A Delos™ and Mayo Clinic collaboration

Indoor Environmental Quality Research at the Well Living Lab

Dr. Nicholas Clements

Presenting for the Federal Interagency Committee on Indoor Air Quality (CIAQ)

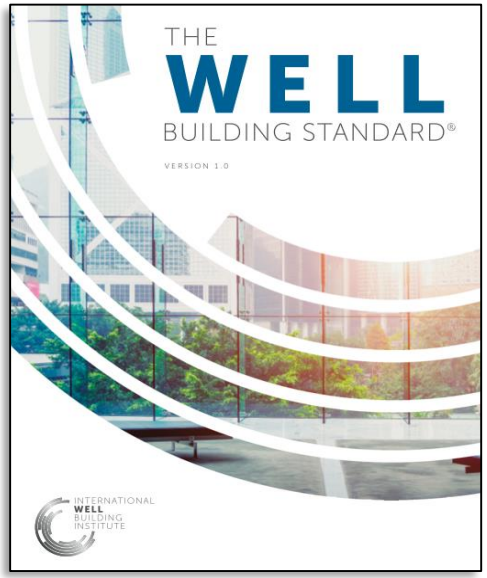
October 12, 2016

Delos™

Innovate Well

WELL LIVING LAB™

+ As the pioneer of Wellness Real Estate™ and founder of the WELL Building Standard™, Delos™ is transforming our homes, offices, schools and other indoor environments by placing health and wellness at the center of design, construction, facilities and operations decisions.



MAYO CLINIC

WELL LIVING LAB™

+ Mayo Clinic treated 1.3 million patients in all 50 states and 143 countries in 2014, is the first and largest integrated nonprofit medical practice in the world, and is ranked #1 in more specialties than any other hospital globally.
+ Mayo's mission statement is "To inspire hope and contribute to health and well-being by providing the best care to every patient through integrated clinical practice, education and research."

WELL LIVING LAB™

Delos™
Innovate Well

Building Science

MAYO CLINIC

Health Science

The Well Living Lab connects building science and health science to discover ways to improve human health in the indoor environment

Well Living Lab Leadership Team

Dana Pillai

- *Executive Director,* Well Living Lab
- *President*, Delos Labs

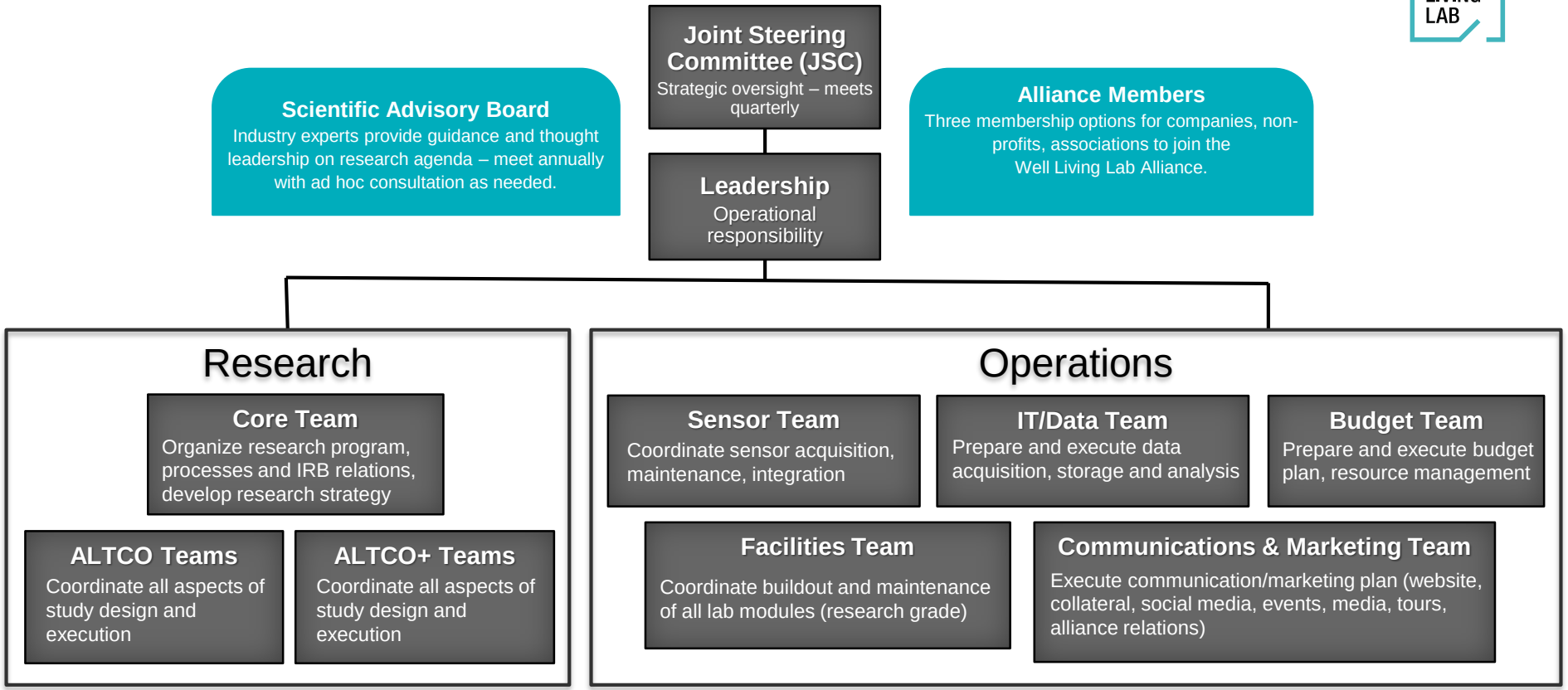
Brent A. Bauer, MD

- *Medical Director,* Well Living Lab
- *Professor of Medicine*, Mayo Clinic College of Medicine
- *Director*, Mayo Clinic Complementary and Integrative Medicine Program

Barbara Spurrier

- *Administrative Director,* Well Living Lab

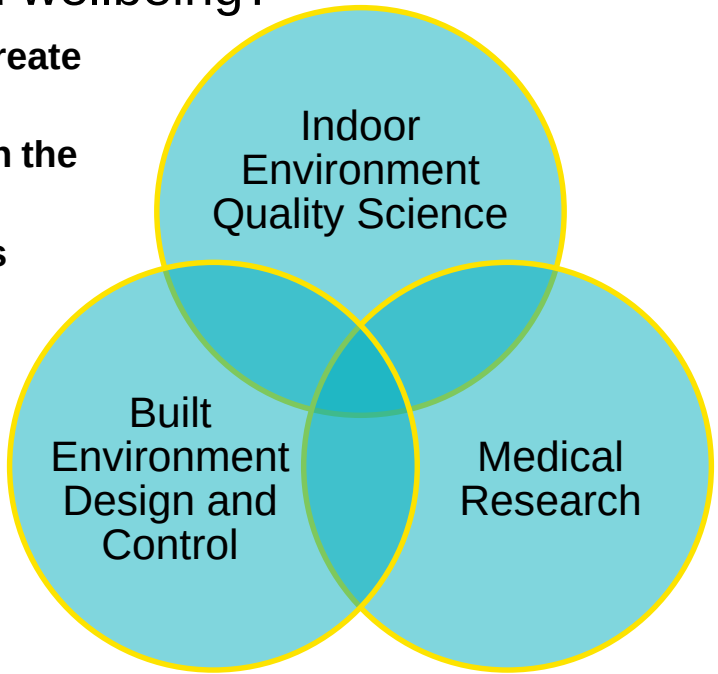
Well Living Lab Organizational Structure



Well Living Lab
A Delos™ and Mayo Clinic Collaboration

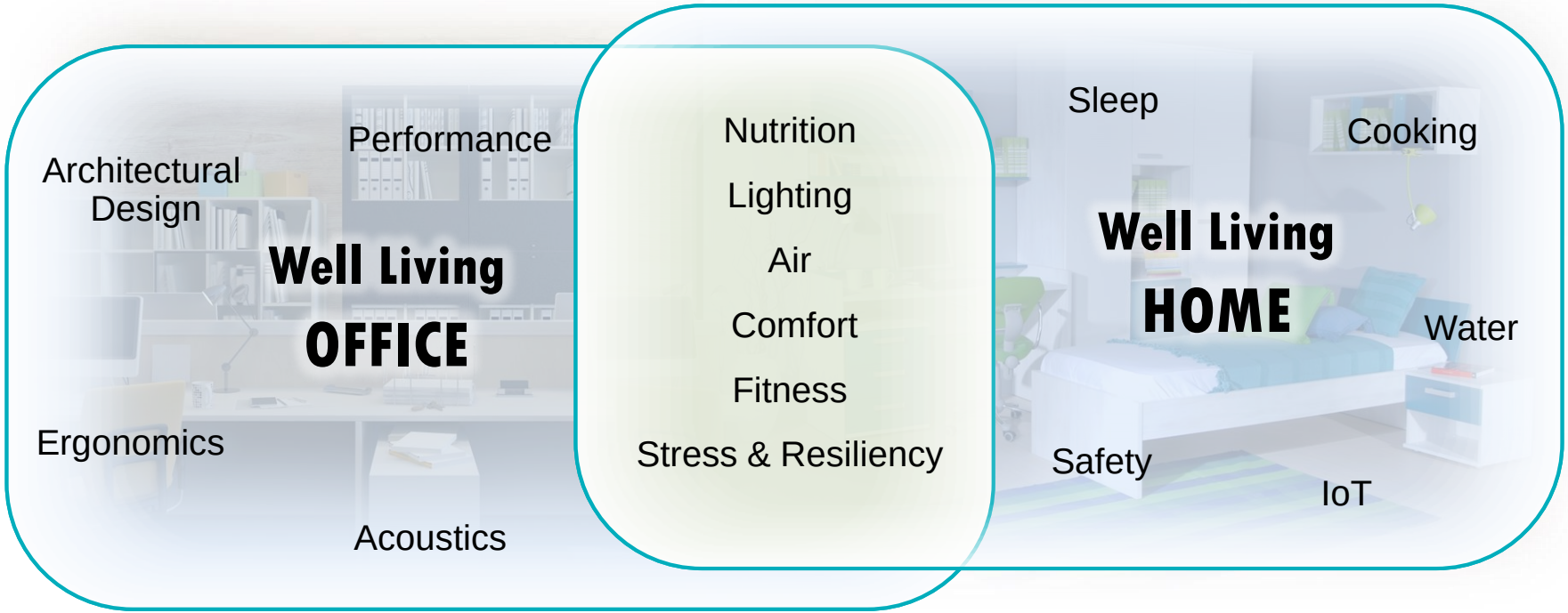
How can we measure and enable health and wellbeing?

- **Goal: Conduct actionable, human-centered research to create healthier indoor environments**
- **How: Simulate and measure real world environments with the use of state-of-the-art technologies**
- **Who: Scientists and experts from multiple research fields**
  - Medical (e.g. sleep, microbiome, nutrition, posture, etc.)
  - Behavior (physiology, psychology, and performance)
  - Indoor Environmental Quality (e.g. air, sound, light, etc.)
  - Architectural Design
  - Building Systems and Internet of Things Infrastructure
- **What: Produce high-quality data to determine the best approaches to improve occupant wellness in the built environment**



MISSION

Transforming human health in the indoor environment



Phases of Development

Concept Development

Define the experiment and how it advances building science and/or health science.

Experiment

Conduct experiment in a controlled environment. Measure impact. Refine as needed.

Extension

Test offering in expanded conditions. Assess opportunity for scaling.

Expand to US and global channels/markets for human/societal/economic impact.

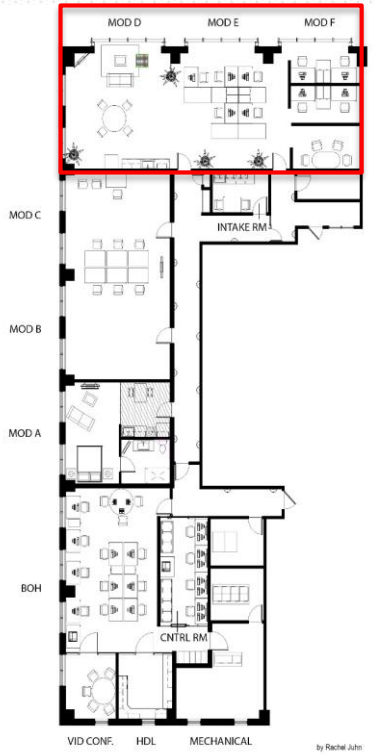
Well Living Lab

Partners

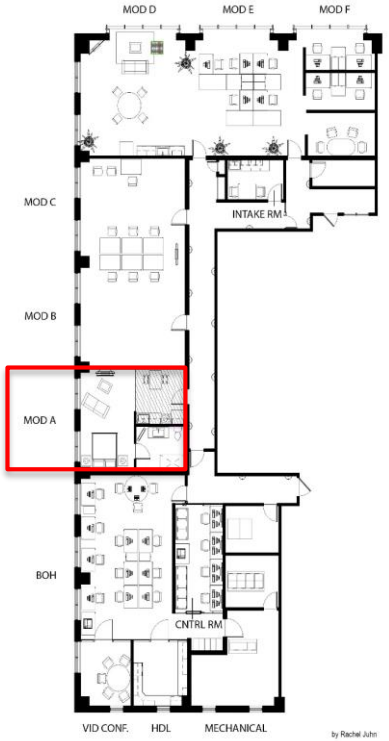
Virtual Lab Tour

https://youtu.be/ajGHHvIU5bo

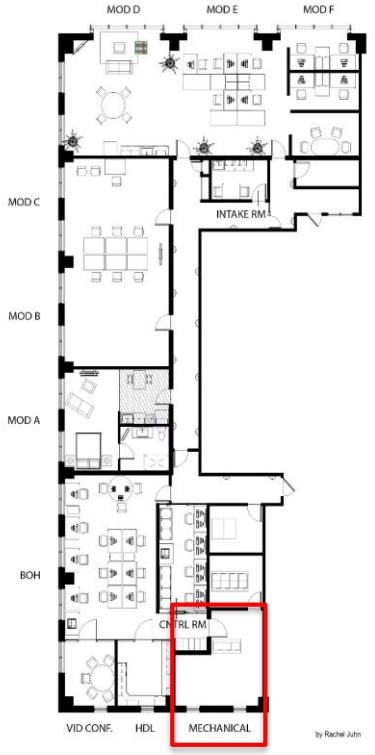
Open Office Configuration (3 modules)



Residential Configuration (1 module)

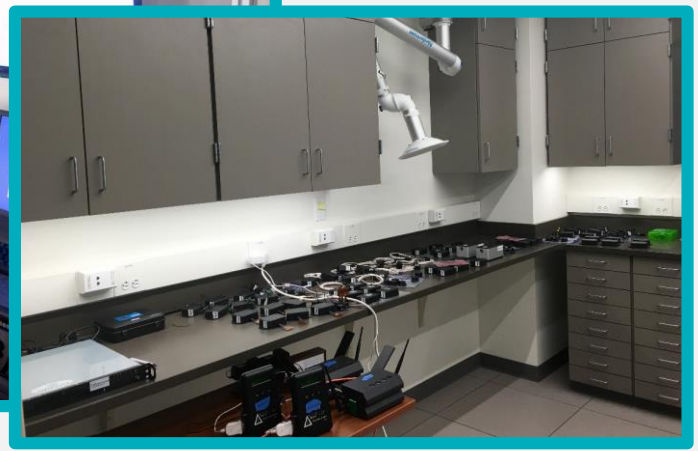


Mechanical Room



Control Center

Hardware Development Lab



Environmental Monitoring and Controls

Note: Italics indicate currently installing or planning to install

Reference-Grade Sensors

- Temperature
- Relative Humidity
- Air Velocity
- Ventilation Flow Rate
- Light
  - Luminance
  - Spectral Power Density
- Sound Level Meter
- Air Quality (CO_2, CO, O_3, PM)
  - Q-Trak CO_2/CO Monitor
  - Li-Cor CO_2/H_2O Monitor
  - Met-One PM Monitor
  - 2B O_3 Monitor and Generator

Building/Data Management

- IoT Hub + Streaming Analytics
  - Real-time Data Viz/Analysis
  - Experimental Scene Definitions
  - Sensor-Based Control Algorithms/Commands
- Building Management System
  - Temp, RH, Airflow Measurements and Set Points
- Window Shade Control
- Electrochromic Tint Control
- Audio System Control
- Energy Monitoring
- *Lights*
  - *Color Temperature*
  - *Brightness/Dimness*

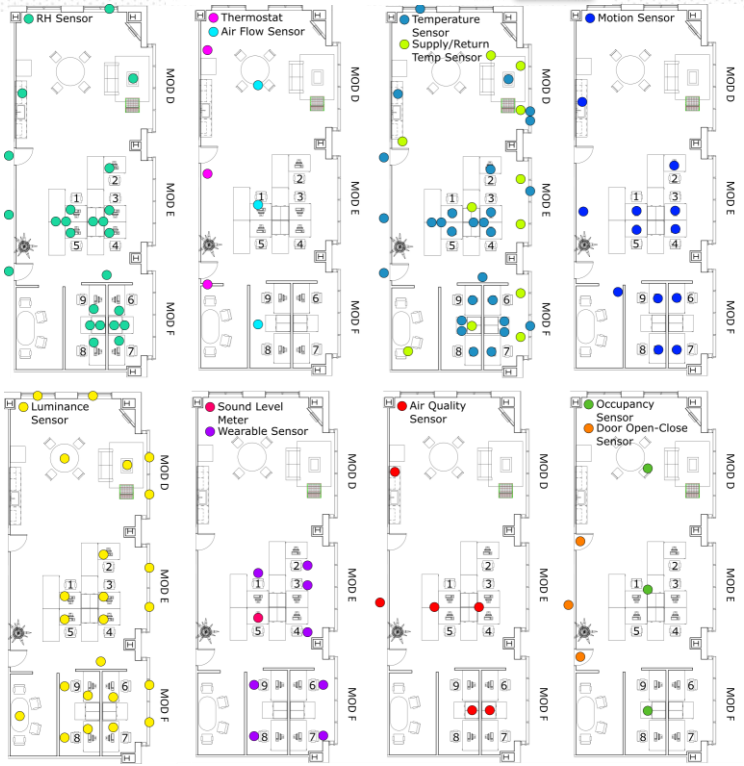
Commercial Sensors

- Wireless Sensor Networks
  - Temperature
  - Humidity
  - Luminance
  - Motion
  - Air Quality (PM, CO_2, TVOCs)
  - *Sound Level*
- Biometric Wearables
- Occupancy
- *Socket Electricity Usage*
- *LED Bulb Status*

ALTCO – Overview

Acoustic, **L**ighting and **T**hermal **C**onditions in **O**ffices and Their Effects on the Health and Wellness of Adult Office Workers

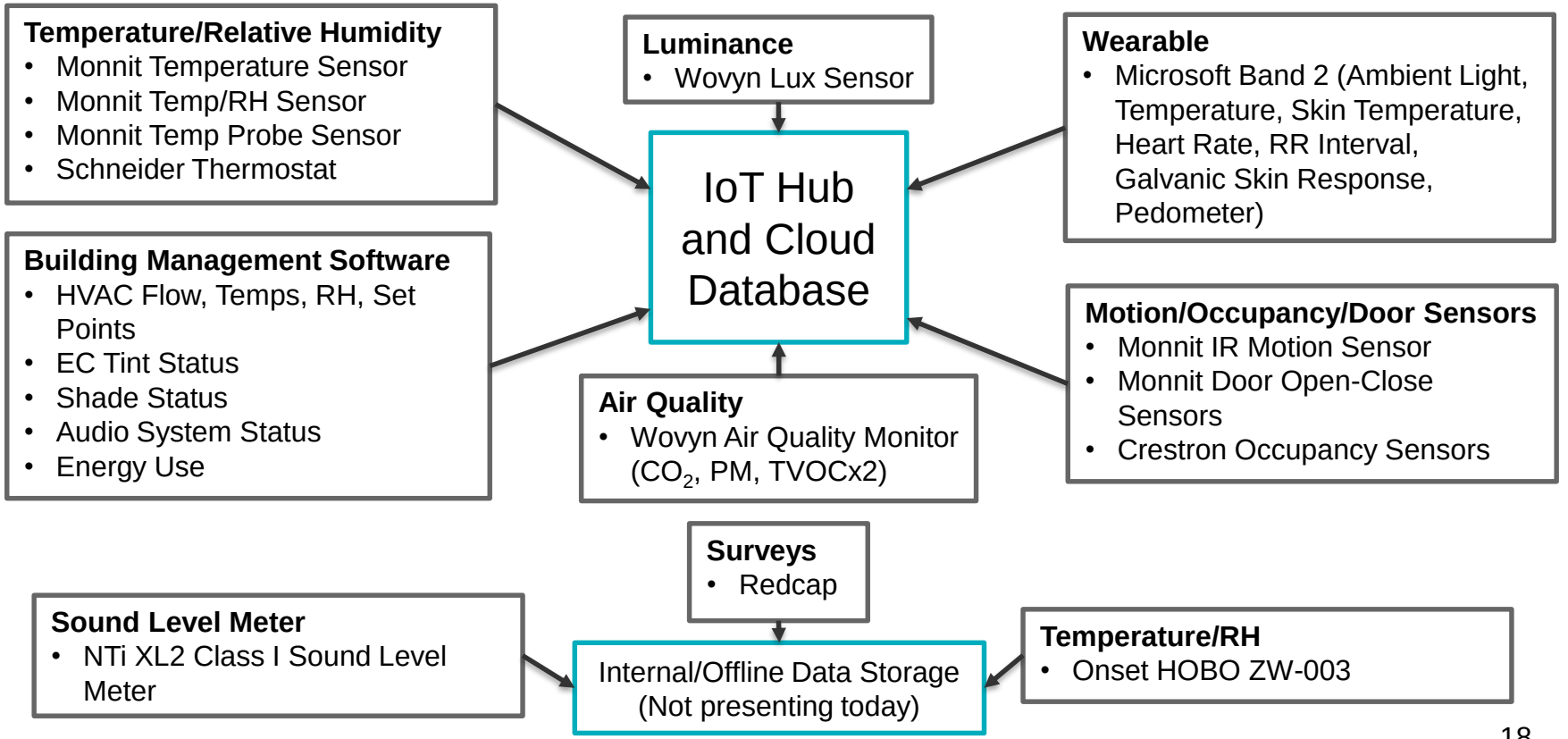
- *First Well Living Lab Research Investigation*
- 8 Human Subjects
- 18 Weeks (6:30 AM – 5:00 PM)
- 3 Modules in an Open-Office Configuration
- **Network of Environmental Sensors**
- **Wearable Data Collection**
- Surveys (Daily, Weekly, 3-Week)
- Mid-Study and Post-Study Interviews
- Focus on Acoustic, Lighting and Thermal Comfort



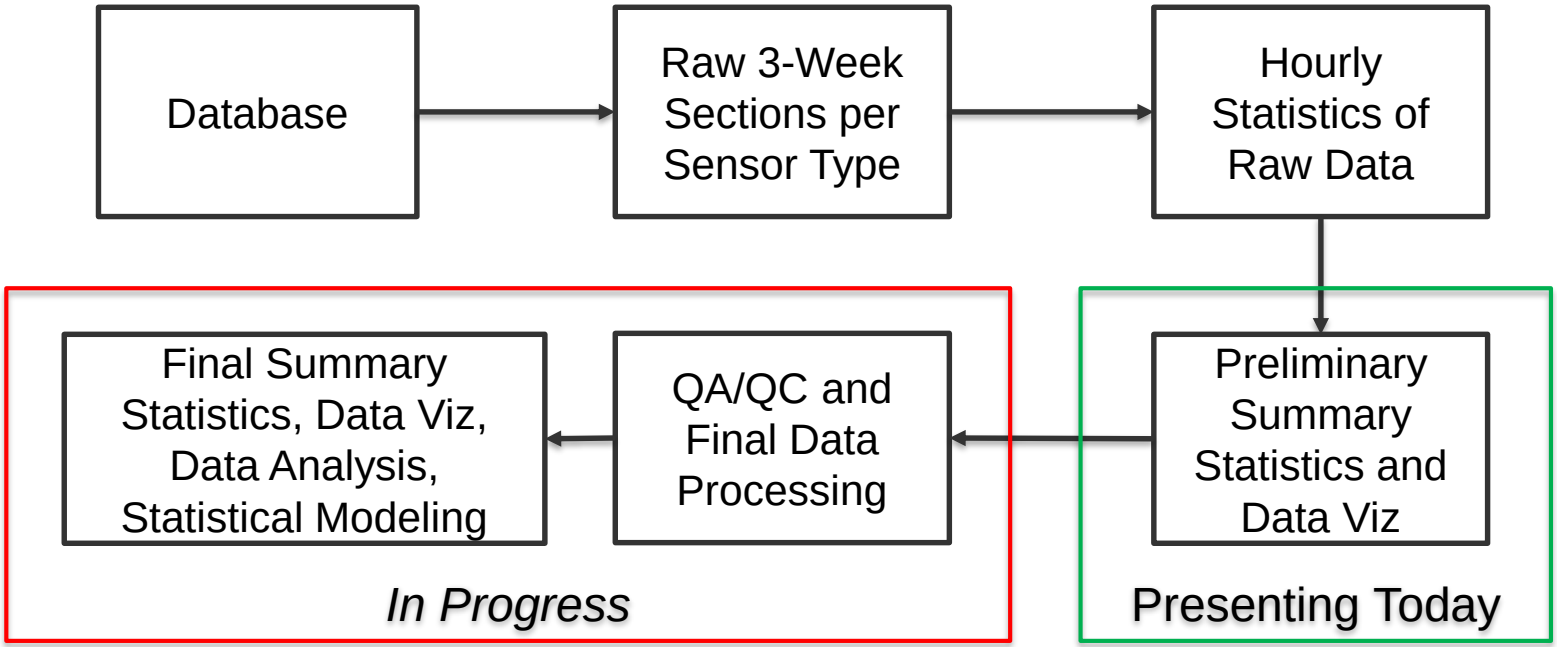
ALTCO – Experimental Design

Week	Start Date	End Date	N. Days	Scene Number	Lights	EC Tint	Shear Shades (Black-Out)	Temperature	Audio
1	5/31/2016	6/3/2016	4	1	3500K	Clear (1)	Open, Controllable (Open)	71 °F	Off
2	6/6/2016	6/10/2016	5	2	4200K	Intelligent	Open, Controllable (Open)	71 °F	Off
3	6/13/2016	6/17/2016	5	3	2700K	Dark (4)	Closed, Not Controllable (Closed)	67 °F	White Noise I (-36 dB)
4	6/20/2016	6/24/2016	5	4	2700K	Clear (1)	Open, Controllable (Open)	75 °F	Simulated Speaking I (-21 dB)
5	6/27/2016	7/1/2016	5	1	3500K	Clear (1)	Open, Controllable (Open)	71 °F	Off
6	7/5/2016	7/8/2016	4	2	4200K	Intelligent	Open, Controllable (Open)	71 °F	Off
7	7/11/2016	7/15/2016	5	5	6500K	Dark (4)	Closed, Not Controllable (Closed)	67 °F	White Noise II (-21 dB)
8	7/18/2016	7/22/2016	5	6	6500K	Intelligent	Open, Controllable (Open)	75 °F	Simulated Speaking II (-12 dB)
9	7/25/2016	7/29/2016	5	2	4200K	Intelligent	Open, Controllable (Open)	71 °F	Off
10	8/1/2016	8/5/2016	5	1	3500K	Clear (1)	Open, Controllable (Open)	71 °F	Off
11	8/8/2016	8/12/2016	5	2	4200K	Intelligent	Open, Controllable (Open)	71 °F	Off
12	8/15/2016	8/19/2016	5	3	2700K	Dark (4)	Closed, Not Controllable (Closed)	67 °F	White Noise I (-36 dB)
13	8/22/2016	8/26/2016	5	4	2700K	Clear (1)	Open, Controllable (Open)	75 °F	Simulated Speaking I (-21 dB)
14	8/29/2016	9/2/2016	5	1	3500K	Clear (1)	Open, Controllable (Open)	71 °F	Off
15	9/5/2016	9/9/2016	5	2	4200K	Intelligent	Open, Controllable (Open)	71 °F	Off
16	9/12/2016	9/16/2016	5	5	6500K	Dark (4)	Closed, Not Controllable (Closed)	67 °F	White Noise II (-21 dB)
17	9/19/2016	9/23/2016	5	6	6500K	Intelligent	Open, Controllable (Open)	75 °F	Simulated Speaking II (-12 dB)
18	9/26/2016	9/30/2016	5	2	4200K	Intelligent	Open, Controllable (Open)	71 °F	Off

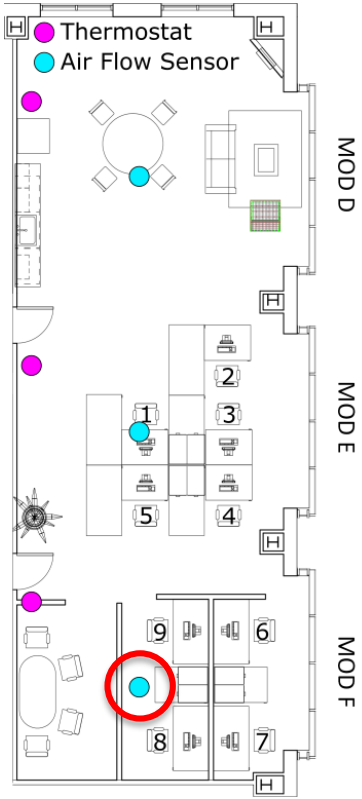
ALTCO – Sensors and Data Collection

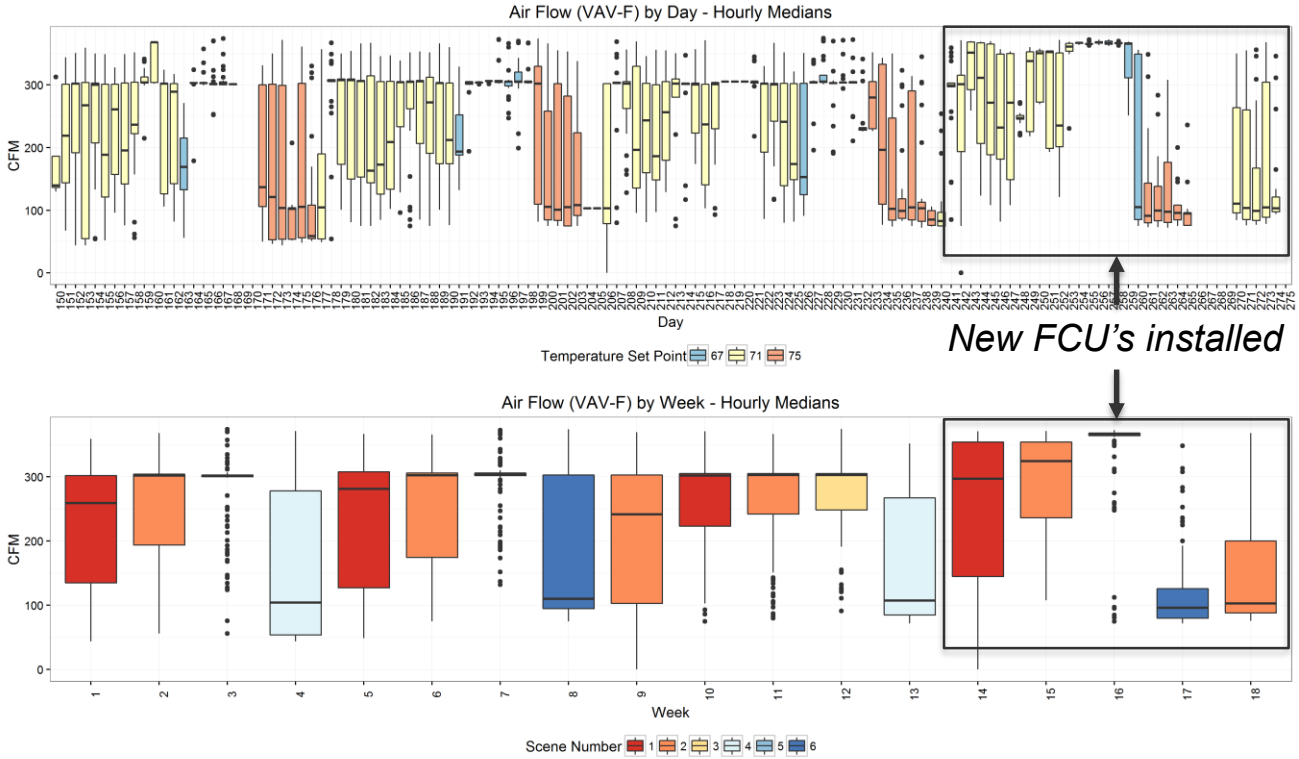


ALTCO – Data Processing



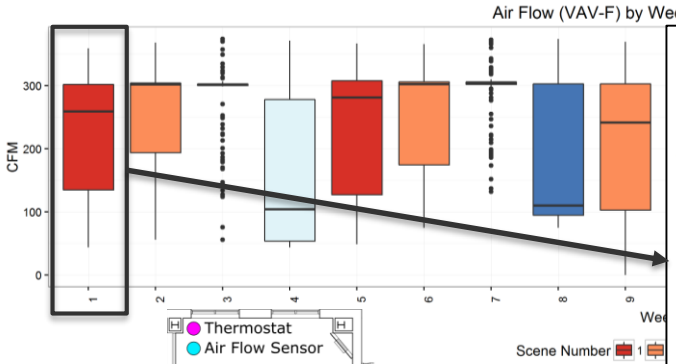
HVAC System – Daily/Weekly Flow Rates

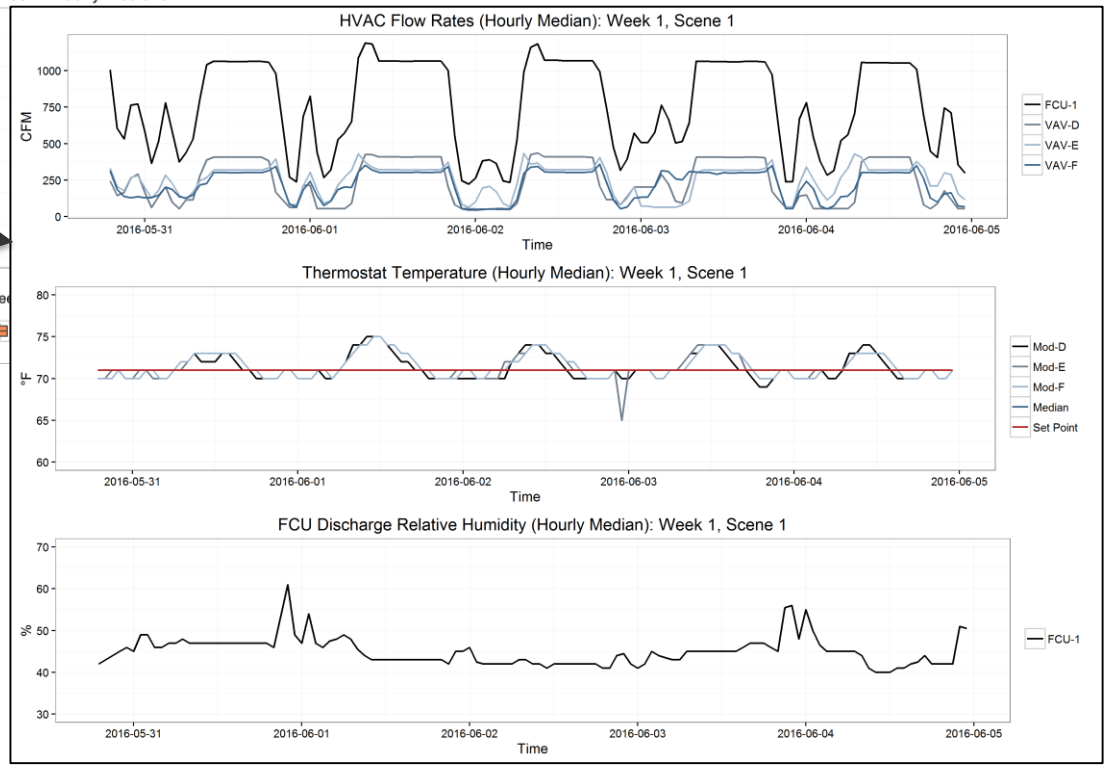




(Note: Preliminary data shown here, final processing is not complete)

HVAC System – Hourly Flow/Temperature/RH





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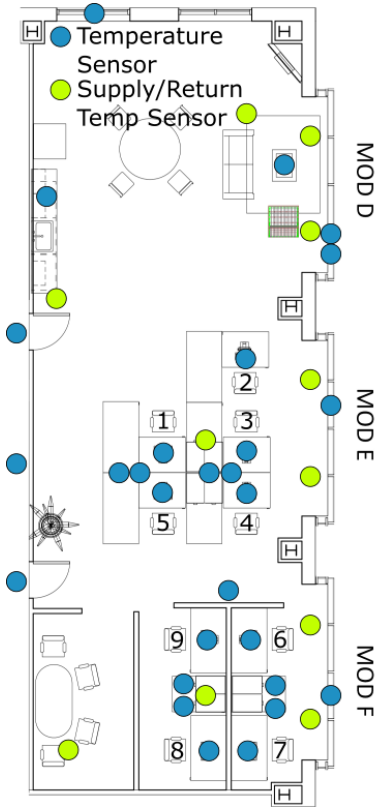
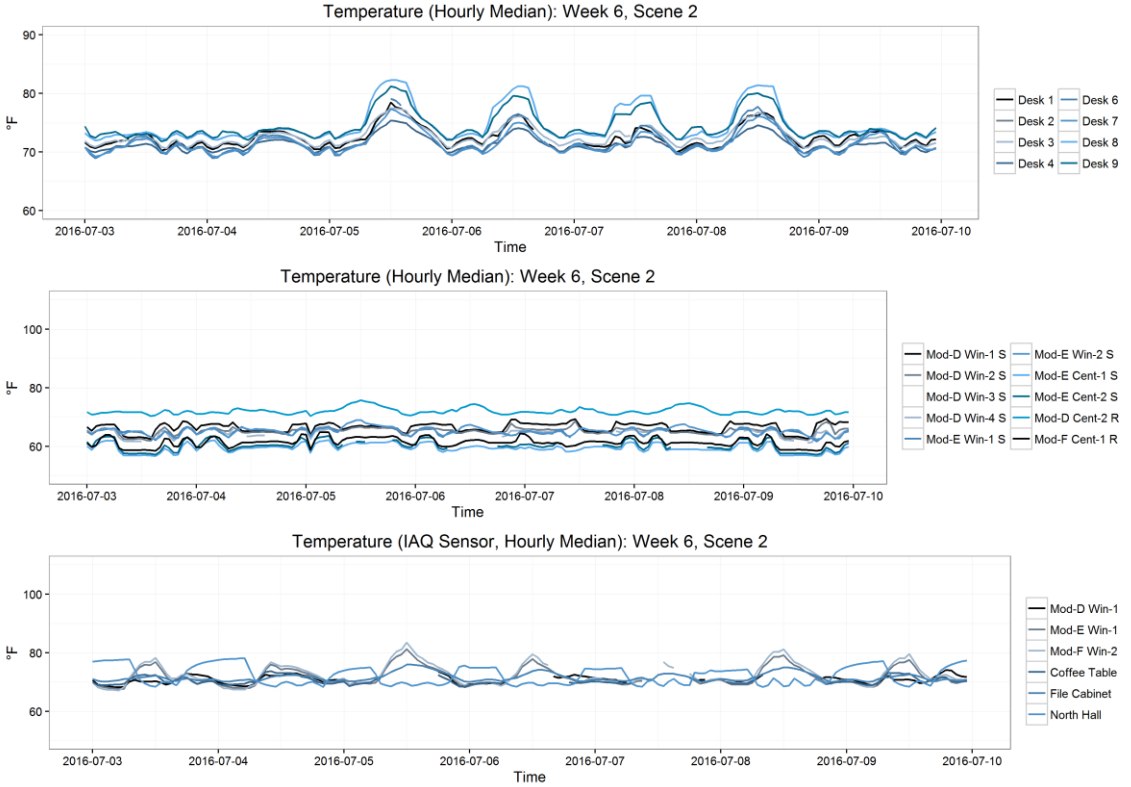
Temperature Sensors – Hourly Temperature





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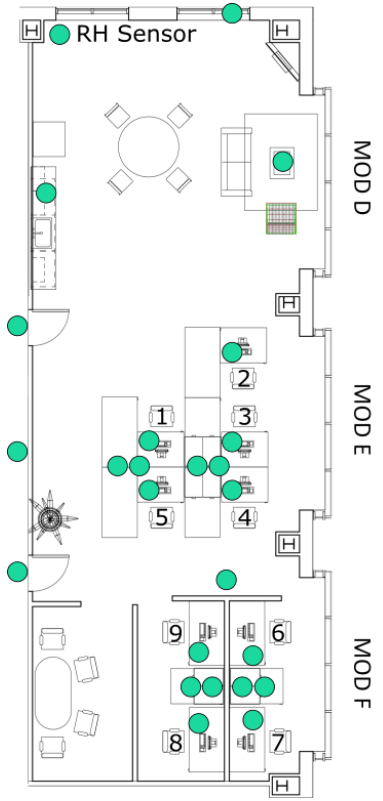
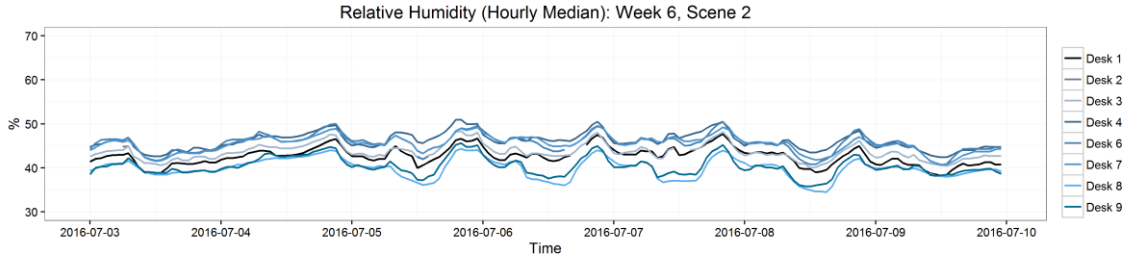
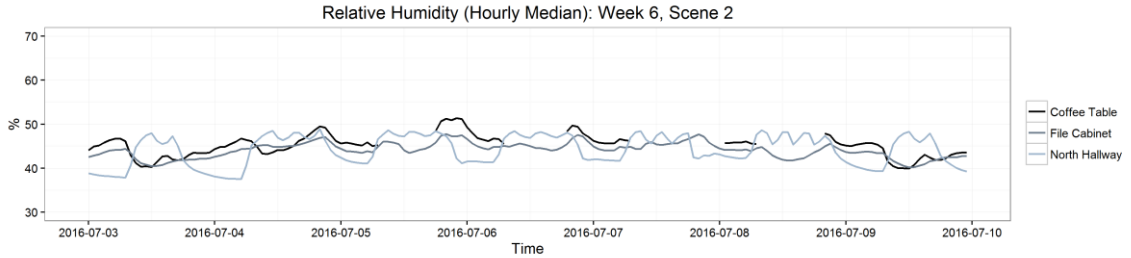
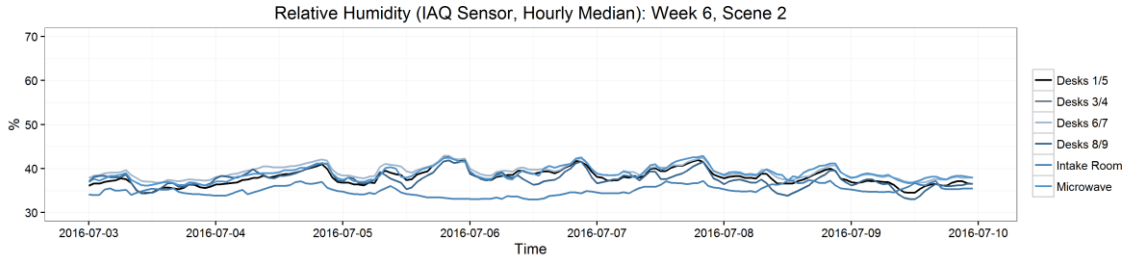
Relative Humidity Sensors - Hourly Humidity









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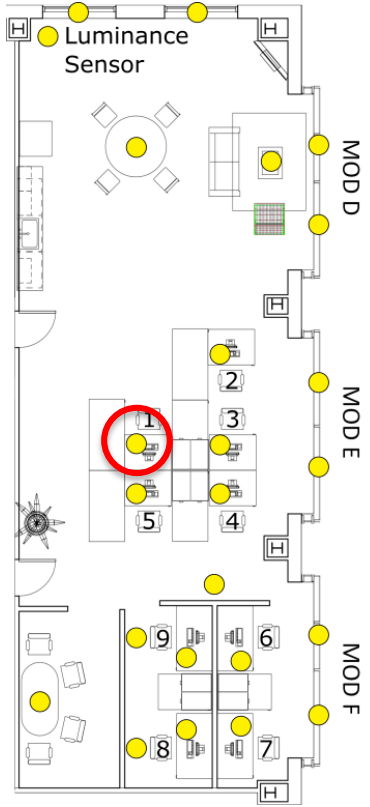
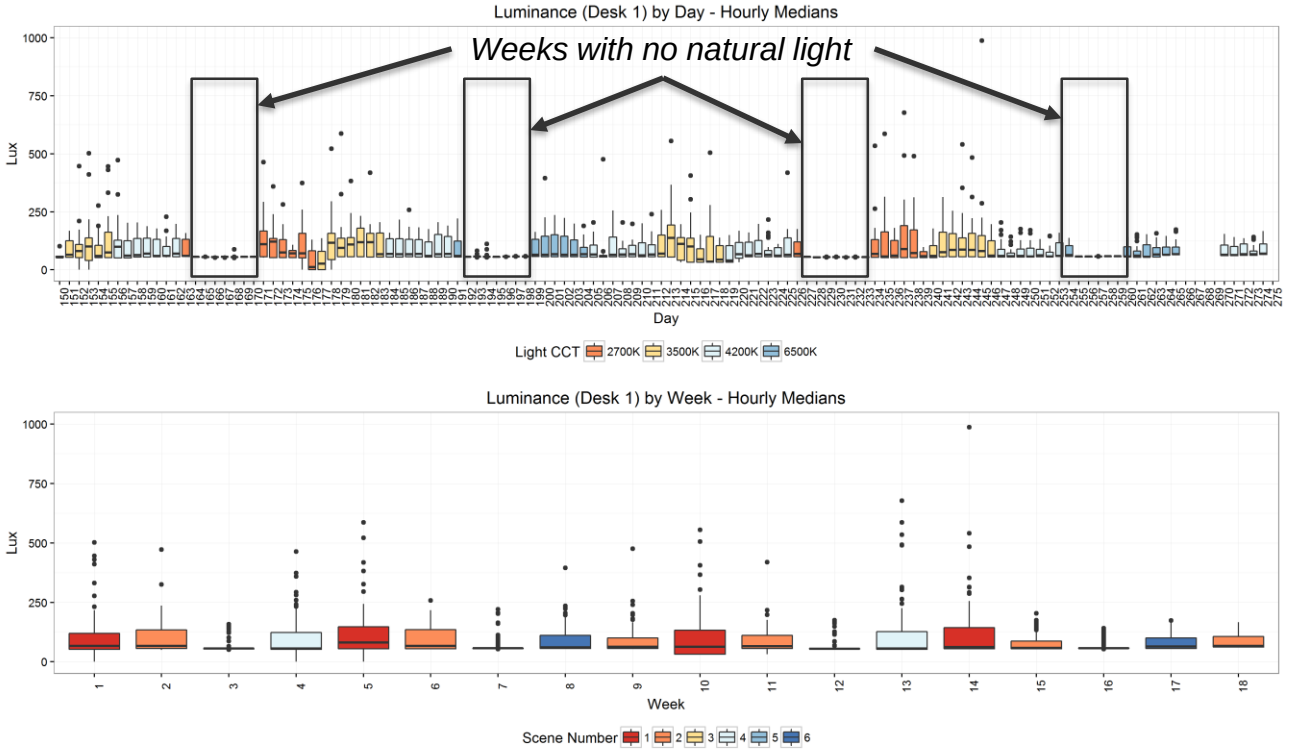
Luminance Sensors – Daily/Weekly Desk Sensor





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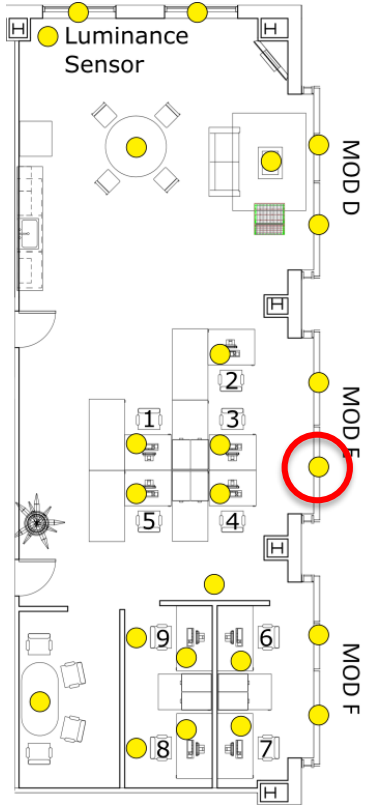
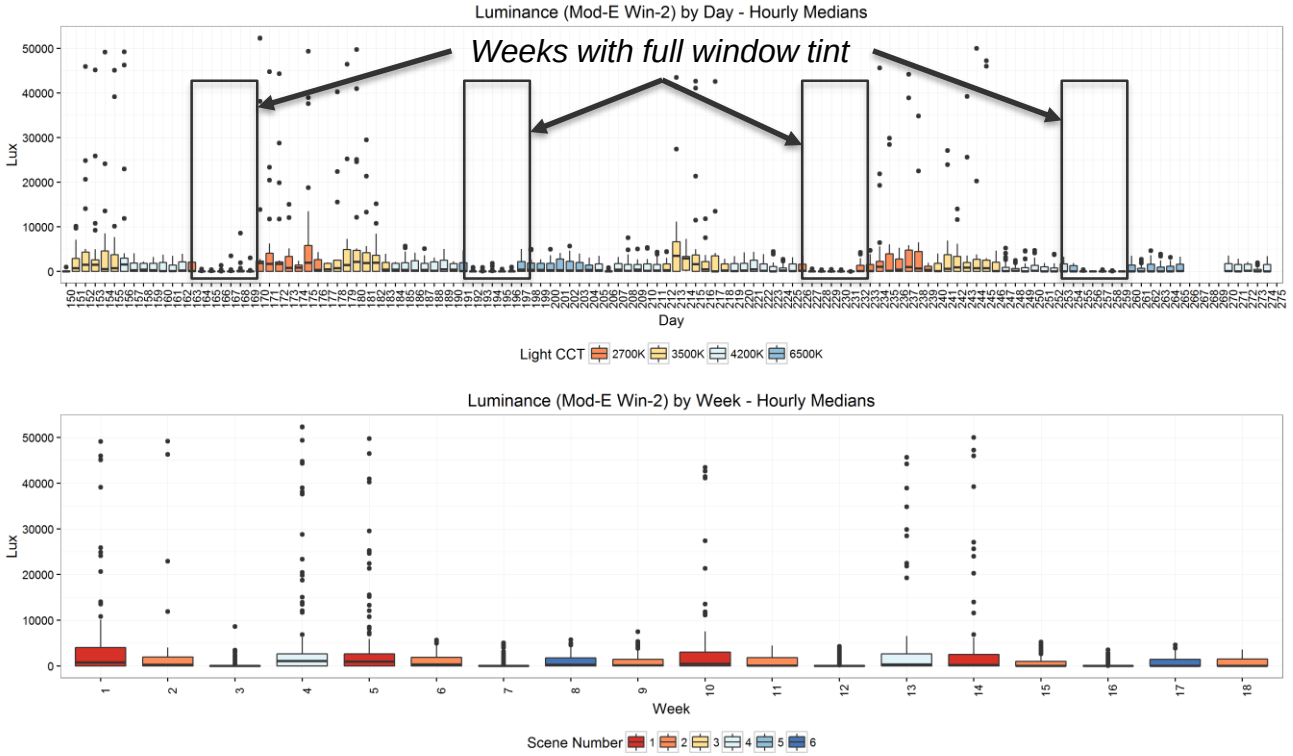
Luminance Sensors – Daily/Weekly Window Sensor





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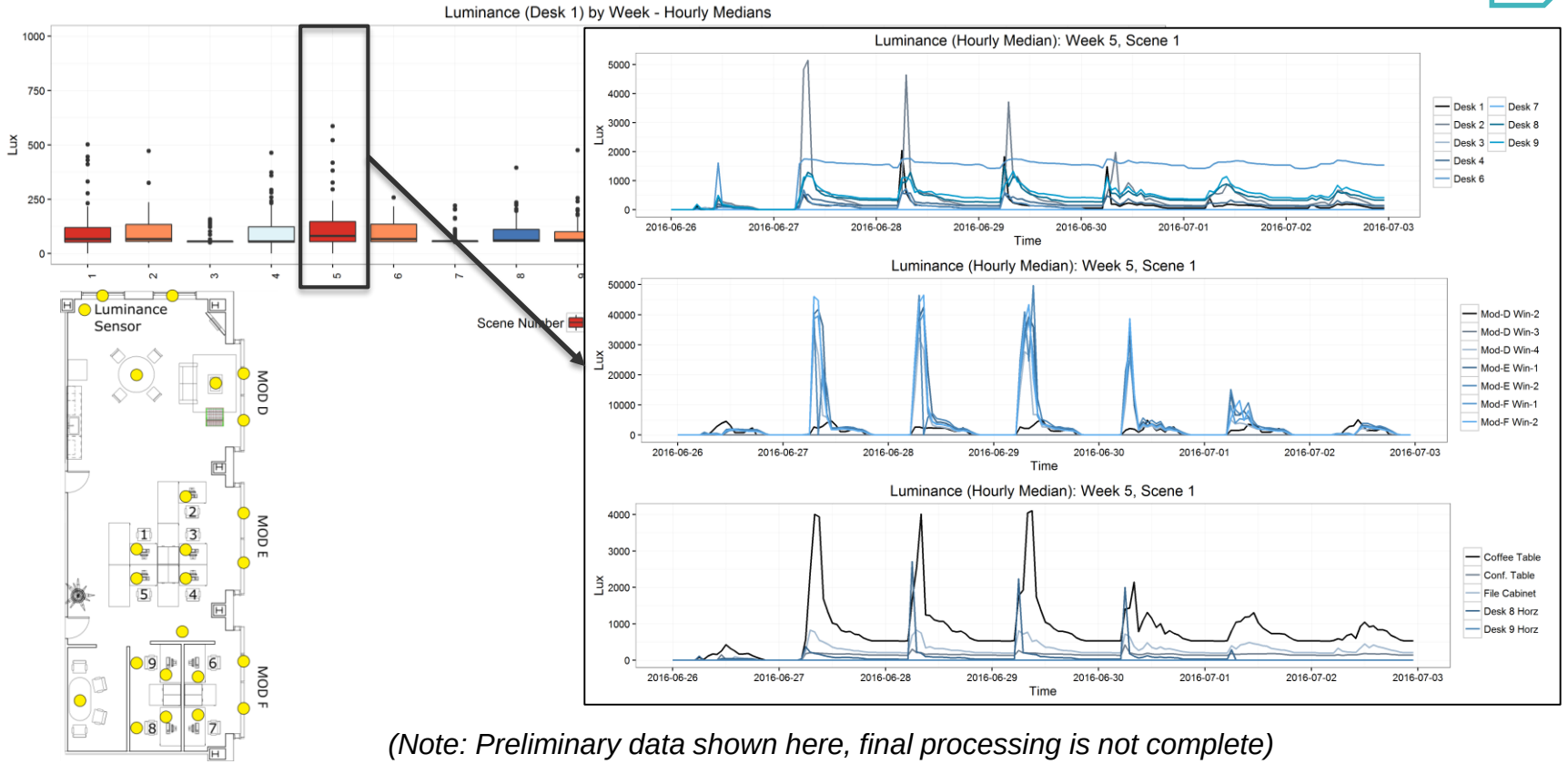
Luminance Sensors – Hourly Lux



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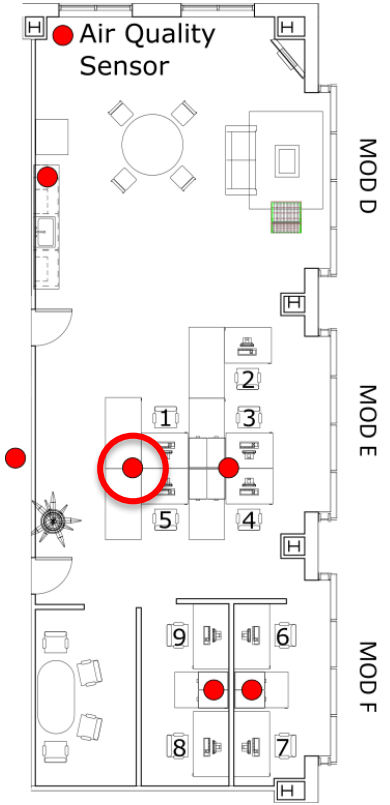
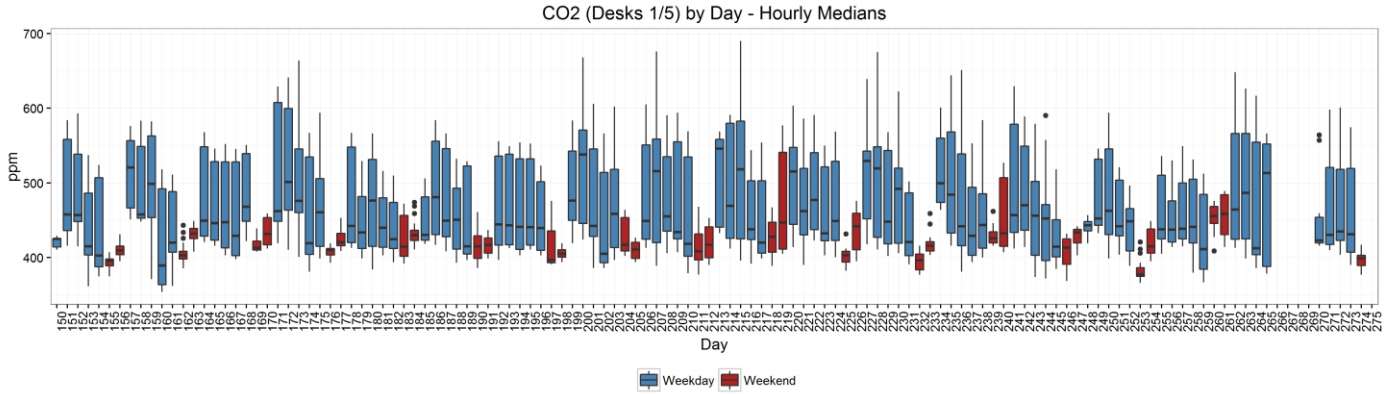
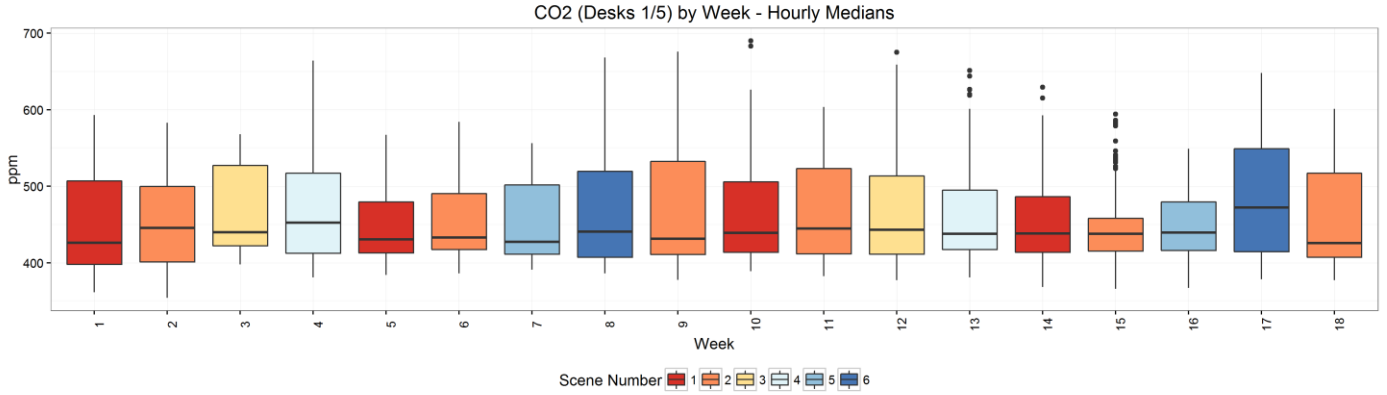
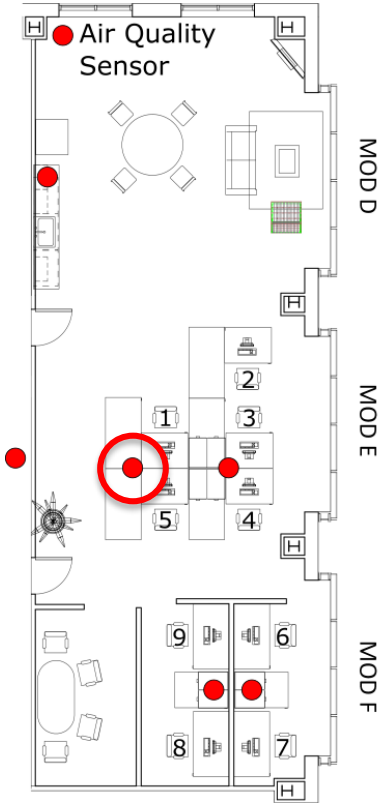
Air Quality Sensors – Weekly/Daily CO_2

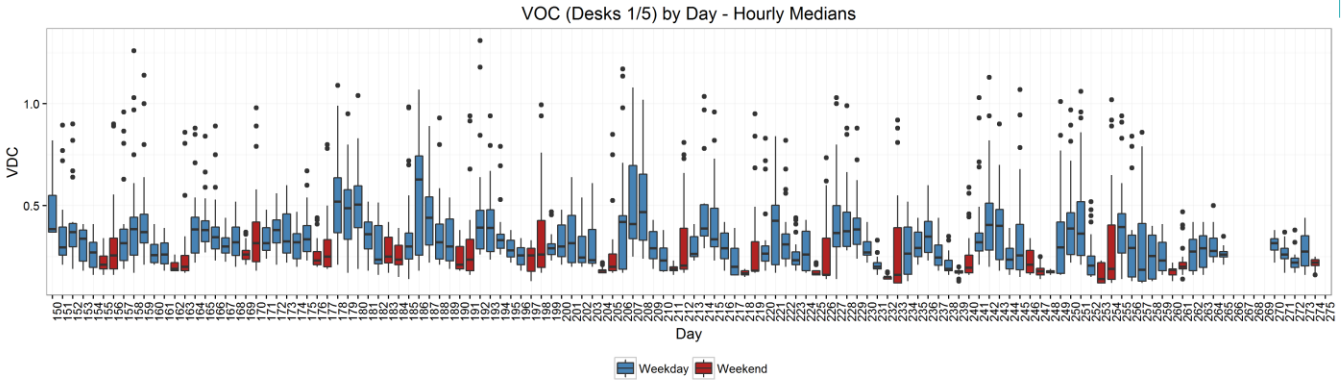


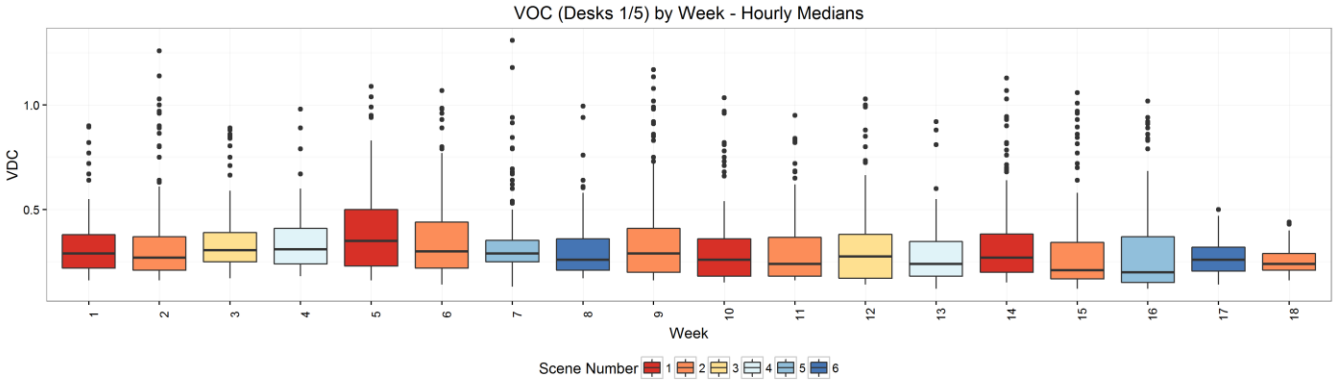




Air Quality Sensors – Weekly/Daily TVOCs

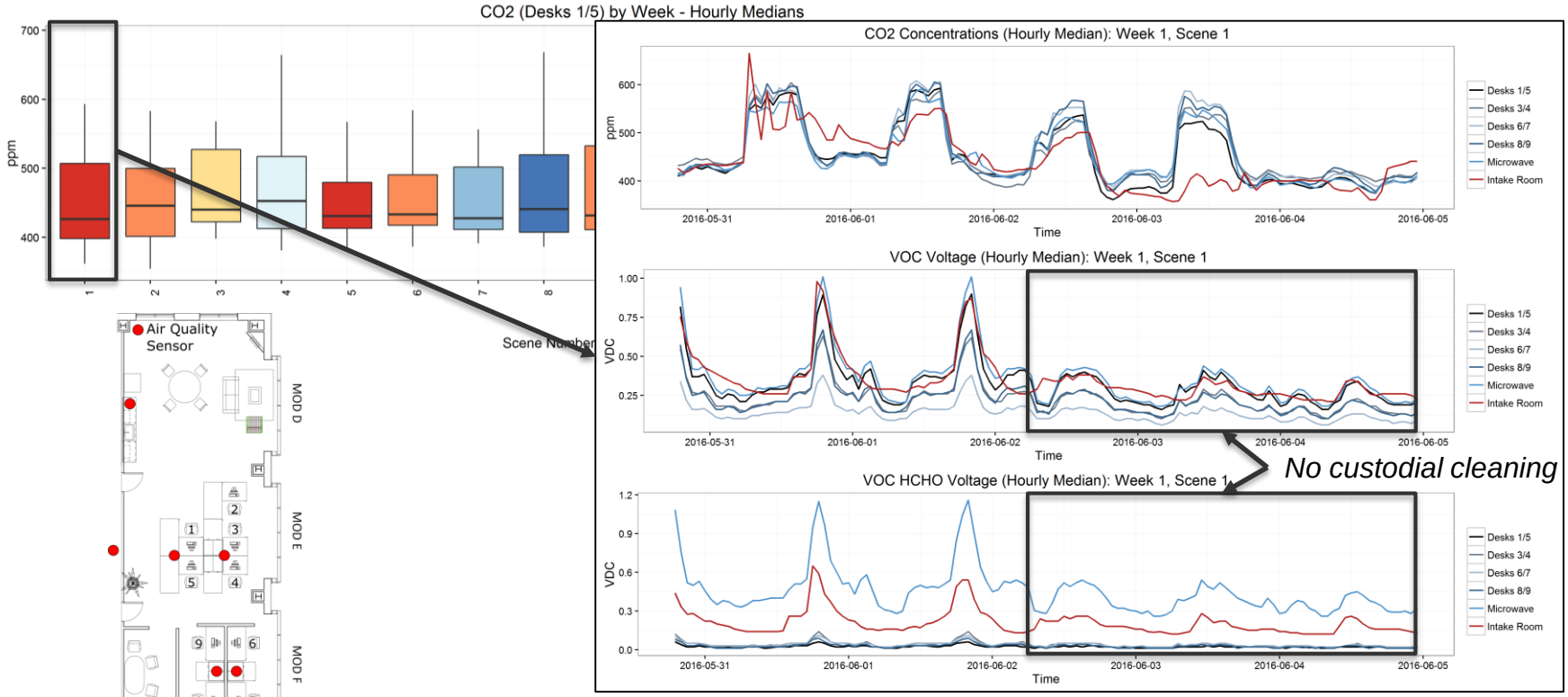






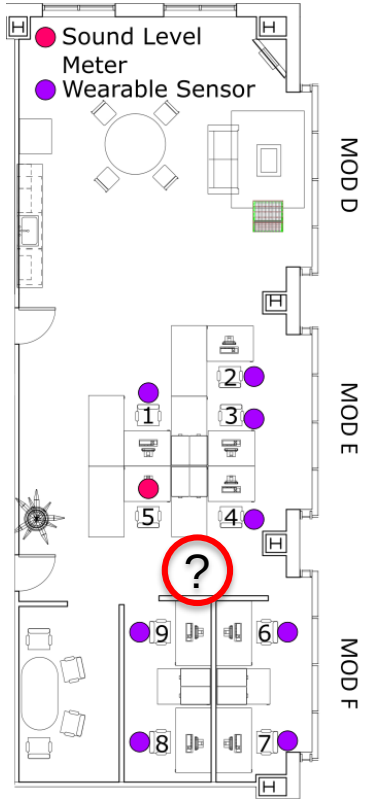
(Note: Preliminary data shown here, final processing is not complete)

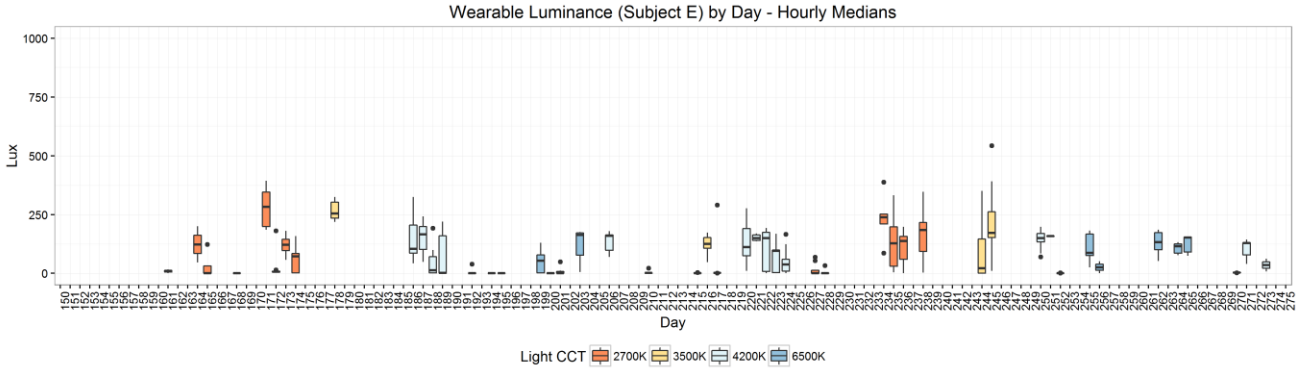
Air Quality Sensors – Hourly CO_2 and TVOCs

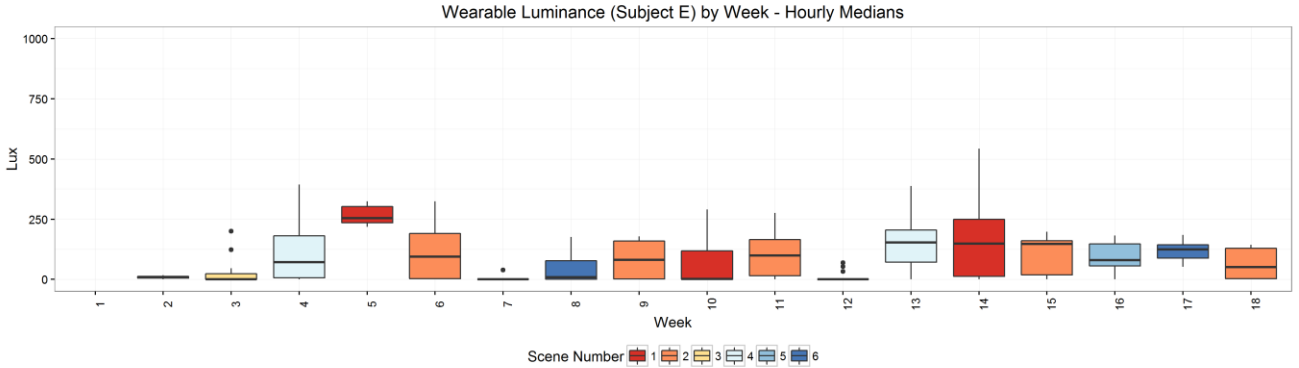


(Note: Preliminary data shown here, final processing is not complete)

Wearable Sensors – Daily/Weekly Luminance

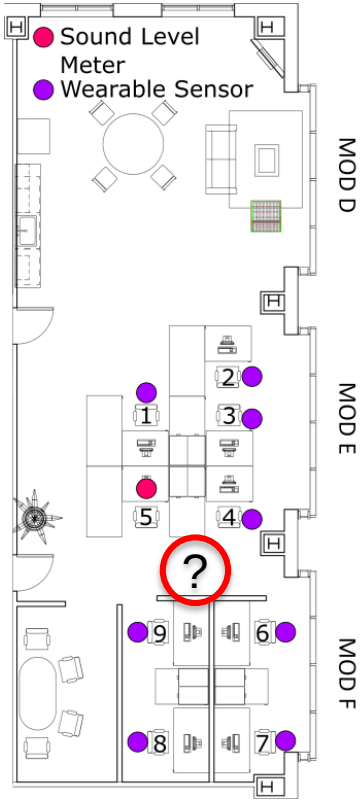


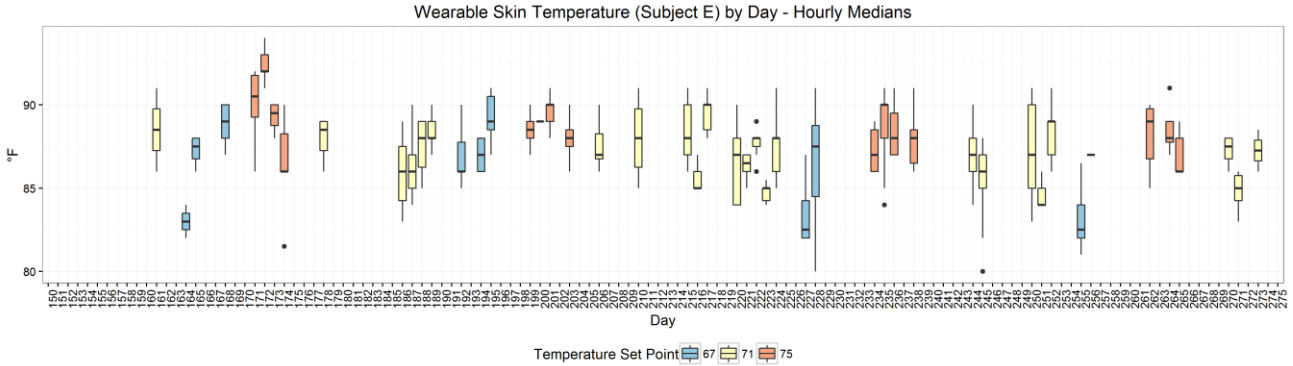


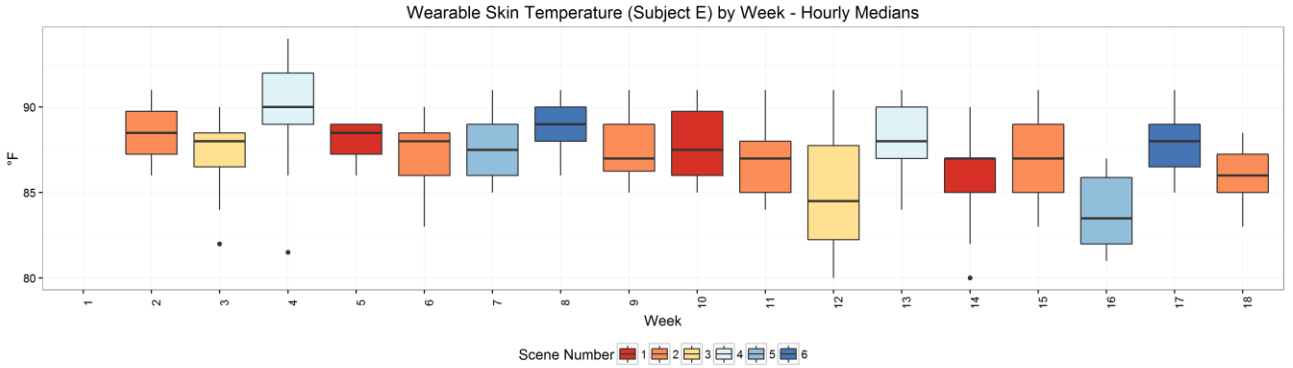


(Note: Preliminary data shown here, final processing is not complete)

Wearable Sensors – Daily/Weekly Skin Temperature

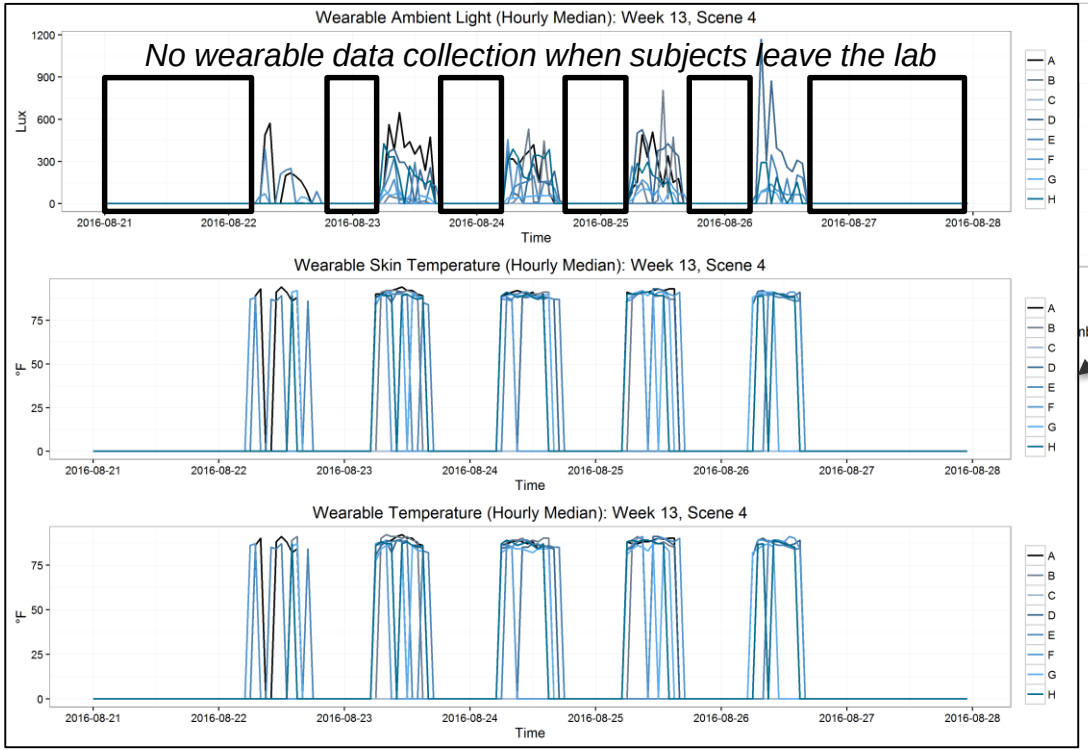


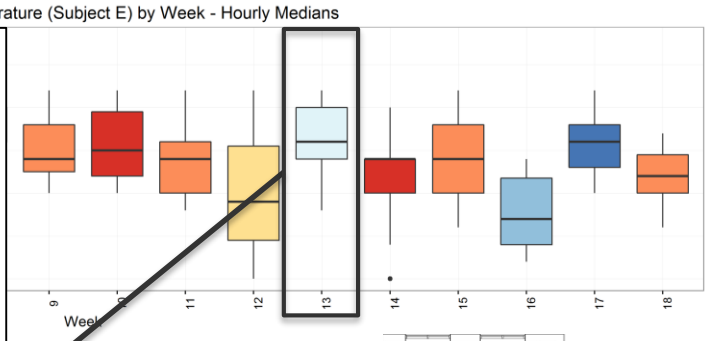


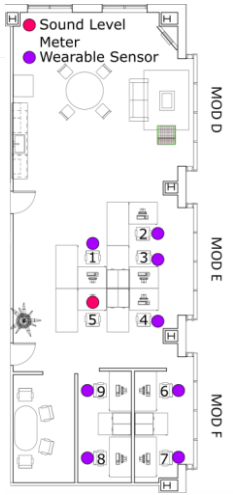


(Note: Preliminary data shown here, final processing is not complete)

Wearable Sensors – Daily/Weekly Environmental Data

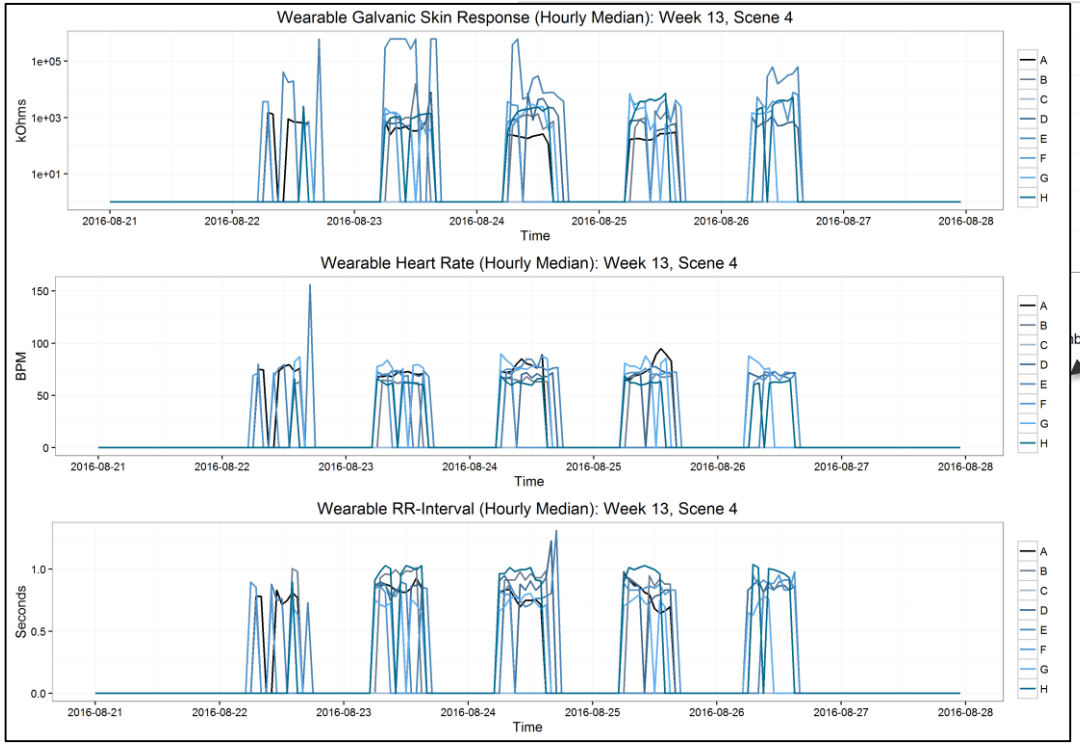


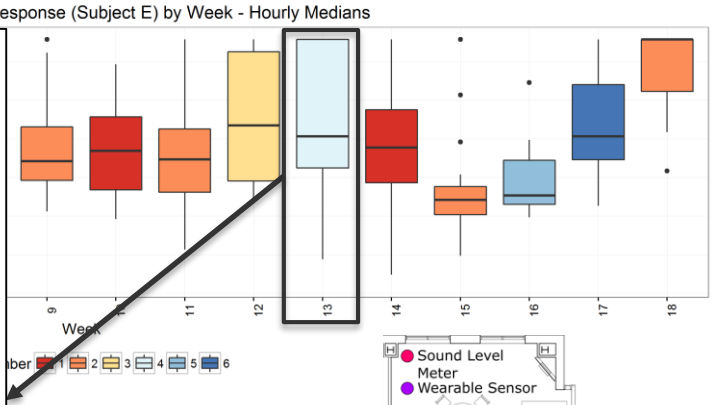


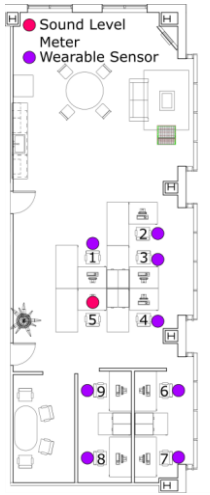


(Note: Preliminary data shown here, final processing is not complete)

Wearable Sensors – Daily/Weekly Physiological Data

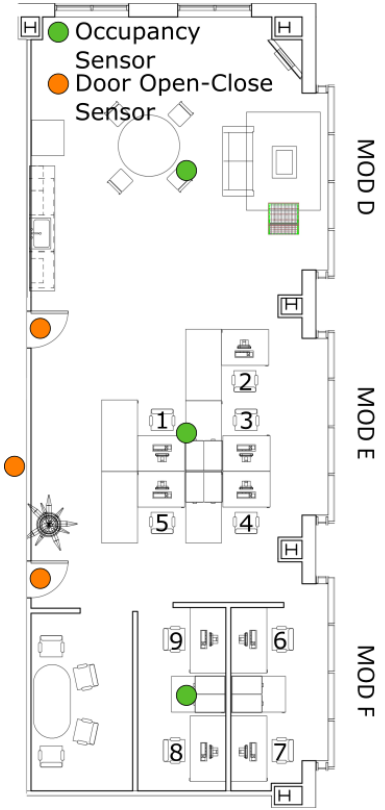


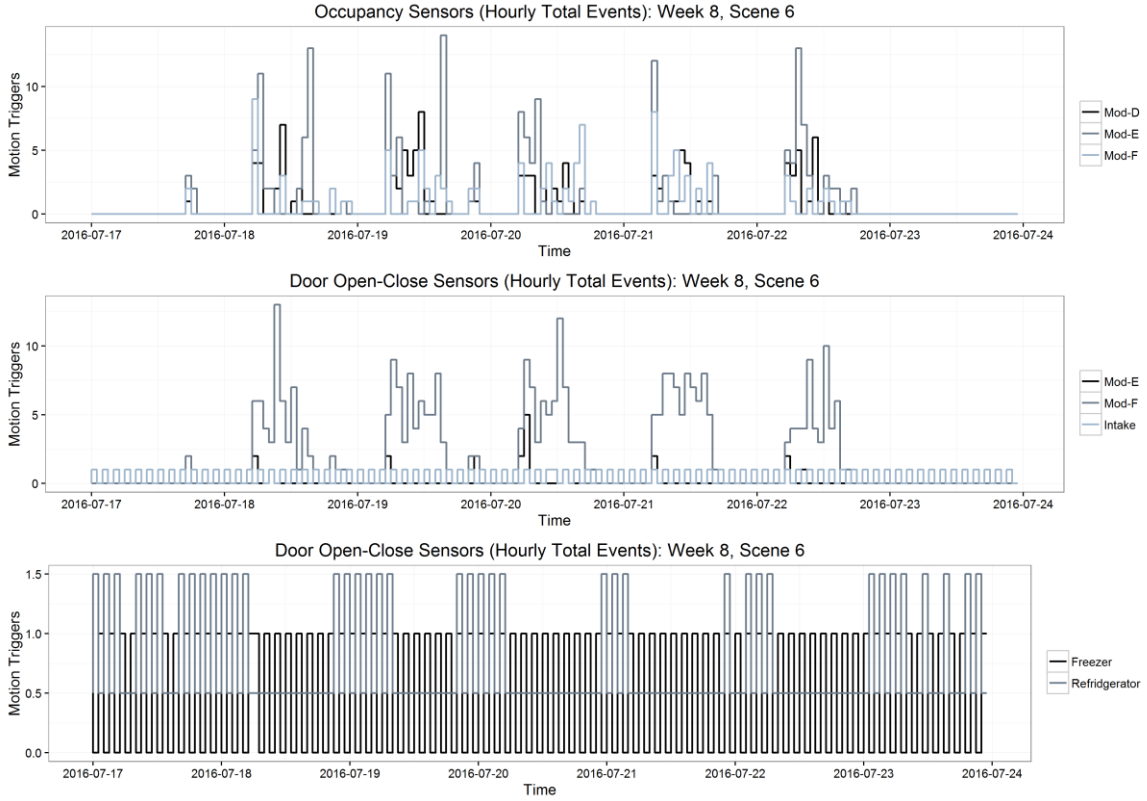




(Note: Preliminary data shown here, final processing is not complete)

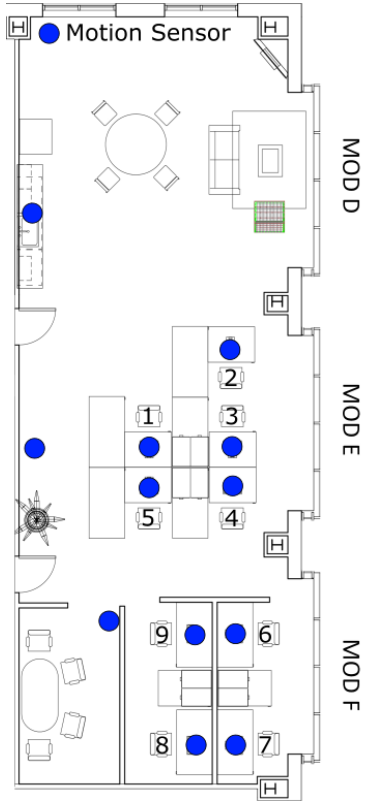
Occupancy and Door Sensors

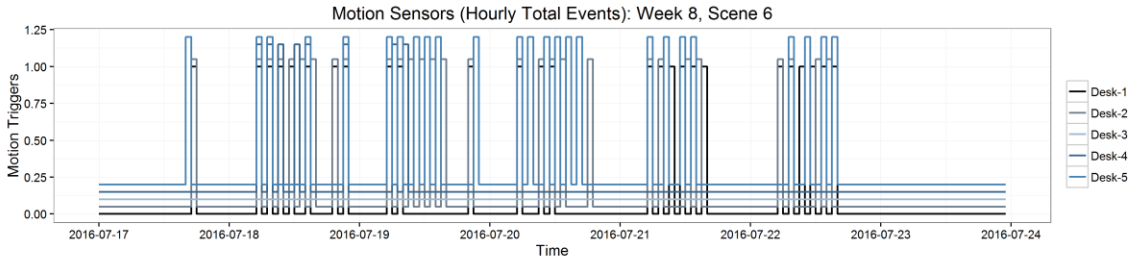


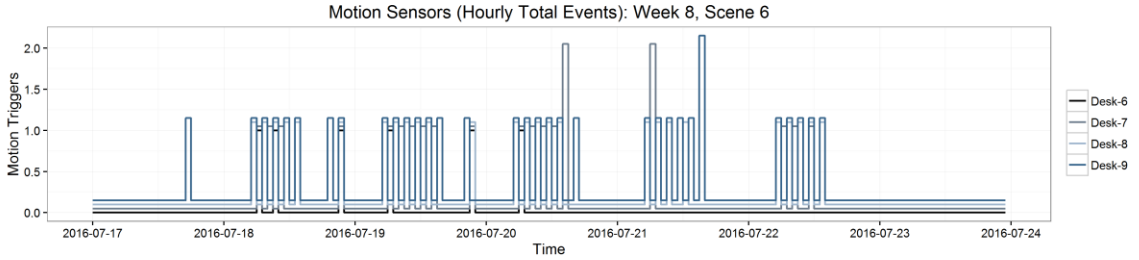


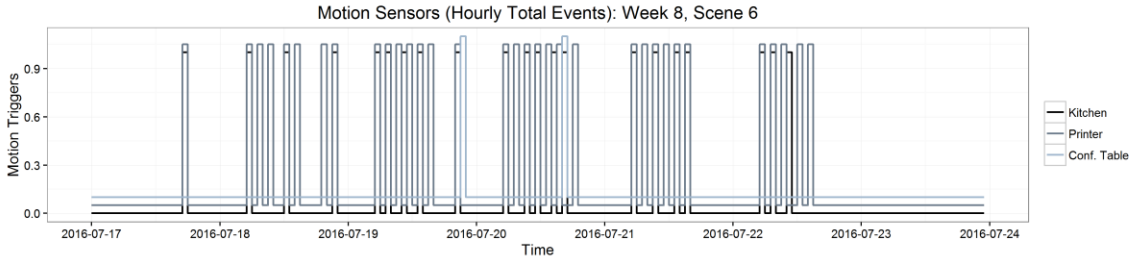
(Note: Preliminary data shown here, final processing is not complete)

Motion Sensors









(Note: Preliminary data shown here, final processing is not complete)

Exploratory and Planning-Phase Research

ALTCO+ Lighting and Performance

Goals: Investigate impact of lighting conditions on worker performance and executive cognitive function in an open-office environment
Status: Planning phases, expect to begin study early Q1 2017

IAQ and Microbiome Sampling

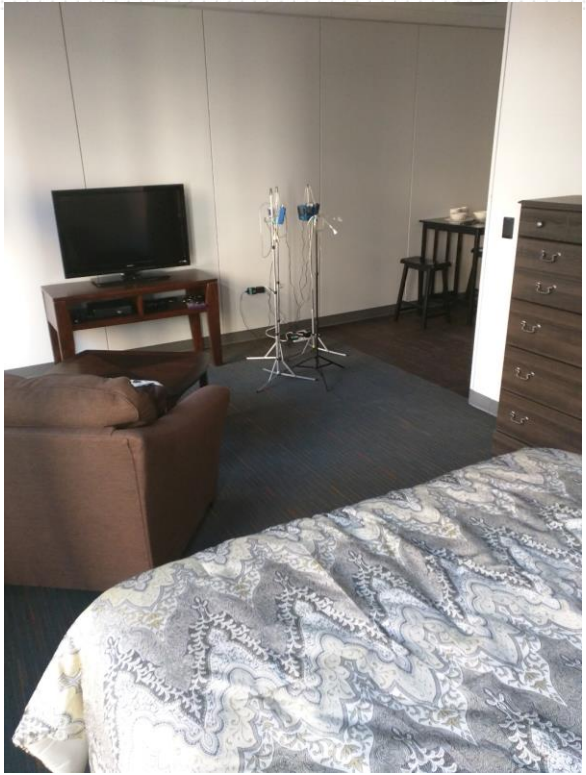
Goals: Conduct pilot investigations to test (1) accuracy of commercial air quality sensors compared to reference-grade instruments, (2) ability to monitor indoor pollutant emissions (e.g. cooking), (3) collect and analyze VOC speciation samples, and (4) ability to collect and analyze microbiome samples
Status: On-going, initial VOC and microbiome samples have been collected, VOC results are being analyzed, side-by-side comparisons have been conducted for suite of reference- and commercial-grade air quality sensors

Residential Usability Pilot Study

Goals: Assess usability and explore unknown aspects of conducting 24-7 research in residential settings
Status: Planning phases, expect to begin study Q4 2016

VOC Sampling

Residential (Module A)



In Prep (Modules B and C)

Office (Modules D, E, and F)

Well Living Lab Alliance

Available for:

- Companies that make products and services for indoor environments and want to play a leadership role in understanding and creating indoor environments to enhance human health and wellness
- Companies that want to conduct and translate research that demonstrates how lighting, temperature, water quality, surfaces and materials, sensor technology, furniture and building materials can be used to improve health and wellness
- Employers and building owners that want to create environments that provide a health benefit for their customers, employees and occupants
- Associations in the built environment space seeking to offer a cutting edge resource for their members
- Non-Profit/Philanthropic/Academic/Research/Governmental organizations that fit into a category above and/or desire to partner to advance the Lab's mission and accelerate impact in the world

Well Living Lab – Alliance Members

WELL LIVING LAB™

Founding

CBRE

IBM

view | Dynamic Glass

Sustaining

IFF

noaber foundation

Supporting

WELSPUN

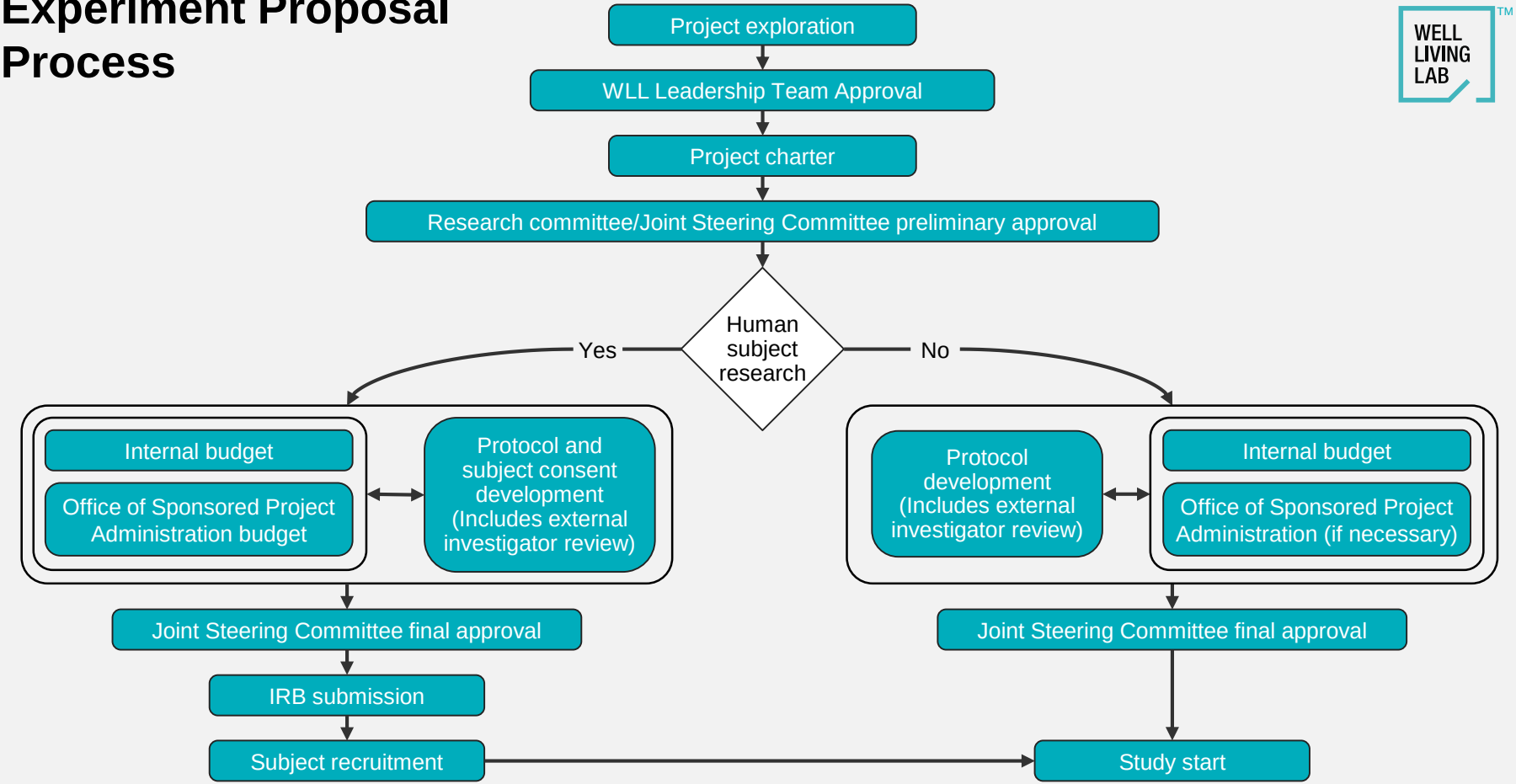
COMFORTING THE PLANET™

Read more about the Well Living Lab in a recent article in Nature by Emily Anthes: [“The office experiment: Can science build the perfect workspace?”]

Questions?

Extra Slides…

Experiment Proposal Process



Research Approach

Areas of Study	Outcomes of Interest	Simulated Spaces	Methods of Measurement	Study Populations
Air	Sleep	Bedroom	Wearable sensors	Healthy individuals
Thermal	Performance	Bathroom	Cognitive tests	Working adults
Light	Reduced exposure	Kitchen	Environmental sensors	Students
Acoustics	Stress	Office	Observation and ethnography	Recovering patients
Ergonomics	Fitness	Classroom	Auto-ethnography and self reports	Seniors
Behavior & physiology	Nutrition	Hotel room		At-risk populations
Physical activity	Comfort			

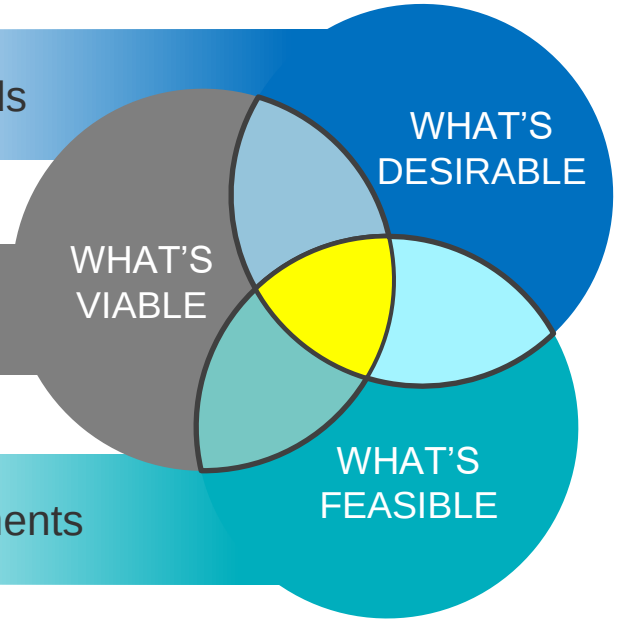
Theme Framework

Themes and experiments selected with a Desirable/Viable/Feasible framework

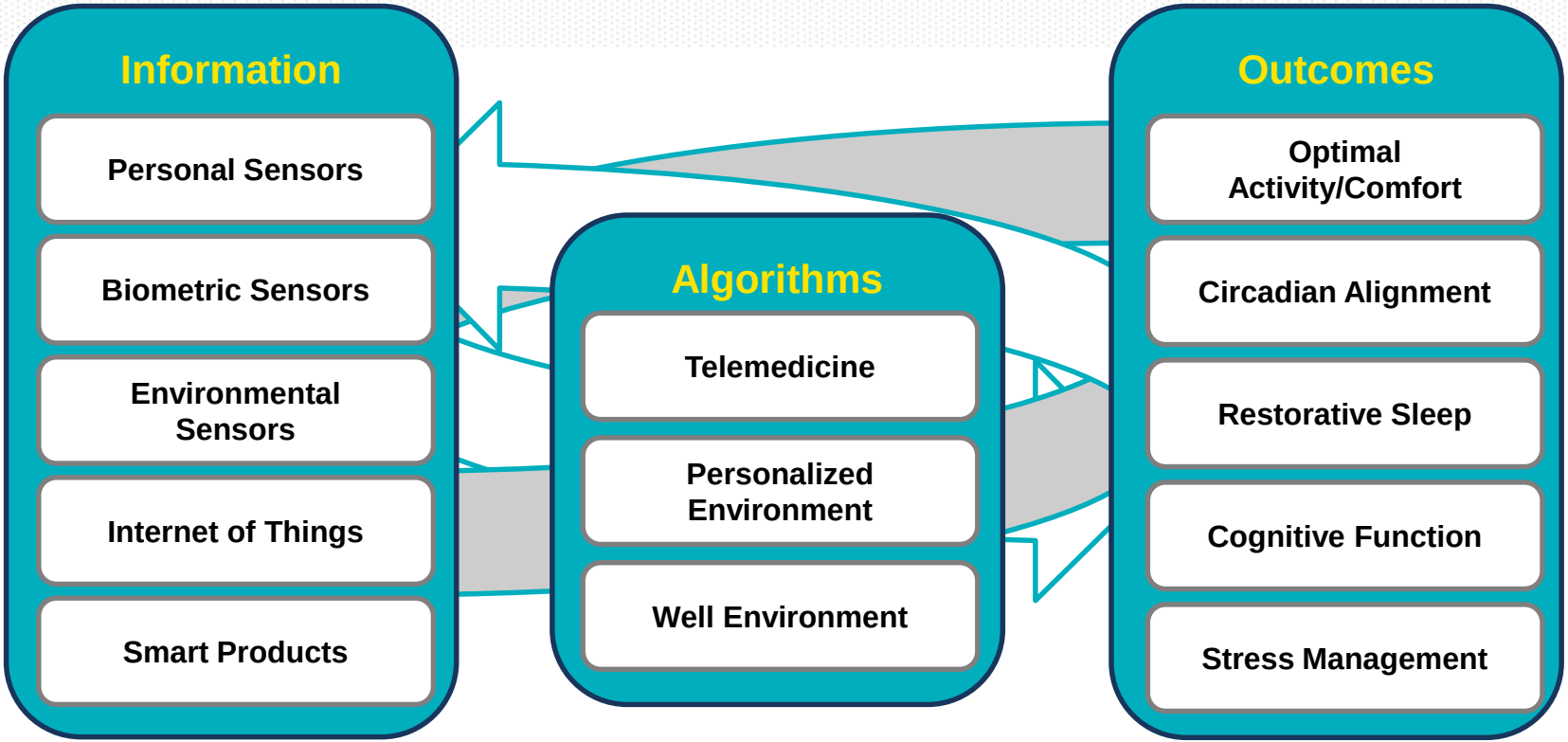
Anchored around scientific exploration and human needs

Informed by assets and capabilities of Delos and Mayo Clinic and partner organizations

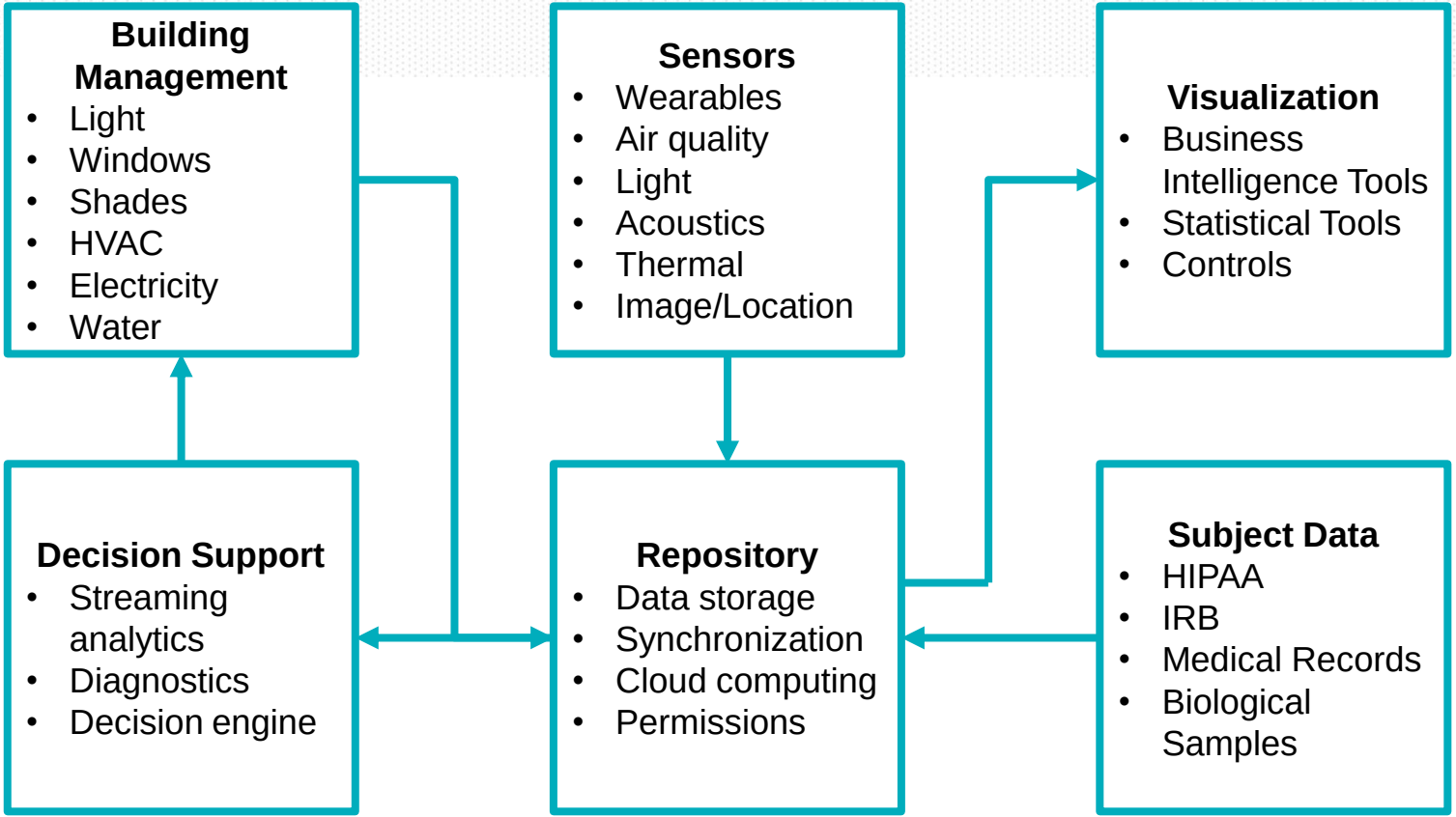
Bolstered by best practices and technological developments



Focus on Wellness Outcomes



Data Infrastructure



Modular Ceilings and Floors