



NEW CONSTRUCTION BUILDING COMMISSIONING

BEST PRACTICES

January 2024

Acknowledgments

The Building Commissioning Association is fortunate to have access to numerous commissioning providers who practice state-of-the-art building commissioning daily. We are grateful for their donated time, and intense effort to bring this New Construction Best Practices update into being. Over the past year, these subject matter experts have authored, touched, interpreted, reviewed, edited, and generated comments on the manuscript. Their insight and vast experience in the field reinforce the building industry's recognition of best practices in commissioning. Thank you!

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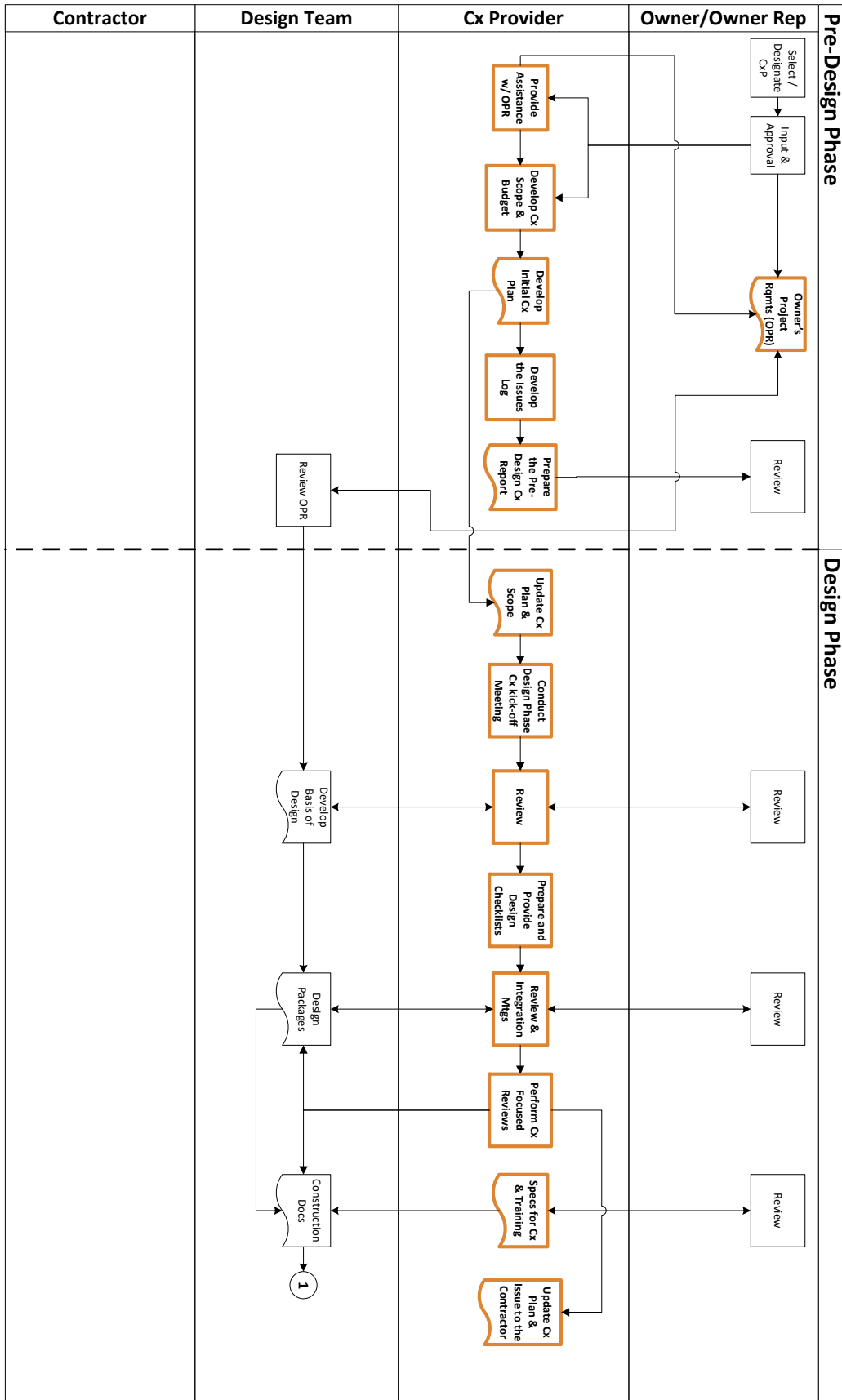
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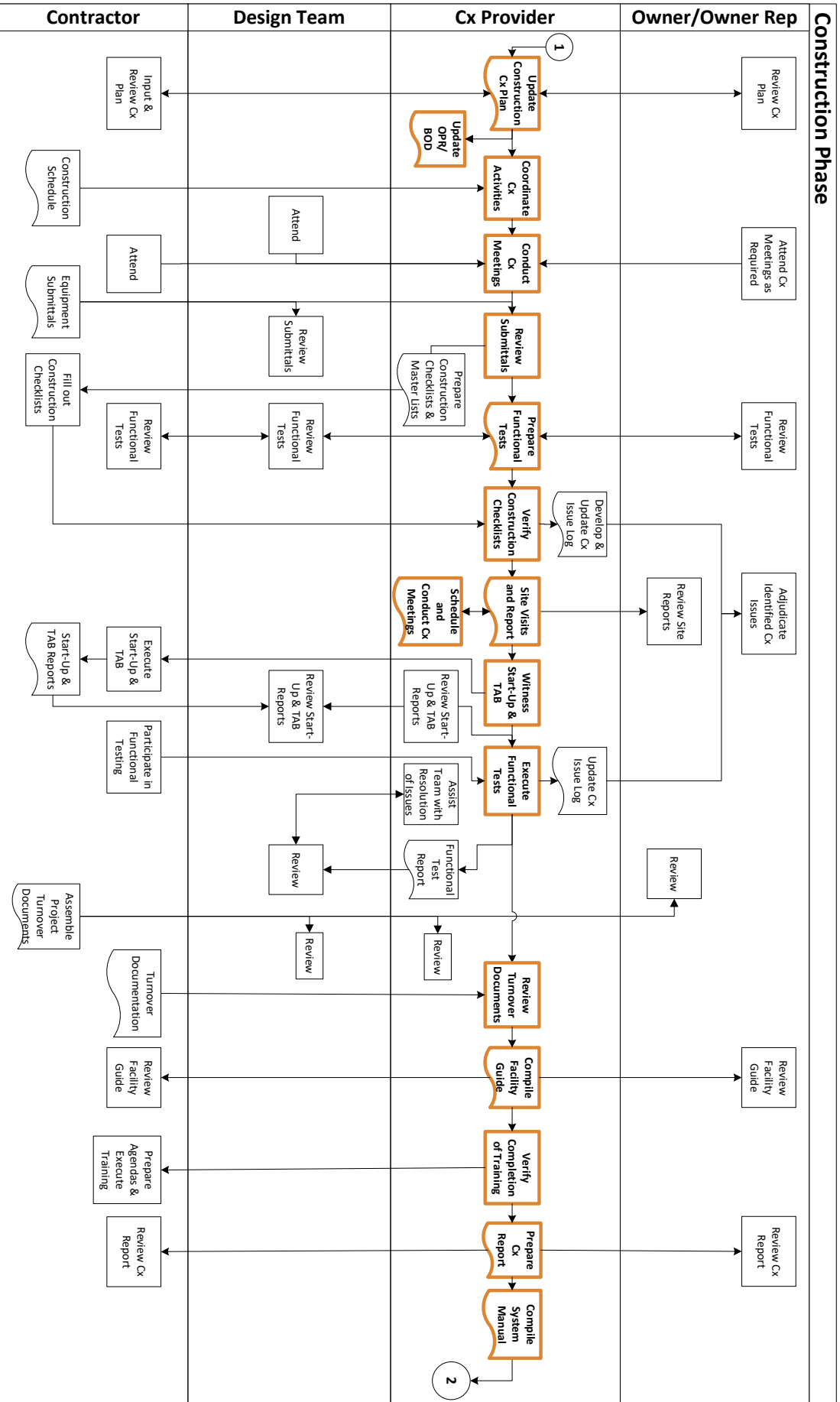
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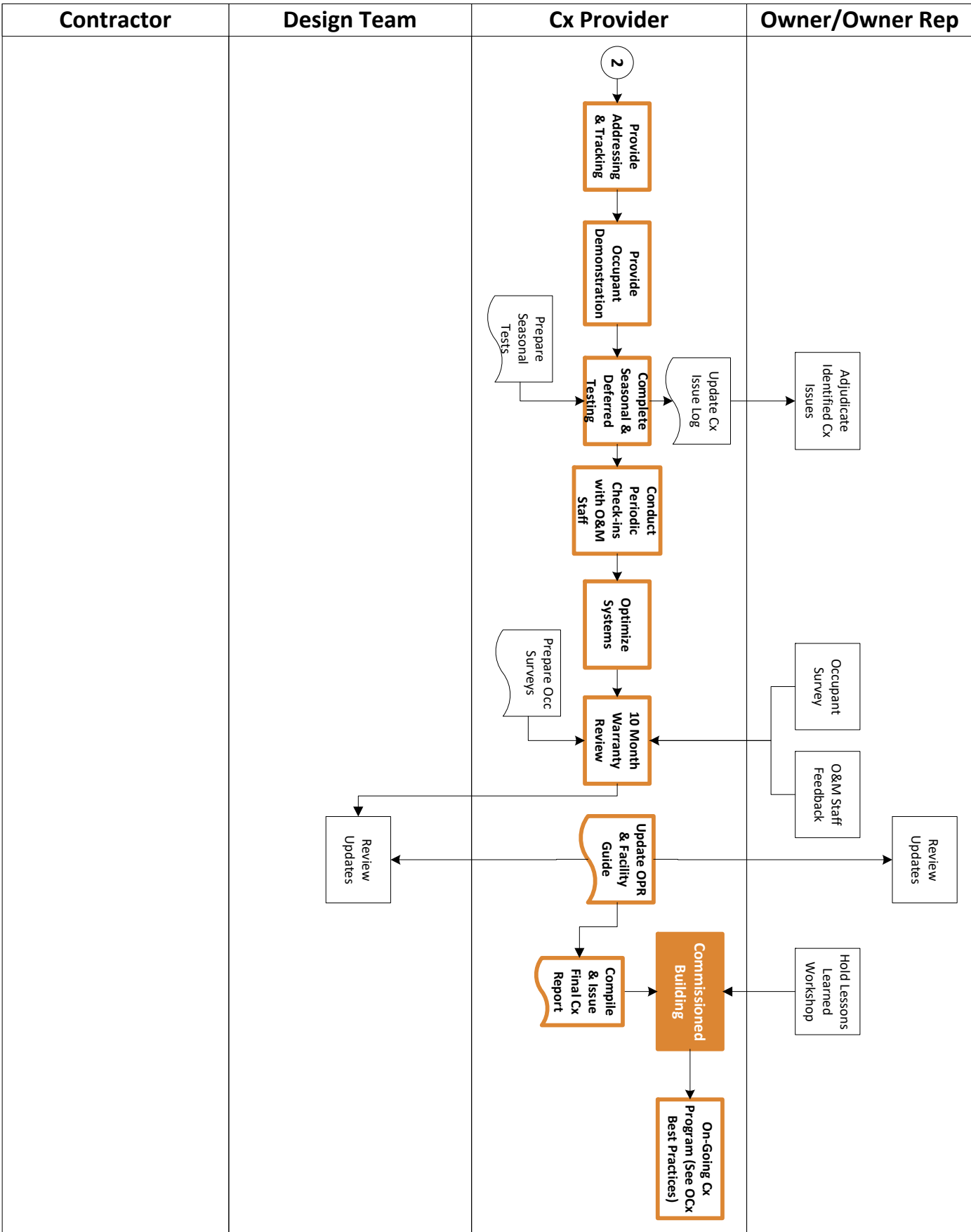
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The following pages illustrate the sequence of best practices for commissioning and the team members responsible for tasks.





Closeout Activities, Occupancy & Operations Phase



Executive Summary

New construction building commissioning (NCCx) is a professional practice that facilitates the planning, design, construction, installation, and testing verification, documentation, and operation of facilities and systems to conform to the Owner's Project Requirements (OPR). Building commissioning comprises specific phases and activities for both new construction and existing buildings. Commissioning (Cx) is the only profession/entity, other than the owner, engaged throughout the design, construction, delivery, and optimizing the performance of facilities.

In any profession, best practices offer value; they provide certainty, cost-effectiveness, and efficiency to practitioners, recipients of services, and other process participants. Over time, commissioning providers (CxP) have developed many best practices. This document is intended to provide combined best practices from a wide range of practitioners. The document is on a continuous maintenance schedule and will be updated as needed.

The Building Commissioning Association (BCxA) states that the basic purpose of commissioning is to provide documented confirmation that building systems and assemblies are designed, installed, and function in compliance with criteria outlined in the project documents to satisfy the Owner's operational needs.

This document describes and defines best practices for conducting New Construction Commissioning (NCCx) projects beyond the minimum practices required to satisfy codes and standards.

Best practice, by definition, creates a benchmark against which the market can gauge quality and professionalism. This Best Practice document allows the BCxA and other organizations to evaluate commissioning initiatives, processes, guidelines, training curricula, and certifications objectively. It facilitates improved and more broadly adopted implementation of high-quality building commissioning processes. This document complements the BCxA Essential Attributes. The Essential Attributes set a minimum and essential standard of care, while the Best Practice helps define outstanding quality for performing commissioning.

Related Definitions

For commissioning-related definitions used in this document, refer to the separate Commissioning Related Definitions document, available free of charge from the BCxA.

Scope and Purpose of NCCx

The NCCx Best Practice is intended to cover a general commissioning process that applies to the new construction of most building systems and assemblies. It is process-driven, with allowable flexibility for unique conditions. More detail is given where a practice seems unclear of its varied application.

For example, the document will give a general statement about the best practice of functional testing but won't delve into the particulars of the best practice of functional testing of any specific piece of equipment or assembly. Likewise, the document describes the recommended commissioning process.

Still, it does not offer guidance on the systems that should be commissioned or the specific rigor that should be applied since those are project specific.

The only notable exception is that the document specifically addresses building automation systems and controls because they have been, and continue to be, the focus of most—if not all—building commissioning projects.

In many places, Best Practices indicate who is expected to be responsible for completing a given task. Where this information is absent, the responsible party may be any qualified member of the Cx Team.

Phases of NCCx

This updated version of the NCCx Best Practices identifies Ongoing Commissioning (OCx) procedures that can be initiated simultaneously with NCCx. OCx is a building operations process that continuously maintains and improves the Basis of Design systems' performance by efficiently guiding operational procedures with information harvested from energy management and information systems. Correlating and integrating NCCx and OCx activities avoids duplication of effort and minimizes costs. If this is desired, OCx can most cost-effectively be implemented by incorporating the requirements into the NCCx process, from pre-design planning through the occupancy and operations phase.

The BCxA published Ongoing Commissioning Best Practices as a complementary volume. It is available free of charge from the BCxA Resources.

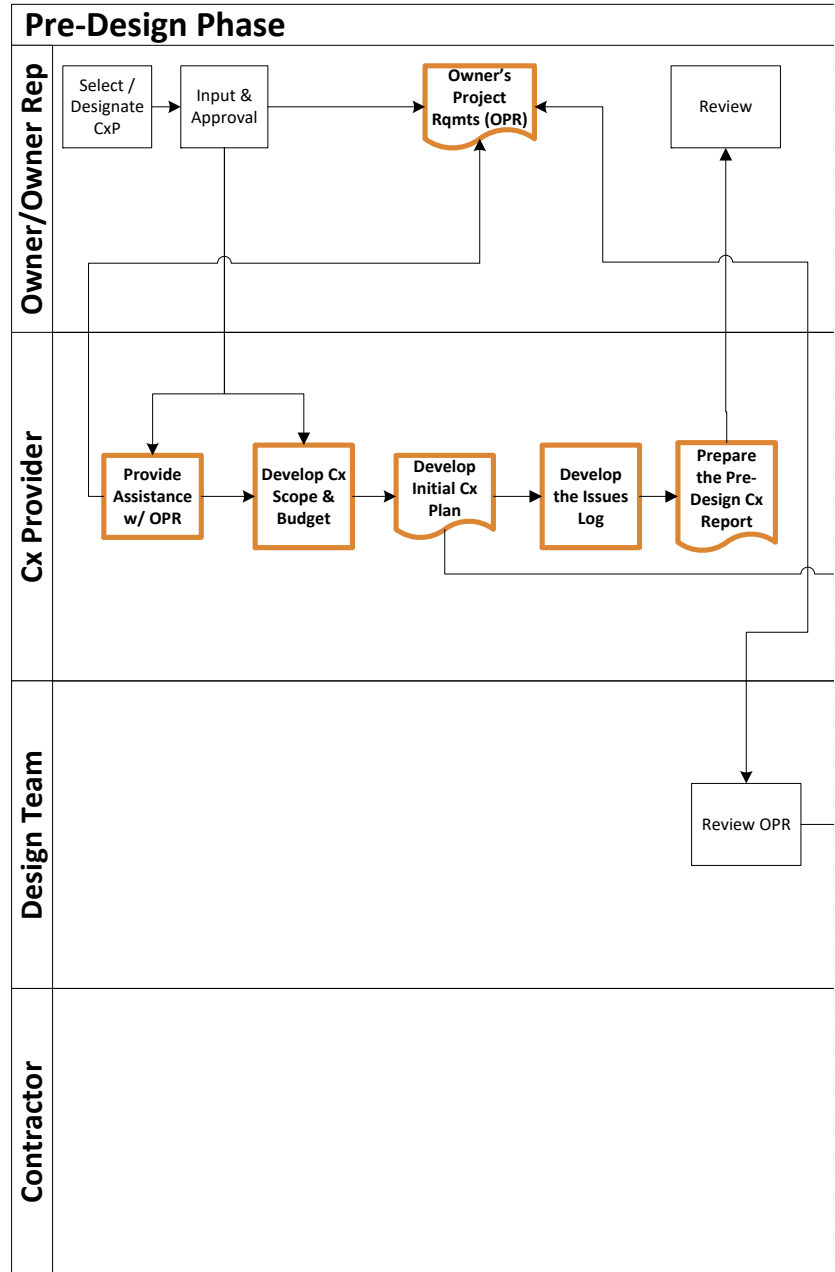
1. Pre-Design Phase

1.1 Introduction/Overview

Commissioning begins in the Pre-Design Phase. The Pre-Design Phase lays the groundwork for the project, defines the Commissioning Plan, and begins the essential team-building process. During this phase, the Design and Commissioning Teams are assembled, and the Owner's Project Requirements (OPR) and the building program are developed. All decisions made in the ensuing phases should be made with reference to the OPR.

1.2 Objectives

- **Identify** the Commissioning Team
- **Develop** the OPR
- **Define** the initial commissioning scope and budget
- **Develop** the initial Commissioning Plan
- **Verify** that the building program is consistent with the OPR.
- **Integrate** commissioning into the overall project delivery process, including ongoing commissioning if planned, and build the Commissioning Team.



1.3 Commissioning Team

Owner/Owner's Representative
Commissioning Provider (CxP)
Design Team
Construction Team Personnel (when available)
Facility Representative
End-User Representatives (when available)

1.4 Pre-Design Activities

- A. The Owner designates an entity as their project representative for commissioning-related activities.**
- B. The Owner selects/designates a Commissioning Provider (CxP) for the project.**

- 1. The CxP directs the overall commissioning process** and makes the final recommendations to the Owner regarding the functional performance of the commissioned building systems.

BCxA Essential Attribute

- 2. The CxP is an objective, independent advocate for the Owner.** *BCxA Essential Attribute*

A conflict of interest exists if the CxP's firm has other project responsibilities or is not under direct contract with the Owner. Wherever this occurs, the CxP discloses, in writing, the nature of the conflict and how the conflict shall be managed.

- 3. In addition to having excellent written and verbal communication skills, the CxP has current engineering knowledge and extensive hands-on field experience regarding:**

BCxA Essential Attributes:

- Building systems commissioning,
- Technical knowledge of building systems,
- Building systems start-up, balancing, testing, and troubleshooting,
- Operation and maintenance procedures,
- The building design and construction processes,
- Automated control systems and control logic.

C. Develop the OPR for the Project

1. The OPR defines the project's expectations, goals, benchmarks, and success criteria. The OPR must be developed with significant Owner input and ultimate approval. The CxP ideally assists the Owner (and, at minimum, reviews results) in identifying the facility's requirements

regarding all building systems and assemblies relative to such issues as design and construction processes and schedules, energy efficiency, sustainability, indoor environmental quality (temperature, humidity, ventilation, lighting, connection to outdoors), safety, security, component and assembly quality, reliability, durability, flexibility, redundancy and cost, staff operations and data management training, operation and maintenance, documentation, commissioning rigor, and monitoring and ongoing commissioning (including OCx Diagnostic Plan and data analytics plans, and other Owner directives).

2. An effective OPR incorporates input early in the project from the Owner, Design Team, Operation and Maintenance staff, and building end-users and is updated throughout the project.
 - a. An effective OPR is developed utilizing accepted methods for obtaining input (e.g., questionnaires, Nominal Group Technique, workshops, etc.).
 - b. The elements of an effective OPR are, at minimum, verifiable and, at best, include success criteria.

D. Define the commissioning scope. The commissioning scope identifies the systems and assemblies to be commissioned and defines the activities and rigor of the commissioning process on a system-by-system basis. Some Owners consider sampling as a means of reducing commissioning costs at the expense of reducing the level of confidence in systems performance provided by the commissioning process. If sampling is requested, the sampling rates, the acceptable failure rate, and repeated work caused by sampling failure should be defined. Sampling may be considered for the following commissioning tasks: design review, submittal review, field installation observation, construction checklist verification, functional testing of multiple identical pieces of non-critical or non-life-safety equipment and assemblies, trend log analysis, and operation and maintenance (O&M) manual review. Typically, a sample rate of 100% is required for life safety and highly mission-critical systems and components.

For each project, **the commissioning purpose and scope shall be clearly defined in the CxP contract.** *BCxA Essential Attribute*

The CxP recommends the commissioning roles and scope for all members of the Design and Construction Teams and, if planned, the OCx team, that the scopes are clearly defined in:

1. Each design consultant's contract
2. The construction manager's contract
3. General Conditions of the Specifications
4. Each division of the specifications covering work to be commissioned.
- 5. The specifications for each system and component for which the supplier's support is required.** *BCxA Essential Attribute*

E. Incorporate commissioning into the project budget and schedule. The design schedule should include the commissioning activities. The project budget should be adequate to support the commissioning activities, and the construction schedule should provide sufficient time to accomplish all commissioning activities. In addition, the commissioning scope should include

provisions for the Occupancy and Operations phase activities, including Ongoing Commissioning if within scope, which is sometimes overlooked by the team focused on the Design and Construction Phases.

F. Develop the Commissioning Plan. Each project is commissioned in accordance with a written Commissioning Plan that is updated as the project progresses. *BCxA Essential Attribute*

The Commissioning Plan:

1. Identifies the systems to be commissioned.
2. Defines the scope of the commissioning process.
3. Defines commissioning roles and lines of communication for each project team member.
4. Identifies the knowledge, skills, and experience required for OCx, if, within scope, that would differ from NCCx.
5. Creates a preliminary OCx Diagnostic Plan, if in scope
6. Estimates the commissioning schedule.

The Commissioning Plan developed during the Pre-Design Phase should detail the development of (and the ongoing management of) the OPR, the development of the Basis of Design (BOD); and the design review process. Other elements of the Plan are typically developed in later phases. Therefore, the Cx Plan should be updated at each formal step of the design and the start of construction.

G. Develop the Issues and Resolution Log format and protocols. The Issues and Resolution Log formats for the Design and Construction Phase should be developed to facilitate the documenting, tracking, and resolution of commissioning-related issues. The CxP manages the Issues and Resolution Logs, which typically contain, at minimum, for each issue a detailed description, the date identified, the party responsible for corrections, issuing party, and completion status. **All findings are documented and distributed as they occur.** *BCxA Essential Attribute*

H. Review the Building Program. The Commissioning team reviews the building program documents and determines whether they are consistent with and support the Owner's Project Requirements.

I. Prepare the Pre-Design Phase Commissioning Report. At the conclusion of the Pre-Design Phase, the CxP develops a report that compiles the commissioning-related documentation from the Pre-Design Phase.

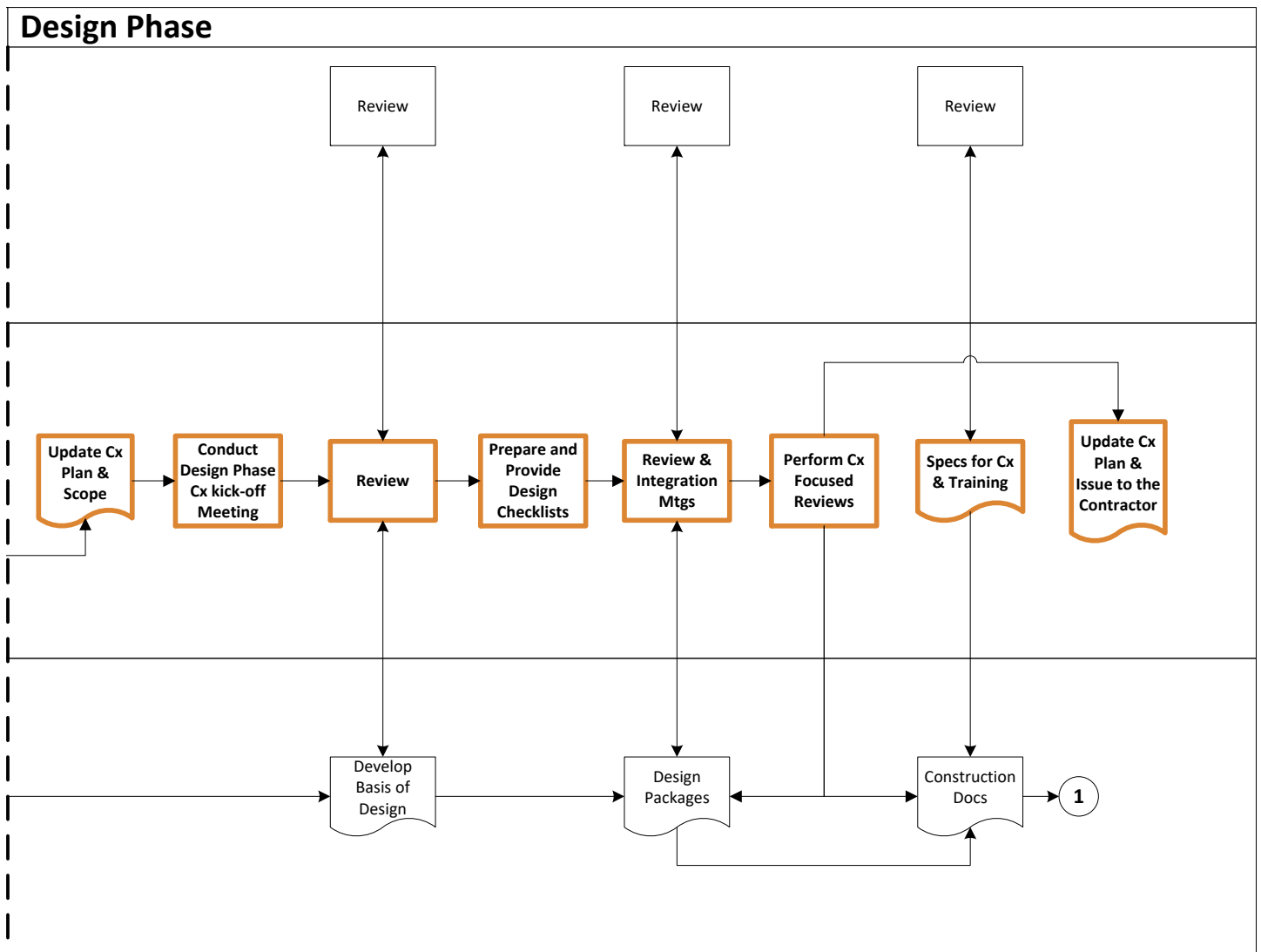
2.0 Design Phase

2.1 Introduction/Overview

During the Design Phase, the commissioning process confirms that design documentations (plans, specifications, Basis of Design [BOD], etc.) are consistent with each other, including commissioning requirements, and meets the Owner's Project Requirements (OPR).

2.2 Objectives

- **Communicate** the commissioning requirements to other project team members.
- **Verify**, through review, that the design documentation is consistent with the OPR and BOD.
- **Ensure** that commissioning requirements are included in the construction documents.
- **Build engagement** and cooperation among the project team members.



2.3 Commissioning Team

Owner Representative
Commissioning Provider (CxP)
Design Team
Construction Team (engaged when known)
Building Operations Representatives
End-User Representatives

2.4 Design Phase Activities

- A. Update the Commissioning Plan and Scope.** If the Cx plan has not been developed, the CxP creates one, as described in the Pre-Design Phase section above, covering the Design Phase in detail and, summarily, the Construction Phase. Updates to the Cx plan during Design should include more detail about the Construction Phase responsibilities, process, new project team members, communication protocols, and schedule for Construction. Later in Design, the Cx Plan is fully developed for Construction. Amendments to the CxP's scope based on the final construction documents and OPR should be made now.
- B. Conduct a Design Phase commissioning kickoff meeting** to review the Commissioning Plan and activities with the Commissioning Team.
- C. Develop a Basis of Design (BOD) (done by the Design Team).**
- D. Review the OPR and BOD for completeness and clarity (by the CxP).** The OPR and BOD should be attached to the construction documents only for the Contractors' information.
- E. Ensure the OPR and BOD documents are updated** and aligned to reflect any Owner-approved changes made during the design process.
- F. Provide focused design checklists** for the Design Team to facilitate important design concepts, lessons learned, and recommendations that promote more concise and integrated construction documents.
- G. Perform commissioning-focused reviews** of the design submissions using experienced qualified CxP or Owner personnel and OCx technology specialists if required.
 - 1. Design reviews should be documented by comment statements appropriate for the level of completeness of the design, with accompanying recommendations. The CxP is respectful in wording comments.
 - 2. In summary, design reviews will accomplish the following:
 - a. Confirm the general quality and completeness of the documents.

- b. Assess discipline-specific compliance with the OPR for commissioned systems and assemblies.
 - c. Confirm that the BOD is accurate and aligns with the OPR.
 - d. Confirm that it is feasible to commission the design.
 - e. Confirm that adequate O&M documentation and training requirements for sustaining performance are included in the specifications.
 - f. Confirm that OCx requirements are integrated into the specifications, if applicable, with provisions for the Diagnostic Plan, OCx Program Plan, Data Monitoring Plan, and OCx operations technology and data analytics.
3. The commissioning reviews focus on verifying that the OPR and BOD are met relative to facilitating the commissioning process, including training and O&M documentation, and ongoing commissioning.
 4. To verify the OPR and BOD, at least for commissioned systems, equipment, and assemblies, the reviews should include reviewing for general document quality and identifying inconsistent or unclear areas that won't meet the OPR or don't represent good practice.
 5. Of particular importance is to perform a thorough review of the building automation controls system, sequence of operations, other building-integrated technologies, and controls systems integration requirements necessary to implement the sequences of operation fully. This review should be completed before late construction documents are issued when it becomes more difficult to make changes.
 6. Early in developing the construction document design packages, the CxP encourages and facilitates integration meeting(s) to coordinate systems and equipment that interact.
 7. The ideal number and timing of reviews vary from project to project. Larger and more complex projects warrant more reviews. The CxP should discuss with the Owner the advantages and disadvantages of more reviews (potential impacts on the design schedule, costs, benefits, etc.). Many, if not most, projects warrant the following reviews with back-checks:
 - a. Schematic Design (primarily a review of the BOD)
 - b. Design Development
 - c. Mid-Construction Documents
 - d. Final Construction Documents (issued for bid including addenda)
 8. The Design Team should provide a written response to each design review comment. These responses should be returned to the CxP and tracked until the design concerns are resolved, with the CxP, Design Team, and Owner all understanding the agreed-upon path forward on each comment. This resolution should be documented in a Design Phase Issues Log managed by the CxP before the Design Team moves significantly into the next phase of the design
 9. At the next design submission, the CxP back-checks the comments from the previous review: i.e., confirms that the agreed-upon resolution for each comment of the prior review has been incorporated into the plans and specifications.

H. Confirm that facility operator training requirements comply with the OPR and are included in the construction documents.

1. The key objective of the Owner's operating staff training is to convey the knowledge and skills required to operate the facility effectively and efficiently. The training includes describing the purpose of the OPR, BOD, and use of the Facility Guide. Training requirements should be thorough and delineated in the construction documents, including training hours (how many times the training should be repeated to cover all shifts) required for all systems and assemblies, and summarized in one section for reference and tracking.
2. Detailed equipment-specific training agendas should be required and should provide trainees with a level of detail appropriate for their job responsibilities. This training would include an overview and specific training on the equipment features, operation, safety, maintenance, alarms, and troubleshooting for typical operators. In addition, specialized training may be necessary to facilitate technical systems management and documentation for OCx, if in scopes such as monitoring-based commissioning (MBCx), energy management and information systems (EMIS), and data analytics.
3. The O&M manual should be utilized in training. This should include requirements for the CxP to provide training on the purpose and use of the Facility Guide. In addition, requirements should be included for verifying training completion and its effectiveness. Video recordings provided to the Owner of most training are considered best practices to accommodate personnel changes. Refer to Section 4.4.U for additional details about training delivery.

I. Develop commissioning specifications to ensure that commissioning requirements are included in the construction documents. The CxP creates or confirms the following:

1. The specifications fully explain all Contractor-related commissioning responsibilities. For clarity and information, summarize the CxP, their sub-consultants, and other non-contractor team members' responsibilities without detailed explanation (Construction Manager [CM], Owner, Design Team). Differentiate between the contractor's responsibilities and the responsibilities of the rest of the team.
2. Commissioning specifications include requirements for:
 - a. Submittals
 - b. Commissioning meetings
 - c. Commissioning schedule development
 - d. Construction checklist development and execution
 - e. Functional test procedure format and development
 - f. Startup process
 - g. Contractor's measuring instrument calibration requirements.
 - h. Test readiness confirmation
 - i. Functional testing process, including management, execution, and documentation.
 - j. Balancing report review and validation of readings in the field with the Contractor.
 - k. Issues log process

l. Deferred functional and seasonal testing and warranty review.

m. Training verification

n. O&M manuals

o. Contractor's Project Turnover Documentation requirements

p. Facility Guide Preparation

q. Electrical Cx management process, if applicable

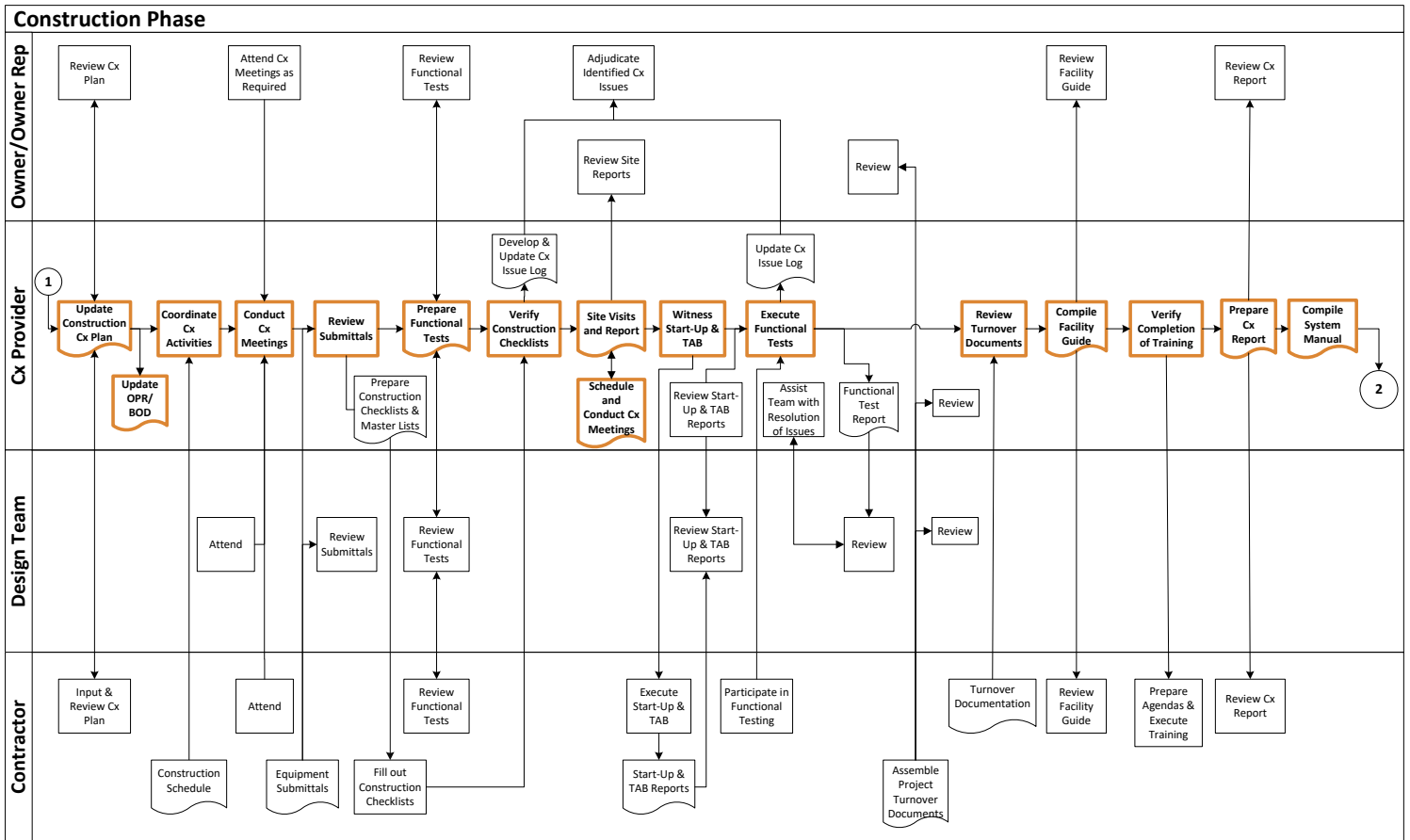
r. OCx requirements, if applicable, in accordance with BCxA Best Practices

3. Sampling. If sampling is requested on a project, the specifications identify the sampling rates, the acceptable failure rate, and who pays for retesting. The Cx specifications should detail the depth, complexity, and level of commission rigor required of the Construction Team. Essential to Cx's success is specifying the functional performance testing scope. The specifications should include an equipment-specific functional testing scope for each piece of equipment or type of assembly or system. Include test form content and format requirements, test rigor, sampling allowed, trending requirements, etc.
4. The Cx specifications should detail the contractors' requirements for functional performance testing readiness and the retesting of failed procedures, including financial ramifications.
5. When determined to be warranted by the CxP, provide supplemental information to bidders one or more representative functional test forms and construction checklists to illustrate the scope and rigor expected and allow the Contractor to bid the work more knowledgeably.
6. Coordinate with the Design Team on the other sections of the specifications for all commissioned systems, equipment, and assemblies to indicate that the components within that specification section will be commissioned and, as applicable, subject to functional testing or commissioning-related activities so they are consistent with the formal commissioning sections. Cross-reference between sections.
7. Include an outline commissioning schedule as part of the specifications, including when commissioning activities related to occupancy permits and project closeout milestones are to be completed. Specifically, the outline schedule should specify whether the successful completion of functional performance testing is to be scheduled before or after the Contractors' substantial completion.
8. The Cx specifications should clearly identify project turnover documentation to be provided by the Contractors to the Owner and CxP. The CxP shall review and include in both the Cx specifications and individual specification sections for commissioned systems, equipment, and assemblies the turnover and closeout documentation required to prepare a complete project-specific Systems Manual. The Contractor's Project Turnover Documentation should include record documents, approved submittals, including controls and balancing, change orders, O&M manuals, and preventive maintenance procedures linked electronically directly from the O&M table of contents, warranties, and training materials.

- J. Update the Cx Plan and design documents to be consistent (near the end of design).** The Cx Plan should include details of the responsibilities and roles of the Contractor, the CxP, Owner, and Designers, which may or may not be articulated in the specifications. The Cx Plan should also include the activities and responsible parties for the Occupancy Phase.

- K. The Commissioning Plan, OPR, and BOD should be provided to the Contractor** during bidding for information, not the obligation, as a supplement to the construction documents to augment the commissioning specifications.
- L. Develop the master list of commissioned equipment, systems, and assemblies.** The Owner may also utilize this list for O&M purposes.
- M. Develop a list of special requirements.** During construction, the CxP, or the Contractor with CxP (with Owner review), should prepare a list of the required warranties, spare parts, training, and closeout documentation from the specifications. The list should be updated as the project progresses. The Owner should accept the completed list, Engineer of Record, or CxP as a condition of final acceptance.

3.0 Construction Phase



3.1 Introduction/Overview

In Construction Phase best practice commissioning, the project team collaboratively provides installation, startup, systems integration, functional performance testing, record documentation, and training to turn over the systems in accordance with the Owner’s documented project requirements. In addition to confirming performance criteria, functional performance testing is designed to provide a performance baseline and benchmarks for the facility’s future operation and ongoing commissioning.

3.2 Objectives

- The Commissioning Plan (Cx Plan), the OPR, and BOD are updated.
- Commissioning Team members understand their roles and responsibilities for the Construction Phase commissioning activities.
- Equipment, systems, and assemblies are installed, maintainable, and functioning in accordance with the OPR, BOD, and contract documents.
- The operations and maintenance (O&M) personnel and occupants are trained and provided with the systems operating materials and documentation needed to sustain Basis of Design systems

performance. Materials and documentation are compiled to facilitate refresher training and training of new staff.

3.3 Commissioning Team

Owner's Representative

Commissioning Provider (CxP)

Design Team

Construction Management Representative

Contractors

Building Occupant or User Group Representatives

Personnel Responsible for the Building's O&M

OCx Team (as applicable)

3.4 Construction Phase Commissioning Activities

- A. Update the Cx Plan, BOD, and the OPR** to reflect changes made to the project. When OCx implementation is planned for the Occupancy and Operations Phase, include relevant functional testing and checklists in Construction Phase documentation and deliverables. As a part of this process, review the master list of commissioned equipment, systems, and assemblies, and the project closeout requirements.
- B. Review requests for information and change orders** for consistency with the OPR.
- C. Consider a web based Cx Management Platform.** Evaluate each project for appropriateness of implementing a web based Cx management platform.
- D. Integrate the Commissioning Schedule with the construction schedule.** The CxP works with the General Contractor to integrate the Cx activities into the construction schedule, with adequate time to complete all commissioning activities.
- E. Conduct a Construction Phase commissioning kickoff meeting.** When the Contractors have mobilized to the site, hold a kickoff meeting to introduce Commissioning Team members and review the specified Cx process, roles and responsibilities, and expectations regarding the schedule and deliverables.
- F. Review submittals.** The CxP reviews submittals of commissioned equipment concurrently with the Design Team in a coordinated process that all parties agree to in advance. Reviews usually focus on issues relative to commissioning facilitation and the OPR.
- G. Hold Construction Phase controls integration meetings.** One or more Construction Phase controls integration meetings are held between the CxP, Designers, controls and equipment

providers and programmers, other appropriate subcontractors, and the building operator(s). Meeting(s) occur after the controls, fire alarm, and emergency power systems submittals are reviewed but before submittal approval. The goal is facilitating resolution of review comments and confirming that the controls, fire alarm, and emergency power systems and sequences of operation are complete, integrated, and consistent with the OPR, BOD, and contact documents.

H. Complete development of project-specific construction checklists. Equipment- and system-specific checklists are prepared using approved construction submittals and installation and startup manuals. Depending on the dynamics of the project team and delivery method, construction checklists may be developed by the CxP for Construction Team acceptance or submitted by the Construction Team for CxP review.

I. Develop functional performance testing procedures and test data forms.

1. The functional performance testing program objectively documents that, at the time of testing, the building systems perform interactively in accordance with the Project Documents. Functional performance test procedures (FPTs) are specifically developed for each project to test all specified functions, modes, sequences of operation, and interaction.
2. FPTs are composed of repeatable, step-by-step procedures with related acceptance criteria and include the test prerequisites, set-up conditions, and data forms for recording performance data and test results. In addition to the detailed step-by-step procedures and acceptance criteria, each FPT should include a summary description of the functions and modes to be tested and the associated test conditions. **These tests are documented to clearly describe the individual systematic test procedures, the expected systems response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion.** *BCxA Essential Attribute* FPTs are distinct from Construction Team quality control testing, such as duct and pipe pressure testing.
3. Functional performance testing typically occurs in phases, or levels, from simple systems components to complete systems and on to integrated systems' interaction and operation. Manual testing of the sequences of operation for dynamic systems is typically best performed in conjunction with, or followed by, the analysis of real-time data trends logged with the central automation system or stand-alone data loggers. This trend log testing, which demonstrates stable real-time performance, is a documented and important part of the FPT procedures.
4. FPTs are usually developed by the CxP, though they are sometimes developed by others and approved by the CxP. FPT development typically occurs soon after construction submittal acceptance, well in advance of startup. The Construction and Design Teams review the FPT procedures and forms for consistency with the Basis of Design and construction contract requirements. After Construction and Design Team acceptance, the FPTs are completed and given to the Construction Team in time for use during controls programming and equipment startup. The Construction Team also uses the FPTs to pre-test the systems and verify acceptance criteria before testing with the CxP.

J. Maintain an Issues and Resolution Log. The CxP maintains an Issues Log to document and track the resolution of commissioning items that do not comply with the construction documents and OPR. The completed Issues Log is a record documenting the specifics of each issue and its

resolution.

- K. Assist the project team with the resolution of issues. The commissioning provider provides constructive input for the resolution of system deficiencies issues identified through commissioning.** *BCxA Essential Attribute*
- L. Conduct regularly scheduled commissioning coordination meetings.** The appropriate number of meetings varies widely depending on the commissioning scope and the project's complexity. These periodic meetings should continue throughout construction and should be timed to coincide with critical construction and commissioning milestones and activities. The CxP scope should include enough commissioning coordination meetings to maintain the integration of commissioning with the overall construction process.
- M. Conduct regularly scheduled site visits.** CxP site visits are typically held in concert with construction or commissioning coordination meetings. The CxP site visits or observations are timed to coincide with critical construction and commissioning milestones and activities. They allow the CxP to continuously review installation and identify commissioning-related issues before systemic issues are extensively repeated.
- N. Execute Construction Checklists and startup and testing procedures (by Contractor).** The Contractor executes the Construction Checklists and other installations, startup, checkout, and testing procedures and documentation (e.g., duct and piping system pressure tests, generator load bank tests, etc.). This documentation is submitted to confirm that the systems are ready for functional performance testing.
- O. Review the Testing, Adjusting, and Balancing (TAB) plan, field measurements, and report.** The TAB plan and report should be reviewed by the CxP concurrently with the Designer. CxP comments and recommendations are provided to the Designer for an integrated review report. The plan should be approved before any TAB work is done. The CxP typically witnesses a sampling of the TAB field measurements as a backcheck of methodology.
- P. Confirm Functional Performance Test Readiness.** The Construction Team confirms that the systems are ready for final functional performance testing (according to the FPTs) before tests are formally executed with the CxP. The procedure for confirming readiness must be specified in the construction contract documents. An efficient and effective approach requires the Construction Team to pre-test the systems utilizing the commissioning FPTs. The Construction Team collaborates with the CxP and other appropriate project team members to resolve issues discovered during pre-testing. After pre-testing confirms the FPT acceptance criteria, FPT readiness certificates, forms, or letters are submitted. Additionally, or alternatively, the CxP might choose to confirm FPT readiness through field observation and review of installation, startup, and Construction Team testing documentation. The CxP reviews the FPT readiness documentation and the Issues and Resolution Log before the formal FPTs are scheduled.
- Q. Coordinate, execute, and document functional testing.** The functional performance testing program objectively verifies that the building systems perform interactively in accordance with the Project Documents. The Commissioning Team is responsible for executing the functional tests. The CxP or designated Cx Team member coordinates, witnesses, and documents the functional performance tests as defined in the Commissioning Plan and specifications.
 1. Perform deferred functional testing during the Occupancy and Operations Phase if required

to demonstrate performance during critical operating conditions (i.e., various weather or other loading conditions not occurring or adequately simulated during the Construction Phase).

2. When testing demonstrates that the systems or equipment fails to meet the acceptance or passing criteria, the issues are logged and resolved, and then retesting occurs until acceptance or passing criteria is successfully demonstrated.

R. Review of Contractor's Project Turnover Documentation. Record documents, warranties, O&M manuals, and other turnover documents, typically provided by the Engineers of Record, are reviewed.

S. Compile the Construction Phase Commissioning Report. The CxP documents every commissioning project with a Commissioning Report that includes:

1. Executive Summary
2. Brief project background, building description, commissioning scope, process, and schedule of activities.
3. Evaluation of the operating condition of each of the systems at the time of functional test completion
4. Deficiencies (issues) that were discovered and the measures taken to correct them.
5. Uncorrected issues and deficiencies
6. Functional test procedures and results
- 7. Description and estimated schedule of required deferred (functional) testing.**
BCxA Essential Attribute
8. List of commissioning field activities
9. Meeting agenda, minutes, and communications
10. Record of operator training completion
11. Description of lessons learned from the project.

In addition, as a best practice, the following should be part of the Construction Phase Commissioning Report or included in the Final Commissioning Report provided later in the Occupancy and Operations Phase:

- a. OPR
- b. BOD
- c. Design Phase reviews
- d. Cx Plan
- e. Cx specifications
- f. Cx submittal reviews
- g. Field reports
- h. Completed construction checklists.
- i. Startup reports

j. Results of Occupancy and Operations Phase activities (deferred testing, near-warranty-end review, baselining, optimization, etc.)

k. List of any OCx functional testing activities remaining to be conducted during the Occupancy and Operations Phase

The report should be submitted to the Owner in electronic copy format unless requested otherwise by the Owner.

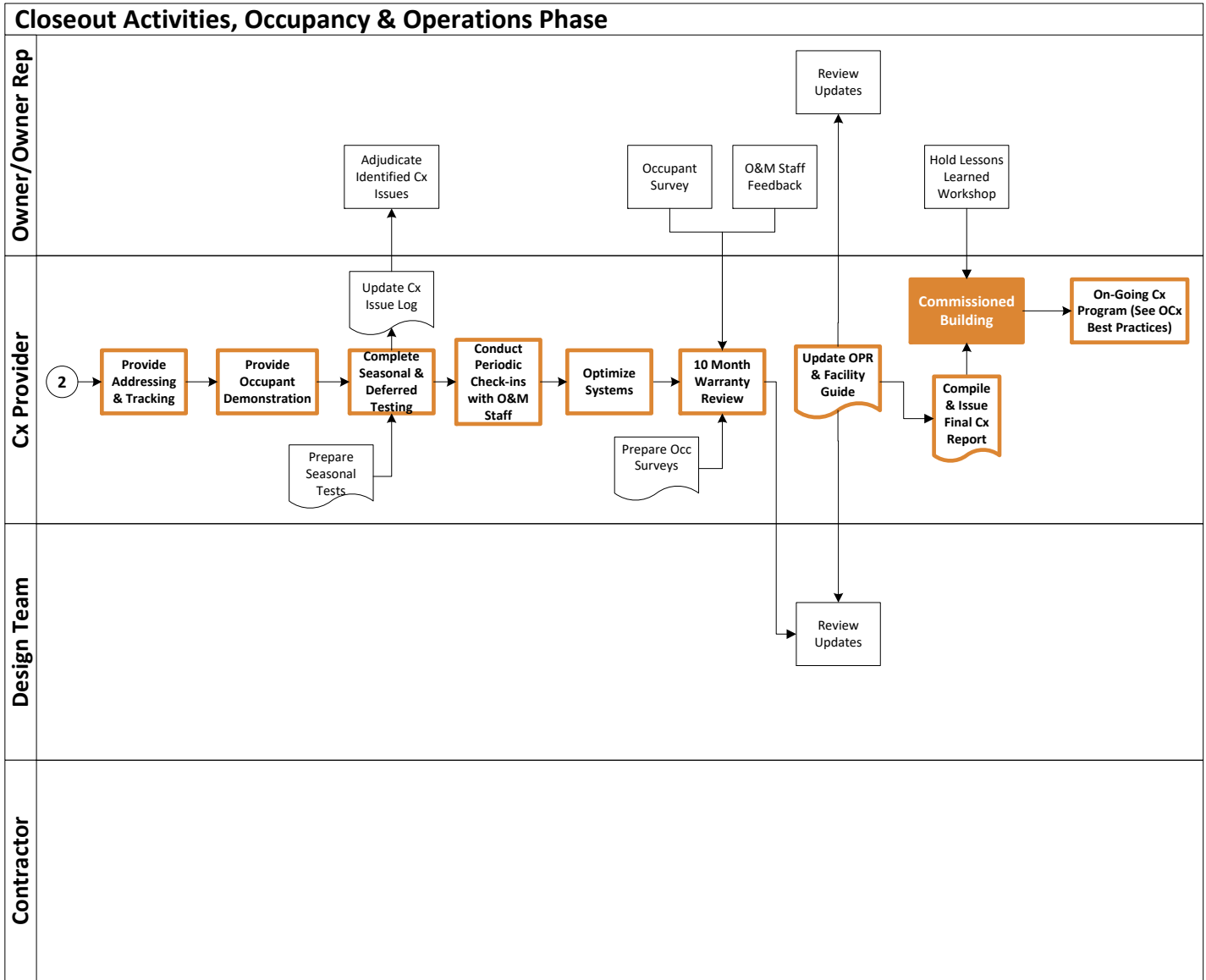
T. Finish Preparing the Facility Guide. The Facility Guide, initially developed during design, is completed based on information obtained during Construction Phase commissioning that helps the Owner's team understand, maintain, and optimize long-term systems operation.

The **Facility Guide** provided by the CxP should include salient information for operating the facility not found in the O&M manuals. For example, the Facility Guide should include the BOD, system single-line flow diagrams, final set points, diagnostic instructions, recalibration information, OCx guidelines, and emergency and maintenance shutdown procedures..

U. Verify training of the Owner's O&M personnel and end-users. The CxP reviews the Contractor's training plan submittal(s) for content, materials, and instructor qualifications compliance with the contract documents. Trainees complete a basic training evaluation form providing feedback regarding effectiveness. Having the CxP participate in, or conduct, key training sessions allows training to include valuable information obtained during commissioning that helps the O&M personnel (and end-users, if applicable) understand, maintain, and optimize long-term systems operation. CxP participation also provides a means of confirming that the training was delivered effectively. Additional training details are found in Section 3.4.

V. Compile Systems Manual. This includes all the Contractor's turnover documentation including; the design and construction documentation, Facility Guide; system specific operation manuals, maintenance information, training information, Cx records, and additional information of use to the Owner during occupancy and operations.

4.0 Occupancy and Operations Phase



4.1 Introduction/Overview

The Occupancy and Operations Phase typically begins at Substantial Completion when the building is turned over to the Owner, though some Construction Phase activities may still be in process. In the Occupancy and Operations Phase, all uncompleted activities from the Construction Phase are finished (project closeout activities), and the long-term processes for ensuring building performance over time are developed and put into place (ongoing maintenance and performance activities).

4.2 Objectives

- **Facilitate** the continued engagement of the Cx team and verify the completion of outstanding Cx issues.
- **Complete** any seasonal and deferred functional testing, O&M and data monitoring and analytics staff training, and occupant orientation.
- **Complete** systems and commissioning documentation.
- **Evaluate** project success.
- **Optimize** building performance.
- **Develop and begin implementing** a plan for commissioning the building over time (Ongoing Commissioning).
- **Survey** occupants, formally check in with operations staff, and assess issues.
- **Benchmark** energy performance and evaluate and track performance over time.

When implementing OCx, the Operations and Occupancy Phase ties directly to the Sustaining Phase as described in the BCxA Ongoing Commissioning Best Practices. For example, the NCCx Functional Testing Plan is followed by a similar document called the Diagnostic Plan, which dovetails into the OCx Plan. The Diagnostic Plan describes how to document/chart building and system metrics, review and analyze monitored and trended data using tools, and collaborate with the Owner's operators and other Commissioning Team members to perform on-site investigations and testing.

4.3 Commissioning Team

Owner/Owner's Representative

Commissioning Provider

Operations Personnel

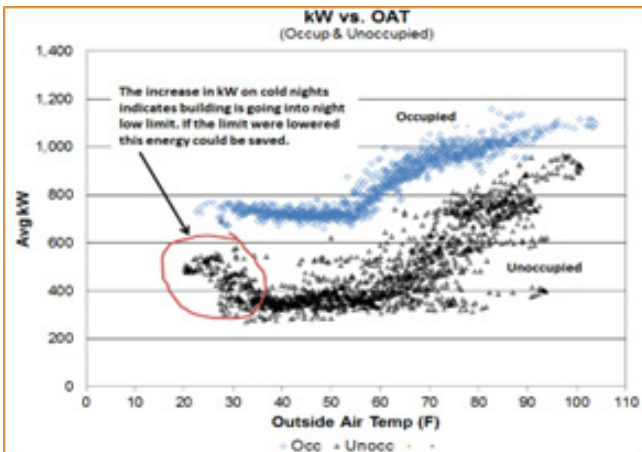
4.4 Occupancy and Operations Activities

Chronologically, Occupancy and Operations Phase activities are grouped into Completion of Project Closeout and Ongoing Performance. These activities are crucial and entail the CxP transferring their engagement from the Owner's Capital Projects (Construction) group to the O&M group, where the CxP encourages the O&M group to incorporate all valuable activities from the list in this section.

Completion of Project Closeout Activities

- Provide timely addressing and tracking** of performance problems and incomplete items from the Issues and Resolution Log. The CxP encourages Owner project managers and Contractors to address issues before the project loses sufficient momentum to deal with them effectively.
- Conduct and verify completion of outstanding O&M personnel training.** According to the contract documents, the Contractor conducts deferred training of the O&M personnel. CxP or Owner personnel evaluate the effectiveness of the training program and make a recommendation as to the need for supplemental training.

- C. Complete seasonal and deferred functional performance testing.** When thorough loading, staging, and capacities are not completed during the initial functional testing, testing is deferred to the appropriate season or load condition during occupancy. This testing is accomplished by or



As a best practice, the CxP should endeavor to complete functional performance testing of systems and assemblies under seasonal weather and full load conditions or occupant interactions. However, actual testing after occupancy may not be feasible or prudent. In this situation, as a next-best practice, the CxP should endeavor to conduct a seasonal or full load condition assessment and observations to document the system or assembly operations to confirm anticipated performance or document any issues observed. This may be referred to as seasonal or deferred observations.

under the direction and approval of, the CxP.

Ongoing Performance Activities

- D. Conduct periodic check-ins with Operation and Maintenance staff.** Two to six times during the first year, as appropriate for the facility, the CxP contacts the operations staff and building manager and asks about building operations and performance issues related to commissioned equipment. The CxP provides technical support and assists within their contract scope to remedy issues or forward them to the Contractor or Design Team.
- E. Optimize systems.** During the Occupancy and Operations Phase, through trend log review and deferred and seasonal testing, the CxP identifies opportunities for fine-tuning system performance, such as optimizing schedules, sequences, and set points, in addition to other perceived improvements and changes to accommodate actual building occupancy and use. The CxP may assist in implementing the changes, which may need to be made after the Contractor's warranty period is over to prevent voiding warranties.
- F. Conduct an occupant survey.** The project team presents a survey to the occupants seven to nine months after move-in but before the Building Operations Review to confirm that a satisfactory indoor environment related to commissioned systems has been achieved for a substantial majority of the occupants. Surveys should address the following elements: thermal comfort, indoor air quality, lighting and daylighting, and acoustic quality. Additional elements may be evaluated when dictated in the Owner's Project Requirements.
- G. Perform a Building Operations Review.** The CxP conducts an on-site review of building operations about 10 months after substantial completion, typically near the end of the warranty period. The Building Operations Review includes a review of the results of the occupant survey and previous check-ins with the O&M personnel, a review of work orders related to commissioned systems, a review of alarm and complaint logs, and a review of selected trend logs of known problem areas and other critical areas to confirm proper performance and equipment operation. Issues identified during the review are documented along with proposed solutions, and the

responsible party for correction is identified. The need for any additional training is also noted. Issues under the original construction contract warranty are provided to the Contractor for resolution. The Commissioning Report is updated to reflect the Building Operations Review and other changes or additions that occur during the Occupancy and Operations Phase.

- H. Compile a Final Commissioning Report.** Commissioning documentation elements listed under the Construction Phase Commissioning Report section above that were not provided at that time are now assembled by the CxP and issued to the Owner.
- I. Evaluate project success.** Key representatives from the Project Design, Construction, Commissioning, Operations, and Maintenance teams participate in a lessons-learned workshop or meeting. The workshop or meeting encourages open discussion and provides additional documentation of project successes; it also identifies opportunities for improvements for future projects relative to the commissioning process. In addition, key metrics and performance indicators of the OPR are evaluated against actual metrics and performance indicators.
- J. Update the Facility Guide.** The Facility Guide should be updated with deferred functional testing, deferred training material, and appropriate documentation from any other changes. Operations personnel are informed how to keep the Systems Operations Guide up to date as changes occur throughout the life of the building.
- K. Ongoing Performance and Persistence Activities.**
Ongoing performance activities are strongly recommended and help building performance persist.
- L. Provide an Occupant User's Guide.** The Guide describes the elements and features in the building that occupants will interact with. Include instructions for use by occupants, as appropriate. Cover the following systems when included in the Cx scope: Lighting controls (schedules, occupancy sensors, daylighting controls, user overrides); thermostats and user adjustments; comfort complaint procedures; time-of-day HVAC schedules by floor; night setback impacts on temperature; overrides; occupancy sensors tied to HVAC; air diffuser design; special room pressure controls; automatic window shades; energy dashboard; and so on. Provide orientation and demonstration to occupants relative to elements of the building systems and the assemblies they interact with.
- M. Develop a preventive maintenance plan.** With input and support from the Owner, and utilizing the O&M manuals and industry resource recommendations, develop a realistic preventive maintenance schedule for commissioned systems and assemblies. This is an enhancement, as necessary, of the links to the PM procedures provided by the Contractor in the O&M manuals that were submitted as part of the Contractor's Project Turnover Documents. When the Owner is developing the PM plan, the CxP should provide input into how appropriate calibrations and elementary tests could be integrated into the PM plan.

The primary goal of commissioning is ongoing, sustained building performance for the long term, and ideally, for the life of the building. As a best practice process complementary to NCCx, OCx assures the building owner that the investment in building systems and the optimization continues to provide optimal performance. The distinction of OCx from other forms of commissioning lies in its application as the continuing, sustaining process of investigation, evaluation, monitoring, and implementation of facility performance measures over time, even as long as the life of the building. OCx Best Practices (download at <https://www.bcx.org/resources/>) can be planned in conjunction with NCCx Best Practices, and implemented when the typical commissioning period for NCCx commissioning services is over, generally one year in duration.

N. Develop and begin implementation of the Ongoing Commissioning Program. The Ongoing Commissioning Program includes periodically repeating selected device span and sensor accuracy verification and functional testing portions of the commissioning process, ongoing monitoring and trending with associated automatic or manual fault detection diagnostics, or a combination of these methods. The likelihood of performance degradation dictates the magnitude, order, and frequency of re-testing components and systems. Therefore, the program should include continuous monitoring of the more energy-intensive systems and those more prone to performance problems.

Benchmarking of building, system, or end-use energy performance and developing correlations to appropriate parameters, such as outside air temperature, should be part of the ongoing Cx Program. In addition, long-term energy monitoring should be put in place, and a method for utilizing the correlations should be employed that alerts the Owner when equipment, systems, and the building are not performing to energy expectations.

- a. Implement new construction commissioning when appropriate.** As changes or additions are made to the building, the new construction commissioning process is applied.
- b. Update the OPR and Facility Guide.** Throughout the life of the building, as alterations are made or as building usage changes, the OPR and Facility Guide may need to be updated to reflect current conditions and requirements.

BCxA Essential Attributes 2018 Update

The BCxA believes that diverse and creative approaches to commissioning benefit the discipline of building commissioning and its clients. Therefore, this document focuses on identifying critical commissioning attributes and components, rather than attempting to dictate a rigid commissioning process. The attributes described herein are called “essential”, because the BCxA believes that they are, in fact, essential to every effective commissioning process. Applying additional commissioning best practices may enhance the process or add commissioning value. However, the BCxA believes that not including any of these Essential Attributes renders a process that becomes something other than formal commissioning. As a result, all BCxA members agree in writing to incorporate all of the Essential Attributes of Building Commissioning into every project for which they serve as a project’s Commissioning Provider, as defined in this document.

In order to clarify context for these Essential Attributes, and because the scope of commissioning varies between projects, the BCxA defines the basic purpose of commissioning as follows: It is the BCxA’s premise that, the basic purpose of building commissioning is to provide documented confirmation that building systems function in compliance with criteria set forth in the Project Documents to satisfy the Owner’s operational needs. Commissioning of existing systems may require the development of new functional criteria in order to address the Owner’s current system’s performance requirements.

The Essential Attributes of building commissioning are:

1. The Commissioning Provider (CxP) is in charge of the commissioning process and makes the final recommendations to the Owner regarding the functional performance of the commissioned building systems.
2. The CxP is an objective, independent advocate of the Owner. If the CxP’s firm has other project responsibilities, or is not under direct contract to the Owner, a conflict of interest exists. Wherever this occurs, the CxP discloses, in writing, the nature of the conflict and the means by which the conflict shall be managed.
3. In addition to having good written and verbal communication skills, the CxP has current engineering knowledge, and extensive hands-on field experience regarding:
 - Building systems commissioning,
 - Technical knowledge of building systems,
 - Building systems startup, balancing, testing, and troubleshooting,
 - Operation and maintenance procedures,
 - The building design and construction processes,
 - Automated control systems and control logic.
4. For each project, the commissioning purpose and scope are clearly defined in the CxP contract.
5. The CxP recommends the commissioning roles and scope for all members of the Design and Construction Teams be clearly defined in:
 - Each design consultant’s contract,
 - The construction manager’s contract,
 - General Conditions of the Specifications,

- Each division of the specifications covering work to be commissioned, and
 - The specifications for each system and component for which the suppliers' support is required.
6. Each project is commissioned in accordance with a written Commissioning Plan that is updated as the project progresses. The Commissioning Plan:
 - Identifies the systems to be commissioned,
 - Defines the scope of the commissioning process,
 - Defines commissioning roles and lines of communications for each member of the project team, and
 - Estimates the commissioning schedule.
 7. On new building commissioning projects, the CxP reviews systems installation for commissioning-related issues throughout the construction period.
 8. All commissioning activities and findings are documented as they occur. Issues are tracked through resolution and acceptance. These reports are distributed as they are generated and included in the final report.
 9. The functional testing program objectively verifies that the building systems within the commissioning scope of work perform interactively in accordance with the Project Documents. Written, repeatable test procedures, prepared specifically for each project, are used to functionally test components and systems in all modes of operating conditions . These tests are documented to clearly describe the individual systematic test procedures, the expected systems response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion.
 10. The commissioning authority provides constructive input for the resolution of system deficiencies.
 11. Every commissioning project is documented with a commissioning report that includes:
 - An executive summary including an overview of the implemented commissioning process, the systems commissioned, the major findings and the operating condition of the systems at the completion of functional testing,
 - Issues that were discovered and the measures taken to correct them,
 - Unresolved operational issues that were accepted by the Owner, along with related recommendations,
 - Operational and ongoing commissioning recommendations based on information discovered during commissioning,
 - Functional test procedures and results,
 - Reports that document all commissioning field activities as they progress, and
 - A description and estimated schedule of required deferred testing.

Endnotes:

- ¹ In this document, the term “building commissioning” refers to commissioning of complete buildings, building systems, and process systems located with the building.
- ² The BCxA recognizes that some projects may benefit from services and deliverables that do not include all of the Essential Attributes of Building Commissioning. While such scopes of work may add value to a project, the BCxA does not recognize them as complete commissioning processes. However, it is not the intent to restrict BCxA members from performing such services when they are clearly described as something other than full commissioning.
- ³ The systems that must be commissioned for a functionally successful project may vary depending on the nature of the project; therefore, specific systems to be commissioned are not listed as essential attributes. However, as a means of maximizing indoor environmental quality and minimizing global environmental impact, the BCxA encourages total building commissioning, including mechanical, electrical, plumbing, automation and building enclosure systems.
- ⁴ In this document, the term Project Documents refers to planning and programming documents, as well as construction documents such as drawings, specifications, submittals, operating procedures and other documents relevant to the construction and operation of the building systems.
- ⁵ The term Commissioning Provider (CxP) is used within this document. Different terms, such as Commissioning Agent, Authority, Manager, etc., may be used in other documents and by other organizations.
- ⁶ Often called functional tests, performance tests, or functional performance test procedures (FPTs), these tests are traditionally focused on confirming that systems function or perform in accordance with clearly defined acceptance criteria, while documenting sufficient data to clearly document a baseline of operation. For more complex or experimental systems, they may also be designed for fine tuning and to establish what the baseline of operation should be.
- ⁷ By the 2nd decade of the 21st century, 2 decades after the Essential Attributes of Building Commissioning were originally adopted, it has become clear that many commissioning stakeholders find tremendous value in using commissioning to facilitate the efficacy of turning over new systems from the installing Contractors to the building operating staff. As 2020 approaches it is becoming more common for Owners to request services such as training by the CxP on information discovered during commissioning and confirming as a part of the commission process that critical operating resources and documentation are provided as a condition of project completion. While this might not be essential for the effective commissioning of all projects it is recommended as good practice for many projects.