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Please note that while this section follows the MasterFormat numbering convention and layout, this is not a specification. It is a description of standard requirements that must be incorporated by the Architect of Record and/or Engineer of Record into project specifications.

PART 1 - INTRODUCTION


1.1 Description

- A. Commissioning is a systematic, quality-focused process for enhancing project delivery and performance. The goals of commissioning are to verify and document that building systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet University requirements, reduce performance cost and risks associated with delivering projects, and to ensure value to owners, occupants, and users.
- B. For major comprehensive scope projects, the commissioning process described in this section shall be followed. For small and limited scope projects, commissioning activities may be selectively applied by the University.
- C. The commissioning process described in this section is generally aligned with the USGBC LEED requirements for Enhanced Commissioning for MEP Systems, Enhanced Commissioning for Building Enclosure, and Monitoring-Based Commissioning with use of an Analytic Platform. Specific LEED requirements for the sequencing and documentation of commissioning activities are defined by USGBC and shall be submitted to GBCI accordingly.

1.2 Responsible Personnel

Note: The Yale team may be supplemented by owner’s agents with expertise in specialized systems such as IT.

- A. Yale University Team
 - 1. Commissioning Authority (CxA)
 - 2. Commissioning Integration Specialist (CxIS)
 - 3. Building Enclosure Commissioning Provider (BECxP)
 - 4. Yale Commissioning Project Manager (CxO)
 - 5. Yale Office of the Fire Marshall (FM)
 - 6. Yale Facilities Operations (FAC OPS)
 - 7. Yale Facilities Engineering (ENG)

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8. Yale Information Technology Systems (IT)
9. Yale Environmental Health & Safety (EHS)

B. Design Team

1. Architect of Record and/or Engineer of Record (AOR/EOR)
2. LEED Accredited Professional (LEED AP)


C. Construction Team

1. Construction Management Project Manager (CM-PM)
2. Construction Management Quality Control Supervisor (CM-QC)
3. Testing, Adjusting, and Balancing Contractor (TAB)
4. Building Automation Systems Contractor (BAS)
5. Construction Sub-Contractor (CM-SUB)
6. Construction Contracts Equipment Suppliers (CM-SUP)

1.3 Definitions


Note: While this definition list is not comprehensive in covering all commissioning related terminology, it is mandatory that these terms be used in specifications for clarity across projects and teams.

- A. Analytics: Commercially available software incorporating real time monitoring of the BAS, automated fault detection and diagnostics, and energy metering to support construction and post-acceptance phase commissioning activities.
- B. Analytics Performance Validation: A process with a designated period of time during which building systems demonstrate that commissioning acceptance criteria is met with the use of analytics.
- C. Basis of Design: Developed by the AOR/EOR to document the primary thought processes and assumptions behind design decisions made to meet the project requirements. The BOD records the concepts, assumptions, calculations, decisions, and product selections used to meet the project requirements and satisfy applicable regulatory requirements, standards, and guidelines, including Yale EHS directives. The BOD expands on how the design requirements will be specifically achieved.
- D. Building Enclosure Commissioning Provider: The designated manager to support the CxA to develop, implement, and manage the commissioning process for enclosure assemblies

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and systems. In the instance of a project involving only building enclosure scope of work, the BECxP will be referred to as the Building Enclosure Commissioning Authority.

- E. Certificate of Commissioning Completion: Provided by the CxA to declare that all construction commissioning steps are complete, and a commissioning report will be issued and then amended following the post-acceptance phase. The Certificate of Commissioning Completion validates that commissioning acceptance criteria has been demonstrated and no major issues remain without a defined path forward and agreed to by Yale.
- F. Certificate of Commissioning Readiness: Provided by the CM-PM to declare that pre-functional checklists are complete, analytics are integrated, no known outstanding deficiencies exist in the systems, and systems are ready for field functional performance testing. The Certificate of Readiness also declares that Testing, Adjusting, and Balancing is complete and comprehensive TAB report may be submitted.
- G. Commissioning Acceptance Criteria: Provided by the AOR/EOR with support from the CxA, CxIS, and BECxP and Yale stakeholders, acceptance criteria define the performance of building systems that must be demonstrated before a Certificate of Commissioning Completion is issued and project is accepted by Yale. Acceptance criteria is project specific and to be included in the commissioning specification sections in matrix format.
- H. Commissioning Authority: The designated manager responsible to Yale to develop and oversee the commissioning team, and to develop, implement, and manage the overall commissioning process.
- I. Commissioning Integration Specialist: The designated manager to support the CxA in virtual bench testing of BAS sequences, to develop and submit an analytics deployment plan, to procure adequate analytics licensing to deploy analytics, and to provide access to appropriate Yale, commissioning, and construction team members.
- J. Commissioning Orientation: A meeting or series of meetings where the CxA describes the commissioning process and requirements so that AOR/EOR and CM understand expectations, deliverables, activities, and milestones.
- K. Commissioning Plan: A project specific document to define the overall management and implementation plan created by the CxA, the specific roles, responsibilities, and deliverables necessary to ensure that all systems may be tested to demonstrate project requirements and acceptance criteria, and process for issue resolution. The plan shall be

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updated regularly to document the structure, schedule, and coordination for the entire commissioning process.

- L. Commissioning Specifications: Provided by the AOR/EOR with input from the CxA, CxIS, BECxP, and Yale stakeholders, a series of specification sections that describe general commissioning requirements, specific systems to be commissioned, pre-functional checklists, functional performance test procedures, performance-based commissioning requirements and commissioning requirements for specific systems such as HVAC, BAS, electrical, plumbing, fire, and building enclosure.
- M. Deficiency: A condition in the installation or function of a component, piece of equipment or system that is not in compliance with the contract documents, does not performance properly, or is not complying with the design intent.
- N. Design Review: Provided by the CxA with input CxIS, BECxP, and members of the Yale team, the design review includes review of clarity and completeness of Yale requirements, basis of design, and resulting building systems. The design review is completed at the design development phase and one or more milestone deliverables during construction documentation phase. Design review comments shall be addressed and resolved in writing by AOR/EOR.
- O. Field Functional Performance Test: A functional performance test (FPT) performed in the field is a critical part of the commissioning process. Equipment operation during the test is performed by the appropriate sub-contractor or equipment manufacturer, but the responsibility for directing, witnessing, and documenting the test rests with the CxA. Functional performance tests must be performed under full operation, all operating modes, failure modes. The systems are run through all the control systems sequences of operation and system components are verified to be responding as required. FPTs are developed in written form by the CxA following system submittals and are performed after the CM-PM issues a Certificate of Commissioning Readiness.
- P. Issues Log: The CxA develops and maintains an issues log for the systems to be commissioned. The issues log documents and tracks resolution of areas of concern identified during design and submittal reviews, and deficiencies identified during construction, testing, and performance validation.
- Q. Post-Acceptance Phase: The period of time after the Certificate of Commissioning Completion and acceptance of the building by Yale Operations during which additional


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commissioning activities are taking place. Activities include, but are not limited to, seasonal performance testing, monitoring of system performance with analytics, and related resolution of deficiencies identified. Post-acceptance phase generally aligns with a one-year warranty period but may be a project-specific duration.

- R. Pre-Functional Checklist: A procedural checklist developed by the AOR/EOR in consultation with the CxA during the design process and required to be completed by the sub-contractors during construction execution and prior to the Certificate of Readiness being issued by the CM. Pre-functional checklists include, but are not limited to, factory start-up reports, field test reports, TAB reports, and all other items required in the contract specifications.
- S. Seasonal Performance Tests: Functional performance tests that are deferred to the Post-Acceptance Period to test how systems are responding to outdoor conditions closer to their design day criteria.
- T. Specialty Commissioning Provider: The designated managers to support the CxA in commissioning specialty systems such as IT required systems. Specialty commissioning providers may be designated by Yale for project specific needs, and their efforts should be reflected in the Commissioning Plan and Final Reports.
- U. Virtual Bench Testing: A type of functional performance test conducted by the CxA or CxIS with the BAS vendor to demonstrate sequences of operation prior to installation. Such testing is conducted following approval of BAS submittal but may result in a clarification and resubmittal of controls sequences, and therefore EOR participation in testing is encouraged. Virtual bench testing is intended to demonstrate the ability of the controls programming to pass field functional performance tests once installed locally. This process serves as a quality control check to resolve deficiencies in programming logic prior to field functional performance testing and analytics performance validation.


1.4 Commissioning Process

Note: The following is an overview of required commissioning activities required during design, construction, and post-acceptance phase, and the general order in which they shall occur. The responsibility of the AOR/EOR is to identify these activities in appropriate specification sections within contract documents so that the construction team is prepared to procure and execute these activities aligned with the CxA’s Commissioning Plan. The CxA is an agent of the owner and a resource for the design and construction team. Yale has


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developed a schematic representation of these activities and additional references to be utilized by the Yale CxO and project management team.


1. Cx Scope Established and Team Contracted:-During SD and early DD, Yale shall work with the AOR/EOR to develop commissioning scope and hire the CxA, CxIS, and BECxP. The project team shall determine the anticipated project timeline, equipment and systems that shall be commissioned, number of design reviews, an estimate of construction phase site visits and meetings, and how the AOR/EOR will engage the CxA, CxIS, and BECxP as resources during the design phase to inform commissioning specification sections.
2. Commissioning Orientation & Project Planning: Before the end of DD, a commissioning orientation meeting shall be held with the assigned CxA, CxIS, and BECxP. The team shall discuss future meeting format, approach to design reviews, development of acceptance criteria, and content for commissioning specifications. CxA shall present and issue an initial Commissioning Plan which will be updated as the project progresses. Team shall not that the commissioning specification sections are provided by AOR/EOR with input from CxA, CxIS, BECxP, and Yale stakeholders to describe the appropriate scope, process, and rigor of the contractors’ commissioning responsibilities. The specification sections shall identify systems to be commissioned, required tests, documentation, forms, checklists, testing procedures, training requirements, and any other requirements.
3. Commissioning Acceptance Criteria Established: Early, transparent, and verifiable acceptance criteria are the foundation of the Yale commissioning program. The team shall collectively establish acceptance criteria that is project and system specific, robust and aggressive enough to demonstrate high performance project delivery. Acceptance criteria shall be included in Construction Documents in matrix form in a Performance-Based Commissioning specification section.
4. Design Reviews: CxA, CxIS, and BECxP shall review progress documents and provide written comments to the design team. Reviews shall be focused on the clarity and completeness of Yale’s project requirements, basis of design, commissioned systems, the required installation checklists, functional tests, turnover requirements, and training. The CxA shall issue a design phase commissioning report to Yale that includes design review comments, how they were resolved by the AOR/EOR, back-check of the final Construction Documentation, and any lessons learned from design activities.

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5. Commissioning Bid Clarifications: The project team shall support the bid process to ensure that commissioning activities are procured appropriately. It is important that the CM-PM and contractors fully understand commissioning requirements included in various commissioning specification sections, particularly related to acceptance criteria.
6. Submittal Reviews: The CxA, CxIS, and BECxP shall identify which submittals are relevant for their review and commentary to be included in the AOR/EOR review comments. CM-PM shall provide relevant parties in distribution for review and approval.
7. Virtual Bench Testing: Following approved submittals, the CM-PM shall schedule virtual bench testing with BAS, CxA, and CxIS. Testing may result in a clarification and resubmittal of controls sequences, and therefore EOR participation in testing is encouraged. Virtual bench testing is intended to demonstrate the ability of the controls programming to pass field functional performance tests once installed locally.
8. Network Live & Analytics Integration: The project shall aim to provide a live network for analytics integration as soon as possible in the construction sequence. It is recommended for the network to be brought online as early as either temporary or permanent power is available, and a BAS controller is in the building. The CM-PM is responsible to coordinate Yale IT to provide either a temporary “network in a box” or permanent installation according to Yale IT system requirements and architecture. Preparation meetings with Yale IT, ENG, and BAS must be held to coordinate and schedule this work scope. Once live, CxIS shall integrate the building automation system with analytics software to allow visibility and analysis of system performance as it is being built. All stakeholders may have remote access to analytics software and BAS once the system is live during construction.
9. Pre-Functional Testing & Functional Testing Readiness: The requirement for a Certificate of Commissioning Readiness shall be identified in project Construction Documents. Certificate is provided by CM-PM to declare that pre-functional checklists are complete, analytics are integrated, no known outstanding deficiencies exist in the systems, and systems are ready for field functional performance testing. The Certificate of Readiness also declares that Testing, Adjusting, and Balancing is complete and comprehensive TAB report may be submitted.

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10. **Functional Performance Testing:** CM-PM shall schedule contractors with CxA for field functional performance tests. Equipment operation during the test is performed by the appropriate sub-contractor or equipment manufacturer, but the responsibility for directing, witnessing, and documenting the test rests with the CxA. Functional performance tests must be performed under full operation, all operating modes, failure modes. The systems are run through all the control systems sequences of operation and system components are verified to be responding as required. FPTs are developed in written form by the CxA following system submittals and are performed after the CM-PM issues a Certificate of Commissioning Readiness.
11. **Analytics Performance Validation:** A process that shall be a minimum of 14 days, during which building systems demonstrate that commissioning Acceptance Criteria is met with the use of analytics. The analytics performance validation period begins after building systems have been migrated from temporary to permanent Yale IT network and from construction BAS server to Yale BAS server. The building systems shall be visible to Yale Operations during this period.
12. **Training & Turnover Package Validation:** The AOR/EOR shall prepare and deliver a systems training describing the design intent of systems and how they serve Yale’s project requirements. In addition, commissioning specification sections outlines the necessary training that shall be coordinated by CM-PM and provided to various Yale stakeholders and OPS. The CxA will validate that the necessary training has occurred. The required turnover package is defined by Yale in project contract documents. The CxA will also validate that the necessary documents have been turned over.
13. **Commissioning Completion:** The requirement for a Certificate of Commissioning Readiness shall be identified in project Construction Documents. Provided by the CxA to declare that all construction commissioning steps are complete, and a commissioning report will be issued and then amended following the post-acceptance phase. The Certificate of Commissioning Completion validates that commissioning acceptance criteria has been demonstrated and no major issues remain without a defined path forward and agreed to by Yale. The CxA shall issue a construction phase commissioning report to Yale that includes a complete report of construction phase activities and deficiency resolution.
14. **Yale Operations Acceptance:** Operations acceptance of the project follows all

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activities described above regarding commissioning, including demonstration that the project has met all Acceptance Criteria during the performance validation period. It is important to note that commissioning is just one aspect of a comprehensive project turnover process otherwise defined by Yale.

15. Post Acceptance Phase Commissioning: AOR/EOR shall define post-acceptance phase commissioning activities which occur after Yale Operations acceptance for a complete 12-month duration. This duration may or may not align with warranty periods. During this time, any second season functional performance testing, TAB verification, or deferred functional performance testing shall be completed, and analytics shall remain active. CxA and CxIS shall continue to be engaged, and meeting regularly as defined by project. New deficiencies may be identified related to design, construction, or post-occupancy changes which may need to be resolved under warranty by the AOR/EOR and CM.
16. Post Acceptance Phase Commissioning Report: The CxA shall issue a post-acceptance phase commissioning report to Yale that includes a report out of all deficiencies identified and resolved with post-acceptance phase activities, as well as lessons learned in the first year of occupancy that may be applied to future projects at Yale.
17. Ongoing Commissioning with Operational Analytics: At the end of the 12-month post acceptance period, Yale ENG and FAC-Ops may elect to retire the analytics software in use and/or transfer select central systems such as air handling units to Clockworks for long-term operational analytics for focused maintenance. There are no requirements for this effort that shall be included in project Construction Documents.

1.5 Commissioning Milestones & Deliverables

Note: The following is an overview of required commissioning milestones and deliverables, and the general responsible party. The required milestones and deliverables shall be reflected in the Commissioning Plan by the CxA, commissioning specification sections by the AOR/EOR, and the commissioning construction schedule by the CM.

A. Commissioning Milestones


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	Milestone	Occurs by:
1	Issuance of Initial Commissioning Plan	End of DD
2	Issuance of Design Phase Commissioning Report	End of CD
3	Issuance of Final Commissioning Specifications with Acceptance Criteria	100% CD
4	Issuance of Certificate of Commissioning Readiness	During Construction
5	Issuance of Certificate of Commissioning Completion	Before Yale Operational Acceptance
6	Issuance of Construction Phase Commissioning Report	Commissioning Completion
7	Issuance of Post Acceptance Phase Commissioning Report	End of Post Acceptance Phase

B. Beyond key commissioning milestones, there are important construction phase and post-acceptance phase activities that shall be clearly delineated on Construction Commissioning Schedules, including:


1. Issuance of Initial Construction Commissioning Schedule
2. Dates of Start / Completion of Virtual Bench Testing
3. Dates of Start / Completion of Building Enclosure Checklists & Tests
4. Dates of Live IT Network
5. Dates of Start / Completion of Analytics Integration
6. Dates of Start / Completion of MEP Pre-functional Checklists
7. Issuance Certificate of Commissioning Readiness
8. Dates of Start / Completion of Field Functional Performance Testing
9. Dates of Start / Completion of Training
10. Date of Transition to Permanent Yale IT Network
11. Date of Transition to Yale BAS Server
12. Dates of Start / Completion of Analytics Performance Validation Period
13. Date of Documentation Turnover
14. Issuance of Certificate of Commissioning Completion
15. Issuance of Construction Phase Commissioning Report
16. Dates of Start / Completion of Post Acceptance Phase
17. Dates of Start / Completion of Post Acceptance Phase Field Activities
18. Issuance of Post-Acceptance Phase Commissioning Report

1.6 Commissioning Written Deliverables

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The commissioning process generates several written deliverables described in the specifications. Below is a list of all the formal written deliverables and who is generally responsible to create them.

	Deliverable	Developed by:
1	Commissioning Specifications	AOR/EOR
2	Commissioning Acceptance Criteria	AOR/EOR
3	Basis of Design	AOR/EOR
4	Commissioning Design Review Reports	CxA with input from CxIS, BECxP
5	Commissioning Plan	CxA with input from CxIS, BECxP
6	Commissioning Meeting Minutes	CxA
7	Commissioning Schedule	CM
8	Equipment Submittals	CM
9	Virtual Bench Tests	CxA with input from CxIS
10	BAS Sequence Clarifications following Virtual Bench Tests	CM / BAS with input from AOR/EOR, CxA, and CxIS
11	Building Envelope Inspection Checklists	CxA
12	Completed Building Envelope Inspection Checklists	CM
13	Pre-functional Checklists	CxA with input from AOR/EOR and CM
14	Completed Pre-functional Checklists	CM
16	TAB Plan	CM / TAB with input from AOR/EOR and CxA
17	Final TAB Report	CM / TAB
18	Certificate of Commissioning Readiness	CM
19	Functional Performance Tests	CxA
20	Completed Functional Performance Tests & Enclosure Tests	CM witnessed by CxA, BECxP
21	Performance Verification Report	CxIS
22	Corrective Action Tracking Logs	CxA with input from CM and CxIS
23	Commissioning Progress Reports	CxA
24	Turnover Documents	CM, AOR/EOR
25	Turnover Verification Report	CxA

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26	LEED Documentation	CxA with input from LEED AP
27	Final Commissioning Report	CxA
28	Certificate of Commissioning Completion	CxA
29	Post-Acceptance Phase Commissioning Report	CxA

PART 2 - TESTING REQUIREMENTS


2.1 General

- A. Testing requirements are project specific and broad ranging: tests may be performed on equipment in the factory, on programming logic in a virtual BAS simulation, or on integrated multi-disciplinary systems in the field, with the assistance of a check list, functional performance test, or analytics system. Witnessing, validating, and performing tests is the most critical aspect of a comprehensive commissioning process.
- B. The AOR/EOR must define testing requirements and the use of pre-functional checklists and functional performance tests in various project specification sections. Relevant specification sections include, but are not limited to:
 - 1. Section 01 91 13 – General Commissioning Requirements
 - 2. Section 01 91 14 – Performance-Based Commissioning Requirements
 - 3. Section 01 91 19 – Building Enclosure Commissioning
 - 4. Section 22 08 00 – Commissioning of Plumbing Systems
 - 5. Section 23 08 00 – Commissioning of HVAC Systems
 - 6. Section 23 08 01– Commissioning of Building Automation Systems
 - 7. Section 26 08 00 – Commissioning of Electrical Systems
 - 8. Section 27 08 00 – Commissioning of Communications Systems
 - 9. Section 28 08 00 – Commissioning of Electronic Safety and Security Systems

2.2 Equipment / Assembly Checklists

2.3 Equipment / Assembly Functional Performance Test

2.4 System Functional Performance Test

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PART 3 - RESOURCES

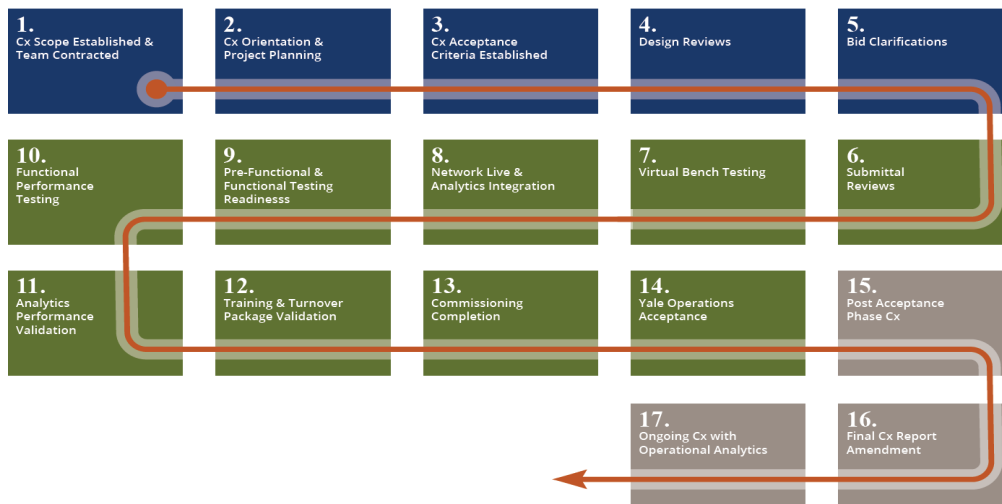
3.1 Commissioning Firms

- A. Yale pre-qualified several firms to provide CxA, CxIS, and BECxP services. Pre-qualified firms are committed to providing high-quality, project-specific services while engaging with Yale to share lessons learned and foster consistent approaches to the various aspects of Yale’s commissioning program.

3.2 Commissioning Tools

- A. Yale has internal resources to support the commissioning process holistically, many of which are living documents under development to incorporate lessons learned as the commissioning program evolves. Yale project managers may choose to share resources and training materials on select projects.

B. Commissioning Process Flow Diagram



Date	Description of Change	Pages / Sections Modified	ID
11/3/24	Entire document	-	JRP