

BUILDING ENVELOPE COMMISSIONING

by

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1. INTRODUCTION

Commissioning is the systematic process that facilitates the communication, coordination, testing, and verification required to deliver building systems in accordance with the intended design.

Commissioning as a construction practice was started by the American Society of Heating Refrigerating and Air-conditioning Engineers (ASHRAE) at its founding and initially associated with mechanical systems. However, the program has since been adopted to include all major building systems. The basic commissioning methodology can be applied to building enclosure systems, claddings, and components including:

- Roofing Systems
- Exterior Walls
- Window Walls, Curtain Walls, and Storefronts
- Exterior Doors and Windows
- Sealants, Joints, and Flashings
- Plaza Decks and Podiums
- Planters
- Foundation Systems
- Below-Grade Walls

Building Envelope Commissioning (BECx) can yield significant life cycle cost savings in new buildings. Similarly, Retro-Commissioning (RCx) can offer greatly reduced operating costs in older buildings.

One of the most common sources of building failures is the Building Envelope. When applied systematically, Building Envelope Commissioning can significantly reduce the risk of water infiltration, improve facility operation and maintenance, reduce capital costs during the first year of operation, and reduce the life cycle costs of the facility for the life of the building.

Commissioning is a comprehensive design and construction/repair process that is woven into a construction project, not as an expensive standalone process, but one that is fully integrated into the project delivery. It is common for Construction Commissioning to be considered on its own; however, for maximum savings it should be planned for all design and construction phases. A commissioning program only implemented after construction commences will be less effective than commissioning that begins during the schematic phase.

Construction projects are complicated, involving many trades that, in many cases, work independently. A commissioning program that employs design reviews and construction validation protocols can minimize building performance issues and offer the owner an assurance of receiving an end-project that will perform as intended, specified, designed, and, of course, paid for.

Commissioning is generally conducted by a third party under contract with the project owner. The third party acts as the owner's representative and provides objective development of programming goals, objectives, and recommendations. In some cases, a project commissioning process is prescribed directly to the project's designer and consultant team members, instead of under a third party commissioning authority. The intent, in these cases, is to have the designer verify that the owner's objectives are defined ahead of the design process, that the objectives are met, and to provide quality assurance during construction.

If a third party is utilized, the owner or owner's representative will select the commissioning agent directly. The agent will lead the commissioning process, in cooperation with the designers and contractors, with the owner's interest as first priority. The commissioning agent should be licensed to practice engineering or architecture in the state that the project is located. The commissioning agent should also be an expert in the systems being commissioned.

2. HISTORY OF BUILDING COMMISSIONING

Historically, ASHRAE were the leaders in building commissioning, focusing originally on mechanical systems and building operations.

In the last ten years, the National Institute of Building Sciences (NIBS), the United States Green Building Council (USGBC) – through the Leadership in Energy and Environmental Design (LEED) process, various state governing agencies, and recently ASTM have added Exterior Enclosure Commissioning as a crucial component of the design and construction process.

- 1982 – ASHRAE begins work on commissioning guidelines.
- 1989 – Publication of the first ASHRAE guideline on commissioning mechanical systems (updated in 1996).
- 2005 – Latest ASHRAE guideline on the commissioning process for the whole building.
- 2006 – First publication of NIBS exterior enclosure technical requirements for the commissioning process.
- 2011 – California Green Building Standards Code, including Commissioning, codified into Title 24.
- 2012 – Latest publication of NIBS exterior enclosure technical requirements for the commissioning process.
- 2012 - ASTM International and NIBS announce their agreement to collaborate on developing a building-enclosure commissioning process that the organizations said would facilitate improved building-enclosure design and commissioning programs. As part of the agreement, *NIBS Guideline 3* will be developed and published as an ASTM Standard Guide by ASTM Subcommittee E06.55 on Building Enclosure Performance, part of ASTM Committee E06 on Performance of Buildings.

NIBS is a non-profit, non-governmental organization that brings together representatives of government, building sciences industry professionals, various labor and consumer interests, and regulatory agencies. A key focus of NIBS is identifying and resolving problems in building science and technology toward improving the built environment. *NIBS Guideline 3-2012 Building Enclosure Commissioning Process BECx* describes the specific applications of the Building Enclosure Commissioning process more generally in ASHRAE Guideline 0-2005. The procedures, methods, and documentation requirements in this guideline describe the application of the commissioning process to building enclosure systems for each building delivery phase, from pre-design through owner occupancy and operation.

3. BUILDING ENVELOPE COMMISSIONING OBJECTIVES AND BENEFITS

Many building owners have benefited from the ASHRAE commissioning process which has been in existence for decades. Currently, the building industry, NIBS, and the USGBC have extended the benefits of commissioning by defining a process that includes exterior enclosures.

The commissioning process allows owners to clearly define their goals and objectives that are often not well understood by design professionals. For example, developers and owners, often have competing goals in the areas of cost savings and high-performance building enclosures. Traditionally the outcome is “value engineering” by specifying cheaper materials and systems.

Through the commissioning process, owners, contractors, and design professionals collaborate to think outside the box by analyzing not only the cost of enclosure systems, but how each solution will impact scheduling, long-term maintenance, and longevity- factors that very often have overarching effects on the cost of construction and long-term ownership of the building.

Collaboration during the commissioning process significantly improves system selection to better meet many of the owner’s objectives, such as longer-lasting systems, reduced maintenance costs, energy efficiency, and remaining within budget without sacrificing quality of construction.

The building envelope commissioning process aims to confirm that the building will fulfill the functional and performance requirements of the owner, occupants, and operators.

Typically, the envelope commissioning process focuses on:

- Heat / Air Flow
- Noise / Acoustics
- Thermal Comfort
- Visual Comfort
- Fire Protection
- Light Management
- Rain Penetration Control
- Moisture Management
- Structural Performance
- Durability – Increased Systems Life
- Reliability
- Aesthetics
- Value
- Constructability
- Maintainability
- Sustainability
- Reduced Energy Costs
- Carbon Footprint Reduction

The main objectives of commissioning are:

- Document the owner’s requirements, to improve the quality of design deliverables.
- Verify that systems and assemblies perform according to the owner’s requirements as stated in the Owners Project Requirements (OPR).
- Memorialize the design requirements in a Basis of Design (BOD) letter.

- Confirm that proper verification is provided to the owner, before, during, and after construction.
- Verify that operating staff are trained in proper operation of the facility.

The commissioning process can cost 2-4% of construction, depending on the project size and complexity. While many owners may give high priority to reducing up-front costs, the commissioning process can be invaluable and pay for itself in the long term. Many owners have spent millions and invested years of effort in repairing construction defects in buildings improperly designed or constructed, or on expensive modifications to improve building performance after initial construction. The long-term effects of poor design and construction include inferior energy efficiency, high operating and maintenance costs, frequent replacement of components, lower reliability, water intrusion, and side effects of poor indoor air quality, such as mold. Building enclosure commissioning can mitigate these risks and offer the owner an array of benefits including:

- Reduced risk of leaks, disruption, lawsuits, loss of rents, and remedial construction.
- Reduced long-term operating costs. Operating costs can represent up to 80% of the total cost of a building over its lifetime. In a study on building commissioning from the U.S. General Services Administration on Building Commissioning, they state that “operating costs for commissioned buildings are reported at 8-20% lower than those of a comparable non-commissioned building.”
- Fewer project delays. Coordination and scheduling programs integrated in project management enables contractors to sequence work more efficiently, thus expediting construction. Common issues can be proactively identified, and resolutions can be implemented to allow the project to remain on its critical path.
- Expedited projects may be completed sooner, by early identification and resolution of issues. For revenue properties, owners can generate rental revenue earlier, reducing the substantial costs of carrying construction money, loans, etc.
- Minimal design impacts. The qualified commissioning agent reviews the design and submittals to identify design issues. Recommending alterations during the design phase is much more cost-effective than field-directed revisions, and reduces change orders and construction delays.
- Quality assurance during construction. Specialized quality assurance protocols on behalf of the owner to observe critical building envelope components during construction, will help validate that the construction is performed in accordance with the design intent. Construction of building envelope systems is extraordinarily complex; quality-assurance protocols enable the commissioning agent to address many unanticipated conditions before they can cause cost overruns and delays.
- Comprehensive documentation of the construction process. When the commissioning process is integrated throughout the design and construction process, valuable information is collected that will assist the owner with future building operation and maintenance. The commissioning process provides facilities staff with detailed information on how their building systems were designed and constructed.

Currently there is no direct method to calculate or quantify anticipated payback that can be achieved utilizing building envelope commissioning. Since every project has its own objectives and construction obstacles there is no definitive savings percentage that can be used in project budgeting. Currently, it is known that commissioning can cost 2-4% of construction and that

abovementioned studies state that operating costs for commissioned buildings can be between 8 and 20% lower than those of comparable non-commissioned buildings.

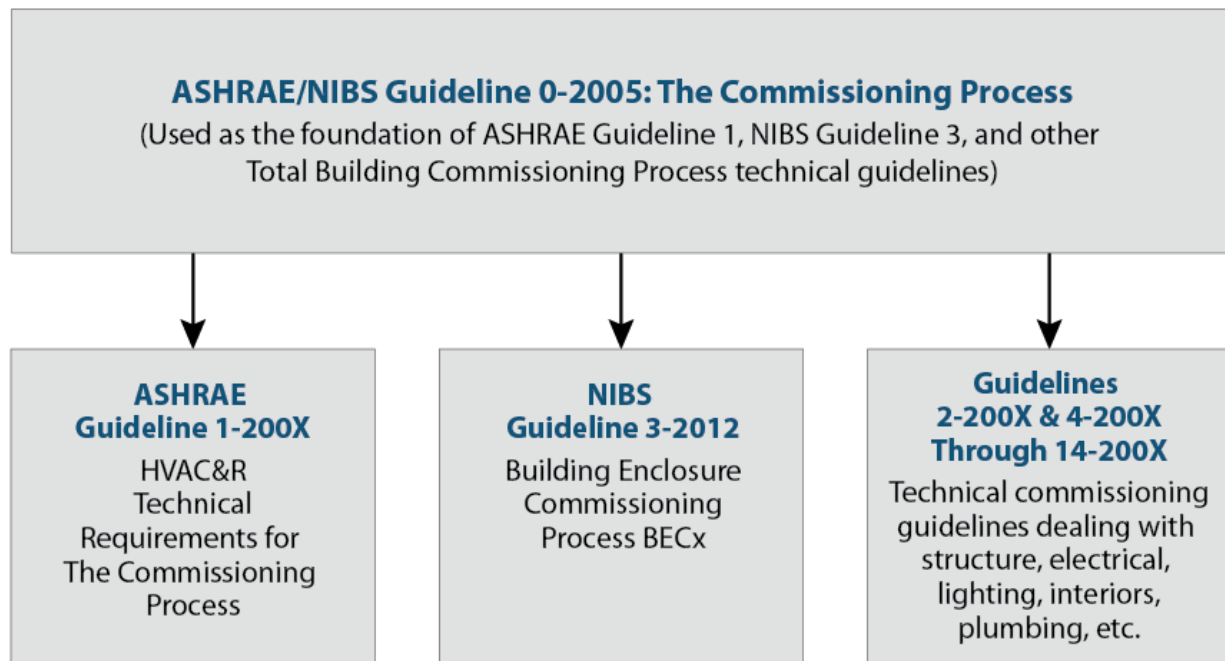
4. BUILDING ENVELOPE COMMISSIONING DEFINED

Current guidelines and documentation for commissioning include ASHRAE guideline 0-2005, which defines the commissioning process for both ASHRAE technical volumes for HVAC&R and NIBS guidelines for roofing, lighting, fire life safety, interiors, envelopes and plumbing. This paper focuses on ASHRAE guideline 0-2005 and NIBS guideline 3-2012, Exterior Enclosure technical requirements.

Per ASHRAE and NIBS, the building commissioning process is:

- A quality-oriented way of achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meets owner-defined objectives, from concept to operations and maintenance.
- A system by which owners, architectural programmers, designers, contractors, and operations and maintenance personnel are fully accountable for the quality of their work.

NIBS defines Exterior Enclosure as “the exterior enclosure of a building includes all systems separating the interior environment from the exterior, including exterior walls, fenestration, and roofing and roof openings, below grade perimeter walls and the slab-on-grade or crawlspace.”



5. BUILDING ENVELOPE COMMISSIONING PROCESS

The basic abbreviated building envelope commissioning process follows these steps:

- Initiate Conceptual Pre-design Consulting with the Team.
- Prepare an Owner’s Project Requirements (OPR).
- Prepare a Basis of Design (BOD) Report.
- Conduct Design Peer Review at determined design stages.
- Supervise Mock-Up Construction and Testing, carrying forward any lessons learned.

- Devise Performance Testing standards.
- Provide Construction Period Commissioning including inspection and testing.
- Develop a Commissioning Report.

The following sections provide details of the building envelope commissioning process:

A. Develop a Building Envelope Scope of Work

In the commissioning process, the first step is to determine the extent of the process to be implemented, and the budget. The building envelope commissioning process can include a very wide range of services, with a correspondingly wide-ranging budget. If you don't receive a clear Scope of Work from the owner, or owner's representative, the building envelope commissioning agent will need to develop the scope of services by asking numerous detailed questions to obtain an in-depth sense of the owner's needs and concerns. The commissioning agent can also question the owner about how issues such as maintenance and operating costs will impact return on investment (ROI) and capitalization rates for resale, as well as payback period for system upgrades. It is very important to understand the owner's project goals before developing the commissioning scope.

The project budget should include the cost of the commissioning process. Funds allocated for commissioning can usually be recouped from savings achieved through fewer change orders during construction, improved building performance, and reduced risk of future system failure. At the very beginning of the project, the commissioning process (Figure 1) needs to be established to all of the team stakeholders as an important part of the project process.

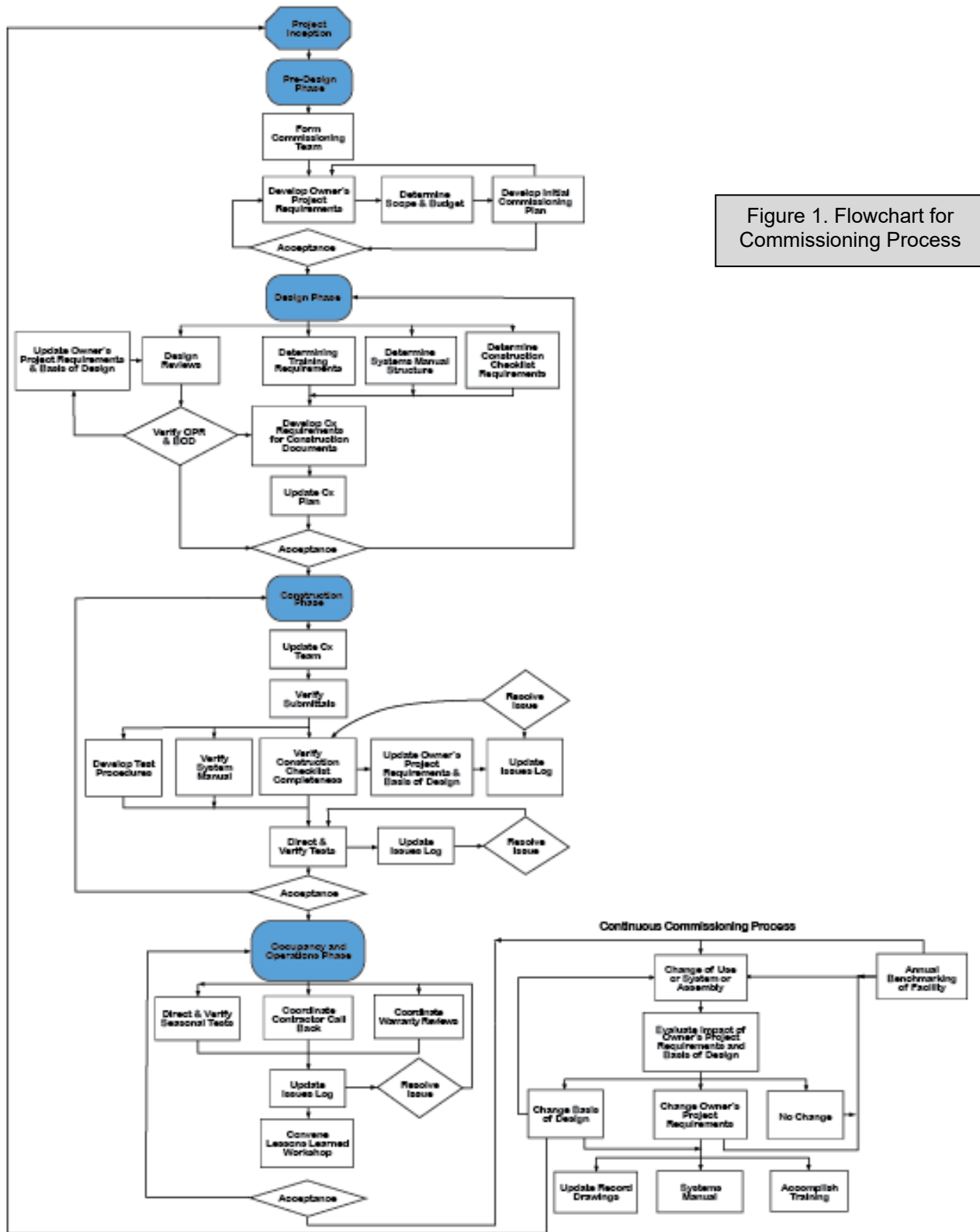


Figure 1. Flowchart for Commissioning Process

B. Pre-Design Phase

The Owner's Project Requirements (OPR) are developed and defined during the Pre-Design Phase. This phase is critical, since the OPR creates the foundation for the design, construction, occupancy, and operation of the facility, and are the basis for the Commissioning Plan and schedule. Each item of the OPR will include well-defined

parameters for performance and acceptance, plus the project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information.

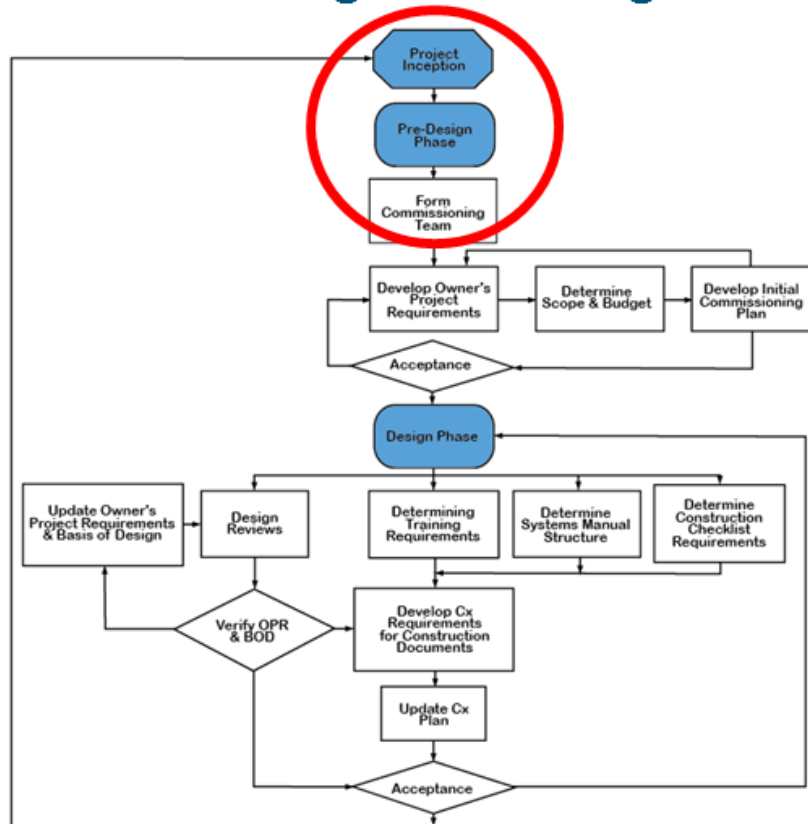
According to NIBS during the Schematic Design stage “In this preliminary phase, emphasis should be on the impact on budget and schedule required for commissioning of various enclosure options. Each building enclosure system has specific tests and tools available for qualitative and/or quantitative analysis of performance, with varying degrees of certainty.” *NIBS Guideline 3-2012 – 5.1.1.*

During the Pre-Design Phase, the Commissioning Plan is developed to address the OPR. The Commissioning Plan identifies processes and procedures and includes a schedule of commissioning activities, team member responsibilities, documentation requirements, communication and reporting protocols, and evaluation procedures. The Commissioning Plan is a “living document” that is continually updated during the life of a project. During the Pre-Design Phase, the Commissioning Plan focuses on defining the scope of the Commissioning Process for the Design Phase.

The following pre-design commissioning objectives must be met for any project:

- Ascertain the owner’s financial and building performance goals.
- Propose Building Enclosure Systems and Assemblies that match their intended use.
- Determine if the Building Enclosure meets the climate conditions.
- Review if the Building Enclosure meets the heating and cooling needs and the owner’s life cycle expectations.
- Confirm that the selected systems meet owner’s budget requirements.

Where Pre-Design Consulting Occurs



C. Design Phase

During the Design Phase, the OPR is translated into construction documents. A document called the Basis of Design Report (BDR) is created to provide a narrative description of the systems and assemblies that fulfills the OPR.

In this phase, the Building Envelope Commissioning Agent reviews the design professional's submittals. This is an extremely important step in ensuring that the OPR is being met, and that the design intent is accurately and thoroughly documented to remove ambiguities from the Building Envelope design. During this "Peer Review" the Building Envelope Commissioning Agent reviews documents at specific points of the design phase, typically during the Design Development and Construction Document phases of the project.

According to NIBS during the Design Development stage: "DD Phase Project Team Commissioning is a crucial phase in the design/ commissioning process, as the concept of the building is well enough established to allow resolution of the building enclosure design against highly defined and precise owners criteria. In this phase more detailed drawings, large-scale wall sections, elevations and details and preliminary specifications for the building enclosure systems are developed in support of the schematic design concept and BOD. The OPR is updated to reflect ongoing decisions. The Design Development Documents are verified against the OPR." *NIBS Guideline 3-2012 – 5.2.1.*

The review includes all building envelope system plans, details and specifications for general conformance with material manufacturers' requirements and industry standards. The review should also address interoperability between systems and coordination between disciplines.

NIBS outlines additional Design Development technical reviews including, but not limited to:

- “Review the design development documents for comparison of building enclosure assemblies and details, required testing and typical details for interfacing continuity. Details to be reviewed should include, but are not limited to: Typical details for roof-to-wall, foundation-to-wall, fenestration, wall-to-floor, wall-to-column, wall-to-floor, penetrations and other features that are common or highly repeated for the various enclosure assembly layering options.” *NIBS Guideline 3-2012 – 5.2.4.4*
- “Review the initial development of typical plans and details for interface of the various enclosure systems. Review both constructability and the design continuity for air, water, thermal and vapor control layer interfacing details are to be evaluated. The DD documents should clearly identify the extent of each control layer. At each interface between systems, i.e. window-to-wall, wall-to-foundation, wall-to-roof, verify continuity and compatibility of control layers and performance. The design review report should advise the project team on technical matters; provide recommendations for the development of details, systems and assemblies; and review documents for completion and coordination.” *NIBS Guideline 3-2012 – 5.2.4.5*

The Design Phase also includes:

Update the Commissioning Plan with processes and procedures for the Construction Phase, as well as the Occupancy and Operations Phase.

Define and develop Commissioning Processes to be included in the Construction Documents including quality-assurance and quality-control procedures. Commissioning processes are defined in the Division 1 to Division 16 specification sections and include processes for documentation, training, testing, and installation of systems and assemblies.

Develop Construction Checklists of equipment/assembly verification, pre-installation checks, and installation checks. These checklists are used to verify that the equipment and materials specified and submitted are what is actually delivered to the site, and that the condition of the equipment/materials has been examined before installation. The installation section of the checklist verifies that the specified testing has been completed and confirms proper installation of systems.

Develop a Systems Manual to contain the information needed to operate and maintain systems and assemblies. The Systems Manual should additionally serve as the source of information about any updates and changes to systems and assemblies as they occur during the Construction, Occupancy and Operations Phase. Contractor contribution requirements for the Systems Manual should be clearly stated in the Construction Documents.

D. Construction Phase

In the Construction Phase, the Building Envelope Commissioning Agent confirms that the systems and assemblies have been installed, inspected, tested, and placed in service in a manner that meets the OPR.

Construction Phase Commissioning Services include the review of submittals, shop drawings, mockups, and sample construction to confirm that the submitted materials meet the project specifications, and testing to confirm performance.

Various field testing protocols are recommended from the NIBS Guideline. They include, but are not limited to:

- “Conduct additional field testing as required if failures occur during the laboratory mock up, field mock up, or the field tests performed during the construction phase. Additional testing may also be needed if substitutions of materials and systems are accepted during the construction submittal phase.” *NIBS Guideline 3-2012 – 6.1.2.*
- “Conduct field review of the aesthetic and performance of mock-up(s). Review of the unique interface conditions with differing materials to verify they meet the design intent and will provide the performance levels and functionality of the building enclosure as specified in the contract documents. Mock-ups construction and testing must be scheduled with float time allowed for the remediation of unforeseen issues by way of iterative repair submittals and field performance testing of the mock up repairs prior to actual construction.” *NIBS Guideline 3-2012 – 6.1.3.*

During the construction phase, the Building Envelope Commissioning Agent will review field mock-ups focusing on general and unique interface conditions, to verify that they meet the design intent and will provide the system performance as specified in the OPR.

The Building Envelope Commissioning Agent witnesses the system testing procedures that were documented in the design phase. The Agent completes periodic site visits, particularly during critical events, and documents all observations. The Commissioning Agent maintains an open issues log to track any items noted during the observation that requires corrective action.

6. CASE STUDY

The following case study highlights the detailed steps required to plan, schedule, lead, coordinate, and manage the documentation for a successful Building Envelope Commissioning. The Building Envelope Consultant becomes involved early in the design process, providing consultation, peer review, and design services; designing and supervising mock up construction; testing; and creating project constructability manuals. This purpose of this process is to confirm that the building envelope system and assembly will meet the Owner’s Project Requirements in terms of their functionality, durability, constructability, quality of design and installation, and interoperability.

A. Case Project Overview

- 1,800+ for-rent residential units to be built in phases.
- Four wood-framed levels over concrete podium.
- Rapidly changing design and a fast-paced construction process.
- The following commissioning process was followed:
 - Met with the owner early on to understand the Owner’s Project Requirements.
 - Developed a Basis of Design letter.
 - Suggested assemblies to meet the owner’s budget goals.
 - Modified the design of assemblies to expedite construction.

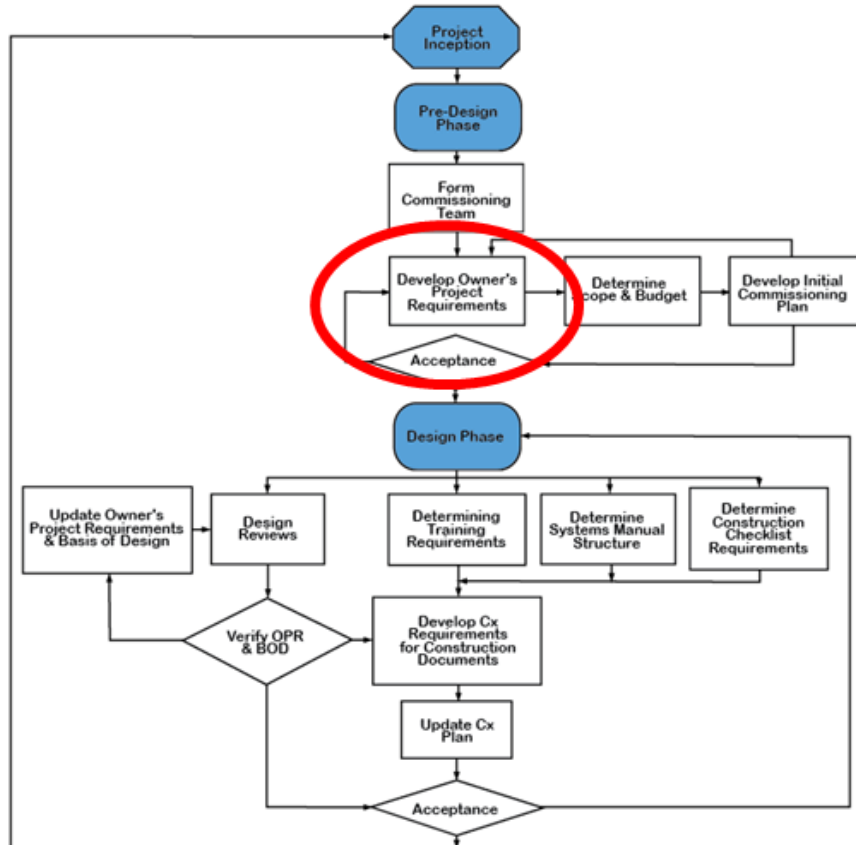
- Employed design development phase documents to establish final pricing and budgeting.
- Prepared a construction quality assurance program that included observations and testing protocols.
- The following building envelope systems were commissioned:
 - Below Grade Waterproofing
 - Landscaping Planter Waterproofing
 - Pedestrian Bridges / Catwalks
 - Podium Waterproofing
 - Private Deck Waterproofing
 - Exterior Wall Assembly
 - Windows
 - Doors
 - Roofs

B. Pre-Design Phase

The Owner's Project Requirements:

- Build and hold property for life.
- Build and operate a sustainable, maintainable property.
- Reduce construction defects and reduce risk of leaks and failure.
- Fastest possible construction pace – bring every unit to “revenue status” as soon as possible.
- Enclose the building as soon as possible.
- Use a small number of suppliers and manufacturers.

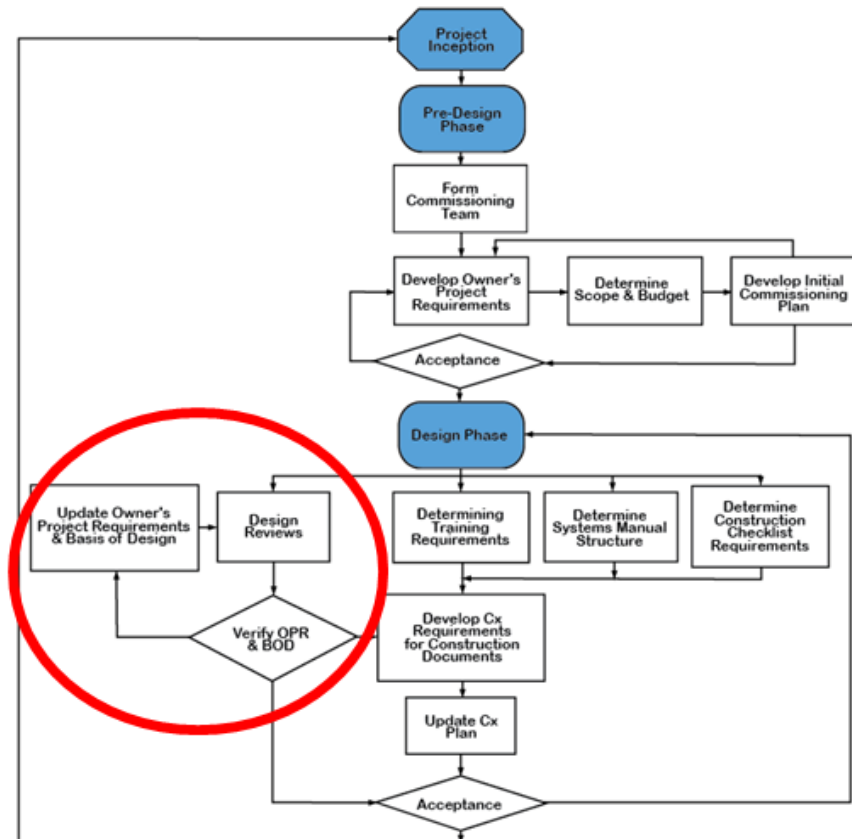
Where the “OPR” Is Developed



Basis of Design

- The following formalized system selections and specifications were approved by the owner:
 - Roofing Systems – Low Slope and Steep Slope
 - Podium and Pedestrian Deck Waterproofing Systems
 - Below-Grade Foundation Perimeter Wall Systems
 - Foundation Footing and Slab Systems
 - Exterior Wall Systems

Where the Basis of Design Is Developed



C. Design Phase

Budget Review

Construction details were developed with a goal of obtaining actual budget numbers before the start of construction. During the budget review phase, the owner received conflicting information about pricing of the recommended roof system. The contractor told the owner that cold polyurethane cost less than \$6 per square foot whereas hot rubberized asphalt would cost more than \$11 per square foot. The owner hesitated to approve the system as recommended and decided to use the cheaper but inferior system recommended by the contractor. However, after researching the issue it was discovered that the sub-contractor had quoted a higher price for the recommended system because they were inexperienced and unequipped for this installation type, and ultimately did not want to install the system. Upon hearing this explanation, the owner was persuaded of the long-term benefits of the system. A request for bids from local waterproofing contractors yielded pricing for the recommended hot rubberized asphalt process similar to the cold process, and the owner agreed to a return to hot rubberized asphalt.

Structural Changes

The original structural design called for spread footings and slab-on-grade foundation. A specific waterproofing method for this type of foundation requires that the waterproofing be applied in stages, with specific curing periods. It is a very complex process, both in phasing and in waterproofing, and some portions of these systems cannot be waterproofed.

Complexity = lengthier construction = increased general conditions + overhead = more \$\$\$

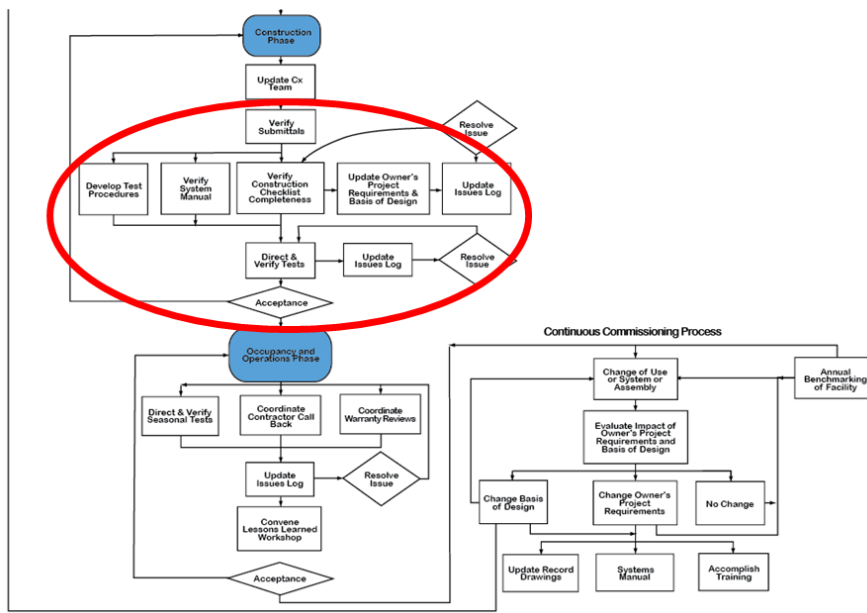
To fast-track construction scheduling, a mat slab with sodium bentonite system was used to allow faster building and waterproofing of the foundation rather than with spread footings.

D. Construction Phase

The following construction commissioning steps were implemented:

- Performance Mock-Up(s)
- Visual Mock-Up(s)
- Material Testing
- Continuous / Part-Time Inspection
- System Testing
- Field Review and Observation
- Compliance Testing
- Wind Uplift and Wind Load Testing
- Seismic Testing
- Vibration Testing
- Membrane Adhesion Performance Testing

Where Construction Commissioning Happens



Mock-Ups

To verify the OPR and BOD, a mock-up was used for waterproofing and building various assemblies. The mock-up provided valuable information whenever a need arose to resolve issues by alternative methods.

The mock-up was built by the trades as a stand-alone mock-up that included most of the typical details. The mock-up used the specified materials in order to simulate actual

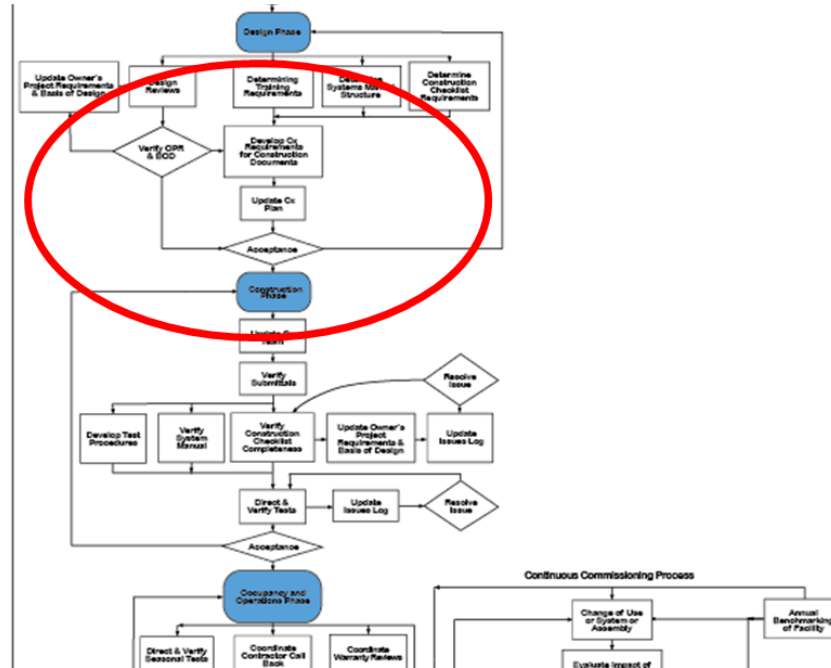
project conditions. The mock-up allowed the team to review how difficult transitions and turns would be constructed. Testing for compliance was conducted on the mock-up and set the level of standard of care and performance. The construction crews used the mock-up in reviewing and adopting best construction practices.

The mock-up stage yielded the following lessons:

- The mock-up supported the evolution of designs.
- The mock-up created a baseline for rapid, ongoing resolution of installation issues.
- The mock-up enabled chemical compatibility testing and adhesion testing
- Resolved dimension issues.
- The size of the mock-up limited the conditions that could be tested and created tight working areas.
- The mock up is not a panacea for resolving every issue.



Where the Mock Up Was Built



Benefits Realized from the Commissioning Process

- 1,800 fully occupied units represents approximately \$4 - \$5 million in monthly revenue. The commissioning process helped expedite the project and realize occupied unit revenues sooner.
- The commissioning process led to many system selections that saved installation time. Time = money.
- Standardizing the waterproofing systems reduced the complexity of installation.
- The building was made weather-tight faster, reducing the risk of weather damage.
- Strategic system selection resulted in faster construction sequencing.

7. CONCLUSION

Commissioning is a systematic quality assurance process that becomes part of the construction process during the early design stages and continues throughout the construction phases. Commissioning protocols can be applied to any building system, and should be especially considered for building envelope systems. The goals of commissioning are to 1) identify and mitigate issues early to allow the project to remain on schedule; and 2) provide a building that meets the Owner's Performance Requirements.

Photo Sources:

- All photos and details used were sourced by Allana Buick & Bers.
- Flow Charts were based on charts found in NIBS Guideline 3-2012 Building Enclosure Commissioning Process BECx.