Monitoring-Based Commissioning
Success Stories from the Left Coast
April 17, 2012
Agenda

• Introduction
• What is MBCx?
• How is MBCx performed?
• Case Study – CSU Long Beach
• Q&A
Introduction & Definitions

• **Commissioning** “is a quality-oriented process for achieving, verifying and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria.” ¹
  
  "The basic purpose of building commissioning is to provide documented confirmation that building systems function in compliance with criteria set forth in the project contract documents to satisfy the owner’s operational needs”. ²

• **Retro-Commissioning** (RCx) “is a systematic method for investigating how and why an existing building’s systems are operated and maintained, and identifying ways to improve overall building performance.” ³

• **Monitoring-Based Commissioning** (MBCx) “is a program approach that combines permanent building-energy-system monitoring with standard retrocommissioning practices to provide substantial, persistent energy savings”⁴

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“Energy doesn’t call in the middle of the night and tell you that it’s getting wasted.”

Chris Powell
Director of Sustainable Energy Initiatives
Brown University
Commissioning projects have varying impacts on building performance at different stages of the building lifecycle.

The graph shows the percentage of energy wasted over time for different commissioning strategies:
- **New Building Cx**
- **RCx**
- **MBCx**
- **No Commissioning**

The graph indicates that MBCx results in the lowest percentage of energy wasted compared to the other strategies, with a significant reduction in energy waste after 8 years.

Source: Lawrence Berkeley National Lab, Benchmarking Analysis of Monitoring-Based Commissioning
What is UC-CSU-IOU MBCx?

- The University of California (UC), California State University (CSU), and Investor-Owned Utility (IOU) Energy Efficiency Partnership is a unique, statewide energy efficiency program achieving cost-effective immediate and persistent peak energy and demand savings.

- MBCx is a highly replicable process for improving and optimizing building performance.
  - This process can be replicated at other campuses outside of California!

- Incentives for kWh and Therm savings found during the process
  - $0.24 / kWh
  - $1 / therm
What is UC-CSU-IOU MBCx?

MBCx Partnership

Campus Facility Staff
• Mechanical Expertise

Utility & Consultants
• Energy Expertise

Energy Monitoring & Software
MBCx Objectives

- Obtain **cost-effective energy savings** from implementing low cost measures and optimizing how the building’s energy using systems are operated and maintained

- Identify previously unrecognized inefficiencies in building and plant system operations

- **Measure and document** energy savings from resulting operational improvements

- Enhance building system performance and occupant comfort

- Facilitate **ongoing re-commissioning** of systems to ensure persistence of savings
MBCx Process

Planning: Introductions & Documentation
- Develop MBCx Plan
- Project Kick-Off Meeting & Site Survey
- Develop Measurement & Verification Plan

Pre-Investigation: Data Gathering
- Develop Pre-Project Baseline
- Collect Sample Trends
- Begin Findings Log

Investigation: Component & Systems Testing
- Pre-Functional Testing
- Functional Performance Testing
- BMS Trend Review

Implementation: Addressing Issues
- Complete Equipment Repairs
- Program Controls Sequences
- Verify Successful Completion

Handoff: Ongoing Maintenance
- Develop Post-Project Baseline
- Conduct Systems Training
- Verify Persistence of Savings
Pre-Investigation Phase

- Baseline Energy Performance
  - Used to judge the performance of the energy project
  - Developed pre-project and updated post-project
  - Regression of energy consumption on weather and occupancy

Pre-Investigation Phase

• Baseline Energy Performance
  - Used to judge the performance of the energy project
  - Developed pre-project and updated post-project
  - Regression of energy consumption on weather and occupancy

Different hours of occupancy for each day of the week!
Investigation Phase Overview

- The investigation phase is largely focused on a methodical, two-step process to ensure the systems are operated according to the sequences of operation.

- **Component (Pre-Functional) Testing**
  - To ensure that the individual components are performing their desired function.
  - Typical component tests include:
    - Sensor Calibration
    - Point-to-Point Tests
    - Alarm Tests

- **System (Functional Performance) Testing**
  - To ensure that the individual components work together according to the sequences of operation.
  - System testing is accomplished through **field testing** and **trend review** of data acquired through the building management system.
Investigation Phase

- **Pre-Functional Tests**
  - Performed to ensure that the individual components are performing their desired function.
  - The typical test involves recording what the building management system (BMS) states as the component status, and comparing that to the observed value in the field.
  - Ultimately, building operators need to be able to trust the values on the BMS!

  - **Temperature Sensors**
    - Observe the BMS value for each temperature sensor.
    - Measure the actual temperature with a calibrated thermometer, and compare to the value reported by the BMS.

  - **Dampers**
    - Command the damper to fully open or fully closed.
    - Observe the damper in the field – does the damper position match that reported by the BMS?

  - **Valves**
    - Command the valve actuator to fully open or fully closed.
    - Observe the valve actuator in the field. Does the position match that reported by the BMS?

  - **VFDs**
    - Command the VFD to a specified speed, and record the VFD speed reported by the BMS.
    - Observe the actual VFD speed on the unit display in the field. Does it match?
### Investigation Phase – Issues Log

- Allows building staff to track status of issue identification and implementation
- Facilitates communication between consultants and campus
  - Identification Notes (by whom, what, where, when)
  - Recommended Course of Action
  - Responsible Party
  - Status
  - Resolution & Verification
- All pre-functional issues should be verified resolved before initiating functional performance testing!

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Equip. Name / Tag</th>
<th>Issue Description</th>
<th>Date Identified</th>
<th>Identified by Whom (Initials)</th>
<th>Phase Identified</th>
<th>Measure Type</th>
<th>Priority</th>
<th>Assigned to Whom</th>
<th>Target Action Date</th>
<th>Current Status</th>
<th>Current Status Date</th>
<th>Open / Closed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All AHUs</td>
<td>Alarms are not programmed for command/status mismatch conditions on AHU fans for this building.</td>
<td>8/27/10</td>
<td>TSP</td>
<td>PF Test</td>
<td>Programming</td>
<td>High</td>
<td>Campus</td>
<td>12/17/10</td>
<td>Identified</td>
<td>8/27/10</td>
<td>Open</td>
</tr>
<tr>
<td>2</td>
<td>AHU-1</td>
<td>Leak at condensate drain connection.</td>
<td>8/27/10</td>
<td>TSP</td>
<td>Pre-Investigation</td>
<td>Repair leak.</td>
<td>O&amp;M</td>
<td>Medium Campus</td>
<td>12/17/10</td>
<td>Identified</td>
<td>8/27/10</td>
<td>Closed</td>
</tr>
<tr>
<td>3</td>
<td>AHU-1</td>
<td>Minimum fan speed of 17 Hz attained when commanded to 25%.</td>
<td>8/27/10</td>
<td>TSP</td>
<td>PF Test</td>
<td>Programming</td>
<td>High</td>
<td>Campus</td>
<td>12/17/10</td>
<td>Identified</td>
<td>8/27/10</td>
<td>Closed</td>
</tr>
<tr>
<td>4</td>
<td>AHU-1</td>
<td>Supply air temperature sensor out of calibration - 60°F value displayed on EMS front end, 65°F measured in field.</td>
<td>8/27/10</td>
<td>TSP</td>
<td>PF Test</td>
<td>Programming</td>
<td>High</td>
<td>Campus</td>
<td>12/17/10</td>
<td>Identified</td>
<td>8/27/10</td>
<td>Closed</td>
</tr>
</tbody>
</table>
Investigation Phase

- **Functional Performance Testing**
  - Designed to ensure that the individual components of a building system work together according to the sequences of operation.
  - The general goal of functional testing is to observe how the system responds to different stimuli. This can be accomplished two ways:
    - **Field Testing** – *simulating* different operating conditions, by overriding sensors or setpoints.
    - **Trend Review Testing** – observing performance during *typical operation*, over a period of two weeks or longer.

- Performing relevant functional tests relies on having well-documented sequences of operation!
FPT Field Testing

1. **Observe** – Document the “as found” conditions of the unit. Record all parameters that are relevant to the control of the system (sensor inputs, setpoints, and control outputs).

2. **Override** – Change *one* parameter to force the system to react. This can usually be achieved by changing a setpoint, but sometimes requires overriding a sensed valued.

3. **Wait** – Building systems are slow to act! Give the system enough time to respond before judging its performance.

4. **Record** – Document the same parameters as in step 1, after the unit has responded to the change made in step 2.

5. **Conclude** – Did the system satisfactorily complete the test?
“When the outside air temperature is lower than the return air temperature, modulate the economizer outside air and return air dampers as required to maintain space temperature setpoint. When the return air temperature is lower than the outside air temperature the economizer dampers shall be positioned to the minimum outside air position.”

Do these trends reflect the equipment being operated according to design?
Ongoing Performance Analysis

Energy Efficiency Measure Overview

- **No Cost**: $48,534
- **Low Cost**: $16,006
- **Cap Ex**: $5,520

Total Savings Identified: $70,059 (113.92% of Total Savings Target)
Total Savings Accepted: $53,746 (87.39% of Total Savings Target)

Total Savings Target: $61,500

Savings Progress

- $16,313 Under Review per year
- $3,465 In Progress per year
- $50,281 Implemented per year

- 154,857 Under Review kWh per year
- 2,484 In Progress kWh per year
- 468,045 Implemented kWh per year

- 58 Under Review Therms per year
- 2,449 In Progress Therms per year
- 3,332 Implemented Therms per year

- 111 Under Review tons of CO₂ per year
- 2 In Progress tons of CO₂ per year
- 338 Implemented tons of CO₂ per year
Case Study – CSU Long Beach

- **Campus Overview**
  - 33,000 Students, 3600 Faculty & Staff
  - 322 Acres
  - 80 Buildings, including specialized facilities
    - Engineering
    - Physical Sciences
    - Music

- **Campus Sustainability**
  - Physical Planning & Facilities Management
    - Energy Efficiency & GHG Reduction
    - Renewable & Clean Energy
    - Recycling
    - Water Conservation
    - Custodial Services
  - Sustainability & Energy Goals
Case Study – CSU Long Beach

- Project Overview
  - 5 Buildings:
    - Engineering & Computer Science
    - Horn Center (Library & Computing)
    - University Music Center
    - Academic Services
    - Molecular & Life Sciences Center
  - Baseline Energy Usage (Approx):
    - 5,000 MWh / year
    - 110,000 therms / year
Case Study – CSU Long Beach

• Project Highlights
  - Installation of sub-metering
    ▪ Electricity
    ▪ Chilled Water
    ▪ Hot Water
  - Energy Performance Baselines
  - Identified Low Cost ECMs
  - Identified Operational Improvements
  - Performance Scorecards
Case Study – CSU Long Beach

Pre-Functional Testing Findings

- Malfunctioning Economizer Dampers
- Static Pressure Sensor Failure
- Failed VFD
- Hot Water Valve Failed
Case Study – CSU Long Beach

Functional Testing Findings

- Leaking Chilled Water Valves
- Low Chilled Water $\Delta T$
- Fans Running in 24/7 Operation
- AHUs Maintaining Constant Supply Air Temperature