George Bourassa, National Director, Commissioning Services
Robert Bucey, Program Manager

RETRO-COMMISSIONING
Learning Objectives

- Demonstrate global results of the analysis of energy conservation measures that represent the body of retro-commissioning activities performed in multiple buildings.
- Describe the processes that were adopted to identify potential energy conservation measures. These varied by client and specific program objectives.
- Describe the process to vet their technical viability and financial return on investment.
- Describe the various processes to implement the selected energy conservation measures and the monitoring and verification protocol for assessing.
- Discuss how to overcome the various challenges of implementing a retro-commissioning program in fully functional, occupied facilities.
Retro-Commissioning

• Over 75 Full-Time Commissioning Professionals
• Commissioned over 150 million SF of Total Space
• Retro-commissioned over 120 million SF
• Multiple client and building types

Cities labeled indicate presence of permanent commissioning personnel. Shaded states indicate project experience.
Experience

Commissioning and Retro-Commissioning

• Federal Government clients
  ○ US Air Force
  ○ USACE
  ○ GSA
  ○ Dept of Commerce
  ○ Dept of Interior
  ○ Dept of State
  ○ US Mission to United Nations
  ○ Environmental Protection Agency
Experience

Commissioning and Retro-Commissioning

• Non-Federal clients
  ○ The Art Institute of Chicago
  ○ Major universities
  ○ Pharmaceutical clients
  ○ Hospitals/Medical Centers
  ○ Local governments
  ○ Private clients
What is Retro-Commissioning?

- Systematic investigation process for improving and optimizing the operation and maintenance of buildings
- Primarily focuses on energy-using equipment and low-cost improvements rather than expensive capital-intensive retrofit measures
- Involves detailed study of building system operation
  - Faults in building systems are identified for resolution
  - Control changes may be recommended that increase energy efficiency
  - Economic analysis that calculates energy savings
  - Follow-up required to verify that measures have been correctly implemented and have held up over time (persistence)
- Can resolve problems that occurred during design or construction, or that have developed throughout the building’s life
Benefits

What is Retro-Commissioning?

• Occupant Comfort
  ○ Indoor air quality concerns
  ○ Reduce employee absenteeism
  ○ Reduce tenant turnover
  ○ Improve employee productivity
  ○ Improve thermal comfort
Benefits

What is Retro-Commissioning

• Improved Operation
  ○ Reduced maintenance calls
  ○ Train building technicians on RCx process
  ○ Create system-level benchmark to facilitate efficient monitoring of systems – ongoing Cx
  ○ Provide single document resource for O&M staff
Benefits

Why Retro-Commissioning

• Reduce Operating cost/Energy consumption
  ○ Problems never identified during initial building start-up
  ○ Systematic problems in building operation
  ○ Environmental problems
  ○ Excessive equipment run times due to changes in occupancy or space use
  ○ Malfunctioning equipment or sensors
  ○ Control optimization issues
  ○ Extend equipment life
Benefits

Where are the RCx opportunities?

• Simultaneous heating and cooling
• BAS programming vs. actual operation
• Correct and most efficient air damper sequencing
• Chilled water bypasses and leaks
• Battery charging schedule changes
• Corroded condenser coils
• Incorrect head pressure control and hot gas bypass connections
• Poor equipment access
• Equipment not responding to control system
• Temperature and humidity sensors out of calibration
• Control sequence not operating correctly
• Electric duct heaters with incorrect wiring
• Incorrect cooling load calculations
Compliance with Executive Orders

Federal clients

• Integrated Assessment, Operation, and Management
• Ongoing Commissioning Program
• Energy Intensity Reduction through Energy Efficiency
• On-Site Renewable Energy
• Measurement and Verification
• Energy Benchmarking/ENERGY STAR® Portfolio Manager
• Water Use Reduction
• Enhance Indoor Environmental Quality
The Process

Retro-Commissioning Process

Planning
- Perform Initial Site Survey
- Review System Design Documentation
- Develop Utility Benchmarking
- Perform Energy Audit
- Identify Initial Energy Conservation Measures
- Generate Issues Log
- Develop Detailed Work Plan

Investigation
- Implement Diagnostic Monitoring Plan
- Establish Current System Performance
- Engage Facility Management Staff in Planned Changes
- Develop Detailed Testing Procedures
- Implement Functional Testing Program
- Perform Seasonal Testing
- Update Energy Conservation Measures
- Prepare Draft Report

Implementation and Turnover
- Provide Detailed Scope of Work for Capital Improvement Projects
- Develop Cost Estimates
- Implement Modifications
- Measurement and Verification
- Provide Operator Training
- Prepare Final Retro-Commissioning Report
- Prepare Re-Commissioning Manual
- Provide Recommendations for Future Initiatives

Review Systems Operations

Optimize Performance

Train Staff
Planning

Initial Site Assessment

- Review Building Equipment
- Review Building Automated System (BAS)
- Identify Functional Testing Approach
- Documentation Review
Planning

Interview Technical Support Staff

- Owner and Occupants
- Operations Staff
- Facility Team
- HVAC/Controls Staff
Planning

Utility Benchmark

• Establish Baseline
  ○ Metering Data
  ○ Modeling
• Energy Use Index (EUI)
• Compare to Like Facilities
• Make Decisions about Facilities Energy Performance

A typical office building has an EUI of 92.9 kBTU/ft² per year. Inpatient healthcare facilities are typically just under 250 kBTU/ft² per year.
Planning

Develop Project Issues Log and List of Potential Energy Conservation Measures (ECMs)

- Issues Log Includes Recommendations and Priority
- ECM List Includes Description, Cost, Estimated Annual Savings and ROI.

<table>
<thead>
<tr>
<th>#</th>
<th>Equipment</th>
<th>Finding</th>
<th>Recommendation</th>
<th>Measurement Category</th>
<th>Priority</th>
<th>Status</th>
<th>Effect</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AHU</td>
<td>Supply VFD will not start or stop by BAC and occurs intermittently. 100% does not bring air to furnace.</td>
<td>Bring in VFD; facility: additional sensors to troubleshoot problem with drive and determine possible solutions.</td>
<td>2</td>
<td>1</td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>AHU</td>
<td>Return VFD needs to be replaced. It is being used for special point.</td>
<td>Replace return to drive and tie back in to DDC.</td>
<td>2</td>
<td>1</td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>AHU</td>
<td>Damper actuators are not responding to BAC.</td>
<td>Troubleshoot modules and replace if necessary.</td>
<td>2</td>
<td>1</td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>AHU</td>
<td>All dampers need adjusting and lubricated.</td>
<td>Adjust and lubricate all dampers and tighten all set-screws.</td>
<td>1</td>
<td>2</td>
<td>F</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>#</th>
<th>Energy Conservation Measure</th>
<th>Project Description</th>
<th>Project Cost</th>
<th>Estimated Annual Operating Savings</th>
<th>ROI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Winter Free Cooling</td>
<td>Install plate and frame heat exchangers piping and increase condenser that allows complete chiller shutdown during periods when outdoor conditions are high.</td>
<td>$350,000</td>
<td>$130,000</td>
<td>34%</td>
</tr>
<tr>
<td>2</td>
<td>Enable occupancy control</td>
<td>This initiative would be to enable the occupancy control feature that is currently programmed into the 2nd floor live spaces on cool utility.</td>
<td>$31,000</td>
<td>$23,000</td>
<td>84%</td>
</tr>
<tr>
<td>3</td>
<td>Implement occupancy strategy</td>
<td>The goal of this measure would be to implement occupancy strategy to ensure that would meet space temperature setpoints as well as airflow requirements.</td>
<td>$99,000</td>
<td>$49,000</td>
<td>50%</td>
</tr>
</tbody>
</table>
Planning

Retro Cx Planning Phase Report

- Retro-Cx Objectives
- Preliminary ECMs
- RCx Plan
- Functional Performance Testing (FPT) Approach
- Testing and Balance (TAB) Approach
Investigation

Diagnostic Monitoring

Fig. 1  Temperature data logger deployed

Fig. 2  Power data logger deployed

Fig. 3  Sample BAS Display

Fig. 4  Occupancy and photo sensor results for Operating Room

Fig. 5  AHU monitoring results
Functional Performance Testing

• Verify System Performance
• Point to Point Testing From BAS
• TAB Survey
• Compare to Design Intent and Current Use
• Update Issues Log and Proposed ECM List
Investigation

Energy Economic Analysis

• Use Baseline and Trend Data
• Energy Analysis
• Energy Calculations
• Cost Estimates
• Savings to Investment Ratio (SIR)
Investigation

Energy Analysis

• Usage Analysis
• Energy End-User Analysis (MMBTU/yr)
• Energy Star® Rating

Table 600-EA-1: Building 600: Emergency 1 Panel

<table>
<thead>
<tr>
<th>Line</th>
<th>Voltage (V)</th>
<th>Current (Amp)</th>
<th>Power (MW)</th>
<th>(MVA)</th>
<th>Power Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>118.5</td>
<td>361</td>
<td>0.046</td>
<td>0.047</td>
<td>0.99</td>
</tr>
<tr>
<td>2</td>
<td>119.2</td>
<td>329</td>
<td>0.044</td>
<td>0.042</td>
<td>0.972</td>
</tr>
<tr>
<td>3</td>
<td>118.5</td>
<td>347</td>
<td>0.047</td>
<td>0.045</td>
<td>0.98</td>
</tr>
</tbody>
</table>

Figure 600-EA-1: Building 600: Estimate of Total Energy Use by End-user (MMBTU/yr)
Investigation

Energy Calculations

- Energy Savings
- Modeling Strategies

![Energy Savings Calculations Table](image-url)
## Cost Estimate

- RSMeans 2010 and Market Estimates
- Includes Soft Costs and O&P

### ECM COST ESTIMATE

<table>
<thead>
<tr>
<th>Item</th>
<th>Description of Items</th>
<th>Quantity</th>
<th>Unit of Measure</th>
<th>Material Cost Per Unit</th>
<th>Labor Cost Per Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Demolition</td>
<td>Motors, 250/460 V, 60 Hz, 3 HP, electrical demolition, remove</td>
<td>2</td>
<td>EA</td>
<td>$ -</td>
<td>$ -</td>
<td>$ 42</td>
</tr>
<tr>
<td></td>
<td>Motors, 250/460 V, 60 Hz, 10 HP, electrical demolition, remove</td>
<td>2</td>
<td>EA</td>
<td>$ -</td>
<td>$ -</td>
<td>$ 47</td>
</tr>
<tr>
<td>2 Installation</td>
<td>Motors, totally enclosed, premium efficiency, 1.15 service factor, 1800 RPM, 250/460 V, 60 Hz, 5 HP</td>
<td>2</td>
<td>EA</td>
<td>$ 465</td>
<td>$ 930</td>
<td>$ 84</td>
</tr>
<tr>
<td></td>
<td>Motors, totally enclosed, premium efficiency, 1.15 service factor, 1800 RPM, 250/460 V, 60 Hz, 10 HP</td>
<td>2</td>
<td>EA</td>
<td>$ 810</td>
<td>$ 1,620</td>
<td>$ 94</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SUBTOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$ 2,859</td>
</tr>
<tr>
<td></td>
<td>Subcontractor Overhead &amp; Profit</td>
<td>20%</td>
<td></td>
<td></td>
<td></td>
<td>$ 765</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eielson Markup</td>
<td>20%</td>
<td></td>
<td></td>
<td></td>
<td>$ 663</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$ 3,978</td>
</tr>
</tbody>
</table>
Investigation

Savings to Investment Ratio (SIR)

• Prioritization Criteria
• Target Minimum SIR of 1.5
• Convert All “Savings” and “Investments” to Present Worth

\[ \text{SIR} = \frac{\text{Equivalent Benefits}}{\text{Equivalent Costs}} \]
Investigation

Investigation Phase Report

• Trend Data Results
• FPT Results
• TAB Results
• Issues Log
• Energy Analysis
Implementation and Training

Implementation

• Minor O&M Fixes During the Investigation Phase
  ○ Balancing Valve Adjustments
  ○ Control Troubleshooting
• Develop Detailed SOW
• Detailed Cost Estimates
• Prioritized Spend Planning
• Measurement and Verification Planning
Implementation and Training

Project Turnover

- Final Report
- Training Plan
- Systems Manual
  - Systems Descriptions
  - O&M Plan
  - Re-commissioning Schedule
  - Single Line Diagrams
  - Ongoing Planning Commissioning
Industry Results

- Our experience: average 15% to 25% savings in energy alone; can be higher
- GSA ARRA Program: Identified 2,794 energy conservation measures in 50 buildings
- LBNL study of 643 buildings: over 10,000 energy-related problems, resulting in 16% median whole-building energy savings, with payback of 1.1 years
- LBNL: High-Tech building: saved $127,800
  Hospital: saved $6,700 – simple payback of 1 year
- LBNL: Office: saved $90,900 with immediate payback
## Industry Results

<table>
<thead>
<tr>
<th>Target</th>
<th>Location</th>
<th>Energy savings</th>
<th>Project cost ($/sf)</th>
<th>Payback time (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local government buildings</td>
<td>California</td>
<td>14.3% source energy, 11% electricity, 34% gas</td>
<td>1.01</td>
<td>3.5</td>
</tr>
<tr>
<td>Class A offices</td>
<td>Connecticut</td>
<td>7.3% electricity</td>
<td>0.62</td>
<td>1.37</td>
</tr>
<tr>
<td>Mixed commercial</td>
<td>Colorado</td>
<td>7% electricity</td>
<td>0.185</td>
<td>1.51</td>
</tr>
<tr>
<td>University buildings</td>
<td>California</td>
<td>10% total source</td>
<td>1.00</td>
<td>2.5</td>
</tr>
<tr>
<td>Supermarkets</td>
<td>Central California</td>
<td>12.1% electricity</td>
<td>0.14</td>
<td>0.25</td>
</tr>
<tr>
<td>Mixed commercial</td>
<td>Oregon</td>
<td>10-15% electricity</td>
<td>0.175</td>
<td>1.24</td>
</tr>
<tr>
<td>Mixed commercial and educational</td>
<td>California</td>
<td>1.7-8.1% electricity</td>
<td>0.40</td>
<td>3.0</td>
</tr>
</tbody>
</table>
ROI Expectations: LBNL Study

Figure 10. Benchmarks for energy savings and cost-efficiency.

Energy Savings (%)
- Upper 25%-ile
- Median
- Lower 25%-ile

Commissioning Cost (US$2009/ft²)
- Existing Buildings (N=317)
- New Construction (N=73)

Cost Savings (US$2009/ft²-year)
- Existing Buildings (N=315)
- New Construction (N=38)
ROI Expectations: LBNL Study
Some RCx Lessons Learned

- Inadequate building documentation
- Access to building automation system data
- Systems “never ran right from day one”
- Zone level adjustments made but never tracked
- Changes made during construction
- “Improving Performance” may not always reduce energy consumption
- Set expectations up front
- Need buy in from all parties
Existing Building Retro-Cx

U.S. Air Force Eielson AFB and Eareckson AFB, Alaska
- Over 1 Million SF
- Comprehensive program
- Identified over $2.2M in Annual Energy Savings
- Prepared Design/Build Scope of Work Documents
- Provided Operator Training
Existing Building Retro-Cx

GSA Recovery Program Management, Nationwide

- 115 Million SF
- Over $5 billion
- Review all Major Modernization and New Construction Projects
- Review All Deep Energy Retrofits
- Engaged throughout Implementation
- 2,800 ECMs
Existing Building Retro-Cx

GSA Recovery Program Management, Nationwide

• Accuracy and Completeness of HPGB Measures
• National Consistency in Reporting and Interpretation to and by our Stakeholders
• Full Transparency and Candor of GSA’s “Story” under Recovery
Sources

- Narendra Amarnani, Brian Roberts, Nora Hernandez and Michael B. Lo. 2007; 1, 3, 5, 16. “Retro-commissioning (RCx) Sustainable Savings: Are We There Yet?”
- Mike Eardley. 2007; 2, 4, 10. “Persistence Tracking in a Retro-commissioning Program”
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