The Building Commissioning Process

Introduction

We expect more of our buildings today than before. We expect greater safety and security, and we expect healthy, productive environments in which our faculty, staff, and students can live, work, and learn. We expect a reduced impact on our world from the construction, operation, use, and finally decommissioning of our facilities.

As our expectations grew over the past decades, so did the sophistication and complexity of our buildings and systems. The continuing growth of sophistication and complexity, however, has outstripped our ability to ensure that quality meets our expectations.

The building commissioning process bridges the gap between our heightened expectations, which lead to more complex and sophisticated facilities, and our need to ensure that our expectations are being met. This chapter introduces a process—the commissioning process—to bridge the gap, improve quality, and achieve our expectations for high-performance buildings. This chapter discusses the commissioning process applied to new construction and major renovations and when and how it should be applied, suggests how to acquire commissioning services, compares costs and benefits, offers steps for getting started, and provides links to resources for more information.

While the term “commissioning” may not yet be a buzzword, it seems that many facilities professionals recognize commissioning as a means of improving the operation of their facilities. In spite of this increasing recognition, confusion remains about what the commissioning process is and when it should start.

For many people, the term “commissioning” evokes a series of activities at the end of the construction phase aimed at making sure that building systems work right. This notion is a holdover from early in the evolution of the commissioning process. Unfortunately, this misconception limits the benefits realized. A brief review of the history of the commissioning process may illuminate the source of this confusion and why you should abandon it.

Genesis of the Commissioning Process

In the beginning, there was a new building that did not work right. The owner called a forensics hotshot to tell her what was wrong and how to correct it. The owner asked the contractor to correct the issues on the hotshot's list, but found completion to be slow and painful to achieve. We now call this retro-commissioning.

On the next project, the owner decided to implement commissioning during the construction phase so it would be easier to correct contract issues. Think of this as "start-up commissioning," or a rescue mission. Corrections of contract issues were completed in a more timely manner and with less conflict. But there remained design issues that were difficult to rectify.

So on the third project, the owner started commissioning in the design phase to try to reduce the number of design issues. Many design issues were corrected before contract documents were issued, so there were fewer issues during construction. However, some design issues seemed to be the result of inadequate communication of the owner's expectations to the design team.

Realizing she was on a roll, the owner started the commissioning process during the predesign phase on the next project. In the course of determining the project requirements, the owner gained a clearer understanding of her own quality expectations. Clear documentation of the owner's project requirements helped the designers target their solutions to the owner's needs. The owner finally evolved to a mature commissioning process, which is well defined in American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)/NIBS Guideline 0-2005, The Commissioning Process.

This narrative of the evolution of commissioning from a reaction to poor quality to a proactive effort to improve quality at each step of the capital acquisition process describes the growth of the state of the art over a period of some 30 years. A similar evolution occurs in many individual organizations as they apply the lessons from their early efforts to apply the commissioning process to their sophisticated grasp of commissioning as their quality process for new construction.

Along the way, the sustainable future movement recognized the importance of the commissioning process. Virtually all sustainable ratings systems require some level of commissioning. This trend results from experiences with sophisticated designs that failed to deliver the promised sustainability benefits, or that failed to meet other important project requirements.

The process of commissioning is relatively new to commercial and institutional building construction. The model for building commissioning derives from commissioning industrial facilities and naval ships. The serious consequences of failure in naval and industrial systems drive the effort to systematically and proactively wring out problems before systems are brought online. The failure of traditional building start-up, combined with the high operating costs, health, safety, and environmental consequences of failure, is the impetus that is driving adoption of the commissioning process in institutional facilities.

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

The ASHRAE/NIBS definition recognizes the importance of the interdependence of systems in delivering high-performance facilities. Early commissioning practice tended to concentrate on mechanical systems and their controls, with energy use an important target. While this is understandable given the important role that utilities played in promoting commissioning, we now understand that a successful facility requires more. Systems must interact on multiple levels to deliver safe, healthy, environmentally responsible facilities that operate at minimum cost. Power quality, which may be compromised by mechanical equipment, impacts the reliability of sensitive electronics. The heating, ventilation, and air-conditioning (HVAC) system and the building envelope work hand in hand to control the migration and condensation of moisture within building assemblies to prevent mold growth.

This definition of the commissioning process requires the definition of the relatively new term, owner’s project requirements (OPR). OPR replaces and clarifies the previously used “design intent.” Guideline 0-2005 defines the OPR:

A written document that details the functional requirements of a project and the expectations of how it will be used and operated. These include project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information.

The OPR is an expression of the owner’s needs and expectations. It requires interactive input by all the major stakeholders in a capital project. While a consultant may lead the OPR workshops and draft the document, the decisions and values expressed must be those of the stakeholders. The OPR becomes the yardstick by which the owner evaluates the success of the capital project team and the operation of the facility throughout its life.

One might think of the OPR as the bull’s-eye of a target. When the bull’s-eye is clearly defined, we hit it more consistently. The advantage of a clearly defined bull’s-eye is twofold. First, it helps the designer find the right solution. Second, it allows us to know if a solution hits the bull’s-eye. That is the core of a quality process: The producer knows that he or she has hit the mark, and the receiver can verify the same. Both have an unambiguous, common measure of quality.

It is important to understand the difference between the proactive quality process that is the state of the art today, and the reactive practices of the past. In a quality process, we establish the criteria for measuring success (the OPR) before we start designing or building a facility. We then use the criteria to guide the actions of all project team members and to evaluate the degree to which they succeeded in producing results that meet or exceed the criteria.

Past practices, and the current practice of those who have not adopted the state-of-the-art commissioning process, are fragmented and reactive. In some cases, the scope of commissioning includes only limited equipment or systems within the facility. In many instances, the commissioning team proceeds based on what they think is best for the owner, without benefit of a well-developed OPR to guide them. The fact that not everyone has adopted a quality commissioning process can result in confusion in the marketplace, which is likely to persist for some years to come.

The commissioning process aims to prevent flaws in design or construction that preclude facility operation in accordance with the OPR. To be sure, discovery does occur regardless of the application of the commissioning process. But without the commissioning process, discovery usually occurs under the most unfavorable circumstances, resulting in operating difficulties that could be critical or, in the extreme, even fatal. At the least, inconvenience for building occupants and maintenance and operations staff results. Commissioning compels discovery under controlled conditions, at a time when dire consequences are least likely to result.

Furthermore, if discovery occurs before the construction contract is accepted as complete, the consultants and contractors will bear the burden of taking corrective action and generally all related costs. When discovery occurs later, the owner inherits the responsibilities and costs, with little or no recourse back to those responsible for the failure.

The basis of design (BoD) document answers the owner’s criteria laid out in the OPR. The OPR and BoD are to commissioning what call-and-response are to jazz. For each OPR Criterion call, the designer responds with a narrative of the proposed design solution. ASHRAE Guideline 0-2005 defines BoD as:

A document that records the concepts, calculations, decisions, and product selections used to meet the Owner’s Project Requirements and to satisfy applicable regulatory requirements, standards, and guidelines. The document includes both narrative descriptions and lists of individual items that support the design process.

Quality-Focused Process

The quality-focused approach to the commissioning process described in this chapter seeks to improve the delivery of a project at every step. It does not limit its attention to the final results. Continuous monitoring and evaluation of the quality of the delivery delivers superior results. Conversely, when we focus solely on the last phase of facility acquisition, we miss important opportunities to improve the outcome.

For example, in a new electrical engineering facility, the design team blindly accepted the department chair’s statement that internal cooling loads would be a whopping 40 watts per square foot. Consequently, they designed a...
grossly oversized chilled water plant, served by a single chiller. The commissioning process flagged the oversized plant and brought stakeholders back to the table to clarify their needs. What the electrical engineering department really wanted was 40 watts per square foot in a small portion of the building to handle graduate computing rooms, but they also wanted flexibility to relocate the high-load portion of the building throughout the building. Redesign reduced the chiller plant to less than 20 percent of the original design, but provided oversized distribution piping within the building with frequently spaced, capped tees for future connection of fan-coil units.

The original plant would have cooled the building, even though the load was less than 10 percent of the plant capacity. The mismatch of capacity and load, however, would have shortened the life of a large, expensive chiller and consumed excess energy. An end-result-focused commissioning effort would have missed the opportunity during design to reduce the plant capacity to better match the load.

**Goals**

The overall goal of building commissioning is to have a facility that operates as intended. However, the commissioning process also achieves several important subgoals.

The primary subgoal is to provide a safe and healthy facility for students, faculty, staff, and the public. Commissioning minimizes functional and operational deficiencies responsible for the majority of indoor air quality problems and comfort complaints. Commissioning also minimizes liabilities inherent in laboratory building operations.

The second subgoal is to improve energy and utility performance. Commissioning is the "tune-up" that yields the most efficient performance from the installed equipment. Commissioning tailors system operating parameters to the conditions of actual use. The holistic perspective of the commissioning process also improves energy and utility performance by careful attention to the interface and coordination of the various building systems.

The third subgoal is to reduce operating costs. Equipment that operates improperly is operating inefficiently. Poor operation usually induces more frequent maintenance activity and results in shorter life expectancy for the equipment. The commissioning process reduces annual operating costs increases and limits the frequency of capital replacement costs.

The fourth subgoal is to improve the capability of the operations and maintenance (O&M) staff. Improved orientation and training coupled with more useful documentation enables the staff to sustain the high performance achieved during the initial commissioning efforts. No matter how well the equipment and systems operate at the onset, they will deteriorate without proper care, and may even be crippled by staff who do not have sufficient training or resources. Staff take ownership and pride in high-performance operation of sophisticated new systems when they are well prepared and have the tools and documents they need.

The fifth subgoal is improved documentation. Specifications and drawings do not provide all of the information needed for operation, troubleshooting, and renovation of the facility. OPR and BoD documentation, one-line diagrams, control logic diagrams, and operating descriptions help to communicate the owners' and designers' intentions to current and future operators and designers. Fully documented testing procedures and results verify the capacity and operating parameters of the facility and systems and facilitate recommissioning as needed in the future.

The final and most important subgoal is to meet the clients' needs. When design and construction work includes a systematic verification of quality, the team will meet the OPR and achieve customer satisfaction.

**Scope of Commissioning**

The commissioning process embraces a holistic understanding of buildings. The successful performance of a building requires coordinated, integrated design, construction, and operation of all building systems and assemblies. Hence, the building commissioning process encompasses all building systems. The weakest link is the one excluded from a quality process.

While not normally addressed specifically by the commissioning process, many systems and assemblies have independent quality processes. From soil testing to concrete slump tests, to weld inspections and X-rays, to masonry waterproofing performance tests, to landscape soil density and water retention tests, there are well-established procedures to evaluate the performance of systems, assemblies, and materials. All of these procedures may be subsumed into the discipline of the commissioning process for ease of management. At the very least, the commissioning process should verify that someone takes responsibility for test execution and acceptability of the results for tests outside of the scope of commissioning.

Consolidation of traditional tests under the discipline of the commissioning process occurs widely in the mechanical and electrical work. The commissioning process did not invent pipe leak tests, for example. But the leak tests are prerequisites of other commissioning tests, so they must be scheduled, coordinated, and documented within the process of commissioning.

Overall, commissioning is the process that manages quality of the entire facility, from the ground up and from concept to demolition.

**The Commissioning Process**

Once it is recognized that all building systems must be commissioned, the process for doing so becomes specific and disciplined. For commissioning to become an effective program, design and construction team members must
understand the commissioning process and willingly accept their responsibilities.

In brief, the owner must make commissioning expectations clear during the predesign phases of each project, as expectations may vary with different kinds of projects. Then the project team must translate the commissioning process into contract documents. Because commissioning scheduling, procedures, and activities are currently not well understood throughout the construction industry, contract documents must be much more comprehensive and specific regarding this process.

It is no longer enough to just build the building. Now the contractors and consultants have to make it work. The following sections elaborate on the steps required to implement an effective commissioning program.

Through multiple, progressive acceptance milestones, the commissioning process creates a structure of verified quality at each step in the life of a facility. Failure to verify the quality at any step along the way reduces the structural integrity of the commissioning process. This section describes the commissioning process for new construction and major renovations sequentially, following the chronology of a typical capital project from predesign through design and construction to occupancy and ongoing commissioning for the life of the facility.

It might appear that if one does not initiate the commissioning process during predesign, all is lost. Never fear, there are ways to compensate for the missed opportunity if commissioning starts later in the project. However, when commissioning does start after predesign, the team has to play catch-up, trying to fill in missing information and performing tasks that should have already been completed. Playing catch-up is inefficient, but is still better than not commissioning at all. The commissioning process returns greater benefits at lower costs when it starts in a timely manner. So the message here is, start the commissioning process during the predesign phase of the project—if not on projects that are already out of the gate, then on future projects.

Finally, a comment about the following discussion of the commissioning process, as distinguished from ASHRAE Guideline 0-2005, seems appropriate. Guideline 0-2005 represents the state of the art in its detailed outline of the commissioning process. This chapter augments Guideline 0-2005 with information and perspectives useful to the higher education facilities professional. Guideline 0-2005 and the associated technical requirements guidelines, ASHRAE Guideline 1.1-2007 HVAC&R Technical Requirements for the Commissioning Process, and NIBS Guideline 3-2006, Exterior Enclosure Technical Requirements for the Commissioning Process, are valuable resources that should be accessible to every facilities management organization.

One source of basic commissioning documents for tailoring and use in projects is APPA: The Association of Higher Education Facilities Officers. APPA’s publication The Building Commissioning Handbook (2nd ed.) includes examples of commissioning documents, test criteria, and test procedures.

**Predesign Phase**

Preparation for the commissioning process occurs in parallel with capital project preparation. The scope of commissioning, the commissioning budget and schedule, a preliminary commissioning plan, and the composition of the commissioning team are established during predesign, and the OPR is documented.

**Owner’s Project Requirements**

Documentation of the OPR represents one of the most important advances in recent years in the quest to improve project quality. Project programming establishes important parameters for a project, but generally does not fully answer the question, “What is required for this project to be a success?” The OPR augments the project program by adding quality and performance criteria for the success of the project. Armed with this information, design professionals deliver design documents that are more responsive to the owner’s expectations.

Detailed performance criteria helped a major university deliver environmental chambers that met researchers’ needs. Previously, the university had suffered an almost unbroken string of failed environmental chambers in its capital projects. The program documents had answered the questions about the size, plumbing needs, operating temperature, storage rack configuration, and door configuration, but the chambers still needed modifications after they were completed in order to support the researchers’ work.

When facilities engineers began asking the right questions, the end products were successful. For example, engineers asked, “What are your expectations for uniformity of temperature from floor to ceiling and wall to wall?” Or, “How quickly must the temperature set point be regained after the door is held open to bring in a load of materials at room temperature?” Or, “Will you ever need to operate this chamber at a different set point? If so, what is the range of temperature set points you anticipate? How quickly must the new set point be reached?”

In some cases, the academic representatives had to refer the questions back to the primary investigators. The academic representatives and the project managers grumbled about delays and nit-picking questions. But once designers had the answers, they delivered designs that worked right from the start.

Because the OPR information is so critical to the success of the project, the final OPR document should be included in the owner-architect agreement as part of the definition of deliverables.

Owners are surprised at the type of information developed in the OPR. The fire department of a large city recently embarked on a program to upgrade all of the city’s fire facilities to meet heightened seismic requirements and to deal with other inadequacies. They sought to implement a standardized commissioning process for work at all the stations. When the commissioning consultant recommended a series of workshops to define the OPR, they resisted, saying they had already spent way too many hours in meetings discussing programming, and that they could not imagine how further time could be spent productively.
They reluctantly agreed to a half-day workshop, at the conclusion of which they would decide if further time was warranted. Representatives from the fire department, capital projects, construction management, O&M, telecommunications, and housekeeping gathered for the workshop facilitated by the commissioning consultant. Participants responded to 3 of the 16 questions proposed for the full workshop series. At the conclusion, they unanimously requested continuation of the workshop to finish working through all the questions. Enthusiastic comments from veteran capital project managers and construction managers included, “This is powerful. No one has ever asked questions like these before,” and “This has to be part of every project from now on.”

So why all the excitement? The workshop elicited input from all stakeholders in a forum that gathered input equally from the most retiring maintenance technician to the most domineering fire commander. The open-ended questions brought forth the widest range of responses, some of which at first appeared a bit unusual but turned out to be important. The ranking of input was accomplished by polling, but all responses were included in the final document.

Examples of the workshop questions may further illustrate the differences from traditional programming:

- What are the key objectives the city wishes to achieve in these projects?
- What are the functional requirements of these stations?
- What conditions and features contribute to maintaining safety and security at fire stations?

The OPR document conveys the raw responses from the workshop plus discussions of the highest ranked responses from each question. The discussion material reflects the workshop discussions and adds the facilitator’s perspective. Workshop participants should review and comment on the draft OPR. The final OPR document becomes a permanent part of the facility record, and should also be included as an attachment to the owner-architect agreement. It should also be made available to the construction contractor. ASHRAE Guideline 0-2005, *The Commissioning Process*, contains recommendations on the content of the OPR and the workshop process.

**Scope of the Commissioning Process**

Because the budget for commissioning needs to be established within the context of the overall project budget during the predesign phase, determining the scope of the commissioning process becomes an early priority.

The OPR may impact the scope of the commissioning process. While we would all like to include all building assemblies, systems, and features in the scope of commissioning, budget realities usually force us to prioritize. The OPR clarifies commissioning priorities. The scope of commissioning should be determined or reviewed after the OPR workshops. When the commissioning scope and the commissioning budget do not seem to align, as is frequently the case, either the scope must be reduced or additional funds must be committed. For those cases in which sufficient funds cannot be obtained, the scope must be reduced.

To reduce the commissioning scope, cut the number of assemblies, systems, or features included in the commissioning scope, not the commissioning process activities. The commissioning process resembles a building structure in some ways. If we remove some of the columns or beams, we compromise the integrity of the structure. Similarly, if we delete some of the commissioning process activities, we compromise the integrity of the commissioning process. When the budget dictates cost reductions, we reduce the square footage of the building rather than cut out structural members. When the budget dictates, we cut systems from the commissioning scope rather than activities. Figure 1 illustrates this concept.
This raises the question of how to prioritize assemblies, systems, and features when it comes time to reconcile the commissioning scope and budget. The OPR document identifies some high-priority systems but may not provide sufficient information to fill in the lower ranks of the prioritization list. A matrix that rates each assembly, system, and feature under consideration for inclusion in the scope of commissioning on its merits for several criteria gives a quick assessment. Input may be sought from the same stakeholders who participated in the OPR workshops. Criteria might include, for example, mission criticality, utility and environmental impact, indoor environmental impact, maintenance implications, life-safety consequences, and political sensitivity. Of course, the preferred solution is to obtain funding to match the scope.

### Budget for the Commissioning Process

The Economics of Commissioning section includes rules of thumb for estimating the budget for commissioning services. The discussion here deals with general budgeting issues.

Establishing budgetary authority for the various components of the capital-project-related first cost of commissioning within the project budget as part of the initial funding request avoids unpleasant discussions later about whose jealously guarded piece of the project budget will be cut to be able to afford commissioning. Responsibility for delivering a fully functional facility should fall squarely on the shoulders of the capital project, so the budget for commissioning should be included in the capital project allocation.

This chapter discusses commissioning throughout the life of the facility, including the occupancy and operations phase. The ongoing commissioning expenses of the occupancy and operations phase need not be funded with the capital project. However, all commissioning costs associated with the predesign, design, and construction phases, up to and including final acceptance, should be funded in the capital budget. These first costs include the services of the commissioning authority, additional services of the architect and engineers, project manager and/or construction manager, and the construction contractor for their support of the commissioning process. The section "Acquiring Commissioning Services" discusses the recommended scope of commissioning services for the various commissioning team members.

### Commissioning Schedule

Tight integration of commissioning process activities with other design and construction activities helps the entire project achieve a higher on-time success rate.

Completion of commissioning activities should be tied to standard project milestones such as design review milestones, as well as substantial completion and final acceptance. To meet commissioning milestones, design and construction activities need to be on schedule. In fact, in most projects, commissioning impacts the sequencing of the design and the construction.

For example, in order for commissioning tests to be incorporated in the bid documents, the facility management system controls design must be substantially complete at the design development submittal. Currently, controls are typically added to the design at the very last minute. Accelerating design of the control systems benefits the quality...
of the project. Similarly, during construction, the need to start testing equipment early in construction induces earlier completion and energizing of the power distribution system.

The commissioning schedule should not only show commissioning activities tied to project milestones, but should also indicate other design or construction activities upon which the commissioning activities depend. Because the commissioning schedule impacts the design deliverable schedule, the commissioning schedule should be developed in time to be included in the owner-architect agreement.

**Commissioning Plan**

A preliminary commissioning plan describes the commissioning process and scope, includes the commissioning schedule, and identifies commissioning team members and their commissioning responsibilities. It is a communication tool intended to inform the commissioning team at all levels, from administrators to trades workers as to how commissioning will be accomplished on a particular project. It is not a contract document, though it may be used as an information document made available to bidders, similar to a soils report.

**Commissioning Team**

Commissioning is no longer accomplished by a hero on a charging white stallion. It is now a team sport. Though not all commissioning team members can be identified by name at this stage, they can at least be identified by organizational role or title: for example, fire alarm subcontractor; heating, ventilation, and air-conditioning maintenance mechanic; landscape architect; or construction manager. A clear description of each team member’s commissioning team roles and responsibilities should be included in the commissioning plan. It is important to verify that each team member is willing and available. In the case of design consultants, for example, “willing” means that their responsibilities are defined in their agreements and that they are compensated.

**Design Phase**

The design phase is characterized by close coordination between the commissioning authority and the design team. Significant commissioning activities during design include basis of design documentation, review of the BoD and other design documents, and the development and coordination of commissioning specifications in the bid documents.

**Basis of Design**

The BoD is the very first deliverable from the design team. Review and acceptance of the BoD should be a prerequisite for proceeding with schematic design. By insisting on acceptance of the BoD before schematic design, we minimize the number of design wrong turns. No communication is perfect, but communication without feedback makes misunderstandings even more likely. Reviewing the BoD verifies that the design team correctly understands the OPR so that their design will be closer to the bull’s-eye.

**Design Review**

Design review continues the quality process of verifying that the design team is delivering a set of solutions that meet the OPR. ASHRAE Guideline 0-2005 identifies the following commissioning design review focus:

- General quality review of the documents, including legibility, consistency, and level of completeness
- Coordination between disciplines
- Discipline-specific review for achieving the OPR
- Specification applicability and consistency with OPR and BoD

As we can see from the list above, this is not a peer review; it is a quality review. There are multiple valid solutions to any design challenge. The commissioning review should not pit one expert against another for who has the “best” solution. It is a review that asks the question, “Does this design deliver a solution that meets the OPR?” If the answer is affirmative, then the project should proceed to the next step. If there are design elements that do not meet OPR criteria, discussion may reveal that the reviewer did not fully comprehend the design or that additional design effort is needed to achieve compliance with the OPR.

Commissioning design reviews should be undertaken at strategic points in the design process, typically at the same milestones at which the owner reviews progress submittals (frequently schematic design, design development, and contract documents). Review comments should be presented to the owner in writing and responded to by the designers, also in writing. On-board design review meetings to kick off the review period enhance the effectiveness of the review.

**Commissioning Specifications**

The construction contractor plays a vital role in the commissioning process. The contractor needs to understand the extent of his or her commissioning responsibilities when he or she prices the work. Therefore, we need to include sufficient information about the contractor’s commissioning work in the bid documents so he or she can develop the pricing accurately and competitively. A more detailed technical discussion of commissioning specifications follows in the Acquiring Commissioning Services section.

Specifications for commissioning encompass general, administrative, and technical requirements. General and administrative provisions include schedule of values, performance of commissioning installation verification and
testing, completion requirements, schedules, submittals, qualifications, and coordination. Technical requirements fall into commissioning sections (XX 08 00) within each division of the specification and include the start-up, installation verification, and testing requirements pertinent to the work of the division.

Start-up, installation verification, and testing provisions describe each activity in sufficient detail that an estimator can assign resources to establish pricing. Failure to specify adequately the scope of the contractor’s technical requirements leads to disagreements over the scope of the work, often costing the owner’s time and money and the contractor’s good will.

To be effective, commissioning specifications must be tailored to the particular systems and assemblies of each project, and must be tightly integrated with other contract provisions. The need to integrate commissioning specifications and tailor them to the project necessitates early coordination between the design professionals and the commissioning authority on two levels. First, the design information upon which the commissioning specifications depend needs to be developed in a timely manner. Second, good specification writing skills must be combined with commissioning process expertise.

The example cited previously of the need to complete the facility management system control design at the completion of design development illustrates the content coordination challenge. Commissioning test specifications depend on the particulars of the systems, especially the sequences of control. The sequence of control for a single system typically generates a number of commissioning tests, each of which must be specified in the bid documents. If the sequences of control are not completed until the 100 percent construction documents submittal, there is simply no time to write the corresponding commissioning tests.

Furthermore, in most cases, the sequences of control generate a significant number of design review comments. The designer needs time to respond to the comments and make changes to the sequences before the commissioning tests can be written.

Much has been written about the advantages of documenting the sequences of control before detailed design of the systems. In his ASHRAE Journal article, Ira Goldschmidt, P.E., writes, “Leaving the controls design to the end of the project will greatly increase the chance that neither the HVAC system nor the controls will work well.” To Mr. Goldschmidt’s comment, we would add that neither will the commissioning tests be properly specified when controls design is left to the end. For this reason, the matrix of design deliverables in Acquiring Commissioning Services calls for completion of controls diagrams and sequences of operation at the design development milestone.

The controls example illustrates the technical content coordination challenges. However, coordination of commissioning requirements also reaches into the supplemental conditions of the contract and the general requirements in Division 01. The challenge here is that some owners, particularly in the institutional realm, provide standardized general and supplemental conditions language to the design consultants with the expectation that the language be included verbatim. The owner’s legal advisers have fine-tuned these provisions to protect the owner’s interests, so they are wary of any suggestions to modify the language. Changes must be reviewed and approved by the legal advisers, and perhaps by other stakeholders, which takes time.

When standardized provisions are not made available to the team until the last weeks before bid document publication, there is really no time left to coordinate any changes. Therefore, we recommend that if owners intend to provide standardized supplemental conditions and general requirements provisions, they do so no later than the end of design development. Acquiring Commissioning Services discusses the specific changes to the supplemental conditions and general requirements needed to make commissioning technical requirements effective.

Depending on the mix of skills and experience, the mechanics of communicating the commissioning information in well-written contract language usually requires collaboration between a professional specification writer and a commissioning process expert. Frequently, commissioning process experts lack spec-writing skills, and specification writers lack depth of knowledge about the commissioning process. Either hiring a commissioning authority with demonstrated specification-writing skills or including in the architect’s agreement provisions for their spec writer to edit the commissioning specification drafts provided by the commissioning authority will result in technically correct specifications that are enforceable.

**Documentation Enhancement**

Commissioning teaches us valuable lessons about how to improve the design documents to improve the performance and quality of the project. A few of the most important improvements:

1. **One-line Diagrams:** Include in contract drawings one-line diagrams depicting operations at various design conditions, including fluid flow rates, temperatures, and pressures as necessary to illustrate the intended operation. Contractors and operators grasp intended system operating modes more quickly with this graphic presentation than they would trying to follow a system from sheet to sheet. Group one-line diagrams on adjacent drawing sheets and place them in close proximity to the sequences of operation.

2. **Sequence of Operation:** Most engineers did not choose engineering because they were particularly skilled writers. Consequently, when they attempt to write a description of a complex sequence of operation, the results are often incomplete, ambiguous, and contradictory. However, when engineers use logic symbols (inputs, decision blocks, outputs) to assemble logic flow diagrams, the results are concise, unambiguous, and complete. Include the sequences of operation in the drawings, not in the specifications.

**Equipment Specifications**

Adding performance criteria to equipment specifications allows responsible evaluation of substitution requests, and
provides information needed to specify commissioning test acceptance criteria.

**Construction Phase**

During the construction phase, scheduling and coordinating commissioning work with other work is an ongoing challenge. Other significant commissioning work during construction includes submittal reviews, installation verification and testing, generation of the systems manual and ongoing commissioning plan, and verification of owner training.

**Prebid Meeting**

While the bid period is not, strictly speaking, included in the construction phase, a brief comment here about commissioning content of the prebid meeting is in order. Unfortunately, many contractors still have not experienced a rigorous commissioning process. If we want contractors to be partners in the quest for quality facilities, we should help them avoid unpleasant surprises. Alerting bidders to the inclusion of significant commissioning requirements during the prebid meeting minimizes the likelihood that they will grossly underestimate the commissioning work in their pricing.

**Commissioning Schedule**

The same contractors who need a heads-up in the prebid meeting may also misunderstand how commissioning work ties into the construction schedule. Commissioning work need never be on the critical path except for a few days immediately before occupancy. Opportunities exist to perform installation verification and commissioning tests months before occupancy.

The proactive quality approach to the commissioning process leads us to perform installation verification progressively as each system or assembly is completed, even if only on part of a floor. Some work, such as site utilities, may be ready for installation verification before the halfway point on the schedule. Performing installation verification as the work progresses reveals issues that can be corrected while installing the remaining work, avoiding the time and expense of rework. If installation verification exposes issues requiring replacement of long-lead items, the earlier this is done the better the results will be.

But all of these opportunities evaporate if the commissioning work is not integrated effectively into the construction schedule. For this reason, the contractor must include commissioning process activities in construction schedule submittals, complete with predecessor and dependent linkages.

**Submittal Review**

While the design professional retains responsibility for reviewing submittals for compliance with the contract, a concurrent commissioning review of a sample of the submittals focuses on evaluating whether submittals meet the criteria of the OPR. Commissioning review may identify variations in equipment configuration, quality, or control, which may meet the letter of the specifications but which compromise criteria such as maintainability, longevity, reliability, or controllability. The commissioning review should be completed in time for comments to be included in the design professional’s formal submittal review response.

**Installation Verification and Commissioning Tests**

Bid documents include descriptions, and perhaps examples, of the installation verification and commissioning tests for use by the bidders. Detailed procedures and forms usually are not included in bid documents for two reasons. First, the final procedures and forms reflect the specifics of the equipment, systems, and assemblies approved for construction through the submittal process during construction. Second, the sheer volume of paper to print all the procedures and forms would typically outweigh the rest of the project manual.

So, we create detailed procedures, checklists, and forms for installation verification and commissioning tests during the construction period, after submittals are approved and installation, operation, and maintenance instructions are received. If the commissioning authority creates these procedures and forms, the contractor should be offered an opportunity to review the drafts for issues pertaining to safety, equipment protection and warranty restrictions, and specified scope of work.

In order for installation verification and commissioning test procedures to be developed in time for use, O&M submittals must be available. Clearly, the typical delivery of O&M materials sometime after occupancy does not meet this need. We have found that specifying submittal of O&M materials within 30 days after approval of product submittals or shop drawings is both necessary and achievable if properly specified. This has the added benefit of making the O&M materials available for training and inclusion in the systems manual.

As work progresses, the contractor fills out the installation verification forms for each piece of equipment, assembly, or section of work (such as piping or wiring). The commissioning authority verifies a sample of the completed installation verification forms during regular site visits, noting any instances of work that do not agree with the requirements.

With this approach, the contractor retains primary responsibility for control of the quality of his or her own work. Verification of the reported results by the commissioning authority seeks to evaluate the effectiveness of the contractor’s quality control. We find that if the individual trades worker, or at least the crew lead, fills out the
installation verification forms, quality improves. On the other hand, if the foreman or project manager fills out the forms, quality suffers. If the individuals doing the work understand our quality expectations (because they are reading and filling out the installation verification forms), they strive to meet them. We succeed in improving the quality of the work.

When the commissioning authority samples the completed installation verification forms, we identify systemic issues early enough to avoid repeating them on the remaining work. Sampling the completed forms also provides a reality check on the extent of completion of the work. This work status informs review of pay applications and may prompt adjustments to the construction schedule to keep it real. Installation verification improves work quality and helps manage the progress of and payment for the work.

Training Verification

Effective training of O&M staff and occupants increases the benefits of the commissioning process. Results-oriented training specifications encourage the contractor to deliver meaningful training targeted to the specific needs of the staff, and allows the commissioning process to verify the effectiveness of the training.

Verification takes place by monitoring the actual training sessions and by sampling the skills, knowledge, and proficiency of the staff. Asking each staff member at the end of a training session to demonstrate how to perform a task or where to find information keeps trainers and trainees fully engaged in the learning process. Gone are the days of a technician pointing to the chiller control panel while jumping from screen to screen and muttering a few expressions, mostly inaudible over the whine of the machine, about set points, alarms, and history, and concluding with “Now, any questions?”

Systems Manual

Think of a systems manual as an O&M manual on steroids, augmented with the information needed to operate the systems in a facility. Traditional O&M manuals are long on exploded parts views and maintenance schedules for individual pieces of equipment and short on discussions about how the various pieces of equipment work together as a system.

That really should not surprise us, should it? After all, the manufacturers of the chillers, valves, pumps, and cooling towers and the manufacturers of the drywall, insulation, vapor barrier, and cladding have no idea how those pieces of equipment and materials will be assembled and used. Nor do they have any idea of how the O&M staff is organized and managed. That information about how stuff will be assembled, used, maintained, and operated is unique to each project. So we must produce information about how systems operate within the context of a particular facility and organization—hence a systems manual.

Typically the commissioning authority writes the systems manual, assembling information gathered from various project team members and filling in the narratives of how the systems operate in their final configuration. The systems manual includes the OPR, the BoD, construction record documents, O&M manuals, system operations narratives and schematic diagrams, training materials, and the commissioning process report. Organizing systems manuals by trade or shop responsibility, with subdivisions by system, makes the manuals more useful. Providing the materials electronically so they may be carried on a laptop or available over the campus network makes the information accessible.

Ongoing Commissioning Plan

Equipment, systems, and assemblies degrade over time. The high performance established during the initial commissioning process deteriorates significantly after three years.

When the commissioning process continues throughout the life of the facility, performance degradations can be monitored and corrected before they have significant impact. An ongoing commissioning plan sets up a schedule of periodic commissioning activities to be handled similarly to other scheduled maintenance activities. The plan also describes continuous monitoring established during initial commissioning, with comments on how to respond to exceptional performance and how to update and maintain these trend and alarm log features.

At a private college in southern California, the system recorded motor amperages every minute for all motors five horsepower and greater. Certainly the volume of data would overwhelm the most robust storage system in a short time. The solution was simple and extremely effective. They used a “collapsing trend log” strategy that reduced minute-by-minute data to hourly averages as the data aged, then to daily averages as it aged further.

The power of this solution became apparent while the facility manager was demonstrating the system to a visitor. During the visit, the facility manager received a call from a building manager complaining that the stuffiness had gotten still worse since he put in a trouble call some weeks earlier. The facilities manager called up the supply fan motor trend log as he spoke with the building manager. The log showed a sharp drop in amperage shortly after the trouble call. The facilities manager looked up the work order and called the mechanic who had adjusted the drive sheave to change the fan speed. The mechanic had adjusted the sheave the wrong way, slowing instead of increasing fan speed. He was dispatched again with instructions to readjust the fan speed and use a tachometer to verify the correct fan speed before leaving. With recent detailed and long-term average motor performance history at his fingertips, the facilities manager quickly diagnosed and resolved the issue for a very grateful building client.

Substantial Completion

The handling of substantial completion, generally recognized as the point at which the owner assumes beneficial occupancy, greatly affects the value realized from the commissioning process. As the substantial completion date
approaches, the contractor gets anxious to demobilize and move on to the next project, the construction manager feels pressure from the client who is impatient to move in, the designers’ construction administration budget evaporates, and the commissioning authority struggles to keep the team engaged in finishing the construction phase commissioning work.

We recommend adding contract provisions that explicitly make completion of specified construction contract commissioning work, including correction of contract deficiencies and completion of the contractor’s draft commissioning report, a prerequisite for issuance of the certificate of substantial completion. The threat of mounting liquidated damages is a powerful inducement. This approach works, but only if it is enforced.

For the inevitable issues that delay completion of commissioning work prior to substantial completion, the owner may choose to grant an exception to allow certain commissioning tasks to be completed after substantial completion. In addition to the deferred tests discussed below, last-minute equipment failures or other unavoidable delays may fall into this category. Failure of the contractor to manage their commissioning work does not qualify the rub is that sometimes the capital project manager fails to verify completion of commissioning work before approving the certificate of substantial completion. At that point, the owner loses his or her leverage to compel the contractor to complete the tests and resolve those last troublesome issues in time for occupancy. Too often we see how difficult it is to use the warranty provisions to complete commissioning work; some things never get resolved. The bottom line is to make sure the contract has enforceable teeth and then insist on compliance with the contract.

**Occupancy Phase**

The commissioning process continues during the warranty correction period and throughout the life of the facility.

**Deferred Tests**

Some tests cannot be completed during the construction phase. These most commonly fall into three categories (these deferred tests are handled as exceptions to the commissioning completion requirements for substantial completion):

1. **Seasonal Tests:** Depending on when the construction period ends, it is likely that ambient weather conditions will not provide a natural load against which to test some systems. A building completed in time for fall classes does not have a design heating load to prove the capacity and control of the heating water system at the time of completion. While tests may simulate a load for the heating water system, we still need to observe the response of the system under a natural load. Some building envelope evaluations also fall into this category.

2. **Occupancy-Dependent Tests:** Some tests require normal building occupancy. A common example is indoor environmental control for temperature, humidity, and air quality. People affect indoor temperature, humidity, and air quality, so they must be present and performing normal activities during the tests. Another example is the three-phase power load balancing evaluation. Distribution of plug loads impacts phase loading, so phase balance must be evaluated when plug loads are powered at normal levels.

3. **Delayed Tests:** Tests performed near the end of the construction period may reveal issues that will require additional time to resolve. If a long lead time piece of equipment must be replaced, the associated test or retest will be delayed.

**End-of-Warranty Review**

The end-of-warranty review aims to identify issues to be corrected while the contractor is still obligated to respond. Failure of equipment due to infant mortality frequently occurs during the warranty correction period. Systems may benefit from fine-tuning of set points, schedules, and control sequences. Reviewing data trend logs, interviewing staff and occupants, and performing targeted tests reveal these early failures and needs for further tuning and adjusting of systems. Those same interviews may reveal the need for additional training, either because the contractor’s training was ineffective or because the staff needs training in greater depth or on subjects not anticipated.

**Ongoing Commissioning**

During the construction and warranty correction periods, the commissioning team creates tools and documentation intended for use throughout the rest of the life of the facility.

The ongoing commissioning plan contains schedules for using these tools and performing periodic commissioning activities to evaluate the condition and performance of systems and assemblies. Incorporate the scheduled commissioning activities into the maintenance management system. In-house staff may have the skills and availability to perform the work themselves, or they may need assistance from outside resources.

Ongoing data trend logs with automated alarm conditions for declining chiller performance, rising water consumption, increasing machine vibration, poor temperature control, or deteriorating air quality (as indicated by increasing carbon dioxide concentration), and other indicators of fading performance should have been left running at the end of the construction period. Review these trend logs periodically to verify that they are still functioning, that the sampling rate meets your needs, and that they are still monitoring parameters of interest. Add new trend logs as needed. Make sure that someone’s job responsibilities include monitoring and maintaining the trend logs and reporting any need for action to a supervisor with the resources to handle the work.

The dividends of proactively maintaining the high performance of facilities more than offset the burden so imposed. For new facilities that have been commissioned during acquisition and maintained through ongoing commissioning,
deferred maintenance may never get a foothold.

The Economics of Commissioning

The benefits of commissioning lie in the avoidance of the costs of not commissioning. The costs of not commissioning may exceed 20 percent of the construction costs of the uncommissioned systems when a broad view is considered.

Benefits

Avoiding the Costs of Not Commissioning

By understanding the costs of not commissioning, one can gain a measure of the benefits of commissioning. The costs of not commissioning include the expenses owners incur to correct design and construction deficiencies and thereby make new or renovated facilities work as they were intended. The costs of not commissioning include staff time to correct problems, additional equipment or materials, lost time and productivity of the occupants, health and safety effects, excess energy costs, effects on central plant utilities, legal fees, and the intangible "hassle factor."

The first cost of the commissioning process from predesign through the end of construction is typically recovered before the end of construction. A higher quality set of bid documents reduces bidder uncertainty, which translates into lower cost bids. The higher quality documents also drastically reduce the number of requests for information and change orders, and those improvements alone typically pay for the first cost of commissioning.

British Columbia Buildings Corporation Study

At the 1993 National Conference on Building Commissioning in Sacramento, a British Columbia Buildings Corporation representative cited estimates of the costs of not commissioning mechanical systems from a study done in 1989. The study drew information from five British Columbia Buildings Corporation buildings that were described as "not problem buildings" that had not been commissioned. Mechanical construction costs averaged $10 per square foot. Note that the per square foot costs cited here are 1989 Canadian dollars.

The study attributed to building commissioning a $0.05-per-square-foot improvement in operations, a 5 to 10 percent reduction in energy consumption, and a cost of 0.75 percent of the original mechanical construction cost to make corrections after the fact. The study concluded that the O&M costs of not commissioning ranged from $0.45 to $0.75 per square foot for the first three years of operation. Thus, the cost of not commissioning these five buildings during the first three years amounted to 4.5 to 7.5 percent of the mechanical construction costs.

The British Columbia Buildings Corporation representative went further to estimate the costs of not commissioning related to occupants. He indicated that occupants' dissatisfaction with environmental conditions in their workspaces results in decreased productivity. "At an annual payroll cost of only $200 per square foot of occupied space, if every fifth employee spent 30 minutes of work time per month on such activities (gripe sessions, letters of complaint, meetings, investigations, etc.) the resulting cost would be $0.13 per square foot per year. Using the same payroll costs, increased absenteeism (every fifth employee takes an extra two days off per year) may cost an additional $0.33 per square foot per year. Over three years, these lost productivity figures may total as much as $1.38 per square foot, or 13.8 percent of the original mechanical contract.

When the occupant effects are added to the O&M costs, the total is $2.43 per square foot or 24.3 percent of the mechanical construction cost. Even if the real costs are only one-fourth of the estimates, they still show the substantial magnitude of the costs of not commissioning.

In addition to the preceding, there are significant intangible costs involved in not commissioning. What does one say when the dean or a department chair calls, exasperated with the endless series of failures in a new facility he or she has helped fund? How does one explain the departure of a leading faculty member who can no longer tolerate the interruptions to her research as a result of building systems failures? How does one counteract the bad press that results from lingering indoor air quality complaints in a new building?

Costs

A rule of thumb for initial estimates of the first cost of the building commissioning process is to allow between 3 and 4 percent of the mechanical system construction cost, plus 2 to 4 percent of the electrical system construction cost. Commissioning costs for other systems pale in comparison to the costs of commissioning the mechanical and electrical systems, and are therefore not significant for initial estimating purposes.

The ranges cited above apply to large projects (greater than $10 million construction cost). Smaller projects experience a slightly higher cost on a percentage of construction cost basis due to reduced economy-of-scale factors. For example, it takes nearly the same amount of time to write a commissioning plan for a $500,000 job as it does for a $500 million project.

Estimating guidelines based on dollars per square foot, or dollars per unit energy saved, do not give reliable results except in very narrow classes of projects that are extremely similar in occupancy and size. The percentage of construction cost estimate scales well regardless of whether the facility is a 100,000-square-foot warehouse or a 100,000-square-foot biotech lab building because the cost of mechanical and electrical construction varies significantly between the two applications.
British Columbia Buildings Corporation Study

The British Columbia Buildings Corporation representative cited the following mechanical systems commissioning cost estimates at the 1993 National Building Conference. The figures are based on an approach in which an independent commissioning authority, the designers, and the contractor shared responsibility for mechanical systems commissioning. Based on a mechanical construction cost of $10 per square foot, the study estimated the following range of per-square-foot costs:

- $0.025 to $0.010 extra designer time
- $0.100 to $0.300 contractor (commissioning authority)
- $0.025 to $0.200 owner (operations staff)

These costs total $0.15 to $0.60 per square foot, which is 1.5 to 6.0 percent of the mechanical construction costs. This compares with the study's previously cited estimates of the costs of not commissioning (i.e., 4.5 to 10.5 percent of the mechanical construction costs, not including occupant impacts).

Summary

In conclusion, the costs of not commissioning exceed the costs of commissioning. Commissioning costs are best estimated based on the construction costs of the commissioned systems: 3 to 4 percent of mechanical construction costs plus 2 to 4 percent of electrical systems costs.

Acquiring Commissioning Services

Three contract documents are required to appropriately execute the commissioning process: the owner-architect agreement, the commissioning authority agreement, and the construction contract.

Owner-Architect Agreement

The owner-architect agreement must be tailored to include commissioning-related services from the architectural and engineering team. These are primarily expansions of the design phase requirements, most of which are not yet included in the American Institute of Architects standard form of agreement. Because some of these deliverables are not universally understood by consultants, elaboration is necessary. This can be conveniently handled by preparing an attachment to the architectural and engineering agreement.

The architectural and engineering scope should include the assistance of the architectural and engineering team in the development of the scope of commissioning services and participation in the selection of a commissioning authority. Assisting in the selection of a commissioning authority helps to engender some sense of ownership of the commissioning program and foster improved working relations with the selected commissioning authority.

The owner-architect agreement should address communication with the commissioning authority during design and construction. The extent of this communication must take into account how the commissioning authority agreement will be written. Construction phase activities of the architectural and engineering team should include review of commissioning-related submittals, although primary responsibility for such review lies with the commissioning authority.

The architectural and engineering team must participate in resolution of problems and conflicts during construction. The architect should retain the final authority during construction, as is current practice. Still, the architectural and engineering scope should require that the direction of the architectural and engineering team be consistent with the recommendations of the commissioning authority on commissioning-related issues.

Traditionally, architectural and engineering agreements have been somewhat generic in their design and document deliverables requirements at each design phase milestone. However, these agreements should be augmented to be much more specific about what the architect/engineer is expected to provide on completion of each design phase. To maintain flexibility, some institutions have a formal architectural and engineering agreement that refers to an attachment that can be conveniently tailored to suit specific project requirements. The attachment is used to specify the detailed documentation required.

These requirements are referred to as deliverables. The accompanying matrix, "Design Deliverables," illustrates one effective method of establishing deliverable expectations. A similar matrix included as an attachment to the owner-architect agreement communicates expectations unambiguously. Some of these deliverables are not universally understood or accepted by consultants, so elaboration and negotiation may be necessary.

Figure 2 is a table of design delivery requirements. It is included in the OPR and should be included in the prime design consultant agreement.

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<th>Item</th>
<th>Phase</th>
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<td>Schematic</td>
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<tr>
<td>SPECIFICATION</td>
<td>System and material narrative description</td>
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### Owner-Commissioning Authority Agreement

The owner negotiates an agreement for commissioning services directly with the selected commissioning firm. This contract should incorporate provisions related to conflict of interest, the scope of commissioning services, lines of communication, and authority.

The owner must have the full allegiance of the commissioning authority during the project. Accordingly, the agreement prohibits the commissioning authority from having any business affiliation with, financial interest in, or contract with the design consultants or subconsultants, the contractor, the subcontractors, or the suppliers for the duration of the agreement. Violation of such prohibitions constitutes a conflict of interest and is cause for the owner to terminate the agreement.

The scope of services includes responsibilities during the predesign, design, construction, and occupancy periods.

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<td>Sequences of operation with logic diagrams</td>
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Note: FA = Fire Alarm; MCC = Motor Control Center; M/E = Mechanical/Electrical; PR = (Owner’s) Project Requirements
Predesign services should include facilitation of, or participation in, the OPR workshops, identification of the scope and budget of the commissioning process, and production of the preliminary commissioning plan.

In the design phase, the commissioning authority should review each design submittal for compliance with the OPR, maintainability, serviceability, and physical provisions for testing. The services provided should also include commissioning specifications, with emphasis on identifying systems to be tested and the associated test criteria.

The commissioning authority participates in on-board review sessions and other design meetings with the design consultants to ensure that the commissioning authority has as much familiarity with the design as feasible. This allows the commissioning authority to understand the design and to be a more effective reviewer. Commissioning authority participation in the design process pays off in increased effectiveness during the construction and occupancy phases of the project.

During construction, the commissioning authority performs a quality assurance role relative to the contractor's commissioning activities. The scope includes a review of the qualifications of the contractor's selected commissioning coordinator, commissioning submittals, samples of equipment submittals and shop drawings related to systems to be commissioned, O&M manuals, and training plans.

The commissioning authority's scope also includes witnessing and verifying the results of commissioning tests. To the extent that the owner's staff is involved in witnessing the commissioning testing, the commissioning authority's scope can be reduced to witnessing critical tests and a sample of other tests. The owner's staff benefit from witnessing as much of the commissioning testing as possible. The commissioning authority's function, then, is to ensure that test technicians understand and properly execute test procedures. The commissioning authority's contract should also include analysis of test results, review of the contractor's proposed corrective measures when test results are not acceptable, and recommendation of alternative or additional corrective measures as appropriate in the commissioning authority's scope.

Clear lines of communication and authority should be indicated in the contract. Communications and authority of the commissioning authority should be tailored to the level of involvement of the owner in the project.

If the owner is intimately involved in all aspects of design and construction, then the owner should manage the commissioning authority's involvement. In this case the commissioning authority would communicate formally with the designers through the owner. During construction, the commissioning authority should communicate formally with the contractor only through the established lines of communication (i.e., directly through the architect or indirectly through the architect via the owner). In either case, it is essential that the owner be kept informed of decision making.

In cases where the owner is only marginally involved in the day-to-day business of the project, it may be desirable to allow the commissioning authority to communicate with the architect directly on commissioning issues. This is recommended only when the owner is confident of the expertise and judgment of the selected commissioning authority and only when the commissioning authority and architect have a good relationship.

The authority of the commissioning authority should be limited to evaluating quality of the design, installation, or operation of the systems; identifying issues and evaluating proposed solutions to problems encountered; and recommending acceptance or rejection of test results. The commissioning authority should not direct the contractor to make changes. Only the architect should make changes in the design or order construction changes. The owner must speak with only one voice.

**Construction Contract**

The construction specifications define the scope of the contractor's participation in commissioning. A brief summary of the recommended specification sections follows.

**Section 01 91 13, General Commissioning Requirements**

This section is intended to clearly indicate that the prime contractor is responsible for the overall commissioning program specified in the construction contract. Furthermore, it requires the prime contractor to identify a commissioning coordinator to carry out these responsibilities and work with the owner or the owner's commissioning authority. On larger projects the commissioning coordinator may be a subcontractor to the general contractor. On smaller projects, or with sophisticated GC's, the commissioning coordinator may be one of the GC's own staff. MEP (mechanical, electrical, plumbing) coordinators may be well-suited to fill this role. The section lists the minimum qualifications of the commissioning coordinator and identifies the scope of the commissioning coordinator's responsibilities. The contractor must submit the qualifications of the proposed commissioning coordinator for approval by the architect and owner. The section also refers to commissioning technical requirements in other divisions (XX 08 00), making the prime contractor responsible for all commissioning scheduling and coordination.

The overall cost for commissioning should be less if contractors are required to perform virtually all of the testing and start-up activities. Furthermore, knowing in advance that they will be required to make everything operate per the owner's project requirements is likely to result in a significant improvement in the overall quality of the submitted equipment, installation, and workmanship.

The general contractor schedules and coordinates construction and commissioning activities. The commissioning coordinator hired by the general contractor schedules the contractor's various commissioning activities and coordinates them with other construction activities, assembles project documentation, reviews the commissioning test procedures, and directs the correction of deficiencies. Subcontractors perform the commissioning tests and make corrections.
Sections XX 08 00, Commissioning of XX

Each division in which equipment, systems, or assemblies included in the scope of the commissioning process are specified contain a section XX 08 00. These sections describe commissioning work applicable to the systems and equipment specified in the division, including the actual installation verification and commissioning test requirements in detail. To provide bidders with sufficient information to estimate the cost of commissioning work, the description of each test should include four characteristics: (1) the equipment, system, or assembly to be tested; (2) the functions to be tested; (3) the conditions under which the tests are to be performed; and (4) the acceptable results.

 Portions of each test specification must be completed by the design consultants in coordination with the commissioning authority, including the functions to be tested, the conditions under which the tests are to be performed, and the acceptable results. Specified acceptable results must be finite, measurable, and achievable and include a range of acceptable error.

The criteria for acceptance must be written to allow objective determination of whether the test results are acceptable. Instead of simply requiring a temperature sensor to be “accurate,” the criteria should specify a range of acceptable performance, such as “within ±0.5°F of the temperature indicated by a calibration-grade instrument.”

Selecting a Commissioning Authority

The commissioning authority is becoming a major player in the overall process of design and construction. In fact, this role is becoming every bit as important as that of a specialist doing a constructability review during design or a construction manager assisting with project management during construction. Therefore, selection of a fully qualified commissioning authority is critical to the success of the project, and the owner should take considerable care to make a good selection.

Criteria

The first step is to decide in which activities the commissioning authority is expected to participate. This is a function of the portion of the commissioning work that can be handled by the owner's staff. Some owners with large engineering staffs benefit greatly by having a commissioning authority on staff, or at least some staff members whose job responsibilities include support of the commissioning process. For such owners, the scope of work of the outside commissioning consultant shrinks.

Beyond comprehensive knowledge of and experience with the commissioning process, the criteria for a good commissioning authority are heavily weighted toward facilities operating experience and extensive field experience in the commissioning evaluation of mechanical and electrical equipment and systems. High on the experience priorities is experience with commissioning environmental control systems. In fact, if funding is extremely limited, the one system that should be commissioned, above all others, is the environmental control system. This will lead to discovery of other components that may not be operating correctly, even if the environmental control system is operating properly.

Request for Qualifications

Once the scope of the commissioning program has been developed, the owner can determine what kind of skills and experience will be required to carry it out. This leads to the development of a request for qualifications to be placed as an advertisement in the appropriate local or regional media (e.g., a daily journal of commerce, a newspaper, or a trade journal such as Engineering News Record, if no other appropriate media are available). However, the owner should shy away from national media, because a local or regional firm is preferred if available and qualified.

An additional resource is the Building Commissioning Association (BCA). The BCA website hosts a database of commissioning provider firms and individuals that can be searched by several criteria, including state and region [http://www.bcxa.org/corporate-directory/](http://www.bcxa.org/corporate-directory/).

It is important for the request for qualifications to clearly indicate the minimum qualifications that will be acceptable for the project. At present, there are highly qualified firms as well as less qualified or unqualified firms. A well-written request for qualifications will discourage some unqualified firms from applying.

It is important to identify the nature of the construction project to be commissioned. It is also important to indicate the types of systems to be commissioned. This gives respondents a sense of the kinds of skills and experience required to commission the building.

In addition, six specific items should be required in the submittals from respondents:

1. History of the company
2. Commissioning expertise and capability
3. Local experience during the previous three years on projects of similar size and type
4. Resumes of personnel to be assigned to the project, with their corresponding project responsibilities
5. Detailed information regarding the onsite project manager
6. References

Furthermore, the advertisement should state that finalists to be interviewed will be required to present comprehensive evidence of prior project commissioning schedules, executed test procedures and commissioning
specifications that they created, and a final report. This will discourage many less qualified firms from applying, as they will not be able to meet the interview requirements.

Selection Process

At the same time the request for qualifications is prepared, a selection evaluation form should be prepared. This evaluation form can be used both in the original screening of submittals and during the interviews of the finalists. To be objective, it is best to develop this evaluation form before the submittals are received.

There are several important considerations that warrant specific comment:

- This is a request for qualifications and does not ask for cost proposals. The commissioning contract should be negotiated with the selected firm, at which point the scope of work and the contract cost will be finalized. It is important to identify the firm's experience in the commissioning field. Specifically, it is important to know of successful commissioning projects of similar facility or system type, complexity, and sophistication. It is important that the firm identify the project manager, who will be the onsite person in charge of the commissioning program. Experience has shown that the person assigned to lead the project (in the field, in this case) is the key to the success or failure of the work to be done. The project manager's background and references should be provided for evaluation.
- The firm should also indicate anyone else who will be involved, how each person will be involved, and prior relevant experience. One must be cautious about what is purported to be commissioning experience. Many testing, adjusting, and balancing firms are quick to suggest that they do commissioning. Testing, adjusting, and balancing work is not commissioning. Commissioning includes testing, adjusting, and balancing verification, but goes beyond the experience of the average testing, adjusting, and balancing firm.

Consulting engineering firms will likely apply, claiming that they do final inspections, prepare construction discrepancy lists (punch-out buildings), and do start-up, and therefore do commissioning. Although most design firms follow their projects completely through the construction process to acceptance, not many have experienced, full-time, field commissioning engineers on staff.

One final critical issue must be considered: Should one of the consulting firms or contractors already associated with the project be considered to be the commissioning authority? The preferred answer is "no." The commissioning process should be viewed as the primary quality process of the project. The commissioning process evaluates the work of the design team as well as that of the contractors. If a member of a design team firm is the commissioning authority, there is a conflict of interest. A similar conflict of interest exists for a contractor serving as the commissioning authority. One would not ask the organization's bookkeeper, regardless of how well qualified and highly regarded he or she might be, to audit his or her own books.

Therefore, it is best if the commissioning authority is an independent, third-party participant who has no emotional or economic tie to the project, other than the commissioning fee. Complete allegiance must be to the owner.

Interviews

Through the interview process, one should learn a great deal about each firm's commissioning experience and the different perspectives represented by the firms. One can also get a sense of the firm's culture, which can be important in relation to the project and the consultants and contractors associated with it. The commissioning authority must complement the project and be accepted appropriately by all other participants.

It is recommended that all finalists be invited to interviews on the same day. This tends to ensure that all of the owner's participants will be available for all interviews and that important points are not forgotten over a period of several days.

Selection of the interview team is important. Because few institutions have completely similar capital improvement program management structures, it is difficult to make precise suggestions. However, a general philosophy suggests that the team members include the owner's project manager, representatives of the engineering and O&M divisions, and a representative of the client (end user).

The client should participate for two reasons. First, because it is difficult to explain to the client what is involved with commissioning and its importance to the successful completion of the project, the client stands to gain considerable education through the interview process. Second, it is important for the client to have confidence that the best selection was made. The same philosophy would apply with regard to the engineering and O&M representative.

Should the design team (or at least the prime consultant) be invited to participate? The answer will differ from project to project. Sometimes the consultant may contribute a great deal to the process. At other times, the owner may prefer not to include the consultant.

Negotiation: Scope and Cost

Following the selection, the first choice commissioning firm prepares a commissioning program proposal. The proposal should be prepared in detail so that the merit of doing or not doing various components of the program can be discussed. Ideally, the entire building, including all systems, should be commissioned. However, available funding may dictate a curtailed scope involving only the most critical systems. If the commissioning firm cannot present an acceptable scope and fee proposal after a bit of negotiation, the owner should exercise his or her option to begin negotiations with the second-place firm. By not commissioning new facilities, there is risk of creating situations that call into question the stewardship of the facilities organization. Ensuring that new facilities work as
Getting Started

Where to start? In this author’s experience, every organization that has implemented a successful commissioning process has done so with the leadership of a dedicated champion, someone who will do whatever it takes to convince decisionmakers that they need the commissioning process. Step one is to find out who your commissioning champion is and give that person the support he or she needs for what may be a protracted campaign.

Two tools may be particularly helpful to the commissioning champion: a pilot project and a commissioning master planning.

Pilot Project

Because there is a first cost to the commissioning process, the keeper of the capital budget keys needs to see the light. That person may be willing to authorize the expenditure for a pilot project if he or she knows the costs and benefits will be analyzed and reported to him or her. Sometimes it takes more incentive, like a commitment to provide some funding for the pilot project from the operations and O&M budget. Sometimes it takes still more incentive, like a call from the chief facilities officer responsible for both the capital projects budget and the O&M budget.

The key to translating a pilot project into standard operating procedure is success. Spare no effort to hire the best commissioning consultant; make sure that firm’s scope includes careful recording, analyzing, and reporting of the avoided costs and other benefits of the commissioning process; and carefully manage the work.

Report progress regularly to decision makers, highlighting how the commissioning process has made their job performance look better. Track staff hours spent during the first year or two of occupancy responding to trouble calls and other unscheduled O&M intervention. A comparison of this data with that of other recent capital projects that were not commissioned should be quite enlightening. Capture the lessons learned to make recommendations for improving the results of the commissioning process on the next project.

Commissioning Master Planning

The second tool for getting started is also useful for restarting or refining your commissioning efforts. For a campus or system with multiple facilities and ongoing capital construction, standardizing the commissioning process bears rich fruit. Standardizing the commissioning process reduces the first cost, increases the benefits, and reduces the stress on staff involved in the process.

Currently, in many organizations, each capital project manager implements commissioning as he or she understands it, if it is implemented at all. This haphazard approach results in a crazy patchwork quilt, with some bright crisp-looking pieces, some tattered and worn, and some just plain missing. There is no way to establish a continuous improvement process in such a jumble.

Commissioning master planning starts with a series of workshops similar to the OPR workshops discussed in the predesign phase. The difference is that the “project” here is the creation of a uniform commissioning process that is tailored to the way the organization does business, takes into account the resources available, and focuses the commissioning effort on the highest priority features.

The products of the commissioning master planning process include a commissioning master plan. The commissioning master plan is a how-to guide for project managers (PMs) to reference at each phase of a capital project. It prompts the PM to take specific actions at various milestones, and gives him or her templates to work with to solicit commissioning consultants, or to establish a database of commissioning issues, for example. It instructs the PM on when and how to set up the OPR workshops and whom to invite. It provides outlines of OPR and BoD documents for the project teams to fill in. It provides master commissioning specifications as starting points for project commissioning specifications. It contains attachments and modifications to the owner-architect agreement to incorporate commissioning into the scope of the design professionals.

One university created a commissioning master plan for in-house renovation projects, with four levels of commissioning intensity, depending on the type of project, from paint and carpet to wet lab modification. A large city fire department established a commissioning master plan for the seismic upgrades and renovations of more than 30 firehouses to be executed over a period of several years.

Commissioning master plans can establish the mechanism for continuous improvement of the application of the commissioning process within an organization. The uniformity of the process creates a common experience across a wide range of staff members. Their collective lessons learned reduce wasted effort, sharpen the focus of the commissioning program, and become a source of organizational pride in high-performance buildings.

Conclusion

When the building commissioning process starts at predesign with a clear statement of the owner’s project OPR, it delivers and maintains a facility that performs to fully meet the owner’s needs. The commissioning process comprises a series of linked activities throughout the life of the facility that form a quality structure in which each activity depends on another for its strength. The OPR is the common thread through the entire life of the facility.
providing a measuring stick against which to evaluate the quality of everything it touches. The intent is to apply the commissioning process to all systems and assemblies in a building to realize their synergistic interaction.

The successful commissioning process requires the participation of a broad variety of groups, from the capital project office, to the design studios, to the manufacturing shops, to the contractors' trailers, to the O&M shops, led by a commissioning consultant selected based on his or her qualifications, not on a low price. Carefully written contract modifications draw the design team and the contractors and their suppliers into the effort.

The operational integrity of the new building, the low numbers of change orders and requests for information, and the reduced number of occupant complaints attest to one’s superior facilities management practices.

Endnotes
5. Ibid.

References


