

## Five Key Elements in Completing and Delivering Your Building to Expectations

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## EH&E Company Profile

- **Established in 1988**
- **Headquarters in Newton, MA**
  - Boston and Cambridge
  - Washington, DC
  - Miami, FL
- *Over 50 technical professionals in building engineering, environmental sciences, and product testing services*

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## EH&E Company Profile

- **Over 4,500 building studies**
- **More than 20M sf in commissioning services**
  - Research laboratories (BL-3+)
  - Hospitals and healthcare facilities
  - Higher educational facilities and dormitories
- **Web-based Cx management and contractor performance tracking**



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## New Construction Client Expectations

- A building that performs as designed (and meets owner's expectations) when completed & occupied
- **Quality Assurance**
  - Review
  - Verify
  - Document, each step of the construction process

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## New Construction Client Expectations

- **Project Design Intent**
  - Design Team creates contract documents
- **Project Delivery**
  - Construction Team agrees to implement project based on contract documents
    - Schedule
      - » Implementation requirements
      - » Owner's occupancy requirements
- **Project Contract**
  - "Promise" that project will be delivered per contract documents and occupancy requirements

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## New Construction Client Expectations

- *Unfortunately, it is rare that contract conformance and owner occupancy complete simultaneously as planned.*

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## Project Completion

### Three Stages to Construction Completion

1. Substantial Completion
2. Occupancy
3. Final Completion

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## Construction Completion Stages Substantial Completion

- **Substantial Completion**

- Certificate of Occupancy
  - Architectural Completion
  - Major Systems Operational
  - Jurisdictional Sign-off

- **On-site Perspective**

Building is “functional” and acceptable to the local code officials having jurisdiction, then the building is substantially complete and all outstanding issues become “punch list” items.

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## Construction Completion Stages Substantial Completion

- **Commissioning Perspective – 100% Completion**

- Installation
- Star-up
- Controls
- Balancing

*Commissioning is essentially an “acceptance process” where systems need to be “complete” prior to performance testing.*

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## Construction Completion Stages Occupancy

- **Tangible**
  - Structure
  - Equipment
  - Finishes
  - Power
  - HVAC Operation
- **Intangible**
  - Controls integration
  - System balancing
  - System performance
  - Knowledge transfer

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## Construction Completion Stages Final Completion

- **100% Completion – 5 Key Elements**
  - Installed
  - Started
  - Controlled
  - Balanced
  - Tested

*Construction is “Walk-Away Done” and  
System performance has been Proven.*

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## Commissioning (Cx)

- Commissioning (Cx) applies a **process of review, verification, and documentation** to the five key construction elements:
  1. Installed
  2. Started
  3. Controlled
  4. Balanced
  5. Tested
- Each element in the construction completion process is a precursor to the next.

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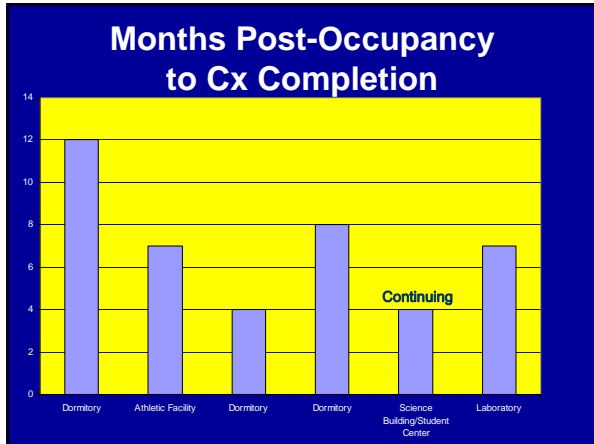
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- ### Five Key Completion Elements Installation
- **Contract Compliance**
    - Design
    - Code
    - Manufacturer Requirements
    - System Integration
  - From a quality assurance process perspective, an incomplete product installation may have an impact on a subsequent completion stage (i.e., missing volume dampers will undoubtedly impact system air balancing)

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- ### Five Key Completion Elements Start-up
- **Complete & Proper Start-up Ensures:**
    - Performance
    - Reliability
    - Equipment Life
    - Warranty

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## Start-up Specification

- **“Unit Manufacturer’s Representative / Start-Up Services:**  
*Each individual unit interior and exterior shall be inspected and reviewed by the unit manufacturer’s representative, before start-up. The unit manufacturer shall supervise the installation of final filters, the removal of all component shipping blocks, removal of any and all interior and exterior cleanliness protection, and the removal of any duct covering protection. Units shall then be started-up by the unit manufacturer in conjunction with the contractor. Start-up shall include run testing the fan, and confirming the vibration parameters, etc., of the fan assembly, all per submitted test procedures. The unit manufacturer shall submit a written start-up report to the architect.”*

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## Five Key Completion Elements Control

- **Intangible**  
 – incomplete installation is not easily detectable
- **Performance**  
 – Incomplete controls may not prevent operation but will absolutely impact system performance
- **Control Point to Point Completion**

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## Control Specification

- **“Upon completion of the project, the Contractor shall:**  
 – *Fine-tune and “de-bug” all software control loops, routines, programs and sequences of control associated with the control system supplied. Completely adjust and make ready for use, all transmitters, relays, damper operators, valves, etc., provided under this Section.*  
 – *This Contractor shall furnish copies of complete, detailed, calibrating checkout and commissioning documentation for each controller. Documentation shall list each procedure and shall be signed by the control specialist performing the service.”*

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## Five Key Completion Elements Balancing

- **Intangible**
  - incomplete balancing is not easily detectable
- **Process**
  - Successful balancing controls completion
- **Performance**
  - Critical
  - Verification

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## Balancing Specification

- *"Balance and testing shall not begin until all HVAC systems have been completed and are in full working order, as determined by the Architect. Where construction is phased, the Testing and Balancing Contractor shall submit a plan of action which outlines how each phase will be balanced and how, when completed, the entire system will be verified to be tested and balanced. The Balancing Contractor shall coordinate his work with the HVAC and ATC Contractors, shall place all heating, ventilating and air conditioning systems and equipment into full operation, and continue the operation of same during each working day of adjusting and balancing."*

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## Five Key Completion Elements Performance Testing

- **System Acceptance**
  - Proof of Performance
    - Completed
    - Started
    - Controlled
    - Balanced
- **Last Step in Contract Compliance Verification**

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## Laboratory Building Project

- 420,000 Square Feet
- 8 Levels
- Wet & Dry Labs
- Vivarium
- Atrium



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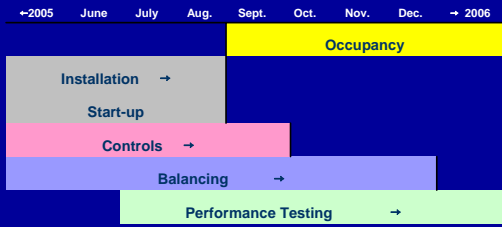
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## Actual Lab Building Timeline




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## Lab Building Performance Test Results

Stage	Test Period	Cx Action List
Pre-move in	7/5 - 8/31	194
Move in	9/6 - 10/25	167
Post move in	10/25 - 1/22	30
<b>Total</b>		<b>391</b>

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## Conclusions

- The importance for owners to fully understand *and appreciate* the elements of construction completion and the ramifications of completing tasks "out of order" is **critical** to ultimately ensuring that building systems perform as intended upon occupancy
- Add completion expectations to the Design Intent or Owner Project Requirements

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## Conclusions

- Utilize commissioning documentation to benchmark completion status
- Require delivery of all successfully completed start-up reports immediately, but no later than 5 days after completion
- Require completed controls "point to point" checkout sheets immediately, but no later than 5 days after completion

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## Conclusions

- Enforce specification requirements
- Document for maintenance staff and building occupants all issues involving completion impacts after occupancy
- Understand the ramifications of schedule impacts on final completion and contract conformance

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