IBACOS®
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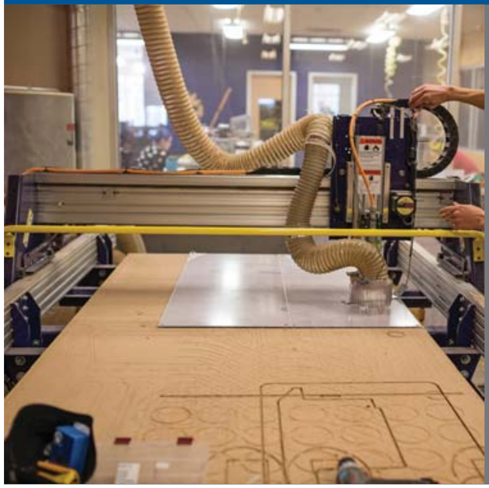
Low-Load HVAC Systems for Single and Multifamily Applications



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Agenda

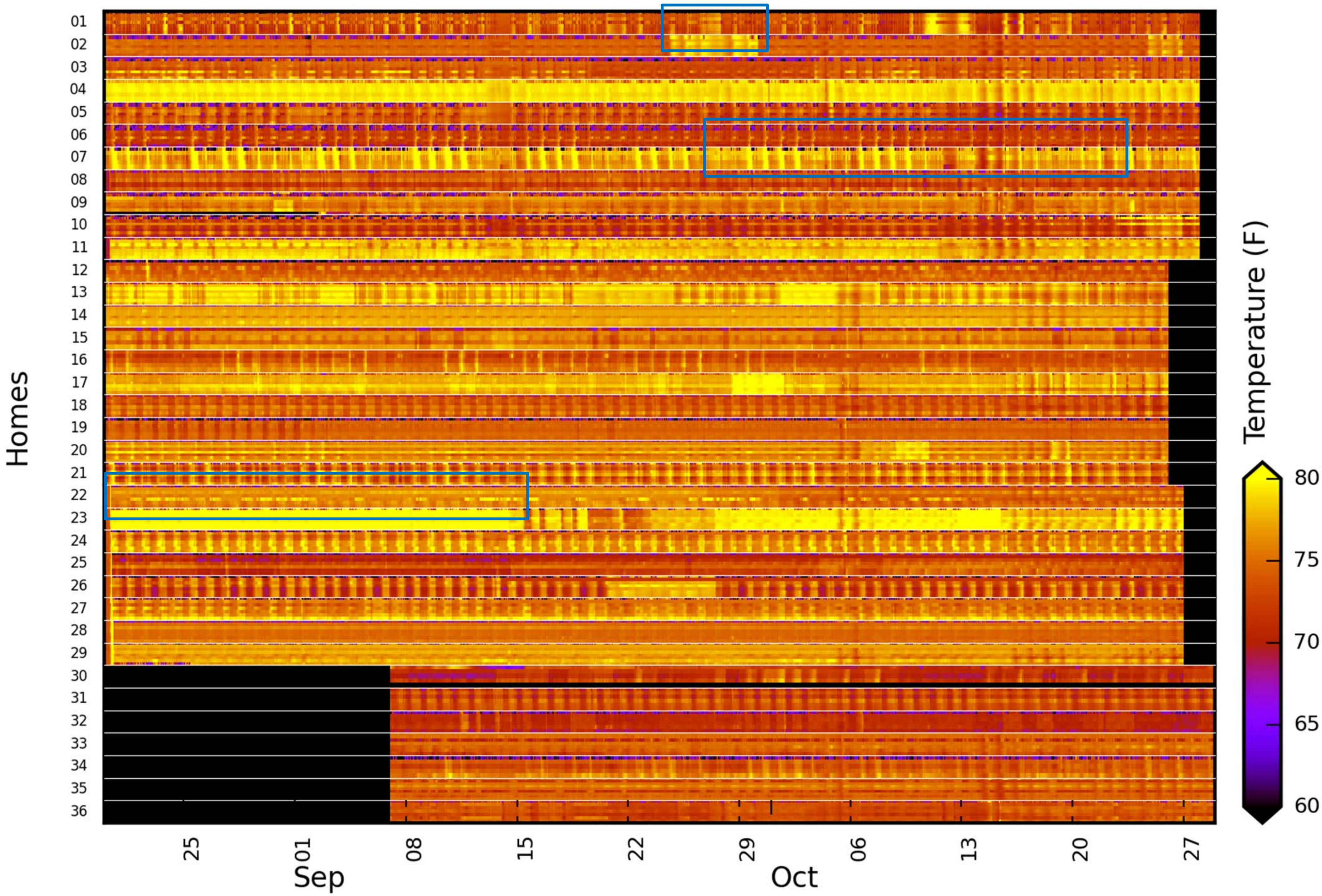
Basis for Thermal Comfort

Comparative Modeling

Newtown Townhouse Case Study

Plug and Play System

Future Work


01
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19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
Homes
25
01
08
15
22
29
06
13
20
27
Sep
Oct
Temperature (F)
80
75
70
65
60

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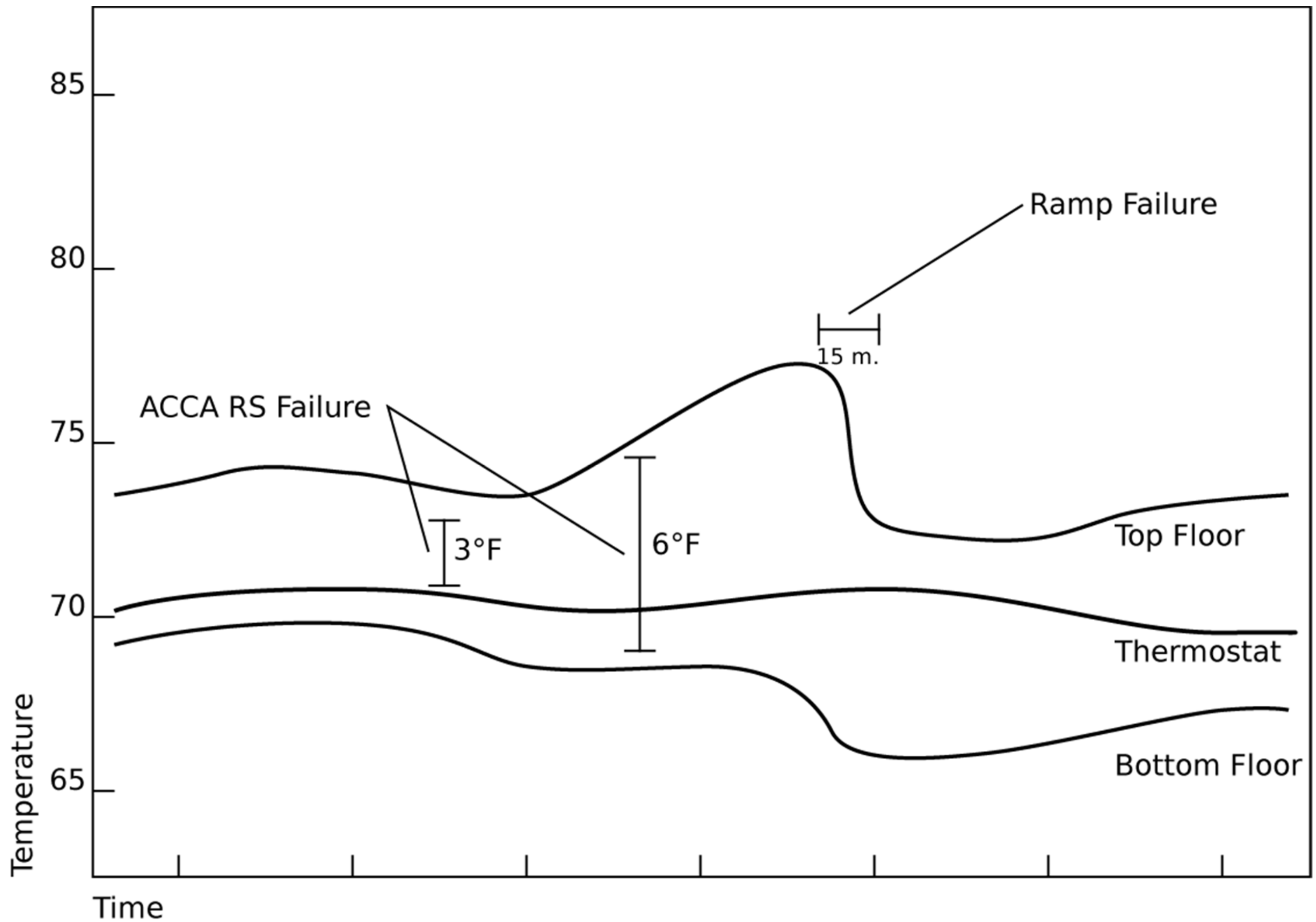
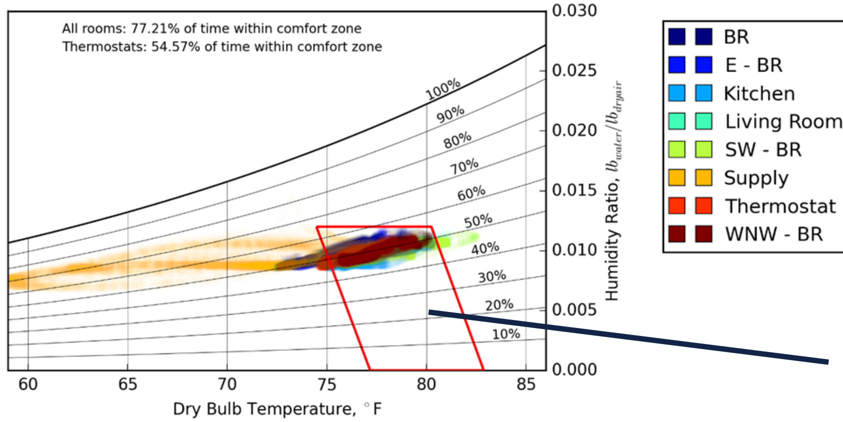
How IBACOS Thinks About Comfort Risks



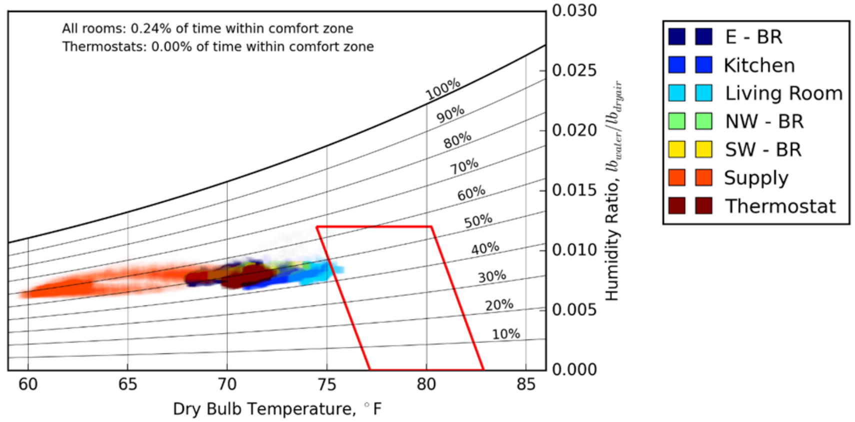
ASHRAE 55 Comfort

Home 24



0.5 CLO
1.0 MET

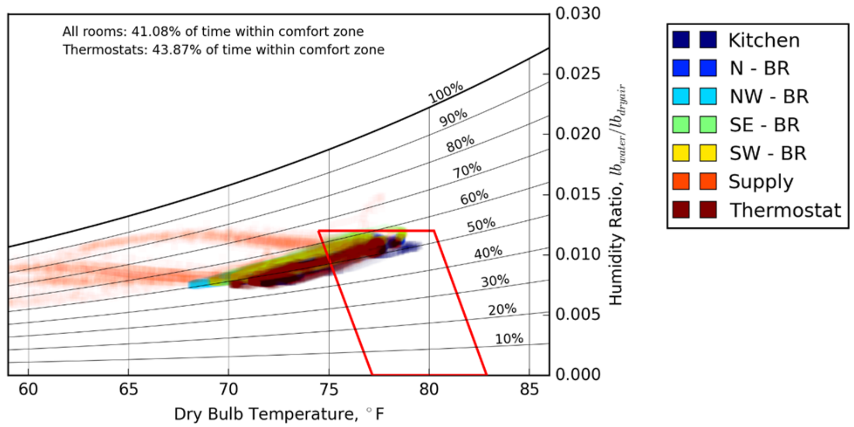
Home 25



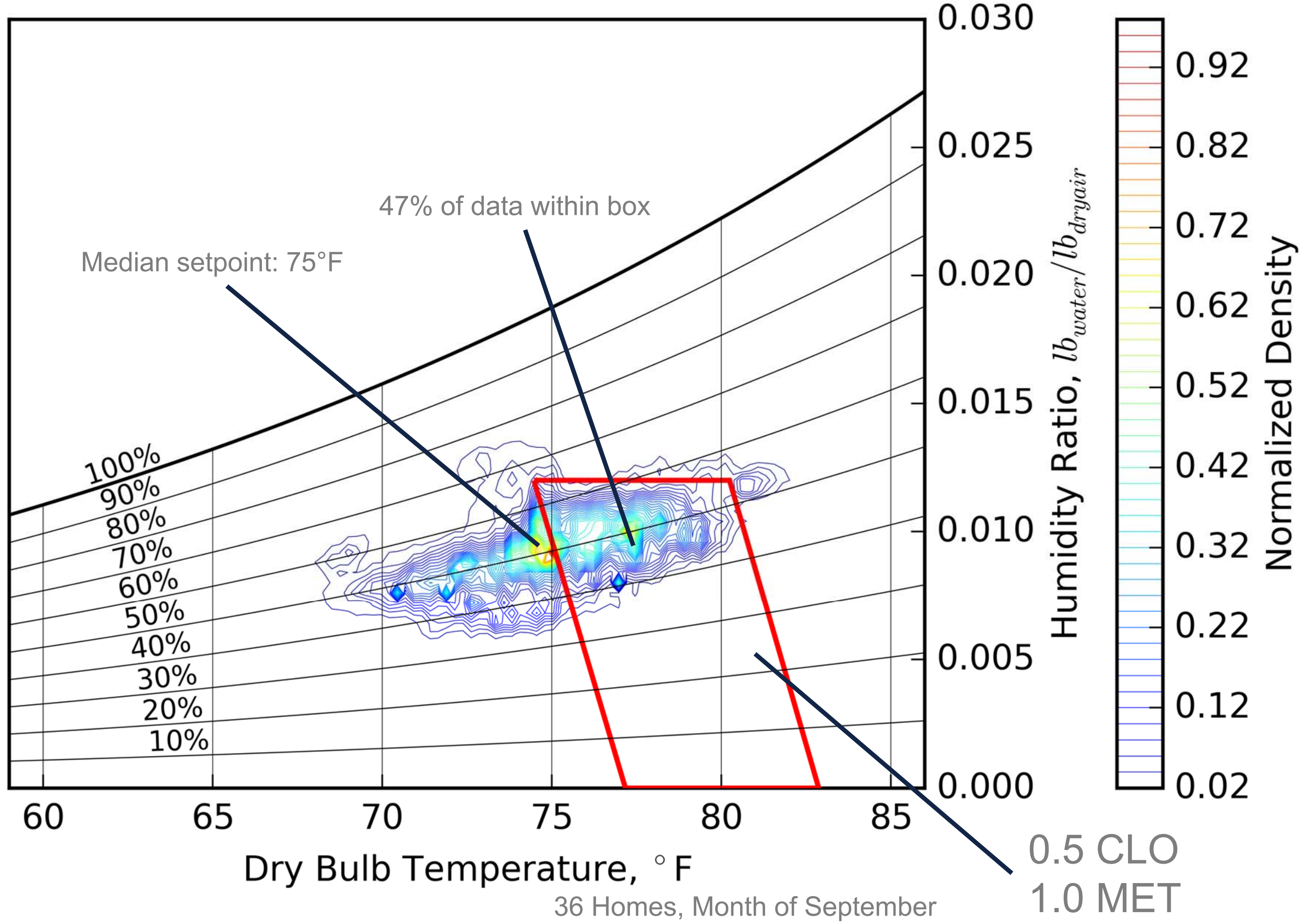
Same Plan
Same Street
Same Orientation

Different Occupants

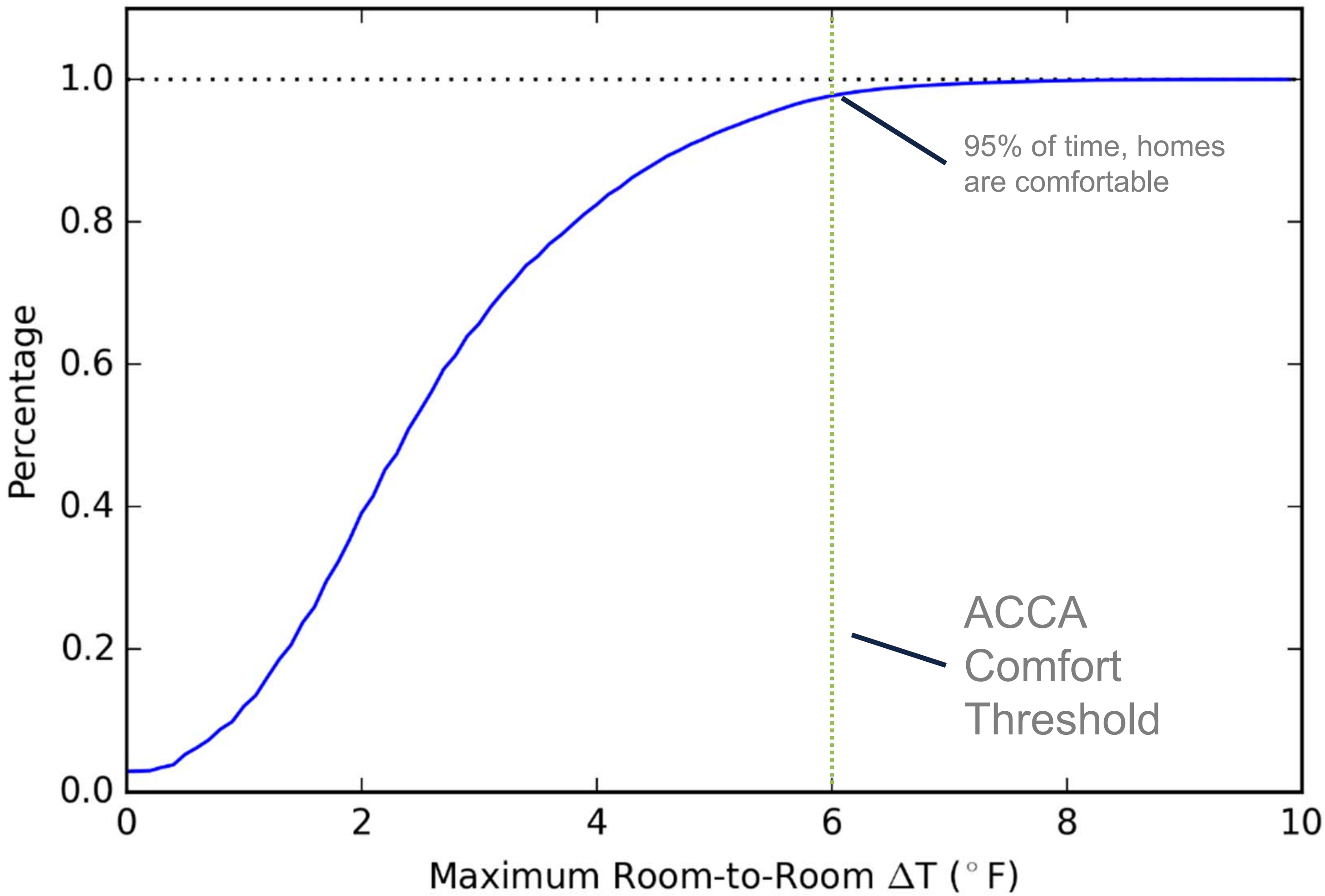
Home 26



Aggregate of 36 Homes

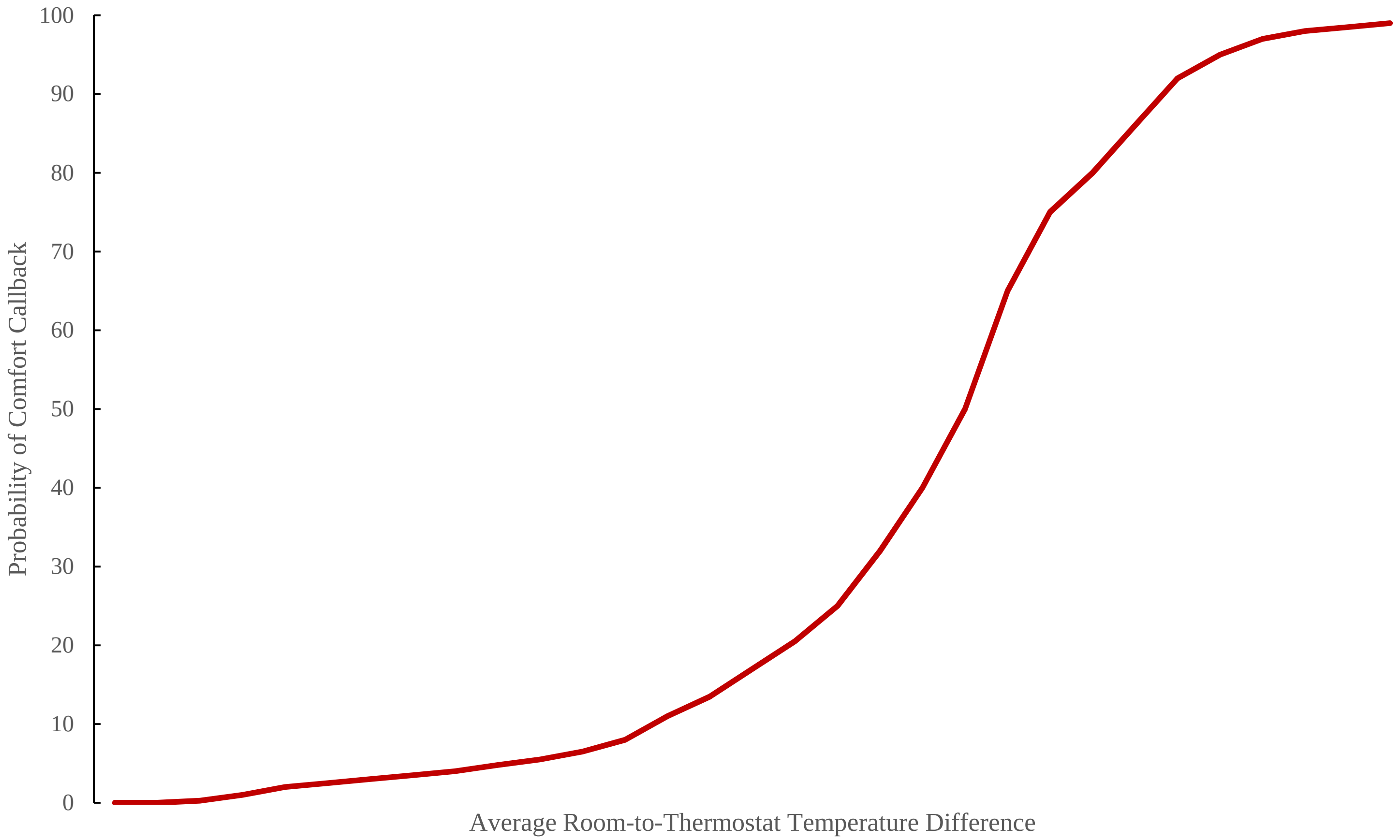


ACCA Comfort, Cumulative Density, 36 Homes



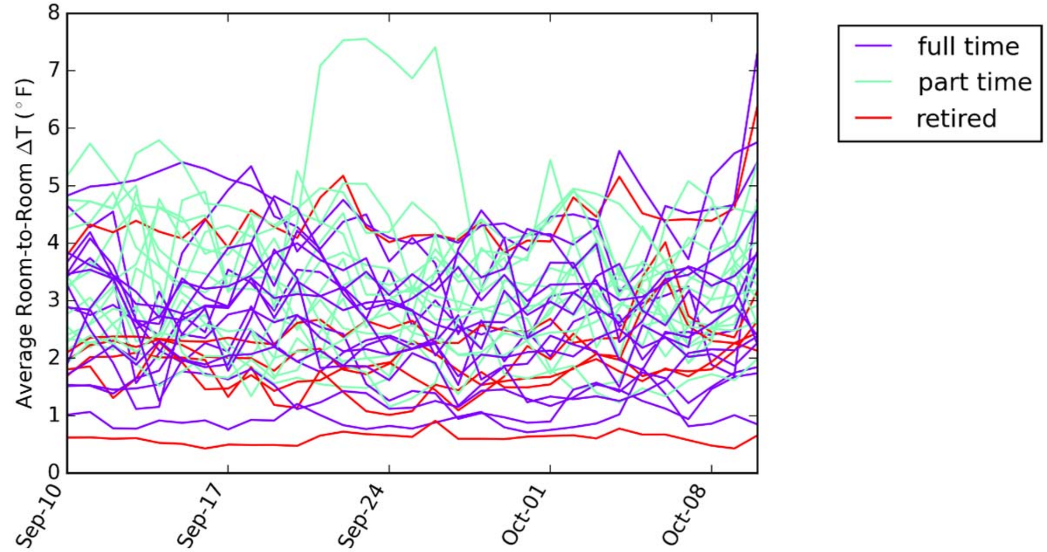
36 Homes, Month of September

Callback Risk, Hypothetical Curve

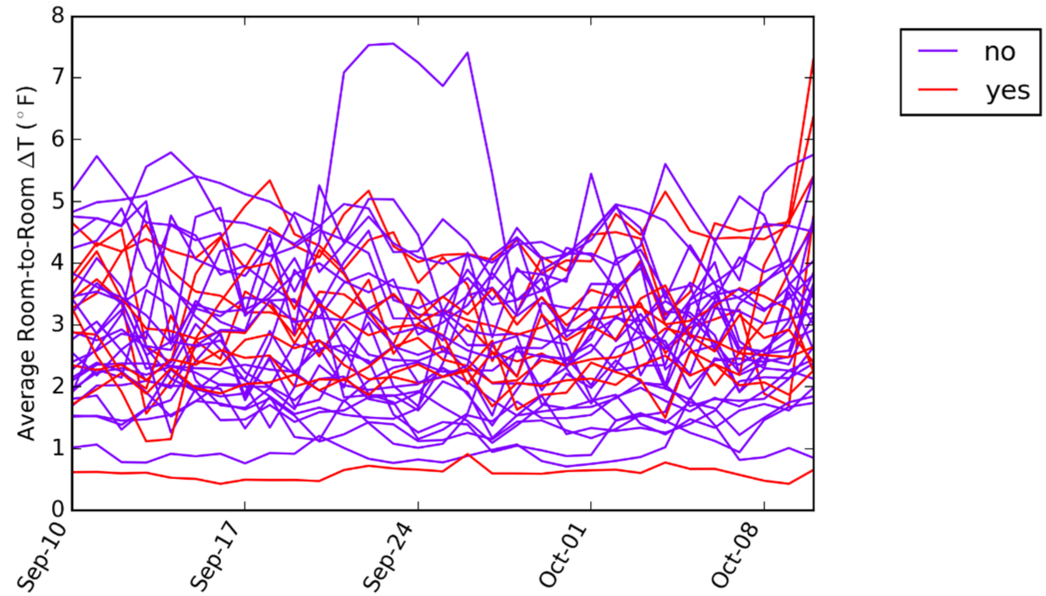


Factors Impacting Comfort

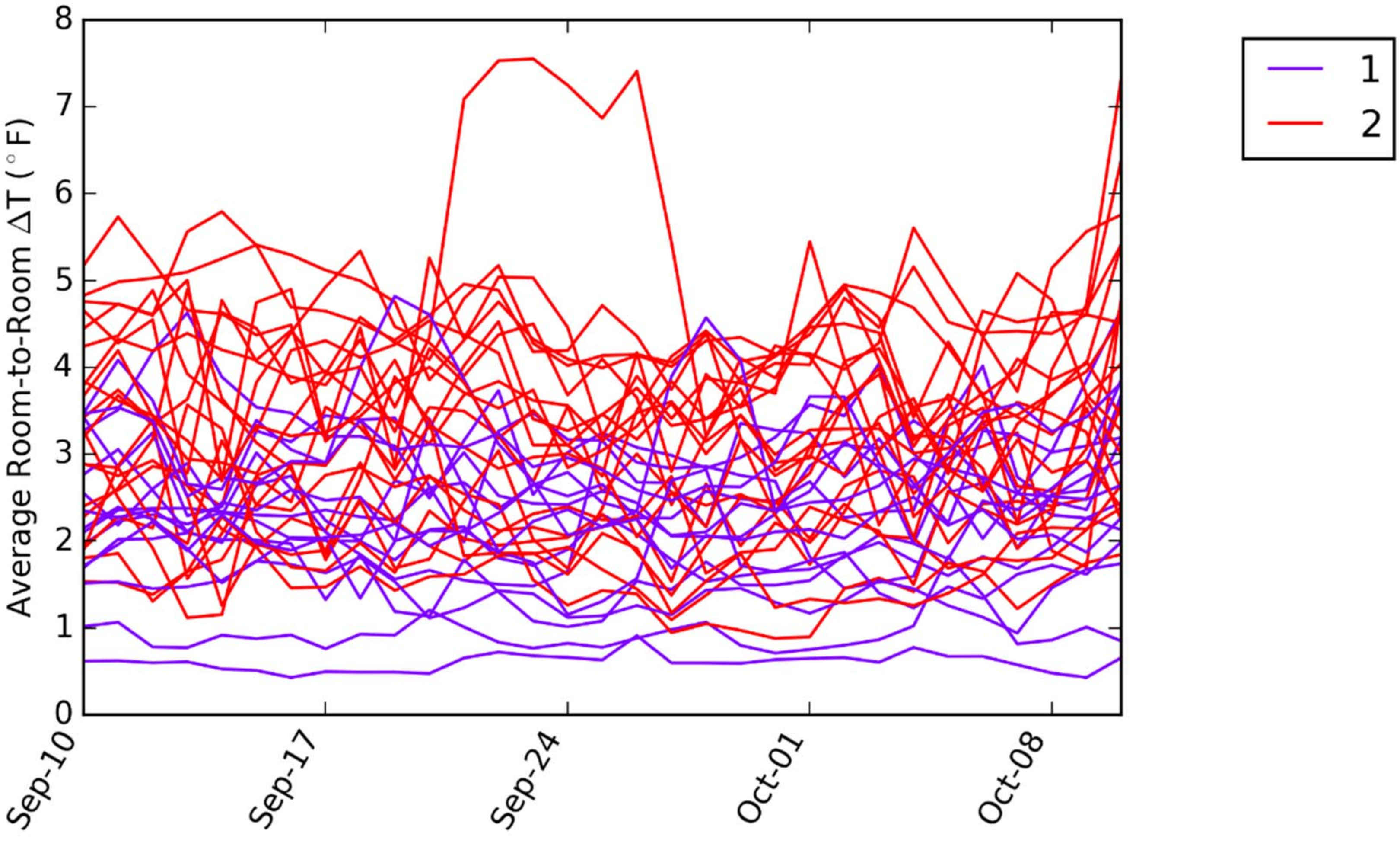
Employment



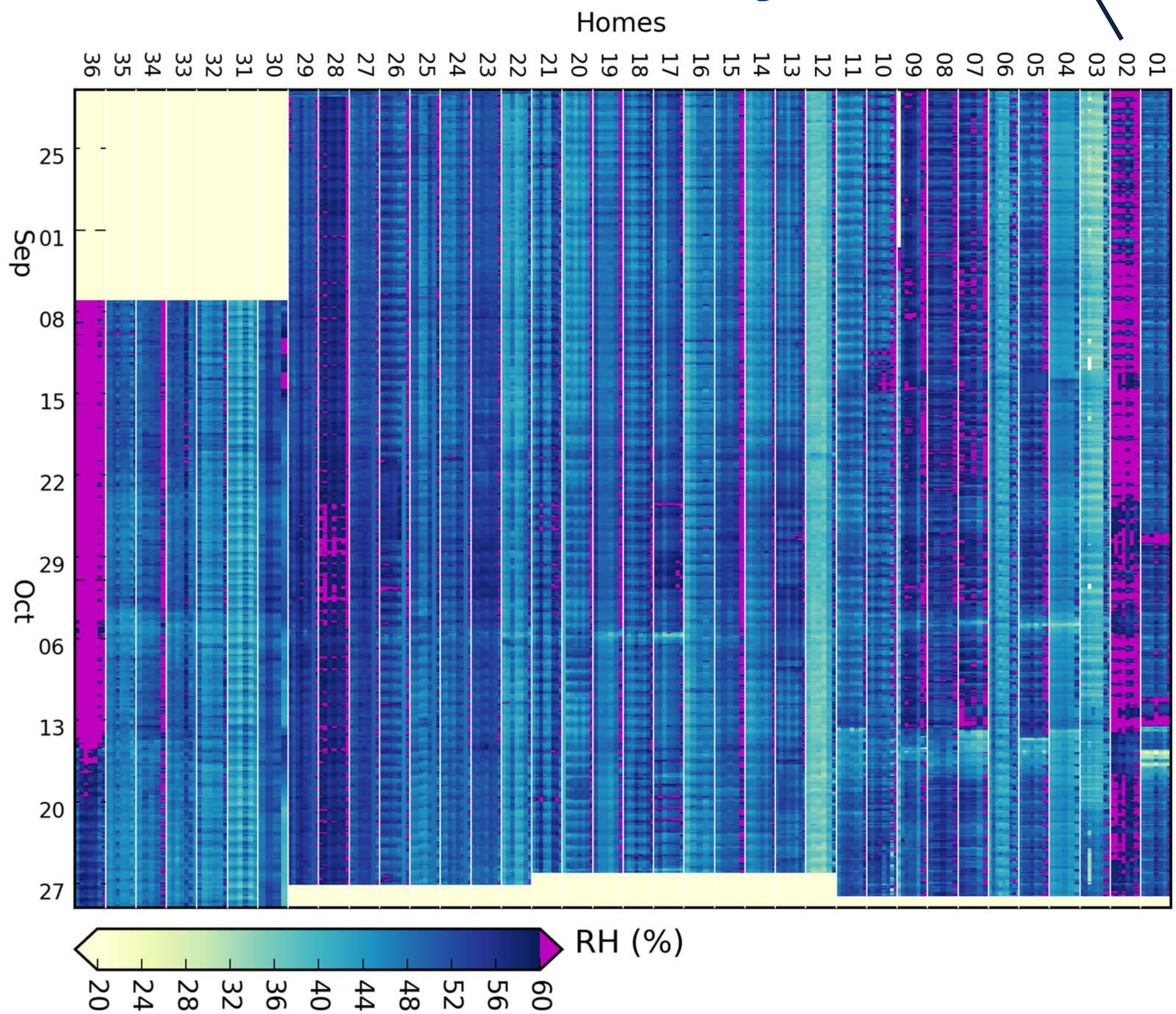
Use of programmable thermostat



Impact of Number of Stories on Comfort



Humidity


Gas Stove
Homes
36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 09 08 07 06 05 04 03 02 01
25
Sep 01
08
15
22
29
Oct
06
13
20
27
RH (%)
20 24 28 32 36 40 44 48 52 56 60

Key Lessons Learned

- “Comfortable” homes can have a wide range of temperatures
- Uniformity is a better metric for judging comfort
- Humidity maintained below 60% without active dehumidification
- Comfort guarantee has added upfront costs, but builders feel it is worth it

Comparative Modeling

TRNSYS Multizone Thermal Model

99 Models

- 3 Home Geometries
- 3 Climate Zones
- 3 System Types
- 5 Control Strategies

Zero Energy Ready Home Enclosure MSHP, Traditional Central, Small Diameter

1	Single Zone, Single Thermostat	Standard set points: 71°F heating, 76°F cooling
2	Single Zone, Two Thermostats	System runs if one thermostat calls for conditioning. Determine ideal location for second thermostat (e.g., South Bedroom, West Bedroom).
3	Two Zone, Two Thermostats	Determine ideal location for second thermostat (e.g., South Bedroom, West Bedroom).
4	Single Zone, Single Thermostat, Fan On	Constant fan operation, conditioning supplied only as called for by the thermostat.
5	Clever Thermostat	Thermostat reads the weather forecast at the top of each hour and cycles fan during conditions that typically would result in asymmetric loads (e.g., sunny midseason day).

Single Story Slab

Two Story Slab

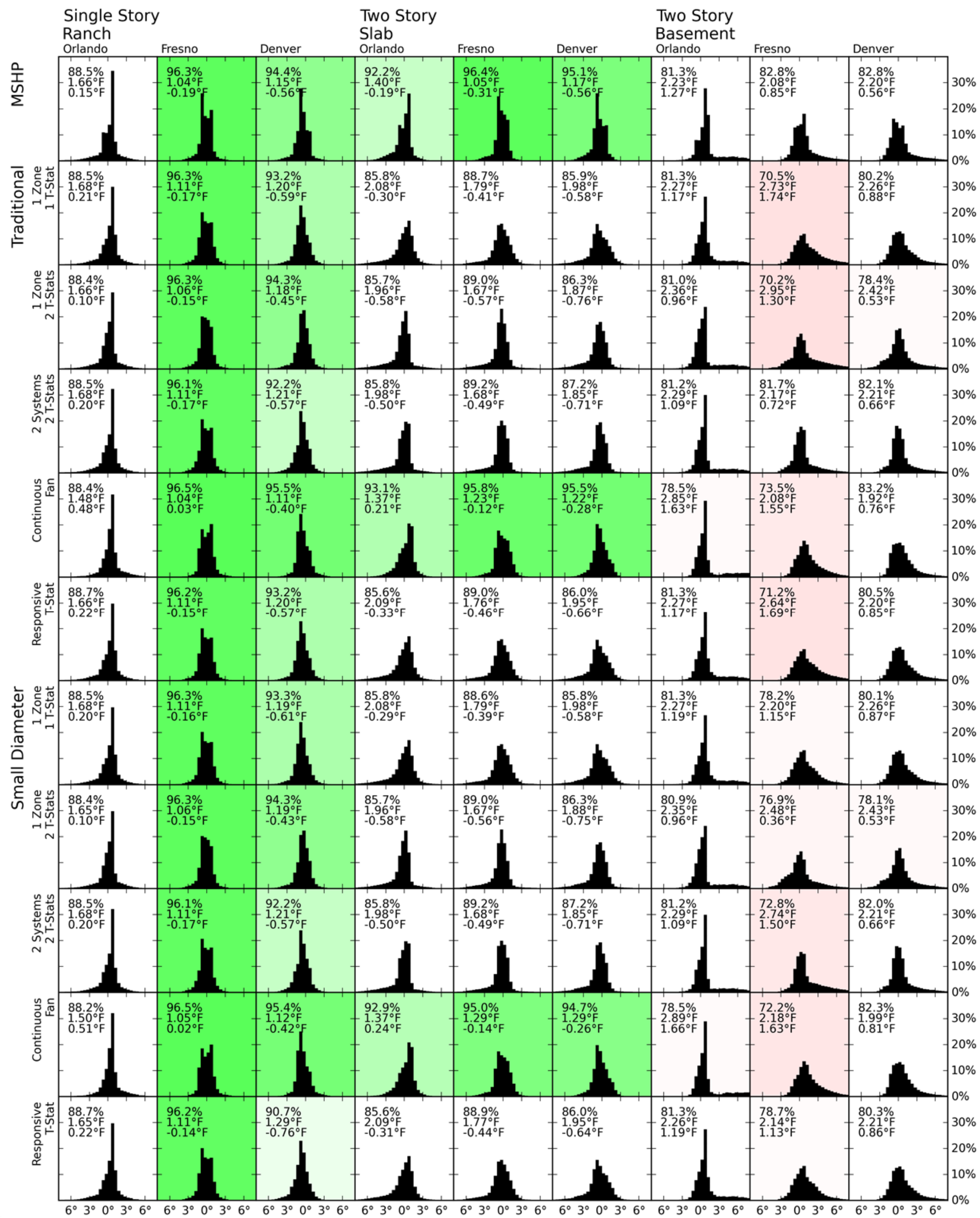
Two Story Basement

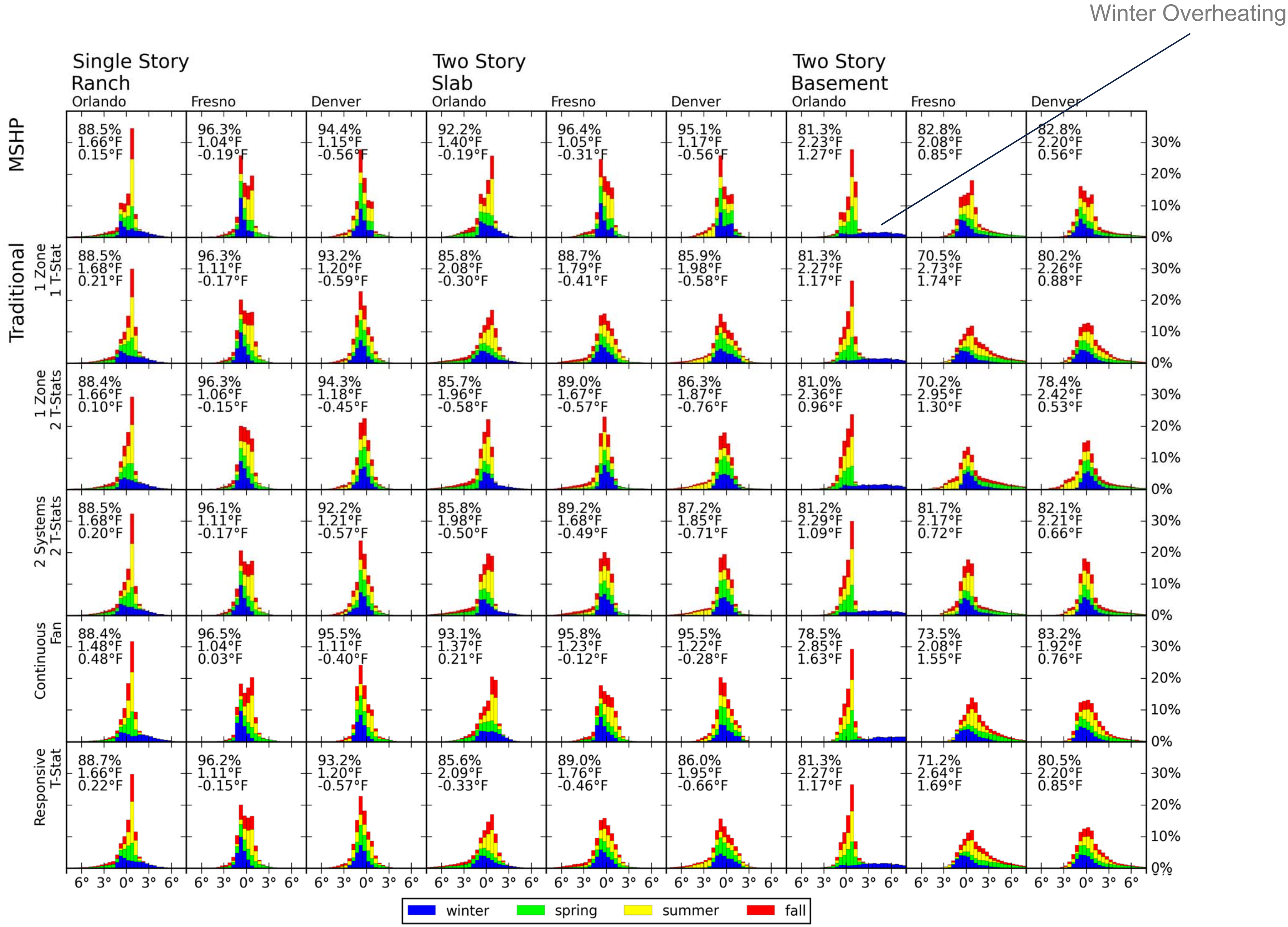
Simple floorplan easy to condition

MSHP among best performers, zone system

In some cases continuous fan made improvements

Differences between small diameter and traditional systems not captured in model





Winter Overheating
Single Story Ranch
Two Story Slab
Two Story Basement
Orlando
Fresno
Denver
Orlando
Fresno
Denver
Orlando
Fresno
Denver
MSHP
88.5% 1.66°F 0.15°F
96.3% 1.04°F -0.19°F
94.4% 1.15°F -0.56°F
92.2% 1.40°F -0.19°F
96.4% 1.05°F -0.31°F
95.1% 1.17°F -0.56°F
81.3% 2.23°F 1.27°F
82.8% 2.08°F 0.85°F
82.8% 2.20°F 0.56°F
Traditional
1 Zone 1 T-Stat
88.5% 1.68°F 0.21°F
96.3% 1.11°F -0.17°F
93.2% 1.20°F -0.59°F
85.8% 2.08°F -0.30°F
88.7% 1.79°F -0.41°F
85.9% 1.98°F -0.58°F
81.3% 2.27°F 1.17°F
70.5% 2.73°F 1.74°F
80.2% 2.26°F 0.88°F
1 Zone 2 T-Stats
88.4% 1.66°F 0.10°F
96.3% 1.06°F -0.15°F
94.3% 1.18°F -0.45°F
85.7% 1.96°F -0.58°F
89.0% 1.67°F -0.57°F
86.3% 1.87°F -0.76°F
81.0% 2.36°F 0.96°F
70.2% 2.95°F 1.30°F
78.4% 2.42°F 0.53°F
2 Systems 2 T-Stats
88.5% 1.68°F 0.20°F
96.1% 1.11°F -0.17°F
92.2% 1.21°F -0.57°F
85.8% 1.98°F -0.50°F
89.2% 1.68°F -0.49°F
87.2% 1.85°F -0.71°F
81.2% 2.29°F 1.09°F
81.7% 2.17°F 0.72°F
82.1% 2.21°F 0.66°F
Continuous Fan
88.4% 1.48°F 0.48°F
96.5% 1.04°F 0.03°F
95.5% 1.11°F -0.40°F
93.1% 1.37°F 0.21°F
95.8% 1.23°F -0.12°F
95.5% 1.22°F -0.28°F
78.5% 2.85°F 1.63°F
73.5% 2.08°F 1.55°F
83.2% 1.92°F 0.76°F
Responsive T-Stat
88.7% 1.66°F 0.22°F
96.2% 1.11°F -0.15°F
93.2% 1.20°F -0.57°F
85.6% 2.09°F -0.33°F
89.0% 1.76°F -0.46°F
86.0% 1.95°F -0.66°F
81.3% 2.27°F 1.17°F
71.2% 2.64°F 1.69°F
80.5% 2.20°F 0.85°F
30% 20% 10% 0%
6° 3° 0° 3° 6°
winter
spring
summer
fall

Animated Plan: Summer

Animated Plan: Winter

Animated Plan: All Homes

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Lessons Learned

Geometry design and HVAC design are highly interdependent. In a low load home, you can't drop in a system and hope it works.

Single floor plan with central connecting space easiest to condition

Window orientation and percentage of wall area significantly impacted comfort. In these cases two thermostats or two systems necessary.

Climate zones with large diurnal swings greater challenge to condition, thermal mass may help. Continuous fan can also help by mixing top and bottom floors.

What works in one home might not work in another.

Shrinking Thermal Loads

2,000 SQ. FT.

5 tons –
2,000 CFM

Past 400 SQ. FT. / TON

2,000 SQ. FT.

3 tons –
1,200 CFM

Present 667 SQ. FT. / TON

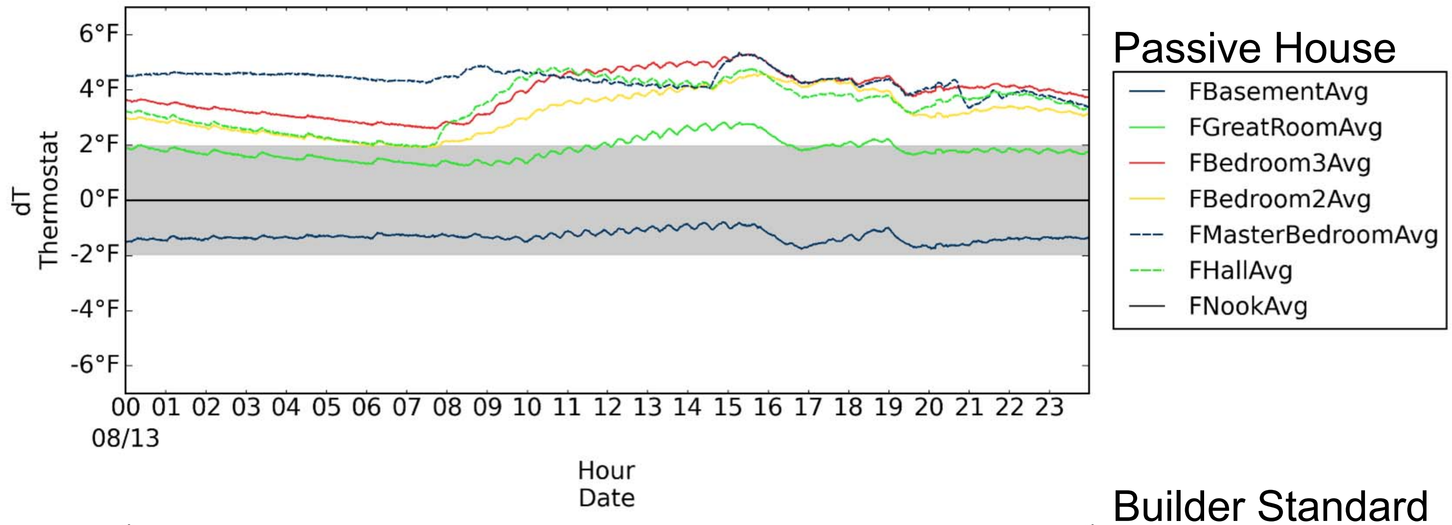
2,000 SQ. FT.

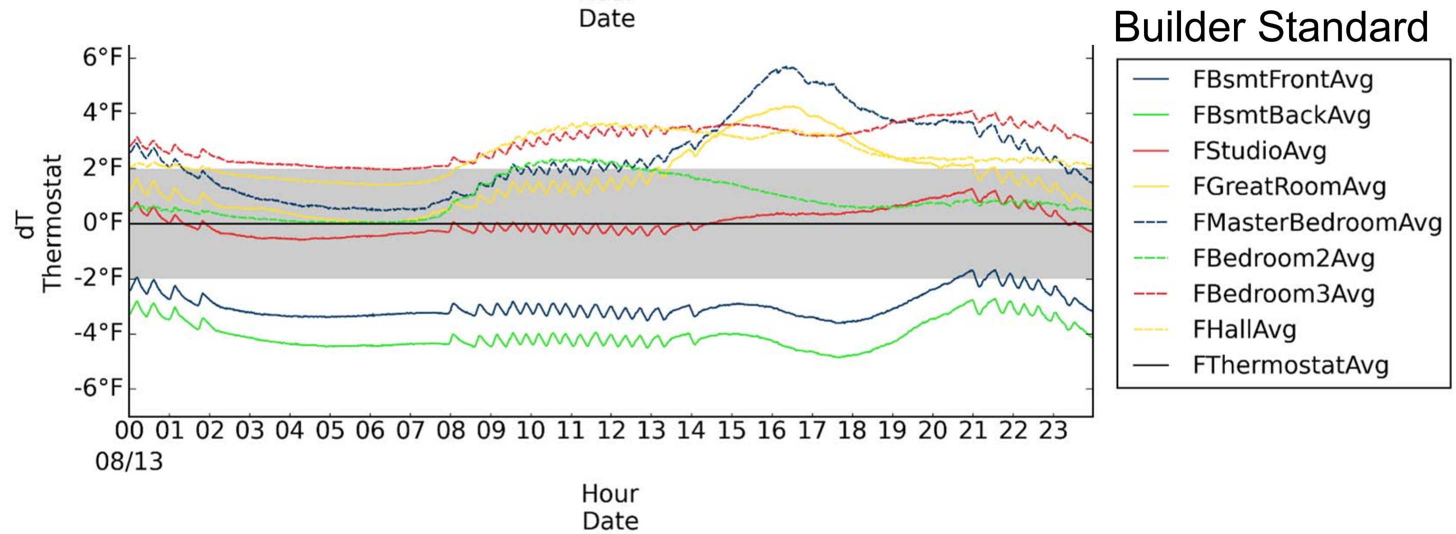
1.5 tons –
600 CFM

Future 1333 SQ. FT. / TON

Challenge:

Providing comfort and efficiency in low load homes





Air Delivery is Key

Multifamily Case Study
Comparing Small Diameter to Traditional Ductwork

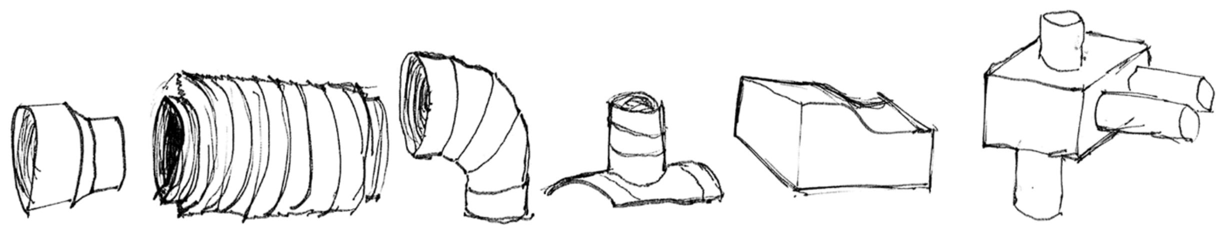
Denver, CO

Stapleton Community

Newtown Builders

3 Unit Town Homes

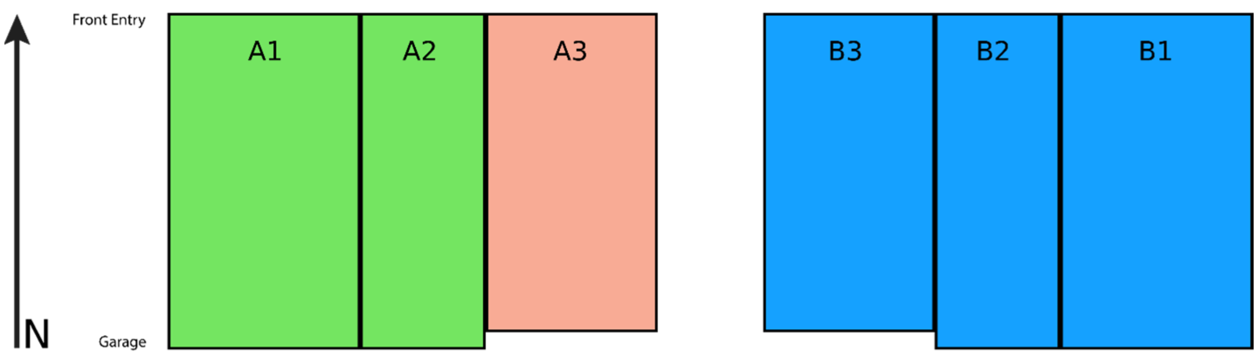
Cooling Season Data



Project Overview

Unico | Standard

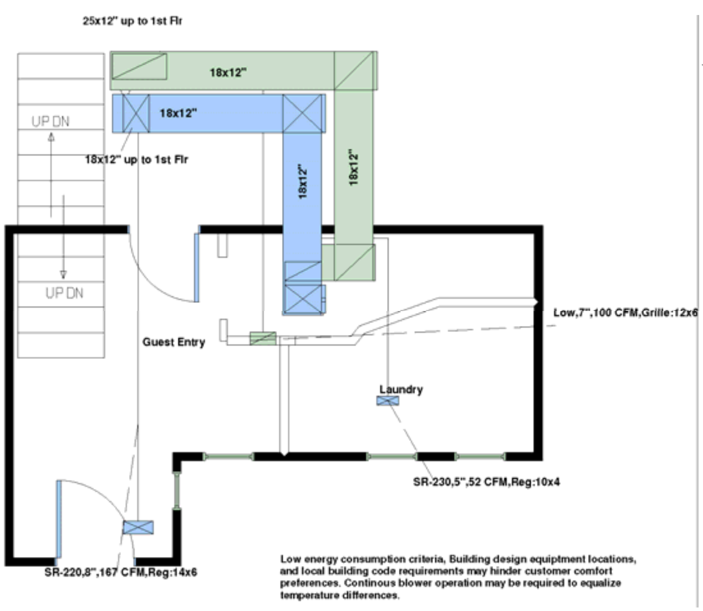
Small Diameter | MSHP | Central DX



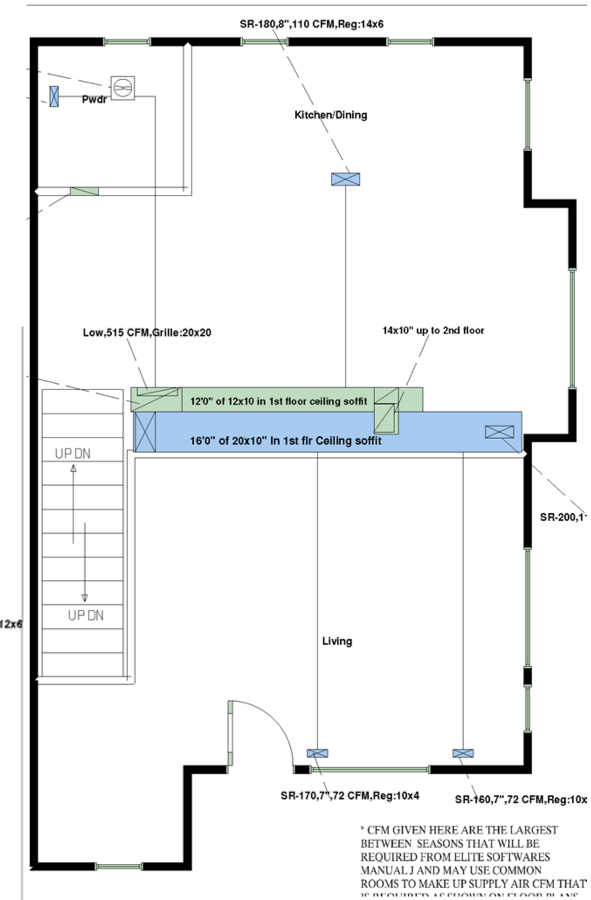
Home Specifications

	A1	A2	A3	B1	B2	B3
Design Cooling Load (kBtu/h)	16	13	18	16	13	18
Air Conditioner Rated Capacity (kBtu/h)	24	24	36	24	18	24
Outdoor Unit Model	IS24G065	IS24G065	IS36G110	CA13NA24	CA13NA18	CA13NA24
Air Handling Unit Model	M2430BL1-EA2	M2430BL1-EA2	IS12MPA	59SC2C040S17	59SC2C040S17	59SC2C040S17
Ductwork Location	Conditioned space	Conditioned space	Conditioned space	Conditioned space	Conditioned space	Conditioned space
Air Handling Unit Location	Second floor	Second floor	High wall fan coil	First floor	First floor	First floor
Building Measured Air Leakage (ACH 50)	2.97	3.49	3.98	2.15	2.73	3.18
Building Measured Air Leakage (CFM 50)	857	750	993	632	585	792
Ductwork Measured Air Leakage (CFM @ 25 Pa)	54	47	N/A	5	5	na
Floor Area	1,300 ft^2	1,100 ft^2	1,600 ft^2	1,300 ft^2	1,100 ft^2	1,600 ft^2
SF / Ton	**977**	**1018**	**1067**	**977**	**1018**	**1068**

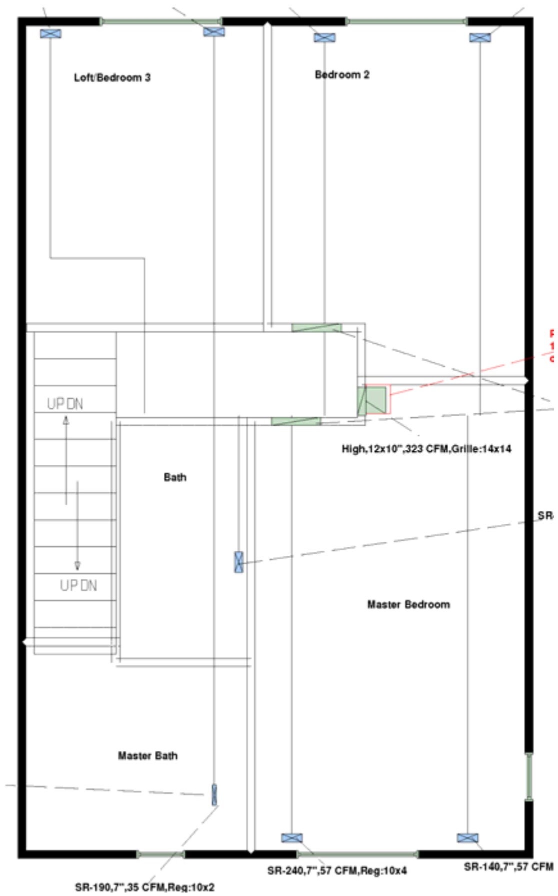
Traditional Ductwork Layout



Floor 1



Floor 2



Floor 3

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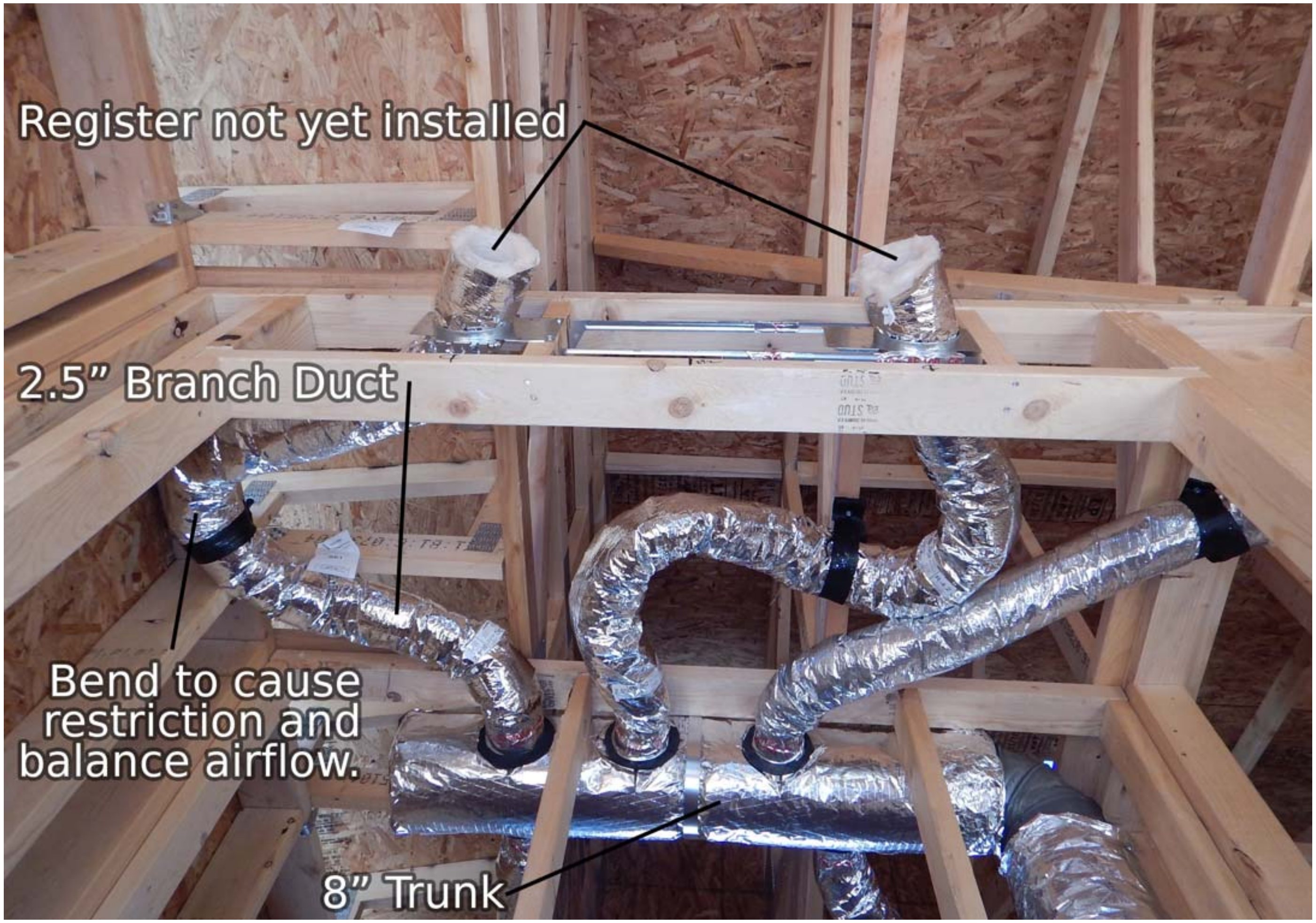
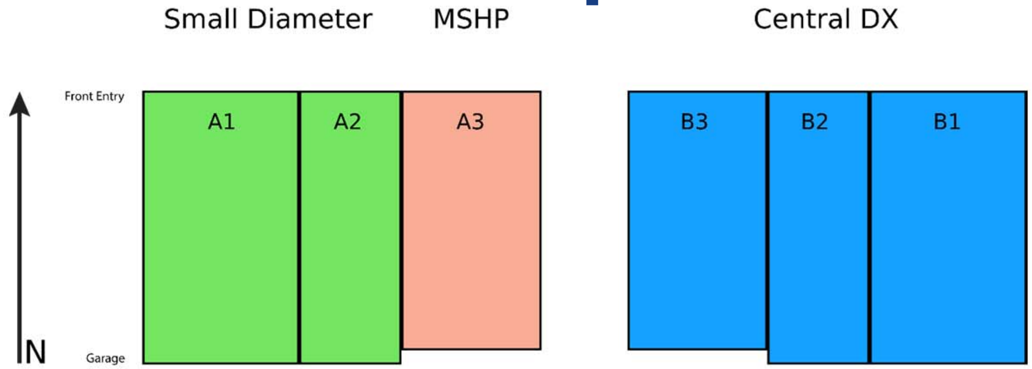
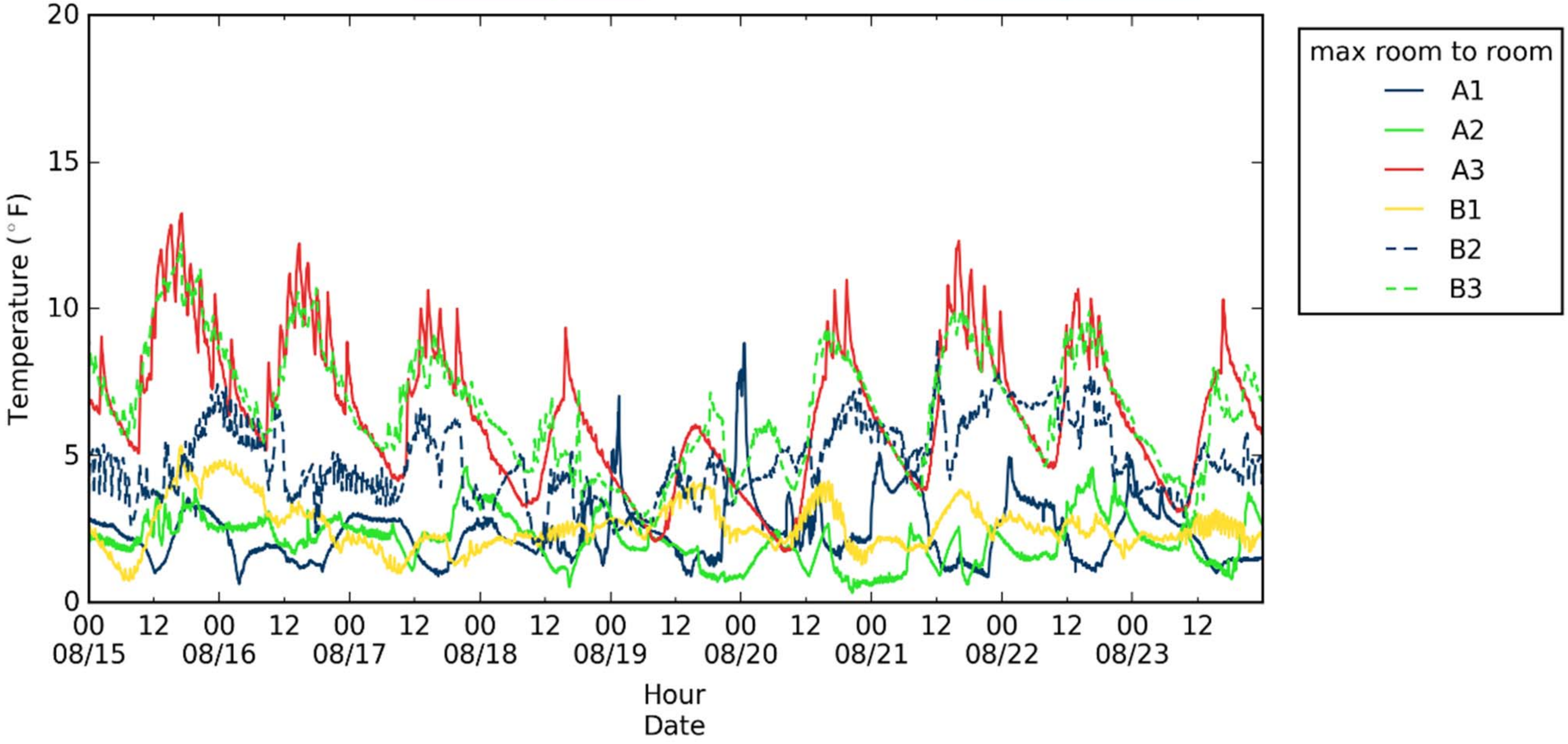
Small Diameter Ductwork Layout

Small Diameter Ductwork

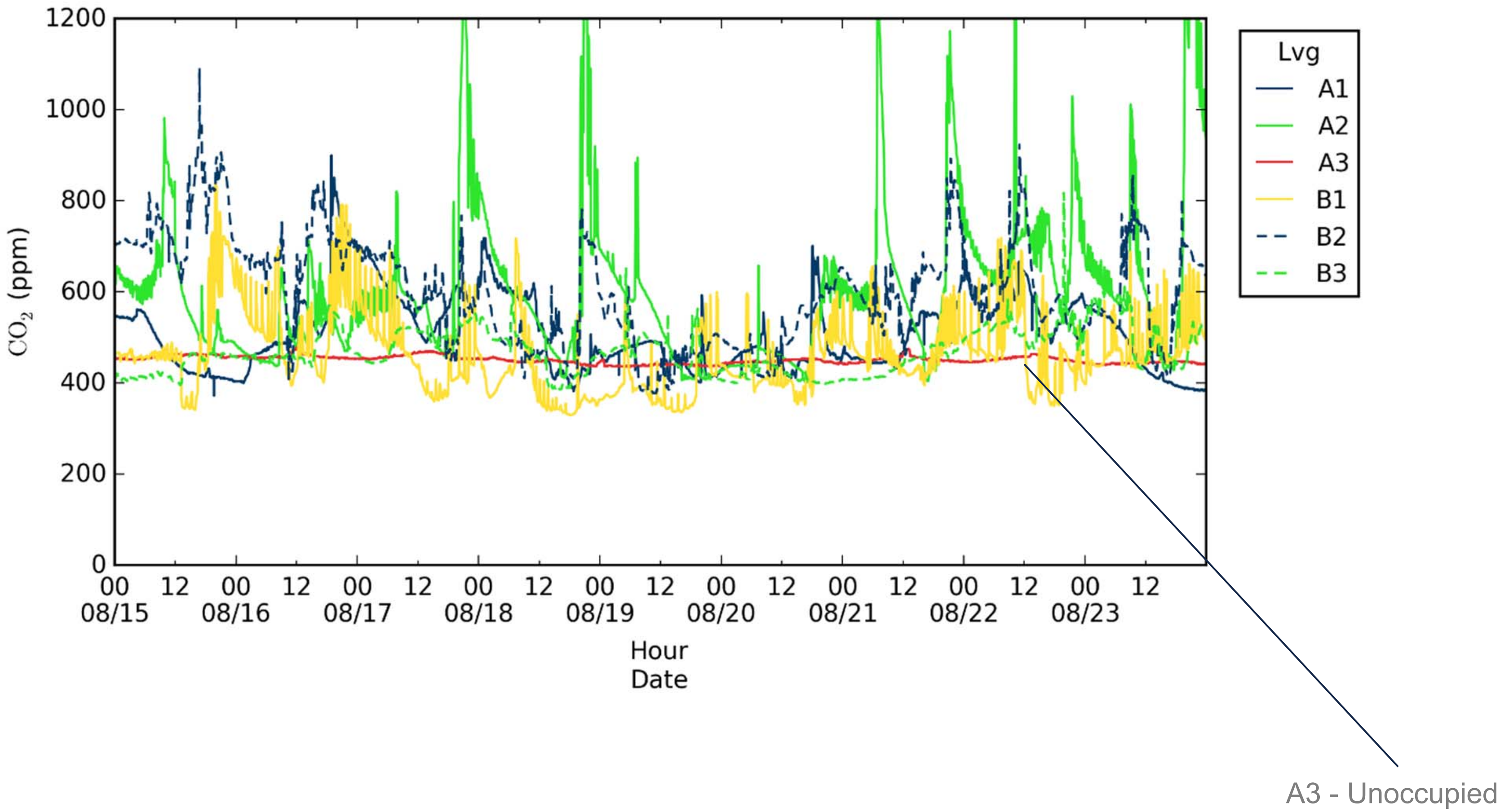


Room-to-Room Temperature Performance





CO2 in Main Living Space of Each Home



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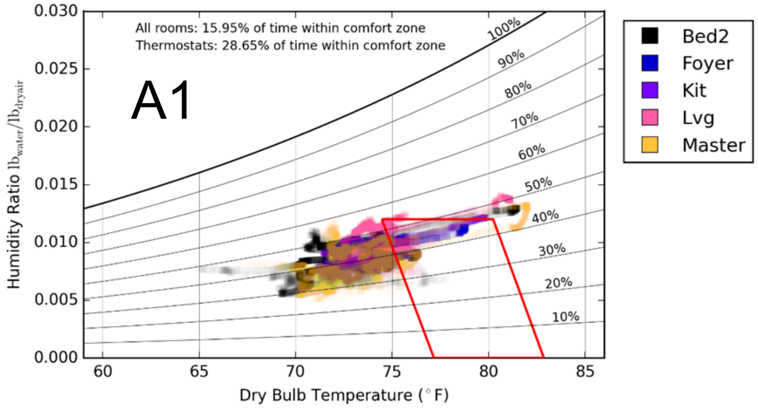
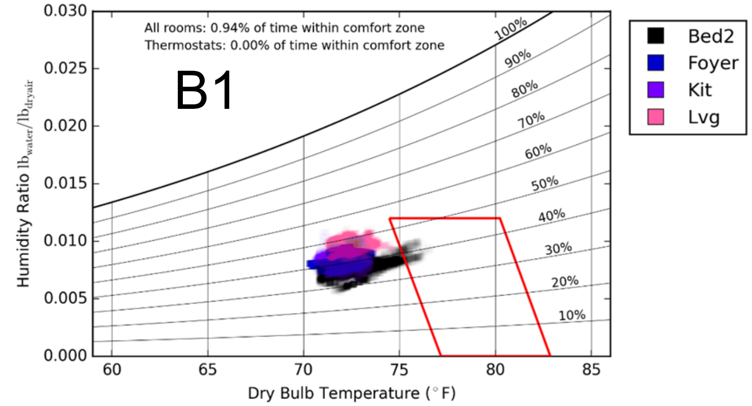
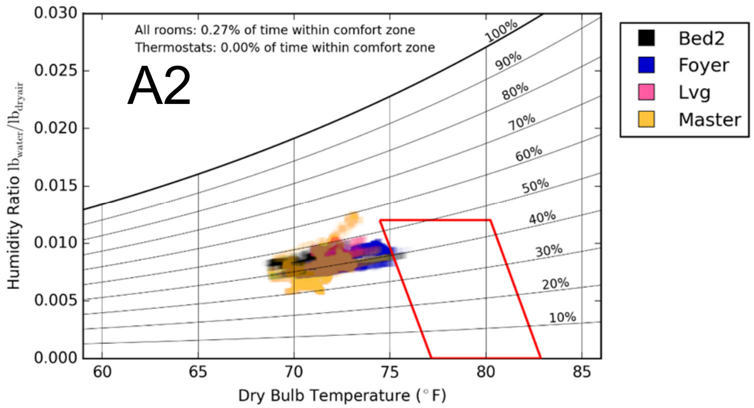
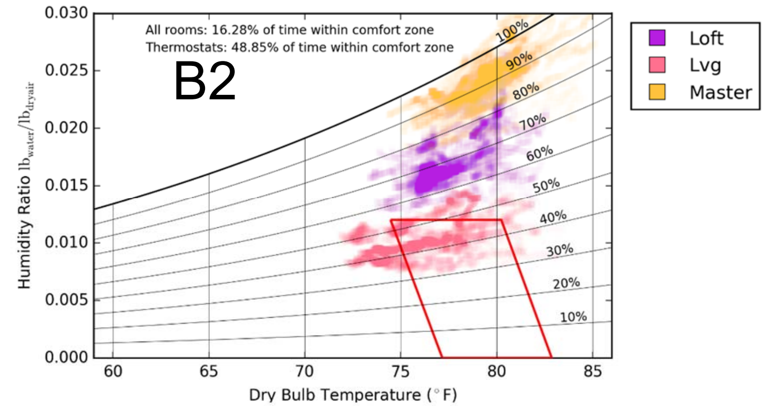
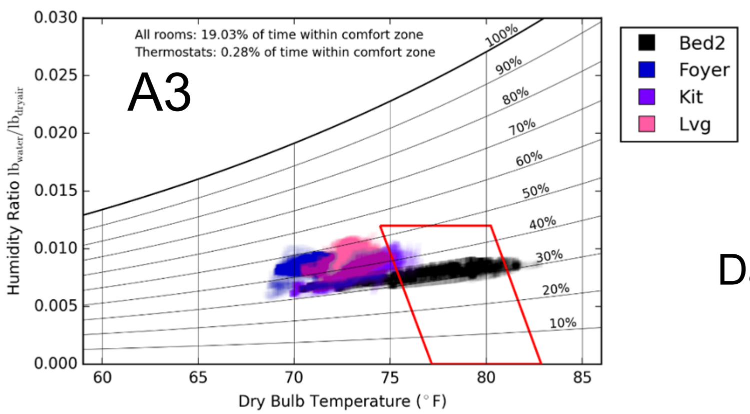
Psychrometrics and ASHRAE 55 Comfort Box



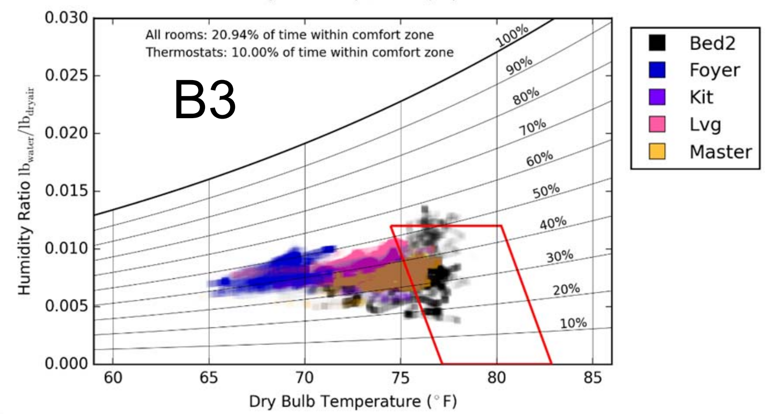




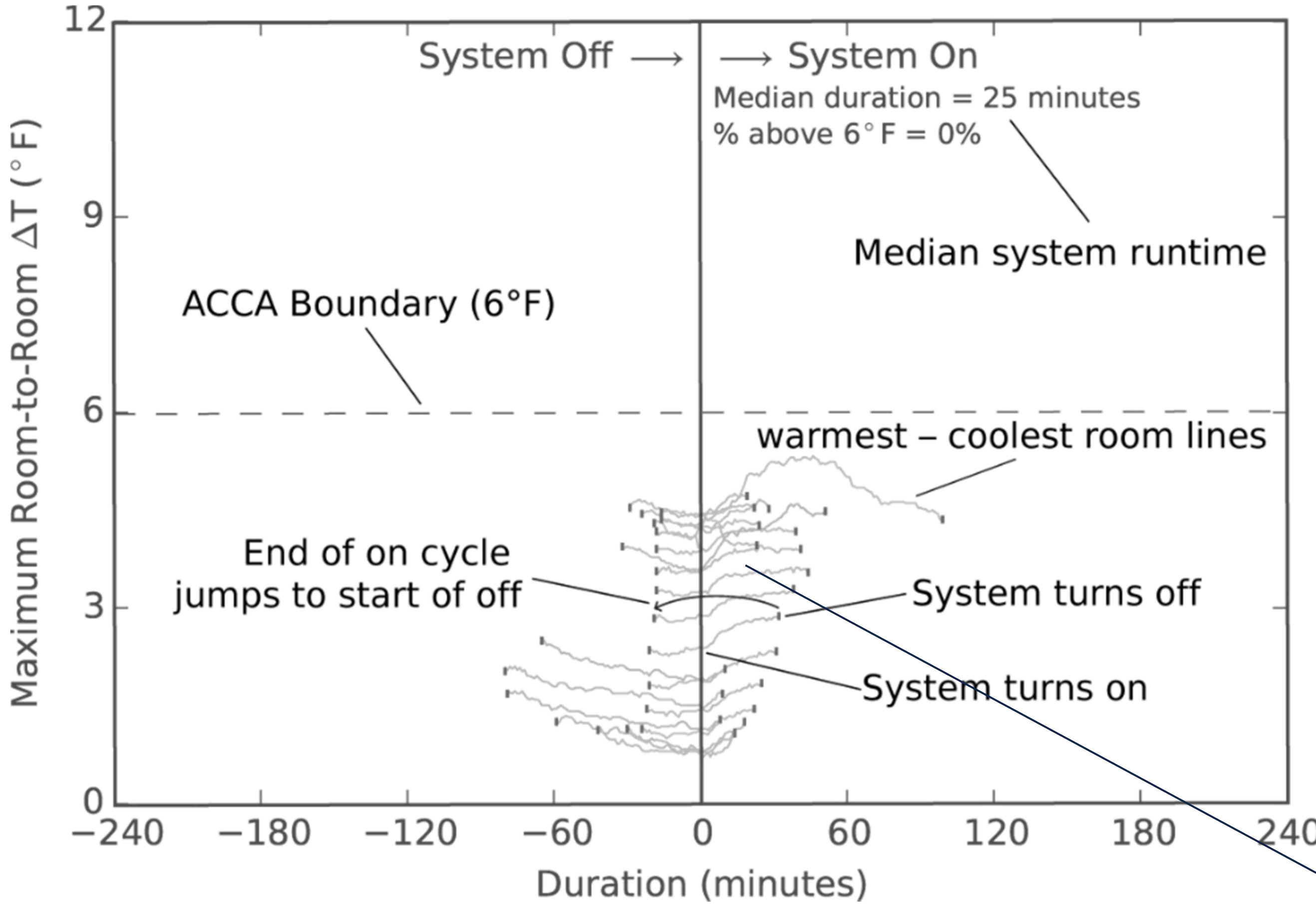




Data from 9 days plotted



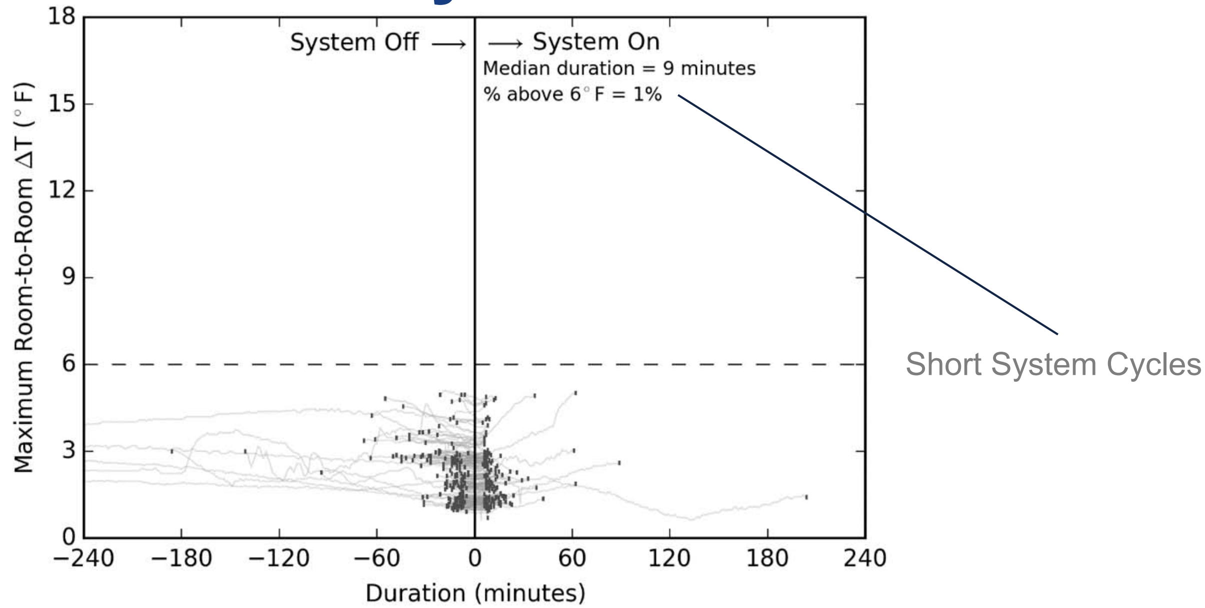
"Hair" Plot Explanation



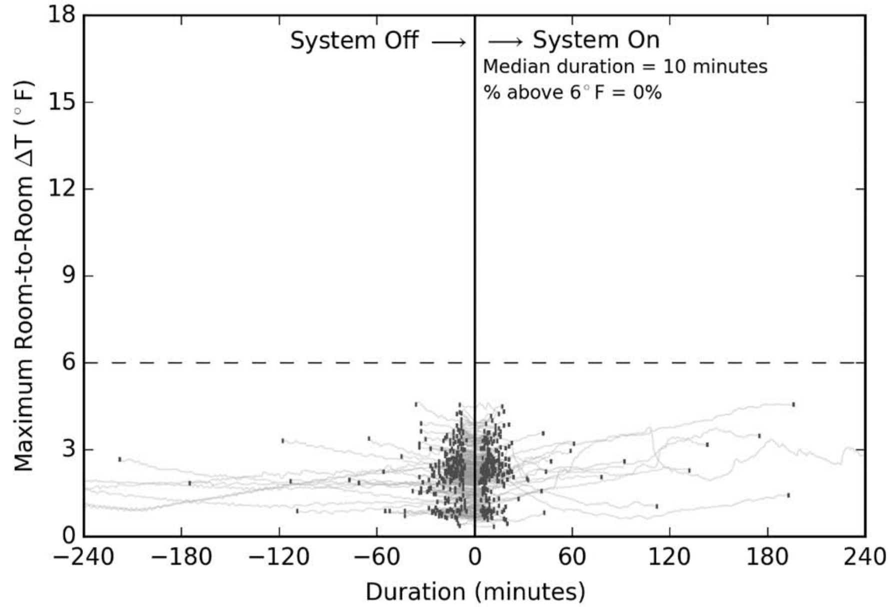
Balanced System Should Maintain Temperature Uniformity

Small Diameter System Hair Plots

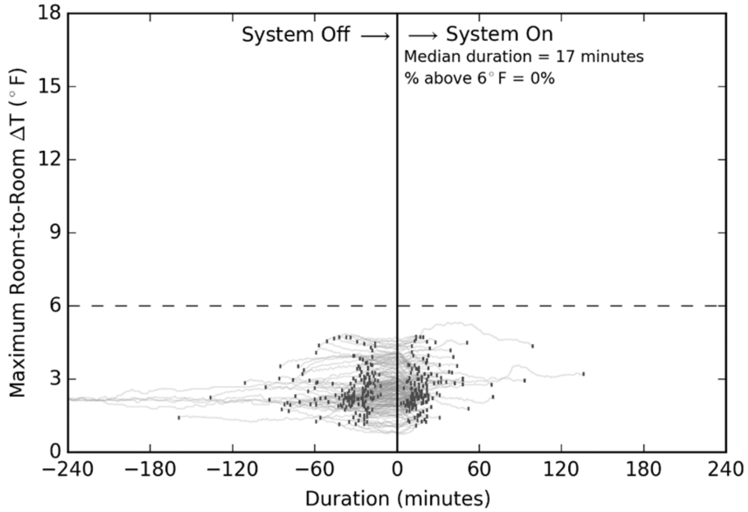
A1



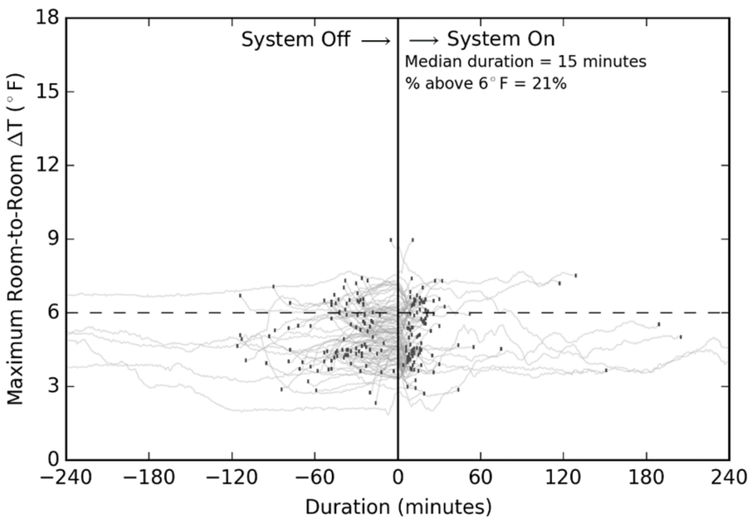
A2



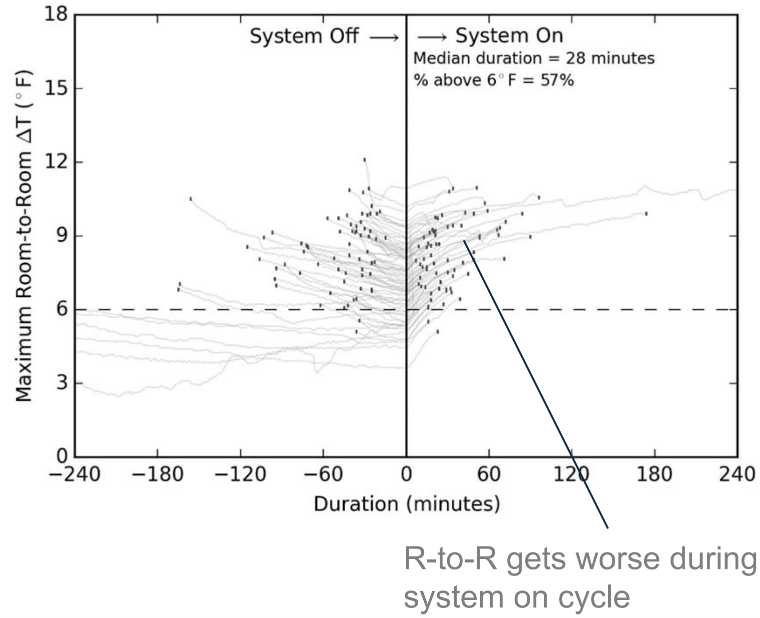
Traditional System Hair Plots



B1

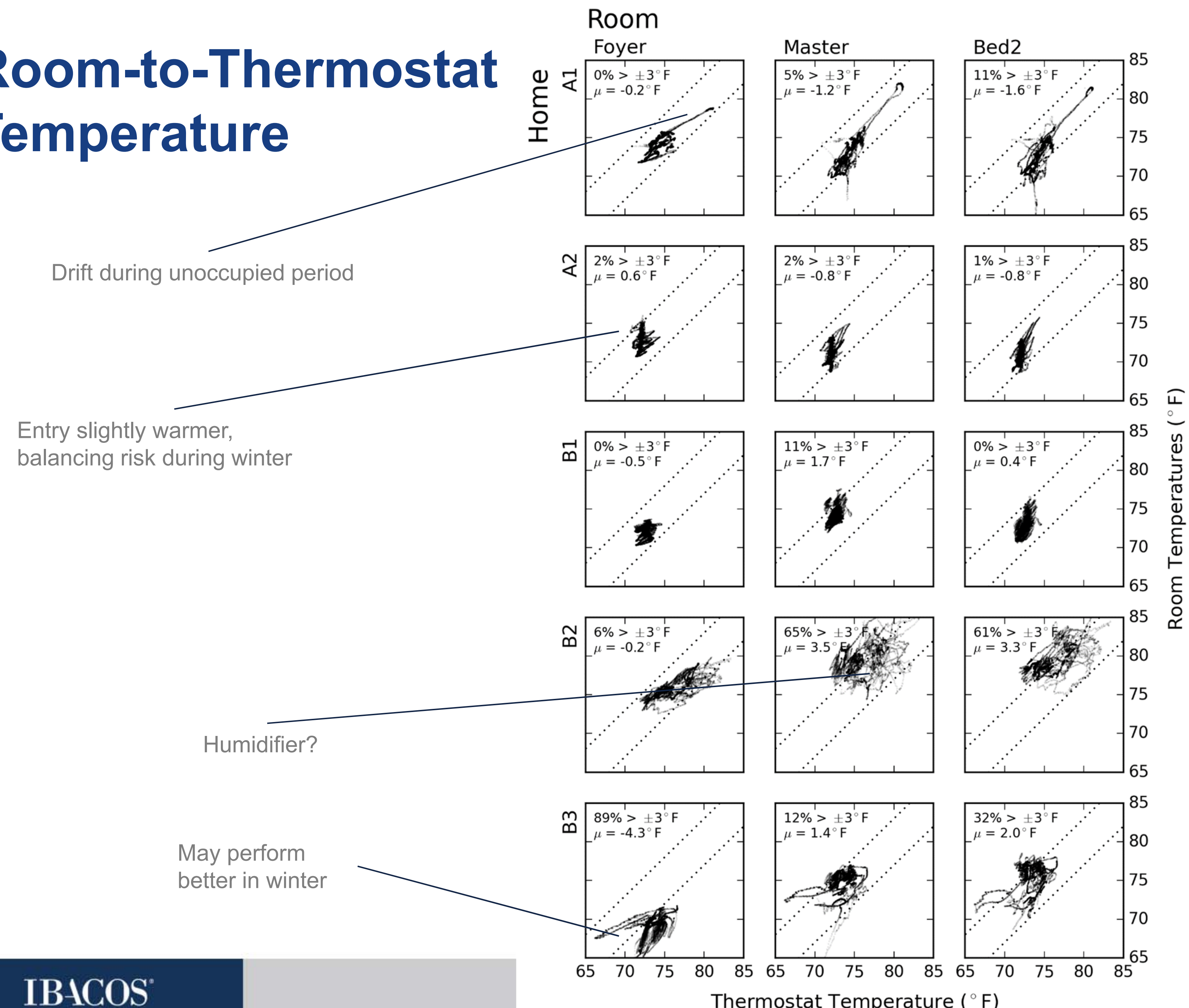


B2



B3

Room-to-Thermostat Temperature



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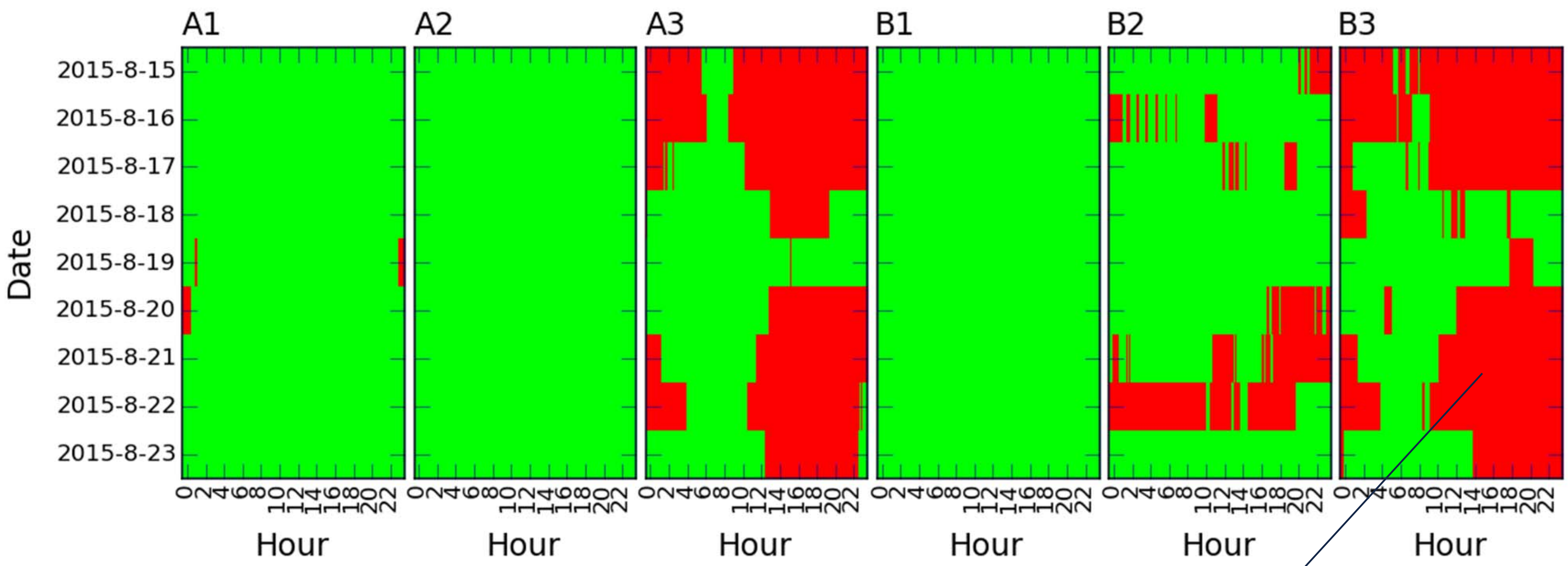
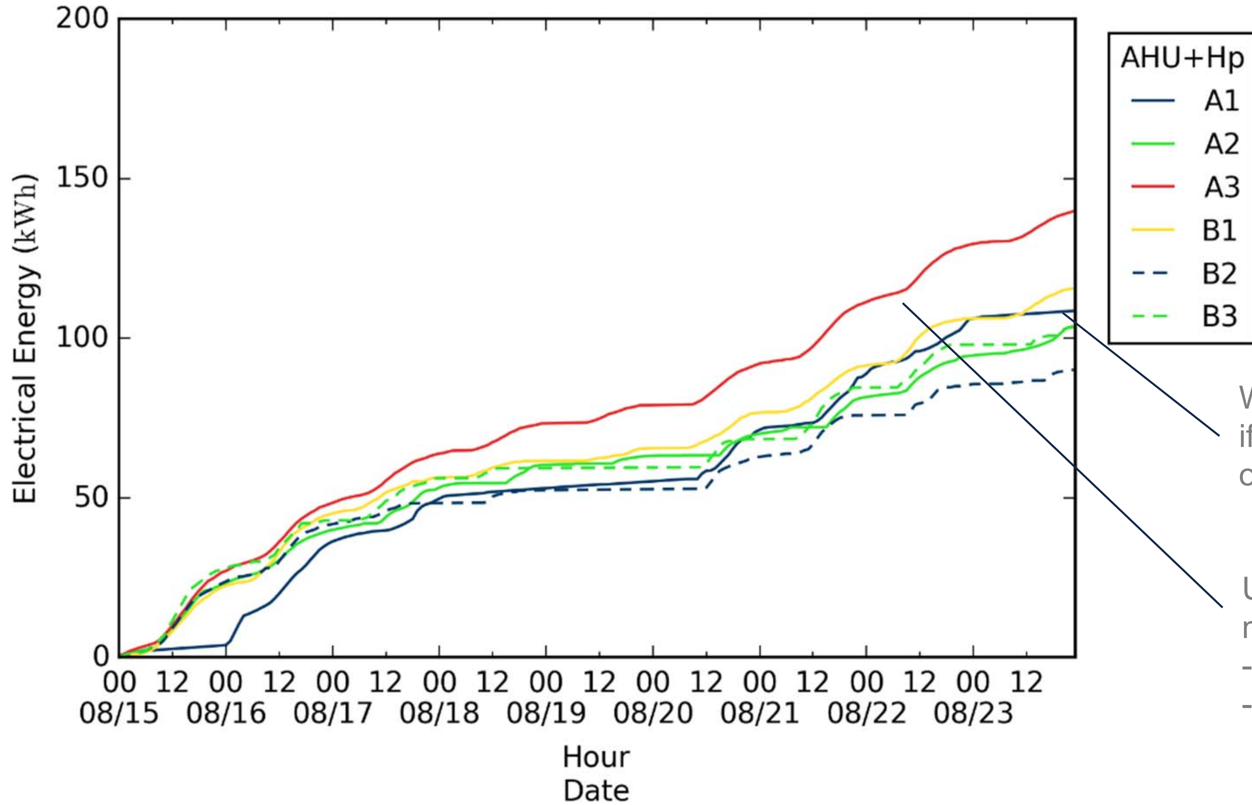
Room-to-Room Temperature Difference



Red indicates
ΔT beyond 6°F

Cumulative Energy Use

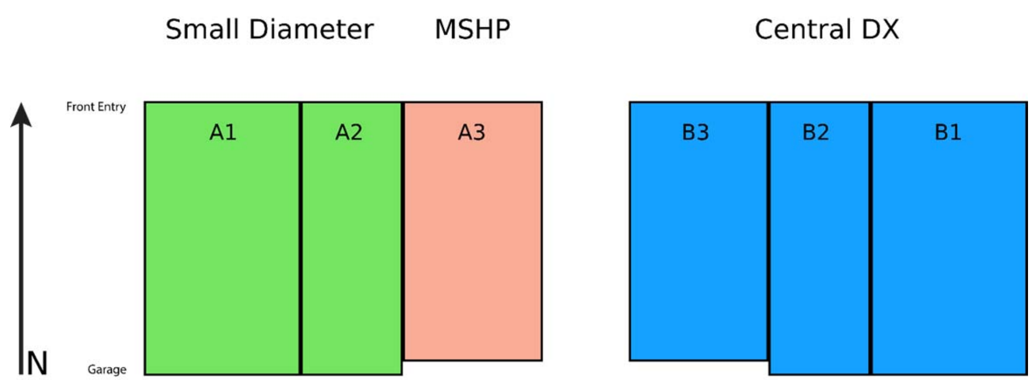


Would use more energy if normalized for occupancy

Unoccupied MSHP uses most energy?
-no shades
-no natural ventilation

System Performance Summary

	A1	A2	A3	B1	B2	B3
Total HVAC Energy (kWh)	109	103	140	116	90	104
Average Daily Runtime (min)	297	562	N/A	415	358	324
Average Thermostat (°F)	74.6	72.1	72.8	72.5	76.1	73.3
Average Room-to-Room ΔT (°F)	2.4	2.1	6.4	2.6	4.8	6.6



Tips for Success for Small Diameter Systems

Evenly space take-offs from plenum

Branch ducts 6 – 10 ft long.

Commission system at rough in stage

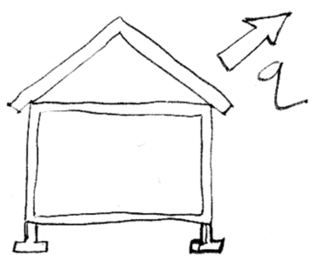
1.2-1.8 in. w.c. target. 1.5 in. optimal

Home Run Manifold System

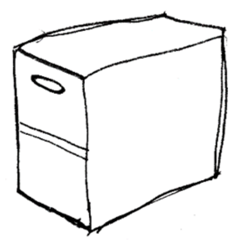
Plug and Play Design Methodology

Predictable airflows

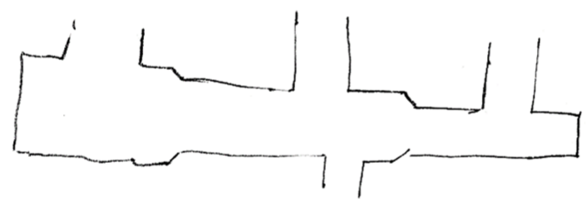
Easily fits within conditioned space



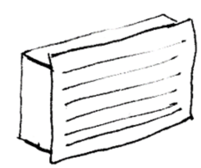
"J"



"S"

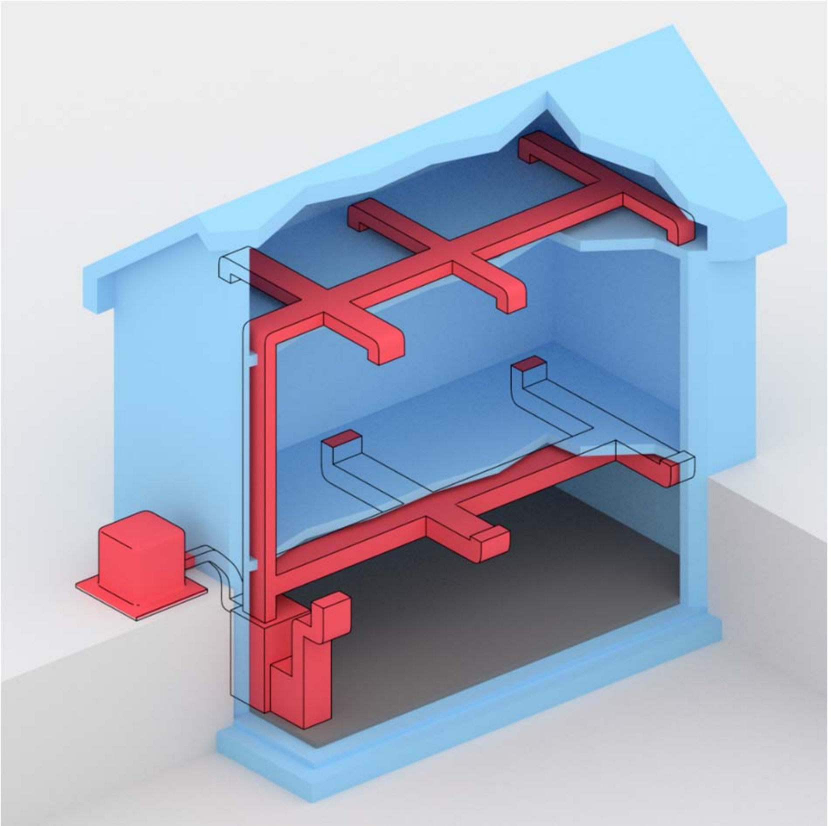


"D"

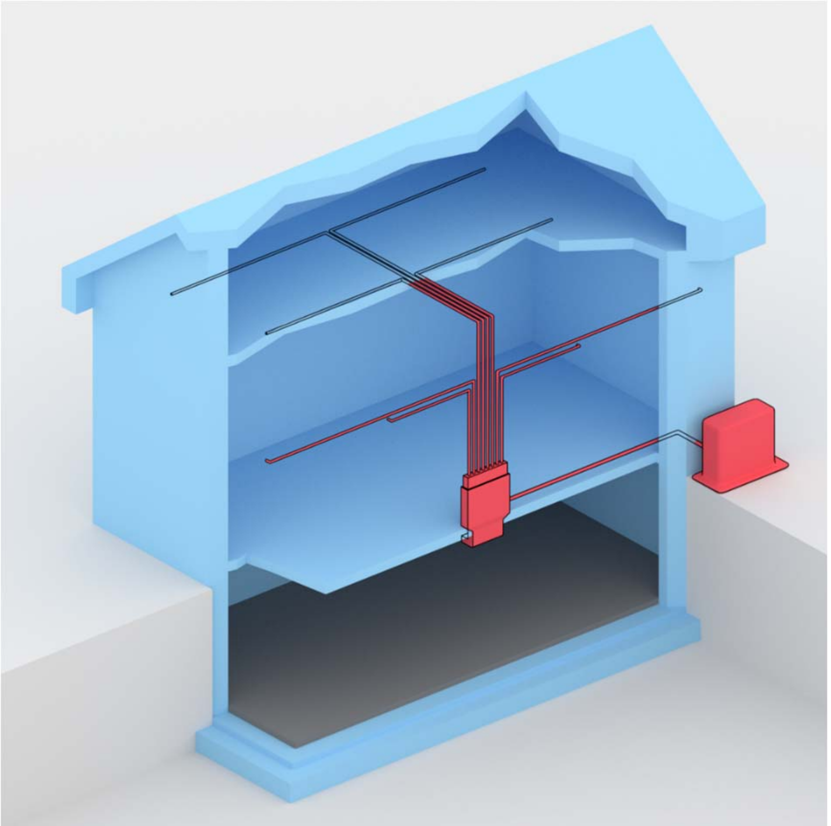


"T"

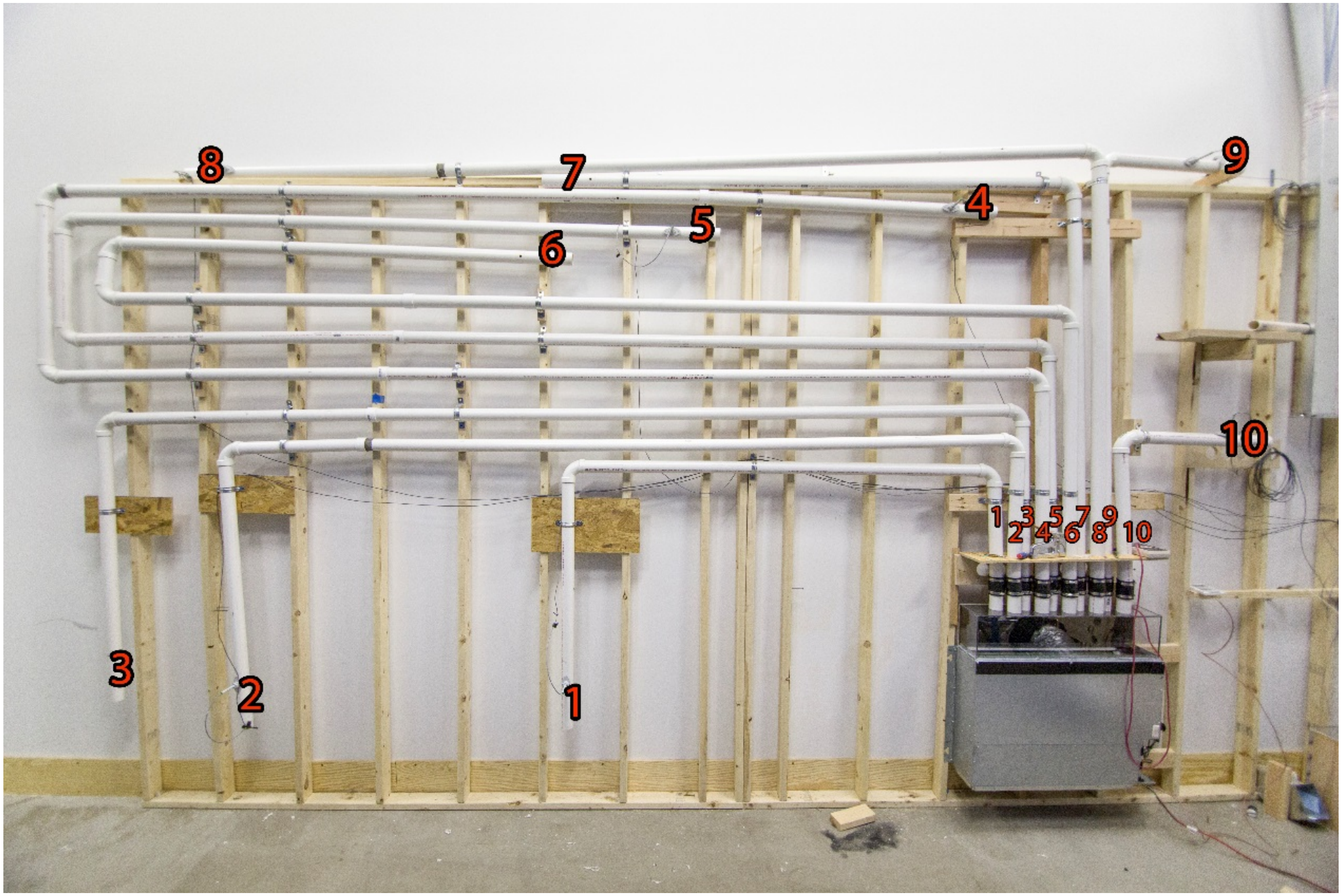
Traditional



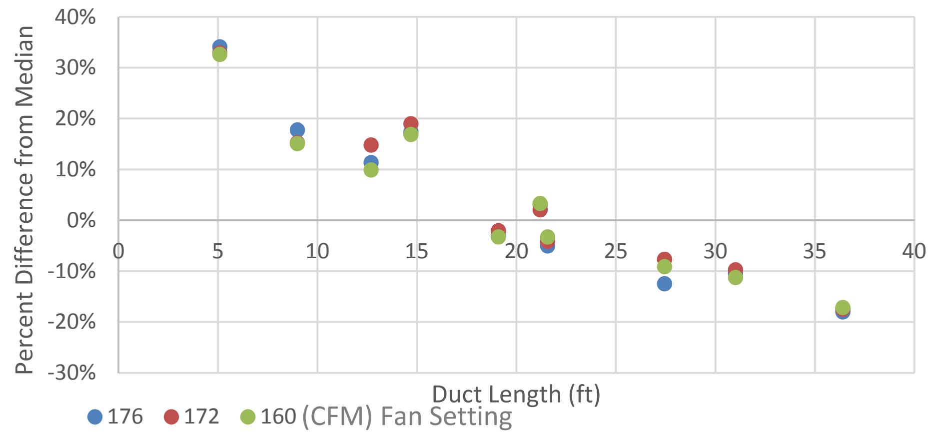
Home Run Manifold



Mock Duct Layout

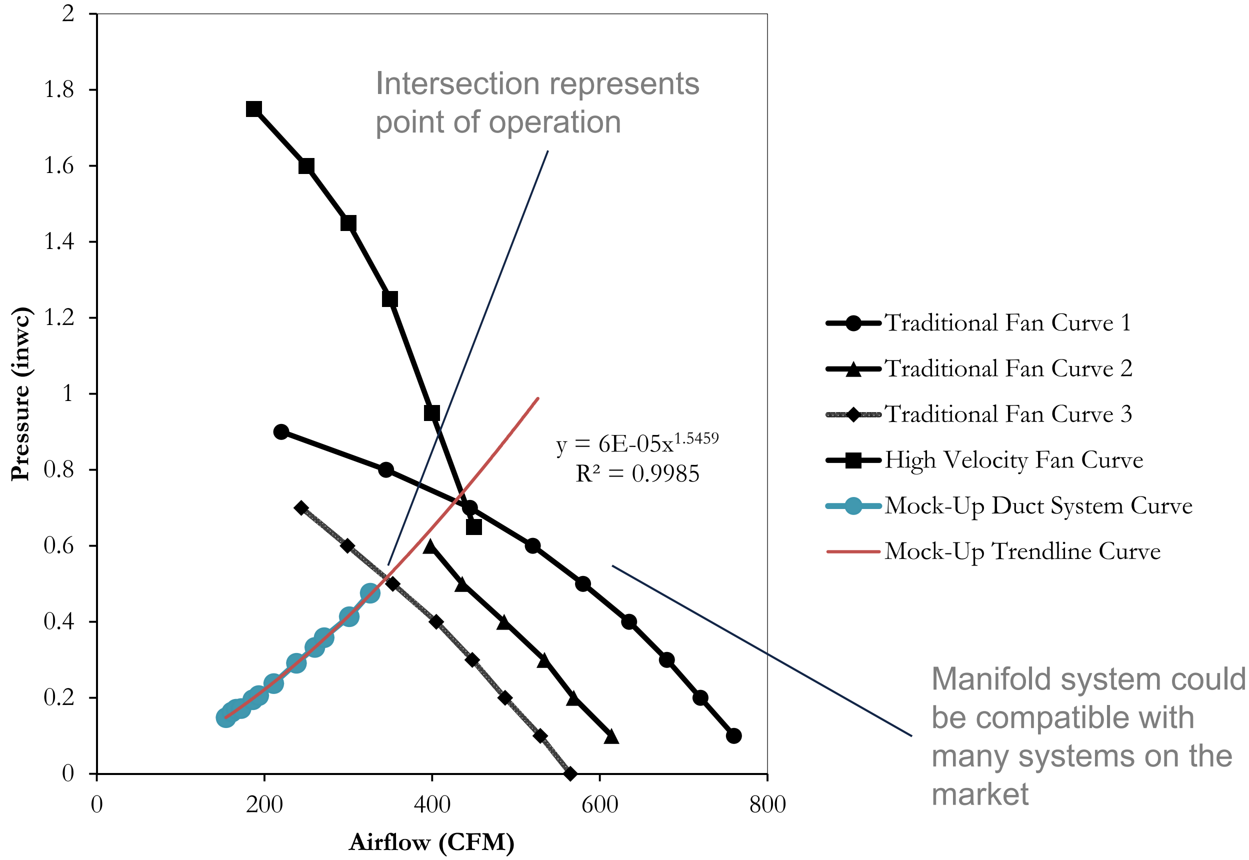


Performance Results



Duct Number	Airflow (CFM)			Length (ft)	Number of Bends
	Fan Speed				
	Low	Medium	High		
1	17	19	19	12.7	2
2	15	16	16	19.1	2
3	15	16	16	21.58	2
4	12	13	14	36.41	3
5	13	15	15	31.02	3
6	14	15	15	27.45	3
7	18	20	20	14.7	1
8	16	17	18	21.2	1
9	18	19	20	9	1
10	21	23	24	5.1	1
Power (Watts)	26.3	32.6	39.2		
Total CFM	160	172	176		
Watt/CFM	0.16	0.19	0.22		
Static Pressure (Pa)	43.0	48.4	51.5		

Duct System and Fan Curves



Manifold system could be compatible with many systems on the market

Summary of Findings

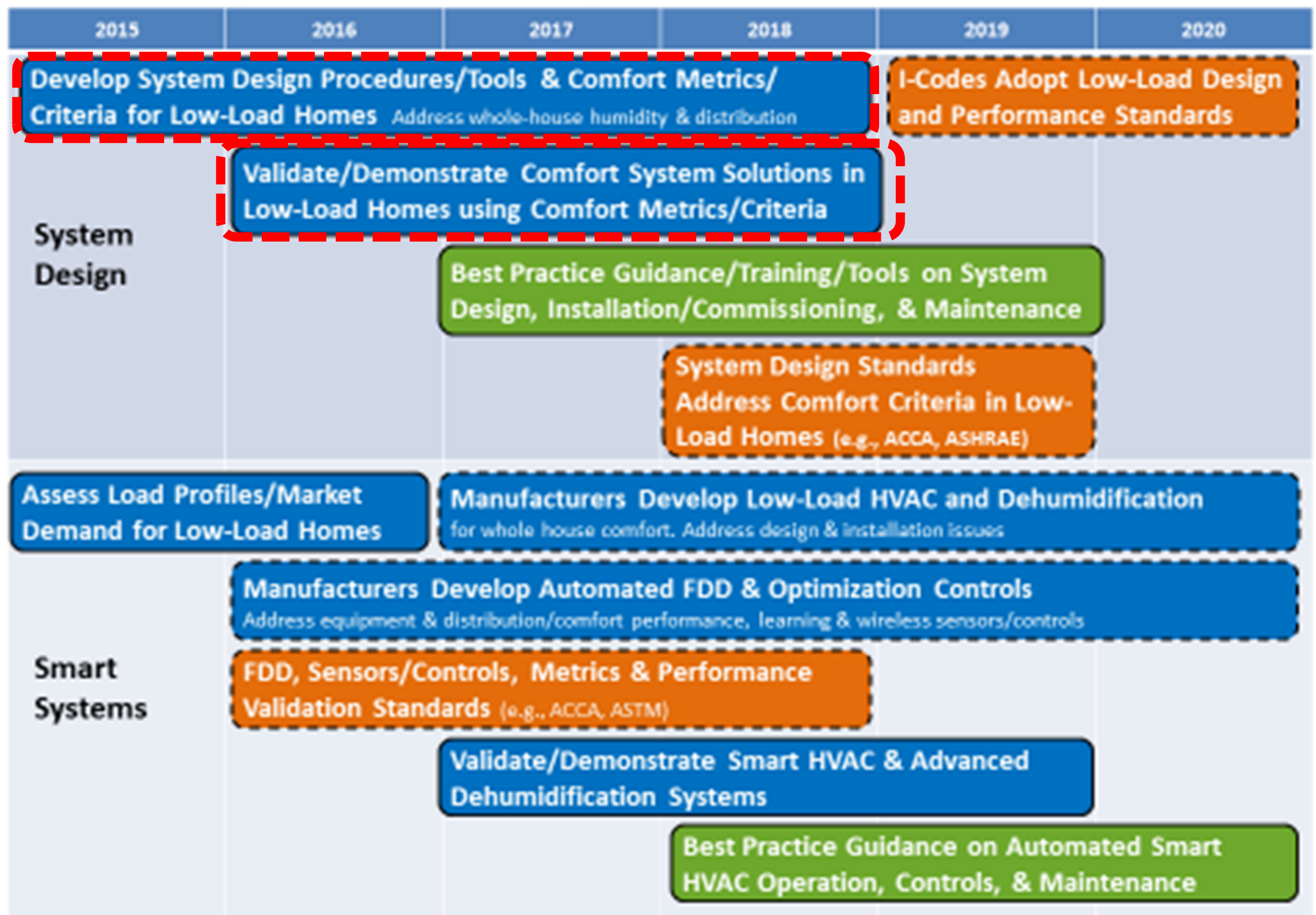
Manifold system shows predictable airflow

Static pressure minimized by using smooth pipe, and compact duct layout

Can supply enough airflow to meet thermal demand of low load homes, may need two systems for larger homes

Potential for easy seasonal balancing from centralized location

Where are we going?



Where Are We Going?
Plug and Play System

Further evolve the plug and play system in un-occupied field tests.

Exhaustive bench testing to develop design methodology.

Time and cost comparison with traditional systems.

Modeling exercise to understand risks and opportunities of manifold system.

Where are we going?
Thermal Comfort Rating Method

1. Focus is to score a home’s ability to deliver thermal comfort

2. Identify industry need for a Thermal Comfort rating for homes

3. Minimize risk to builders from comfort callbacks

4. Work with existing standards organizations to develop methodology

5. Give home buyers tools to compare the performance of homes and weight comfort with energy

Questions?

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