BUILDING COMMISSIONING FROM A CONTRACTOR'S PERSPECTIVE

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
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To Mom and Dad

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I would like to thank God, my family, my understanding girlfriend, and the members of my committee for all their support and help.

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My study is about the commissioning process as it relates to contractors and the building construction industry. Commissioning provides a valuable tool to ensure that building's systems work in harmony with other, ultimately producing a better product for the owner and society. However, many contractors lack an understanding about the commissioning process.

The study's main goal was to gather and analyze contractor's perceptions about the commissioning process in order to assess what changes need to be made. A critical review of literature is structured under the following: history and definition of commissioning, objective of commissioning, benefits and costs of commissioning, types of commissioning, commissioning team, documentation, commissioning process, and the trends/future of commissioning.

The study consisted of a survey that was used to gauge awareness and provide insight on what changes need to be made for contractors to keep up with the rapidly evolving commissioning industry. The survey results showed that many contractors had only a basic understanding of the commissioning process. The survey also went on to show that their was indeed an increase in the amount of buildings that were being commissioned and revealed many other insights on improving and streamlining the commissioning process from a contractor's perspective.

CHAPTER 1
INTRODUCTION

Building systems are becoming increasingly more complex and are constantly evolving over time. The construction industry is constantly striving to keep up with these changes to meet the needs of owners who expect more out of their buildings than ever before. Unfortunately, many owners are finding that they are not getting the desired performance they expect from their buildings.

A study conducted by the University of Wisconsin, found that 81 percent of building owners surveyed encountered problems with new heating and air conditioning systems. Another study of 60 buildings by the Ernest Orlando Lawrence Berkeley National Laboratory (LBNL), found that nearly half of building owners surveyed were experiencing controls problems. In addition, 40 percent had heating, ventilation and air conditioning (HVAC) equipment problems, 15 percent had missing equipment, and 25 percent had energy management systems, economizers, and/or variable speed drives that were not functioning properly (Claridge 2003).

A building that performs poorly can have many other consequences. It can result in excessive repair and replacement costs, employee absenteeism, indoor air quality problems, increased construction team liability, and unnecessary tenant turnover which in turn costs building owners, employers and the United States construction industry billions of dollars each year. However, there is one process that can help ensure that many of these problems can hopefully be avoided. That process, known as building commissioning, is a quality-assurance process that increases the likelihood that a newly constructed building will meet client expectations.

CHAPTER 2
LITERATURE REVIEW

History of Commissioning

Commissioning is a term that originated in the Navy. The act of placing a ship in commission marks her entry into active Navy service. The first step of this type of commissioning involves the new ship going through several sea trials in which all deficiencies can be identified and corrected. This can last for only several days for a basic vessel or for up to several years for a nuclear submarine. This is to make sure that crew and ship are running at maximum efficiency. After this is completed, the prospective commanding officer comes on board and calls the crews to quarters and orders are issued for a pennant to be hoisted (a long streamer with the national colors on it) which officially signifies the ship is acceptable enough to be an operating part of the Navy.

Building commissioning is not unlike the original commissioning that occurred in the Navy. Commissioning was introduced into the building industry in the late 1970's. The main reason commissioning emerged was a response to an energy crisis and also due to new advances in technology. One of those advances in technology was directed toward improving occupant comfort. At that time, many designers began utilizing sophisticated equipment that required continuous maintenance, which in turn required commissioning.

In 1977, Public Works Canada is the first organization to use building commissioning in their project delivery system. Soon after, in 1981, Disney used building commissioning to during the design, construction, and start-up of Epcot. Then in 1984, The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) formed the Commissioning Guideline Committee. The task of the committee was to define a process which guarantees that only fully functional buildings would be turned over to owners. The motivation for the

ASHRAE Commissioning Committee was the growing number of complaints about unmanageable HVAC systems, increasing operation expenses, decreasing comfort levels, and uneducated operations and maintenance personnel who did not understand how to run complex building systems. From there many governmental and private organizations began to take interest in building commissioning. In 1993, the first National Conference on Building Commissioning (NCBC) was held. In 1996, the Building Commissioning Association was established to help regulate and connect the commissioning industry (Turkaslan-Bulbul 2006). Finally, in 2000, the United States Green Building Council (USGBC) mandated commissioning as part of its Leadership in Energy and Environmental Design (LEED) requirements.

Definition of Building Commissioning

Building commissioning is the systematic process of ensuring that a building's complex array of energy-related systems are designed, installed, and tested to perform according to the design intent and the building owner's operational needs. (Energy 2005). In essence, the building commissioning process is to help ensure that a new building begins its life cycle at an optimal productivity, and improves the likelihood that the building will maintain this desired level of performance.

Commissioning usually spans the entire design and construction process. Ideally, it would begin at the design phase with the selection of a commissioning provider who helps ensure that the building owner's and designers' intent gets written into project documentation. However, sometimes commissioning occurs after the project has already been built, resulting in a post-occupancy commissioning effort to bring the building up to the required performance. Then, with the help of the commissioning provider, building designers would then incorporate any commissioning requirements into project specifications. Next, with the supervision of the owner and commissioning provider, installing contractors put in any necessary equipment to satisfy any

building systems that are in the contract. Then the commissioning provider and contractor conduct rigorous performance tests. The project team hopefully uncovers any deficiencies in design or installation using peer review and field verification. Finally, at the end of the commissioning process, building operators receive training and documentation to ensure proper operation and maintenance for the life of the building. This is because commissioning is a quality assurance-based process that delivers preventive and predictive maintenance plans, tailored operating manuals, and training procedures that will hopefully prevent future problems (Energy 2005).

Essentially, the commissioning process formalizes review and integration of all project expectations during planning, design, construction, and occupancy phases. They accomplish this by through inspection and functional performance testing, as well as in-depth operator training and comprehensive record documentation throughout the life of the building (Energy 2005).

Commissioning Objectives

There are numerous objectives of an owner to pursue commissioning. It could be to meet the requirements for a LEED certification, to improve occupant satisfaction through improved comfort and indoor air quality, or to ensure a more efficient construction process through reduced change orders and callbacks. However, most project teams and owners would identify the following items as the cornerstone commissioning objectives (Jeannette, 2006):

- Ensure facility meets the owner's performance requirements and project specifications
- Provide a safe and healthy environment for building occupants
- Provide optimum energy performance from all building systems
- Supply a building that can be efficiently operated and maintained throughout the life of the building
- Provide complete orientation and training to facility operations and maintenance staff and to occupants

- Provide a smoother construction process through more efficient communication between project team members and improved documentation of the building system characteristics
- Detect potential problems in building systems early on to prevent incurring unnecessary costs

Benefits from Building Commissioning

There are many different benefits that can result from a well commissioned building. These benefits range from optimized energy-efficient design features to reduced litigation resulting from poor indoor air quality. Obviously, some of these items are more beneficial to particular parties. For example, possibly the most important benefit of commissioning is that the building owner receives a building that functions according to the design intent.

Commissioning a building can also result is savings from a financial standpoint. For example, some estimates suggest that the operating cost for commissioned buildings is 8-20% less than the cost of operating a non-commissioned building (Engineered 2005).

Reduced O&M costs coupled with the potential savings from reduced energy costs can really add up for an owner. Beyond financial savings, there are many other benefits to commissioning a building. These differ for each type of commissioning project, but some of the usual benefits include:

- Reduced quantity of change orders through better communication between project team members and early detection of potential problems
- Proper and efficient equipment operation that leads to fewer breakdowns and emergency repairs
- Better trained building operators through hands-on training and comprehensive O&M manuals
- Savings in energy costs through improved building systems performance and preventative maintenance
- Better documentation of building systems as a result of required commissioning paperwork and improved communication

- Fewer occupant complaints about broken or poorly performing building systems
- Verifies that owner intended design features are properly installed in the facility
- Improved indoor air quality leading to increased occupant comfort and hopefully an increase in productivity amongst workers
- Early detection of potential problems – results in less expensive repairs
- Reduced operation and maintenance costs through precise tune-ups of systems and equipment controls
- Shorted occupancy transition period

Cost of Commissioning

Currently, no standard accounting method exists for calculating the cost of commissioning and measuring the expected savings. For many projects, commissioning costs are not separated from other project costs. When these costs have been tracked separately, various methods have been used to report both the costs and the benefits.

With that being said, the average cost of total building commissioning can run anywhere from 0.5% to 1.5% of the total construction cost according to U.S. Department of Energy's Rebuild America Program, written by Portland Energy Conservation, Inc., (PECI) in 2002. This only covers the commissioning provider fees and the services that they provide.

There are also costs to the contractor, the designers and owner staff for their part in the commissioning process. The costs for the contractor attending meetings, documenting the construction checklists and assisting with testing will roughly equal 10% to 25% of the commissioning provider's costs. The designer's fee may range anywhere from one to three tenths of 1% of the total construction cost for a typical office building (PECI 2000). A breakdown of average construction phase commissioning costs is shown in Table 2-1.

Figure 2-1 and Table 2-2 show a study of over 100 commercial buildings by the Portland Energy Conservation, Inc. (PECI) in 2002. It shows the average commissioning costs broken

down by building size and complexity. These costs are averages and can vary considerably, since the number of pieces of equipment and commissioning scope vary significantly from building to building.

Table 2-1. Construction phase commissioning costs

Commissioning Scope	Cost
Electrical Systems*	1.0%-1.5% of *electrical* system cost
HVAC and Automated Control System**	1.5%-2.5% of *mechanical* system cost
Entire Building including: HVAC, Controls, Electrical, Mechanical	0.5%-1.5% of total construction cost

*Commissioning of the electrical system includes: lighting controls, emergency power and limited connection and grounding checks. **Commissioning of the HVAC system includes all systems, including fire, life, safety and controls

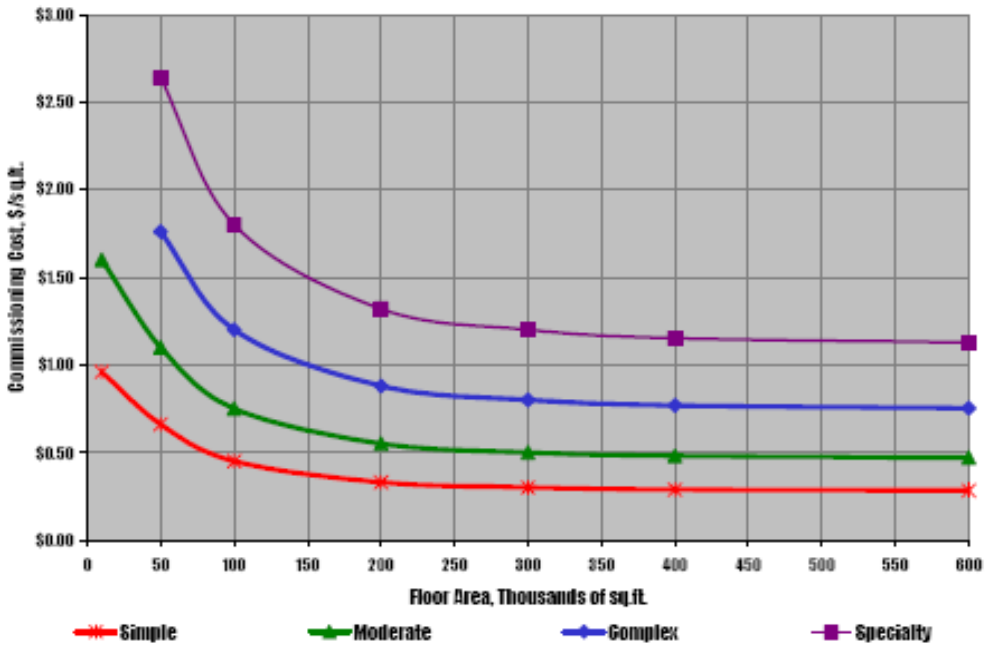

Figure 2-1. Estimates of construction phase commissioning costs

Table 2-2. Explanation of Figure 2-1 construction phases commissioning costs

Building Type	Example
Simple(Red)	Common systems w/ few pieces of equipment - office buildings, schools, etc.
Moderate (Green)	More involved building systems – complex office buildings, water treatment plants, etc. (more automation)
Complex (Blue)	Complex systems – hospitals, clean rooms, operating rooms, etc.
Specialty (Purple)	Very complex facilities – nuclear facilities

Factors Affecting Commissioning Costs

As stated before commissioning costs can vary considerably from building to building. The cost of commissioning is dependent upon many factors including: commissioning scope, a building's size and complexity, equipment type to be installed, traveling requirements, and whether the project consists of new construction or building renovation. Until recently, building commissioning has focused more on maximizing energy efficiency and the HVAC side of construction. However, with the increase of owners who want more elaborate buildings systems, the costs of commissioning have changed dramatically. Below outlines several factors that can influence the cost of commissioning. (PECI 2002)

Number and Complexity of Systems to be Commissioned

Building systems are becoming increasingly more complex. Hospitals, Prisons, and laboratories that require building systems with large amounts of equipment to test will have much higher commissioning costs than less sophisticated office buildings and schools. One reason this is true is because more complex systems will need the commissioning provider to attend more frequent site inspections and more coordination meetings. But another reason this is true is because more complex systems require more review and coordination during design to assure that they are properly implemented. They also require more sophisticated functional testing during startup and more involved levels of documentation to assure that performance of the system meets the owner’s project requirements and the basis of design. An example of this is floor distribution systems. They often require constant attention from the commissioning agent to ensure that they are fabricated in an air-tight manner and kept clean to prevent IAQ problems down the road (PECI 2002).

Commissioning Scope

The required scope of a project has a large influence on the cost of commissioning. The level of detail required during the testing and documentation process can vary considerably from project to project. Each commissioning plan requires its own set of deliverables. This may include items such as: design intent documentation, O&M manual, commissioning report, etc. Thus, cost is directly tied to what and how many deliverables are required by the owner in the commissioning plan and subsequent contracts. An example of this is zone counts. A zone count involves equipment that must be checked out and tested by the commissioning process. Zone counts can especially be costly if the zone density is high relative to the building square footage. This is because the tests the commissioning agents must perform to find any potential problems are more involved (Energy 2005).

Another factor to consider in the commissioning scope is whether the owner is trying to achieve any accreditations as part of the commissioning process. For example, LEED (Leadership in Energy and Environmental Design) is an accreditation process offered by the USGBC (United States Green Building Council) for buildings that meet certain levels of sustainable design. As a prerequisite to becoming certified, the building must be commissioned to achieve optimal energy efficiency. Depending on the LEED accreditation level that is being attempted and how involved the commissioning agent is may weigh heavily on the cost of commissioning for a particular building (PECI 2002).

Project Meeting/Traveling Requirements

The modern construction process often can involve a large number of meetings and commissioning is no different. The requirements of the commissioning plan or contract and/or needs of the project may obligate the commissioning agent to attend some or all of these meetings. As a result, there is a variable cost associated with the project that can have much

more to do with the length of the construction cycle than the systems to be commissioned.

Also, important to realize is that traveling requirements can have a great impact on cost. If the project is far away from the commissioning agent and requires long drives or flights, this may cause costs to rise accordingly (PECI 2002)

When the Commissioning Process Begins/Duration of Construction

Another aspect that affects cost is at what point in the construction process commissioning is introduced. Ideally, all projects would start commissioning during the design phase to realize the full benefits that can commissioning can offer. However, many owners choose to wait and end up retrocommissioning after the building has been around awhile. This can be an expensive process if equipment has to be replaced and new training has to be done for facility managers.

Another item to consider is the duration of the construction process itself, which often has a direct impact on the commissioning costs for a project. Even if the current project phase does not require a significant involvement on behalf of the commissioning team; extended project duration will still involve a greater amount of planning time, miscellaneous phone calls, and other project related business to attend to that will inevitably raise costs (PECI 2002).

Type and Size of Project to be Commissioned

Even though larger buildings are cheaper to commission per square foot, they are usually more expensive in the long run. This is because large buildings tend to require more sophisticated and complex building systems to achieve the desired levels of performance and efficiency. As a result, large buildings on average usually cost more to commission than their smaller counterparts. Smaller buildings tend to be better served by more standardized, packaged arrangements and thus are generally cheaper. Another cost factor to consider is the type project.

Whether the project is a design-build, retrofit, etc. will determine what type of commissioning is most appropriate and thus will control the cost (Energy 2005).

Types of Commissioning

Retrocommissioning

Retrocommissioning is a systematic, documented process that identifies operation and maintenance improvements in an existing building that can be implemented to make up for the fact that there was no or little initial commissioning done in the first place. In many cases as a building is used over time, equipment efficiency, tenant build-outs, and/or renovations change how the building functions. Owners, looking for a way to remedy these problems, often consider using retrocommissioning to improve the processes and efficiency in their building (Energy 2005).

The process may or may not emphasize bringing the building back to its original intended design. In fact, the original design documentation may no longer exist or be relevant. The important thing to realize is that this is not a repair process. The goals and objectives for applying the process, as well as the level of rigor, may vary depending on the current needs of the owner, budget, and condition of the equipment. The retrocommissioning process focuses on dynamic energy-using systems with the goal of reducing energy waste, obtaining energy cost savings, and identifying and fixing existing problems (PECI 2001).

Retrocommissioning also identifies and solves comfort and operational problems, explores the full potential of the facilities energy management system, and ensures that the equipment performs properly after space changes have been made (EPA 2001).

The following goals have been identified as the primary objectives for retrocommissioning a project (PECI 2001):

- Bring equipment to its proper operational state
- Reduce complaints
- Reduce energy and demand costs
- Increase equipment life
- Improve indoor air quality
- Increase tenant satisfaction
- Improve facility operation and maintenance
- Reduce staff time spent on emergency calls

Even though there are many goals of retrocommissioning, most of the time this process involves tweaking the HVAC systems so they will perform as efficiently as possible. It is important for building owners to focus on this, because usually HVAC systems account for the majority of building operating costs. On average, the retrocommissioning process can save 5-20% percent of total building energy costs (PECI 2007).

Some typical retrocommissioning activities include: tightening loose fan belts, fixing leaky valves, balancing valves that are not functioning properly, adjusting thermostats and sensors that are out of calibration, fixing variable-air-volume boxes that are not working properly, ensuring that controls sequences that are functioning incorrectly, and verifying that economizer sequences are working as designed.

The cost of retrocommissioning varies from building to building. Costs for the process will depend on the type of facility involved, the complexity of its systems, and the type and number of systems that are going to be retrocommissioned. Typical costs for retrocommissioning can range from as low as $0.50 per square foot up to $2 per square foot. The savings of retrocommissioning can be significant. Depending upon the problems identified and recommendations implemented, annual operating cost savings can range from $0.15 per square foot to $1.15 per square foot (Gilmer 2008).

Re-Commissioning

Often confused with retrocommissioning, re-commissioning involves the evaluation of a building's existing equipment systems and determining how effective the initial commissioning was. Other reasons to re-commission include: a modification in the user requirements, the discovery of poor system performance, or desire to fix errors that were made during the initial commissioning of the building. However, re-commissioning is not a standard maintenance issue. This is because re-commissioning plays an integral role in the process of identifying potential upgrade opportunities that could be potentially implemented in the future and thus should be viewed, planned, and funded as a process separate from standard maintenance. Building owners should re-commission their building systems on a regular basis, perhaps every 2-3 years, depending on building usage, equipment complexity, and number of occupant complaints.

However, unlike the other types of commissioning, re-commissioning does not usually involved the purchasing and installation of new equipment and technology. It usually involves working with existing systems and fine tuning them to maximize their commissioning potential.

A study conducted at the Energy Systems Laboratory located on the Texas A&M University campus helps quantify the costs and benefits of tuning up buildings using re-commissioning. It was conducted based on a survey of results from more than forty re-commissioning projects. Results from the study suggest that re-commissioning can typically translate into energy savings of 5 to 15 percent. Although it is difficult to pinpoint exactly which of the re-commissioning procedures generates the greatest savings, about 80 percent of all savings come from optimizing building control systems (Texas 2008). The large portion of the remaining savings came from decreasing operations and maintenance usually associated with faulty or inefficient HVAC equipment (DOE 2007).

Continuous Commissioning

Sometimes referred as on-going commissioning, this fairly new process was pioneered by the Energy Systems Laboratory at Texas A&M University. Continuous commissioning begins by identifying and fixing HVAC and comfort problems in the building. In continuous commissioning, even after the initial commissioning is complete, the team continues to work together to monitor and analyze building performance data provided by permanently installed metering equipment. The process works to ensure that the savings achieved from the commissioning continue to persist over time. Beyond that, continuous commissioning is a maintenance function through which all critical elements of a building's energy and mechanical systems are routinely monitored for proper adjustment and functioning. The idea is to enhance preventative maintenance chores and solve difficulties before they become real problems.

Typical problems that are identified include: buildings negatively pressurized, reheat coils are blocked, controls not set/working right, cold deck set too low, broken thermostats, economizer cycle not working, and a high exhaust duct pressure that is incorrect (Texas 2008).

Commissioning Team

The members of the commissioning team are very integral to the building commissioning process. It is important to understand what role each member has and how they interact in order to grasp the how the commissioning process works. First, the commissioning team does not manage the design or construction of the project. The team is concerned with making sure each of the complex building systems are working as efficiently and problem free as possible (Energy 2005).

Good communication amongst the team members is important to identify and solve problems early rather than later to prevent expensive schedule delays and excessive change orders. In order to promote good communication between the team members, it is important to

hold a commissioning scoping meeting before the project begins. This will help the project get off to the right start. It also helps to identify the roles of each member and to create a tentative schedule and budget.

Each building requires a different type of commissioning and therefore has various needs for commissioning personnel. Although each project has different needs, there are basic roles of most commissioning members. Below is an outline of typical commissioning team members and their responsibilities in the process.

Building Owner/Property Manager

The building owner and property manager serve basically the same role in the commissioning process. Their most important responsibility is to clearly communicate expectations about the project outcome to the other members of the project team. They control the budget and schedule which in turn drives how fast or slow the project progresses and who gets paid when. Beyond that, other responsibilities of the building owner or owner's representative include (Energy 2005):

- Determining the goals and direction of the project
- Attending building training sessions to understand all intricacies of the operations and maintenances of the facility
- Hiring the commissioning provider if necessary
- Creating avenues of communication between the commissioning provider and other project team members
- Determining the budget, schedule, and team members needed to successfully complete the project
- Working with the commissioning provider (if there is one) to work through the details and technical aspects of the commissioning process
- Approving start-up and functional test completion

Commissioning Provider/Agent

Commissioning providers are not all the same. They vary depending on the needs, complexity, and size of the project. The commissioning provider's main responsibility is to verify that all aspects of the design meet the requirements of the design intent and basis of design throughout the entire process. They are an advocate for the owner and are paid a fixed fee. This fee is usually broken into two parts. The first part of the fee includes all the commissioning services that are provided in the design phase of the project. An example of this may include ensuring that the owner's objectives are accurately reflected in the design. The second part of the fee includes all services for construction, testing, and post-acceptance paperwork and training. An example of this may include writing an operations and maintenance manual for the staff that are in charge of running a specific facility.

Typically, most commissioning providers are independent of the project team. This is a requirement in the LEED certification process and is a good idea to promote a system of checks and balances between the members of the team. As far as existing building systems, an independent third party commissioning agent is likely to bring a fresh outlook and possibility new ideas to the table. This often translates into a better, more rounded product for the owner. Other responsibilities of the commissioning provider include (Energy 2005):

- Seeing that all project documentation is compete and in order
- Assisting in the development of commissioning specifications for the bid documents
- Developing and implementing a commissioning plan that includes equipment and systems to be commissioned
- Ensuring that all team members understand their specified commissioning responsibilities
- Providing advice regarding commissioning design features and future operation and maintenance of the building

- Witnessing and verifying that the contractors who perform start-up tests, air and water testing and balancing, and duct pressure testing do so according to the owner's wishes
- Writing construction, functional, and performance tests to ensure that all systems are functioning properly.
- Submitting regular reports to the building owner or project manager updating them on everything from potential delays to outcomes of diagnostic tests.
- Conducting all functional and performance testing of systems
- Reviewing and commenting on technical considerations from design through installation, in order to facilitate sound operation and maintenance of the building.
- Reviewing contractor and manufacturer training plans prior to delivery to facility staff.
- Developing diagnostic and/or test plans for all the systems that will be commissioned
- Reviewing operation and maintenance manuals documentation for completeness.
- Writing a final commissioning report documenting the final evaluation of the systems' capabilities to meet design intent and owner needs.
- Developing an operations and maintenance manual that details the most important equipment and system O&M parameters

Installing Contractors and Manufacturer Representatives

Contractors and manufacturer representatives are responsible for several facets of the commissioning process. Their primary responsibility is any relevant commissioning functions described in the project specifications. This includes working with the owner and commissioning provider to develop the commissioning schedule, documenting system startup, and conducting regular performance tests (with the help of the commissioning provider) of the equipment systems they install. Contractors and manufacturer representatives are also responsible for training facility managers the proper operation and maintenance of systems they have installed. Also, it is their job to provide operation and maintenance manuals to the owner for any of the equipment they install (Energy 2005).

Design Professionals

The responsibilities of the design professionals will vary with the interests of the designers and the needs of the project and owner. The primary commissioning-related responsibilities of design professionals are to document the design intent (owner's project requirements and related acceptance criteria) for all systems, to write system descriptions and record design basis information, answer questions and issues brought up by the commissioning provider during design, and to make sure that commissioning is included in the bid specifications. During construction, the designers are tasked with clarifying design issues related to system operation and design intent and to assist in resolving construction and operational deficiencies illuminated by the commissioning process. For complex projects, the designer may even review commissioning plans, functional performance test plans, and may witness selected functional testing (Energy 2005).

Facility Manager/Building Operator

The building operator's primary task is to assist with (or at least observe) as much of the functional testing as possible. This is to gain insight on the commissioning process and the equipment or systems they will encounter as they maintain the building. As this employee observes the commissioning tests this will improve the operators understanding of the equipment and control strategies. It also trains the operator to be able to retest systems periodically as part of their ongoing O&M protocol.

Another possible task of the facility manager is to provide insight for the commissioning team. Often times there are details of the design that can be adjusted and modified at no cost yet will provide significant benefits to the ongoing operation of the building. Specific examples might include point naming conventions, alarm messages, and graphic layouts of the energy

management system. The operator can also help in interfacing any existing facilities management software, owner's standards, and equipment preferences into the project.

The operator should also attend training sessions provided by manufacturer's representatives and or contractors. The goal is to have this employee obtain significant hands on experience and understanding of any installed equipment so that they may ultimately take charge of the operation and maintenance activities when the project is completed (Energy 2005).

Testing Specialists

If the complexity of the project requires special testing, the specialists performing these tests may also need to be involved in the commissioning process. Test results and recommendations from these specialists should be submitted to the commissioning provider for review in order to reduce the amount of potential problems down the road. Testing specialists may also be required to review documentation relating to the systems they test and to train operators on the proper use of testing equipment (Energy 2005).

Commissioning Documentation

Documentation is a very important part of commissioning process. The primary purpose of documenting during commissioning is to record the standards of performance for different building systems and to verify that what is designed and constructed meets those standards. Documentation is also the web that intertwines building systems and those installing them. It helps to provide continuity between parties involved in the commissioning process, thus helping to reduce potential errors and schedule delays.

Another reason for commissioning documentation to be accurate is for when the building is eventually turned over to the owner/facility manager. Commissioning documentation becomes the road map for the operations, maintenance, and calibration of building systems that are put in

service. In essence, proper documentation becomes the benchmark to ensure any commissioned part of the building can be changed or updated easily to meet future needs of the owner.

The commissioning team prepares documentation of the following items: benchmarks for energy use, equipment efficiencies, seasonal operational issues, start-up and shutdown procedures, diagnostic tools, and guidelines for energy accounting. Ultimately, by accurately and consistently recording and documenting the commissioning process, it creates a better end product for the owner and the eventual occupants.

Commissioning Process

Commissioning is a complex and intricate process that vary greatly from project to project. This can depend on the extent of the commissioning, as well as the building type and overall objective. However, for the scope of this paper, the recommended sequence will come mostly from the ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) Commissioning Guidelines 0-2005. These guidelines are well accepted throughout the commissioning industry and provide a comprehensive overview of the commissioning process.

The commissioning process can be broken down into four phases: Pre-design, Design, Construction, Occupancy and Operations (ASHRAE 2005). Each step in the process has different responsibilities for each member of the commissioning team. Below outlines the goals of each phase of commissioning and which team members are involved:

Pre-Design

One of the first items to occur during pre-design is that the Owner or Project Manager must select a commissioning provider. They can come from an in-house or outside source. Once the selection process has been completed the commissioning provider can help the owner complete the next parts of the pre-design phase.

The main goal of pre-design is to establish the parameters and expectations for the commissioning process. It is a critical preparatory phase in which the Commissioning Provider works with the owner to create the Owner's Project Requirements in order to outline the expectations for the project. Other important objectives include: developing the initial commissioning plan, identifying a scope and budget, establishing issues log procedures, and reviewing and implementing lessons learned information from previous or similar projects.

Another important goal of the pre-design phase is to form a commissioning team. This is usually done by the owner with the help of the commissioning provider. The team is established to oversee, implement, and accomplish the goals set out by the Owner's Project Requirements and the Commissioning Plan. In this initial phase each member's roles are outlined and lines of communications are established. Finally, in the Pre-Design Acceptance Phase, the owner will review all aspects of the Owner's Project Requirements, Commissioning Plan, and any other documentation. In acceptable, the owner will sign off and the process can proceed to the next step (ASHRAE 2005).

Design Phase

After the pre-design acceptance has occurred, the process then transitions into the design phase. During the design phase, the Owner's Project Requirements and the Commissioning Plan are translated into the construction documents. In order to accomplish this, a document called the Basis of Design is created. The basis of design is a narrative and analytical documentation prepared by the Architect/Design team to describe how the Owner's Project Requirements are to be met by the proposed design. It describes the technical details of the following: systems selections, sequence of operations, performance targets, narrative system and assembly descriptions, owner guidelines and directives, codes, standards, guidelines, regulations, and other design specific references.

After the Basis of Design is created the Commissioning Plan must be updated to reflect the changes made in the Owner's Project Requirements as a result of any new items developed during the design phase. An example of these changes would be the addition of the testing requirements of the building systems and assemblies to the Commissioning Plan. Next, the team is tasked with developing the Commissioning Process Requirements for inclusion in the constructions documents. The Commissioning Process Requirements make sure that certain quality assurance and control procedures are performed as part of the construction contract.

Also an important part of the design process is developing a draft of construction checklists which aid equipment and system installers by providing specific information regarding equipment/assembly verification, pre-installation checks, and any problems that may arise during installation. Along with the construction checklist, a systems manual is created so that those not involved in the construction process can understand how to operate any or all of the systems that have been installed. This is a user friendly document that helps anyone that was not part of training to be able to understand how each system works.

The final item to occur before design phase acceptance by the owner is to outline the training requirements for the operations and maintenance personnel. This is a critical step because the O&M personnel must needs this information to repair and upkeep equipment to prevent expensive problems from occurring down the road. The training requirements should outline the following: systems and equipment for which training is required, the capabilities and knowledge of O&M personnel, the number and type of training sessions, and measurable learning objectives and teaching outlines that clearly describe the specific skills and knowledge that each participant is expected to master. Another important item to cover in the training requirements is any emergency instruction and procedures that would be relevant to any installed

equipment. After these training requirements are identified and all other design phase documentation has been reviewed by the owner, the process can continue onto the next phase.

But before that can happen, there is step known as the elaboration step. This is a transitional step between the completion of design work and the start of construction. During this step, the duties of either the owner or project manager include: completion of the construction documents, bid submission, bid assessment, and selection of the contractor for the construction are performed. Often a pre-bid conference is held to alert bidders to any commissioning process requirements for which they may not be familiar (ASHRAE 2005).

Construction Phase

During the Construction Phase, the Commissioning team works to verify that all systems and assemblies are installed in a manner that will achieve the Owner's Project Requirements. The first objecting of the construction phase is updating the Commissioning Plan and Owner's project requirements to reflect any changes that occurred during bidding or any design/construction process initiated changes to the Construction Documents. Next, a pre-construction commissioning meeting is held to review the intricacies of the Owner's Project Requirements, Basis of Design, and any unique contract documents. Also, the specific roles and responsibilities of each of the contractors is examined and reviewed. Next, the process of verifying that submittals meet the owners wishes. This usually involves taking 5% to 10% of submittals and making sure they adhere to the Owner's Project Requirements.

After those items are complete, it is the job of the project team to integrate the commissioning activities into the construction schedule. Examples of items to be included in this combined schedule include: commissioning team meeting times, start and completion of each construction phase, key system and assembly completion tests, training sessions, substantial

completion, occupant move-in, and warranty start date. Detailed integration of commissioning work with the construction schedule is critical to maintaining project schedule milestones.

Next important step of the construction phase is to develop test procedures that define the means and methods to carry out testing of equipment and systems. This may include participants required for the tests, pre-requisites to performing the test, instructions to perform the test, a listing of tools and supplies required, what observations or measurements that must be recorded, and the range of acceptable results. After the tests are complete, it is important for the commissioning team to verify that the data collected complies with the Owner's Project Requirements. After that is complete the commissioning team is tasked with developing test data reports to document any observations or measurements. There are two last items to complete before the formal acceptance by the Owner. The first is verifying that the Systems and Basis of Design manuals created in the design phase are updated to reflect any incorporated materials generated during the Construction Phase. The second item is verifying any training of Operations and Maintenance personnel and occupants (ASHRAE 2005).

Occupancy and Operations Phase

This phase begins at substantial completion and ideally continues throughout the life of the building. This phase is intended to respond to the dynamic changes that may occur in a facility or system over time. This phase also includes many activities that have not been completed in the previous phases. For example, any training that may have not been completed during the Construction Phase will be finished up. In addition, the team needs to verify that an on-going continuing training program is in place for all operation and maintenance personal. This is essential to be sure the facility will run at the desired performance in the future.

Another goal of this phase is to make sure that all systems meet the performance and desired outcomes of the Owner's Project Requirements. This includes any testing that may have

been left over from the Construction Phase that time, weather, or occupant interference did not permit. The commissioning team also works to verify that there is a system in place to for seasonal testing of facility systems in the future. Other objectives of this phase include: complete the final project Systems Manual, update the Basis of Design, and make sure all items are completed in that were outlined Commissioning plan. The last item that occurs is that the final project Commissioning Report written up and handed over to the Owner.

Even though this is the official final phase, it is certainly not the end of the commissioning process for a building. As the needs and demands of the owner and occupants change over time, so will the required performance of building systems. With that change will come the need for new equipment and ultimately more commissioning (ASHRAE 2005).

Trends and Future of Commissioning

Demand Exceeding Supply

With estimates showing growth from $114 million in 2001 to $806 million in 2004, it is safe to say that the commissioning industry is growing. This is could be due to the introduction of several new Federal mandates requiring more efficient building systems in government buildings and the requirements of commissioning to satisfy provisions in LEED mandates. With these new provisions and other contributing factors, the demand for commissioning services has far outpaced the supply of competent commissioning professionals. Between 2001 and 2004, the commissioning field is estimated to have grown 600 percent (through a study conducted by FMI, a Raleigh, NC-headquartered consulting firm for the construction industry) with the scope of services ranging from testing and balancing to full-scale independent third-party commissioning starting with pre-design and extending to one year after occupancy.

With that demand outpacing supply many experts in the commissioning industry feel that not enough has been done to expand the supply of commissioning professionals. To remedy this

problem many experts feel that there needs to be more training and apprentice programs offered around the country. That includes training operations who are currently conducting training events to consider providing instruction and certification in other underrepresented regions of the country. Without an increase in the amount of training offered, there may continue to be a lack of qualified and competent commissioning professionals to help meet this recent increase in demand (Shoop 2005).

Automated Commissioning

During the design and construction of a building, a great deal of information is generated and transferred amongst all of the parties involved in the commissioning process. Essential to this process is the effective management of the myriad of information required in the design, construction, and operations of a facility. If the project is not managed well, this overabundance of paperwork can become cumbersome and could take a larger fraction of the total commissioning time, thus allowing less effort to be directed on improving and verifying system design and performance. Fortunately, technology can play a helpful role in reducing both the time and cost of commissioning building systems. Because of this there has been more and more interest in computer based commissioning tools that can help facilitate the organization and use of commissioning data.

Current efforts to automate commissioning fall into four categories: developing and managing building design information, developing test procedures, managing data, and automating functional testing. Automated systems that use smart control devices and easy to use commissioning tools with advanced building automation system capabilities can help to manage the commissioning process by quickly collecting, analyzing, and reporting system performance data. Automation also allows tracking and reporting to be completed more accurately and consistently. Because of this, fewer errors occur, producing a shorter and hopefully less

expensive commissioning process. In addition, many automation systems have tools that track building system information that could be very helpful to the Owner and maintenance staff over the life of the building. By having easily obtained and up-to-date information about the building's systems, it allows the O&M staff to quickly diagnose and fix problems before they get out of control.

Automating aspects of the commissioning process could make the commissioning process more efficient and as a result more cost effective. Because of this, the automation of commissioning is and will continue to be an important trend for the building industry (Brambley and Katipamula 2005).

Total Building Commissioning

During the early days of building commissioning services, the typical Owner and Project Team only considered the heating, ventilating and air conditioning system when trying to optimize the performance of the building. There was rarely any mention of commissioning any other building systems unless they directly affected the performance of the HVAC components. In essence, the commissioning process was usually limited to testing, aligning and balancing the HVAC equipment according to established industry standards.

Due to today's demand for healthier and more energy efficient buildings, a new approach to commissioning has evolved, which embraces a comprehensive process that verifies a building's complete overall performance. This concept is known as total building commissioning and represents a fundamental shift in attitude toward quality control. While traditional commissioning focused mainly properly functioning mechanical and control systems, total building commissioning strives to ensure the performance of all the building systems of a modern building. The systems generally included in total building commissioning include: Mechanical and Energy Systems, Structural Systems, Exterior Envelope Systems, Roofing

Systems, Interior Systems, Elevator Systems, Plumbing Systems, Lighting Systems, Electrical Systems, Fire Protection Systems, and Telecommunications Systems.

Many owners are seeing the benefits from total building commissioning. By commissioning all systems, they are realizing both initial and long term savings from reduced operations and maintenance costs, more satisfied occupants, and higher levels of energy efficiency. The other members of the project team (contractors, designers, etc.) are also realizing benefits from this more integrated approach. Many find that total building commissioning provides a better product to the owner with a higher level of satisfaction and less callbacks (3 D/I 2007).

Green Building and Commissioning

From 2005 to 2006, the cumulative number of LEED registered projects (for all rating systems) grew by 50%, while the number of LEED certified projects grew by nearly 70%. In addition, more than 6,000 other projects are currently registered with the USGBC to acquire LEED certification in the future (Judelson 2007).

The USGBC recognizes the importance of the commissioning process in green buildings and mandated it as part of the LEED requirements. Fundamental building commissioning is a prerequisite for receiving any of the credits in the Energy and Atmosphere Section. There also an Enhanced Credit for those teams trying to receive additional credits by beginning the commissioning process early in the design process and executing additional activities after systems performance verification is complete. Figure 2-2 outlines the commissioning scope for LEED Version 2.0 - New Construction.

LEED V 2.0 New Construction
Energy Prerequisite 1: Fundamental building systems commissioning (required)

- Engage a commissioning authority
- Develop the design intent and basis of design
- Include commissioning requirements in the construction documents
- Develop and utilize a commissioning plan
- Verify installation, functional performance, training and documentation
- Complete a commissioning report

Energy Credit 3: Enhanced commissioning (1 Point)

- Conduct a focused review of the design prior to the construction-documents phase
- Conduct a focused review of the construction documents when close to completion
- Conduct a selective review of contractor submittals of commissioned equipment
- Develop a recommissioning-system-and-energy-management manual
- Have a contract in place for a near-warranty-end and post-occupancy review

Figure 2-2. Leadership in energy and environmental design version 2.0 new construction: commissioning scope

CHAPTER 3
RESEARCH METHODOLOGY

Overview/Goals

The purpose of this study was to examine how contractors relate to the commissioning process in the building construction industry. The study targeted contractors who attended the Fall 2007 and Spring 2008 M.E. Rinker, Sr. School of Building Construction Career Fairs at the University of Florida. The study's main goal was to gather and analyze contractor's perceptions about the commissioning process. Other goals of this study were to investigate the following:

- What level of awareness do contractors have about the commissioning process?
- Is there is a trend towards an increase in the amount of buildings that are being commissioning and why?
- To examine the relationships between the parties who are involved in the commissioning process
- To determine whether there is a link between an increase in the amount of LEED certified/green buildings and a greater interest in the commissioning process.
- To gauge the perceived value of commissioning from a contractor standpoint and to determine it's effectiveness in helping streamline the building process.
- To understand how to best improve the commissioning process based on the responses gathered from the survey.

Development and Explanation of Survey

The research method used was an industry specific survey for contractors. The survey was developed by choosing topics relative to commissioning and then compiling a list of relative questions that would best determine the role of commissioning for the contractor's surveyed. With the help of a research committee composed of faculty members from the University of Florida's M.E. Rinker, Sr. School of Building Construction, the questions were then narrowed down to best assess which aspects of the commissioning process to investigate further to accomplish the goals of the study.

The first part of the commissioning survey is the demographics and background section. In this section there are questions about LEED certification status, years of experience, title, company name, and company annual volume. These questions were specifically designed to help later stratify the data and gain a better understanding of how the data collected would be best organized. The next section includes a definition of building commissioning as it relates to the construction industry. The purpose of this section is creating a basic understanding of what commissioning is so that all participants are starting from the same place.

After the definition section, there is a section of general questions aimed at establishing the how involved the individual and their company is with the commissioning process. There are also trend questions regarding whether there is an increase of commissioning in LEED and non-LEED projects. The goals of this section are to gauge the individual's basic involvement with commissioning process and to gauge how the contractors felt about which direction the commissioning industry was heading.

Finally, the last section of the survey is a set of Likert scale questions. There were a total of eight questions in this section and were scaled from 1 to 5, with 1 being "None" and 5 being "High". The first two questions are used to measure the perception of each individual's personal and company knowledge about the commissioning process. The next two questions try to gain a grasp on the relationships between parties that are involved with commissioning.

The last four questions attempt to assess the value of the commissioning process from an owner and contractor standpoint. The purpose of these questions is to try to gain insight on what value the process has and to help understand which parts need improvement.

Distribution and Compilation of Survey

Before the survey could be distributed, it first had to be approved by the Institutional Review Board (IRB). The IRB is a regulatory board for University of Florida faculty members,

staff members, and students who want to conduct or participate as investigators in research with human subjects. Part of the compliance to the IRB is that every survey included an informed consent form which every participant must fill out. This form stated the objectives of the research, whether there was any compensation or benefits (not in this study), any risks, contract information for my committee, and the fact that everything was completely anonymous. To help protect the identities of those involved in the study, each participant was assigned an ID number which helped to anonymously organize participants during the analysis of the results.

The next step involved submitting a copy of the survey, informed consent, and research proposal to the research committee for approval. After receiving feedback, the necessary changes were made and the corrected packet of information was ready to be submitted to the IRB. Finally, after several weeks of waiting, the survey received approval and was ready to distribute to human subjects.

Next, a list of attendees from the University of Florida Fall 2007 M.E. Rinker, Sr. School of Building Construction Career Fair was compiled. Each contractor on the list was then given a packet. Included in each packet was: a copy of the commissioning survey, an informed consent form/cover letter, and a self-addressed stamp envelope for return. After waiting several weeks, each unresponsive contractor was methodically called and sent follow-up emails to attempt to receive more surveys back. After waiting several months and not receiving a large enough sample size to draw conclusions, the decision was made to attempt to collect more surveys at the Spring 2008 M.E. Rinker, Sr. School of Building Construction Career Fair. During this career fair, the experimenter attempted to follow up with any companies who did not submit surveys during the first distribution.

Finally, after receiving back a sufficient number of surveys from both fairs, the results were compiled into an Excel spreadsheet. Each survey question had its own section on the Excel spreadsheet and each individual's answer was placed in a particular worksheet category. The results were then analyzed using descriptive statistics in order to draw conclusions and to answer the study questions/goals posed by the experimenter.

Limitations of Study

The main limitation of this study was the limited amount of time to collect surveys during the career fair. This was mainly due to the fact that many companies were also trying to recruit potential employees, while also trying to fill out the survey. This obviously limited the amount of surveys that were collected. Along with some of these distractions, many of the representatives of the companies were there mainly to recruit and may or may not have been the best person to talk to about such a specific issues like building commissioning. Many of the responses on the questionnaire were "I don't know" to very basic questions about the company or the commissioning process. That leads to the possibility that some of the respondents were not qualified enough to give accurate information about their company or offer accurate insight for the experiment.

Another potential limitation of the study was the fact that a few of the questions may have been leading or confusing. This was evident because many of the respondents either all answer a question one way or another or put questions marks down for the answer. Another potential problem was the fact that a couple of the question referred to a very specific LEED credit that many of the respondents were not familiar with. This was difficult because many of the respondents were not LEED certified. With that being the said, it was difficult for many of the respondents to answer any of those questions with any degree of certainty. One final problem was the fact that the companies that attended the career fairs may or may not represent the

building industry as a whole. Because of this problem, some of the conclusions that were drawn about the commissioning process may not apply to certain regions of the country that were not present during the fair.

CHAPTER 4
ANALYSIS OF RESULTS

There were thirty-one completed surveys collected from the Fall 2007 and Spring 2008 M.E Rinker, Sr. School of Building Construction Career Fairs. The completed surveys came from companies specializing in all types of construction with varying sizes and annual volumes. The demographic represented from the completed surveys collected during the career fair was also very diverse. The respondents that filled out the survey were primarily Project Managers (almost two-thirds), followed by a small number of Estimators and upper management employees such as Project Executives and Vice-Presidents, and then finally a smattering of various other positions such as recruiters and human resource employees.

The average years of experience that each employee possessed varied anywhere from one to in upwards of twenty-five years in some cases. The average amount of experience was approximately eight years. Of the 31 completed surveys, nearly a 1/3 of those surveyed claimed to be LEED certified. The average number of LEED projects that the thirty-one respondents reported that their company was involved in on annual basis was three. Nearly 58% of respondents claimed to be currently working a project that was being commissioned. The results from the building commissioning survey (Appendix B) were analyzed and broken down into two sections: general survey questions and Likert Scale responses. Both results are found below summarized in Tables 4-1 and 4-2 respectively.

Table 4-1. Analysis of building construction survey: general questions

Question #	General Questions	Results
#1	Are any of your projects currently being commissioned?	Yes – 58% No – 42%
#2	Approximately what percentage of your project involved building commissioning?	49% was average amount
#3	Do you think there is a trend towards commissioning in construction?	Yes – 100% No – 0%
#4	Do you think there is a trend towards building owners in the private sector requiring more commissioning?	Yes – 94% No – 6%
#5	How many LEED project is your company involved with on an annual basis?	3 – average number of projects
#6	Approximately what percentage of the Project Managers in your company are LEED Accredited Professionals?	20% was average amount
#7	For what percentage of your LEED projects was there a third party commissioning agent involved?	20% was average amount
#8	What percentage of your LEED projects does the owner try to receive the Enhanced Commissioning LEED credit (EA3)?	10% was average amount
#9	What is the job title of the person in your firm that provides the expertise for the commissioning process?	Project Manager – 40% MEP coordinator – 13% Others – 47%
#10	Do you feel there is a trend towards commissioning in non-LEED projects?	Yes – 55% No – 33% Do Not Know – 12%

Table 4-2. Analysis of commissioning survey: Likert Scale questions

Question #	Likert Scale Questions	Results
#1	What is your level of personal knowledge of the commissioning process?	Approximately “3” or about average
#2	What is your company’s level of knowledge of the commissioning process?	Approximately “4” or above average
#3	What is your company’s level of reliance on the mechanical engineer during the commissioning process?	Approximately “3” or about average
#4	What is your company’s level of reliance on subcontractors during the commissioning process?	Approximately “3.5” or between average and above average
#5	How beneficial do you feel that the commissioning process is in helping to meet the owner’s expectations?	Approximately “4” or above average
#6	How effective do you feel that commissioning is in reducing the amount of call-backs after a project is completed?	Approximately “4” or above average
#7	From an economic standpoint, what is the value of commissioning in comparison to cost?	Approximately “3.5” or between average and above average
#8	How effective do you feel that a third party commissioning agent is in terms of streamlining the commissioning process?	Approximately “3.5” or between average and above average

CHAPTER 5
SUMMARY AND CONCLUSIONS

Results from the survey certainly helped me to drawn a number of conclusions and to satisfy some of the goals of the study. For example, I expected the results of the survey to show that there is a trend towards an increase in the amount of building commissioning due to an increase in the amount of green buildings. With nearly all of respondents answering "Yes," to questions regarding general trends regarding the increase in the amount of commissioning in the private and public sectors, it is clear that there is perceived notion that there is a trend towards increased building commissioning being done. However, it is unclear from the results whether this is directly a by-product of the increasing number of LEED buildings requiring commissioning or there are other contributing factors. I theorize that some of these other contributing factors include: owners that are requesting more complex building systems to meet the demands of occupants, the need for better performing HVAC systems to keep pace with rising energy costs, owners that are beginning to realize that better training for building operators usually results in lower maintenance and repair costs, and finally an increase in the amount of contractors that are beginning to see that commissioning may help to streamline the construction process; thus producing a better product and ultimately a more satisfied owner.

The second major conclusion that the survey helped to highlight was that there is likely a lack of awareness and understanding of the commissioning process by contractors and construction managers. The survey answers pointed to the idea that many individuals, even those who had been in construction for several years, had only a basic understanding of the commissioning process. From my research during the literature review and the answers from the collected surveys, I believe this a result of two contributing factors. First, that there has been too much reliance by contractors on the mechanical engineer, the commissioning agent, and

subcontractors during the commissioning process in the past. A second reason is that many companies do not focus enough resources exposing their employees to nuances of the commissioning process. Without an increase in the number of adequate commissioning awareness and training programs for employees of contractors, their will still continue to be a knowledge gap between contractors and the other project team members who are actively involved in the commissioning process. I believe that there needs to be a major increase in the number of in-house contractor training programs in order to close that gap.

The last major conclusion that can be drawn from the survey results is that there is definitely value in the commissioning process, but how exactly how much is certainly questionable. This conclusion is partially drawn from the answers from the Likert scale questions found on the survey and also from extensive investigation of this problem during the literature review. My theory on why the value of the commissioning process is not fully realized by the project team is mainly due the fact that implementing building commissioning is sometimes very cumbersome and not always cost efficient. One way to increase the value of commissioning for the construction team is to automate as much of the commissioning process as possible in order to cut out many of the unnecessary meetings and to cut down on the amount of paperwork involved in documentation. Automated systems that use smart control devices and easy to use commissioning tools can help to manage the commissioning process by quickly collecting, analyzing, and reporting system performance data in a very accurate manner. This is important because errors that occur during commissioning usually result in more reports and paperwork, ultimately producing a longer and more expensive process for the project team.

Finally, building commissioning is a process that is here to stay. With the ever-increasing demand for more complex systems and the shift towards increased demand for energy efficient

buildings, it is safe to say that building commissioning will be an important tool for assuring that a building's systems will work in harmony with each other and also with the eventual owners and occupants they will help to serve.

CHAPTER 6
RECOMMENDATIONS FOR FUTURE RESEARCH

The possibilities to expand on this area of research are nearly endless. Some promising areas for future research include: examining the key differences between enhanced versus fundamental commissioning for a project, pinpointing the inefficiencies in the building commissioning process and to how to best streamline it, studying the effectiveness of a third party commissioning agent on the project team, developing a more in-depth survey/questionnaire for industry professionals to pinpoint what areas of building commissioning they lack, and finally developing an awareness/training commissioning program for contractors and construction professionals.

APPENDIX A
ASHRAE COMMISSIONING GUIDELINE 0-2005: DOCUMENTATION RESPONSBILITIES BY TEAM MEMBER

Documentation Matrix Phase	Document	Input By	Provided By	Reviewed/ Approved By	Used By	Notes
Pre-Design	Owner's Project Requirements	O&M, Users, Capital Projects, Design Team	CA or Designer	Owner	CA, Design Team	Design Team may not be hired yet.
	Commissioning Plan	Owner, Design Team, CA	CA	Owner	CA, Owner, Design Team	Design Team may not be hired yet.
	Systems Manual Outline	O&M, CA	Owner or CA	Owner	Design Team	May be included in OPR
	Training Requirements Outline	O&M, Users, CA, Design Team	Owner or CA	Owner	Design Team	May be included in OPR
	Issues Log	CA	CA	N/A	CA, Design Team	May be only format at this phase
	Issues Report	CA	CA	Owner	Design Team, Owner	
	Pre-Design Phase Commissioning Process Report	CA	CA	Owner	Owner	Close of Phase report
Design	Owner's Project Requirements Update	O&M, Users, Capital Projects, Design Team	CA or Designer	Owner	CA, Design Team	
	Basis Of Design	Design Team	Design Team	Owner, CA	Design Team, CA	
	Construction Specifications for Commissioning	Design Team, CA, Owner	Design Team or CA	Owner	Contractors, CA, Design Team	May also be provided by Project Manager / Owner's Rep.
	Systems Manual Outline-Expanded	Design Team, CA, O&M, Contractor	Design Team or CA	Owner, CA	Design Team, Contractor	Contractor may not be hired yet.
	Training Requirements In Specifications	O&M, Users, CA, Design Team	Owner or CA	Owner	Design Team	Contractor may not be hired yet.
	Design Review	CA	CA	Owner	Design	

	Comments				Team	
	Issues Log	CA	CA	N/A	CA, Design Team	
	Issues Report	CA	CA	Owner	Design Team, Owner	
	Design Phase Commissioning Process Report	CA	CA	Owner	Owner	Close of Phase report
Construction	Owner's Project Requirements Update	O&M, Users, Capital Projects, Design Team	CA or Designer	Owner	CA, Design Team, Contractors	
	Basis of Design Update	Design Team	Design Team	CA, Owner	Design Team, CA	
	Commissioning Plan Update	Design Team, CA, Owner, Contractor	CA	CA, Owner, Design Team, Contractor	CA, Owner, Design Team, Contractors	
	Submittal Review Comments	CA	Design Team	Design Team	Contractor	
	System Coordination Plans	Contractor, Design team	Contractor	CA, Design Team	Contractor, CA	
	Inspection Checklists	CA, Contractor, Design Team	CA	CA, Design Team	Contractor	
	Inspection Reports	Contractor	CA	CA, Owner	Contractor	
	Test Procedures	CA, Contractor, Design Team	CA	Ca, Design Team	Contractor	
	Test Data Reports	Contractor	CA	CA, Owner	Contractor	
	Commissioning Meeting Agendas and Minutes	CA	CA	All	All	
	Training Plans	Design Team, CA, O&M, Contractor	Contractor or CA	Owner, CA	O&M, Users, Contractor	
	Systems Manual	Design Team, CA, O&M, Contractor	Contractor	Owner, CA	O&M, Users	
	Issues Log	CA	CA	N/A	CA, Design Team, Contractor	
	Issues Report	CA	CA	Owner, Design Team	Design Team, Owner, Contractor	

	Preliminary Construction Commissioning Process Reports	CA	CA	Owner	Owner	Prior to Occupancy
	Final Construction Phase Commissioning Process Report	CA	CA	Owner	Owner	Close of Phase Report
Occupancy and Operations	Owner's Project Requirements Update	O&M, Users, Design Team	CA or Designer	Owner	CA, Design Team, Contractors	
	Basis of Design Update	Design Team	Design Team	CA, Owner	Design Team, CA	
	Maintenance Program	O&M, Contractor, CA	Owner or CA	Owner, CA	O&M, Users	
	Test Procedures	Contractor, CA, O&M, Design Team	CA	Design Team, CA	Contractor	
	Test Data Reports	Contractor	CA	CA, Owner	Contractor, O&M	
	Issues Log	CA	CA	N/A	CA, Design Team, Owner, Contractors	
	Issues Report	CA	CA	Owner	Design Team, Owner, Contractors	
	Commissioning Process Report	CA	CA	Owner	Owner	Final Report
	Re-Commissioning Plan	O&M, Users, CA	CA or Owner	Owner	Owner	

APPENDIX B
COMMISSIONING SURVEY

Building Commissioning Survey

Background Information

Survey ID:_____

Job Title:_____

Years of Experience_____

Company Name:_____

Type of Construction:_____

Annual Volume: ($)_____

Are you a LEED Accredited Professional (LEED-AP)? _____YES ____ NO

Definition of Commissioning

Building commissioning is the systematic process of ensuring that a building's complex array of energy-related systems are designed, installed, and tested to perform according to the design intent and the building owner's operational needs.

General Questions

Please answer the following questions to the best of your knowledge.

1) Are any of your projects currently being commissioned?
Yes or No

2) Approximately what percentage of your projects involve building commissioning?
_____

3) Do you think there is a trend towards commissioning in construction?
Yes or No

4) Do you think there is a trend towards building owners in the private sector requiring more commissioning?

Yes No Do not know

5) How many LEED projects is your company involved with on an annual basis?

_____

6) Approximately what percentage of the PM's in your company are LEED Accredited Professionals (LEED-AP)?

_____

7) For what percentage of your LEED projects was a third party commissioning agent involved?

_____

8) What percentage of your LEED projects does the owner try to receive the Enhanced Commissioning LEED credit (EA 3)?

_____ _____

9) What is the job title of the person in your firm that provides the expertise for the commissioning process?

_____

10) Do you feel there is a trend towards commissioning on Non-LEED projects?

Yes No Do not know

Please circle the number that best describes your response to the following questions.

Ranking	None	Below Average	Average	Above Average	High
1) What is your level of personal knowledge of the commissioning process?	1	2	3	4	5
2) What is your company's level of	1	2	3	4	5

knowledge of the commissioning process?					
3) What is your company's level of reliance on the mechanical engineer during the commissioning process?	1	2	3	4	5
4) What is your company's level of reliance on subcontractors during the commissioning process?	1	2	3	4	5
5) How beneficial do you feel that the commissioning process is in helping to meet the owner's expectations?	1	2	3	4	5
6) How effective do you feel that commissioning is in reducing the amount call-backs after a project is completed?	1	2	3	4	5
7) From an economic standpoint, what is the value of commissioning in comparison to the cost?	1	2	3	4	5
8) How effective do you feel that a third party commissioning agent is in terms of streamlining the commissioning process?	1	2	3	4	5

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BIOGRAPHICAL SKETCH

Ryan David Dorsett was born on a United States Air Force Base in Ipswich, England in 1984 to Mark and Kim Dorsett. Two years later he and his family moved to Oklahoma. After that, they moved to an Air Force Base in Tampa, Florida, and finally to Tallahassee, Florida, in 1993. On receiving admittance to the University of Florida in 2002, Ryan Dorset moved down to Gainesville, Florida to begin his undergraduate studies in business. Upon earning a Bachelor of Science in business administration with a major of marketing in 2006, he was accepted into the master's program at the M.E. Rinker, Sr. School of Building Construction at the University of Florida. Then in May 2008, he earned a Master of Science in Building Construction with a concentration in sustainable construction. He is currently taking a position with Brasfield & Gorrie, a general contractor based out of Birmingham, Alabama.