Get It Right the First Time
A Case Study on Monitoring-based Commissioning for Lab Construction

Presented by B2Q Associates, Inc.
Chris Schmidt & Sam Deptula

A Woman Business Enterprise (WBE)

UMass Amherst
Physical Sciences Building
Learning Objectives

• Understand the limitations and risks that exist with “conventional” new construction commissioning

• Understand the capabilities of modern Monitoring-based Commissioning (MBCx) software and how it can be leveraged for new construction laboratory commissioning

• Discover why MBCx software is so effective during the project turnover phase

• Learn the benefits and impacts to different stakeholders of adding MBCx software to a new construction commissioning program
New Construction Commissioning

Commissioning is a continuous process that, when executed properly, helps ensure that building equipment, systems, and envelope perform as intended by the design team and meet the needs of the Owner, occupants, and facilities maintenance staff.

- Long Term Performance
- Occupant Safety & Comfort
- Meets Owner Requirements
- Complete Documentation
- Energy Efficiency
- Reliable Operation
- Staff Training

GET IT RIGHT THE FIRST TIME - A CASE STUDY ON MONITORING-BASED COMMISSIONING FOR LAB CONSTRUCTION

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Commissioning & Project Turnover

- Turnover is the systematic transition from construction to occupancy & use
- Physical completion of construction & transfer of knowledge
- Owner formally assumes the responsibilities of operation and maintenance
- Cx & Turnover process continues post-occupancy to complete all punch list items, perform seasonal commissioning, and hold close-out meetings
The Reality of Building Turnover

• Commissioning ends with Cx report and ‘final’ punch list submission
• Seasonal trend log reviews and end of warranty reviews don’t happen or are not comprehensive
• This phase does not receive the necessary level of focus, oversight, and commitment
Why is Commissioning Not Successful?

- Vague or incomplete specifications
- Limited scope, insufficient budget allocation, or “low bid” for commissioning
- Weak or inadequate functional performance tests
- Ineffective communication, lack of leadership, or accountability
- Constrained or accelerated schedules, especially at the end of construction

**Turnover & Warranty Phase Trend Log Review Cost Example**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Floor Area</td>
<td>90,000 ft²</td>
</tr>
<tr>
<td>HVAC Equipment Quantity</td>
<td>350 AHUs, Terminal Devices, Fume Hoods, Zones, HXs, etc.</td>
</tr>
<tr>
<td>Sample Rate</td>
<td>100%</td>
</tr>
<tr>
<td>Trend Log Review &amp; Reporting Hours</td>
<td>0.5 hours each, average</td>
</tr>
<tr>
<td>Quantity Trend Log Reviews</td>
<td>3 Initial + 2 additional seasons</td>
</tr>
<tr>
<td>Total Hours</td>
<td>525 hours, total</td>
</tr>
<tr>
<td>Labor rate</td>
<td>$150/hour</td>
</tr>
<tr>
<td>Initial &amp; Seasonal Trend Log Review Cost</td>
<td>$78,750</td>
</tr>
<tr>
<td>Cost per Square Foot</td>
<td>$0.88/ft²</td>
</tr>
</tbody>
</table>
Impacts of Incomplete Commissioning

- Lost Opportunities for Warranty Coverage
- Potential Safety Risks
- Occupant Complaints: Temp, Odor, Noise
- Excess Energy Cost
- ...Re-Commission Building?
Monitoring-Based Commissioning (MBCx)

Data Aggregation

Web-based & Mobile Visualization Platform

Fault Detection, Diagnostics, Causal Analysis

Energy Management & Benchmarking

Fault Prioritization, Alerts, Reporting

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The Value of MBCx in New Construction Cx

MBCx provides an opportunity to build a more successful Cx program

1. Continuous analysis of equipment and system performance, efficiency, comfort, and safety during the warranty period (and beyond)
2. All systems and equipment are monitored. No sampling.
3. Uncovers issues not caught by even well written functional performance tests and assigns priority with avoidable costs
4. Alerts construction team and Cx agent to new issues immediately or on-demand
5. Transparency and accountability; Entire project team has access to system. Findings provide supporting evidence to go after warranty issues.
Case Study: UMass Amherst
Physical Sciences Building

- 90,000 GSF
- 20 faculty-led research groups
- 3 make-up air units with heat recovery
- 47 lab zones
- 90 fume hoods
- Initial occupancy in spring 2018
- Warranty period through May 2019
- LEED Gold Certified
Case Study: UMass Amherst
MBCx Deployed 4 Months After Occupancy
Case Study: UMass Amherst
Equipment Monitored

- All airside HVAC equipment including air handlers, terminal devices, hoods, and lab controls
- Chilled and hot water loops, pumps, domestic hot water
- Electrical sub-meters

<table>
<thead>
<tr>
<th>Equipment Types</th>
<th>Quantity</th>
<th>Quantity Analytics, each</th>
<th>Total Analytic Instances</th>
</tr>
</thead>
<tbody>
<tr>
<td>UMass Amherst Physical Sciences Building (PSB)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Recovery Units</td>
<td>3</td>
<td>28</td>
<td>84</td>
</tr>
<tr>
<td>Lab Zones</td>
<td>48</td>
<td>4</td>
<td>192</td>
</tr>
<tr>
<td>General Exhaust Boxes</td>
<td>45</td>
<td>7</td>
<td>315</td>
</tr>
<tr>
<td>Supply VAV Boxes</td>
<td>133</td>
<td>15</td>
<td>1,995</td>
</tr>
<tr>
<td>Fume Hoods</td>
<td>90</td>
<td>12</td>
<td>1,080</td>
</tr>
<tr>
<td>Snorkel, Cabinet Exhaust</td>
<td>12</td>
<td>7</td>
<td>84</td>
</tr>
<tr>
<td>Zone Exhaust Fans</td>
<td>15</td>
<td>3</td>
<td>45</td>
</tr>
<tr>
<td>AC Units</td>
<td>7</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Hydronic Loops</td>
<td>4</td>
<td>15</td>
<td>60</td>
</tr>
<tr>
<td>Heat Exchangers</td>
<td>6</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Pumps</td>
<td>11</td>
<td>3</td>
<td>33</td>
</tr>
<tr>
<td>Electric Meters</td>
<td>11</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>385</strong></td>
<td><strong>96</strong></td>
<td><strong>3,901</strong></td>
</tr>
</tbody>
</table>
Case Study: UMass Amherst
MBCx Software Deployment Process

- Reviewed latest record drawings, TAB reports, Cx report including FPT results, control sequences of operation, building automation system graphics

- Mapped 10,600 building automation system points using MBCx software standardized naming convention

- Configured nearly 100 analytics to mine 385 systems and equipment for issues and opportunities
Case Study: UMass Amherst
Initial Results – 4 Weeks

Initial Results - 43 Unique Issues

• 10 of 47 labs (21%) with improper pressurization
• 6 Labs operating well above design min ACH
• Broken fume hood sash position sensors
• Widespread valve and damper hunting
• Broken communication between lab controllers and supervisory controllers – ‘flat lined’ points
• Inefficient ERU heat recovery control

Most classified as issues covered under warranty
Case Study: UMass Amherst
Valve and Damper Hunting

VAV Box Discharge Air Temperature 55-76°F
Every 10 Minutes

Air Handler Discharge Air Temperature Stable

VAV Reheat Coil Valve Position 0-50%
Case Study: UMass Amherst
Improper Lab Pressurization – Clean Room

Exhaust Flow: 775 cfm
Supply Flow: 625 cfm

Exhaust Flow: 1,000 cfm
Supply Flow: 1,050 cfm
Case Study: UMass Amherst
Improper Lab Pressurization – ‘High Hazard’ Chem Storage

Exhaust Flow: 1,175 cfm
Supply Flow: 1,400 cfm

Exhaust Flow: 1,175 cfm
Supply Flow: 1,075 cfm

225 CFM POSITIVE
100 CFM NEGATIVE

10/21/2019
Case Study: UMass Amherst
Failed Fume Hood Sash Sensor – High Lab ACH

Hood Air Valve at Maximum (800+ cfm)
Design Hood Min/Max = 190/490 cfm

Hood Sash SensorDisconnected

The air change rate is higher than necessary due to excess fume hood flow while at least one hood is above minimum and general exhaust flow is zero. The air change rate is 41.88 compared to the target of 16.40.
Case Study: UMass Amherst
Ineffective Energy Recovery Unit Heat Pipe Operation

Heat pipe OA bypass damper (green) not closing while preheat coil valve (red) open

OA bypass damper only closes when OAT < 33
Case Study: UMass Amherst
Ineffective Energy Recovery Unit Heat Pipe Operation

Heat pipe leaving air temperature (green) meeting set-point of 51°F

Preheat (yellow) and cooling (red) discharge air temps both 4-5°F lower than heat pipe temp with heating valve open
Case Study: UMass Amherst
Results at End of Warranty Period

10 Month MBCx Issues Log Summary – 97 Issues Total

- Warranty Issues Resolved to Date, 46, 48%
- Open Warranty Issues, 40, 41%
- Open Non-Warranty Issues & ECMs, 5, 5%
- Issues Resolved by UMA, 6, 6%
# Case Study: UMass Amherst

## Top Findings & Energy Cost Savings

### Top Findings with Energy Cost Savings at end of 10 Months

<table>
<thead>
<tr>
<th>Top Findings with Energy Savings</th>
<th>Annual Electric Savings</th>
<th>Annual CHW Savings</th>
<th>Annual Steam Savings</th>
<th>Annual Cost Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>#</td>
<td>kWh</td>
<td>ton-hrs</td>
<td>Mlbs</td>
<td>$</td>
</tr>
<tr>
<td>1 Resolve High Minimum ACH</td>
<td>44,754</td>
<td>10,815</td>
<td>463</td>
<td>$15,548</td>
</tr>
<tr>
<td>2 Improve ERU Heat Pipe Control</td>
<td>0</td>
<td>6,765</td>
<td>469</td>
<td>$9,957</td>
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<tr>
<td>3 Repair GEX Airflow Controls</td>
<td>24,528</td>
<td>2,964</td>
<td>228</td>
<td>$7,807</td>
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<tr>
<td>4 Replace Hood Sash Position Sensors</td>
<td>15,217</td>
<td>3,677</td>
<td>158</td>
<td>$5,287</td>
</tr>
<tr>
<td>5 Improve ERU Static Pressure Reset</td>
<td>25,405</td>
<td>0</td>
<td>0</td>
<td>$3,049</td>
</tr>
<tr>
<td>6 Improve CHW Loop dP Reset</td>
<td>5,752</td>
<td>0</td>
<td>0</td>
<td>$690</td>
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<tr>
<td><strong>Totals</strong></td>
<td><strong>115,656</strong></td>
<td><strong>24,221</strong></td>
<td><strong>1,318</strong></td>
<td><strong>$42,338</strong></td>
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</table>

October 21, 2019

*GET IT RIGHT THE FIRST TIME - A CASE STUDY ON MONITORING-BASED COMMISSIONING FOR LAB CONSTRUCTION*

*B2Q ASSOCIATES*
Case Study: UMass Amherst  
Summary of Benefits

Physical Plant / Facilities Maintenance
• Nearly 100 issues impacting energy use, long term equipment reliability, comfort, and safety identified. Over 50% resolved to date.
• Smoother, more transparent building turnover. Increased communication and collaboration.

Department of Construction Management (DCM)
• >90% of issues identified covered under equipment and installation warranty
• Improved communication and overall relationship with Physical Plant

Environmental Health & Safety
• Better understanding of and confidence in lab HVAC & controls performance, fume hood use/performance
• Potential risks to occupant safety flagged and resolved

LEED Measurement & Verification Team
• Access to equipment and metering trend logs, visualization and analysis tools for M&V
Case Study: UMass Amherst Lessons Learned & Future Plans

• Increase dialog between General Contractor, Commissioning Team, and MBCx Team
• Deploy and leverage MBCx earlier in the new construction commissioning process
• Integrate MBCx as part of commissioning specifications & standard Cx processes
• Continue using MBCx post-warranty to maintain benefits
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Case Study: UMass Amherst
EH&S Summary Views

### Calculated Lab Air Change Rate

<table>
<thead>
<tr>
<th>Name</th>
<th>Equipment</th>
<th>History</th>
<th>Value</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Derived Lab Air Change Rate</td>
<td>Z000 &gt; 182 Hydrogenation</td>
<td>42.461</td>
<td>High Lab ACH</td>
<td></td>
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<tr>
<td>Derived Lab Air Change Rate</td>
<td>Z000 &gt; 035 Chem Prep</td>
<td>15.116</td>
<td>Normal</td>
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<tr>
<td>Derived Lab Air Change Rate</td>
<td>Z000 &gt; 029 Chem Prep</td>
<td>15.077</td>
<td>Normal</td>
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<td>Derived Lab Air Change Rate</td>
<td>Z000 &gt; 240 Chem Lab</td>
<td>14.482</td>
<td>Normal</td>
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<tr>
<td>Derived Lab Air Change Rate</td>
<td>Z000 &gt; 140 Chem Lab</td>
<td>14.392</td>
<td>Normal</td>
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<tr>
<td>Derived Lab Air Change Rate</td>
<td>Z000 &gt; 130 Chem Lab</td>
<td>13.523</td>
<td>Normal</td>
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<tr>
<td>Derived Lab Air Change Rate</td>
<td>Z000 &gt; 032 High Bay Lab</td>
<td>12.311</td>
<td>Normal</td>
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<tr>
<td>Derived Lab Air Change Rate</td>
<td>Z000 &gt; 150 Chem Lab</td>
<td>11.073</td>
<td>Normal</td>
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<tr>
<td>Derived Lab Air Change Rate</td>
<td>Z000 &gt; 234 Support</td>
<td>10.683</td>
<td>Normal</td>
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<tr>
<td>Derived Lab Air Change Rate</td>
<td>Z000 &gt; 250 Chem Lab</td>
<td>10.519</td>
<td>Normal</td>
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<tr>
<td>Derived Lab Air Change Rate</td>
<td>Z000 &gt; 120 Storage</td>
<td>8.538</td>
<td>Normal</td>
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<tr>
<td>Derived Lab Air Change Rate</td>
<td>Z000 &gt; 072 High Bay Lab</td>
<td>7.880</td>
<td>Normal</td>
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<tr>
<td>Derived Lab Air Change Rate</td>
<td>Z000 &gt; 180 Support</td>
<td>7.675</td>
<td>Normal</td>
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<tr>
<td>Derived Lab Air Change Rate</td>
<td>Z000 &gt; 036 High Bay Lab</td>
<td>7.705</td>
<td>Normal</td>
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<tr>
<td>Derived Lab Air Change Rate</td>
<td>Z000 &gt; 122 Support</td>
<td>7.394</td>
<td>Normal</td>
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<tr>
<td>Derived Lab Air Change Rate</td>
<td>Z000 &gt; 034 Fum Chun</td>
<td>7.174</td>
<td>Normal</td>
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</table>

### Fume Hood Sash Position

<table>
<thead>
<tr>
<th>Name</th>
<th>Equipment</th>
<th>History</th>
<th>Value</th>
<th>Status</th>
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</thead>
<tbody>
<tr>
<td>Percent Position</td>
<td>182 Fume Hood &gt; Sash</td>
<td>100.000</td>
<td>Sash 100% Open</td>
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<tr>
<td>Percent Position</td>
<td>230 WNW Fume Hood &gt; Sash</td>
<td>18.880</td>
<td>Sash Partially Open</td>
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<tr>
<td>Percent Position</td>
<td>230 WNW Fume Hood &gt; Sash</td>
<td>18.590</td>
<td>Sash Partially Open</td>
<td></td>
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<tr>
<td>Percent Position</td>
<td>130 NW Fume Hood &gt; Sash</td>
<td>12.608</td>
<td>Sash Partially Open</td>
<td></td>
</tr>
<tr>
<td>Percent Position</td>
<td>250 ENE Fume Hood &gt; Sash</td>
<td>9.706</td>
<td>Sash Closed</td>
<td></td>
</tr>
<tr>
<td>Percent Position</td>
<td>250 EE Fume Hood &gt; Sash</td>
<td>9.000</td>
<td>Sash Closed</td>
<td></td>
</tr>
<tr>
<td>Percent Position</td>
<td>250 WNW Fume Hood &gt; Sash</td>
<td>9.027</td>
<td>Sash Closed</td>
<td></td>
</tr>
<tr>
<td>Percent Position</td>
<td>240 SWEY Fume Hood &gt; S...</td>
<td>8.386</td>
<td>Sash Closed</td>
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<tr>
<td>Percent Position</td>
<td>240 SWEY Fume Hood &gt; S...</td>
<td>8.105</td>
<td>Sash Closed</td>
<td></td>
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<tr>
<td>Percent Position</td>
<td>240 NW Fume Hood &gt; Sash</td>
<td>7.721</td>
<td>Sash Closed</td>
<td></td>
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<tr>
<td>Percent Position</td>
<td>250 E Fume Hood &gt; Sash</td>
<td>6.900</td>
<td>Sash Closed</td>
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<tr>
<td>Percent Position</td>
<td>240 SSE Fume Hood &gt; Sash</td>
<td>6.134</td>
<td>Sash Closed</td>
<td></td>
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<tr>
<td>Percent Position</td>
<td>250 E Fume Hood &gt; Sash</td>
<td>6.934</td>
<td>Sash Closed</td>
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<tr>
<td>Percent Position</td>
<td>130 NW Fume Hood &gt; Sash</td>
<td>5.637</td>
<td>Sash Closed</td>
<td></td>
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<tr>
<td>Percent Position</td>
<td>150 WNW Fume Hood &gt; Sash</td>
<td>5.608</td>
<td>Sash Closed</td>
<td></td>
</tr>
<tr>
<td>Percent Position</td>
<td>130 WNW Fume Hood &gt; Sash</td>
<td>5.205</td>
<td>Sash Closed</td>
<td></td>
</tr>
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</table>