

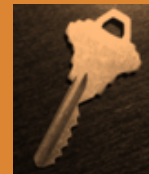
Building Commissioning Association

NEW CONSTRUCTION BUILDING COMMISSIONING BEST PRACTICES

Including

BCA Essential Attributes

Revised and Updated February 2016



Contents

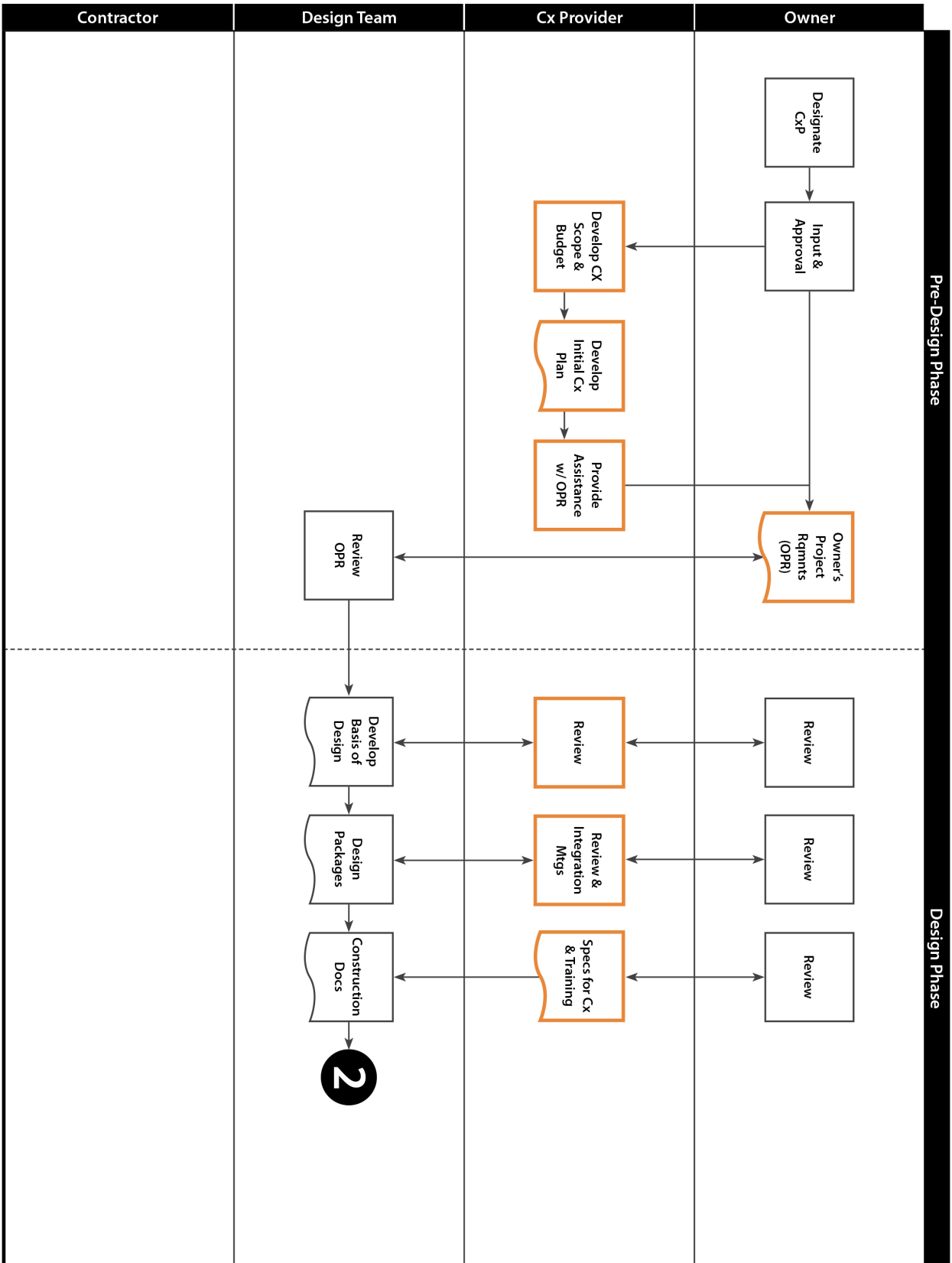
1. Introduction	1
2. Pre-Design Phase	6
Introduction/Overview	6
Objectives	6
Commissioning Team	7
Pre-Design Activities	8
3. Design Phase	11
3.1 Introduction/Overview	11
3.2 Objectives	11
3.3 Commissioning Team	12
3.4 Design Phase Activities	13
4. Construction Phase	19
4.1 Introduction/Overview	19
4.2 Objectives	20
4.3 Commissioning Team	20
4.4 Construction Phase Commissioning Activities	21
5. Occupancy and Operations Phase	27
5.1 Introduction/Overview	27
5.2 Objectives	28
5.3 Commissioning Team	28
5.4 Occupancy and Operations Activities	29
Appendix	
Definitions	1
BCA Essential Attributes	6



The following three pages graphically illustrate the sequence of best practices commissioning and the project team members responsible for tasks:

- **Pre-design Phase**
- **Design Phase**
- **Construction Phase**
- **Occupancy and Operations Phase**

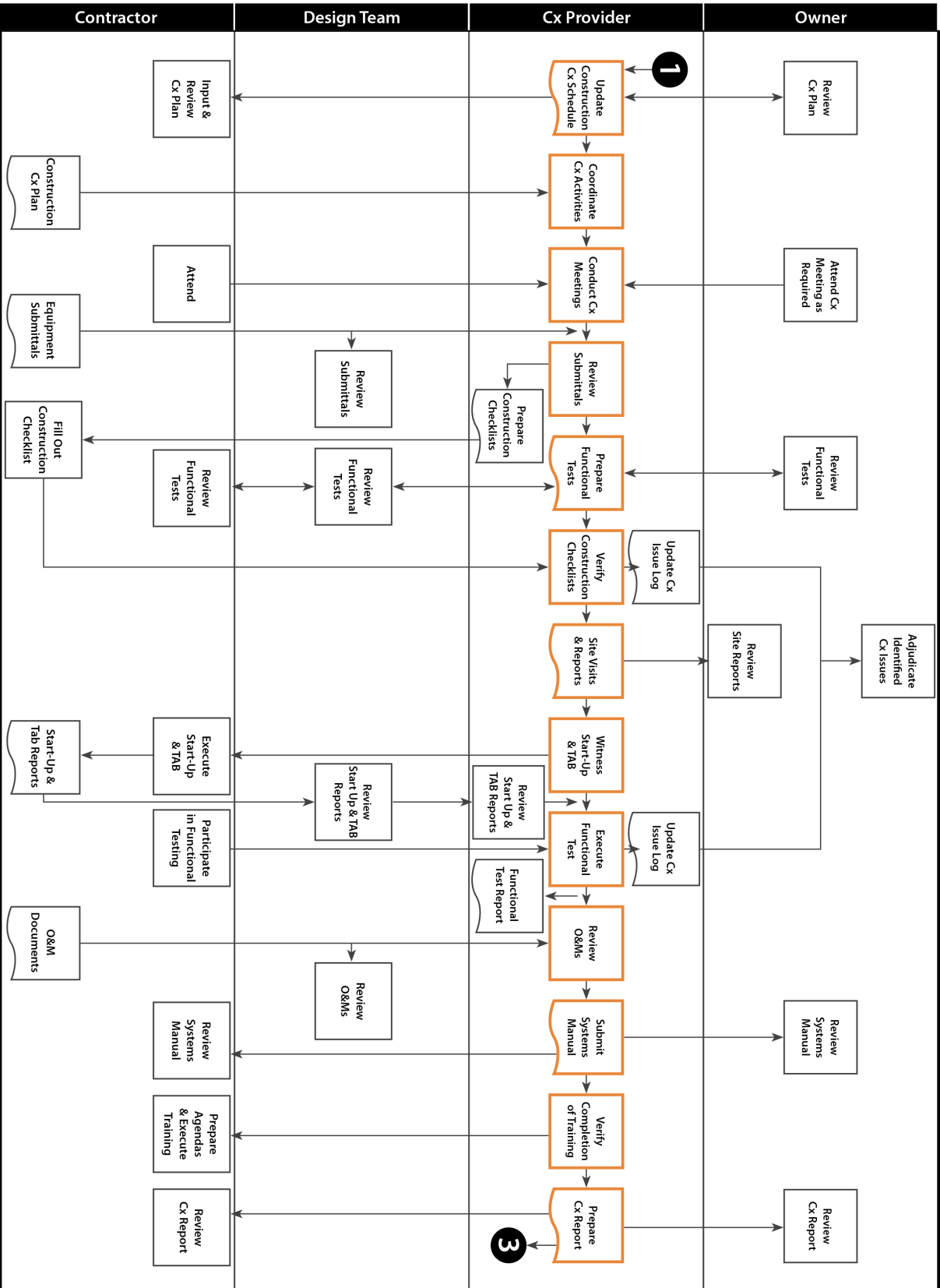
Thereafter, each section of the document begins with the graphic associated with its project phase as listed above.

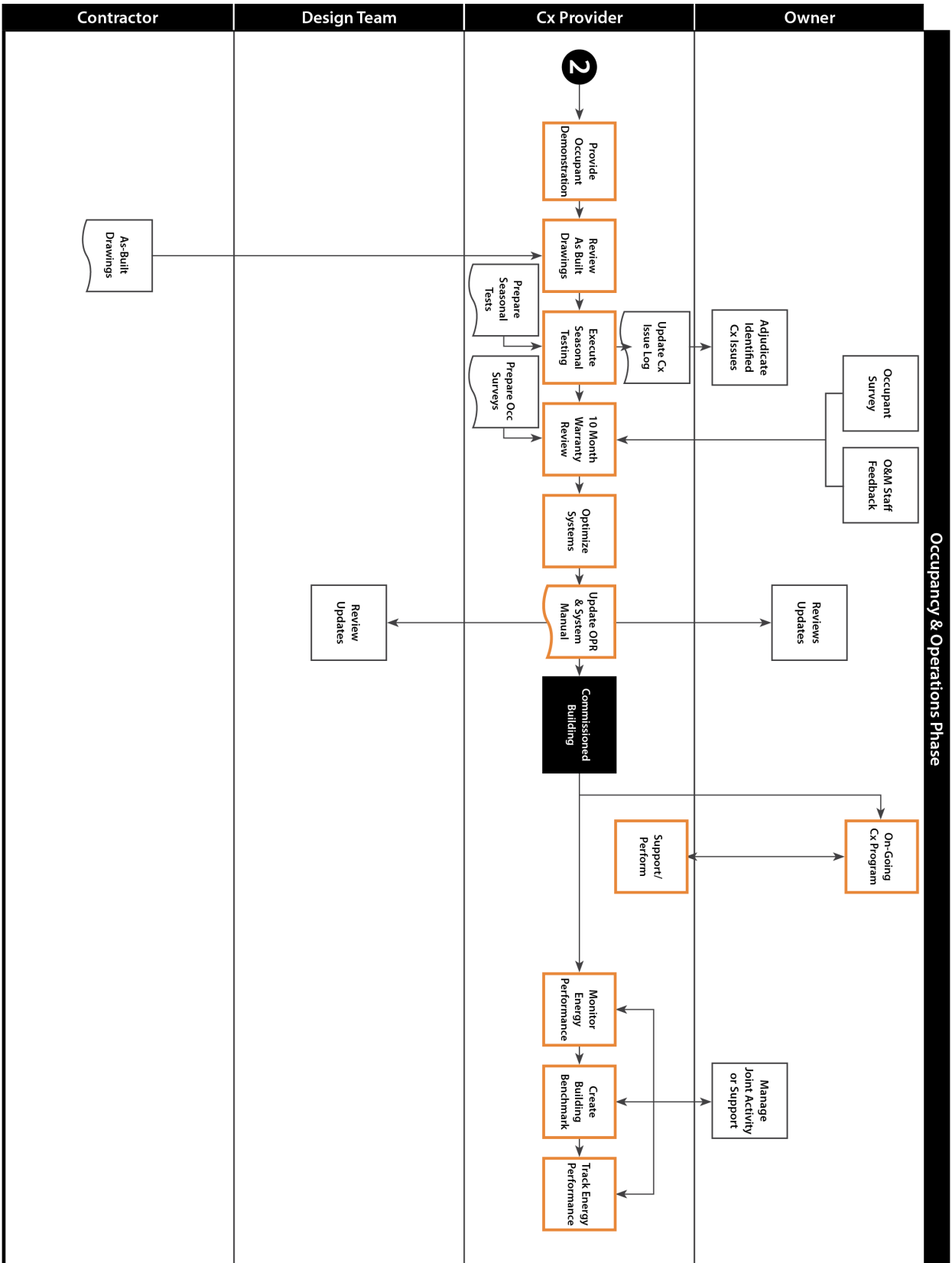


Pre-Design Phase

Design Phase

Construction Phase





1. INTRODUCTION

Overview and Purpose

The Building Commissioning Association (BCA) is composed of commissioning providers, building owners, engineers, architects, contractors, and users of commissioning services in their day-to-day operations. BCA's purpose is to serve the building community by upholding best practices and to be the industry resource for support, education, and advocacy for the profession of building commissioning. Members represent a broad cross-section of interests and are associated with many sectors of the facilities and construction community. The BCA considers that the basic purpose of commissioning is to provide documented confirmation that building systems and assemblies function in compliance with criteria set forth in the Project Documents to satisfy the owner's operational needs.

New construction commissioning has matured as an industry practice. Codes, standards, guidelines, protocols and certifications have been created to define and clarify the commissioning process. Some fundamental elements of the process have been enhanced, modified, redefined or de-emphasized and new elements added. Some elements are not well implemented or understood. Subsequently, the BCA felt that updating the best practices document would help distill the long list of guidelines and longer list of tasks into primary activities that represent the ideal commissioning process, applicable to most building types and projects.

The BCA is committed to defining best practices in the building commissioning industry and to providing documents that describe these practices and offer practical solutions to issues in the industry. Best Practices documents that communicate sound processes and a generally accepted ideal standard of care have been developed by the BCA for both existing buildings and new construction. These Best Practices have been shown over time to be justified in a wide variety of systems and building types.

The definition of best practice creates a benchmark against which the market can gauge quality and professionalism. This Best Practices allow the BCA and other organizations to objectively evaluate commissioning initiatives, processes and guidelines. It facilitates improved implementation of high quality building commissioning processes and promotes standardization of commissioning. This document complements the BCA Essential Attributes, which set a minimum basis for commissioning performance, while the Best Practices help define top quality.

Scope and Level of Detail

The New Construction Building Commissioning Best Practice is intended to cover a general new construction commissioning process that is applicable to most building systems and assemblies. It is necessarily non-specific in most cases, but where a practice seems unclear by its varied application, more detail is given. 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 functional testing of any specific piece of equipment or assembly. The document describes the recommended process of commissioning, but 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 the specific addressing of building automation systems and controls because they have been and continue to be the focus of most if not all building commissioning projects.

Best Practice

The term “best practice” generally refers to the best possible way of doing something. There is no single universally “best” way to apply commissioning in all circumstances. “Best” is taken in context of reasonable cost and schedule limitations; desires for objectivity and rigor; differing building and equipment types, project size, and complexity. The best practice is done to achieve optimal results and is thus a benchmark for quality and professionalism.

Development Process

This BCA New Construction Building Commissioning Best Practices document was developed and refined over a two year period by a volunteer Task Force of BCA practitioners with oversight from time to time by the International Board of

Directors. The Task Force was selected for deep commissioning experience and commitment to the commissioning profession. Each member of the Task Force brings extensive knowledge, practical skills and solutions-based abilities resulting from practice in a wide range building types, with a variety of owners and project teams. They represent a cross-section of regions across the USA.

The Task Force utilized the following primary reference sources: ASHRAE Guideline 0-2005 The Commissioning Process, Guideline 1.1-2007 The HVAC Commissioning Process, the BCA Essential Attributes and Valuable Elements of Commissioning. The Task Force had the latitude to vary from these and other reference documents, but was essentially consistent with them. Other reference sources included the BCA Commissioning Handbook, BCA training curriculum, and the National Institute of Building Science (NIBS) Whole Building Design Guide.

To inform the original development of the Best Practices in 2008, the BCA surveyed its members to identify major issues of concern, areas for improvement, observations about where the industry is going, and where potential pitfalls or roadblocks for the advancement of commissioning for new construction might exist. The BCA Task Force analyzed each concern or issue and identified best practice solutions which were then included in the Best Practices published pursuant to International Board approval in 2011.

2016 Revision

In 2015 the BCA Best Practices Committee worked to revise the New Construction Best Practices utilizing essentially the same process. Newer guidelines and standards were referenced such as ASHRAE Standard 202-2013 Commissioning Process for Buildings and Systems. The revised version includes minor clarifications to a number of terms and concepts. It also includes added detail to the description of construction checklists, test readiness tasks, functional testing scripts, testing rigor, and training and the addition of a systems integration meeting during design, a requirement for trend analysis and facilitation of closing all issues during occupancy and operations.

In addition, for use by practitioners numerous terms and phrases in the 2016 Best Practices document will be linked, by June 30, 2016, to over a hundred

online resource documents illustrating the elements of the commissioning process, creating a reference guide to the practices.

Updates

As the commissioning industry matures and practicing professionals continue to gain experience, the list of best practices set forth here will be refined and modified. Accordingly, suggestions through respective commissioning organizations are invited.

Acknowledgments

The Best Practice Task Force acknowledges the thoughtful and essential contributions made by members of the BCA who provided invaluable input and comments on each draft. Listed alphabetically, the original Task Force consisted of: Mark Miller, Bruce Pitts and Karl Stum (chairs) and Stacy Abbott, J.R. Anderson, Laurie Catey, Brian Hennig, A.J. Kindya, Nathaniel Mostajo, Todd Rindlisbaker, John Villani and Evan Wyner.

The 2016 Best Practices revision was led by Karl Stum as Chair of the BCA Best Practices Committee. The final document was completed by J.R. Anderson, Wade Berner, Daniel Boyton, Doug Cansdale, A.J. Kindya, David Lewis, Jack Schirpke and Robert Smith with technical editing by Diana Bjornskov. The ongoing task of reviewing and editing the BCA library of over 100 commissioning templates and reference documents is in progress and will be completed by Wade Berner, Doug Cansdale, Kevin David, A.J. Kindya, David Lewis, Kevin Knueven, Jack Schirpke, Karl Stum, Gary Sturgill and Mike Watts.

2. PRE-DESIGN PHASE

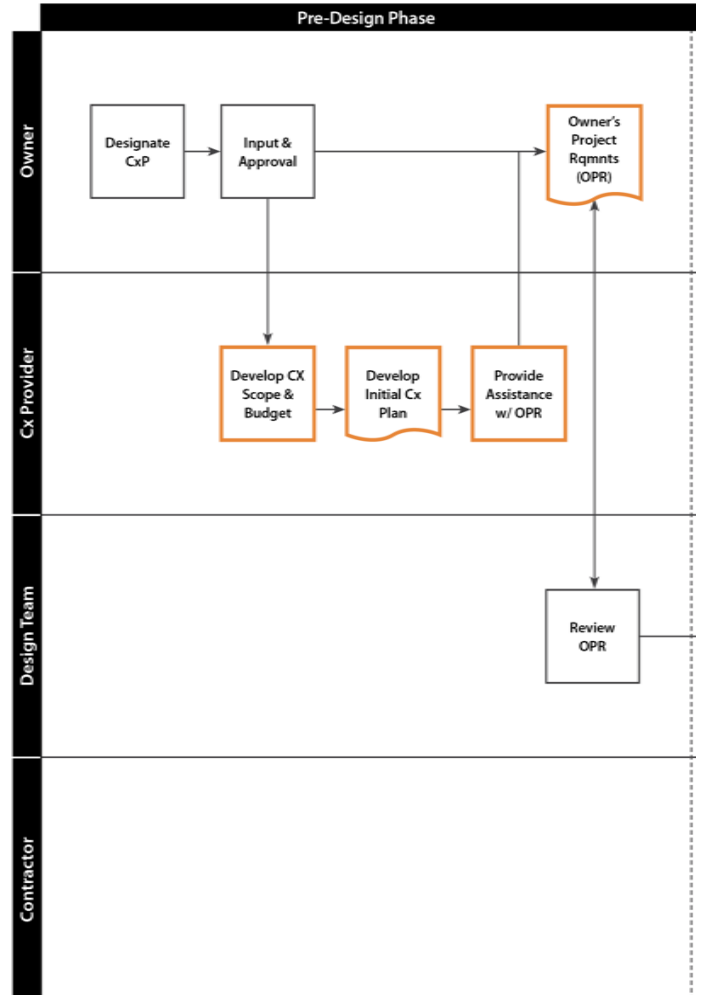
Introduction/Overview

Commissioning ideally begins in the pre-design phase.

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

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 and begin building the Commissioning Team.



Commissioning Team

Owner/ Owner's representative
Commissioning Provider (CxP)
Design team
Operating and Maintenance Personnel (when available)
Construction Team Personnel (when available)
Building End User Representatives (when available)



Pre-Design Activities

- A. **Owner designates a party to act as their project representative** for commissioning related activities.
- B. **Owner selects /designates a Commissioning Provider** for the project.
- 1 **The CxP directs the overall commissioning process** and makes the final recommendations to the owner regarding functional performance of the commissioned building systems. BCA Essential Attribute
 - 2 **The CxP is an objective, independent advocate for the Owner.**
BCA Essential Attribute

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 excellent written and verbal communication skills, **the CxP has current engineering knowledge and extensive hands-on field experience regarding** BCA Essential Attributes:
 - a. Building systems [including building enclosure]
 - b. The physical principles of building systems performance
 - c. Building systems start-up, balancing, [functional] testing and trouble shooting
 - d. Operation and maintenance procedures
 - e. The building design and construction process
- C. **Develop the OPR for the Project**
- 1 The OPR defines the expectations, goals, benchmarks and success criteria for the project. The OPR must be developed with significant owner input and ultimate approval. The CxP typically assists the Owner in identifying the facility's requirements regarding all building systems and assemblies, relative to such issues as energy efficiency, sustainability, indoor environmental quality, safety, security, assembly quality, reliability,



flexibility, redundancy and cost, staff training, operation and maintenance and commissioning rigor.

- 2 An effective OPR incorporates input early in the project from the Owner, design team, operation and maintenance staff and end users of the building and is updated throughout the project.
 - a. An effective OPR is developed utilizing accepted methods for obtaining input (e.g. questionnaires, or 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, schedule and budget. The design schedule should include the commissioning activities. The commissioning scope identifies the systems and assemblies to be commissioned and outlines the activities and the rigor of the commissioning process.

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

The CxP recommends the commissioning roles and scope for all members of the design and construction teams and 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** BCA Essential Attribute

E. Incorporate commissioning into the project budget and schedule. Incorporate commissioning into the project budget and schedule. The project budget should be adequate to support the commissioning activities and the construction schedule should provide sufficient time to accomplish all commissioning activities.



F. Develop the Commissioning Plan. Each project is commissioned in accordance with a written commissioning plan that is updated as the project progresses. BCA 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 communications for each member of the project team
- 4 Estimates the commissioning schedule

The Commissioning Plan developed during the Pre-Design Phase should address in 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 normally developed in later phases. The Cx plan should be updated at each formal step of design and at the start of construction.



G. Develop the Issues Log format and protocols. The Issues Log format should be developed to facilitate the documenting, tracking and resolution of commissioning related issues. Issues Logs typically contain at a minimum a detailed description of the issue, date identified, party responsible for corrections, issuing party and completion status. **All findings are documented and distributed as they occur.** BCA 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 a report is developed that compiles the commissioning related documentation from the Pre-Design Phase.

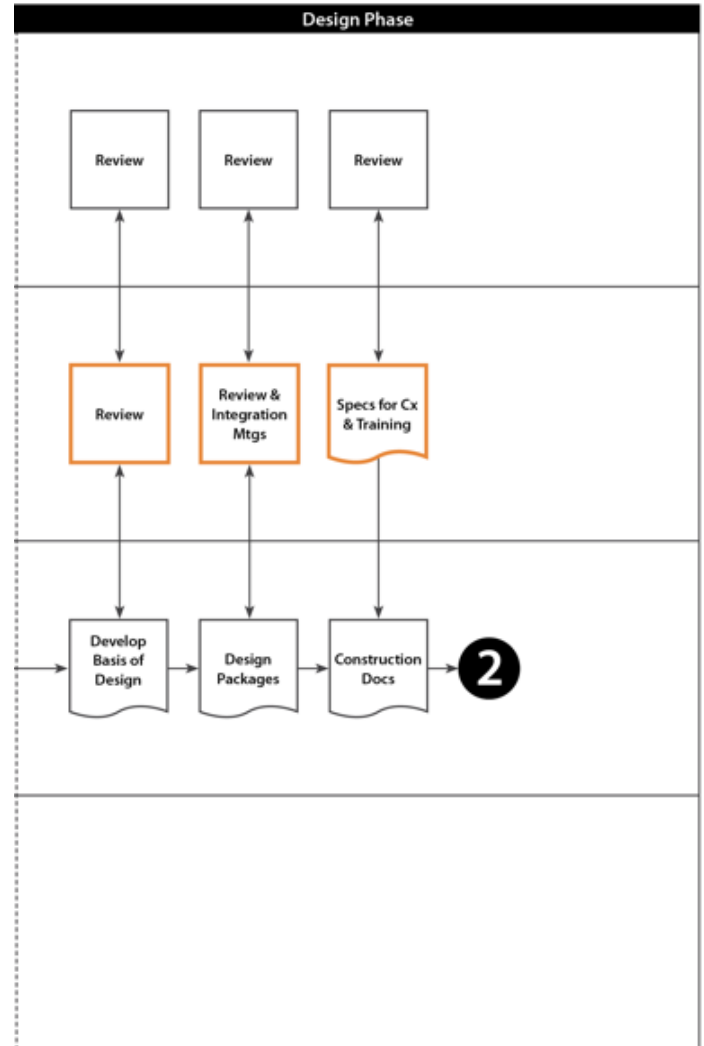
3. DESIGN PHASE

3.1 Introduction/Overview

During the design phase, the commissioning process confirms that design documentation (plans, specifications, Basis of Design (BOD), etc.) are consistent with each other, include commissioning requirements and meet the Owner's Project Requirements (OPR).

3.2 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.



3.3 Commissioning Team

Owner Representative

User Representatives

Commissioning Provider (CxP)

Design Team

Construction Team



3.4 Design Phase Activities

- A. **Update the commissioning plan.** If a plan has not been developed, create one as described in the pre-design phase. Updates to the plan during design may include more detail about the construction phase schedule and responsibilities, new project team members and communication protocols. The commissioning plan should be consistent with the specifications.
- B. **The commissioning plan should be provided to the contractor** as a supplement to the construction documents to augment the commissioning specifications.
- C. **Conduct a design phase commissioning kick-off meeting** to review the commissioning plan and activities with the commissioning team.
- D. **Review the OPR for completeness and clarity.** The OPR should be included as a supplement to the construction documents.
- E. **Ensure the OPR and BOD documents are updated** to reflect any Owner-approved changes made during the design process.
- F. **Perform periodic commissioning-focused reviews** of the design submissions using experienced qualified personnel.
 - 1 Design reviews shall be documented by comment statements appropriate for the level of completeness of the design. The CxP is respectful in wording comments.
 - 2 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 – in particular, for example for HVAC systems, that the reviews confirm that there are adequate access points, test ports, monitoring capabilities and points, and control features. Reviews also verify that energy-efficiency, operation, control sequences, maintenance, training and O&M documentation requirements are consistent with the OPR and BOD.

Depending on the review scope desired by the Owner, extended depth to the design reviews beyond commissioning facilitation may be part of the project.



- 3 Of particular importance is to perform a thorough review of the control logic, sequences of operation and integration issues of the dynamic equipment prior to late construction documents phase when changes can still be made. The review comments are resolved and necessary changes and clarifications are made to the design documents. Making recommendations for a rigorous controls submittal is also warranted.
- 4 Prior to design packages being submitted for review, the CxP encourages and facilitates integration meeting(s) held to coordinate systems and equipment that interact with each other such as M&V monitoring needs between the HVAC and electrical disciplines, interplay with the HVAC building automation system (BAS) and fire alarm and emergency power, lighting and access control with the BAS and integration of the building enclosure with the HVAC system.
- 5 The ideal number and timing of reviews varies 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 review (potential impacts to the design schedule, costs, benefits, etc.). On most projects there should be one early review of the basis of design and at least three design reviews and back-checks during the design process. These three reviews occur ideally at the end of design development and two during construction documents phase, one being at 90-95% completion. Fewer reviews may be warranted for smaller or simple projects.
- 6 The design team should provide written response to each of the design review comments. These responses should be returned to the CxP and issues resolved, with the CxP, design team and Owner all understanding the agreed upon path forward on each comment. This resolution should be documented prior to the design team moving significantly into the next design phase.
- 7 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 from the previous review has been incorporated into the plans and specifications.



- G. Ideally the prime consultant determines and documents the Owner's training requirements in compliance with the OPR** and provides them to the design team for inclusion in the construction documents. The CxP ensures this is reflected in the construction documents.
- H. Training requirements should be thorough.** Detailed equipment-specific training agendas should be required that provide for trainees to be instructed to the level of detail appropriate for their job responsibilities. For typical operators this would include an overview and specific training on the equipment features, operation, safety, maintenance, alarms and troubleshooting. The O&M manual should be utilized in the training. This should include requirements for the CxP to provide training on the purpose and use of the Systems Manual. Requirements should be included for verifying training completion and its effectiveness. Video recordings provided to the owner of most trainings is considered best practice. Refer to Section 4 for additional detail about training delivery.
- I. Develop commissioning specifications** to ensure that commissioning requirements are included in the construction documents.
- 1 In the specifications, fully explain all contractor-related commissioning responsibilities. For clarity and information, summarily list the CxP, their subconsultants, and other non-contractor team member responsibilities without detailed explanation (Construction Manager (CM), Owner, design team). Clearly delineate between the contractor responsibilities and the responsibilities of the rest of the team.
 - 2 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 testing
 - m. Training verification
 - n. O&M manuals
 - o. System Manual requirements
3. Sampling. The specifications should include specifics as to the allowed or required sampling. 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 equipment and assemblies, trend log analysis and operation and maintenance (O&M) manual review. The more rigid random statistical sampling may be superior in certain cases, but there is not agreement among commissioning practitioners as to the efficacy of this method in many situations, and therefore is not recommended generally as a best practice. The owner should clearly define the desired level of sampling, objectivity and rigor in the CxP request for proposals (RFP). CxPs should identify their level of sampling in their proposals, when not explicitly dictated in the RFP.
4. Include an equipment-specific functional testing scope for each piece equipment or type of assembly or system. Include test form format requirements, test rigor, any sampling allowed, trending requirements, etc. Functional testing requirements should also list the modes to be tested, under what conditions and give the acceptance criteria. Identify what testing is and is not part of the formal commissioning process. Delineate between commissioning functional testing and contractor



quality control and other testing specified elsewhere in the specifications (e.g., duct and pipe pressure testing, generator load bank testing, etc.)

5. Normally require the manual testing rigor to include testing each sequence in the sequence of operations and other significant modes, sequences, interlocks, control strategies and alarms and packaged control elements. Refer to Section 4 for detail of the test procedure forms.
6. Require that all larger more complex or life-safety equipment be individually tested. Testing only a sample of some equipment or assemblies may be allowed where such equipment or assemblies are small in physical size or importance, are numerous and are not complex or critical for process or life-safety.
7. Require for systems that are monitored through a building automation system, that trending of systems is conducted as part of the functional testing after manual testing is complete. Trends shall confirm proper operation of all major control loops, equipment staging and time of day scheduling, etc.
8. Provide one or more representative functional test forms to illustrate the scope and rigor of the functional testing and allow the contractor to bid the work.
9. Provide a few example representative construction checklists or detailed checklist requirements to allow the contractors to bid the work. Construction checklists consist of data forms specifically applicable to the project that list tasks to be completed by trade to confirm that the equipment and its components have been properly installed, set up, adjusted, and as applicable started and tuned and ready for permanent operation.
10. Coordinate with the design team on other sections of the specifications that mention functional testing or commissioning-related activities so they are consistent with the formal commissioning sections. Cross reference between sections.
11. Include how completion of commissioning activities relates to occupancy permits and project closeout milestones.

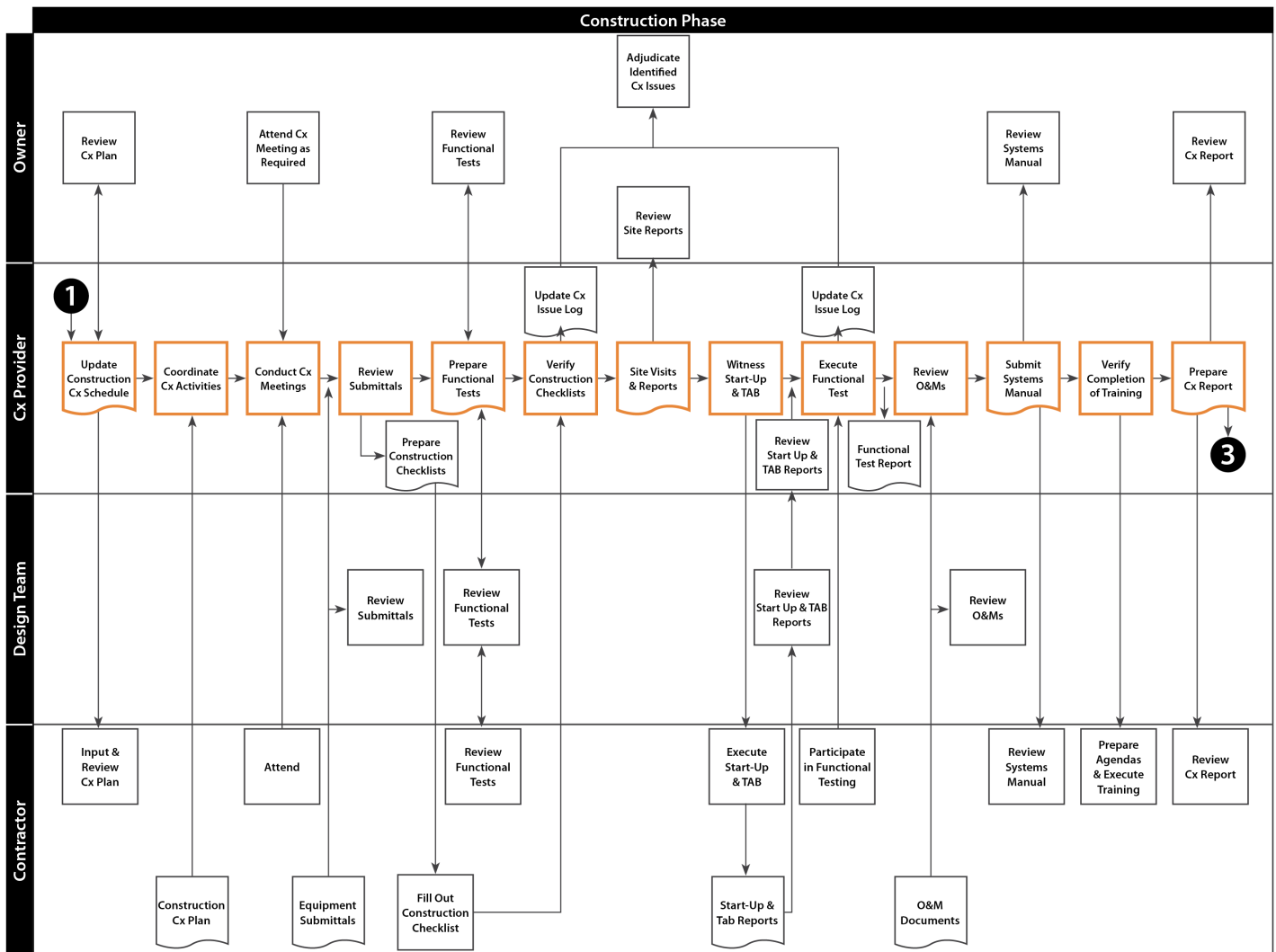


12. With the Owner, determine the scope of the Systems Manual and include requirements for its development in the contract documents for the CxP, design team and contractor. It is recommended that the manual minimally include: table of contents, overview, OPR, BOD, system schematic diagrams, sequences of operation and control drawings, any needed operational information not included in the O&M's such as power outage response and reset procedures, fire alarm matrix, list of user adjustable set points and resets, energy saving features and ongoing commissioning and recalibration guidelines. Additionally, it could include training videos, commissioning reports, BIM models, traditional O&M's and as-built drawings.
13. The CxP works to build cohesiveness and cooperation among the project team by clearly communicating the commissioning process and the role of each party.



4. CONSTRUCTION PHASE

4.1 Introduction/Overview



Successful construction phase commissioning is a well coordinated quality assurance process that encompasses installation, start-up, functional testing and training. During the construction phase the commissioning team works to ensure that equipment, systems and assemblies are properly installed, integrated, and operating in a manner that meets the Owner's Project Requirements (OPR). Functional testing and documentation provide valuable performance benchmarks, acceptance criteria and a baseline for the future operation and ongoing commissioning of the facility.

4.2 Objectives

- ⇒ The Commissioning Plan (Cx Plan) and the OPR, BOD are updated.
- ⇒ Commissioning team members understand their roles and responsibilities for the construction phase commissioning activities.
- ⇒ Equipment, systems, and assemblies are properly installed, maintainable, and functioning properly as required to meet the OPR.
- ⇒ The operations and maintenance (O&M) personnel are provided with complete and proper systems operating documentation.
- ⇒ The O&M personnel, and occupants as needed, are properly trained. Training materials and documentation compiled to facilitate repeating training and training new staff in the future.

4.3 Commissioning Team

Owner's representative

Commissioning Provider (CxP) and sub-consultants

Design team

Construction Management Representative

Contractors

Building occupant or user group representatives

Personnel responsible for the building's O&M

4.4 Construction Phase Commissioning Activities

- A. **Update Cx Plan, BOD, and the OPR** to reflect changes made to the project.
- B. **Integrate the Commissioning Schedule into construction schedule.**
The CxP works with the contractor to integrate the Cx activities into the construction schedule, with adequate time to complete all commissioning activities.
- C. **Conduct construction phase commissioning kick-off meeting.** The kick-off meeting is most effectively held when the contractors have mobilized to the site. The Cx plan is reviewed, along with roles and responsibilities, schedule, and deliverables.
- D. **Review submittals.** The CxP reviews submittals of commissioned equipment concurrently with the design team. Reviews normally focus on issues relative to commissioning facilitation.
- E. **Hold construction phase controls integration meetings.** One or more construction phase integration meetings between the CxP, the designers, the controls contractor, and other appropriate subcontractor(s), and the building operator are held after the controls and fire alarm and emergency power systems submittal review and prior to submittal approval. The goals of this meeting are to facilitate resolution of review comments; verify that the controls system and system sequences are complete, verifiable, coordinated and meet the OPR; and that fire alarm and emergency power systems are coordinated with the controls and each other. Follow-on meetings may be required with the equipment programmers to ensure they understand the project requirements.
- F. **Develop the master list of commissioned equipment, systems and assemblies.** This list may also be utilized by the owner for O&M purposes.
- G. **Complete development of project specific Construction Checklists.**
The checklists should be prepared utilizing the approved construction submittals and installation manuals to make the checklists specific to the



installed equipment. Construction Checklists should be given to the contractor for review and comment prior to beginning installation.

- H. **Develop functional testing procedures and test data forms.** The preliminary functional test procedure forms are developed, usually by the CxP, after the controls submittals and other commissioned systems and assemblies are approved. The contractor and designers review the forms and provide comments back to the CxP. The functional test procedures forms are completed and given to the contractor as soon as possible after acceptance of the submittals, prior to controls programming and equipment start-up. Contractors run equipment through these tests using the forms to verify that the systems are ready for later functional testing with the CxP. Test procedures are developed uniquely for each project and are composed of repeatable, step-by-step narrative procedures and include the test prerequisites and set up conditions, the test process of perturbing or observing the system or set points, the expected outcomes, the acceptance criteria and a place to record the results. Refer to Section 3.4 for details of the scope of the tests.
- I. **Maintain Issue Log.** The CxP maintains an Issues Log to document and track commissioning items that do not comply with the construction documents and OPR.
- J. **Conduct regularly scheduled commissioning coordination meetings.** The number of meetings varies widely depending on the commissioning scope and the project complexity. These periodic construction-phase commissioning meetings should continue throughout construction with major efforts at key periods of the construction and commissioning. However, the CxP scope should include enough commissioning coordination meetings to keep the CxP involved in the project to help the contractors follow the Cx Plan.
- K. **Construction Checklists.** The contractor thoroughly executes the Construction Checklists and other required startup and checkout documentation and submits to the CxP and other required parties in a timely manner so they can be used in developing functional test procedures and to aid confirming test readiness.



- L. Conduct regularly scheduled site visits.** The site visits are often held in concert with the construction or commissioning coordination meetings. Objectives of the commissioning site visits are to verify completion of construction checklists, quality control and proper installation early and to prevent systemic problems when there are numerous similar or identical equipment or devices. For example, the building enclosure commissioning lead could review enclosure mock-ups prior to full installation.
- M. Assist project team with resolution of issues. The commissioning provider provides constructive input for the resolution of system deficiencies.** BCA Essential Attribute
The CxP verifies that the resolution is compatible with the contract documents.
- N. Review Start-up Reports.** The CxP reviews contractor and special agency equipment start-up and quality control testing documents and witness selected or critical startups and contractor quality control tests (e.g., duct and piping system pressure tests, generator load bank tests, etc.).
- O. Review the Testing, Adjusting and Balancing (TAB) plan and report.** The TAB plan and report should be reviewed by the CxP concurrently with the designer and comments and recommendations provided to the designer. The TAB report is typically verified by the CxP witnessing repeatability of original TAB field measurements through sampling techniques prior to or during functional testing as appropriate.
- P. Confirm Functional Test Readiness.** The CxP confirms test readiness through the construction phase activities (field observation, review of start-up reports and construction checklists, observation of control system and equipment operation, including trending and when required review of contractor's pre-tests of system operation) or receiving a letter of test readiness prior to beginning the functional testing program to ensure that the functional testing process will run smoothly. Providing functional test procedures to the contractor early and having them be required to



execute the tests on their own prior to formal functional testing with the CxP is generally recommended for most systems.

Q. Coordinate, execute and document functional testing. The functional testing program objectively verifies that the building systems 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 specified for testing. **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.** BCA Essential Attribute

- 1 The commissioning team is responsible for executing all functional tests. The CxP-designated Cx Team member coordinates, witnesses and documents the functional tests as defined in the commissioning plan and specifications.
- 2 Perform deferred functional testing during Occupancy and Operations phase as required so tests are performed during proper weather or operating conditions.
- 3 Systems and assemblies that fail to meet the passing criteria shall be retested until accepted by the commissioning team.
- 4 When a central building automation system (BAS) is part of the project, trend logs of temperature, flow, current, status, pressure, set points etc. are utilized to confirm proper operation over time of all systems possible. This augments the manual functional testing.



- 5 When critical data is not available through a BAS, monitoring and recording of performance data is accomplished by using stand-alone data loggers.

R. Review contractor as-built documents, warranties and O&M Manuals. Verify that the operations & maintenance manuals comply with the contract documents. BCA Essential Attribute

S. Compile the Construction Phase Commissioning Report. Every commissioning project is documented with a commissioning report that includes:

- 1 An Executive Summary
- 2 An evaluation of the operating condition of the systems at the time of functional test completion
- 3 Deficiencies (issues) that were discovered and the measures taken to correct them
- 4 Uncorrected operational issues/deficiencies
- 5 Functional test procedures and results
- 6 Reports that document all commissioning field activities as they progress
- 7 **Description and estimated schedule of required deferred [functional] testing.** BCA Essential Attribute

In addition, as best practice the following should also be part of the commissioning report:

- a) OPR
- b) BOD
- c) Design phase reviews
- d) Cx plan
- e) Cx specifications
- f) Submittal reviews
- g) Field reports
- h) Completed construction checklists
- i) Start-up reports



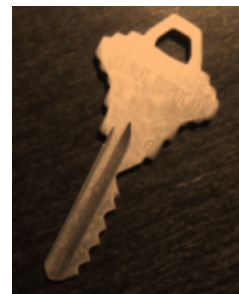
j) Test and balancing report

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

- T. Finish Preparing the Systems Manual.** The Systems Manual, whose preparation began during design, provides the information needed to understand and properly operate, the building systems and assemblies. It should be understandable to people unfamiliar with the project. The Systems Manual documentation is provided by the CxP, Owner, Designers, and Contractors. It is important that the commissioning documentation requirements are included in the construction documents and the designers' contracts. Additional details of the Systems Manual are provided in Section 3.

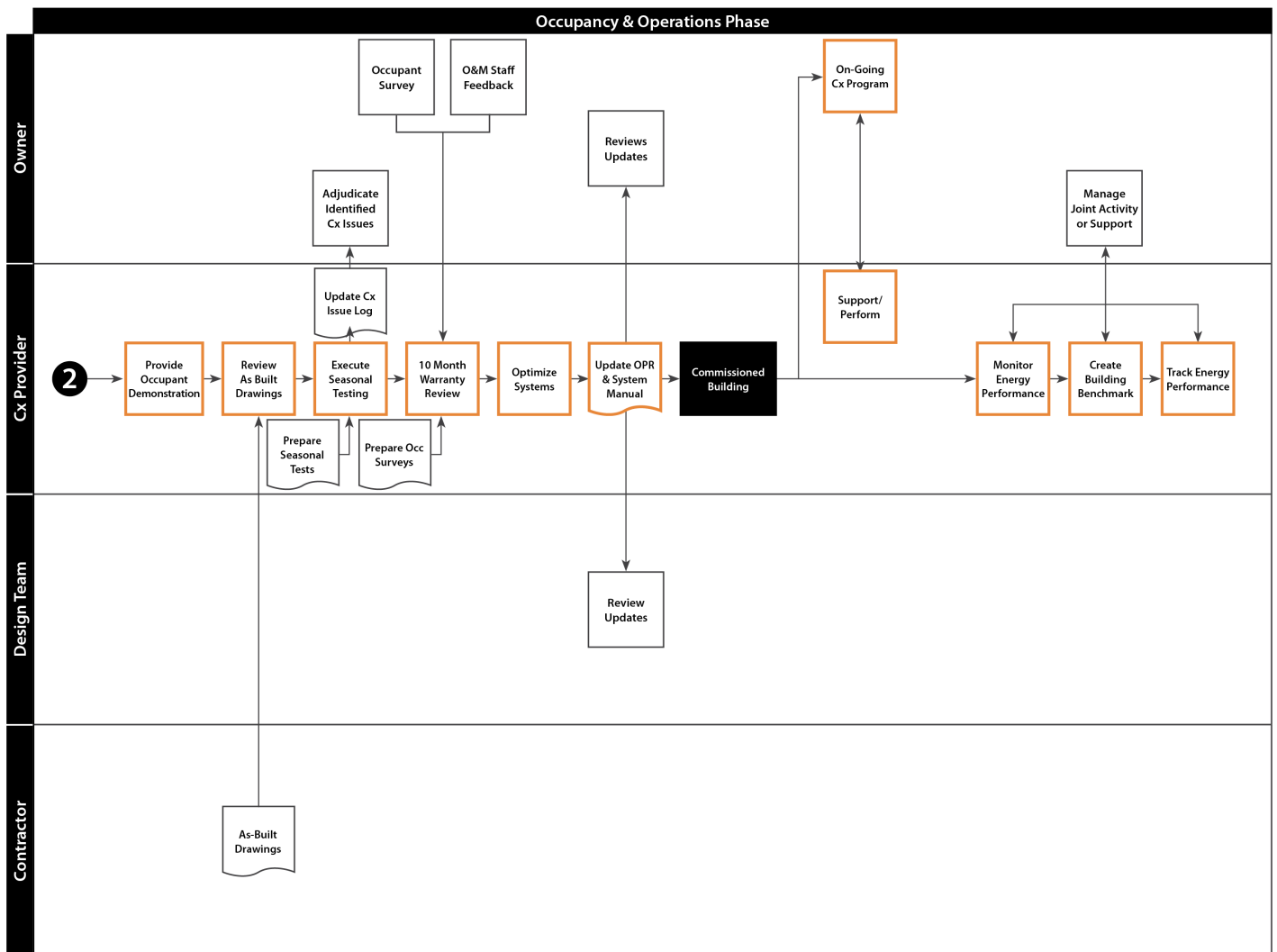
- U. Verify training of the owner O&M personnel and end users. Verify that the training for the owner's operating staff is conducted in accordance with the project documents.** BCA Essential Attribute

The key objective of the owner's operating staff training is to convey knowledge and skills required to effectively and efficiently operate the facility. This includes an understanding of the OPR and BOD as well as training on the purpose and use of the Systems Manual. The CxP reviews the contractor's submittals of the training content, materials, and instructor qualifications to verify that the training will meet the requirements of the commissioning plan and the contract documents. Trainees complete a basic training evaluation form providing feedback regarding effectiveness. The owner ideally should have the CxP participate in key training sessions, including usage of the Systems Manual, and/or use other methods to confirm that the training was delivered effectively. Additional training details are found in Section 3.



5. OCCUPANCY AND OPERATIONS PHASE

5.1 Introduction/Overview

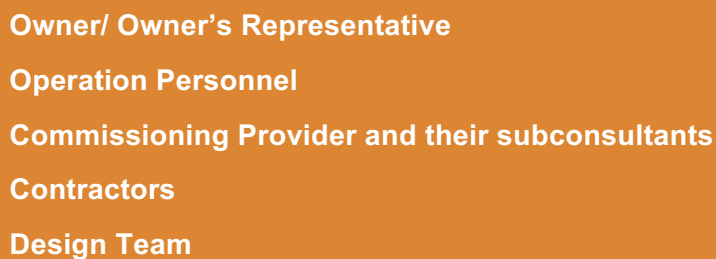


The Occupancy and Operation Phase normally begins at Substantial Completion. This last phase of the New Construction Commissioning focuses on finalizing all uncompleted functional testing, training and project documentation while fine tuning building performance prior to project completion.

5.2 Objectives

- ⇒ **Facilitate** the continued engagement of the Cx team and verify the completion of outstanding Cx issues.
- ⇒ **Complete** any seasonal and deferred functional testing and O&M staff training and occupant orientation.
- ⇒ **Complete** systems and commissioning documentation.
- ⇒ **Evaluate** project success.
- ⇒ **Optimize** building performance.
- ⇒ **Develop and begin implementation** of 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.

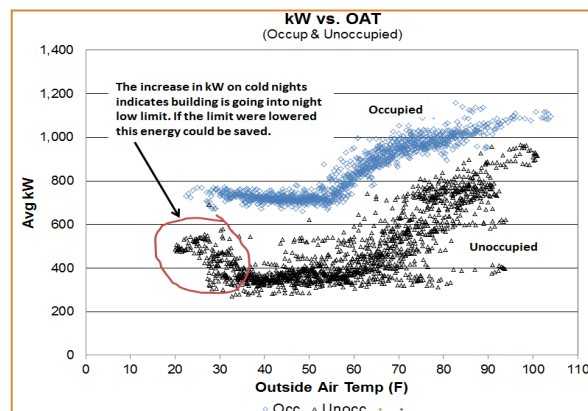
5.3 Commissioning Team



Owner/ Owner's Representative
Operation Personnel
Commissioning Provider and their subconsultants
Contractors
Design Team

5.4 Occupancy and Operations Activities

- A. **Provide timely tracking and reporting** of the status of performance problems and incomplete items from the Cx Issues Log. Encourage project managers and contractors to address issues before the project loses sufficient momentum to effectively deal with them.
- B. **Maintain and update the Issues Log**
- C. **Verify completion of outstanding O&M personnel training.** Conduct deferred training of the O&M personnel. Evaluate the effectiveness of the training program and make a recommendation as to the need for supplemental training.
- D. **Complete seasonal and deferred functional testing.** When thorough testing of loading, staging and capacities can't be completed during the initial functional testing, testing is deferred to the appropriate season or load condition during occupancy.
- E. **Provide occupant orientation and demonstration.** Provide orientation and demonstration to occupants relative to elements of the building systems and the assemblies they interact with.
- F. **Evaluate project success.** Key representatives from the project design, construction, commissioning and operations and maintenance teams participate in a lessons learned workshop. The workshop or meeting openly discusses and documents project successes and identifies opportunities for improvements for future projects. The metrics and performance indicators of the OPR are evaluated against actuals.
- G. **Optimize systems within the OPR.** In the course of their occupancy phase activities of 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 implementation of the changes.

- H. **Update the Systems Manual.** The Systems Manual should be updated with deferred functional testing, deferred training material and appropriate documentation from any optimization. Operations personnel are informed how to keep the Systems Manual up to date as changes occur throughout the life of the building.
- I. **Develop and begin implementation of the Ongoing Commissioning Program.** The Ongoing Commissioning Program includes the repeating of selected device span and sensor accuracy verification and functional testing portions of the commissioning process on a periodic basis, or ongoing monitoring and trending with associated automatic or manual diagnostics, or a combination of these methods. The magnitude, order and frequency of the re-testing of components and systems are dictated by the likelihood of performance degradation. The program should include continuous monitoring of the more energy intensive systems and those more prone to performance problems. Utilization of periodic or continuous automatic fault detection monitoring should also be considered. The Ongoing Cx Program is ideally managed by the Owner, but may need to be outsourced to others.
- J. **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 performance issues related to commissioned equipment. The CxP provides technical support and assists within their contract scope to remedy issues or forward them on to the Contractor or design team.
- K. **Conduct an occupant survey.** The project team presents a survey to the occupants 9 to 12 months after move-in 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 day lighting, and

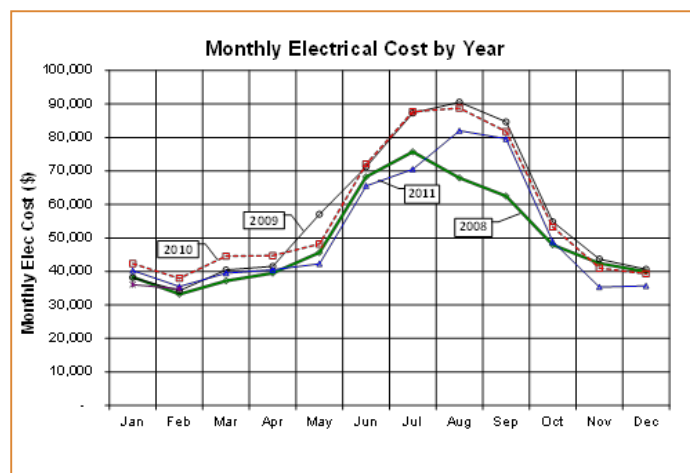


acoustical quality. Additional elements may be evaluated when dictated in the Owner's Project Requirements.

- L. 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 check-ins with the O&M personnel, a review of work orders related to commissioned systems and a review of alarm logs and 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 a proposed solution and identification is made of the responsible party for correction, as well as any need for additional training. Issues under warranty of the original construction contract 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.

- M. Benchmark Building Energy Performance.** After implementing optimization changes, energy performance and independent variables such as time of day, weather, hours of operation and percent occupancy should be monitored for 6-12 months.

Correlations should then be developed between whole building energy use and the variables. Similarly, for larger buildings, correlations for the primary end-uses and major equipment should be developed (heating hot water, fans, DX compressors, chiller plant, lighting, etc.).



- N. Evaluate and track building energy performance.** At the end of one year of occupancy the building's energy performance should be compared to appropriate peer indices such as Energy Star, ASHRAE, regional energy use indices, the OPR, etc. Though this method is only approximate it can identify anomalies that indicate where further investigation of building performance is warranted and improvement is possible.

In addition to the above evaluation to peer indices, once benchmarking and correlating to relevant parameters during or at the end of year one are complete, the building and benchmarked equipment and end-uses can be periodically compared to expected performance benchmarks. This frequency can be every few months, or as frequently as daily via integrated monitoring with the building automation or third party system. Anomalies and excursions from expected should be investigated.

Optionally, a building energy model may be calibrated to as-built and as-operated conditions to evaluate building performance, when there is sufficient budget and interest, though results often have wide error bands leading to inconclusive results.

The monitoring, benchmarking and tracking activities should ideally be managed by the Owner, but may need to be outsourced to others better suited, which may be a specialty firm.

- O. Implement New Construction Commissioning When Appropriate.** As changes or additions are made to the building the new construction commissioning process is applied.
- P. Update the OPR.** Throughout the life of the building as alterations are made or as building usage changes, the OPR may need to be updated in order to reflect current conditions and requirements.



DEFINITIONS

Acceptance. Acceptance is a formal action to declare that some aspect of the project meets defined requirements, thus permitting subsequent activities to proceed.

Architect/Engineer (A/E). See Design Team.

Automated Fault Detection. A technology that monitors components, equipment and/or systems and recognizes when they are failing, they have failed or when environmental conditions have drifted outside optimal capability range. The technology may potentially optimize operation and/or notify personnel, possibly ensuring timely identification and correction of operating and service issues.

Back-Check. A back-check is a verification that an agreed upon solution to a design comment has been adequately addressed in a subsequent design review.

Basis of Design (BOD). A document that records concepts, calculations, decisions and product selections used to meet the Owner's Project Requirements and to satisfy applicable regulatory requirements, standards and guidelines. The document includes both narrative descriptions and lists of individual items that support the design process. Also known as the Design Criteria.

Benchmarks. Benchmarks are the comparison of a building's energy usage to other similar buildings and to the building itself. Developing standards and goals for energy management is a good way to motivate people to improve towards the goal of optimal energy performance. For example, ENERGY STAR Portfolio Manager is a frequently used and nationally recognized building energy benchmarking tool.

Building program. A document prepared by the owner or architect that describes the facility's space and function requirements.

Commissioning Provider (CxP). An entity identified by the Owner who plans, schedules and coordinates the commissioning team to implement the Commissioning Process.

Commissioning Plan. A document that outlines the organization, schedule, allocation of resources and documentation requirements of the commissioning process.

Commissioning Process. A quality-focused process for enhancing the delivery of a project and includes verifying and documenting that the facility and its systems and assemblies are planned, designed, installed, tested, operated and maintained to meet the Owner's Project Requirements.

Commissioning Report. A document recording the activities and results of the commissioning process. Usually developed from the final Commissioning Plan with all of its attached appendices.

Commissioning Review. The commissioning review is a collaborative review of the design professionals design documents for items pertaining to the following: owner's project requirements; basis of design; operability and maintainability (O&M) including documentation; functionality; training; energy efficiency, control systems' sequence of operations including building automation system features; commissioning specifications and the ability to functionally test the systems. This review is not a holistic "peer" review.

Commissioning Specifications. The contract document that details the objective, scope and implementation of the commissioning process as developed in the Commissioning Plan.

Commissioning Team. A team comprised of the CxP, Owner, A/E, Construction Manager/General Contractor, Contractors, maintenance and operations personnel, and occupants. Individuals, each having the authority to act on behalf of the entity he or she represents, explicitly organized to implement the commissioning process through coordinated action.

Construction Checklists. A form used by the contractor to verify that appropriate components are onsite, ready for installation, correctly installed, set up, calibrated and functional.

Contract Documents. The documents binding on parties involved in the construction of this project (drawings, specifications, change orders, amendments, contracts, Cx Plan, etc).

Contractor. The general contractor's or subcontractor's authorized representative.

Construction Documents. Construction documents include all building plans, specifications, general conditions of the contract and supporting documents (such as change orders and submittals) used for the completion of a construction project.

Construction Manager (CM). The owner's representative managing the construction project. Often the construction manager and the general contractor are the same entity.

Construction Team. A team comprised of Construction Manager/General Contractor, sub-contractors and equipment vendors & suppliers.

Data Logging. The monitoring and recording of temperature, flow, current, status, pressure, etc. of equipment using stand-alone' data recorders.

Deferred Functional Testing. Tests that are performed after substantial completion, due to ambient load or occupancy conditions, not allowing a thorough test during the initial testing period.

Design Team. The professionals (architects, engineers and consultants) responsible for developing the project's design concepts, interim and final drawings, specifications and basis of design.

Functional Test. The testing of the dynamic function and operation of components, equipment and systems using manual (direct observation) and monitoring (data-logging/trending) methods.

Functional Test Procedure. A written protocol that defines methods, steps, personnel, and acceptance criteria for tests conducted on components, equipment, assemblies, systems, and interfaces among systems.

Issues Log. A formal and ongoing record of problems or issues – and their resolution – that have been raised by members of the commissioning team during the course of the commissioning process.

Lessons Learned Workshop. A workshop conducted to discuss and document project successes and identify opportunities for improvements for future projects.

Manual Test. Testing using hand-held instruments, immediate control system readouts or direct observation to verify performance (contrasted to analyzing monitored data taken over time to make the ‘observation’).

Monitoring. The recording of parameters (temperature, flow, current, status, pressure, etc.) of equipment operation using data loggers or the trending capabilities of control systems.

Nominal Group Technique. A formal, structured brainstorming process used to obtain the maximum possible ranked input from a variety of viewpoints in a short period of time. The typical approach is a workshop session where a question is presented, the attendees record their responses individually on a piece of paper, the individual responses are recorded on a flip chart without discussion in a round robin fashion, all of the responses are discussed, and then the participants rank their top five responses.

Ongoing Commissioning. The application of commissioning related process activities on an ongoing basis to ensure that operations are being met to support the ongoing improvement of system performance. The Ongoing Commissioning Plan details how these activities and goals will be achieved.

Operations and Maintenance (O&M) Manual. O&M manuals describe key components of each system or piece of equipment and explain how they should be operated and maintained for optimum performance.

Owner's Project Requirements (OPR). A written document that details the requirements of a project and the expectations of how it will function. These include project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information.

Owner's Representative or Project Manager (Owner). The contracting and managing authority for the Owner who oversees the design and/or construction of the project.

Peer Review. A formal in-depth review separate from the commissioning review processes. The level of effort and intensity is much greater than a typical commissioning facilitation or extended commissioning review.

Sampling. Performing observation, review, testing or other verification on only a fraction of the total number of identical or near identical pieces of equipment, drawings, events, etc. Sampling techniques include random statistical sampling and less formal professional judgment methods.

Seasonal Testing. See Deferred Testing.

Systems Manual. A manual organized by system which contains the information needed to optimally operate the building systems. Much of the Systems Manual is not found in traditional vendor O&M Manuals. For reference, ASHRAE includes all maintenance and design documentation in their definition of Systems Manual. *See Appendix C for further details.*

Trending. Monitoring over a period of time with the building automation system.

Verification. The process by which specific documents, components, equipment, assemblies, systems, and interfaces among systems are confirmed to comply with the criteria described in the Owner's Project Requirements or other project documents.

Warranty Period. Period of time in which the contractor is responsible for equipment repairs following turnover to the owner. The warranty period is defined in the construction contract.

BCA ESSENTIAL ATTRIBUTES

BCA considers the following attributes to be so fundamental to effective building commissioning that all members agree in writing to adhere to them whenever they serve as a project's Commissioning Provider:

1. The Commissioning Provider (CxP) is in charge of the commissioning process and makes the final recommendations to the owner regarding 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 and recent hands-on field experience regarding:
 - a. Building systems commissioning,
 - b. The physical principles of building systems performance and interaction,
 - c. Building systems start-up, balancing, testing and troubleshooting,
 - d. Operation and maintenance procedures, and
 - e. The building design and construction process.
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:
 - a. Each design consultant's contract,
 - b. The construction manager's contract,
 - c. General Conditions of the Specifications,
 - d. Each division of the specifications covering work to be commissioned, and
 - e. 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:
 - a. Identifies the systems to be commissioned,
 - b. Defines the scope of the commissioning process,
 - c. Defines commissioning roles and lines of communications for each member of the project team, and
 - d. 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. 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 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 specified for testing. 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 provider provides constructive input for the resolution of system deficiencies.
11. Every commissioning project is documented with a commissioning report that includes:
 - a. An evaluation of the operating condition of the systems at the time of functional test completion,
 - b. Deficiencies that were discovered and the measures taken to correct them,
 - c. Uncorrected operational deficiencies that were accepted by the owner,
 - d. Functional test procedures and results,
 - e. Reports that document all commissioning field activities as they progress, and
 - f. A description and estimated schedule of required deferred testing.

Valuable Elements Of Building Commissioning

Building commissioning is of greatest value to the owner when it provides, throughout the many phases of design and construction, a means of continuously communicating their building systems criteria and rigorously verifying compliance with these. In order to accomplish this BCA recommends that the building commissioning scope include the following elements.

1. Prior to design, assist the Owner in evaluating the facility's requirements regarding such issues as energy conservation, indoor environment, staff training, and operation and maintenance.
2. Review all phases of design and construction documents for:
 - a. Compliance with design criteria
 - b. Commissioning requirements
 - c. Bidding issues
 - d. Construction coordination and installation concerns
 - e. Performance aspects
 - f. Facilitation of operations and maintenance, including training and documentation
3. Review the equipment submittals for compliance with commissioning issues.
4. Verify or manage the scheduling and procedures used for system start-up.
5. Verify that the training for the owner's operating staff is conducted in accordance with the project documents.
6. Verify that the operations & maintenance manuals comply with the contract documents.
7. Prior to expiration of the construction contract warranty, assist the owner in assessing the systems' performance and addressing related issues.