

Caltech

Commissioning Guidelines

Prepared by:

GLUMAC

A Tetra Tech Company

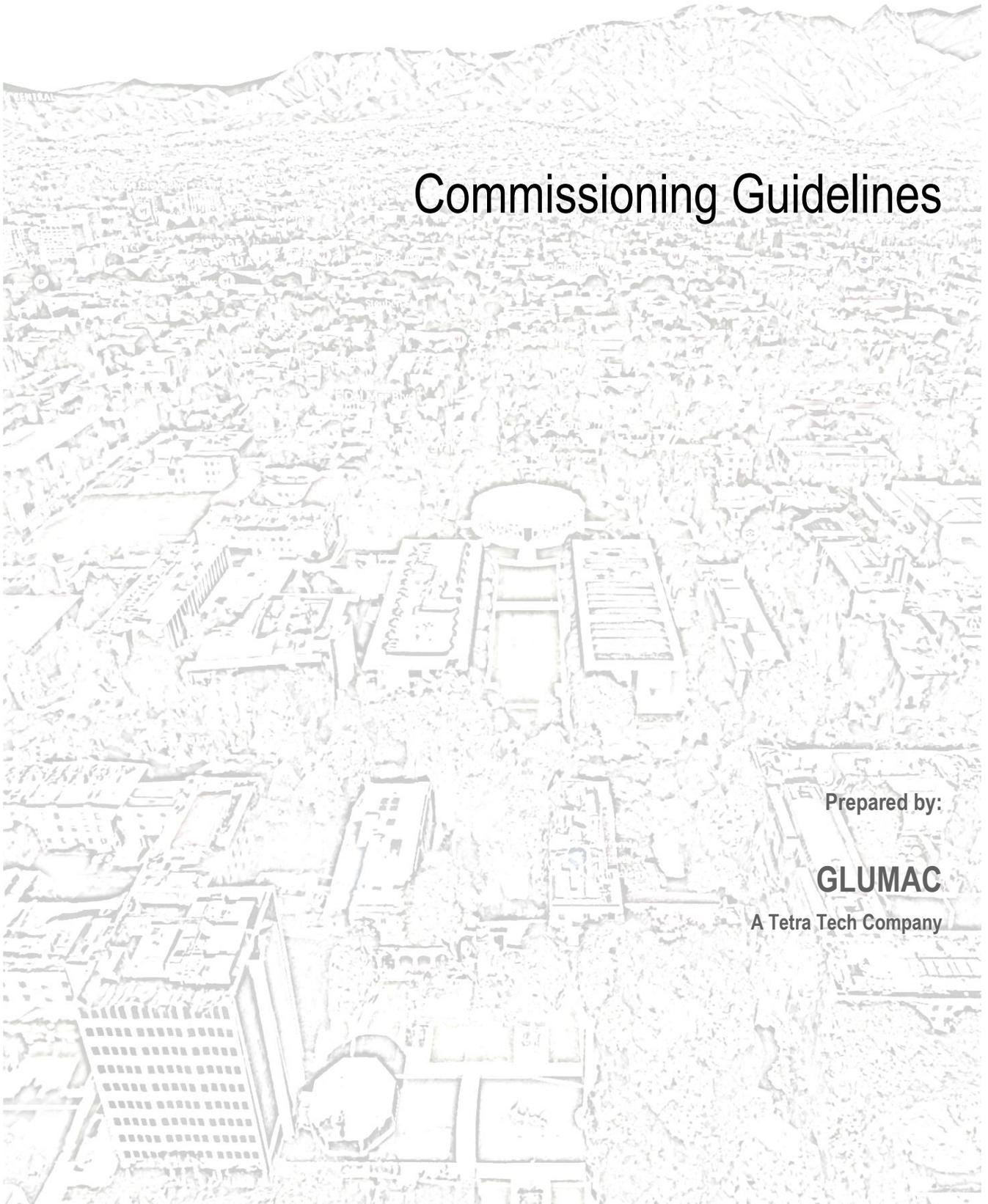


Table of Contents

Revision History	4
01 Introduction	5
01.01 Intended Audience.....	6
01.02 Additional References.....	6
01.03 Definitions.....	7
01.04 Acronyms	11
02 Commissioning Process.....	11
03 Phases.....	13
03.01 Planning	13
03.01.01 RACI Table	13
03.01.02 Organization Chart.....	14
03.01.03 Tasks	14
03.02 Design	22
03.02.01 RACI Table	23
03.02.02 Flow Charts.....	25
03.02.03 Organization Chart.....	26
03.02.04 Issues Resolution.....	26
03.02.05 Tasks	26
03.03 Construction	35
03.03.01 RACI Table	36
03.03.02 Flow Charts.....	43
03.03.03 Organization Chart.....	44
03.03.04 Issues Resolution.....	44
03.03.05 Tasks	44
03.04 Occupancy	64
03.04.01 RACI Table	64
03.04.02 Flow Charts.....	66
03.04.03 Issues Resolution – Occupancy Phase	67
03.04.04 Tasks	67
04 Appendices	69
04.01 Sample Scope for Commissioning Services	70
04.02 Owner Project Requirements.....	77
04.03 Commissioning Specifications	84
04.03.01 Division 1	85
04.03.02 Division 22	108
04.03.03 Division 23	114
04.03.04 Division 26	120
04.04 Commissioning Plan.....	126
04.05 Issues Log.....	131
04.06 Design Review Checklist	133

04.07 Submittal Review Checklist.....	140
04.08 Pre-Functional Checklists	142
04.09 Functional Test Plan	152
04.10 Project Handoff Form.....	155
04.11 Cx Readiness Form	157
04.12 Commissioning Report	159
04.13 Systems Manual	162
04.14 Lessons Learned Workshop	166
04.15 Tier 3 Project Cx.....	169
04.15.01 RACI Table	169
04.15.02 General Cx.....	177
04.15.03 Design Phase.....	177
04.15.04 Construction Phase.....	177
04.15.05 Post-Occupancy.....	178

Charts and Tables

Table 1 RACI Table – Planning Phase.....	14
Table 2 Organization Chart – Planning Phase	14
Table 3 Sampling Rate – CIT Shops.....	16
Table 4 Sampling Rate – CxA.....	16
Table 5 RACI Table – Design Phase.....	23
Table 6 Design Phase DBB Flow Chart	25
Table 7 Design Phase DB Org Chart	26
Table 8 Design Phase DBB Org Chart	26
Table 9 Issues Resolution.....	26
Table 10 Design Phase SD Submittal Flow Chart	28
Table 11 Design Phase DD Submittal Flow Chart.....	31
Table 12 Design Phase CD Submittal Flow Chart.....	32
Table 13 Construction Phase RACI Table.....	36
Table 14 Construction Phase Flow Chart - DBB.....	43
Table 15 Construction Phase Org Chart DB.....	44
Table 16 Construction Phase Org Chart DBB	44
Table 17 Issues Resolution.....	44
Table 18 PFC Flow Chart.....	47
Table 19 FPT – Manual Flow Chart.....	55
Table 20 FPT – Automatic Flow Chart	56
Table 21 Occupancy Phase RACI Table.....	64
Table 22 Occupancy Phase Flow Charts	66
Table 23 Occupancy Phase Org Chart DB.....	67
Table 24 Occupancy Phase Org Chart DBB	67
Table 25 RACI Table – Tier 3.....	170
Table 26 Tier 3 Construction Phase Flowchart.....	176

Revision History

Version	Date	By	Notes
1.0	11/1/20	Glumac	Original Version

01 Introduction

This Caltech Commissioning Guidelines outlines the process for achieving, validating, and documenting the performance of facility elements in meeting the defined objectives and criteria of Caltech. This quality process extends through all phases of all projects, from Planning to Occupancy, with tasks during each phase to ensure verification of design, construction, and operator training meeting the Owner's Project Requirements (OPR). This guideline describes the overall commissioning process in providing a uniform, integrated, and consistent approach for commissioning facilities.

This guideline recognizes and addresses changes in project delivery systems resulting from the evolution of whole-building commissioning into the life cycle, sustainable facilities measurement & verification processes and asset management. This guideline describes methods in performing, measuring, validating, and documenting information in the design and building processes used in constructing new facilities and renovating existing facilities. These commissioning processes are applicable to all building elements used in the construction process.

This guideline applies to all project delivery phases in identifying and applying the whole-building commissioning processes, activities, and requirements for all building elements and assemblies. This guideline provides the format that serves as the pattern for the Commissioning Plan for specific facility elements or assemblies. This common content organization focuses on specific information in achieving a closely coordinated set of documents used together in any combination accommodating specific OPRs. Varying OPRs and applicable levels of commissioning follow a uniform method. Guideline organization also provides for technical commissioning guidelines that avoid repeating general commissioning processes, activities, and requirements, making them more concise in focusing on their technical subjects.

The integration and interdependency of facility elements; i.e., a performance deficiency of one element can result in less than optimal performance by other elements is acknowledged here. To achieve satisfactory performance of the facility and all of its elements, the entire facility should experience commissioning beginning at the inception of the project.

Clear, concise, complete, and correct documenting of the OPR allows for emphasis on commissioning as an integral process for achieving Caltech's expectations. The goal of this process is a fully functional, fine-tuned facility, including all facility elements and assemblies, complete documentation, and a trained operating and maintenance staff at the significant completion milestone. It provides a methodology for implementing the commissioning process to building elements and assemblies for new construction, and major renovations to existing facilities at a level compatible with Caltech input.

Emphasis is placed on documentation that transfers the OPR to the design criteria and construction documents, and on continuity of information from one party to the next, providing value and the opportunity to improve the work process. The Commissioning Plan also provides for the facility operating and maintenance personnel training using actual performance documentation demonstrating the design, installation, and intent of the building elements and assemblies in meeting the OPR. Caltech can use this process in validating their stated objectives and criteria from the significant completion milestone onward. Application of this facility performance documentation provides Caltech with the opportunity to continue the benefits of whole-building commissioning in improving facility performance during the post occupancy phase and beyond.

The commissioning process, beginning at project inception, is a valuable tool to Caltech in controlling the project through each milestone. Structuring the phases of a typical project around the OPR gives Caltech the advantage of continuously monitoring the progress and the cost of the project on a real time basis. This includes planning, design development, construction documents, construction, and occupancy phases.

This guideline describes the total building commissioning process and the responsibilities of the Commissioning Authority and the Owner. Selecting and developing a Commissioning Plan following this guideline assures Caltech of whole-building commissioning meeting the OPR, and a sustainable facility at the time of final acceptance of the work.

01.01 Intended Audience

This guideline is targeted to all parties that are responsible for executing or supporting the commissioning process for Caltech projects.

01.02 Additional References

The documents below are additional references that related to the source material here and can provide additional information on the topics discussed herein.

01.02.01.01 Caltech Design Guide

This document includes general Design Guidelines for the campus as a whole, as well as specific standards for precincts with particular design needs.

<https://dandc.caltech.edu/design-guidelines>

01.02.01.02 Caltech Asset Data Commissioning User Manual

The goal of the user manual is to train CIT Asset Managers, Contractors and Cx Authorities on the use of SAM throughout the design, construction and post occupancy phases of a project. These SAM-related tasks are based on the workflow and responsibilities in Caltech's Smart Commissioning Process Responsibility Matrix

<https://facilitiesoperations.caltech.edu/assetmanagement/asset-data-commissioning/user-manual>

01.02.01.03 ASHRAE Guideline 0 - The Commissioning Process

This Guideline describes the Commissioning Process capable of verifying that a facility and its systems meet the Owner's Project Requirements. The procedures, methods, and documentation requirements in this guideline describe each phase of the project delivery and the associated Commissioning Processes from pre-design through occupancy and operation.

<https://www.ashrae.org/technical-resources/bookstore/commissioning>

01.02.01.04 Standard 202 - Commissioning Process for Buildings and Systems

ASHRAE/IES Standard 202 describes the Commissioning Process, the roles of the principal authorities and stakeholders, and a framework for developing design documents, specifications, procedures, documentation, and reports. It also describes the general requirements for a training program for continued successful system and assembly performance.

<https://www.ashrae.org/technical-resources/bookstore/commissioning>

01.02.01.05 California Building Energy Efficiency Standards - Title 24

California's energy code is designed to reduce wasteful and unnecessary energy consumption in newly constructed and existing buildings. The California Energy Commission updates the Building Energy Efficiency Standards (Title 24, Parts 6 and 11) every three years by working with stakeholders in a public and transparent process.

<https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards>

01.02.01.06 U.S. Green Building Council - Leadership in Energy and Environmental Design

To support the design, construction, and eventual operation of a project that meets the owner's project requirements for energy, water, indoor environmental quality, and durability.

<https://www.usgbc.org/>

01.02.01.07 Caltech Environment, Health, and Safety

Caltech is committed to complying with all applicable laws and regulations concerning construction activities on campus. The purpose of the Caltech Construction Safety Guide is to reduce incidents that may cause personal injury, property damage, and/or liability losses due to construction work of Caltech-owned buildings and facilities.

<https://safety.caltech.edu/>

01.03 Definitions

The following terms and phrases are used throughout this document.

Acceptance

A formal action, taken by a person with appropriate authority (which may or may not be contractually defined) to declare that some aspect of the project meets defined requirements, thus permitting subsequent activities to proceed.

A/E

A/E is defined as the architect and engineer assigned to the project either by the owner or as part of the design build team. This includes the Architect or Record (AOR) and Engineer of Record (EOR) which are integral to the commissioning process. Approvals referenced in this document by the A/E shall be performed by the AOR or EOR as applicable.

Asset Data Commissioning

The process of collecting, standardizing and conforming operational building and equipment data from construction documents into a database format that can be loaded to Caltech's IWMS.

Basis of Design (BOD)

A document that records the 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.

Checklists

Verification checklists that are developed and used during all phases of the commissioning process to verify that the Owner's Project Requirements are being achieved. This includes checklists for general verification, plus testing, training, and other specific requirements.

Commissioning (Cx)

See Commissioning Process.

Commissioning Authority (CxA)

An entity identified by the Owner who leads, plans, schedules, and coordinates the commissioning team to implement the Commissioning Process.

Commissioning Plan (Cx Plan)

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

Commissioning Process (Cx Process)

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

Commissioning Process Activities (Cx Process Activities)

Components of the Commissioning Process.

Commissioning Report (Cx Report)

A document that records the activities and results of the Commissioning Process. Usually developed from the final Commissioning Plan with all of its attached annexes.

Commissioning Team (Cx Team)

The individuals who through coordinated actions are responsible for implementing the Commissioning Process.

Construction Checklist

A form used by the contractor to verify that appropriate components are on-site, ready for installation, correctly installed, and functional. Also see checklists.

Construction Documents

These include a wide range of documents that vary from project to project and with the Owner's needs and with regulations, laws, and countries. Construction documents usually include the project manual (specifications), plans (drawings), and general terms and conditions of the contract.

Contract Documents

These include a wide range of documents that vary from project to project and with the Owner's needs and with regulations, laws, and countries. Contract documents frequently include price agreements, construction management process, subcontractor agreements or requirements, requirements and procedures for submittals, changes, and other construction requirements, timeline for completion, and the construction documents.

Coordination Drawings

Drawings showing the work of all trades to illustrate that equipment can be installed in the space allocated without compromising equipment function or access for maintenance and replacement. These drawings graphically illustrate and dimension manufacturers' recommended maintenance clearances.

Design Checklist

A form developed by the CxA Team to verify that elements of the design are in compliance with the OPR.

Design Guide

A document to provide durable, maintainable and sustainable solutions for the various standards and building systems, infrastructures, and renovation projects at California Institute of Technology.

Design Review, Code or Regulatory

A review of a document conducted by staff or designated entity of an authority having jurisdiction to determine whether the content of the document complies with regulations, codes, or other standards administered by the jurisdiction.

Design Review, Commissioning (Cx Design Review)

A review of the design documents to determine compliance with the OPR, including coordination between systems and assemblies being commissioned, features and access for testing, maintenance, and other reviews required by the OPR and Cx Plan.

Design Review, Constructability

The review of effective and timely integration of construction knowledge into the conceptual planning, design, construction, and field operation of a project to achieve project objectives efficiently and accurately at the most cost-effective levels to reduce or prevent errors, delays, and cost overruns.

Design Review, Peer

An independent and objective technical review of the design of the project, or a part thereof, conducted at specified stages of design completion by one or more qualified professionals for the purpose of enhancing the quality of the design.

Evaluation

The process by which specific documents, components, equipment, assemblies, systems, and interfaces among systems and their performance are confirmed with respect to the criteria required in the OPR.

Issues Log

A formal and ongoing record of problems or concerns—and their resolution—that have been raised by members of the Commissioning Team during the course of the Commissioning Process.

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 Process

A continuation of the Commissioning Process well into the Occupancy/Operations Phase to verify that a project continues to meet current and evolving Owner's Project Requirements. Ongoing Commissioning

Process Activities occur throughout the life of the facility; some of these will be nearly close to continuous in implementation, and others will be either scheduled or unscheduled (as needed).

Owner's Project Requirements (OPR)

A document that details the functional requirements of a project and the expectations of how it will be used and operated. These include project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information. (The term Project Intent is used by some owners for their Commissioning Process Owner's Project Requirements.)

Project Tier

Caltech uses a TIER Protocol to classify the scope of Cx projects based on the level of project complexity.

This guide is intended to be used for Tier 4 projects only which includes all new construction and other large projects which include scope for MEP systems and controls for HVAC and/or lighting. Includes SkySpark integration to DDC and Asset Management. May be a LEED v4 project. Includes significant design review, including sequence of operations and TAB plan. Includes post-occupancy testing.

Quality-Based Sampling

A process for evaluating a subset (sample) of the total population. The sample is based on upon a known or estimated probability distribution of expected values; an assumed statistical distribution based on upon data from a similar product, assembly, or system; or a random sampling that has scientific statistical basis.1, 2, 3

RACI (Responsible, Accountable, Consulted, Informed) Table

Caltech uses a RACI matrix to assign roles and responsibilities in order to achieve key milestones during a Cx project. Shows key activities as rows and participating parties as columns. For each participating party is indicated as to whether they're responsible, accountable, consulted, or informed.

Recommissioning

An application of the Commissioning Process requirements to a project that has been delivered using the Commissioning Process. This may be a scheduled recommissioning developed as part of an Ongoing Commissioning Process, or it may be triggered by use change, operations problems, or other needs.

Retro-Commissioning

The Commissioning Process applied to an existing facility that was not previously commissioned. This guideline does not specifically address retro-commissioning. However, the same basic process should be followed from Predesign through Occupancy and Operations to optimize the benefits of implementing the Commissioning Process philosophy and practice.

Systems Manual

A system-focused composite document that includes the operation manual, maintenance manual, and additional information of use to the Owner during the Occupancy/Operations Phase.

Test Procedure

A written protocol that defines methods, personnel, and expectations for tests conducted on components, equipment, assemblies, systems, and interfaces among systems.

Training Plan

A written document that details the expectations, schedule, budget, and deliverables of Commissioning Process Activities related to training of project operating and maintenance personnel, users, and occupants.

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.

01.04 Acronyms

The following terms and phrases are used throughout this document.

BMS – Building Management System	FDD – Fault Detection and Diagnosis
BOD – Basis of Design	FPT – Functional Performance Test
Caltech – California Institute of Technology	IWMS - Integrated Work Order Management Systems
CIT – California Institute of Technology	OPR – Owner’s Project Requirements
CD – Construction Document	PFC – Pre-Functional Checklist
Cx – Commissioning	PM – Project Manager
CxA – Commissioning Authority	RACI – Responsible, Accountable, Consulted, Informed
DB – Design/Build	SAM – SkySpark Asset Manager
DBB – Design/Bid/Build	SD – Schematic Design
DD – Design Development	

02 Commissioning Process

The Commissioning Process (Cx) is a quality-focused process for enhancing the delivery of a project. Cx focuses on evaluating and documenting that all of the commissioned systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the Owner's Project Requirements (OPR).

Caltech commissioning (Cx) is an enhanced form of building commissioning that utilizes traditional commissioning, FDD processes, and asset management to ensure construction projects are delivered according to requirements. Cx processes span the entire project lifecycle and the scope covers all assets including new buildings and any fixtures, furnishings and equipment installed on campus. Cx places emphasis on data collection to provide visibility to information needed during the construction process and throughout the lifetime of the building. Data is gathered through traditional commissioning, asset data collection, and FDD.

FDD supports and relies on the integration of various systems utilized in construction and operations including building controls automation, building data analytics, asset data management, and Facilities’

Integrated Work Order Management systems (IWMS). The integration of these systems at the onset of a project improves the efficiency and lasting impact of the commissioning process, ensures continuity of building information transfer from design & construction into operations, and ultimately improves and extends the operations and performance of buildings.

Caltech utilizes the SkySpark platform, an analytics software platform that can automatically analyze building, energy and equipment data to identify issues, faults, and opportunities for operational savings. SkySpark is used at Caltech as:

- A data repository and real-time trend historian for BAS, metering and other networked device points.
- An Asset Data commissioning tool, with integration to the IWMS for operationalizing maintainable assets
- A fault detection & diagnostics tool, with integration to the IWMS for automated work order generation.
- An automated functional testing tool, and general commissioning/verification tool.
- For energy performance and Monitoring & Verification.

Cx assumes that programmers, designers, contractors, and facilities entities are fully accountable for the quality of their work. The Commissioning Team uses methods and tools to evaluate that the project is achieving the OPR throughout the delivery of the project.

Cx begins at project inception (during planning) and continues for the life of the facility. Because this guideline details a process, it can be applied to both new and renovation projects. Cx includes specific tasks to be conducted to evaluate whether the design, construction, testing, documentation, and training meet the OPR. This guideline describes the overall minimum Cx necessary to provide a uniform, integrated, and consistent approach for delivering projects and providing Caltech the information for operating facilities that meet the OPR.

Due to inherent variations in the planning and data gathering process for existing buildings and ongoing commissioning, this guideline and process is intended for projects including construction and renovation. For existing buildings, if the project is making capital improvements that require construction, this standard would be appropriate to use for the existing building implementation phase. The OPR may transition to the Current Facility Requirements (CFR), and the Cx Plan may transition to an Ongoing Cx (OCx) Plan. If these documents do not exist, this guideline would be used to develop the necessary documentation.

Emphasis is placed on documentation of the OPR at inception of the project and the proper transfer of this information from one party to the next.

This standard describes Cx; the roles of the CxA and Cx Team; and a framework for developing an OPR, Basis of Design (BOD), Cx Plan, specifications, procedures, documentation, and reports. This standard also describes the general requirements for a training program for continued successful system and assembly performance.

03 Phases

03.01 Planning

The Planning Phase lays the groundwork for the project, defines the plan for commissioning, 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 ensuing phases should be made with reference to the OPR

During the Planning Phase, a Cx Team is formed to oversee, implement, and accomplish the Cx Activities detailed in this guideline. Responsibility for leadership of the Cx Team is assigned at the beginning of the Planning Phase. The term used for the person with overall responsibility for the Cx Process is "Cx Authority (CxA)." The Cx Team members must be available for meetings, have the technical qualifications to contribute to the development of the Owner's Project Requirements. Lines of authority and lines of communication in determining Cx Team members' responsibilities are included in this guideline.

Caltech will assign appropriate representatives to participate on the Cx Team, both from within and external to their organization.

Essential team members during the Planning Phase include Caltech's representatives, the CxA, predesign and programming professionals, internal or external design professionals. Caltech's representatives will include the project manager, engineers, occupants or users, facility manager, and operation and maintenance personnel. Including operation and maintenance personnel on the Cx Team will help ensure that important operation and maintenance issues are included in the Owner's Project Requirements. The Caltech Project Manager will generally need to reconcile conflicting project requirements and provide feedback on decisions to the Cx Team. The design team members and CxA can assist Caltech in reconciling conflicting technical requirements.

The Cx Team will evolve as a project progresses. During successive phases, the active membership of the Cx Team may shift to meet the unique requirements of each phase. Contractors and vendors, for example, may join the Cx Team after they are under contract or after the start of construction.

03.01.01 RACI Table

Caltech Commissioning processes are supported by a Commissioning Team. This team evaluates projects based on their complexity and assigns a commissioning tier which determines the Cx roles and responsibilities of project participants according to a responsibility matrix (RACI chart). The RACI outlines steps in order of occurrence based on a project timeline and assigns actions according to the project complexity tier.

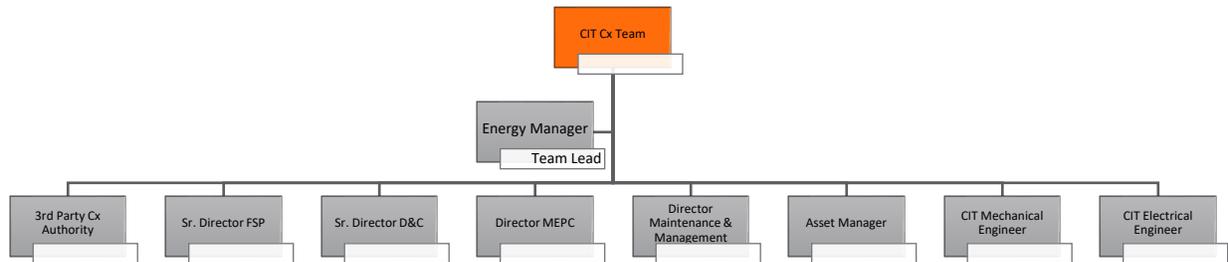
The RACI tables provide the responsibilities of each participant in a comprehensive Cx Process.

Table 1 RACI Table– Planning Phase

Task #	Task Name	Description	Cx Authority	CIT Cx Team	CIT PM	CIT Space Manager	CIT Technical Reviewers	CIT Asset Manager	CIT Energy Manager	Architect/Engineer of Record	General Contractor	CIT Facilities Maintenance	Comments
P1	OPR	Create OPR	-	C	R	I	-	C	C	-	-	C	Includes selecting project tier
P2	Delivery Method	Select project delivery method	-	I	R	-	-	-	-	-	-	-	
P3	Procurement	Selection of Design or Design/Build team	-	I	R	-	C	-	-	I	I	-	
P4	Cx Authority Selection	Select the 3rd party Cx Authority for the project	I	C	R	-	-	-	-	I	I	-	

03.01.02 Organization Chart

Table 2 Organization Chart– Planning Phase



03.01.03 Tasks

03.01.03.01 OPR

The Owner’s Project Requirements (OPR) form the foundation for the design, construction, and occupancy and operation of the facility and is the basis for the Commissioning Plan and schedule. It is the primary tool for benchmarking project requirements at all phases of project delivery.

Requirements

During the Planning Phase, the Caltech PM facilitates development and documentation of the OPR.

The OPR document shall address the following for the commissioned systems:

- Select project tier
- Facility objectives, size, location, user requirements, and Owner directives
- Environmental, sustainability, and efficiency goals and benchmarks
- Indoor environment requirements, including temperature, humidity, and ventilation

- Space use and occupancy and operations schedules
- Clearly defined Cx scope and requirements
- Maintainability, access, and operational performance requirements
- Project Schedule and Milestones
- Project documentation, Systems Manual requirements and formats
- Applicable codes and standards in addition to local building codes
- Special project requirements

The OPR will be updated regularly at the direction of Caltech. The OPR will be reviewed and updated as needed due to scope changes. If updates to the OPR made by the CxA at any time during the project, they shall be required and accepted by Caltech.

03.01.03.01.01 Project Tier

Project tier is also determined and documented in the OPR by the Caltech PM.

03.01.03.02 Define Project Cx Team

During the Planning Phase, a Cx Team is formed to oversee, implement, and accomplish the Cx Activities detailed in this guideline. Responsibility for leadership of the Cx Team is defined and assigned at the beginning of this phase. The Cx Team members must be available for meetings, have the qualifications to contribute to the development of the Owner's Project Requirements, and have the authority to make decisions binding on the firms/constituencies they represent. Lines of authority and lines of communication in determining Cx Team members' responsibilities shall be documented. The Cx Team composition is based on upon the scope of the Cx services established for the project.

03.01.03.02.01 Cx Scope

The Caltech PM will determine the scope for is also responsible to make final selections regarding commissioning services in conjunction with the project tier.

Design Phase Involvement

The expected level of involvement of the CxA which may include the , number of commissioning design reviews, and meetings expected during this phase should be determined as part of this task.

Commissioned Systems Selection

The systems and assemblies to be commissioned should be selected as part of this task.

Sampling Strategies

Typical sampling rates are listed below and may be determined during planning, this can also occur during schematic design or design development:

Table 3 Sampling Rate – CIT Shops

Discipline	Rehab Projects		New Construction Projects		Comments
	Installation	Testing	Installation	Testing	
Plumbing					
Water closet	100	100	100	100	
Mixing faucets, Sensor type	100	100	100	100	
Lavatory or shower Mixing faucets, manual	100	100	100	100	
thermostatic mixing valves or tempering valves	100	100	100	100	
Lavatory mixing faucet, sensor type	100	100	100	100	
Water closet flushometer, sensor type	100	100	100	100	
Water closet flushometer manual	100	100	100	100	
Urinal Service sink	100	100	100	100	
Hydration station	100	100	100	100	
Trap primer	100	100	100	100	
Trap guards	100	100	100	100	

Table 4 Sampling Rate – CxA

Discipline	All Projects		Comments
	Installation	Testing	
Plumbing			
Sewage ejection pumps	N/A	N/A	
Storm drain sump pumps & ejectors	N/A	N/A	
Acid waste ejection pumps	N/A	N/A	
Air compressor	10	N/A	
Vacuum pump	10	N/A	
Backflow preventer	10	N/A	Certified, installed and tested by the installer. CxA collects certification
End suction pumps	N/A	N/A	
Vibration isolators	5	N/A	
DI water system piping	N/A	N/A	
Special lab gas system piping	N/A	N/A	
Emergency drench shower/eyewash	5	N/A	Certified, installed and tested by the installer. CxA collects certification

Discipline	All Projects		Comments
	Installation	Testing	
Fuel oil system / Generator	N/A	N/A	
Electric water heaters	N/A	N/A	
Gas-fired water heaters	N/A	N/A	
Steam fired clean Steam generators	N/A	N/A	
Electric fired clean Steam generators	N/A	N/A	
Water filtration system	N/A	N/A	
Pipe insulation	N/A	N/A	
Pipe jacketing	N/A	N/A	
Pipe labels	5	N/A	
Booster pumps	N/A	N/A	
Thermometer & gauges	5	N/A	
HVAC			
Heating hot water heat exchangers	10	N/A	
Process cooling water heat exchanger	10	N/A	
Medium temperature water heat exchangers	10	N/A	
Chillers	100	N/A	
Cooling towers	100	N/A	
Fluid coolers	N/A	N/A	
Air handling units	100	10	
Computer room air conditioners	10	10	
Ductless cassette type Fan coil units	10	10	
Cabinet type Fan coil units	10	10	
Exhaust fans	100	10	
Active chilled beams	10	10	
Radiant panels	N/A	N/A	
Motorized dampers	N/A	N/A	
Backdraft dampers	N/A	N/A	
Variable frequency drives	10	N/A	
Air distribution systems	10	N/A	
Fan-powered HEPA filter modules	10	N/A	
Laboratory fume hoods	10	10	
Terminal units, Conventional with reheat coil	10	N/A	
Terminal units, Conventional without reheat coil	10	N/A	
Terminal units, Accuvalve with reheat coil	10	N/A	
Terminal units, Accuvalve without reheat coil	10	N/A	
Thermostats and temperature sensors	5	5	
Humidity sensors and transmitters	5	5	
Differential pressure sensors	5	5	

Discipline	All Projects		Comments
	Installation	Testing	
Chilled water pumps	100	N/A	
Heating hot water circulation pumps	100	N/A	
Condenser water pumps	100	N/A	
Filter housing assembly	N/A	N/A	
Combination fire smoke dampers	N/A	N/A	
Hydronic piping trim	N/A	N/A	
Hydronic pipe work materials, seismic bracing and workmanship	N/A	N/A	
Insulation	N/A	N/A	
Jacketing	N/A	N/A	
Pipe labels	N/A	10	
Manual volume dampers	N/A	N/A	
Isolation valves	5	10	
Chemical water treatment system	N/A	N/A	
Steam condensate receiver & pump assembly	N/A	N/A	
Duct silencers	N/A	N/A	
Vibration isolators, fans, FCUs & AHUs	5	N/A	
Vibration isolators, pumps	10	N/A	
Room thermostats and combination sensors	5	N/A	
Electrical			
MV Cables	10	N/A	
MV Switches	10	N/A	
Relays	10	N/A	
Feeder Cables ($\geq 250A$)	10	N/A	
Transformers ($\geq 100kVA$)	10	N/A	
Switchgears	10	N/A	
Panelboards	10	N/A	
Circuit Breakers ($\geq 250A$)	10	N/A	
Electrical Panels	10	N/A	
Electric meters	10	100	
Generator	10	N/A	
Automatic Transfer Switches	10	N/A	
Lighting Inverters	10	N/A	
UPS	10	N/A	
Harmonics Filters	10	N/A	
Arc Flash coordination	10	N/A	
Ground Resistance	10	N/A	
BAS and DDC			
Temperature sensor FPT and Calibration	10	100	
Relative humidity sensor FPT and Calibration	10	100	

Discipline	All Projects		Comments
	Installation	Testing	
Differential pressure sensor FPT and Calibration	10	100	
Current relay sensor FPT and Calibration	10	100	
Sequence of operation, AHUs, Temperature control valves	N/A	100	
Sequence of operation, AHUs, OSA, EA and mixing dampers	N/A	100	
Sequence of operation, AHUs, UVC light emitters	N/A	100	
Sequence of operation, AHUs, Filter banks, DP transmitters	N/A	100	
Sequence of operation, AHUs, heating coil temperature transmitter	N/A	100	
Sequence of operation, AHUs, cooling coil temperature transmitter	N/A	100	
Sequence of operation, AHUs, Variable frequency drive	N/A	100	
Sequence of operation, AHUs, Fire alarm interlock and shut down	N/A	100	
Sequence of operation, AHUs, Deck temperature and deck pressure reset	N/A	100	
Sequence of operation, AHUs, Alarms and points of contact	N/A	100	
Sequence of operation, FCUs, Temperature control valves	N/A	100	
Sequence of operation, FCUs, Filter banks, DP transmitters	N/A	100	
Sequence of operation, FCUs, heating coil temperature transmitter	N/A	100	
Sequence of operation, FCUs, cooling coil temperature transmitter	N/A	100	
Sequence of operation, FCUs, Variable frequency drive	N/A	100	
Sequence of operation, FCUs, Fire alarm interlock and shut down	N/A	100	
Sequence of operation, FCUs, Condensate pump	N/A	100	
Sequence of operation, FCUs, Alarms and points of contact	N/A	100	
Sequence of operation, Exhaust fans, motorized isolation dampers	N/A	100	
Sequence of operation, Exhaust fans, Variable frequency drives	N/A	100	
Sequence of operation, Exhaust fans, main plenum DP transmitter	N/A	100	
Sequence of operation, Exhaust fans, main plenum temperature transmitter	N/A	100	

Discipline	All Projects		Comments
	Installation	Testing	
Sequence of operation, Exhaust fans, main plenum relative humidity transmitter	N/A	100	
Sequence of operation, EFs, Alarms and points of contact	N/A	100	
Sequence of operation, Heat exchangers, temperature sensor and steam control valve modulation	N/A	100	
Sequence of operation, Heat exchangers, DP sensor and pump speed control	N/A	100	
Sequence of operation, Heat exchangers, Variable frequency drive	N/A	100	
Sequence of operation, Heat exchangers, Alarms and points of contact	N/A	100	
Sequence of operation, Terminal unit, Controller & actuator	N/A	100	
Sequence of operation, Terminal unit, Reheat coil control valve	N/A	100	
Sequence of operation, Terminal unit, DAT temperature sensor	N/A	100	
Sequence of operation, Terminal unit, DAT RH sensor	N/A	100	
Sequence of operation, Alarms and points of contact	N/A	100	
Sequence of operation, Terminal unit, DAT RH sensor	N/A	100	
Sequence of operation, Humidifier, electric steam generator	N/A	100	
Sequence of operation, Humidifier, Stem to steam, steam control valve	N/A	100	
Sequence of operation, Humidifier, Make-up water level sensor and solenoid valve	N/A	100	
Sequence of operation, Humidifier, Duct humidistat, hard wired	N/A	100	
Sequence of operation, Humidifier, Duct temperature sensor, hard wired	N/A	100	
Sequence of operation, Humidifier, Duct DP sensor, hard wired	N/A	100	
Sequence of operation, Humidifier, room temperature sensor	N/A	100	
Sequence of operation, Humidifier, room RH sensor	N/A	100	
Sequence of operation, Humidifier, Alarms and points of contact	N/A	100	
Graphic display, AHUs	N/A	100	
Graphic display, FCUs	N/A	100	
Graphic display, Exhaust fans	N/A	100	

Discipline	All Projects		Comments
	Installation	Testing	
Graphic display, Heat exchangers	N/A	100	
Graphic display, Terminal units	N/A	100	
Fault detection rules	N/A	100	
Temperature trend logs	N/A	100	
Relative humidity trend logs	N/A	100	
Static pressure trend logs	N/A	100	
I/O point network communication via JACE	N/A	100	
IP address	N/A	100	
Occupancy schedule	N/A	100	
Status review screen and checks	N/A	100	
Alarm classification and points of contact	N/A	100	
Asset naming and asset tagging, QR, signage, etc.	N/A	100	

03.01.03.03 Delivery Method

A recommendation on the delivery method may be provided in the OPR.

03.01.03.04 Procurement

The timing for procurement may be recommended in the OPR as well as the procurement for other services needed for a project to include commissioning, geotechnical and special inspection.

03.01.03.05 Cx Authority Selection

The OPR may address the need and timing for the selection of a 3rd party Cx Authority for the project. This will also be determined by the tier selection for the project.

03.02 Design

During the Design Phase, the OPR is applied to the construction documents. The BoD, created during design, created will convey the design approach, selection of materials and systems, decisions made and any assumptions or recommendations based on the criteria in the OPR. Narrative descriptions of facility systems and assemblies are provided in the BoD, and the Cx Plan is expanded to include the details of Construction and Occupancy Phase activities.

During the design phase, the commissioning team confirms that design documentation (plans, specifications, BOD, etc. are consistent with each other, include commissioning requirements and meet the OPR.

The Cx Process on a particular project starts at the Design Phase and the OPR shall be provided to the CxA during the design phase.

03.02.01 RACI Table

Table 5 RACI Table – Design Phase

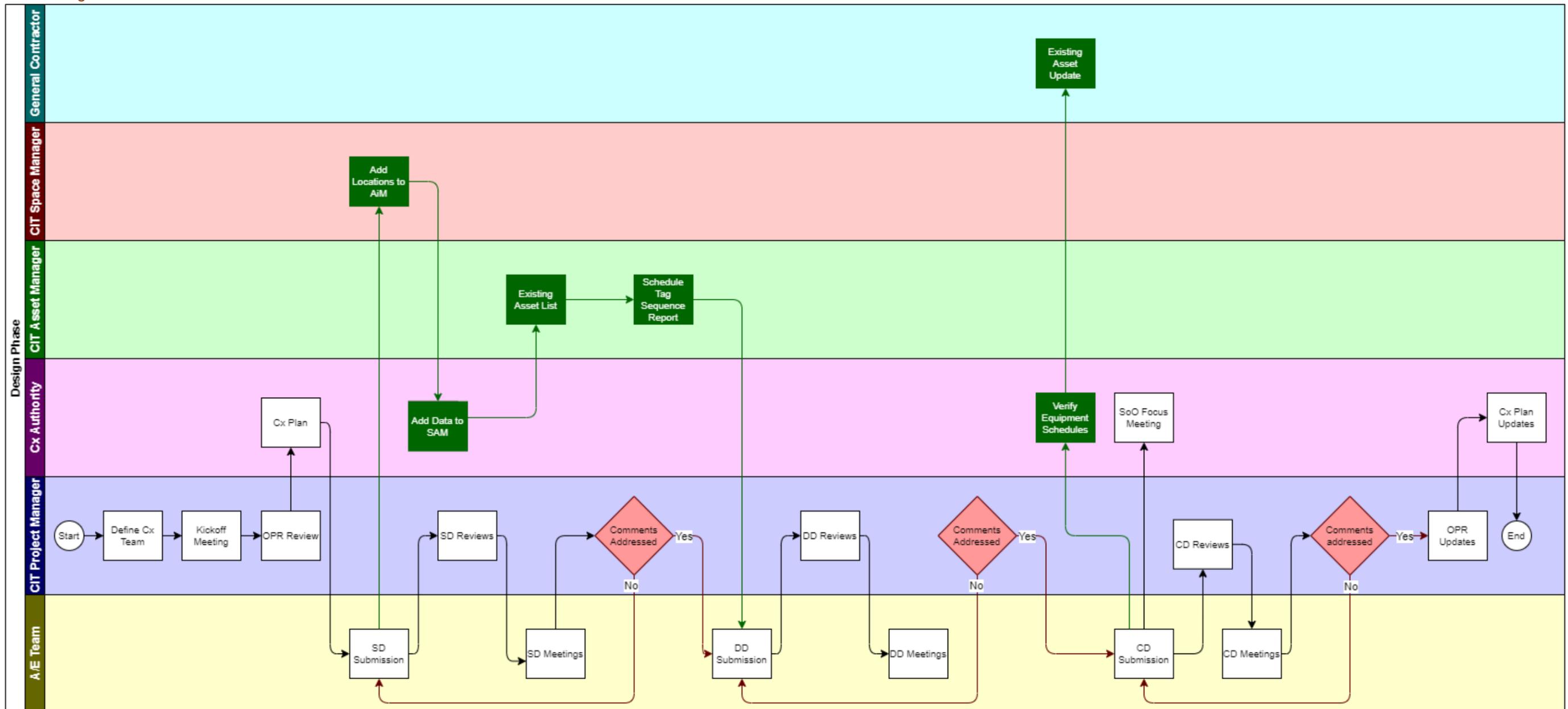
Task #	Task Name	Description	Cx Authority	CIT Cx Team	CIT PM	CIT Space Manager	CIT Technical Reviewers	CIT Asset Manager	CIT Energy Manager	Architect/Engineer of Record	General Contractor	CIT Facilities Maintenance	Comments
D1	Start of Phase	Issue notification to team for start of phase	-	I	R	I	I	I	I	I	-	I	
D2	Define Project Cx Team	Define all members and roles of the Cx Team for the Design Phase	I	-	R	-	I	I	I	-	-	-	
D3	Meeting	Design Phase Kickoff Meeting	I	-	R	-	I	-	-	A	A	-	Includes Asset Data presentation, point naming standards and discussion
D4	OPR Review	OPR review and comment	C	C	R	C	C	C	C	-	-	C	
D5	Cx Plan	Create document outlining Cx process, roles and expectations of team members.	R	-	A	-	-	-	-	-	-	-	
D7	Schematic Design Submissions	Drawings, Outline Specifications, Calculations, Basis of Design are included	-	-	A	-	-	-	-	R	-	-	Typically, 1 -3 rounds of SD submissions, when applicable.
D8	Schematic Design Reviews	Review and comment on deliverables	C	-	R	C	C	-	C	I	-	C	BOD to be reviewed by the CxA
D9	Schematic Design Review Meetings	Meet after each SD submission	I	-	A	-	I	-	-	R	-	I	
D10	Asset Management	Resolve project locations and numbering in IWMS	C	-	A	R	I	-	-	I	I	-	Project Architect shall also be Informed.
D11	Asset Management	Add project and locations to SkySpark Asset Manager (SAM).	R	-	-	A	-	I	-	-	-	-	Includes adding team members to SAM.
D12	Asset Management	Provide Engineer of Record with a list of existing assets within project space and generate schedule tag sequence report.	I	-	A	-	-	R	-	C	-	-	New assets to begin with next sequential Schedule Tag.

Task #	Task Name	Description	Cx Authority	CIT Cx Team	CIT PM	CIT Space Manager	CIT Technical Reviewers	CIT Asset Manager	CIT Energy Manager	Architect/Engineer of Record	General Contractor	CIT Facilities Maintenance	Comments
D13	Design Development Submissions	Drawings, Draft Specifications, Calculations, Basis of Design are included	-	-	A	-	-	-	-	R	-	-	Typically, 1 -3 rounds of DD submissions
D14	Design Development Reviews	Review and comment	C	-	R	C	C	-	C	I	-	C	BOD to be reviewed by the CxA
D15	Design Development Meetings	Design review meeting	I	-	A	-	I	-	-	R	-	I	
D16	Construction Documents Development Submissions	Drawings, Draft Specifications, Calculations, Basis of Design are included	-	-	A	-	-	-	-	R	-	-	Typically, 1 -3 rounds of CD submissions
D17	Construction Document Reviews	Review and comment	C	-	R	C	C	-	C	I	-	C	BOD to be reviewed by the CxA
D18	Construction Document Meetings	Design review meeting	I	-	A	-	I	-	-	R	-	I	
D19	100% Construction Document Final Backcheck	Backcheck of final round of CD comments	C	-	R	C	C	-	C	I	-	C	
D20	MEP/BAS/SOO Spec Review	Full review of MEP, BAS spec, including sequence of operations.	R	-	I	-	A	-	I	C	-	I	
D21	Asset Management	Verify equipment schedules are complete and correct.	R	-	I	-	A	I	-	C	-	-	
D22	Asset Management	Advise Asset Manager of any changes to existing equipment (removal, deactivated, renamed, remapped, etc.)	C	-	A	-	-	I	-	-	R	I	
D23	OPR	Update OPR if needed	C	-	R	-	C	-	-	I	-	-	
D24	Cx Plan	Update Cx Plan if needed	R	-	A	-	C	-	-	I	-	-	

03.02.02 Flow Charts

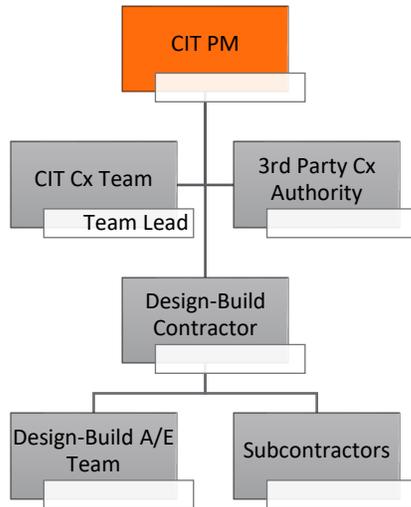
03.02.02.01 Design-Bid-Build

Table 6 Design Phase DBB Flow Chart



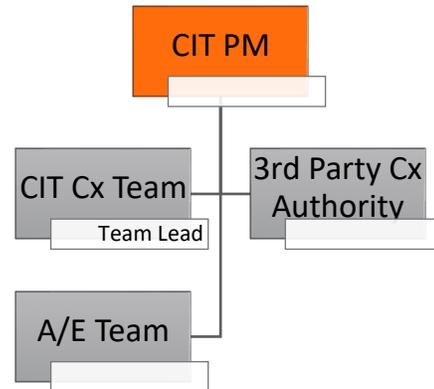
03.02.03 Organization Chart *Design-Build*

Table 7 Design Phase DB Org Chart



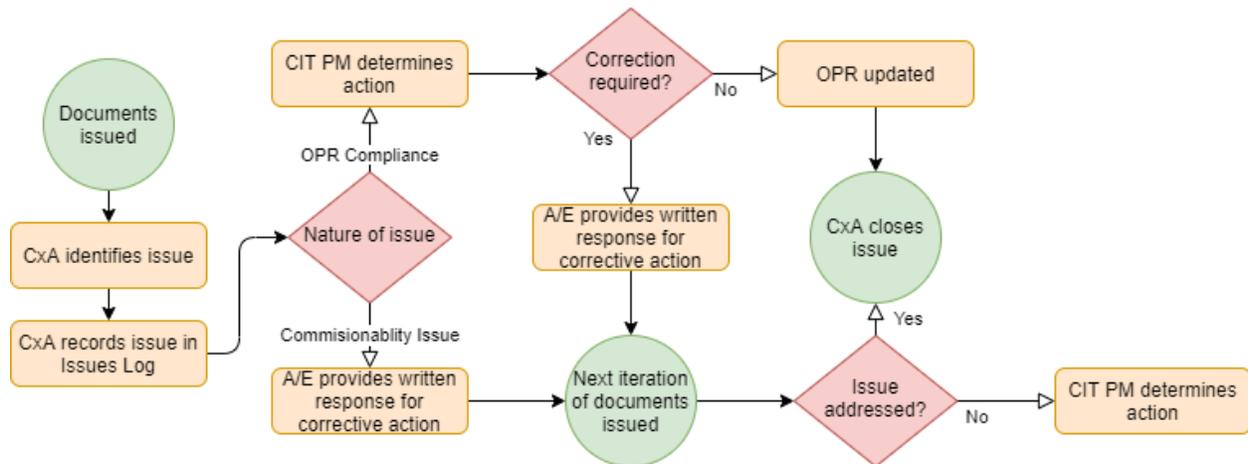
Design-Bid-Build

Table 8 Design Phase DBB Org Chart



03.02.04 Issues Resolution

Table 9 Issues Resolution



03.02.05 Tasks

03.02.05.01 Start of Phase

Notice to proceed is issued to team members to commence this phase.

03.02.05.02 Update Cx Team

If needed, the previously defined Cx Team is updated. See [03.01.03.02 Define Project Cx Team](#) for details.

03.02.05.03 Meeting

Design Phase Kickoff Meeting, meeting minutes to be issued by the design team.

03.02.05.04 OPR Review

OPR review for alignment.

03.02.05.05 Cx Plan

The Cx Plan is a document produced by the CxA that provides organization, documentation requirements, and tools to evaluate and document that the design, construction, and operation of the project or facility, systems, and assemblies meet the OPR. The Cx Plan identifies a series of project specific processes and procedures necessary for a successful Cx Process. The Cx Plan addresses the OPR and reflects the defined scope and budget for the Cx Process.

The Cx Plan includes a schedule of Cx Process Activities, individual responsibilities, documentation requirements, communication and reporting protocols, and evaluation procedures. Evaluation procedures include the review and verification to the OPR of the design documents, contract documents, construction and test procedures.

The Cx Plan is continually updated during the life of a project to reflect changes in planning, design, construction, and occupancy and operations

Requirements

The CxA shall, with input from the Owner's Project Team, develop the initial Cx Plan at the initiation of the project. The Cx Plan shall be updated and expanded during design and construction as the project evolves.

A copy of the final Cx Plan shall be included in the final Cx Report.

The Cx Plan shall include the following information:

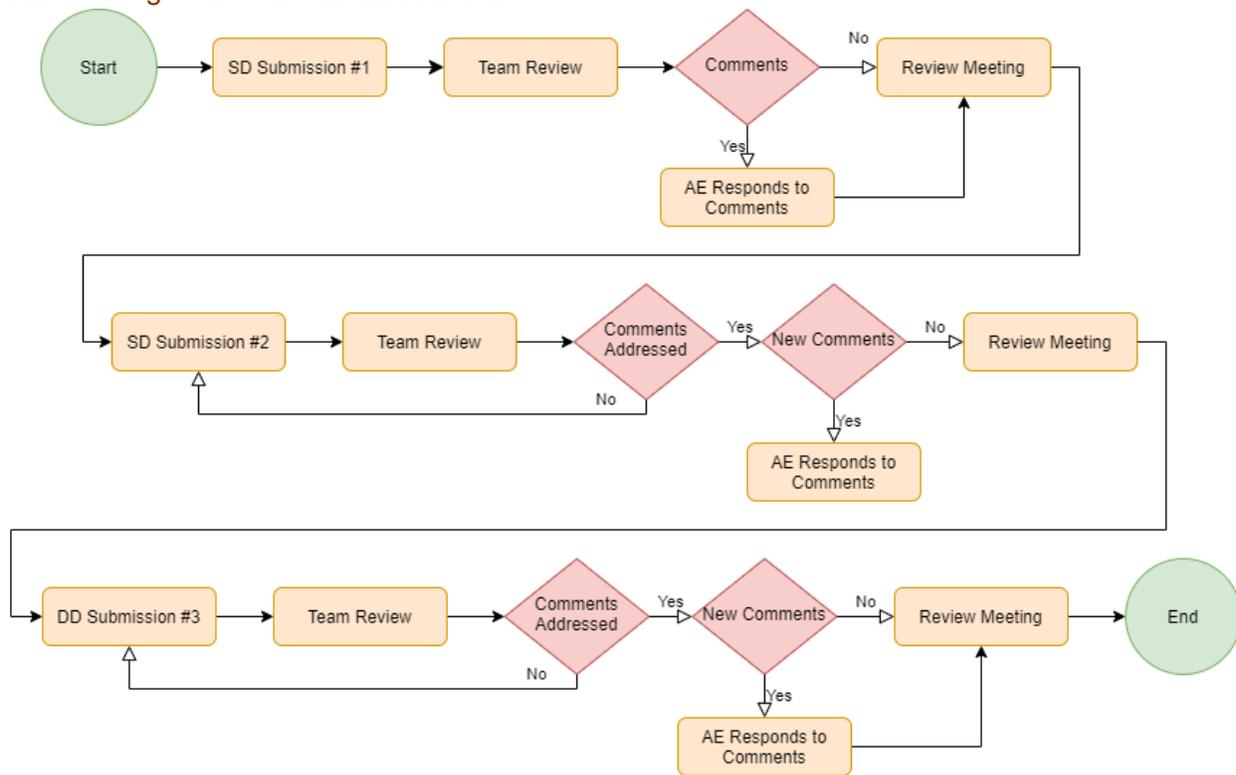
- Overview of the Cx Activities developed specifically for the project
- Roles and responsibilities for the Project Team throughout the project
- Documentation of general communication channels, including the distribution of the Cx Plan during the design and construction process
- Detailed description of Cx Activities and a schedule of activities
- Project design documentation evaluation procedures
- General description of Cx Activities that will occur during design, construction, and occupancy and operations
- Guidelines and format that will be used to develop the Cx documentation, including Systems Manual and training plans
- Listing and format for Design Review, checklists and testing forms, and Issues Log, that will be used during the project to communicate and track critical Cx Activities information
- List of project commissioned systems and assemblies and description of evaluation procedures
- The framework for procedures to follow whenever Cx evaluation does not meet the OPR

The Cx Plan shall be approved by the Owner and include a process for approval of the subsequent revisions.

03.02.05.06 Schematic Design Submissions

Drawings, Outline Specifications, Calculations, Basis of Design are included

Table 10 Design Phase SD Submittal Flow Chart



03.02.05.07 BOD

The BOD records the design approach and selection of materials, systems, equipment and all aspects of the project as well as design decisions made to meet the OPR. The OPR is intended to capture "what" the owner needs and expects from a project. The construction documents detail "how" the OPR will be physically achieved. The BOD captures important information linking the "what" and "how."

The objective of specifically documenting BOD information is to provide the parties involved with a project, at each phase in the process, an understanding of the underlying thinking that led to the selection of specific components, assemblies, systems, and system integrations. A design narrative that provides an overview of assemblies and systems in verbal format is usually an integral element of the BOD.

Content of the BOD will vary from project to project and system to system, but in general it should address the following:

- Specific codes, standards, and guidelines considered during design of the facility and designer interpretations of such requirements.
- Information regarding ambient conditions (climatic, geologic, structural, existing construction) used during design.
- Assumptions regarding usage of the facility.
- Expectations regarding system operation and maintenance.
- Performance criteria that the system was designed to meet—linked to the OPR.
- Specific design methods, techniques, software used in design.

- A narrative statement of design that verbally describes how the designer intends to meet the OPR.
- A narrative statement of operation that verbally details how the facility is expected to operate under various situations (such as normal operation, extreme event, emergency).
- A listing of specific manufacturer makes and models used as the basis for drawings and specifications.

The CxA shall document and track issues related to the BOD using the Cx issues and resolution log, including issues identified by Caltech and members of the Design Team.

The Design Team shall work with Caltech and CxA to resolve Cx issues.

Each submission of the BOD shall be formally reviewed and accepted by the Caltech to facilitate the next step in the design process.

03.02.05.08 Schematic Design Reviews

A critical step in Cx is the review of the design submissions from the design professionals. It is important to remember that the role of the CxA is to verify that the Owner's Project Requirements (OPR) are met and that the system is designed in a quality manner. Three distinct types of reviews can be completed on a drawing set—general, coordination, and field specific. A review of the specifications is also required.

Requirements

The CxA shall perform a review of the commissioned systems and assemblies in the design documents to evaluate compliance with the OPR. Cx Design Review shall be completed, and issues resolved, prior to the issuing the next round of documents for systems being commissioned. The OPR and the Cx Plan shall define any sampling strategies for Cx Design Review.

The CxA shall conduct Cx Design Reviews, as contained in the Cx scope, and develop corresponding reports with comments, suggestions, clarifying questions, and observations in the Issues Log, evaluating compliance with the OPR.

General Review

The general steps of completing a drawing review are as follows:

Review the OPR

Because the drawing review is to verify that the OPR has been met, prior to the design review, the OPR should be reviewed to familiarize the reviewer with the key criteria of the facility.

Document the General Review Criteria

The criteria from which to accomplish the general review of the submission must be documented. The criteria should be based on specific OPR criteria.

Review Expectations

The criteria will vary by commissioned system, and there is no industry consensus as to what the standard of care is in this case. However, Caltech will implicitly expect, without listing every item in the OPR, for a reviewer familiar with a particular trade (mechanical, electrical, plumbing, telecom, building enclosure, security, fire/life safety, etc.) to use such criteria to find and report errors or shortcomings in the design.

Reviewer Qualifications

Reviewers should have a technical background related to the systems they are reviewing, as described in the Job Task Analyses (JTAs) issued by the U.S. Department of Energy (USDOE) Better Buildings Workforce Guidelines (BBWG).

OPR Versus Review Scope

Cx Design Review can include the following:

- Evaluation of continuity of commissioned systems (e.g., air/water/thermal barriers with the building enclosure assemblies, air distribution and return air paths, infrastructure in support of commissioned systems).
- All information is legible (not hidden by crossing lines or text).
- Contract documents incorporate the OPR goals and objectives as stipulated by the Owner for systems and assemblies contained in the Cx scope.
- Accomplish a quick general review: The general review is intended to familiarize the reviewer with the submission. If, during this review, significant items are identified as missing (relative to the submission content requirements), then the review process should be stopped, the Owner should be contacted to confirm whether or not the Cx Design Review should continue, and the design professionals should be contacted to discuss the submission concerns. If the Owner directs the review to proceed, move on to the coordination review.

Cx Design Review

Based on the focus of the Cx Design Review, the CxA shall develop a report capturing areas of concern. The report can consist of populating a comment form provided by Caltech. Comments can include:

- Identify locations in the design documents where concern was identified;
- Ask a question to gain clarity or provide a narrative regarding the concern;
- Suggest a recommendation, if appropriate, for the designer to consider; and
- Identify areas of the OPR affected.

Conduct Review

Document Concerns. During the review of the drawings, keep detailed notes of problems found or concerns with certain items. Also, at the end of the review, a general summary of the quality of the drawings should be developed via a memorandum to Caltech. In addition, all comments shall be captured in a comments form provided by Caltech.

Design Professional Actions

Comments provided by the CxA need to be formally replied to by the design professionals. If systemic issues are identified during the CxA's review, the design process should be resolved.

Backchecking of the specific items may be appropriate but not as the sole means of verifying resolution of the issue.

Issues Log

All issues noted during the review should be documented in the Issues Log and follow the resolution process outlined in [03.02.04 Issues Resolution](#) above.

03.02.05.09 Schematic Design Review Meetings

A meeting is held after each submission to allow the designers to present the design to the team. If this is a subsequent submission, this also allows reviewers to discuss any previous comments or concerns. The agenda and minutes are provided by the design team.

03.02.05.10 Asset Management

Resolve project locations and numbering in IWMS

03.02.05.11 Asset Management

Add project and locations to SkySpark Asset Manager (SAM).

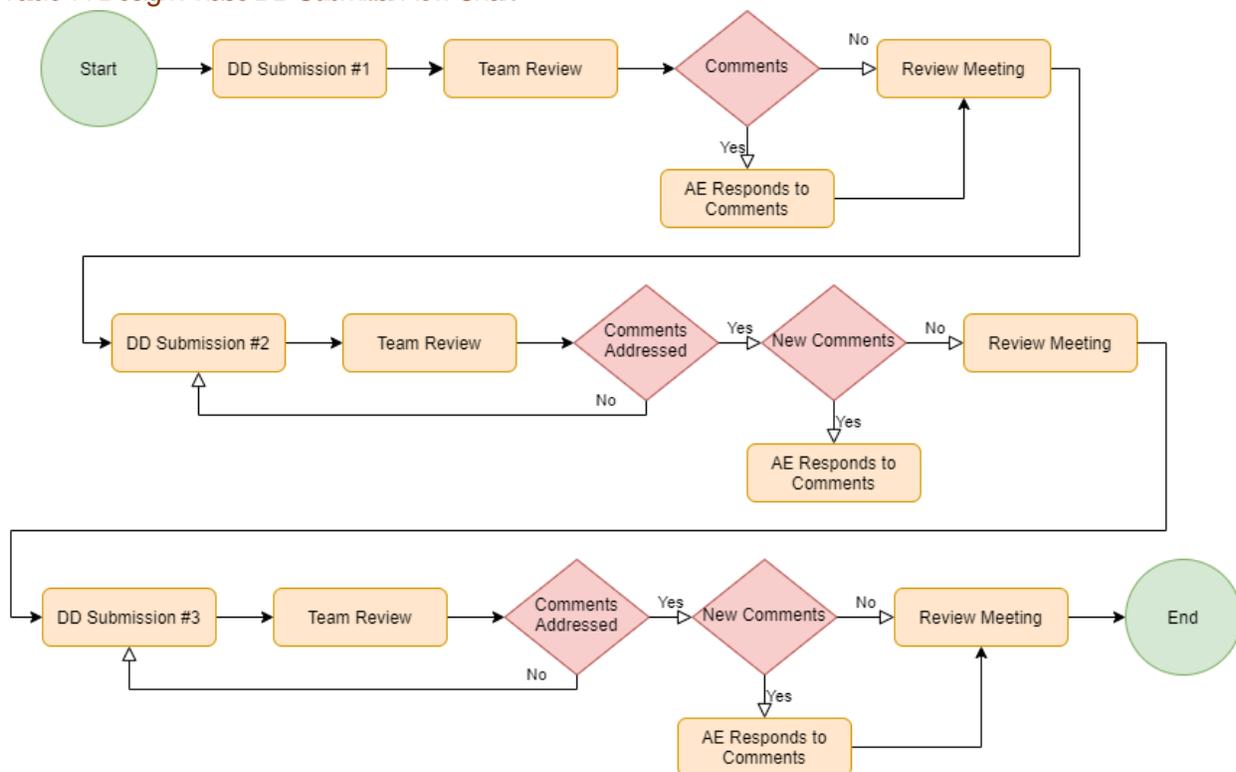
03.02.05.12 Asset Management

Provide Engineer of Record with a list of existing assets within project space and generate schedule tag sequence report.

03.02.05.13 Design Development Submissions

Drawings, Draft Specifications, Calculations, Basis of Design are included

Table 11 Design Phase DD Submittal Flow Chart



03.02.05.14 Design Development Reviews

Reviews per 03.02.05.08 Schematic Design Reviews above.

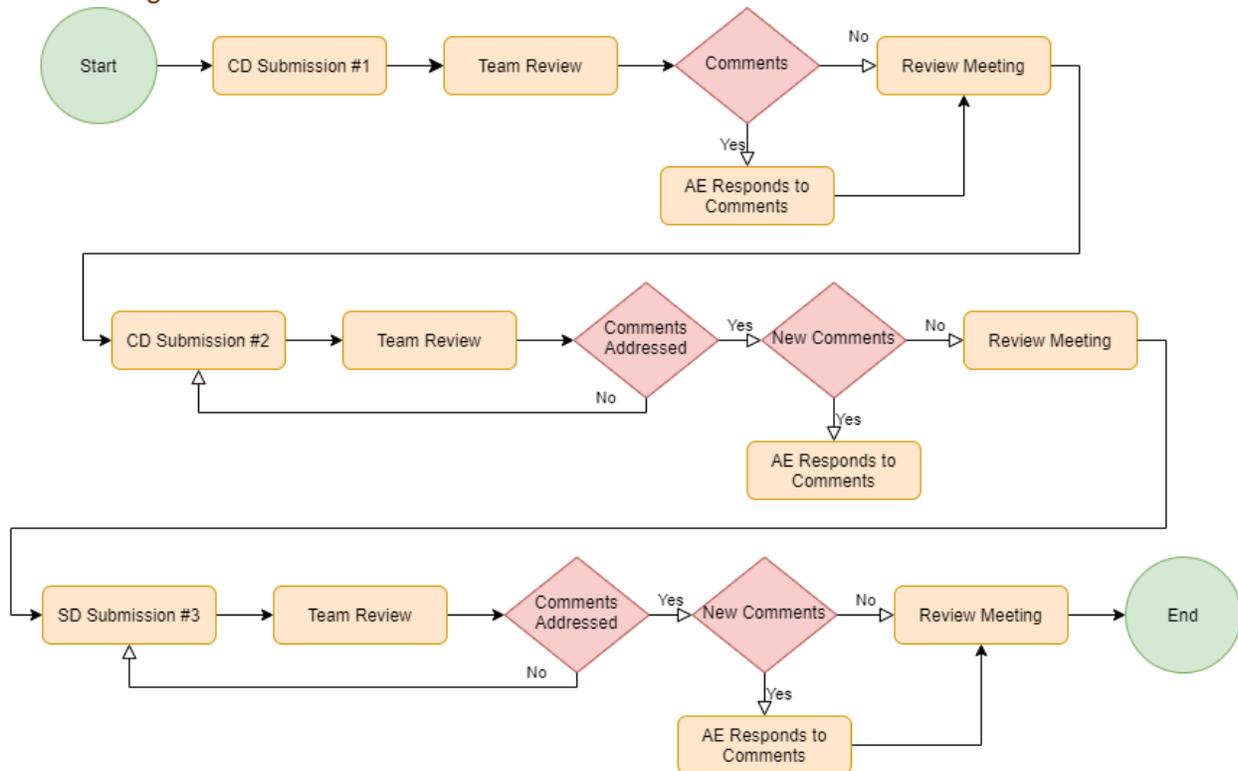
03.02.05.15 Design Development Meetings

Meeting per 03.02.05.09 Schematic Design Review Meetings above.

03.02.05.16 Construction Documents Development Submissions

Drawings, Draft Specifications, Calculations, Basis of Design are included

Table 12 Design Phase CD Submittal Flow Chart



03.02.05.17 Cx Specification

The responsibilities of the contractors, suppliers, and manufacturers, including those contracted directly to Caltech, will follow the contract documents, including Commissioning Activities and procedures defined by the Cx specifications.

Requirements

Cx specifications shall be developed and included in the contract documents with contractors, subcontractors, suppliers, service providers, and manufacturers for systems and assemblies being commissioned.

Contractors, subcontractors, suppliers, service providers, and manufacturers shall provide the required documentation as defined in the contract documents. Examples of these include submittals; shop drawings; installation, operations, and maintenance training agendas and associated training materials and close-out documents; code compliance; and existing conditions documentation.

Caltech shall approve the Cx specifications included in the contract documents.

03.02.05.18 Construction Document Reviews

Reviews per [03.02.05.08 Schematic Design Reviews](#) above.

03.02.05.19 Construction Document Meetings

Meeting per [03.02.05.09 Schematic Design Review Meetings](#) above.

03.02.05.20 100% Construction Document Final Backcheck

Revised documents shall be backchecked by the CxA. Any unresolved issues shall be reported to Caltech for direction to the design and Project Team on final disposition and direction.

A copy of the Cx Design Review reports and response shall be included in the final Cx Report.

03.02.05.21 MEP/BAS/SOO Spec Review

Specifications

Comments on the specifications shall be captured in the issues log and the comment form provided by Caltech. Comments shall be resolved thru discussion at the submission review meeting and via the response to comments provided by the design team.

Sequence of Operation

A detailed review of all sequences for commissioned systems and assemblies performed by the Cx Team.

The review will focus on the following:

- Thoroughness of the sequences
- Integration between disciplines
- Integration between controls systems, such as package controls integration with the BMS.
- Integration with existing system, when applicable
- SkySpark integration points

03.02.05.22 Asset Management

Verify equipment schedules are complete and correct.

03.02.05.23 Asset Management

Advise Asset Manager of any changes to existing equipment (removal, deactivated, renamed, remapped, etc.)

03.02.05.24 OPR Updates

Changes to the OPR may be initiated as the result of Caltech-directed changes or design process-initiated changes to the construction documents. When Caltech initiates a change to the OPR, the design is modified and reviewed as necessary to meet the change.

When Caltech considers changes initiated through the design process, the Cx Team may review the proposed changes to determine if they compromise the OPR, paying special attention to the functional impacts of value management proposals. If Caltech chooses to initiate a change after reviewing the Cx Team's comments, the OPR may be updated as necessary to match the change.

03.02.05.25 Cx Plan

The Cx Plan must be updated to reflect changes in the OPR and/or the BOD and include additional information developed during the Design Phase. During the Design Phase, the following is added to or updated in the Cx Plan:

- Systems and assemblies to be verified and tested
- Schedule of Construction-Phase and Occupancy/Operations-Phase Cx Process Activities
- Roles and responsibilities of new Cx Team members

- Construction-Phase and Occupancy/Operations-Phase documentation and reporting requirements, including procedures and formats
- Construction-Phase and Occupancy/Operations-Phase communication protocols
- Construction-Phase and Occupancy/Operations-Phase Cx Process procedures

03.03 Construction

During the Construction Phase of the project delivery process, systems and assemblies are installed, inspected, tested, and placed into service to meet the Owner's Project Requirements and the approved BOD. Cx Activities may be more than are normally required in their scope of services. The Design and construction team shall cooperate with the CxA during all phases of the project. This may include material testing, TAB, performance tests, records, photography, outside training, Owner's furnished equipment vendors, and other requirements during the Construction Phase.

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.

Note that the Cx Process may begin at the Construction Phase. Efforts shall be made to complete the Cx Process Activities described for the Predesign and Design Phases.

03.03.01 RACI Table

Table 13 Construction Phase RACI Table

Task #	Task Name	Description	Cx Authority	CIT Cx Team	CIT PM	CIT Space Manager	CIT Technical Reviewers	CIT Asset Manager	CIT Energy Manager	Architect/Engineer of Record	General Contractor	CIT Facilities Maintenance	Comments
C1	Start	Notification of start of phase	I	I	R	-	-	I	-	-	-	I	
C2	Project Schedule	Issue CPM Schedule	C	I	A	-	-	-	-	-	R	-	
C3	Project Schedule Review	Review schedule for inclusion of Cx activities	R	C	A	-	-	-	-	-	-	-	
C4	Meeting	Construction Phase Kickoff Meeting	C	C	R	I	I	I	I	I	I	I	
C5	Update Cx Plan	Update construction phase Cx Plan	R	C	A	I	I	I	I	I	I	C	
C6	Update Project Cx Team	Define all members and roles of the Cx Team for the Construction Phase	C	C	R	I	I	I	I	I	I	I	
C7	Prepare Submittals	General Contractor Prepares submittals and hands over to the project manager	I	I	A	I	I	I	I	I	R	I	
C8	Process Submittals and Consolidate Issues	Shop drawings, product data, samples, and mock-ups to be delivered to be coordinated with the design professional. All review (MEPC/TAB) comments shall be consolidated by PM.	C	C	R	I	I	I	I	I	I	I	For Design Build, all drawings are to be coordinated with the Engineer of record. For design bid build all coordination happens via GC.

Task #	Task Name	Description	Cx Authority	CIT Cx Team	CIT PM	CIT Space Manager	CIT Technical Reviewers	CIT Asset Manager	CIT Energy Manager	Architect/Engineer of Record	General Contractor	CIT Facilities Maintenance	Comments
C9	MEP & BAS Submittals Review	Review with focus on MEP, BAS controls & energy efficiency; augments internal Caltech review.	R	-	I	-	A	-	I	I	C	I	LEED v4 EAc3. In addition to Cx Authority review, Submittals need to be reviewed by Senior Mechanical Engineer, Senior Electrical Engineer and Facilities Operations.
C10	TAB Plan Review	Review TAB plan for proper coverage and methods.	RA	-	I	-	-	-	-	-	C		Provide pre-read report of the air balance.
C11	Asset Management	Complete Contractor Asset Data Submittals Form in SAM.	C	-	A	-	-	-	-	-	R		
C12	Asset Management	Backcheck data entry in Contractor Submittals Form.	RA	-	I	-	-	I	-	-	C		
C12	PFCs	Issue PFCs	R	C	A	-	-	-	-	I	I	C	CxA to issue independent pre functionals if manufacturer's startup forms have not covered all the items.
C13	FPT Development	Document the test procedures and share with the team for review.	RA	-	-	-	-	-	-	I	C	I	LEED v4 EAp1
C14	Meetings	Periodic Cx Meetings	C	C	R	I	I	I	I	I	I	I	

Task #	Task Name	Description	Cx Authority	CIT Cx Team	CIT PM	CIT Space Manager	CIT Technical Reviewers	CIT Asset Manager	CIT Energy Manager	Architect/Engineer of Record	General Contractor	CIT Facilities Maintenance	Comments
C15	Controls Bench Testing / Review	Review of point naming, folder organization, override-ability, wire logic & graphics.	RA	-	I	-	-	-	I	-	C	I	Per current Caltech Design Guidelines. Provide complete DDC submittal/as-built package documentation. Review for discrepancies with the latest point naming standards.
C16	Site Observations	Track issues in Caltech issue log or in Caltech approved tool, track resolution, add to punchlist as needed	R	I	I	I	I	I	I	I	I	I	
C17	Installation	Installation of commissioned equipment	I	I	A	I	I	I	I	I	R	I	
C18	Asset Management	Apply QR labels to equipment.	-	-	A	-	-	C	-	-	R	-	See "QR Code Tagging Guide".
C19	Shops Initial Walk-Through & Observations Tracking	Initiate scheduling coordination, attend and track observations.	I	-	A	-	-	-	-	I	C	R	Verify QR label placement.
C20	Asset Management	Complete Contractor Asset Data As-Builts Form in SAM.	C	-	A	-	-	-	-	-	R	-	
C21	Asset Management	Backcheck data entry in Contractor As-Builts Form.	RA	-	I	-	-	I	-	-	C	-	

Task #	Task Name	Description	Cx Authority	CIT Cx Team	CIT PM	CIT Space Manager	CIT Technical Reviewers	CIT Asset Manager	CIT Energy Manager	Architect/Engineer of Record	General Contractor	CIT Facilities Maintenance	Comments
C22	Pre-Startup	Duct air leakage testing Piping pressure tests Coordination studies, etc.	C	C	A	I	I	I	I	I	R	C	Contractor activities. Observation and witnessing listed in separate tasks.
C23	PFCs	Completion of PFCs	C	C	A	I	I	I	I	I	R	C	
C24	Startup	Equipment startup activities Direct Digital Controls point to point verification	C	C	A	I	I	I	I	I	R	C	Contractor activities. Observation and witnessing listed in separate tasks.
C25	Asset Management	Complete Contractor Warranty Form in SAM.	C	-	A	-	-	-	-	-	R	-	
C26	Asset Management	Overall review and approval of asset data in SAM.	C	-	I	-	-	RA	-	-	I	I	
C27	Asset Management	Load asset data to IWMS via AssetSync.	C	-	-	I	-	RA	-	-	-	-	
C28	SkySpark Integration to BAS	Perform point discovery, import, tagging & naming, applying sparks, user account management.	RA	-	I	-	-	-	I	-	C	I	
C29	TAB	Testing Adjusting and Balancing Submit certified report	I	I	I	-	-	-	-	I	R	I	
C30	TAB Approval	Review TAB Report	I	I	I	-	-	-	-	R	I	I	
C31	TAB Validation	Field validate TAB report values	R	I	AR	-	-	-	-	I	I	I	
C32	Meeting	Functional Test requirements review	C	C	R	-	-	-	-	C	C	C	

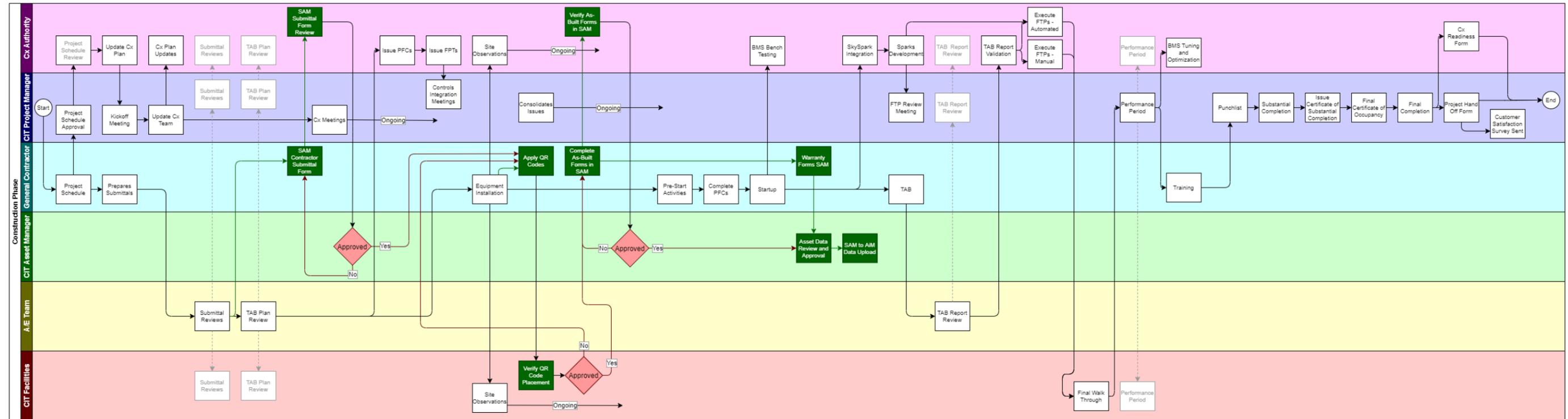
Task #	Task Name	Description	Cx Authority	CIT Cx Team	CIT PM	CIT Space Manager	CIT Technical Reviewers	CIT Asset Manager	CIT Energy Manager	Architect/Engineer of Record	General Contractor	CIT Facilities Maintenance	Comments
C33	Sparks Development	Consult Caltech and Develop sparks for continuous monitoring.	RA	-	-	-	-	-	C	-	-	-	For large projects only (>15 zones).
C34	Functional Performance Test (FPT) Execution - Manual/Field Testing	Execute FPTs in the field and prepare issue log.	RA	-	I	-	-	-	-	I	C	-	LEED v4 EAp1
C35	Functional Test Procedure Execution - Automated Testing	Run automated tests to augment manual testing and add items to issue log.	RA	-	I	-	-	-	-	I	C	-	LEEDv4 EAp1. For large projects only (>25 zones).
C36	Shops Final Walk-Through & Observations Tracking	Initiate scheduling coordination, attend and track observations.	I	-	A	-	-	-	-	I	C	R	
C37	Training and O&M Manuals	O&M Manuals and training to be provided to be submitted as part of required submittals.	I	-	A	-	-	-	-	-	R	-	
C38	Punchlist	Punchlist review	C	C	A	I	I	I	I	I	R	C	

Task #	Task Name	Description	Cx Authority	CIT Cx Team	CIT PM	CIT Space Manager	CIT Technical Reviewers	CIT Asset Manager	CIT Energy Manager	Architect/Engineer of Record	General Contractor	CIT Facilities Maintenance	Comments
C39	Substantial Completion	As-Builts (Submittals required at the time of closeout include as-builts), warranties. Warranty Starts during this date and substantial completion certificate is issued.	I	-	A	C	-	I	I	I	R	I	The Project is ready to be used by CALTECH, even though minor Punchlist items remain to be corrected (provided such Punchlist items do not have a material or adverse effect on CALTECH's ability to utilize the Project for its intended purpose). The certificate of substantial completion is also issued by the GC.
C40	Certificate of Occupancy	Certifying building's compliance with applicable building codes and other laws and indicating it to be in a condition suitable for occupancy.	I	C	R	I	I	I	I	I	A	I	
C41	Performance Period	Period of automatic operation and BAS Controls Optimization	AR	-	-	-	-	-	C	-	C	C	Continually tune BAS setpoints, control loops, resets, etc. using trend data analysis.
C42	Final Completion	Punchlist Items are resolved.	I	-	A	-	-	-	-	-	R	-	Resolve all the remaining punchlist items.

Task #	Task Name	Description	Cx Authority	CIT Cx Team	CIT PM	CIT Space Manager	CIT Technical Reviewers	CIT Asset Manager	CIT Energy Manager	Architect/Engineer of Record	General Contractor	CIT Facilities Maintenance	Comments
C43	Certificate of Readiness	To be completed by Cx Authority	R	-	I	C	-	-	A	-	-	-	Caltech to provide the template.
C44	Commissioning Report and Systems Manual	Provide a Cx report and create a useful document which details the building systems.	R	-	I	C	-	-	A	-	-	-	LEED v4 EAc3
C45	Update FCA (ISES Report)	Equipment and systems affected by project should be updated in FCA database.		-	AR	-	-	-		-			Update ISES database.
C46	Occupant Satisfaction Survey	PM to send occupant satisfaction survey to the user group.	-	-	AR	-	-	-					
C47	Project Handoff Form	Caltech internal handoff form submitted to Maintenance Management	-	-	AR	-	-	-	-	-	-	C	All documents uploaded to Meridian.

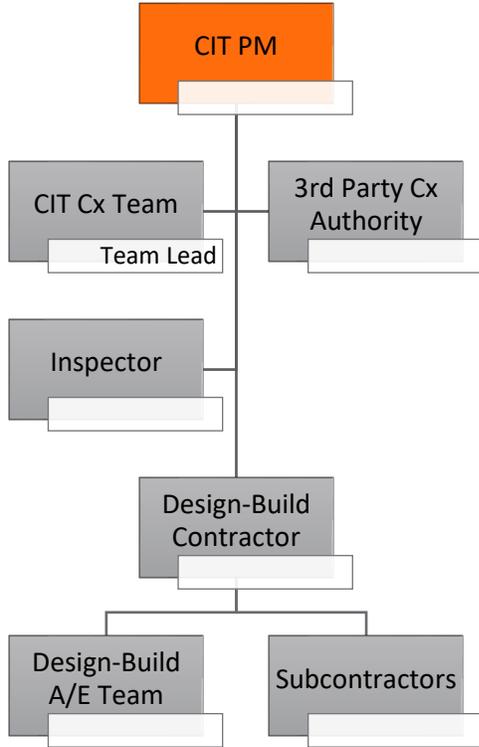
03.03.02 Flow Charts

Table 14 Construction Phase Flow Chart - DBB



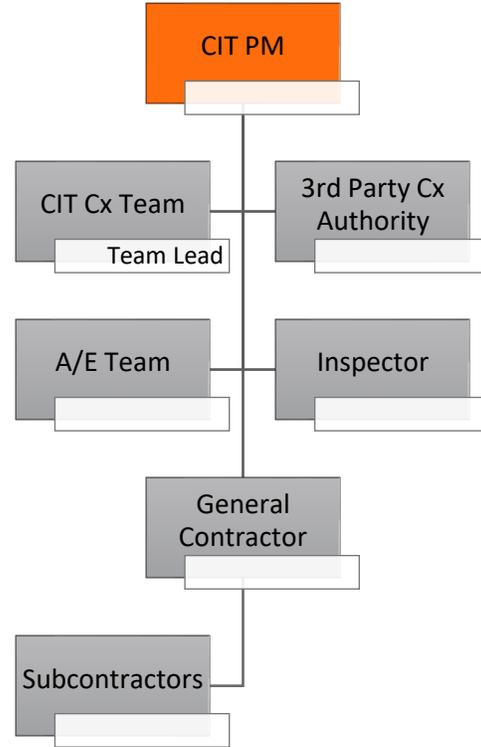
03.03.03 Organization Chart *Design-Build*

Table 15 Construction Phase Org Chart DB



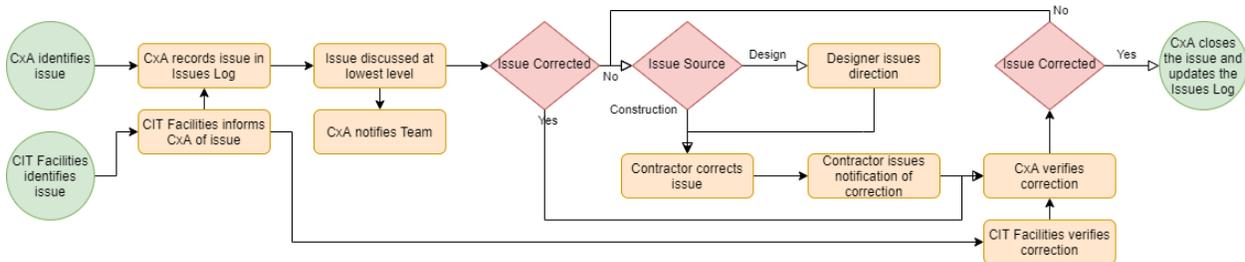
Design-Bid-Build

Table 16 Construction Phase Org Chart DBB



03.03.04 Issues Resolution

Table 17 Issues Resolution



03.03.05 Tasks

03.03.05.01 Start

Notification of start of phase

03.03.05.02 Project Schedule

The objective of scheduling Cx Process Activities is to integrate and coordinate them with other Construction- Phase activities and to allow all Cx Team members to plan their work to achieve the OPR. Cx Process Activities should be integrated into the construction schedule.

The project schedule needs to include the start date, duration, description, and entity responsible for completion.

As a minimum, the following should be included in the project schedule:

- Cx Team meetings
- Start and completion of each Construction Phase
- Key system and assembly completion and tests
- Training sessions
- Performance Period
- Substantial completion
- Warranty start date
- Occupant move-in
- Warranty review two months prior to end of warranty period
- Lessons-learned meeting
- Project Schedule Review

Review schedule for inclusion of Cx activities

03.03.05.03 Meeting

A combined Construction and Cx Kickoff meeting will be schedule by the CIT PM with all members of the construction phase Cx Team.

The Cx portion of the meeting will cover the OPR, BOD, and unique contract document requirements are reviewed. In addition, the specific roles and responsibilities of the contractors relative to the Cx Process Activities are reviewed.

03.03.05.04 Update Cx Plan

The CxA will update the Cx Plan with the new information gathered during the beginning of this phase. Once approved by Caltech, the updated Cx Plan will be provided to the team for review and comment. Comments be any team member will be considered for inclusion in the Cx Plan, as direct by the Caltech PM.

03.03.05.05 Update Project Cx Team

Define all members and roles of the Cx Team for the Construction Phase

03.03.05.06 Prepare Submittals

General Contractor Prepares submittals and hands over to the project manager

03.03.05.07 Process Submittals and Consolidate Issues

Shop drawings, product data, samples, and mock-ups shall be sent to and coordinated by the Caltech PM. All review (MEPC/TAB) comments shall be consolidated by PM and the CxA.

For Design Build, all drawings are to be coordinated with the Engineer of record. For Design Bid Build, all coordination happens via GC.

03.03.05.08 MEP & BAS Submittals Review

Review with focus on MEP, BAS controls & energy efficiency; augments internal Caltech review.

Submittals shall be reviewed for compliance with the Owner's Project Requirements (OPR). The commissioning submittal review does not replace the designer of record submittal review.

The CxA shall:

- Identify construction submittals to be reviewed by the CxA.
- Review project submittals for systems and assemblies to be commissioned for compliance with the OPR.

The designer or design build team shall:

- Respond to the CxA's comments and shall resubmit the submittal addressing all comments.

In the event that Caltech does not retain the designer for construction administration services, Caltech shall do the following:

- Require the CxA to review the construction submittals for the systems being commissioned concurrently with Caltech and provide comments to Caltech.
- Consider the CxA's comments and provide direction to the contractor in accordance with the Caltech's best professional judgment. A copy shall be provided to the CxA.

The submittal log shall include a listing of the submittals reviewed, the date reviewed, and a summary of the submitted equipment/material properties that appear not to meet the OPR. Any sampling review process used on the submittals shall conform to the OPR and Cx Plan.

The submittal log shall be included in the final Cx Report.

The CxA shall maintain a record of all Cx submittal reviews, summarized in the submittal log. If it is determined that any reviewed submittals do not comply with the OPR, that submittal shall be provided to the Owner to determine whether the system or equipment shall be accepted or rejected.

It is recommended that a sampling strategy of randomly selecting 5% to 10% of the submittal be used to focus on upon the quality and ability of the submittal to achieve the OPR. If deviations are substantial, then review an additional 5% to 10%. If substantial deviations still exist, then reject the submittal and return it with comments.

Any substitutions or proposed deviations must be reviewed and approved by Caltech before implementation.

03.03.05.09 TAB Plan Review

The TAB plan and report should be reviewed by the CxA. The plan should include pre-read report of the air balance, when applicable. The plan should be approved prior to any TAB work.

The TAB Plan will be developed and submitted for approval and will include:

- Identification of system components on mechanical drawings with location numbers.
- TAB procedures.
- Data sheets setup:
 - By systems
 - With location numbers

- With submittal data

03.03.05.10 Asset Management

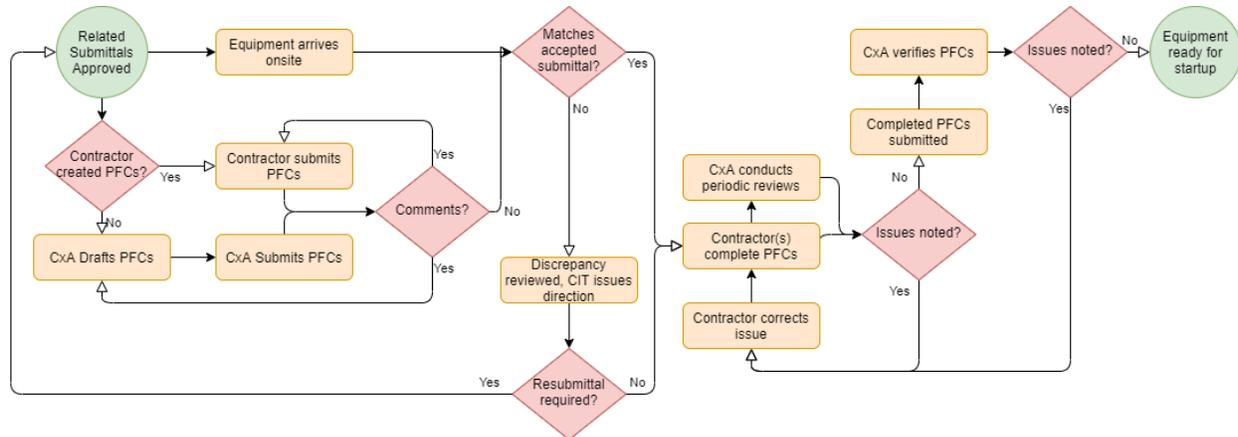
Complete Contractor Asset Data Submittals Form in SAM.

03.03.05.11 Asset Management

Backcheck data entry in Contractor Submittals Form.

03.03.05.12 PFCs

Table 18 PFC Flow Chart



Pre-Functional Checklists (PFC) are a key metric used in evaluating the proper installation of commissioned systems and assemblies. They provide a detailed list of installation, operational, and documentation requirements that need to occur or be submitted before a piece of equipment or assembly can move to the next step in the process, which is typically startup.

As part of Caltech commissioning standard, CxA is responsible for witnessing startups of selected commissioned systems and perform installation checks on selected equipment. Caltech requires 100% automated functional performance testing of all equipment in the building management system via SkySpark. For the system's not on the BMS, Caltech requires CxA to do an installation check and review contractor's pre functional checklist (if any).

Pre functional checklist items are to be completed as part of initial checkout by the contractor before startup of equipment. This checklist augments but is not meant to replace recommendations or requirements for installation, checkout and startup from standards, manufacturers, codes or governing bodies.

If the CxA believes that the manufacturer checklist items cover all items as part of pre functionals, contractor will not be required to submit separate pre functional checklists. If the CxA believes that the checklist cannot be used for documenting, CxA approved form of similar rigor may be used.

Contractors assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.

If required, PFCs are developed by the CxA after submittal approval, completed by the installing contractor during equipment or assembly installation, and verified by the CxA. All completed PFCs shall be included in the final Cx Report.

Project-specific PFCs, created by the CxA,, are reviewed by Caltech and appropriate team members.

Sampling procedures can be used only if defined in the Cx specifications. Otherwise, 100% of all commissioned equipment and assemblies will have PFCs created by the CxA and completed by the Contractor.

PFCs will include:

- Vital information on the equipment or materials being supplied.
- Information shall detail what equipment/material was specified, submitted and installed.
- The condition of the equipment at the time it is delivered at the site and prior to its installation.
- Proper installation of the systems and assemblies.
 - Evaluation shall focus on the physical installation of the systems and assemblies, on their ability to meet the contract documents requirements, and on accessibility for Cx, testing, and maintenance operations.

PFCs are a list of items to be noted, checked, or remembered and are used in the context of this guideline for general evaluation of compliance with construction requirements. Checklists should not be considered a detailed or exhaustive list of all items that may require further review and evaluation to ensure compliance with the OPR, contract documents, or manufacture's requirements. The skills and experience of the CxA and Cx specialists are needed in each Cx Activity to interpret and apply the listed items.

Construction checklists consist of two general types:

- Component/Equipment Based
 - These construction checklists are used for components and pieces of equipment that are delivered, installed, and started up during construction. There is an individual checklist for each individual component or piece of equipment.
- System/Assembly Based
 - These construction checklists are used for systems and assemblies where separate checklists cannot be applied to subcomponents of the system or assembly. There is a single checklist for the entire system often assembled around the sequence of operation.

These may be developed and submitted for consideration by the manufacturer/installation team of the equipment. Final acceptance will be by Caltech with input by the CxA. Otherwise, all PFCs are developed by the CxA.

PFCs are developed by the CxA once each related submittal is accepted, maintained by the general contractor, and used by the general contractor and subcontractors. Progress will be tracked via a cloud-based system acceptable to the owner.

The approach to the structure of the checklists is to focus on key elements. For unique pieces of equipment, manufacturer, make, model, and serial number information should be captured. When multiple components are to be installed, such as lighting components, then there shall be generic PFCs that are not specific to a particular piece of equipment.

During each site visit during this phase, the CxA will randomly verify a sample of the PFCs completed since the CxA's previous site visit. Both positive and negative items from this review are to be conveyed to the project team. Once a PFCs is completed with no negative responses, the equipment or assembly in question should be ready for the next step in the process, typically startup.

Each contractor involved in the installation of the subject of the PFC will have sections dedicated to their scope that they are responsible for completing during the installation process.

CxA to issue independent pre functionals if manufacturer's startup forms have not covered all the items.

See [03.03.05.24 Complete PFCs](#) below for information on completion of PFCs

03.03.05.13 FPT Development

Test procedures define the means and methods to carry out the tests that are accomplished during the Construction-Phase. Test procedures provide the following:

- Participants required for the test, which may include the primary contractor, secondary contractors, design professionals, the CxA, operators, the local authority having jurisdiction, and manufacturers associated with the equipment, system, or assembly.
- Prerequisites for the test performance in terms of completion of systems and assemblies and acceptable completion of other activities.
- Step-by-step instructions to exercise the specific systems and assemblies under test. Instructions include how to configure the system or assembly to start the test and how to restore the system to normal operation at the conclusion of the test.
- List of instrumentation, tools, and supplies required for the test. The list should indicate which of the participants is responsible for each of the items listed. The list should be specific as to make, model, range, capacity, accuracy, calibration, and other pertinent performance requirements.
- An indication, for each step of the procedure, of what observations or measurements must be recorded and the range of acceptable results.

The Cx Team will develop a range of test verification procedures. These procedures include the following:

- Component test procedures: verify the performance of components under a full range of actions, responses to inputs, and loads.
- System/assembly test procedures: verify the performance of subsystems, systems, and assemblies under a full range of operating conditions (both normal and emergency), responses to inputs, and loads.
- Intersystem test procedures: verify the interactions between systems and assemblies.
- OPR test procedures: verify that the various systems and assemblies that comprise the facility deliver the intended OPR at the point of use.
- Use quality-based sampling for verification of each test determined to be related to the OPR. Please refer to ASHRAE Standard 202 - Commissioning Process for Buildings and Systems Informative Appendix B – Quality-Based Sampling Process for details on sampling.

In developing the test procedures, special attention must be paid to issues of personnel safety, equipment/ assembly protection, and manufacturer's recommendations to protect the validity of the warranty.

Develop Test Data Records

Test data records capture test data, observations, and measurements. Data may be recorded on photographs, forms, or other means appropriate for the application. The following minimum information should be recorded:

- Test number.
- Date and time of the test.
- Indication of whether the record is for a first test or retest following correction of a problem or issue.
- Identification of the system, equipment, or assembly under test. List the location and the construction document designation. Include the sampling strategy to be used for the test.
- Conditions under which the test was conducted. For example, when testing, fully describe the ambient conditions, setpoints, overrides, and the status and operating condition of devices, systems, and equipment that impact the results of the test.
- Expected performance of the systems and assemblies at each step of the test.
- Observed performance of the system, equipment, or assembly at each step of the test. When data forms are used, check boxes generally do not adequately describe the system performance and therefore should be avoided in most cases. A blank space in which the observed or measured performance may be described provides more information for diagnostics and a future baseline for performance.
- Notation to indicate whether the observed performance at each step meets the expected results.
- Other observations about system performance or test procedure.
- Issue number, if any, generated as a result of the test.
- Dated digital signatures of the person performing the test and of the witness, if applicable.

03.03.05.14 Meetings

Consistent, periodic Cx Team meetings are essential to maintaining the progress of the project.

The schedule of meetings should be documented as early as possible during the Construction Phase and updated as required due to schedule changes. The meeting dates and times should be known a minimum of two weeks in advance and should be coordinated with other meetings to minimize travel time and costs for various attendees.

Team members represented at the meeting must be authorized to make commitments and decisions for their respective organizations to facilitate an effective Cx Team meeting.

Prior to a meeting (usually a minimum of three days) an agenda should be distributed to all invited attendees. The agenda should include the following:

- Meeting location
- Start time

- List of invited attendees
- List of items to cover (previous action items, outstanding issues, schedule review, new issues, and other business) along with defined time allotments for each item
- End time
- Attachments, if applicable

The meeting time and duration should be strictly adhered to. This will set the tone for other Cx Process Activities.

Within a reasonable and established period (frequently, three days) after the meeting, the CxA will distribute meeting notes or minutes. This should include the following:

- Date, time, and location of the meeting
- List of attendees
- Resolved action items and issues
- Outstanding action items and issues, including clear identification of the responsible party and due dates
- Date, time, and location of the next meeting
- Controls Bench Testing / Review

Review of point naming, folder organization, override-ability, wire logic & graphics. **Per current** Caltech Design Guidelines. Provide complete DDC submittal/as-built package documentation. Review for discrepancies with the latest point naming standards.

03.03.05.15 Bench Testing

In order to ensure an efficient delivery of the controls and analytics package during the final construction period, the BAS controls contractor shall work with the CxA to bench test all control hardware and software before it is field deployed. The CxA will provide the controls contractor with the Caltech commissioning specifications as they pertain to the BAS controls programming and bench testing. These will enable the CxA to leverage the analytics-based approach to commissioning. Expectations/specifications will include:

- Connection of system supervisors to typical field controllers, to test typical communications.
- CxA coordinated controls point database, and programming configuration that meets the latest Caltech BAS Naming Standards (points list will be provided by CxA).
- Remote access to the bench programming.
- Availability and verification of functional commissioning override points available to the commissioning team as specified in the Caltech commissioning specifications (points list will be provided by CxA).
- Programming Review
 - Prior to final commissioning of the controls programming into the system, the controls contractor will provide some electronic format of the field-controller level programming for the CxA to review and compare to the Sequence of Operations within the design specification. This programming review allows potential issues in the programming to be caught earlier on prior to deploying the automation in the field.

03.03.05.16 Site Observations

The systems and assemblies to be commissioned, identified in the Owner's Project Requirements (OPR) and Cx Plan, shall have their proper installation, coordination, testing, and interaction among commissioned systems and assemblies evaluated to confirm compliance with the OPR and with the contract documents. Site visits are a primary method used during the Construction Phase to verify that the installed systems and assemblies comply with the OPR.

The contractor is responsible for installing and starting up 100% of the equipment and assemblies, the design professional is responsible for verifying adherence to the project specifications, and it is the Commissioning Authority's responsibility to accomplish ongoing verification that the contractor's work achieves the OPR.

A clear, concise, and consistent procedure must be followed for each site visit to properly identify Construction-Phase process problems and issues. As outlined in the OPR and Cx Plan, the site visit procedure uses statistical sampling techniques for verification of the construction checklists and record documents. This provides assurance that the verification process is not biased and has reliable consistency. The recommended procedure has the following general steps:

- Identify the current state of construction to define the scope of systems and assemblies that can be verified.
 - The PFC progress since the previous site visit provide one way to define this scope.
- Randomly selected samples, at the rate outlined in the OPR and Cx Plan, of the systems and assemblies identified for verification.
 - This can be accomplished by randomly selecting a starting point and selecting every tenth item from a list or by automatically generating a random sample from a computerized database.
- Identify Cx Team members for the site visit.
- Any inconsistent problems (one or two occurrences) are sent to the contractor, detailing the specific component, system, or assembly for resolution.
- Meet with contractors to discuss any issues identified and the general progress of the project.
- Meet with the Owner's representative to review the findings, project schedule, and outstanding issues.
- Develop a site visit report and distribute to the Cx Team members and other interested parties.
- Update the Issues Log.

Any consistent problems with the installation identified (typically more than 10% of the sample has the same issue), including record documents, are documented in general terms and provided to the contractor for resolution. The contractor is then responsible for 100% checking of all affected systems or assemblies and making corrections as required.

03.03.05.17 Installation

Installation of all equipment and systems is completed by the Contractor. Installation should begin only after all associated submittals have been accepted. The Contractor is responsible for the QA/QC of all

installations. This includes completing & submitting all required documentation and performing, documenting & submitting results from all required testing.

03.03.05.18 Asset Management

Apply QR labels to equipment.

03.03.05.19 Shops Initial Walk-Through & Observations Tracking

Initiate scheduling coordination

03.03.05.20 Attend and track observations.

Verify QR label placement.

03.03.05.21 Asset Management

Complete Contractor Asset Data As-Builts Form in SAM.

03.03.05.22 Asset Management

Backcheck data entry in Contractor As-Builts Form.

03.03.05.23 Pre-Startup

These are contractor-driven activities required by the contract documents that are required to be complete prior to startup of the associated equipment. These activities may include:

- Duct air leakage testing
- Contractor activities.
- Observation and witnessing listed in separate tasks.
- Piping pressure tests
- Coordination studies, etc.

03.03.05.24 Complete PFCs

Pre-Functional Checklists shall be completed and digitally signed by the Contractor, verifying that systems, subsystems, equipment, and associated controls are ready for startup. The CxA will review the PFCs to verify accuracy and readiness for startup. Inaccurate or incomplete PFCs will be returned to the Contractor for correction and resubmission.

See [03.03.05.12 PFCs](#) above for additional details.

03.03.05.25 Startup

The performance of the startup shall be directed and executed by the Contractor. Startup is performed by either or a combination of the installing contractor and/or the manufacturer or their authorized representative. Startup shall not be performed on any piece of equipment prior to submittal and approval of the related completed Pre-Functional Checklists and proposed Startup Reports.

The Contractor shall develop Startup Reports by combining, or adding to, the checklists with the manufacturer's detailed startup and checkout procedures from the O&M manual data and the field checkout sheets normally used by the Contractor for each piece of equipment requiring startup. The report shall be prepared and submitted by the Contractor immediately after the related equipment submittal(s) has been approved.

The report shall include checklists and procedures with specific boxes or lines for recording and documenting the checking and inspections of each procedure and a summary statement with a signature block at the end of the plan. Startup Reports shall be completed during the startup process by qualified individuals with direct knowledge of the procedure.

Two weeks (minimum) prior to equipment startup, the Contractor shall schedule startup and checkout.

Functional Testing shall not be started on any system until Startup Reports for all associated equipment are submitted and approved.

For all direct digital controls, prepare a Point to Point Report that verifies each point is communicating, reporting, calibrated, and controlling properly. Submit all results in writing, including: system name, sensor/point name, measured value, DDC value, and Correction Factor.

The CxA reviews contractor and special agency equipment start-up and quality control testing documents and witness selected or critical startups and contractor quality control tests.

03.03.05.26 Asset Management

Complete Contractor Warranty Form in SAM.

03.03.05.27 Asset Management

Overall review and approval of asset data in SAM.

03.03.05.28 Asset Management

Load asset data to IWMS via AssetSync.

03.03.05.29 SkySpark Integration to BAS

Perform point discovery, import, tagging & naming, applying sparks, user account management.

03.03.05.30 TAB

TAB can begin once startup of associated equipment is complete. During TAB, testing and balancing of all equipment, sub-systems, systems, and system interfaces is accomplished, reported, and verified by the TAB contractor. The results of each component's actual operating tests are recorded. After testing is completed, the certified TAB Report is compiled, stamped, and submitted.

03.03.05.31 TAB Approval

The certified TAB Report is reviewed per the 03.03.05.07 Process Submittals and Consolidate Issues above.

03.03.05.32 TAB Validation

Once the TAB work is complete and the report has been submitted and approved, the CxA will validate a sample, usually 10%, of the values in the report by witnessing the TAB contractor repeat the procedures used in obtaining the original measurements. If the current values are within the contract-allowable tolerances, usually +/-10%, the CxA will consider the report to be validated and recommend acceptance.

If the variation of the results is outside of the acceptable range, the CxA will notify the team and discuss next steps. This may include invalidation of the report, which would require retesting by the TAB contractor and resubmittal of the report.

03.03.05.33 Meeting

Functional Test requirements review

03.03.05.34 Sparks Development

Consult Caltech and Develop sparks for continuous monitoring.

For large projects only (>15 zones).

03.03.05.35 Analytics Driven Verification

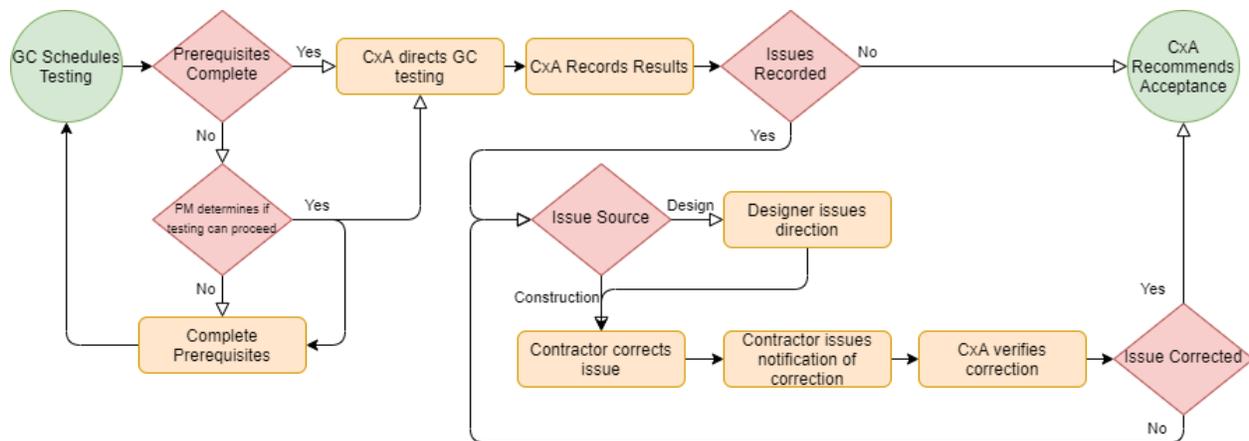
Once startup is complete, CxA will begin utilizing the SkySpark database to gain visibility into the operation of the systems as they come online. This provides early visibility into automation system issues that would otherwise not be discovered until functional testing. Finding these issues prior to functional testing provides the contractors with the information they need to address problems while they are still on site and engaged in the project, simplifying the resolution process.

03.03.05.36 Functional Performance Test (FPT) Execution

03.03.05.36.01 Manual Field Testing

Execute FPTs in the field and prepare issue log.

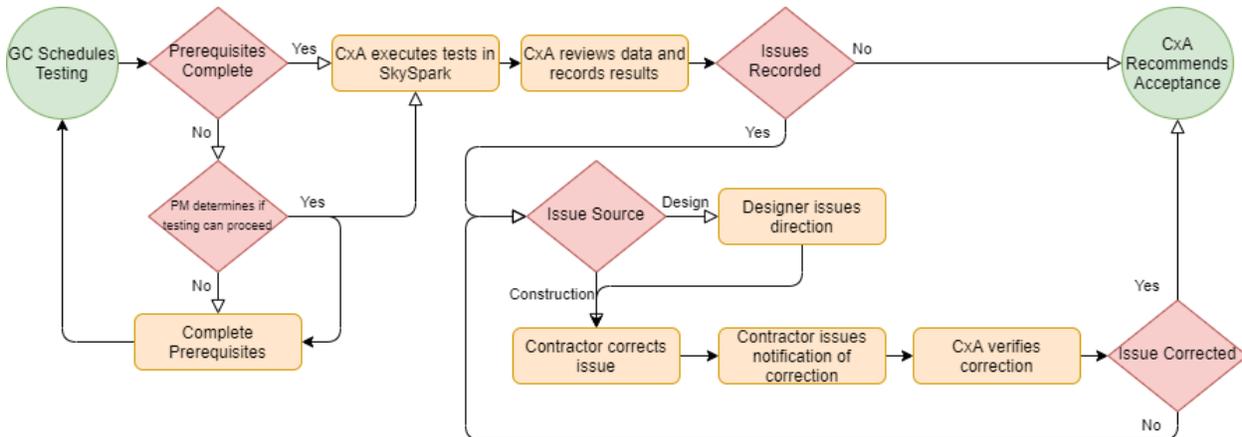
Table 19 FPT – Manual Flow Chart



03.03.05.36.02 Functional Test Procedure Execution - Automated Testing

Run automated tests to augment manual testing and add items to issue log.

Table 20 FPT – Automatic Flow Chart



For large projects only (>25 zones).

03.03.05.37 Shops Final Walk-Through & Observations Tracking

Initiate scheduling coordination

Attend and track observations.

03.03.05.38 Training and O&M Manuals

O&M Manuals and training to be provided to be submitted as part of the required submittals, as required in the Contract Documents.

03.03.05.39 Training

The specifications define the required training for each project. A training manual may be required that includes the training plan, which is composed of the training syllabus and agenda that are provided to the contractor by the Owner with help from the CxA. The training manual also contains the results of training, including the training material and training evaluations completed by the contractor. It is an example to provide direction, in that training needs vary substantially for each construction project or new building. The following is an example of a training manual outline or syllabus for the Training Manual with a focus on electrical and mechanical systems.

Training Syllabus

This syllabus describes the objectives of the various sessions, lectures, and demonstrations that form a part of the training program developed for the Do-It-Right Building.

There are two main sessions on the electrical systems and two main sessions on the mechanical systems that will provide training to the OK Service personnel. The first session will be conducted at the time of start-up and check-out and the second session will be about two months later. Sessions will be a minimum of two days duration for the basics in each system and be conducted as specified below. The sessions will be conducted at the site.

All training sessions will be video recorded.

A training agenda that follows Caltech's requirements will be provided for each session. This will be submitted three weeks prior to the scheduled training session. All listed Caltech representatives will sign this prior to proceeding with the training.

A list of training topics that are appropriate for consideration are listed in the attached Training Agenda Topics list.

The CxA will be notified of the scheduled training time and provided with a copy of the training material fifteen days prior to each training session. The CxA will review the material and share comments with the Caltech and the design professionals. If any aspects do not meet the requirements of the specifications, this will be communicated through the design professionals. The CxA will attend 25% or more of the training sessions.

A receipt acknowledging completion of each item of instruction will be secured.

The training will be evaluated based upon on the criteria in the attached evaluation form.

Electrical Systems

The training shall include the following:

- General familiarization and operating procedures for the entire electrical installation
- Routine maintenance procedures for equipment
- Specific operating and maintenance procedures for the following:
 - Switchboards
 - Emergency power supply system
 - Fire alarm system

Factory-trained technicians will provide operating and maintenance instructions on the following:

- Emergency power supply system
- Fire alarm system
- Lighting control systems
- Medium voltage pad-mounted switchgear
- Mechanical Systems.

Mechanical Systems

The training shall include the following:

- General familiarization with and operating procedures for the entire plumbing, laboratory gas, pure water, compressed air, fuel, HVAC&R, and fire protection systems installation.
- Routine maintenance procedures for equipment.
- Specific operating and maintenance procedures for the following:
 - Hot-water system consisting of boilers, pumps, controls, and hydronic specialties
 - Chilled-water systems consisting of chillers, cooling towers, pumps, controls, and hydronic specialties
 - Automatic temperature control system consisting of all associated hardware, software, and program logic; this is to be, arranged by systems

- Laboratory air-side control system consisting of supply, hood, and general exhaust valves, reheat coils, and room control panel
- Clean authority fire suppression systems, including emergency procedures, abort functions, and safety requirements
- Laboratory hood exhaust air system
- Factory-trained technicians will give instruction on the following specialty systems and equipment:
 - Variable speed drives
 - Chillers
 - Automatic temperature controls
 - Water treatment systems
 - Laboratory control systems

DDC System.

There will be two formal training sessions on the DDC system. Each of the sessions will be conducted by factory-trained personnel for a minimum duration of 2 8-hour days. Materials and training will be provided for up to 5 operators per session, selected by the Caltech.

There will be a separate training course provided on the DDC system for Caltech supervisory personnel. This training will briefly cover the material of the operator training session but will be focused on the more advanced features of the system with emphasis on the energy conservation strategies and reporting capabilities of the system and how to implement them. The training session will be conducted by factory trained personnel for a minimum duration of 2 8-hour days, for a total of 16 training hours. Materials and training will be provided for up to 2 persons, selected by Caltech.

03.03.05.40 Punchlist

The Contractor's final punchlist will be given to the CxA for review of the list and the completed work to determine whether the list is both accurate and complete. Items which require correction and/or completion, that are not included in the contractor's punchlist, shall be supplemented by the CxA. Caltech should be informed that the items on the punch list shall be rectified and/or completed within the time limit set forth in the Substantial Completion. The Contractor shall also be advised that any correction and/or completion of punch list items shall be conducted in a manner so as not to adversely affect or disrupt the Owner's occupancy of the facility.

03.03.05.41 Substantial Completion

Substantial Completion refers to the date when all systems have been tested and found to be working properly, all punchlist items have been identified, major punch has been addressed & approved by Caltech, all Services & Work called for by the Contract Documents (other than Punchlist items) is complete, and the Project is ready to be used by CALTECH, even though minor Punchlist items remain to be corrected, provided such Punchlist items do not have a material or adverse effect on CALTECH's ability to utilize the Project for its intended purpose.

03.03.05.42 Warranties

The Warranty Period, as defined in the Contractor Documents, begins at Substantial Completion.

03.03.05.43 Certificate of Occupancy

Certifying building's compliance with applicable building codes and other laws and indicating it to be in a condition suitable for occupancy.

03.03.05.44 Performance Period

The Performance Period is intended to demonstrate that all equipment and assemblies can operate as integrated systems under automatic control without any issues or interventions required. This activity should be included in the project's schedule after completion of functional tests and shown as complete prior to Substantial Completion.

After the acceptance of all Functional Tests, or as directed by the CIT PM, a performance period of 5 consecutive calendar days will commence. This period shall be completed prior to final acceptance of the project. In event of failure to meet the standard of performance during any initiated performance period, it is not required that one 10-calendar day period expire in order for another performance period to begin.

If equipment or system operate and demonstrate continuing compliance with the requirements outlined in the construction documents for period of 5 consecutive calendar days from commencement date of performance period, the test will be considered to have passed.

Successful operation includes automatic operation without manual intervention, without malfunction, without alarm caused by control action or device failure, and with smooth and stable control of systems and equipment in conformance with the contract documents.

Equipment will not be accepted by Caltech and final payment will not be made by the Owner until acceptable performance is met.

Trends taken at the specified intervals will be reviewed by the CxA during this period as the primary form of evaluation.

Systems shall be first tested as independent building systems followed by tests of systems tied into existing systems, where applicable.

One the Contractor meets all of the requirements of the Commissioning Plan and the successful completion of the performance period, and receipt of the required documentation, the CxA provide Caltech with a statement of acceptable performance.

03.03.05.45 BMS Tuning and Optimization

Caltech leverages advanced analytics tools connected to the building automation system to improve the efficiency and impact of the commissioning process, while streamlining handover to operations and warranty period testing. This approach also supports measurement and verification (M&V) and on-going commissioning. The BMS tuning and optimization period involves using advanced algorithms in SkySpark to automatically fine-tune and control heating, air-conditioning, and ventilation systems while maintaining or improving building comfort. Examples may include tuning minimum VFD speeds and temperature optimization.

03.03.05.46 Final Completion

Punchlist Items are resolved

Resolve all the remaining punchlist items.

03.03.05.47 Certificate of Readiness

To be completed by Cx Authority

Caltech to provide the template.

03.03.05.48 Commissioning Report and Systems Manual

03.03.05.48.01 Cx Report

Provide a Cx report and create a useful document which details the building systems.

The Cx Report is the documentation of the commissioning work and results accomplished during the Cx Process. The Report contains the following:

Identification of any systems or assemblies that do not perform in accordance with the OPR. For various reasons, Caltech may choose to accept performance that is at variance with the OPR, either permanently or until schedule and budget constraints allow for correction. Acceptance of these conditions should be documented along with the environmental, health, safety, comfort, energy, and operating and maintenance cost impacts. The OPR must be updated to match the revised expectations.

Evaluations of the operating condition of the systems at the time of test completion.

Construction checklist completion and verification summary.

Results from the Issues Log, including the descriptions of issues and the measures taken to correct them. The description should assess the importance of the issues.

Test procedures and results. This section should incorporate the original test procedures and completed forms, including additional data such as photos, computerized documentation, and other records of the tests. Data should include the final accepted test, as well as earlier tests that failed to meet the specified criteria. This section should also include a set of blank data forms for future use in the Ongoing Continuous Cx Process and Recommissioning.

Deferred tests. Execution of some tests may be deferred until appropriate natural loads, such as occupancy or design weather conditions, are available. For these deferred tests, the prerequisite conditions and an estimated schedule for their completion should be included.

Lessons learned. Evaluation of the Cx Process used and changes that will improve the delivered project and form the basis for the Final Cx Process Report developed during the Occupancy/Operations Phase. This is essential to ensure that issues, benefits, and recommendations are captured in a written document while all team members are available, and information is fresh.

03.03.05.48.02 Systems Manual

Developing the systems manual encompasses gathering all of the information related to the systems, assemblies, and the Cx Process and incorporating it into a usable information resource with indexes and cross-references. This resource shall include the final OPR, BOD, the final Cx Plan, Cx Process Report, manufacturer installation manuals, manufacturer operations and maintenance manuals, system schematics, verified record drawings, and test results. This information is edited and organized to focus upon on the key systems (roofing, walls, fire alarm, chilled water, hot water, etc.) in the building.

Coordination with operations and maintenance personnel in developing standard formats and divisions (shops) is accomplished to simplify future systems manual development.

Also included in the systems manual is the development of periodic maintenance and information for insertion into a computer maintenance management system (CMMS), including equipment make and model information, checking requirements, maintenance requirements, and troubleshooting items.

The entity responsible for developing the systems manual shall include all items involved in the project and capture the system and assembly data in either an electronic or printed version. In addition, printed operations, service, maintenance, spare parts list, and repair manuals may be provided. This entity (owner, contractor, design professional, other) shall have the skills of design, construction, and operations required to develop a cohesive Systems Manual.

The required details for a full systems manual are enhanced in each of the technical Cx Process guidelines. The systems manual will have multiple sections depending upon on the number of systems focused upon on during the Cx Process. The systems manual will include a detailed table of contents with a notation as to resource storage location if not in the actual manual.

The following outline is a recommended format:

- Executive summary (facility level). This section includes an overall description of the building and its systems, including a listing of major capabilities and limitations imposed by the design or building code. The description should include type of facility, general description (number of floors, gross area, net area, type of occupancy, etc.), and general system descriptions. A list of contractors, subcontractors, suppliers, architects, and engineers involved in the project along with their contact information should be included in this section.
- OPR (facility level). A copy of the final OPR for the facility is included in this section. This document was initially developed during the Predesign Phase and was updated throughout the project by the Owner, CxA, or design professionals.
- Basis of Design (facility level). This section includes the final BOD document at a facility level. This document is written by the design professionals during the Design Phase and is updated by them to include any changes during the Construction Phase.
- Construction record documents and specifications (not included in specific systems sections). This section includes elements of the record set of construction documents (including specifications) that are not covered under specific systems—updated to reflect the final installation.
- Approved submittals (not included in specific system sections). This section includes a copy of the approved submittals (not included under specific systems) with all field modifications and accessories clearly marked. In addition, the comments from original submittals shall be included.
- Facility operating procedures for all normal, abnormal, and emergency modes of operation (facility level). This section includes detailed operating procedures for the facility during normal, abnormal, and emergency modes of operation. This is not intended to be automatic control sequences, but general operating procedures. This would include items such as building access during various situations (normal operation, after-hours operation, fire alarm, civil disturbance operation, emergency power operations, etc.).

- A list of recommended operational record keeping procedures at the facility level, including sample forms, trend logs, or others, and a rationale for each. This section includes direction to the operation and maintenance personnel as to what information needs to be documented and kept on the operation of the facility and why these records are important or will benefit the Owner or operations and maintenance personnel in the future.
- Maintenance procedures, schedules, and recommendations (facility level). This section includes the manufacturer's recommendations for maintenance procedures and when maintenance should be performed on systems not included in specific system sections.
- Ongoing optimization (facility level). This section includes guidance for the ongoing optimization of the facility. Included in the section are schedules of periodic benchmarking using checklists and tests developed for the original construction, procedures for maintaining the OPR and BOD documents, and guidance on what to do when the OPR are is not achieved, met.
- Attachments. Cx documents listing and storage location.

The following section is completed for each system or assembly requiring operation and maintenance:

- Executive summary, per system/assembly. This section includes a description of the systems/assemblies covered in this section, including a listing of capabilities and limitations imposed by the design or building code. The description should include type of system/assembly, general description, and schematics. A list of contractors, subcontractors, suppliers, and design professionals involved with this system along with their contact information should be included.
- Operating procedures for all normal, abnormal, and emergency modes of operation, per system/assembly). This section includes detailed operating procedures during normal, abnormal, and emergency modes of operation. This is not intended to be automatic control sequences, but general operating procedures.
- A list of recommended operational record-keeping procedures, including sample forms, trend logs, or others, and a rationale for each system/ assembly). This section includes direction to the operations and maintenance personnel as to what information needs to be documented and kept on the operation of the systems and why these records are important or will benefit the Owner or operations and maintenance personnel in the future.
- Maintenance procedures, schedules, and recommendations, per system/assembly. This section includes the manufacturer's recommendations for maintenance procedures and when maintenance should be performed.
- Ongoing optimization, per system/assembly. This section includes guidance for the ongoing optimization of the system/assembly. Included in the section are schedules of periodic benchmarking using check lists and tests developed for the original construction, procedures for maintaining the OPR and BOD documents, and guidance on what to do when the OPR is not achieved.
- Operations and maintenance manuals, per system/assembly. This section includes the manufacturer's printed operations and maintenance manuals for the specific equipment/components provided for the system/assembly. Also included is a recommended spare parts list, a troubleshooting guide for common situations, and one-line diagrams for each applicable system.

- Training records, per system/assembly. This section includes information on training provided and attendees. In addition, information on ongoing training shall be provided.
- Cx blank and completed for, including PFCs and FTPs, per system/assembly.

03.03.05.49 Update FCA (ISES Report)

Equipment and systems affected by project should be updated in FCA database.

Update ISES database.

03.03.05.50 Occupant Satisfaction Survey

PM to send occupant satisfaction survey to the user group.

03.03.05.51 Project Handoff Form

Caltech internal handoff form submitted to Maintenance Management

All documents uploaded to Meridian.

03.04 Occupancy

The Occupancy/Operations Phase of the Cx Process begins at substantial completion. As a minimum, the Cx Process Activities begun at this point should continue through the end of the contractual warranty/correction period and ideally continue throughout the life of the facility. During the Occupancy/Operations Phase, the ongoing operation, maintenance, and modification of the facility systems and assemblies, and their associated documentation, are verified against the updated OPR.

03.04.01 RACI Table

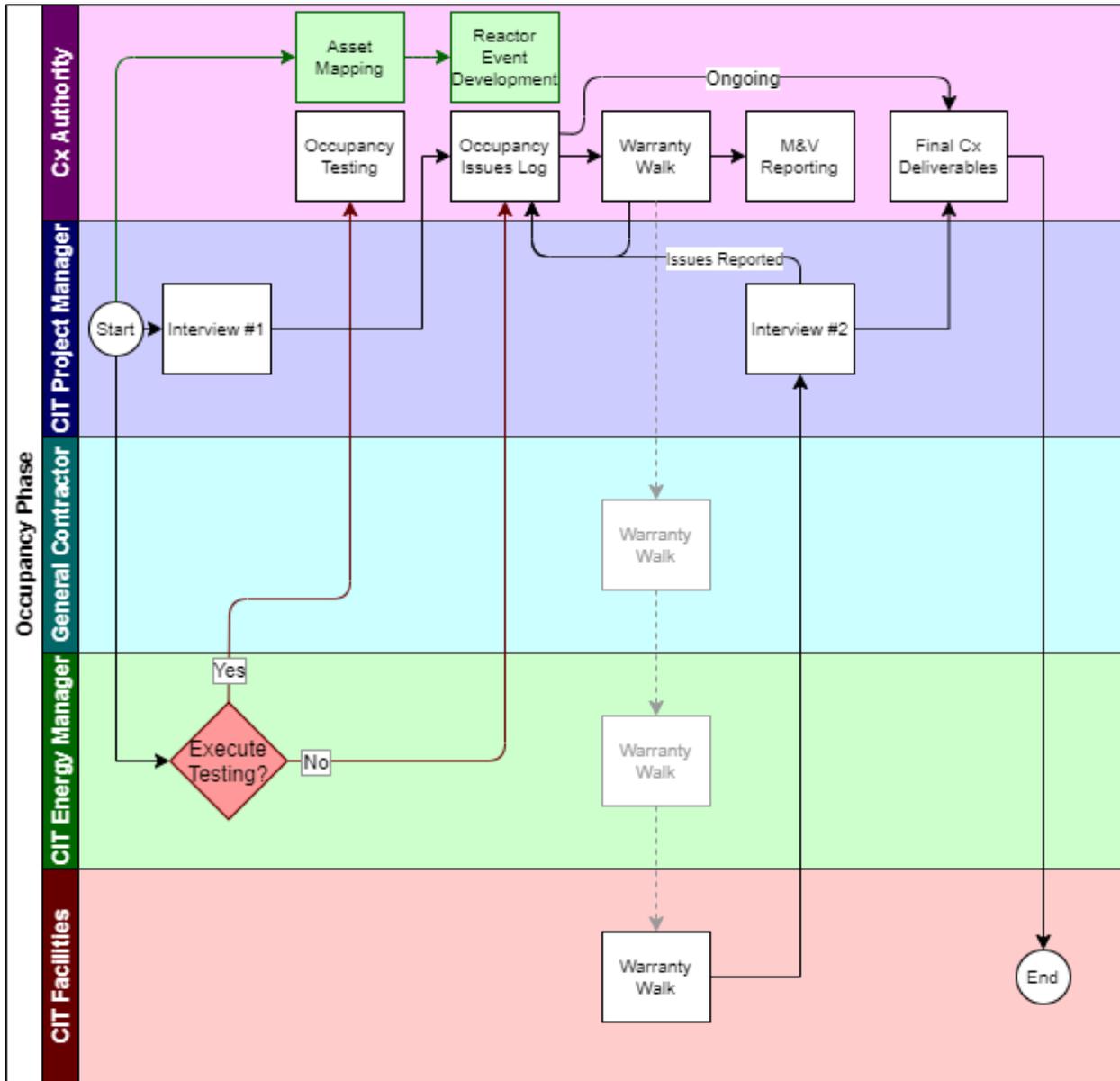
Table 21 Occupancy Phase RACI Table

Task #	Task Name	Description	Cx Authority	CIT Cx Team	CIT PM	CIT Space Manager	CIT Technical Reviewers	CIT Asset Manager	CIT Energy Manager	Architect/Engineer of Record	General Contractor	CIT Facilities Maintenance	Comments
O1	Start	Notification of start of phase	I	I	R	I	I	I	I	I	I	I	
O2	Initial Survey	Occupant and facilities interviews	C	I	R	-	-	I	I	-	C	C	
O3	SkySpark-IWMS Asset Mapping	Map IWMS assets to SkySpark BAS equips for automated work order generation.	AR	-	-	-	-	-	C	-	-	C	
O4	SkySpark-IWMS Reactor Event Deployment	Provide sparks with reactor event table for IWMS. Loading is performed by Caltech Asset Manager.	R	-	-	-	-	A	C	-	-	-	
O5	Occupancy Testing	Re-run automated functional tests, track issues and present findings at Post-Occ Cx Meeting(s).	R	-	-	-	-	-	A	-	C	I	
O6	Occupancy Cx Issues Log	Maintain detailed list of issues with assigned responsibility. Track to resolution.	R	-	I	-	-	-	A	-	C	I	Provide Post-Occ Issues Log document.

Task #	Task Name	Description	Cx Authority	CIT Cx Team	CIT PM	CIT Space Manager	CIT Technical Reviewers	CIT Asset Manager	CIT Energy Manager	Architect/Engineer of Record	General Contractor	CIT Facilities Maintenance	Comments
O7	M&V Reporting	Include pre/post-Cx energy baselines, predicted/actual performance & energy savings.	R	-	-	-	-	-	A	I	-	-	For CECIP projects only.
O8	Warranty Walk	Walk the site with the shops, CxA, Contractor and Energy Manager	C	C	R	C	C	C	C	C	C	C	
O9	Warranty Review Meeting	Meet 10 mo post-occ to handover project from D&C team to Facilities Maintenance.	R	-	A	-	-	C	C	I	C	C	LEED v4 EAc3
O10	Final Cx Report	Amended Final Cx Report and Systems Manual, User Guide Template, Provide test results, validated asset list, SkySpark trends, IWMS Reactor Event Rules, etc.	R	-	A	-	-	-	I	-	-	I	Update and install the "User Guide Template" that reflects occupant-interfacing systems in the space. (See Caltech "Building User Guide Template". Contractor to install upon completion.)
O11	Interview	Occupant and facilities interviews	C	C	R	-	-	I	-	-	-	C	

03.04.02 Flow Charts

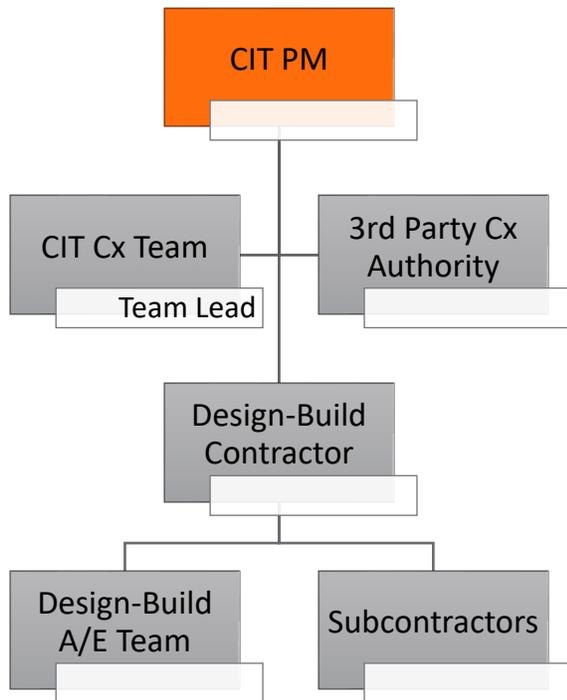
Table 22 Occupancy Phase Flow Charts



03.04.02.02 Organization Chart

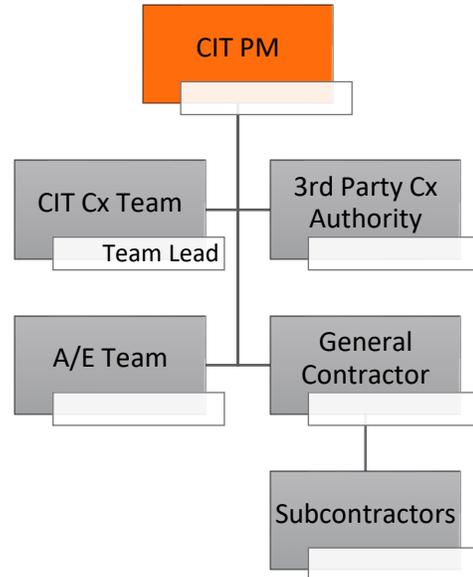
Design-Build

Table 23 Occupancy Phase Org Chart DB



Design-Bid-Build

Table 24 Occupancy Phase Org Chart DBB



03.04.03 Issues Resolution – Occupancy Phase

CxA will provide the issue log to the contractor by reviewing the trend data and/or running the automated functional performance tests. Contractor is responsible for addressing all the issues identified by the CxA in the occupancy/warranty phase.

03.04.04 Tasks

03.04.04.01 Start

Notification of start of phase

03.04.04.02 Initial Survey

Occupant and facilities interviews

03.04.04.03 SkySpark-IWMS Asset Mapping (Optional)

Map IWMS assets to SkySpark BAS eqips for automated work order generation.

03.04.04.04 SkySpark-IWMS Reactor Event Deployment (Optional)

Provide sparks with reactor event table for IWMS. Loading is performed by Caltech Asset Manager.

03.04.04.05 Occupancy Testing

Re-run automated functional tests, track issues and present findings at Post-Occ Cx Meeting(s).

03.04.04.06 Occupancy Cx Issues Log

Maintain detailed list of issues with assigned responsibility, track to resolution, and provide Post-Occupancy Issues Log document.

03.04.04.07 M&V Reporting

Include pre/post-Cx energy baselines, predicted/actual performance & energy savings. For CECP projects only.

03.04.04.08 Warranty Walk

Walk the site with the shops, CxA, Contractor, and Energy Manager

During the first year of the system and buildings' operation, it is important to assure that the performance of the facility is maintained, particular before the warranty period expires. At 10 months into a 12-month warranty period, operation of system and components is reviewed by Caltech, the Contractor, and the CxA to identify any items that must be repaired or replaced under warranty. CxA will also interview building operating personnel to identify any outstanding warranty failures and any persistent equipment failures that should be handled within the warranty period. This review is based on warranty items and continued performance with Owner's project Requirements. The CxA will document the results and forwards recommendations to Caltech and Contractor for resolution.

03.04.04.09 Warranty Review Meeting

After the Warranty Walk outlined in 03.04.04.08 Warranty Walk above, a meeting will be held to review the findings and determine next actions.

03.04.04.10 Final Cx Report

Amended Final Cx Report and Systems Manual, User Guide Template, Provide test results, validated asset list, SkySpark trends, IWMS Reactor Event Rules, etc.

Update and install the "User Guide Template" that reflects occupant-interfacing systems in the space. (See Caltech "Building User Guide Template". Contractor to install upon completion.)

03.04.04.11 Interview

Occupant and facilities interviews

04 Appendices

04.01 Sample Scope for Commissioning Services

Background

Caltech is seeking the services of a qualified Commissioning firm for the [Project Name].

The project is a [square footage] gross ft², [# of stories] story, Class [type] building in [city & state], with a project budget of [project budget]. The facility is expected to be composed of [space type%], [space type%], and [space type%].

The project is currently in the [current] phase. The expected schedule is to start [next phase] by [date], start construction by [date], and occupy by [date].

The Delivery method is traditional [design/bid/build] [design/build] with full design documents and specifications being developed by a/an [design/build contractor] [architectural/engineering firm]. The construction documents will be let out to bid and a general contractor is/will be hired to complete the construction. Caltech's primary construction representative on site will be provided by a Caltech project manager. The Commissioning firm will be hired by and report directly to Caltech.

Objectives

The objective of commissioning is to provide documented confirmation that a facility fulfills the functional and performance requirements of Caltech. To reach this goal, it is necessary for the commissioning process to establish and document the owner's criteria for system function, performance, and maintainability; and to also verify and document compliance with these criteria through all phases of the project. In addition, complete operation and maintenance (O&M) manuals, as well as training on system operation, should be provided to Caltech to ensure the building continues to operate as intended.

Scope of Work

The Owner has adopted the Cx Process as their quality process to plan, design, construct, and operate this facility. As with any quality process, the Cx Process provides tools to enable everyone involved in the construction of the facility to verify that the final facility meets the OPR. Refer to the [attached] Caltech Commissioning Guidelines for details on the required Commissioning Scope.

The Commissioning Firm shall be responsible for carrying out, at a minimum, the following tasks. For this proposal, it is assumed by Caltech that all of these tasks will be completed.

Compliance

The proposed scope of work should include compliance with the following:

- California's Building Energy Efficiency Standards, Title 24, Part 6 – [2016]
- USGBC LEED [version 4] Fundamental Commissioning
- USGBC LEED [version 4] Enhanced Commissioning [select Path and Options]

Task by Phase

Cx Process During the Predesign Phase

The Cx Process Activities completed by the CxA during the Predesign Phase include the following:

- Reviewing and supporting updates to the OPR
- Developing the initial Cx Plan
- Acceptance of Predesign-Phase Cx Process Activities

Cx Process During the Design Phase

The Cx Process Activities completed by the CxA during the Design Phase include the following:

- The CxA will work with Caltech to provide asset upload application to the appropriate project team members to capture all maintainable asset data and train the project team on proper asset data entry. The development and training on the use of this asset upload application shall be in coordination with the project team and Caltech. The attributes shall match with attribute fields in the asset templates.
- The CxA shall also manage a tool (input/output function) that will allow the asset template tables to be automatically transformed into a format that can be easily uploaded into IWMS. This may include validation and standardization of attribute fields to ensure data quality and consistency.
- Reviewing and supporting updates to the OPR
- Reviewing the BoD for alignment with the OPR and completeness of the BOD
- Developing a Cx Plan encompassing the Design, Construction, Occupancy/Operations Phases
- Determining the commissioning requirements and activities to include in the construction documents, with review by the design team, for integration into the project's construction specifications
- Review of all specifications and submittal register pertaining to commissioning
- Reviewing the in-depth design documentation developed by the design professionals
- Performing statistically based quality design review at [expected submission iterations] completion of the drawings and specifications
- Lead the asset data commissioning efforts through enforcing naming standardization and creating team and managing user training and access in SkySpark Asset Manager (SAM) Cx
- Create a Measurement and Verification Plan per IPMVP protocol [select option]

Process During the Construction Phase

The Cx Process Activities accomplished by the CxA during the Construction Phase include the following:

- Train the construction team on asset data entry into the Caltech's SkySpark Asset Manager Application
- Verify asset data entry by the construction team and resolve any errors
- Confirm placement of field asset labeling
- Organizing the Cx Process components and conducts a design and construction meeting where the Cx Process requirements are reviewed with the Cx Team
- Organizing and conducts periodic Cx Team meetings necessary to plan, develop the scope of, coordinate, and schedule activities and resolve problems
- Reviewing submittals
- Creating Pre-Functional Checklists for each piece of commissioned equipment

- Verifying the contractors complete Pre-Functional Checklists
- [Statistically sampling] completion of construction check lists on a periodic basis to verify that contractor's quality process is achieving the Owner's Project Requirements
- Developing specific test procedures. The contractors review the procedures

BAS Controls Bench Testing

To ensure an efficient delivery of the controls and analytics package during the final construction period, the BAS controls contractor shall work with the CxA to bench test all control hardware and software before it is field deployed. The CxA will provide the controls contractor with the smart commissioning specifications as they pertain to the BAS controls programming and bench testing. These will enable the CxA to leverage the analytics-based approach to commissioning. Expectations/specifications will include:

- Connection of system supervisors to typical field controllers, to test typical communications.
- CxA coordinated controls point database, and programming configuration that meets the latest Caltech BAS Naming Standards (points list will be provided by CxA).
- Remote access to the bench programming.
- Availability and verification of functional commissioning override points available to the commissioning team as specified in the Caltech Commissioning Guidelines Specifications (points list will be provided by CxA).

Programming Review

Prior to final commissioning of the controls programming into the system, the controls contractor will provide some electronic format of the field-controller level programming for the CxA to review and compare to the Sequence of Operations within the design specification. This programming review allows potential issues in the programming to be caught earlier on prior to deploying the automation in the field.

Integrate SkySpark into the Building Management System

The CxA will integrate all the relevant HVAC, lighting, and metering control points from the building BAS system into the SkySpark analytics platform. Part of the point integration involves validation and commissioning of the BAS system around using proper point naming convention and database organization. This allows the SkySpark integration to be much more efficient and scalable. Upon integration into SkySpark organizes and defines all data into easy and intuitive trend views for the users. This standardized organization is the basis for all analytics rules and features that are then applied to the data and the data quality control around this is critical. It allows the database to then be used to deploy FDD rules and computed histories across the various building and equipment systems that benchmark performance and identify issues and faults that can lead to automated work orders.

- Directing the execution of the tests by the contractors
- Documenting the results of the tests
- Documenting the correction and retesting of noncompliance items by the contractor
- Reviewing, preapproving, and verifying the training provided by the contractors
- Completing the Cx Report
- [Verifying delivery of] [Creating] the systems manual

Cx Process During the Occupancy/Operations Phase

The Cx Process Activities accomplished by the CxA during the Occupancy/Operations Phase include the following:

- Scheduling and verifying deferred and seasonal testing by the contractor
- Verifying continuing training
- Accomplishes a Reviewing warranties with the operations and maintenance staff two months prior to expiration of warranty
- Scheduling, organizing, and attending a lessons-learned workshop. The workshop is facilitated by an independent member of the CxA's firm
- Updating the final Cx Process Report, including Measurement and Verification Report.

USGBC LEED Commissioning Tasks

The following tasks shall be included in the Commissioning Scope of Services and submitted to LEED Online as need to achieve the Fundamental Commissioning prerequisite and Enhanced Commission credits.

Project phases	Fundamental Commissioning	Enhanced Commissioning
Construction Documents	Commissioning plan	
	Owner Project requirement and Basis of Design	
	Commissioning requirements in Construction Documents	
50% CD		50% CD drawing review
GMP/ buy out		Mechanical Contractor submittals review
Construction	Installation checklist	
Installation	Installation inspection	
	Systems functional performance testing	
Post-construction		O&M System Manual development
		O&M Staff Training requirement
	Commissioning report	
10 Month into occupancy		10-month post-construction follow up

Limit of Responsibilities

The CxA is not responsible for design and construction. The CxA may assist with problem-solving or resolving nonconformance or deficiencies, but ultimately that responsibility resides with the general contractor and design professionals.

Focus of The Cx Process

The following systems and assemblies are the focus of the Cx Process:

[Insert list of systems and assemblies]

Desired Qualifications

It is desired that the person designated as the CxA satisfy as many of the following requirements as possible:

- Has acted as the principal CxA for at least three projects during the past year. [Note that the size of the project should be accounted for. Whereas one proposer may have done ten projects all small in size, another proposer that accomplished one large and complex project may have equal credentials].
- Experienced in quality processes.
- Knowledgeable in building operation and maintenance training.
- Excellent verbal and written communication skills. Highly organized and able to work with both management and trade contractors.
- A bachelor's degree in [insert discipline] is strongly preferred and [insert type] certification or professional license is desired.
- The CxA's firm will demonstrate depth of experienced personnel and capability to sustain loss of assigned personnel without compromising quality and timeliness of performance.
- The CxA will be an independent contractor and not an employee or subcontractor of the general contractor or any other subcontractor on this project, including the design professionals.
- [Insert any qualifications or special requirements for a specific system or assembly].

Instructions to Proposers

A proposer must propose to execute all phases of the Cx Process in a single proposal. The proposal must be signed by an officer of your firm with the authority to commit the firm and must include the following information:

- List the key individual who will be the CxA for this contract and describe his or her relevant qualifications and experience. This information is required in addition to any detailed resumes the proposer submits. The contract will require that this individual be committed to the project for its duration.
- Provide project and professional references and experience for three to five commissioning projects for which the proposer was the principal CxA in the last three years. Include a description of the projects, identify when the proposer came into the projects, and describe the involvement of each individual on the proposer's team in the projects. For each project, attach a sheet that includes the name and telephone number of the Owner's project manager, construction manager, facility administrator of the building, the design professionals, and the contractors.
- Describe any experience of the proposer's team in the following areas. List each party's involvement.
 - Quality process experience.
 - Operation and maintenance experience.
 - Design experience.

- Life-cycle costing.
- [Insert other system or assembly specific experience requirements].
- Describe your proposed approach to managing the project expertly and efficiently, including your team participation. Describe what approach you will take to integrate the Cx Process into the normal design and construction process in order to make it "business as usual."
- Describe what you will do to foster teamwork and cooperation from contractors and designers and what you will do to minimize adversarial relationships.
- Describe how your work will facilitate the use of your product as a prototype that may be subsequently used by the Owner in future projects, including access to the electronic versions of all documents and forms.
- As an attachment, provide the following work products that members of the proposer's team wrote:
 - Cx Plan that was executed
 - Integrated commissioning specifications
 - Electronic Issues and Resolution Log
 - Construction checklists
 - Test procedure that was executed
- Detailed breakdown of staffing, hours, and rates
- List inclusions and exclusions or any deviations related to bid documents
- [Insert any other desired instructions].

04.02 Owner Project Requirements

Caltech

OWNER'S PROJECT REQUIREMENTS

FACILITIES | DESIGN & CONSTRUCTION

PROJECT SUMMARY

[CIT PM TO FILL]

GENERAL PROJECT REQUIREMENTS

[CIT PM TO FILL/EDIT]

1. All design and construction consultants shall be responsible for reading and understanding the contents of the Design Guidelines and Cx guidelines and fully implementing its intent whether implied or inferred. Any questions and/or discrepancies noted should be clarified via submission of a formal RFI to Caltech project manager. Refer to the following link: <http://dandc.caltech.edu/design-guidelines> for the latest revision of the Design Guidelines.
2. Projects may require commissioning by an independent Cx authority. Commissioning shall be procured directly thru Caltech. Construction contractor or Design-build team shall interact, coordinate and closely work with the Cx team throughout the entire design, construction and close-out process. See Caltech Commissioning Guidelines for Caltech commissioning requirements. Commissioning activities shall be reflected in all schedules.
3. Information provided in this document shall be used as preliminary project requirements. The design team or design build team shall validate the requirements and propose how these requirements are met and implemented.
4. All abandoned plumbing electrical & associated and/or un-necessary hardware will be removed. All open electrical, plumbing, piping and HVAC shall be installed in a neat and orderly manner, providing a clean appearance.
5. Subsequent design deliverable shall address asset management to entail adding QR codes and/or field labeling to be identified on drawings.

ARCHITECTURAL AND STRUCTURAL

[CIT ARCHITECT/PM TO FILL/EDIT]

GENERAL ARCHITECTURAL & STRUCTURAL

PROJECT SPECIFIC ARCHITECTURAL & STRUCTURAL

1. EXISTING CONDITIONS
2. DEMOLITION
3. OWNER PROVIDED MATERIALS
4. NEW REQUIREMENTS
5. COORDINATION

CIVIL AND LANDSCAPING

[CIT PM/OPS (DELMY) TO FILL]

GENERAL CIVIL & LANDSCAPING

PROJECT SPECIFIC CIVIL & LANDSCAPING

1. EXISTING CONDITIONS
2. DEMOLITION
3. OWNER PROVIDED MATERIALS
4. NEW REQUIREMENTS
5. COORDINATION

MECHANICAL

[CIT MECHANICAL TO FILL/EDIT]

GENERAL MECHANICAL

1. Heat load and/or flow rate quantities mentioned in the OPR documents or the OPR matrix are approximate and are intended to assist the Design-build team with the preparation of their proposal. The quantities shall not be used for sizing the HVAC equipment. Perform detailed heat load and ventilation calculations and submit the results to CIT team for review.
2. Engineer of record shall establish HVAC system capacities based on heat load calculations, ventilation calculations and pressurization calculations. The most stringent requirement shall determine the system capacity. These calculations shall be used as the basis of design and must be submitted to CIT project manager and mechanical engineer for review.
3. Disconnection and relocation of existing utilities shall not affect other parts of the building that are not in the scope and are being served by same utilities. Make any provisions necessary to ensure continuous service to other parts of the building outside the project scope. Common critical utilities include, SA, RA, EA, HHW, DCW, DHW, DHWR, ICW, IHW, IHWR, DI, HPA, CA, NG, AW, W, etc.
4. Areas outside the project scope that are currently being served by common HVAC systems shall remain active and operational for the duration of this project and beyond. Said areas shall be de-coupled from the new labs.
5. Evaluate the size and assess the condition of the existing utilities and ductwork feeding the proposed new labs. If necessary, dismantle and replace partial sections of pipes and duct work with larger pipes and ducts as needed for demands of the new design. Air and water velocity and pressure drops shall not exceed acceptable industry standards. Refer to design guideline for specific information.

PROJECT SPECIFIC MECHANICAL

1. EXISTING CONDITIONS
2. DEMOLITION
3. OWNER PROVIDED MATERIALS
4. NEW REQUIREMENTS
5. COORDINATION

MECHANICAL PIPING

[CIT MECHANICAL TO FILL/EDIT]

GENERAL MECHANICAL PIPING

1. Dismantle and relocate the existing utility branch pipe work as necessary to accommodate the new HVAC and plumbing systems serving the new labs.
2. Dismantle and relocate the existing fire protection pipe work as necessary to accommodate the new fire protection system serving the new labs.
3. Specialty gas and Inert gas piping shall be run in oxy-med grade copper tubing.
4. High-purity gases shall be run in 316L stainless steel tubing with tube fitting joints.
5. Field-verify the POC and size of heating hot water pipes necessary to accommodate the new reheat coils.
6. Field-verify the POC and size of Nitrogen pipe main available to accommodate the new labs. Intercept and extend the campus Nitrogen branch main pipe and run a 1" branch pipe to the 3rd floor labs. Exact location for the POC and pipe routing to be field- verified by the Design-build team prior to bid.
7. Exact location of the nitrogen meter needs to be reviewed and approved by CIT's project manager and project engineer.
8. Install new combination eyewash and drench shower and deck-mounted eyewash as shown. Provide dedicated isolation valve on DCW feeding the said fixtures.

PROJECT SPECIFIC MECHANICAL PIPING

1. EXISTING CONDITIONS
2. DEMOLITION
3. OWNER PROVIDED MATERIALS
4. NEW REQUIREMENTS
5. COORDINATION

PLUMBING

[CIT MECHANICAL TO FILL/EDIT]

GENERAL PLUMBING

PROJECT SPECIFIC PLUMBING

1. EXISTING CONDITIONS
2. DEMOLITION
3. OWNER PROVIDED MATERIALS
4. NEW REQUIREMENTS
5. COORDINATION

ELECTRICAL

[CIT ELECTRICAL TO FILL/EDIT]

GENERAL ELECTRICAL

1. Verify manufacturer's instructions for all equipment.
2. Provide submittals for electrical equipment (such as panelboards, transformers, light fixtures and controls, floor boxes, general electrical material, etc.) as applicable, for CIT-EE review prior to installation. Allow a minimum of seven business days for review of each revision.

3. In addition to the new loads, contractor shall conduct a survey of existing-to-remain loads to ensure that upon completion of power upgrades those loads will have proper power. Provide buck-boost transformers and/or other similar gear as needed. During the shutdown for power upgrade, provide temporary power if required by the users.
4. Light fixtures to be replaced to comply with new Campus (Retrofit) Energy Standards

PROJECT SPECIFIC ELECTRICAL

1. EXISTING CONDITIONS
2. DEMOLITION
3. OWNER PROVIDED MATERIALS
4. NEW REQUIREMENTS
5. COORDINATION

COMMUNICATION/DATA

[CIT IMSS/SHOPS TO FILL/EDIT]

GENERAL COMM/DATA

PROJECT SPECIFIC COMM/DATA

1. EXISTING CONDITIONS
2. DEMOLITION
3. OWNER PROVIDED MATERIALS
4. NEW REQUIREMENTS
5. COORDINATION

ENVIRONMENT, HEALTH, AND SAFETY (EHS)

[CIT IMSS/SHOPS TO FILL/EDIT]

GENERAL EHS

PROJECT SPECIFIC IMSS

1. EXISTING CONDITIONS
2. DEMOLITION
3. OWNER PROVIDED MATERIALS
4. NEW REQUIREMENTS
5. COORDINATION

SECURITY

[CIT SECURITY/PM TO FILL/EDIT]

GENERAL SECURITY

PROJECT SPECIFIC SECURITY

1. EXISTING CONDITIONS
2. DEMOLITION
3. OWNER PROVIDED MATERIALS

4. NEW REQUIREMENTS
5. COORDINATION

AUDIO VISUAL

[CIT BECCA ROSE TO FILL/EDIT]

GENERAL AUDIO VISUAL

PROJECT SPECIFIC AUDIO VISUAL

1. EXISTING CONDITIONS
2. DEMOLITION
3. OWNER PROVIDED MATERIALS
4. NEW REQUIREMENTS
5. COORDINATION

ENERGY AND WATER CONSERVATION

(LARGE PROJECTS ONLY, FOR SMALL/MED PROJECTS INC WITHIN THE DISCIPLINES ABV)

[CIT SUSTAINABILITY (MAX) TO FILL/EDIT]

GENERAL ENERGY AND WATER CONSERVATION

PROJECT SPECIFIC ENERGY AND WATER CONSERVATION

1. EXISTING CONDITIONS
2. DEMOLITION
3. OWNER PROVIDED MATERIALS
4. SPECIFIC AREA REQUIREMENTS
5. COORDINATION

ATTACHMENTS

OPR Matrix

Layouts, Sketches, Drawings

Equipment list

Chemical inventory

04.03 Commissioning Specifications

SECTION 019113 - GENERAL COMMISSIONING REQUIREMENTS

PART 1 - GENERAL

1.1. RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section.
- B. Commissioning Plan shall be used to meet project requirements, provided under separate cover.

1.2. SUMMARY

A. Section Includes:

1. General requirements for coordinating and scheduling commissioning activities.
2. Commissioning meetings.
3. Commissioning reports.
4. Use of commissioning process test equipment, instrumentation, and tools.
5. Construction checklists, including, but not limited to, installation checks, startup, performance tests, and performance test demonstration.
6. Commissioning tests and commissioning test demonstration.
7. Adjusting, verifying, and documenting identified systems and assemblies.
8. The mention of a subcontractor is not meant to usurp the Contractor's responsibility to assign the work. The commissioning team is assigned tasks to be completed to demonstrate completion and operation of the systems. The tasks described in this Section will be performed by the commissioning team. Contractor shall ensure the responsible subcontractor performs the assigned commissioning tasks.
9. Asset Management.

B. Related Requirements:

1. [Section 011000 "Summary" for Commissioning Authority responsibilities.]
2. [Section 013200 "Construction Progress Documentation" for inclusion of Cx-related activities in the Construction Progress Documentation.]
3. [Section 013300 "Submittal Procedures" for submittal procedure requirements for commissioning process.]
4. [Section 017700 "Closeout Procedures" for Certificate of Construction-Phase Commissioning Process Completion submittal requirements.]
5. [Section 017823 "Operation and Maintenance Data" for preliminary operation and maintenance data submittal requirements.]

6. [Section 017900 "Demonstration and Training" for Owner Training requirements]
7. [Section 220800 "Commissioning of Plumbing" for technical commissioning requirements for plumbing.]
8. [Section 230800 "Commissioning of HVAC" for technical commissioning requirements for HVAC.]
9. [Section 260800 "Commissioning of Electrical Systems" for technical commissioning requirements for electrical systems.]

1.3. REFERENCES

- A. 2016 California Energy Code
- B. 2016 California Energy Code and Building Energy Efficiency Standards Reference Appendices
- C. 2016 Building Energy Efficiency Standards Nonresidential Compliance Manual
- D. ASQ/ANSI Quality Standards Z1.4
- E. Caltech Asset Data Commissioning User Manual

1.4. DESCRIPTION

- A. Commissioning Process: A quality-focused process for enhancing the delivery of a project. The process focuses on verifying and documenting that all of the commissioned systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the Owner's Project Requirements (OPR).
- B. The commissioning process does not take away from or reduce the responsibility of the Contractor to provide a finished and fully functioning product.
- C. Commissioning activities supplement field quality and testing procedures described in relevant technical sections.

1.5. DEFINITIONS

- A. Acceptance Criteria: Threshold of acceptable work quality or performance specified for a commissioning activity, including, but not limited to, construction checklists, performance tests, performance test demonstrations, commissioning tests, and commissioning test demonstrations.
- B. Asset Data Commissioning: The process of collecting, standardizing and conforming operational building and equipment data from construction documents into a database format that can be loaded to Caltech's Integrated Work Management System (IWMS). See Caltech Asset Data Commissioning User Manual for requirements.
- C. Basis-of-Design Document: A document prepared by Architect that records concepts, calculations, decisions, and product selections used to comply with Owner's Project Requirements and to suit applicable regulatory requirements, standards, and guidelines.

- D. Commissioning: A quality-focused process for verifying and documenting that the facility and all of its systems and assemblies are planned, designed, installed, and tested to comply with Owner's Project Requirements. The requirements specified here are limited to the construction phase commissioning activities. The scope of the commissioning process is defined in [Section 011000 "Summary."]
- E. Commissioning Authority: An entity engaged by Owner, and identified in [Section 011000 "Summary,"] to evaluate Commissioning-Process Work.
- F. Commissioning Plan: A document, prepared by Commissioning Authority, that outlines the organization, schedule, allocation of resources, and documentation of commissioning requirements.
- G. Construction-Phase Commissioning-Process Completion: The stage of completion and acceptance of commissioning process when resolution of deficient conditions and issues discovered during commissioning process and retesting until acceptable results are obtained has been accomplished. Owner will establish in writing the date construction-phase commissioning-process completion is achieved. See [Section 017700 "Closeout Procedures"] for Certificate of Construction-Phase Commissioning Process Completion submittal requirements.
 - 1. Commissioning process is complete when the Work specified of this Section and related Sections has been completed and approved, including, but not limited to, the following:
 - a. Completion of tests and acceptance of test results.
 - b. Resolution of issues, as verified by retests performed and documented with acceptance of retest results.
 - c. Comply with requirements in Section [017900 "Demonstration and Training."]
 - d. Completion and acceptance of submittals and reports.
 - e. Verification of asset as-built data entry and field labeling of assets.
- H. Owner's Project Requirements: A document that details the functional requirements of a project and the expectations of how it will be used and operated, including Project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information. This document is prepared either by the Owner or for the Owner by the Architect or Commissioning Authority.
- I. Owner's Witness: Commissioning Authority, Owner's Project Manager, or Architect-designated witness authorized to authenticate test demonstration data and to sign completed test data forms.
- J. Performance Period: A period that is intended to demonstrate that all equipment and assemblies can operate as integrated systems under automatic control without any issues or interventions required.

- K. "Systems," "Assemblies," "Subsystems," "Equipment," "Assets", and "Components": Where these terms are used together or separately, they shall mean "as-built" systems, assemblies, subsystems, equipment, and components.
- L. Sampling Procedures and Tables for Inspection by Attributes: As defined in ASQ/ANSI QUALITY STANDARDS Z1.4.
- M. Test: Performance tests, performance test demonstrations, commissioning tests, and commissioning test demonstrations.

1.6. COMPENSATION

- A. If Architect, Commissioning Authority, other Owner's witness, or Owner's staff perform additional services or incur additional expenses due to actions of Contractor listed below, Contractor shall compensate Owner for such additional services and expenses.
 - 1. Failure to provide timely notice of commissioning activities schedule changes.
 - 2. Failure to meet acceptance criteria for test demonstrations.

1.7. COMMISSIONING TEAM

A. Members Appointed by Contractor:

- 1. Commissioning Coordinator: A person or entity employed by Contractor to manage, schedule, and coordinate commissioning process.
- 2. Project superintendent and other employees that Contractor may deem appropriate for a particular portion of the commissioning process.
- 3. Subcontractors, installers, suppliers, and specialists that Contractor may deem appropriate for a particular portion of the commissioning process.
- 4. [For Design-Build] [Architect, plus employees and consultants that Architect may deem appropriate for a particular portion of the commissioning process.]
- 5. Appointed team members shall have the authority to act on behalf of the entity they represent.

B. Members Appointed by Owner:

- 1. Commissioning Authority, plus consultants that Commissioning Authority may deem appropriate for a particular portion of the commissioning process.
- 2. Owner representative(s), facility operations and maintenance personnel, plus other employees, separate contractors, and consultants that Owner may deem appropriate for a particular portion of the commissioning process.
- 3. [For Design-Bid-Build] [Architect, plus employees and consultants that Architect may deem appropriate for a particular portion of the commissioning process.]

1.8. RESPONSIBILITIES

- A. Services for the Owner and Commissioning Authority are not provided for in this Contract. That is, the Contractor is not responsible for providing their services. Their responsibilities are listed here to clarify the commissioning process.
- B. Contractor
 1. The Contractor is fully responsible to the Owner for all Subcontractor and Manufactures & Suppliers listed responsibilities in the specifications. Separate responsibility listings are given in this Section for clarity purposes.
 2. The Contractor shall assign an individual to manage commissioning activities of the Contractor, and subcontractors.
 3. The Contractor shall ensure that the commissioning responsibilities outlined in these specifications are included in all subcontracts and that subcontractors comply with the requirements of these specifications.
 4. The Contractor shall ensure that each installing subcontractor shall assign representatives with expertise and authority to act on behalf of the subcontractor and schedule them to participate in and perform commissioning team activities including, but not limited to, the following:
 - a. Participate in commissioning coordination meetings.
 - b. Conduct training sessions in accordance with approved training plans.
 - c. Verify that Work is complete, and systems are operational according to the Contract Documents, including calibration of instrumentation and controls.
 - d. Evaluate commissioning issues and commissioning observations identified in the Commissioning Issues Log, field reports, test reports or other commissioning documents. In collaboration with entity responsible for system and equipment installation, recommend corrective action.
 - e. Review and comment on commissioning documentation.
 - f. Participate in meetings to coordinate Systems Functional Performance Testing.
 - g. Provide schedule for operation and maintenance data submittals, equipment startup, and testing to Commissioning Authority for incorporation into the commissioning plan.
 - h. Provide information to the Commissioning Authority for developing commissioning plan.
 - i. Participate in Owner training sessions.
 - j. Provide technicians who are familiar with the construction and operation of installed systems and who shall execute specific test procedures to conduct Functional Performance Testing of installed systems.
 - k. Perform asset data entry according to Caltech Asset Data Commissioning User Manual.
 5. Contractors providing and/or installing equipment and systems included in the 'Scope of Work' above are required to participate fully in the Commissioning Process.

6. Participating Contractors shall include all costs to complete the commissioning requirements in their contract price including all costs for Sub-Contractors, vendors and suppliers.
7. Participating Contractors shall ensure acceptable representation, with the means and authority to prepare, coordinate and execute the Commissioning Process as described in the contract documents.
8. Contractors shall participate in the resolution of system deficiencies identified during the commissioning process, according to the contract documents.
9. Each Contractor participating in the Commissioning Process will each designate a single-point contact.
10. Ensure that the Contractor Commissioning Documents are being maintained, well organized and current as required in item the 'Commissioning Documentation' paragraph of this specification.

C. Subcontractors

1. Each Subcontractor shall provide qualified field technicians who are trained and familiar with installation, operation and troubleshooting of systems and equipment being commissioned for participation in the commissioning activities outlined in this document.
2. These same technicians shall be made available to assist the Owner in resolving commissioning issues and for repeat and follow-up commissioning tasks as required.

D. Manufactures and Suppliers

1. Provide requested submittal data, including detailed start-up and checkout procedures and specific responsibilities of the Owner to keep warranties in force for all commissioned equipment or assemblies.
2. Assist in equipment or assembly testing per agreements with Subcontractors.
3. Include all special tools and instruments, when only available from vendor, specific to a piece of equipment, required for testing equipment according to these Contract Documents in the base bid price to the Subcontractors.
4. Review test procedures for equipment installed by factory representatives.
5. Provide expert qualified staff for equipment training per agreements with Subcontractors.

E. Commissioning Authority

1. Revise, as necessary, the construction phase commissioning plan developed during design, including scope and schedule.
2. The Commissioning Authority may assist with problem-solving nonconformance or deficiencies, but ultimately that responsibility resides with the Contractor.
3. Coordinate the commissioning work and with the Contractor to ensure that commissioning activities are being scheduled into the master schedule.

4. Plan and conduct commissioning meetings including the planning and kick-off meetings as needed and distribute minutes.
5. Develop a Master Equipment List of commissioned equipment in a computerized spreadsheet in a grouped and organized format.
6. Track the status of each piece of equipment in the Master Equipment List.
7. Request and review additional information required to perform commissioning tasks, including O&M materials, start-up, or checkout procedures.
8. Review submittals applicable to systems being commissioned for compliance with commissioning requirements.
9. Review bulletins, requests for information, and change orders for impact on commissioning and Owner's objectives.
10. Develop Pre-Functional Checklists and the Functional Test Plan.
11. Document completion of the Subcontractor-completed Pre-Functional Checklists by reviewing completed checklists and by selected site observation.
12. Witness and document execution of the Functional Test Plan, as performed by the installing Subcontractors.
13. Review and comment, if necessary, on the Contractor's training plan.
14. During the Warranty Period, coordinate and supervise required deferred testing and update documentation for the Commissioning Report.
15. Manage the Asset Data Commissioning process

F. Architect of Record

1. Review the Commissioning Plan.
2. Attend the commissioning kick-off meetings and selected commissioning team meetings.
3. The Engineer or Record shall attend the controls integration meetings.
4. Perform normal submittal review, construction observation, O&M manual review.
5. Review the coordination Drawings.
6. Assist, along with the Owner, in clarifying the operation and control of commissioned equipment in areas where the Specifications, control Drawings or equipment documentation is not sufficient for writing detailed testing procedures.
7. Witness selected testing.
8. Coordinate resolution of system deficiencies and warranty issues identified during commissioning.
9. Provide design basis and design narratives documentation for the Systems Manual.

10. Review Systems Manual.
 11. During the Warranty Period, coordinate resolution of design non-conformance and design deficiencies identified during warranty-period commissioning activities.
- G. Owner
1. Furnish a copy of all Construction Documents, addenda, requests for information, change orders and approved submittals and Shop Drawings related to commissioned equipment to the Commissioning Authority.
 2. Arrange for facility operating and maintenance personnel to attend various field commissioning activities and field training sessions according to the Commissioning Plan.
 3. Participate in issue resolution, as necessary.
 4. Provide final approval for the completion of the commissioning work.
- 1.9. COMMUNICATION
- A. No communications (verbal or written) from the Commissioning Authority shall be deemed to constitute direction that modifies the terms of any contract.
- 1.10. SUBMITTALS
- A. Comply with requirements in Section [013300 "Submittal Procedures"] for submittal procedure general requirements for commissioning process.
- B. Commissioning Plan Information:
1. List of Contractor-appointed commissioning team members to include specific personnel and subcontractors performing the various commissioning requirements.
 2. Schedule of commissioning activities, integrated with the Construction Schedule. Comply with requirements in Section [013200 "Construction Progress Documentation"] for the Construction Schedule general requirements for commissioning process.
 3. Contractor personnel and subcontractors participating in each test.
 4. List of instrumentation required for each test to include identification of parties that will provide instrumentation for each test.
- C. Commissioning schedule.
- D. Two-week look-ahead schedules.
- E. Certificate of Construction-Phase Commissioning Process Completion
- F. Documentation Required in Other Sections
1. Where individual testing, adjusting, or related services are required in the project specifications and not specifically required by this commissioning requirements specification, the specified

services shall be provided and copies of documentation, as required by those specifications shall be submitted.

1.11. COMMISSIONING DOCUMENTATION

A. Commissioning Plan

1. A document prepared by Commissioning Authority that outlines the commissioning process, including schedule, allocation of resources, team members, roles & responsibilities, and documentation requirements.

B. Commissioning Issues Log

1. A document prepared, maintained, and updated by the Commissioning Authority.
2. Describes Commissioning Issues identified during the Commissioning process.
3. These issues include, but are not limited to, those that are at variance with the Contract Documents or Owner's requirements.
4. The Commissioning Issues Log will identify and track issues as they are encountered, progress toward resolution, and document how the issue was resolved.

C. Commissioning Meeting Agendas and Minutes

1. Prepared by the Commissioning Authority for each schedule Commissioning Meeting.
2. The agenda will present items to be discussed by the Commissioning Team during the meeting. Agenda to be submitted prior to the meeting to the owner.
3. Action items identified during the meeting will have a responsible party assigned to address the item with a due date.
4. These discussions will be captured by the Commissioning Authority, documented in the Meeting Minutes, and distributed to the Commissioning Team issued by the next business day.
5. Any exceptions taken to the meeting minutes must be provided in written within one week of the issuance of the minutes.
6. Action items that are not addressed by the due date noted in the meeting minutes shall be considered a non-conforming item and added to the Commissioning Issues Log.
7. Once the minute are issued, they shall become part of Project Record.

D. Master Equipment List

1. Prepared, maintained, and updated by the Commissioning Authority that tracks the status of each piece of equipment in the equipment list matrix for: receipt of the submittal, asset data entry, Pre-Functional Checklists, startup, Functional Performance Testing, O&M manual submission, and Owner training.

E. Pre-Functional Checklists

1. No equipment shall be installed prior to approval of the related submittal.
2. The Commissioning Authority will generate Pre-Functional Checklists once the related equipment submittal has been made by the Contractor and approved.
3. The installing Subcontractor(s) shall complete Pre-Functional Checklists for each piece of equipment.
4. No sampling strategies shall be applied for completion of Pre-Functional Checklists. 100% of commissioned equipment shall have a contractor-complete Pre-Functional Checklist submitted upon completion.
5. All Pre-Functional Checklists will be maintained as digital documents held on a cloud-based platform maintained by the Commissioning Authority that will be accessible by the Contractor.

F. Startup Reports

1. Startup shall not be performed on any piece of equipment prior to submittal and approval of the related completed Pre-Functional Checklists and proposed Startup Reports.
2. The Contractor shall develop Startup Reports by combining, or adding to, the checklists with the manufacturer's detailed startup and checkout procedures from the O&M manual data and the field checkout sheets normally used by the Contractor for each piece of equipment requiring startup.
3. The report shall include checklists and procedures with specific boxes or lines for recording and documenting the checking and inspections of each procedure and a summary statement with a signature block at the end of the plan.
4. The report shall be prepared and submitted by the Contractor immediately after the related equipment submittal(s) has been approved.
5. For all direct digital controls, prepare a Point to Point Report that verifies each point is communicating, reporting, and controlling properly. Submit all results in writing, including: system name, sensor/point name, measured value, DDC value, and Correction Factor.

G. Functional Test Plan

1. The CxA develops the Functional Test Plan, shall be approved by the owner and is based upon the sequence of operations laid out in the contract documents, approved submittals, and with review and input from the rest of the Commissioning Team.
2. The relevant contractors shall review the plan for consistency with the current contract document requirements and actual field conditions. Any issues or discrepancies found shall be reported in writing within 14 days or receipt.

H. Training Plan

1. The Owner's personnel shall be trained on the systems being commissioned, in accordance with the Contract Documents, to operate and maintain the building systems and assemblies.

The Training Plan shall be approved by the owner and is considered an essential element in designing, preparing, and delivering the training to the participants.

I. Commissioning Report

1. At Construction-Phase Commissioning Completion, the Commissioning Authority prepares a report that include the following:
 - a. Pre-Functional Checklists
 - b. Startup Reports
 - c. Commissioning Issues Log
 - d. Commissioning issue narrative discussing resolution of issues
 - e. Correspondence or other documents related to resolution of issues
 - f. Other reports required by commissioning process.
 - g. Report shall include commissioning work of Contractor.
 - h. Report shall certify Asset Data Commissioning process is verified and complete.

J. Systems Manual

1. The Commissioning Authority will gather required information and compile the Systems Manual. The Systems Manual will include, but is not limited to, the following:
 - a. Design Narrative, including system narratives, schematics, single-line diagrams, flow diagrams, equipment schedules, and changes made throughout the Project.
 - b. Reference to Final Commissioning Plan.
 - c. Reference to Final Commissioning Report.
 - d. Approved Operation and Maintenance Data as submitted by the Contractor.

1.12. FUNCTIONAL PERFORMANCE TESTING

- A. In general, Systems Functional Performance Testing will be scheduled only after the following prerequisites, at a minimum, have been met:
 1. Pre-Functional Checklists have been completed, submitted, and approved.
 2. Startup Reports have been completed, submitted, and approved.
 3. Controls Point to Point Checkouts have been completed, submitted, and approved.
 4. The control system shall be sufficiently tested and approved by the Commissioning Authority before it is used to verify performance of other components or systems.
 5. Testing, Adjusting, and Balancing work shall be complete, and the Final Report has been submitted and approved.

6. All issues, or other non-compliance items, that may affect system performance have been resolved.
7. Any other items deemed as required by the Owner.
- B. The test procedure forms developed by the Commissioning Authority will include, but not be limited to, the following information:
 1. System and equipment or component name(s)
 2. Equipment location and ID number
 3. Unique test ID number, and reference to unique Pre-Functional Checklists and startup documentation, and ID numbers for the piece of equipment
 4. Date
 5. Project name
 6. Participating parties
 7. A reference to the specific sequence of operations or other specified parameters being verified
 8. Specific step-by-step procedures to execute the test, in a clear, sequential and repeatable format
 9. Acceptance criteria of proper performance with a Yes / No check box to allow for clearly marking whether or not proper performance of each part of the test was achieved.
 10. A section for comments.
 11. Digital signature and date blocks for all witnesses and participants.
- C. All Functional Performance Tests will be maintained as digital documents held on a cloud-based platform maintained by the Commissioning Authority that will be accessible by the Contractor.

1.13. PERFORMANCE PERIOD

- A. The Performance Period will begin once all associated functional tests have been completed and approved.
- B. This activity should be included in the project's schedule after completion of functional tests and shown as complete prior to Substantial Completion.
- C. Successful completion of the Performance Period is a prerequisite to Substantial Completion.

1.14. CLOSEOUT SUBMITTALS

- A. The following submittal are required prior to completion of the construction phase commissioning process:
 1. Request for Certificate of Construction-Phase Commissioning Process Completion.
 2. Pre-Functional Checklists

3. Startup Reports
4. Testing, Adjusting, and Balancing Report
5. Operation and Maintenance Data
6. Final As-Builts Record Documents
7. Training plan and agenda
8. Asset As-Built Data CxA verification

1.15. SYSTEMS TO BE COMMISSIONED

- A. [Insert project-specific commissioned systems list]

PART 2 - PRODUCTS

2.1. TEST EQUIPMENT, INSTRUMENTATION, AND TOOLS

- A. Test equipment and instrumentation required to perform the commissioning process shall remain the property of Contractor unless otherwise indicated.
- B. Test equipment and instrumentation required to perform commissioning process shall comply with the following criteria:
 1. Be manufactured for the purpose of testing and measuring tests for which they are being used and have an accuracy to test and measure system performance within the tolerances required to determine acceptable performance.
 2. Calibrated and certified.
 - a. Calibration performed and documented by a qualified calibration agency according to national standards applicable to the tools and instrumentation being calibrated. Calibration shall be current according to national standards or within test equipment and instrumentation manufacturer's recommended intervals, whichever is more frequent, but not less than within six months of initial use on Project. Calibration tags shall be permanently affixed.
 - b. Repair and recalibrate test equipment and instrumentation if dismantled, dropped, or damaged since last calibrated.
 3. Maintain test equipment and instrumentation.
 4. Use test equipment and instrumentation only for testing or monitoring Work for which they are designed.

2.2. PROPRIETARY TEST EQUIPMENT, INSTRUMENTATION, AND TOOLS

- A. Proprietary test equipment, instrumentation, and tools are those manufactured or prescribed by tested equipment manufacturer and required for work on its equipment as a condition of equipment warranty, or as otherwise required to service, repair, adjust, calibrate, or perform work on its equipment.

1. Identify proprietary test equipment, instrumentation, and tools required in the test equipment identification list submittal.
2. Proprietary test equipment, instrumentation, and tools shall become the property of Owner at Substantial Completion.

PART 3 - EXECUTION

3.1. PREPARATION

- A. Review Commissioning Documentation.
- B. Identify any conflicts between the checklists, contract documents, and manufacture's requirements and notify the Commissioning Team.

3.2. GENERAL EXECUTION REQUIREMENTS

- A. Schedule and coordinate commissioning process with the Construction Schedule.
- B. Perform activities identified in construction checklists, including tests, and document results of actions as construction proceeds.

3.3. EQUIPMENT ACCESS

- A. During installation, provide access clearance to allow for maintenance, service, repair, removal, and replacement without the need to disassemble or remove other equipment or building elements.
- B. Access shall be coordinated with other building elements and equipment, including, but not limited to, ceiling and wall access panels, in a manner consistent with OSHA fall-protection regulations and safe work practices.
- C. Notify the Owner immediately in writing if required access cannot be provided.

3.4. PRE-FUNCTIONAL CHECKLISTS

- A. Pre-Functional Checklists cannot modify or conflict with the Contract Documents.
- B. Distribute Pre-Functional Checklists to installing contractors before they start work.
- C. Pre-Functional Checklists shall be completed during the installation process by qualified individuals with direct knowledge of the installation.
- D. The Contractor shall clearly list any outstanding items that were not completed successfully on the Pre-Functional Checklist or on an attached sheet.
- E. Provide Commissioning Authority with access to the Commissioning Documentation.
- F. The completed checklists and any outstanding deficiencies shall be submitted within two days of completion.

- G. Record as an installation compliance issue Work found to be incomplete, inaccessible, at variance with the Contract Documents, nonfunctional, or that does not comply with construction checklists at the time they are identified.

3.5. STARTUP

- A. Two weeks (minimum) prior to equipment startup, the Contractor shall schedule startup and checkout with the Owner.
- B. Verify readiness of equipment to be energized. Include manufacturer's standard startup procedures and forms.
- C. Perform and document initial operation of equipment to prove that it is installed properly and operates as intended according to manufacturer's standard startup procedures, at minimum.
- D. Startup Reports shall be completed during the startup process by qualified individuals with direct knowledge of the procedure.
- E. The performance of the startup shall be directed and executed by the Contractor.

3.6. POINT TO POINT CHECKOUT REPORT

- A. For Direct Digital Controls:
 - 1. Field installed sensor readings shall be verified and calibrated after installation.
 - 2. Factory calibrated sensors shall have calibration verified after installation.
 - 3. Proper device-to-controller communication and configuration shall be verified after installation.
 - 4. Submit results in writing.

3.7. DELAYED PRE-FUNCTIONAL CHECKLISTS AND STARTUP REPORTS

- A. Obtain Owner approval of proposed delayed construction checklists, including proposed schedule of completion of each delayed construction checklist, before submitting request for Certificate of Construction-Phase Commissioning Process Completion.
- B. When approved, delayed construction checklists may be completed after date of Construction-Phase Commissioning Completion.
- C. Include, at a minimum, the following in a request for Certificate of Construction-Phase Commissioning Process Completion:
 - 1. Identify delayed construction checklist by construction checklist number and title.
 - 2. Provide a target schedule for completion of delayed construction checklists.
 - 3. Written approval of proposed delayed construction checklists, including approved schedule of completion of each delayed construction checklist.

3.8. FUNCTIONAL PERFORMANCE TESTS

- A. Functional Performance Test procedures shall define the step-by-step procedures to be used to validate the performance of commissioned systems.
- B. The test procedures shall be specific to the make, model, and application of the equipment and systems being tested.
- C. Completed test forms are the official records of the test results.
- D. Commissioning Authority will provide test forms after approval of relevant Product Data, Shop Drawings, and operation and maintenance manuals.
- E. Review test forms, and provide comments within 14 days of receipt. Review shall address the following:
 - 1. Equipment protection and warranty issues, including, but not limited to, manufacturers' installation and startup recommendations, and operation and maintenance instructions.
 - 2. Applicability of the procedure to the specific software, equipment, and systems approved for installation.
- F. After Contractor has reviewed and commented on the test forms, Commissioning Authority will revise and reissue the approved revised forms.
- G. Use only approved test forms to perform testing.
- H. Commissioning Issues
 - 1. Test results that are not within the range of acceptable results are commissioning issues and shall be recorded in the Commissioning Issues Log by the Commissioning Authority.
 - 2. Commissioning Issues are tracked by the Commissioning Authority until resolution and retesting are successfully completed.
 - 3. If a test demonstration fails, determine the cause of failure. Direct timely resolution of issue and then repeat the demonstration. If a test demonstration must be repeated due to failure caused by Contractor work or materials, reimburse Owner for billed costs for the participation in the repeated demonstration.
 - 4. Do not correct commissioning compliance issues during test demonstrations.
 - a. Exceptions will be allowed if the cause of the issue is obvious and resolution can be completed in less than fifteen minutes. If corrections are made under this exception, note the deficient conditions on the test data form.
- I. Provide full access to Owner's witness to directly observe the performance of all aspects of system response during the test demonstration.

3.9. TEST METHODS

- A. Functional Performance Testing shall be achieved by automated and manual testing (i.e. persons manipulate the equipment and observe performance) and/or by monitoring the performance and analyzing the results using the control system's trend log capabilities or by standalone data

loggers. The Contractor and Commissioning Authority shall determine which method is most appropriate for tests that do not have a method specified.

B. The following test methods will be considered for this Project:

1. Simulated Conditions

- a. Simulating conditions (not by an overwritten value) shall be allowed, although timing the testing to experience actual conditions is encouraged wherever practical.

2. Overwritten Values

- a. Overwriting sensor values to simulate a condition, such as overwriting the outside air temperature reading in a control system to be something other than it really is, shall be allowed, but shall be used with caution and avoided when possible. Such testing methods often can only test a part of a system, as the interactions and responses of other systems will be erroneous or not applicable. Simulating a condition is preferable. e.g., for the above case, by heating the outside air sensor with a hair blower rather than overwriting the value or by altering the appropriate setpoint to see the desired response. Before simulating conditions or overwriting values, sensors, transducers and devices shall have been calibrated.

3. Simulated Signals

- a. Using a signal generator which creates a simulated signal to test and calibrate transducers and DDC constants is generally recommended over using the sensor to act as the signal generator via simulated conditions or overwritten values.

4. Altering Setpoints

- a. Rather than overwriting sensor values, and when simulating conditions is difficult, altering setpoints to test a sequence is acceptable. For example, to see the Air Conditioning compressor lockout initiate at an outside air temperature below 12 C (54 F), when the outside air temperature is above 12 C (54 F), temporarily change the lockout setpoint to be 2 C (4 F) above the current outside air temperature.

5. Indirect Indicators

- a. Relying on indirect indicators for responses or performance shall be allowed only after visually and directly verifying and documenting, over the range of the tested parameters, that the indirect readings through the control system represent actual conditions and responses. Much of this verification shall be completed during systems startup and initial checkout.

C. Automated Testing

1. Monitoring of system performance and analyzing of results shall be conducted by using the SkySpark Fault Detection and Diagnostics platform integrated with the BAS.
2. For zone-level BAS-integrated equipment, execution of functional tests shall be executed by overriding the system directly through SkySpark, using automated functional testing procedures. 100% of equipment shall be tested under this condition.

3.10. FUNCTIONAL PERFORMANCE TEST SAMPLE RATES

- A. The sampling rate for manual tests is [100] percent.
- B. The sampling rate for test demonstrations is [100] percent, unless otherwise indicated.
- C. The sampling rate for automated tests is 100 percent, unless otherwise indicated.

3.11. DEFERRED TESTS

- A. Identify, in the request for Certificate of Construction-Phase Commissioning Process Completion, proposed deferred tests or other tests approved for deferral until specified seasonal or other conditions are available. When approved, deferred tests may be completed after the date of Construction-Phase Commissioning Completion. Identify proposed deferred tests in the request for Certificate of Construction-Phase Commissioning Process Completion as follows:
 - 1. Identify deferred tests by number and title.
 - 2. Provide a target schedule for completion of deferred tests.
- B. Schedule and coordinate deferred tests. Schedule deferred tests when specified conditions are available. Notify Architect and Commissioning Authority at least three working days (minimum) in advance of tests.
- C. Where deferred tests are specified, coordinate participation of necessary personnel and of Architect, Commissioning Authority, and Owner's witness. Schedule deferred tests to minimize occupant and facility impact. Obtain Architect's approval of the proposed schedule.

3.12. PERFORMANCE PERIOD

- A. All equipment and assemblies capable of automatic operation shall be included in the Performance Period, unless excepted per 3.11 DEFERRED TESTS above.
- B. Successful operation includes automatic operation without manual intervention, without malfunction, without alarm caused by control action or device failure, and with smooth and stable control of systems and equipment in conformance with the contract documents.
- C. In event of failure to meet the standard of performance during any initiated performance period, it is not required that [##] calendar day period expire in order for another performance period to begin.
- D. If equipment or system operate and demonstrate continuing compliance with the requirements outlined in the construction documents for period of [##] consecutive calendar days from commencement date of performance period, the test will be considered to have passed.
- E. Equipment will not be accepted by the Owner and final payment will not be made by the Owner until acceptable performance is met.
- F. Trends taken at the specified intervals will be reviewed by the Commissioning Authority during this period as the primary form of evaluation.

3.13. TRAINING

- A. Training will not begin until functional testing and Operation and Maintenance Manuals for the related system are accepted.
- B. Training Schedule
 - 1. All training activities shall be included in the Construction Schedule.
- C. Training Plan
 - 1. The Training Plan shall include the following items:
 - a. Level of training for O&M staff, emergency response personnel, and occupants.
 - b. Outline of instructional topics related to the systems, subsystems, equipment, and assemblies. These topics shall address the design, construction, operation, and maintenance of specific systems, assemblies, and equipment.
 - c. Learning objectives and training delivery methods for each instructional topic.
 - d. The planned location of the training sessions (classroom, on site, and off site) and the minimum duration of each training session, in hours, to be completed as required in the OPR, Cx Plan, or contract documents.
 - e. Instructor's qualifications, including
 - 1) Specific experience of the systems, equipment, and/or project knowledge that relate to the instructional topics
 - 2) Experience related to the systems, subsystems, equipment, and assemblies
 - 3) Formal education and factory training
 - 4) Skills related to the operation and maintenance of systems, subsystems, equipment, and assemblies
 - f. Training materials requirements to be employed during the instructional process.
 - g. Training report, records, and recording requirements.

3.14. COMMISSIONING MEETINGS

- A. The Commissioning Authority will conduct periodic Commissioning Coordination Meetings of the commissioning team to review status of commissioning activities, to discuss scheduling conflicts, and to discuss upcoming commissioning process activities. Comply with requirements in Section [013100 "Project Management and Coordination."]

3.15. SEQUENCING

- A. Sequencing of Commissioning Verification Activities: For a particular material, item of equipment, assembly, or system, perform the following in the order listed unless otherwise indicated:
 - 1. Submittals

2. Submittal asset data entry verification
 3. Operations and Maintenance Manual submission
 4. Pre-Functional Checklists
 5. Startup
 6. Testing, Adjusting, and Balancing
 7. Asset as-built data entry verification
 8. Functional Performance Testing
 9. Performance Period
 10. Owner Training
- B. Each prerequisite activity shall be completed and approved prior to beginning the subsequent activity.
- C. Verify readiness of materials, equipment, assemblies, and systems by performing tests prior to performing test demonstrations. Notify Owner if acceptable results cannot be achieved due to conditions beyond Contractor's control or responsibility.
- D. Commence tests as soon as installation checks for materials, equipment, assemblies, or systems are satisfactorily completed. Tests of a particular system may proceed prior to completion of other systems, provided the incomplete work does not interfere with successful execution of test.

3.16. SCHEDULING

- A. Commence commissioning process as early in the construction period as possible.
- B. Commissioning Schedule: Integrate commissioning activities into Construction Schedule. See Section [013200 "Construction Progress Documentation."]
1. Include detailed commissioning activities in updated Construction Schedules and short-interval schedule submittals.
 2. Schedule the start date and duration for the following commissioning activities, including documentation submittal:
 - a. Commissioning-related submittals
 - a. Operation and Maintenance manual submittals
 - b. Asset data entry submittals
 - c. Pre-Functional Checklists
 - d. Startup, where required
 - e. Testing, Adjusting, and Balancing

- f. Functional Performance Tests
 - g. Performance Period
 - h. Training
3. Schedule shall include a line item for each installation check, startup, and test activity specific to the equipment or systems involved.
 4. Determine milestones and prerequisites for commissioning process. Show commissioning milestones, prerequisites, and dependencies in updated Construction Schedule and short-interval schedule submittals.
- C. Two-Week Look-Ahead Commissioning Schedule
1. Two weeks prior to the beginning of tests, submit a detailed two-week look-ahead schedule. Thereafter, submit updated two-week look-ahead schedules weekly for the duration of commissioning process.
 2. Two-week look-ahead schedules shall identify the date, time, beginning location, Contractor personnel required, and anticipated duration for each startup or test activity.
 3. Use two-week look-ahead schedules to notify and coordinate participation of Owner's witnesses.
- D. Owner's Witness Coordination
1. Coordinate Owner's witness participation via Architect.
 2. Notify Architect of commissioning schedule changes at least five workdays in advance for activities requiring the participation of Owner's witness.
- 3.17. CERTIFICATE OF CONSTRUCTION-PHASE COMMISSIONING PROCESS COMPLETION
- A. When Contractor considers that construction-phase commissioning process, or a portion thereof which Owner agrees to accept separately, is complete, Contractor shall prepare and submit a comprehensive list of items to be completed or corrected. Failure to include an item on such list does not alter Contractor's responsibility to complete commissioning process.
 - B. On receipt of Contractor's list, Commissioning Authority will make an inspection to determine whether the construction-phase commissioning process or designated portion thereof is complete. If Commissioning Authority's inspection discloses items, whether included on Contractor's list, which is not sufficiently complete as defined in "Construction-Phase Commissioning Process Completion" Paragraph in the "Definitions" Article, Contractor shall, before issuance of the Certificate of Construction-Phase Commissioning Process Completion, complete or correct such items on notification by Commissioning Authority. In such case, Contractor shall then submit a request for another inspection by Commissioning Authority to determine construction-phase commissioning process completion.
 - C. Contractor shall promptly correct deficient conditions and issues discovered during commissioning process. Costs of correcting such deficient conditions and issues, including

additional testing and inspections, the cost of uncovering and replacement shall be at Contractor's expense.

- D. When construction-phase commissioning process or designated portion is complete, Commissioning Authority will prepare a Certificate of Construction-Phase Commissioning Process Completion that shall establish the date of completion of construction-phase commissioning process. Certificate of Construction-Phase Commissioning Process Completion shall be submitted prior to requesting inspection for determining date of Substantial Completion.

END OF SECTION 019113

SECTION 220800 - Commissioning of Plumbing

PART 1 - GENERAL

1.1. RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section.
- B. Commissioning Plan shall be used to meet project requirements, provided under separate cover.

1.2. SUMMARY

A. Section Includes:

- 1. General requirements for coordinating and scheduling commissioning activities.
- 2. Commissioning meetings.
- 3. Commissioning reports.
- 4. Use of commissioning process test equipment, instrumentation, and tools.
- 5. Construction checklists, including, but not limited to, installation checks, startup, performance tests, and performance test demonstration.
- 6. Commissioning tests and commissioning test demonstration.
- 7. Adjusting, verifying, and documenting identified systems and assemblies.
- 8. Asset Management.

B. Related Requirements:

- 1. [Section 019113 "General Commissioning Requirements"]
- 2. Other sections, as specified in [Section 019113 "General Commissioning Requirements"]

1.3. REFERENCES

- A. As specified in [Section 019113 "General Commissioning Requirements"].

1.4. DESCRIPTION

- A. As specified in [Section 019113 "General Commissioning Requirements"].

1.5. DEFINITIONS

- A. As specified in [Section 019113 "General Commissioning Requirements"].

1.6. COMPENSATION

- 1. [NOT USED]

1.7. COMMISSIONING TEAM

- A. As specified in [Section 019113 “General Commissioning Requirements”].

1.8. RESPONSIBILITIES

- A. The plumbing (Division 22) contractor’s responsibilities are defined in [Section 019113 “General Commissioning Requirements”]. These responsibilities apply to all specialty sub-contractors and major equipment suppliers within Division 22. Each contractor and supplier shall review [Section 019113 “General Commissioning Requirements”], and their bids shall include for carrying out the work described, as it applies to each Section within the Division 22 specifications, individually and collectively
- B. Other requirements, as specified in [Section 019113 “General Commissioning Requirements”]

1.9. COMMUNICATION

- A. No communications (verbal or written) from the Commissioning Authority shall be deemed to constitute direction that modifies the terms of any contract.

1.10. SUBMITTALS

- A. As specified in [Section 019113 “General Commissioning Requirements”].

1.11. COMMISSIONING DOCUMENTATION

A. Commissioning Plan

- 1. As specified in [Section 019113 “General Commissioning Requirements”].

B. Commissioning Issues Log

- 1. As specified in [Section 019113 “General Commissioning Requirements”].

C. Commissioning Meeting Agendas and Minutes

- 1. As specified in [Section 019113 “General Commissioning Requirements”].

D. Master Equipment List

- 1. As specified in [Section 019113 “General Commissioning Requirements”].

E. Pre-Functional Checklists

- 1. The Division 22 contractor shall complete all assigned sections for each Pre-Functional Checklist.
- 2. If any section in the Pre-Functional Checklist assigned to the Division 22 contractor is not in the scope of this contractor, notify the General Contractor in writing within [5 days] of receipt of the Pre-Functional Checklists.
- 3. Other requirements, as specified in [Section 019113 “General Commissioning Requirements”].

F. Startup Reports

- 1. As specified in [Section 019113 “General Commissioning Requirements”].

G. Functional Test Plan

1. As specified in [Section 019113 “General Commissioning Requirements”].

H. Training Plan

1. As specified in [Section 019113 “General Commissioning Requirements”].

I. Commissioning Report

- i. As specified in [Section 019113 “General Commissioning Requirements”].

J. Systems Manual

- e. As specified in [Section 019113 “General Commissioning Requirements”].

1.12. FUNCTIONAL PERFORMANCE TESTING

- A. As specified in [Section 019113 “General Commissioning Requirements”].

1.13. PERFORMANCE PERIOD

- A. As specified in [Section 019113 “General Commissioning Requirements”].

1.14. CLOSEOUT SUBMITTALS

- A. Once all Work in this division is complete, the Division 22 contractor will issue a letter to the General Contractor certifying completion.
- B. Other requirements, as specified in [Section 019113 “General Commissioning Requirements”].

1.15. SYSTEMS TO BE COMMISSIONED

- A. [Insert project specific Div 22 commissioned systems list]

PART 2 - PRODUCTS

2.1. TEST EQUIPMENT, INSTRUMENTATION, AND TOOLS

- A. As specified in [Section 019113 “General Commissioning Requirements”].

2.2. PROPRIETARY TEST EQUIPMENT, INSTRUMENTATION, AND TOOLS

- A. As specified in [Section 019113 “General Commissioning Requirements”].

PART 3 - EXECUTION

3.1. PREPARATION

- A. Review Commissioning Documentation.
- B. Identify any conflicts between the checklists, contract documents, and manufacture’s requirements and notify the General Contractor.

3.2. GENERAL EXECUTION REQUIREMENTS

- A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.3. EQUIPMENT ACCESS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
 - B. Notify the General Contractor immediately in writing if required access cannot be provided.
- 3.4. PRE-FUNCTIONAL CHECKLISTS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.5. STARTUP
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.6. POINT TO POINT CHECKOUT REPORT
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.7. DELAYED PRE-FUNCTIONAL CHECKLISTS AND STARTUP REPORTS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.8. FUNCTIONAL PERFORMANCE TESTS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.9. TEST METHODS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.10. FUNCTIONAL PERFORMANCE TEST SAMPLE RATES
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.11. DEFERRED TESTS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.12. PERFORMANCE PERIOD
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.13. TRAINING
 - b. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.14. COMMISSIONING MEETINGS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.15. SEQUENCING
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.16. SCHEDULING

A. As specified in [Section 019113 “General Commissioning Requirements”].

3.17. CERTIFICATE OF CONSTRUCTION-PHASE COMMISSIONING PROCESS COMPLETION

A. [NOT USED]

END OF SECTION 220800

SECTION 230800 - Commissioning of MECHANICAL

PART 1 - GENERAL

1.1. RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section.
- B. Commissioning Plan shall be used to meet project requirements, provided under separate cover.

1.2. SUMMARY

A. Section Includes:

- 1. General requirements for coordinating and scheduling commissioning activities.
- 2. Commissioning meetings.
- 3. Commissioning reports.
- 4. Use of commissioning process test equipment, instrumentation, and tools.
- 5. Construction checklists, including, but not limited to, installation checks, startup, performance tests, and performance test demonstration.
- 6. Commissioning tests and commissioning test demonstration.
- 7. Adjusting, verifying, and documenting identified systems and assemblies.
- 8. Asset Management.

B. Related Requirements:

- 1. [Section 019113 "General Commissioning Requirements"]
- 2. Other sections, as specified in [Section 019113 "General Commissioning Requirements"]

1.3. REFERENCES

- A. As specified in [Section 019113 "General Commissioning Requirements"].

1.4. DESCRIPTION

- A. As specified in [Section 019113 "General Commissioning Requirements"].

1.5. DEFINITIONS

- A. As specified in [Section 019113 "General Commissioning Requirements"].

1.6. COMPENSATION

- 1. [NOT USED]

1.7. COMMISSIONING TEAM

- A. As specified in [Section 019113 “General Commissioning Requirements”].

1.8. RESPONSIBILITIES

- A. The mechanical (Division 23) contractor’s responsibilities are defined in [Section 019113 “General Commissioning Requirements”]. These responsibilities apply to all specialty sub-contractors and major equipment suppliers within Division 23. Each contractor and supplier shall review [Section 019113 “General Commissioning Requirements”], and their bids shall include for carrying out the work described, as it applies to each Section within the Division 23 specifications, individually and collectively
- B. Other requirements, as specified in [Section 019113 “General Commissioning Requirements”]

1.9. COMMUNICATION

- A. No communications (verbal or written) from the Commissioning Authority shall be deemed to constitute direction that modifies the terms of any contract.

1.10. SUBMITTALS

- A. As specified in [Section 019113 “General Commissioning Requirements”].

1.11. COMMISSIONING DOCUMENTATION

A. Commissioning Plan

- 1. As specified in [Section 019113 “General Commissioning Requirements”].

B. Commissioning Issues Log

- 1. As specified in [Section 019113 “General Commissioning Requirements”].

C. Commissioning Meeting Agendas and Minutes

- 1. As specified in [Section 019113 “General Commissioning Requirements”].

D. Master Equipment List

- 1. As specified in [Section 019113 “General Commissioning Requirements”].

E. Pre-Functional Checklists

- 1. The Division 23 contractor shall complete all assigned sections for each Pre-Functional Checklist.
- 2. If any section in the Pre-Functional Checklist assigned to the Division 23 contractor is not in the scope of this contractor, notify the General Contractor in writing within [5 days] of receipt of the Pre-Functional Checklists.
- 3. Other requirements, as specified in [Section 019113 “General Commissioning Requirements”].

F. Startup Reports

- 1. As specified in [Section 019113 “General Commissioning Requirements”].

G. Functional Test Plan

1. As specified in [Section 019113 “General Commissioning Requirements”].

H. Training Plan

1. As specified in [Section 019113 “General Commissioning Requirements”].

I. Commissioning Report

- j. As specified in [Section 019113 “General Commissioning Requirements”].

J. Systems Manual

- f. As specified in [Section 019113 “General Commissioning Requirements”].

1.12. FUNCTIONAL PERFORMANCE TESTING

- A. As specified in [Section 019113 “General Commissioning Requirements”].

1.13. PERFORMANCE PERIOD

- A. As specified in [Section 019113 “General Commissioning Requirements”].

1.14. CLOSEOUT SUBMITTALS

- A. Once all Work in this division is complete, the Division 23 contractor will issue a letter to the General Contractor certifying completion.
- B. Other requirements, as specified in [Section 019113 “General Commissioning Requirements”].

1.15. SYSTEMS TO BE COMMISSIONED

- A. [Insert project specific Div 23 commissioned systems list]

PART 2 - PRODUCTS

2.1. TEST EQUIPMENT, INSTRUMENTATION, AND TOOLS

- A. As specified in [Section 019113 “General Commissioning Requirements”].

2.2. PROPRIETARY TEST EQUIPMENT, INSTRUMENTATION, AND TOOLS

- A. As specified in [Section 019113 “General Commissioning Requirements”].

PART 3 - EXECUTION

3.1. PREPARATION

- A. Review Commissioning Documentation.
- B. Identify any conflicts between the checklists, contract documents, and manufacture’s requirements and notify the General Contractor.

3.2. GENERAL EXECUTION REQUIREMENTS

- A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.3. EQUIPMENT ACCESS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
 - B. Notify the General Contractor immediately in writing if required access cannot be provided.
- 3.4. PRE-FUNCTIONAL CHECKLISTS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.5. STARTUP
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.6. POINT TO POINT CHECKOUT REPORT
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.7. DELAYED PRE-FUNCTIONAL CHECKLISTS AND STARTUP REPORTS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.8. FUNCTIONAL PERFORMANCE TESTS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.9. TEST METHODS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.10. FUNCTIONAL PERFORMANCE TEST SAMPLE RATES
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.11. DEFERRED TESTS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.12. PERFORMANCE PERIOD
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.13. TRAINING
 - c. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.14. COMMISSIONING MEETINGS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.15. SEQUENCING
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.16. SCHEDULING

A. As specified in [Section 019113 “General Commissioning Requirements”].

3.17. CERTIFICATE OF CONSTRUCTION-PHASE COMMISSIONING PROCESS COMPLETION

A. [NOT USED]

END OF SECTION 220800

SECTION 260800 - Commissioning of electrical

PART 1 - GENERAL

1.1. RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section.
- B. Commissioning Plan shall be used to meet project requirements, provided under separate cover.

1.2. SUMMARY

A. Section Includes:

- 1. General requirements for coordinating and scheduling commissioning activities.
- 2. Commissioning meetings.
- 3. Commissioning reports.
- 4. Use of commissioning process test equipment, instrumentation, and tools.
- 5. Construction checklists, including, but not limited to, installation checks, startup, performance tests, and performance test demonstration.
- 6. Commissioning tests and commissioning test demonstration.
- 7. Adjusting, verifying, and documenting identified systems and assemblies.
- 8. Asset Management.

B. Related Requirements:

- 1. [Section 019113 "General Commissioning Requirements"]
- 2. Other sections, as specified in [Section 019113 "General Commissioning Requirements"]

1.3. REFERENCES

- A. As specified in [Section 019113 "General Commissioning Requirements"].

1.4. DESCRIPTION

- A. As specified in [Section 019113 "General Commissioning Requirements"].

1.5. DEFINITIONS

- A. As specified in [Section 019113 "General Commissioning Requirements"].

1.6. COMPENSATION

- 1. [NOT USED]

1.7. COMMISSIONING TEAM

- A. As specified in [Section 019113 “General Commissioning Requirements”].

1.8. RESPONSIBILITIES

- A. The electrical (Division 26) contractor’s responsibilities are defined in [Section 019113 “General Commissioning Requirements”]. These responsibilities apply to all specialty sub-contractors and major equipment suppliers within Division 26. Each contractor and supplier shall review [Section 019113 “General Commissioning Requirements”], and their bids shall include for carrying out the work described, as it applies to each Section within the Division 26 specifications, individually and collectively
- B. Other requirements, as specified in [Section 019113 “General Commissioning Requirements”]

1.9. COMMUNICATION

- A. No communications (verbal or written) from the Commissioning Authority shall be deemed to constitute direction that modifies the terms of any contract.

1.10. SUBMITTALS

- A. As specified in [Section 019113 “General Commissioning Requirements”].

1.11. COMMISSIONING DOCUMENTATION

A. Commissioning Plan

- 1. As specified in [Section 019113 “General Commissioning Requirements”].

B. Commissioning Issues Log

- 1. As specified in [Section 019113 “General Commissioning Requirements”].

C. Commissioning Meeting Agendas and Minutes

- 1. As specified in [Section 019113 “General Commissioning Requirements”].

D. Master Equipment List

- 1. As specified in [Section 019113 “General Commissioning Requirements”].

E. Pre-Functional Checklists

- 1. The Division 26 contractor shall complete all assigned sections for each Pre-Functional Checklist.
- 2. If any section in the Pre-Functional Checklist assigned to the Division 26 contractor is not in the scope of this contractor, notify the General Contractor in writing within [5 days] of receipt of the Pre-Functional Checklists.
- 3. Other requirements, as specified in [Section 019113 “General Commissioning Requirements”].

F. Startup Reports

- 1. As specified in [Section 019113 “General Commissioning Requirements”].

G. Functional Test Plan

1. As specified in [Section 019113 “General Commissioning Requirements”].

H. Training Plan

1. As specified in [Section 019113 “General Commissioning Requirements”].

I. Commissioning Report

- k. As specified in [Section 019113 “General Commissioning Requirements”].

J. Systems Manual

- g. As specified in [Section 019113 “General Commissioning Requirements”].

1.12. FUNCTIONAL PERFORMANCE TESTING

- A. As specified in [Section 019113 “General Commissioning Requirements”].

1.13. PERFORMANCE PERIOD

- A. As specified in [Section 019113 “General Commissioning Requirements”].

1.14. CLOSEOUT SUBMITTALS

- A. Once all Work in this division is complete, the Division 26 contractor will issue a letter to the General Contractor certifying completion.
- B. Other requirements, as specified in [Section 019113 “General Commissioning Requirements”].

1.15. SYSTEMS TO BE COMMISSIONED

- A. [Insert project specific Div 26 commissioned systems list]

PART 2 - PRODUCTS

2.1. TEST EQUIPMENT, INSTRUMENTATION, AND TOOLS

- A. As specified in [Section 019113 “General Commissioning Requirements”].

2.2. PROPRIETARY TEST EQUIPMENT, INSTRUMENTATION, AND TOOLS

- A. As specified in [Section 019113 “General Commissioning Requirements”].

PART 3 - EXECUTION

3.1. PREPARATION

- A. Review Commissioning Documentation.
- B. Identify any conflicts between the checklists, contract documents, and manufacture’s requirements and notify the General Contractor.

3.2. GENERAL EXECUTION REQUIREMENTS

- A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.3. EQUIPMENT ACCESS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
 - B. Notify the General Contractor immediately in writing if required access cannot be provided.
- 3.4. PRE-FUNCTIONAL CHECKLISTS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.5. STARTUP
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.6. POINT TO POINT CHECKOUT REPORT
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.7. DELAYED PRE-FUNCTIONAL CHECKLISTS AND STARTUP REPORTS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.8. FUNCTIONAL PERFORMANCE TESTS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.9. TEST METHODS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.10. FUNCTIONAL PERFORMANCE TEST SAMPLE RATES
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.11. DEFERRED TESTS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.12. PERFORMANCE PERIOD
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.13. TRAINING
 - d. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.14. COMMISSIONING MEETINGS
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.15. SEQUENCING
 - A. As specified in [Section 019113 “General Commissioning Requirements”].
- 3.16. SCHEDULING

A. As specified in [Section 019113 “General Commissioning Requirements”].

3.17. CERTIFICATE OF CONSTRUCTION-PHASE COMMISSIONING PROCESS COMPLETION

A. [NOT USED]

END OF SECTION 260800

04.04 Commissioning Plan

Background

The following is an example outline for a Cx Plan. The basic structure of this example is such that each phase of the plan has its own section detailing what activities will be accomplished and guidance on who accomplishes them and how they are completed.

Required Table of Contents

Revision History

With each iteration, include the following –

- Version
- Author
- Summary of changes

Definitions and Abbreviations

Definitions of common words & phrases and explanation of abbreviations used the in the Cx Plan

Commissioning Plan Overview

Provide project identifying information, including:

- Project name, owner, and location.
- Building type and area.
- Project schedule.
- Contact information of individual or company providing the commissioning services.

Commissioning Goals

Record the commissioning goals, including:

- Code requirements.
- OPR and BOD requirements.
- Requirements for commissioning activities in plans and specifications.

Commissioning Team Information

Provide a contact list for all Commissioning team members, including:

- Owner and/or owner's representative
- Architect and engineers
- Designated commissioning representative
- General contractor
- Sub-contractors

Commissioning Process Description

Include details for each of the following steps.

Planning Phase

Develop OPR

Develop Initial Cx Plan

Cx Process Issues

Design Phase

Design Phase Kickoff Meeting

Commissioning Specifications

Asset Management Tasks

- Add Locations to AiM
- Add Data to AiM
- Update Existing Asset List
- Generate Schedule Tag Sequence Report
- Verify Equipment Schedule
- Existing Asset Update

Verify BOD

Accomplish Design Reviews

Develop Commissioning Process Contract Document Requirements

Update Commissioning Plan

Construction Phase

Include details for each of the following steps.

Construction Phase Kickoff Meeting

Contractor Submittal Review

Asset Management Tasks

- SAM Submittal Form Submittal and Review
- Apply and Verify QR Code Placement
- Complete and Verify As-Built Forms in SAM
- SAM Warranty Forms
- Asset Data Review and Approval
- SAM to AiM Data Upload

Installation and Testing Process

- Issue PFCs
- Issue FPTs

- Site Observations
- Pre-Start Activities
- Complete PFCs
- Startup
- Bench Testing
- Skyspark Integration
- TAB
- TAB Validation
- Execute FTP
 - Automatic Testing
 - Manual Testing

- Performance Period

Contractor Closeout Documents

Training

- Acceptance
- Punchlist
- Substantial Completion
- Final Completion
- Cx Readiness Form

Commissioning Report

Systems Manual

Occupancy Phase

Asset Management Tasks

- Asset Mapping
- Reactor Event Development

Occupancy Testing

Issues Log

Warranty Walk

M&V Reporting

Commission Report Update

Systems Manual Update

Appendix

Owner's Project Requirements

Basis of Design

Communication Structures

Roles and Responsibilities

Commissioned Systems

Commissioning Process Schedule

Issues Log

Issues identified during commissioning are documented the Issues Log. The CxA shall develop a formal Issues Log with supporting documentation that is maintained on a cloud-based platform. The Issues Log will have all open and continuing items, with status and responsible party for resolution. The Issues Log is maintained throughout the project until all issues are resolved or accepted by Caltech. The Issues Log is made available to authorized members of the team at any time via the cloud-based platform and will be included with distribution of commission communications, including meeting minutes and Site Observation Reports. Caltech will review and accept the final Issues Log. Upon acceptance, the Issues Log will be included in the final Cx Report.

The Issues Log will include the following information:

- Issue Number
- Issue investigation source (i.e. design review iteration, site visit, testing, etc.)
- Date of discovery
- Name of discovering party
- Current status
- Issue description
- Associated or effected equipment or assembly
- Location/Level/Area
- Pictures of item, if available and appropriate
- Recommendation for resolution, if available
- Expected date of resolution and impacts is resolution is not achieved on date
- Party assigned responsibility to resolve the issue
- Actions taken
- GC Punchlist ID (If Applicable)
- Summary information, including
 - Number of total items, by status
 - Number of total items, by responsible party
 - Number of total items, by equipment or assembly
 - Time to close

04.06 Design Review Checklist

Design Review Checklist

The following list contains typical items to check during a design review. Before implementing, this list should be tailored to the subject project. All issues found should be identified in the Issues Log.

OPR & BOD

- OPR submitted for review
- BOD submitted and reviewed to be consistent with OPR.
- The OPR addresses the following items: Owner and user requirements, Environmental and sustainability goals, Energy efficiency goals, Indoor environmental quality requirements, Equipment and Systems requirements, and the Building occupant and O&M personnel
- The Basis of Design should include the following items: Primary design assumptions, Standards including codes and regulations, etc. and Narrative descriptions of the HVAC&R, Lighting and Domestic Hot water.
- In the OPR or BOD, recommended Set Points are listed for each piece of equipment/zone in each mode of operation.

Drawings

- All equipment shown on drawings is included and labeled in the schedules in all disciplines (MEP).
- Schedules include the following:
 - Total capacity the equipment specified. (i.e. Total SA/RA air flow, water flow, coil delta-T's, minimum OA CFM, static pressures and total displaced head, etc.)
 - Life safety equipment such as fire extinguishers, exit and emergency lights, and eyewash stations.
 - Thermostats
 - Existing equipment, including field verified ID
- System one-line, flow and riser and other needed schematic diagrams are included and complete.
- Equipment is coordinated between MEP. Does the mechanical have the electrical load requirements etc.?
- Service and maintenance access are clear for all equipment shown on the plans.
- Thermostats are shown on the drawings for control of HVAC equipment. Ensure none are located on exterior walls or on walls adjacent to unconditioned spaces.
- Requirements for test ports for temperature and pressure, temperature wells and pressure gauge manifolds are provided.
- Confirm that occupancy sensors/daylight lighting controls are shown on the plans.
- Confirm CO2 sensors are show on plans (if applicable)
- Energy Metering locations and specifications are shown
- Schedule tags should conform to Asset Naming Standards and begin at the correct schedule tag sequence number.

Specifications

- The project specifications include mechanical, electrical and plumbing sections. All sections include a sequence of operations for the specified equipment for each discipline with sequences for all modes of operation.
- Specified labeling requirements are adequate and complete
- Specified Training requirements are clear and complete.
- O&M documentation requirements are adequate.
- Contractor and supplier commissioning requirements included in the specifications are complete, clear and consistent. There is clear responsibility for the contractors for commissioning documentation and performance of equipment start-up / functional testing.
- Control points list is provided in the Sequence of operation section of the specifications.
- Documentation requirements for contractor provided pre-functional testing is included in the appropriate specification sections (i.e. Duct/piping pressure test results, 3rd party electrical circuit testing, TAB reports, etc.).

Maintainability

- Maintenance features are included, such: sump float alarms, filter alarms, access doors, isolation valves, when equipment is accessible only by ladder disconnect switches are within reach of equipment.
- Equipment located above hard lid ceilings need to have access doors specified. Equipment mounted above the ceiling has access heights specified on the drawings.
- Requirements for service outlets such as drain and hose valves and power outlets near mechanical units are provided.
- Filters and strainers are specified on the drawings and in the specifications for each equipment item.

Sequence of Operations and Control Drawings

- Control schematics are provided in the drawings for each piece of equipment and all input and output devices
- Sequences are clear and coordinated.
- Recommended Set Points are listed for each mode of operation.
- Response to power and controller failures and reset requirements are provided.
- Lead/Lag rotation of redundant equipment is defined.
- Alarms and their initiators are defined.
- Sequences of Operations meet the intent of the OPR.
- Sequence of operations for Lighting controls is included in the documents.
- All sensors are clearly shown on the control schematic drawings/diagrams.

Sensor Items

- All the sensor locations are specified or shown in the drawings and are of the correct type and location for the specified use and control sequence. For example, at a minimum all AHU's

should have SAT, RAT, MAT and OAT. It is recommended that all AHU's also have fan status, fan speed, duct static pressure and set points for all the above.

- Requirements for field calibrating sensors are provided in the specifications.

Control Software & Hardware compatibility

- Network architecture and interoperability meet the owner's project requirements and follow good industry practice.
- Network protocol is specified for each packaged equipment and BAS controls so that systems can communicate. (i.e. LON, Bacnet, Modbus, etc.)
- Control system specifications include quantitative network speed performance criteria
- Clear control authorities are shown between packaged equipment and BAS controls
- Clear control authorities are shown between packaged equipment and BAS controls
- Control valves are properly located and specified.
- Control dampers are properly located and specified.
- Acceptance criteria are specified for control loop stability.

Energy Efficiency & Title 24 Requirements

- Equipment meets efficiency requirements of energy code.
- Pipe for space conditioning and service water – heating with fluid temperature above 105 °F have appropriate insulation levels.
- HVAC motors for fan that are less than 1 hp and 1/12 hp or greater are ECM or have a min. motor efficiency of 70%. Motor also have means to adjust motor speed for balancing or remote control.
- Outdoor air supply and exhaust equipment shall be installed with damper that automatically closed upon fan shutdown.
- The outdoor air ventilation rate and air-distribution assumption made in the design of the ventilating system are clearly identified on the plans.
- The minimum and maximum outdoor air rates for each air handler are listed on the equipment schedules.
- The outdoor air-ventilation rates are based on planned owner occupancy as defined in owner's design intent and are not based on maximum egress occupancy rates.
- Heat recovery is specified on fan system where the design OA flow rate is greater than 75% and design supply air flow rate is greater than 5,000 cfm.
- Economizer dampers are specified to be driven by direct drive actuators rather than rod linkage, which can be a major cause of economizer malfunction.
- Duct branches with significantly differing pressures requirements have volume control strategically placed to aid in TAB work.
- Requirements for functional performance tests are reflected in the construction documents
- Each wall mounted thermostat is located away from potential sources that would adversely affect the reading (close to copiers, direct sunlight, below or above a supply air diffuser or

convector, etc.). Any thermostats mounted on exterior walls are installed in sealed and insulated junction boxes.

- Outdoor air temperature sensors should be in a commercially designed solar shield located on a north wall or some other location out of direct sunlight and away from building exhaust air or heat rejection equipment.
- SAT reset established with an aggressive reset schedule of 10 °F, e.g. 55 °F during warm weather and 65 °F during cool weather zones with high internal loads with near constant airflow are designed for the elevated reset SAT.
- SAT reset off terminal box damper position or thermostat demand does not rely on a low worst zone, but average over a few zones with greatest demand
- Air handler economizer and outside air control are clearly defined in the construction documents and sequence of operations.
- Air handler duct static pressure and supply air temperature reset control features are utilized when applicable.
- VAV air terminal unit control incorporates occupied/unoccupied reset control when applicable
- Heating water plant incorporates supply temperature reset control where applicable.
- Hydronic pumping system(s) utilize reset control strategies where applicable.

Testing, Adjusting, and Balancing

- Drawings and specifications are coordinated and contain sufficient technical data
- Flow and riser diagrams for major systems (chilled water, heating water, and air) are included on the plans.
- Confirm that Fans and Pumps that are specified for a variable volume/flow system have a Variable Frequency Drive or continuously variable ECM. This can assist with balancing especially on Stair/Elevator pressurization fans, etc.
- Do VAV boxes appear to be correct sizes? Velocity through VAV box max should not exceed 2100 ft/min. Note: If the velocity is higher than 2100 fpm, the box is at the upper limit of being able to flow the air flow specified on the plans. This will also cause the static pressure required to flow the specified flow rates to be high and cause fan control issues and waste energy.
- Summation of max cfm on VAV boxes equal Air Handling Unit airflow +/- 20% (80% diversity).
- Summation of max flow on water coils equal Total on pump +/-20% (80% diversity).
- Reheat coils: Minimum HW flow rates specified should not be less than 0.5 gpm.
- If there are DCV control VAV terminal units, the max/min cfm are specified with the allowable CO2 levels. (Example: The min cfm is for CO2 below 500 ppm and max cfm for CO2 above 800 ppm)
- TAB verification with CxA requirements are included
- Duct Air Leakage Testing requirements are included

Staging & Low-Flow Operations

- Chiller, boiler or DX staging plan is clear and will work as intended
- Chillers and boilers can operate at low loads without short cycling

- Varying water flow through the chillers or boilers will not result in chiller surge, boiler high-limit cut out and equipment short-cycling

Outdoor Air Control

- Ventilation air quantities and calculations for each air handler are provided
- Basis of design is clear, and effective control logic and setup procedures for each air handling unit's minimum outside air control are clearly specified
- Demand controlled ventilation strategy is clearly specified in the construction documents and documented in the basis of design
- Economizer sequence of operation is clear and adequately describes proper operation.
- If there is a DCV system, the CO2 upper/lower limits/set points are specified.

Ductwork

- Duct requirements and definitions are clear and take advantage of energy savings potential
- Duct lengths, fittings, turning vanes and transition requirements are clear and take advantage of energy savings potential
- Calculated velocity in Return Air/ Exhaust Air ducts does not exceed 1000-1200 ft/min.
- Calculated velocity in Exhaust Air ducts does not exceed 1000-1200 ft/min.
- Calculated velocity in Supply Air ducts does not exceed 2000 ft/min. (for medium pressure systems, will be lower for low pressure systems)
- Duct seal class and leakage rates are clearly defined
- Duct Air Leakage Testing requirements are clearly defined
- All balancing devices are shown, described, and detailed

Pump, Piping & Central Plan

- Cleaning, flushing and water treatment appears to be specified adequately.
- Flow measuring stations are specified on all supply and by-pass lines. Confirm that the flow measuring station is in the correct location per the manufacturer's instructions. (i.e. With the correct amount of straight pipe on the inlet and outlet.
- Temperature sensors are specified on all main supply and return piping.

Building & Space Pressurization Issues

- Building pressurization basis of design, control logic and setup procedures are specified, clear & effective
- The basis of design, control logic and setup procedures for pressure relationship between interior spaces are specified, clear and effective
- Building static pressure sensors are properly specified

Daylight, Occupancy, & Dimming Lighting Issues

- Design criteria and sequences of operation are clear and complete
- Field set up and acceptance requirements are complete
- Sensor position and quantity are properly specified and shown

- Operation manuals and operator and staff training requirements are complete
- Verify daylight zoning – in atrium/ lobby areas confirm that the lights are dimmable / programmable to be dimmed/turned off when appropriate light levels are attained via daylighting.

Indoor Environmental Quality

- No noise generated from the HVAC system those results in distraction of the occupants, including central system, ductwork, unitary units and room air distribution.
- Velocity at supply/return grills is lower than 500 fpm, velocity in hydronic piping is less than 8 fps
- Vibration from HVAC & R components shall not be transmitted where it is felt by the occupants.

Plumbing Items

- All plumbing equipment is on the drawing schedules. Compare the plumbing details and schematic diagrams with the equipment schedules.
- Compare the plumbing details and schematic diagrams with the equipment schedules.
- Verify the plans show cleanouts are provided on the waste lines.
- Confirm that backflow prevention devices are shown on the plans for the main water supply lines into the building.
- Confirm that all bathrooms with more than one flush valve fixture have a floor drain shown on the plans.
- Confirm that P-traps have a trap primer.
- Confirm that the water heater tanks have a detail that shows seismic restraints and an expansion tank.

04.07 Submittal Review Checklist

Submittal Review Checklist

The review of the manufacturer and contractor submittals is intended to evaluate conformance to the project specifications developed in accordance with the Owner's Project Requirements (OPR) and to gather information for the Commissioning Process for commissioned systems.

The CxA selection of submittals to be reviewed directly correlate to the systems included in the Cx scope. The focus of the CxA reviews will focus on considerations identified in the OPR, BOD, and construction documents including accessibility and maintainability, control sequences of operation, layout and general sizing conditions, warranty requirements and useful service life, durability, and capacity.

The submittal review report should contain the following information:

- Project Title, Number, and Date of Review
- Overview: The overview mirrors the Cx specifications submittal process that defines the goals of the commissioning-focused submittal review process and procedures. For example, submittals for systems in the Cx scope will be submitted to both the Design Team and CxP Team for review. The Caltech Project Manager shall distribute submittals to the CxA. The CxA Team will submit comments to the Caltech Project Manager who will distribute to the general contractor and project stakeholders as appropriate. In a design build project delivery, the design team has provided their disposition on the submittal prior to being sent to Caltech Project Manager via the design builder. In a design bid build delivery, the general contractor shall submit submittals to the Caltech Project Manager and the Project Manager shall distribute to the design team and the CxA in parallel for review. The Caltech Project Manager shall return comments from the all reviewers to the design builder or general contractor.
- Where the disposition on a submittal is revise and resubmit or rejected, the design builder or general contractor shall respond to all comments provided on the submittal in writing when they resubmit the submittal.
- Issues, Comments, and Variances from Contract Documents Based on OPR: Include copies of unresolved review comments associated with the specific submittal and supporting documentation relative to the concern.
- All issues identified during review are added to the Issues Log.

04.08 Pre-Functional Checklists

Pre-Functional Checklists

Pre-Functional Checklists are intended to capture delivery & installation information and indicate that, once complete, the subject equipment or assembly is ready for startup. The CxA generates the PFCs based on the contract documents and associated submittals. The installing contractor completes each checklist item within their scope and the general contractor signs for final completion once all scope is complete. All CxA-generated checklists should be maintained on a cloud-based platform.

PFCs consist of two types:

- Component/Equipment Based
 - These construction checklists are utilized used for components and pieces of equipment that are delivered, installed, and started up during construction. There is an individual checklist for each individual component or piece of equipment.
- System/Assembly Based
 - These construction checklists are utilized used for systems and assemblies where separate checklists cannot be applied to subcomponents of the system or assembly. There is a single checklist for the entire system.

The PFCs should include the following:

- Vital information on the equipment or materials being supplied.
 - Information details what equipment/material was specified and submitted.
 - What was actually delivered on the site is documented and verified on the PFC.
 - The condition of the equipment at the time it is delivered at the site and prior to its installation.
- Proper installation of the systems and assemblies.
 - Evaluation shall focus on the physical installation of the systems and assemblies, on their ability to meet the contract documents requirements, and on accessibility for Cx, testing, and maintenance operations.
 - Successful testing results of systems and assemblies.
- The first section of the checklist is equipment/ assembly verification.
 - This section should include vital information on the equipment or materials being supplied.
 - This section contains information on what equipment/material was specified/submitted and space to document/verify what was actually delivered to the site.
 - The preinstallation section of the checklist is used to verify the condition of the equipment/material at the site immediately prior to its installation.
- The installation section of the checklist is used to verify proper installation.
 - This section focuses on the ability of the installation to meet the construction documents and the OPR.
 - For equipment, this section focuses on the physical installation and its start-up when applicable.
 - For assemblies, the focus is typically on installation and performance.

- The negative responses section is a space provided to document the reason for any negative responses and whether any action has been taken to correct the problem or problems that led to the negative responses.

Construction checklists consist of two types:

- Component/Equipment Based
 - These construction checklists are utilized used for components and pieces of equipment that are delivered, installed, and started up during construction. There is an individual checklist for each individual component or piece of equipment.
- System/Assembly Based
 - These construction checklists are utilized used for systems and assemblies where separate checklists cannot be applied to subcomponents of the system or assembly. There is a single checklist for the entire system.

The following provides a generic structure to follow for the development of construction checklists for any equipment, component, system, or assembly.

Contractor Provided Checklists

If requested, the contractor may submit checklists to be used in lieu of the CxA-generated PFCs for consideration. If these contractor-submitted checklists meet or exceed the expected level of rigor and information, they may replace the CxA-generated PFCs.

Sample Checklists

The following are examples to show the typical rigor that PFCs should attempt to achieve. This is not intended to be an exhaustive list and should not be approached as such.

Air Handling Unit (AHU)

Model Verification

- Manufacturer
- Model
- Serial Number
- Cooling Capacity (MBH/gpm)
- Heating Capacity (MBH/gpm)
- Supply Air flow, Design / Minimum (cfm)
- Supply Fan Motor Power / Speed (hp / rpm)
- Return Air flow, Design / Minimum (cfm)
- Return Fan Motor Power / Speed (hp / rpm)
- Voltage / Phase / Frequency (V / - / Hz)

Physical Checks

- Unit is free from physical damage

- Coil surface areas are free of damage
- The air openings are sealed with plastic
- The water openings are sealed with plastic plugs
- All components present and in proper order
- All access doors are operable
- Installation and startup manual provided
- Unit tags affixed

Construction Checklist

- Installation of AHU
- Unit secured as required by manufacturer and specifications
- Adequate clearance around unit for service
- All components accessible for maintenance
- Unit can be removed from the building
- Cooling coil drain pan slopes correctly
- Internal vibration isolators in good condition and shipping bolts are removed
- Belts are tight
- Unit labeled and is easy to see

Chilled Water Piping

- All piping components have been installed (in the correct order) as required by detail drawing
- Piping arranged for ease of unit/coil removal
- Piping supported as required by specifications
- Piping is clean
- Piping insulation is complete and installed as per specifications
- All valves and test ports are easily accessible
- Valve tags attached

Hot Water Piping

- All piping components have been installed (in the correct order) as required by detail drawing
- Piping arranged for ease of unit/coil removal
- Piping supported as required by specifications
- Piping is clean
- Piping insulation is complete and installed per specifications
- All valves and test ports are easily accessible
- Valve tags attached

Ductwork

- Adequate locations available for testing and balancing of unit
- All dampers and sensors are accessible (access panels)

- Outdoor and return air arrangement will not freeze coils, i.e. outdoor air and return air is adequate
- Vibration isolators installed
- All dampers close tightly and stroke fully and easily
- Ductwork is clean and free of debris

Electrical

- Local disconnect installed in accessible location
- Motor rotation in the proper direction
- All electrical connections are tight
- All electrical components are grounded
- VFD installed (if applicable)

Controls

- Control panel accessible and labeled properly
- Temperature, humidity, pressure, and CO₂ sensors (as applicable) are installed and calibrated
- Dampers actuators installed and calibration verified
- Hot and chilled water actuators installed, and calibration verified
- Safety items installed and verified (freezestat, high pressure, motor overload, etc.)

Heating Hot Water Boiler

Model Verification

- Manufacturer
- Model
- Serial Number
- Total Heating Capacity (MBH)
- Voltage / Phase / Frequency (V / - /Hz)
- Entering / Leaving Hot Water Temperature (°F)

Physical Checks

- Unit is free from physical damage
- The water openings are sealed with plastic plugs
- All components present
- Installation and startup manual provided
- Unit tags affixed
- Unit secured as required by manufacturer and specifications
- Adequate clearance around unit for service
- All components accessible for maintenance
- Unit can be removed from building
- Flue completely installed and properly sloped
- Unit labeled and is easy to see

Piping

- All piping components have been installed (in the correct order) as required by detail drawing
- Piping arranged for ease of unit removal
- Piping supported as required by specifications
- Piping is clean
- Piping insulation is complete and installed as per specifications
- Thermometers and pressure gauges on supply and return lines
- All valves and test ports are easily accessible
- Valve tags attached

Electrical

- Local disconnect installed in accessible location
- All electrical connections are tight
- All electrical components are grounded

Controls

- Control panel accessible and labeled properly
- Remote start and stop verified
- Hot water temperature reset signal verified (if applicable)
- Test ports installed near all control sensors
- Actuators installed and calibration verified

HVAC Piping: Insulation

Installation Checks

- Piping is clean, dry and free of damage prior to installation.
- Pressure and leakage tests performed, and reports have been submitted prior to insulation installation.
- All chilled water piping is insulated with 1 1/2-inch-thick fiberglass pipe insulation with vapor barrier except runouts to radiant cooling panels located beyond 1'-0" within room being served.
- Secondary chilled water, low temperature chilled water (2 1/2-inch-thick), fan coil drain piping 4 (1/2" thick), and piping with electric trace freeze protection is insulated in the same manner as the chilled water pipes.
- All chilled water pumps are insulated with a 1 1/2 inch thick rectangular box made of Manville 5 817 rigid fiberglass board having a density of 6 lb/ft³ with a rated vinyl coated and embossed laminate vapor seal (ASJ) jacket.
- The insulation box for the pump is open at top and bottom with a removable top to affect a complete insulation for each base mounted pump.
- The pipe insulation sections are firmly butted together, and the longitudinal seam of the vapor barrier is cemented with Foster No. 85-75.

- End joints are sealed with a minimum of 3-inch-wide factory furnished vapor barrier strips cemented with Foster No. 85-75.
- All fittings, valves, strainers etc. is insulated as described in the specifications.
- Exterior piping has a 0.016-inch aluminum jacket with moisture barrier lock seam and Gasco of equal factory applied fittings in lieu of glass cloth jackets. A sample is submitted.

HVAC Ductwork

Sheet Metal Ductwork Installation Checks

- Ductwork is clean and free of damage prior to installation.
- Ductwork is installed in accordance with SMACNA HVAC Duct Construction Standards, 2005
- All hat sections and standoff brackets are at the same height as the duct lining.
- Access doors are installed in all casing, plenums, ductwork adjacent to fire dampers, automatic dampers, smoke dampers, and reheat coils, and as indicated on drawings.
- The access doors on casings or housings open to the inside on the discharge side and to the outside on the suction side.
- All galvanized sheet metal is separated from aluminum and copper with lead or felt gaskets.
- Ductwork is structurally sound to prevent drumming and sagging.
- All transverse and longitudinal joints are sealed.
- All branch and tee connections are 4degree.
- All medium pressure branch and tee connections are expanded 30 degrees on at least three sides.
- Ductwork meets static pressure requirements specified below and leakage class A for these pressures as defined by SMACNA HVAC Duct Construction Standards, 1985.
- All ductwork except as noted in the specification is leak tested.
- Elbows have an inside radius equal to a minimum of 3/of the width of the duct.
- All square elbows and radius elbows larger than 18 inches have turning vanes.
- All wall and floor penetrations are sealed.
- Volume dampers are at minimum provided for each horizontal branch from vertical risers serving two or more floors and branches serving two or more outlets.
- All equipment requiring maintenance is accessible (valves, junction boxes, etc.).
- All duct openings temporary sealed to maintain duct system cleanliness.
- Record drawings have been updated to reflect any changes made.

Flexile Ductwork Installation Checks

- Flexible ductwork is clean and free from damage prior to installation.
- Flexible ductwork is free of sags and kinks.
- Flexible ductwork is installed using extra heavy flexible duct straps.
- The maximum length of flexible ductwork is feet.
- Flexible ductwork does not penetrate walls.
- Flexible ductwork does not have 90-degree bends.

Ductwork Type Static Pressure Classification Installation Checks

- From fan discharge to and including vertical risers, +in. static pressure
- Branch supply ductwork, +in. static pressure.
- Branch supply ductwork from terminal to room outlet, +in. static pressure.
- Exhaust/return ductwork, \pm in. static pressure.
- All other ductwork, \pm in. static pressure.

Exhaust Fan

Model Verification

- Manufacturer
- Model
- Serial Number
- Fan Type
- Capacity / Static Pressure (cfm / in. wg)
- Motor Power / Speed (hp / rpm)
- Motor Voltage / Phase / Frequency (V / - / Hz)

Physical Checks

- Unit is free from physical damage
- The air openings are sealed with plastic
- All components present (belt guard, motor, damper, spring isolators, etc.)
- Installation and startup manual provided
- Unit tags affixed

Installation of Exhaust Fan

- Unit secured as required by manufacturer and specifications
- Adequate clearance around unit for service
- All components accessible for maintenance
- Unit can be removed from building
- Shipping bolts have been removed (if applicable)
- Belts are tight (if applicable)
- Back draft damper installed and moves freely
- Protective shrouds for fan and belts in place and secure
- Unit labeled and is easy to see

Ductwork

- Adequate locations available for testing and balancing unit
- All dampers and sensors are accessible (access panels)
- Vibration isolators installed
- All dampers close tightly and stroke fully and easily

- Ductwork is clean and free of debris

Electrical

- Safety disconnect installed in an accessible location
- Motor rotation is in correct direction
- All electrical connections are tight
- All electrical components are grounded

Controls

- Control panel accessible and labeled properly
- Dampers actuators installed and calibration verified
- Safety items installed and verified (high pressure, motor overload, etc.)

Fan Coil Unit

Model Verification

- Manufacturer
- Model
- Serial Number
- Capacity / Static Pressure (cfm / in. wg)
- Fan Motor Power (hp)
- Fan Motor Voltage / Phase / Frequency (V / - / Hz)
- Total / Sensible Cooling Capacity (MBH)
- Cooling Fluid Flow / Pressure Drop (gpm / ft wg)
- Total Heating Capacity (MBH)
- 10 Heating Fluid Flow / Pressure Drop (gpm / ft wg)

Physical Checks

- Unit is free from physical damage
- Coil surface areas are free of damage
- The water openings are sealed with plastic plugs
- All components present
- Installation and startup manual provided
- Unit tags affixed

Installation of Fan Coil Unit

- Unit supported using adequately sized mounting anchors
- Metal-to-metal connections eliminated to prevent noise problems
- Adequate clearance around unit for service
- All components are accessible for maintenance
- Unit can be removed from building
- Unit labeled and is easy to see

Chilled Water Piping

- Condensate piping properly installed (trapped and run to a drain)
- P/T ports installed across the cooling coil
- All piping components have been installed (in the correct order) as required by detail drawing
- Piping arranged for ease of unit/coil removal
- Piping supported as required by specifications
- Piping is clean
- Piping insulation complete and installed as per specifications
- All valves and test ports are easily accessible
- Valve tags attached

Hot Water Piping

- All piping components have been installed (in the correct order) as required by detail drawing
- Piping arranged for ease of unit/coil removal
- Piping is supported as required by specifications
- Piping is clean
- Piping insulation complete and installed as per specifications
- All valves and test ports are easily accessible
- Valve tags attached

Ductwork

- Adequate locations available for testing and balancing of unit
- All dampers and sensors are accessible (access doors)
- All dampers close tightly and stroke fully and easily
- Filter is clean
- Filter is properly installed (air bypassing the filter is prevented)
- Ductwork is clean and free of debris

Electrical

- Local disconnect installed in an accessible location
- Motor rotation in the proper direction
- All electrical connections are tight
- All electrical components are grounded

Controls

- Control panel accessible and labeled properly
- Room thermostat installed and calibration verified
- Chilled and hot water actuators installed, and calibration verified

04.09 Functional Test Plan

Functional Test Plan

The Functional Test Plan (FTP) refers to the collection of Functional Tests required for a project. Each project requires creation of test procedures unique to that project. The objective of these procedures is the verification that all Caltech requirements have been achieved through a full range of control, loads, and modes that may be experienced during operation of the tested system. The focus is on the facility and system level, which is made up of the equipment, components, and assemblies verified using the PFCs and startup reports throughout construction.

CxA will create automated and manual test procedures to verify the performance of the commissioned systems against the intents and targets defined in the owner project requirements or program.

automatically 3-4 times during the Period to gain insight on device and systems performance.

The CxA generates the FTP based on the contract documents and associated submittals. Once generated, the functional tests should be maintained on a cloud-based platform accessible to the entire Cx Team. Once made available, the Cx Team for review and comment on the plans to verify understanding and accuracy. The intent is that there should not be any negative or not applicable response to any test line on a functional system. Any comments returned by the team should be reviewed and discussed for action. Any disagreements between the team should be resolved by Caltech.

When planning the tests, consideration should be given to including logical groups the same equipment or assemblies in a single procedure but expanding the scope of a test beyond what is manageable should be avoided. The key points of evaluation for each test should be identified. The tests should identify what information must be documented to show compliance.

The test procedures should verify proper operation of all control strategies, energy efficiency, and self-diagnostics features by stepping through each sequence and documenting equipment and system performance. Tests should include significant modes, sequences, and operational features not mentioned in written sequences, including startup, normal operation, shutdown, scheduled on and off, unoccupied and manual modes, safeties, alarms, overrides, lockouts, and power failure and recovery.

Automatic Testing

SkySpark will be used to monitor and verify system performance during automatic functional testing. SkySpark will bind to the control points of the building automation system and create trends on SkySpark server (SkySpark does not create trends on the BAS) to monitor to live monitor the controls system 24/7.

SkySpark fault detection and analytics will support automatic functional testing by identifying issues across multiple system and aid in accomplishing testing of 100% of the HVAC equipment installed for equipment that is integrated into the building automation system. As issues are identified during testing, special rules will be added to SkySpark fault detection to look for these specific issues across the entire facility. As systems are functionally tested and commissioned, SkySpark will continue to monitor these systems and look for anomalies in the trend data to ensure the systems continue to operate as intended. This data will be crucial to determining which factors have the largest impact on the building systems and will ultimately be used to drive the changes required to tune building systems.

CxA will deploy key functional performance tests from the construction phase functional testing during the Phase to identify issues with controls programming and equipment, ensuring issues are identified and resolved early in the project lifecycle. The intent will be to run the Functional Test Scripts automatically 3-4 times during the Period to gain insight on device and systems performance.

Testing Expectations

The following items should be included in the test procedures and verified during testing:

- Verify all alarm and high- and low-limit functions and messages generated on all points with alarm settings.
- Verify integrated performance of all components and control system components, including all interlocks and interactions with other equipment and systems.
- Verify shutdown and restart capabilities both for scheduled and unscheduled events.
- Verify control system stability and tuning by upsetting various control loops under different load conditions and observing the system response.
- When applicable, demonstrate a full cycle from off to on and no load to full load and then to no load and off.
- Verify time-of-day schedules and set points.
- Verify all energy-saving control strategies.
- Verify that control system graphics are representative of the systems and that all points and control elements are in the same location on the graphic as they are in the field.
- Verify operator control of all control system points, including proper access level as agreed to during the controls integration meetings.
- Verify operation of systems and components under low, normal, and high load conditions.
- Verify operation of systems and components during combinations of environmental and equipment interaction conditions that could reasonably exist.
- Verify Analytics and Fault Detection and Diagnostics configuration and reporting.

04.10 Project Handoff Form

Caltech

Facilities Design & Construction

PROJECT HAND-OFF FORM

Project Name:	
Project Number:	
Project Locations (Building/Room #)	
Project Manager:	
Substantial Completion Date:	

As of the indicated date, Facilities D&C has completed all of Facilities requirements for the above referenced project. Facilities Operation accepts this project hand-off as referenced to the date below:

DATE OF PROJECT HAND-OFF	
---------------------------------	--

Facilities D&C will provide Facilities Operation all associated documentation as required including but not limited to: Project Directory, Punch List, Permits, Training, Test Reports & Certifications, As-Built Drawings, Asset Management Logs, O&M, and Warranties.

All closeout documentation has been received and accepted by Caltech.
 Required closeout documents have been uploaded into Meridian.
 Cx Readiness form has been received and accepted by Caltech.

Project Warranty Main Point of Contact:

Contractor:	
Name:	
Phone Number:	
Email:	

Requested by:

Accepted by:

 Project Manager
 Facilities Design & Construction

 Director of Maintenance Management
 Facilities Management

04.11 Cx Readiness Form

Commissioning Certificate of Readiness

Project # _____

Project Name _____

Caltech D&C Project Manager Name _____

Commissioning Authority Name, Company _____

Commissioning Authority Contact Info _____

Controls Contractor Name, Company _____

Controls Contractor Contact Info _____

Certificate Date _____

Commissioning Scope - The Cx scope and this certificate covers the equipment and system(s) below:	
Statement of Readiness	
All systems within the commissioning scope have passed functional testing (with no exceptions).	<input type="checkbox"/>
All systems within the commissioning scope have passed functional testing (with exception of the open issues in the attached "Functional Test Procedures & Results").	<input type="checkbox"/>

Commissioning Closeout Checklist				
	Complete	Excluded from Cx Scope	N/A	Not Provided by Contractor
Commissioning Deliverables				
Commissioning Issues Log	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Functional Test Procedures & Results	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Systems Manual	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Completed independent field inspection and startup checklists.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Configured SkySpark Site	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
SkySpark user accounts and access	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
SkySpark License	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Contractor Deliverables Verified by Commissioning Authority				
Asset Submittal, As-Built, and Warranty Data in SAM.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Operations and Maintenance Manuals	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Warranty Manuals	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
As-Built Drawings	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
As-Built Submittals	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Systems Training	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Background

The following is an example outline for a Cx Report. The basic structure of this example is such that each phase of the plan has its own section detailing what activities will be accomplished and guidance on who accomplishes them and how they are completed. The results from each activity are then included in an appendix. The intent of this format is for the Cx Plan to become the Final Cx Process Report at the end of the project by filling in the results as the project progresses.

Required Table of Contents

Revision History

With each iteration, include the following –

- Version
- Author
- Summary of changes

Executive Summary

This section includes an overall description of the building and its systems, including a listing of major capabilities and limitations imposed by the design or building code. The description should include type of facility, general description (number of floors, gross area, net area, type of occupancy, etc.), and general system descriptions. A list of contractors, subcontractors, suppliers, architects, and engineers involved in the project along with their contact information should be included in this section.

Commissioning Summary

Include a summary of the commissioning process, including results.

Issues Summary

This section includes a summary of significant or noteworthy issues discovered during the process, including their resolution and benefit.

Training

Include a summary of training, including schedule.

End-Of-Warranty Review

Recommendations for end-of-warranty review activities.

Attachments

Final Issues Log

Design Phase

The Design Phase Issues Log for the project, including all comments and attachments.

Construction Phase

The Construction Phase Issues Log for the project, including all comments and attachments.

Final Cx Plan

The projects final Cx Plan

OPR

A copy of the final OPR for the facility is included in this section. This document was initially developed during the Predesign Phase and was updated throughout the project by the Owner, CxA, or design professionals.

Basis of Design

This section includes the final BoD document at a facility level. This document is written by the design professionals during the Design Phase and is updated by them to include any changes during the Construction Phase.

Commissioning Meetings

Include a complete record of all Commissioning Meetings held throughout the projects, including Design Phase, Kickoff, and any other focused meetings.

Commissioning Site Observation Reports

Include all Commissioning Site Observation Reports, including all attachments.

Measurement and Verification

Include a Measurement and Verification Report per IPMVP protocols.

Description

The required details for a full systems manual are enhanced in each of the technical Cx guidelines. The Systems Manual will have multiple sections depending upon on the number of systems focused upon on during the Cx Process. The systems manual will include a detailed table of contents with a notation as to resource storage location if not in the actual manual. The following outlines the minimum requirements.

Required Table of Contents

Revision History

With each iteration, include the following –

- Version
- Author
- Summary of changes

Executive Summary

This section includes an overall description of the building, its systems, and, when applicable, its history. This should include a listing of major capabilities and limitations imposed by the design or building code. The description should include type of facility, general description (number of floors, gross area, net area, type of occupancy, etc.), and general system descriptions.

Facility Description

- Use/function
- Square footage
- Occupancy Type
- Construction Type
- Location of major systems & equipment

Facility Operating Procedures

This section includes detailed operating procedures for the facility during normal, abnormal, and emergency modes of operation. This is not intended to be automatic control sequences, but general operating procedures. This would include items such as building access during various situations (normal operation, after-hours operation, fire alarm, civil disturbance operation, emergency power operations, etc.).

Final Control Sequences

Include final sequence of operations for all commissioned equipment and assemblies, including:

- Building operating schedules
- Space temperature, humidity, & pressure, CO2 setpoints
- Summer and winter setback schedules
- Chilled & hot water temperatures
- As-built control setpoints and parameters

Maintenance Procedures, Schedules, and Recommendations

This section includes the manufacturer's recommendations for maintenance procedures and when maintenance should be performed on systems not included in specific system sections.

Ongoing Optimization

This section includes guidance for the ongoing optimization of the facility. Included in the section are schedules of periodic benchmarking using checklists and tests developed for the original construction, procedures for maintaining the OPR and BOD documents, and guidance on what to do when the OPR are is not achieved, met.

Site Contact Information

A list of Caltech personnel, utility providers, contractors, subcontractors, suppliers, architects, and engineers involved in the project along with their contact information should be included in this section.

Attachments

Commissioned Equipment and Systems List

A list of all equipment and systems commissioned as a part of the project.

Pre-Functional Checklists

Blank PFCs

The blank forms are included to support future commissioning efforts.

Completed PFCs

The completed forms are included as an ongoing reference for Caltech.

Startup Reports

Completed startup reports for all commissioned systems are included.

TAB Report

Include the final approved TAB Report with verification results.

Title 24 Acceptance Testing Forms

Include the completed Title 24 Acceptance Testing Forms, as completed by the contractor.

Functional Test Plans

Blank FTPs

The black forms are included to support future commissioning efforts.

Completed FTPs

The completed forms are included as an ongoing reference for Caltech.

Construction As-Built Record Documents and Specifications

This section includes elements of the record set of construction documents updated to reflect the final installation.

Operations and Maintenance Manuals

This section includes the manufacturer's printed operations and maintenance manuals for the specific equipment/components provided for the xxx system/assembly. Also included is a parts and recommended spare parts list, a troubleshooting guide for common situations, and one-line diagrams for each applicable system.

Training Records

This section includes information on training provided and attendees. In addition, information on ongoing training shall be provided.

Special Inspections

A copy of all special inspection verifications required by the enforcing agency of this code.

04.14 Lessons Learned Workshop

Lessons Learned

At the end of a project, the successes and shortcomings of the project should be reviewed with the project team. The purpose of documenting lessons learned is to share and use knowledge derived from experience to promote the recurrence of desirable outcomes. The team will review the outcome of the project, assess the status of any outstanding items, and review the lessons learned. The discussion would include the project in general, identifying areas of change or improvement for the next project. All findings should be thoroughly documented with a clear plan regarding how to implement the lessons in future projects. By not learning from project failures we are doomed to repeat similar situations. By not maximizing on project successes, we miss opportunities to implement good processes and practices to successfully complete existing and future work.

The Project Managers, team members and occupants should all participate in the lessons learned sessions, review the lessons learned reports and make decisions on how to use the knowledge gained. Sharing lessons learned among project team members prevents the same mistakes from repeating and allows the team to take advantage of organizational best practices. Innovative approaches and good work practices can be shared with others.

The commissioning authority shall provide a list of lessons learned at the end of each project as part of the readiness form. The lessons learned provided by the commissioning authority can range from commissioning specific activities to any area of the project where they see an opportunity for improvement.

Process

The process steps are broadly defined below.

Identify

Identify comments and recommendations that could be valuable for future projects. This is done via a Lessons Learned workshop and guided by the project survey prepared by the Project Manager.

Documents

Document and share findings

Analyze

Analyze and organize for application of the results.

Action

Determine the proper action plan for each item.

Project Survey

The project survey should also include specific questions for each category below. These responses will be used by the Project Manager to guide the discussion during the lessons learned session. Three key questions should be included as part of the survey: 1) what went right, 2) what went wrong and 3) what needs to be improved.

Organization

The following is the suggested organization that should be used to guide the discussion.

<u>Project Management</u>	<u>Technical Management</u>	<u>Human Factors</u>	<u>Overall</u>
Project Planning	Requirements	Communication	Customer Satisfaction
Resource Management	Specification	Team Experience	Technical Success
Risk Management	Test Plan	Interaction with End User	Quality product
Change Control	Construction	Interaction with Management	Project Accepted
Procurement	Testing	Management Facilities	On Time
Budget Management	Rollout	Quality of meetings	Within Budget
Quality Control	Training	Vendor interaction	Met Project Objectives
Status Reports	Documentation		Met Business Objectives
Vendor Selection	Vendor Management		

Lessons Learned Workshop

A Lessons Learned workshop focuses on identifying project success and project failures and includes recommendations to improve future performance on projects. The Project Manager should invite all key internal and external stakeholders. The Lessons Learned workshop is a very important part of the process. If the session is not successful, the organization loses out on the lessons learned opportunity. Once all key items are identified, a specific action should be assigned to each item that clearly defines how the item will be avoided in future projects.

04.15 Tier 3 Project Cx

The following details the commissioning process for projects determined by Caltech to be qualified as Tier 3.

04.15.01 RACI Table

The Tier 3 RACI table, as defined in 03.01.01 RACI Table above, should be followed for all Tier 3 projects.

Table 25 RACI Table – Tier 3

Task #	Task Name	Description	Cx Authority	CIT PM	CIT Space Manager	CIT Design Reviewer	CIT Asset Manager	CIT Energy Manager	Engineer of Record	Contractor	CIT Facilities Maintenance	Comments
		<u>GENERAL CX</u>										
G1	CxA Engagement	Attend OAC meetings, maintain email/phone correspondence.	I	A			C	C	C	R	I	
G3	Cx Plan	Create document outlining Cx process, roles and expectations of team members.	R	A								LEED v4 EAp1
G4	Cx Kickoff Meeting	Present Cx Plan including overview of Data Collection process.	R	A	I	I	C	I	I	I	I	Training for Asset Management may also be provided.
		<u>DESIGN PHASE: Design Through Construction Review</u>										
D1	Asset Management	Add locations to AiM.	C	A	R	I	C		I	I		Project Architect shall also be Informed.
D2	Asset Management	Provide Engineer of Record with a list of existing assets within project space and generate schedule tag sequence report.	I	A			R		C			New assets to begin with next sequential Schedule Tag.

Task #	Task Name	Description	Cx Authority	CIT PM	CIT Space Manager	CIT Design Reviewer	CIT Asset Manager	CIT Energy Manager	Engineer of Record	Contractor	CIT Facilities Maintenance	Comments
D3	100% CD Review	Review 100% CD drawings.		I		AR		I	C		I	LEED v4 EAp1
D4	Asset Management	Verify equipment schedules are complete and correct	C	I		A	R		C			Prerequisite to C5
		<u>CONSTRUCTION PHASE</u> : Submittals Review										
C1	HVAC & BAS Submittals Review	Review with focus on BAS controls & energy efficiency; augments internal Caltech review.	R	I		A		I	I	C	I	LEED v4 EAc3 (Cx review BAS submittal only for Tier 3)
		<u>CONSTRUCTION PHASE</u> : Pre-functional Testing Period										
C4	Asset Management	Apply QR labels to equipment.		A			C				R	See "QR Code Tagging Guide".
C5	Asset Management	Enter Assets and Attributes in Go Asset Management (AiM) .		A			C				R	
C6	Asset Management	Backcheck data entry in AiM	I	A			R			C		
C7	FPT Development	Document the test procedures and share with the team for review.	RA						I	C		LEED v4 EAp1

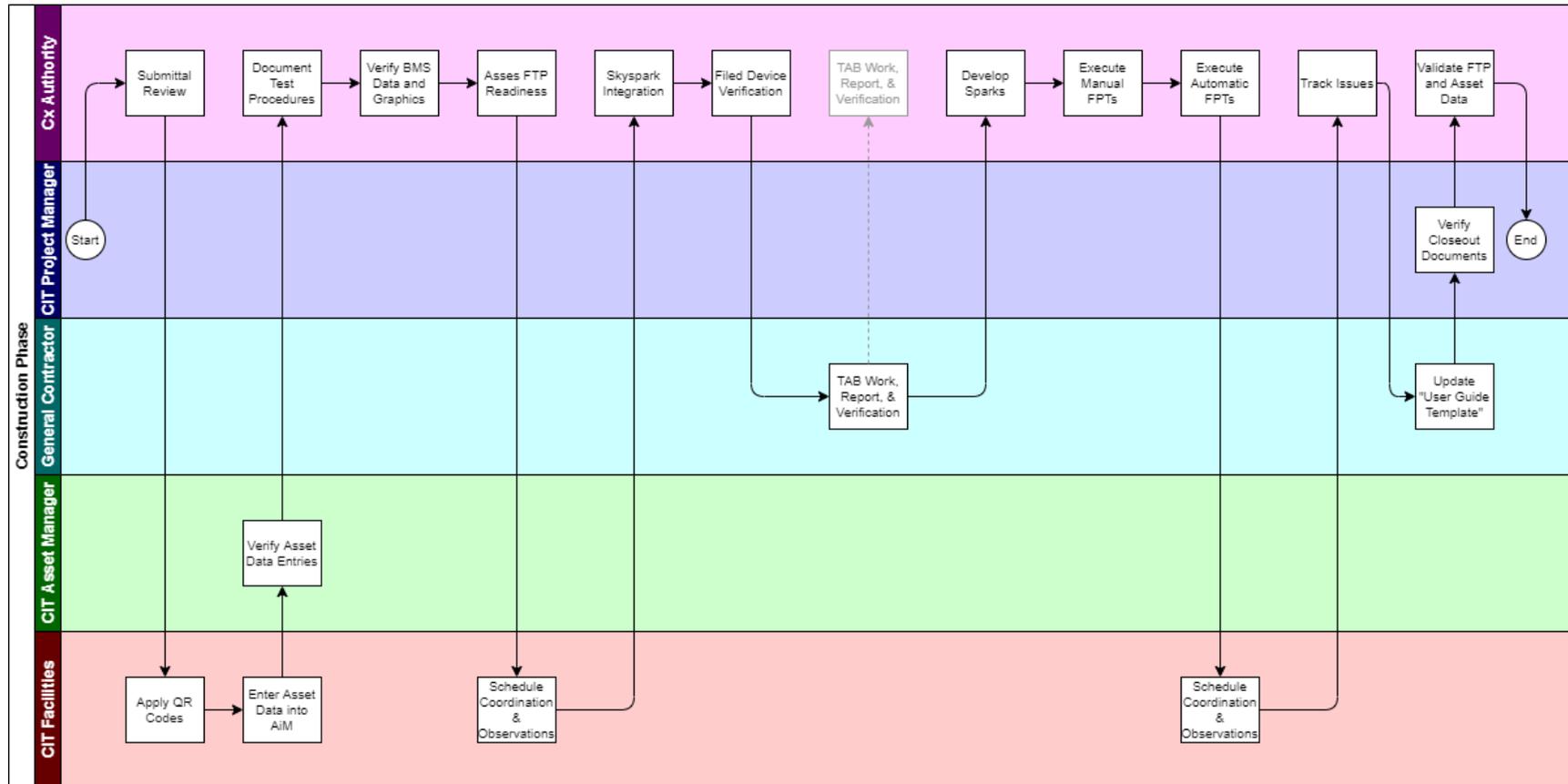
Task #	Task Name	Description	Cx Authority	CIT PM	CIT Space Manager	CIT Design Reviewer	CIT Asset Manager	CIT Energy Manager	Engineer of Record	Contractor	CIT Facilities Maintenance	Comments
C8	Controls Bench Testing	Review of point naming, folder organization, override-ability, wire logic & graphics.	RA	I				I		C	I	Per current Caltech Design Guidelines. Provide complete DDC submittal/as-built package documentation.
C10	Witness Major Startups, Pre-Testing Site Visits	Assess Functional Performance Test (FPT) readiness, clarify outstanding issues with contractors, support Caltech requests.	RA	I						C	I	May be combined with Shops Initial Walk-Through.
C11	Shops Initial Walk-Through & Observations Tracking	Initiate scheduling coordination, attend and track observations.	I	A					I	C	R	Verify QR label placement.
C15	SkySpark Integration to BAS	Perform point discovery, import, tagging & naming, applying sparks, user account management.	RA	I				I		C	I	
C16	Pre-functional Checks and	Perform tests such as stroking valves/dampers and review results via SkySpark data.	RA	I				I		C		

Task #	Task Name	Description	Cx Authority	CIT PM	CIT Space Manager	CIT Design Reviewer	CIT Asset Manager	CIT Energy Manager	Engineer of Record	Contractor	CIT Facilities Maintenance	Comments
	Trend Review											
C18	TAB Verification	TAB contractor to provide pre-read report and final TAB report. Review of reports, coordinate with TAB contractor for backchecks if needed	RA	C				I		C		Provide final air balance report document.
		<u>CONSTRUCTION PHASE:</u> Functional Testing										
C19	Sparks Development	Develop sparks for continuous monitoring.	RA					C				For large projects only (>25 zones).
C20	Functional Performance Test (FPT) Execution - Manual/Field Testing	Execute FPTs in the field.	RA	I					I	C		LEED v4 EAp1
C21	Functional Test Procedure Execution -	Run automated tests to augment manual testing.	RA	I					I	C		LEED v4 EAp1. For large projects only (>25 zones).

Task #	Task Name	Description	Cx Authority	CIT PM	CIT Space Manager	CIT Design Reviewer	CIT Asset Manager	CIT Energy Manager	Engineer of Record	Contractor	CIT Facilities Maintenance	Comments
	Automated Testing											
C22	Shops Final Walk-Through & Observations Tracking	Initiate scheduling coordination, attend and track observations.	I	A					I	C	R	
C23	Cx Issues Log	Maintain detailed list of functional test issues with assigned responsibility. Track to resolution.	R	A				I		C	I	LEED v4 EAp1. Provide Cx Issues log document.
		CONSTRUCTION PHASE: Commissioning Closeout Docs/Checks										
C25	Create User Guide	Update the "User Guide Template" to reflect occupant-interfacing systems in the space.		I				A		R		See Caltech "Building User Guide Template". Contractor to install upon completion.
C26	Verify Owner Record Documents	Verify warranty, O&M manuals, submittals, cut-sheets, and record drawings are provided, including the complete DDC submittal/as-built package.	I	R						C	A	Provide training, as-built drawings, warranties, O&M manuals, submittals and cut sheet documents.

Task #	Task Name	Description	Cx Authority	CIT PM	CIT Space Manager	CIT Design Reviewer	CIT Asset Manager	CIT Energy Manager	Engineer of Record	Contractor	CIT Facilities Maintenance	Comments
C27	Final Cx Report	Provide functional performance test results, validated asset list, SkySpark database (trends and sparks), AiM Reactor Event Rules	R	A				I				LEED v4 EAp1. Provide report document.
		<u>POST-OCCUPANCY: SkySpark-AiM Reactor Integration (Optional)</u>										
P1	SkySpark-AiM Asset Mapping (Optional)	Map AiM assets to SkySpark BAS equips for automated work order generation.	R					C			A	
		<u>POST-OCCUPANCY: Cx Support</u>										
P7	Post-Occ Cx Meetings	Conduct one 11-month Post-Occ Cx meetings after handover to Facilities Management.	R	I			C	A	I	C	C	LEED v4 EAc3
		<u>POST-OCCUPANCY: Energy Monitoring & Verification</u>										
P8	M&V Reporting	Include pre/post-Cx energy baselines, predicted/actual performance & energy savings.										For Tier 4 CECIP projects only.

Table 26 Tier 3 Construction Phase Flowchart



04.15.02 General Cx

04.15.02.01 CxA Engagement

Attend OAC meetings, maintain email/phone correspondence.

04.15.02.02 Cx Plan

See [03.02.05.05 Cx Plan](#)

04.15.02.03 Cx Kickoff Meeting

Present Cx Plan including overview of Data Collection process.

04.15.03 Design Phase

04.15.03.01 Asset Management

See [03.02.05.10 Asset Management](#)

04.15.03.02 Asset Management

See [03.02.05.11 Asset Management](#)

04.15.03.03 100% CD Review

See [03.02.05.08 Schematic Design Reviews](#) and [03.02.05.16 Construction Documents Development Submissions](#)

04.15.03.04 Asset Management

See [03.02.05.22 Asset Management](#)

04.15.04 Construction Phase

04.15.04.01 Submittals Review

See [03.03.05.08 MEP & BAS Submittals Review](#)

04.15.04.02 Pre-functional Testing Period

04.15.04.03 Asset Management

See [03.03.05.18 Asset Management](#)

04.15.04.04 Asset Management

See [03.03.05.21 Asset Management](#)

04.15.04.05 Asset Management

See [03.03.05.22 Asset Management](#)

04.15.04.06 FPT Development

See [03.03.05.13 FPT Development](#)

04.15.04.07 Controls Bench Testing

See [03.03.05.15 Bench Testing](#)

04.15.04.08 Witness Major Startups, Pre-Testing Site Visits

Assess Functional Performance Test (FPT) readiness, clarify outstanding issues with contractors, support Caltech requests.

04.15.04.09 Shops Initial Walk-Through & Observations Tracking

See [03.03.05.19 Shops Initial Walk-Through & Observations Tracking](#)

04.15.04.10 SkySpark Integration to BAS

See [03.03.05.29 SkySpark Integration to BAS](#)

04.15.04.11 Pre-functional Checks and Trend Review

Perform tests such as stroking valves/dampers and review results via SkySpark data.

04.15.04.12 TAB Verification

See [03.03.05.30 TAB](#), [03.03.05.31 TAB Approval](#), and [03.03.05.32 TAB Validation](#)

04.15.04.13 Construction Phase: Functional Testing

04.15.04.14 Sparks Development

See [03.03.05.34 Sparks Development](#)

04.15.04.15 Functional Performance Test (FPT) Execution - Manual/Field Testing

See [03.03.05.36 Functional Performance Test \(FPT\) Execution](#)

04.15.04.16 Functional Test Procedure Execution - Automated Testing

See [03.03.05.36 Functional Performance Test \(FPT\) Execution](#)

04.15.04.17 Shops Final Walk-Through & Observations Tracking

See [03.03.05.36 Functional Performance Test \(FPT\) Execution](#)

04.15.04.18 Cx Issues Log

See [03.03.04 Issues Resolution](#)

04.15.04.19 Commissioning Closeout Docs/Checks

- Create User Guide
- Update the "User Guide Template" to reflect occupant-interfacing systems in the space.
- Verify Owner Record Documents
- Verify warranty, O&M manuals, submittals, cut-sheets, and record drawings are provided, including the complete DDC submittal/as-built package.

04.15.04.20 Final Cx Report

See [03.03.05.48.01 Cx Report](#)

04.15.05 Post-Occupancy

04.15.05.01 SkySpark-AiM Reactor Integration (Optional)

SkySpark-AiM Asset Mapping (Optional)

See [03.04.04.03 SkySpark-IWMS Asset Mapping \(Optional\)](#)

04.15.05.02 Cx Support

Post-Occ Cx Meetings

See [03.04.04.09 Warranty Review Meeting](#)

04.15.05.03 Energy Monitoring & Verification

M&V Reporting

See [03.04.04.07 M&V Reporting](#)