0915	0.0564	0.1290	0.0955	0.1441	0.1304	0.2301	0.3497	0.0474	0.0606	0.0853	0.0518	0.1226
Sanitize	0.0061	0.0038	0.1806	0.1337	0.2018	0.1304	0.1381	0.2098	0.0474	0.0606	0.0853	0.0518	0.1041
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

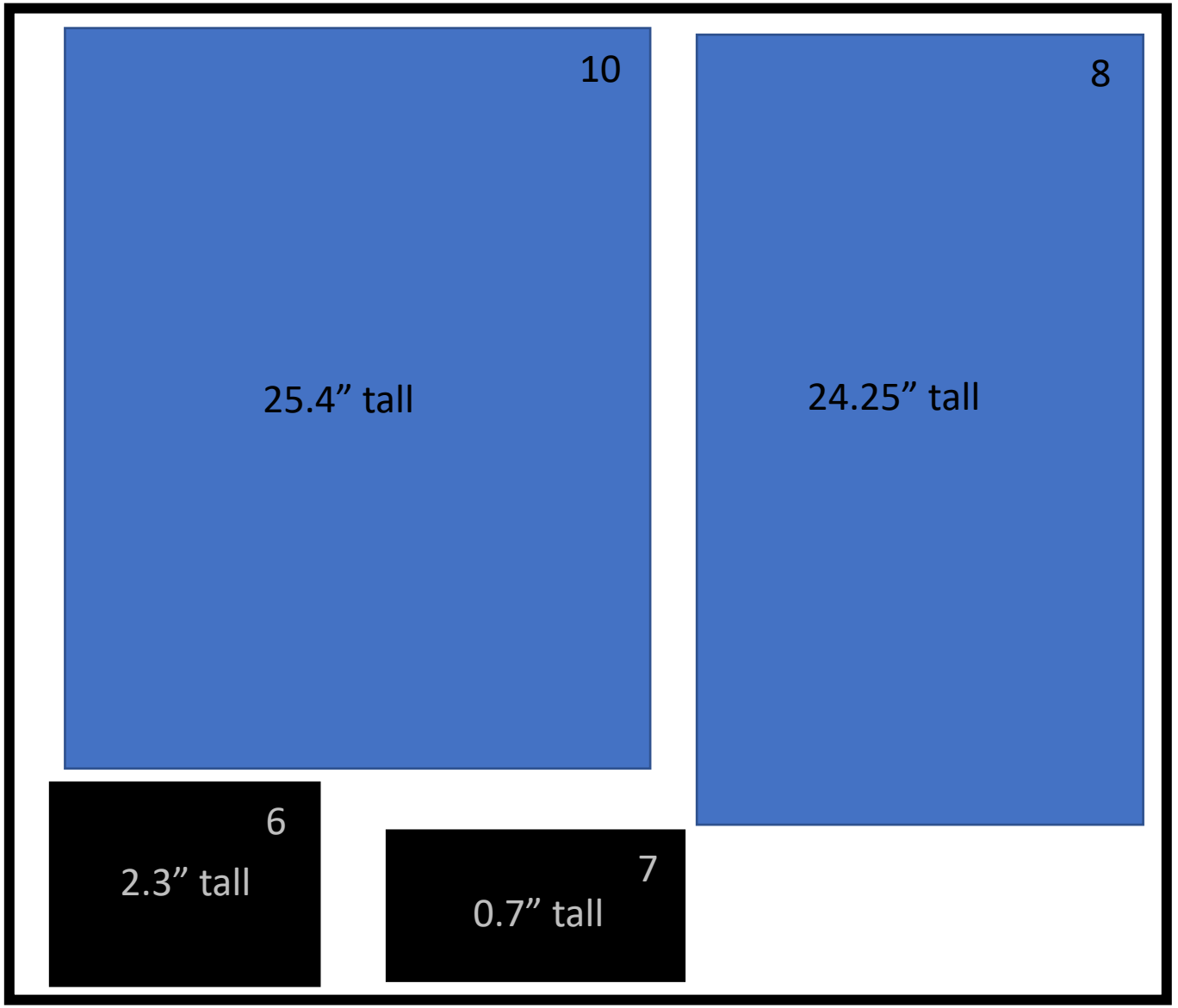
Development of Weighted Sum Vectors {Ws}													
Engineering Characteristics	**Portability**	**Sense air Quality**	**Propeller Activation**	**Propeller Modulation**	**Purifier Activation**	**Purifier Modulation**	**Air Propulsion**	**Air Purification**	**Air Treatment**	**Filter Particulates**	**Air Humidification**	**Sanitize Contaminants**	**Weighted Sum {Ws}**
Portability	0.0311	0.1034	0.0072	0.0046	0.0081	0.0051	0.0116	0.0226	0.0279	0.0444	0.0245	0.0312	0.3218
Sense air Quality	0.0104	0.0345	0.0072	0.0065	0.0113	0.0071	0.0116	0.0161	0.0199	0.0317	0.0409	0.0521	0.2493
Propeller Activation	0.2177	0.1724	0.0502	0.2266	0.0566	0.1068	0.0194	0.0161	0.0199	0.0317	0.0245	0.0015	0.9435
Propeller Modulation	0.2177	0.1724	0.0072	0.0324	0.0081	0.0356	0.0194	0.0161	0.0199	0.0317	0.0245	0.0015	0.5865
Purifier Activation	0.2177	0.1724	0.0502	0.2266	0.0566	0.1781	0.0194	0.0161	0.0279	0.0444	0.0245	0.0015	1.0354
Purifier Modulation	0.2177	0.1724	0.0167	0.0324	0.0113	0.0356	0.0194	0.0226	0.0279	0.0444	0.0245	0.0021	0.6270
Air Propulsion	0.1555	0.1724	0.1506	0.0971	0.1699	0.1068	0.0581	0.0376	0.0465	0.0444	0.0245	0.0035	1.0670
Air Purification	0.1555	0.2413	0.3514	0.2266	0.3965	0.1781	0.1742	0.1129	0.1395	0.0741	0.0245	0.0035	2.0780
Air Treatment	0.1555	0.2413	0.3514	0.2266	0.2832	0.1781	0.1742	0.1129	0.1395	0.0741	0.3680	0.0312	2.3359
Filter Particulates	0.1555	0.2413	0.3514	0.2266	0.2832	0.1781	0.2903	0.3388	0.4186	0.2222	0.6133	0.0521	3.3712
Air Humidification	0.1555	0.1034	0.2510	0.1619	0.2832	0.1781	0.2903	0.5647	0.0465	0.0444	0.1227	0.0104	2.2119
Sanitize Contaminants	0.0104	0.0069	0.3514	0.2266	0.3965	0.1781	0.1742	0.3388	0.0465	0.0444	0.1227	0.0104	1.9067
Sum	1.70	1.83	1.95	1.69	1.96	1.37	1.26	1.62	0.98	0.73	1.44	0.20	16.73

Function	Part Number	Part Name	Vendor	Part Model Number	Weight (lbs)	Dimensions (inches)	Unit Cost	Number of Units	Cost
storage	1	3-Shelf Utility Cart	Uline	H-5007BL	46	44 x 25 x 33	$ 125.00	2	$ 250.00
sensing	2	HPM Series PM2.5 Particulate Matter Sensor	Honeywell	HPMA115C0-XXX	N/A	1.7 x 1.4 x 0.9	$ 42.01	1	$ 42.01
	3	BW Ultra Multi-Gas Detector	Honeywell	DS01195	0.9	5.8 x 3.3 x 1.6	$ 2,515.00	1	$2,515.00
	4	IntelliDox Docking Station	Honeywell	DS20151112	4.2	5.4 x 14.3 x 4.3	$ 1,890.14	1	$1,890.14
	5	Honeywell Humidity Monitor With Digital Display	Honeywell	HHM10	0.14	3.54 x 1.18 x 3.1	$14.95	1	$ 14.95
	6	Anemometer	Grainger	AN100-NIST	1.6	7 x 2.9 x 1.3	$ 342.00	1	$ 342.00
	7	Dual UV Lamp	Honeywell	UV100E2009	N/A	19 x 15 x 8.5	$ 446.04	1	$ 446.04
	8	ComfortPoint Open Controller	Honeywell	CPO-PC400	N/A	5.7 x 4.3 x 2.3	By Quote Only	1	N/A
	9	CT60 Mobile Computer	Honeywell	CT60	0.77	6.3 x 3.2 x 0.7	$ 2,050.00	1	$2,050.00
cleaning	10	Honeywell Professional Series True HEPA Air Purifier	Honeywell	HPA600B	32	16.73 x 9.45 x 24.25	$ 699.99	1	$ 699.99
	11	Honeywell TurboForce Floor Fan	Honeywell	HF-910	8.58	23.8 x 6.8 x 22.9	$ 49.45	1	$ 49.45
	12	Honeywell 70-Pint Energy Star Dehumidifier	Honeywell	TP70PWKN	43.6	15.7 x 12.4 x 25.4	$ 374.95	1	$ 374.95
	13	Honeywell UV Cool Moisture Germ Free Humidifier	Honeywell	HCM-350	8.36	17.5 x 9.4 x 11.9	$ 69.95	1	$ 69.95
Power	14	APC Back-UPS	APC	BE850M2	9.04	5.5 x 12.9 x 4.1	$ 113.99	1	$ 113.99
								Total Cost	$8,858.47



1	HPM Series PM2.5 Particulate Matter Sensor
2	BW Ultra Multi-Gas Detector
3	IntelliDox Docking Station
4	Honeywell Humidity Monitor With Digital Display
5	Anemometer
6	ComfortPoint Open Controller
7	CT60 Mobile Computer
8	Honeywell Professional Series True HEPA Air Purifier
9	Honeywell TurboForce Floor Fan
10	Honeywell 70-Pint Energy Star Dehumidifier
11	Honeywell UV Cool Moisture Germ Free Humidifier

- Lower Cabinet: Inside: 21 x 24 1/2 x 25 1/2" (L x W x H)
- 3.5 scale
- All dimensions in inches



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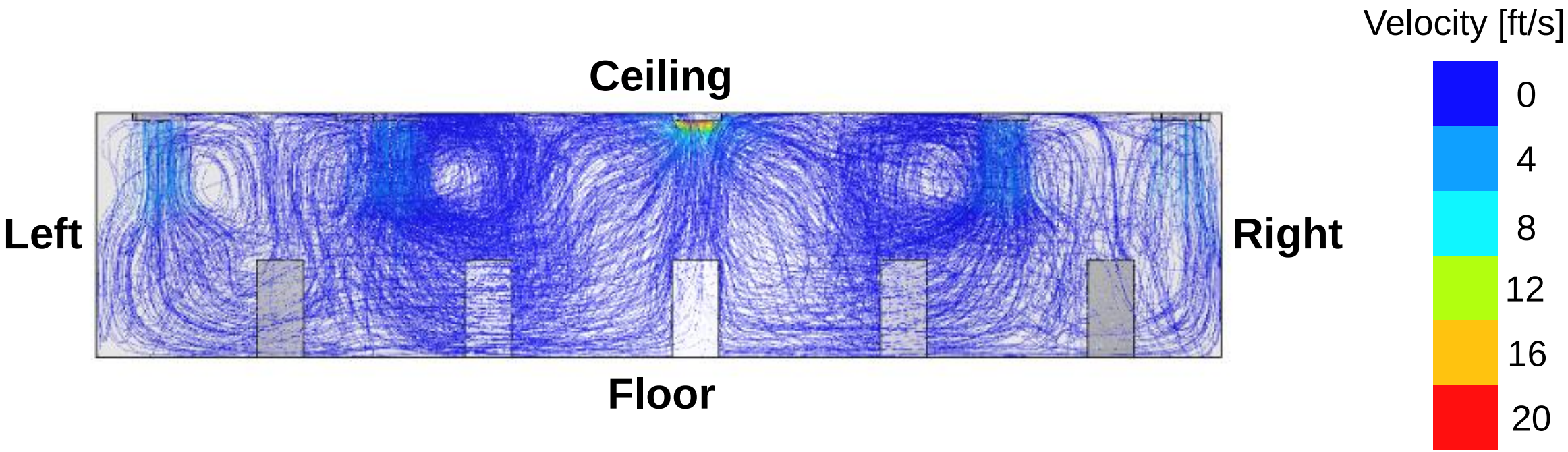
- Lower Cabinet: Inside: 21 x 24 1/2 x 25 1/2" (L x W x H)
- 3.5 scale
- All dimensions in inches

Simulation – Back View



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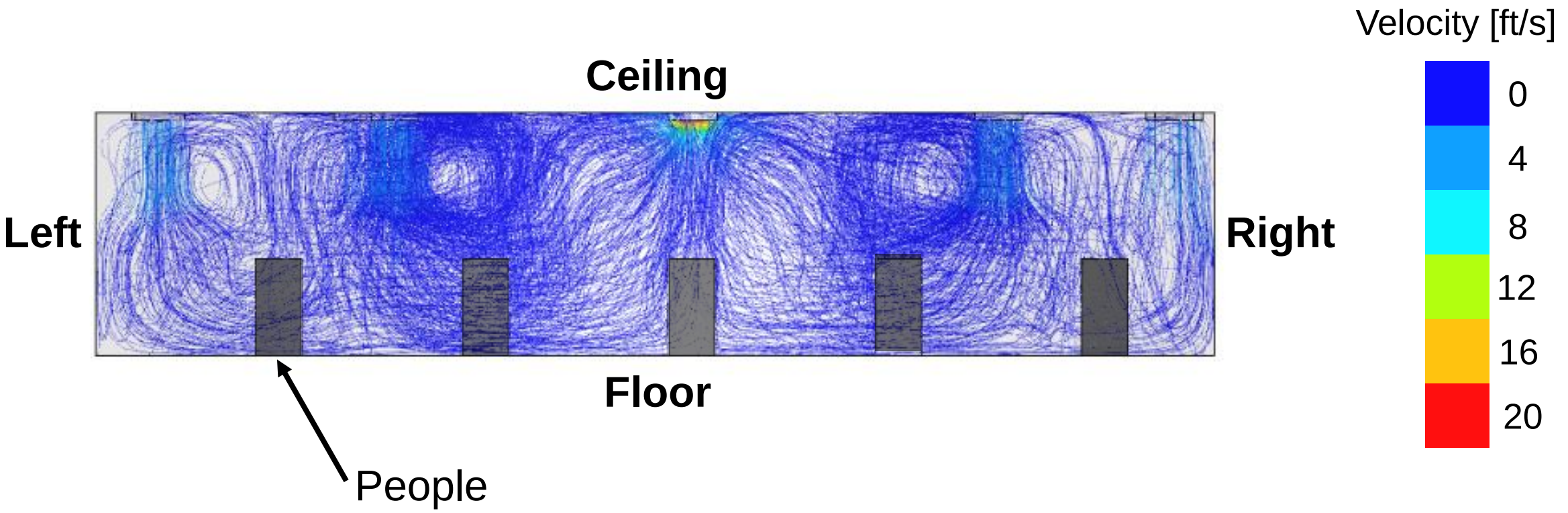
Simulation – Back View



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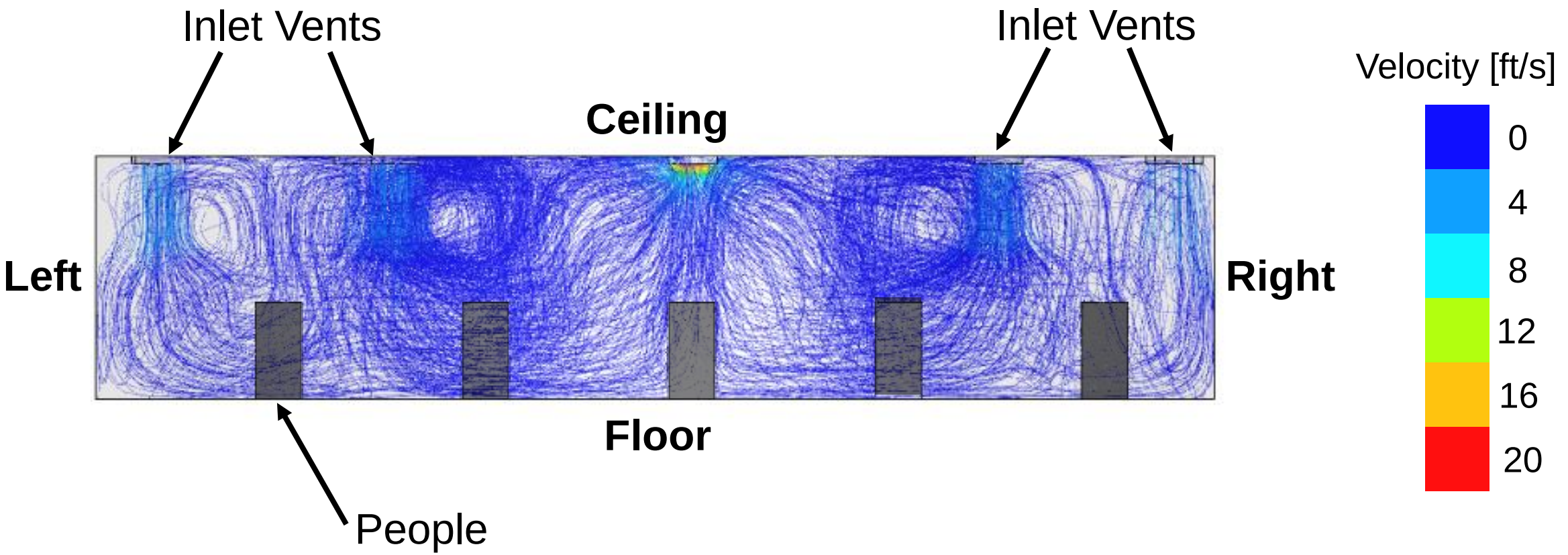
Simulation – Back View



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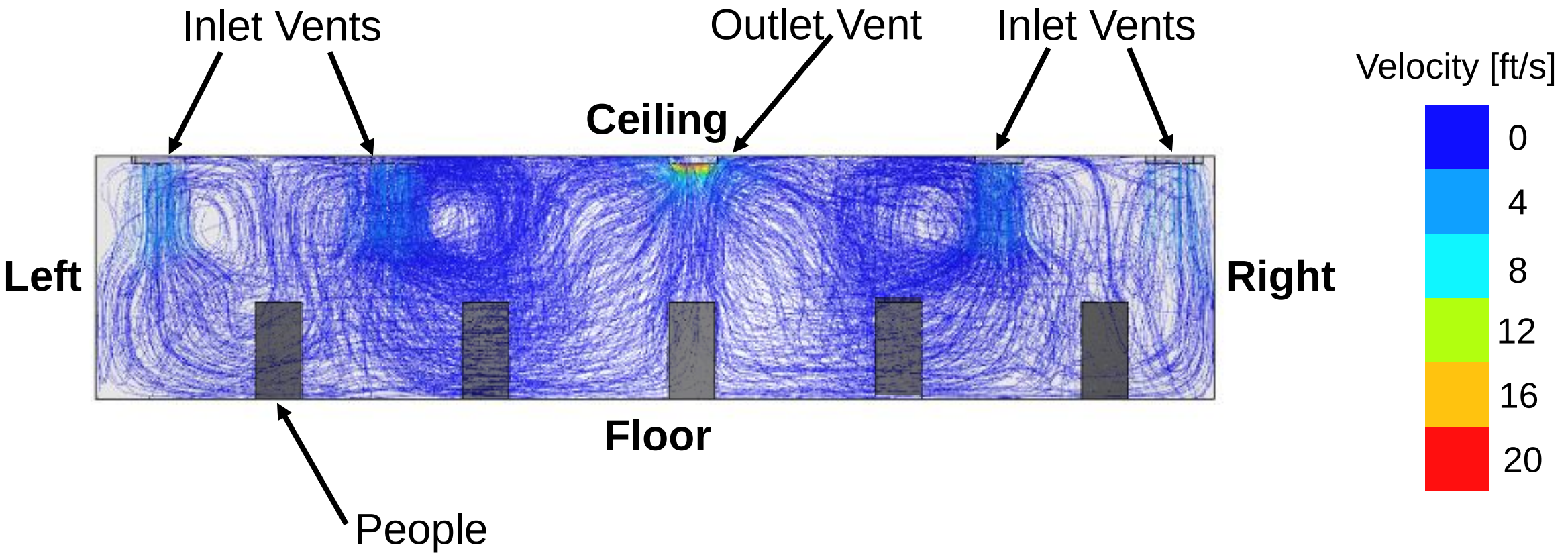
Simulation – Back View



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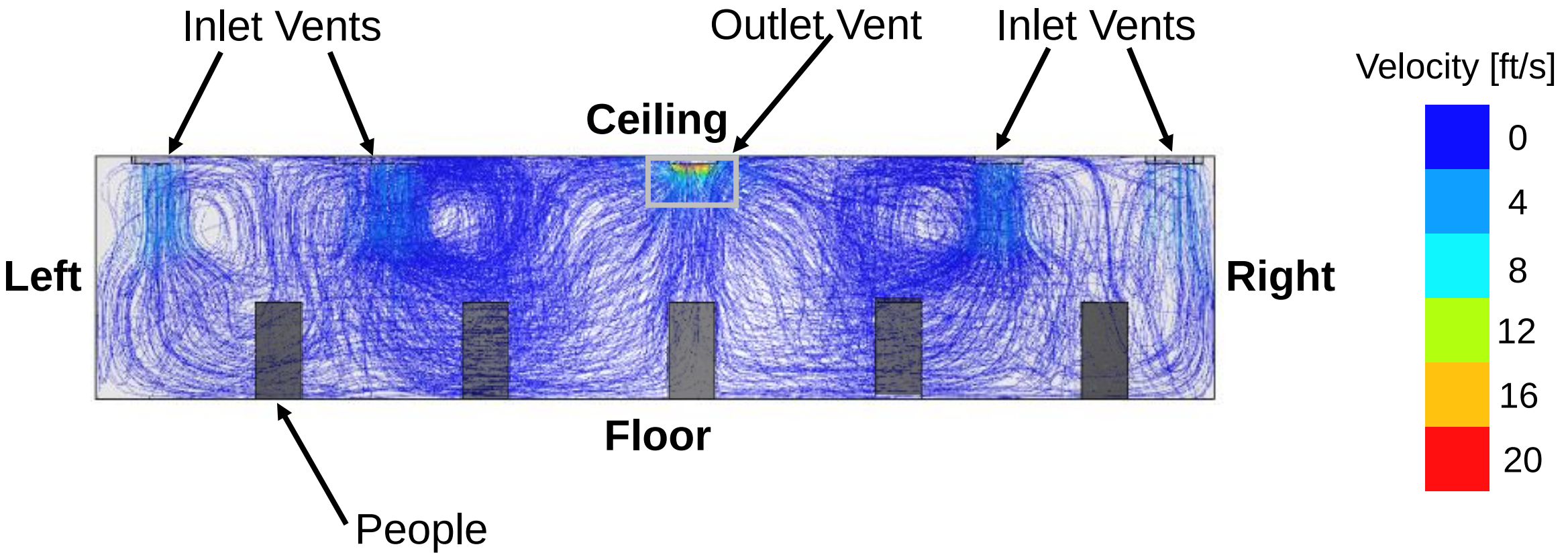
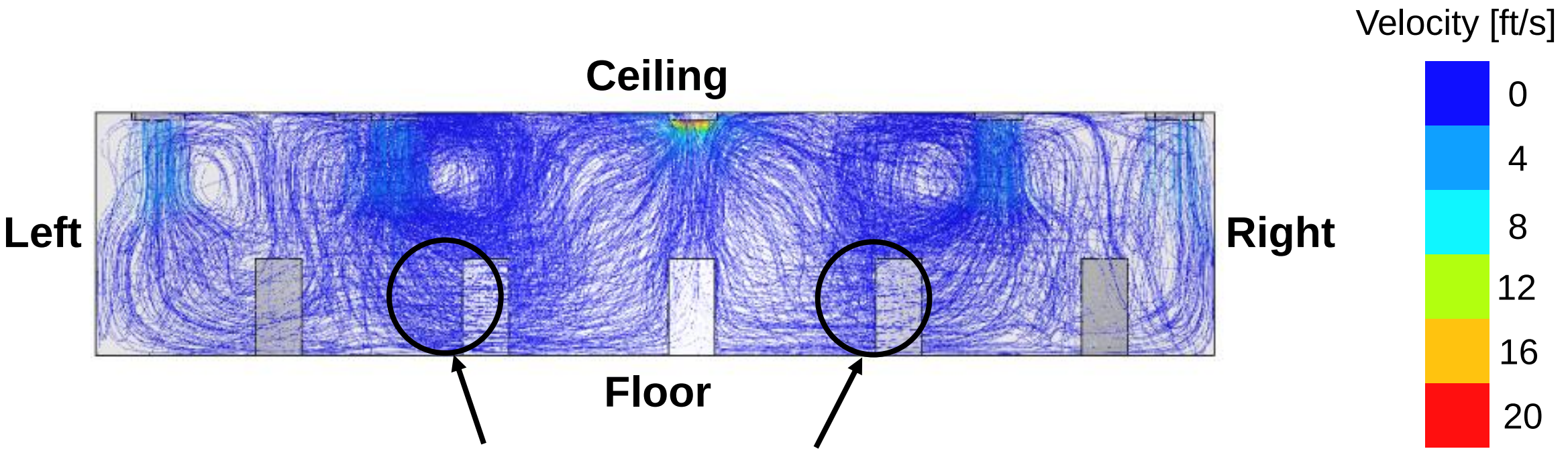
Simulation – Back View



Leon Johnson

Simulation – Back View



Place air purifiers and other cleaning devices in high airflow areas at ground level

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