Successes and Hurdles in Embedding SkySpark During the Post-occupancy Phase of New Construction Commissioning

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Contents

List of Figures

List of Tables

Successes and Hurdles in Embedding SkySpark During the Post-occupancy Phase of New Construction Commissioning

Abstract

Energy efficient buildings require a thorough commissioning process to successfully transition from design to operation. However, many new buildings leave their warranty period not operating the way they were designed. This thesis aims to share UC Davis' Energy and Engineering approach to implementing SkySpark in the post-occupancy phase of commissioning. This thesis also considers other facilities management groups using similar methods to more broadly understand challenges. The insight is used to qualitatively assess SkySpark-driven commissioning and provide a framework for future implementations. Major considerations identified were the workload of the commissioning agent, the availability of data on the first day of the warranty period, the costs of monitoring a building, and the necessity of a two-year warranty period.

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On a more personal note: To Theo, despite his illiteracy, for his persistent nose nudges hinting that perhaps throwing the tennis ball might be more beneficial than making sense of buildings. To my housemates, for putting up with my constant energy efficiency recommendations and for holding down the fort when my work-life balance was off. To Victor, for his LaTex support and everything else. To my family and friends, seeing the interest on your face or hearing the sincerity in your voice whenever I explained what the heck I was working on was a warm reminder I am loved.

Lastly, I'd like to end with a land acknowledgement. From grade school to grad school, I've been educated on land that was first stewarded by indigenous peoples. Although my formal education is coming to a close, learning how my work affects indigenous communities is only just beginning. I am committed to continual learning (and in some cases, unlearning) and I will continue to make informed actions to support the indigenous land on which I inhabit.

Chapter 1

Introduction and aims

1.1 Motivation

The University of California, Davis (UC Davis) Facilities Management (FM) Engineering team manages the heating and cooling needs of over 1,000 campus buildings from relatively simple administrative buildings to energy-intensive lab buildings. Thanks to their continual efforts, the campus has continued to grow while the Energy Use Intensity (EUI), or energy per square foot, has decreased. During the 2022-2023 Fiscal Year, the team saved over $3M in energy costs through both Monitoring-based Commissioning via a building monitoring tool known as SkySpark and simple improvements like proactive equipment scheduling. Although the team finds pride in mitigating energy waste, many newer buildings that are designed to be "energy efficient" have mechanical deficiencies that lead to runaway energy usage.

In an effort to improve the quality of new building stock, the FM team has begun taking a more active role in new buildings in partnership with Design and Construction Management (DCM). Specifically, FM began implementing SkySpark during the post-occupancy period of the Teaching and Learning Complex (TLC). This thesis aims to summarize the lessons learned from implementing SkySpark during the TLC's post-occupancy phase of commissioning and offer a proposed framework for future new construction projects. Chapter 2 covers background information related to SkySpark and building Commissioning (Cx); Chapter 3 summarizes the effort of implementing SkySpark at the TLC; Chapter 4 considers other case studies of campuses using SkySpark; Chapter 5 proposes a framework for incorporating SkySpark; Chapter 6 considers key lessons from UC Davis and other case studies; Chapter 7 draws conclusions and identifies future areas of study.

Chapter 2

Background

2.1 SkySpark description and significance

SkySpark is a software platform built by SkyFoundry that uses data analytics to enhance building monitoring [1]. SkySpark's foundational feature and namesake is its ability to compare live and historical time series data against a building's expected behavior [2]. SkySpark uses rules and generates "sparks" when a failure is detected. These rules might look for deviations from set points or inefficient behavior like valve hunting. Figure 2.1 shows the view of the sparks generated, or the rules that were broken, and their duration on a given day at the Teaching and Learning Complex (TLC). In this particular example, one can see, among other things, that the airflow set point for the Variable Air Volume (VAV) equipment in Room 4300 was not met between 9AM-12PM or between 7PM-9PM.

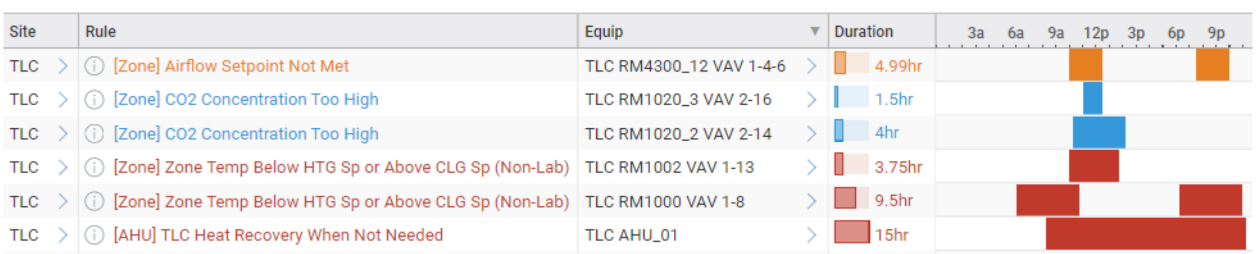

Figure 2.1: A sample view of the"sparks" at the Teaching and Learning Complex

The platform uses Project Haystack's semantic data model for the built environment which allows data streams and equipment to have classification tags. There is also a way to associate relationships with other equipment or flows to model the complex relationships that exist in building and plant level systems. [3]. This method gives the data context and is helpful for finding operational issues and their root cause. Included with SkySpark is a flexible Web API, allowing users to specialize their data analysis tools beyond what has been available in most building automation software. It should be noted that SkySpark is not the only software to perform Fault Detection and Diagnostics. Others include Clockworks Analytics and

SkySpark is widely used in industry, but there are a limited number of academic publications exploring SkySpark and building control and none specifically regarding SkySpark and post-occupancy commissioning. In fact, SkySpark has been deployed in over 1B square feet and over 15,000 facilities worldwide [4], but the literature review yielded only three SkySpark studies, which are summarized below. Researchers at Lawrence Berkeley National Laboratory (LBNL) used SkySpark as an Operational Data Analytics (ODA) tool for meeting organizational energy efficiency performance goals [5]. Researchers at the University of British Columbia offered an approach to track campus energy flows via a Sankey diagram using SkySpark to collect the data [6]. An Association of Energy Engineers (AEE) 2020 conference paper argued that analytic technologies like SkySpark are helpful in mitigating performance drift, but that successful facilities management requires streamlined communication and teamwork [7]. Lastly, researchers at the Beijing University of Civil Engineering and Architecture proposed fault diagnostic methods for Variable Air Volume (VAV) systems using SkySpark [8]. SkySpark is an important part of managing building performance and energy data, but few have published papers on the subject and none have published regarding SkySpark-aided building commissioning.

2.2 SkySpark at UC Davis

UC Davis' HVAC systems operate primarily on Siemens building management software. Although powerful, the platform has limited capabilities for tracking building performance. Most notably, it is difficult to query the necessary data and/or gather multiple sets of relevant data in one view. In 2016, an energy consultant introduced SkySpark to track the energy savings projects at two specific buildings, Ghausi Hall and the Plant and Environmental Sciences building. In this implementation, there were more sparks than the team had the bandwidth to address and there was no ability to customize the code. In 2019, the Facilities Management (FM) team decided to implement SkySpark in-house. This decision required more time and resources, but gave the FM team more control over tailoring SkySpark to the campus' needs.

As was argued in an AEE conference paper, data analytic tools have little value without good management and teamwork [7]. Currently, an FM sub-team made up of engineers and student interns actively implement SkySpark which includes managing the data and resolving maintenance issues. A data engineer manages the SkySpark operations and manages one to two graduate student interns who carry out importing and tagging points. An energy engineer manages one to two undergraduate student interns who monitor sparks throughout the week. On a weekly basis, the team reviews sparks and decides which require further inspection and/or maintenance. Given that SkySpark's usefulness has been proven, the FM team is interested in exploring the next stages of SkySpark and how it might aid in monitoring new construction commissioning.

2.3 Building commissioning description and significance

Building commissioning is a quality assurance process that ensures that all of a building's systems and components are installed and operating according to the owner's requirements and expectations [9]. Building commissioning, often written as 'Cx,' has become industry standard with many trade organizations and government agencies publishing building commissioning recommendations and resources [10]. For example, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has published many commissioning resources including *Standard 202: Commissioning Process for Buildings and Systems* and *Guideline 0: The Commissioning Process*, which were published in 1989 and 2005 respectively and both of which are updated every 3 years [11]. The International Energy Agency's (IEA) Energy in Buildings and Communities Program (EBC, formerly ECBCS) has published two reports related to commissioning: *Annex 40 Building Commissioning to Improve Energy Performance* [12] and *Annex 47 Cost Effective Commissioning of Existing and Low Energy Buildings* [13]. Additionally, the US Green Building Council's Leadership in Energy and Environmental Design (LEED) version 4.0 certification includes 6 possible points dedicated to enhanced commissioning, which can be found in Appendix A [14].

Although definitions vary, there are four distinct types of commissioning, all related to the project stage and function of the Cx process. New Construction Commissioning (NCCx) focuses on new buildings with the goal of ensuring that the building runs the way it was designed to run. Re-Commissioning (ReCx) or Ongoing Commissioning (OCx) both aim to maintain the performance of a project that has already been commissioned. Retro-Commissioning (RCx), on the other hand, focuses on buildings that have not been commissioned before and aims to improve the performance. Lastly, Monitoring Base Commissioning (MBCx) aims to monitor the building over time and optimize the performance as the building drifts from its original purpose and design [15].

2.4 Building commissioning cost-effectiveness

Building commissioning is often considered a cost saving measure, however it is difficult to measure the monetary benefit. There have been some previous studies aimed at quantifying the economics of building commissioning. A Lawrence Berkeley National Laboratory (LBNL) report studied 224 buildings in 2009, later expanded to 643 buildings in 2020. Researchers found that the median cost of NCCx was $0.82 per square foot [16], compared with $1.03 per square foot from the initial 2009 study [17]. The LBNL study also found that NCCx costs 0.25 percent of the overall construction cost [16], compared with 0.57 percent from the intial 2009 study [17]. Authors theorize that a combination of market competition, software, and a more experienced workforce have contributed to the reduction in costs. A 2011 LBNL study focused on energy costs found that NCCx resulted in 13% total primary energy savings and had a simple payback of 4.2 years [18]. The City of Madison found cost savings for RCx ranged from $0.13 to $2.00 per square foot, paybacks ranging from 0.2 to 2.1 years, and overall energy savings of roughly 15% [19]. Although difficult to assess, the research regarding building commissioning suggests that the overall cost of NCCx is small compared to the savings generated.

2.5 Building commissioning at UC Davis

There are many regulatory committees that set standards for building energy and sustainability that UC Davis must meet. The State of California Building Standards Code, or Title 24, sets the standards for California buildings' structural safety and sustainability. Title 24's Part 6 is the state's Energy Code which defines mandatory building commissioning for new and remodeled building and Part 11 which defines extra voluntary energy provisions known as CALGreen [20]. California is unique with respect to energy codes as most states follow the International Energy Conservation Code (IECC) [21]. Additionally, the University of California Office of the President (UCOP) sets its own Green Building Standards, with which all UC campuses must comply with. These standards require all new UC buildings to earn a LEED Gold rating or higher from the US Green Building Council's LEED BD+C (Building Design and Construction) rating system (out of four possible levels in ascending order: bronze, silver, gold, and platinum) [22].

In addition to UC and California-wide building standards, each University of California campus sets and follows their own building standards and guidelines. The UC Davis Design and Construction Management (DCM) team publishes a yearly Campus Design Guide (CDG) which summarizes the design expectations for campus construction projects [23]. In Part IV of the CDG (which can be found in Appendix B) is a section dedicated to HVAC commissioning. In 2012, an effort was made to develop New Construction Guidelines (NCG) which outlined the phases of new construction and the involvement of DCM and FM. These can be found in Appendix C. Table 2.1 summarizes all of the committees that set building standards starting at the broad level and descending to more specific.

Historically, UC Davis has pursued and been awarded the LEED three Enhanced Commissioning credits for New Construction. The most recent examples include the Engineering Student Design Center and the UC Center Sacramento. They were awarded Gold (as stipulated by UCOP) in September and October of 2023, respectively. For additional detail, see their score cards in Appendix D. These three credits involve commissioning process activities beyond those required under the Energy and Atmosphere Prerequisite Fundamental Commissioning and Verification. However, UC Davis has not pursued the one Monitoring-Based Enhanced Commissioning credit which was made available in LEED version 4.0. This last credit involves developing monitoring-based proce-

Table 2.1: Building Energy and Sustainability Regulations that affect UC Davis

Scope	**Standard / Code / Certification**	**Overview**
US-Wide	LEED BD+C	Widely used green building rating certification system.
State-wide	Title 24 / California Buildings Standards Code	Sets the standards for buildings' structural safety and sustainability.
State-wide	Energy Code	Found in Part 6 of Title 24; stipulates energy efficiency requirements; mandatory building commissioning for new and remodeled building
State-wide	CALGreen	Found in Part 11 of Title 24; stipulates additional voluntary energy provisions
UC-wide	University of California Office of the President Sustainable Practices Policy	Guides sustainability efforts; must Design and construct all new buildings to a minimum LEED BD+C (Building Design and Construction) Gold rating.
UCD-wide	UC Davis Campus Design Guide	Summarizes the design expectations for campus construction projects.
UCD-wide	UC Davis New Construction Guidelines (not in use)	An effort to clarify the phases of new construction.

dures and identifying points to be measured and evaluated to assess performance of energy- and water-consuming systems.

Chapter 3

UC Davis Commissioning Projects

3.1 UC Davis Teaching and Learning Complex

The UC Davis Teaching and Learning Complex (TLC) shown in Figure 3.1 is a general assignment building centered around optimizing student learning outcomes [24]. The TLC became the case study for implementing SkySpark during post-occupancy commissioning for two reasons. First, because its timeline matched well with the SkySpark endeavor and second, because its innovative design included many systems that were well suited for SkySpark-assisted commissioning. Some of the building's notable design features include windows for natural daylight and a rooftop solar array that doubles as a shading canopy over the south stairway entrance [25]. The building is served by two Air Handling Units (AHUs), AHU-1 on the west side and AHU-2 on the east side. AHU-1 delivers 100% outside air (full displacement volume) and has an air-to-air heat recovery loop. AHU-2 is a single duct design with economizing air circulation and has a run-around coil for heat recovery. For detailed renderings, see Figure E.1 and Figure E.2. In conjunction with the displacement ventilation are ceiling fans and radiant ceiling panels served by a Medium Temperature Chilled Water (MTCW) Loop.

3.2 TLC post-occupancy commissioning

The TLC became open to students on a floor-by-floor basis starting in 2021. The first floor began beneficial occupancy on December 22nd, 2021. The second and third floors began

Figure 3.1: The Teaching and Learning Complex

beneficial occupancy on February 25th, 2022. The Functional Performance Testing (FPT) phase of commissioning was completed on March 24th, 2022. The Final Certificate of Occupancy (FCO) was signed on August 18th, 2022. The site was accepted on April 28th, 2022. The site system warranty started on April 28th, 2022. The fourth floor, which had added scope for tenant improvements, began beneficial occupancy on July 19th, 2022. Between the various beneficial occupancy dates, February 25th, 2022 was chosen as the justified beneficial occupancy. Thus, the warranty period ended on February 25th, 2024.

Engineers from Facilities Management (FM) and Design and Construction (DCM) first met in February of 2023. This meeting initiated a joint project with the goal of developing a framework for incorporating SkySpark as a monitoring and fault-detection tool in the post-occupancy period. FM engineers began regularly attending meetings between the contractor and building manager in August of 2023. During this time, the TLC data was imported into SkySpark and the team began actively tracking TLC sub-systems including the Heating Hot Water (HHW) system, the Low Temperature Chilled Water system, and the Supply Static Pressure Control. Given that this was a full year into the warranty period, there were many missed opportunities to use SkySpark to its fullest, however there were still many lessons learned. Summarized below are notable issues that came up during the post-occupancy commissioning process and how SkySpark was or could have been involved.

3.2.1 Demand response malfunction

Since 2019, California's Title 24 has required that building systems have a Demand Response (DR) capability, or the ability to shed load during grid events (found in Part 6 - California

Energy Code) [26]. The campus made efforts to shed load during the September 2022 heat wave both at the central plant and building-level. During this time, the TLC entered its Automated Demand Response (ADR) mode where the cooling temperature set point was relaxed. However, after the need was lifted, the Building Management Software (BMS) did not properly exit ADR loop and the TLC continued to incrementally raise its temperature set point. This can be seen in Figure 3.2 where the daytime cooling set point went from 74 to 85° F over the course of a week. For context, the figure shows typical building behavior in the days prior to the ADR mode where the building cools to 74 ° F during the day time and to 85° F during the night time. The team became aware of and remedied the issue after receiving a complaint on September 12th. At this point, SkySpark was not fully integrated and was not involved with finding the issue.

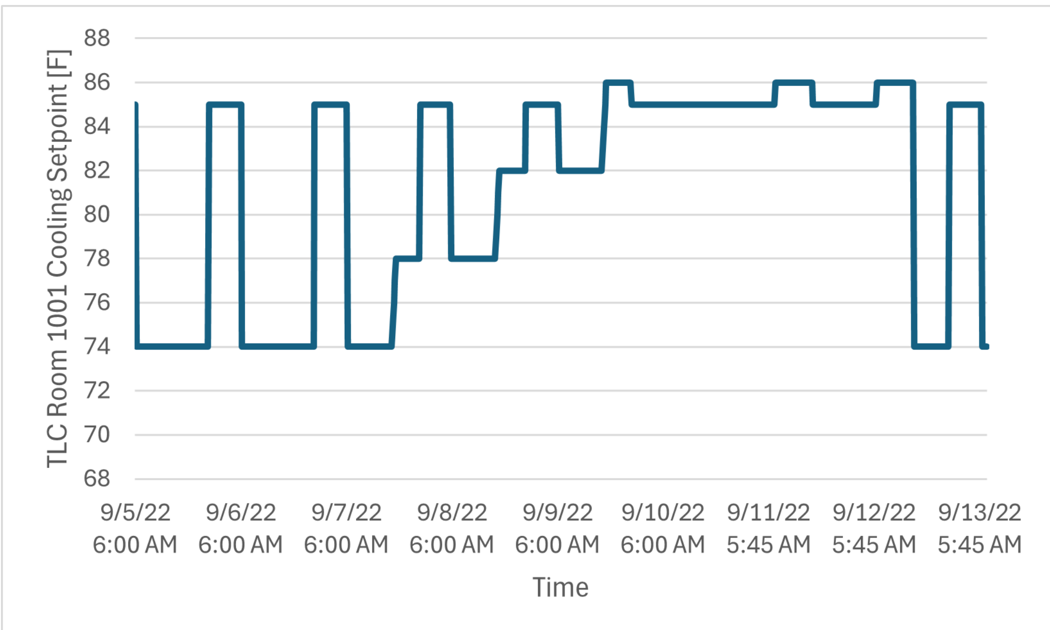

Figure 3.2: The TLC Demand Response Malfunction

A flaw in the control logic caused the previous day's cooling set point to be used as the baseline for the following day which caused the temperature to increment upward. Although there was no mechanical damage and the mistake in the code was quickly remedied, this situation caused unnecessary burden on the FM team and extremely hot conditions for building occupants. This example highlights the importance of Functional Performance Testing (FPT) where systems like the ADR mode are tested. Unfortunately, the FPT, which took place in March of 2022, missed the flaw in the ADR logic and the system was approved. It is important to note that FPT is typically done "off-line" or before the building has been fully integrated into the campus servers, so SkySpark would not have been able to directly assist the FPT. However, leveraging SkySpark throughout the post-occupancy commissioning ensures FPT was done correctly. Additionally, the ADR mode malfunction would have been detected instantaneously if SkySpark been had integrated earlier into the post-occupancy commissioning.

3.2.2 AHU-1 zone temperature control design flaw

In the first year of occupancy (2021), the classrooms served by AHU-1 were unable to adequately stay cool via the radiant cooling panels and ceiling fans alone. The original Demand Control Ventilation (DCV) used CO_2 and thermal sensors to regulate fresh air and temperature which would call for more air supply from AHU-1 and more flow from the Medium Temperature Chilled Water (MTCW) loop respectively. AHU-1 originally provided 70° F discharge air which was designed to be cooled to 68° F via the radiant panels. In addition, the ceiling fans were designed to turn on when CO_2 levels reached 1000 parts per million (PPM) to encourage air mixing. Unfortunately, with the MTCW valve fully open and the fans at full speed, the space was not able to meet the temperature set point in a timely manner and occupants were uncomfortably hot. To increase comfort, the Discharge Air Temperature (DAT) and the CO_2 set points were lowered. This effectively provided cooler air and increased the cool air flow. Despite these changes, certain rooms still struggle to stay fresh and cool. This can be seen in Figure 3.3 which shows three specific zones that repeatedly reach above 75° during the first week of February. The month of February is considered the heating season which is not when rooms should struggle to stay cool. Depending on how extreme the cooling problem becomes, there might be more extensive operational changes in the future.

The shortcomings of the radiant panel and fan cooling system highlight the shortcomings of two-year commissioning at UCD and how SkySpark could fill those gaps. First and foremost, DCM is not taking full advantage of the two year system warranty with respect to HVAC systems. Running these systems with actual people occupying the space over a two year period effectively allows the building owner to 1) uncover the deficiencies, 2) make adjustments, and 3) confirm that the adjustments are working. Little effort was put toward confirming the adjustments to

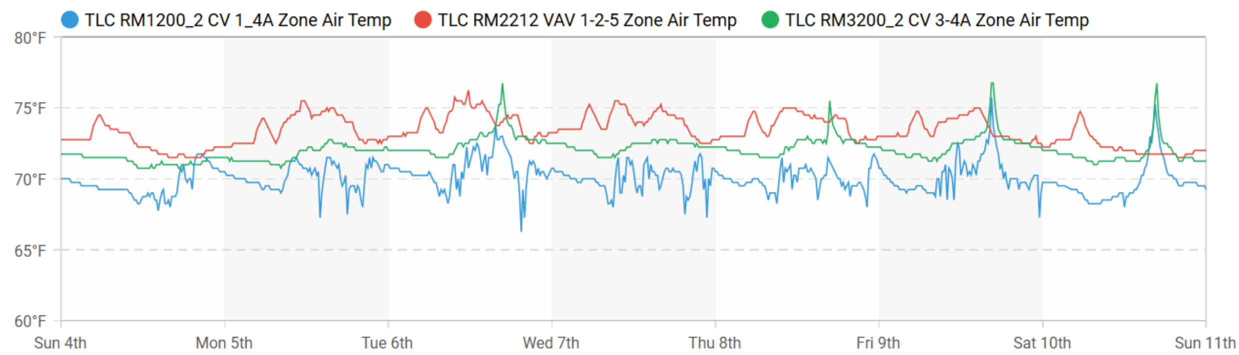

Figure 3.3: AHU-1 Room Temperatures for the week of February 4th regularly reaching 75°

TLC's HVAC systems during the second year of occupancy. Having SkySpark integrated when set points and parameters are changed during post-occupancy commissioning could have supported this third step. For example, when AHU-1's operation was switched from being *ventilation-only* to *ventilation-and-temperature-regulation*, SkySpark would have shown that several rooms are still struggling to stay cool and more effort is needed in guaranteeing the temperature control was fully operational. This example also points to a hole in the commissioning process where, when changes are made, it becomes hard to track them. Having a more clear commissioning process and line of command for when changes are made during the post-occupancy could be clarified in the Campus Design Guide. Although SkySpark would not have changed the radiant panel design shortcomings, SkySpark could have confirmed whether the changes made were adequate.

3.2.3 Pressurization issues

The interaction between the two AHUs (AHU-1 with full air displacement and AHU-2 with recirculation) led to issues in overall building pressurization. During and after the warranty period, the building regularly reached extremely low static pressures. During one instance of low pressure, engineers found both the Outside Supply Air (OSA) and Return Air (RA) dampers completely closed despite being commanded fully open (the OSA damper was commanded at 100% for Demand-Controlled Ventilation and Minimum OSA damper commanded at 30%). During this time, the Supply Air (SA) fans were operating at 100% speed. This created extreme negative pressure in the mixed air plenum which led to structural damage of the plenum wall which can be seen in Figure F.1. The building was still under warranty and the contractor was responsible for fixing the damage.

AHU-2's economizing mode was one of the factors leading to this situation. When AHU-2 goes into economizing mode, the OSA damper takes roughly 15 minutes to open 10%, which can take two hours to go from minimum to maximum position. During this time, the supply fans cannot create enough discharge pressure and there is little to no OSA flow increase. Despite this, the exhaust fans run at high speed because they are tracking the supply fans. This condition creates strong negative building pressure. To remedy this, engineers decided to configure the OSA damper and the Minimum Outside Air Damper and Outside Air Damper to be one Unified OSA Damper. This required modification of the programming to eliminate the separate control of the Economizer damper and combine the signals virtually.

Similar to the temperature control, the changes that were made to fix the building pressurization issues were not fully verified and the building still experiences large pressure fluctuations. For example, there is a significant interaction between AHU-1 and AHU-2. When the AHU-2 exhaust fans and no air is exhausted through AHU-2, the AHU-2 outside air (7,400 cfm) seems to be exhausted through AHU-1. This can be seen in Appendix G which shows the pressure behavior on November 16th between 6 am and 9:30 am. The effectiveness of the displacement ventilation is highly questioned under this condition because no air is returning from the lecture halls.

The TLC's building pressurization issues again highlight the shortcomings of two-year commissioning at UCD and how SkySpark could fill those gaps. The TLC's data had been fully imported into SkySpark when the plenum was damaged which ameliorated the process of discovering the issue and figuring out what was happening. Although there wasn't a rule dedicated to tracking dampers and fans, engineers were able to quickly detect the pressure issue. SkySpark's simple views also made it much easier to capture the errant behavior of the building. Although SkySpark did not stop the plenum from being damaged, having the pressure data available made it possible to uncover.

Chapter 4

Other Case Studies

To better understand other successes and hurdles in implementing SkySpark-driven commissioning, this paper considers other groups using similar approaches.

4.1 UC Davis Health

UC Davis Health, which serves as both a Sacramento-based academic health center and Northern California's main Level 1 Trauma Center, is also pursuing SkySpark-driven commissioning. The UC Davis Health campus buildings include the UC Davis Medical Center, UC Davis Children's Hospital and UC Davis Rehabilitation Center [27]. Despite sharing a name, UC Davis and UC Davis Health are unique campuses and have different approaches to implementing SkySpark-based commissioning which are further explored.

Before pursuing SkySpark, new UC Davis Health buildings were commissioned for one year and building performance was monitored via quarterly Excel files. UC Davis Health is currently undergoing a 1,500,000 SQFT expansion which led their Operations team to leverage SkySpark to assist in Measurement and Verification. In 2020, UC Davis Health added two-year monitoring-based commissioning to their new construction contracts. Per the contract, the Commissioning Agent and the Project Owner and Manager meet quarterly to review the building EUI against the design EUI and troubleshoot issues for 2 years after building turn-over. This aligns with UCOP Sustainability Policy, which requires reporting the final building EUI. A key difference in UC Davis Health's approach to MBCx is that it is carried out by a 3rd-party commissioning consultant via

SkySpark and PowerBI. The MBCx is being paid for out of the construction budget. Both UC Davis and UC Davis Health have switched to two-year monitoring.

Chapter 5

Proposed framework for integrating Skyspark

5.1 Proposed Framework

There are many 3rd party vendors who import and organize data for Facilities Management groups, but at UC Davis, the data is managed in-house. Part of this project's aim was to understand the time and cost involved with this model of implementing SkySpark in-house. Two main components of SkySpark management were considered: (1) importing the data and (2) designing the rules and trends appropriate for monitoring the building. Much of the first step has been automated using regular expressions, but a human brain is still required for verifying the data is imported correctly. This work has primarily been carried out by graduate students. Based on data from current importing, importing a full building takes take roughly 15 hours to import, assuming 300 to 500 points per building. The import process includes:

- Checking that the regular expressions are correctly finding equipment
- Importing the equip
- Checking that the regular expressions are correctly finding points
- Importing the points
- Studying the building to understand equipment that was not caught by a regular expressions

- Manually importing those equipment or writing regular expressions to find them
- Studying the building to understand the points that were not caught by a regular expressions
- Manually importing those points or writing regular expressions to find them

After correctly importing and tagging the data, the second step involves building the rules and views that are relevant for tracking that building's behavior. The time it takes to build views varies based on the complexity of the building and how closely the building is to be monitored. In the TLC's case, views were built over a four-week period. This involved studying the as-built drawings to understand the building behavior and consulting Project Haystack's literature. Views were then built for the Central Air, Chilled Water System, Hot Water System, and Building Static Pressure.

In both steps, as more regular expressions, more rules, and more template views are built out, the faster a building can be up and running in SkySpark.

Chapter 6

Discussion

6.1 The role of the commissioning agent

A key hindrance in implementing Skyspark during the TLC's warranty period was not a lack of willingness, but the workload of the commissioning agent. Currently, UC Davis employs one commissioning agent to manage the entirety of the new construction projects on campus. To put the magnitude of this work in perspective, the budget for current new construction is roughly $201M and there are typically several large-scale new construction projects going on at once [28]. Although the commissioning agent was excited about this SkySpark endeavor, their schedule prevented them from regularly monitoring the TLC, let alone using SkySpark to do so. SkySpark as a tool helps bring clarity to a building's behavior during the warranty period, but immense workload of campus new construction projects has hindered the commissioning agent from using SkySpark to its fullest.

Relying on one person to oversee commissioning for all new construction at UC Davis makes it difficult to achieve thorough commissioning. It effectively requires UC Davis to put its faith in its contractors to carry out many of the responsibilities of a commissioning agent. In the TLC's case, contractors were not highly concerned with resolving issues unless FM engineers advocated for repairs and controls adjustments (see Section 3.2.3). Work of this magnitude is typically contracted out to a 3rd party commissioning firm, as is being done at UC Davis Health. To more make better use of SkySpark, UC Davis needs to have a commissioning team whose capacity is commensurate with the commissioning work load. This could look like hiring more agents or hiring a third party commissioning firm to be overseen by the commissioning agent.

6.2 The availability of data

An additional hurdle in achieving a SkySpark-aided commissioning process is the data availability. Data is sometimes treated like an afterthought and often not available when the warranty period starts. In the TLC's case, data was not added to SkySpark until one full year into its warranty period. In many other buildings on campus, the data is not imported to SkySpark until after the warranty period has ended. In UC Davis Health's case, data has not been accessible at the onset of their two-year measurement and verification projects due to delays in data being available in their Building Management Software (BMS). Having the data trended in the BMS so that it is able to be imported to SkySpark needs to be prioritized during the construction process. This ensures that when a building enters its warranty period, the building owner can effectively asses the building's performance. This could look like stipulating that the data is fully trended and accessible before starting the warranty period.

6.3 The costs of SkySpark

Beyond having the data fully accessible, another consequence of using SkySpark during the warranty period is the cost associated with importing and monitoring buildings in SkySpark. Since adopting SkySpark, the FM team has been responsible for importing buildings' data into SkySpark, but this is not a sustainable model going forward. Similar to how new construction projects' scopes include setting up a building in Desigo, future contracts should also include setting up a building in SkySpark. In UC Davis Health's case, SkySpark implementation is part of the MBCx contract paid for by the new construction budget. At UC Davis, a similar structure could be used where DCM creates a work-order to pay FM to import data into SkySpark.

6.4 The two-year warranty period

A final reality of implementing SkySpark during the warranty period is the overall time frame of the warranty period. It is difficult to thoroughly commission a building in one year because the changes made during the first year need to be confirmed the second year. The TLC did have a two-year warranty period, and the second year proved very valuable (see Section 3.2.3). However, not all building's receive a two-year warranty period. Running these systems with actual people occupying the space over a two year period allows the building owner to 1) uncover the deficiencies, 2) make adjustments, and 3) confirm that the adjustments are working. It is imperative that all future buildings have a two-year warranty period and that the second year is fully used. A combination of having a stronger campus commissioning team, having the data in SkySpark on the first day of the warranty period, and paying for the Facilities Management team to monitor the building in SkySpark could all lead to a more successful two-year warranty period.

Chapter 7

Conclusions and future work

This project began with the goal of reducing the mechanical deficiencies and boosting the energy efficiency of new UC Davis buildings. The project focused on a specific stage in a building's lifetime known as commissioning, where the building and all of its systems' functionality are verified. The project ameliorated the commissioning process using SkySpark, which is a tool that has been successfully adopted by Facilities Management for monitoring building behavior. The ultimate hope of these findings are for others to learn from the successes and hurdles and to encourage adoption of tools such as SkySpark to aid building commissioning.

The project began with a literature review that found that few have published papers on the subject of SkySpark and none have published regarding SkySpark-aided building commissioning. The lack of academic interest is not a reflection of SkySpark's utility. In fact, the literature review also found that SkySpark is widely used in industry. Lastly, the literature review found studies of New Construction Commissioning (NCx) projects that show that the overall cost of NCx is small compared to the savings generated.

The Teaching and Learning Complex was UC Davis' first effort to implement SkySpark during the commissioning process. The TLC became the case study for implementing SkySpark during post-occupancy commissioning for two reasons. Firstly, because its timeline matched well with the SkySpark endeavor and secondly, because its innovative design included many systems that were well suited for SkySpark-assisted commissioning. There were some missed opportunities to use SkySpark to its fullest, however there were still many lessons learned. Notable issues that came to light during the commissioning process include the Automated Demand Response malfunction, AHU-1's zone temperature control flaw, and pressurization issues.

Major considerations identified were the workload of the commissioning agent, the availability of data on the first day of the warranty period, the costs of monitoring a building, and the necessity of a two-year warranty period. To more effectively use SkySpark-aided commissioning, UC Davis should provide more resources to the commissioning agent, either by hiring more agents to distribute the load or hiring a third party commissioning firm to be overseen by the commissioning agent; place a higher priority on the building data by setting requirements for the warranty period to only begin when the data has been trended within building monitoring software; include the work of importing data and building views in SkySpark to the construction costs; and lastly, stipulate two-year warranty periods and fully use the entire warranty period.

Originally, this study hoped to include more case studies of SkySpark-aided commissioning. Unfortunately, UC Davis Health was the only group that was able to participate in this project. Future work should include a broader investigation of other campuses. It is also recommended that Facilities Management continue strengthening this framework for tracking new buildings via SkySpark to ensure every building leaves its warranty period functioning the way it was designed to. And lastly, it is recommended that the University of California Office of the President continues fostering an ecosystem of collaboration amongst energy managers.

Appendices

Appendix A

LEED Enhanced Commissioning

LEED BD+C: New Constructionv4 - LEED v4

Enhanced commissioning

Energy and Atmosphere
Possible 6 Points

Intent

To further support the design, construction, and eventual operation of a project that meets the owner's project requirements for energy, water, indoor environmental quality, and durability.

Requirements

Implement, or have in place a contract to implement, the following commissioning process activities in addition to those required under EA Prerequisite Fundamental Commissioning and Verification. **Commissioning authority**

- The CxA must have documented commissioning process experience on at least two building projects with a similar scope of work. The experience must extend from early design phase through at least 10 months of occupancy;
- The CxA may be a qualified employee of the owner, an independent consultant, or a disinterested subcontractor of the design team.

Option 1. Enhanced systems commissioning (3-4 points)

Path 1: Enhanced commissioning (3 points)

Complete the following commissioning process (CxP) activities for mechanical, electrical, plumbing, and renewable energy systems and assemblies in accordance with ASHRAE Guideline 0–2005 and ASHRAE Guideline 1.1–2007 for HVAC&R systems, as they relate to energy, water, indoor environmental quality, and durability.

Figure A.1: LEED Enhanced commissioning page 1

The commissioning authority must do the following:

- Review contractor submittals.
- Verify inclusion of systems manual requirements in construction documents.
- Verify inclusion of operator and occupant training requirements in construction documents.
- Verify systems manual updates and delivery.
- Verify operator and occupant training delivery and effectiveness.
- Verify seasonal testing.
- Review building operations 10 months after substantial completion.
- Develop an on-going commissioning plan.

Include all enhanced commissioning tasks in the OPR and BOD.

OR

Path 2: Enhanced and monitoring-based commissioning (4 points)

Achieve Path 1.

AND

Develop monitoring-based procedures and identify points to be measured and evaluated to assess performance of energy- and water-consuming systems.

Include the procedures and measurement points in the commissioning plan. Address the following:

- roles and responsibilities;
- measurement requirements (meters, points, metering systems, data access);
- the points to be tracked, with frequency and duration for trend monitoring;

Figure A.2: LEED Enhanced commissioning page 2

- the limits of acceptable values for tracked points and metered values (where appropriate, predictive algorithms may be used to compare ideal values with actual values);
- the elements used to evaluate performance, including conflict between systems, out-of-sequence operation of systems components, and energy and water usage profiles;
- an action plan for identifying and correcting operational errors and deficiencies;
- training to prevent errors;
- planning for repairs needed to maintain performance; and
- the frequency of analyses in the first year of occupancy (at least quarterly).

Update the systems manual with any modifications or new settings, and give the reason for any modifications from the original design.

AND/OR

Option 2. Envelope commissioning (2 points)

Fulfill the requirements in EA Prerequisite Fundamental Commissioning and Verification as they apply to the building's thermal envelope in addition to mechanical and electrical systems and assemblies.

Complete the following commissioning process (CxP) activities for the building's thermal envelope in accordance with ASHRAE Guideline 0–2005 and the National Institute of Building Sciences (NIBS) Guideline 3–2012, Exterior Enclosure Technical Requirements for the Commissioning Process, as they relate to energy, water, indoor environmental quality, and durability.

Commissioning authority must complete the following:

- Review contractor submittals.
- Verify inclusion of systems manual requirements in construction documents.

Figure A.3: LEED Enhanced commissioning page 3

- Verify inclusion of operator and occupant training requirements in construction documents.
- Verify systems manual updates and delivery.
- Verify operator and occupant training delivery and effectiveness.
- Verify seasonal testing.
- Review building operations 10 months after substantial completion.
- Develop an on-going commissioning plan.

Figure A.4: LEED Enhanced commissioning page 4

Appendix B

Campus Design Guide HVAC Commissioning

PROJECT TITLE
CONTRACT TITLE
UNIVERSITY OF CALIFORNIA, DAVIS
CITY, CALIFORNIA

PROJECT NO: 0000000
GRANT NO: 0000000

The following standard specification is intended to be edited according to the specifics of the project. Brackets [ ] and areas shaded in gray [e.g. format] indicate requirements that are optional depending upon the type of system being provided or per instructions associated with the [ ] and project requirements. Consult with University's Representative and campus stakeholders.

DOCUMENT UTILIZES TRACK CHANGES TO RECORD YOUR CHANGES AS YOU EDIT.
DO NOT CHANGE THE FOOTER OF THE DOCUMENT

SECTION 23 08 00 COMMISSIONING OF HVAC

PART 1 - GENERAL

1.1 DESCRIPTION

A. Commission all systems and equipment listed in the table below per the requirements of Section 01 91 00 Commissioning. The Installation/Start-up Verification (ISV) and Functional Performance Test (FPT) forms listed are required [and templates will be provided by the University].

[Edit the table and the checklists as required by the project.]

Equipment/System	ISV Form	FPT Form
Testing, Adjusting, and Balancing for HVAC	ISV-23 05 93	FPT-23 05 93
Instrumentation and Control for HVAC (Building EMS)	ISV-23 09 00-1	FPT-23 09 00
Instrumentation and Control for HVAC (Laboratory Air Flow Control Systems)	ISV-23 09 10-2	FPT-23 09 10
Control Air Compressor for HVAC	ISV-23 09 43	
Chilled Water Systems	N/A	FPT-23 21 00-1
Heating Water Systems	N/A	FPT-23 21 00-2
Hydronic Piping (Chilled Water and Heating Hot Water)	ISV- 23 21 13	N/A
Hydronic Pumps CHW	ISV-23 21 23	w/ FPT-23 21 00-1
Hydronic Pumps HHW	ISV-23 21 23	w/ FPT-23 21 00-2
Steam and Condensate Heating Piping	ISV-23 22 13	N/A
Metal Ducts	ISV-23 31 13	N/A
HVAC Fans	ISV-23 34 00	w/ FPT-23 73 00
Air Terminal Units - Commercial	ISV-23 36 23	w/ FPT-23 73 00
Air Terminal Units - Laboratory	ISV-23 36 33	w/ FPT-23 73 00
Heat Exchangers for HVAC CHW	ISV-23 57 00-1	w/ FPT-23 21 00-1
Heat Exchangers for HVAC HHW	ISV-23 57 00-2	w/ FPT-23 21 00-2
Cooling Towers	ISV-23 65 00	w/ FPT-23 65 00
Air Handling Systems	N/A	FPT-23 73 00
Packaged, Outdoor, Central-Station Air-Handling Units	ISV 23 74 13	FPT-23 74 13
Custom-Packaged, Outdoor, Central Station Air-Handling Units	23 75 13	FPT-23 75 13
Evaporative Air-Cooling Equipment	23 76 00	FPT-23 76 00
Split-System Air-Conditioners	ISV-23 81 26	N/A

February 2018
Revision: 3

Commissioning of HVAC
23 08 00-1

Figure B.1: Campus Design Guide HVAC Commissioning page 1

Fan Coil Units	ISV-23 82 19	FPT-23 82 19
Induction Units	ISV-23 82 26	w/ FPT-23 73 00

1.2 RELATED WORK AND DOCUMENTS

A. Section 01 79 00 Demonstration and Training

B. Section 01 91 00 Commissioning

C. Division 23 Heating, Ventilating, and Air Conditioning

1.3 COMMISSIONING DEFINITIONS AND ABBREVIATIONS

A. Refer to Section 01 91 00 Commissioning.

1.4 REFERENCE STANDARDS

A. Sheet Metal and Air Conditioning Contractors National Association (SMACNA) Guidelines

B. American Society for Testing and Materials (ASTM)

C. Associated Air Balance Counsel (AABC) Guidelines for Balancing Procedures and Documentation

1.5 SUBMITTALS

A. Submit commissioning documents for all equipment and systems listed in table above per the requirements of Section 01 91 00 Commissioning.

PART 2 - PRODUCTS

2.1 INSTRUMENTATION

A. Refer to Section 01 91 00 Commissioning.

PART 3 - EXECUTION

3.1 INSTALLATION/START-UP VERIFICATION

A. Perform all checks and tests included in the ISV checklists and complete the checklists as specified in Section 01 91 00 Commissioning.

3.2 FUNCTIONAL PERFORMANCE TESTS

A. Perform all checks and tests included in the FPT checklists and complete the checklists as specified in Section 01 91 00 Commissioning.

3.3 TRAINING OF UNIVERSITY PERSONNEL

A. Provide training of University's personnel for the number of hours specified in the table below and as specified in Section 01 79 00 Demonstration and Training.

Figure B.2: Campus Design Guide HVAC Commissioning page 2

[Edit the table as required by the project. Project Manager to coordinate with DCM Engineering and O&M Facilities]

Equipment/System	Section Number	Orientation Hours	Training Hours	DVD Recording
Instrumentation and Control for HVAC (Building EMS)	23 09 00	TBD	TBD	N/A
Instrumentation and Control for HVAC (Laboratory Air Flow Control Systems)	23 09 10	TBD	TBD	N/A
Chilled Water Systems	23 21 00	2	4	N/A
Heating Water Systems	23 21 00	2	4	N/A
Condenser Water Systems	23 21 00	2	4	N/A
Steam and Condensate Systems	23 22 13	1	2	N/A
Air Handling Systems	23 73 00	4	8	N/A

END OF SECTION 23 08 00

Figure B.3: Campus Design Guide HVAC Commissioning page 3

Appendix C

Design and Construction Management Commissioning Flowchart

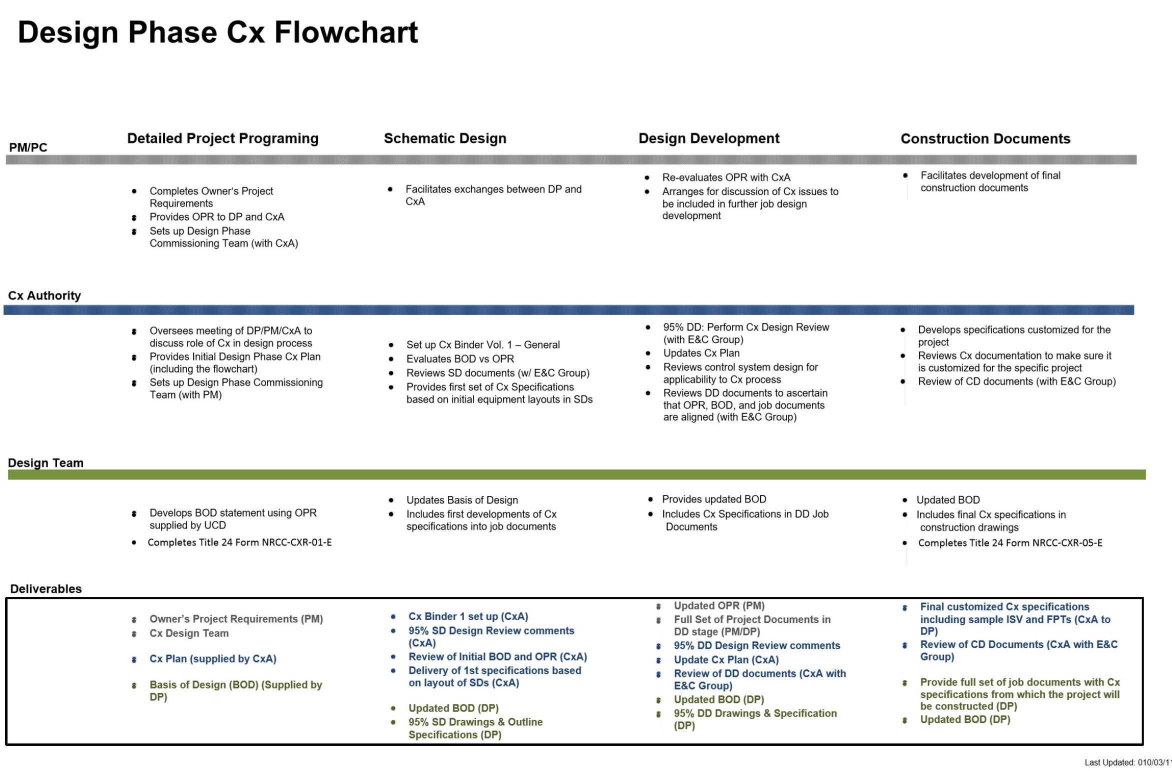

Figure C.1: Design Phase Cx Flowchart

Construction Phase Cx Flowchart

General Notes: *This chart is for the Contractor's information only and does not supersede the requirements of the Commissioning Specification included in the Contact Documents.*
Numbered Notes: *1. See University Cx Tasks Matrix for additional details.*
Italicized-Bolded Text*: Designates ongoing activities throughout the Construction Period.*

	Phase 1 – Submittals: General Submittals	Phase 1 – Submittals: O&M Submittals	Phase 2 – ISV	Phase 3 – FPT	Phase 4 – Training/Handoff
Contractor – Quality Assurance Manager (Contractor's Commissioning Manager)	• Conducts Cx Kick-off Meeting • Assembles Cx Team • Assembles Cx Plan • ***Develops and maintains Cx Schedule*** • Reviews equipment submittals • ***Schedules and conducts monthly Cx meetings***	• Coordinates preparation of and reviews Cx Checklist Index • Coordinates preparation of and reviews O&M Manual Index • Coordinates preparation of and reviews O&M Manuals • Coordinates preparation of and reviews Preliminary Warranty Binder	• Assembles and reviews customized ISV checklists • Schedules and supervises ISV checks • Signs-off ISV checklists	• Assembles and reviews customized FPT checklists • Schedules and supervises FPT checks • Signs-off FPT checklists	• Coordinates preparation of and reviews Orientation and Training Plans & Schedule • Schedules and supervises Orientation and Training Sessions • Coordinates preparation of and reviews Final Warranty Binder & Contact List
Contractor – Sub Contractor	• Attends Cx Kick-off Meeting • Provides Cx Team Member • Provides information for Cx Plan • Provides information for Cx Schedule • Provides equipment submittals • ***Attends CX meetings***	• Provides information for Cx Checklist Index • Provides information for O&M Manual Index • Prepares O&M Manuals • Prepares Preliminary Warranty Binder	• Provides customized ISV checklists • Performs ISV checks • Fills out ISV checklists	• Provides customized FPT checklists • Performs FPT checks • Fills out FPT checklists	• Prepares Orientation and Training Plans • Conducts Orientation and Training Sessions • Prepares Final Warranty Binder
University[1]	• Attends Cx Kick-off Meeting • Provides Cx Team Member • Reviews and accepts Cx Plan • Reviews and accepts Cx Schedule • Reviews equipment submittals • ***Attends Cx meetings***	• Reviews and accepts Cx Checklist Index • Reviews and accepts O&M Manual Index • Reviews and accepts O&M Manuals • Reviews and accepts Preliminary Warranty Binder	• Reviews and approves customized ISV checklists • Verifies ISV checks are performed • Witnesses ISV testing • Signs-off ISV checklists	• Reviews and approves customized FPT checklists • Verifies FPT checks are performed • Witnesses FPT testing • Signs-off FPT checklists	• Reviews and approves Orientation and Training Plans & Schedule • Verifies that training sessions are provided • Reviews and accepts Final Warranty Binder • Coordinate Punchlist Walk Thru & Handoff (DCM & FM)
Contractor Deliverables	• Cx Team • Cx Plan • Cx Schedule (Task, Duration, Sequence)	• Cx Checklist Index • O&M Manual Index • Warranty Binder Index • Training Index • O&M Manuals • Preliminary Warranty Binder	• Accepted ISV checklists before starting of ISV checks • 3 Week Look-Ahead Cx Schedule • Completed ISV checklists	• Accepted FPT checklists before starting of FPT checks • 3 Week Look-Ahead Cx Schedule • Completed FPT checklists	• Training Plans & Schedule • Documentation of training completion • Final O&M Manuals • Final Warranty Binder & Contact List • Final Punchlist • System Completion Summary w/ Issues Log

Figure C.2: Construction Phase Cx Flowchart

Post-Construction Commissioning Flowchart

* Designates Warranty only activities or deliverables.
Italicized-Bolded Text Designates ongoing activities throughout the Warranty Period.

	1 Month	6 Month + all ongoing activities listed in the 1st Month column	10 Month + all ongoing activities listed in the 1st Month column	12 Month	22 Month (for DB Projects)
PM/PC	• Set up Cx/Warranty Meetings • ***Conduct Cx/Warranty Meetings****** • ***Initiate Work Orders for Facilities work as needed*** • ***Oversee warranty issues resolution****** • Review System Completion Summary w/ Issues Log • ***Initiate Guarantee Defect Notices as needed******	• Conduct Partial Building Occupant Survey (Comfort only) • Discuss issues and Building Occupant Survey with MSOs • Conduct Building Operation Review with FM • Address issues identified by Occupancy Survey & Building Operation Review	• Conduct full Building Occupant Survey • Discuss issues and Building Occupant Survey with MSOs • Conduct Building Operation Review with FM • Address issues identified by Occupancy Survey & Building Operation Review • Confirm closed Work Orders and total spent	• Conduct final Cx/Warranty Meeting	• Conduct final Cx/Warranty Meeting
DCM E&C	• Compile Cx Team Contact List • Set up System Training • Set up EMS SOO Training • Prepare Building Operation Review Plan per LEED EA Credit 3 • ***Review EMS trend reports with EMO*** • ***Prepare Trend Documentation*** • ***Attend Cx/Warranty Meetings*** • ***Update Cx Issues Log*** • Update PM of Issues	• Customize Building Occupant Survey (Comfort) • Request supplemental trends as needed • Determine possible Set-point adjustments based on EMS data, Building Occupant Survey & FM Building Operation Review	• Same as 6 month • Complete Summary of Findings per LEED EA Credit 3	• Prepare final Building Operation Documentation	• Prepare final Building Operation Documentation
Facilities	• Coordinate System Training • Attend EMS SOO Training • ***Attend Cx/Warranty Meetings****** • ***Forward Warranty Issues to PM****** • ***Follow up on Warranty Issues & GDN******	• EMO concurrently monitors Building Performance, notifies CxA of issues and provides feedback on Building operation • EMO sets-up trends requested by CxA • EMO adjusts Set-points per CxA direction • Conduct walk-thru, compile issues & meet with PM to review*	• Same as 6 month	• Review ________	• Review ________
Deliverables	• Warranty Meeting Schedule* • *Warranty Meeting Minutes & Warranty Issues Log** • Cx Team Contact List • Building Operation Review Plan • Trend Documentation • System Training Materials • EMS SOO Training Materials • *Cx Issues Log*	• Building Occupant Survey • Trend Documentation • Set-Point & Sequence Adjustments Documentation • Walk-Thru Issues List*	• Same as 6 month + • Confirmation of closed Work Orders and total spent	• System Completion Summary with Issues Log • Final Building Operation Documentation	• System Completion Summary with Issues Log • Final Building Operation Documentation

Last Updated: 06/29/12

Figure C.3: Post-Construction Commissioning Flowchart

Appendix D

UC Davis LEED Certification Scorecards

1000122997, Davis, California

UC Davis Teaching and Learning Complex

LEED BD+C: New Construction (v4)

GOLD, AWARDED JUN 2023

SUSTAINABLE SITES		AWARDED: 7 / 10
Prereq	Construction activity pollution prevention	0 / 0
Credit	Site assessment	1 / 1
Credit	Site development - protect or restore habitat	0 / 2
Credit	Open space	1 / 1
Credit	Rainwater Mgmt	2 / 3
Credit	Heat island reduction	2 / 2
Credit	Light pollution reduction	1 / 1

WATER EFFICIENCY		AWARDED: 3 / 11
Prereq	Outdoor water use reduction	0 / 0
Prereq	Indoor water use reduction	0 / 0
Prereq	Building-level water metering	0 / 0
Credit	Cooling tower water use	0 / 2
Credit	Water metering	1 / 1
Credit	Outdoor water use reduction	1 / 2
Credit	Indoor water use reduction	1 / 6

ENERGY & ATMOSPHERE		AWARDED: 31 / 33
Prereq	Fundamental commissioning and verification	0 / 0
Prereq	Minimum energy performance	0 / 0
Prereq	Building-level energy metering	0 / 0
Prereq	Fundamental refrigerant Mgmt	0 / 0
Credit	Enhanced commissioning	5 / 6
Credit	Advanced energy metering	0 / 1
Credit	Demand response	2 / 2
Credit	Renewable energy production	3 / 3
Credit	Enhanced refrigerant Mgmt	1 / 1
Credit	Green power and carbon offsets	2 / 2
Credit	Optimize energy performance	18 / 18

MATERIAL & RESOURCES		AWARDED: 4 / 13
Prereq	Storage and collection of recyclables	0 / 0
Prereq	Construction and demolition waste Mgmt planning	0 / 0
Credit	Building life-cycle impact reduction	0 / 5
Credit	Building product disclosure and optimization - environmental product d...	1 / 2
Credit	Building product disclosure and optimization - sourcing of raw materia...	0 / 2
Credit	Building product disclosure and optimization - material ingredients	1 / 2
Credit	Construction and demolition waste Mgmt	2 / 2

INDOOR ENVIRONMENTAL QUALITY		AWARDED: 5 / 16
Prereq	Minimum IAQ performance	0 / 0
Prereq	Environmental tobacco smoke control	0 / 0
Credit	Enhanced IAQ strategies	2 / 2
Credit	Low-emitting materials	1 / 3
Credit	Construction IAQ Mgmt plan	1 / 1
Credit	IAQ assessment	0 / 2
Credit	Thermal comfort	0 / 1
Credit	Interior lighting	1 / 2
Credit	Daylight	0 / 3
Credit	Quality views	0 / 1
Credit	Acoustic performance	0 / 1

INNOVATION		AWARDED: 6 / 6
Credit	Innovation	5 / 5
Credit	LEED Accredited Professional	1 / 1

REGIONAL PRIORITY CREDITS		AWARDED: 3 / 4
Credit	Renewable energy production	1 / 1
Credit	Optimize energy performance	1 / 1
Credit	Reduced parking footprint	1 / 1
Credit	Rainwater Mgmt	0 / 1
Credit	Outdoor water use reduction	0 / 1
Credit	Indoor water use reduction	0 / 1

LOCATION & TRANSPORTATION		AWARDED: 9 / 20
Credit	LEED for Neighborhood Development location	0 / 16
Credit	Sensitive land protection	1 / 1
Credit	High priority site	0 / 2
Credit	Surrounding density and diverse uses	4 / 5
Credit	Access to quality transit	2 / 5
Credit	Bicycle facilities	1 / 1
Credit	Reduced parking footprint	1 / 1
Credit	Green vehicles	0 / 1

INTEGRATIVE PROCESS CREDITS		AWARDED: 1 / 1
Credit	Integrative process	1 / 1

TOTAL	69 / 110

40-49 Points	50-59 Points	60-79 Points	80+ Points
CERTIFIED	SILVER	GOLD	PLATINUM

Figure D.1: UC Davis Teaching and Learning Complex Scorecard

1000147985, Sacramento, California

UC Center Sacramento

LEED BD+C: New Construction (v4)

GOLD, AWARDED OCT 2023

SUSTAINABLE SITES		AWARDED: 3 / 10
Prereq	Construction activity pollution prevention	0 / 0
Credit	Site assessment	0 / 1
Credit	Site development - protect or restore habitat	0 / 2
Credit	Open space	0 / 1
Credit	Rainwater Mgmt	0 / 3
Credit	Heat island reduction	2 / 2
Credit	Light pollution reduction	1 / 1

WATER EFFICIENCY		AWARDED: 7 / 11
Prereq	Outdoor water use reduction	0 / 0
Prereq	Indoor water use reduction	0 / 0
Prereq	Building-level water metering	0 / 0
Credit	Cooling tower water use	0 / 2
Credit	Water metering	1 / 1
Credit	Outdoor water use reduction	2 / 2
Credit	Indoor water use reduction	4 / 6

ENERGY & ATMOSPHERE		AWARDED: 16 / 33
Prereq	Fundamental commissioning and verification	0 / 0
Prereq	Minimum energy performance	0 / 0
Prereq	Building-level energy metering	0 / 0
Prereq	Fundamental refrigerant Mgmt	0 / 0
Credit	Enhanced commissioning	3 / 6
Credit	Advanced energy metering	1 / 1
Credit	Demand response	1 / 2
Credit	Renewable energy production	0 / 3
Credit	Enhanced refrigerant Mgmt	0 / 1
Credit	Green power and carbon offsets	0 / 2
Credit	Optimize energy performance	11 / 18

MATERIAL & RESOURCES		AWARDED: 9 / 13
Prereq	Storage and collection of recyclables	0 / 0
Prereq	Construction and demolition waste Mgmt planning	0 / 0
Credit	Building life-cycle impact reduction	4 / 5
Credit	Building product disclosure and optimization - environmental product d...	1 / 2
Credit	Building product disclosure and optimization - sourcing of raw materia...	1 / 2
Credit	Building product disclosure and optimization - material ingredients	1 / 2
Credit	Construction and demolition waste Mgmt	2 / 2

INDOOR ENVIRONMENTAL QUALITY		AWARDED: 8 / 16
Prereq	Minimum IAQ performance	0 / 0
Prereq	Environmental tobacco smoke control	0 / 0
Credit	Enhanced IAQ strategies	2 / 2
Credit	Low-emitting materials	3 / 3
Credit	Construction IAQ Mgmt plan	1 / 1
Credit	IAQ assessment	1 / 2
Credit	Thermal comfort	0 / 1
Credit	Interior lighting	1 / 2
Credit	Daylight	0 / 3
Credit	Quality views	0 / 1
Credit	Acoustic performance	0 / 1

INNOVATION		AWARDED: 5 / 6
Credit	Innovation	4 / 5
Credit	LEED Accredited Professional	1 / 1

REGIONAL PRIORITY CREDITS		AWARDED: 4 / 4
Credit	Optimize energy performance	1 / 1
Credit	Access to quality transit	1 / 1
Credit	Building product disclosure and optimization - sourcing of raw materia...	0 / 1
Credit	Outdoor water use reduction	1 / 1
Credit	Indoor water use reduction	1 / 1

LOCATION & TRANSPORTATION		AWARDED: 14 / 20
Credit	LEED for Neighborhood Development location	0 / 16
Credit	Sensitive land protection	1 / 1
Credit	High priority site	1 / 2
Credit	Surrounding density and diverse uses	5 / 5
Credit	Access to quality transit	5 / 5
Credit	Bicycle facilities	1 / 1
Credit	Reduced parking footprint	1 / 1
Credit	Green vehicles	0 / 1

INTEGRATIVE PROCESS CREDITS		AWARDED: 1 / 1
Credit	Integrative process	1 / 1

TOTAL	67 / 110

40-49 Points	50-59 Points	60-79 Points	80+ Points
CERTIFIED	SILVER	GOLD	PLATINUM

Figure D.2: UC Center Sacramento Scorecard

Appendix E

TLC Mechanical Drawings

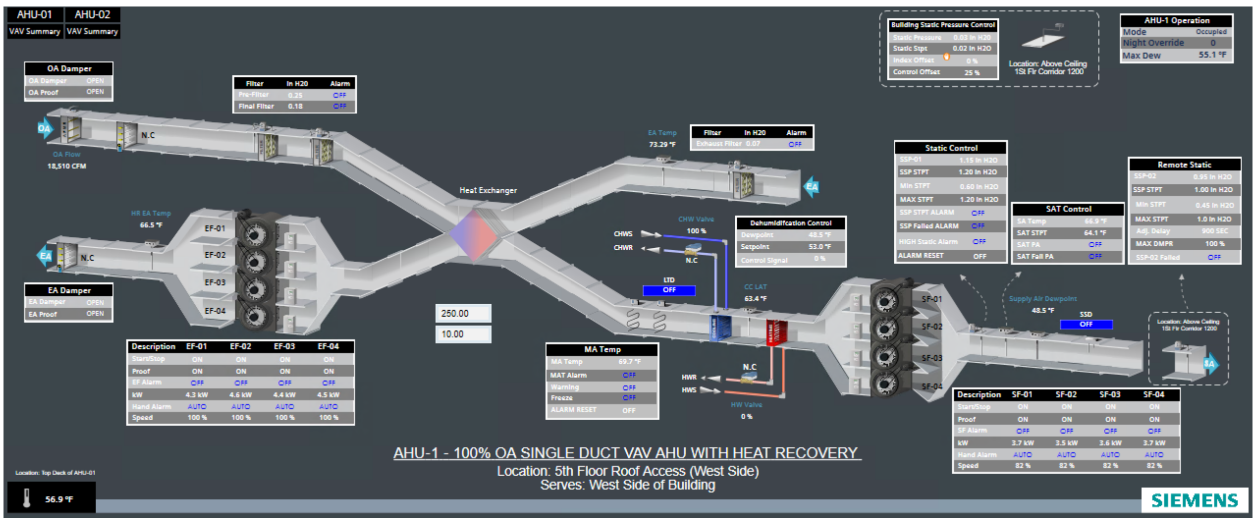

Figure E.1: AHU-1 100% Outside Air with Heat Recovery

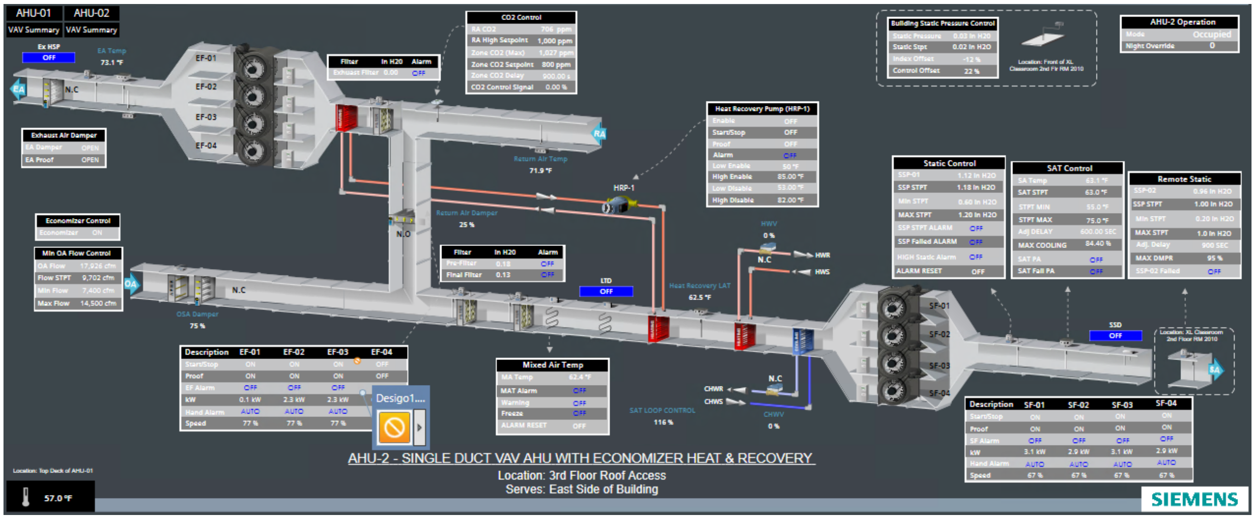

Figure E.2: AHU-2 Economizer with Heat Recovery

Appendix F

TLC Plenum Damage

Figure F.1: Damage to TLC AHU1 Plenum

Appendix G

TLC Building Pressure

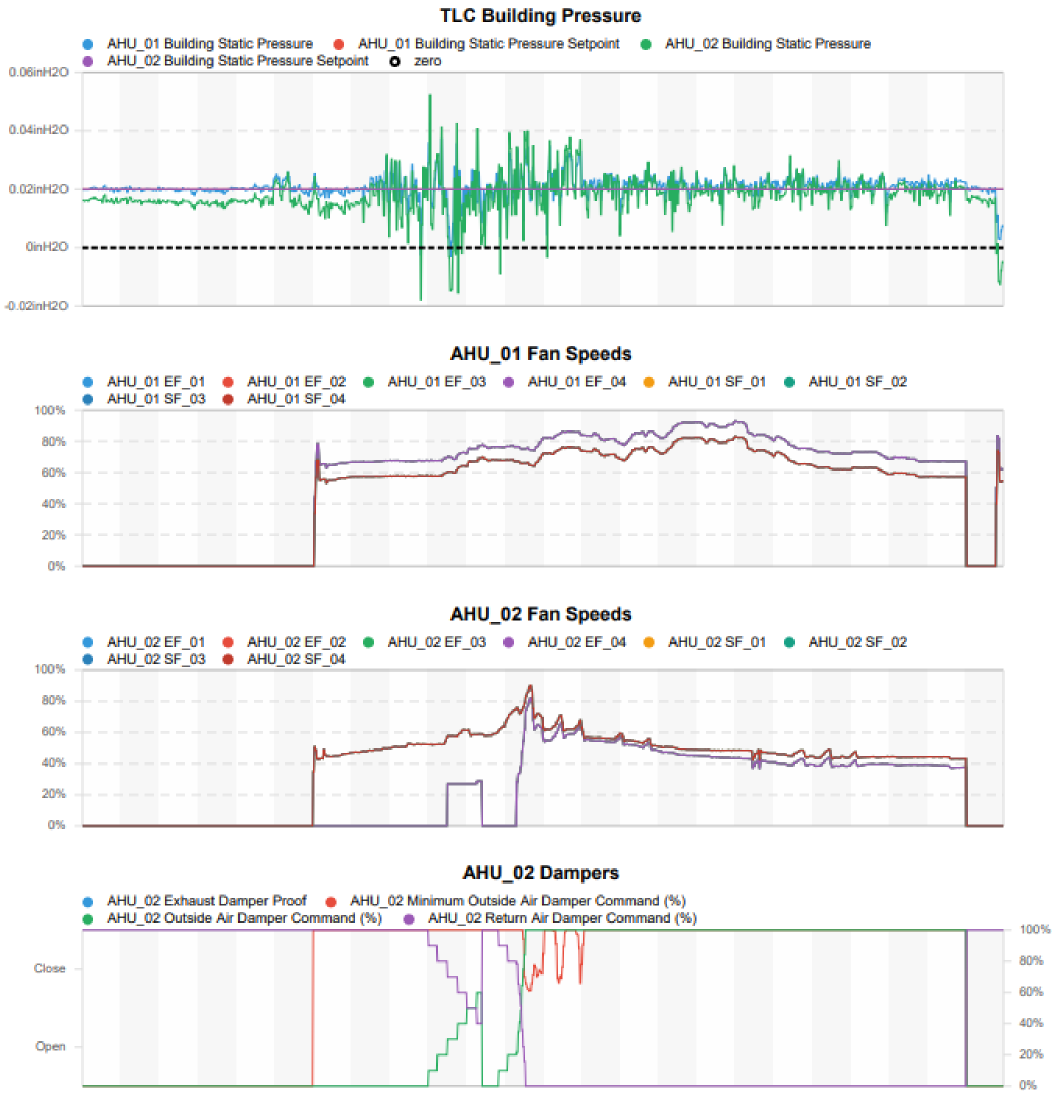

Figure G.1: TLC building pressure

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