

RCx 101

A Technical Introduction to Existing Building Commissioning

Existing Building Commissioning Concepts and the Ten Key Skills



Instructor:

David Sellers

Senior Engineer

Facility Dynamics Engineering

Agenda

- A Bit About Me
- What Is Building Commissioning?
- Why Do We Need To Commission?
- Commissioning's Benefits
- Functional Testing And The Commissioning Time Line
- The System Concept
- The Load Profile
- The Control System
- Commissioning And The Broader Perspective



A Bit About Me

or

What it takes to
become a
commissioning
provider



An Unanticipated Turn of Events



Image Courtesy www.kpluwonders.org/

A Bit of Inspiration Early On

1976

- Bill Coad inspires me to think a different way...

... that is to practice our profession with an emphasis upon our responsibility to protect the long-range interests of the society we serve and, specifically, to incorporate the ethics of energy conservation and environmental preservation in everything we do.

- ASHRAE Journal, vol. 42, no. 7, p. 16-21
- <http://www.av8rdas.com/bill-coads-writings.html#ethic>

Energy Conservation Is an Ethic

William J. Coad, P.E.
Fellow/Life Member ASHRAE

Professionalism means different things to different people. For some, professionalism in engineering describes a method of charging for services; others believe it simply describes a credential achieved. But Webster's Collegiate Dictionary defines "professional" as: "...characterized by or conforming to the technical or ethical standards of a calling requiring specialized knowledge and often long and intensive academic preparation."

Thus, a "professional" is a person who can be so described.

Just what is it that the mechanical/electrical engineering professional does to earn that title?

In a way, the engineering professional hasn't had good "press" or public relations for the past 150 years. It started in the early to mid-19th century when Maxwell, Sadi Carnot, Diesel, Otto, and the other thermodynamicists and energy engineers unlocked the secrets to turning the resources of the world into the slaves of mankind. Since that time, the mechanical/electrical engineering community has held the goose that laid the golden egg. And somewhere within that community, they became so intent upon serving humanity in the short run that they lost sight of their long-range responsibility.

This is a good news/bad news story, and, as society stands here today, they cannot be too critical of their performance over the past 150 years. The mechanical/electrical engineering professionals have provided humanity with a massive population of "mechanical slaves." That analogy is borrowed from Oscar Wilde, who wrote in an essay in 1894:

"The fact is that civilization requires slaves. The Greeks were quite right there. Unless there are slaves to do the ugly horrible uninteresting work, culture and contemplation become almost impossible. Human slavery is wrong, insecure and demoralizing. On mechanical slavery, on the slavery of the machine, the future of the world depends."

The result of our success in creating this mechanical slave is the world in which we live today. We have the mechanical slave at our bidding to wash our clothes, cook our food, wash our dishes, move us about over long and short distances, stoke our fires, keep us cool, clean our homes, operate our factories, perform complicated calculations at unbelievable speeds, keep our records, and on and on. Oscar Wilde could not have envisioned, in his wildest dreams, the prophetic significance of that statement.

It is not within the context of this article to expound on the influence of technology upon the state of mankind—the social structures, economy, and human relationships. In his book, *The Fifties*, David Halberstam, discussing the sociological revolution unfolding in the fifties, said:

"The list of technological and scien-

tific changes that transformed America in those years (the fifties) is an extraordinary one—the coming of network television to almost every single home in the country changed America's politics, its leisure habits, and its racial attitudes; the arrival of air conditioning opened up southern and southwestern regions; the early computers were transforming business and the military; the coming of jet planes revolutionized transportation."

And that was but one decade! And in one country! So, looking back, the engineering community can bask in the knowledge that they did a pretty good job. They certainly changed the world.

But going back to Oscar Wilde's mechanical slave—the mechanical slave, like the human slave, needs food. The food for the mechanical slave is energy. The most available energy sources, those that are most readily available and which we have been using for these 150 years, are the nonreplenishable energy resources of the earth.

Now, returning to the topic of professionalism, and paraphrasing the definition for engineering professionalism:

Engineering professionalism is characterized by conformance to the technical and ethical standards related to the practice of engineering.

The technical standards are self-evident. So, focusing on the ethical standards, the definition of ethics is "...a set of moral principles or standards."

Now, consider our situation as we stand

About the Author

William J. Coad, P.E., is with McClure Engineering Associates in St. Louis. He serves on the ASHRAE executive committee as treasurer, and is vice chair of Regions Council. He has held various leadership positions within ASHRAE and is presently active on Technical Committees 1.10, 6.1, and 8.10.

Visit ASHRAE's Online Magazine
www.ashraejournal.org

A Bit of Inspiration Early On

that connects me with my roots



A Bit of Mentoring Along the Way (a Lot Actually)





Maybe your heart is telling
you something and you
should listen





Davey, no matter how much you love what you do, it should never be more than 49% of your life





Kiss on nose and vigorous
tail wagging when you
arrive home at 3 am after a
week out of town





A bit of Mentoring By
Buildings (a Lot Actually)



A bit of Mentoring By Buildings (a Lot Actually)

- Willing to work hard



$$F=ma$$

(And the rest is intuitively obvious)

Mr. Nickels, Highschool Junior Year Physics



A bit of Mentoring By Buildings (a Lot Actually)

- Willing to work hard
- Belief in physical principles



$$F=ma$$

(And the rest is intuitively obvious)

Mr. Nickels, Highschool Junior Year Physics



A bit of Mentoring By Buildings (a Lot Actually)

- Willing to work hard
- Belief in physical principles
- Curiosity
- Learning to say *I could be wrong*



$$F=ma$$

(And the rest is intuitively obvious)

Mr. Nickels, Highschool Junior Year Physics



A bit of Mentoring By Buildings (a Lot Actually)

- Willing to work hard
 - Belief in physical principles
 - Curiosity
 - Learning to say *I could be wrong*
- But ...*





$$F=ma$$

(And the rest is intuitively obvious)

Mr. Nickels, Highschool Junior Year Physics



A bit of Mentoring By Buildings (a Lot Actually)

- Willing to work hard
- Belief in physical principles
- Curiosity
- Learning to say *I could be wrong*
But ...
- Learning to follow your nose





$$F=ma$$

(And the rest is intuitively obvious)

Mr. Nickels, Highschool Junior Year Physics



A bit of Mentoring By Buildings (a Lot Actually)

- Willing to work hard
- Belief in physical principles
- Curiosity
- Learning to say *I could be wrong*
But ...
- Learning to follow your nose and your heart



Let's Take a Poll

1. How many of you in your current position are doing what you went to college to learn to do?

☐

Yes I am doing what I set out to do or something very close to it.

☐

No, I am doing something totally different.

Let's Take a Poll

1. How many of you in your current position are doing what you went to college to learn to do?

☐

Yes I am doing what I set out to do or something very close to it.

☒

No, I am doing something totally different.

NEVER NEVER LOOSE SIGHT
OF THE FACT THAT YOU CAN BE ANYTHING
YOU WANNA BE... YOU COULD BE SOMETHING
AS SIMPLE AS A NOSE, MUSTACHE OR A SMILE.
OR, FOR THAT MATTER, AS COMPLEX AS A DOG, TREE
OR BARBED WIRE FENCE...
HECK, YOU COULD BE
THE PRESIDENT!



AN INSPIRATIONAL
APPROACH TO CARTOONING

RJ BALLARD

<http://www.rjballard.com/thefront.htm>

The 10 Key Skills



Key EBCx Skills

1. Be able to benchmark and perform utility analysis
2. Be able to scope a facility for obvious indicators of opportunity
3. Be familiar with fundamental principles and building systems
4. Understand and apply the system concept
5. Be able to perform data logging and trend analysis
6. Be familiar with functional testing techniques
7. Be familiar with data analysis techniques
8. Be familiar with basic HVAC and energy calculations
9. Be familiar with cost/benefit and return on investment calculations
10. Be familiar with implementation strategies and techniques

Key EBCx Skills – Skill 3 is a BIG ONE!

1. Be able to benchmark and perform utility analysis
2. Be able to scope a facility for obvious indicators of opportunity
3. Be familiar with fundamental principles and building systems
4. Understand and apply the system concept
5. Be able to perform data logging and trend analysis
6. Be familiar with functional testing techniques
7. Be familiar with data analysis techniques
8. Be familiar with basic HVAC and energy calculations
9. Be familiar with cost/benefit and return on investment calculations
10. Be familiar with implementation strategies and techniques

Key EBCx Skills – Skill 3 is a BIG ONE!

3. Be familiar with fundamental principles and building systems

- i. Saturated systems
- ii. Loads, psychrometrics and envelopes
- iii. Centrifugal machines
- iv. Refrigeration and cooling equipment
- v. Heating equipment
- vi. Piping systems
- vii. Variable flow water systems
- i. Duct systems
- ii. Air and water side economizers
- iii. Make up air systems and exhaust systems
- iv. Variable air volume systems
- v. Control systems
- vi. Electrical systems
- vii. Life safety systems

5

Television, radio & news for x FDE-Intranet :: TimeSheet x Pacific Northwest Environm x Television, radio & news for x Car Rental: Save More on R x Home x rcxu-v2 x New Tab x + -

https://www.rcxuniversity.org

Apps 00-Kathy's Calendar 00 OPB On-Line 00-Weather Airplanes Building Benchmarks Copy Right Energy Financial Fit Bit Hawaii Trip Heart Heart Home Improvements Music Nature Oregon PID Other bookmarks

RCx University is a Great Resource

Skills

Login/Sign up

Search Site

RCxU

Learn your building.

What is RCx?

What is RCxU?

Explore RCx Skills

Scroll down to learn about RCx?

V2

RCx is about optimizing a facility's energy systems

<https://www.rcxuniversity.org/>

What is RCx?

top

Television, radio & news for xFDE-Intranet :: TimeSheet xPacific Northwest Environm xTelevision, radio & news for xCar Rental: Save More on R xHome xrcxu-v2 | Skills xNew Tab x

https://www.rcxuniversity.org/skills

Apps00-Kathy's Calendar00 OPB On-Line00-WeatherAirplanesBuilding BenchmarksCopy RightEnergyFinancialFit BitHawaii TripHeartHeartHome ImprovementsMusicNatureOregonPIDOther bookmarks

HomeSkills

Login/Sign up

RCxU focuses on10 key RCx skills

HVAC FundamentalsBenchmarksScopingSystem DiagramsTrendingFunctional TestsData AnalysisEnergy CalcsROI CalcsImplementation

?

Click on the skill you'd like to explore

Thinking about skipping this one?
Assess your skills with our HVAC Pre-Test

Safety First
Terms of Use

Contact RCxU

RCxUV2

HertzReservation-2.....ics ^HertzReservation-2.....ics ^

Show all x

Television, radio & news for xFDE-Intranet :: TimeSheet xPacific Northwest Environm xTelevision, radio & news for xCar Rental: Save More on R xHome xrcxu-v2 | Benchmarks xNew Tab x

https://www.rcxuniversity.org/benchmarks

Apps00-Kathy's Calendar00 OPB On-Line00-WeatherAirplanesBuilding BenchmarksCopy RightEnergyFinancialFit BitHawaii TripHeartHeartHome ImprovementsMusicNatureOregonPIDOther bookmarks

HomeSkills

Login/Sign up

Search Site

RCx Skill #2

HVAC FundamentalsBenchmarksScopingSystem DiagramsTrendingFunctional TestsData AnalysisEnergy CalcsROI CalcsImplementation

Back to main10 RCx Skills page

Benchmarks

(35 mins of video)

The RCx process begins with an off-site evaluation of existing energy profiles.

In this module, we'll look at how comparing a building's performance against that of its peer groups and analyzing energy usage trends can help set early savings and budget estimates.

1 comment

Leave a message...

☆☆☆☆☆

great job

hover over icons for module description

Transition to RCx-Specific Skills

David's Introduction and Approach to Benchmarking

Industry Estimates on RCx Savings & Cost

Practice Benchmarking a Building

The EBCx Skills Guidebook is Built Around the 10 Skills

<http://www.av8rdas.com/ebcx-skills-guidebook.html>

Existing Building Commissioning Skills Guidebook

The guidebook is organized using the 10 Key Commissioning Skills as a framework and provides:

- A description and example of why the skill is important;
- Learning objectives to help guide a self study effort;
- Links to primary resources that can be used to learn about the skill in a self study effort;
- Links to secondary resources that can be used to dig in deeper if you have a particular interest in a particular topic.

The *10 Skills Learning Objectives Checklist* is intended to complement the guidebook by providing a list of all of the learning objectives with a check-box that allows you to track your progress as you work your way through the guidebook in a self study effort.



EBCx Skills Guidebook (ebcx_technical_skills_guidebook_v2017-07-07_web.pdf)

[Download File](#)



10 Skills Learning Objectives Checklist (skills_table_web_v5.xlsx)

[Download File](#)



Existing Building Commissioning Guidebook

Introduction

Over the years, Facility Dynamics has been involved with providing technical training with a focus on existing building commissioning in a number of different venues and for a number of different clients including the Pacific Energy Center, Marriott, and IMCOM. For those programs, I have frequently been the lead technical trainer.

As the training agendas evolved, it started to become clear that there were a number of key skills that it would be desirable to develop if you were going to pursue existing building commissioning. About 5 years ago, Russ Good and Barry Estes of Marriott International asked me to make a list of the ten most important skills and to complement it with a list of the three primary resources that were available were available to help develop each skill.

At that point in time, I had already compiled a list of technical resources that we used to support the classes, but it was about 40 pages long and always growing. So, it could be a bit overwhelming if you were just getting into this and Russ and Barry wanted me to figure out how to focus things a bit.

That forced me to think about what really mattered from a technical stand point if you are out in the field doing this sort of work. It was really hard for me to whittle the list down to only 10 skills, but Barry and Russ were pretty firm on that, and I finally pulled it off. Truth be told, I kind of cheated in a way because I made one of the skills Familiarity with HVAC fundamentals and then put 10 sub-skills under that.

But the exercise was a really good one and when I was finished, I realized that the list was a pretty good framework for organizing the technical side of any of the training classes and I have been using it ever since in that manner. In addition, I reorganized the resource list so that the resources were grouped under headings that correlated with the 10 skills.

I also should point out that while the driver for developing the list of the 10 skills was Existing Building Commissioning training, the skills really apply across the boards. In other words, you generally will use the same skills for new construction commissioning, ongoing commissioning, and general building operations.

In fact, one of my little jokes in class is that there are all sorts of names and acronyms applied to processes where you apply the 10 skills, including Existing Building Commissioning, EBCx, Retrocommissioning, RCx, Building Tune-ups, Ongoing Commissioning, NCx, Facility Operations, etc. I have had the opportunity to work on projects where all of those names have been applied to what I was doing.

But when I think about it, all of them generally are technically the same thing that I was doing back in 1976, when I first became involved with the industry. Back then, we just called it

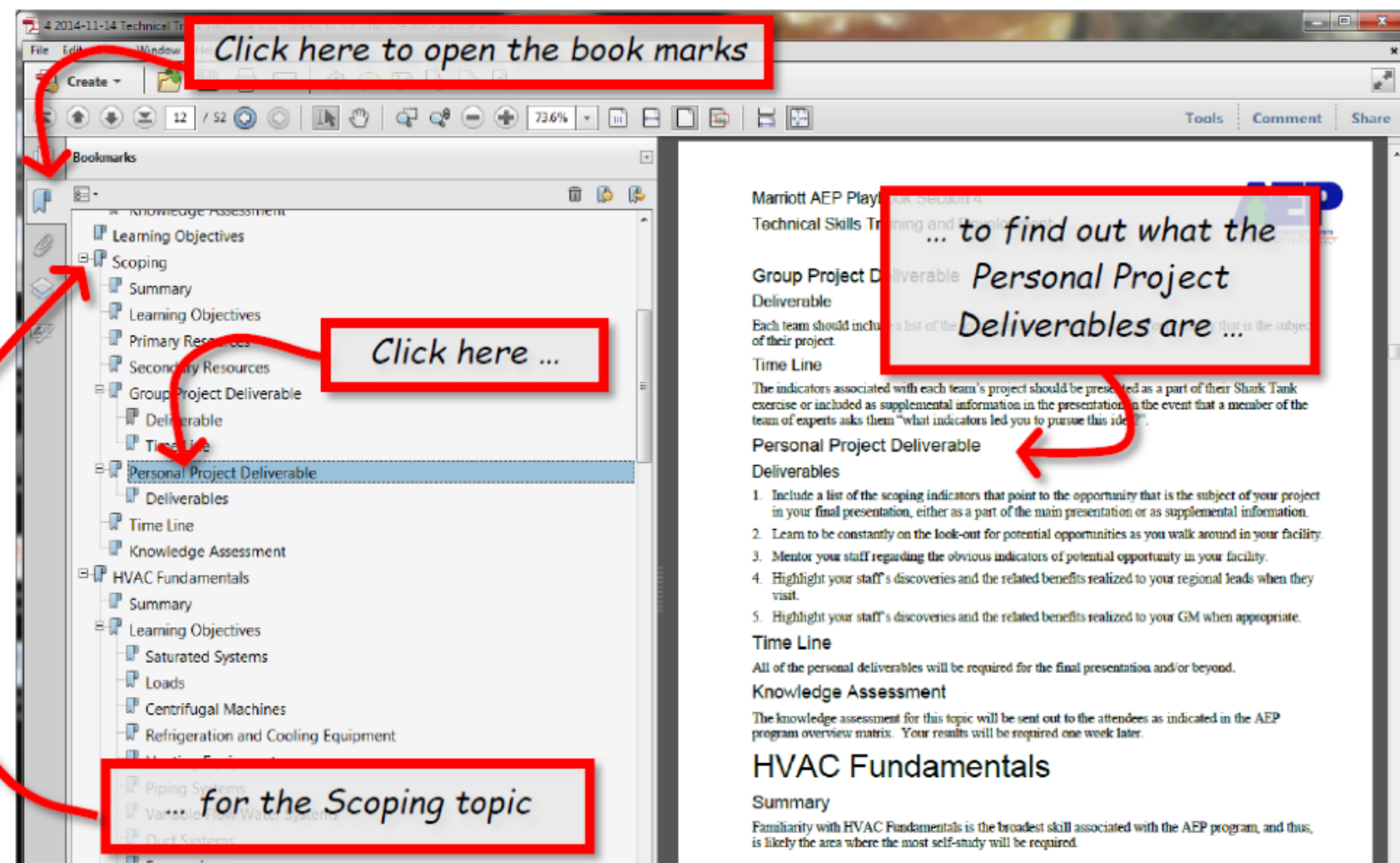


Bookmarks

- Introduction
- Contents
- Navigating Through the Guidebook
- The Resource List; a Living Document
- The Ten Key Commissioning Skills
- Benchmarking and Utility Analysis
 - Summary
 - Learning Objectives
 - Primary Resources
 - Secondary Resources
- Scoping
 - Summary
 - Learning Objectives
 - Primary Resources
 - Secondary Resources
- HVAC Fundamentals
 - Summary
 - Learning Objectives

Navigating Through the Guidebook

If you are reading this document in the electronic version, you can use the bookmarks included in this document to jump to a topic of interest as indicated in as illustrated in Figure 1.



The Resource List is Organized Around the 10 Skills

<http://www.av8rdas.com/resource-list.html>

Resource List

The list is organized by the ten key technical skills we think are important for anyone who wants to work in the commissioning and building operations fields. If you want to know what we think those skills are and why, just click here.

If you turn on the bookmarks in the .pdf document (typically, you can do that by clicking on the little ribbon shaped icon on the left side of the Acrobat window), you will find links that will let you easily and quickly move around in the document. The document also includes a description of how to navigate through it in a section that starts on page 2.

We try to update the document every year or so, adding new things we have found, removing items that are obsolete, and



N.W. Satellite Office
8560 North Buchanan Avenue
Portland, Oregon 97203
Phone: (503) 266-1494
Email: info@FacilityDynamics.com

Home Office
6780 Alexander Bell Drive, Suite 200
Columbia, MD 21046
Phone: (410) 290-0900
www.FacilityDynamics.com

Resources and Reading List

Date: November 2, 2011, (Revised October 9, 2014)

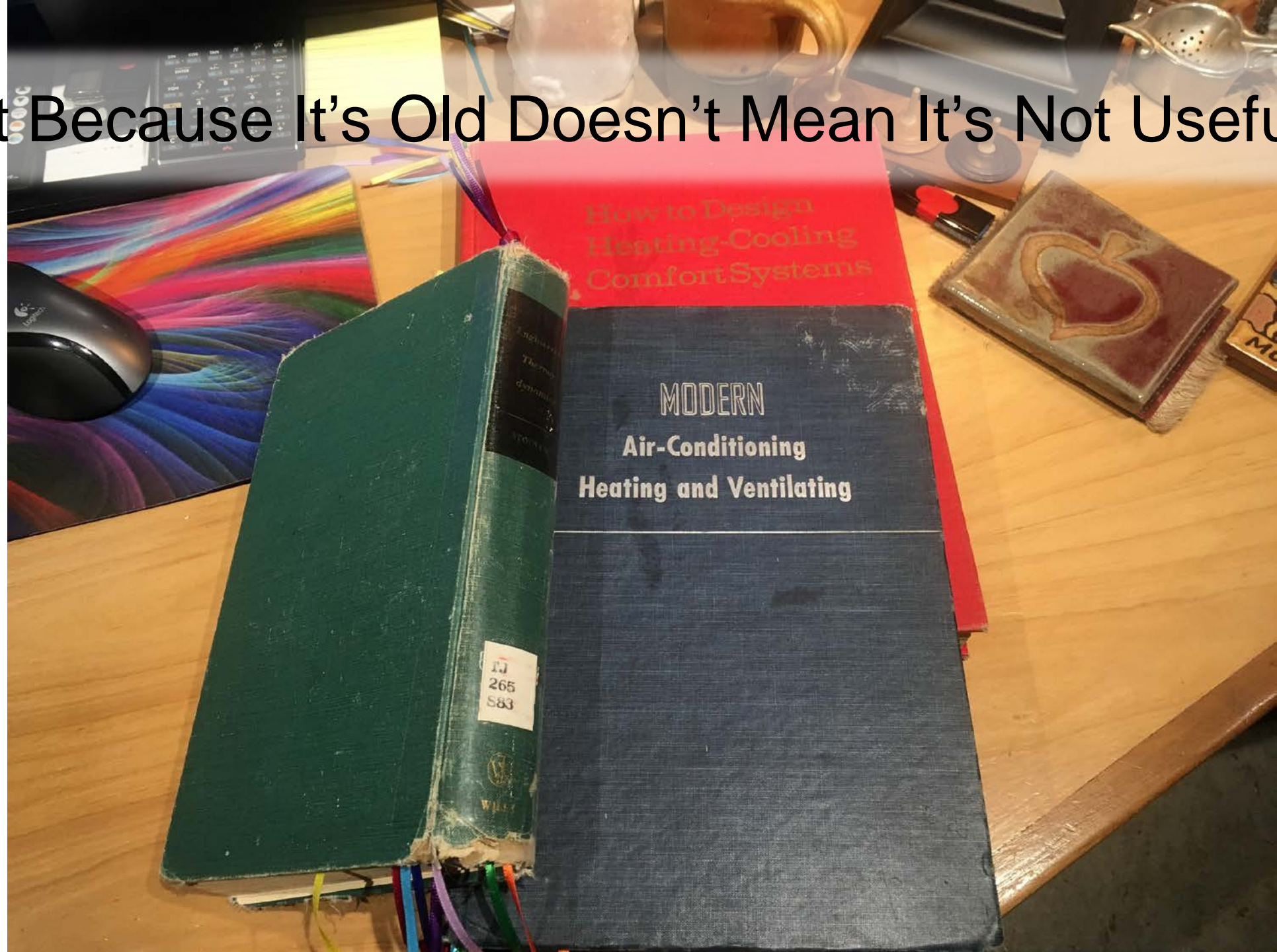
Overview

Over the years, one of the challenges we have faced in delivering technical classes for the Pacific Energy Center, the University of Wisconsin, SMUD, and other venues is to establish a common level of understanding of the fundamentals behind the topics to be discussed. Classes are often attended by people with a broad range of experience, including operators and facilities engineers who deal with technical issues and machinery on a day to day basis at one end of the technical spectrum and people new to the industry or who function more in management roles than technical roles at the other end. There can also be people with very deep knowledge in a focused area of expertise who have less depth in other areas.

Initially, we tried to address this by starting with the fundamentals and working our way up to the targeted content. But this tended to frustrate the more experienced attendees, reduced the time we had to spend on the intended topic, and could be overwhelming for the less experienced folks because we went at a pretty fast pace.

Over the past several years, we have successfully experimented with a different approach where-in we distribute a resource and reading list to attendees prior to class to allow them to self-educate where necessary. Typically, we supplement this list with a class specific cover memorandum to focus the pre-class preparation effort on topics we feel it is essential for you to understand to fully appreciate the class

Just Because It's Old Doesn't Mean It's Not Useful



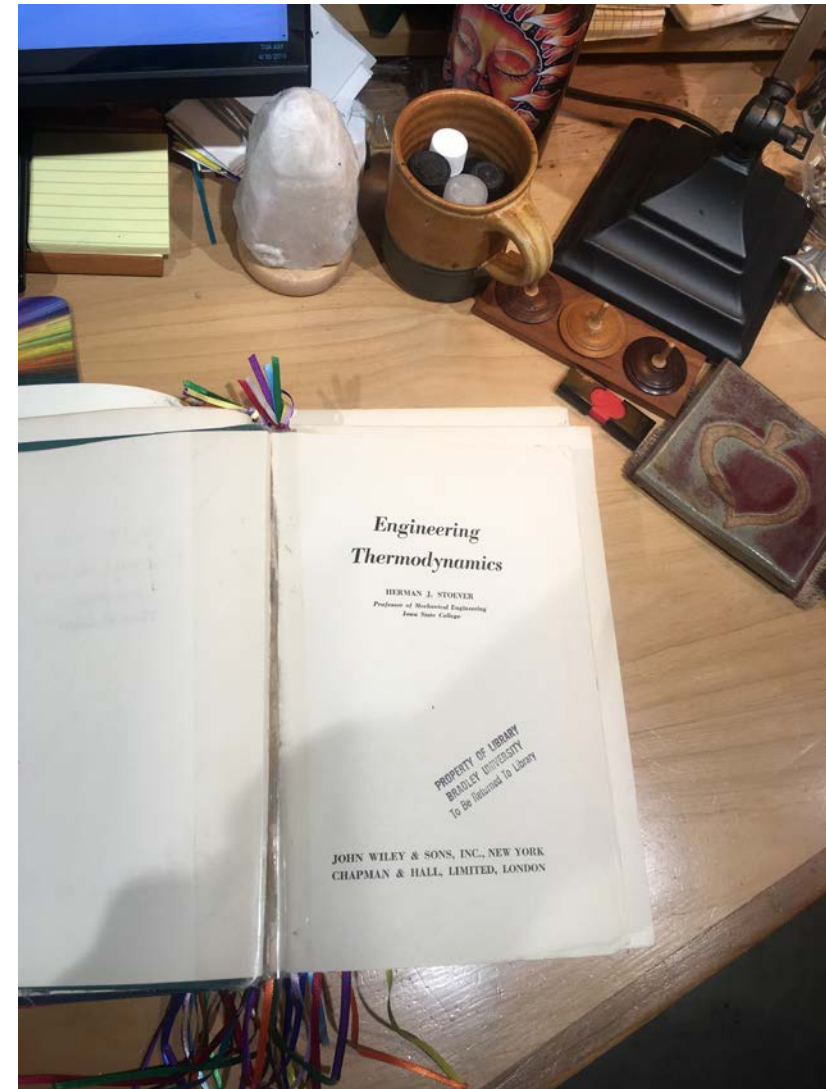
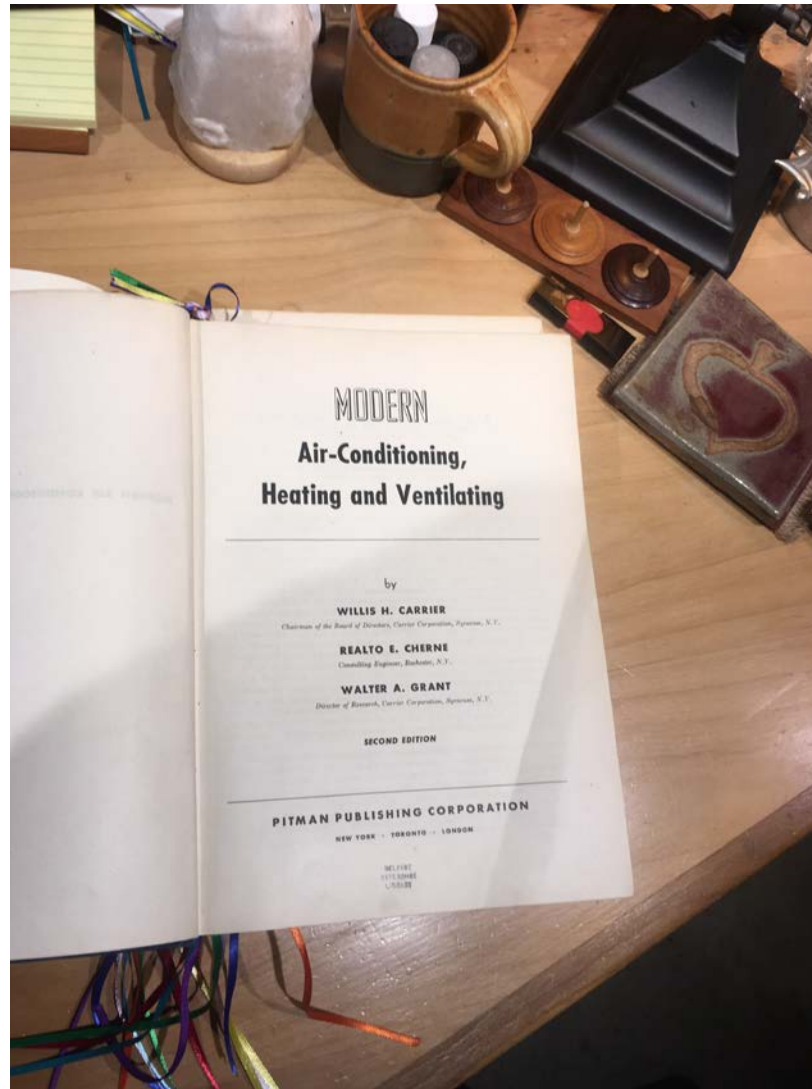
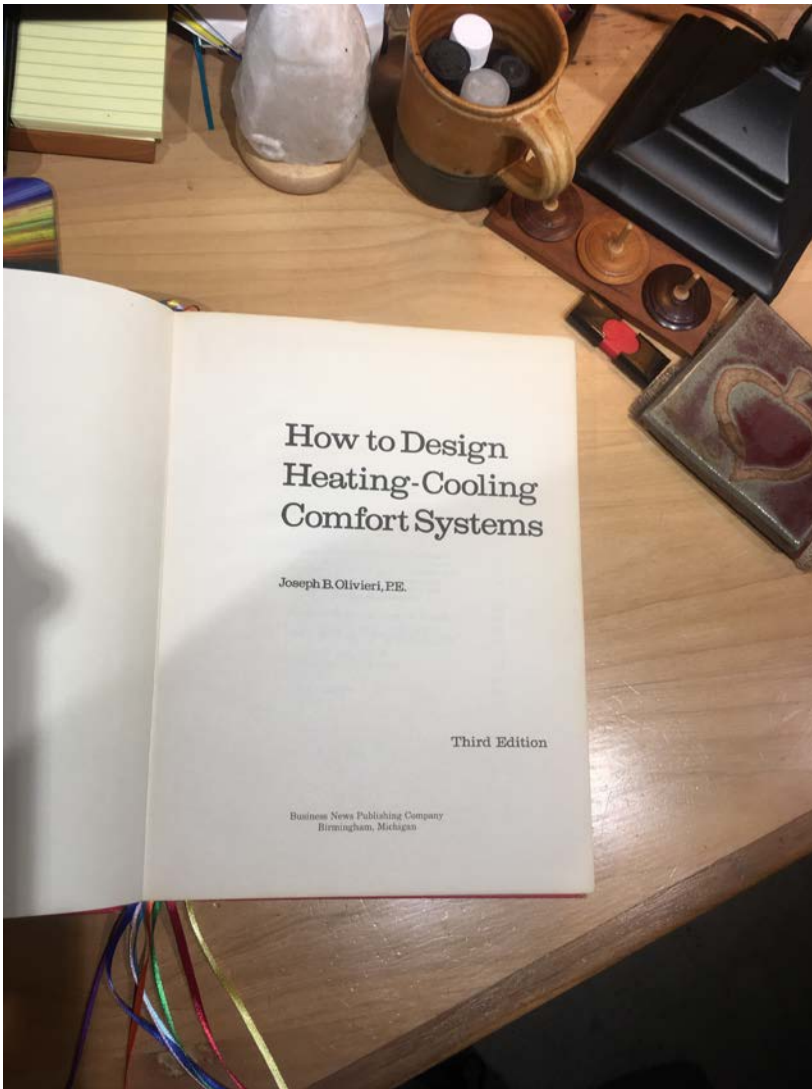


PRINCIPLES OF REFRIGERATION

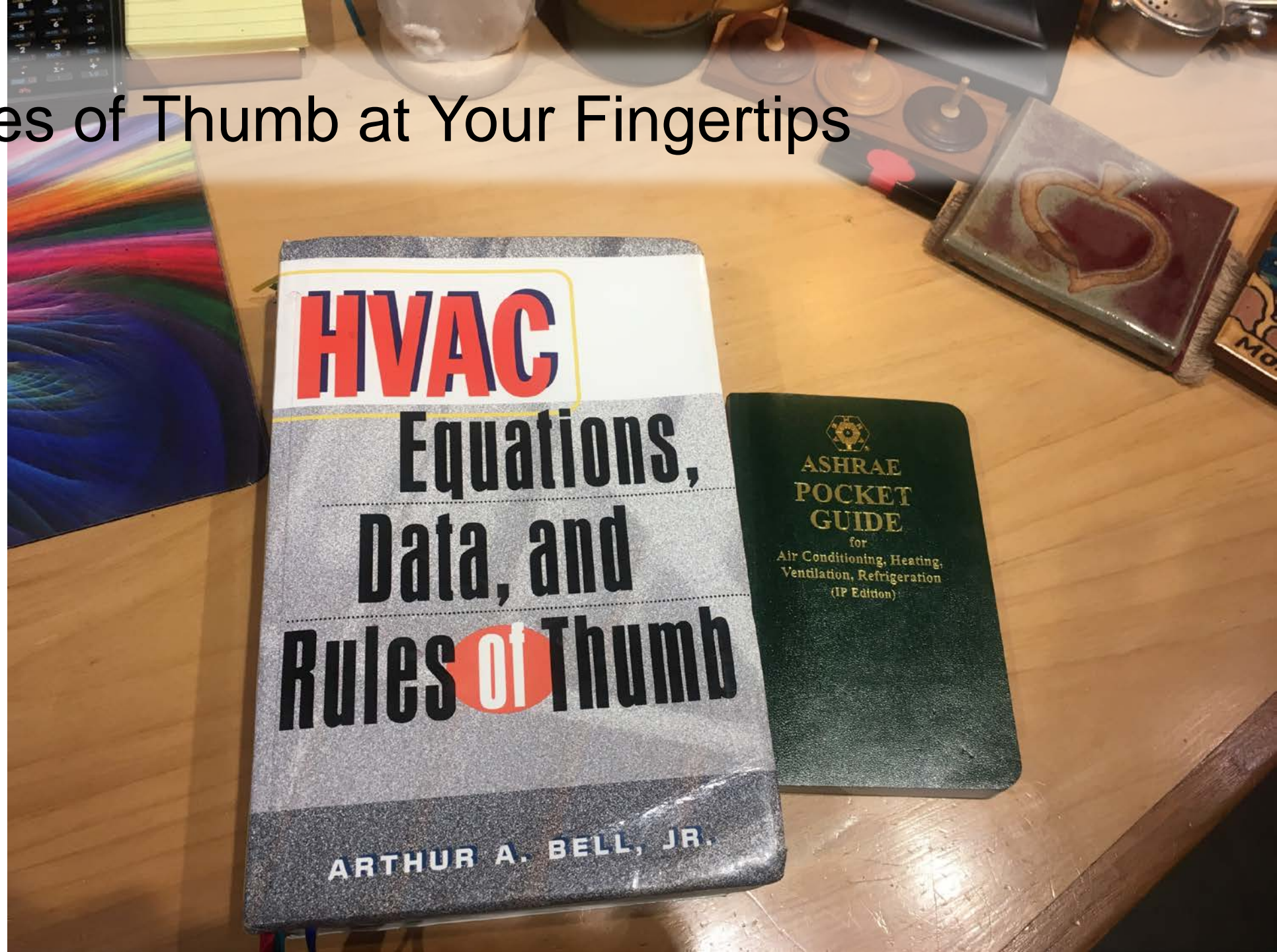
F I F T H E D I T I O N

ROY J. DOSSAT

THOMAS J. HORAN



Rules of Thumb at Your Fingertips



Search



My Goal



Facility Dynamics
ENGINEERING

<http://www.av8rdas.com//>

What Is Building Commissioning?



Dictionary definition



Com·mis·sion

kə'miSHən

Verb; Gerund or present participle: Commissioning

1. Give an order for or authorize the production of (something such as a building, equipment, or work of art).

The portrait was commissioned by his widow in 1792

synonyms: order, authorize, bespeak

2. Bring (something newly produced, such as a factory or machine) into working condition.

We had a few hiccups getting the heating equipment commissioned

3. To put a ship into commission

Dictionary definition

An analogy to a ship's sea trials or "shake-down" cruise

3. To put a ship into commission

Industry Definition

Commissioning is a systematic process of ensuring that all building systems perform interactively according to the contract documents, the design intent and the Owner's operational needs

- Begins in predesign
- Documents the design intent
- Continues through construction, acceptance, the warranty period, and through the building's life cycle
- Includes functional testing
- Includes training
- Documents performance

Industry Definition

Commissioning is a **systematic** process of ensuring that all building systems perform interactively according to the contract documents, the design intent and the Owner's operational needs

- Begins in predesign
- Documents the design intent
- Continues through construction, acceptance, the warranty period, and through the building's life cycle
- Includes functional testing
- Includes training
- Documents performance

Industry Definition

Commissioning is a systematic process of ensuring that all building systems perform interactively according to the contract documents, the design intent and the Owner's operational needs

- Begins in predesign
- Documents the design intent
- Continues through construction, acceptance, the warranty period, and through the building's life cycle
- Includes functional testing
- Includes training
- Documents performance

Industry Definition

Commissioning is a systematic process of ensuring that all building systems perform interactively according to the contract documents, the design intent and the Owner's operational needs

- Begins in predesign
- Documents the design intent
- Continues through construction, acceptance, the warranty period, and **through the building's life cycle**
- Includes functional testing
- Includes training
- Documents performance

Industry Definition

Commissioning is a systematic process of ensuring that all building systems perform interactively according to the contract documents, the design intent and the Owner's operational needs

- Begins in predesign
- Documents the design intent
- Continues through construction, acceptance, the warranty period, and through the building's life cycle
- Includes functional testing
- Includes training
- Documents performance

Industry Definition

Commissioning is a systematic process of ensuring that all building systems perform interactively according to the contract documents, the design intent and the Owner's operational needs

- Begins in predesign
- Documents the design intent
- Continues through construction, acceptance, the warranty period, and through the building's life cycle
- Includes functional testing
- Includes training
- Documents performance

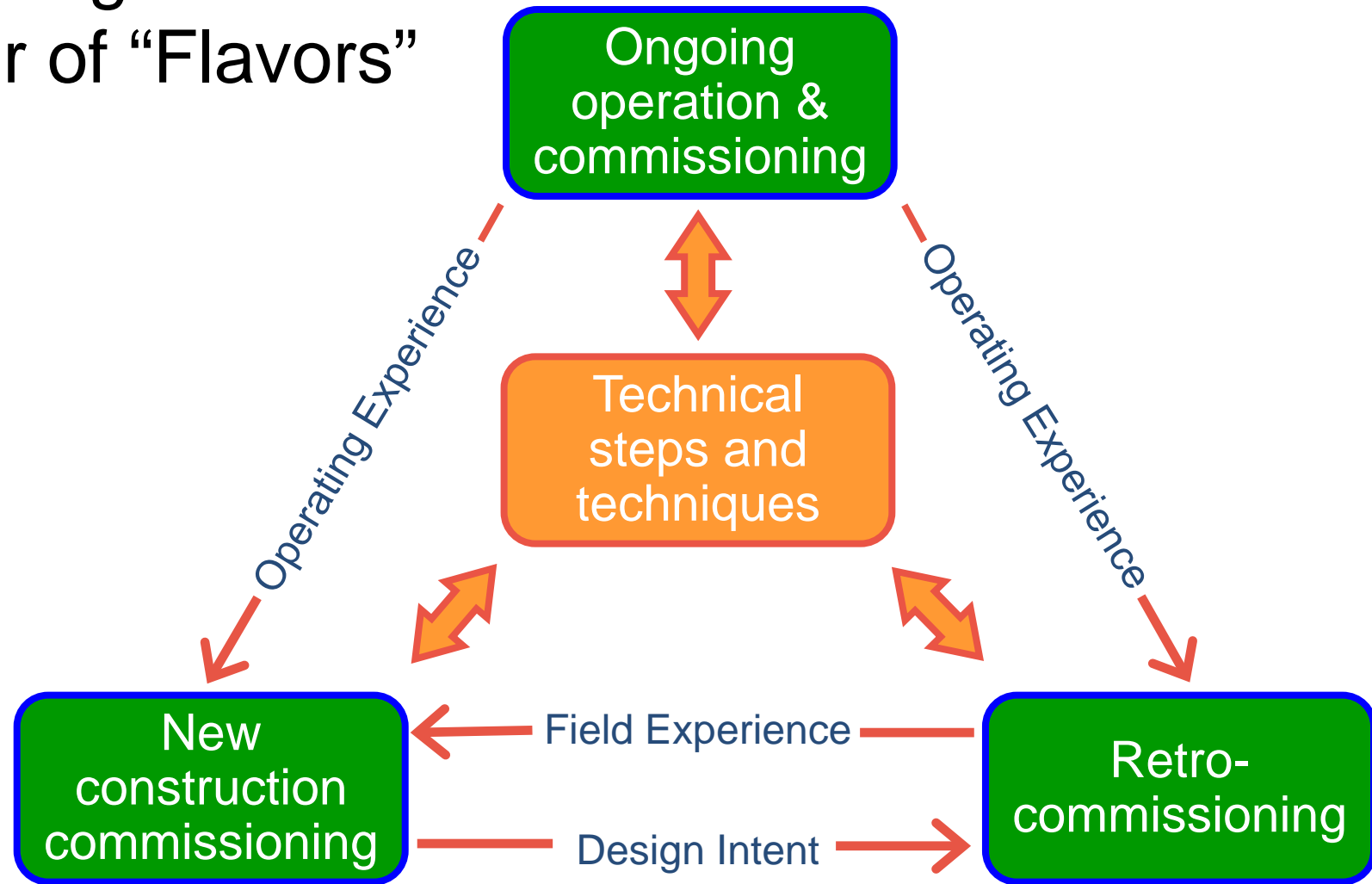
Industry Definition

Commissioning is a systematic process of ensuring that all building systems perform interactively according to the contract documents, the design intent and the Owner's operational needs

- Begins in predesign
- Documents the design intent
- Continues through construction, acceptance, the warranty period, and through the building's life cycle
- Includes functional testing
- Includes training
- Documents performance

Commissioning is about performance and integration

Commissioning comes in a Number of “Flavors”



What is Retrocommissioning?

In general terms, it's the same thing as:

- RCx
- Existing Building Commissioning
- EBCx
- Recommissioning
- Building tune-up

What is Ongoing Commissioning?

Continuous Commissioning™

A Trademarked Process Developed by Texas A&M

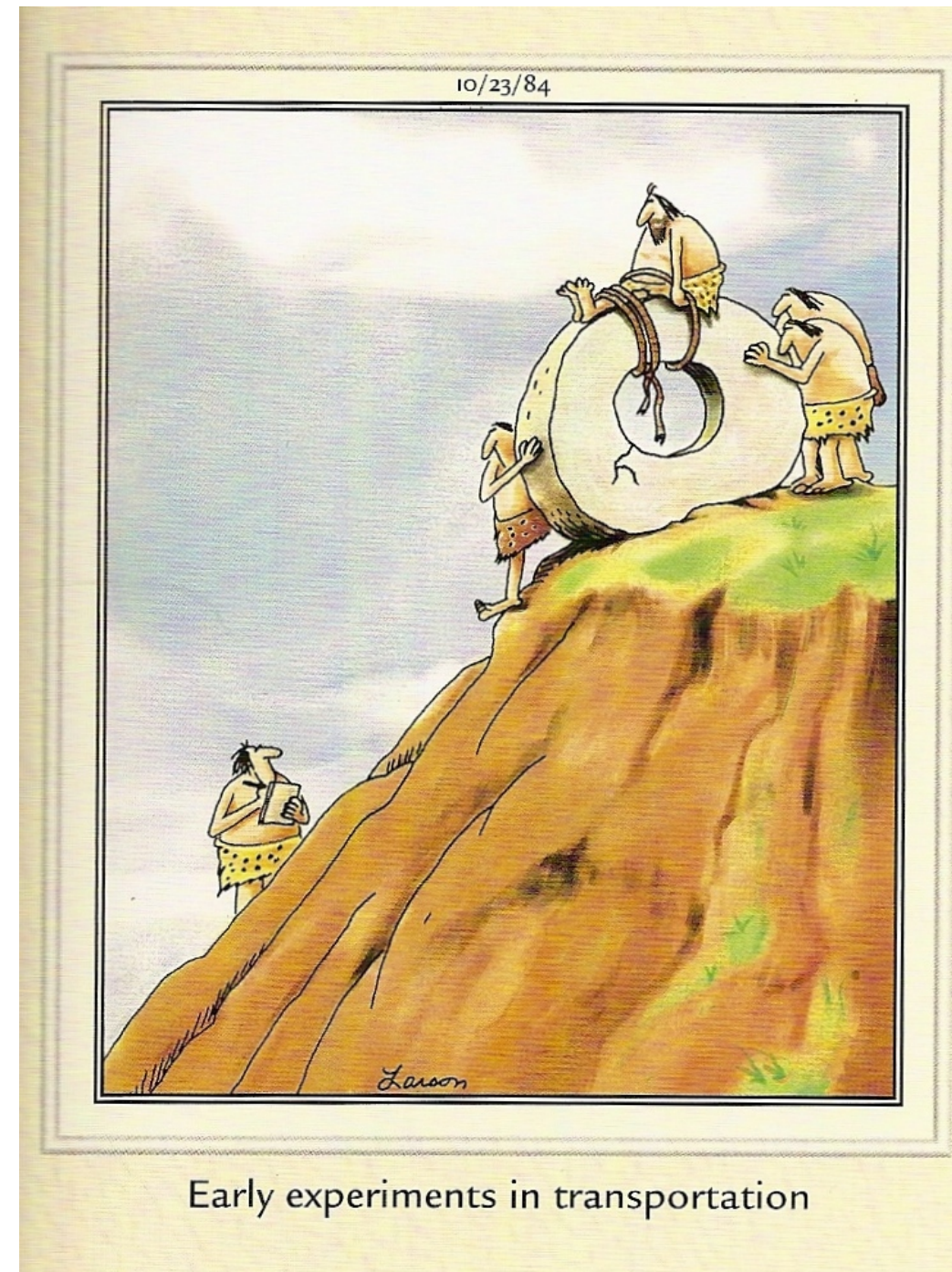
Operating the building properly

What folks called it when I started doing this stuff (1976)

Commissioning is a Team Effort

No matter what the flavor

The building systems aren't the only thing that will be interactive and require integration from the Cx provider.



Time for Another Poll

2. Do you think operating issues like instability in a single air handling system can ripple out and impact other systems in the facility?

☐

Yes I think they can.

☐

No, I think it would be unusual if it happened at all.

Time for Another Poll

2. Do you think operating issues like instability in a single air handling system can ripple out and impact other systems in the facility?



Yes I think they can.



No, I think it would be unusual if it happened at all.

Why Do We Need to Commission?



You May Not Fully Comprehend the Situation

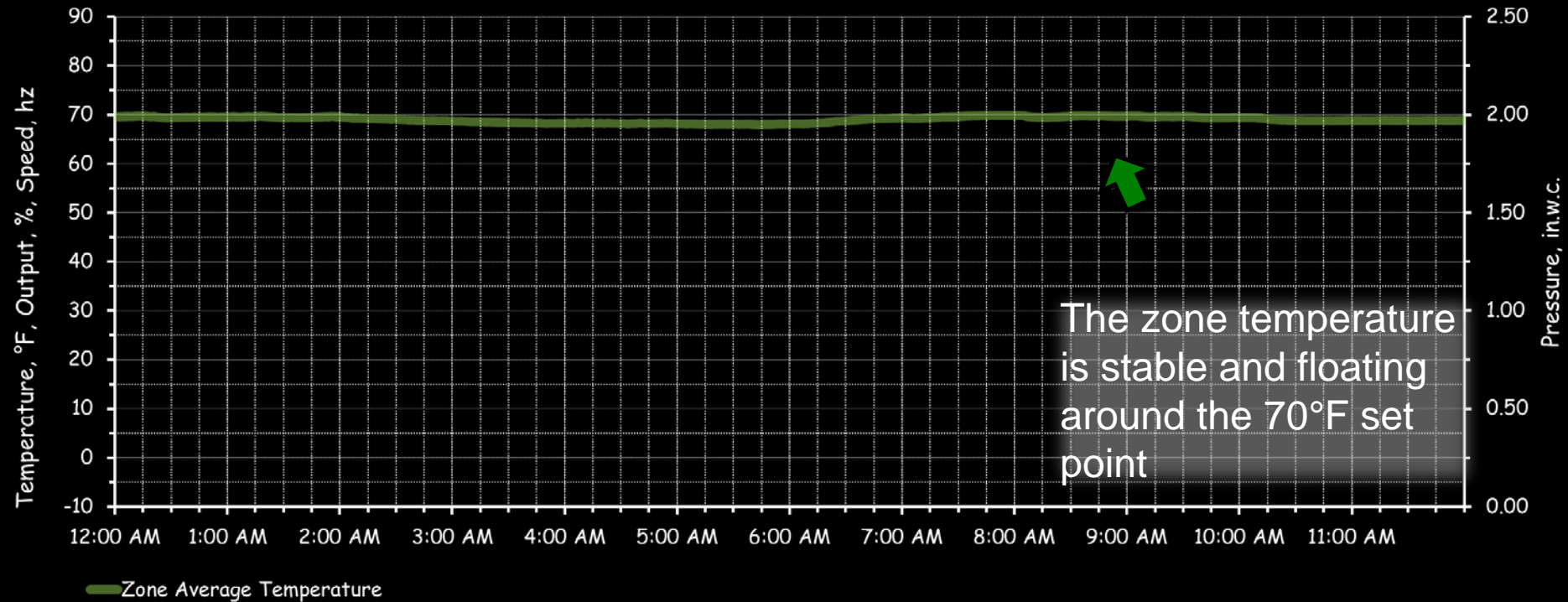
“... If you are piloting an untested vehicle on it's first test flight and that vehicle contains more propellant than was ever placed on a launch pad before and the vehicle was assembled by the low bidder and you aren't a little nervous, then you don't fully comprehend the situation”

*Paraphrased; John Young to Barbara Walters
when asked if he would be nervous as the
test pilot on the first manned shuttle flight*

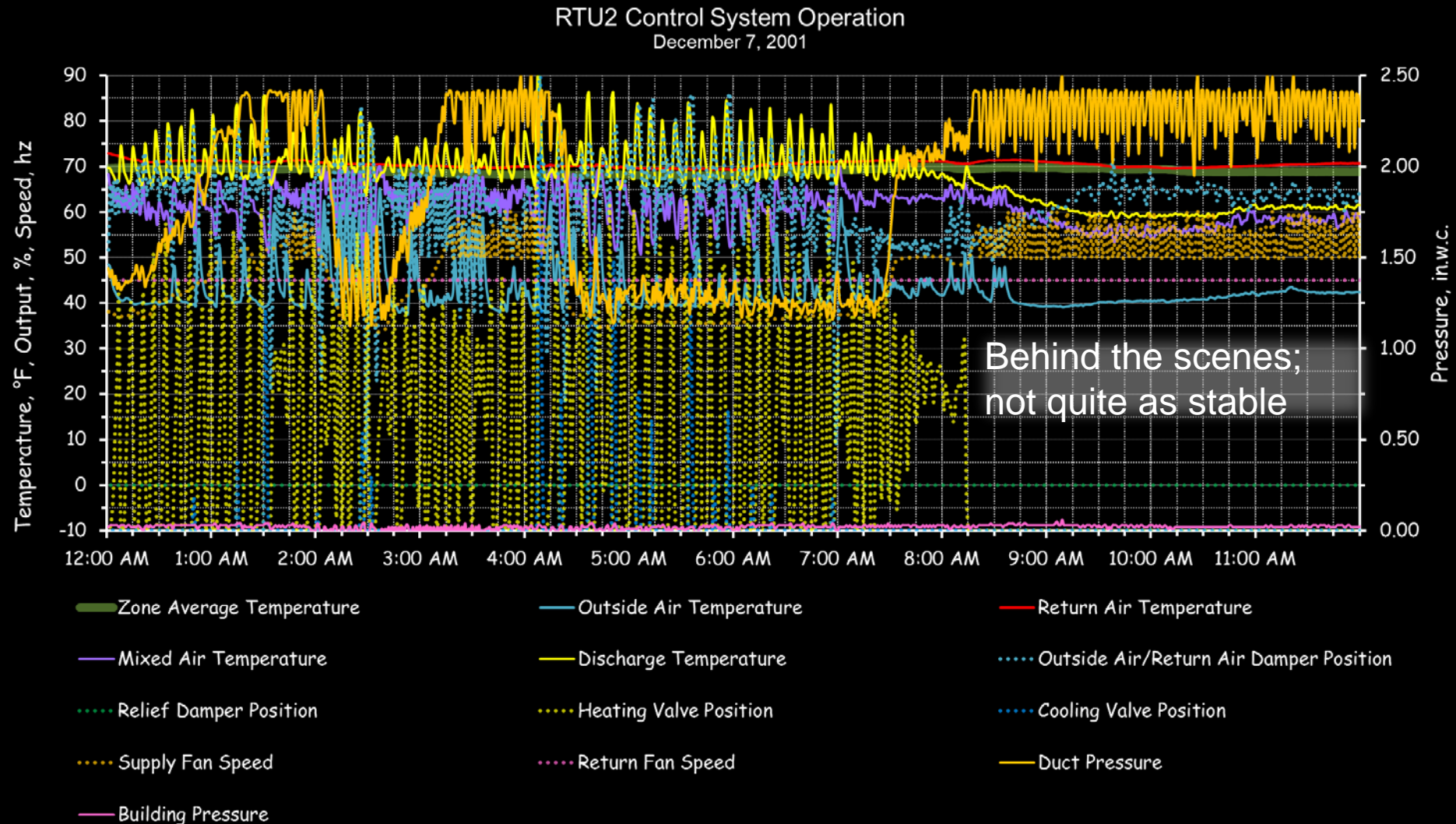


Things may seem fine at the office ...

RTU2 Control System Operation
December 7, 2001

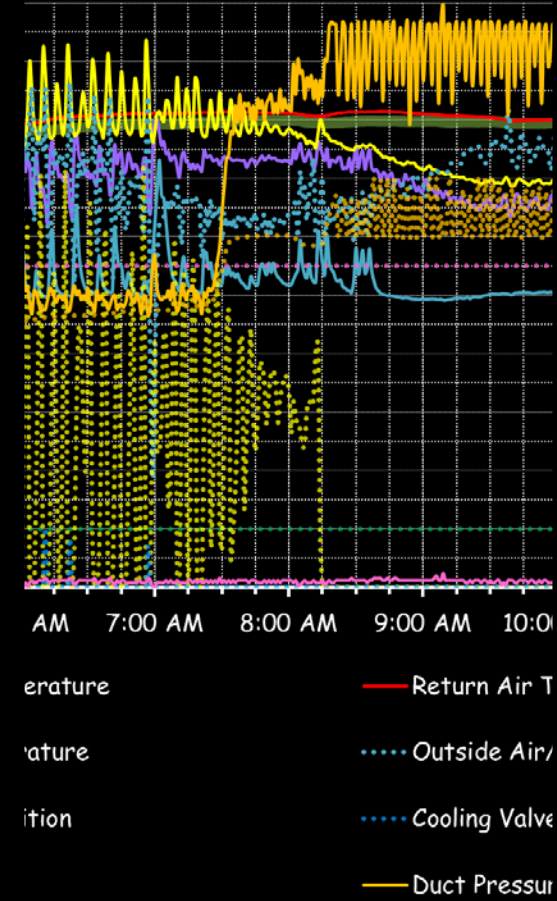


... but HVAC is dynamic and complex

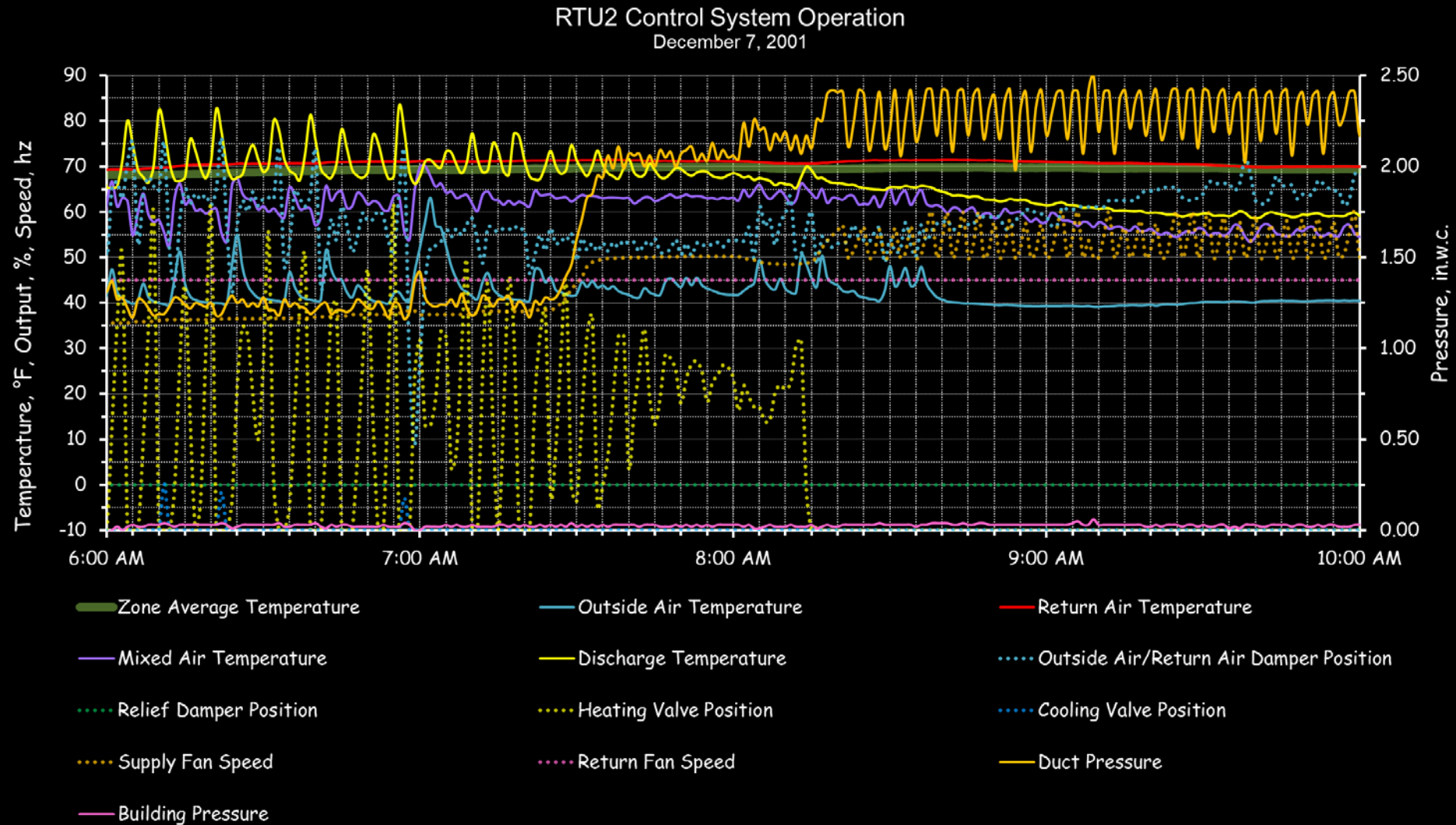


... but HVAC is dynamic and complex

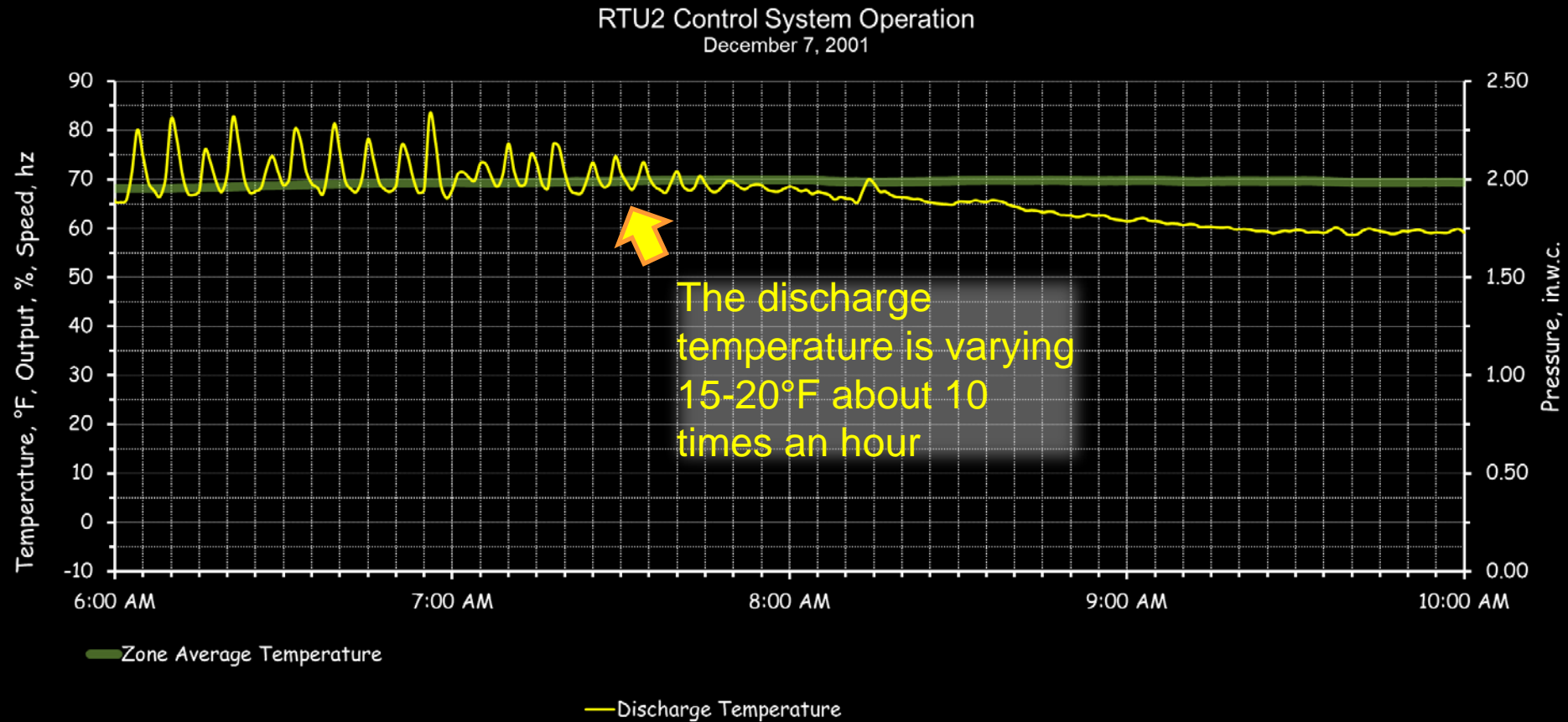
System Operation
7, 2001



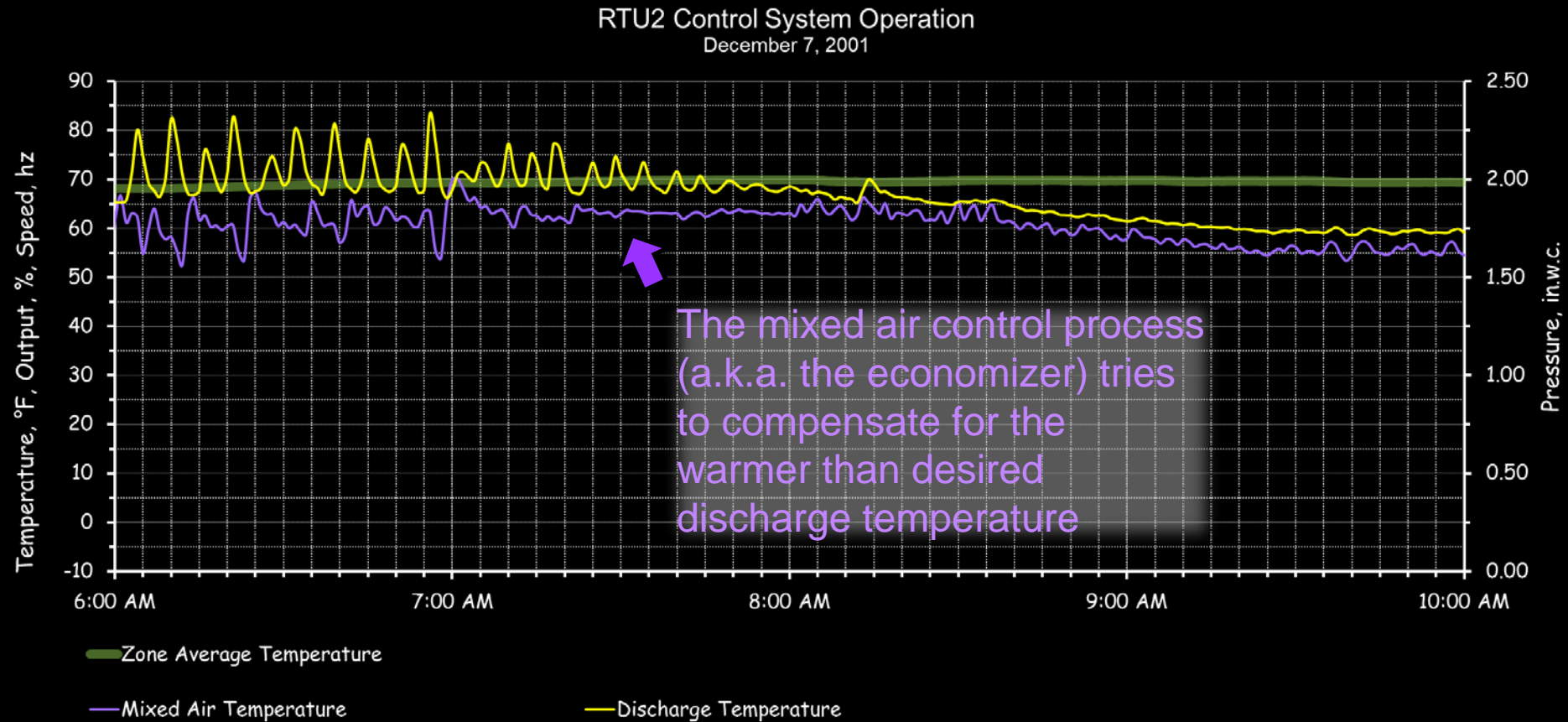
... and HVAC can be insidious



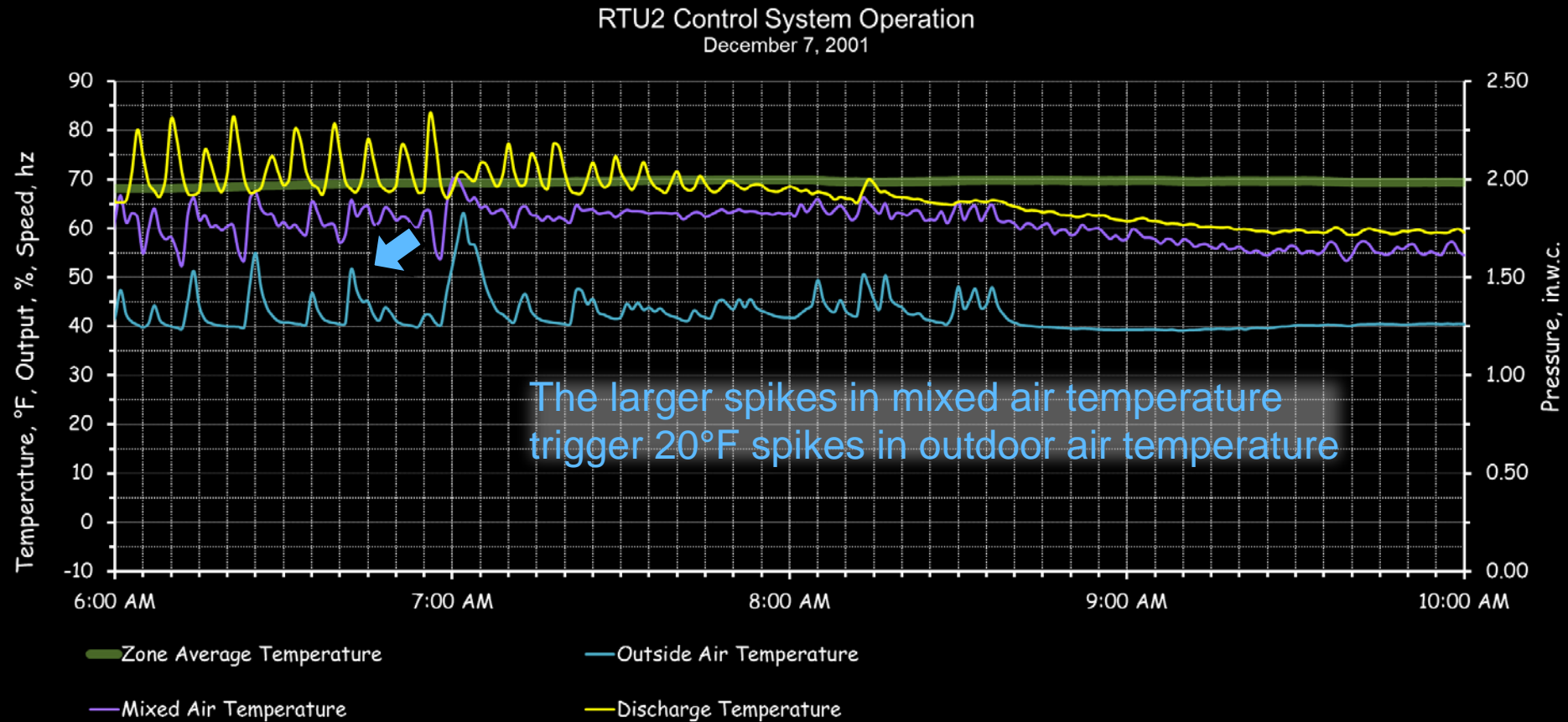
... and HVAC can be insidious



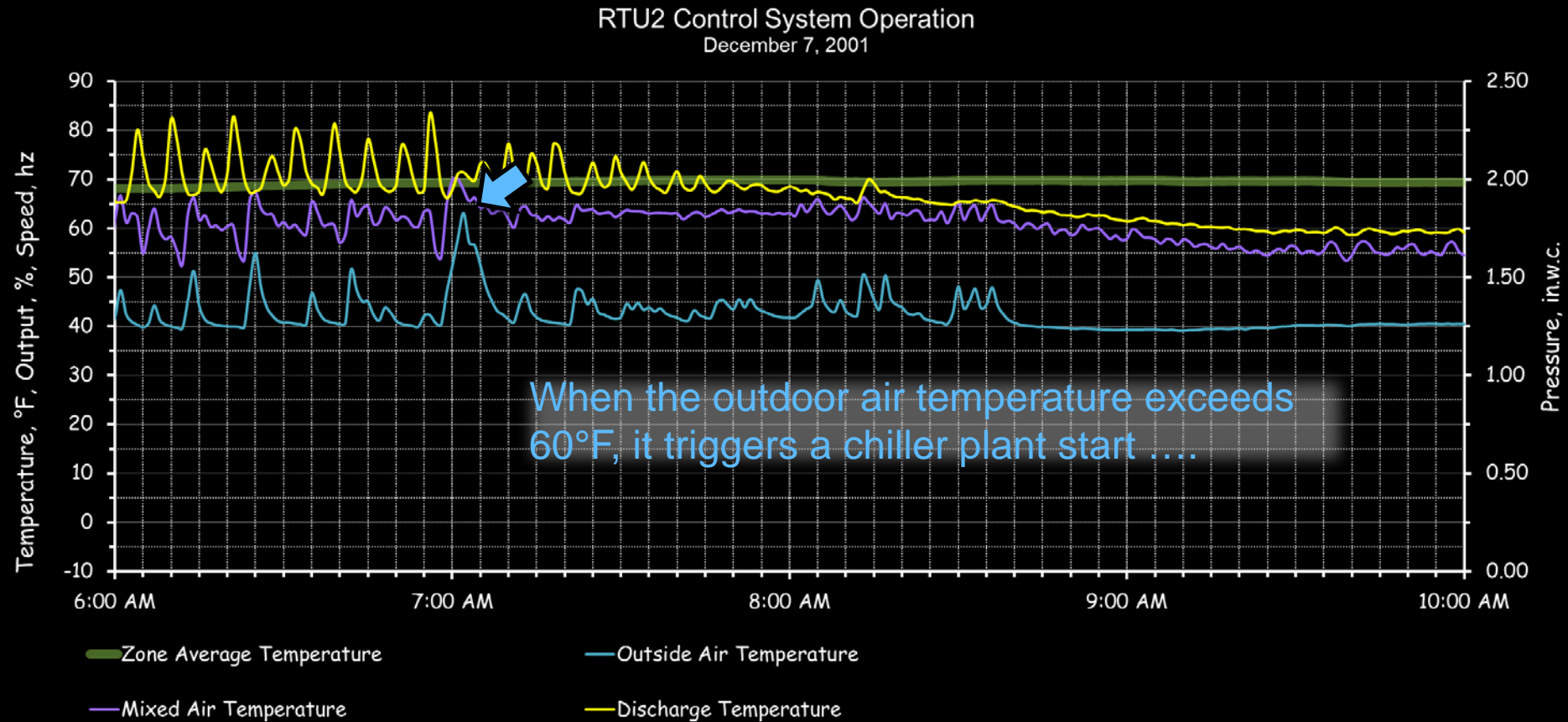
... and HVAC can be insidious



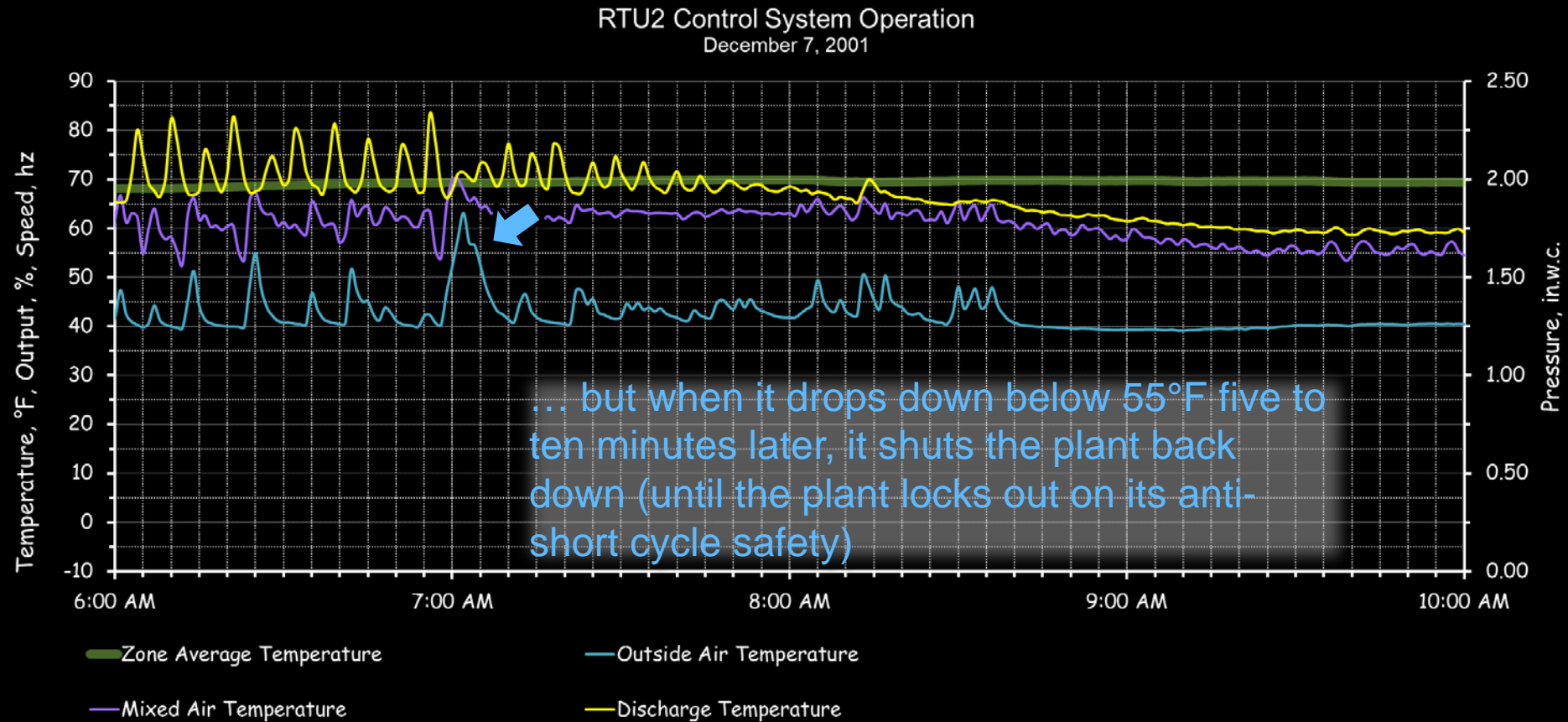
... and HVAC can be insidious



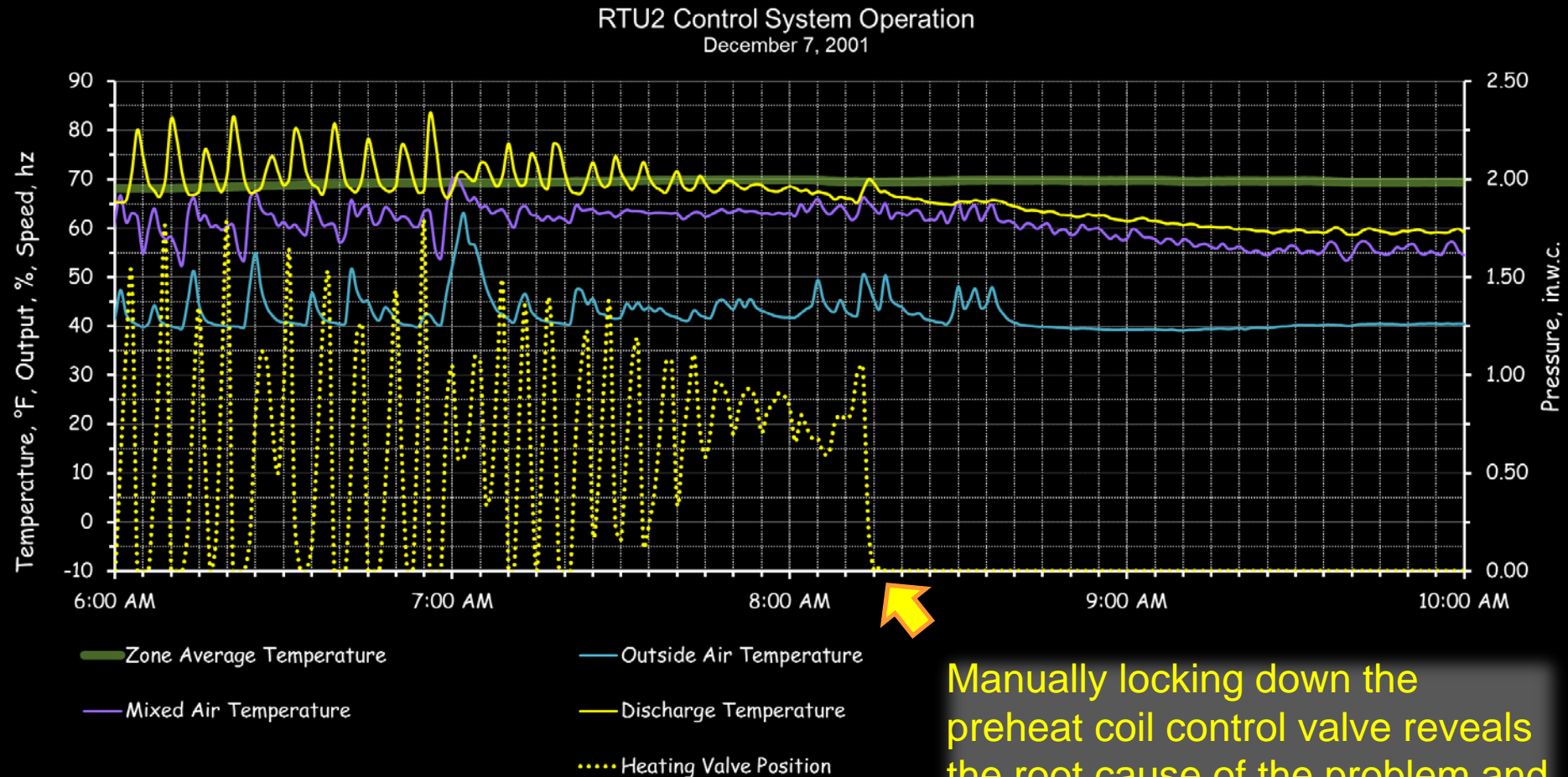
... and HVAC can be insidious



... and HVAC can be insidious

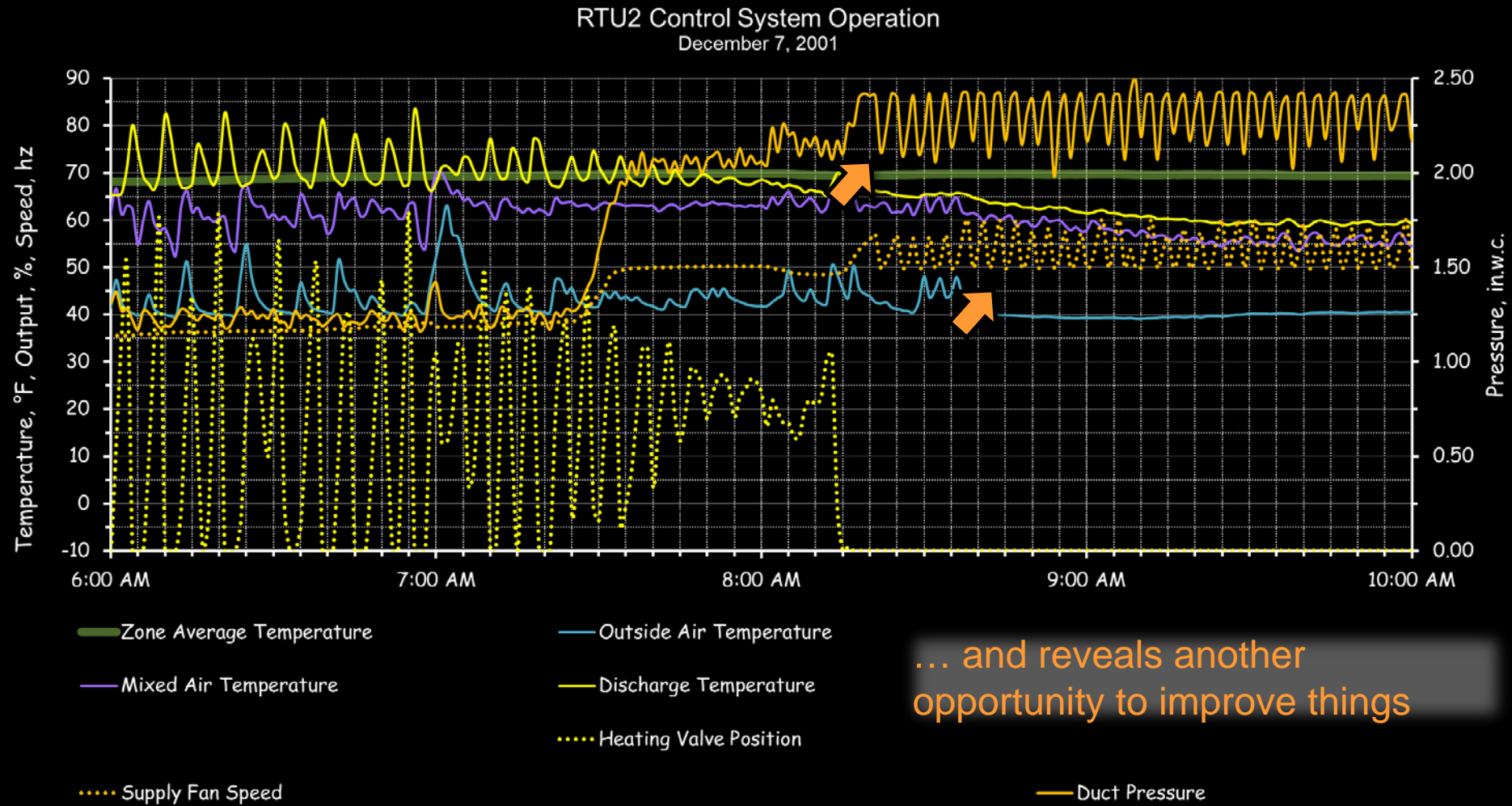


... and HVAC can be insidious



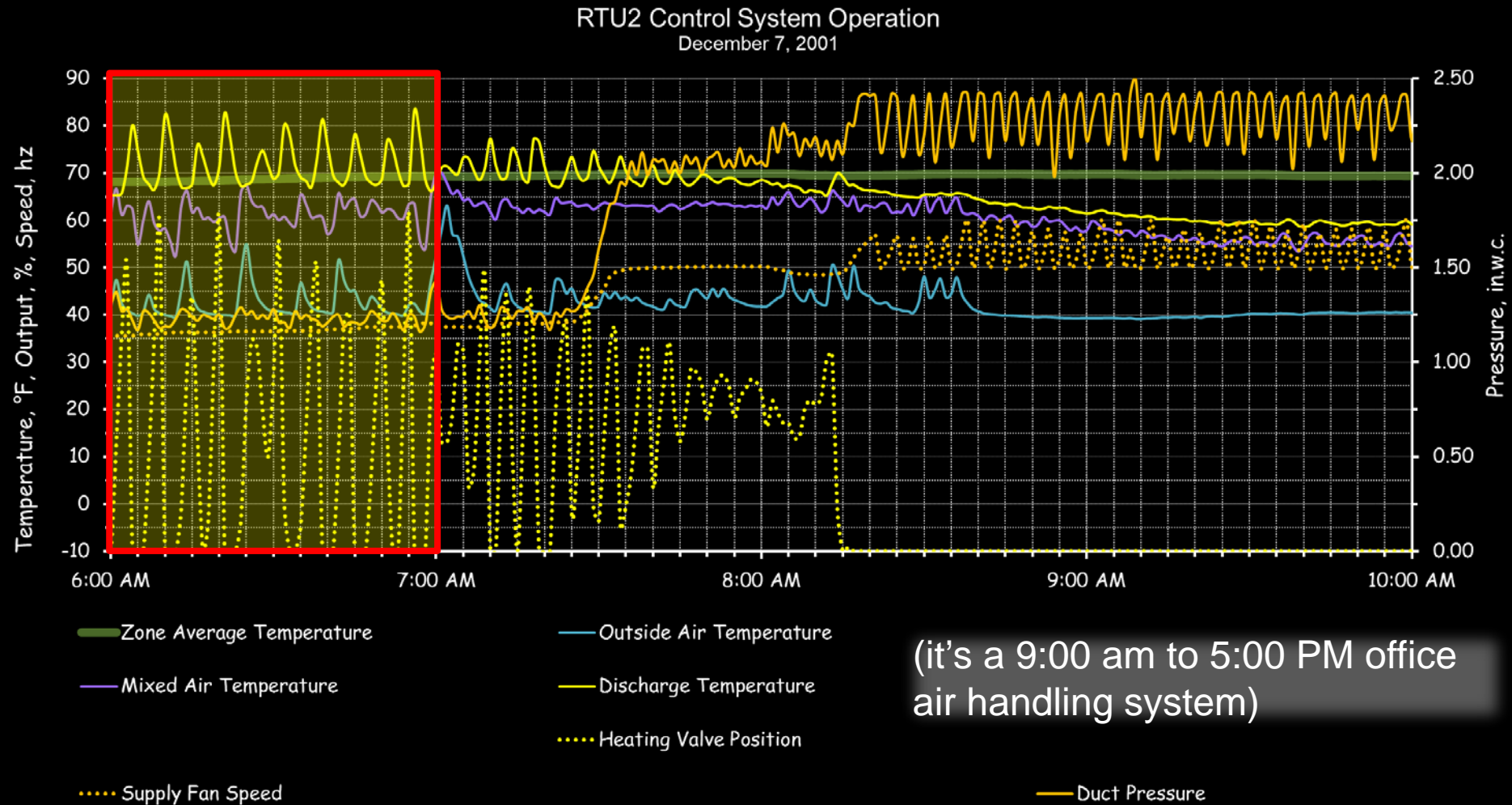
Manually locking down the preheat coil control valve reveals the root cause of the problem and how to solve it ...

... and HVAC can be insidious



... and reveals another opportunity to improve things

And let's not miss the obvious



(it's a 9:00 am to 5:00 PM office
air handling system)

Bottom Line

Buildings frequently don't perform as intended

The future is not in plastics, my boy, the future is in construction.

Dr. Joseph Lstiburek

Bottom Line

Buildings frequently don't perform as intended

*The future is not in plastics, my boy, the future is in construction.
Actually, the future is in fixing construction.*

Dr. Joseph Lstiburek

It's Poll Time

3. Which of the following items are the goals behind the energy consuming systems in our facilities (select all that apply)

☐

a. Keep the building comfortable

☐

b. Keep the people using the facility productive

☐

c. Keep the building safe

☐

d. Keep the building clean

It's Poll Time

3. Which of the following items are the goals behind the energy consuming systems in our facilities (select all that apply)

- ☒ a. Keep the building comfortable
- ☒ b. Keep the people using the facility productive
- ☒ c. Keep the building safe
- ☒ d. Keep the building clean

Commissioning's Benefits

03/17/2008 01:37 PM



Typical new construction Cx issues

- Poor turn-down capabilities
- Unanticipated interactions
- Pump head is excessive
- Fan static is insufficient
- Rouge zones
- Control sensor calibration
- Control sensor location
- Control system logic
- Control system design
- Schedules missing
- Equipment missing



Typical existing building Cx issues

- Poor turn-down capabilities
- Unanticipated interactions
- Pump head is excessive
- Fan static is insufficient
- Rouge zones
- Control sensor calibration
- Control sensor location
- Control system logic
- Control system design
- Schedules missing
- Equipment missing



Typical existing building Cx issues

- Poor turn-down capabilities
- Unanticipated interactions
- Pump head is excessive
- Fan static is insufficient
- Rouge zones
- Control sensor calibration
- Control sensor location
- Control system logic
- Control system design
- Schedules missing
- Equipment missing
- Most existing building commissioning issues are unresolved new construction commissioning issues or design issues
- Existing building commissioning issues are excellent design review targets

Yet Another Poll

4. Once I have made an improvement to a building system that makes it more efficient, I will not really need to worry about it anymore and can focus on something else.

☐ True

☐ False

Yet Another Poll

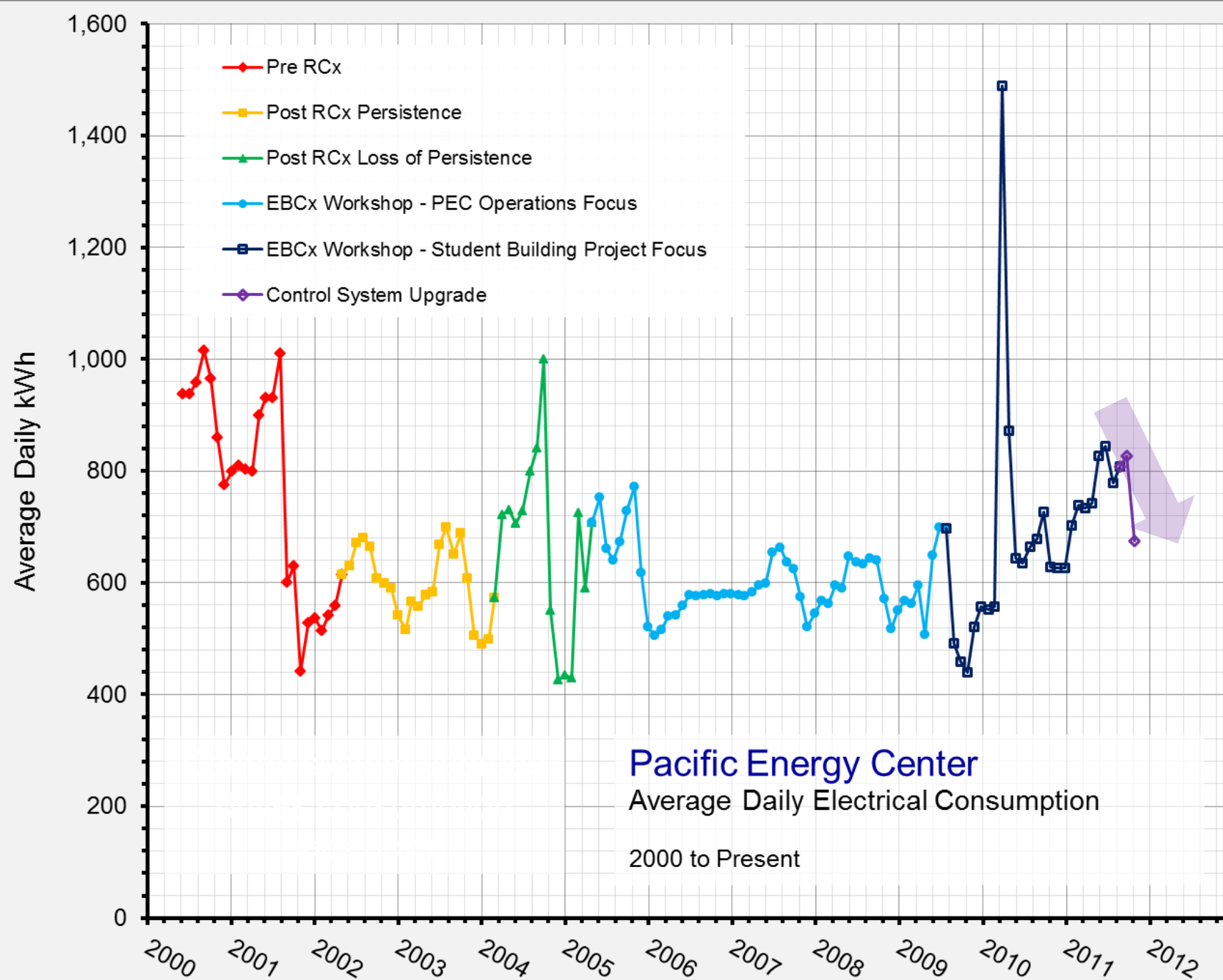
4. Once I have made an improvement to a building system that makes it more efficient, I will not really need to worry about it anymore and can focus on something else.

☐

True

☒

False



Achieving Persistence is the Challenge

In a system, a process that occurs will tend to increase the total entropy of the universe.

2nd Law of Thermodynamics

- Things wear
- Heat transfer characteristics change
- Things break
- People forget
- People make mistakes

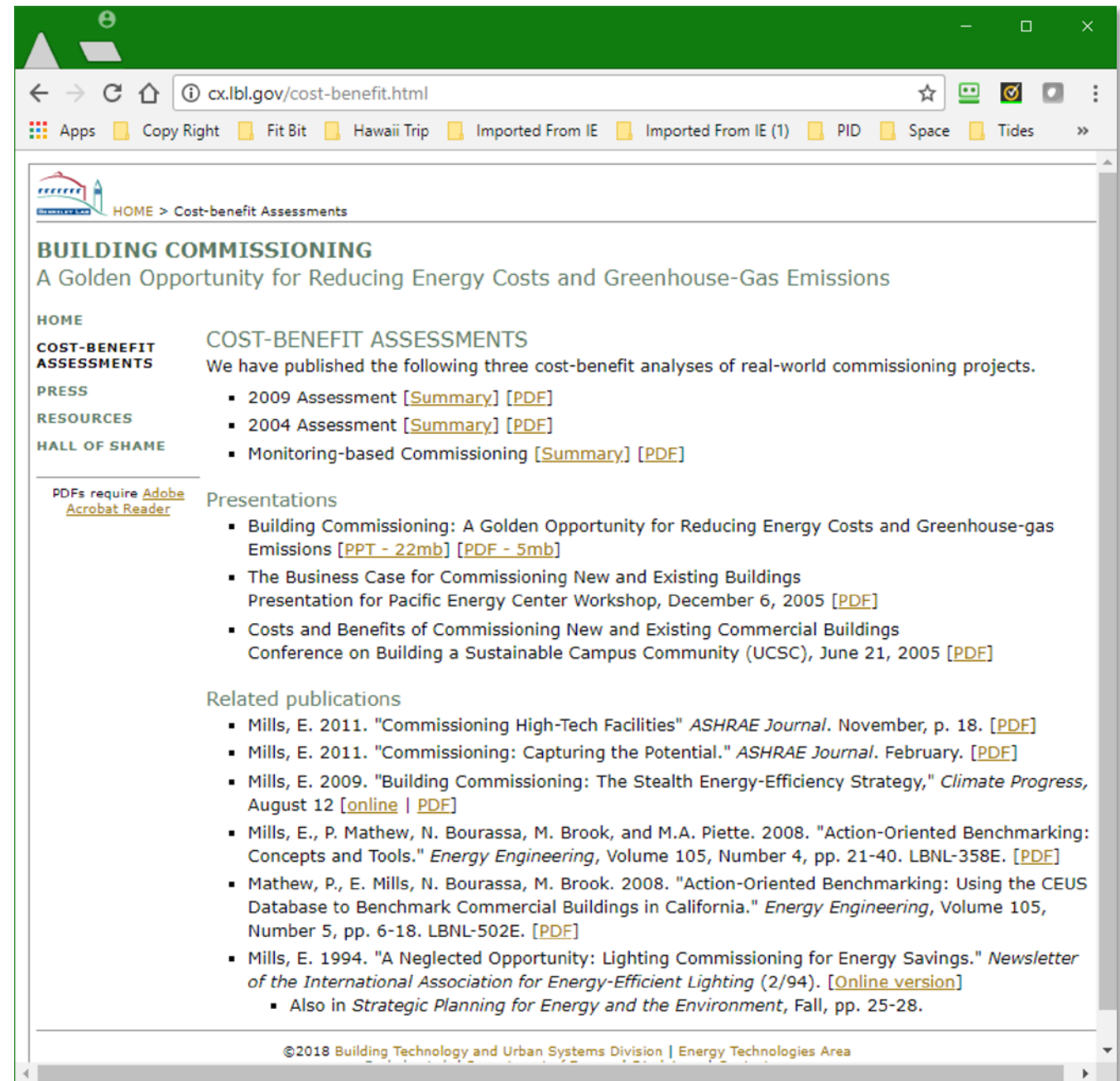


Image courtesy Jay Cmiel, San Jose Marriott

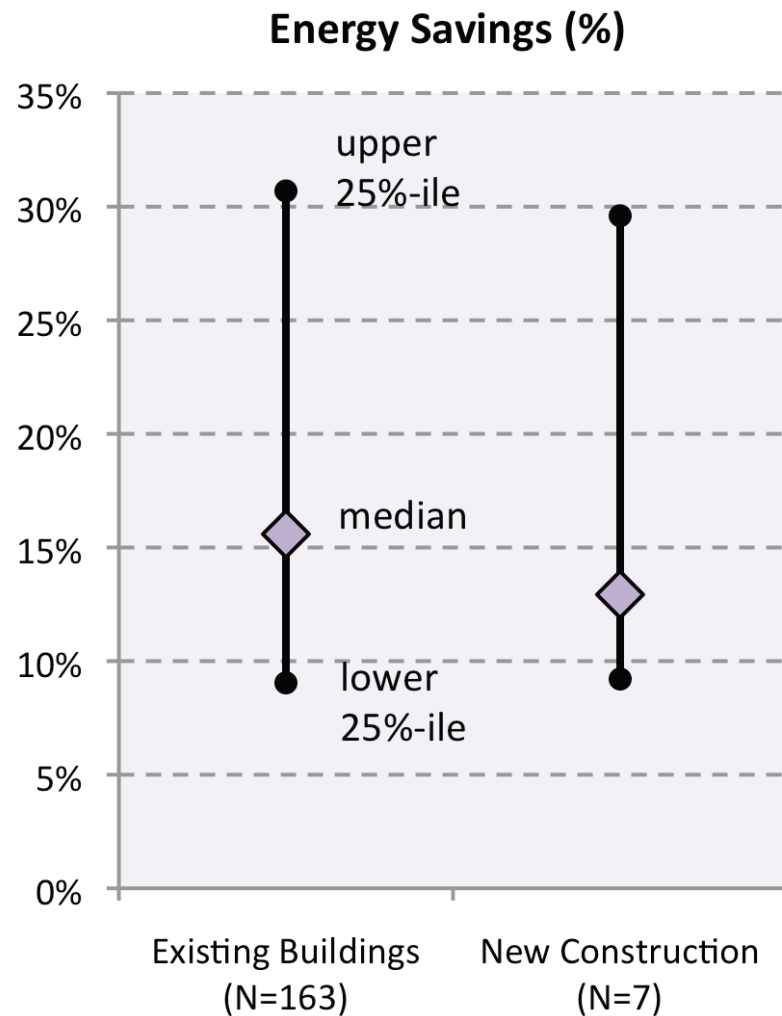
Achieving Persistence is Rewarding

Lawrence Berkeley National Labs published a meta-study on the benefits of commissioning in 2004

- Updated on 2009
 - Currently being updated again
- <http://cx.lbl.gov/cost-benefit.html>



Achieving Persistence is Rewarding



cx.lbl.gov/cost-benefit.html

Apps Copy Right Fit Bit Hawaii Trip Imported From IE Imported From IE (1) PID Space Tides

HOME > Cost-benefit Assessments

BUILDING COMMISSIONING

A Golden Opportunity for Reducing Energy Costs and Greenhouse-Gas Emissions

HOME
COST-BENEFIT ASSESSMENTS
PRESS
RESOURCES
HALL OF SHAME

PDFs require [Adobe Acrobat Reader](#)

COST-BENEFIT ASSESSMENTS

We have published the following three cost-benefit analyses of real-world commissioning projects.

- 2009 Assessment [[Summary](#)] [[PDF](#)]
- 2004 Assessment [[Summary](#)] [[PDF](#)]
- Monitoring-based Commissioning [[Summary](#)] [[PDF](#)]

Presentations

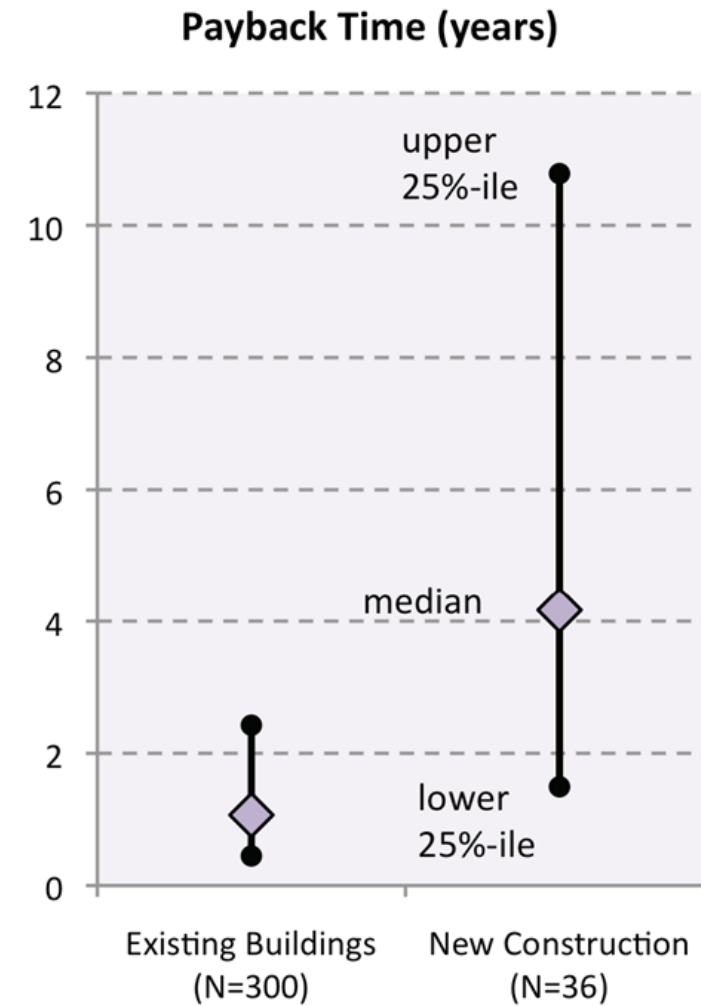
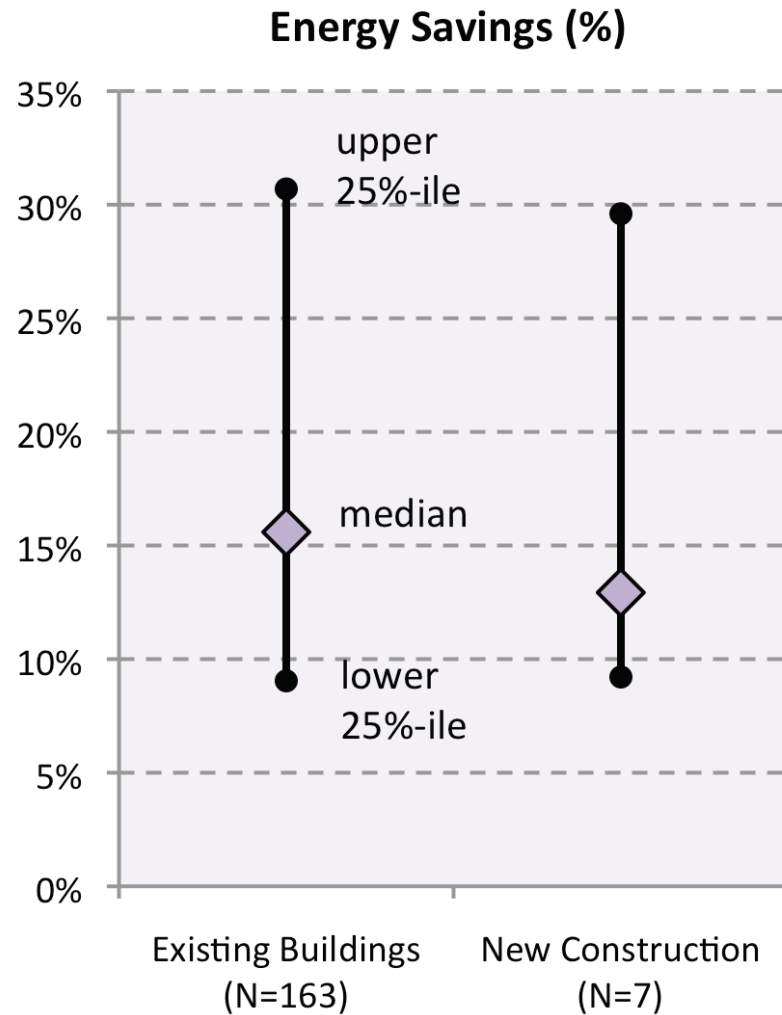
- Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse-gas Emissions [[PPT - 22mb](#)] [[PDF - 5mb](#)]
- The Business Case for Commissioning New and Existing Buildings Presentation for Pacific Energy Center Workshop, December 6, 2005 [[PDF](#)]
- Costs and Benefits of Commissioning New and Existing Commercial Buildings Conference on Building a Sustainable Campus Community (UCSC), June 21, 2005 [[PDF](#)]

Related publications

- Mills, E. 2011. "Commissioning High-Tech Facilities" *ASHRAE Journal*. November, p. 18. [[PDF](#)]
- Mills, E. 2011. "Commissioning: Capturing the Potential." *ASHRAE Journal*. February. [[PDF](#)]
- Mills, E. 2009. "Building Commissioning: The Stealth Energy-Efficiency Strategy," *Climate Progress*, August 12 [[online](#)] [[PDF](#)]
- Mills, E., P. Mathew, N. Bourassa, M. Brook, and M.A. Piette. 2008. "Action-Oriented Benchmarking: Concepts and Tools." *Energy Engineering*, Volume 105, Number 4, pp. 21-40. LBNL-358E. [[PDF](#)]
- Mathew, P., E. Mills, N. Bourassa, M. Brook. 2008. "Action-Oriented Benchmarking: Using the CEUS Database to Benchmark Commercial Buildings in California." *Energy Engineering*, Volume 105, Number 5, pp. 6-18. LBNL-502E. [[PDF](#)]
- Mills, E. 1994. "A Neglected Opportunity: Lighting Commissioning for Energy Savings." *Newsletter of the International Association for Energy-Efficient Lighting* (2/94). [[Online version](#)]
- Also in *Strategic Planning for Energy and the Environment*, Fall, pp. 25-28.

©2018 Building Technology and Urban Systems Division | Energy Technologies Area

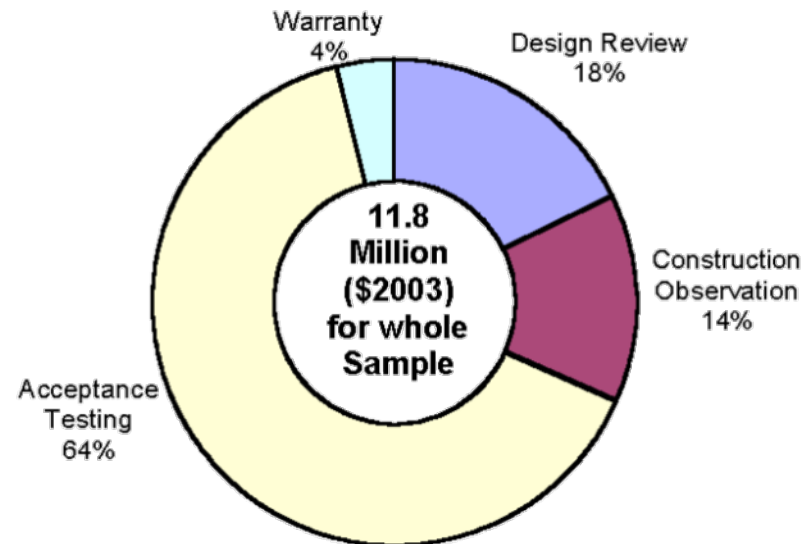
Achieving Persistence is Rewarding



Achieving Persistence is Rewarding

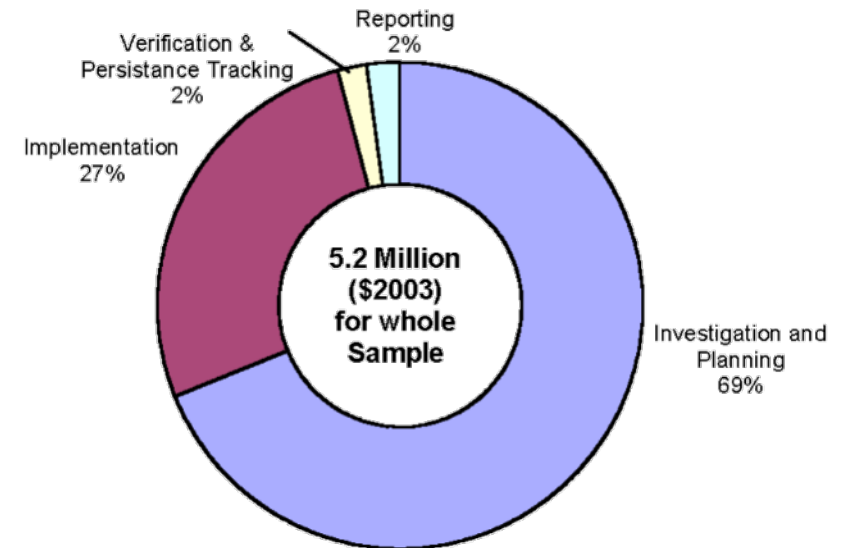
New Construction Cx

Fig 30. Commissioning Cost Allocation
(New Construction, N=5)



Existing Building Cx

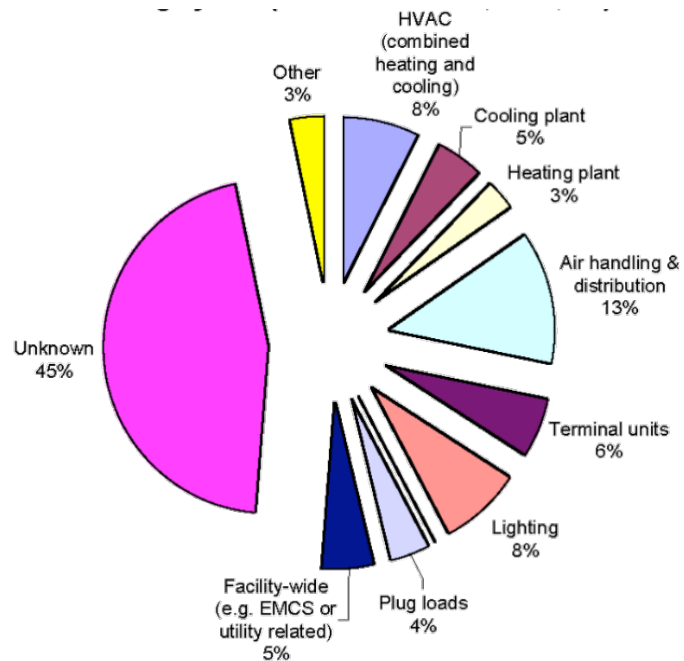
Fig 14. Number of Deficiencies Identified by Building System
(Existing Buildings, N = 3,500)



Achieving Persistence is Rewarding

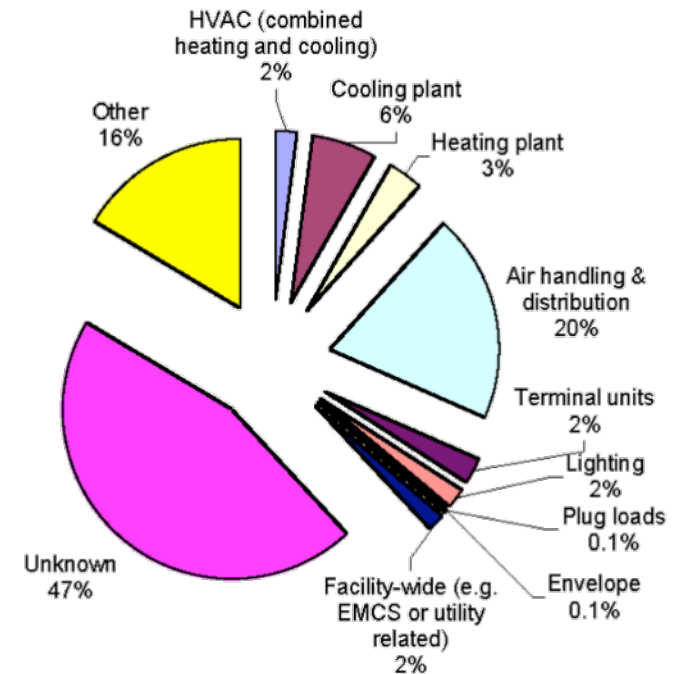
New Construction Cx

Fig 31. Number of Deficiencies Identified by Building System (New Construction, N = 3,305)



Existing Building Cx

Fig 14. Number of Deficiencies Identified by Building System (Existing Buildings, N = 3,500)



There's More to Save Than Energy

From the 2004 LBNL Report:

- Median NCx energy savings
\$0.05 per square foot
- Median NCx NEB savings
\$1.24 per square foot
- Median EBCx energy savings
\$0.26 per square foot
- Median EBCx NEB savings
\$0.18 per square foot

NEB = NEI = Non Energy Benefit or Impact
NCx – New Construction Cx
EBCx = Existing Building Cx
Cx = Commissioning
(from Rx as in a prescription)

Figure 16. *Non-energy benefits observed following commissioning.*

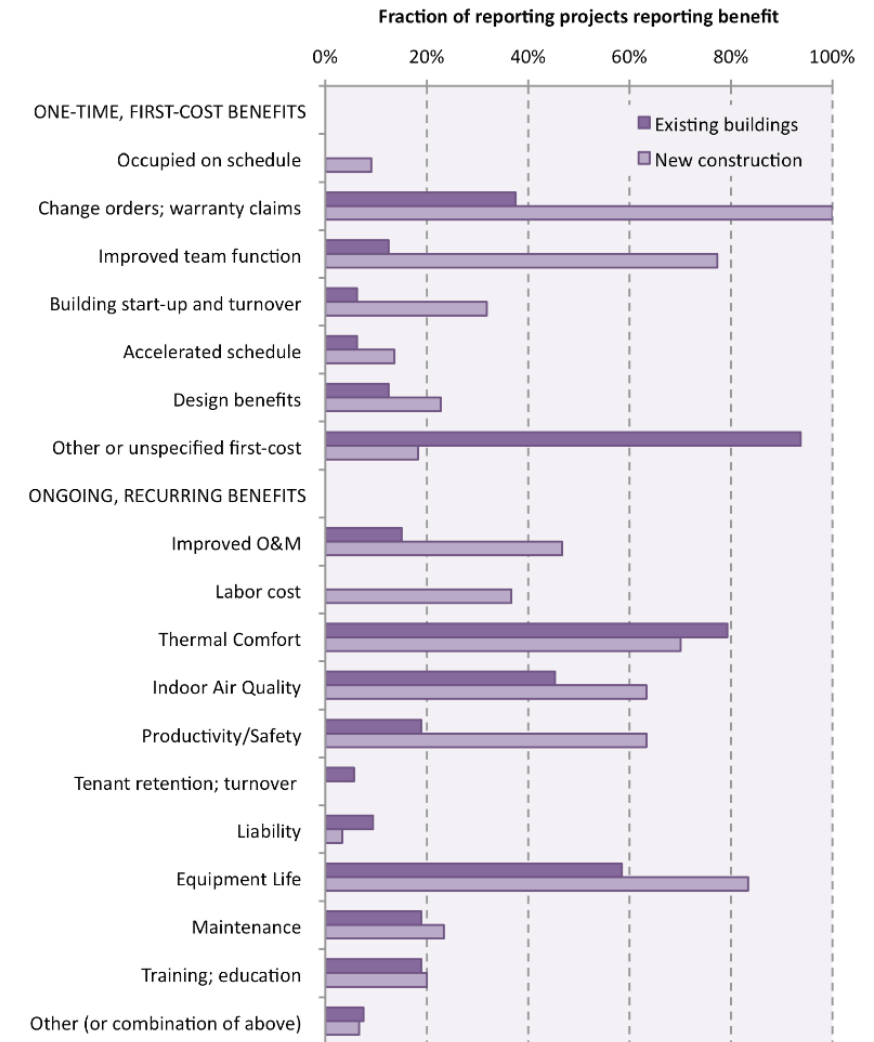


Figure 16. *Non-energy benefits observed following commissioning.*

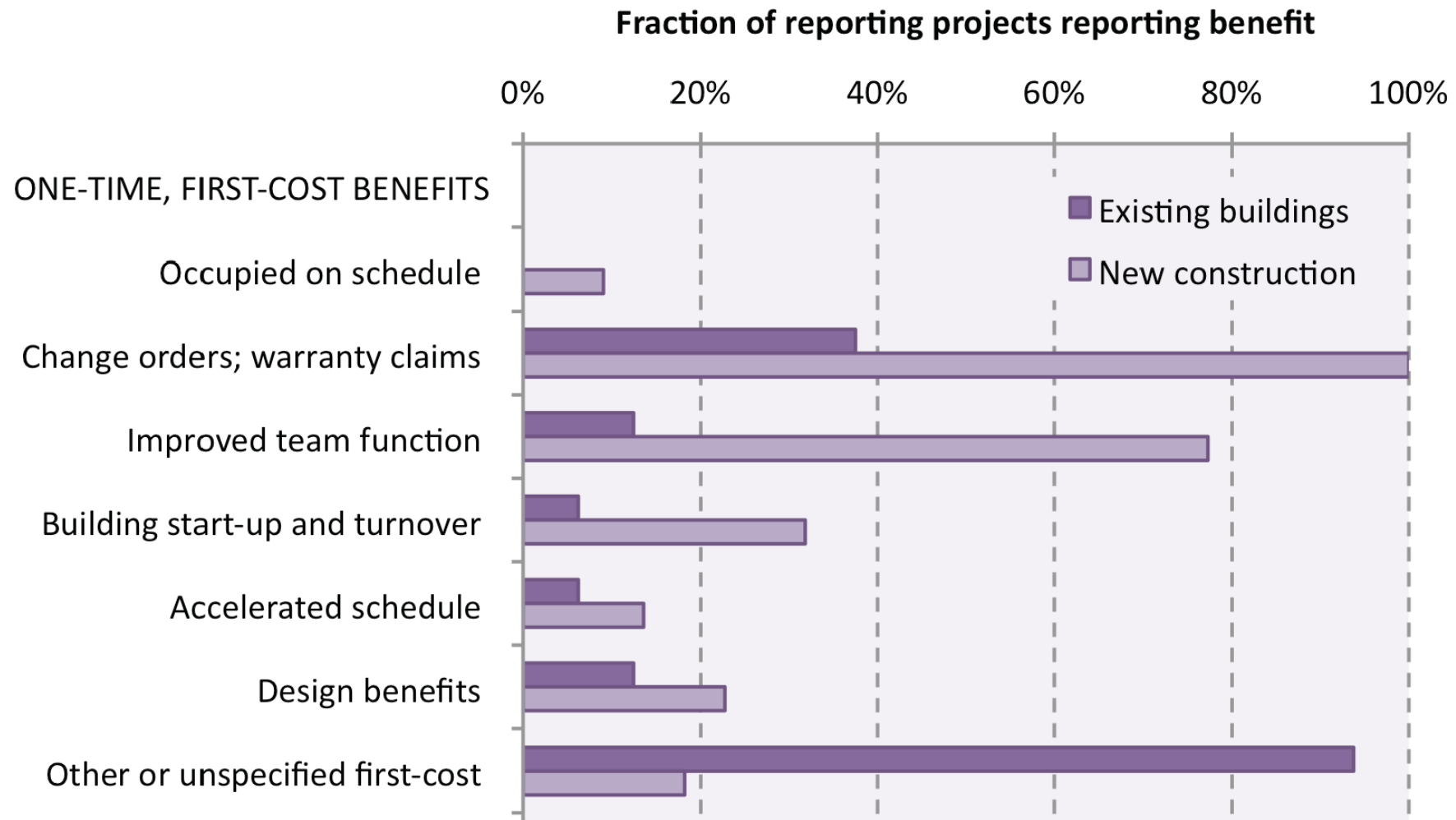
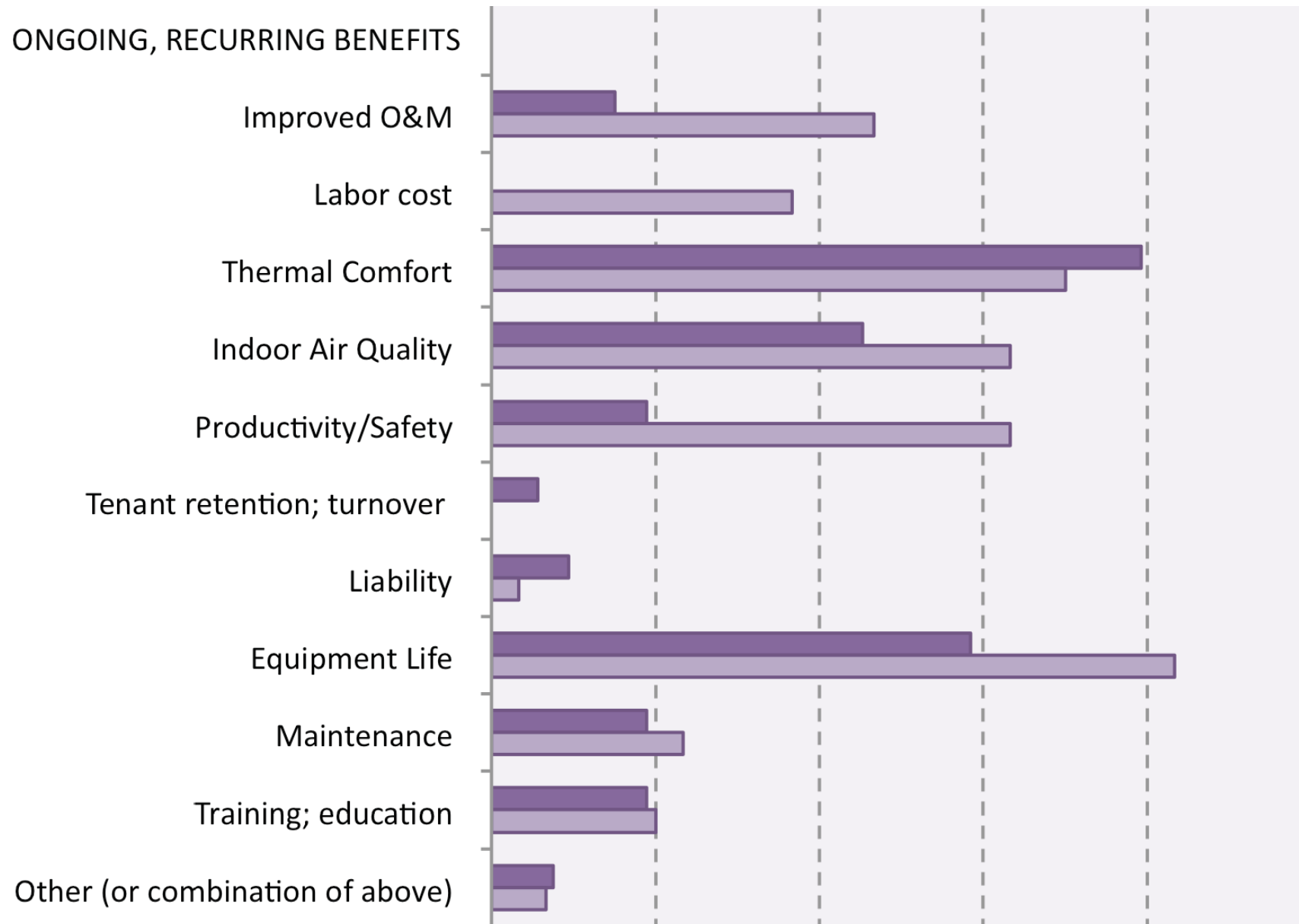


Figure 16. *Non-energy benefits observed following commissioning.*



Functional Testing and the Commissioning Time Line



Functional Testing and the Commissioning Time Line



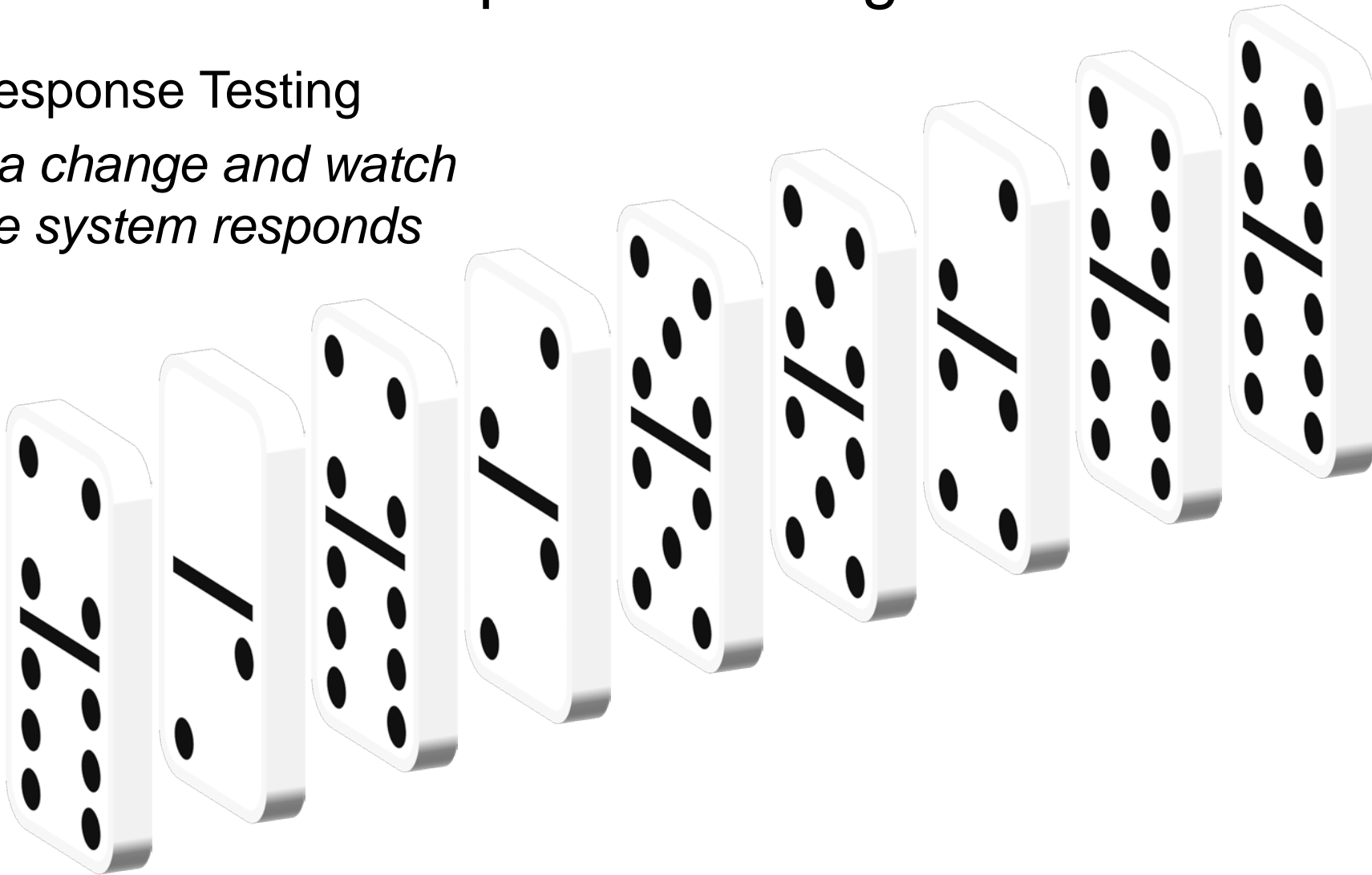
Functional testing

- Core element of any commissioning process
- Validates machinery and systems
 - Do they deliver?
 - Why don't they deliver?
 - Do they work well together?
 - Why aren't they working well together
 - Was it big enough?
 - How big should it be?

Forced vs. Natural Response Testing

Forced Response Testing

*I force a change and watch
how the system responds*



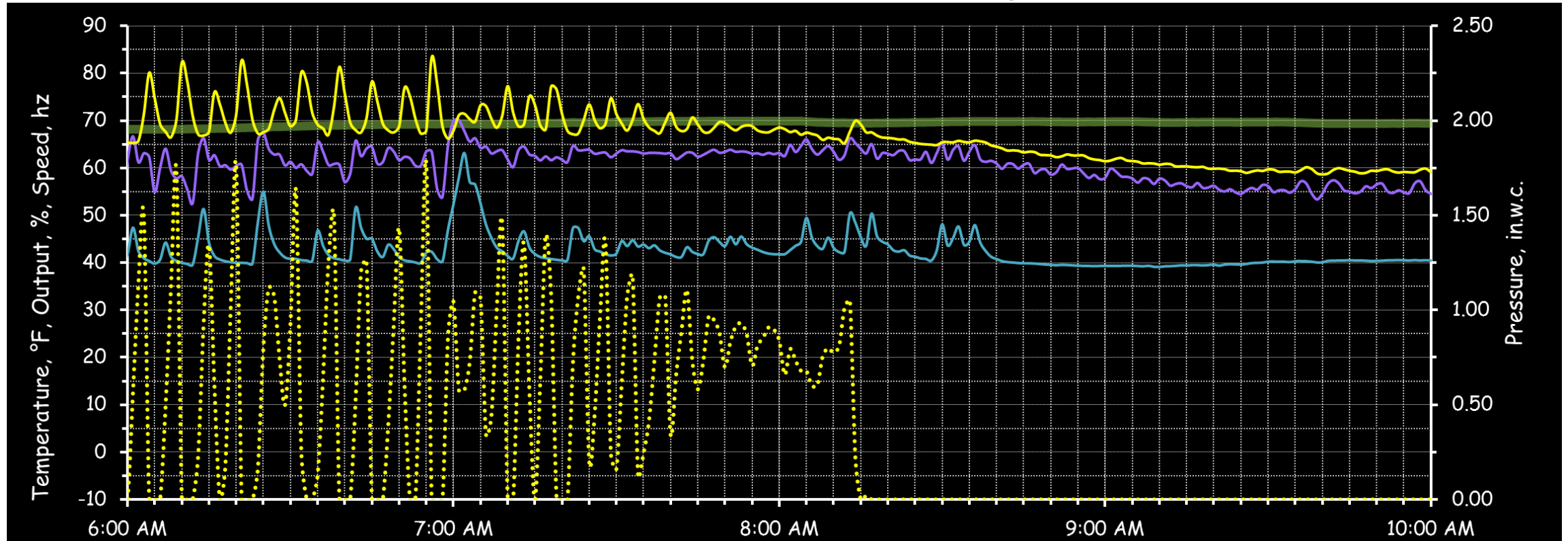
Forced vs. Natural Response Testing

Forced Response Testing

I force a change and watch how the system responds

Natural Response Testing

Mother Nature makes a change and I discover how the system responds



Forced vs. Natural Response Testing

Forced Response Testing

I force a change and watch how the system responds



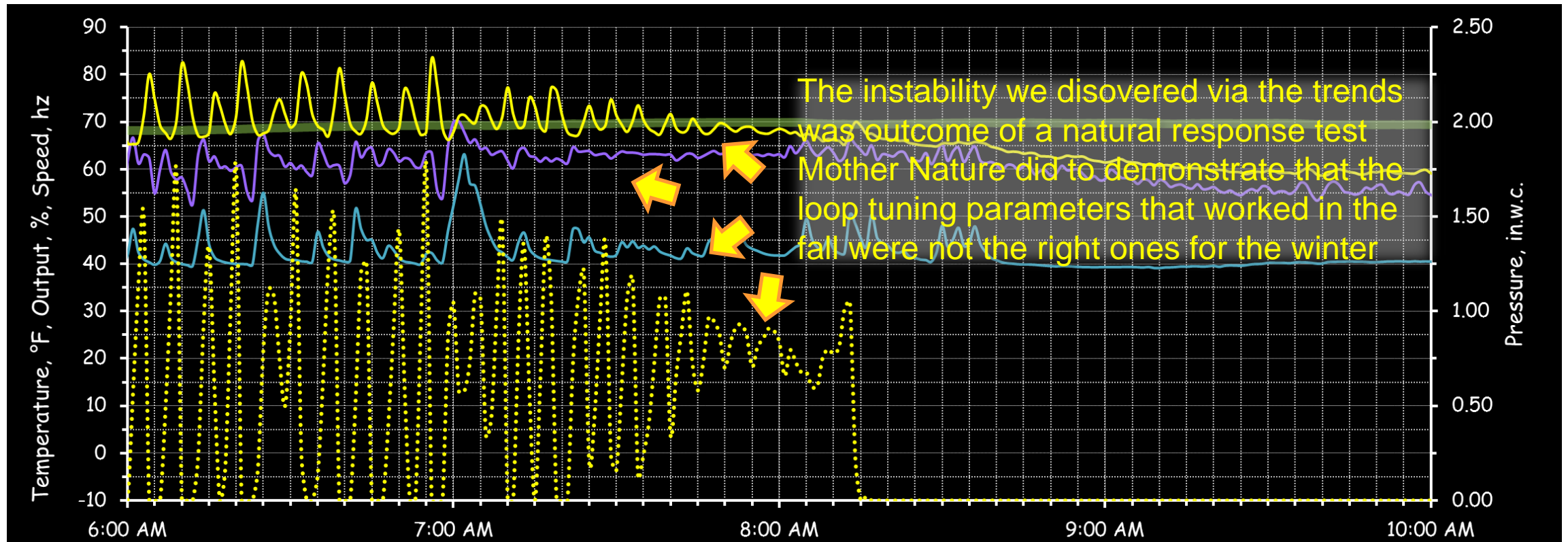
Forced vs. Natural Response Testing

Forced Response Testing

I force a change and watch how the system responds

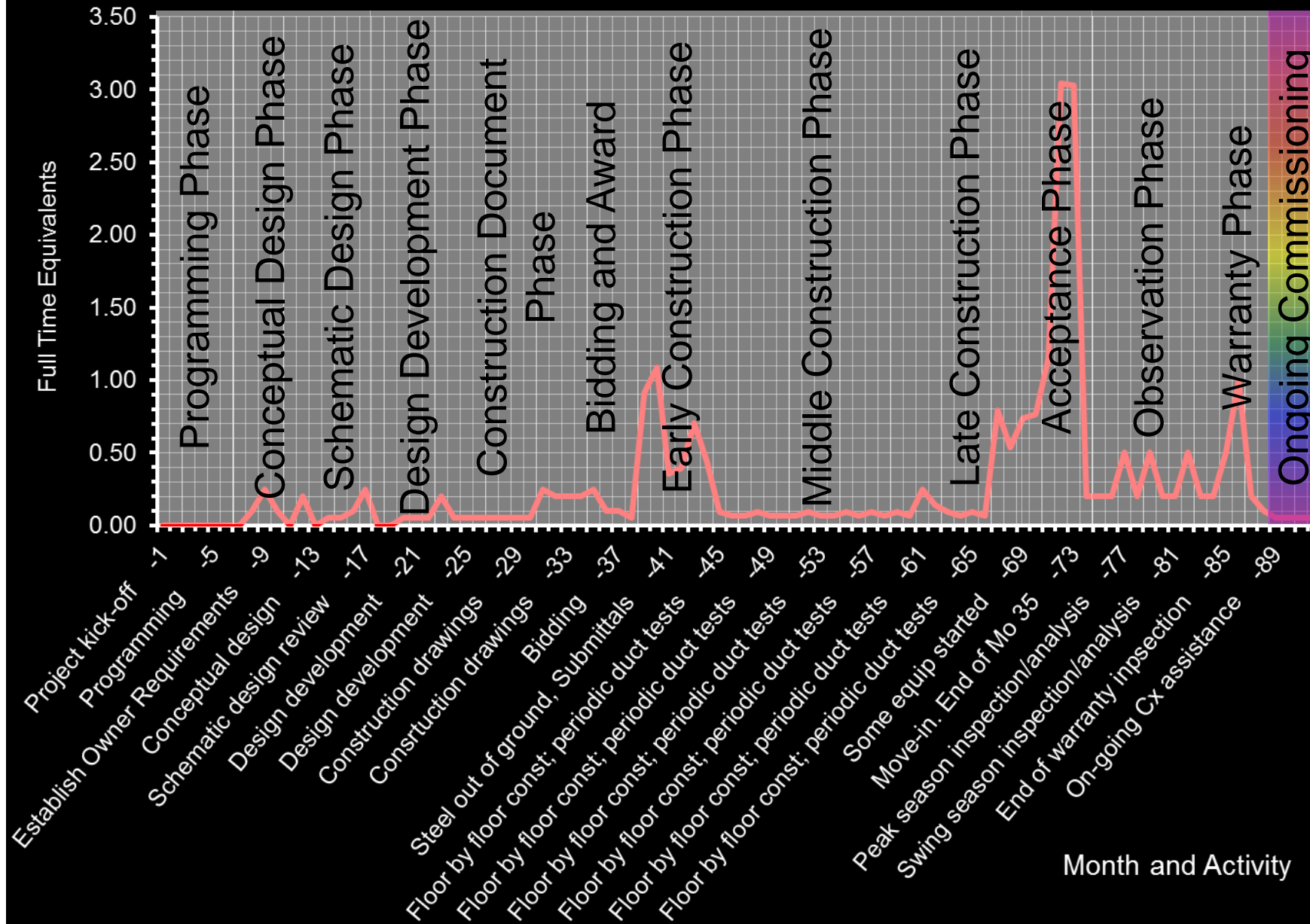
Natural Response Testing

I observe how a system responds to the normal course of events



Typical New Construction Commissioning Activity

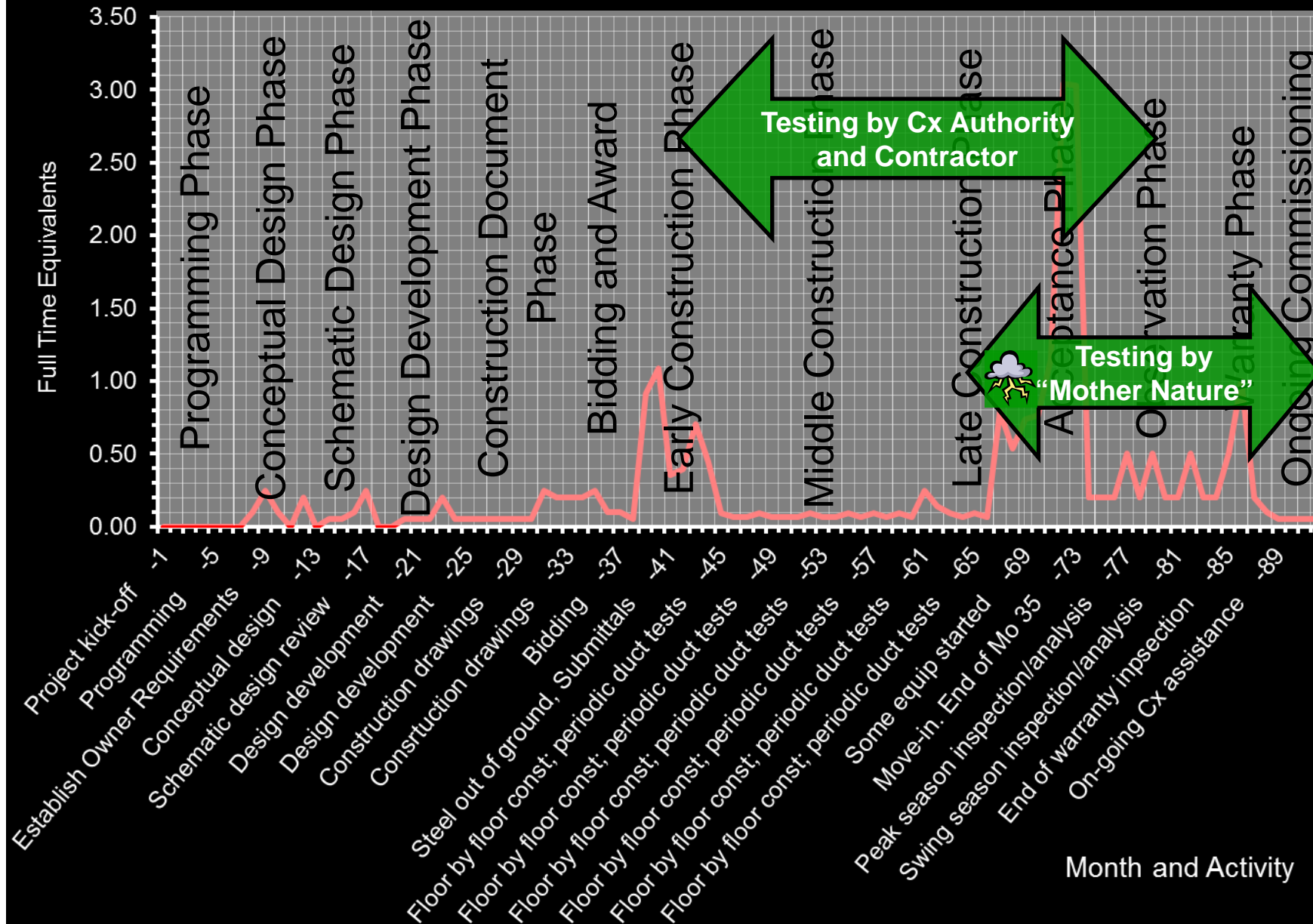
600,000 sq.ft. High Rise Basis



Month and Activity

Typical New Construction Commissioning Activity

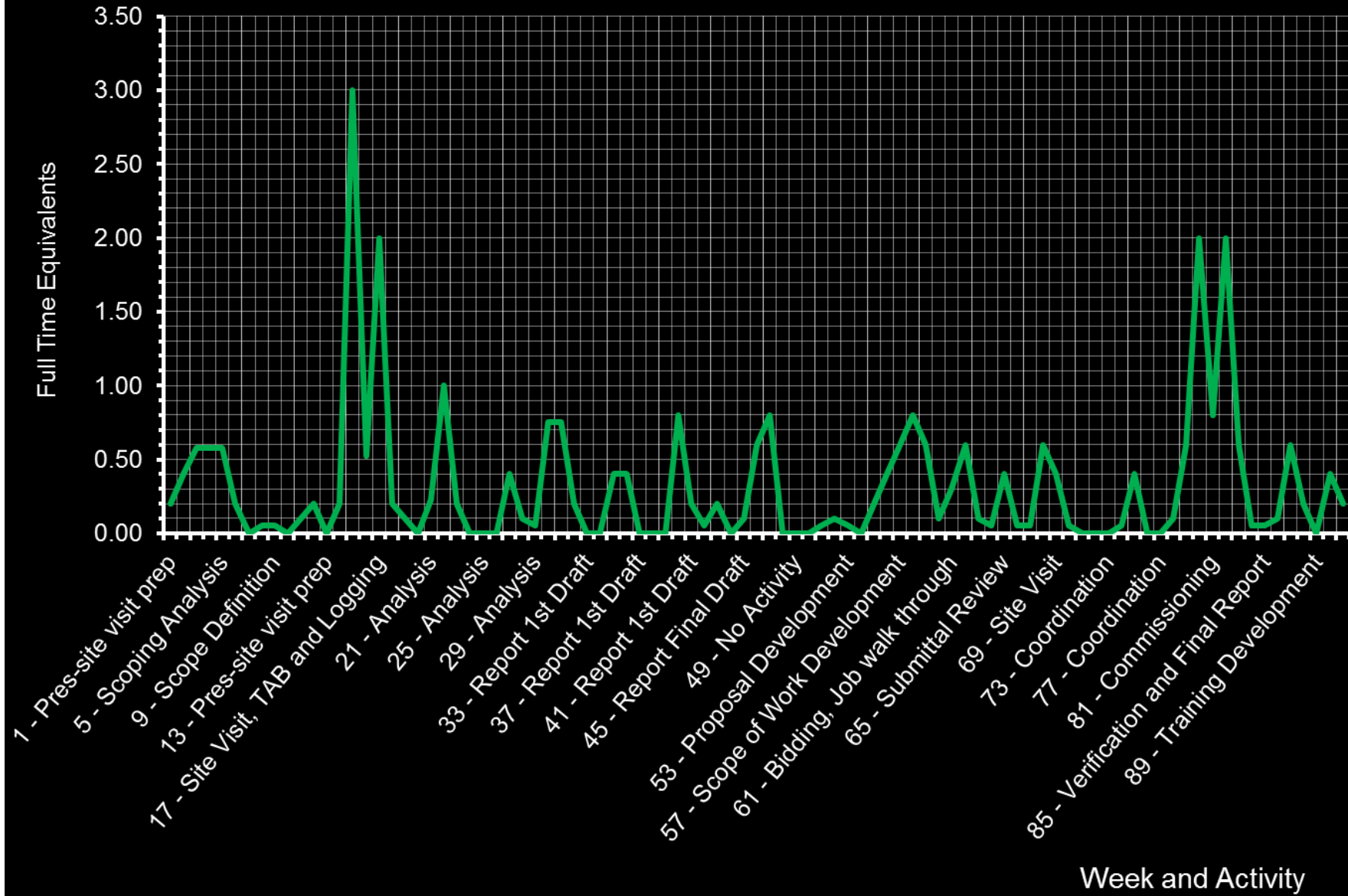
600,000 sq.ft. High Rise Basis



Month and Activity

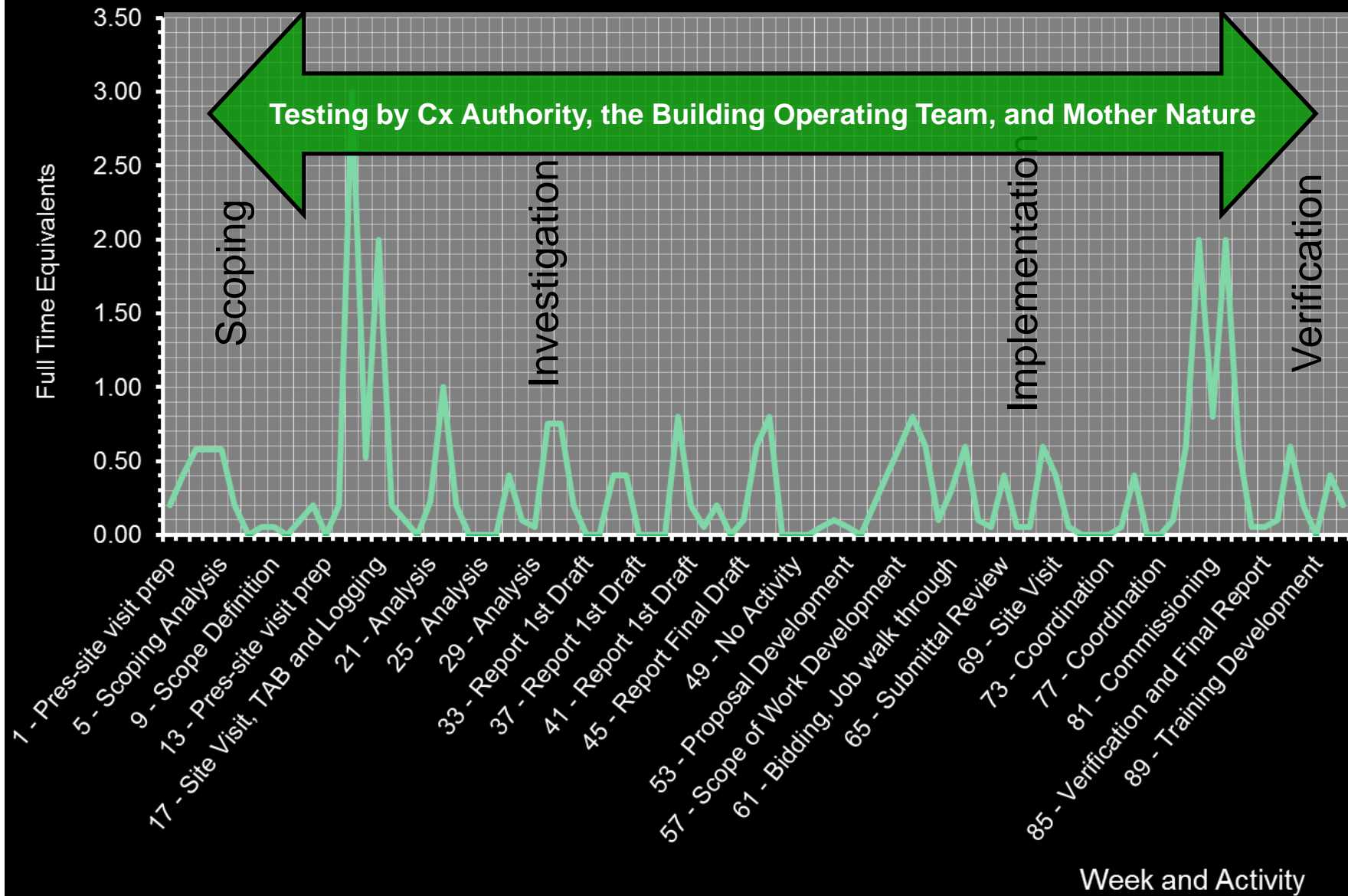
Typical Existing Building Construction Commissioning Activity

750,000 sq.ft. Hospital Basis



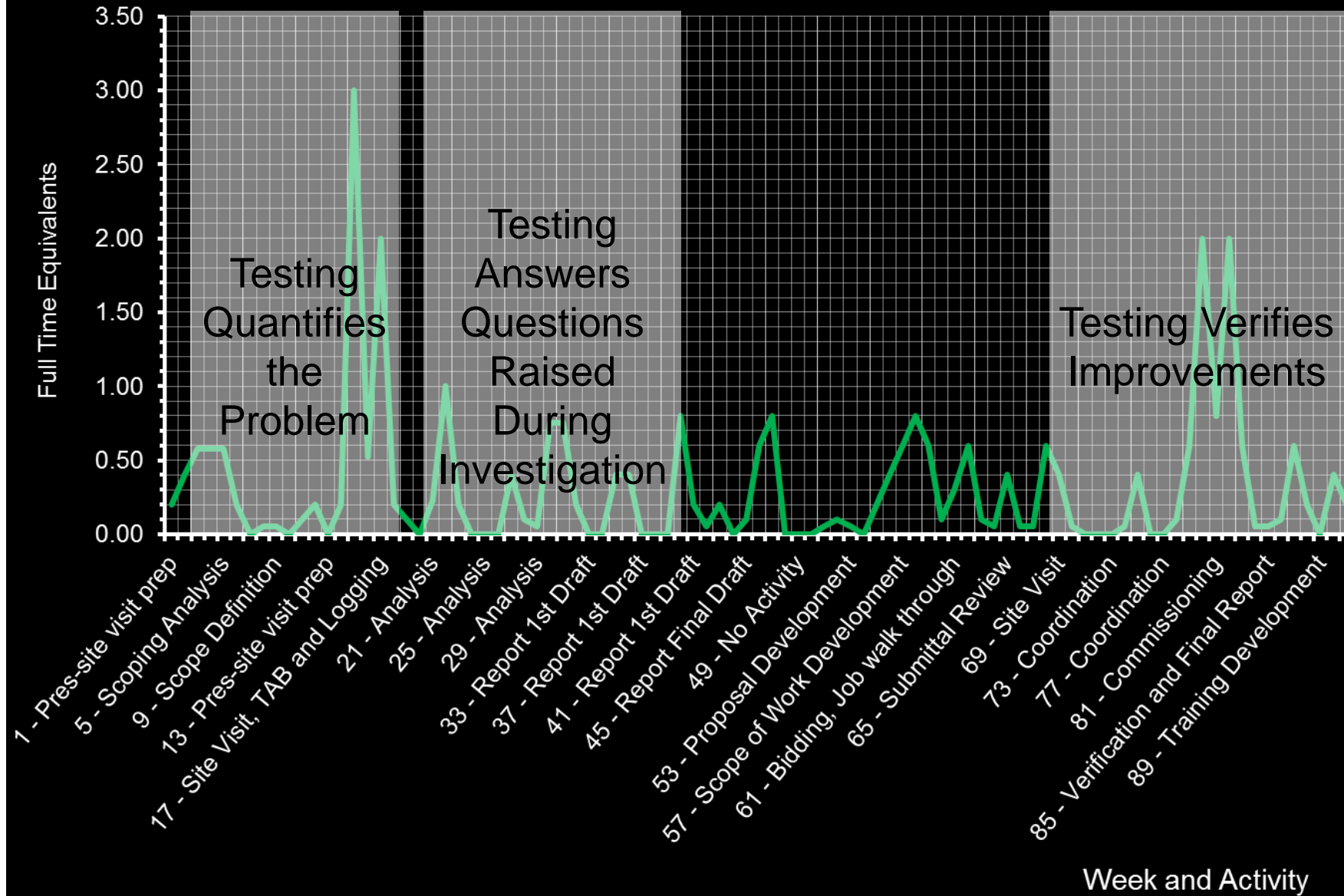
Typical Existing Building Construction Commissioning Activity

750,000 sq.ft. Hospital Basis



Typical Existing Building Construction Commissioning Activity

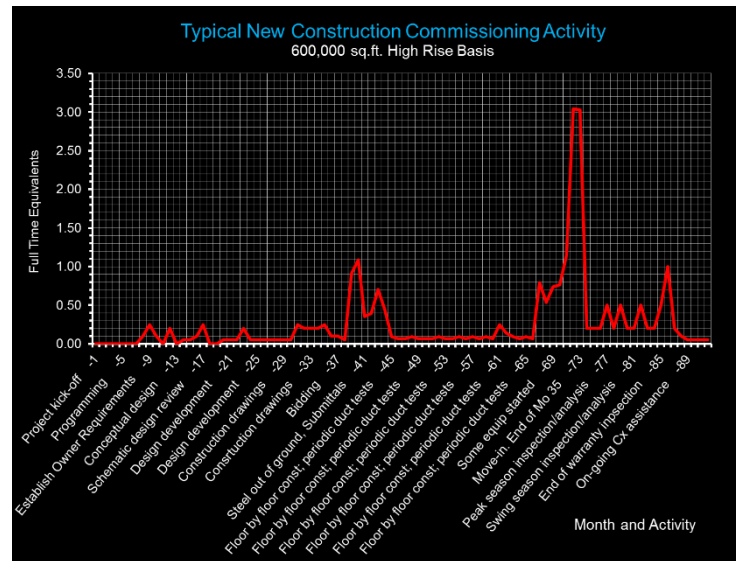
750,000 sq.ft. Hospital Basis



Key differences

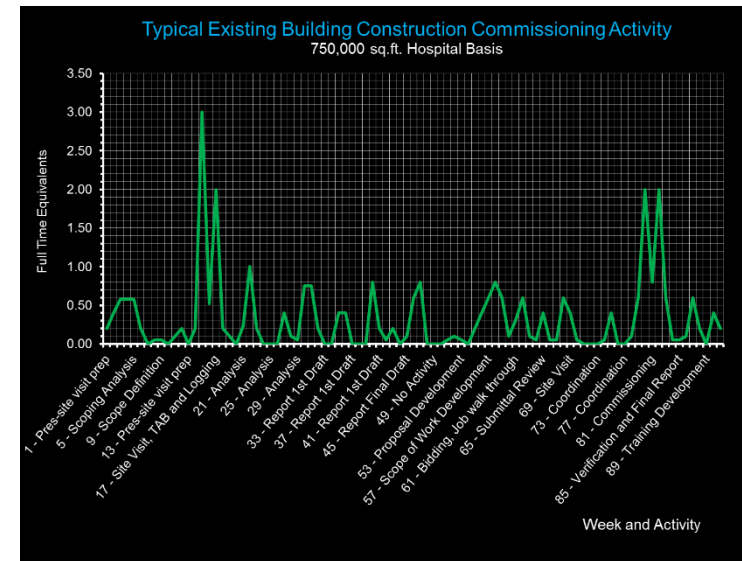
New construction

- Trying to prove design intent
- Demonstrate all elements of the system meet requirements
- Verification and quality assurance process



Existing building

- Trying to understand design intent
- Focused on certain elements of the system
- Diagnostic and troubleshooting process

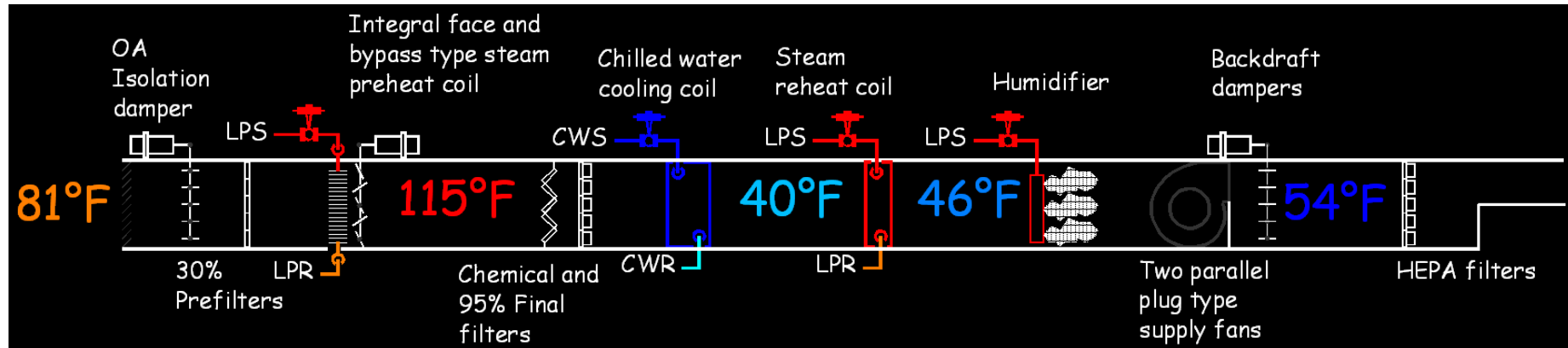


The System Concept

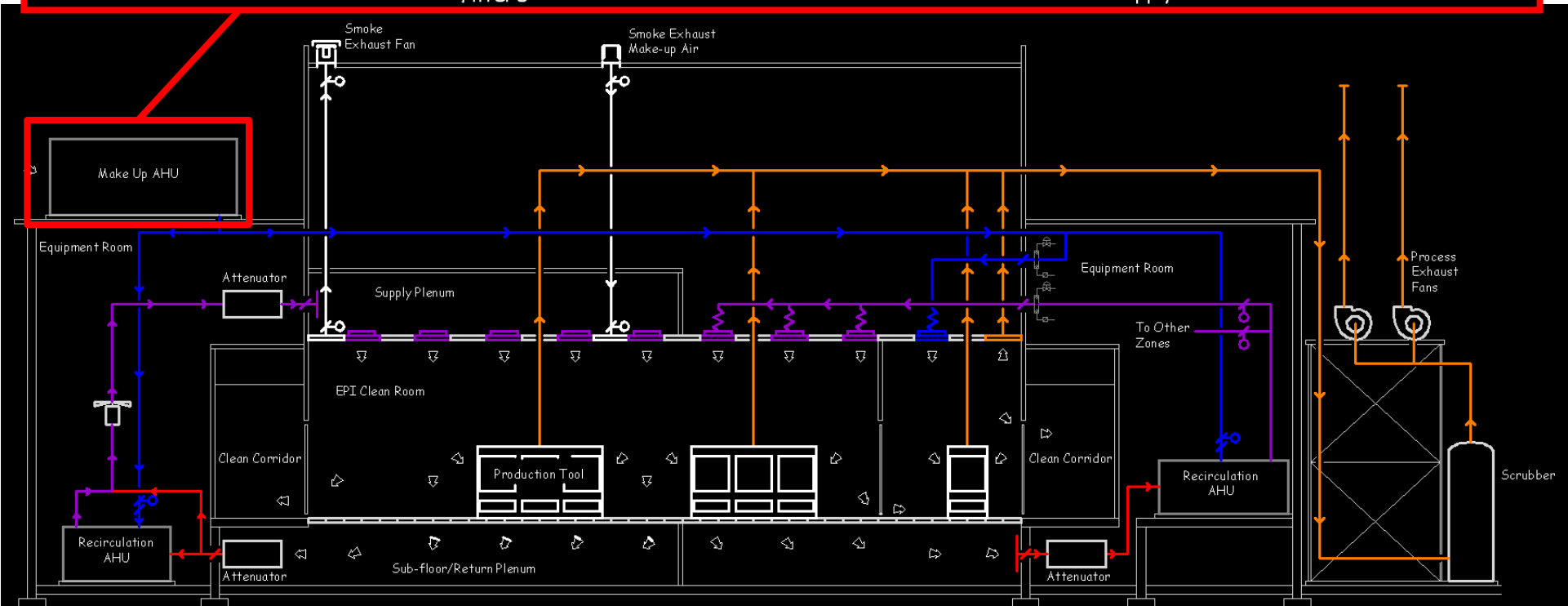
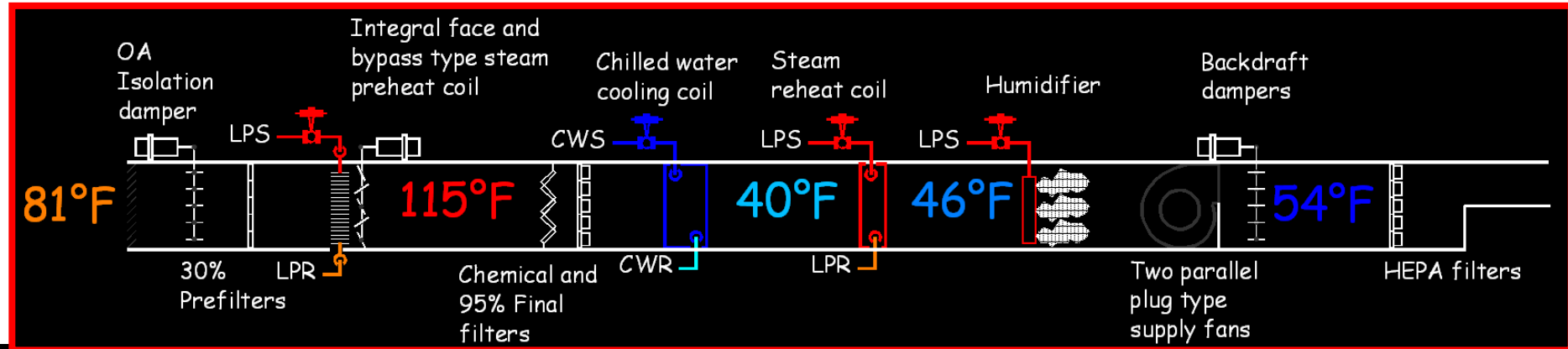
Critical to success for
design, commissioning
and operation



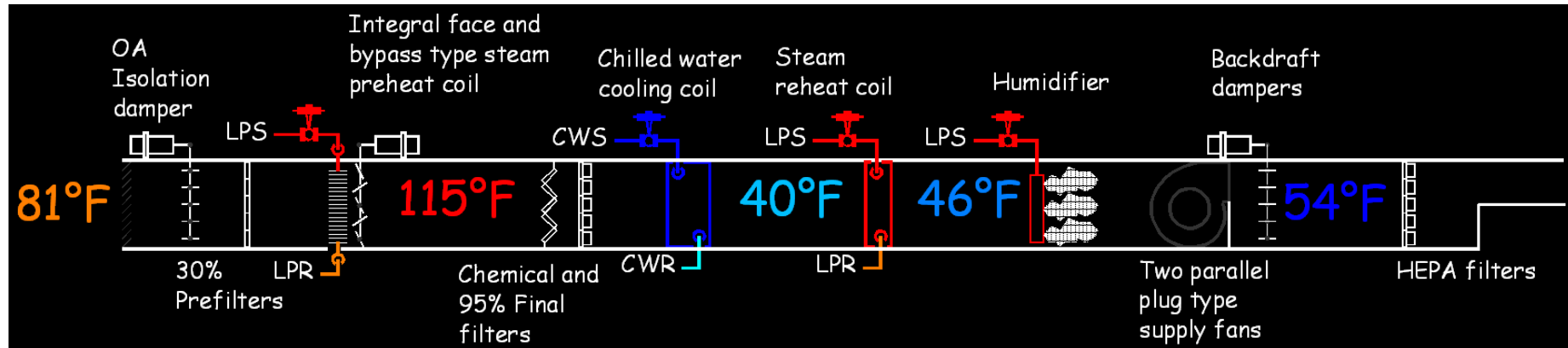
It's not just an air handling unit ...



... it's an air handling system



... it's an air handling system



Visit <http://www.av8rdas.com/case-studies.html#MAUOptimize> for details

Almost Done Polling

5. I am tired of polling.

☐

True

☐

False

Almost Done Polling

5. The conditions my systems see on a day to day basis can be quite different from the conditions they were designed to handle.

☐

True

☐

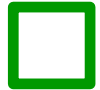
False

Almost Done Polling

5. The conditions my systems see on a day to day basis can be quite different from the conditions they were designed to handle.



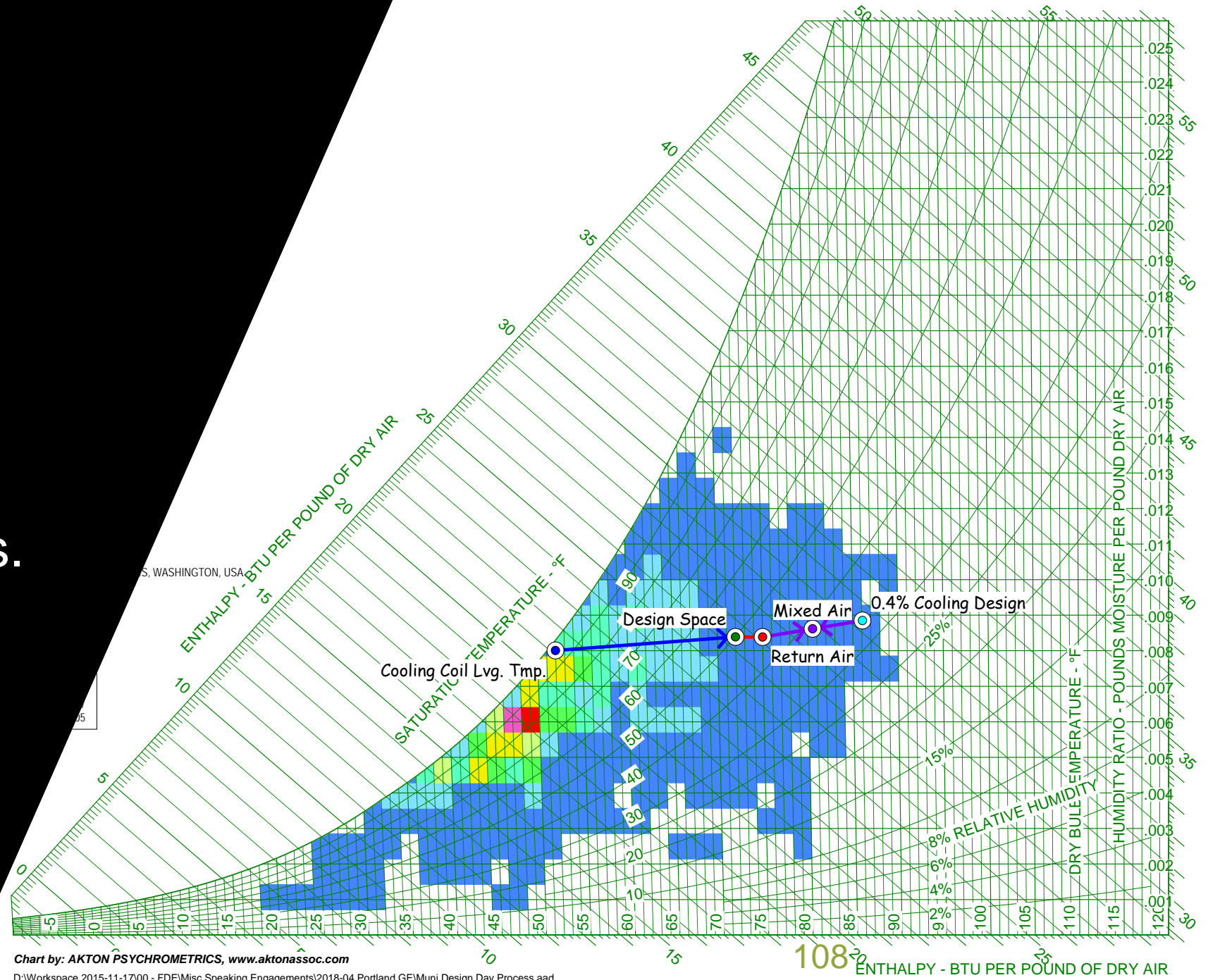
True



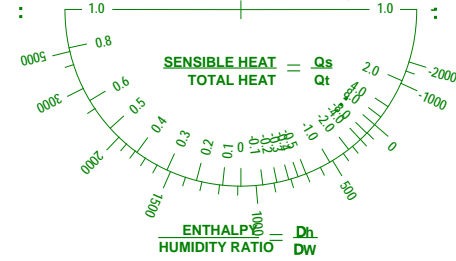
False

The load profile

The design day vs. reality



ALTITUDE: 66 FEET
 BAROMETRIC PRESSURE: 29.851 in. HG
 ATMOSPHERIC PRESSURE: 14.661 psia



Weather Data Location:
 SEATTLE_BOEING_FIELD_ISIS, WASHINGTON, USA

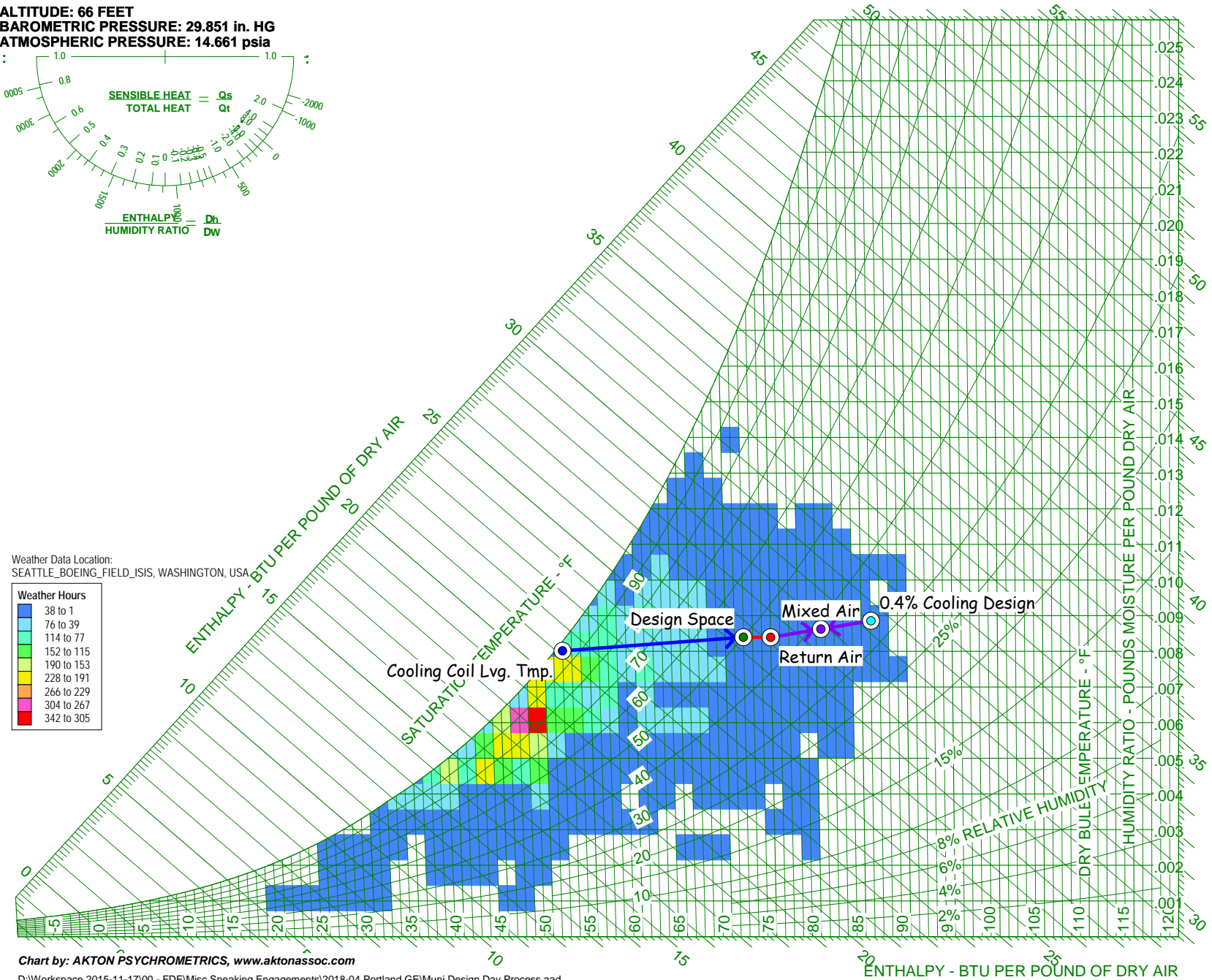
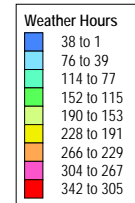


Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com

D:\Workspace 2015-11-17\00 - FDE\Misc Speaking Engagements\2018-04 Portland GE\Muni Design Day Process.aad

Load profile drivers

1. The state of the air

$$v = \frac{1}{x_a} \left[\left| \frac{RT}{p} \right| \cdot \frac{1}{a} \cdot (x_a^2 A_{aa} + 2x_a x_w A_{aw} - x_a^3 A_{www} p) \beta \right]$$

$$h = \left[x_a h_a^\circ + (0.62198 x_w h_w^\circ) \beta - (x_a^2 B_{aa} + 2x_a x_w B_{aw} + x_w^2 B_{aw} + x_w^2 B_{ww}) \cdot p \alpha - \frac{1}{2} x_w^3 B_{www} p^2 \alpha \right] \frac{1}{x_a} + \bar{h}_a W \bar{h}_w$$

2. The nature of the process occurring at the load

$$\bar{Q} + \sum_1 \left[\dot{m} \times \left(u_1 + \frac{p_1 v_1}{J} + \frac{z_1}{J} + \frac{V_1^2}{2gJ} \right) \right] = \frac{\bar{W}}{J} + \sum_2 \left[\dot{m} \times \left(u_2 + \frac{p_2 v_2}{J} + \frac{z_2}{J} + \frac{V_2^2}{2gJ} \right) \right]$$

3. The process design target

$$t_{db} = 72.000^\circ\text{F}, t_{wb} = 60.064^\circ\text{F}, t_{dp} = 52.370^\circ\text{F}, h = 26.435 \text{ Btu/lb}_m,$$

$$w = 58.73 \text{ grains}_{\text{H}_2\text{O}}/\text{lb}_{m_A}, \text{RH} = 50.000, v = 13.611 \text{ ft}^3/\text{lb}_m, \rho = .0741 \text{ lb}_m/\text{ft}^3$$

ALTITUDE: SEA LEVEL
BAROMETRIC PRESSURE: 29.921 in. HG
ATMOSPHERIC PRESSURE: 14.696 psia

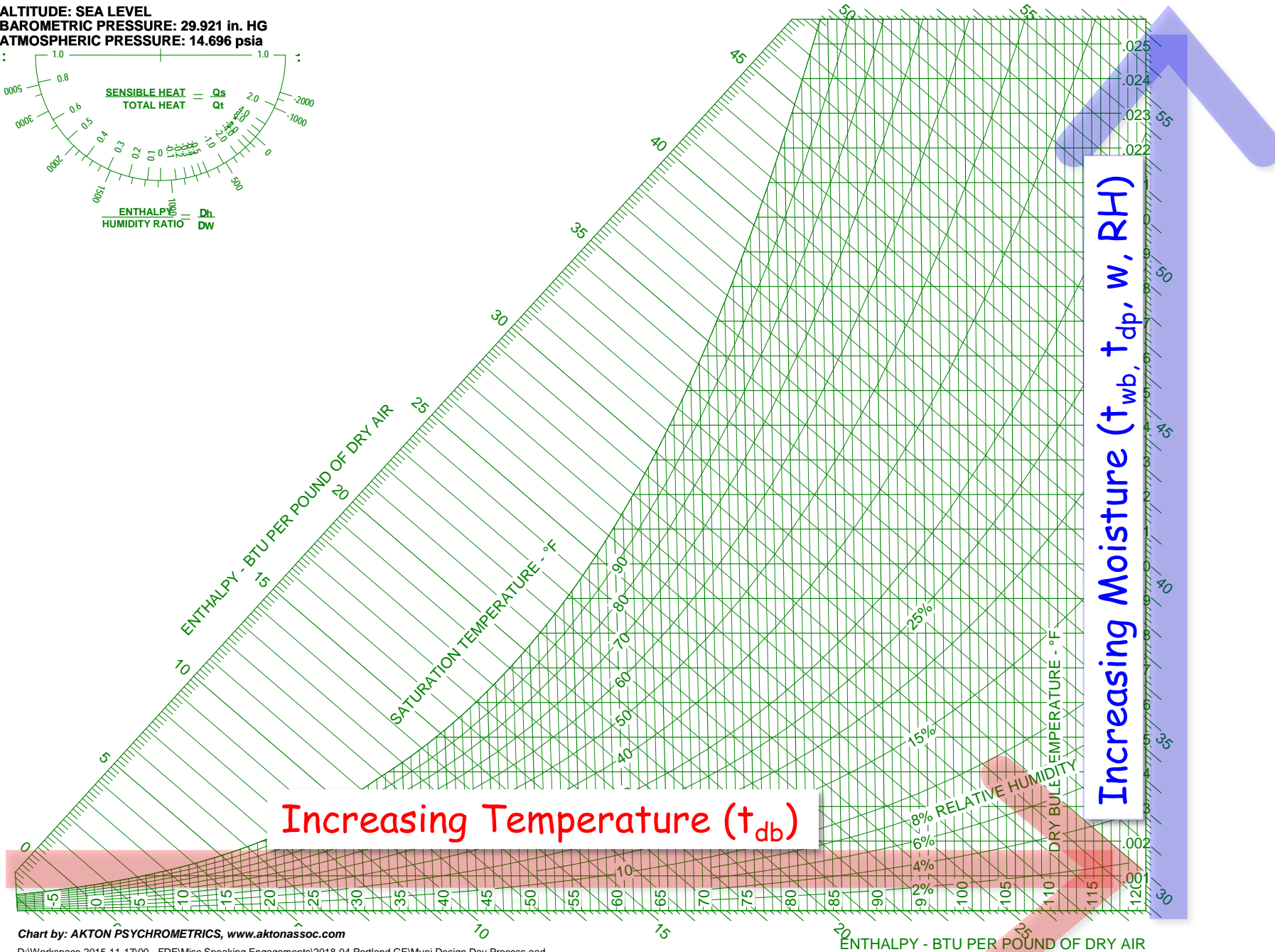
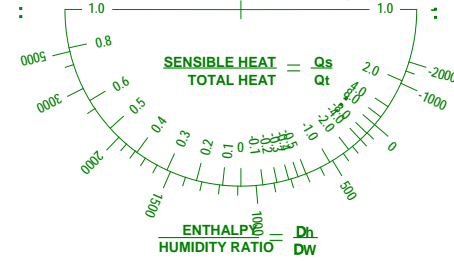
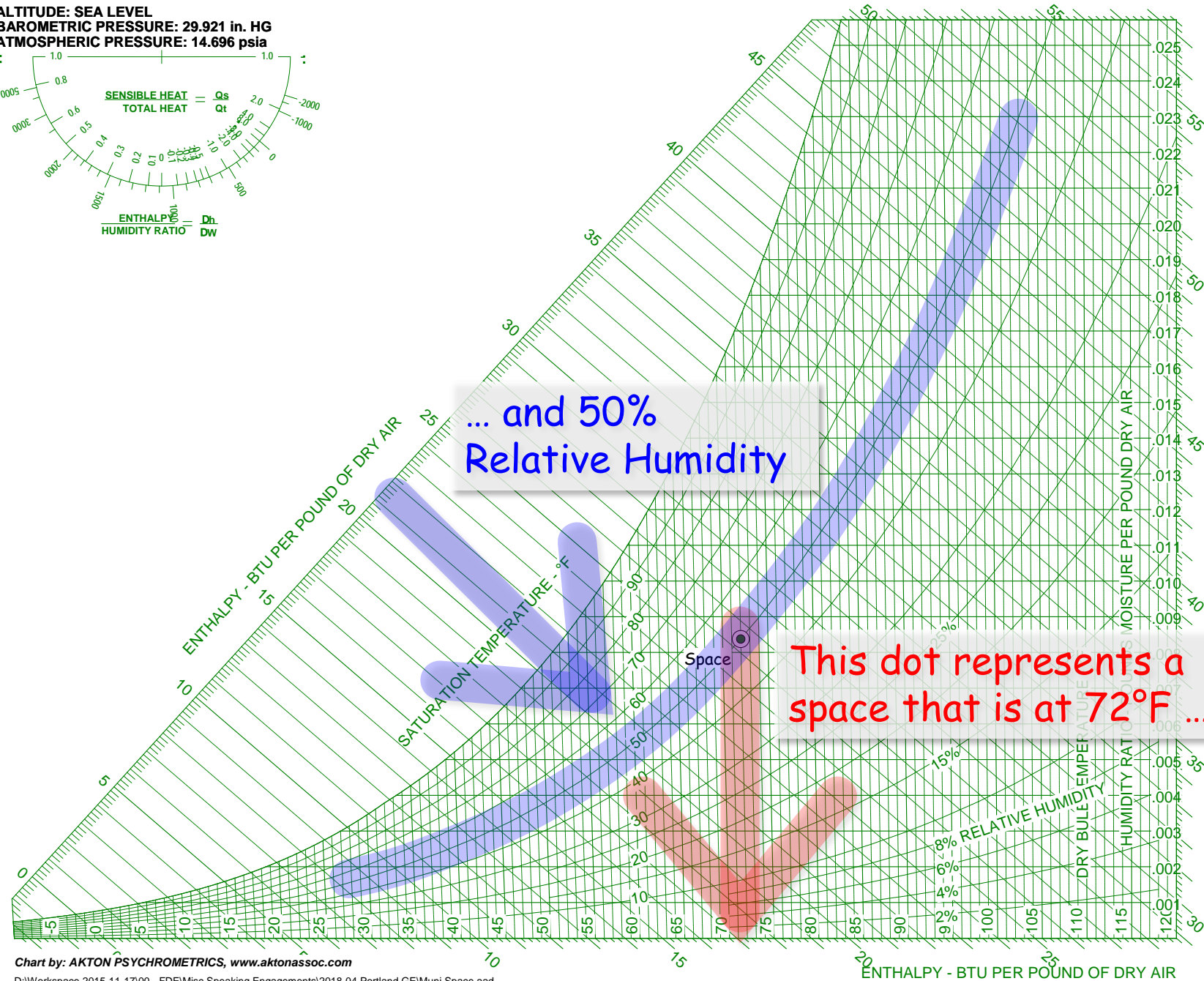
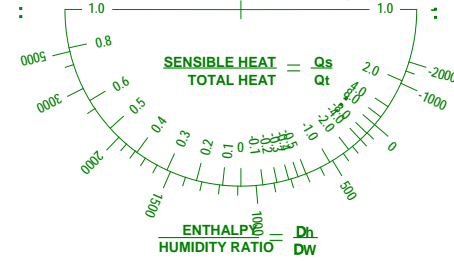


Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com

D:\Workspace 2015-11-17\00 - FDE\Misc Speaking Engagements\2018-04 Portland GE\Muni Design Day Process.aad

ALTITUDE: SEA LEVEL
BAROMETRIC PRESSURE: 29.921 in. HG
ATMOSPHERIC PRESSURE: 14.696 psia



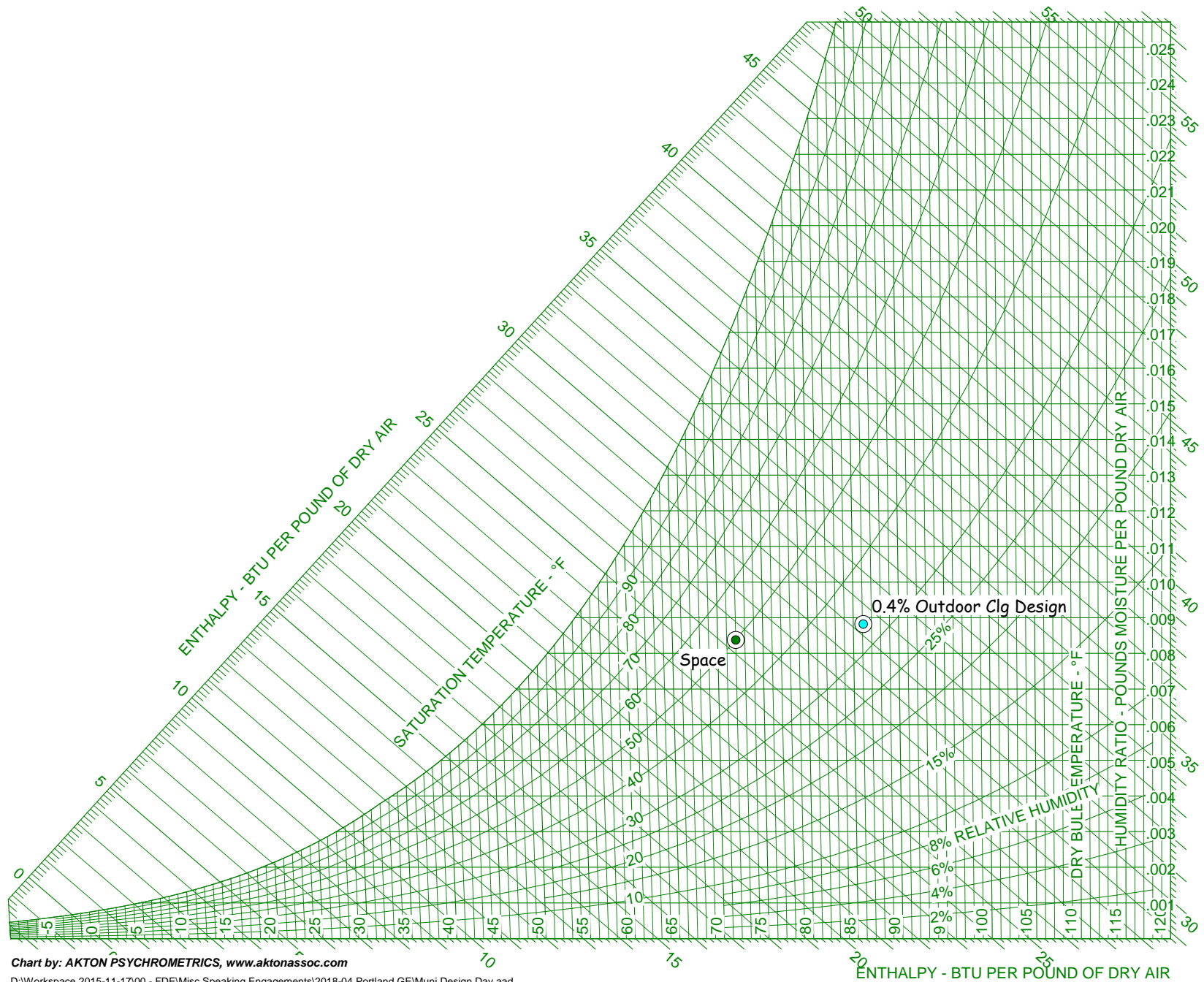
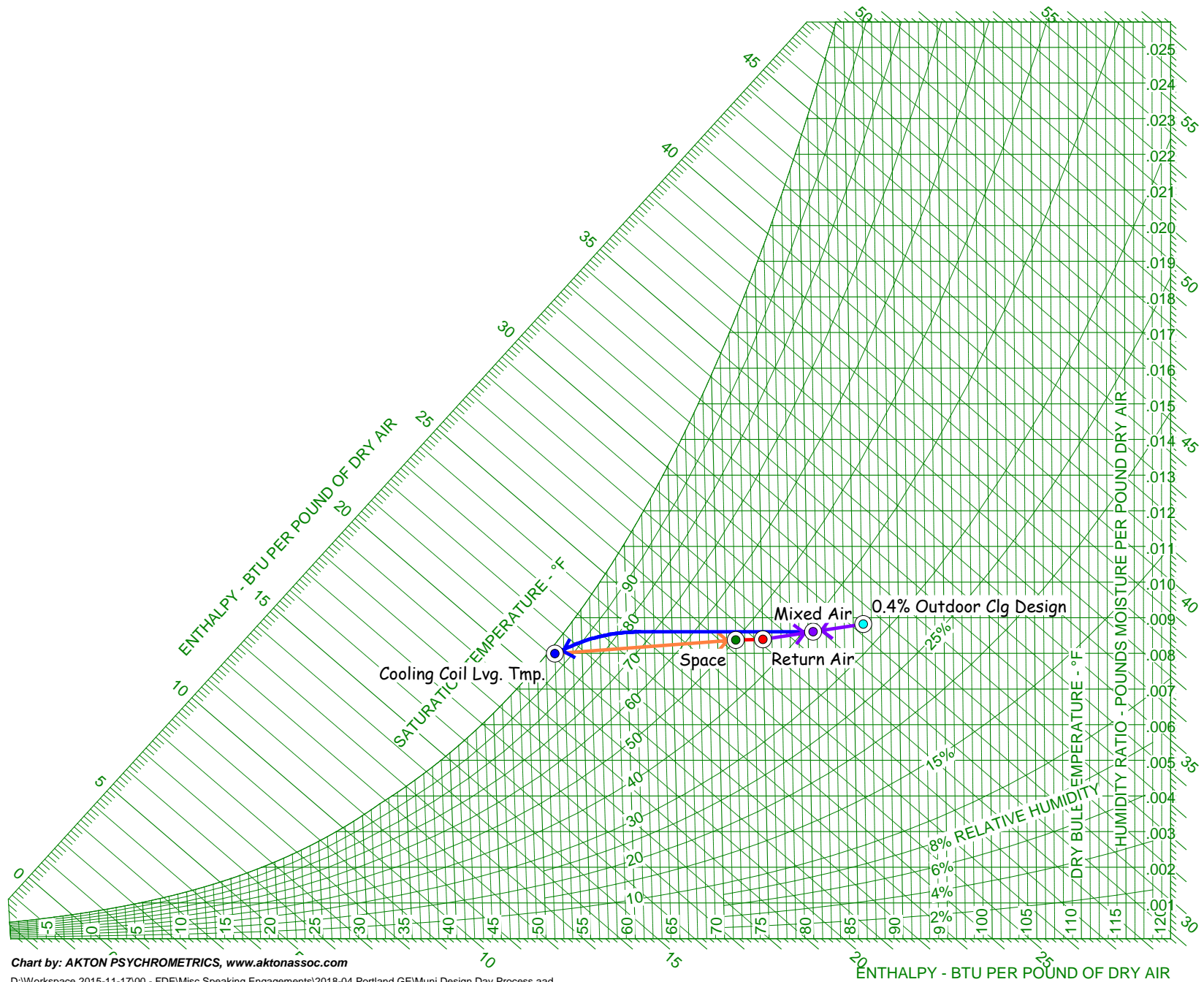
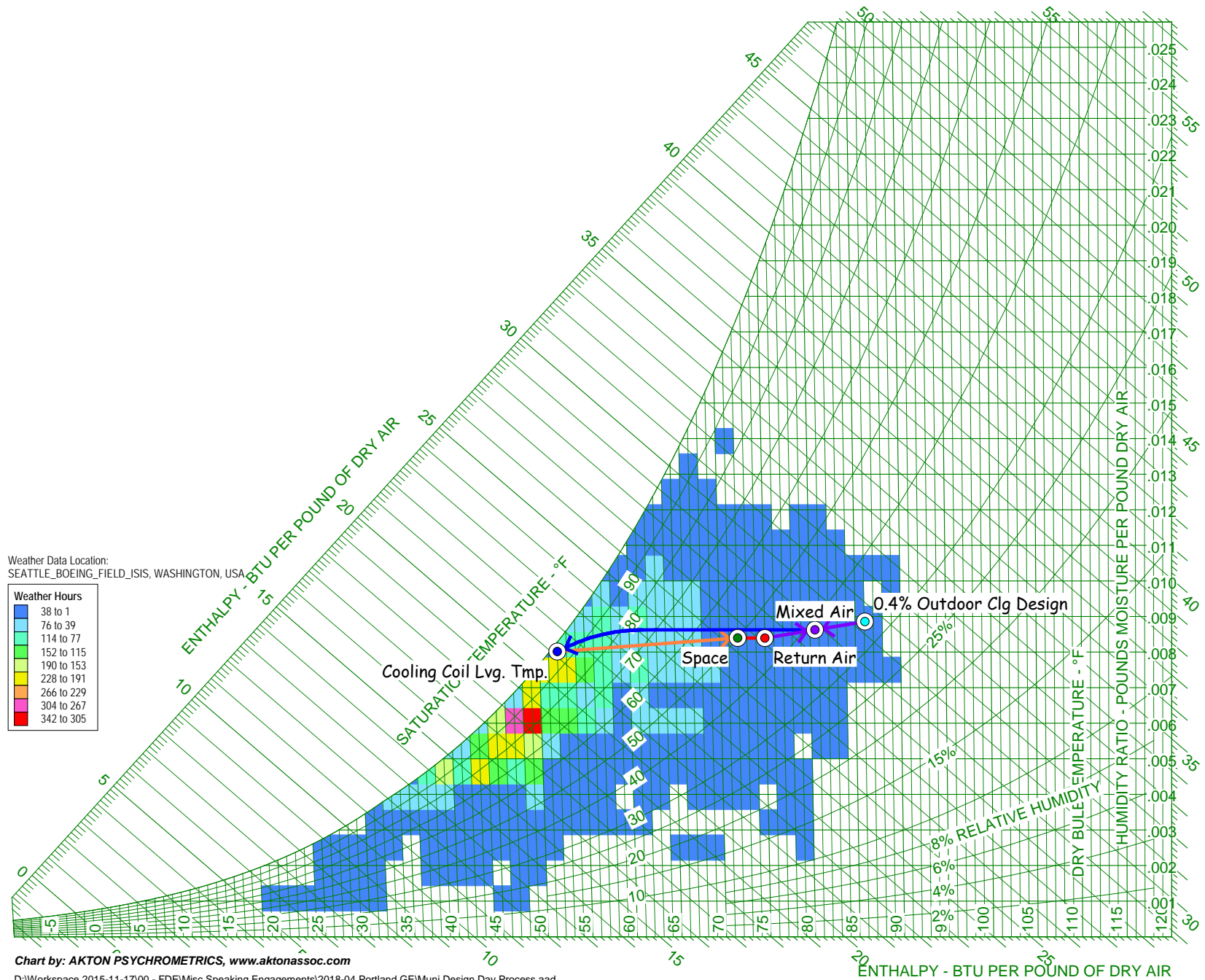


Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com

D:\Workspace 2015-11-17\00 - FDE\Misc Speaking Engagements\2018-04 Portland GE\Muni Design Day.aad





The mixed air temperature will be moved around by the economizer control process and ventilation requirements and will always be between the outdoor temperature and return temperature

The space temperature will not move but the humidity will drop if it is dry outside

The cooling coil leaving condition dot will be moved around by HVAC optimization strategies like discharge temperature reset

The outdoor air condition dot could be any of the colored squares

The return temperature will move a little bit depending on the space sensible load and the humidity will drop if it is dry outside

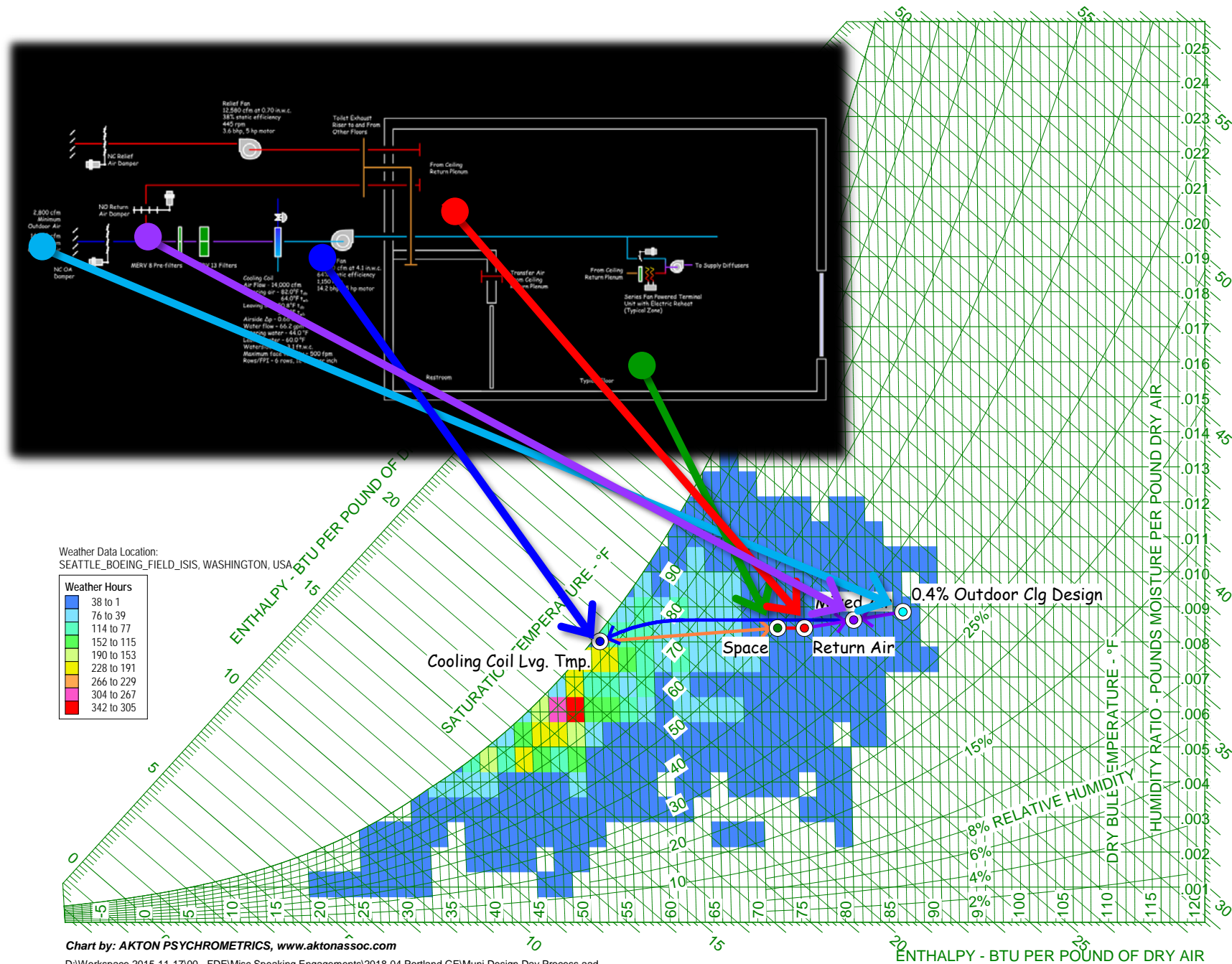
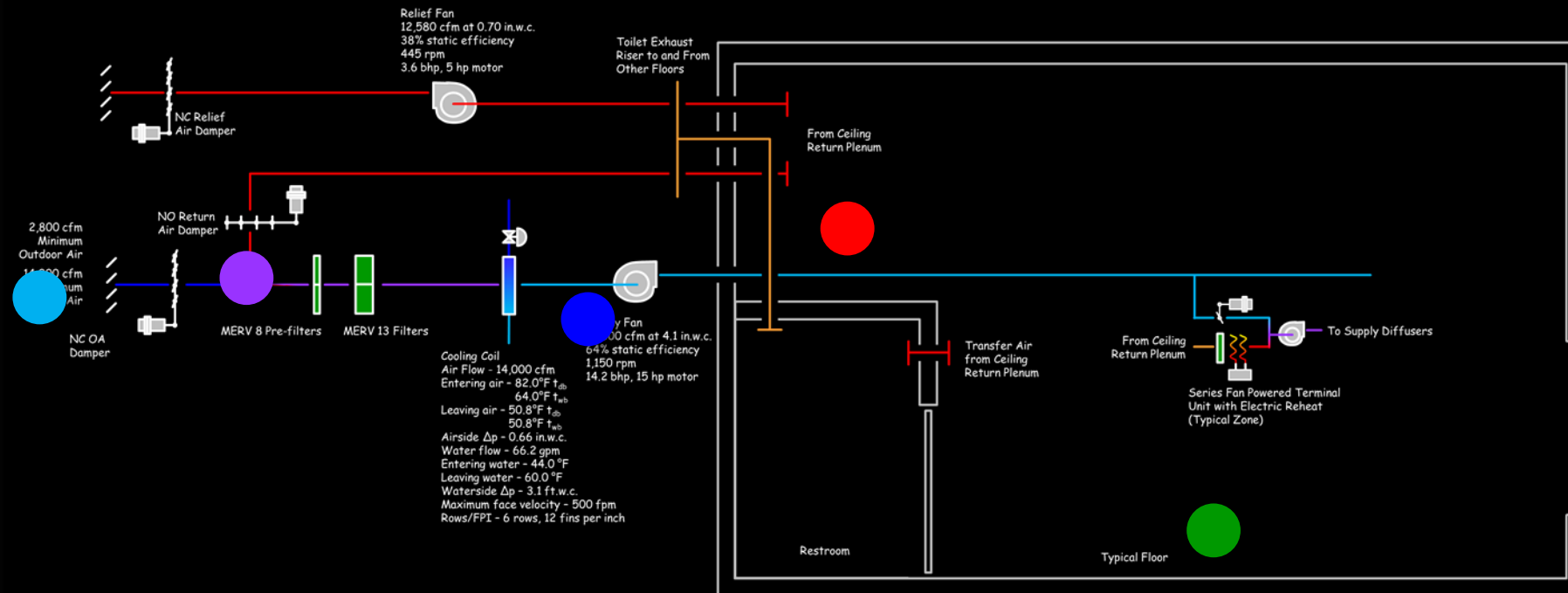


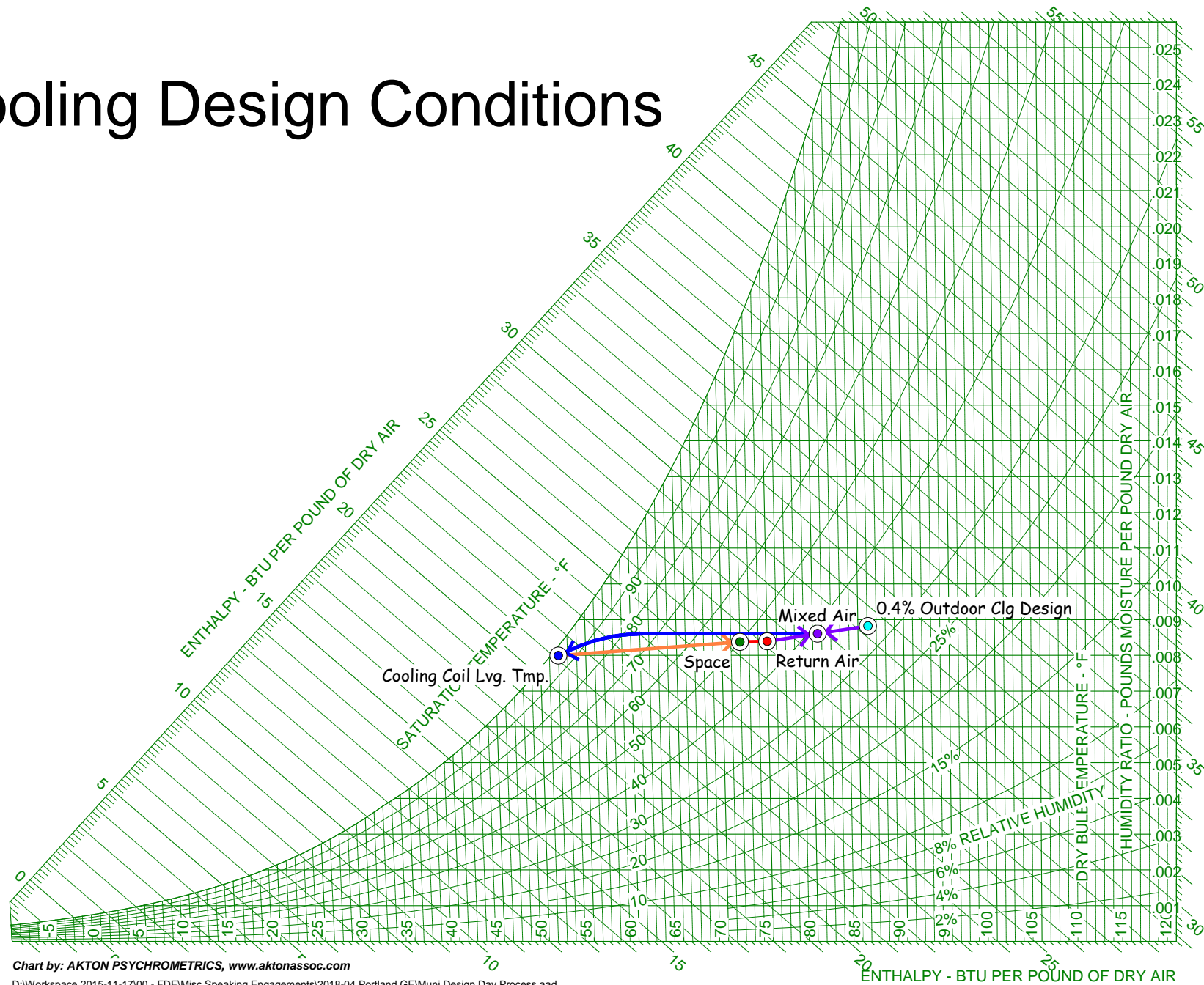
Chart by: AKTON PSYCHROMETRICS, www.aktonnassoc.com

D:\Workspace 2015-11-17\00 - FDE\Misc Speaking Engagements\2018-04 Portland GE\Muni Design Day Process.aad



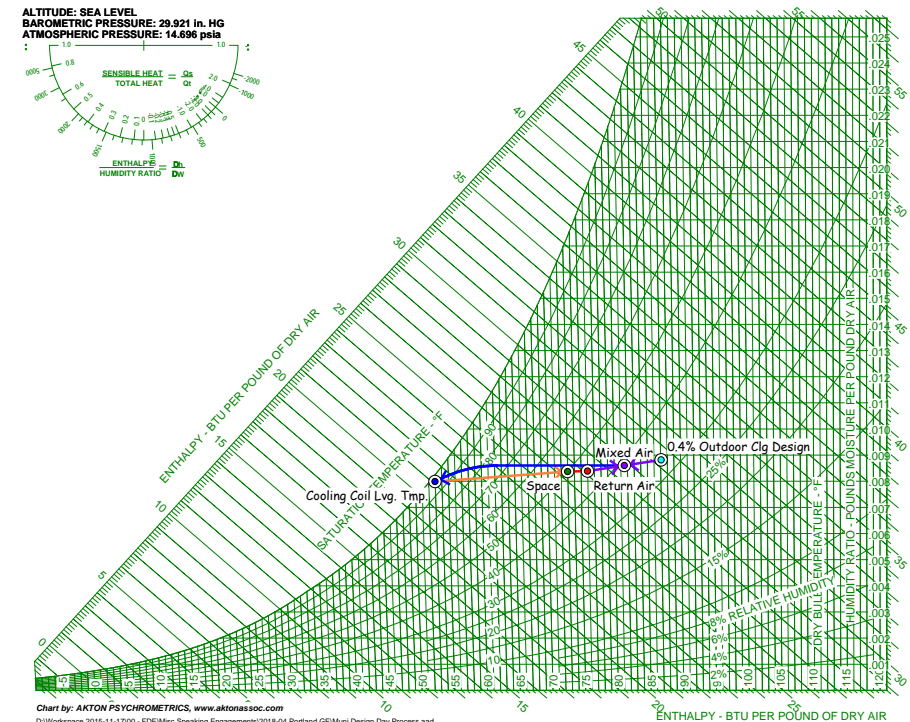
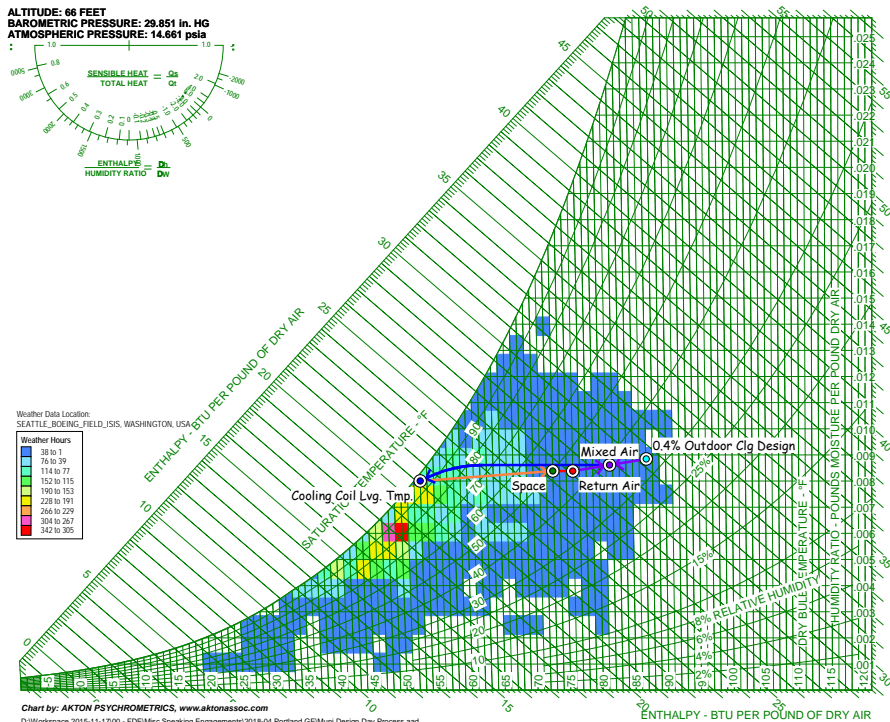
Which means the cooling coil entering condition is highly variable

The Cooling Design Conditions



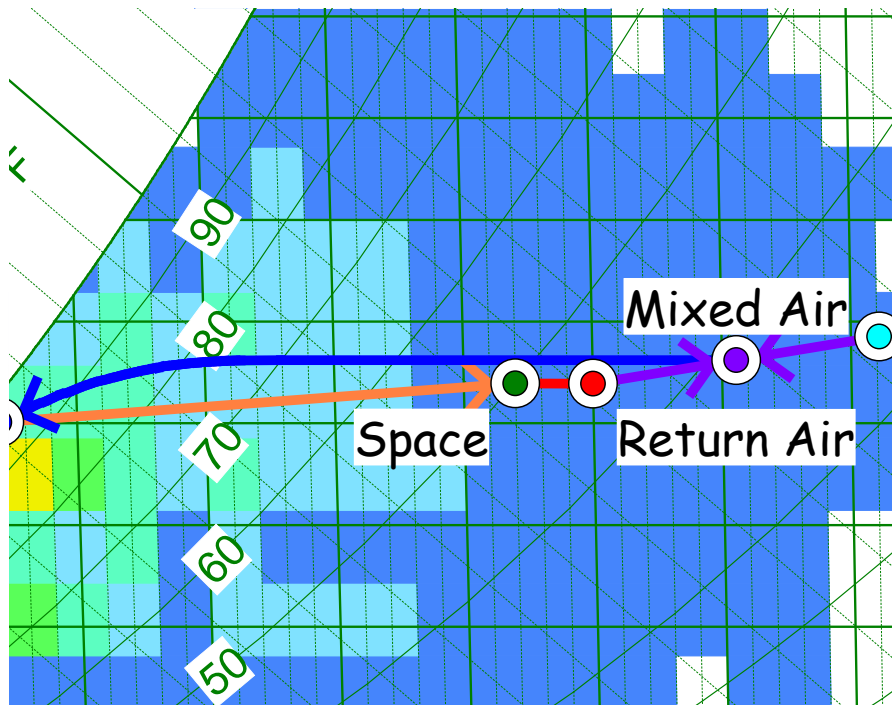
The Cooling Design Conditions

The seasonal and daily load profile seen by our building systems will vary a lot due to the nature of the climate and the performance characteristics of the equipment dealing with the climate.



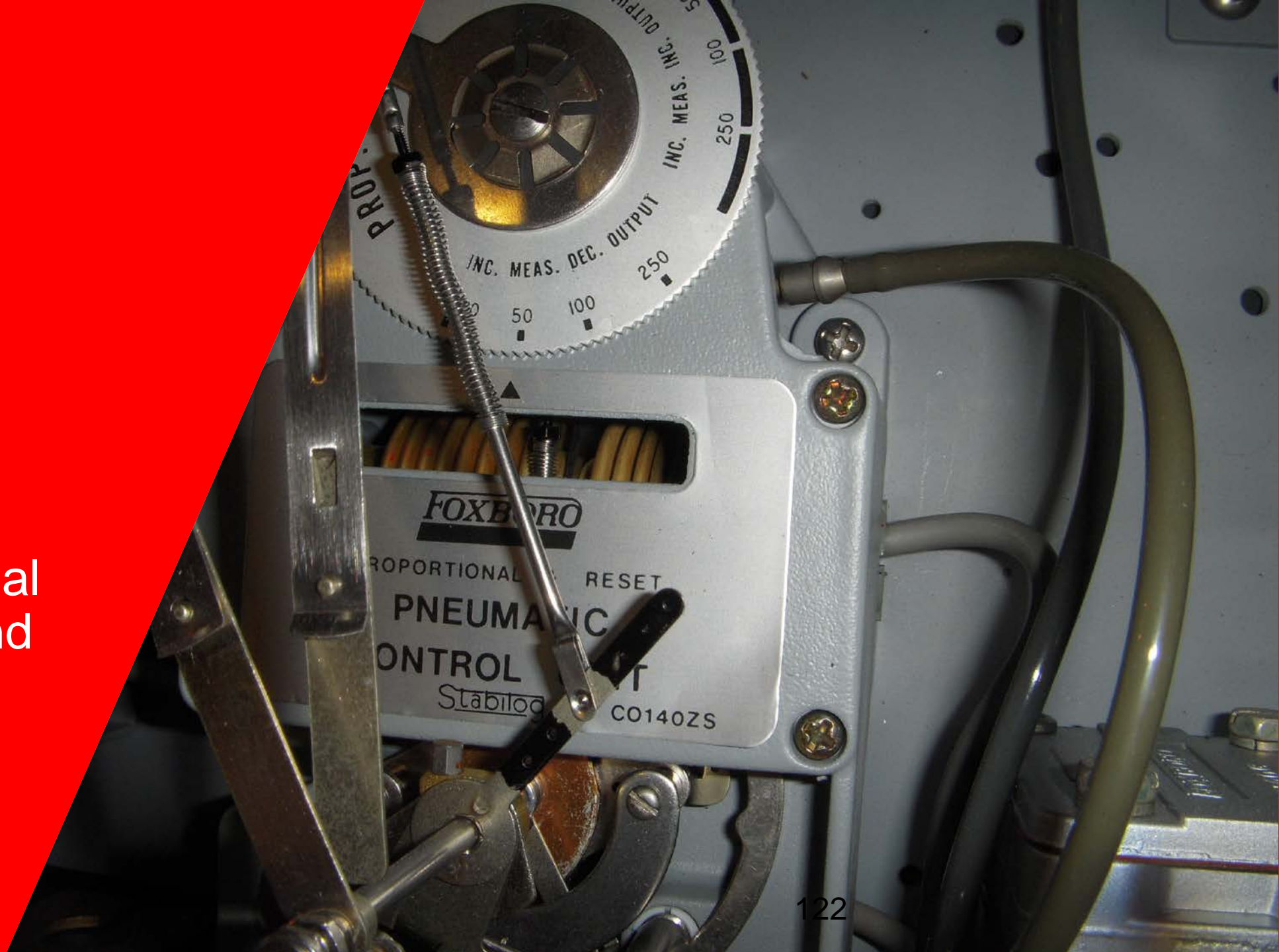
The Cooling Design Conditions

The seasonal and daily load profile seen by our building systems will vary a lot due to the nature of the climate and the performance characteristics of the equipment dealing with the climate.



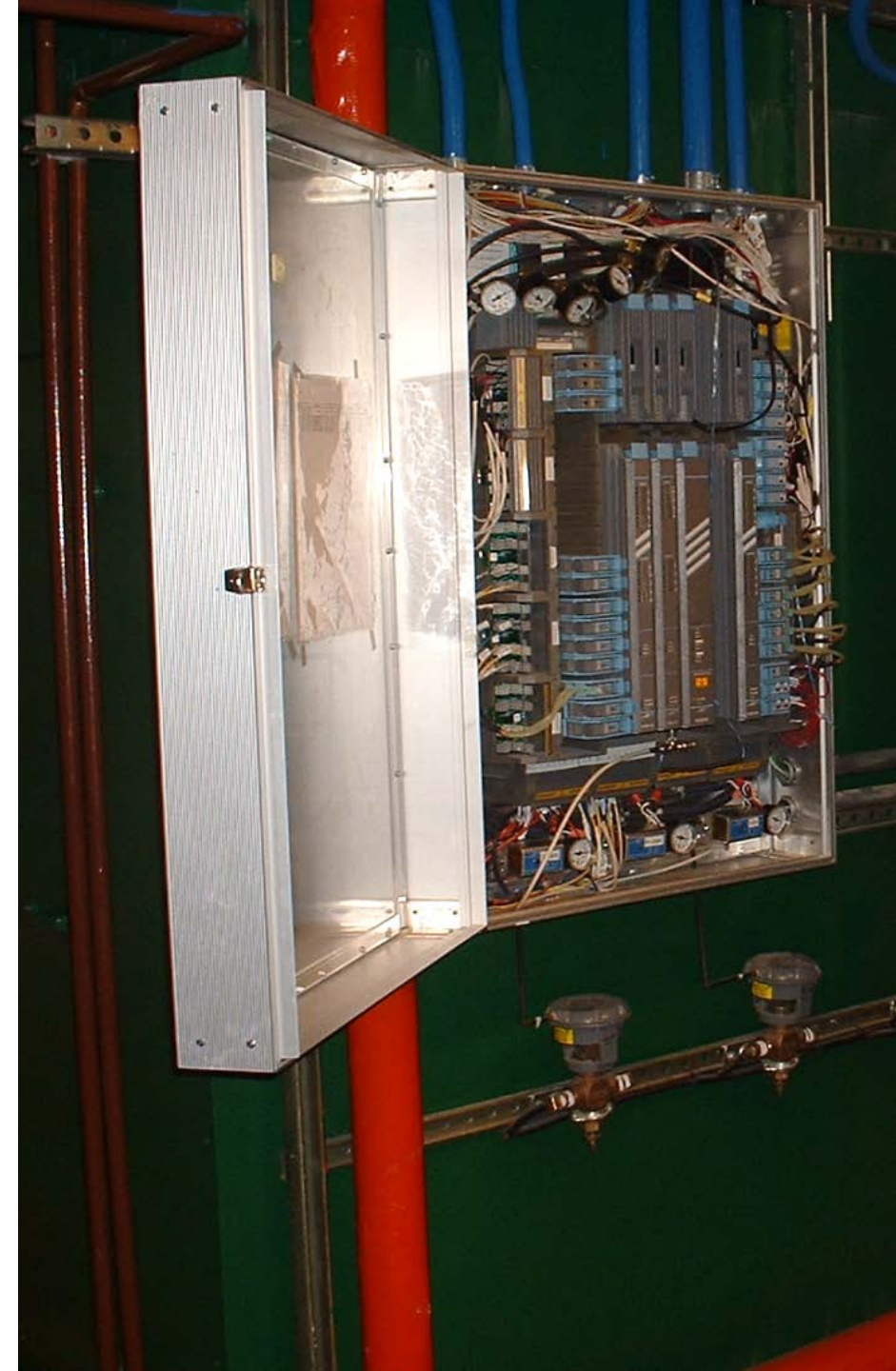
The Control System

Crucial to optimal performance and energy saving



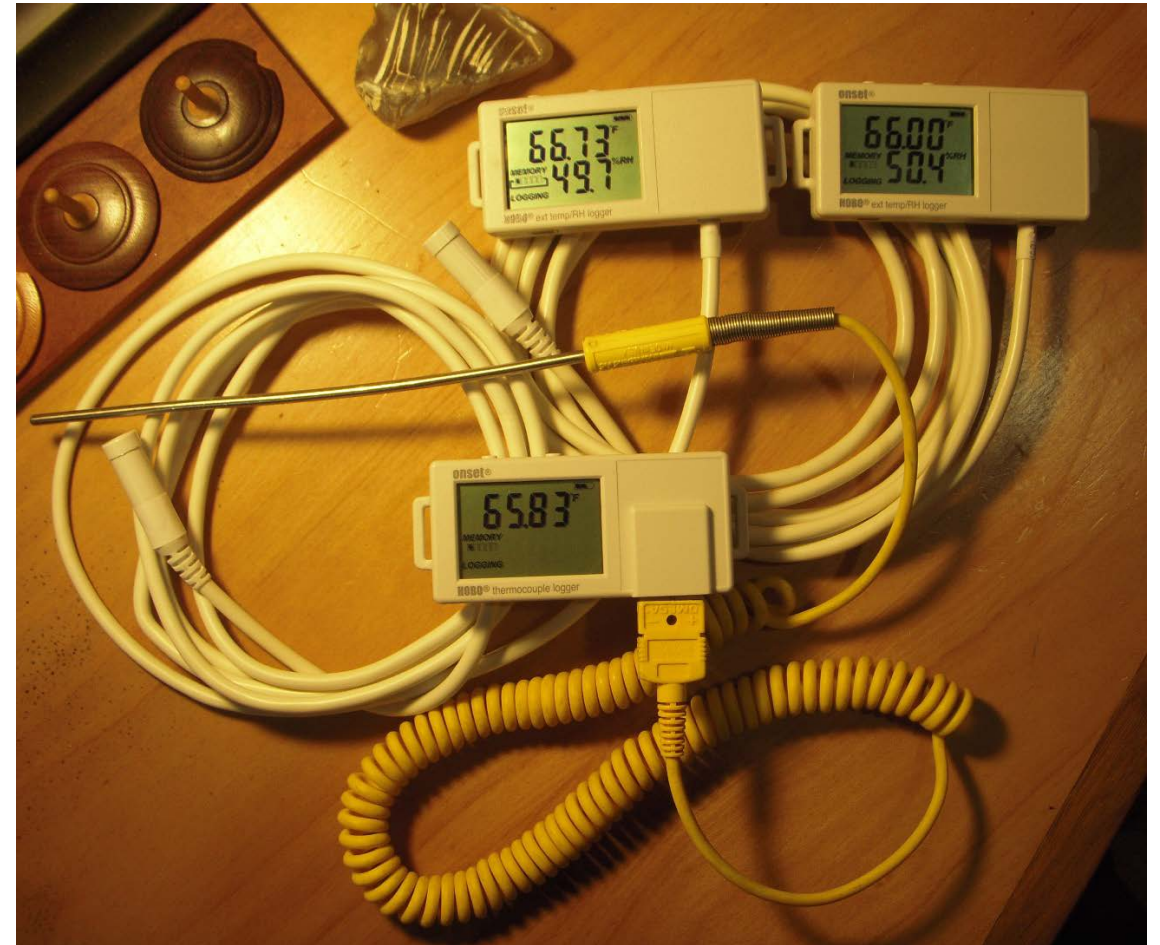
The Control System's Crucial Role

- Ensures systems perform as intended
- Manages system dynamics associated with load profile variations
- Supports functional testing
- Supports data logging and trending
- Supports persistence
- Informs future decisions

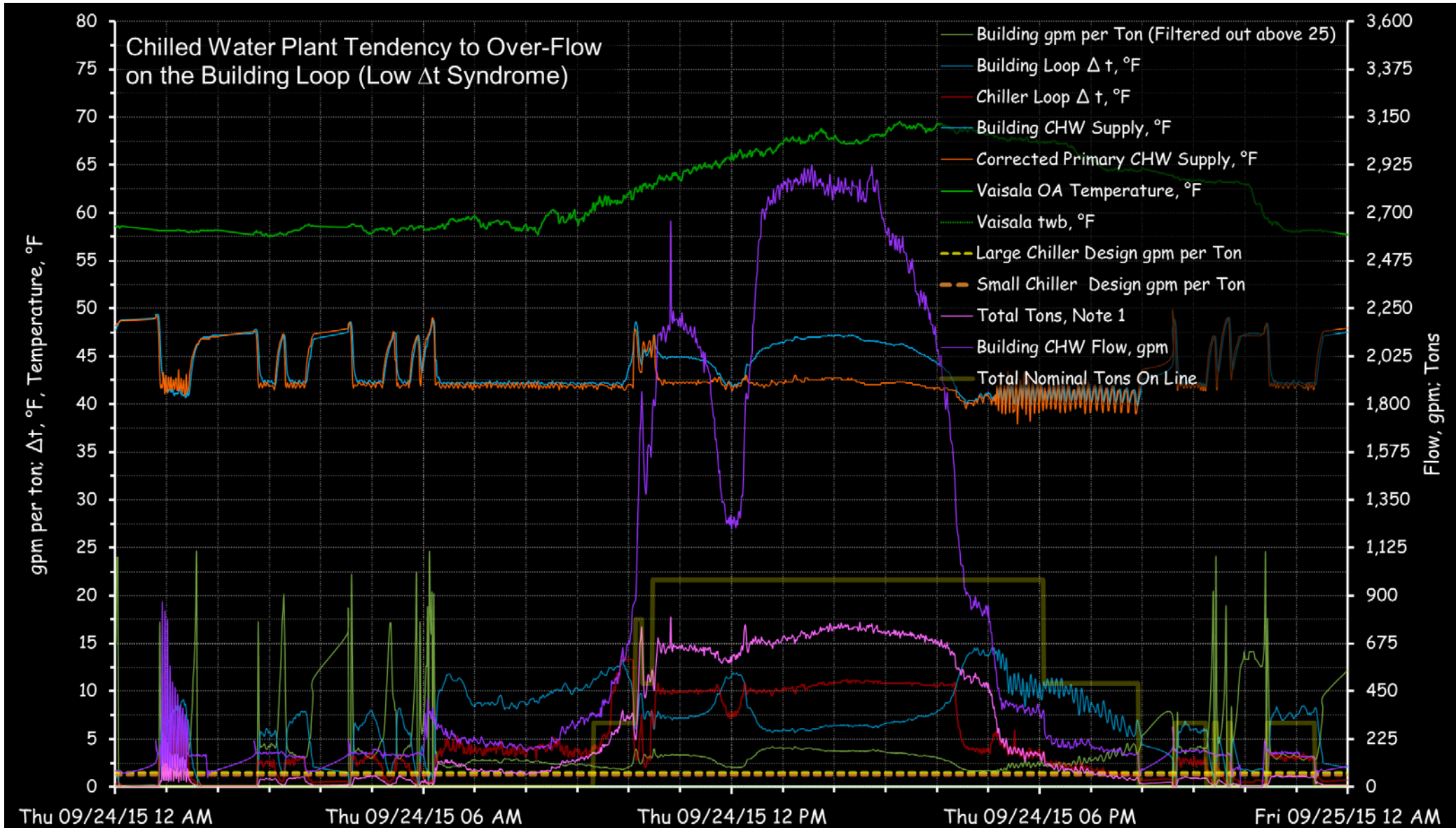


Data loggers

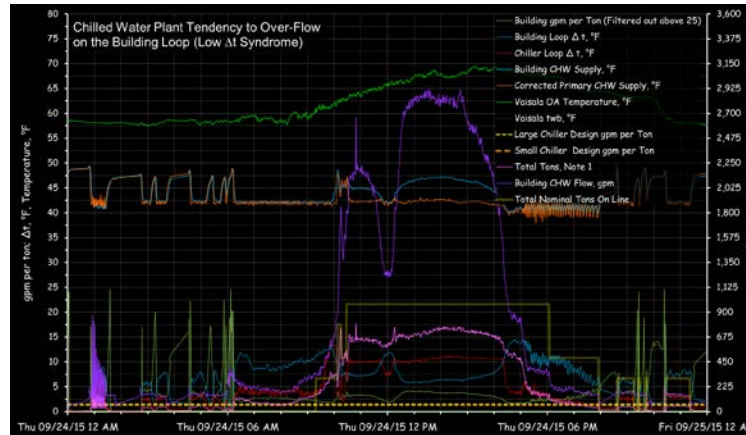
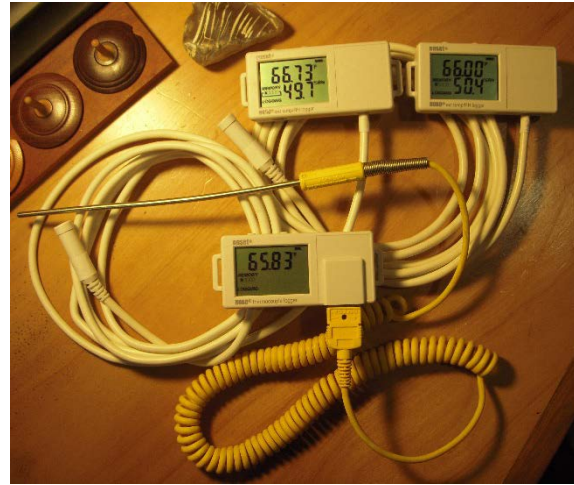
- Data loggers supplement the control systems trending capabilities
- Potential for faster sampling rates
- Pick up data where points are missing in the control system



Data_{Controller} + Data_{Logger} = Trend Analysis



Trend analysis + Testing = A Building Dialog

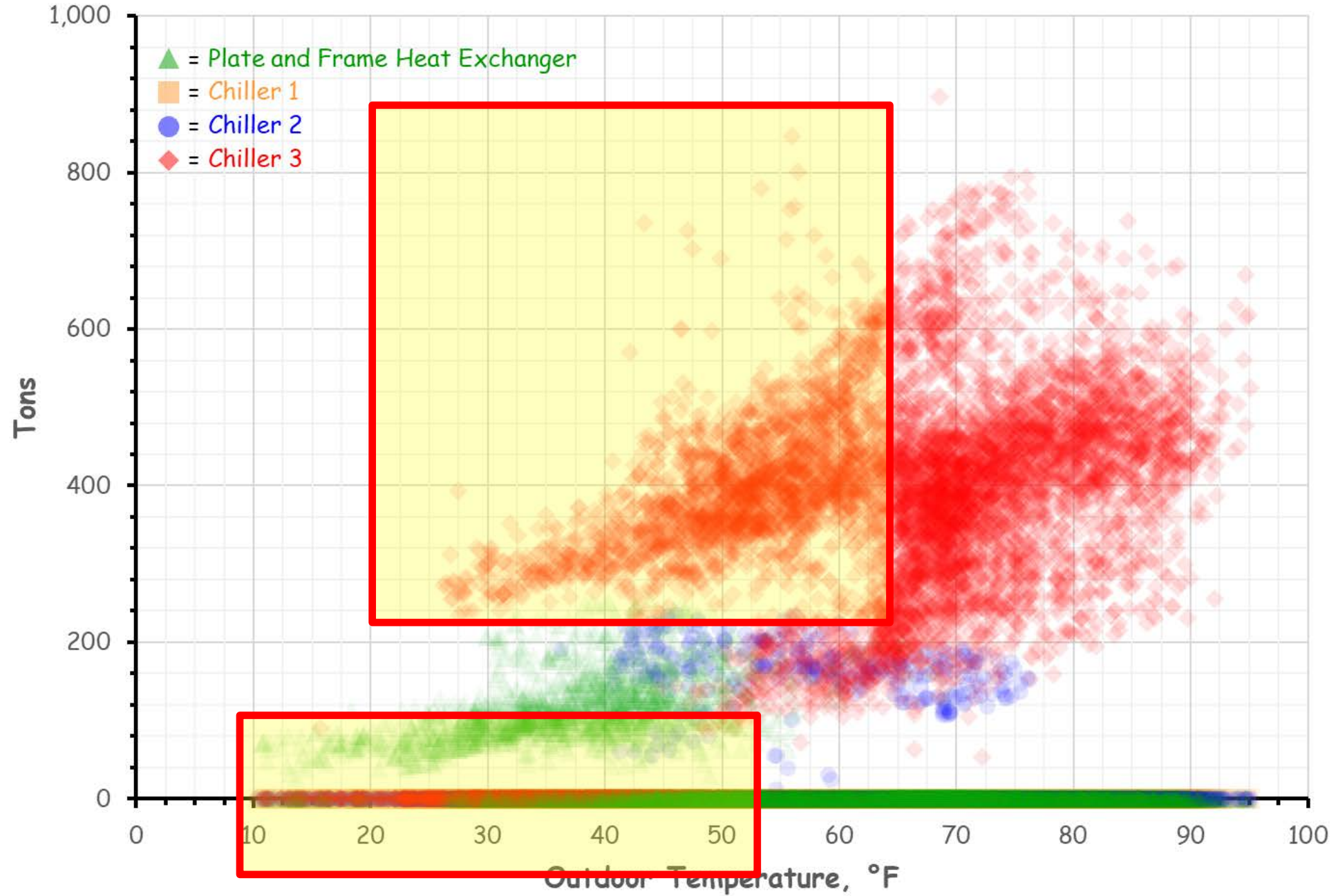


I'm Currently Dialoging with the Atlanta Airport Marriott

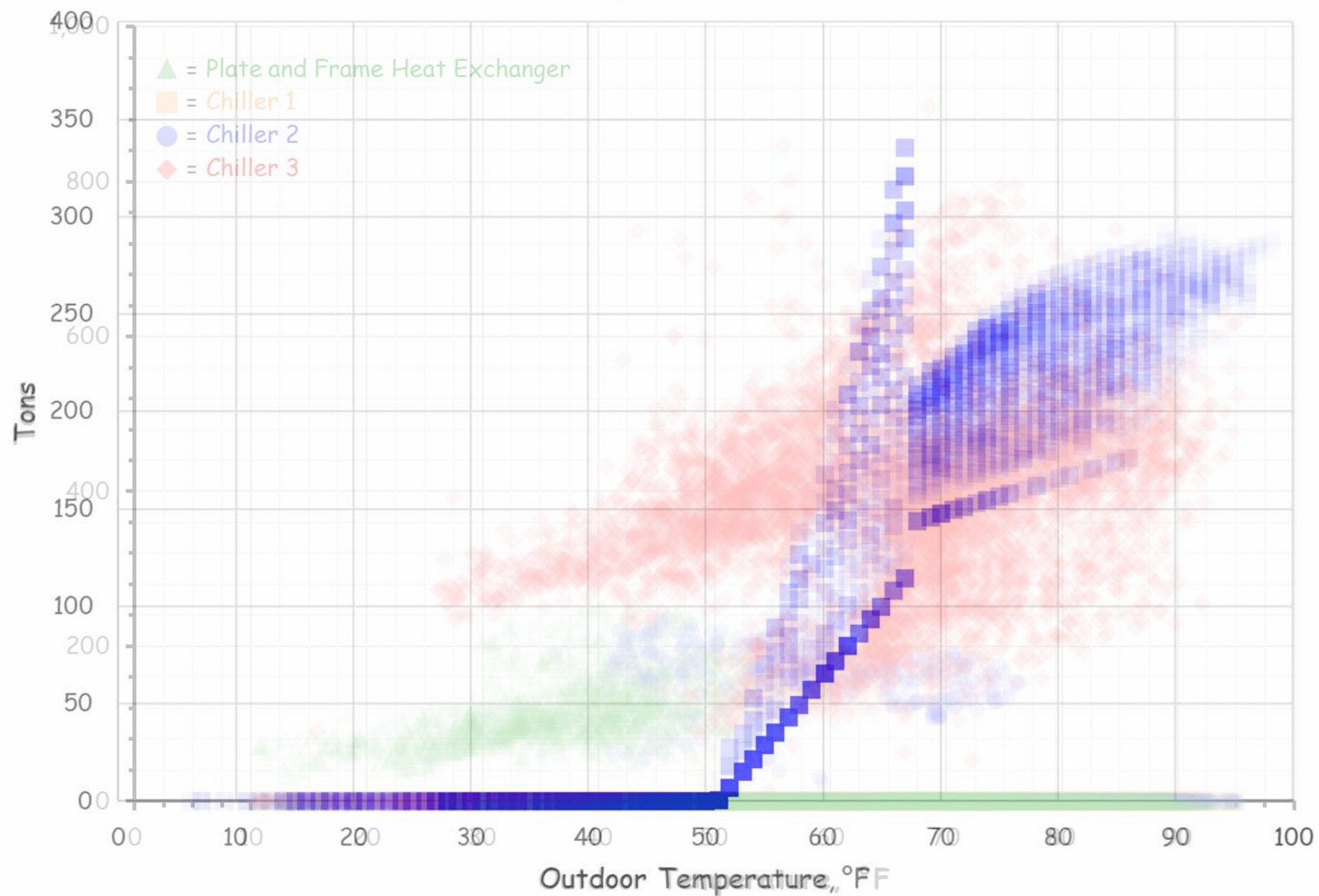
I've already started the discussion and am learning some pretty interesting things



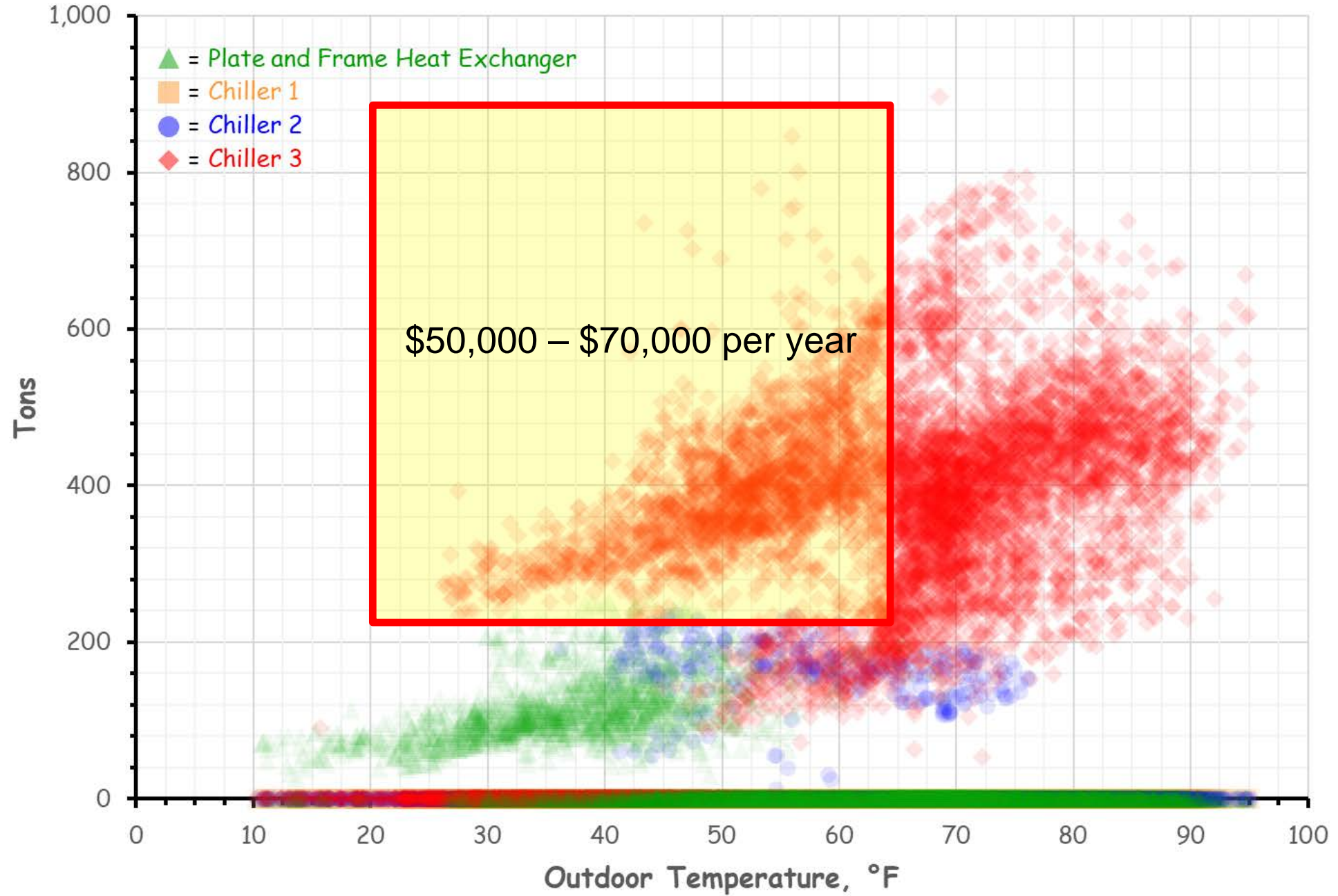
Tons vs. OAT Per Chiller



Tons vs. OAT Per Chiller



Tons vs. OAT Per Chiller



Bottom line

Com·mis·sion

kə'miSHən/Submit

Verb; Gerund or present participle:
Commissioning

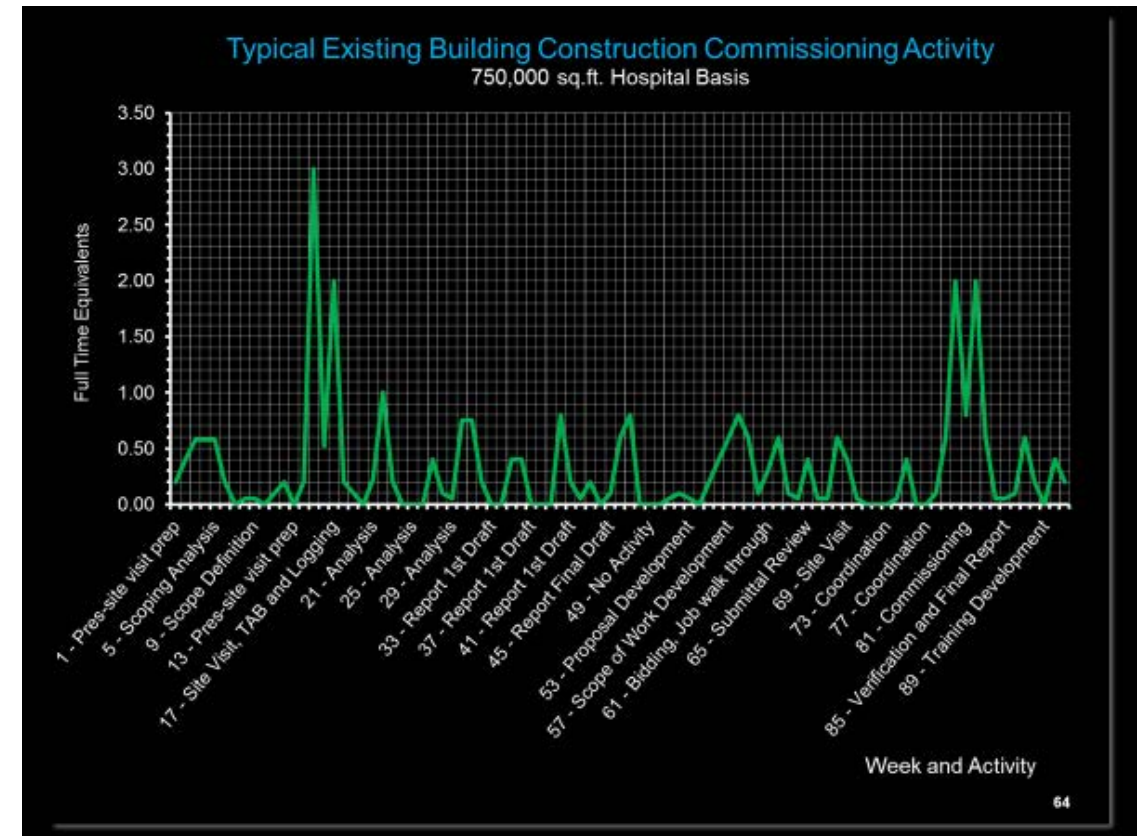
1. A process during which buildings are mentoring us about design



The 10 Key Skills and the EBCx Process

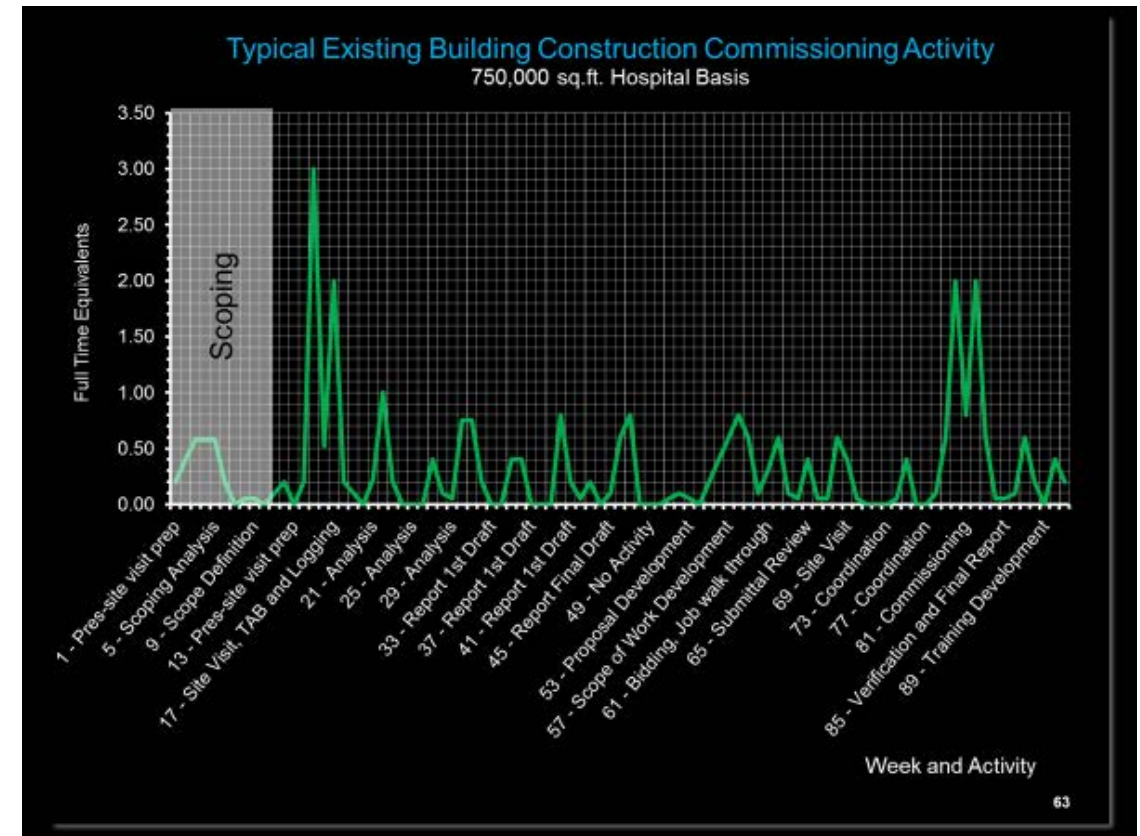


How the Skills Map to the Process



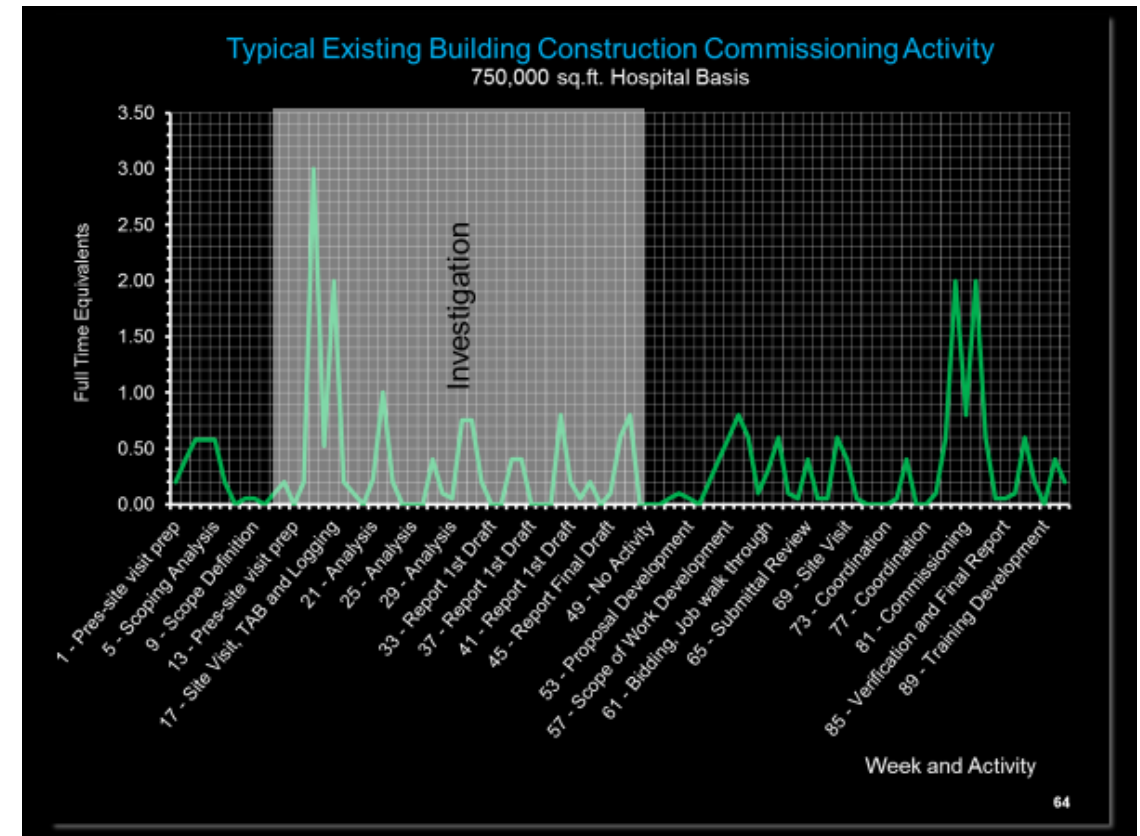
How the Skills Map to the Process

1. Scoping



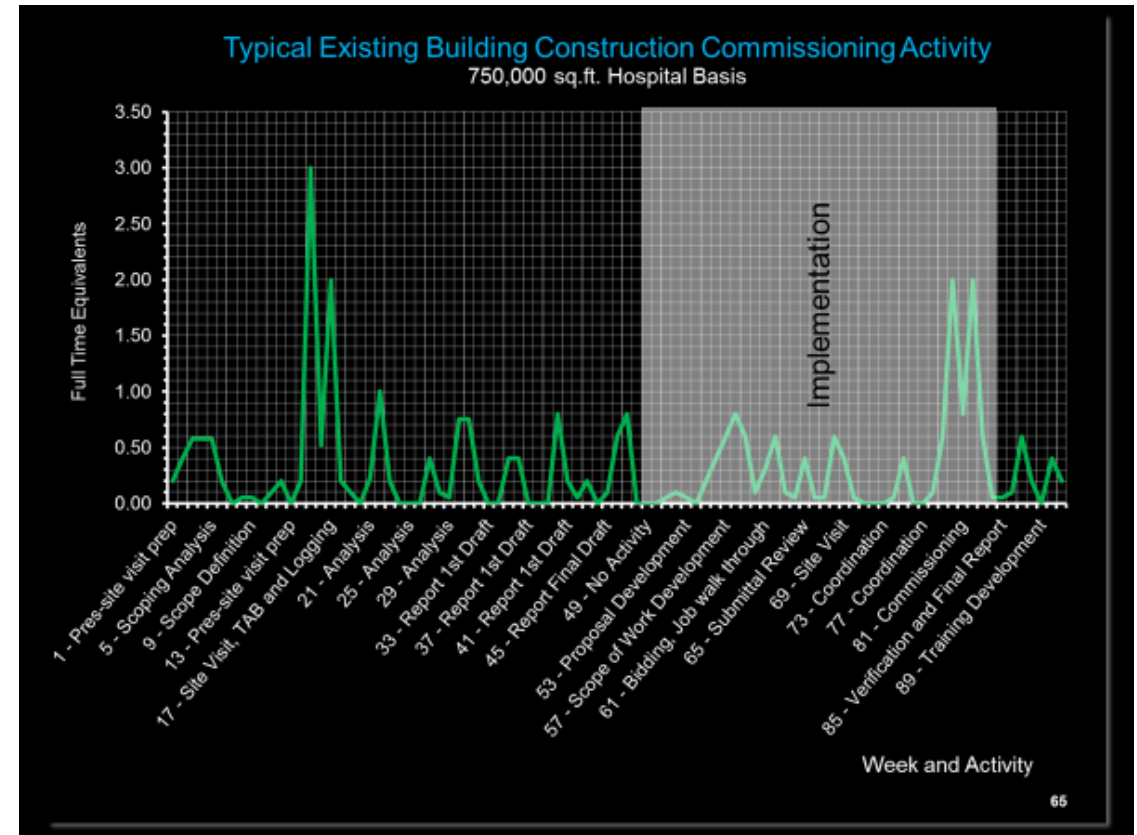
How the Skills Map to the Process

1. Scoping
2. Investigation



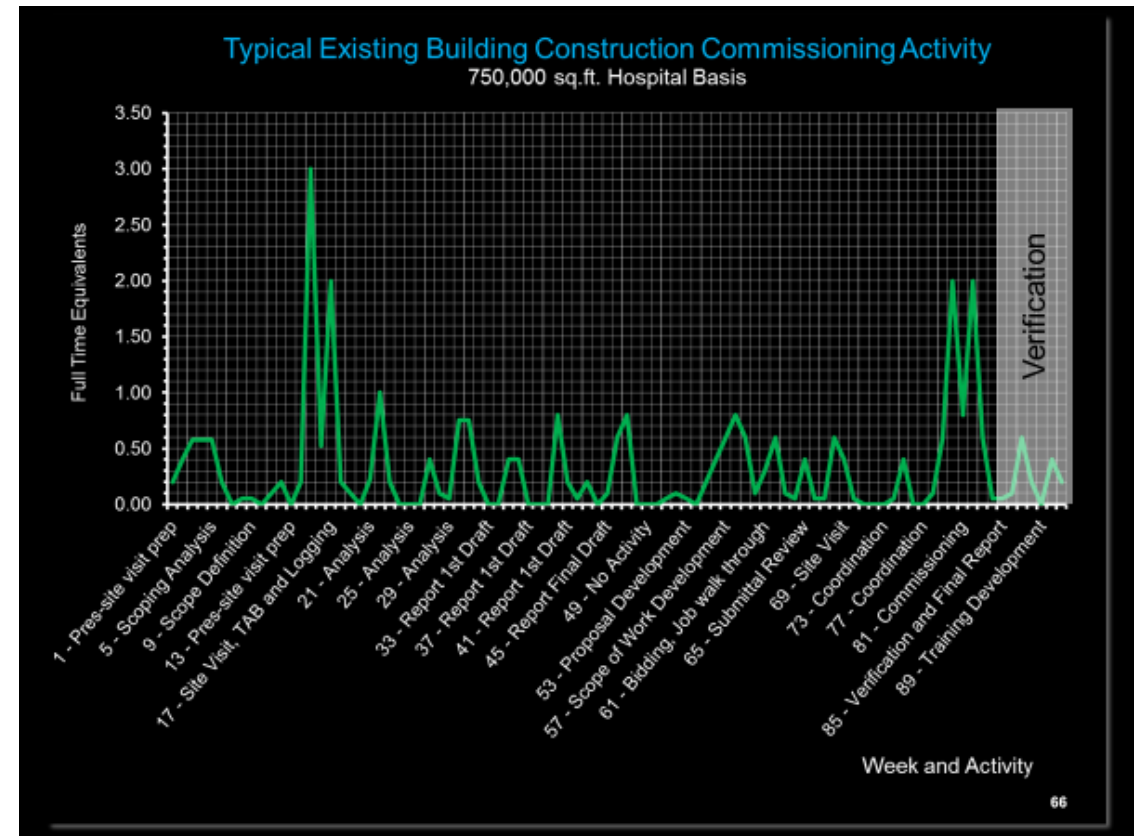
How the Skills Map to the Process

1. Scoping
2. Investigation
3. Implementation



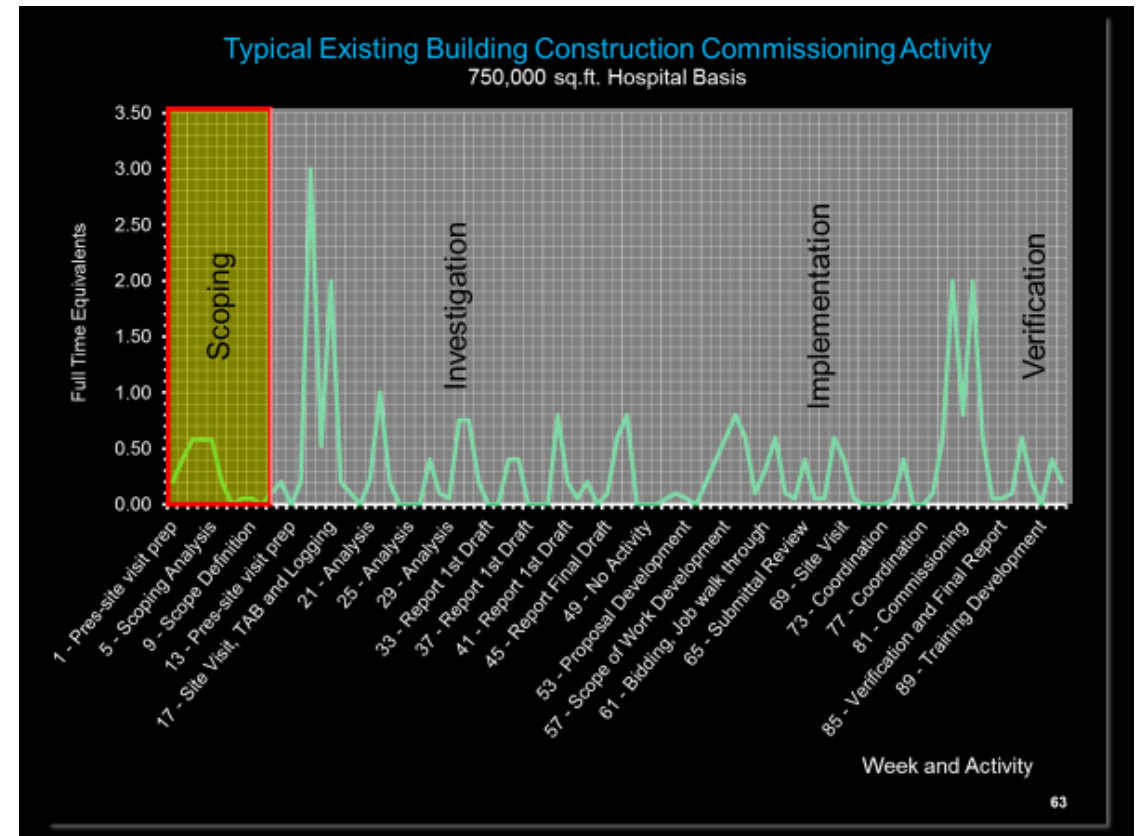
How the Skills Map to the Process

1. Scoping
2. Investigation
3. Implementation
4. Verification



Scoping

- Looking at the big picture
- Finding opportunities
- “Following your nose”
- Framing up the project



Scoping

- Looking at the big picture
- Finding opportunities
- “Following your nose”
- Framing up the project

Associated Skills

Key EBCx Skills

- ✓ 1. Be able to benchmark and perform utility analysis
- ✓ 2. Be able to scope a facility for obvious indicators of opportunity
3. Be familiar with fundamental principles and building systems
4. Understand and apply the system concept
5. Be able to perform data logging and trend analysis
6. Be familiar with functional testing techniques
7. Be familiar with data analysis techniques
8. Be familiar with basic HVAC and energy calculations
9. Be familiar with cost/benefit and return on investment calculations
10. Be familiar with implementation strategies and techniques

Scoping

- Looking at the big picture
- Finding opportunities
- “Following your nose”
- Framing up the project

Associated Skills

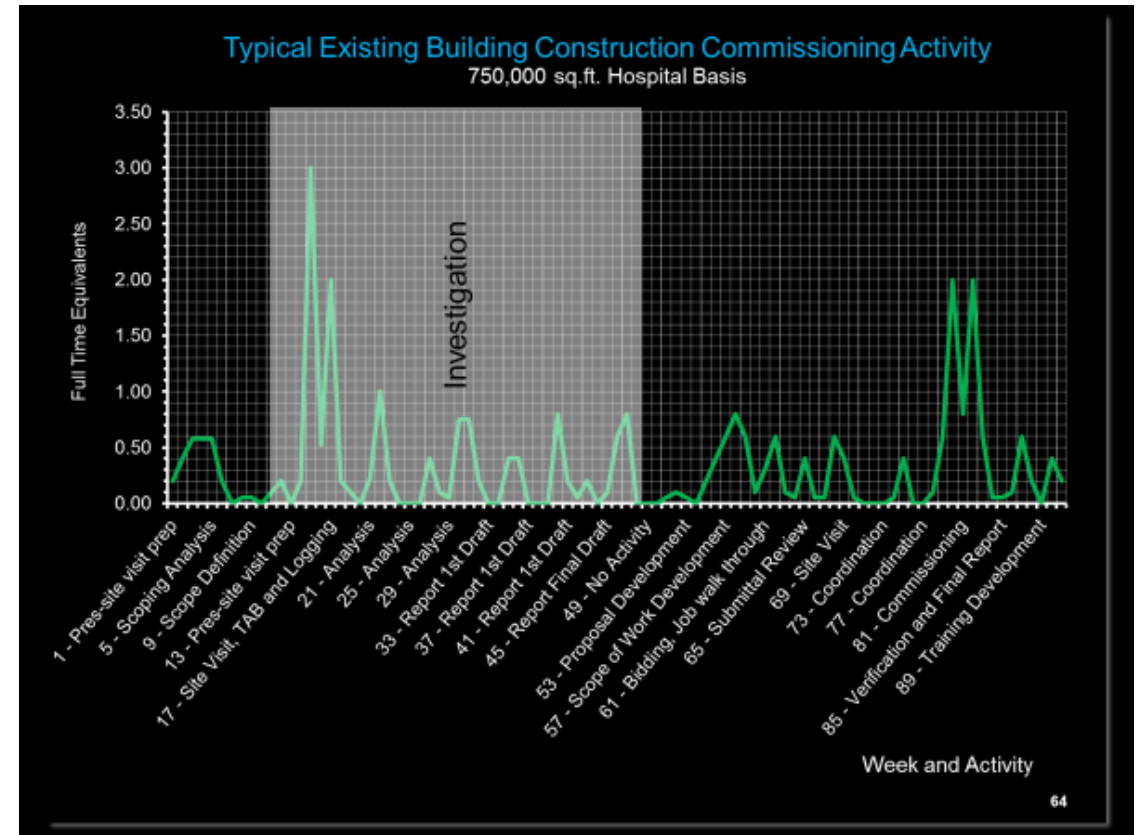
Bonus!

Key EBCx Skills

- | | |
|------------------------------------------------------------------------|------------------------------------------------------------------------|
| ✓ 1. Be able to benchmark and perform utility analysis | ✓ 6. Be familiar with functional testing techniques |
| ✓ 2. Be able to scope a facility for obvious indicators of opportunity | 7. Be familiar with data analysis techniques |
| ✓ 3. Be familiar with fundamental principles and building systems | 8. Be familiar with basic HVAC and energy calculations |
| ✓ 4. Understand and apply the system concept | 9. Be familiar with cost/benefit and return on investment calculations |
| ✓ 5. Be able to perform data logging and trend analysis | 10. Be familiar with implementation strategies and techniques |

Investigation

- Narrowing the focus
- Firming up what your “nose” told you
- Putting numbers to the opportunities
- Firming up the project



Investigation

- Narrowing the focus
- Firming up what your “nose” told you
- Putting numbers to the opportunities
- Firming up the project

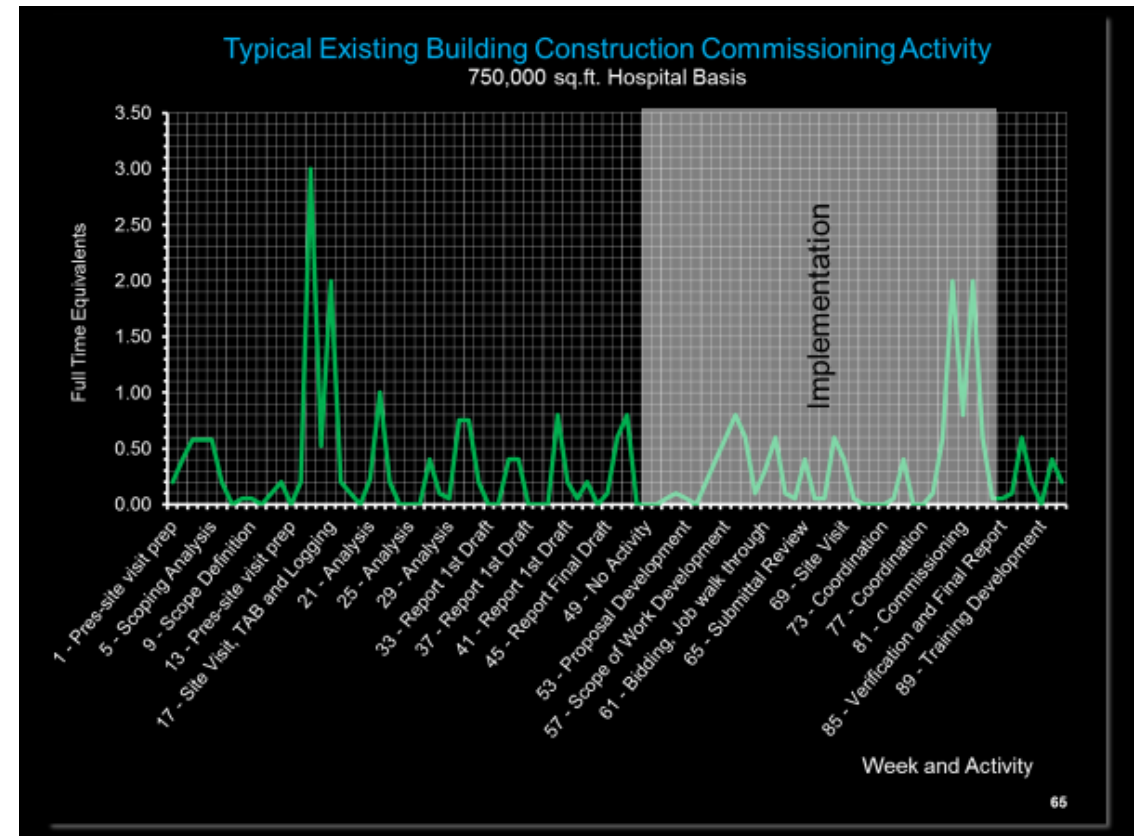
Associated Skills

Key EBCx Skills

1. Be able to benchmark and perform utility analysis ✓
2. Be able to scope a facility for obvious indicators of opportunity
- ✓ 3. Be familiar with fundamental principles and building systems
- ✓ 4. Understand and apply the system concept
- ✓ 5. Be able to perform data logging and trend analysis
6. Be familiar with functional testing techniques ✓
- ✓ 7. Be familiar with data analysis techniques
- ✓ 8. Be familiar with basic HVAC and energy calculations
- ✓ 9. Be familiar with cost/benefit and return on investment calculations
10. Be familiar with implementation strategies and techniques

Implementation

- Moving from concept to reality
- Frequently low cost – no cost measures
- Sometimes capital projects with very good ROIs (Return on Investment or Payback)



Implementation

- Moving from concept to reality
- Frequently low cost – no cost measures
- Sometimes capital projects with very good ROIs (Return on Investment or Payback)

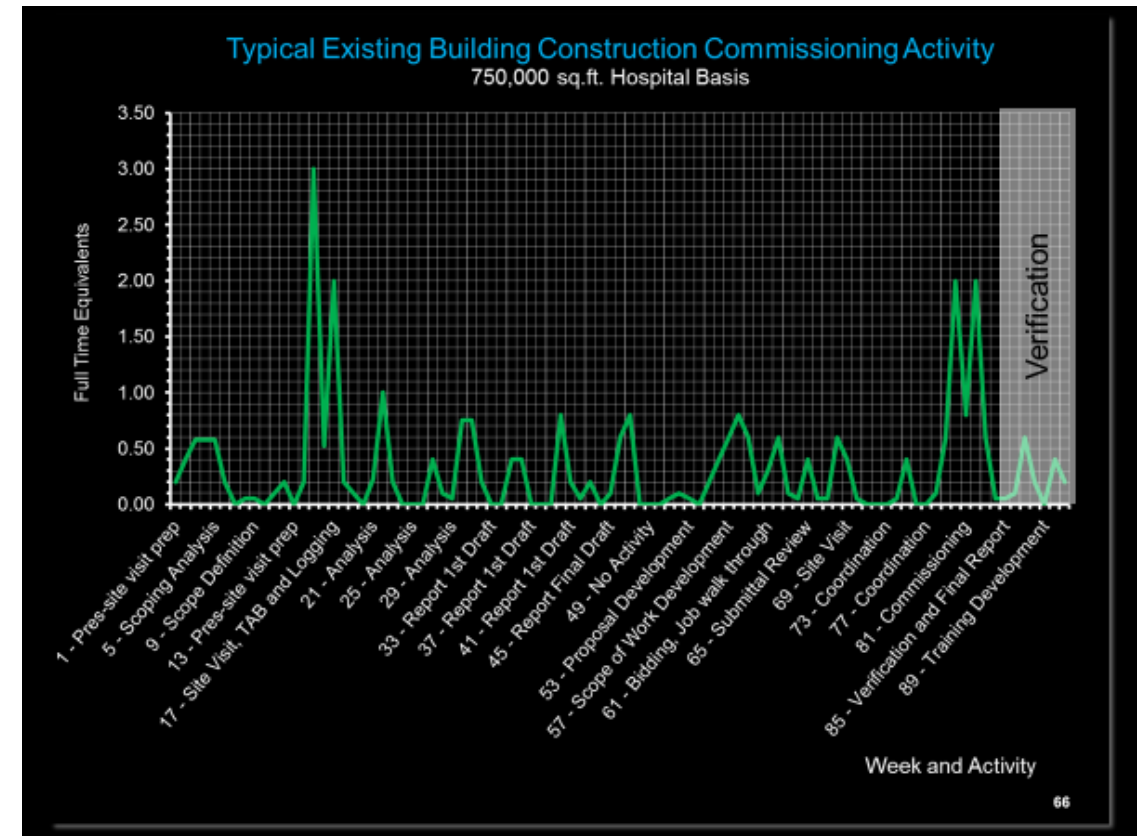
Associated Skills

Key EBCx Skills

1. Be able to benchmark and perform utility analysis ✓
2. Be able to scope a facility for obvious indicators of opportunity
- ✓ 3. Be familiar with fundamental principles and building systems
- ✓ 4. Understand and apply the system concept
5. Be able to perform data logging and trend analysis
6. Be familiar with functional testing techniques
7. Be familiar with data analysis techniques
8. Be familiar with basic HVAC and energy calculations
9. Be familiar with cost/benefit and return on investment calculations
- ✓ 10. Be familiar with implementation strategies and techniques

Verification

- Making sure your idea delivers
- Essentially, a mini new construction commissioning process



Verification

- Making sure your idea delivers
- Essentially, a mini new construction commissioning process

Associated Skills

Key EBCx Skills

- | | |
|----------------------------------------------------------------------|--------------------------------------------------------------------------|
| 1. Be able to benchmark and perform utility analysis ✓ | 6. Be familiar with functional testing techniques |
| 2. Be able to scope a facility for obvious indicators of opportunity | ✓ 7. Be familiar with data analysis techniques |
| ✓ 3. Be familiar with fundamental principles and building systems | ✓ 8. Be familiar with basic HVAC and energy calculations |
| ✓ 4. Understand and apply the system concept | ✓ 9. Be familiar with cost/benefit and return on investment calculations |
| ✓ 5. Be able to perform data logging and trend analysis | ✓ 10. Be familiar with implementation strategies and techniques |

Operator Training

The key to persistence of the benefits of commissioning



Empower Your Team



The Bigger Picture






Why This Matters

*We went to explore the Moon, and in fact
discovered the Earth*

Gene Cernan
Apollo 17 Commander

Why This Matters



*In a highway service station
Over the month of June
Was a photograph of the earth
Taken coming back from the moon
And you couldn't see a city
On that marbled bowling ball
Or a forest or a highway
Or me here least of all*

*Joni Mitchell
Refuge of the Roads*

Why This Matters

Interviewer:

What is your strongest memory of Apollo 11?

Michael Collins; Command Module Pilot, Apollo 11

Looking back at Earth from a great distance.

I really believe that if the political leaders of the world could see their planet from a distance of 100,000 miles their outlook could be fundamentally changed.

The earth must become as it appears: blue and white, not capitalist or Communist; blue and white, not rich or poor; blue and white, not envious or envied.

Small, shiny, serene, blue and white, FRAGILE.



Why This Matters

Interviewer:

That was 40 years ago. Would it look the same today?

Michael Collins; Command Module Pilot, Apollo 11

... It's certainly not serene, but definitely fragile, and growing more so. When we flew to the moon, our population was 3 billion; today it has more than doubled and is headed for 8 billion...

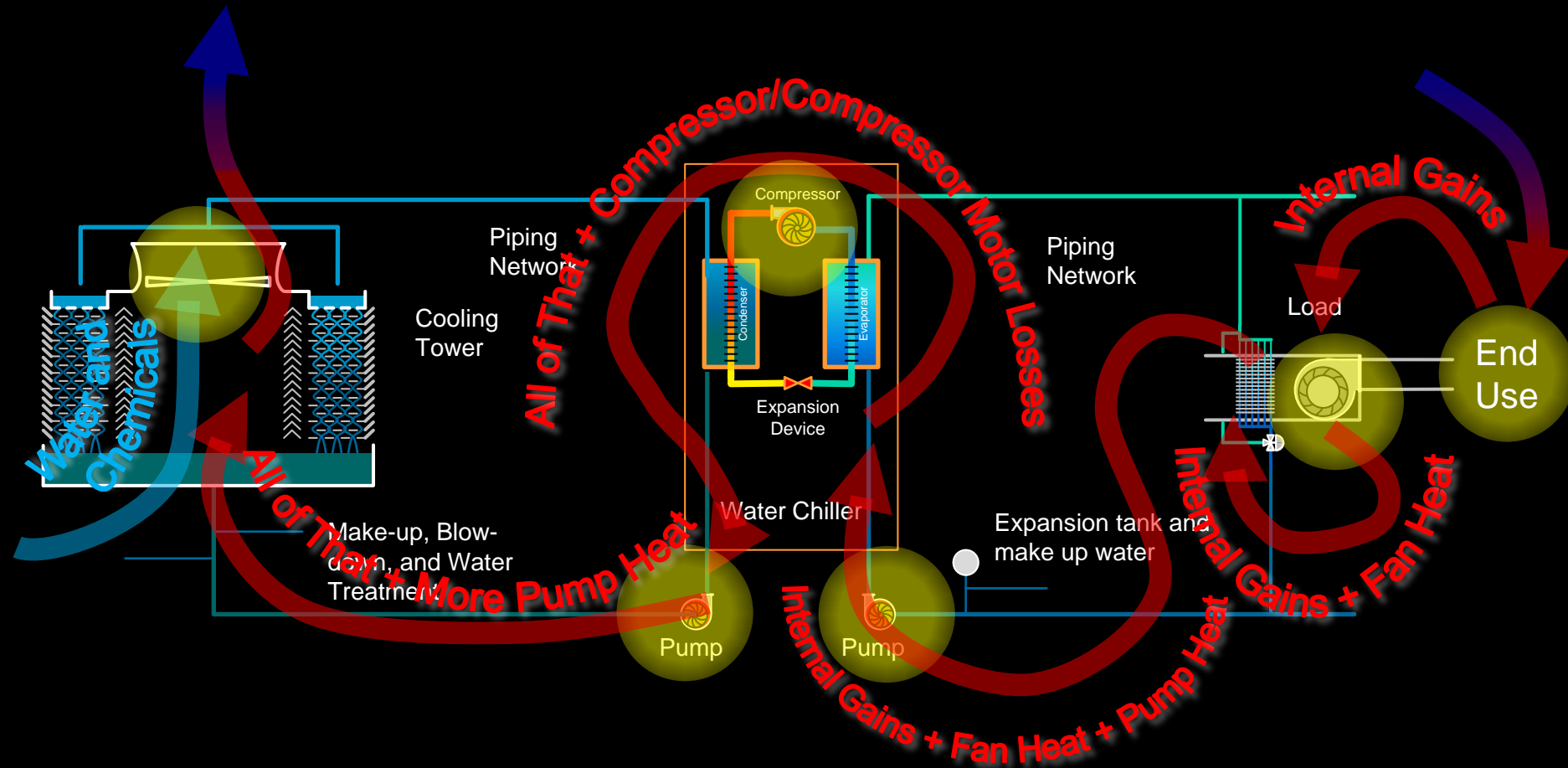
... The loss of habitat, the trashing of oceans, the accumulation of waste products - this is no way to treat a planet.

*We don't inherit the world from our ancestors,
we borrow it from our children*

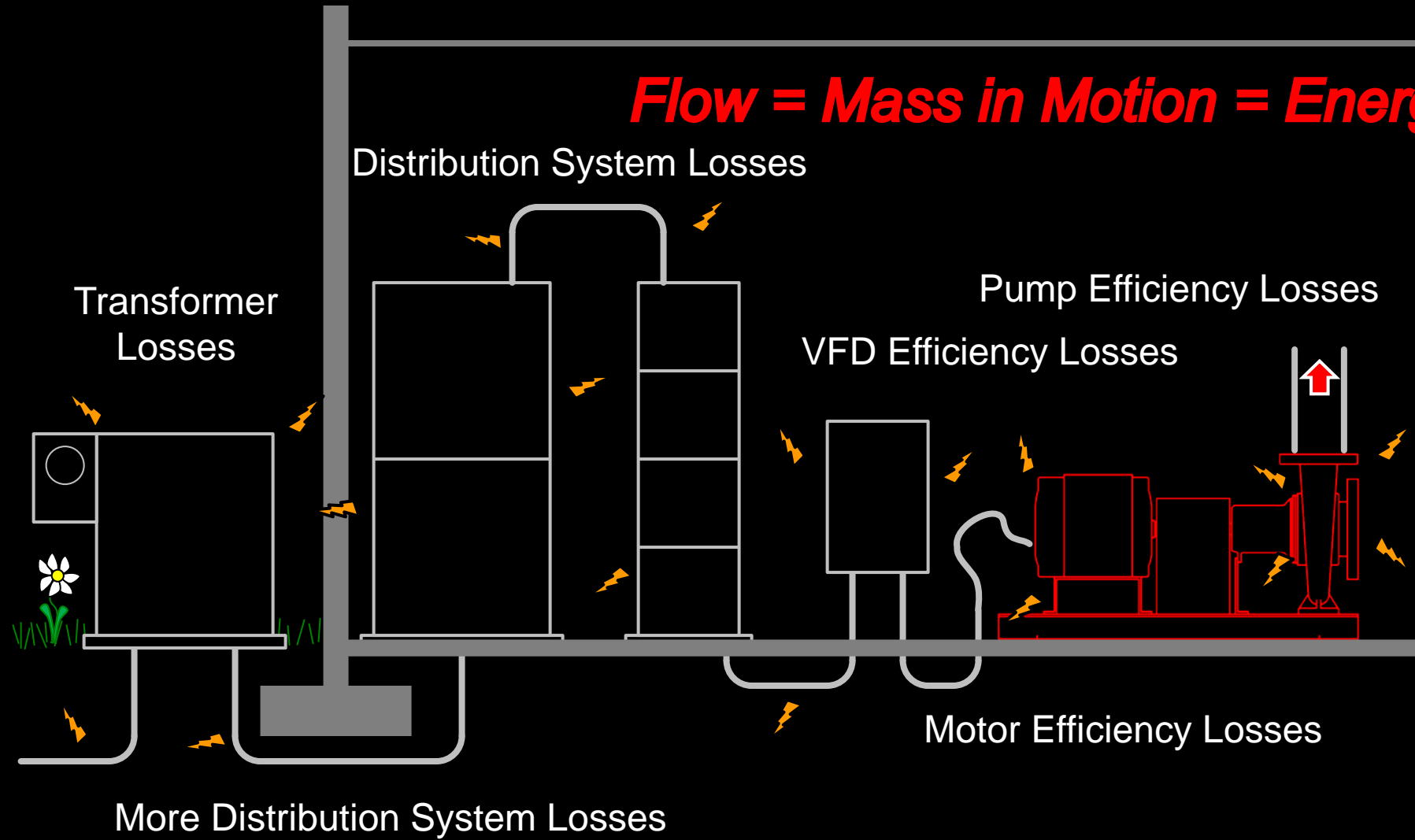
Unknown



Applying the Commissioning Tool Set can Have Ripple Effects



Flow = Mass in Motion = Energy



Transmission Losses are Significant



A coal fired Midwest power plant

Conversion losses are significant

The current average heat rate for fossil fuel fired plants is 10,000 Btus in for every 3,413 Btus out (1 kW)



Image Landsat / Copernicus

A coal fired Midwest power plant

Google Earth

Physical Principles Will Prevail

Conservation of mass and energy says that all of the mass in this pile of coal other than the fly ash will end up in the atmosphere



Image Landsat / Copernicus

A coal fired Midwest power plant

Google Earth

Bottom Line

Generating power consumes finite resources and impacts the environment



Reducing Atmospheric Impacts

We expect our energy mix to be 70% carbon free by 2040 based on current commitments and mandates, and we're working to deliver the right resources and technologies to make that happen.

Energy Strategy; www.portlandgeneral.com

Integrated Resource Planning

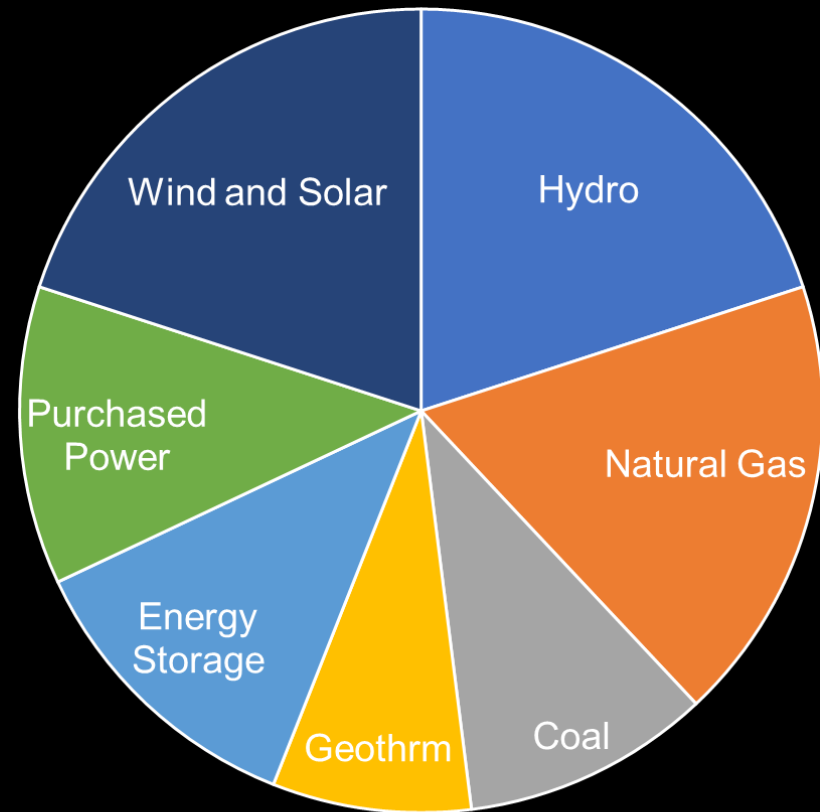
Preparing for Oregon's energy future



Reducing Atmospheric Impacts

Moving away from carbon fuels is common, long term goal for many utilities

XYZ Power Company Generating Mix

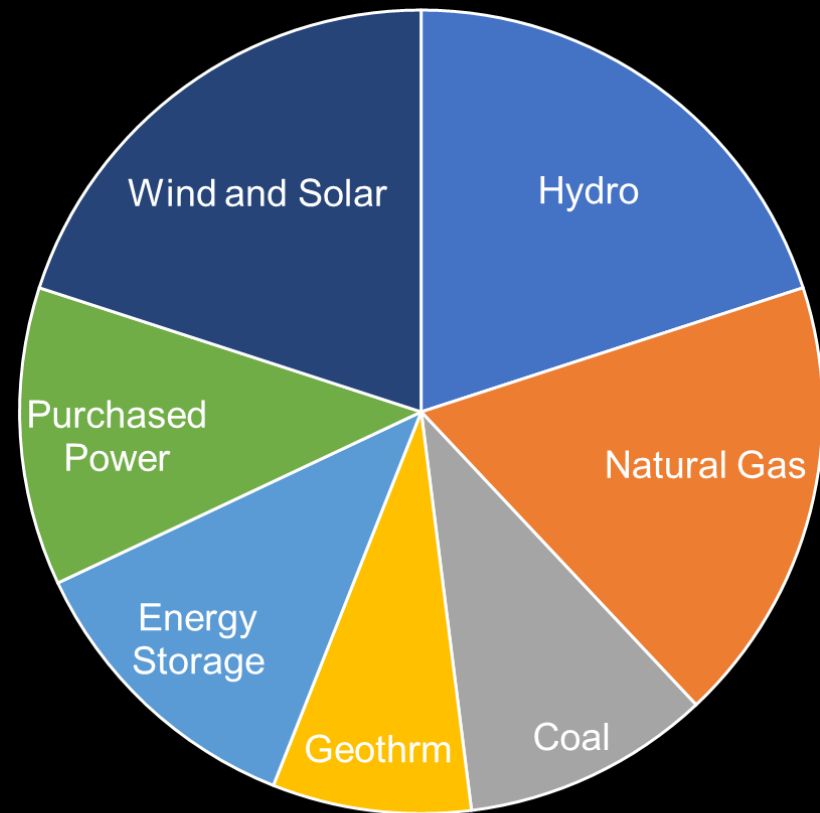


Reducing Atmospheric Impacts

Applying the commissioning tool set can have an immediate impact by reducing the need for energy in the first place

It's a win-win situation

XYZ Power Company Generating Mix



Start to Have Your Own Impact

Survey your facility for big energy users and poorly performing systems

- Read LBNLs report on the costs and benefits of commissioning at <http://cx.lbl.gov/cost-benefit.html>
- LBNL metrics indicate that the median savings from an EBCx process will be a significant portion of the annual energy cost

Building Commissioning:

A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions

Evan Mills, Ph.D.
Lawrence Berkeley National Laboratory
Berkeley, CA 94720 USA

Report Prepared for:
California Energy Commission
Public Interest Energy Research (PIER)

July 21, 2009

For a downloadable version of the report and supplementary information, visit:
<http://cx.lbl.gov/2009-assessment.html>

Sponsored by the California Energy Commission, Public Interest Energy Research Program, through the U.S. Department of Energy under Contract No. DE-AC02-05C1111231.

Bottom Lines

You can have a positive impact that is even bigger than you might have imagined

- Existing buildings are full of opportunities to save energy and other resources and improve performance
- The 10 Key RCx Skills can help you:
 - Identify the opportunities
 - Identify the savings potential they represent
 - Identify the steps required to capture the savings
 - Verify that the savings have been achieved
 - Ensure that the savings persist
 - Open the door to additional opportunity

Bottom Lines

You can have a positive impact that is even bigger than you might have imagined

- Existing buildings are full of opportunities to save energy and other resources and improve performance
- The 10 Key RCx Skills can help you:

Make the world a better place and have a good time doing it



One Last Poll

6. I can hardly wait to get started.

☐ True

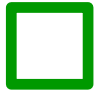
☐ False

One Last Poll

6. I can hardly wait to get started.



True



False