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PREPARED BY:

Primary Author(s):
Russ Derickson

Architectural Energy Corporation
Boulder, CO

Contract Number: 500-99-013

Prepared for:

California Energy Commission

Matthew Fung
Contract Manager

Virginia Lew
Office Manager
Energy Efficiency Research Office

Laurie ten Hope
Deputy Director
ENERGY RESEARCH AND DEVELOPMENT DIVISION

Robert P. Oglesby
Executive Director

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PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

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ABSTRACT

The goal of this project was to improve the realization and persistence of proper operation and resource efficiency in new California buildings or major renovations by developing a comprehensive commissioning framework, resulting in lower energy use, lower operation and maintenance costs for California, longer building life, and greater worker productivity and user comfort. The project was intended to benefit California's Department of General Services, other state agencies, and the general public. This report was developed from the material detailed in the Task 2 through Task 7 reports of this project on incorporating an in-house commissioning framework into the Department of General Services capital outlay projects. Task 1 was the overall management task for the project, including development of this report. The project tasks included: 1) exploring the feasibility of the project goals; 2) assessing the cost benefits of an integrated commissioning framework to California; 3) developing a preliminary in-house commissioning framework for California's Department of General Services; 4) exploring the commissioning framework in the context of a pilot program with a state construction project; 5) revising the in-house commissioning framework based on review by a project advisory committee and lessons learned from the pilot construction project; and 6) developing training material on the commissioning process for communication to the Department of General Services, other state agencies, and the general public. The overall project was successful, and the project advisory committee recommended that the proposed in-house commissioning framework be considered for implementation in a step-wise, phased manner. The training material on the commissioning process for outreach to other state agencies and the general public was suitable for incorporating into web-based instruction, other electronic educational media, classroom presentation, or a combination of presentational modalities.

Key words: Department of General Services, commissioning benefits, integrated commissioning, commissioning framework, training, State-wide communication.

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EXECUTIVE SUMMARY

Introduction

California's Department of General Services is responsible for the procurement and construction of California real property. California's current capital outlay process for new construction projects does not adequately document, integrate, and track the owner's and client's project requirements throughout the design and construction process. It does not adequately ensure that buildings perform as desired or as designed, or that operation and maintenance staff members are adequately trained or prepared to operate the facility into the future. These conditions result in less than optimal energy usage and decreased building systems life, increased costs to California, and reduced productivity and comfort of the building occupants. The Department of General Services believed that a properly structured and staffed total building commissioning process would ensure that buildings perform as intended from initial occupancy, and that such a process was needed to improve the way real property is planned, designed, and operated by California.

Project Purpose

The goal of this project was to improve the realization and persistence of proper operation and resource efficiency in new California buildings or major renovations by developing and implementing a comprehensive commissioning framework, resulting in lower energy use, lower operation and maintenance costs for California, longer building life, and greater worker productivity and user comfort. The comprehensive goal included extending the intended benefits to California's Department of General Services to other state agencies and to the general public. The results of the project would be openly communicated in a practical, easy-to-understand presentational format that elucidated the critical commissioning sequences vital in the planning, design, and construction of buildings.

The overall project tasks for achieving this goal included: 1) exploring the feasibility of the program goals; 2) assessing the cost benefits of integrating building commissioning into California building projects; 3) developing a preliminary commissioning framework for California's Department of General Services; 4) exploring the commissioning framework in the context of a pilot program with a state construction project; 5) revising the commissioning framework based on review by a project advisory committee and lessons learned from the pilot construction project; and 6) developing training materials on the commissioning process for communication to the Department of General Services, other state agencies, and the general public.

Project Results

The overall program was successful, and the project advisory committee recommended that the proposed in-house commissioning framework be considered for implementation in a step-wise, phased manner. The training materials for outreach to other state agencies and the general public was suitable for incorporating into web-based instruction, other electronic educational media, classroom presentation, or a combination of presentational modalities.

Key results of the project included:

- Integrating commissioning into California capital outlay projects was shown to be operationally and economically feasible.
- Direct evidence from the lessons learned in the pilot program of this project for integrating commissioning into a new California construction project demonstrated the potential cost savings to California from an integrated commissioning framework within the Department of General Services.
- A team-based, in-house commissioning authority role would enable better coordination between key branches and sections within the Department of General Services. Particularly vital was better coordination between the Project Management Branch and the Building and Property Management Branch, which collectively were responsible for the project management and life-cycle stewardship of capital outlay projects. This lesson had counterpart roles in the project managers and operation and maintenance crews in the private sector.
- It was vital to incorporate "upstream" quality in the commissioning of all capital outlay projects to maximize occupant comfort and productivity and to minimize operational and maintenance costs over the project's life-cycle, which is typically 30-50 years. A well-structured framework for the commissioning process achieved this goal.
- Education and training about the purpose, merit, and processes of commissioning were essential for state personnel and the general public. It may be particularly essential to educate construction contractors, who as a group appear to have several misconceptions and a lack of knowledge about commissioning.
- Commissioning as a profession needed to reform itself to be less adversarial (in reality and perception) in its style of operation and conduct.

Project Benefits

The comprehensive building commissioning framework described in this report can help improve the commissioning process for new building construction in California, which could result in better designed buildings that use less energy, have lower operation and maintenance costs and longer lives, and facilitate greater worker productivity and user comfort.

CHAPTER 1: Introduction

This report chronicles the efforts of the *Integrating Building Commissioning into State Building Construction* project to improve the realization and persistence of proper operation and resource efficiency in new State buildings or major renovations through development of a comprehensive commissioning framework, resulting in lower energy use, lower operation and maintenance costs to the State, longer building life, as well as greater worker productivity and user comfort. The project was funded by the California Energy Commission under the Public Interest Energy Research program. The comprehensive goal of the project is to extend the intended benefits to the State's Department of General Services to other State agencies and to the general public. This is achieved through the introduction of a practical, easy-to-understand approach to quality assurance through guided commissioning sequences in the planning, design, and construction of buildings. This Final Report was developed from the material detailed in the Task 2 through Task 7 reports on incorporating an in-house commissioning framework into the Department of General Services capital outlay projects. Task 1 comprises the management of the overall project and includes the development of this Final Report.

The overall project tasks, in composite, include: 1) exploring the feasibility of the program goals; 2) assessing the cost benefits of integrating building commissioning into State building projects; 3) developing a preliminary commissioning framework for the State's Department of General Services; 4) exploring the commissioning framework in the context of a pilot program with a state construction project; 5) revising the commissioning framework based on review by a project advisory committee and lessons learned from the pilot construction project; and 6) developing training material on the commissioning process for communication to Department of General Services, other state agencies, and the general public.

The overall program was successful, with the project advisory committee recommendation that the proposed in-house commissioning framework be considered for implementation in a step-wise, phased manner. The training material for outreach to other state agencies and the general public is suitable for incorporation into web-based instruction, other electronic educational media, classroom presentation, or a combination of presentational modalities.

1.1 Background and Overview

Today's buildings serve complex needs and functions and require complicated equipment and sophisticated, complex systems for their effective operation. However, new buildings often do not operate optimally or as effectively as intended, undermining energy efficiency and human comfort and productivity. Total building commissioning is a sequential, quality assurance process − from planning to design to construction to occupancy − for accomplishing, demonstrating, and documenting that the total building and its systems perform as intended. Thus, a building's performance is properly assured by commissioning all building systems including electrical, mechanical, lighting, exterior envelope, landscaping, storm water control, plumbing, and acoustics.

The State of California Department of General Services (DGS) is responsible for the procurement and construction of State real property. For new construction projects, the State's current capital outlay process does not adequately document, integrate, and track the owner's and client's project requirements throughout the design and construction process. It does not adequately ensure that buildings perform as desired or as designed, or that operation and maintenance staff members are adequately trained or prepared to operate the facility into the future. These conditions result in less than optimal energy usage and decreased building systems life, increased costs to the State, and reduced productivity and comfort of the building occupants. The DGS believes that a properly structured and staffed total building commissioning (Cx) process within DGS' Real Estate Services Division (RESD) will ensure that buildings perform as intended from initial occupancy, and that such a process is needed to improve the way real property is planned, designed, and operated by the State. Thus, an integrated commissioning framework within State agencies can improve the realization and persistence of proper operation and resource efficiency in new State buildings, resulting in lower energy use, lower operation and maintenance costs to the State, longer building life, and greater worker productivity and user comfort.

Following the signing of California Executive Order S-20-04, all State buildings larger than 10,000 square feet (ft^2) must achieve USGBC LEED® (Leadership in Energy and Environmental Design) certification, and some level of commissioning is required. Currently, most of the commissioning is being performed by third-party commissioning authorities, not DGS personnel.

The *Global Warming Solutions Act of 2006* (AB 32, Nuñez/Pavley) was passed by the California Legislature on 31 August 2006 after the bill's authors, Assembly member Fran Pavley and Assembly member Speaker Fabian Nuñez, and Senate President Don Perata, announced they had reached an agreement with Governor Arnold Schwarzenegger on the landmark law. In June 2005, Gov. Schwarzenegger issued an executive order (S-3-05) that established a target for reducing global warming pollution to 1990 levels by 2020, and 80 percent below 1990 levels by 2050.

LEED, which is becoming the de facto standard for "green buildings," ensures that buildings have a lower carbon footprint. *Thus, Executive Order S-20-04, which requires that new buildings be LEED certified at the silver level or higher, directly supports the mandated goals of AB 32.*

Recent DGS and State activities related to new-building commissioning include the following:

- In 2002/2003, DGS staff worked with an outside consultant to investigate commissioning approaches, and the result of that work is documented in the report titled, *Total Building Commissioning Process Strategic Plan FY 2002-2003.*
- In 2002/2003, the Division of the State Architect worked with a consultant to develop a document titled *Adopting the Commissioning Process for the Successful Procurement of Schools*, which was "intended to be used by school districts, programmers, design professionals, contractors, operations and maintenance personnel, and Commissioning Authorities to understand the Commissioning Process and their role in it."

- In 2004, the Governor Schwarzenegger signed Executive Order S-20-04. The associated Green Building Action Plan includes the requirement that all State buildings larger than 10,000 ft^2 achieve LEED certification at a level of Silver or better. The effect of this policy is that a minimum level of commissioning is required for each of those projects.
- In 2005, the California Energy Commission's Public Interest Energy Research (PIER) program funded the work that has resulted in this report and will support development of an implementation plan.
- In 2006, the California Commissioning Collaborative published a Commissioning guideline for California buildings.
- In 2006 and 2007, with assistance from Architectural Energy Corporation on the *Integrating Building Commissioning into State Building Construction* project, the DGS developed a toolkit for commissioning of small buildings. http://www.green.ca.gov/CxToolKit.

1.2 Project Goal, Objectives, and Approach

1.2.1 Goal

The goal of this project is to improve the realization and persistence of proper operation and resource efficiency in new State buildings, *resulting in lower energy use, lower operation and maintenance costs to the State, longer building life and greater worker productivity and user comfort.* (Italics added for emphasis)

The project meets the PIER goal of *Improving the Reliability, Quality, and Sufficiency of California's Electricity* by creating a framework and process for commissioning projects constructed by the State of California Department of General Services (DGS), thereby improving performance and reducing energy consumption. This project also meets the secondary PIER goal of *Addressing Important R&D* gaps by creating commissioning procedures and processes that can be used by other organizations within California.

1.2.2 Objectives

The overall objective of this project is to establish and implement quality and consistent commissioning services by the DGS during their building planning, design, construction, and operation processes, resulting in lower overall cost of delivering service to the taxpayer. This objective will be achieved by collaborating with key staff and management within the DGS to develop procedures, protocols, and specifications for commissioning new State buildings.

1.2.3 Approach

The DGS will implement the total building commissioning process as standard procedures within the DGS. The process will be integrated with and implemented through modified DGS design and operational procedures, creation of new DGS staff positions, roles, and responsibilities; and by properly training DGS personnel in their expanded roles to support the commissioning process. In addition, the project will provide information on the costs and benefits of commissioning State buildings for use by the DGS in justifying personnel assignments and procedural changes to the State's building procurement processes. The DGS

has made a strong commitment to this project, in terms of management and staff time as well as the availability of an actual state construction project for the commissioning pilot.

CHAPTER 2:
Preliminary Assessment of Feasible Options to Provide Commissioning Services to DGS

Appendix A contains the full report on the preliminary assessment of feasible options to provide commissioning services within the Department of General Services (Task 2). An overview, summary, and conclusion of the Task 2 report are presented here.

2.1 Overview and Summary

The State of California Department of General Services (DGS) and the Department of Finance (DOF) intend to incorporate commissioning services into the planning, design review, construction management, and operation and maintenance (O&M) services already provided by the DGS during new construction projects. The initial step in executing this Public Interest Energy Research (PIER) project for achieving the above stated goal was to perform a preliminary assessment of feasible options for integrating commissioning services within the Department of General Services in its capital outlay projects. The sequence for assessing feasible options in pursuit of integrating commissioning within DGS included: a) literature search and interviews on commissioning projects at other institutions; b) examination of the structure, operations, and personnel roles and costs in relevant branches and sections within DGS engaged in capital outlay projects; c) interviews with key personnel within DGS; d) evaluation of commissioning activities and their costs for recent DGS construction projects; e) examination of Executive Order S-20-04 and its associated Green Building Action Plan; f) examination of The *Global Warming Solutions Act of 2006* (AB 32, Nuñez/Pavley); and g) examination of The California Energy Efficiency Strategic Plan (CEESP).

The preliminary assessment provided information to assist DGS in developing a budget change proposal, if appropriate, to develop commissioning staff capability. This information included the skills required of commissioning providers, the number of staff required to serve the DGS project load, and the costs to provide commissioning services for DGS projects. Most importantly, the findings of the preliminary assessment, in conjunction with other key tasks in this overall project, provide a solid basis for the development of an in-house commissioning framework within DGS. The proposed framework and other task sequences leading to its development and viability are described later in this report.

In the literature review and interviews conducted for this feasibility study, it was discovered that in-house commissioning to complement or replace third-party commissioning has met with various degrees of success in other institutions around the country. A summary of findings is as follows:

- The University of California at Davis is one example of a State organization that commissions most of its projects with in-house staff. UC Davis has a staff classification of Commissioning Analyst under the Quality Assurance group which is a part of the Commissioning and Engineering classification. Other than this classification, there are

not specific civil service levels or job duty statements that come into play for UC Davis' commissioning activities.

- About 60-70 percent of the commissioning services at the University of Minnesota are performed in-house. The remaining projects (30-40 percent) are sub-contracted. To make this possible, much of the document review and reporting involved in the commissioning process has been eliminated to reduce costs. They also note that with an in-house commissioning authority, it is easier to keep them involved through the warranty period compared to third-party commissioning.
- A major thrust of the new strategy for the University of Iowa is combining commissioning activities with controls checks. A major problem that developed is that the controls engineers would not do a thorough job knowing that University staff would be coming through to check their work (as a part of the commissioning process). By combining the controls work with the commissioning tasks, a redundant step is taken out.
- A paper by Ralph Wrons, Sandia National Laboratory, "Developing and Keeping In-house Commissioning Expertise," is a case study involving commissioning a wide range of buildings (offices buildings to clean rooms) at Sandia National Laboratories, New Mexico. (Ralph Wrons, National Conference on Building Commissioning: May 4-6, 2005).

The preliminary assessment revealed that successful commissioning authorities (CxAs) come to the role from a number of different backgrounds. Regardless of their background, there are several characteristics that are especially valuable, such as fundamental knowledge of how building systems and their controls function, understanding of both design and construction processes, ability to manage complex long-term projects, sufficient experience to earn respect from both the design and the construction teams, and personal qualities that enable one to be a problem solver in a "politically charged" environment. The subsequent development of an in-house commissioning framework for DGS leveraged and augmented this theme to advantage as will be described later in this report.

Typical salaries for commissioning authorities in the private sector range between $85,000 and $120,000, with some potentially as high as $150,000 with managerial responsibilities. DGS classifications that appear to match up fairly well with industry commissioning authorities salaries include Construction Supervisor II ($81,444 to $99,000), Senior Mechanical Engineer ($88,452 to $107,460) and Construction Supervisor III ($97,164 to $118,104).

Analysis undertaken for this report indicates that five in-house commissioning authorities would be required to handle the DGS project workload, based on the snapshot of 29 projects that were reviewed. This estimate is based on detailed time estimates for several typical project types, which are then extrapolated to the total set of projects. This method estimates close to 7,800 hours per year of commissioning project time. Assuming that each staff member has 1,600 hours per year available, then five staff members are needed. If one or more junior engineer support staff is provided, then four commissioning authorities could likely handle the workload.

There are many alternative paths for providing commissioning services on DGS projects, and three approaches are discussed as follows:

- **In-house commissioning authorities.** DGS staff serves as commissioning authority (CxA) for the majority of projects, with supplementary assistance from third-party contractors in special cases.
- **In-house commissioning project managers**. Regional commissioning managers would be responsible for overseeing the work of third-party commissioning contractors. These managers would develop an in-depth understanding of the commissioning process and would also develop relationships with regional commissioning providers. It is likely that two regional managers would be able to handle the workload.
- **Third-party contractor commissioning authorities**. DGS would continue to use third-party contractors to provide commissioning services. DGS project directors would oversee the work of the commissioning contractors.

2.2 Conclusions and Recommendations

<u>Note</u>: Knowledge and experience gained subsequent to this task on the *Preliminary Assessment of Feasible Options to Provide Commissioning Services Within the Department of General Services* led to some revision of its findings, including the development of a comprehensive, flexible in-house commissioning framework for DGS. Deviations and revisions to the original feasibility study are noted parenthetically in the recommendations and conclusions that follow.

There are significant potential benefits to developing in-house DGS commissioning expertise *Perhaps the greatest benefits are retained knowledge, consistent application of methods, and better access to that expertise throughout the life of the building from design to operation and maintenance.* (These potential benefits were explored in much greater detail in subsequent tasks in this project, and, along with lessons learned in the pilot program with a State construction project, guided the development of the in-house commissioning framework.)

Probably the most significant disadvantages to using in-house commissioning authorities are the ability to respond quickly to changes in workload − i.e. quickly adding or subtracting staff − and the relatively high hourly billing rate that DGS staff charges to projects. An obvious solution to the issue of varying workload is to rely on third-party commissioning contractors to handle peaks in workload when in-house commissioning authorities are busy. Regardless, it is likely third-party commissioning contractors will be needed for specific expertise on some (complex) projects (at least for some period of time until the in-house commissioning framework − developed in subsequent tasks of this project − improves with experience and organizational adjustments over time.)

The original feasibility analysis revealed that about five commissioning authorities would be required to handle the current workload. It is not clear from this simple analysis what minimum base load of commissioning work would always be present, but it seems likely that at least three commissioning authorities could be busy full time. Those three could be supplemented by third-party contractors as needed. (As will be discussed later, the proposed in-house framework

developed in subsequent tasks, which deviates from the scenarios presented in the feasibility study, was developed to adjust to the workload faced at any given time.)

If several in-house commissioning staff were hired, then obtaining a diversity of skills would be beneficial. It is unlikely that one person will have all the knowledge and skills desired in a commissioning authority, a team-based approach was taken in subsequent tasks in this project in developing the in-house commissioning framework. Clearly, the team can benefit if individual members have expertise in areas such as controls, HVAC, plumbing, and electrical systems. It is envisioned that DGS personnel from: 1) the Design Services Section (DSS) and Construction Services Section (CSS) of the Professional Services Branch (PSB); and 2) the Building Property Management Branch (BPM) will serve key roles in in-house Cx at DGS.

The salary level for commissioning authorities working in the private sector appears to be in-line with the DGS classifications of Construction Supervisor II ($81,444 to $99,000), Senior Mechanical Engineer ($88,452 to 107,460), or Construction Supervisor III ($97,164 to $118,104).

While each project needs an experienced commissioning authority, some commissioning tasks can be performed by a junior engineer under direction of the commissioning authority. As a rough estimate, about 20 percent of the commissioning work on a typical project can be performed by someone at a lower salary level (Note: It was subsequently learned that this percentage value is quite higher, given the large number of small projects – less than 10,000 ft²). Therefore, after the State hires a few commissioning authorities, the team's capacity could be extended by adding a junior staff member. This approach could lower the overall cost to the State of providing commissioning services and provides a career path for junior staff members. (The basic approach of incorporating junior personnel holds, but is structured within the in-house commissioning framework developed in subsequent tasks.)

The alternative approach of using DGS commissioning project managers rather than commissioning authorities can also be successful. This approach offers the primary benefit of requiring fewer additional DGS staff, and the project management skills required for the role are familiar to DGS. This approach also helps retain some commissioning knowledge within DGS, though not to the same extent as the commissioning authority approach. (In subsequent tasks, it was decided that the in-house commissioning framework would basically not rely on commissioning project managers, except for complex projects requiring third-party commissioning authorities.)

CHAPTER 3:
Estimate of Statewide Benefits of Integrating Cx into State Building Construction Projects

The full (Task 3) report on the *Estimate of Statewide Benefits of Integrating Cx into State Building Construction Projects* is published separately through the California Energy Commission (CEC), and is not included in an appendix in this Final Report. The report includes a supplemental appendix that documents, with pictures and cost analysis, deficiencies and avoided costs determined through on-site inspection by the Chief Engineer of the building employed for the pilot study of this project (Task 5). An overview, summary, and conclusion of the Task 3 report are presented here.

3.1 Overview and Summary

An estimate of statewide benefits of integrating commissioning into state building construction projects was based on literature reviews, interviews with DGS staff and Cx professionals, and a Cx pilot study of a current DGS capital outlay project in Marysville (Task 5 of this project). Benefits of Cx were quantified through avoided costs − realized especially during design review and construction inspections and annual energy and maintenance/repair savings. "Qualified benefits" are extensive: improved building operation, thermal comfort and air quality for occupants, effective training for building operators, reduced change orders and improved communications during construction, and many "lessons learned" carried forward for future design, construction and maintenance processes.

Information about the benefits and costs of commissioning is needed by the State to justify allocating funds for commissioning staff and activities. The intent of this report is to provide information needed as part of the Capital Outlay Budget Change Proposal (COBCP) process to justify establishing commissioning positions within DGS and to provide project funding for commissioning.

Previous studies and a case study database by the California Commissioning Collaborative have shown that Cx on new buildings cost $0.55 to $1.10 per square foot, or 0.4 to 1.5 percent of the cost of construction. Payback periods (typically one year or less) are attractive and the occupant/operator benefits and institutional memory are invaluable. At Marysville, the site of the pilot program with a state construction project (Task 5), Cx cost $0.59/ft^2, but it achieved an avoided one-time cost benefit of $.61/sf and annual savings of $46K. Cx costs vary depending on the complexity of the project, when Cx services commence, which systems are being commissioned, and additional monitoring that may be performed post-occupancy. Third-party Cx cost data was not provided to evaluate past and current spending by DGS on their new construction projects. This would be a valuable exercise to ascertain if the third-party cost of Cx per square foot is congruent with the CCC database and cost-benefit studies discussed in this report. *Having third-party Cx cost from DGS for past and current projects would also provide a direct rational basis for establishing the merit of the proposed in-house Cx framework developed as the main intent of this project.*

Retro-commissioning (RCx) is performed on existing buildings and is found to cost $0.27 to $0.49/sf, resulting in an annual energy savings of $0.27/sf to $0.40/sf. It is easier to quantify these RCx savings because baseline energy costs are available for comparison; annual energy savings have been significant. New Cx relies on "what if" estimates, assumptions, and energy models to quantify annual energy savings and other benefits such as cost reduction or avoidance during design review and/or construction, reduced call-backs during start-up or warranty phases, and improved operations and reduced maintenance.

DGS experience with Cx on other past projects was used as a potential source of cost/benefit information, but cost information was never provided, as previously mentioned. Several DGS personnel were interviewed to discuss their Cx experience. Most found the process to be beneficial, especially if Cx was started early in the project and consistency was maintained from start to finish. All agree that training of building operators and engineers with the Building and Property Management Branch was invaluable, especially if personnel were assigned to the facility during functional testing or prior. One DGS/BPM engineer commented (regarding the Butterfield/DOR project), "There is a definite "lip service" that is given to the Cx process by contractors, while not fully embracing it. There appears to be a disconnect between what DGS/AEC's vision and understanding are of a holistic Cx program, versus the contractor's view that Cx = Start Up (even though it is pretty clearly defined in the Request For Proposal)." Thus, contractor education is a critical need. This is addressed in Task 7 (communication and training).

3.2 Conclusions and Recommendations

The research and case study on the cost and benefits of commissioning provided herein justify establishing commissioning positions within DGS and providing project funding for commissioning. There is ample evidence of substantial tangible (cost savings) and non-tangible (productivity and improved relations) benefits of involving engineers and operators from the Building and Property Management branch (BPM) to commission projects, starting as early in the design process as possible. Lessons learned from the pilot study of the capital outlay project at Marysville (Task 5) were particularly fruitful in this regard. Thus, the presence of BPM as stakeholders early on would provide retention of valuable lessons learned within BPM and the Design Services Section (DSS) of the Professional Services Branch (PSB) as well as accountability to those BPM staff responsible for maintaining and operating these facilities for many years to come.

Numerous DGS managers, engineers, and operators were interviewed or consulted for their opinions of the Cx process and consideration to housing these services internally (especially within BPM) versus hiring third-party Cx Authorities. It was unanimous that Cx brings ample value to DGS projects, and involving building operators in the early stage of design of larger projects is crucial. Cx staff should reside in BPM where their skills and experience lend the most value to the process and their (post-occupancy) operations will receive the greatest benefits.

Based on 2008 projections for new State construction projects, 4 additional BPM staff-members could manage the 3.3 million square feet (projects either under construction or in the "working drawings" phase) of new construction Cx. Assuming an average annual salary, benefit, and overhead cost to DGS of $150,000 per person, this would require additional funding of $600,000 for the four new DGS Cx staff positions. Based on the benefit value tabulated from the Marysville case study ($0.76/sf in the first year, near the average $/ft2 benefit value derived from the literature review), this 3.3 million square feet of project area could see a total initial benefit of nearly $2.5M.

Finally, it should be noted that these results will be contributed to the ongoing Cx cost-benefit study and meta-analysis by Evan Mills of Lawrence Berkeley National Labs, to be finalized in early 2009.

CHAPTER 4:
Pilot the Commissioning Services Implementation Plan Within a New State Building Project

Appendix C contains the full report on the pilot construction project for integrating the commissioning services implementation plan in capital outlay projects within the Department of General Services (Task 5). An overview, summary, and conclusion of the Task 5 report are presented here.

4.1 Overview and Summary

The goal of this task is to demonstrate the process of implementing commissioning services in an actual State building construction project, and to guide the development of an effective in-house commissioning framework (Task 6) from the lessons learned on the project. The execution and outcomes of this task also have provided information needed to complete Task 7 – Communicate Results to State Agencies and to the General Public. The project team provided a person to be the commissioning authority to work with Department of General Services (DGS) staff in commissioning the Cal Trans District 3 office complex in Marysville, California. The commissioning process began during the pre-design activities and extended through design, construction, and nearly the first year of occupancy.

The new Caltrans building consists of a 220,832 ft^2 five-story building on 820 Chestnut Street in Marysville, California. The project has been conceived for Caltrans to fit within the community, using a truly collaborative approach; an integral design, engineering and construction solution that combines architecture, structure, interiors and building systems. The facility will accommodate various office, meeting, and presentation areas with a day-lit atrium. This report summarizes the commissioning activities performed by Architectural Energy Corporation's (AEC) San Francisco Office. The report is a compilation of the project's commissioning history, with valuable information to help future facility operators understand the decision making process that occurred during the design and construction of this project, and to help in future maintenance operations.

The following building systems were commissioned by AEC:

- Roof top AC units with water cooling
- Make air unit
- CRAC units
- Packaged cooling units
- Dry cooler
- Boilers
- Cooling towers
- Heat exchanger

- Exhaust fans
- Electric and gas water heater
- Lighting controls and daylight dimming controls

The AEC commissioning team performed the following activities to achieve the project objectives:

1) Prepared a commissioning plan
2) Performed design and submittal reviews
3) Organized commissioning scoping meetings
4) Reviewed completed pre-functional inspection checklists
5) Performed jobsite inspections
6) Completed functional performance testing
7) Prepared and updated issues logs
8) Prepared the commissioning report

4.2 Conclusions and Recommendations

The pilot program for developing and initiating an in-house Cx capability, Task 5 of the overall PIER project, entailed commissioning the Caltrans District 3 building in Marysville, California. The lessons learned during this task served to guide the development of the in-house Cx framework, to validate the cost-benefit of commissioning, and to forge a better coordination between various DGS branches and sections. An important lesson gleaned is the critical need for active participation of the building's operation and maintenance (O&M) staff as part of the commissioning authority (CxA) team in the commissioning process. The O&M staff's participation in the commissioning activities can leads to better design, based on their practical field experience, and supports their efforts to operate and maintain the commissioned systems at peak performance over the lifecycle of the building. The most challenging part of this process was to coordinate commissioning-related activities between several different stake holders in this project, reinforcing the need for an effective team-based structure in the in-house framework. Of major concern was that occupancy of the building was initiated prior to all issues with systems and controls being resolved.

A clear finding from the Task 5 efforts is the need to forge a stronger, integrated relationship between DGS's Project Management Branch (PMB) and the Building and Property Management Branch (BPM), and to integrate the Design Services Section (DSS) and Construction Services Section (CSS) - which reside within the Professional Services Branch (PSB) - into the in-house framework. The PMB project director (PD), who has authority over a project, including the Cx process, is most effective if his or her role is better structured within a team framework as elaborated in the Task 6 report. Critically, BPM needs to be fully recognized and accepted as a stakeholder in capital outlay projects from the inception. This became abundantly clear during the Task 5 efforts.

Task 5 reinforced that the hardest part of the commissioning process was initiating it and maintaining commitment from critical stakeholders in the Cx team. Things got better when it became increasingly awkward that the building was occupied while in a dysfunctional state, prior to all systems being commissioned and accepted. A positive lesson was that all Cx team participants - including DGS personnel, the contractor, and sub-contractors - learned more about building systems and their interaction through the Cx process than they have acquired through the many technical classes they may have attended. Also, there is a great deal of satisfaction in discovering the underlying reasons a particular building system or piece of equipment has problems and creating a means to fix or preclude those problems for proper system function.

CHAPTER 5:
Plan to Integrate Commissioning into DGS Capital Outlay Projects

Appendix D contains the finalized report on the preliminary plan (Task 4) and revised plan (Task 6) to integrate commissioning into Department of General Services capital outlay projects. An overview, summary, and conclusion of the Task 6 report, which is a revision of the Task 4 report, are presented here. Revisions of the Task 4 report were based on lessons learned from the pilot project (Task 5) and recommendations from the program advisory committee. The full Task 6 report chronicles the revision process.

5.1 Overview and Summary

A comprehensive plan for an in-house Cx (commissioning) framework has been developed for implementation within the Real Estate Services Division (RESD) of the California Department of General Services (DGS). This report constitutes a detailed presentation of the proposed Cx framework. It was developed from revisions and expansion of the preliminary plan (Task 4 report), stemming from a final Program Advisory Committee (PAC) meeting that was held at DGS on December 22, 2008, subsequent individual discussions and written communication with PAC members, and final "lessons learned" from the pilot Cx program for the Caltrans building in Marysville, California (Task 5). It does not differ in basic concept from the preliminary plan (Task 4), but is significantly expanded from the original report to incorporate critical additions and recent insights. Vitally, it includes two critical new elements: 1) a transitional, multi-step process that was not included in the preliminary Cx framework (Task 4) for sequentially integrating Cx within DGS over time; and 2) an emphasis on applying the concept of "upstream" quality, introduced by Dr. Edwards Deming in the 1950s for product manufacturing, to building commissioning. The PAC felt the transitional approach would be essential for minimizing or precluding disruptions within current DGS Cx operations. Incorporating Deming's upstream quality aspect for Cx was introduced at the PAC meeting on December 22, 2008 in an overview of the training material being developed for the project, and was met with great enthusiasm and support.

The Task 2 and Task 3 reports served to demonstrate the cost-benefit advantage of the proposed DGS in-house Cx framework over the use of third-party Cx. The highly informative "lessons learned" in the Task 5 pilot study were invaluable in developing the proposed in-house Cx framework. Though fundamentally in-house, the proposed Cx framework does not exclude third-party Cx consultants on DGS projects. Complex buildings and overflow projects that exceed internal DGS bandwidth will continue to be done by third-party Cx authorities. third-party Cx expertise will also serve to "jump start" the proposed in-house Cx framework and work with DGS in implementing the framework in transitional steps.

The proposed commissioning (Cx) framework establishes DGS as the commissioning authority (CxA) on all capital outlay projects in a team-based structure. While the Project Management Branch (PMB) has authority over a project, including the Cx process, a key aspect of the in-

house Cx framework is that the Building and Property Management Branch (BPM) has a lead role both administratively and on-site in the Cx process. To detail the DGS team-based structure, the commissioning authority (CxA) on each capital outlay project is an assigned team, not a single individual, which consists of the project director (PD) from PMB, members from BPM as CxA lead, and members from the Design Services Section (DSS) and Construction Services Section (CSS) in support roles related to design and field testing, respectively. The Green Team serves primarily in a policy-setting role, also setting policy and procedures for LEED certification of small projects and for "campuses" with several small buildings, but will engage in some Cx activities directly. BPM is involved from project inception through O&M over the life cycle of the building.

An important aspect of the framework is that engagement of DGS personnel in Cx activities is economic and requires only intermittent time commitment in various phases of commissioning to instill upstream quality. During construction, the commissioning authority (CxA) roles of BPM personnel and the PD become more continuous to enforce upstream design measures and assure construction quality, while other DGS personnel drop off of the CxA team. This process is consistent with BPM and BPM as stakeholders in the welfare of the building, its owner, and its occupants. *Critically, the Building and Property Management Branch (BPM), in the CxA lead role, orchestrates Cx outcomes with the Project Management Branch (PMB) Project Director (PD) to achieve project quality assurance relative to the owner's project requirements (OPR). That synergy is absolutely crucial to project success and requires a clear understanding of roles and commitment to the Cx process.*

The proposed in-house Cx framework will address capital outlay projects that are either design-build or design-bid-build in format. Because small projects (less than 10,000 ft^2 in floor area) tend to receive less attention in the Cx process, yet represent a significant number of construction initiatives -- in fact 77 percent of new construction in the DGS green building program for 2009 is less than 10,000 ft^2 (cited on the DGS web site) -- a scaled down version of the fundamental in-house Cx framework will be implemented to address them. An exception would be small projects that are complex, such as a central plant. Depending on complexity, the full-scale Cx framework would be employed on complex projects, or third-party Cx would be utilized.

The scaled down version of the Cx framework will differ somewhat from the current *Cx Toolkit for Small Projects* (developed early on in Task 4; http://www.green.ca.gov/CxToolKit), in that it is critical to administrate the Cx process within BPM, given the large number of small projects, but fewer BPM personnel (perhaps only one individual) would be involved with on-site Cx efforts for small projects. Unlike the proposed in-house Cx framework, the *Cx Toolkit for Small Projects* does not link the critical roles of the various DGS branches and sections in assuring project quality.

A critical key in bringing Cx in-house to DGS is to maintain "institutional memory" as personnel get promoted to new positions, retire, or leave employment for other opportunities within or external to DGS. A framework with web-based Cx training material and a database on design, installation, and O&M "gotchas" would serve to minimize degradation of "institutional memory." *For an in-house Cx framework to be embraced and successful, it is essential to show the cost-*

benefit advantage over the use of third-party Cx. The in-house Cx framework also needs to be perceived by all parties as beneficial to their roles and responsibilities and not as an added burden without practical worth.

5.2 Conclusions and Recommendations

This report describes a plan to integrate commissioning (Cx) into DGS capital outlay projects in place of solely third-party Cx. Feedback from the Project Advisory Committee (PAC) and in-depth interviews with various DGS personnel were invaluable. Lessons learned from Task 5, which entailed Cx on a pilot Cx program at the Caltrans building in Marysville, California, have been particularly compelling in key components of the proposed Cx framework, specifically emphasizing the key role to be played by the on-site Building and Property Management (BPM) personnel. The Task 2 and Task 3 reports served to demonstrate the cost-benefit advantage of the proposed DGS in-house Cx framework over the use of third-party Cx. However, the proposed Cx framework does not exclude third-party Cx consultants on DGS projects. Complex buildings and overflow projects that exceed internal DGS bandwidth will continue to be done by third-party Cx authorities. Because the project advisory committee (PAC) felt that attempting to establish DGS as Cx agent on its capital outlay projects to too quickly would cause major disruption and chaos, third-party Cx expertise will serve to "jump start" and provide for the transitional, step-wise development of the proposed in-house Cx framework.

It has been discussed at DGS that CSS serve as CxA on projects under 10,000 ft², using the *Cx Toolkit for Small Projects* (http://www.green.ca.gov/CxToolKit). However, even though small projects do not get reviewed in the LEED process, they are still required to be stepped through the Cx process at the prerequisite level. The effort and paperwork requirements remain the same as for full LEED certification. It is therefore recommended that the proposed DGS Cx Framework be used in a scaled down version, so that CSS is not unduly shackled with duties that exceed its current bandwidth. The scaled down Cx Framework has the same structure as the full scale, with the same team members, but fewer personnel are required on the CxA team and fewer Cx steps are undertaken.

If DGS is not responsible for operating and maintaining a building constructed under its guidance, the appropriate facility person would be assigned to serve on-site on the CxA team. PMB would have a PD on the project overseeing the Cx effort, DSS would still be involved in design reviews, and CSS engaged in startup and functional testing activities, as appropriate.

Finally, as part of the proposed in-house commissioning framework, a system of feedback is suggested that signals and acknowledges performance success for all DGS branches and sections involved in a capital outlay project. The idea is for the in-house Cx framework to be a substantial advancement over the current third-party-based Cx process, with a mechanism for continuous improvement.

CHAPTER 6:
Communicate Results to State Agencies and to the General Public

Appendix E contains the full report on the material developed for communication and training (Task 7) based on the efforts to integrate commissioning into state capital outlay projects. An overview, summary, and conclusion of the Task 7 report are presented here

6.1 Overview and Summary

This document contains training materials for understanding and implementing the commissioning process for new buildings and major renovations. Funded by the California Energy Commission (CEC) under the Public Interest Energy Research (PIER) program, the intent is to establish an effective training protocol for integrating commissioning within the State of California's Department of General Services (DGS) for State buildings. The development of the training material, which was one task (Task 7) of a more comprehensive set of tasks in a comprehensive effort (Tasks 1-7), was strongly informed by a commissioning pilot program (Task 5) entailing the design and construction of a large State office building. The lessons learned from the pilot program were invaluable to the outcome of this overall project and critical to the development of the training material contained in this report. While, the training material is targeted for use as part of a proposed in-house commissioning framework at DGS (Task 6) for its capital outlay projects, the material is also intended for use by other State agencies and for the private construction industry within the state. This goal conforms to the philosophy of the PIER program as a whole.

The training material is presented in appendices in the Task 7 report. There are four man parts:

1. An introduction to the concept and practice of building commissioning. The introduction is also included in a web-based mockup. The introductory material seeks to impart a basic overview and understanding of commissioning to the intended audience. It sets the stage for subsequent training material on the specifics of the commissioning sequences relative to the phases of a capital outlay project.
2. The critical sequences that constitute the practical implementation of the commissioning process.
3. Definitions and narratives of key terms critical to understanding the commissioning process as presented in 2 above.
4. Sample forms that are essential to the commissioning process presented in 2 above.

Collectively, the material as a whole can be used verbatim in a comprehensive training protocol in the classroom or web-based.

6.2 Conclusions and Recommendations

The substance of the Task 7 report embodies comprehensive training material on building commissioning. The material will be placed on the DGS website and can be used verbatim as part of a commissioning training protocol. Although designed for use by DGS in a proposed in-house commissioning program for State buildings, the material is suitable for other State agencies, and for a general audience within the construction industry in the State's private sector.

CHAPTER 7:
Final Conclusions

The processes and sequences that unfolded in performing the comprehensive study outlined in this Final Report revealed a multitude of possibilities for improving not only State capital outlay projects, but the profession of commissioning as a whole. Detailed interviews with personnel within the Department of General Services (DGS) and an exploration of the department's organizational structure and intrinsic capabilities relative to construction projects provided an excellent start. However, the pilot project (Task 5) entailing the commissioning of a new state owned building provided the most useful information.

Three lessons are most critical.

1. It is essential for the commissioning process to embody upstream quality in a building project to assure quality downstream performance.
2. The process of commissioning requires a highly orchestrated team effort driven by all stakeholders, but must be led by a strong alliance between a project director and the O&M crew that will end up as stewards of the finished building over its lifecycle.
3. Education and training are indispensable in achieving and maintaining core competence and quality capital outlay projects. The need for education may be particularly critical with contractors, who view commissioning primarily as on-site functional testing, and not all the upstream activities that actually matter more.

Currently, the commissioning profession is viewed by contractors as adversarial, or a nuisance at best. But it is also frequently true that design teams and other building stakeholders view commissioning negatively. This has to change, and the first step is to develop a true team-based approach to commissioning. An inherent problem is that third-party commissioning authorities are often too distant from the planning, design, and construction processes, appearing only intermittently at meetings or at on-site inspections and tests. Within DGS, the proposed in-house Cx framework strives to make friends and allies out of otherwise "siloed" parties. In the commissioning profession in the private sector as a whole, a key will be for third-party commissioning agents to dissolve the distance between themselves and all project stakeholders. A start would be to enlist O&M personnel early on and consistently as co-leads throughout the entire commissioning sequences.

It is the hope and desire of this project to present a new and comprehensive view of the commissioning process for a broad, inclusive audience of potential users to complement the many and useful documents on commissioning, public and private, that currently exist.

GLOSSARY

Specific terms and acronyms used throughout this work statement are defined as follows:

A&E	Architect & Engineer
AEC	Architectural Energy Corporation
BOD	Basis of Design
CCC	California Commissioning Collaborative
CD	Construction Document
COBCP	Capital Outlay Budget Change Proposal
Cx	Commissioning
DD	Design Development
DGS	State of California Department of General Services
DOF	Department of Finance
KSA	Knowledge, Skills, and Abilities
O&M	Operations and Maintenance
OPR	Owner's Project Requirements
PAC	Project Advisory Committee
PIER	Public Interest Energy Research
RESD	Real Estate Services Division
RFP	Request for Proposal
RFQ	Request for Quote
SD	Schematic Design