Commissioning Guide

For New and Existing Buildings

November 2015

National Aeronautics and Space Administration

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1. Introduction

NASA is committed to building world-class and state-of-the-art sustainable facilities that are cost efficient and safe. This commissioning guide is a result of the findings from NASA's first four postoccupancy evaluations (POEs) of new constructed buildings. These POEs consistently found issues with NASA's commissioning process, which evolved into a series of commissioning training classes being offered across the Agency, as well as this commissioning guide. Facilities shall be commissioned to ensure the applicable criteria are met and all of the buildings systems operate according to their design intent and manufacturers' specifications.

Total Building Commissioning addresses all of the buildings' critical systems. As new and innovative systems are developed to meet sustainability requirements, the need to provide a commissioning quality control process becomes more critical. These innovative building systems are often new to the building industry and designers, contractors, and operations and maintenance personnel aren't as familiar with their unique characteristics as they are with building systems that have been used for decades. Buildings that have had their systems commissioned typically are more energy efficient, have higher quality indoor environments, and have reduced operating costs and better trained operation and maintenance personnel.

This commissioning guide addresses all of the commissioning phases. Part One of this guide describes best practices for procuring and executing the commissioning process for new buildings and major renovations. Commissioning for new buildings and major renovations starts in the project planning phase and proceeds through the design, construction, and occupancy and operations phases. The Commissioning Guide also addresses recommissioning, retrocommissioning, and continuous/ongoing commissioning. The recommissioning process is used for existing buildings that previously have been commissioned. Retrocommissioning is used for existing buildings that never have been commissioned and is required for NASA to meet their 2015 Sustainable Building requirements. It often has the quickest financial payback of all of the commissioning phases. The continuous/ongoing commissioning process is used to provide continuous/ongoing commissioning for buildings that have been commissioned using one of the methods described above.

The NASA Commissioning Guide is intended to be used by Center personnel to facilitate the commissioning process for projects being executed at their Center. This document does not prohibit use of Center best practices or current management methods being used to execute the planning, design, construction, or operation of facilities.

The commissioning process is defined by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) as "a quality oriented process for achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria." Several guidelines defining the commissioning process have been developed by well-known international and national organizations. This guideline has been developed by NASA and is intended to capture how to incorporate Commissioning (Cx) into the

predesign, design, construction, and occupancy phases of Construction of Facilities (CoF) projects. This guideline is not intended to be considered as required to be followed fully but as a guide to assist NASA personnel in making decisions about how to incorporate the Commissioning process into CoF projects.

2. Procurement Guidelines

Commissioning services should be procured following the requirements of procuring Architect/Engineer (A/E) professional consulting services. The commissioning firm that manages the commissioning process should be contracted directly to the Government and should not work as a subcontractor to the contractor providing engineering or construction services. It is recommended that the Center have an Indefinite Delivery/Indefinite Quantity (IDIQ) Contract in place to procure commissioning services on a task order basis. This procurement approach will allow the Government to contract the commissioning agent (CxA) as needed for the various phases of commissioning. To maintain specific project knowledge and team continuity, it is recommended to have the same commissioning firm under contract for all commissioning phases. Due to the extended duration of some large projects, it may only be practical for the same firm to be under contract for the design and construction commissioning phases. See Appendix E for a sample commissioning firm solicitation.

The project A/E Contractor is the designer of record and is responsible for the accuracy and completeness of the design and construction documents. The construction contract specifications should clearly identify the specific systems being commissioned, submittal review requirements, and the commissioning responsibilities of the General Contractor (GC) and the subcontractors working for the GC. The CxA shall provide guidance to the A/E contractor for developing commissioning construction contract specification details during the design phase commissioning process. It is important that the various contractual relationships are clearly defined and maintained. There are a number of commissioning agents that provide both new and existing building commissioning. However, it should be noted that new building commissioning and existing building commissioning often require different skills.

Before the commissioning firm is hired, the Government should evaluate potential CxA candidates on:

- Extent of experience in Commissioning, facilities operations and maintenance, design engineering, etc.
- Certifications – Building Commissioning Association (BCA), ASHRAE, American Air Balancing Council (AABC), and National Environmental Balancing Bureau (NEBB)
- Sample documents from previous projects
- Types of facilities and complexity of systems previously commissioned
- Professional Engineer registration
- Internet-based collaboration and communication tools
- Hands-on experience with building HVAC, plumbing, electrical systems, and controls

Equipment operations experience, clear understanding of control sequences and strategies, and air and water balancing experience. **Note: It may be difficult to find someone with all these qualifications**.

3. Planning for the Commissioning Process

3.1. General

As described within this document, commissioning new and/or existing buildings is a lengthy process that requires a significant financial investment. Depending on the NASA Center, the responsibilities associated with the commissioning process could span multiple contracts, such as:

- Commissioning Agent (see Section 5.0)
- A/E Design Firm (for newly constructed buildings)
- Construction Contractor (for newly constructed buildings)
- Operations & Maintenance Contractor

Depending on the Center, the above services may be obtained through individual stand-alone contracts or through large contracts that consolidate the above responsibilities. Regardless of the contract structure, Centers need to develop a project-specific business plan to ensure that adequate financial resources are available throughout the life of the commissioning process.

Typically, a rough budget for Cx services can be expected to be **0.4**% of the construction cost or $0.30/sf for existing buildings, depending on scope. Consequently, Centers should consider planning for a multitude of different funding streams to meet the required Cx budget figure.

3.2. New Buildings (Design-Bid-Build)

Most NASA projects for new buildings have historically been procured using a Design-Bid-Build approach (e.g., there is an A/E Design Contract, a subsequent Government procurement process, then a Construction Contract). The business plan for this approach may be slightly different than the approach for Design-Build projects.

Generally, commissioning new buildings begins during the Predesign Phase and lasts through the Operations Phase. Realistically, this requires that commissioning services be sustained for as much as 4 or 5 years.

3.2.1. Predesign Phase

Funding is usually required during the Predesign Phase to finance the contracted CxA. For most Centers, there are two funding options for this phase of the project.

In some instances, Centers may be successful in advocating for Agency-provided Construction of Facilities (CoF) Preliminary Engineering Report (PER) funding for a significant building project. Advocacy for PER funding needs to occur through the Center's CoF point of contact 5 years prior to the construction year of the building. If successfully obtained, a portion of the PER funding can be used to finance the Cx services through the Predesign Phase of the project.

In the more likely event that PER funding is not available, Centers should plan to use the Facility Organization's Center Management & Operations (CMO) funding to sustain Cx services through the Predesign Phase.

3.2.2. Final Design and Preconstruction Phases

Centers should plan on funding multiple contracts for Cx services during the Final Design Phase of a project. This could include funding for the CxA, the Final Design A/E Contractor, and the Operations and Maintenance (O&M) Contractor (assuming early involvement).

The Brooks Act of 1972 stipulates a 6% (of the overall construction budget) limitation for the final design services for Federal projects. These services are associated with the production and delivery of designs, plans, drawings, and specifications. In addition, the Agency has historically planned for an additional 4% funding requirement for "other required services" such as field investigation, cost estimating, and implementation plan development. Commissioning services during the Final Design & Preconstruction phases can be included as "other required services."

During the planning process for new building projects (typically 4 years prior to the construction year), Centers should work with their CoF point of contact to incorporate the required funding for Cx services into the overall project budget. This includes identifying Cx services to be financed with CoF Facilities Planning and Design (FP&D) funding 2 years prior to the construction year and Cx services to be financed with CoF Construction Funding (see Section 3.2.3) during the Construction Phase and beyond. This should be clearly identified on a NASA Form 1510 "Facility Project Cost Estimate" that is initially submitted during the Agency's CoF Prioritization process.

Although the Agency model has been based on a need for 10% FP&D funding (6% for design, 4% for other required services), recent year budgets have not allowed for full funding. The typical Center allocation of FP&D for new building projects is approximately 8% (6% for design, 2% for other required services). Consequently, the allocated FP&D is largely consumed by the A/E's final design contract, and little remains for Cx services.

If no FP&D funding is available, Centers should again plan to use Facility Organization's Center Management & Operations (CMO) funding to sustain Cx services through the Final Design and Preconstruction phases.

3.2.3. Construction, Activation, Occupancy, and Operations Phases

As was the case for the Final Design phase, Centers should plan on funding multiple contracts for Cx services during the construction, activation, and occupancy and operations phases of the project. This could include funding for the CxA, the Final Design A/E Contractor, the Construction Contractor, and the O&M Contractor. An option to consider would be hiring a civil

servant to perform the commissioning. Another option would require the O&M contractor to supply a CxA through the O&M contract.

As described in Section 3.2.2, Centers should work with their CoF point of contact to incorporate the required funding for Cx services into the overall project budget. Upon receipt of CoF Construction funding, project managers should immediately obligate the correct amounts to the various contracts as required.

3.3. New Buildings (Design-Build)

Another delivery model for new building projects is the Design-Build approach (i.e., a single procurement is issued for services to design and construct the building). For this process, the Agency typically issues a small amount of FP&D funding (~ 2%) to enable Centers to produce a bridging document that is used to define requirements for the Design-Build procurement. The remainder of the financing is delivered as CoF Construction funding for a single contractor to provide the design-build services.

3.3.1. Predesign Phase

Funding is usually required during the Predesign Phase to sustain the contracted CxA. Centers should plan to use the Facility Organization's CMO funding or possibly FP&D funding to sustain Cx services through the Predesign Phase.

3.3.2. Final Design, Preconstruction, Construction, Activation, Occupancy, and Operations Phases

For these phases, Cx funding may be required for the contracted CxA, the Design-Build Contractor, and the O&M Contractor.

As was the case for new buildings delivered via the Design-Bid-Build process, Centers should work with their CoF point of contact to incorporate the required funding for Cx services into the overall project budget and clearly identify the needs on a NASA Form 1510, "Facility Project Cost Estimate." Upon receipt of CoF Construction funding, project managers should immediately obligate the correct amounts to the various contracts as required.

3.4. Existing Buildings (Retrocommissioning and Recommissioning)

Typically, recommissioning and retrocommissioning of existing buildings requires funding for two activities:

- A contracted CxA to perform the assessment of the existing building
- The Center's O&M Contractor's providing access to all areas requested by the CxA and performing the repairs/modifications identified in the CxA's final report

Options for funding the commissioning of an existing building are limited. Centers finance their institutional facility operations, maintenance, and repair function using local Facility Organization's CMO funding. As CMO budgets continue to decline, Centers are challenged to maintain and repair all of the facilities within their real property inventory. Therefore, fencing CMO funding for commissioning activities is often difficult.

Facilities organizations need to promote the idea that investment in commissioning an existing facility will eventually result in lower O&M costs for that facility in the future. Consequently, planning and advocacy are the keys to ensuring that CMO funding can be obtained.

It is often difficult to budget for the overall commissioning requirements since the magnitude of the repairs/modifications identified in the final report is a variable (and often in excess of $100,000). One business approach is to advocate for CMO to fund developing a building commissioning report one year and to advocate for funding the repairs/modifications in a subsequent year.

3.5. Agency Energy Savings, Commissioning, and Similar Initiatives for Existing Buildings.

On occasion, the Agency is able to advocate for special funding allocations for projects that promote energy savings, conservation of natural resources, or specifically for recommissioning/retrocommissioning initiatives. In these instances, a call will be issued to the Centers for candidate projects. A Center will increase its likelihood of obtaining funding if there is a completed commissioning report and a repair initiative can lead to quick obligations.

3.6. Internal Existing Building (EB) Commissioning

Most Centers have an Indefinite Delivery/Indefinite Quantity (IDIQ) portion of their maintenance contract that they can use for projects and services outside the scope of their baseline maintenance services. If the maintenance contractor either has on staff or the ability to subcontract a CxA to do "lite" commissioning on some selected facilities, this might include limited services for known problem areas such as:

- Testing, Adjusting, and Balancing (TAB) work in certain areas or buildings
- Testing and proving out the sequence of operations for selected mechanical and electrical equipment in the facility

This could provide a less expensive way to accomplish some abbreviated building commissioning.

3.7. Reliability Centered Building and Equipment Acceptance

Reliability Centered Building and Equipment Acceptance (RCB&EA) is the process of using Reliability Centered Maintenance (RCM) and Predictive Testing and Inspection (PT&I) techniques on newly installed equipment and components to:

- Identify and eliminate manufacturing defects
- Verify proper installation
- Baseline new equipment characteristics for the maintenance organization to compare to throughout the life of the equipment

RCB&EA shall be used on all new construction, renovation, and new equipment installations as required by NPR 8820.2, Sections 2.2.6.9 (2), 4.7.4 (j), and 5.4.1. The process can be specified using the Unified Facilities Guide Specification (UFGS) Sections 01 83 and 01 86. RCB&EA does not replace commissioning but instead supplements the traditional commissioning process.

Traditional commissioning historically has not included using PT&I technologies to check for latent manufacturing and installation defects. Traditional commissioning acceptance requirements are met as long as the installation complies with the design intent and reflects the proper process parameters for equipment acceptance. This process does not detect underlying defects, which may result in premature equipment failure. Regardless of whether the failure occurs within or outside of the warranty period, the facility incurs costs associated with correcting the problem or enforcing the contractor's warranty at a later date.

NASA's approach to commissioning conforms rather closely to the Total Building Commissioning. The commissioning concept includes additional commitment to integrate RCM. RCM is an ongoing process that determines the most effective approach to maintenance by assessing equipment function and determining risks to safety and economy should a failure occur.

3.7.1. RCB&EA Process Overview

1. During the project planning stage, NASA requires the designer to use UFGS Sections 01 83 and 01 86 in the design by specifically requesting their use in the A/E scope of work. Be sure the A/E has a copy of the RCB&EA Guide.

2. RCM or the RCB&EA Guide can be used to determine what equipment will be tested and which PT&I techniques will be used on each piece of equipment.

3. The Contractor shall:

- Deliver equipment and services that meet the requirements and specifications of their respective contract. All equipment covered by the specifications shall be free of latent manufacturing and installation defects and acceptance criteria will be defined to ensure, to the maximum extent possible within economic reason, that these criteria are met

- Perform acceptance testing as defined in their contract, using both traditional and PT&I technologies. The acceptance criteria, as defined in the contract, also may be used to establish the required baselines for future maintenance. Not until the requirements of acceptance are

met will the equipment or facility be accepted by NASA. Be sure the contractor has a copy of the RCB&EA Guide.

4. At NASA's option, NASA may elect not to have the contractor perform acceptance testing, but instead the acceptance testing may be performed either by NASA personnel or other designated third party personnel. This option can be exercised on a case-by-case basis. Regardless of who performs the acceptance testing, the requirements of acceptance shall still be met by the Contractor.

5. Each machine shall have all nameplate information, all hardware, and general condition noted and documented for inclusion in NASA's electronic inventory database (Computerized Maintenance Management System).

6. Each contractor shall have a quality control plan outlining the intended methods of receiving, testing, and installing equipment. The contractor shall use personnel trained and adequately certified in the appropriate acceptance testing PT&I technologies to ensure that the results are accurate and consistent.

7. PT&I involves the use of acceptance and inspection techniques that are nonintrusive and nondestructive to avoid introducing problems. It also involves the use of data collection devices, data analysis, and computer databases to store and trend information. Typical PT&I technologies used during equipment acceptance include, but are not limited to, vibration analysis, oil and hydraulic fluid analysis, temperature monitoring, airborne ultrasonic testing, electrical system testing, and fluid flow and process analysis.

8. The contactor will submit reports to the project manager and the O&M staff that include the applicable equipment manufacturer's data, including acceptable test range criteria, test results, and test equipment information including the most recent calibration.

For more details see the NASA RCB&EA Guide (July 2004) and the UFGS sections 01 83 and 01 86 available at the Whole Building Design Guide (WBDG) Web site.

4. Commissioning Process for New Buildings

4.1. Predesign Phase Commissioning Process

During this phase, the overall project scope and criteria for design are developed and documented in the Owner's Project Requirements (OPR), Basis of Design (BOD), or Preliminary Engineering Report (PER) documents.

Information provided by the stakeholders and designers is captured and documented to define the owner's objectives and requirements criteria. It is critical that the OPR are developed as accurately and detailed as possible. This documentation process is typically done by contracting an Architect and Engineer (A&E) firm. An effective commissioning process depends on a clear, concise, and comprehensive OPR document including performance and acceptance criteria. However, the Commissioning Agent (CxA) is not always contracted at this time. On large projects, it is good practice to contract a CxA to participate in development of the OPR.

4.1.1. The Commissioning Plan

The Commissioning plan identifies the Commissioning Team individuals who will coordinate with Government personnel. Essential members include the Commissioning Agent, Government representatives, design engineers, construction manager, contractor personnel, and Government Project Manager/Lead Design Engineer.

4.1.2. The CxA

The CxA assists the Government, A&E, and stakeholders to develop the project requirements, listed in the OPR. The CxA should participate in meetings, communicate with the different stakeholders, perform field investigations, and review existing documents to help develop the requirements. Many of the requirements that are collected in the Functional Requirements Document (FRD) are identical to the elements in the OPR. To prevent duplication of effort and data, the FRD can be included as an appendix to the OPR. If the FRD hasn't been completed prior to contracting the CxA, the CxA can assist in preparing the FRD. Depending on the scope of the project, the OPR should include the following requirements as applicable:

- Commissioning purpose and Scope of Work
- Justification
- Budget and source
- Existing conditions
- Constructability

- Environmental management
- Energy and sustainability
- Quality and materials
- Acceptance criteria
- Preliminary Cx Plan requirements
- Cx team members and responsibilities
- Cx intent and procedures
- Cx documentation
- Codes and standards
- Systems (components) to be commissioned
  - HVAC
  - Electrical
  - Building envelope
  - Security
  - Fire suppression and alarms
  - Communication
  - Acoustical
  - Vibration
  - Seismic
  - Accessibility
  - Plumbing
- Equipment and systems tests
  - Prefunctional (installation) tests
  - Startup tests
  - Functional equipment and system tests
- Operations manuals
- Training requirements for owner's personnel
- Warranty requirements
- Applicable studies from owner

The CxA develops the initial Commissioning Plan. This plan is continually updated throughout the project. It addresses the requirements and scope of commissioning to be performed and identifies the processes and procedures for the project. The Commissioning Team individuals and their respective responsibilities are identified in the Commissioning Plan. In general, the primary components of the Cx Plan are those shown above for the OPR as applicable. The Cx Plan documents the intent of how commissioning will be carried out, including testing and

documentation. The OPR states criteria for commissioning. The initial Cx Plan is modified throughout design and prior to the start of commissioning during construction. The modifications are to incorporate design decisions and contractor proposed and accepted equipment that is not known early in the project.

4.2. Design Phase Commissioning Process

This section has been developed with the understanding that the Commissioning Agent is working directly for the Government. The Commissioning Agent should be contracted directly by the Government. The CxA should be empowered with the necessary authority to ensure the contractor performs through the construction documents phase. The CxA performs with diligence to provide a high-performing facility for the Government. This section identifies roles and responsibilities of individuals assigned to the Commissioning Team. Tasks also are identified that may be performed during this phase of the project. Not all projects will necessarily encompass all of the tasks listed. How extensive the scope of commissioning work will be depends on complexity of the project and available budget.

4.2.1. The Commissioning Agent

The Commissioning Agent:

- Coordinates with the Designer of Record (DOR) to identify systems and components to be commissioned for the project.
- Assists the Designer of Record, DOR, through review and input, to develop checklists for construction. These can be component checklists or procedural checklists.
- Reviews design documents and submits comments for inclusion of commissioning requirements
- Reviews the construction documents for errors and omissions and submits comments for corrections. Assists the Designer of Record, DOR, through review and input, to develop the Commissioning specification. A general specification with optional discipline specifications will be generated.
- Initiates and develops preliminary test procedure format as the design documents are developed and establishes an understanding of the magnitude of scope of testing that will be involved
- Continually updates the Commissioning Plan with Construction and Occupancy and Operations Phase commissioning tasks.
- Identifies required Operations and Maintenance training.
- Provides input to DOR on the required Operations and Maintenance training to be included in construction specification.

- Conducts and records commissioning meetings.
- Integrates commissioning activities into the schedule.
- Reviews design and construction schedules and provides input for integration of key commissioning activities into schedules. Updates Owner's Project Requirements and ensures that Basis of Design or Design Intent is updated as necessary.
- Tracks issues and deviations between the design documents and the Owner's Project Requirements.
- Ensures that requirements for systems manuals are contained in the construction specifications.
- Tracks development of the Systems Manual and ensures closeout of requirement.

4.2.2. The Architect/Engineer

The Architect/Engineer:

- Develops the OPR with input from the FRD, owner, Contracting Officer and Commissioning Agent.
- Evaluates comments from the Commissioning Agent during review periods for consideration of incorporation into the design documents.
- Incorporate the RCB&EA specification section into the construction documents.
- Incorporates the commissioning requirements into the construction documents for the contractor to perform while supporting commissioning.
- Incorporates Commissioning Specification section(s) into the construction documents to ensure that construction-related commissioning activities are executed.

4.2.3. Predesign Conference

When commissioning is contracted at the beginning of the design phase, a predesign conference should be held to familiarize all team members with the commissioning processes. Roles and responsibilities are discussed, agreed on, and assigned to each of the team members. The commissioning process augments the Government's quality assurance program throughout the entire project.

How commissioning is incorporated into the contractual documents during design is also explained. It is explained that the Commissioning Authority's role during the design phase is to assist the Design Engineer's professional efforts to develop and incorporate all necessary commissioning components into the construction package. The Commissioning Authority's efforts in no way replace any responsibilities of the design professionals.

4.2.4. Basis of Design (BOD)

The design professional should develop the Basis of Design (BOD), which describes how the Government's Project Requirements are implemented into the design. This document typically comprises:

- System types
- Calculations and assumptions
- Analysis types
- Environmental conditions
- References
- Operational aspects
- Codes, standards, and similar documents referenced
- Guidelines used
- Project description
- Applicable criteria
  - National codes & standards, state, and local codes
  - Executive Orders, Federal Laws, and Federal Guidance
  - NASA Policy Directives (NPDs)
- Primary design assumptions
- Existing conditions survey
- Architectural design narratives
- Engineering design narratives
- Fire protection and life safety design narratives and life safety code analysis
- Hazardous material survey and narrative
- Sustainability narrative
- Operational and maintenance requirements
- Energy analysis
- Life cycle cost analysis

4.2.5. Commissioning Plan

The Commissioning Plan is developed and updated throughout the design phase. The plan acts as a map of the commissioning process throughout the project. The plan is a report of aspects of the commissioning process and contains, but is not limited to:

- Definitions
- Commissioning Team roles and responsibilities
- Schedule of activities
- List of products
- Overview of Functional Performance Tests
- Description of processes during each phase
- Basis of Design
- Forms
- Checklists
- Manuals

4.2.6. Commissioning Authority

The Commissioning Authority will at minimum perform a review of the construction documents at midpoint and final and attend the respective design review meetings. The Commissioning Authority will provide comments for the review meeting and ensure commissioning processes are properly incorporated into the construction documents. The Commissioning Authority will also assist by providing recommendations on constructability, design improvement, or efficiency comments, as necessary.

4.2.7. Construction Checklist and Functional Test

The Designer of Record, with input from the Commissioning Authority, will ensure that requirements are provided in the construction specifications for checklists and Functional Tests as part of the submittal review and approval process during the construction phase to ensure that commissioning-related activities are executed. Examples are as follows:

- Component verification prior to installation
- System assembly verification during installation
- Preinstallation of equipment on arrival at site
- Installation - activities to be performed during installation
- Startup of equipment
- Pretests to be performed for readiness verification prior to tests
- Functional tests

4.2.8. Commissioning Specification

The Designer of Record, with input from the Commissioning Agent will develop the Commissioning Specification for insertion into the Construction Specification document. This specification will be detailed enough to inform the Contractor what their roles and responsibilities will be regarding the commissioning activities during construction. Generally, only one Commissioning Specification in the general section will be required. Examples of subject areas address within the Commissioning Specification are:

- General
- References
- Definitions
- Administrative requirements
- Submittals
- Quality control
- Design review and documentation
- Description of systems
- Test equipment
- Commissioning Plan
- Startup checklists
- Prefunctional checklists
- Functional tests
- Commissioning Report
- Systems manuals
- Postoccupancy surveys

4.2.9. Systems Manual

The Systems Manual should provide information that the operators of the systems need to properly operate and maintain the systems that were installed during the construction phase. The Systems Manual contains:

- Executive summary
- Government's project requirements
- Basis of design
- Construction records including submittals

- Updates and optimization of systems
- O&M manuals
- Training materials
- Final Commissioning Report

4.3. Construction Phase

4.3.1. CxA Tasks

The CxA has a considerable list of tasks he/she is responsible for conducting during the construction phase. This phase is when the CxA is most active throughout the project.

The CxA shall:

- Attend preparatory meetings for construction-related activities and ensure that activities are executed and witness activities as required by contract.
- Schedule and conduct the preconstruction commissioning meeting. During this meeting the contractor shall perform the following:
  - Identify commissioning team individual roles and responsibilities during the construction and postoccupancy phases.
  - Explain the commissioning testing process and how it is integrated into the construction schedule
  - Emphasize which subcontractors are responsible for performing tests initially to ensure systems, components, and controls are functioning properly to minimize failures during the formal testing process
  - Develop an issue log and reporting system to track issues and concerns that arise during the construction phase. These could be design or material deficiencies, schedule impacts, labor problems, etc.
- Conduct weekly progress meetings throughout the construction phase to:
  - Review the past week's issues and address corrective measures
  - Review and update the commissioning schedule
  - Discuss commissioning activities for the previous and upcoming weeks
- Review submittals for accuracy and correctness
- Attend construction meetings and discuss integration of commissioning activities.
- Periodically inspect installations for correctness to ensure:
  - Field installations allow appropriate clearances for access
  - Instrumentation is properly installed per manufacturer requirements
  - Installation satisfies requirements
  - Safety provisions are satisfied

- Provide construction checklists for the CxA Contractor and Government to review prior to testing
- Develop a component verification list to ensure parts and equipment are delivered per specification
- Witness startup of major components, e.g., switchgear, motor control centers, chillers, air handlers, and controls for successful operation
- Review startup reports
- Periodically witness Test, Adjust, and Balance (TAB) procedures and review completed reports for completeness and accuracy
- Develop and obtain Government review and approval of test procedures and data forms including:
  - Participants required—typically the CxA; customer; general contractor; mechanical, electrical, and controls contractors; design engineer
  - Record of completed checklists, TAB procedures, and other prerequisites required prior to initiation of testing
- Review completed checklists and report deficiencies

4.3.2. Step-by-Step Test Procedure

The test procedure will have steps explaining test setup, input variables, and response required to meet an acceptable outcome. A place to stamp/initial completion of each step shall be provided. Steps may also have space to record descriptive results such as data, calibration dates of test equipment, deficiencies, and abnormalities. Procedures should include:

- A list of tools, test equipment, and supplies required to conduct tests. This list includes manufacturer, test equipment scaling/units and calibration dates, tools, and materials that will be needed in the field for adjustments, measurements, etc.
- Results section for recording results. An appendix for recording more comprehensive results when the body of the test procedure cannot accommodate extensive space.
- A change process for in-field changes and documentation of any diversion or changes from the original procedure
- Multiple types of tests may be required:
  - Component tests – Proving components function as specified and intended
  - System tests – Proving systems function as designed per Sequence of Operations
  - Integrated system tests – Proving multiple systems operate and function correctly in unison

  - Failure switchover tests for proof of redundancy – In critical facilities, redundancy at the component level, e.g., controllers, pumps, chillers, may need to be tested for proof of automatic switchover
- Emergency power switching tests – In cases where critical power is required, emergency power switching, e.g., from facility to generator, needs to be tested. Coordinated with the CxA. The Contractor, with CxA as witness at times, verifies test results meet required criteria and ensures the tests are completed correctly and accurately. Continually updates Commissioning Plan
- Continual development and update of the Systems Manual
- Development and maintenance of the Commissioning Process Report, which documents system changes, test results, the issues log, and other results from the Commissioning process.
- Verification that training is coordinated properly with manufacturers and vendors for the Operations and Maintenance (O&M) engineers and technicians
- Training witnessed and report of results and deficiencies

4.4. Occupancy and Operations Phase

The Occupancy and Operations phase of a building typically begins after substantial completion of construction and lasts through the contractual warranty period or possibly as long as the lifetime of the building.

4.4.1. Commissioning Agent

The CxA will be involved with:

- Evaluating systems performance against Government Project Requirements.
- Analyzing trends and data logs at the workstation.
- Measurement and verification
- Seasonal testing
- Troubleshooting problems
- Reviewing as-built drawings
- Reviewing final Systems Manual for compliance with the Construction Contract and OPR.
- Ensuring that the contractor incorporates changes in the way the systems are operated as opposed to the original intent
- Ensuring that Lessons Learned are documented
- Finalizing Commissioning Process Report.

- Verifying heating, ventilating, and air-conditioning (HVAC) set points and ranges have been adjusted as necessary and systems are operating properly. Adjustments may be necessary.
- Verifying completion of training

4.4.2. Measurement and Verification of the Systems

Measurement and verification of the systems validates they are working properly or identifies out-of-tolerance system performance for resolution. Seasonal testing may be performed if the regularly scheduled testing does not occur during climatic design days.

4.4.3. Final Commissioning Report

The Final Commissioning Report is completed during the Occupancy and Operations Phase. The Commissioning Process Report lists the work and results accomplished during the Construction Phase. It identifies systems that have been adjusted or changed to operate differently than intended per the Government's Project Requirements. It also contains the construction checklists, Issues Log and resolutions, test procedures and data, progress reports, deferred tests, and Lessons Learned data.

5. Retrocommissioning Process For Existing Buildings

5.1. Retrocommissioning Outline/Actions/Guide

5.1.1. Retrocommissioning, Recommissioning, Continuous/Ongoing Commissioning Process Flow for Existing Buildings

Figure 5-1 explains the differing types of commissioning that can be performed on existing buildings:

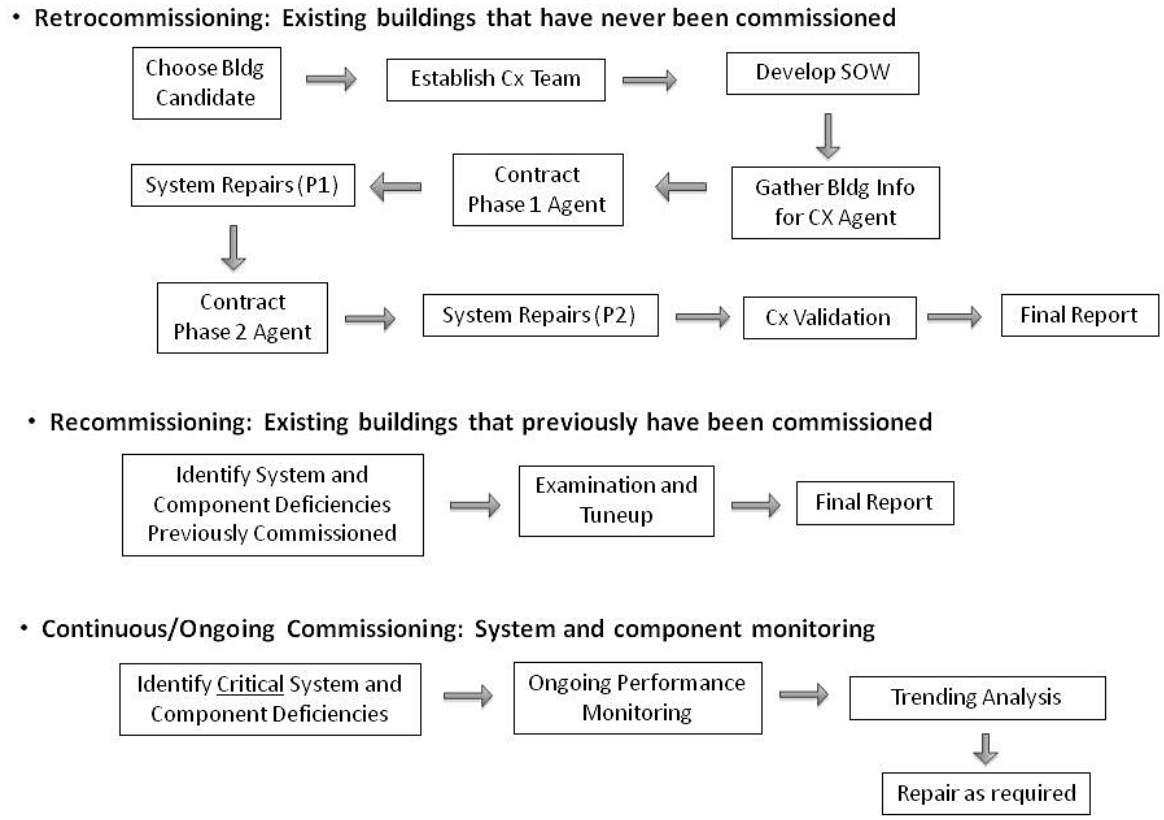

Figure 5-1 O&M Commissioning Flowcharts

5.2. Precommissioning Planning

5.2.1. Choosing a Candidate Building

There are many indicators that a building is a good candidate for retrocommissioning. Several of these are:

- Unexplained increases in energy use over time
- High energy use index (BTUs/square foot) compared to other similar buildings
- Excessive complaints from occupants regarding comfort, temperature, or ventilation
- Relatively new buildings that were never commissioned when built.

Larger buildings or buildings with complex mechanical systems that may have drifted from their original sequence of operation make good candidates for retrocommissioning.

There also are instances where a building will not be an ideal candidate for retrocommissioning. In buildings where most of the equipment and systems are at the end of their useful life or obsolete and need to be replaced, retrocommissioning will not improve the performance of the building and in fact would be a waste of money versus replacing or rehabbing the building. Buildings with outdated pneumatic controls would not make good candidates; although they would benefit from retrocommissioning, these types of systems are heading towards obsolescence and tend to drift, which can make any improvements from retrocommissioning short lived.

Data to consider when choosing a building for retrocommissioning should include the following:

- HVAC System
  - HVAC schedules and setbacks
  - Set points
  - Minimum outside air ventilation rates
- CMMS data
  - Service history
  - Trouble call history
  - Repair history
  - Magnitude of repair costs
- Maintenance costs comparison
  - Comparison of maintenance costs to similar buildings
  - Current maintenance costs trend direction and percentage
- Current/future plans
  - Master Plan – are changes scheduled for building?
  - Is building currently on a demolition list?
- Type of building

  - Original function/use of the building
  - New function/use of the building
  - History of Changes
  - Original Design versus Current Design – red line drawing of any changes
  - Type of exterior
  - Building envelope type/insulation levels
- Number of occupants
- Size (gross square feet)
- Annual hours of operation
- Year constructed
- Year of last renovation
- Type and size of all building systems, including but not limited to:
  - Mechanical systems
  - Lighting systems
  - Plumbing systems
  - Sewer and storm water systems
  - Fire detection and fire protection systems
  - Building automation systems
- Energy data, including but not limited to:
  - Energy Management Systems information
  - Average annual energy use index (EUI) for similar type building
  - Annual electricity use, peak demand, and current trend
  - Annual propane use, peak demand, and current trend
  - Annual natural gas use, peak demand, and current trend
  - Annual fuel oil use, peak demand, and current trend
  - Annual steam/hot water use, peak demand, and current trend
  - Annual chilled water use, peak demand, and current trend
  - Annual water use, peak demand, and current trend
  - Electrical load balancing
- Sequence of operations

5.2.2. Establishing a Commissioning Team

There are several ways to assemble and structure a commissioning team. Each phase of retrocommissioning may require a different person to lead the retrocommissioning effort, but the overall process, principles, and objectives are constant. The question of who should be responsible for planning and overseeing retrocommissioning may be driven by budget

constraints and expertise available within the project delivery team and on the needs of each project and. At a minimum and depending on project size, the retrocommissioning team should consist of the following members and roles:

- O&M representative: Develop a team consisting of facility staff members, establish project goals and expectations, and provide the team with information and resources needed to complete the project; produce data records for electrical usage, sequences of operation, etc.
- Facility staff members: Conduct all necessary system maintenance and servicing before system testing and work with the retrocommissioning agent on running system operations tests.
- Retrocommissioning agent: Assist O&M representative in developing scope of work for contractors and facility staff; develop reports that outline project opportunities; and work with facility staff on running tests and verifying system operations.
- Contractors: Perform tasks as required through contracts on all design changes or on all controls or electrical and HVAC systems and test equipment for efficiency after implementation or installation.
- Customer/User/Operator: Assist O&M representative in understanding customer-driven requirements or special needs required by current or projected building occupant.
- Program Representative: Assist O&M representative in understanding any special requirements, equipment, or other needs that need to be taken into account when developing a retrocommissioning plan.
- Original Construction or Rehab: It would be very beneficial, where possible, to include members of the original construction team. Their knowledge would be invaluable to the retrocommissioning team. If any major rehabilitation projects have occurred, members of the rehab team would also provide valuable insight into the construction and operation of the building.

5.2.3. Preparing a Scope of Work

The Scope of Work (SOW) needs to clearly identify what objectives are expected to be covered by the retrocommissioning process. It is imperative that the scope of work include everything the retrocommissioning team expects to accomplish. Anything not in the scope of work, whether it is data to be gathered or work to be accomplished, will not take place. The SOW should:

- Identify the systems to be commissioned; the design parameters to be used; and type, content, and detail of testing expected during the retrocommissioning
- Include a detailed list of all equipment that is expected to be commissioned and what level of testing, inspection, and repair is expected for each piece of equipment, as well as for each major section of the building.

- Clearly identify what level of repairs are to be made as part of the initial phase of retrocommissioning, what level of repairs will be completed by the in-house contractor, and what level of repairs are to be deferred to a separate contractor or outside vendor.
- Any nonstandard systems or program-specific equipment listed separately and may need to include special instructions or testing methods.
- Clearly identify a strategy for closing out the project and include a transition plan to move from retrocommissioning to ongoing commissioning if desired.

5.2.4. Gathering Building Information to Provide to Commissioning Agent

As a minimum, the following information should be gathered for retrocommissioning a building:

- CMMS Data:
  - PM schedules (review to ensure minimum manufacturers' maintenance requirements are being met)
  - Equipment nomenclature and data
  - Trouble and repeat trouble call history
  - Repair history
  - Condition-based maintenance data
  - Predictive testing and Inspection data.
- Size (gross square feet)
- Design date
- Basis of design
- Information about the building envelope, including roof, exterior surface, and windows
- Utilities systems information
- Annual hours of operation
- Type and size of mechanical, lighting, and control systems
- Metered (submetered where available) utility data and energy information for at least 12 months:
  - Annual electricity use (kWh/year)
  - Peak demand
  - Annual natural gas/propane/fuel oil/water/steam /chilled water/ and all other pertinent utilities that serve the building
- Sequences of operation:

  - HVAC schedules and setbacks
  - Set points
  - Minimum outside air ventilation rates

- Drawings and specifications relevant to the systems scheduled for commissioning, especially control drawings
- Building construction type, specifications, and drawings.
- Existing control points list for each building
- Operating strategies programmed into the Energy Management and Controls System (EMCS)
- Equipment list with nameplate information for equipment controlled by the EMCS
- Existing O&M and system manuals and information for equipment
- Test and balance (TAB) reports
- Sensor calibration documentation
- Existing design and data management system information

5.3. Contracting a Phase I Commissioning Agent

Retrocommissioning (RTCx) is the task of commissioning a building that has never been formally commissioned. Final testing of various systems may have been done per NASA specifications such as Test and Balance of HVAC systems; however, the formal process defined as commissioning was not completed by a licensed Commissioning Agent (CxA). In some cases, documentation of the systems tested in the original construction project may be available; however, this may not be the case depending on the age of the facility. In addition, changes to the facility such as additions, modifications, and demolition of various systems may have occurred in the time between the original construction project and the planned RTCx activity. If the original testing submittals and test reports are available, these may be used as a reference for the testing planned in the RTCx. The original testing methods may be repeated or new methods may be developed during this process.

Once selection of the candidate building or buildings is made and the selected systems to be commissioned are identified, the maintenance team will begin Retrocommissioning to evaluate the systems. The CxA selected may be one used for new building construction at the Center or may be a CxA selected for specific knowledge or experience related to this project. The RTCx project will perform testing of all identified systems and compare this to the original design or any design modifications that have occurred. In the absence of the original design criteria, the systems may be tested based on industry standards or site needs.

5.3.1. Team Selection

The Retrocommissioning team shall have members from all pertinent stakeholders. Members from the maintenance and operations contractor and NASA workforce are key members, as well as those from the original design and construction projects if they are available.

5.3.2. CxA Qualifications and Selection

- The Commissioning Agent (CxA) should have experience in Commissioning (Cx), Recommissioning (RCx), and Retrocommissioning (RTCx) in the climate and type of commissioning to be performed. For example, if the building to be commissioned is a laboratory, office, or warehouse, the firm should have experience with the systems and equipment in that type of building. And as climates often dictate the type of HVAC, lighting, and other controls used, experience in the geographic area is required
- The firm should have experience on any local code requirements that NASA adopts; for example in California, the California Green Building Standard determines commissioning requirements
- Ensure that the firm selected is knowledgeable in the field of commissioning and has experience in various areas. An AE firm that performs commissioning for projects designed in house may not have broad experience as needed

5.3.3. Procurement

The CxA may be procured either directly through Government procurement sources or may be contracted through other available contracts at the Center including the M&O contractor, an inspection contractor, or an AE. Repairs may be combined in the contract when procurement is through the M&O contractor so that validation is included. The GSA Schedule of contractors also is available for a more direct selection of firms suited for this work. In any case, an independent firm shall be used. The firm selected should be contracted with NASA or its representative, not the firm that constructed or designed the original building. Criteria to be used for selection may include:

- References of completed projects where RTCx was performed. At least three positive references of projects similar in size, location, and type of systems should be provided
- Training and certifications held by the firm. The Building Commissioning Association (BCA) provides certification to commissioning firms
- Site visits of buildings that were commissioned
- Final reports delivered to the owner representative for completed projects

5.3.4. Scope of Work (SOW)

The SOW should include information on the building, systems, and testing needed. The systems to be commissioned will be defined in this scope as well as the design (or operational) parameters to be used. This SOW will define the type, content, and detail of the testing

expected. This may include the full testing performed in the original construction project if the original test reports are available. Test and Balance type system testing may be included, as well as specific component and equipment testing as needed. Nonstandard systems or unique components may require detailed specific test procedures to be developed by the CxA with input from the maintenance team members. These may have been developed during the building's original commissioning or may be developed during this phase as new procedures. Information to be included in the SOW is detailed in Section 5.2.1 and as a minimum should include:

- Facility or project name and location
- Approximate square footage, use, and occupancy of buildings
- Types of systems to be commissioned
- Test reports from original construction (if available)
- Special considerations
- Specifications and drawings (if available)

5.3.5. Deliverables

The CxA shall provide a full report including facility description; project overview; the Retrocommissioning process including testing reports, schedule of the commissioning and its completion, photographs, final analysis, findings and recommended repairs and checklists; and an executive summary. The number of bound copies required will be defined in the SOW, as well as the electronic submittal required. The CxA shall also deliver a complete list of repairs needed, as well as testing to be performed after the repairs are completed.

5.3.6. Responsibilities of the CxA

- The CxA will schedule and conduct a pre-RTCx meeting to:
  - Introduce the team members
  - Define roles and responsibilities
  - Present a schedule of completion
  - Develop an issue log and track all issues and actions
  - Provide minutes and distribute them to all team members
- Conduct follow-on status meetings as needed and provide minutes of the meetings for all team members
- Ensure systems and components to be commissioned for the project are as included in the original commissioning or as needed based on any modifications to the facility. Note any systems that were missed, require additional oversight for inclusion in the SOW, or need to be modified
- Develop checklists for maintenance repair/correction. These can be component checklists or procedural checklists

- Review original and any revised design documents for building system requirements as originally designed or as changed based on modifications
- Ensure commissioning activities are properly scheduled
- Initiate and develop preliminary test procedure format and establish an understanding of the magnitude of scope of testing that will be involved
- Perform or witness all testing performed on the defined systems
- Revise test procedures as needed and document changes
- Document all testing, changes, and final conditions
- Validate final acceptance of the changes, system configuration, and data
- Record with photographs all necessary conditions, repairs, or changes
- Develop the final report for review and approval by NASA
- Verify drawings, O&M manuals, and all pertinent documentation are updated and correct at the conclusion of the contract

5.3.7. Final Acceptance

Review of all test reports, recommended repairs and checklists, and the final report by all team members is required for final acceptance.

5.4. System Repair and Correction (Phase I)

After the investigation phase of the retrocommissioning, an implementation plan needs to be developed to define the requirements for system repair and correction. Operational improvements shall be prioritized based on life cycle cost analysis and criticality.

5.4.1. Choosing the Repair Team

When conducting the first phase of repairs associated with the retrocommissioning, there are several options to be considered in regard to choosing the repair team. The options available are utilizing the current retrocommissioning agent, offsite construction contractors, or the onsite maintenance staff.

- Utilizing the Commissioning Agent if a contracted effort will provide a turn-key process – This ensures total responsibility is kept in one area. A downside is that the contractor does not understand the repair procedures that are used at the site. They might not be aware of how the system is utilized in facility operations, thus potentially impacting operations supporting mission. Be careful that they do not create their own potential projects. They may identify low-criticality repair projects so they can get the follow-on work.

- Utilizing the services of an offsite contractor to implement repairs – Utilizing an offsite contractor has most of the same downside issues from the preceding paragraph. These include lack of knowledge of repair processes utilized at the site. Positive impacts include little if any disruption to the in-house workforce, allowing them to remain focused on their primary areas of responsibilities.
- Utilization of the onsite staff to implement repairs – The onsite workforce, whether contractor or civil service, takes advantage of the familiarity of the workforce in onsite procedures and knowledge of how the equipment is used in facility systems. A drawback to utilizing the onsite support is taking them away from their other responsibilities.

Several options may be available here depending on funding. The first would be to handle minor repairs as Trouble Calls under the base services if the contract allows this. The second option is to fund an IDIQ contract. The IDIQ option may be more efficient, as it will allow the onsite subcontractor to hire additional staff for the duration of the IDIQ contract. EMCS staffing may be required whether using onsite or offsite staffing.

5.4.2. Preparing a Repair Schedule

The first consideration in developing a repair schedule is to be cognizant of the overall commissioning effort schedule. Scheduling the Phase I repairs will need to be accomplished in a manner that does not negatively impact the agreed-on commissioning schedule. Another consideration is to make repairs around environmental concerns, such as HVAC repairs in the heat of summer. The repair team chosen shall present an implementation schedule to be reviewed and approved by the Government to make sure facility operations are not unduly impacted.

5.4.3. Oversight of Repair Activities

Oversight of the Phase I repairs will normally be accomplished using the Center's established oversight procedures, particularly when utilizing the onsite workforce. Experienced construction management staff who understand commissioning and retrocommissioning are the key to success. Training is required for them to understand the difference between new construction and retrocommissioning.

5.4.4. Testing, Adjusting, and Balancing (TAB) Contractor Certification

An important aspect of commissioning is ensuring a Certified Testing, Adjusting and Balancing (TAB) contractor to perform the TAB work, since in almost all cases, the building to be commissioned is out of balance. Out of balancing occurs over time by occupants and maintenance personnel adjustments, moving walls, changing sheaves, piping changes, etc. A certified TAB contractor goes through rigorous training and testing that noncertified contractors may not have completed. Certifications does not always guarantee, but it is one way to make sure the TAB contractor meets some minimum qualification. There are three major providers of TAB certification systems:

- AABC – American Air Balancing Council

- NEBB – National Environmental Balancing Bureau
- TABB – Testing, Adjusting and Balancing Bureau

Any one of these certification systems is acceptable and may be specified.

5.4.5. Commissioning Provider Certification Systems

It is important to require the commissioning agent to have some creditable qualifications. One way to accomplish this is to make sure the commissioning agent has the appropriate commissioning certification. While certifications do not guarantee competence, they are one way to make sure the commissioning agent meets some minimum qualification. Currently, there are seven major providers of commissioning certification systems:

- AABC – American Air Balancing Council
- AEE - Association of Energy Engineers
- ASHRAE – American Society of Heating, Refrigeration and Air conditioning Engineers
- BCA – Building Commissioning Association
- NEBB – National Environmental Balancing Bureau
- TABB – Testing, Adjusting and Balancing Bureau
- University of Wisconsin

Each of these providers has different requirements to obtain certification and some of these certifications are geared more towards new construction rather than existing buildings. See Appendix G, which summarizes the requirements of each certification.

Review in detail of the certification programs in the appendix is recommended, including the appropriate certification(s) in the commissioning scope of work, which will vary depending on the type of commissioning required. See Appendix G for additional information.

5.5. Contracting a Phase II Commissioning Agent

After the identified repairs have been made, the maintenance team will conduct the second phase of commissioning, which will validate the effectiveness of the repairs or modifications and complete the commissioning process. Although the commissioning agent may not be the same as was originally used, it is important to provide continuity during the process. All original conditions and data points shall be well documented, as well as the subsequent repairs and the final data and conditions. A well-documented project will include a final report with all of these items included.

5.5.1. Team Selection

The Commissioning team shall have members from all pertinent stakeholders. Inclusion of members from the maintenance and operations contractor and NASA workforce are key members, as well as inclusion of those from the original design and construction projects if they are available.

5.5.2. Qualifications and Selection

The Commissioning Agent (CxA) should have experience in Commissioning (Cx), Recommissioning (RCx), and Retrocommissioning (RTCx) in the climate and type of commissioning to be performed. For example, if the building to be commissioned is a laboratory, office, or warehouse, the firm should have experience with the systems and equipment in that type of building. And as climates often dictate the type of HVAC, lighting, and other controls used, experience working in the geographic area is required.

5.5.3. Procurement

The CxA may be procured either directly through Government procurement sources or may be contracted through other available contracts at the Center, including the M&O contractor, an inspection contractor, or an AE contract. Repairs may be combined in the contract when procurement is through the M&O contractor so that validation is included. The GSA Schedule of contractors also is available for a more direct selection of firms suited for this work. In any case, an independent firm shall be used.

5.5.4. Scope of Work (SOW)

The SOW should include validation of the original points, as well as validation of repairs and final commissioning of all identified systems. The systems to be commissioned will be defined in this scope, as well as the design parameters to be used. Repairs made since the Phase I commissioning effort will be documented here for the CxA's use. This SOW will define the type, content, and detail of the testing expected. This may include the full testing performed in the original scope or may include only those areas in question. Test and Balance type system testing may be included, as well as specific component and equipment testing as needed. Nonstandard systems or unique components may require detailed specific test procedures. These may have been developed during the building's original commissioning, the first phase of the RCx or RTCx, or may be developed during this phase as new procedures.

5.5.5. Deliverables

The CxA shall provide a full report including all testing reports, the schedule of the commissioning and its completion, photographs, final analysis, and an executive summary. The number of bound copies required will be defined in the SOW, as well as the electronic submittal required.

5.5.6. Responsibilities of the CxA

- Schedule and conduct a pre-Cx meeting to
  - — Introduce the team members,

  - Define roles and responsibilities,
  - Present a schedule of completion
- Develop an issue log and track all issues and actions
- Provide minutes and distribute them to all team members
- Conduct follow-on status meetings as needed
- Verify systems and components to be commissioned for the project are as included in the original commissioning. Note any systems that were missed, require additional oversight for inclusion in the SOW, or need to be modified
- Verify repairs or corrections have been conducted and documentation is available for any changes or upgrades to the systems. Verify checklists for maintenance repair/correction have been completed. These can be component checklists or procedural checklists
- Review revised (redlined) design documents for building system requirements as changed based on repairs or modifications
- Ensure commissioning activities are properly scheduled
- Perform or witness all testing performed on the defined systems
- Revise test procedures as needed and document changes
- Document all testing, changes, and final conditions
- Validate final acceptance of the changes, system configuration, and data
- Record with photographs all necessary conditions, repairs, or changes
- Develop the final report for review and approval by NASA
- Verify drawings, O&M manuals, and all pertinent documentation are updated and correct at the conclusion of the contract

5.5.7. Final Acceptance

Review of all repair reports, test reports, and the final report by all team members is required for final acceptance.

5.6. System Repair and Correction (Phase II)

5.6.1. Personnel Involved

The personnel involved in the repair process will vary depending on if it was determined earlier to accomplish the repairs using onsite personnel, the Commissioning Agent, or a separate

offsite contractor. Regardless of this decision, this effort will entail coordination between the TAB contractor, the Commissioning Agent (if separate from the TAB contractor), representatives from the building automation system contractor, facilities personnel, facilities inspectors (if this is how the Center's oversight procedures operate), and the personnel performing the repairs.

5.6.2. Process

It is assumed that by this point, either through an initial inspection and repair plan performed before a retrocommissioning contractor was hired or through findings of the retrocommissioning contractor during their initial visit, the individual units involved in the process have been repaired and are operating as intended. This step involves detailing the process involved to correct the numerous repairs that will likely be discovered during the testing and balancing phase of the project.

5.6.3. Types of Repair Expected To Be Found

Depending on the scope decided on for the project, this step will likely entail inspecting all variable air valves (VAVs) and air handling units located in the facility being retrocommissioned. It may also include piping, pumps, and other equipment depending on scope. Repairs found during this process can be wide-ranging. The typical problems encountered involve issues with ductwork (torn flex duct, connections that have come loose either at the diffuser or the VAV box, holes left from previous sensors or testing, poor installation practices). There can also be issues with the piping systems (e.g., deteriorated insulation, leaks at connections, blocked strainers, etc.). Another basic problem area entails the utility control systems (e.g., nonoperating control valves, broken or loose connections at flow sensors in VAV boxes, bad pressure sensors). The required repairs can also be not so evident such as air handlers that need to have sheaves replaced from having incorrectly sized replacements put on in the past. The larger the scope of the project, the broader the areas that repairs can be found in (if lighting is included in the scope for instance).

5.6.4. Repair Personnel and Scheduling Repairs

There should be a timeframe established between the decided-upon repair personnel, the TAB contractor, and the Commissioning Agent. This is to reduce the effect of repairs on the timeline for the TAB contractor to perform their work. If a repair will require time outside this timeframe, the TAB contractor and the Commissioning Agent need to be made aware, as this may affect their scheduled completion times (especially if it is something that keeps them from progressing to later areas). If the repair work is being performed by onsite personnel, it is recommended that certain standard parts (such as actuators) be purchased beforehand to better facilitate the repairs that are found during this phase if funding allows.

5.6.5. Issues Log

Regardless of the party responsible for the work, it is recommended that some type of facilities representative (either Government or facilities contractor personnel) be on hand for TAB

activities to note what repairs are needed and the work that is being performed. It is recommended that an issues log be kept up to date that at the minimum lists the following things:

- Issue number
- Date of finding
- Location of issue
- Description of issue
- Effect of issue
- Personnel who noted issue
- Whether the issue has been repaired
- The date the issue was repaired

More information can easily be added to this log to tailor it to the project. Depending on the amount of work/issues being found, the choice may to update this list daily or just at the end of the week. This information will need to be made available to all parties involved in the project (especially if work is being performed by an onsite contractor, as it will allow for proper inspection of pre-repair and postrepair conditions by local inspectors to keep track of the quality of work being performed). Most Retrocommissioning contractors will also want to keep this log so that it can be included in their final report.

5.6.6. Notification of Repair Completion

If the work is being performed by onsite personnel, they should ensure that they notify the TAB contractor after completion of repairs so that they may come back to the area in question and finish their work.

If any repair work is found during the TAB process that is not required to complete their work and is outside the scope of the project, these items can be kept in a separate list and submitted in the final report as future repairs to be performed as funding is available.

5.7. CxA Final Validation

Once an improvement is completed, it is important to retest the equipment or systems to ensure that the improvements are working as expected. Retesting can be done using Energy Management Control Systems (EMCS) trending, data logging, functional testing, simple observation, or a combination of these methods. For example, retesting might involve manually testing the repaired items, such as dampers or valves, to verify that they stroke properly followed by trending or data logging to determine that they are modulating to maintain the desired set point at the appropriate times.

To confirm that each improvement, as well as the combination of improvements, are integrated and have the desired effect, the postimplementation data is compared to the original baseline data. This final verification data can also be used to update the energy savings estimates, if needed. The data gathered as a result of verification activities along with the updated energy cost savings information is compiled in the Implementation Summary Report. Also, future performance of each improvement periodically can be compared against the verification data to ensure benefits persist.

5.7.1. Commissioning Agent Responsibilities

The Commissioning Agent shall:

- Compile the Implementation Summary Report
- Develop and implement a functional testing program that objectively verifies that the building systems perform interactively in accordance with the Project Documents. Written repeatable test procedures, prepared specifically for each project, are used to functionally test components and systems in all modes of operating conditions specified for testing. These tests are documented to clearly describe the individual systematic test procedures, the expected systems response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion
- Update the System Manual to include results of the validation testing
- Develop a comprehensive training plan for O&M staff. Assess the level of training received and identify any additional training recommendations for system technicians/operators
- Verify the accuracy and completeness of documentation including the Equipment List, O&M Manuals, EMCS documentation, and system diagrams
- Provide a summary of lessons learned during the commissioning process

5.7.2. Testing, Adjusting, and Balancing

The standards and procedures for providing these services are referred to as Testing, Adjusting, and Balancing (TAB) and are described by AABC, NEBB, and TABB.

The TAB report includes the balancing or rebalancing of units such as:

- Air inlets and outlets
- Terminal units
- Air handling units
- Outside airflows
- Exhaust fans
- Building pressurization
- Hydronic flows at coils, pumps, chillers, cooling towers, boilers

5.7.3. Utility Control Systems

EMCS documentation shall include the following:

- Points list: A complete list of all input and output points in the EMCS including
  - Point name
  - Point type
  - Sensor or actuator type
  - Expected accuracy
  - Name and type of associated equipment
  - Panel location
  - Alarm limits
  - Trending frequency
- Sequences of operation: A description of how the system is intended/programmed to operate for each control system
- System diagram: A one-line diagram of each of the buildings systems

5.7.4. Final Adjustments

Any final adjustments to a retrocommissioned system will be recorded and reflected in the appropriate system documentation.

5.8. Final Retrocommissioning Report

The Final Report for a Retrocommissioning project is an accumulation of all the components of the project that reflects the final status of the building, the final list of recommendations, and the certification of the report. The attachments need to include all of the supporting documentation and calculations.

The Final Report is not a static document that gets put on the shelf after completion. The Final Report is a living document for the building until all of the viable projects are completed. It should lead to project planning and budgeting for future projects. Upon completion of each project, the Final Report requires an update.

All tested items or systems included in the RTCx-EB Report shall be clearly identified with a unique designation. The method of identification may use unique numbers, mechanical plans identification, or an appropriate narrative description. All pages shall contain the name of the project and be identified with a unique page number.

The Retrocommissioning Final Report includes the following information:

1. REPORT TITLE PAGE

The report title page shall include the following:

- The heading: “Certified Retrocommissioning Report”
- Project Name/Project Address

- Owner Name/Address/Contact Numbers
- Certified RTCx-EB Firm Name/Address/Contact Numbers/Certification Number

2. REPORT CERTIFICATION PAGE

The report certification page shall include the following:

- Project Name
- Certified RTCx-EB Professional's Name
- Firm Name; Certification Number; Expiration Date
- Commissioning Phases performed to NEBB standards

Certified RTCx-EB Professional's Stamp (signed & dated); and the following verbiage: "THE DATA, CONCLUSIONS AND RECOMMENDATIONS PRESENTED IN THIS REPORT ARE A RECORD OF THE RETROCOMMISSIONING PROCESS UTILIZED ON THIS PROJECT IN ACCORDANCE WITH THE AABC, NEBB, OR TABB RETROCOMMISSIONING PROCEDURAL STANDARDS AND THE CONTRACT REQUIRMENTS"

- Statement of Scope of Work and variance deviation documentation

3. TABLE OF CONTENTS PAGE

The Table of Contents shall serve as a guide to the organization of the RTCx-EB report. Include page numbers in the report.

4. EXECUTIVE SUMMARY

The executive summary shall include the following information:

- Review of the Retrocommissioning Project processes utilized
- Review of any deviations used
- Review of each recommended corrective action and its relative priority
- Review of any areas of concern that are not addressed in the corrective action report and the reasons these issues were not addressed
- Review of each deferred system test that is to be performed in the future

5. PROJECT CURRENT FACILITES REQUIREMENTS (CFR)

The CFR should include the following information:

- Current occupancy information
- Change of use documentation
- Zoning changes
- Owner's sustainability and building rating requirements
- Energy and efficiency requirements
- Operation and maintenance issues
- Floor plans

6. RETROCOMMISSIONING PLAN

The Retrocommissioning Plan shall include the following information:

- Retrocommissioning scope
- Retrocommissioning team
- Retrocommissioning team member responsibilities
- Channels of communication
- Retrocommissioning procedures utilized
- Retrocommissioning schedule

7. DATA LOGS

Data Logs should include the following information:

- Project name
- Date and time of data
- Location
- Variables recorded
- Parameters

8. INTERVIEW RECORDS

The interview records should include the following:

- Project name
- Date of interview
- Person conducting the interview
- Persons interviewed or group type
- Interview questions
- Interviewee responses
- Interviewer comments

9. TESTING CHECK SHEETS

A Certified RTCx-EB Report shall include completed copies of all testing records including check sheets and forms or data trends or logs that indicate testing results

10. UTILITY USAGE EVALUATION

The utility usage evaluation shall include the following information:

- Utility usage cost per square foot per month and per year per utility
- Utility units' quantity usage per month and per year per utility
- Water Utility usage costs per occupant per month per year
- Water utility GPM per occupant per month per year
- Submetering usage and deductions

11. QUICK FIX REPORT

A Certified RTCx-EB Report shall include a report of all quick fixes performed during the site inspection phase. The following items should be included in the quick fix report:

- System adjustments made
- Sensor calibration performed
- Repairs performed
- Sequences that were changed or modified
- Operations that were modified
- Operator training given

12. CORRECTIVE ACTIONS RECOMMENDATION REPORT

The Corrective Action Recommendation Report shall include the following information for each recommended corrective action:

- Project name
- Description of deficiency
  - Descriptive narrative
  - Pictures
  - Test data
- Recommended Solution
  - Engineering calculations
  - Drawings and sketches
  - Sequence of Operations or other descriptive narratives
- Predicted costs of recommended corrective action
- Calculation of predicted payback and return on investment (ROI)
- Predicted results of recommended corrective action
- Predicted schedule of corrective action

13. COMMISSIONING REPORT OF CORRECTIVE ACTIONS

The Commissioning report shall include the following information:

- Report title page
- Report certification page
- Table of contents page
- Executive Summary
- Project CFR
- Commissioning plan
- Final Issue Log
- Completed prefunctional test forms and check sheets
- Completed functional performance test forms and check sheets
- Observation reports
- Training verification records

- Commissioning communications
- Test instrument page

14. TAB REPORT

A Certified RTCx-EB Report should include a TAB report if test and balance work was performed.

15. COMMISSIONING COMMUNICATIONS

Commissioning communications will include the following information:

- Letters between the commissioning team members that are pertinent to the Retrocommissioning process performed or not performed for the project
- E-mails or other written documentation covering issues or issue resolution for the project

16. TEST INSTRUMENT PAGE

The Test Instrument page may include following information:

- List of NEBB-required tools employed on the project
- Model number and serial number of each instrument
- Certification date of each instrument

6. Recommissioning Process For Existing Buildings

6.1. Precommissioning Planning

6.1.1. Choosing a Candidate Building for Recommissioning

Choosing a candidate building for recommissioning entails many if not all of the recommendations for choosing a building for initial and retrocommissioning. Since recommissioning is a process for optimizing building performance and obtaining cost savings, a candidate building needs to have systems that are fully functional and have a reasonable life expectancy. Generally, recommissioning is not appropriate for buildings where the equipment and systems are obsolete or at the end of their life; in this case, it may be better to replace the equipment. Recommissioning is also not recommended when major system design problems exist or when equipment malfunctions exist that can only be corrected through replacement.

Data to consider when choosing a building for recommissioning should include the following:

- Type of Building
  - Original function/use of the building
  - New function/use of the building
  - History of changes
  - Original design versus current design – red line drawing of any changes
  - Type of exterior
  - Building envelope type/insulation levels
- Number of occupants
- Size (gross square feet)
- Annual hours of operation
- Year constructed
- Year of last renovation
- Type and size of all building systems, including but not limited to:
  - Mechanical systems
  - Lighting systems
  - Plumbing systems
  - Sewer and storm water systems
  - Fire Detection and Fire protection systems
  - Building automation systems
- Energy data, including but not limited to:

  - Energy management systems information
  - Average annual energy use index (EUI) for similar type building
  - Annual electricity use, peak demand, and current trend
  - Annual propane use, peak demand, and current trend
  - Annual natural gas use, peak demand, and current trend
  - Annual fuel oil use, peak demand, and current trend
  - Annual steam/hot water use, peak demand, and current trend
  - Annual chilled water use, peak demand, and current trend
  - Annual water use, peak demand, and current trend
  - Electrical load balancing

- Sequence of operations:
  - HVAC schedules and setbacks
  - Set points
  - Minimum outside air ventilation rates

- CMMS Data
  - Service history
  - Trouble call history
  - Repair history
  - Magnitude of repair costs

- Maintenance Costs comparison
  - Comparison of maintenance costs to similar buildings
  - Current maintenance costs trend direction and percentage

- Current/Future plans
- Master Plan – are changes scheduled for building?
- Is building currently on a demolition list?
- Changes made since last commissioning

6.1.2. Establishing a Recommissioning Team

There are several ways to assemble and structure a recommissioning team. Each phase of recommissioning may require a different person to lead the recommissioning effort, but the overall process, principles, and objectives are constant. The question of who should be responsible for planning and overseeing recommissioning may be driven by budget constraints and expertise available within the project delivery team and on the needs of each project. At a minimum and depending on project size, the recommissioning team should consist of the following members and roles:

- O&M representative: Develop a team consisting of facility staff members, establish project goals and expectations, and provide the team with information and resources needed to complete the project; produce data records for electrical usage, sequences of operation, etc.

- Facility staff members: Conduct all necessary system maintenance and servicing before system testing and work with the recommissioning agent on running system operations tests.
- Recommissioning Agent: Assist O&M representative in developing scope of work for contractors and facility staff, develop reports that outline project opportunities, and work with facility staff on running tests and verifying system operations.
- Contractors: Perform tasks as required through contracts on all design changes or on all controls or electrical and HVAC systems, and test equipment for efficiency after implementation or installation.
- Customer/User/Operator: Assist O&M representative in understanding customer-driven requirements or special needs required by current or projected building occupant.
- Program Representative: Assist O&M representative in understanding any special requirements, equipment, or other needs that should be taken into account when developing a recommissioning plan.
- Original Commissioning Team: It is very beneficial, where possible, to include members of the original commissioning team. Their knowledge would be invaluable to the recommissioning team. If any major rehabilitation projects have occurred, members of the rehab team would also provide valuable insight into the construction and operation of the building.

6.1.3. Preparing a Scope of Work

The Scope of Work (SOW) needs to:

- Clearly identify what objectives are expected to be covered by the recommissioning process
- Include everything the recommissioning team expects to accomplish. Anything not in the scope of work, whether it is data to be gathered or work to be accomplished, will not take place
- Identify the systems to be commissioned, the design parameters to be used, and type, content, and detail of testing expected during the recommissioning
- Identify all equipment that is expected to be commissioned and what level of testing, inspection, and repair is expected to be accomplished for each piece of equipment, as well as for each major section of the building
- Clearly identify what level of repairs are to be made as part of the initial phase of recommissioning, what level of repairs will be completed by the in-house contractor, and what level of repairs are to be deferred to a separate contractor or outside vendor

- Specify any nonstandard systems or program-specific equipment listed separately, including special instructions or testing methods if needed
- Clearly identify a strategy for closing out the project
- Include a transition plan to move from recommissioning to ongoing commissioning if desired.

6.1.4. Gathering Building Information to Provide to Commissioning Agent

As a minimum, the following information should be gathered for the recommissioning of a building:

- Original Commissioning Report
  - Include documentation of completed repairs
- CMMS Data:
  - PM schedules (review to ensure minimum manufacturers' maintenance requirements are being met)
  - Equipment nomenclature and data
  - Trouble and repeat trouble call history
  - Repair history
  - Condition-based maintenance data
  - Predictive testing and inspection data
- Size (gross square feet)
- Design date
- Basis of design
- Information about the building envelope, including roof, exterior surface, and windows
- Utilities systems information
- Annual hours of operation
- Type and size of mechanical, lighting, and control systems
- Metered (submetered where available) utility data and energy information for at least 12 months:
  - Annual electricity use (kWh/year)
  - Peak demand
  - Annual natural gas/propane/fuel oil/water/steam /chilled water/ and all other pertinent utilities that serve the building
- Sequences of operation:
  - HVAC schedules and setbacks

  - Set points
  - Minimum outside air ventilation rates
- Drawings and specifications relevant to the systems scheduled for commissioning, especially control drawings
- Building construction type, specifications, and drawings.
- Existing control points list for each building
- Operating strategies programmed into the Energy Management and Controls System (EMCS)
- Equipment list with nameplate information for equipment controlled by the EMCS
- Existing O&M and system manuals and information for equipment
- Test and balance (TAB) reports; sensor calibration documentation
- Existing design and data management system information

6.2. Contracting a Phase I Recommissioning Agent

Recommissioning (RCx) is the task of commissioning a building that previously has been formally commissioned. Final testing of various systems has been done per NASA specifications such as TAB of HVAC systems and the formal process defined as commissioning was completed by a licensed Commissioning Agent (CxA). In some cases, documentation of the systems tested in the original construction project may be available; however, this may not be the case depending on the age of the facility. In addition, changes to the facility such as additions, modifications, and demolition of various systems may have occurred in the time between the original construction project and the planned RCx activity. If the original testing submittals and test reports are available, these may be used as a reference for the testing planned in the RCx. The original testing methods may be repeated or new methods may be developed during this process.

Once selection of the candidate building or buildings is made and the selected systems to be commissioned are identified, the maintenance team will begin recommissioning to evaluate the systems. The CxA selected may be one used for the new building construction. The RCx project will test all identified systems and compare the results to the original design or any design modifications that have occurred. In the absence of the original design criteria, the systems may be tested based on industry standards or site needs.

6.2.1. Team Selection

The Recommissioning team shall have members from all pertinent stakeholders. Inclusion of members from the maintenance and operations contractor and NASA workforce is key, as well as inclusion of those from the original design and construction projects if they are available.

6.2.2. Qualifications and Selection

- The Commissioning Agent (CxA) should have experience in Commissioning (Cx), Recommissioning (RCx), and Retrocommissioning (RTCx) in the climate and type of commissioning to be performed. For example, if the building to be recommissioned is a laboratory, office, or warehouse, the firm should have experience with the systems and equipment in that type of building. And as climates often dictate the type of HVAC, lighting, and other controls used, experience in the geographic area is required.
- The firm should have experience on any local code requirements that NASA adopts; for example in California, the California Green Building Standard determines commissioning requirements.
- Ensure that the firm selected is knowledgeable in the field of commissioning and has experience in various areas. An AE firm that performs commissioning for projects designed in house may not have broad experience as needed.

6.2.3. Procurement

The CxA may be procured either directly through Government procurement sources or may be contracted through other available contracts at the Center including the M&O contractor, an inspection contractor, or an AE. Repairs may be combined in the contract when procurement is through the M&O contractor so that validation is included. The GSA Schedule of contractors also is available for a more direct selection of firms suited for this work. In any case, an independent firm shall be used. The firm selected should be contracted with NASA or its representative, not the firm that constructed or designed the original building. Criteria to be used for selection may include:

- References of completed projects where RCx was performed. At least three positive references of projects similar in size, location, and type of systems should be provided
- Training and certifications held by the firm. The Building Commissioning Association (BCA) provides certification to commissioning firms
- Site visits of buildings that were commissioned
- Final reports delivered to the owner representative for completed projects

6.2.4. Scope of Work (SOW)

The SOW should include information on the building, systems and testing needed. The systems to be commissioned will be defined in this scope as well as the design (or operational) parameters to be used. This SOW will define the type, content, and detail of the testing expected. This may include the full testing performed in the original construction project if the original test reports are available. Test and Balance type system testing may be included, as well as specific component and equipment testing as needed. Nonstandard systems or unique components may require detailed specific test procedures to be developed by the CxA with input from the maintenance team members. These may have been developed during the

buildings original commissioning or may be developed during this phase as new procedures. Information to be included is as detailed in 5.2.1 and as a minimum should be:

- Facility or project name and location
- Approximate square footage, use, and occupancy of buildings
- Types of systems to be commissioned
- Test reports from original construction (if available)
- Special considerations
- Specifications and drawings (if available)

6.2.5. Deliverables

The CxA shall provide a full report including facility description; project overview; the Recommissioning process including testing reports, schedule of the commissioning and its completion, photographs, final analysis, findings and recommended repairs and checklists; and an executive summary. The number of bound copies required will be defined in the SOW as well as the electronic submittal required. The CxA shall also deliver a complete list of repairs needed, as well as testing to be performed after the repairs are completed.

6.2.6. Responsibilities of the CxA

- The CxA will schedule and conduct a pre-RCx meeting to
  - Introduce the team members,
  - Define roles and responsibilities,
  - Present a schedule of completion
  - Develop an issue log and track all issues and actions
  - Provide minutes and distribute them to all team members
- Conduct follow-on status meetings as needed and provide minutes of the meetings for all team members
- Verify systems and components to be commissioned for the project are as included in the original commissioning or as needed based on any modifications to the facility
  - Note any systems that were missed or require additional oversight for inclusion in the SOW are to be modified
  - Develop checklists for maintenance repair/correction. These can be component checklists or procedural checklists
  - Review original and any revised design documents for building system requirements as originally designed or as changed based on modifications
  - Ensure commissioning activities are properly scheduled

  - Initiate and develop preliminary test procedure format and establish an understanding of the magnitude of scope of testing that will be involved
  - Perform or witness all testing performed on the defined systems
- Revise test procedures as needed and document changes
- Document all testing, changes, and final conditions
- Validate final acceptance of the changes, system configuration, and data
- Record with photographs all necessary conditions, repairs, or changes
- Develop the final report for review and approval by NASA
- Verify drawings, O&M manuals, and all pertinent documentation are updated and correct at the conclusion of the contract

6.2.7. Final Acceptance

Review of all test reports, recommended repairs and checklists, and the final report by all team members is required for final acceptance.

6.3. System Repair and Correction (Phase I)

After the investigation phase of the recommissioning, an implementation plan needs to be developed to define the requirements for system repair or tuneup. Operational improvements shall be prioritized based on life cycle cost analysis and criticality. The repairs are typically in the following areas:

- Lighting
- Building envelope
- Heating and cooling system
  - Controls
  - Testing, adjusting, and balancing
  - Heat exchange equipment

6.3.1. Choosing the Repair Team

When conducting the repairs associated with the building recommissioning, there are several options to be considered in regard to choosing the repair team. The options available are utilizing an offsite contractor or the onsite maintenance staff. In some areas, repairs are best addressed using certified contractors in their specialty such as Testing, Adjusting and Balancing (TAB).

6.3.2. Utilizing the Services of an Offsite Contractor To Implement Repairs

Utilizing an offsite contractor reduces many impacts to the onsite workforce such as adversely impacting existing scheduled work. A properly qualified offsite contractor will be familiar with

typical building systems. A drawback to their performing recommissioning repairs is that they are not as familiar as the onsite workforce with the site equipment nuances, documentation, and repair procedures.

6.3.3. Utilizing Onsite Staff To Implement Repairs

The onsite workforce, whether contractor or civil service, takes advantage of the familiarity of the workforce in onsite procedures and knowledge of how the equipment is used in facility systems. A drawback to utilizing the onsite support is taking them away from their other responsibilities. Several options may be available here depending on funding. The first would be to handle minor repairs as Trouble Calls under the base services if the contract allows this. The second option is to fund an IDIQ contract. The IDIQ option may be more efficient, as it will allow the onsite subcontractor to hire additional staff for the duration of the IDIQ contract. It also provides a single document to define and track the scope of the repairs.

EMCS staffing may be required whether using onsite or offsite staffing.

6.3.4. Preparing a Repair Schedule

Consideration should be given to make repairs around environmental concerns such as HVAC repairs in the heat of summer or heating season. The repairs should be scheduled to make sure facility operations are not unduly impacted.

6.3.5. Oversight of Repair Activities

Oversight of the repairs will normally be accomplished using the Center's existing established oversight procedures, particularly when utilizing the onsite workforce. Experienced construction management staff who understand the strategy of recommissioning are the key to success.

6.3.6. TAB Contractor Certification

An important aspect of recommissioning is ensuring a certified Testing, Adjusting, and Balancing (TAB) contractor is utilized to perform TAB work, since in almost all cases, the building being recommissioned is out of balance. Out of balancing occurs over time by occupant and maintenance personnel adjustments, moving walls, changing sheaves, piping changes etc. A certified TAB contractor goes through a rigorous training and testing process that noncertified contractors may not have completed. Certification does not always guarantee competence, but it is one way to make sure the TAB contractor meets some minimum qualification. The three major providers of TAB certification systems are:

- AABC – American Air Balancing Council
- NEBB – National Environmental Balancing Bureau
- TABB – Testing, Adjusting and Balancing Bureau

Any one of these three certification systems is acceptable and may be specified. See Appendix G for additional information.

6.4. Contracting a Phase II Commissioning Agent

After the identified repairs have been made, the maintenance team will conduct the second phase of commissioning, which will validate the effectiveness of the repairs or modifications and complete the commissioning process. Although the commissioning agent may not be the same as was originally used, it is important to provide continuity during the process. All original conditions and data points shall be well documented, as well as the subsequent repairs and the final data and conditions. A well-documented project will include a final report with all of these items included. The Phase II Recommissioning effort also should make a comparison between the original commissioning effort (as a Leadership in Energy and Environmental Design (LEED)-New Construction (NC) certified facility), the Phase I results, and the results after the repairs. This is follow-on to the work done in Phase I, which compared the original design and commissioning results to the actual findings in the field.

6.4.1. Team Selection

The Commissioning team shall have members from all pertinent stakeholders. Members from the maintenance and operations contractor and NASA workforce are key, as well as those from the original design and construction projects if they are available. In the case of Recommissioning, it is important to include the original design, construction, and project management personnel if they are available. This should provide insight into the original process. However, an independent effort should be performed that is not influenced by the original results or process.

6.4.2. Selecting a Phase II Commissioning Agent

The Commissioning Agent (CxA) should have experience in Commissioning (Cx), Recommissioning (RCx), and Retrocommissioning (RTCx) in the climate and type of commissioning to be performed. For example, if the building to be Cx is a laboratory, office, or warehouse, the firm should have experience with the systems and equipment in that type of building. And as climates often dictate the type of HVAC, lighting, and other controls used, experience in the same geographic areas is required. The firm used in the original LEED-NC commissioning or the Phase I commissioning will provide continuity of effort and reduce the learning curve of the team; however, this is not required.

6.4.3. Procurement

The CxA may be procured either directly through Government procurement sources or may be contracted through other available contracts at the Center including the M&O contractor, an inspection contractor, or an AE contract. Repairs may be combined in the contract when procurement is through the M&O contractor so that validation is included. The GSA Schedule of contractors also is available for a more direct selection of firms suited for this work. In any case, an independent firm shall be used.

6.4.4. Scope of Work (SOW)

The SOW should provide details for the comparison of the original points, systems, and components from the LEED-NC original commissioning work, validation of the subsequent repairs, and final commissioning of all identified systems. The systems to be commissioned will be defined in this scope, as well as the design parameters to be used. This should be based on the original design, energy model, and LEED-NC commissioning report. Additional systems and equipment may be added if significant modifications have been made to the building. This should be well documented in the scope of work. Repairs made since the Phase I commissioning effort will be documented here for the CxA's use. This SOW will define the type, content, and detail of the testing expected. This may include the full testing performed in the original scope or may include only those areas in question. Test and Balance type system testing may be included, as well as specific component and equipment testing as needed. Nonstandard systems or unique components may require detailed specific test procedures. These may have been developed during the buildings original commissioning, the first phase of the RCx or RTCx, or may be developed during this phase as new procedures. Also included should be the original LEED-NC (if applicable) commissioning report, the Phase 1 Recommissioning Report, and the list of repairs made and any testing done after the repairs were completed.

6.4.5. Deliverables

The CxA shall provide a full report including all testing reports, the schedule of the commissioning and its completion, photographs, final analysis, and an executive summary. The number of bound copies required will be defined in the SOW, as well as the electronic submittal required.

6.4.6. Responsibilities of the CxA

- The CxA will schedule and conduct a pre-Cx meeting to
  - — Introduce the team members
  - — Define roles and responsibilities
  - — Present a schedule of completion
  - — Develop an issue log and track all issues and actions
  - — Provide minutes and distribute to all team members
- Conduct follow-on status meetings as needed and provide minutes of the meetings for all team members.
- Verify systems and components to be commissioned for the project are as included in the original commissioning.
  - — Note any systems that were missed or require additional oversight for inclusion in the SOW as to be modified.

  - Verify repairs or corrections have been conducted and documentation is available for any changes or upgrades to the systems.
  - Verify checklists for maintenance repair/correction have been completed. These can be component checklists or procedural checklists.
  - Review revised (red-lined) design documents for building system requirements as changed based on repairs or modifications
  - Ensure commissioning activities are properly scheduled
  - Perform or witness all testing performed on the defined systems
- Revise test procedures as needed and document changes
- Document all testing, changes, and final conditions
- Verify final acceptance of the changes, system configuration, and data
- Record with photographs all necessary conditions, repairs, or changes
- Develop the final report for review and approval by NASA
- Verify drawings, O&M manuals, and all pertinent documentation are updated and correct at the conclusion of the contract

6.4.7. Final Acceptance

Review of all repair reports, test reports, and the final report by all team members is required for final acceptance.

6.5. System Repair and Correction (Phase II)

6.5.1. Personnel Involved

The personnel involved in the repair process will vary depending on if it was determined earlier to accomplish the repairs using onsite personnel, the Commissioning Agent, or a separate offsite contractor. Regardless of this decision, this effort will entail coordination between the TAB contractor, the Commissioning Agent (if separate from the TAB contractor), representatives from the building automation system contractor, facilities personnel, facilities inspectors (if this is how the respective Center's oversight procedures operate), and the personnel performing the repairs.

6.5.2. Process

It is assumed that by this point either through an initial inspection and repair plan performed before a recommissioning contractor was hired or through findings that the recommissioning contractor found during their initial visit, that the individual units involved in the process have been repaired and are operating as intended. This step involves detailing the process to correct the numerous repairs that will likely be discovered during the testing and balancing phase of the project.

6.5.3. Types of Repair Expected To Be Found

Depending on the scope decided on for the project, this step will likely entail inspecting all VAVs and air handling units located in the facility being recommissioned. It may also include piping, pumps, and other equipment depending on scope. Repairs found during this process can be wide ranging. The typical problems encountered involve issues with ductwork (e.g., torn flex duct, connections that have come loose either at the diffuser or the VAV box, holes left from previous sensors or testing, poor installation practices). There can also be issues with the piping systems (e.g., deteriorated insulation, leaks at connections, blocked strainers). Another basic problem area entails the utility control systems (e.g., nonoperating control valves, broken or loose connections at flow sensors in VAV boxes, bad pressure sensors). The required repairs can also be not so evident, such as air handlers that need to have sheaves replaced from having incorrectly sized replacements put on in the past. The larger the scope of the project, the broader the areas in which repairs can be found (if lighting is included in the scope for instance).

6.5.4. Repair Personnel and Scheduling Repairs

There should be a timeframe established between the decided-on repair personnel, the TAB contractor, and the Commissioning Agent. This is to reduce the effect of repairs on the timeline for the TAB contractor to perform their work. If a repair will require time outside this timeframe the TAB contractor and the Commissioning Agent need to be made aware as this may affect their scheduled completion times (especially if it is something that keeps them from progressing on to later areas). If the repair work is being performed by onsite personnel, it is recommended that certain standard parts (such as actuators) be purchased beforehand in order to better facilitate the repairs that are found during this phase if funding allows.

6.5.5. Tracking of Issues Log

Regardless of the party responsible for the work, it is recommended that some type of facilities representative (either Government or facilities contractor personnel) be on hand for TAB activities to note what repairs are needed and the work that is being performed. It is recommended that an issues log be kept up to date that at the minimum lists the following things:

- Issue number
- Date of finding
- Location of issue
- Description of issue
- Effect of issue
- Personnel who noted issue

- Whether the issue has been repaired
- The date the issue was repaired

More information can easily be added to this log to tailor it to the project. Depending on the amount of work/issues being found, the choice may to update this list daily or just at the end of the week. This information will need to be made available to all parties involved in the project (especially if work is being performed by an onsite contractor, as it will allow for proper inspection of pre-repair and postrepair conditions by local inspectors to keep track of the quality of work being performed). Most Retrocommissioning contractors will also want to keep this log so that it can be included in their final report.

6.5.6. Notification of Repair Completion

If the work is being performed by onsite personnel, they should ensure that they notify the TAB contractor after completion of repairs so that they may come back to the area in question and finish their work.

If any repair work is found during the TAB process that is not required to complete their work and is outside the scope of the project, these items can be kept in a separate list and submitted in the final report as future repairs to be performed as funding is available.

6.6. CxA Revalidation

Once an improvement is completed, it is important to test the equipment or systems to ensure that the improvements are working as expected and to provide a new baseline for future recommissioning efforts. Testing can be done using Energy Management Control Systems (EMCS) trending, data logging, functional testing, simple observation, or a combination of these methods. For example, testing might involve manually testing the repaired items such as dampers or valves to verify that they stroke properly, followed by trending or data logging to determine that they are modulating to maintain the desired set point at the appropriate times.

To confirm that each improvement, as well as the combination of improvements is integrated and has the desired effect, the postimplementation data is compared to the original baseline data. This final verified data also can be used to update the energy savings estimates if needed. The data gathered as a result of verification activities along with the updated energy cost savings information, is compiled into the Implementation Summary Report. Also, future performance of each improvement can be periodically compared against the verification data to ensure benefits persist.

6.6.1. Responsibilities of the Commissioning Agent

The Commissioning Agent shall:

- Compile the Implementation Summary Report
- Develop and implement a functional testing program that objectively verifies that the building systems perform interactively in accordance with the project documents.

Written repeatable test procedures, prepared specifically for each project, are used to functionally test components and systems in all modes of operating conditions specified for testing. These tests are documented to clearly describe the individual systematic test procedures, the expected systems response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion

- Update the System Manual to include results of the revalidation testing
- Identify training needs for the O&M staff, and assess the existing level of knowledge for current and newly installed systems and identify any additional training recommendations for system technicians/operators
- Verify the accuracy and completeness of documentation including the Equipment List, O&M Manuals, EMCS documentation, and system diagrams
- Provide a summary of lessons learned during the recommissioning process

6.6.2. Test and Balance

The standards and procedures for providing testing, adjusting, and balancing (TAB) services are described in the NEBB Procedural Standards for the Testing, Adjusting and Balancing of Environmental Systems. The TAB report includes the balancing or rebalancing of the following units:

- Air inlets and outlets
- Terminal units
- Air handling units
- Outside airflows
- Exhaust fans
- Building pressurization
- Hydronic flows at coils, pumps, chillers, cooling towers, boilers, etc.

6.6.3. Utility Control Systems

The Commissioning Agent shall verify that the EMCS documentation is revised and complete. The documentation should include the following:

- Points List: A complete list of all input and output points in the EMCS including
  - — Point name
  - — Point type
  - — Sensor or actuator type
  - — Expected accuracy
  - — Name and type of associated equipment
  - — Panel location
  - — Alarm limits

  - Trending frequency

- Sequences of Operation: A description of how the system is intended/programmed to operate for each control system
- System Diagram: A one-line diagram of each of the buildings systems

6.6.4. Final Adjustments

Any final adjustments to a recommissioned system will be recorded and reflected in the appropriate system documentation.

6.7. Final Recommissioning (RCx) Report

A key responsibility of the recommissioning provider during the Handoff Phase is to develop the Recommissioning (RCx) Final Report. The RCx Final Report brings together important information from other recommissioning deliverables into a single document. As a comprehensive record of the project, it should become a part of the onsite resources for facility staff. The specific contents of the RCx Final Report will vary according to owner needs, but should include the following:

1. REPORT TITLE PAGE

The report title page shall include the following:

- The heading: “Certified Recommissioning Report”
- Project name/project address
- Owner name/address/contact numbers
- Certified RCX firm name/address/contact numbers/certification number

2. REPORT CERTIFICATION PAGE

The report certification page shall include the following:

- Project name
- Certified RCX professional’s name
- Firm name; certification number; expiration date
- Commissioning phases performed
- Certified RCX professional’s stamp (signed & dated)

3. TABLE OF CONTENTS PAGE

The Table of Contents shall serve as a guide to the organization of the RCX report.

4. EXECUTIVE SUMMARY

The executive summary shall include the following information:

- Review of the recommissioning project processes utilized
- Review any deviations used

- Review of each recommended corrective action and its relative priority
- Review any areas of concern that are not addressed in the corrective action report and the reasons these issues were not addressed
- Review of each deferred system test that is to be performed in the future

5. OWNER'S OPERATING REQUIREMENTS

The operating requirements should include the following information:

- Current occupancy information
- Change of use documentation
- Zoning changes
- Owner's sustainability and building rating requirements
- Energy and efficiency requirements
- Operation and maintenance issues
- Floor plans

6. THE FINDINGS LOG WITH DESCRIPTIONS OF THE IMPLEMENTED MEASURES

The Findings Log shall include the following information:

- Description of deficiency
  - Descriptive narrative
  - Pictures
  - Test data
  - Date and time of data
- Recommended Solutions
  - Engineering calculations
  - Drawings and sketches
  - Sequence of operations or other descriptive narratives
- Recommissioning schedule

7. UPDATED SAVINGS ESTIMATES AND ACTUAL IMPROVEMENT COSTS

The updated savings estimates and actual improvement costs should include the following information:

- Project name
- Predicted costs of recommended corrective action
- Actual costs of corrected actions
- Calculation of predicted payback and ROI

8. THE EMCS TRENDING PLAN AND DATA LOGGER DIAGNOSTIC/MONITORING PLAN

The EMCS trending plan and data logger diagnostic/monitoring plan should include the following information:

- Trending points list
- Date and time of data
- Location
- Variables recorded
- Parameters

9. ALL COMPLETED FUNCTIONAL TESTS AND RESULTS

The Final Report shall include completed copies of all testing records including check sheets and forms, data trends, or logs that indicate testing results. A list of deficient points shall be provided. Corrections to the deficiencies shall be scheduled.

10. RECOMMENDED FREQUENCY FOR RECOMMISSIONING

The Final Report shall recommend the frequency required for Recommissioning. Each building will be unique due to existing systems. For example, a building with pneumatic controls would require recommissioning more often than a Direct Digital Control (DDC) system. Criteria for triggering a recommissioning should be identified. Monitoring the base kWh load may be the key indicator. An increase to the base line of 10% may trigger recommissioning. The need for the next recommissioning process depends on several things: Changes in the facility's use, quality and schedule of preventive maintenance activities, and frequency of operational problems.

Indicators of a need to schedule a recommissioning may include the following:

- Is there an unjustified increase in energy use? Is energy use more than 10% higher than previous years?
- Have comfort complaints increased compared to previous months or years?
- Has nighttime or weekend/holiday energy use increased?
- Is the building staff aware of problems but unable to find the time or in-house expertise to fix them?
- Has control programming been modified or overridden to provide a quick fix to a problem?
- Are there frequent equipment or component failures?
- Have there been significant occupant improvement projects (build-outs or remodels)?
- Have there been significant changes in building use or the proportion of used to unused space?
- Have there been major upgrades on main energy consuming equipment (boilers, chilled water plant, large HVAC systems)?

- Has the operations staff changed since the last recommissioning process?

11. COMPLETE DOCUMENTATION OF REVISED OR NEW CONTROL SEQUENCES

The Final Report shall include detailed documentation of new control sequences or revisions to the original control sequences. At minimum, any changes that were made to the control sequences as a result of recommissioning should be carefully documented, along with the reasons for the changes.

12. RECOMMENDATIONS FOR MAINTAINING THE NEW IMPROVEMENTS

Recommendations for maintaining the new improvements should include an updated preventative maintenance schedule. This should also include improved procedures and maintenance goals. Incorporating operational activities in the preventive maintenance plan encourages building operators to continually ask questions such as:

- Have occupancy patterns or space layouts changed?
- Have the occupants added or removed loads from the space?
- Have temporary occupancy schedules been returned to original settings?
- Have altered equipment schedules or lockouts been returned to original settings?
- Is equipment short-cycling?
- Are timeclocks checked monthly to ensure proper operation?
- Have any changes in room furniture or equipment adversely affected thermostat functions?
- Are new occupants educated in the proper use and function of thermostats and lighting controls?
- Are the building's sequences of operation performing as intended?
- Are discretionary systems, such as lighting or computers, being turned off during unoccupied periods?

13. TRAINING SUMMARY INCLUDING TRAINING MATERIALS

To ensure that the benefits of recommissioning are maintained over the long term, building operators and managers shall have the right knowledge and skills. In addition to involving facility staff during the course of the project, it is important to request that the recommissioning provider develop and conduct additional training for facility staff at the end of the project.

The Training Summary should include the following:

- Energy usage analysis

- Energy accounting and benchmarking
- Operating schedules and operating requirements
- Investigation process and methods used to identify problems and deficiencies
- Master list of findings
- Measures that were implemented and by whom
- Expected performance improvements from these measures (showing before and after trends if applicable)
- O&M requirements to keep these improvements
- Working staff's role in helping to maintain the persistence of savings
- Retraining, as on the operation of the more complex systems or those that have undergone important recommissioning changes

14 – A LIST OF CAPITAL IMPROVEMENTS RECOMMENDED FOR FURTHER INVESTIGATION

A complete list of observed capital opportunities that will require further investigation. Feasibility studies are a good method to see if an energy project is worth pursuing. An asset capital replacement plan is another good method when reviewing the life expectancy of equipment and the building envelop components.

7. Continuous/Ongoing Commissioning Process for Existing Buildings

7.1. Precommissioning Planning

7.1.1. Choosing a Candidate Building

Continuous/ongoing commissioning is based on the ongoing collection and analysis of data provided through dedicated metering or existing building automation systems (BAS) or energy management systems (EMS). While this data can be manually collected through the use of system-level meters, it is much more efficient and practical to use a BAS to collect and analyze this data. Systems can be monitored for unusual or unexplained energy consumption, invalid operating parameters, or unusual or incorrect sequences of operation. Therefore, to be considered a good candidate for continuous/ongoing commissioning, a building should have a functional BAS or EMS.

Just as in retrocommissioning and recommissioning, there are instances where a building will not be an ideal candidate for continuous/ongoing commissioning. In buildings where most of the equipment and systems are at the end of their useful life or obsolete and need to be replaced, continuous/ongoing commissioning will not improve the performance of the building and in fact would be a waste of money versus replacing the equipment and systems or rehabbing the building.

Data to consider when choosing a building for continuous/ongoing commissioning should include the following:

- Type of building
  - Original function/use of the building
  - New function/use of the building
  - History of changes
  - Original design versus current design – red line drawing of any changes
  - Type of exterior
  - Building envelope type/insulation levels
- Number of occupants
- Size (gross square feet)
- Annual hours of operation
- Year constructed
- Year of last renovation

- Type and size of all building systems, including but not limited to:
  - Mechanical systems
  - Lighting systems
  - Plumbing systems
  - Sewer and storm water systems
  - Fire detection and fire protection systems
  - Building automation systems
- Energy data, including but not limited to:
  - Energy management systems information
  - Average annual energy use index (EUI) for similar type building
  - Annual electricity use, peak demand, and current trend
  - Annual propane use, peak demand, and current trend
  - Annual natural gas use, peak demand, and current trend
  - Annual fuel oil use, peak demand, and current trend
  - Annual steam/hot water use, peak demand, and current trend
  - Annual chilled water use, peak demand, and current trend
  - Annual water use, peak demand, and current trend
  - Electrical load balancing
- Sequence of operations:
  - HVAC schedules and setbacks
  - Set points
  - Minimum outside air ventilation rates
- CMMS Data
  - Service history
  - Trouble call history
  - Repair history
  - Magnitude of repair costs
- Maintenance Costs comparison
  - Comparison of maintenance costs to similar buildings
  - Current maintenance costs trend direction and percentage
- Current/Future Plans
  - Master Plan – are changes scheduled for building?
  - Is building currently on a demolition list?

7.1.2. Establishing a Commissioning Team

The continuous/ongoing commissioning team at a minimum should consist of the project manager, the commissioning engineer(s), commissioning technician(s), contractors, customer and program representatives, and the O&M staff.

- Project Manager: The project manager is responsible for coordinating the activities of the building personnel and the commissioning team and for managing the project schedule
- Commissioning Engineer: The commissioning engineer, with the help of the O&M staff, develops sequences of operations, metering plans, operational control schedules, and set points and conducts an engineering analysis of the system changes
- O&M staff and technicians: The O&M staff and technicians implement programming changes developed by the engineer
- Contractors: Perform tasks as required through contracts on all design changes or on all controls or electrical and HVAC systems and test equipment for efficiency after implementation or installation
- Customer/User/Operator: Assist O&M staff in understanding customer-driven requirements or special needs required by current or projected building occupant
- Program Representative: Assist O&M representative in understanding any special requirements, equipment, or other needs to be taken into account when developing a continuous/ongoing commissioning plan

7.1.3. Preparing a Scope of Work

The Scope of Work (SOW) needs to clearly identify what objectives are expected to be covered by the continuous/ongoing commissioning process. It is imperative that the scope of work include everything the team expects to accomplish. Anything not in the scope of work, whether it is data to be gathered or work to be accomplished, will not take place. It should identify the systems to be commissioned, the design parameters to be used, and type, content, and detail of testing expected during the continuous/ongoing commissioning. The scope should also include a detailed listing of all equipment that is expected to be commissioned and what level of testing, inspection, and repair is expected to be accomplished for each piece of equipment, as well as for each major section of the building. The scope of work should clearly identify who is responsible for developing sequences of operation, programming changes, and implementing changes. The scope of work should also include a robust measurement and verification plan to ensure that projected efficiencies are actually achieved.

7.1.4. Gathering Building Information to Provide to Commissioning Agent

As a minimum, the following information should be gathered for the continuous/ongoing commissioning of a building:

- CMMS data:
  - PM schedules (review to ensure minimum manufacturers' maintenance requirements are being met)

  - Equipment nomenclature and data
  - Trouble and repeat trouble call history
  - Repair history
  - Condition-based maintenance data
  - Predictive testing and inspection data
- Size (gross square feet)
- Design date
- Basis of design
- Information about the building envelope, including roof, exterior surface, and windows
- Utilities systems information
- Annual hours of operation
- Type and size of mechanical, lighting, and control systems
- Metered (submetered where available) utility data and energy information for at least 12 months:
  - Annual electricity use (kWh/year)
  - Peak demand
  - Annual natural gas/propane/fuel oil/water/steam /chilled water/ and all other pertinent utilities that serve the building
- Sequences of operation:
  - HVAC schedules and setbacks
  - Set points
  - Minimum outside air ventilation rates
- Drawings and specifications relevant to the systems scheduled for commissioning, especially control drawings
- Building construction type, specifications, and drawings.
- Existing control points list for each building
- Operating strategies programmed into the Energy Management and Controls System (EMCS)
- Equipment list with nameplate information for equipment controlled by the EMCS
- Existing O&M and system manuals and information for equipment
- Test and balance (TAB) reports; sensor calibration documentation
- Existing design and data management system information

7.2. Contracting a Continuous/Ongoing Commissioning Agent

Continuous/ongoing commissioning (CCx) allows the previously commissioned systems to be monitored continuously and indicates when systems require additional commissioning to ensure optimal performance and efficiency. System performance data is monitored continuously using building automation systems, data-loggers, or other installed data acquisition systems. Analysis of the systems within predetermined limits allows indication of problem areas that would benefit from intervention. For example, if data is collected continuously, analysis can be done continuously as well, or comparison algorithms can be run at set intervals such as monthly. When parameters exceed set limits, noted either with a automatically generated message such as an alarm, or during the monthly analysis, action is expected in the form of testing similar to that done in the commissioning.

Continuous/ongoing commissioning cannot be done unless Commissioning, Recommissioning, or Retrocommissioning has first been done. This provides the baseline for the systems and parameters and sets up the limits for the alarm points. To provide the framework for this system, a continuous/ongoing commissioning firm may be hired or this can be done in house. If a firm is hired, qualifications are similar to hiring any commissioning firm with the addition of expertise in the operational systems and the design intent behind them. Documentation of the commissioning testing, any repairs made, and the final commissioning work is crucial to this phase. The CCx phase can be done in conjunction with any of the above commissioning efforts. The CCxA should evaluate the commissioning work, whether done by the firm hired or another, and put in place the evaluation points for the systems needing evaluation.

Future CCx of these systems may be done by bringing the firm hired in again or by the maintenance personnel if they are properly trained. The CCxA selected may be one used for new building construction at the Center or may be a CCxA selected for specific knowledge or experience related to this project and to CCx.

7.2.1. Team Selection

The Continuous/ongoing Commissioning team shall have members from all pertinent stakeholders. Personnel from the maintenance and operations contractor and NASA workforce are key members, as well as those from the original design and construction projects if they are available.

7.2.2. Qualifications and Selection

- The Commissioning Agent (CxA) should have experience in all phases of commissioning including Commissioning (Cx), Recommissioning (RCx) and Retrocommissioning (RTCx) and particularly in Continuous/ongoing Commissioning in the climate and type of commissioning to be performed. For example, if the building to be continuously commissioned is a laboratory, office, or warehouse, the firm should have experience with the systems and equipment in that type of building. And as climates often dictate the type of HVAC, lighting, and other controls used, experience in these the same geographic area is required. The firm selected also should have experience in CCx,

specifically in the systems needed and in developing algorithms for alarms and notification.

- The firm should have experience on any local code requirements that NASA adopts; for example in California, the California Green Building Standard determines commissioning requirements.
- Ensure that the firm selected is knowledgeable in the field of continuous/ongoing commissioning and has experience in various areas, as listed above. An AE firm that performs commissioning for projects designed in house may not have experience as broad as needed.

7.2.3. Procurement

The CCxA may be procured either directly through Government sources or may be contracted through other available contracts at the Center including the M&O contractor, an inspection contractor, or an AE. Repairs may be combined in the contract when procurement is through the M&O contractor so that validation is included. The GSA Schedule of contractors is available for more direct selection of firms suited for this work. In any case, an independent firm shall be used. The firm selected should be contracted with NASA or its representative, not the firm that constructed or designed the original building. Criteria to be used for selection may include:

- References of completed projects where CCx was performed. At least three positive references of projects similar in size, location, and type of systems should be provided
- Training and certifications held by the firm. The Building Commissioning Association (BCA) provides certification to commissioning firms
- Site visits of buildings that are being continuously commissioned
- Final reports delivered to the owner representative for completed projects

7.2.4. Scope of Work (SOW)

The SOW should include information on the building, systems, and testing needed and the original commissioning documents. The systems to be continuously commissioned will be defined in this scope, as well as the design (or operational) parameters to be used. This SOW will define the type, content, and detail of the testing expected. This shall include the full testing performed in the original commissioning, by whatever method it was performed. Information to be included is as detailed in Section 5.2.1 and as a minimum should be:

- Facility or project name and location
- Approximate square footage, use, and occupancy of buildings
- Types of systems to be commissioned
- Test reports from original construction (if available)
- Commissioning reports from RCx or RTCx

- Special considerations
- Specifications and drawings (if available)

7.2.5. Deliverables

The CCxA shall provide a full report including facility description; project overview: the Continuous/ongoing commissioning process including testing reports, schedule of the continuous/ongoing commissioning , photographs, final analysis, recommended algorithms, and parameters for evaluation; any follow-on actions; impacts to the system after the changes from the CCx actions; and an executive summary. The number of bound copies required will be defined in the SOW, as well as the electronic submittal required. The CxA shall also deliver a complete list of repairs needed, as well as testing to be performed after the repairs are completed.

7.2.6. Responsibilities of the CxA

- The CxA will schedule and conduct a pre-CCx meeting to
  - Introduce the team members,
  - Define roles and responsibilities,
  - Present a schedule of completion,
  - Develop an issue log and track all issues and actions
  - Provide minutes and distribute them to all team members
- Conduct follow-on status meetings as needed and provide minutes of the meetings for all team members
- Verify systems and components to be commissioned for the project are as included in the original commissioning or as needed based on any modifications to the facility. Note any systems that were missed, require additional oversight for inclusion in the SOW, or need to be modified
- Develop checklists for maintenance repair/correction. These can be component checklists or procedural checklists
- Review original and any revised design documents for building system requirements as originally designed or as changed based on modifications
- Ensure commissioning activities are properly scheduled
- Initiate and develop preliminary test procedure format and establish an understanding of the magnitude of scope of testing that will be involved
- Perform or witness all testing performed on the defined systems
- Revise test procedures as needed and document changes

- Document all testing, changes, and final conditions
- Validate final acceptance of the changes, system configuration, and data
- Record with photographs all necessary conditions, repairs, or changes
- Develop the final report for review and approval by NASA
- Verify drawings, O&M manuals, and all pertinent documentation are updated and correct at the conclusion of the contract

7.2.7. Final Acceptance

Review of all test reports, recommended repairs and checklists, and the final report by all team members is required for final acceptance.

7.3. System Repair and Correction

After the investigation phase of the continuous/ongoing commissioning effort, an implementation plan for the proposed CCx measures needs to be developed to define the requirements for system repair or tuneup. Operational improvements shall be prioritized based on life cycle cost analysis and criticality. CCx Implementation should start by solving existing problems. These include comfort issues and control problems. The reason for prioritizing these types of projects is twofold. First, the projects that are the customer's top priority are being addressed early on. Second, these projects buy good will from the occupants, which will perhaps make it easier to obtain buy-in for future CCx projects. An implementation plan should be developed that lists each major activity. Items to consider are: Availability of funding to replace/repair parts found broken, time commitment of the in-house staff, and training needs of the in-house staff.

7.3.1. Choosing the Repair Team

Typically, repairs are implemented by the in-house maintenance staff. They are the most knowledgeable with the building systems and the operational schedule. An issue to discuss during planning for the repairs is the availability of a dedicated workforce. Often, since the in-house workforce has their normal duties to perform, additional time has to be included in the schedule to allow for their time away from the project. When possible, a dedicated workforce should be obtained that is able to stay through the term of the project to facilitate the quickest completion of the identified repairs. Several options are available for utilizing the in-house workforce depending on funding. The first would be to handle minor repairs as Trouble Calls under the base services if the contract allows this. The second option is to fund an IDIQ contract. The IDIQ option may be more efficient, as it will allow the onsite subcontractor to hire additional staff for the duration of the IDIQ contract. It also provides a single document to define and track the scope of the repairs. The EMCS staff also may be required to provide support.

7.3.2. Preparing a Repair Schedule

Consideration should be given to make repairs around environmental concerns such as HVAC repairs in the heat of summer or heating season. The repairs should be scheduled to make sure facility operations are not unduly impacted.

7.3.3. Oversight of Repair Activities

Oversight of the repairs will normally be accomplished using the Center's established oversight procedures, particularly when utilizing the onsite workforce. Experienced construction management staff who understand the strategy of recommissioning are the key to success.

7.3.4. Testing, Adjusting and Balancing (TAB) Contractor Certification

An important aspect of continuous/ongoing commissioning is ensuring a certified Testing, Adjusting, and Balancing (TAB) contractor is utilized to perform TAB work, since in almost all cases the building being commissioned is out of balance. Out of balancing occurs over time by occupant and maintenance personnel adjustments, moving walls, changing sheaves, and piping changes. A certified TAB contractor goes through rigorous training and testing process that noncertified contractors may not have completed. Certification does not always guarantee competence, but it is one way to make sure the TAB contractor meets some minimum qualification. The three major providers of TAB certification systems are:

- AABC – American Air Balancing Council
- NEBB – National Environmental Balancing Bureau
- TABB – Testing, Adjusting and Balancing Bureau

Any one of these certification systems is acceptable and may be specified. See Appendix E for additional information.

7.4. Periodic Revalidation

7.4.1. Introduction

Under a continuous/ongoing commissioning process, it is important to periodically test the equipment or systems to ensure that they are working as expected. Testing can be done using Energy Management Control Systems (EMCS) trending, data logging, functional testing, simple observation, or a combination of these methods. For example, testing might involve manually testing the repaired items, such as dampers or valves to verify that they stroke properly, followed by trending or data logging to determine that they are modulating to maintain the desired set point at the appropriate times. Test results should be compared to the original, baseline data to ensure that expected performance benefits persist.

The data gathered as a result of verification activities along with the updated energy cost savings information is compiled in a System Summary Report.

7.4.2. Commissioning Agent Responsibilities

The Commissioning Agent shall:

- Compile the System Summary Report
- Execute a functional testing program that objectively verifies that the building systems perform interactively in accordance with the project documents. Written repeatable

test procedures, prepared specifically for each project, are used to functionally test components and systems in all modes of operating conditions specified for testing. These tests are documented to clearly describe the individual systematic test procedures, the expected systems response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion

- Update the System Manual to include results of the latest periodic testing
- Identify training needs for the O&M staff. Assess the existing level of knowledge about current and newly installed systems and identify any additional training recommendations for system technicians/operators
- Verify the accuracy and completeness of documentation including the Equipment List, O&M Manuals, EMCS documentation, and system diagrams
- Provide recommendations for equipment replacement and upgrades based on observed performance

7.4.3. Test and Balance

The standards and procedures for providing testing, adjusting, and balancing (TAB) services are described in the NEBB Procedural Standards for the Testing, Adjusting and Balancing of Environmental Systems.

The TAB report includes the balancing or rebalancing of the following units:

- Air inlets and outlets
- Terminal units
- Air handling units
- Outside airflows
- Exhaust fans
- Building pressurization
- Hydronic flows at coils, pumps, chillers, cooling towers, boilers, etc.

7.4.4. Utility Control Systems

Verify that the EMCS documentation is current and complete. The documentation should include the following:

- Points List: A complete list of all input and output points in the EMCS including
  - — Point name
  - — Point type
  - — Sensor or actuator type

  - Expected accuracy
  - Name and type of associated equipment
  - Panel location
  - Alarm limits
  - Trending frequency

- Sequences of operation: A description of how the system is intended/programmed to operate for each control system

- System diagram: A one-line diagram of each of the building's systems

7.4.5. Final Adjustments

Any final adjustments to a system will be recorded and reflected in the appropriate system documentation.

7.5. Continuous/Ongoing Commissioning (CCx) Final Report

Continuous/ongoing commissioning (CCx) differs from Commissioning (Cx), Retrocommissioning (RTCx), and Recommissioning (RCx). Cx, RTCx and RCx are scheduled processes that encompass the entire building, all systems, and system components. CCx is implemented after the completion of one of the other commissioning processes and is an ongoing process designed to immediately address specific issues as they arise. CCx is the convergence of Energy Monitoring, EMCS monitoring and preventative maintenance. Properly executed, CCx has the potential to eliminate the need for RTCx and RCx.

USGBC defines CCx as "a continuous process that methodically identifies and corrects system problems to maintain optimal building performance; it includes regular measurement and comparative analysis of building energy data over time." More simply—continuous/ongoing commissioning is an ongoing process to resolve operating problems, improve comfort, and optimize energy use.

The Final Report for CCx is a followup report to a Cx, RCx, or RTCx report. The Final Report for CCx identifies the tools and tracking software needed to benchmark the utility consumption, as well as the alarm points and diagnostic software needed for the EMCS (Energy Management Control System). As a comprehensive record of the project, it should become a part of the onsite resources for the facility staff. The specific contents of the CCx Final Report will vary according to owner needs, but should include the following:

1 - REPORT TITLE PAGE

The report title page shall include the following:

- The heading: "Certified Continuous/Ongoing Commissioning Report"

- Project name/project address

- Owner name/address/contact numbers

- Certified CCx firm name/address/contact numbers/certification number

2 - REPORT CERTIFICATION PAGE

The report certification page shall include the following:

- Project name
- Certified RCx professional's name
- Firm name; certification number; expiration date
- Commissioning phases performed
- Certified CCx professional's stamp (signed & dated)

3 - TABLE OF CONTENTS PAGE

The Table of Contents shall serve as a guide to the organization of the CCx report. Include page numbers in the report.

4 - EXECUTIVE SUMMARY

The executive summary shall include the following information:

- Review of the continuous/ongoing commissioning project process utilized
- Review of any deviations used
- Review of each recommended corrective action and its relative priority
- Review any areas of concern that are not addressed in the corrective action report and the reasons these issues were not addressed

5 – COPY OF COMMISSIONING REPORT

A copy of the Cx, RCx, or RTCx report upon which the CCx report was based

6 – OWNER'S OPERATING REQUIREMENTS

The operating requirements should include the following information:

- Current occupancy information
- Change of use documentation
- Zoning changes
- Owner's sustainability and building rating requirements
- Energy and efficiency requirements
- Operation and maintenance issues
- Floor plans

7 – ENERGY PERFORMANCE BASELINES

The Final Report shall detail energy performance baselines that need to be maintained. Seasonal baselines are preferable – winter/summer.

- Electricity baselines
- Natural gas baselines
- Water usage baselines
  - Domestic water
  - Industrial water – cooling towers, etc.
  - Irrigation water
- Miscellaneous – steam, chilled water, heating hot water, #2 oil, etc.

8- COMPLETE DOCUMENTATION OF CONTROL SEQUENCES

The Final Report shall include detailed documentation of new control sequences

9 - THE EMCS TRENDING PLAN AND DATA LOGGER DIAGNOSTIC/MONITORING PLAN

The EMCS trending plan and data logger diagnostic/monitoring plan should include the following information:

- Trending points list
- Location
- Variables recorded
- Baseline parameters
- Alarm points

10 – PREVENTATIVE MAINTENANCE OUTLINE

The Final CCx report shall include a detailed outline of a basic Preventative Maintenance Program needed to maintain energy baselines and comfort requirements. The following information is required:

- Major equipment lists
- system components
- EMCS control points
- Frequencies for PMs (daily, weekly, monthly, quarterly, semiannual, or annual)

11 - TRAINING SUMMARY INCLUDING TRAINING MATERIALS

To ensure that the benefits of continuous/ongoing commissioning are maintained over the long term, building operators and managers shall have the right knowledge and skills. In addition to involving facility staff during the course of the project, it is important to request that the CCx

provider develop and conduct additional training for facility staff to implement and maintain the program. The Training Summary should include the following:

- Energy usage analysis
- Energy accounting and benchmarking
- Operating schedules and requirements
- Investigation process and methods used to identify problems and deficiencies
- O&M requirements to keep these improvements
- Working staff ’s role in helping to maintain the persistence of savings
- Retraining on the operation of the more complex systems as they are introduced

Appendix A – Definitions

Addition. A physical increase to a real property facility that adds to the overall dimensions of the facility.

Alterations. Work that changes the configuration of a facility (not maintenance or repairs) but that does not increase the value of the facility, e.g., moving a door or electrical outlet.

Assets. Any items of economic value owned by NASA. Items may be physical (tangible) or a right to ownership (intangible) that is expressed in terms of cost or some other value.

Availability. The ratio of the actual run time of a machine or system divided by the scheduled time for the machine or system. Usually expressed as a percentage. For example, if an air handler is scheduled to run from 6 a.m. to 6 p.m., 5 days a week and, in fact, does run during those times, its availability was 100 percent. If the air handler was stopped one day during the week for one hour, its availability for that week was 98.3 percent (59 hours divided by 60 hours).

Benchmark. A standard against which something is measured.

Breakdown Maintenance. See Repair.

Budget. A formal estimate of future revenues, obligations to be incurred, and outlays to be made during a definite period and when determined to be appropriate on the basis of accrued expenditures and costs to be incurred.

Buildings. The classification that includes the cost of buildings, capital improvements of buildings, and fixed equipment that is normally required for the functional use of the buildings and becomes permanently attached to and made a part of the buildings and that cannot be removed without cutting into the walls, ceilings, or floors, such as plumbing, heating, and lighting equipment; elevators; central air-conditioning systems; and built-in safes and vaults. Also included is all equipment of any type built in, affixed to, or installed in real property in such manner that the installation cost, including special foundations or unique utilities or services, or the facility restoration cost after removal is substantial.

Central Utility Plant Operations and Maintenance. This category is unique in that it includes the cost of operations in addition to maintenance costs. It should be used only to capture the costs of operating and maintaining institutional central utility plants, such as a central heating or steam plant, wastewater treatment plant, or a central air-conditioning (chiller) plant. The concept is that operators are assigned full time to operate the plant, but they perform maintenance between various operating tasks, making it almost impossible to segregate operational and maintenance costs; therefore, the costs of the full-time operators and operations personnel (and their materials) are included in this category.

Collateral Equipment. Encompasses building-type equipment, built-in equipment, and large, substantially affixed equipment/property that are normally acquired and installed as part of a facility project as described below (also see Noncollateral Equipment):

Building-Type Equipment. A term used in connection with facility projects to connote the equipment normally required to make a facility useful and operable. It is built in or affixed to the facility in such a manner that removal would impair the usefulness, safety, or environment of the facility. Such equipment includes elevators; heating, ventilating, and air-conditioning systems; transformers; compressors; and like items generally accepted as being an inherent part of a building or structure and essential to its utility. It also includes general building systems and subsystems, such as electrical, plumbing, pneumatic, fire protection, and control and monitoring systems.

Built-in or Large, Substantially Affixed Equipment. A term used in connection with facility projects of any type other than building-type equipment that is to be built in, affixed to, or installed in real property in such a manner that the installation cost, including special foundations or unique utilities service, or the facility restoration work required after its removal is substantial.

Commissioning. Traditional commissioning involves performing random tests and checks on facility systems to ensure that they are properly balanced, functionally operational, and comply with the design intent. It systematically checks operating parameters such as pressure, temperature, minimum and maximum air flow, lighting levels, electrical amperage and voltage, torque, fluid volumes, and other thermodynamic measures at key locations, as well as balanced conditions. It is a method of acceptance testing that, when performed on a random basis at random sampling points, checks to ensure that the outcome indices at those points are in compliance with the outcome requirements stated in the design specification.

Building and equipment acceptance is one element of a larger, more comprehensive construction quality program known as "commissioning." Currently, there are four variations of commissioning being practiced:

- Traditional commissioning
- Total building commissioning
- Total building recommissioning or retrocommissioning
- NASA’s customized application of a portion of commissioning called, Reliability Centered Building and Equipment Acceptance (RCB&EA)

Component Facility. Center organizations that are geographically separated from the parent Center.

Computerized Maintenance Management System (CMMS). A set of computer software modules and equipment databases containing facility data with the capability to process the data for facilities maintenance management functions. They provide historical data, report writing capabilities, job analysis, and more. The data describe equipment, parts, jobs, crafts, costs, step-by-step instructions, and other information involved in the maintenance effort. This

information may be stored, viewed, analyzed, reproduced, and updated with just a few keystrokes. The maintenance-related functions typically include the following:

- Facility/equipment inventory
- Facility/equipment history
- Work input control
- Job estimating
- Work scheduling and tracking
- Preventive and predictive maintenance
- Facility inspection and assessment
- Materials management
- Utilities management
- Corrective maintenance and repair

Condition Assessment. The inspection and documentation of the material condition of facilities and equipment, as measured against the applicable maintenance standards. It provides the basis for long-range maintenance planning, as well as annual work plans and budgets.

Condition-Based Maintenance (CBM). Facility and equipment maintenance scheduled only when the condition of the facility or equipment requires it. CBM replaces maintenance scheduled at arbitrary time or usage intervals. It usually involves the application of advanced technology to detect and assess the actual condition. See Predictive Testing & Inspection and Reliability Centered Maintenance.

Condition Monitoring. Also known as Predictive Maintenance. The continuous or periodic monitoring and diagnosis of systems and equipment to forecast failure. Also see Predictive Testing and Inspection.

Construction. The erection, installation, or assembly of a new or replacement facility or an addition in area, volume, or both to an existing facility.

Construction Project. A facility project relating to the erection, installation, or assembly of a new facility, replacement facility, or an addition in area, volume, or both to an existing facility.

Continuous/Ongoing Commissioning (CCx) - An ongoing process designed to resolve operating problems, improve comfort, optimize energy use, and identify retrofits for existing facilities. The approach is integrated into a facility's standard operations and maintenance (O&M) program with commissioning activities completed on an ongoing basis.

- Continuous/Ongoing commissioning is the most costly commissioning approach for existing buildings due to necessary staff and equipment allocations. However, the process

can identify equipment inefficiencies as they occur, allowing for quick remediation and greater energy and cost savings.

- Continuous/Ongoing commissioning is ideal for facilities with building automation systems, advanced metering systems, and well-run O&M programs. Federal agencies should consider continuous/ongoing commissioning for large and complex facilities that have high energy consumption and tenant complaints and those with a metering system and a preventive maintenance program.

Continuous Inspection. A program of periodic, scheduled inspections of facilities and equipment to determine their condition with respect to specified standards (including safety).

Contracting Officer's Representative. Any person who, by appointment in accordance with procedures prescribed by the NASA FAR Supplement, has the authority to enter into and administer contracts and to make determinations and findings with respect thereto or has any part of such authority.

Contractor. The supplier of an end item and associated support items to the Government under the terms of a specific contract.

Contracts. All types of agreements and orders for the procurement of supplies or services. Includes awards and notices of award; contracts of a fixed-price, cost, cost-plus-a-fixed-fee, or incentive type; contracts providing for the issuance of job orders, task orders, or task letters incentive type; contracts providing for the issuance of job orders, task orders, or task letters thereunder; letter contracts; and purchase orders. It also includes supplemental agreements with respect to any of the foregoing.

Corrective Maintenance. See Repair.

Current Replacement Value (CRV). Escalated value of the initial cost of an asset including all subsequent modifications for all facilities. CRV is developed by escalating facility and collateral equipment acquisition cost and any incremental book value changes to current-year dollars using the Engineering News Record (ENR) Building Cost Index (BCI). Refer to NPR 8800.15 for dollar value. The NASA Real Property Management System (RPMS) is used in performing the required calculations. CRV is solely an escalated value and should not be used as an actual replacement cost.

Current Year (CY). The fiscal year immediately preceding the budget year.

Deferred Maintenance (DM). The total of essential but unfunded facilities maintenance work necessary to bring facilities and collateral equipment to the required acceptable facilities maintenance standards (as defined in NPR 8831.2). It is the total work that should be accomplished but that cannot be achieved within available resources. It does not include new construction, additions, or modifications. DM does include unfunded maintenance requirements, repairs, replacement of obsolete items (ROI), and CoF repair projects.

Design. This term encompasses both preliminary design and final design for facility projects. Design costs are normally funded under the CoF appropriation. Design costs of facility projects proposed for funding under appropriations other than CoF are normally funded under the same

appropriation from which the facility project is to be funded with such costs being identified separately from the facility project cost estimate.

Drawings. Graphical data, including drawings as defined in MIL-STD 100A and prepared in accordance with MIL-STD-1000, Category D; aperture cards in accordance with MIL-C-9877; and graphs or diagrams in accordance with industry standards and industry specifications on which details are represented with sufficient information to define completely, directly, or by reference the end result for use in the selection, procurement, or manufacture of the item required.

Emergency Repair. The restoration of an existing facility or the components thereof when such facilities or components have been made inoperative by major breakdown, accident, or other circumstances that could not be anticipated in normal operations, and the repair thereof is of such urgency that it cannot await programming and accomplishment in the normal budget cycle. In the process of emergency repair, the replacement of components or materials shall be of the size or character currently required to meet firm demands or needs.

Estimated Cost. A calculated, anticipated amount, as distinguished from an actual outlay, based on related cost experience, prevailing wages and prices, or anticipated future conditions, usually for the purposes of contract negotiation, budgetary control, or reimbursement.

Facilities Condition Assessment. See Condition Assessment

Facilities Contract. A contract type under which Government facilities and equipment are provided to a contractor by the Government for use in connection with the performance of separate, related procurement or support services contract(s) for supplies or services. The term includes facilities acquisition contracts, facilities use contracts, and consolidated facilities contracts.

Facilities Management. Planning, prioritizing, organizing, controlling, reporting, evaluating, and adjusting facility use to support NASA activities based on customers' facility needs and Center mission requirements. See also Facilities Maintenance Management.

Facilities Maintenance. The recurring day-to-day work required to preserve facilities (buildings, structures, grounds, utility systems, and collateral equipment) in such condition that they can be used for their designated purpose over an intended service life. It includes the cost of labor, materials, and parts. Maintenance minimizes or corrects wear and tear and, thereby, forestalls major repairs. Facilities maintenance includes PM, PT&I, grounds care, Programmed Maintenance (PGM), repair, TCs, ROI, and service requests (SRs) (not a maintenance item but work performed by maintenance organizations). Facilities maintenance does not include new work, work on noncollateral equipment, or maintenance performed in the Central Plant by plant operations personnel.

Facilities Maintenance Management. Planning, prioritizing, organizing, controlling, reporting, evaluating, and adjusting facilities maintenance operations to support NASA activities with

quality facilities based on customers' facility needs and predetermined maintenance goals at minimum cost.

Facility. A term used to encompass land, buildings, other structures, and other real property improvements, including utilities and collateral equipment. The term does not include operating materials, supplies, special tooling, special test equipment, and noncapitalized equipment. The term facility is used in connection with land, buildings (facilities having the basic function to enclose usable space), structures (facilities having the basic function of a research or operational activity), and other real property improvement.

Facility Improvement. That construction necessary to upgrade or replace obsolete facilities or to expand a facility to improve the operating efficiency of an installation.

Facility Project. The consolidation of applicable, specific individual types of facility work, including related collateral equipment, that is required to fully reflect all of the needs generally relating to one facility that has been or may be generated by the same set of events or circumstances that are required to be accomplished at one time in order to provide for the planned, initial operational use of the facility or a discrete portion thereof.

Find. Discovery utilizing PT&I of an impending failure or degrading condition of a facility, system, or equipment that indicates action is required to prevent failure.

Improvements. Additions to land, buildings, other structures, and other attachments or annexations to land that are intended to remain so attached or annexed, such as sidewalks, drives, tunnels, utilities, and installed collateral equipment.

Inventory. The facilities and equipment inventory is the foundation of an effective facilities maintenance management program. It is the baseline for what is to be maintained. The inventory permits identifying maintainable items, including those subject to preventive maintenance or operator maintenance.

Life Cycle Costs (LCC). A form of economic analysis that considers the total cost of owning, operating, and maintaining a building over its useful life. Life cycle costs are the sum of the present value of the following:

- Investment costs, less salvage values, at the end of a study period
- Nonfuel operation and maintenance costs
- Costs of replaced building systems, less salvage costs
- Energy costs

Major Facility Work (Discrete Institutional or Program Funded). Construction and revitalization work in excess of $5 million, land acquisition, and emergency repair approved under the provisions of Section 308(b) of the National Aeronautics and Space Act of 1958, as amended, at any cost.

Metrics. Meaningful measures. For a measure to be meaningful, it needs to present data that encompasses the right action. In the context of NPR 8831.2, metrics refer to management and performance measures.

Minor Facility Work (Institutional or Program Funded). Construction and revitalization work in excess of $1 million but not exceeding $5 million

Mission Critical. A building, area, or system that is critical to the Center's mission or is essential for Center of Excellence performance.

Mission Support. A building, area, or system that provides support to the Center's primary mission or Center of Excellence assignment.

Modification. See Rehabilitation and Modification.

New Building Commissioning. New building commissioning happens during the design and construction of new facilities. The process ensures that systems and equipment in new buildings operate properly. This is done through design reviews, functional testing, system documentation, and operator training.

Federal agencies should consider new building commissioning when building new facilities or undergoing major facility renovations. The process is best implemented through all phases of construction.

Noncollateral Equipment. All equipment other than collateral equipment. Such equipment, when acquired and used in a facility or a test apparatus, can be severed and removed after erection or installation without substantial loss of value or damage thereto or to the premises where installed. Noncollateral equipment imparts to the facility or test apparatus its particular character at the time (e.g., furniture in an office building, laboratory equipment in a laboratory, test equipment in a test stand, machine tools in a shop facility, and computers in a computer facility) and is not required to make the facility useful or operable as a structure or building (See also Collateral Equipment).

Obligation. A legally binding agreement that will result in the outlay or expenditure of funds immediately or in the future. A bona fide need shall exist to create an obligation, such as when a contract is awarded, an order is placed, or a service is received.

Operator Maintenance. The examination, lubrication, minor repair (usually no larger than trouble call scope), and adjustment of equipment and systems in the assigned plant.

Outage. The planned or unintentional interruption or termination of a utility service, such as electricity, water, steam, chilled water, or communication.

Payback. The amortization period, in years, calculated by dividing the budget estimate by the total expected annual savings.

Planned Repair. Repair performed prior to failure. Material condition degradation, usually identified through PM, PT&I, or other inspection, is repaired to prevent catastrophic failure. Also, see Repair.

Predictive Testing & Inspection (PT&I). The use of advanced technology to assess machinery condition. The PT&I data obtained allows for planning and scheduling preventive maintenance or repairs in advance of failure. Also, see Condition Monitoring and Condition-Based Maintenance.

Preventive Maintenance (PM). Also called time-based maintenance or interval-based maintenance. PM is the planned, scheduled periodic inspection (including safety), adjustment, cleaning, lubrication, parts replacement, and minor (no larger than trouble call scope) repair of equipment and systems for which a specific operator is not assigned. PM consists of many checkpoint activities on items that if disabled would interfere with an essential Center operation, endanger life or property, or involve high cost or long lead time for replacement. To progress away from reactive maintenance, PM schedules periodic inspection and maintenance at predefined time or usage intervals in an attempt to reduce equipment failures. Depending on the intervals set, PM can result in a significant increase in inspection and routine maintenance. However, a weak or nonexistent PM program can result in safety and/or health risks to employees, much more emergency work, and costly repairs.

Proactive Maintenance. The collective efforts to identify, monitor, and control failure with an emphasis on understanding and eliminating the cause of failure. Proactive maintenance activities include developing design specifications to incorporate maintenance lessons learned and to ensure future maintainability and supportability, developing repair specifications to eliminate underlying causes of failure, and performing Root Cause Failure Analysis (RCFA) to understand why in-service systems failed.

Programmed Maintenance (PGM). Those maintenance tasks whose cycle exceeds 1 year, such as painting a building every 5th year. (This category is different from PM in that if a planned cycle is missed, the original planned work still remains to be accomplished. In PM, only the next planned cycle is accomplished instead of doing the work twice, such as two lubrications, two adjustments, or two inspections.)

Project. Within a program, this is an undertaking with a scheduled beginning and end that normally involves one of the following primary purposes: (1) Design, development, and demonstration of major advanced hardware items; (2) design, construction, and operation of a new launch vehicle (and associated ground support) during its R&D phase; or (3) construction and operation of one or more aeronautical or space vehicles; this includes the necessary ground support to accomplish a scientific or technical objective.

Reactive Maintenance. See Repair.

Real Property. Land, buildings, structures, utility systems, and improvements and appurtenances, thereto, permanently annexed to land. Also includes collateral equipment (i.e., building-type equipment, built-in equipment, and large substantially affixed equipment).

Real Property Management System (RPMS). A NASA-wide data system for real property that serves as an automated method for maintaining and reporting all real property data. The RPMS includes the forms, codes, and procedures used in the RPMS that conform to NASA guidance and requirements. The RPMS contains information on all NASA real estate including land, buildings, structures, utility systems, improvements, and appurtenances thereto permanently annexed to land. The data in the RPMS includes age, classification, CRV, and other information.

Recommissioning and Retrocommissioning. Recommissioning and Retrocommissioning both cover the practice of commissioning existing buildings. The processes include testing and adjusting building systems to meet original design intent and/or optimize systems to satisfy shifting operational needs. Recommissioning and Retrocommissioning rely on building and equipment documentation along with functional testing to optimize performance.

- Recommissioning is ideal to tune buildings that have already been commissioned. The process brings building performance back to its original design intent and operational efficiency. Federal agencies should consider recommissioning for relatively new buildings that were commissioned during construction but have experienced increased energy needs.
- Retrocommissioning is ideal for older facilities that have never been through the commissioning process. Federal agencies should consider retrocommissioning if facility systems are old, expensive to operate, and experiencing a lot of equipment failures.

Recurring Maintenance. Maintenance performed on an item of equipment that is planned and performed on a set work schedule. The work and work schedules are based on established standards.

Rehabilitation and Modification. Facility work required to restore, enhance, alter, or adjust a facility or component thereof, including collateral equipment, to such condition that it can be more effectively used for its presently designated purpose or to increase its functional capability. To simplify facility project titles, work may be properly identified as rehabilitation provided the primary reason for accomplishment is that the basic restoration work shall be done in any event. It is prudent to accomplish any related enhancement, alteration, or adjustment work concurrently. If the pressing requirement is for alteration and adjustment work to achieve an increase in functional capability, then this may be simply classified as "modification," even though restoration is also involved.

Reliability-Centered Building and Equipment Acceptance (RCB&EA). The use of Reliability-Centered Maintenance (RCM) and PT&I technologies in conjunction with traditional and total building commissioning processes prior to and during the equipment startup/checkout phase of new construction, repair, and rehabilitation projects to ensure quality installation and accurate baseline documentation.

Reliability-Centered Maintenance (RCM). The process that is used to determine the most effective approach to maintenance. It involves identifying actions that, when taken, will reduce

the probability of failure and that are the most cost effective. It seeks the optimal mix of condition-based actions, other time- or cycle-based actions, or a run-to-failure approach. (See also Condition-Based Maintenance, Predictive Testing & Inspection.)

Repair. Facility work required to restore a facility or component, including collateral equipment, to a condition substantially equivalent to its originally intended and designed capacity, efficiency, or capability. It includes the substantially equivalent replacements of utility systems and collateral equipment necessitated by incipient or actual breakdown. It includes restoration of function, usually after failure. (Also, see Planned Repair.)

Replacement of Obsolete Items (ROI). There are many components of a facility system that should be programmed for replacement as a result of becoming obsolescent (no longer parts-supportable), not meeting electrical or building codes, or being unsafe. The components, however, are still operational and would not be construed as a system repair. Examples are as follows:

- Electric switchgear, breakers, and motor starters
- Elevators
- Control systems
- Boiler and central HVAC systems and controls
- Fire detection systems
- Cranes and hoists
- A/C and other systems using chlorofluorocarbon (CFC) refrigerants

Root-Cause Failure Analysis (RCFA). The process of exploring in increasing detail all possible causes related to a machine failure. Failure causes are grouped into general categories for further analysis. For example, causes can be related to machinery, people, methods, materials, policies, environment, and measurements.

Service Requests (SR). Service requests are not maintenance items, but are so often performed by facilities maintenance organizations that they become a part of the baseline. Service requests are requests for facilities-related work that is new in nature and, as such, should be funded by the requesting organization. Requests are initiated by anybody at the Center, are usually submitted on a form, often require approval by someone before any action is taken, and usually are planned and estimated. Examples of these requests include installation of an outlet to support a new copier machine, providing a compressed air outlet to a new test bench, renovating an office, and installing special cabinetry.

Specifications. A document that stipulates methods, materials, performance, testing, limitations, or other criteria that shall be adhered to during the construction of a facility.

Standard. Maintenance standards are defined as the expected condition or degree of usefulness of a facility or equipment item. A maintenance standard may be stated as both a

desired condition and a minimum acceptable condition beyond which the facility or equipment is deemed unsatisfactory.

Time-Based Maintenance. See Preventive Maintenance.

Trouble Calls (TC). Trouble calls are generally submitted by telephone or electronically by occupants of a facility (or facility managers or maintenance workers). This category is composed of two types of work:

- Routine Calls are minor facility problems that are too small to be estimated (usually less than about 20 work hours or $2,000) and generally are responded to by grouping trouble calls by craft and location.
- Emergency Calls, which normally start as trouble calls, require immediate action to eliminate hazards to personnel or equipment, to prevent loss of or damage to Center property, or to restore essential services that have been disrupted. Emergency work is usually a response-type work effort, often initially worked by trouble call technicians. Due to its nature, emergency work is not restricted to a level of effort, as are trouble calls.

Unconstrained Maintenance and Repair (M&R). Maintenance and repair work that a reasonable manager would estimate is needed to maintain a facility inventory in “good commercial” condition without funding restraints. The estimate would not allow DM to grow and would provide a level of reliability that the supported programs would find acceptable for their missions.

Work Control Center (WCC). The central organization point for receipt, tracking, and management of work generated from all sources.

Work Generation. The process of identifying and documenting maintenance deficiencies and requirements.

Work Order. The document directing shops to perform certain items of maintenance work. It includes the specific maintenance task requirements (usually by craft), labor, material, and equipment estimates; coordinating instructions; and administrative and financial information.

Work Request. A written or oral request from customers or internal maintenance personnel who have observed deficiencies and perceive a need for maintenance or repair work or who have a request for new work. The work request is evaluated by management and, if approved, converted into a work order for accomplishment.

Appendix B – Acronyms

A&E - Architect and Engineer

A/C - Air Conditioning

CADD - Computer-Aided Design and Drafting

CBM - Condition Based Maintenance

CFC - Chlorofluorocarbons

CMMS - Computerized Maintenance Management System

CMO - Center Management and Operations

CoF - Construction of Facilities

CCx – Continuous/Ongoing Commissioning

COR - Contracting Officers Representative

COSS - Center Operations Support Services

CRV - Current Replacement Value

Cx - Commissioning

CxA - Commissioning Agent

DDC - Direct Digital Control

DM - Deferred Maintenance

EMCS - Energy Monitoring and Control System

ENR - Engineering News Record

EPA - Environmental Protection Agency

EPS - Engineered Performance Standards

ESPC - Energy Savings Performance Contract

FAR - Federal Acquisition Regulation

FCA - Facility (Facilities) Condition Assessment

FM - Facility Management

FP&D - Facilities Planning and Design

FY - Fiscal Year

GIS - Geographic Information System

HVAC - Heating, Ventilating, and Air-Conditioning

IDIQ - Indefinite Delivery/Indefinite Quantity

IRT - Infrared Thermography

LCC - Life Cycle Cost

LEED - Leadership in Energy and Environmental Design

M&R - Maintenance and Repair

NASA - National Aeronautics and Space Administration

NPD - NASA Policy Directive

NPR - NASA Procedural Requirements

O&M - Operations and Maintenance

OSHA - Occupational Safety and Health Administration

PER - Preliminary Engineering Report

PGM - Programmed Maintenance

PM - Preventive Maintenance

POE - Postoccupancy Evaluation

PP&E - Property, Plant, and Equipment

PT&I - Predictive Testing and Inspection

RCB&EA - Reliability Centered Building and Equipment Acceptance

RCFA - Root-Cause Failure Analysis

RCM - Reliability Centered Maintenance

RCx - Recommissioning

RTCX - Retrocommissioning

ROI - Replacement of Obsolete Items; Return on Investment

RPMS - Real Property Management System

SeqOp - Sequence of Operation

SOW - Statement of Work

SR - Service Request

TAB - Test & Balance Contractor

TC - Trouble Call(s)

USGBC - U.S. Green Building Council

VFD - Variable Frequency Drive

WBS - Work Breakdown Structure

WCC - Work Control Center

Appendix C– Commissioning Task Responsibility Matrix

New Buildings: Predesign Phase	FPM	CxA	DOR	GC	O&M
1. Select Commissioning Authority (CxA) (or write task order to IDIQ Commissioning Contractor). CxA to support project through 12 month construction warranty period	P				
2. Develop Government's project requirements document with the commissioning authority (CxA).					
a. Review Center lessons learned & NASA Postoccupancy Surveys	S	S			P
b. Review lessons learned from CxA		P			
c. Hold PDRI workshop	P	S			S
d. Develop building performance and benchmarks	P	S			S
e. Document project budget	P				
f. Review PER or programming document	S	P			S
g. Constructability report	P	S			S
h. Establish definition of project success	P	S			
i. Maintainability of each system		S			P
j. Maintenance and operations capabilities of staff		S			P
k. Systems manual requirements	S	P			S
l. Training and documentation requirements	S	P			S
3. Recommend to owner if existing O&M staff capabilities will have to be enhanced	S	P			S
4. Assist development of the initial commissioning process plan	S	P			S
5. Develop the scope of work for the commissioning process with the commissioning authority	P	S			S
6. Prepare commissioning process milestones and schedule	S	P			
7. Prepare Issues and Resolution Log format	S	P			
8. Prepare Cx Report Format	S	P			
9. Verify that the basis of design, Commissioning Plans, and OPR requirements are in the contract with the designer	P	S			

10. Identify commissioning activities that should be included in the scope of work for the design team	S	P			S

LEGEND	
CxA	Commissioning Authority
DOR	Designer of Record
FPM	Facility Project Manager
GC	General Contractor or their Subcontractor
O&M	Operations and Maintenance
P	Primary person responsible for task
PDRI	Project Definition Rating Index
PER	Preliminary Engineering Report
S	Provides support to Primary person responsible

New Buildings: Design Phase	FPM	CxA	DOR	GC	O&M
1. Verify the completion of the basis of design and compliance with the Owner's Project Requirements (OPR)	S	P	S		
2. Oversee the commissioning component of the design review process (e.g., comment incorporation, work changes, issue logs, progress reports, checklists, construction documents)	S	P	S		
3. Ensure the inclusion of the commissioning team and requirements in the design process (e.g., communications, meetings, team members, assigned responsibilities)	S	P	S		
4. Manage the commissioning team (e.g., identify specialists, document meeting content, communicate action items, resolve resistance from key members)	S	P	S		S
5. Ensure that commissioning activities are included in the contract documents	S	S	P		
6. Ensure the commissioning plan is updated	S	P			
7. Analyze cost-benefit values	S	S	P		
8. Ensure the documentation of commissioning process activities					
a. Update Owner's project requirements	S	P			
b. Ensure an updated basis of design document is received	S	S	P		
c. Define what should be included in the systems manuals	S	P			S

d. Refine training requirements in the contract documents	S	P			S
e. Confirm maintenance and operations capabilities of facilities staff	S	S			P
f. Issues and Resolution Log	S	P			

LEGEND	
CxA	Commissioning Authority
DOR	Designer of Record
FPM	Facility Project Manager
GC	General Contractor or their Subcontractor
O&M	Operations and Maintenance
P	Primary person responsible for task
PDRI	Project Definition Rating Index
PER	Preliminary Engineering Report
S	Provides support to Primary person responsible

New Buildings: Construction Phase	FPM	CxA	DOR	GC	O&M
1. Facilitate inclusion of commissioning activities during the prebid process	P	S			
2. Verify that commissioning activities have been integrated into construction schedules as needed	S	P		S	
3. Ensure the commissioning process and activities are presented during the construction kick-off meeting	P	S			
4. Validate execution of the commissioning plan	S	P		S	
5. Provide commissioning review of submittals, resolve commissioning exceptions of approved submittals & document	P	S	S	S	S
6. Ensure construction checklists are developed and completed	S	P		S	
7. Facilitate the assessment of whether checklists and tests are specific to the project within the commissioning scope, e.g.					
a. Testing protocols	S	P	S	S	S
b. Construction checklists	S	P	S	S	S
c. Startup review	S	P	S	S	S
d. Reports validation	S	P	S	S	S
e. Resolution of testing issues	S	P	S	S	S
8. Construction Observation and Testing					
a. Visually inspect installation of commissioned systems to ensure compliance with OPR and report on deficiencies	S	S		S	
b. Witness performance testing and report on deficiencies	S	P	S	S	
9. Facilitate updating of commissioning documents, e.g.					
a. Owner's project requirements	S	P	S	S	
b. Commissioning plan	S	S	S	S	
c. Issues and Resolution Log	S	S	S	P	
d. Basis of design	S	P	S		
e. Record documentation	S	S	S		
f. Systems manual	S	S	S		S
g. Training requirements	S	S			S
h. Commissioning meeting agendas, sign-in sheets and minutes	S	S		P	

10. Produce commissioning progress reports & Final Construction Commissioning Report	S				

LEGEND	
CxA	Commissioning Authority
DOR	Designer of Record
FPM	Facility Project Manager
GC	General Contractor or their Subcontractor
O&M	Operations and Maintenance
P	Primary person responsible for task
PDRI	Project Definition Rating Index
PER	Preliminary Engineering Report
S	Provides support to Primary person responsible

New Buildings: Occupancy and Operations Phase	FPM	CxA	DOR	GC	O&M
1. Ensure delivery of training for operations and maintenance staff	S	S		P	S
2. Assess the effectiveness of training for facilities operations and maintenance staff	S	P		S	S
3. Ensure seasonal testing of the facility as required	S	P	S	S	
4. Evaluate effectiveness of the systems manual	S	P		S	S
5. Direct updates to the system manual	S	S		P	
6. Resolve system deficiencies	S	S		P	
7. Convene a lessons learned workshop	S	P	S	S	S
8. Ensure development of an ongoing commissioning program for the facility	S	S			P
9. Ensure the commissioning authority participates in the evaluation of systems and assemblies performance before the one-year contractor warranty expiration	P				
10. Ensure the final commissioning documents are is delivered					
a. Government's project requirements	S	P			

b. Commissioning Report	S	P			
c. Issues and Resolution Log	S	P			
d. Basis of design	S	P			
e. Record documentation	S	P			
f. Systems manual	S	P			

LEGEND	
CxA	Commissioning Authority
DOR	Designer of Record
FPM	Facility Project Manager
GC	General Contractor or their Subcontractor
O&M	Operations and Maintenance
P	Primary person responsible for task
PDRI	Project Definition Rating Index
PER	Preliminary Engineering Report
S	Provides support to Primary person responsible

Appendix D – Lessons Learned From Postoccupancy Surveys

D.1 Postoccupancy Evaluations

NASA started a Postoccupancy Evaluation (POE) Program in 2011. At the time the program was started there was no design or construction feedback mechanism in place as a result, both HQ and the Centers were interested in establishing a lessons learned database to share with all communities of practice across the agency.

The NASA POE program consists of a series of surveys, the process evaluation, an independent evaluation and benchmarking. Besides interviewing the occupants, the facility manager and O&M staff also are surveyed. The process evaluation consists of interviewing the project planning, design, and construction teams, as well as the end user. This is done to extract the lessons learned from the process; plan through occupancy; and determine how well the facility meets the needs of the end user. The team conducting the POE also provides an independent evaluation and the facility is benchmarked against industry standards for energy, water, O&M costs, carbon emissions, and occupant satisfaction.

This commissioning guide is a result of the findings from the first four postoccupancy evaluations. These POEs consistently found issues with our commissioning process, which evolved into a series of commissioning training classes being offered across the Agency, as well as this commissioning guide. Some of the deficiencies found included that the Commissioning Agent was not always:

1. Working directly for the owner and they were not brought on early in the project planning process nor did they continue to work with the project team through turnover.

2. Comprehensive (looking at the entire building), rather than just looking at the third party certification attributes or sequence of operation verification.

3. Spot checking the TAB contractor's measurements to verify the TAB report.

4. Conducting constructability reviews.

5. Overseeing training to make sure it was adequate. This means ensuring the training is provided by the manufacturer, not the installer, that sessions are videotaped, providing multiple sessions and having at least one session scheduled 6 months after occupancy.
6. Overseeing the submittals for as-builts and O&M documentation.

7. Witnessing acceptance testing or including accommodations for seasonal testing and testing when the building was occupied, more rigorous acceptance testing and conducting additional performance testing of more complex systems such as ERUs (energy recovery

units), computerized lighting systems, and building automation systems. Also field verifying equipment performance against the design as well as verifying the contractor develops PT&I baselines for equipment and verifying that equipment installation were correct based on the PT&I tests performed (also see the RCB&EA section for more details).

8. Writing/specifying the test plans and witnessing the tests.

9. Ensuring O&M was involved in design reviews, construction inspection, testing, and submittal reviews.

10. Verifying equipment was accessible and/or maintainable.

This guide, along with the additional commissioning training, should help improve the commissioning process so that completed construction projects are delivered with no further work required after turnover to the maintenance organization.

Appendix E – Sample RFP for Commissioning Agent Solicitation

Request for Commissioning Services Proposal

Issuance Date:

Closing Date:

[CENTER], Facilities Division henceforth known as the Government, requests written proposals to secure commissioning authority (CxA) services for **[PROJECT]**. The Government is committed to commissioning this facility to systematically optimize the building and ancillary systems so that they operate efficiently and effectively in accordance with Project Requirements, and that the facility staff has adequate system documentation, and training. It is the intent of the Government to ensure that the fundamental systems are calibrated and operating as required to deliver functional and efficient performance.

The project provides a [**PROJECT/BUILDING DESCRIPTION; INCLUDE BUDGET, CURRENT PROJECT PHASE]**. The project is currently in the requirements development phase. A Project Requirements Document developed through the Conceptual Phase including space programming is provided in Appendix A. The expected schedule is to start design by **[MONTH/YEAR]**, start construction by **[MONTH/YEAR]**, and occupy by **[MONTH/YEAR]**.

The new **[PROJECT]** will incorporate the tenets of sustainability and the design principles of high performance buildings. A requirement of the project is to achieve at minimum a Leadership in Energy and Environmental Design (LEED) Silver certification by the U.S. Green Building Council (USGBC).

The CxA will plan, manage, perform and report on the commissioning activities from design through beneficial occupancy in accordance with the responsibility matrix contained within Appendix A. The CxA will submit deliverable reports to the Government Project Manager (PM) according to a project schedule set by CxA and agreed upon by the PM. It is extremely important that all commissioning tasks be conducted in a transparent manner and that they involve the Government's facility system managers, building manager, and operations staff to the greatest degree possible.

The management structure is traditional design/bid/build with full design documents and specifications to be developed by an architectural/engineering (A&E) firm. The construction documents will be let out to bid and a general contractor will be hired to complete the construction. The Government's primary construction representative onsite will be a Contracting Officers Representative who will report to the Contracting Officer and the PM.

The systems to be commissioned are:

1. Refrigeration systems
2. Heating systems

3. Steam systems
4. Air handling systems
5. Runaround loop energy recovery system
6. HVAC controls systems. The system shall tie into the building automation system and the Utility Control System.
7. Plumbing water systems
8. Life safety system including fire alarm system, standpipe and sprinkler systems, fire pump and controller, and all piping and ancillary hardware
9. Electrical systems consisting of substation transformers, switchboards, motor control centers, power and lighting panel boards, lighting fixtures, lighting controls, and connections to equipment
10. Emergency power supply systems.
11. Security systems consisting of access control and alarm monitoring
12. Indoor air quality
13. Building Envelope
14. LEED silver certification is required for this project

Scope of Work

Commissioning is required to augment the quality assurance measure of the construction of this building in order to assure that the project meets the original intent of the Owner Project Requirements. The offeror is free to suggest changes and improvements to this process. Following is a summary of the commissioning process and scope of work.

Commissioning Process During Predesign

The commissioning process activities completed by the commissioning authority (CxA) during the predesign phase include:

1. Review the Government's Owner Project Requirements (OPR) documentation for clarity and completeness, including language on the following features: mechanical, electrical, plumbing, architectural, structural, lighting, energy consumption, commissioning, indoor environmental quality, environmental sustainability, siting, exteriors, landscaping, interiors, and functionality for tenants, budget, and schedule. This will be accomplished by the commissioning authority by: extracting salient concepts from the Government's existing programming report; conducting a focus group; conducting interviews with Government system managers.

2. Identifying a scope and budget for the commissioning process.

3. Developing the initial commissioning plan.

4. Acceptance of predesign phase commissioning process activities.

Commissioning Process During Design

The commissioning process activities completed by the commissioning authority during the design phase include:

1. Work with the commissioning team to document the Government's OPR for the facility.

2. Provide input to the design professionals for documenting the Basis of Design.

3. Verify the Basis of Design in regard to the Government's OPR.

4. Attend design workshops, design reviews, and value engineering discussions held prior to the start of the construction documents phase of this work.

5. Participate in discussions relating to new technologies being evaluated to meet sustainability and energy reduction goals.

6. Complete a thorough review of the design documents, at minimum at midpoint and final design. Comments will be submitted in writing to the PM, the A&E team and the LEED consultant.

7. Provide input to A&E team to assist the A&E in development of a commissioning specification for building systems and components identified.

8. Commissioning specification shall follow the intent of ASHRAE Guideline 0-2005 *The Commissioning Process.* The commissioning specification will include a detailed description of the responsibilities of all parties, details of the commissioning process; reporting and documentation requirements (including formats), alerts to coordination issues, deficiency resolution, construction checklist and startup requirements, the functional testing process, and specific functional test requirements including testing conditions and acceptance criteria for each piece of equipment being commissioned.

9. Develop an initial commissioning plan during the predesign phase with revision during the Design Phase. Revise the commissioning plan during the Construction, Occupancy and Operations Phases.

10. Determine the minimum commissioning requirements and activities to include in the construction documents, with review by the design team, for integration into the project's construction specifications.

11. Perform commissioning design reviews at the 30%, 60%, 90%, and 100% completion of the drawings and specifications.

Commissioning Process During the Construction Phase

The commissioning process activities accomplished by the CxA during the construction phase include:

1. Organize the commissioning process components and conduct a prebid and preconstruction meeting where the commissioning process requirements are reviewed with the commissioning team.

2. Coordinate and direct commissioning activities in a logical, sequential and efficient manner using consistent protocols, clear and regular communications and consultations with all necessary parties, frequently updated timelines, schedules, and technical expertise.

3. Perform site visits, as necessary, to observe component and system installations. Accomplish a statistical review of construction focusing on the design intent and the quality process. Attend selected planning and job-site meetings to obtain information on construction progress. Review construction meeting minutes for revisions/substitutions relating to the design intent. Assist in resolving any discrepancies.

4. With necessary assistance and review from the installing contractors, develop and write construction checklists. Submit to Government PM for approval.

5. Organize and conduct periodic commissioning team meetings necessary to plan, develop the scope, coordinate, schedule activities and resolve problems.

6. Review submittals concurrent with the design professional's review.

7. Work with contractors in completing construction checklists and tracking of checklist completion.

8. Statistically sample completion of construction checklists on a periodic basis to verify that contractor's quality process is achieving the project requirements.

9. Approve systems startup by reviewing startup reports and by selected site observation.

10. With necessary assistance and review from installing contractors, write the test procedures. Submit to PM for review and approval.

11. Assist Government PM or his representative to coordinate the execution of contractor's the tests.

12. Coordinate, witness, and recommend approval of test procedures performed by installation contractors. Coordinate retesting as necessary until satisfactory performance is achieved.

13. Recommend approval of air and water systems balancing through statistical sampling of the report and separate field verification.

14. Maintain a master issues log and a separate testing record. Provide to the PM written progress reports and test results with recommended actions; report on deficiencies not corrected in a timely manner.

15. Document the correction and retesting of noncompliance items by the contractor.

16. Reviews the systems manual for achieving the owner's project requirements.

17. Review, recommend preapproval, and verify the training provided by the contractors.

Commissioning Process During the Occupancy and Operations Phase

The commissioning process activities accomplished by the CxA during the occupancy and operations phase include:

1. Schedule and verify deferred and seasonal testing by the contractor.

2. Verify continuing training.

3. Schedule, organize, and attend a lessons-learned workshop. The workshop is facilitated by an independent member of the commissioning authority's firm.

4. Complete the final Commissioning Process Report.

5. Assist in the development of a preventative maintenance plan, a detailed operating plan or an energy and resource management plan.

6. Return to the site at 10 months into the 12-month warranty period. Review with facility staff the current building operation and the condition of outstanding issues related to the original and seasonal commissioning. Also interview facility staff and identify problems or concerns they have with operating the building as originally intended. Make suggestions for improvements and for recording these changes in the O&M manuals. Identify areas that may come under warranty or under the original construction contract. Assist facility staff in developing reports and documents and requests for services to remedy outstanding problems.

Responsibilities Not Attributable to the Commissioning Authority

The CxA is not required to:

1. Establish design concepts, design criteria for compliance with codes, design or general construction scheduling, cost estimating, or construction management. The CxA may assist with problem-solving or resolving nonconformance or deficiencies, but ultimately that responsibility resides with the A&E, general construction contractor, or Government PM. The CxA will report to the Government any deficiencies or discrepancies.

2. Issue change orders; CxA may be required to review change orders for compliance with the construction documents. Noncompliances will be reported to the PM.

Observation and Testing Requirements

Equipment or Systems	Sampling Rate
HVAC Systems	
Chillers	100%
Cooling Towers/Evaporative Fluid Cooler	100%
Boilers and Associated Equipment	100%
Heating Heat Exchangers	100%
Pumps	100%
Air Handling Units	100%
Laboratory Exhaust Fan Systems	100%
Ventilation Fans	25%
VFDs	100%
Air Terminal Units	25%
Laboratory Air Valves	100%
Ductwork	50%
HEPA Filter Systems	100%
Piping	25%

Temperature Control	75%
Building Automation Systems	
Temperature/Humidity Sensors	100%
Pressure Sensors and Controllers	100%
Sequence of Operation	100%
Airflow Stations	100%
Damper/Valve Actuators	100%
Plumbing and Fire Protection Systems	
Plumbing Equipment	25%
Plumbing Fixtures	25%
Plumbing Piping Systems	25%
Effluent Decontamination System	100%
Animal Watering System	100%
Fire Pump	100%
Electrical Systems	
Normal Power Electrical Systems	50%
Emergency Power Systems	100%
Fire/Life Safety Systems	50%
Security Systems	100%
Miscellaneous Systems	
IAQ Preoccupancy - office	100%
IAQ Postoccupancy - office	100%

Desired Qualifications

It is the Government's desire for the person(s) designated as the site commissioning authority (CxA) to satisfy as many of the following requirements as possible:

- Has acted as the principal commissioning authority for at least three projects of comparable size, type, and scope.
- Extensive experience in the operation and troubleshooting of HVAC systems and energy management control systems.
- Extensive field experience. A minimum of 5 full years in this type of work is required.
- Knowledgeable in building operation and maintenance and O&M training.

- Knowledgeable in national building and fire codes as well as water-based fire extinguishing systems, detection systems and alarms systems.
- Knowledgeable in test and balance of both air and water systems.
- Experienced in energy-efficient equipment design and control strategy optimization.
- Demonstrated experience with total building commissioning approach including building envelope, data and communication systems and other specialty systems.
- Direct experience in monitoring and analyzing system operation using energy management control system trending and stand-alone data logging equipment.
- Excellent verbal and writing communication skills. Highly organized and able to work with both management and trade contractors.
- Experienced in writing commissioning specifications.
- A bachelor's degree in mechanical or electrical engineering is strongly preferred, and P.E. license is desired. However, other technical training and past commissioning and field experience will be considered as a substitute.
- Membership and certification as a Certified Commissioning Professional with the Building Commissioning Association is desired but not required.

The required expertise for this project will be based on the skill and experience set of the full team making the proposal. A member of the prime firm will be the designated commissioning authority who is the member of the team that will coordinate the commissioning activities from the technical perspective. This party may not necessarily be the team's overall project or contract manager. The commissioning authority must have significant in-building commissioning experience, including technical and management expertise on projects of similar scope. If the commissioning authority or prime firm does not have sufficient skills to commission a specific system, the prime firm shall subcontract with a qualified party to do so. Subcontractor qualifications shall be included and clearly designated in the response to this scope of work.

Preproposal Meeting

A preproposal meeting will be held to answer questions and clarify any project issues. Attending the meeting is not required to submit a proposal. The meeting will be held at: **[location and time of the meeting]**

Proposal

Proposals need not be voluminous, but shall provide sufficient information to allow the Government to evaluate the consultant's approach, experience, staff and availability. The proposer shall:

1. Limit their proposal to 20 single-sided pages, including graphics. A letter of introduction, section dividers, detailed resumes and the sample work products are not included in this limit.

2. Have the proposal signed by an officer of the proposing firm with the authority to commit the firm.

3. Fill out the attached Commissioning Firm Experience form and the Commissioning Task Listing form (Exhibits 1 and 2) for each firm on the team. List no more than four projects in Exhibit 2.

4. List the individual(s) who will serve as the lead CxA for the design phase and for the construction phase of the contract.

5. Provide resumes for key staff and subconsultants. The resumes shall include specific information about expertise in commissioning tasks, (e.g. design reviews, specification writing, commissioning management, troubleshooting, test writing, test execution, energy management, sustainable design, etc.).

6. Briefly describe "relevant" experience (project phasing, life cycle costing, testing, adjusting and balancing, building simulation, IAQ, campus projects, etc.) of the proposer's team in the following areas. List involvement of key team members.

- Projects similar to this one
- O&M experience
- Energy-efficient equipment design and control strategy optimization
- Project and construction management
- System design (specify)
- Troubleshooting

7. Describe your proposed approach to managing the project expertly and efficiently, including distribution of tasks, travel, and duration of which staff will be on site during what periods of time, etc. Describe how you intend to determine the appropriate level of commissioning effort for the various systems and equipment.

8. As an attachment, provide the following work products that members of the proposer's team developed. List the team member who actually wrote the document and the projects on which they were used. Work from the designated CxA is preferred.

- Retrocommissioning plan that was executed (the process part of the plan)
- An actual functional test procedure form that was executed

9. Provide a statement of proposer's liability insurance coverage (type, and dollar amount of coverage). Proof of this insurance will be required prior to the award of this contract to the winning proposal.

10. Provide a fixed, lump sum total cost to accomplish the work for the following phases: predesign and design, construction, occupancy and operations. All task amounts include associated meetings, progress reports and direct costs (travel, mileage, per diem, communications, etc.). Use the budget table shown in Exhibit 3 (or a suitable equivalent) to provide a cost breakdown. Also provide an hourly rate for each team member for work that may exceed the scope. For each phase, provide the percentage level of effort for each primary team member.

11. For planning purposes, the proposer must also provide a cost "estimate" range for the construction and warranty phase tasks using the form below. Also provide an hourly rate

for each team member for work that may exceed the scope. For each phase, provide the percentage level of effort for each primary team member.

12. Use the budget table shown in Exhibit 3 (or a suitable equivalent) to provide a cost breakdown.

The respondent must submit three (3) copies of the proposal, each signed by an authorized representative of the firm. Facsimiles will not be accepted. Proposals must be submitted to arrive no later than close of business, 5:00 p.m. [EST] [CST] [MST] [PST], on [Insert Date] to:

[Location for Proposal Delivery]

Selection Process

Government staff shall review all proposals and select and rank the three (3) most qualified consultants. The selection and ranking shall be based on the following criteria (not necessarily listed in order of importance):

☐ Key individual experience	20 points
☐ Past experience in performing similar projects	20 points
☐ Expertise of the team in performing the services required by the project	15 points
☐ Management approach	20 points
☐ Staff experience	15 points
☐ Work examples	10 points

The Government [or the Government's representative] will negotiate/interview with the highest ranked consultant on the tasks, staffing, schedule, and fee proposal. Negotiations may be formally terminated if they fail to result in a contract within a reasonable time period. Negotiations will then ensue with the second ranked consultant, and if necessary, the third ranked consultant.

Commissioning Firm Experience

FILL OUT A SEPARATE FORM FOR EACH FIRM ON THE TEAM

Company Name Contact Person
Title

Address City State Zip/Postal Code

Telephone Fax E-Mail

Description of Business

Commissioning Activities

Percentage of overall business devoted to commissioning _____%
How long has the firm offered commissioning services _____years
Average number of commissioning projects performed each year: _____projects

Number of registered engineers on staff who have directed commissioning projects:

The firm has provided commissioning services in the following: (check all that apply)

Building Sector	New Construction Major Renovation	Existing Building Retrocommission/ Recommission	Existing Building Equipment Replacement
Office or retail	☐	☐	☐
Hospitals	☐	☐	☐
Assisted Living	☐	☐	☐
Laboratories	☐	☐	☐
Multi Family	☐	☐	☐
Industrial/Manufacturing	☐	☐	☐
Special purpose–prisons, museums, libraries, etc.	☐	☐	☐
Other; Describe	☐	☐	☐

Commissioning Task Experience for Similar Projects

FILL OUT A SEPARATE FORM FOR EACH FIRM ON THE TEAM

Project (Name, Date, Bldg Size, Type, new or existing)	
Owner Contact (Title, City, State, and Phone)	
Name & Role of Persons(s) Assigned to Project by Firm (identify any sub-consultants)	

	Task	✓	Comments
Commissioning	Developed Owner's Project Requirements		
	Wrote commissioning plan		
	Wrote commissioning specs		
	Wrote construction checklists		
	Wrote functional test procedures		
	Witnessed and documented functional tests		
	Performed functional tests (hands-on)		
	Wrote systems manual		

	Task	✓	Comments
	Used data loggers or EMS trend logs for testing		
	Developed or approved staff training		
	Reviewed completed O&M manuals		
Management	Commissioning provider was part of the firm		
	Supervised a subconsultant commissioning provider to our firm.		
	Worked with a commissioning provider hired by others		

	✓	System or Equipment
Commissioning Tasks Performed	☐	Central building automation system
	☐	All equipment of the heating, ventilating and air conditioning systems
	☐	Enhanced filtration units
	☐	Scheduled or occupancy sensor lighting controls
	☐	Daylight dimming controls
	☐	Refrigeration systems
	☐	Emergency power generators and automatic transfer switching
	☐	Uninterruptible power supply systems
	☐	Life safety systems (fire alarm, egress pressurization, fire protection)
	☐	Electrical (service switchgear, switchboards, distribution panels, transformers, motor control centers, power monitoring and metering, transient voltage surge suppressors, variable speed drives, grounding and ground fault systems, over current protective devices, low-voltage bussway, thermographic survey, white sound system).

	✓	System or Equipment
	☐	Domestic and process water pumping and mixing systems
	☐	Equipment sound control systems and testing
	☐	Data and communication
	☐	Paging systems
	☐	Security system
	☐	Irrigation
	☐	Plumbing
	☐	Vertical transport
	☐	Building envelope including the different types of curtain wall assemblies (specify roofing, windows and doors, construction joints, etc.)
	☐	Sustainability features
	☐	Effluent decontamination systems
	☐	Process instrumentation and controls
	☐	Other: Describe as an attachment to this exhibit

Budget Table

	Task	Budget ($)
Predesign and Design		
1.	Develop or review Owner's Project Requirements (per scope)	
2.	Design documents reviews of plans, specifications; narratives	
3.	Commissioning plan, specification development and bid meeting	
4.	Other	
	Subtotal	
Construction		
1.	Commissioning plan and submittal reviews	
2.	Construction checklists; observation of installation and startup	
3.	Functional test writing	
4.	Functional test execution and documentation	
5.	O&M manual review and training review	
6.	Compilation of commissioning record	
7.	Systems manual development	
8.	Other	
	Subtotal	
Occupancy and Operations		
1.	Seasonal testing	
2.	Near-warranty end review	
3.	Other	
4.	Other	
	Subtotal	

Task	Budget ($)
Total	

Appendix F – Sample Commissioning Plan Outline

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Appendix G – Building Commissioning Certification/Training Programs*

CERTIFICATION	ELIGIBILITY		TRAINING	
Certification Title & Provider	**Cx experience required?**	**Membership required?**	**Required, optional, or not provided?**	**Covers NC or EB commissioning?**
CxA Certified Commissioning Authority AABC Commissioning Group	yes	yes	optional	both
CxT Certified Commissioning Technician AABC Commissioning Group	no	yes	required	both
CBCP Certified Building Commissioning Professional Association of Energy Engineers	no	no	required	both
EBCP Existing Building Commissioning Professional Association of Energy Engineers	no	no	N/A	N/A

CPMP Certified Process Management Professional American Society of Heating, Refrigerating and Air-Conditioning Engineers	yes	no	not provided	N/A
CCP Certified Commissioning Professional Building Commissioning Association	yes	no	optional	either
BSC certification Building System Commissioning certification National Environmental Balancing Bureau	no	yes	optional	New Construction (NC)
RCx certification Retrocommissioning certification National Environmental Balancing Bureau	no	yes	optional	Existing Building (EB)
CCS Certified Commissioning Supervisor Testing Adjusting and Balancing Bureau	no	yes	optional	both
CCC Certified Commissioning Contractor Testing Adjusting and Balancing Bureau	yes	yes	N/A	N/A

QCxP or QCP Accredited Qualified Commissioning Process Provider University of Wisconsin-Madison	no	no	required	both
CxAP or CAP Accredited Commissioning Process Authority Professional University of Wisconsin-Madison	yes	no	required	both
CxM Accredited Commissioning Process Manager University of Wisconsin-Madison	yes	no	required	both
CxTS or CTS Accredited Commissioning Process Technical Support Provider University of Wisconsin-Madison	yes	no	required	both
GCxP or GCP Accredited Green Commissioning Process Provider University of Wisconsin-Madison	yes	no	required	both

*The reference for the commissioning certification is the California Commissioning Collaborative.

1. Certified Commissioning Authority (CxA)

Provider

AABC Commissioning Group (ACG)

Eligibility

Certification is open to independent commissioning companies that are eligible for ACG membership and employ at least one person who qualifies for and passes the ACG certification examination. Certification is issued in the name of the company and designated individual, who

shall be a registered engineer, licensed architect or certified test and balance engineer, or be able to demonstrate sufficient commissioning experience. Applicants shall have completed at least three projects as a commissioning service provider.

Training

Candidates may attend an ACG seminar, but are not required to. Seminars cover both existing building and new construction commissioning. Participants may complete the training either during a 5-hour, in-person workshop or 2.5-hour, virtual, instructor-led Webinar. Training does not offer a hands-on lab or continuing education units. In-person workshops are offered each year before ACG's annual conference, as well as at two or three additional locations that vary from year to year.

Exam

The multiple-choice exam is closed-book and lasts 3 hours. It covers the commissioning process and knowledge of the HVAC industry gained through field experience. Candidates can schedule the exam at testing centers in most metropolitan areas or sit for it immediately after a workshop or seminar. The passing score is 70%.

Cost

- Membership application and exam fee: $250
- Annual corporate membership dues: $1,500
- Certification renewal fee: $100 per person
- Workshop (including exam): $650 per person
- Webinar (does not include exam): $650 (one connection, unlimited participants)

Renewal

Certification is renewable annually, subject to receipt of a completed certification renewal form, compliance with continuing education requirements, review of past performance, and payment of dues and fees.

2. Certified Commissioning Technician (CxT)

Provider

AABC Commissioning Group (ACG)

Eligibility

The Certified Commissioning Technician (CxT) is a second-tier certification for those who do not yet possess the technical, industry, or commissioning experience to qualify for the CxA. CxT candidates shall work for an ACG member company, under the supervision of a CxA. Additional prerequisites for CxT certification include a minimum of 2 years' field testing experience, at least 6 months working for the ACG Member Company at which the candidate is presently employed, and endorsement by a CxA at that company.

Training

Candidates shall attend an ACG workshop or Webinar before becoming certified. See ACG CxA description for training details.

Exam

The multiple-choice exam is closed-book and lasts 3 hours. It is based on material in the ACG Commissioning Guideline and the CxT Study Guide. Candidates can schedule the exam at testing centers in most metropolitan areas or sit for it immediately after a workshop or seminar. The passing score is 70%.

Cost

- Membership application and exam fee: $200
- Annual corporate membership dues: $1,500
- Certification renewal fee: $50 per person
- Workshop (including exam): $650 per person
- Webinar (does not include exam): $650 (one connection, unlimited participants)

Renewal

Certification is renewable annually, subject to receipt of a completed certification renewal form, compliance with continuing education requirements, review of past performance, and payment of dues and fees.

3. Certified Building Commissioning Professional (CBCP)

Provider

Association of Energy Engineers (AEE)

Eligibility

AEE certifies individuals. Candidates shall have one of the following:

- A 4-year technical degree in a specified field or engineer or architect registration, plus 3 years' experience in one of the following:
  - Facilities management
  - HVAC
  - Process engineering design; construction project management; electrical/controls design; installation or operations; testing, adjusting, and balancing; or building commissioning
- A 2-year technical degree or vocational school certificate in HVAC/electrical; valid HVAC or electrician contracting license; or 4-year nontechnical degree with 5 years of HVAC/electrical experience
- 10 years of HVAC/electrical experience, if no degree
- The current status of Certified Energy Manager (CEM)

Training

Certification requires 3- or 5-day in-person training. Classroom lectures focus on process rather than technical subjects. Training covers project scheduling, roles and responsibilities, new building commissioning, retro- and recommissioning, system-by-system commissioning requirements, TAB and verification procedures, the LEED rating system, building code issues, and commissioning tools and technologies. Training is scheduled in Las Vegas and Washington, DC and earn AIA Continuing Education Units (CEUs) and Professional Development Hours (PDHs).

Exam

A 4-hour, open-book exam immediately follows the training. Multiple choice and true or false questions cover the basic building commissioning process. The passing score is 70%.

Cost

- Certification application and examination: $200
- 3-day CBCP Seminar: $1,250 for AEE members/Government/nonprofit; $1,350 for nonmembers
- 5-day CBCP seminar: $1,695 for AEE members/Government/nonprofit; $1,895 for nonmembers

- Certification renewal: $200 every 3 years

Renewal

A CBCP shall accumulate 10 professional credits every 3 years to maintain certification. Credits accrue from continued commissioning activities, professional memberships, continuing education, awards, and offices held in trade societies.

4. Existing Building Commissioning Professional (EBCP)

Provider

Association of Energy Engineers (AEE)

Eligibility

Candidates shall meet the experience qualifications for the AEE CBCP described above.

Training

Candidates may attend an AEE Fundamentals of Existing Building Commissioning (prep: EBCP Certification) before taking exam. See AEE link for details.
http://www.aeeprograms.com/store/detail.cfm?id=1044&category_id=4

Exam

The EBCP exam follows the same criteria as the CBCP exam listed above.

Cost

- Certification application and examination: $200
- Certification renewal: $200 every 3 years

Renewal

An EBCP shall follow the same certification maintenance requirements as a CBCP listed above.

5. Certified Process Management Professional (CPMP)

This certification helps building owners, developers, standards writing agencies and others assess the capability of individuals to manage the whole building commissioning process. The CPMP oversees and coordinates the commissioning process and communicates on behalf of the building owner with the commissioning provider and the commissioning team.

Provider

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

Eligibility

ASHRAE certifies individuals who have been involved with at least three Cx projects and have one of the following:

- Professional engineer, architect or building contractor license with a minimum of 3 years' facilities operations/management, construction, design or consulting experience
- Bachelor's Degree in engineering, architecture or related field and a minimum of 6 years' facilities operations/management, construction, design, or consulting experience
- Associate's degree or technical diploma in building design, construction, construction management, facility operation, or a related field and a minimum of 7 years' facilities operations/management, construction, design, or consulting experience
- High school diploma or equivalent or construction-related trades training or building operations training from a nationally or internationally recognized trade association with a minimum of 10 years' facilities operations/management, construction, design, or consulting experience

Training

No training required. ASHRAE, however, provides a list of resources that candidates may choose to review.

Exam

The multiple-choice exam is closed-book and lasts 2.5-hours. ASHRAE administers exams by computer at 150 test centers distributed geographically throughout the United States. Topics include the Cx process for new buildings (60% weighting), the Cx process for existing buildings (25% weighting) and the ongoing Cx process (15% weighting). ASHRAE does not publish its minimum passing score.

Cost

- Exam fee: $295 for members, $415 for nonmembers
- Certification renewal fee: $125 for members, $195 for nonmembers

Renewal

Certification is renewable every 3 years. Certificates shall earn 45 continuing education units, as defined by ASHRAE, during that time.

6. Certified Commissioning Professional (CCP)

Provider

Building Commissioning Association (BCA)

Eligibility

BCA certifies individuals. Candidates shall:

- Have at least a high school education
- Have at least 36 continuous months of experience as a commissioning services provider in a lead project role within 5 years preceding the date of application. (Projects shall total a minimum of 150,000 square feet and $30,000,000 construction costs)
- Meet additional experience requirements based on level of education

Training

No training required. The BCA certifies seasoned professionals who meet the minimum requirements of experience and years in the commissioning industry. However, candidates may prepare for the exam by attending training offered by BCA.
http://www.bcxa.org/training/classes/

Exam

The BCA exam is a closed-book, 2-hour, multiple-choice test containing 125 questions. Some questions are scenario-based. The exam is available via computer at testing centers in most metropolitan areas. The passing score is 70%.

Cost

- Application: $350 for BCA members, $550 for nonmembers
- Exam: $150

Renewal

Certification is renewable every 3 years, based on evidence of continued competence, as demonstrated by additional work experience and other related professional activities.

7. Building System Commissioning (BSC) Certification

The BSC is a certification for firms that employ an NEBB-certified representative who receives the designation BSC Certified Professional (CP).

Provider
National Environmental Balancing Bureau (NEBB)
Eligibility
Firms shall be in business for 1 year; provide six letters of endorsement; be affiliated with a local NEBB chapter; possess and maintain the required calibrated instruments; confirm in writing that they will follow NEBB's standards; and possess the current Procedural Standards. CPs shall have one of the following:

- Bachelor's Degree in engineering with 2 years of supervisory experience in HVAC installation or design
- An Associate's Degree in engineering technology with 4 years of supervisory experience in TAB or in the HVAC industry
- 4 years of TAB or design experience and 4 years of supervisory experience in TAB or HVAC
- 4 years of HVAC and 2 years of TAB experience, plus 4 years of supervisory experience in TAB or HVAC

Training
NEBB offers a 4-day BSC seminar, but candidates are not required to complete any training. The NEBB Training & Educational Center (NEBB TEC) in Tempe, AZ, hosts the seminar, which covers both process management and technical topics within the overall subject of existing building commissioning. The seminar has hands-on elements and is not accredited to provide continuing education units.
Exam
Candidates shall pass multiple-choice, open-book examinations on procedural standards, whole building commissioning processes and deliverables, and HVAC and building control system commissioning. Altogether, the exams comprise 6 hours of testing. Exams are administered after seminars in Tempe and from time to time after seminars in other locations. The passing score is 70%.
Cost
Firms pay a $1,300 base fee, plus $50 for each CP, plus a $250 quality assurance process fee, plus a $225 BSC discipline fee annually (if a firm has only one CP the total annual fee would be $1,825, and if the firm has two CPs the annual fee would be $1,875). The optional seminar costs $1,500.
Renewal
Firm and individual certification is renewable every 2 years. Firms shall provide evidence of ownership and calibration of all required instrumentation. BSC renewal also requires maintenance of a full-time CP. CP renewal requires 12 hours of continuing education and participation in commissioning review assignments.

8. Retrocommissioning (RCx) Certification

The NEBB RCx is a certification for firms that employ a NEBB-certified representative who receives the designation RCx Certified Professional (CP).
Provider
National Environmental Balancing Bureau (NEBB)
Eligibility

Eligibility requirements are the same as for the NEBB BSC described above.

Training

Attendance at a NEBB RCx seminar is not required. The seminar occurs at least annually at various locations and dates. It includes process management and technical topics with hands-on components and is not accredited for continuing education units.

Exam

Both NEBB and TABB administer the exams, which are multiple-choice and open-book, and comprise 4 hours of testing. Exams are administered after seminars in Tempe and from time to time after seminars in other locations. The passing score is 70%.

Cost

Fees are the same as for the NEBB BSC described above, except for training. The optional seminar costs $1,150.

Renewal

Firm and individual renewal requirements are the same as for the NEBB BSC described above.

9. Certified Commissioning Supervisor

Provider

Testing Adjusting and Balancing Bureau (TABB)

Eligibility

TABB certifies that individuals are competent and trained in commissioning HVAC systems to Sheet Metal and Air Conditioning Contractors National Association (SMACNA) standards. To qualify, applicants shall be working for a contractor that makes contributions to the National Energy Management Institute Committee (NEMIC). Applicants also shall have one of the following:

- A 4-year degree in engineering with at least 1 year of experience in HVAC installation or design
- A 2-year degree in HVAC with at least 3 years of experience in HVAC installation or design
- International Training Institute certification as a TAB technician and 5 years of experience in HVAC installation or design, at least 1 year of which shall be in testing, adjusting, and balancing
- 5 years of experience in testing, adjusting, and balancing and a written recommendation for the exam by the applicant's employer, who shall be eligible to be an ICB/TABB certified contractor, except for the requirement of employing a Certified Commissioning Supervisor

Training

Eligible applicants may attend a training session when scheduled. Sessions are conducted by the National Energy Management Institute and cover the commissioning process and technical topics using the SMACNA Commissioning of HVAC Systems standards as a guideline. Participants receive a certificate of completion.

Exam

Applicants shall pass a 2.5-hour written exam that is available immediately after the training or at testing centers in most major cities. The test is open-book with multiple choice questions. The passing score is 70%.

Cost

- Application: $50
- Training: free to eligible applicants
- Renewal: free

Renewal
Certification is renewable every 2 years. Certificants shall retain employment with a TABB-approved contractor and earn 6 CEUs.

10. Certified Commissioning Contractor (CCC)

Provider
Testing Adjusting and Balancing Bureau (TABB)
Eligibility
The CCC is TABB's statement that a contractor has all the necessary resources, competence, and integrity in commissioning building environmental systems to produce the design objectives or optimum system performance. TABB certifies firms that make contributions to the National Energy Management Institute Committee (NEMIC). Firms also shall:

- Employ a TABB Certified Commissioning Supervisor and a technician who has approved certification
- Possess the required manuals and forms
- Adopt the TABB Customer Satisfaction Procedure
- Have been in business for 12 months with demonstrable competence and integrity in the HVAC business
- Furnish five reference letters from local architects, building owners, consulting engineers, or contractors
- Demonstrate a history of commissioning to SMACNA standards and commissioning work that conforms with TABB standards

Exam
TABB may perform a site visit.
Cost

- Application: $50
- Renewal: free

Renewal
Certification is renewable every 2 years. Certificants shall show that they continue to meet all qualifications and requirements for initial certification.

11. Accredited Qualified Commissioning Process Provider (QCxP℠ or QCP)

Provider
University of Wisconsin-Madison (UWM)
Eligibility
All applicants receive this certification upon successful completion of an examination (no application form is necessary). The QCxP℠ is valid for 5 years to allow the applicant time to gain project experience necessary for any of the other certifications.
Training
Applicants shall complete the 3-day "Commissioning Process for Delivering Quality Constructed Projects" course plus at least one of the 2-day UWM specialized Cx topic courses. These classroom courses may be taken at different offerings. The courses are offered in either Madison or Las Vegas and shall be completed before taking the exam. Completion of the 5-day

BCA course offered by UWM is an approved alternative for satisfying the coursework requirement. All training is heavily process oriented, with some hands-on activities in the classroom. It covers new construction commissioning, with special topic courses available for existing building commissioning or LEED Cx. All applicants shall complete the certification orientation/review training session before the exam.

Exam

Applicants shall receive a score of 80% on a four-part exam that includes a mix of exercises and multiple-choice questions. The exam is offered after the required training.

Cost

- Orientation/review, study guide, examination: $675
- Recertification: $195
- "Commissioning Process for Delivering Quality Constructed Projects" course: $1,495
- Special Cx topic courses: $995
- Both courses in 1 week: $2,195
- BCA 5-day course at UWM: $2,195
- BCA member discounts are available for courses.

Renewal

Certification is renewable every 5 years. Renewal applicants shall answer a survey and complete a short, nongraded quiz.

12. Accredited Commissioning Process Authority Professional (CxAP℠ or CAP)

Provider

University of Wisconsin-Madison (UWM)

Eligibility

The CxAP℠ acknowledges individuals who have served as the primary commissioning authority during all project stages (predesign through occupancy) on a minimum number and size of projects. Applicants shall provide documentation on two major or four smaller new construction or rehab projects or equivalent existing building projects, including letters of reference by project owners. Applicants shall pass the examination before submitting the application for CxAP℠.

Training

Applicants shall complete the 3-day "Commissioning Process for Delivering Quality Constructed Projects" course plus at least one of the 2-day UWM specialized Cx topic courses. These classroom courses may be taken at different offerings. The courses are offered in either Madison or Las Vegas, and shall be completed before taking the exam. Completion of the 5-day BCA course offered by UWM is an approved alternative for satisfying the coursework requirement. All training is heavily process oriented, with some hands-on activities in the classroom. It covers new construction commissioning, with special topic courses available for existing building commissioning or LEED Cx. All applicants shall complete the certification orientation/review training session before the exam.

Exam

Applicants shall receive a score of 80% on a four-part exam that includes a mix of exercises and multiple-choice questions. The exam is offered after the required training.

Cost

- Orientation/review, study guide, examination: $675

- Recertification: $195
- "Commissioning Process for Delivering Quality Constructed Projects"course: $1,495
- Special Cx topic courses: $995
- Both courses in one week: $2,195
- BCA 5-day course at UWM: $2,195
- BCA member discounts are available for courses.

Renewal

Certification is renewable every 5 years. Renewal applicants shall answer a survey and complete a short, nongraded quiz.

13. Accredited Commissioning Process Manager (CxM℠)

Provider

University of Wisconsin-Madison (UWM)

Eligibility

The CxM℠ distinguishes individuals who have managed commissioning process activities within their organizations, such as university or Government in-house programs. Applicants shall provide documentation on two major or four smaller new construction or rehab projects or equivalent existing building projects, including letters of reference. Applicants shall pass the examination before submitting the application for CxM℠.

Training

Applicants shall complete the 3-day "Commissioning Process for Delivering Quality Constructed Projects" course, plus at least one of the 2-day UWM specialized Cx topic courses. These classroom courses may be taken at different offerings. The courses are offered in either Madison or Las Vegas, and shall be completed before taking the exam. Completion of the 5-day BCA course offered by UWM is an approved alternative for satisfying the coursework requirement. All training is heavily process oriented, with some hands-on activities in the classroom. It covers new construction commissioning, with special topic courses available for existing building commissioning or LEED Cx. All applicants shall complete the certification orientation/review training session before the exam.

Exam

Applicants shall receive a score of 80% on a four-part exam that includes a mix of exercises and multiple-choice questions. The exam is offered after the required training.

Cost

- Orientation/review, study guide, examination: $675
- Recertification: $195
- "Commissioning Process for Delivering Quality Constructed Projects" course: $1,495
- Special Cx topic courses: $995
- Both courses in one week: $2,195
- BCA 5-day course at UWM: $2,195
- BCA member discounts are available for courses.

Renewal

Certification is renewable every 5 years. Renewal applicants shall answer a survey and complete a short, nongraded quiz.

14. Accredited Commissioning Process Technical Support Provider (CxTS℠ or CTS)

Provider

University of Wisconsin-Madison (UWM)

Eligibility

The CxTS℠ highlights the skill and experience of individuals who have provided commissioning services primarily in select project stages, on small or limited scope projects, or who provide key technical support to commissioning activities. Applicants shall provide documentation on two major or four smaller new construction or rehab projects or equivalent existing building projects, including letters of reference. Applicants shall pass the examination before submitting the application for CxTS℠.

Training

Applicants shall complete the 3-day "Commissioning Process for Delivering Quality Constructed Projects" course plus at least one of the 2-day UWM specialized Cx topic courses. These classroom courses may be taken at different offerings. The courses are offered in either Madison or Las Vegas, and shall be completed before taking the exam. Completion of the 5-day BCA course offered by UWM is an approved alternative for satisfying the coursework requirement. All training is heavily process oriented, with some hands-on activities in the classroom. It covers new construction commissioning, with special topic courses available for existing building commissioning or LEED Cx. All applicants shall complete the certification orientation/review training session before the exam.

Exam

Applicants shall receive a score of 80% on a four-part exam that includes a mix of exercises and multiple-choice questions. The exam is offered after the required training.

Cost

- Orientation/review, study guide, examination: $675
- Recertification: $195
- "Commissioning Process for Delivering Quality Constructed Projects" course: $1,495
- Special Cx topic courses: $995
- Both courses in one week: $2,195
- BCA 5-day course at UWM: $2,195
- BCA member discounts are available for courses.

Renewal

Certification is renewable every 5 years. Renewal applicants shall answer a survey and complete a short, nongraded quiz.

15. Accredited Green Commissioning Process Provider (GCxP℠ or GCP)

Provider

University of Wisconsin-Madison (UWM)

Eligibility

This certification recognizes individuals who lead commissioning process activities as commissioning authorities (the CxP team leader) on new or existing building projects that emphasize green and sustainable building principles. This includes the Commissioning Process team leader as designated by titles other than commissioning authority, which may be used by some organizations. Applicants shall provide documentation on four green building new

construction or major rehab projects or existing building projects, including letters of reference (or two projects that achieve either LEED Enhanced Commissioning or all six LEED EB commissioning points). Applicants shall pass the examination before submitting the application for GCxP℠.

Training

Applicants shall complete the 3-day "Commissioning Process for Delivering Quality Constructed Projects" course, plus at least one of the 2-day UWM specialized Cx topic courses. These classroom courses may be taken at different offerings. The courses are offered in either Madison or Las Vegas, and shall be completed before taking the exam. Completion of the 5-day BCA course offered by UWM is an approved alternative for satisfying the coursework requirement. All training is heavily process oriented, with some hands-on activities in the classroom. It covers new construction commissioning, with special topic courses available for existing building commissioning or LEED Cx. All applicants shall complete the certification orientation/review training session before the exam.

Exam

Applicants shall receive a score of 80% on a four-part exam that includes a mix of exercises and multiple-choice questions. The exam is offered after the required training.

Cost

- Orientation/review, study guide, examination: $675
- Recertification: $195
- “Commissioning Process for Delivering Quality Constructed Projects” course: $1,495
- Special Cx topic courses: $995
- Both courses in one week: $2,195
- BCA 5-day course at UWM: $2,195
- BCA member discounts are available for courses.

Renewal

Certification is renewable every 5 years. Renewal applicants shall answer a survey and complete a short, nongraded quiz.

Appendix H – Sample Commissioning Scopes of Work

H.1 Retrocommissioning Lite Sample SOW

SCOPE OF WORK

RETROCOMMISSIONING LITE

Trenton Federal Courthouse Project

402 East State Street, Trenton, NJ 08608

AND

Camden Federal Courthouse Project

401 Market Street, Camden, NJ 08101

December 18, 2006

PURPOSE

Retrocommissioning Lite applies a systematic investigation process for improving and optimizing a building's operation with respect to the energy management control of most of the HVAC components. It may or may not emphasize bringing the building back to its original intended design. In fact, the original design sequence of operations may be adequate but there are generally opportunities to improve on them. Retrocommissioning ensures system functionality. Recommendations shall be made to investigate further capital improvements but it is the operation tune-up activities and diagnostic testing that is the function of this scope and will be used to optimize the building systems. The Retrocommissioning process will focus on the dynamic energy-using systems with the goal of reducing energy waste, obtaining energy cost savings for the owner, and identifying and fixing existing problems.

For purposes of this evaluation the retrocommissioning team shall consist of:

- Maintenance Contractor

- Controls Contractor
- Testing and Balance Contractor
- Mechanical Engineer with extensive controls experience

The project team leader will be the Mechanical Engineer since it will be his responsibility to coordinate the team efforts, assign tasks, and identify control modifications/enhancements and record changes. This project consists of approximately three intensive weeks (120 hrs) of onsite commissioning. It is not the intent of the project to solve all issues but to provide a more efficient system and allow the maintenance contractor to obtain better understanding of relationships between the engineers design intent and the control system execution of the sequence of operation.

TYPICAL RETROCOMMISSIONING PHASE TASKS

The retrocommissioning process can be viewed as consisting of four primary phases:

1. Planning phase – Mechanical Engineer

- Review available documentation
- Develop retrocommissioning plan

2. Investigation phase – All team members shall:

- Perform site walk thru
- On site meeting with the Building manager and their technical advisors
- Obtain or develop missing documentation as practical
- Develop and execute diagnostic monitoring and testing
- Develop and execute functional test
- Measure and Record chilled and heating water flows
- Measure and Record supply, return and outside air flow for various troublesome Air Handling Units and as time dictates gather additional TAB data as directed by the engineer, owner or as suggested by the TAB engineer
- Perform trial and error solutions and analyze results
- Develop Master List of deficiencies and any improvements performed as part of this work
- Recommend most cost-effective improvements for implementation

3. Implementation phase

- Implement repairs and improvements as practical during the course of this work
- Retest and remonitor for results
- Fine-tune improvements as needed
- (Optional) Develop a list of future work items that should be performed to further optimize the systems. This shall include a cost estimate for the work and calculations of the anticipated annual energy savings and the simple payback

4. Project hand-off and integration phase

- Prepare and submit final report. The mechanical engineer shall gather all data to incorporate into his final report. Provide six copies for review with photographs as necessary in support of the report.

An overview of the specific tasks is requested for this cost proposal. The specific tasks recommended for this project are noted below:

After reviewing the building documentation package and gaining a clear understanding of the project objectives, the Mechanical Engineer has the primary responsibility for developing the plan.

The plan will include the following information:

- Preliminary review of the documentation
- Commissioning Plan and Objectives
- Scope of Commissioning
- Commissioning team members and their roles and responsibilities
- Description of diagnostic monitoring and use of energy management control system trending

Preliminary review of the documentation

Provide review comment comments/questions in order to be better prepared for the three weeks of onsite work. The maintenance contractor shall provide four weeks of data trending (including weekend operation) for review by the mechanical engineer prior to the onsite effort.

Commission Plan and Objectives

The scoping meeting brings all of the team members together to review, discuss, and agree to the retrocommissioning plan. The goal of the meeting and site assessment is to gain an understanding of how the building systems and equipment are currently operated, why they are operated in that way, and what building staff and occupants consider to be the most significant problems.

Scope of Commissioning

It is not the intent for the commissioning team to test all systems from the air handler to the final diffuser or the flow rate to every fan coil or VAV Reheat coil (unless time permits and the number of systems are not excessive). The purpose of the commissioning is to greatly improve the system operation by determining whether or not the system is operating as designed or its operation has been tweaked by the maintenance contractor which in itself may have consequences not fully understood by those involved. Once an understanding of the system is developed the team shall incorporate and document the control and operation changes.

Commission Team Members

Mechanical Engineer – This individual shall be responsible for working with the team to ensure that something is being measured, reviewed, tested and/or captured at all times. This trending, measuring, testing, recording shall be performed during the entire three week period and consolidated for inclusion into the final report. The engineer shall direct the Owner's maintenance staff in the implementation of minor O&M recommendations as part of the ongoing system adjustment. Conduct overall system level training of maintenance staff to communicate the design intent, theory of system operation, delineate

the function of individual components in the system, and intersystem functional operations.

Control Contractor – The individual shall have the knowledge and ability to analyze and program the existing system so that the latest in energy strategies can be put into operation. The modifications shall be based on both their knowledge of the system and the mechanical engineers sequences. It is vital that the person working on this project be very familiar with the current DDC front.

Testing and Balance Engineer – This individual will be responsible for gathering existing information, troubleshooting balance issues and making recommendations to be incorporated during the course of this project. Any existing test and balance (TAB) reports shall be compared by checking system readings for the mechanical equipment.

Maintenance Contractor – The maintenance group responsible for the building shall work closely with the team. They will perform most work necessary to ensure that the systems are functioning properly.

SUBMITTALS

1. Preliminary Review Report with comment/questions and responses
2. List of Deficiencies found and corrective measures performed
3. Final Report including potential Energy Efficiency Capital Improvements

SYSTEM DESCRIPTIONS

The Trenton building complex consists of 357,350 SF, separated into various areas including office space, courtrooms, and public areas. The following table lists the specific systems and sub system items identified for retrocommissioning activities (if known). Additional information about the systems will be provided during the planning phase activities. Notes at the bottom of the table provide additional information relevant to specific items.

The Camden building complex consists of 290,688 SF, separated into various areas including office space, courtrooms, and public areas. The following table lists the specific systems and sub system items identified for retrocommissioning activities (if known). Additional information about the systems will be provided during the planning phase activities. Notes at the bottom of the table provide additional information relevant to specific items.

NOTE: List specific equipment below to be included in the retrocommissioning effort.

Systems and Major Items	Included in Scope of Work?	Notes
Mechanical Equipment		5
Air Handling Units	Yes	1, 3
Terminal Units	Yes	1

Central Plant Heating Equipment	Yes	1
(Includes boilers, pumps, piping systems)		
Unit Heaters	No	
Central Plant Cooling Equipment	Yes	
(Includes chillers, pumps, cooling tower)		
Exhaust Fans	Yes	
HVAC Controls	Yes	2

Note 1: HVAC systems (AHUs, heating and cooling) will be reviewed under one system-wide test during the investigation phase.

Note 2: Controls system operation will be primarily verified through data trending using the existing controls front end system. If necessary, functional testing would occur during investigation phase to examine specific issues of concern.

Note 3: Electrical testing services for emergency power, grounding or power quality are not currently included as part of the initial scope of work.

Note 5: Mechanical systems not included in commissioning activities include ductwork, fire and smoke dampers, equipment sound and equipment vibration measurements.

Note 6: Electrical systems not included in scope of work include (day) lighting controls, power quality, security systems, UPS, fire and smoke alarms, fire protection, communications, and public address/paging systems.

Note 7: Miscellaneous systems not included in scope of work include plumbing systems, service hot water, refrigeration systems, and vacuum systems.

H.2 Retrocommissioning Sample Scope of Work

Objectives of Retrocommissioning

The primary objectives of retrocommissioning Building #XXXX are as follows:

List examples of objectives based on the current condition or operation of the building. Two are listed below:

Improve Operation of the DDC/UCS Control Systems – The entirety of the DDC system of the UCS has never been commissioned. Point-to-point controls points checks are important to evaluate in order to ensure the intended control points are actually the intended recipients of the control commands. Calibration accuracies need verification. Setpoints should be tested and adjusted as necessary. All of these items will ensure the system is being controlled as efficiently as possible.

Improve Energy Efficiency – There are many ways energy consumption could be reduced. The following ECMs could be implemented through commissioning the building:

- Identifying torn or missing piping insulation on steam, hot water and chilled water lines for NASA to repair through the baseline maintenance contractor.

- Finding opportunities to repair compressed air leaks found in lines serving HVAC and lab process equipment.

- Finding opportunities to replace existing inefficient inlet vane operated variable airflow HVAC units with high efficiency fan motor and VFD operated units.

- Sequences of Operation have been developed and are listed in Appendix F. The control setpoints for supply air static pressure and temperature could be evaluated for each AHU and each zone by implementing specific Functional Performance Test evaluation on each air handling unit. Quite often it is found through these FPTs that the current operating setpoints can be adjusted to optimize the efficiency and effectiveness of the systems.

LEED EB Requirement – One of the goals of this effort is to obtain the credits available with EA Cr 2.2 of the LEED 2009 for Existing Buildings Program.

Quoting the U.S. Department of Energy's publication entitled *Commissioning for Federal Facilities*, "retrocommissioning is a systematic process for improving and optimizing building performance in an existing building that has never gone through any type of commissioning or quality assurance process. Its focus is usually on energy-using equipment such as mechanical equipment, lighting and related controls."

The publication goes on to elaborate on some of the more common reasons why an owner may want to consider retrocommissioning his/her facility. Many of these reasons have also been cited as specific reasons for NASA's consideration. Some of these general reasons are:

- It addresses the gap between a building that does not work as intended and an already overburdened maintenance and engineering staff.
- The building is not providing an adequate work environment.
- There are air quality issues.
- Mold is present in the building.
- The building's energy costs are too high compared with similar facilities.

- Equipment and systems are sustaining damage over the long term from the indoor environment.
- It is a prerequisite for LEED-EB (Existing Building).

Project Scope

As a part of the work order issued the Scope of Work for RTCx was described as a two-phase process. **Phase I of the RTCx has been satisfied.** The findings of the Phase I investigations is the foundation for the development of this RTCx Plan.

The completed Phase I Scope of Work is as follows:

Phase 1: RTCx Study

(The numbering sequence was kept the same as the original scope in order to simplify the referencing between this RCx Plan document and the NASA issued documents.)

- Planning: Review building drawings and documentation to understand the building energy usage, initial basis of design and evaluate the system integration. The review process includes the evaluation of all old and new drawings, specifications, Test and Balance (TAB) reports, Operations & Maintenance (O&M) manuals (typically related to mechanical, electrical and controls), and any past Commissioning Reports. Review the current facility functions to identify changes from the original design criteria and assumptions. Review current codes and standards to identify those applicable to the CFR.
- Onsite Investigation:
  – System condition analysis: Check systems for conditions that may impact operation of the respective systems. This shall include items such as cleanliness of coils, condition of filters and belts, and required preventative maintenance actions.
  – Site Review/Survey: Conduct a thorough and detailed building walk through with maintenance personnel to evaluate the issues identified in the Planning Phase and observed during the drawing and documentation review. Important facility information not found during the Documentation Review may need to be recreated during the site survey via readings of available equipment gauges (assuming current calibration). Reasonable functional testing (i.e. to determine if damper linkage is working) may be conducted as needed. Invasive testing of equipment and/or systems (i.e. to quantify air & water flows) is not required. During this step additional issues which are not captured through the Documentation Review should be noted.

– Building Occupant Interviews: Interview the Owner's maintenance personnel, utility personnel, occupants, and other relevant parties to understand the current needs and issues related to system operations and maintenance. A formal interview process is recommended to systematically assist in understanding potential issues and problems, uncover potential improvement opportunities, confirm the CFR and to develop consensus on the commissioning process goals.

- Facility Performance Analysis and Performance Baseline Establishment:
  – Collect and analyze available energy, non-energy and other system performance data to establish baseline benchmarks for facility performance. Available facility performance baseline data shall include utility billing data, sub-metering data, work orders, comfort complaint logs, indoor air quality parameters, occupant satisfaction

survey results, UCS trend data, and/or stand-alone data logger data and other data deemed necessary to develop and establish the facility baseline.
– Gather data a minimum of 2 weeks prior to commencing any modifications to the systems and after completion of any modifications.

- Systems Diagnostic Monitoring: Develop a diagnostic monitoring strategy and then perform comprehensive system diagnostic monitoring. Diagnostic monitoring methods can include UCS trending, portable data logger trending, and energy and weather data collection. The collected data is analyzed to identify issues and improvement opportunities and highlight particular problems that may require more rigorous and focused investigation.
- Test Development: Develop Test Procedures for the systems identified in the project scope. Test plans typically focus on confirming that the system performance is meeting the performance requirements of the occupants set forth in the CFR.
- System Testing: Necessary system testing to be performed in Phase 2 shall be identified. Such system testing will be to evaluate the building systems performance. In addition, any anomalies or issues identified in earlier Investigation Phase steps should be considered for further evaluation during system testing to determine root causes and possible solutions. The testing process may include the verification and calibration of all sensors.
  – Special consideration should be given to chiller plants and conventional atmospheric boilers—specifically, operational efficiency performance evaluation and requirements. The timing of this contract and seasonal operation of this equipment may not coincide. Every attempt should be made on these systems so they are evaluated and adjusted during the season while in use, regardless whether the execution of the contract is in the planning, investigative or Implementation phase.
- Develop the retrocommissioning plan with input from the facilities staff. The plan shall at a minimum contain the following information, description of what was evaluated including scope and methodology, findings and proposed implementation plan.
- Conduct a scoping meeting to review, discuss, and agree to the retrocommissioning plan.
- Deliverable: RTCx Study Report
  – Phase 2 Proposal & Feasibility Analysis
  – Retrocommissioning Plan

The objective of this RTCx Plan is to satisfy the following phase of the retrocommissioning project:

Phase 2: RTCx Implementation

- General, this phase implements and executes any/all projects recommended as part of the Phase 1 proposal and corresponding RTCx plan which are accepted and funded by the NASA facility .

- The following paragraphs make reference to sketches or marked up “As Built” drawings. The intent of this requirement is to have the RTCx Consultant provides a document that shows the pertinent information in a clear and understandable fashion that will be a useable reference for the future. This does not need to be a CAD drawing but must

be a legible document. Likewise the Consultant expects to receive copies of all previously developed "As-Built" drawings, diagrams or specifications.

- Systems Testing: Implement systems testing as identified previously in Phase 1 (section 5.6).
- Implement modifications to control settings to reflect changes to code or the CFR.
- Chiller Plant: Sketch system schematic or mark up "As-Built" drawings and evaluate for given application. Document set points (e.g. chilled water temperatures and normal refrigeration checks, supply air temperature). Document Sequence of Operation (SeqOp). Evaluate SeqOp for the given application.
- Cooling Towers: Sketch system schematic (may be included in chiller plant schematic) or mark up "As-Built". Document set points (e.g. condenser water leaving temperature). Measure supply, return condenser water temperatures, flow. Document SeqOp. Evaluate SeqOp for the given application.
- Boilers: Combustion analysis and operational checks and adjustments on conventional atmospheric boilers. Combustion analysis will not be required on the modular high performance boilers. Verify operations and sequence of boiler and pumps.
- Air Distribution System (Includes air handling unit, ducting, related fans in zone, related terminal boxes, etc.): Sketch system schematic or mark up "As-Built" and evaluate for given application. Document set points (e.g. supply air temperature), measure supply, return, mixed, outside air temperatures. Verify proper chilled water, hot water, and/or steam valve operation. Verify proper economizer operation (if present). Document SeqOp Evaluate SeqOp for the given application. Balance check of exhaust air vs. outside air and building pressures, identifying excess infiltration or outside air. Testing and balancing of all diffusers and VAV boxes.
- DX Air Conditioning System (Includes all items associated with packaged DX system, such as compressors, condenser fans, economizer, air distribution system, etc.): Sketch system schematic or mark up "As-Built" and evaluate for given application. Document set points (e.g. supply air temperature). Measure supply, return, mixed, outside air temperature. Verify proper economizer operation (if present). Document SeqOp. Evaluate SeqOp for the given application.
- Various other HVAC components such as VFDs, Outside Air resets, and economizer operations, assuring proper operation and evaluate given applicability.
- Building Automation and Energy Management Control Systems: Verify that remote monitoring of points and system are established and properly reporting. Verify operation and accuracy of all sensing and control points.
- HVAC Control Systems: Verify accuracy of all sensors falls into the range established by the manufacture. Calibrate or replace as required. Modify sequence of operations or reprogramming. Recommend software upgrades and connectivity and system network compatibility. Verify compliance with control sequences of operation.
- VAV Boxes: Verify VAV box response to room temperature set point adjustment. Adjust as required. Verify reheat coil operation. Check primary air damper maximum/minimum flow settings and compare to actual measured flows. Adjust as required.
- Hydronic Systems: Test and balance. Operation of pumps.
- Building Exhaust Systems: Check fan operations and do a TAB.

- Lighting: Evaluate facility lighting levels and identify areas that seem excessive lit.

Lighting Controls: Verify acceptable operation and settings of occupancy sensors. Identify locations where operational changes could and should be implemented. Verify operation and settings of daylighting sensors. Adjust levels as necessary. Identify recommended location changes to improve operation of occupancy and or daylighting sensors.

Phase 2 Deliverables

At Conclusion of the Implementation Phase a Final Retrocommissioning Report (five copies, paper & electronic) will be presented that includes the following information:

- Executive summary
- Project background and scope of the commissioning project
- Facility Metrics. Provide data on conditions and utility consumption rates at the start of the process and upon completion, highlighting the changes. Provide data for the following:
  - Building energy usage.
  - Conditions in areas of concern. Data shall include temperatures, humidity, air velocity, etc, as appropriate.
- Details of all potential improvements identified and other findings, including:
  - Documentation of equipment conditions
  - Identify Operational & Maintenance (O&M) practices that could be implemented and recommended training that would benefit the staff.
  - Missing critical documentation
- Current system operation sequences for all equipment and systems included
  - Results of systems testing conducted in Phase 2.
  - RCx project descriptions, including:
    - Implementation scope & corresponding cost.
    - Estimated utility cost savings.
    - Simple payback period of each respective project (possibly refined via data resulting from actual systems testing in Phase 2)
- In Appendix:
  - The Retrocommissioning Plan (possibly refined via data resulting from actual systems testing in Phase 2)
  - UCS/data logger trended data, analysis, and annotated results. Electronic copies of the data shall be provided if applicable.
  - Completed calibration worksheets
  - TAB/systems testing work forms

Responsibilities of Retrocommissioning Team Members

Commissioning Authority (CxA)

The Commissioning Authority (CxA) leads, plans, schedules and coordinates the commissioning process according to the contract scope. It is the CxA's responsibility to develop the Retrocommissioning (RCx) Plan and submit this Plan for approval. It is also the

CxA's responsibility to conduct the necessary RCx scoping (i.e., kickoff) meeting, as well as any necessary followup and/or regular milestone review meetings. The CxA directs the activities of the field technicians as information is gathered and evaluated, systems are tested for functionality, and implementation of changes required. The CxA may make recommendations to the Owner regarding Facility Improvement Measures and assist in verifying their continued performance over time.

Contracting Officer for NASA

The Contracting Officer (CO) issues the initial Request for Proposal for the RTCx services. The CO is also responsible for implementing the contract for services. The CO reviews and approves the formal RTCx plan. The CO attends the initial scoping meeting (i.e., Kick-off meeting), the final RTCx report meeting, as well as any other progress meetings as necessary. Evaluation of all Capital Expenditure recommendations for approval and implementation is also the responsibility of the CO. Should any repair or replacement funds be made available to the RTCx team for simple repairs and/or replacements in order for the continuation of the functional testing, the CO provides, and approves as necessary, these limited supplemental funds. These funds could be utilized during the RCx process for labor, parts, and/or equipment in order for the CxA to execute Facility Improvement Measures (FIMs) or quick fixes, without hindering the progress of the RTCx process.

Building Operations Technical Project Manager (PM) at MSFC Facilities Engineering Department

The PM attends the initial scoping meeting (i.e., Kick-off meeting) with the CxA and the CO. The PM provides all of the necessary onsite and daily support via the maintenance or the UCS personnel. The PM provides access into all areas of Building 4487. The PM also reviews RCx plan with the CO for approval. The PM also attends the final RTCx report meeting, as well as any other progress meetings as necessary.

Add any additional team members as needed.

Building Description

In this section list all pertinent portions of the building description to include (but not limited to) construction date, any major renovations performed and date performed, building construction materials, use of the facilities (office, lab, etc.), operating hours, any special function areas, types of air handling systems in the facility, type of control systems, etc. Include photos of the facility if available to give the proposer an idea of the facility condition to include equipment as well.

Retrocommissioning (RTCx) Process

The total process for an HVAC retrocommissioning project includes the actions that have already been completed in Phase I (i.e., Planning, Onsite Investigation, Facility Performance Analysis and Performance Baseline Establishment, and Diagnostic Monitoring of the Systems), plus the detailed functional testing of all of the pieces of mechanical equipment. This functional testing includes not just the individual pieces of mechanical equipment, but that equipment coupled with the building automation system. The development of these

individual Functional Performance Tests (FPTs) and the implementation of these tests is the primary objective of Phase II of this RCx portion of the Tri-Fold project.

Tests are developed specifically for the type of equipment being tested. Each type of air handling unit (AHU) will be tested in accordance with its design and purpose, as will all of the other components of a completely functioning system (e.g., VAV/terminal boxes, pumps, exhaust fans, heat exchangers, chillers, boilers, etc.) These tests are tailored for the equipment being tested and the application in which they are being used. Such tests are often developed by the CxA and his/her team based on practical field experience and training. Other times these tests are designed after recommendations by various commissioning certification organizations like AABC Commissioning Group (ACG), the Building Commissioning Association (BCA), etc. As the basis of the FPTs in this project, the tests recommended in the Unified Facilities Guide Specifications (UFGS) 23 08 00.00 10 was used as this guide for the commissioning of HVAC systems was developed in part for NASA facilities. However, additional FPT components may be added from other certifying bodies like ACG, BCA, etc. These specific Functional Performance Tests are included in Section #4 and will be completed for each piece of equipment in the building.

Test, Adjust, and Balance Verification
Purpose

To document and verify that the HVAC systems have been tested, adjusted and balanced in order to make certain the overall HVAC system functions as intended. No documentation was found that indicated a TAB analysis has ever been performed on this building. The airflow patterns have been disturbed by the addition of many ceiling supply air filter units (Control-A-Flow Draft Eliminators and Anti-microbial filters). For these reasons, it is recommended that these TAB procedures be exercised throughout the building.

Test Equipment

All instrumentation shall be in calibration within NIST traceable standards.

Procedure

1. Receive TAB plan and review for acceptance.
2. Record copies of instrumentation calibration certificates within the Cx Report.
3. Monitor TAB procedures onsite to verify plan conformity.
4. Review final TAB report.

Definitions

Current Facility Requirements (CFR): Defines the users' current operational needs and requirements for a building. It typically includes items addressing temperature and humidity set points, lighting levels, operating hours, filtration, vibration, sound and/or specialty needs.

Facility Improvement Measure (FIM): Alterations or revisions to systems or equipment planned to improve building and system performance, reduce Operations and Maintenance (O&M) costs and/or improve the indoor environmental quality.

Retrocommissioning (RTCx): The application of the commissioning process to an existing building that has either not previously undergone the commissioning process, or having been previously commissioned at construction or at a later time, may not now be operating as intended due to alterations to systems, building envelope and/or space changes, or occupancy and usage requirements.

Return on Investment (ROI). The ratio of the money gained or lost on an investment relative to the cost of the investment. To calculate ROI, the benefit (return) of an investment is divided by the cost of the investment; the result is expressed as a percentage or a ratio. ROI = (Gain from Investment - Cost of Investment)/Cost of Investment.

Sequence of Operation (SeqOp): The sequence of operations whether to start up, shut down or as running responses to system inputs or variables.

Test and Balance (TAB): The measurement and verification of air-flows from supply terminals to returns in a ducted air system, allowing for fresh air intakes and exhausts in a steady state system, or where lightly unbalanced systems allow for judicious use of negative or positive pressure zones to achieve a directed air movement, for example near entry vestibules, bathroom or kitchen exhausts.

Add any definitions as needed.

Section 1: Current Facility Requirements

In this section include a copy of the buildings CFR obtained either through the facilities department or through the building occupants/users.

Subsection 1: Energy Efficiency Goals

a. What are the project goals relative to local energy codes, ASHRAE standards, or LEED requirements?

Specify and maintain the most energy efficient equipment which provides user friendly operation, maintainability and excellent indoor environmental quality.
Compliance with the following:
Local Energy Codes: *List codes to be followed*
ASHRAE Standards: *List codes to be followed*
LEED Requirements:

✓ *List targeted sections*

Subsection 2: Indoor Environmental Quality Requirements

a. What is the anticipated occupancy schedule (number of occupants and time-frames) for all occupied spaces? Indicate the default occupancy schedule below as well as for all spaces that have an occupancy schedule that differs from the default.

There are approximately *XXX* Full-Time Employees (FTEs) at any given time.
General Office spaces - M–F: Occupied?
Laboratory spaces - M-F: Occupied?
Saturday and Sunday: Occupied?

b. What is the desired level of occupant adjustability for system controls? List those controls which occupants will have control over (e.g., thermostat +/– adjustability, ventilation air, humidity control).

Individual control by wall thermostat for a variation of +/– 2 °F from the UCS setpoints. (*List what these setpoints are for the facility*)
No individual occupant controls for space relative humidity.

c. What accommodations for after-hours use of the building are required? List those systems that will be allowed to operate outside of the normal occupancy schedule (e.g., air handling, DHW).

After-hours air handler operation (i.e., On/Off) with system override wall switch.

d. What are the temperature, humidity, air quality, and ventilation and filtration requirements for all spaces served by the commissioned systems? Indicate the default requirements for these spaces and detail the requirements for spaces that differ from the default requirements.

Temp = 75 °F (summer)/72°F (winter); RH=55% max/30% min
Ventilation as required to meet current ASHRAE 62.1-2010 Standard
Air Quality = “Normal” office environment
Filtration = Standard pleated filters (MERV 8)

Section 2: HVAC Equipment Lists as Determined in Phase I Evaluations

Provide a basic list of the HVAC equipment contained in the facility to include (but not limited to) location, HP rating, variable or constant speed, operating hours, etc (see below for example).

For a complete list of this equipment with more details, see Appendix D (HVAC Equipment Data). Additional details found in that appendix will be the following:

- System Type Description
- Operating hours (if known)

- Manufacturer
- Model #
- Year installed or Manufactured
- Unit condition (Poor, Fair, Good)
- Type of system controls (Pneumatic, DDC, Hybrid)
- Condition of the controls (Poor, Fair, Good)
- Fan Capacity Control Device (e.g., VFD, Inlet Vanes, etc.)
- Cooling Method
- Cooling Stage Control Device
- Heating Method
- Heating Stage Control Device
- Economizer
- Estimated Damper Leakage When Closed
- Design Data (as determined from any available drawings such as Supply air CFM and Static Pressure, Return Air CFM and Static Pressure, Outside Air (min/max), Cooling and Heating Btu/Hr capacities, and any special notes describing the specific piece of equipment.)

CHILLED WATER & HOT WATER CIRCULATION PUMPS

Pump	HP	FLA	Eff.	VV or CV?	Location	Areas Served

Notes: VV – Variable Volume; CV – Constant Volume; Eff. – Efficiency of the Motor

FLA – Full Load Amperes

AIR HANDLING UNIT FAN MOTOR DATA

Unit	Type	Speed Control	24/7?	Motor Data		
				HP	FLA	Eff. (%)

Section 3: Documented Sequences of Operation

In this section list any details you have of the sequences of operation for the equipment to be looked at in the retrocommissioning report.

Section 4: HVAC Equipment Functional Performance Tests (FPTs)

In this section include any performance tests developed by your Center or during the Phase I work.

Appendix I – Federal High-Performance Sustainable Buildings

The purpose of this list is to assist NASA Centers with assessing their existing building stock against the five Guiding Principles for Sustainable Existing Buildings, and for reporting sustainability data element on the Energy Star Portfolio Manager Web site. All commissioning, recommissioning and retrocommissioning efforts shall be aligned towards meeting the five Guiding Principles.

1. Employ Integrated Assessment, Operation, and Management Principles

Integrated Assessment, Operation, and Management

- Use an integrated team to develop and implement policy regarding sustainable operations and maintenance.
- Establish operational performance goals for energy, water, material use and recycling, and indoor environmental quality, and ensure incorporation of these goals throughout the remaining lifecycle of the building. Incorporate sustainable operations and maintenance practices within the appropriate Environmental Management System (EMS).
- Incorporate a building management plan to ensure that operating decisions and tenant education are carried out with regard to integrated, sustainable building operations and maintenance.
- Augment building operations and maintenance as needed using occupant feedback on work space satisfaction.

Commissioning

Assess existing condition and operational procedures of the building and major building systems and identify areas for improvement. Employ recommissioning, tailored to the size and complexity of the building and its system components, in order to optimize and verify performance of fundamental building systems. Commissioning must be performed by an experienced commissioning provider. When building commissioning has been performed, the commissioning report, summary of actions taken, and schedule for recommissioning must be documented. Building recommissioning must have been performed within four years prior to reporting a building as meeting the Guiding Principles. Meet the requirements of EISA 2007, Section 432.

2. Optimize Energy Performance

Energy Efficiency

Option 1: Receive an ENERGY STAR® rating of 75 or higher.

Option 2: Reduce measured building energy use by 20% compared to building energy use in 2003 or a year thereafter with quality energy use data

Option 3: Reduce energy use by 20% compared to the ASHRAE 90.1 2007 baseline building design if design information is available. Use ENERGY STAR and FEMP-designated Energy Efficient Products, where available.

Onsite Renewable Energy

Implement renewable energy generation projects on Agency property for Agency use, when life cycle cost effective.

Measurement and Verification

Per the Energy Policy Act of 2005 (EPAct2005) Section 103, install building level electricity meters to track and continuously optimize performance. Per the Energy Independence and Security Act (EISA) 2007, the utility meters must also include natural gas and steam, where natural gas and steam are used.

Benchmarking

Compare annual performance data with previous years' performance data, preferably by entering annual performance data into the ENERGY STAR Portfolio Manager and/or Labs 21 for laboratories.

3. Protect and Conserve Water

The installation of water meters for building sites with significant indoor and outdoor water use is encouraged. Process Water: Per EPAct 2005 Section 109, when potable water is used to improve a building's energy efficiency, deploy lifecycle cost effective water conservation measures.

Indoor Water

Option 1: Reduce potable water use by 20% compared to a water baseline calculated for the building. The water baseline, for buildings with plumbing fixtures installed in 1994 or later, is 120% of the Uniform Plumbing Codes (UPC) 2006 or the International Plumbing Codes (IPC) 2006 fixture performance requirements. The water baseline for plumbing fixtures older than 1994 is 160% of the UPC 2006 or the IPC 2006 fixture performance requirements.

Option 2: Reduce building measured potable water use by 20% compared to building water use in 2003 or a year thereafter with quality water data. If only one meter is installed for the site, reduce the water use (indoor and outdoor combined) by at least 20% compared to building water use in 2003 or a year thereafter.

Outdoor Water

Option 1: Reduce potable irrigation water use by 50% compared to conventional methods.

Option 2: Reduce building related potable irrigation water use by 50% compared to measured irrigation water use in 2003 or a year thereafter with quality water data. If only one meter is installed for the site, reduce the potable water use (indoor and outdoor combined) by at least 20% compared to building water use in 2003 or a year thereafter.

Option 3: Use no potable irrigation water.

Storm Water

Employ strategies that reduce storm water runoff and discharges of polluted water offsite. Per EISA Section 438, where redevelopment affects site hydrology, use site planning, design, construction, and maintenance strategies to maintain hydrologic conditions during development, or to restore hydrologic conditions following development, to the maximum extent that is technically feasible.

Water Efficient Products

Where available, use EPA's WaterSense® labeled products or other water conserving products. Choose irrigation contractors who are certified through a WaterSense-labeled program.

4. Enhance Indoor Environmental Quality

Ventilation and Thermal Comfort

Meet ASHRAE Standard 55-2004 Thermal Environmental Conditions for Human Occupancy and ASHRAE Standard 62.1-2007: Ventilation for Acceptable Indoor Air Quality.

Moisture Control

Provide policy and illustrate the use of an appropriate moisture control strategy to prevent building damage, minimize mold contamination, and reduce health risks related to moisture. For facade renovations, Dew Point analysis and a plan for cleanup or infiltration of moisture into building materials are required.

Daylighting and Lighting Controls

Provide automated lighting controls (occupancy/vacancy sensors with manual-off capability) for appropriate spaces including restrooms, conference and meeting rooms, employee lunch and break rooms, training classrooms, and offices.

Option 1: Achieve a minimum daylight factor of 2 percent (excluding all direct sunlight penetration) in 50 percent of all space occupied for critical visual tasks.

Option 2: Provide occupant controlled lighting, allowing adjustments to suit individual task needs, for 50% of regularly occupied spaces.

Low-Emitting Materials

Use low-emitting materials for building modifications, maintenance, and cleaning. In particular, specify the following materials and products to have low pollutant emissions: composite wood products, adhesives, sealants, interior paints and finishes, solvents, carpet systems, janitorial supplies, and furnishings.

Integrated Pest Management

Use integrated pest management techniques as appropriate to minimize pesticide usage. Use EPA-registered pesticides only when needed.

Tobacco Smoke Control

Prohibit smoking within the building and within 25 feet of all building entrances, operable windows, and building ventilation intakes.

5. Reduce Environmental Impact of Materials

Recycled Content

Per section 6002 of RCRA, for EPA-designated products, meet or exceed EPA's recycled content recommendations for building modifications, maintenance, and cleaning. For other products, use materials with recycled content such that the sum of postconsumer recycled content plus one-half of the preconsumer content constitutes at least 10% (based on cost or weight) of the total value of the materials in the project. If EPA-designated products meet performance requirements and are available at a reasonable cost, a preference for purchasing them shall be included in all solicitation relevant to construction, operation, maintenance of or use in the building. EPA's recycled content products designations and recycled content recommendations are available on EPA's Comprehensive Procurement Guideline Web site at www.epa.gov/cpg.

Bio-based Content

Per section 9002 of FSRIA, for USDA-designated products, use products with the highest content level per USDA's bio-based content recommendations. For other products, use biobased products made from rapidly renewable resources and certified sustainable wood products. If these designated products meet performance requirements and are available at a reasonable cost, a preference for purchasing them should be included in all solicitations relevant to construction, operation, maintenance of or use in building. USDA's bio-based product designations and bio-based content recommendations are available on USDA's Bio-Preferred Web site at www.usda.gov/biopreferred.

Environmentally Preferable Products

Use products that have a lesser or reduced effect on human health and the environment over their life cycle when compared with competing products or services that serve the same purpose. A number of standards and ecolabels are available in the marketplace to assist specifiers in making environmentally preferable decisions. For recommendations, consult the Federal Green Construction Guide for Specifiers at www.wbdg.org/design/greenspec.php

Waste and Materials Management

Provide reuse and recycling services for building occupants, where markets or onsite recycling exist. Provide salvage, reuse and recycling services for waste generated from building operations, maintenance, repair and minor renovations, and discarded furnishings, equipment and property. This could include such things as beverage containers and paper from building occupants, batteries, toner cartridges, outdated computers from an equipment update, and construction materials from a minor renovation.

Ozone-Depleting Compounds

Eliminate the use of ozone-depleting compounds where alternative environmentally preferable products are available, consistent with either the Montreal Protocol and Title VI of the Clean Air Act Amendments of 1990, or equivalent overall air quality benefits that take into account life cycle impacts.

Appendix J – References

1. ACG Commissioning Guideline – http://www.commissioning.org/commissioningguideline/ACGCommissioningGuideline.pdf

2. ASHRAE Guideline 0-2013 – The Commissioning Process

3. ASHRAE Guideline 1.1-2007 – HVAC&R Technical Requirements for the Commissioning Process

4. ASHRAE Standard 189.1 – Design of High-Performance Green Buildings - https://ashrae.org/resources--publications/bookstore/standard-189-1

5. ASHRAE Standard 202 – Commissioning Process for Buildings and Systems

6. Building Commissioning Association Guidelines on New and Existing Buildings

7. Federal Facilities Commissioning Guide – http://energy.gov/sites/prod/files/2014/07/f17/commissioning_fed_facilities.pdf

8. NASA – Reliability-Centered Maintenance Guide, September 2008

9. National Institute of Building Sciences Guideline 3-2006 – Exterior Envelope Technical Requirements for the Commissioning Process

10. NEBB Procedural Standards for Retrocommissioning of Existing Buildings

11. NEBB Procedural Standards for Whole Building Systems Commissioning of New Construction

12. NFPA 3 – Commissioning and Integrated Testing of Fire Protection and Life Safety Systems

13. Portland Energy Conservation Inc. (PECI), purchased by CLEAResult, in 2014 - http://www.clearesult.com

14. SMACNA HVAC Systems Commissioning Manual

15. Whole Building Design Guide, http://www.wbdg.org/ccb/GSAMAN/buildingcommissioningguide.pdf

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16. ASHRAE Guideline, The Commissioning Process for Smoke Control Systems 1.5-2012

17. Cx Specs UFGS Format Section 01 91 13

18. Cx Specs UFGS Format Section 23

19. GSA Cx Guide, Index - comparing to NASA Cx Guide index, sections - http://www.wbdg.org/ccb/GSAMAN/buildingcommissioningguide.pdf

20. GSFC B.36 FPB - Cx Contract Role in Development of the Prefunctional Checklists

21. GSFC Flight Project Building Commissioning Services SOW

22. GSFC Task CxA for IDF design

23. GSFC, Establishing Commissioning Fees, by Ronald J. Wilkinson, P.E.

24. http://www.cacx.org/meetings/meetings/2013-07-18/Standard_202-Seidl.pdf

25. https://www.ashrae.org/resources--publications/bookstore/commissioning-essentials

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27. National Conference of Bldg Cx, RE: What ASHRAE Std 202 is and is not - http://www.bcxa.org/wp-content/2013BCAPresentations/Kettler-Codes-Standards.pdf

28. U.S. General Services Administration, Request for Qualifications (RFQ) for Commissioning Agent, http://www.gsa.gov/portal/content/101964

29. RBC &EA Guide, http://www.hq.nasa.gov/office/codej/codejx/Assets/Docs/RCB&EGuideJUL04.pdf

30. SpecsIntact, (Unified Construction Specifications), http://specsintact.ksc.nasa.gov/

31. AABC, American Air Balancing Council

32. TABB, Testing Adjusting and Balancing Bureau