AN EVALUATION OF BENEFITS OF BUILDING COMMISSIONIONG ON CAPITAL PROJECTS AT VIRGINIA TECH

By

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PROJECT & REPORT

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ABSTRACT

As building systems and their inter-relation become more complex, building owners are seeking ways to ensure that the design and construction of these buildings meet their intent. The concept of building commissioning has emerged to assist in meeting this need. Proponents believe that building commissioning is beneficial to energy savings, equipment functionality and longevity, worker productivity, as well as reductions in liability insurance claims. Building costs for maintenance, a potential decrease in operational costs, and more comfortable work environments are more than attractive for facilities managers as well as building occupants.

Building commissioning is becoming a global effort. The United States is taking a leading role in conducting research in this area and incorporating commissioning efforts in construction projects, particularly in the public sector. The Commonwealth of Virginia has also recognized the potential benefits of commissioning and is now including building commissioning in many of their capital projects. Virginia Tech, a decentralized agency within the Commonwealth, has recently announced its commitment to incorporate building commissioning in all current and future capital projects on the Virginia Tech campus.

A comparative study of the commissioning efforts at Virginia Tech to date indicates that these efforts have identified many issues that may otherwise not have been addressed during the construction process. However, as building commissioning has only recently become a part of construction at Virginia Tech, little comparable data is available to qualitatively evaluate the value added by building commissioning on these projects.

It is recommended that building commissioning continue to be incorporated into capital projects at Virginia Tech, preferably during the design stage of each project. It is further recommended that protocol be established that will ensure detailed, comparable data be recorded for each project. As efforts advance at Virginia Tech, this data can be used in evaluating the full benefits of commissioning in capital projects.

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CHAPTER 1: Introduction

The goal of all capital projects is to ensure a building is built on time, within the scope, and within the budget. For the owner and/or operator of the building, it is also most important to ensure the building is built as intended and operates at an efficient and effective level post construction. By choosing qualified architects, engineers, and constructors, the owner can be confident that the building will meet their expectations as a whole. However, even the best built buildings can experience problems resulting from design errors, change proposals, ineffective coordination, and poor craftsmanship.

As buildings become more and more complex, a system of checks and balances is becoming more and more necessary. In order to ensure buildings perform as intended, many building owners, particularly those in the public sector, are incorporating building commissioning into their projects. Commissioning is not only promoted in the United States but is also becoming a global effort.

Recognizing the benefits offered by the process, the Commonwealth of Virginia has begun to implement building commissioning into their capital projects. Although limited commissioning has occurred on capital projects built in the past five years, a plan is in place that will incorporate commissioning in all future Virginia Tech projects.

This report discusses the concept of commissioning at various levels (globally, nationally and locally). It also attempts to demonstrate the benefits of commissioning at Virginia Tech. Five capital projects with similar date of completion, scope and size are discussed. All projects discussed have had some level of commissioning incorporated. Recommendations for further research are included.

CHAPTER 2: Literature Review and Background

2.1 Overview of Building Commissioning

Over the last two decades, building systems and their inter-relation have become more complex and sophisticated. As these systems operate more and more dynamically with one another, it has become not only important but essential for building functionality to ensure that all components work together as intended. Additionally, energy conservation efforts resulting from the Efficiency and Water Conservation at Federal Facilities Act have established energy guidelines and safety standards for many public buildings (DOE & GSA, 1998). LEED certification requirements also have encouraged owners to involve processes that ensure energy-saving measures are addressed. In order to verify that the design and installation of a building's equipment and systems satisfy the owner's intent and meet energy conservation requirements, the concept of building commissioning has emerged.

There are differing opinions as to the definition of building commissioning. Some consider commissioning to be a special one-time check on testing and balancing of safety and service systems conducted at the completion of a construction project, while others view the process as more comprehensive and ongoing (Frye, et al., 2002). For the intent of this report, building commissioning will be defined as

> "..a systematic process of assuring by verification and documentation, from the design phase to a minimum of one year after construction, that all building facility systems perform interactively in accordance with design documentation and intent, and in accordance with the owner's operational needs, including preparation of operation personnel" (Ellis, 2004).

Problems, to some extent, exist in all buildings. Deficiencies resulting from design oversights, poor construction processes, and lack of continuous maintenance can result in a less than desirable building. As a result, the owner or occupant can be left with equipment failures, poor indoor air quality and comfort, as well as elevated energy use (Mills, et. al, 2004). In order to avoid many of these problems, more and more owners are recognizing the need to commission buildings in order to verify that the building meets design intent and that associated equipment are well maintained throughout their lifecycle (Friedman, Potter, Haasl & Claridge, 2002).

A well commissioned building assures that equipment, systems, and controls providing light, heat, cooling and ventilation are working together effectively. The process encompasses a thorough examination of the HVAC system, exhaust systems, electrical, life safety, lighting, plumbing, as well as the building envelope (Mills, et al.).

Various individuals can perform commissioning. The following list outlines resources available (in order of preference):

- Owner/third party commissioning consultant (commissioning agent)
- Test and balancing contractor
- Design engineer
- Installation contractor

It is apparent from this list that the best choice to perform commissioning would be a neutral party not directly responsible for the design and construction of the building or individuals responsible for installation of the equipment (DOE & GSA).

Commissioning is performed on both new and existing buildings. New building construction is a collaborative process of review and testing conducted throughout the construction project, from planning and pre-design through owner turnover. Planning for commissioning must begin in the very early stages of the project and evolve progressively in more detail throughout all phases of work. During the planning stage, consideration must be given to the budget as well as to the end users' needs. It is recommended that training of system operators also be incorporated at this early stage and carried throughout the process (Frye, 2002).

The new building commissioning process includes a phased development of a commissioning plan which addresses key planning and design activities as well as construction phase commissioning activities and documentations. Thorough documentation of the planned systems' intent must be a part of the process as well. Throughout the construction phase, rigorous testing and inspection of systems and operating sequences must be performed ensuring that functional testing and measurements verify system performance. Upon completion of the project, O&M manuals that have been prepared throughout the project will be submitted to the owner. Training of building operations staff on system operations and maintenance procedures will be conducted at this time. In best practices, ongoing monitoring of system performance will be included in the commissioning agreement (WDBG, 2005).

Commissioning of existing buildings falls into two categories: re-commissioning and retro-commissioning. Re-commissioning, as its name implies, is the commissioning of a building that has been previously commissioned, and should be performed every three to five years (Wigfield, 2003). Retro-commissioning, on the other hand, is the commissioning of buildings that have never before been commissioned. The process involves the identification and remedy of problems within specific systems and can be quite complex. However, it can identify problems due to wear and tear or changes made to complete systems, or components of the system. Some of the problems identified during this process include simultaneous heating and cooling; frozen valves; stuck dampers; fouled filters; and excessive equipment cycling (Mills, et al., 2004). Figure 1 provides examples of conditions identified during the retro-commissioning.

Proponents of commissioning believe that the process to be beneficial from both a functional aspect as well as a cost-saving measure. As commissioning is a relatively new field, however, methods for obtaining cost/benefit analysis are still evolving (Mills, et al., 2004). Therefore, the statistics presented in this report are provided for example only, and may not be representative of all commissioning efforts. The cost of commissioning can vary depending on the scope and complexity of the project. Factors impacting the cost include the number of systems to be commissioned, the complexity of the systems, the timeframe of starting and stopping commissioning, and the total project size (Ellis, 2004). Whether the building is new or existing also affects the cost (Mills, et al., 2004).

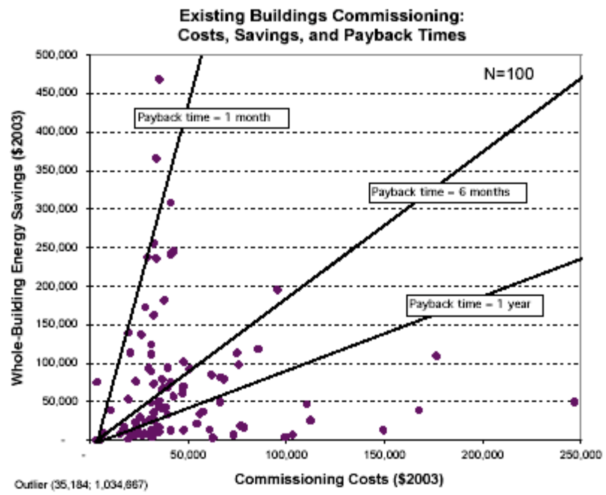
For new construction, the most common method of calculating costs for commissioning is based on a percentage of the total construction cost or a percentage of the cost for the individual components to be commissioned. On average, an owner should plan to budget between .5% and 2% of the total construction cost, or 2% to 3% of the construction cost of the systems being commissioned (Ellis, 2004; PECI, 2000). Those wishing to perform retro-commissioning should anticipate spending $0.40 to $1.20 per square foot depending on the complexity, size and location of the building.

Figure 1: Common deficiencies identified during a commissioning of an existing building

Source: Minnesota Center for Energy and Environment (in Mills, et. al 2004)

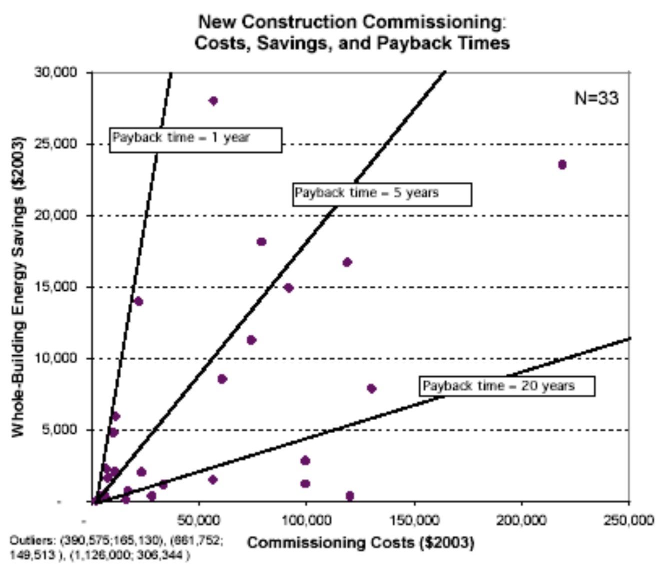
Although additional funds must be incorporated into the project, proponents of commissioning believe the benefits realized more than outweigh the initial cost. A building with mechanical and electrical systems that operate efficiently results in a reduction in operational costs, extends the life of equipment, and minimizes downtime due to equipment failure (Tormenta, et al., 1999). According to a study conducted by Portland Energy Conservation, Inc. (PECI), building owners indicate the primary reasons to commission a building are to ensure system performance and to reduce energy costs. Figures 2 and 3, an excerpt from an analysis conducted by researchers form the Lawrence Berkeley National Laboratory, Portland Energy Conservation, Inc., and Texas A& M Energy Systems Laboratory, show a comparison between costs, savings and payback times of building commissioning.

Figure 2. Return on Investment – Existing Buildings



Source: Mills et al 2004

Figure 3. Return on Investment – New Construction



Source: Mills et al 2004

In support of PECI's findings, the Department of Energy estimates that more than $40 million in potential energy savings could be gained from commissioning only 1% of existing buildings greater than 25,000 square feet (PECI, 2005). Based on available information, a building owner can anticipate an 8% to 20% reduction in operating costs for a building that has been commissioned. Cost savings for retro-commissioning range from 5% to 20% reduction in operating costs (Wigfield, 2003).

Payback on new building commissioning can be realized in 1.5 to 3.5 years due to fewer change orders, lower energy usage, and a reduction in operational problems (Wigfield, 2003). Please note, however, that "percentage savings are generally not available for new construction, as there is no opportunity to measure energy use in the hypothetical (not built) non-commissioned building" (Mills, et al., 2004). Energy costs for existing buildings were reduced by 10% by re-commissioning within three to five years of initial commissioning efforts. For retro-commissioning, simple payback has been realized from 1.5 to 7.5 years (Wigfield, 2003).

Other payback benefits of commissioning are harder to measure but still provide a return on investing in the commissioning process. Some of these include having comfortable working space more conducive to increased productivity; extended equipment life; reduction in change orders; and, most elusive, reduced liability or insurance claims. Although not completely accurate due to comparison variables such as regional costs and building size, tools for measuring return on investment from an energy-saving perspective are more accurate than for those of a non-energy nature (Mills, et al., 2004).

2.2 An International Perspective on Building Commissioning

Recognizing the potential for better built buildings offered by the commissioning process, building commissioning is becoming a global effort. In the United States, energy conservation efforts have resulted in commissioning activities being incorporated in public buildings as well as encouraging private owners to follow suit. In an effort to better understand the process at an international level, an investigation on commissioning activities in Australia, Canada, the Netherlands, the United Kingdom and the United States was performed.

Based on the research conclusions of this study, there are a number of reasons to perform building commissioning. Of the countries researched, the most predominant benefits shared globally include:

- assurance that the building is constructed as the owner intended
- minimized cost for construction
- promotion of energy efficiency
- minimized cost of operation
- comfort and safety considerations for end users
- increased resale value of property
- reduction in liability and litigations

Of these, the majority (Australia, Canada, UK and US) indicate ensuring that the building meets owner specifications and energy efficiency as the primary reasons to perform commissioning activities. Surprisingly, only three countries (Netherlands, US and Australia) recognized a primary role of commissioning to be the reduction of lawsuits resulting from "sick building syndrome" as (Maxey, 2005).

2.3 Incorporating Building Commissioning into Capital Projects at Virginia Tech

At a more local level, the Commonwealth of Virginia has also recognized the importance of building commissioning. Various state agencies have incorporated commissioning into their capital projects, including Virginia Tech. In October 2006, Mr. James Hyatt, Executive Vice President for Administration at Virginia Tech, announced the University's initiative in making the campus more energy efficient. As a part of this priority, the Virginia Tech Design and Construction Standards were revised to incorporate sustainable design components necessary in obtaining LEED Certified Building status. These revised standards include additional energy-efficient and sustainable design practices such as day-lighting measures, recycling of construction debris as applicable, and improving indoor air quality through the reduction of VOC products.

In addition, a building commissioning program has been included in support of developing the basis for project design and construction. The intent of this implementation is to improve occupant comfort, reduce life-cycle operations and maintenance cost, and to extend the life of building equipment (Hyatt, 2006).

Commissioning at Virginia Tech focuses on new construction, and specifically on ensuring proper installation and operation of HVAC systems and automated control systems. There are also limited efforts in commissioning emergency electrical power systems. Currently, three commissioning firms, selected through the Commonwealth's Architectural and Engineer Consultant Selection Process, perform commissioning activities for Virginia Tech capital projects. (Kuykendall & Elvey, 2006). According to Elvey (2006), "[Virginia Tech] Facilities ideally attempts to utilize third-party, independent commissioning consultants who are under contract to the university, as this provides the least amount of 'conflict of interest' and best protects the interests of Virginia Tech and the future occupants." Commissioning activities have also been performed by agents hired by the A/E consultants, although this arrangement may introduce a potential conflict of interest when design flaws are identified. In a like manner, commissioning services provided through a contract with the general contractor creates a similar conflict of interest where less than quality construction is identified as a problem. In addition, having commissioning activities incorporated into the construction contract eliminates the potential of identifying problems during the design phase.

Commissioning efforts at Virginia Tech began with the construction of the Bioinformatics Phase I project in 2004. Since then, the university has attempted to incorporate commissioning at the onset of design and continue through owner turnover on all new construction to ensure that completed projects meet the requirements specified by the end users. It is the intention of Virginia Tech Facilities to commission all major building and utility projects.

In order to better understand Virginia Tech's decision making role in capital projects constructed at Virginia Tech, the following information is provided.

2.4 Capital Outlay Process for the Commonwealth of Virginia

Policies and procedures for the procurement of professional and construction services for Commonwealth capital projects are developed by the Bureau of Capital Outlay Management (BCOM), an entity of the Department of General Services. However, in recent years the Virginia General Assembly has granted some agencies more autonomy in developing their own policies and procedures in managing the capital process for projects built with non-general funds. Known as decentralized agencies, those awarded this designation do not submit plans and drawings, contracts or change orders for BCOM approval on non-general funded projects as do centralized agencies (APA, 2004).

Capital Outlay is defined as "the process by which agencies of the Commonwealth obtain real property" (APA, 2004). Both a legislative approval process in disbursing funds and a process to manage the constructed properties is included in capital outlay practices. From a budgeting perspective, capital projects fall within the following criteria:

- Acquisition – buying land or land with buildings (no monetary limits)
- Construction – building a structure greater than 5,000 square feet or greater than $1 million in total project costs, including additions to existing buildings
- Improvements – renovating, repairing or altering a building with a cost greater than $1 million
- Equipment – permanent or long term in nature used in an operation or activity (APA, 2004)

Cost, size and scope also assist in determining whether or not a project is designated as an operating or capital budget project.

Three primary players participate in Centralized Agency projects are: the Commonwealth agencies and institutions conducting capital outlay projects; the Department of Planning and Budget; and BCOM. The Commonwealth agencies work closely with Planning and Budget and BCOM in developing budgets, determining feasibility of funding, and appropriations. BCOM then determines if an agency has adequate resources to construct the project as requested. BCOM monitors the project throughout its lifecycle following the requirements of the Construction and Professional Services Manual (APA, 2004).

Although a similar process applies to Decentralized Agencies as it relates to budget development, Decentralized Agencies conduct their own review and follow their own standards, terms and procedures from their independent Higher Education Capital Outlay Manual. The primary difference between the two processes is that the BCOM review is eliminated in decentralized projects (APA, 2004).

2.5 The Construction Process

The construction process can be broken into five primary phases: planning and approval; design; bid; construction; and owner turnover and closeout. Primary players within the construction process include the owner and owner reps; the architect and engineering team, and the contractor. The Figure 4 summarizes these phases and the key players within each. As noted in this breakdown, Virginia Tech, being a decentralized agency, maintains a fair amount of autonomy in decisions relative to scope and budget of capital projects under their jurisdiction.

Figure 4: The Commonwealth of Virginia construction process

Phase I: Planning/Approval
- Recognize need
- Status of current facility
- Long range plans
- Consideration for future construction, renovation

Players:
- Senior management
- Board of Directors
- Planning and Budget
- BCOM (Centralized)
- Treasury Board (Dept-related)
- Governor
- General Assembly
- Dept. of Environmental Quality

- **Phase II: Design**
- Owner hires A/E
- Scope defined, considering available resources
- Development of plans
- Schematic drawings
- Value engineering review (>$5M)
- Preliminary drawings
- Thorough review
- Working drawings
- BCOM reviews to issue permit

Players:
- Owner/Owner rep
- BCOM
- A/E

Phase III: Bid
- Open invitation to qualified contractors
- Plans provided to all bidders
- Determination of construction management method
  - Agency personnel
  - External firm
- Approval from General Services Division of Engineering and Buildings
- Contract awarded
  - BCOM approval (Centralized)

Players:
- Owner/Owner rep
- Contractor
- Construction Manager
- General Services
- BCOM (Centralized)

Phase IV: Construction
- Contractor responsible for:
  - Monitoring and control
  - Resource management
  - Documentation and communication
  - Safety and environmental impacts
- Recommendations of changes confirmed by all stakeholders; change proposals submitted
- Owner monitors processes
- Perform inspections identified by A/E
- BCOM tracks and manages changes submitted

Players:
- Contractor/Sub-contractors
- Owner/Owner rep
- Construction Manager
- A/E
- BCOM (Centralized)

Phase V: Owner Turnover and Closeout
- Construction complete
- Final inspections performed (BCOM performs for all buildings)
- Contractor provides all operations and maintenance manuals
- Owner assumes maintenance responsibility
- Contractor and A/E provide as-built drawings to owner
- End user moves into the building

Players:
- Contractor/Sub-contractors
- Owner/Owner rep
- Construction Manager
- A/E
- Inspectors
- BCOM (Centralized and Decentralized)

2.6 Capital Projects at Virginia Tech

The design and construction of capital projects at Virginia Tech is managed through the Facilities division of Virginia Tech, and specifically the Capital Design and Construction (CDC). The mission of this department is “to manage the process by which capital outlay projects are designed and constructed so as to maximize the program goals of the end user(s) while effectively balancing each project's established parameters for cost, schedule, and quality.” Figures 5 and 6 below outline the organizational structure of those involved in capital design projects at Virginia Tech.

Figure 5: Virginia Tech Facilities organizational structure

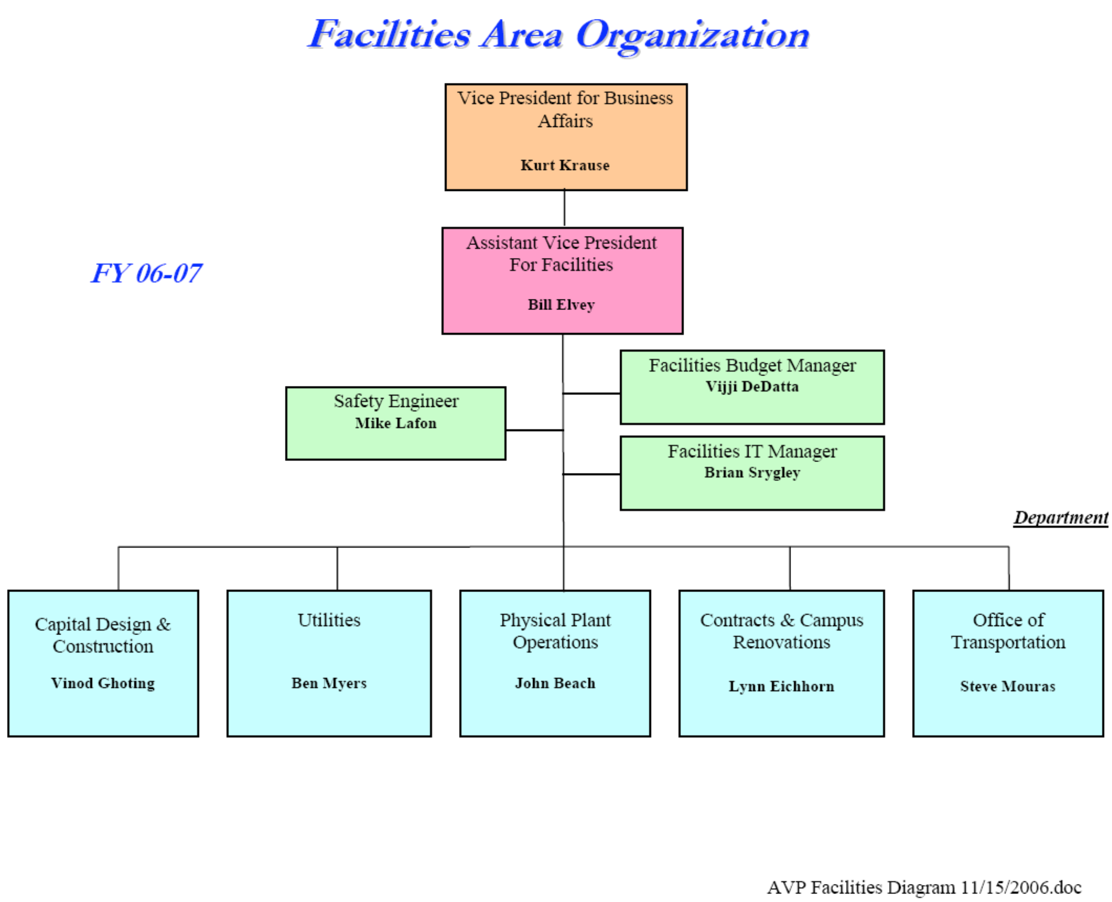
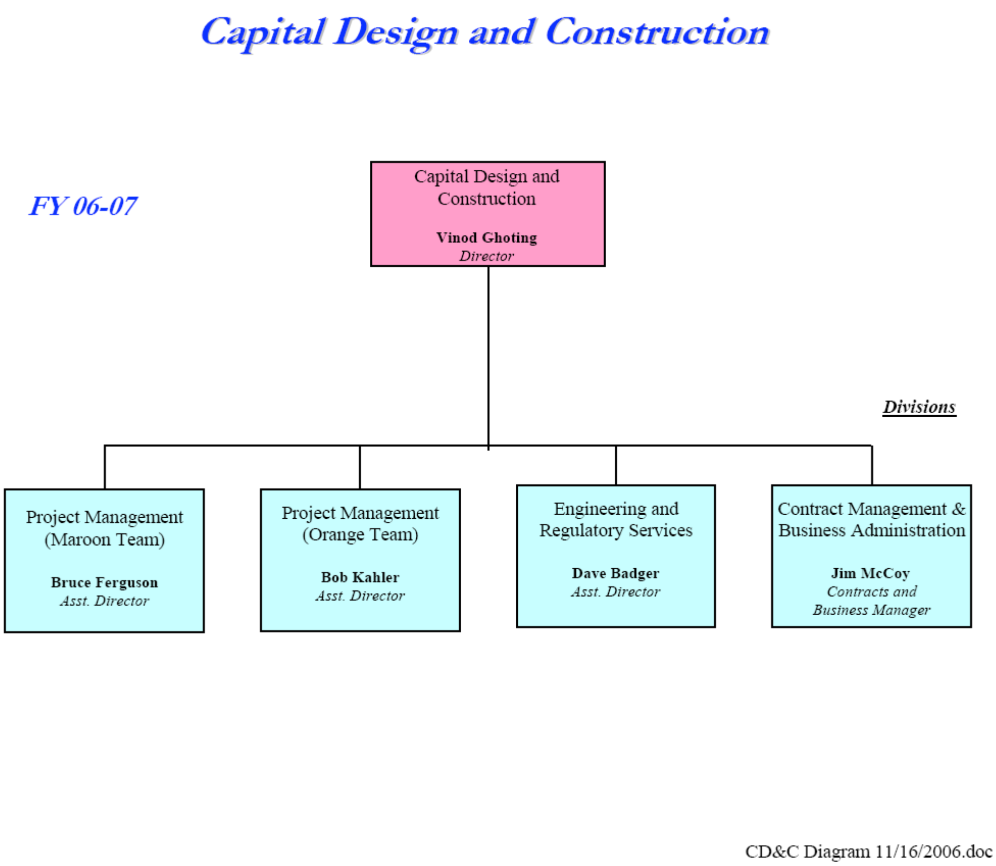


Figure 6: Virginia Tech Capital Design and Construction organizational structure



Each project is managed by a team of project managers and owner representatives (typically assigned from the department or unit that will occupy the facility). This team works closely with the A/E professionals, the general contractor and subcontractors to ensure owner requirements are addressed throughout the construction process, including turning over the facility to the end users.

Chapter 3: Problem Definition/Methodology

3.1 Objective

Research performed during this project focused on the capital construction process at Virginia Tech. The objective was to determine potential benefits resulting from building commissioning activities, particularly for the stakeholders involved in the construction and occupancy of these facilities.

3.2 Test Hypothesis

3.3 Methodology

In an effort to better understand the nature and complexity of capital projects at Virginia Tech, a review of current projects and those completed within the past 10 years was conducted. A summary of these projects can be found in Appendix 1. These are categorized by size and budget; the type of construction (new, addition, renovation or upgrade); the purpose of the facility; and the anticipated or final completion date. As shown, within the past 10 years, CDCD has managed the completion of 50 projects totaling more than $436M. This summary does not include projects still in the design, development and bid process.

After reviewing this data, interviews were conducted with members of VT Facilities to gain a better understanding of commissioning efforts at Virginia Tech, and to determine which buildings had incorporated commissioning in the project scope. Commissioning efforts on new construction was then documented, indicating the level of commissioning efforts, if any, included in the design and construction process. From this data collection, five facilities were chosen based on those with the most similarities (similar size, date of completion and similar scope). A breakdown of this information is available in Appendix 2.

More in-depth research was then performed on the chosen building sample to determine commonalities in warranty issues and current status of the facilities. Reviews of commissioning reports were performed to determine at what level commissioning was incorporated, and to assess the types of issues that were identified through this effort. Warranty callback logs were reviewed in an attempt to assess the number of issues that may have been identified and addressed by commissioning efforts prior to occupancy. Personal interviews with building managers and Virginia Tech Facilities personnel were conducted to obtain information as to the current status of the sample facilities. This information was used to obtain information at the end-user level that is not captured in records obtained by VT Facilities. A copy of the tool used in conducting these interviews may be found in Appendix 3.

Once information was collected, a breakdown of each sample facility was performed. Information on building size, function, and commissioning efforts were compiled. Random samples of issues identified during commissioning were compiled to illustrate the varying types of systems, issues, and areas of responsibility. Warranty logs were reviewed and a summary was provided in the building discussion. Information obtained from building managers was also summarized to be included in the building discussion section. Once all information was compiled for each sample facility, building managers were asked to review the content of the section relative to their respective buildings to validate information documented is correct.

Upon completion of data analysis, information received on all projects was reviewed. A summary of activities, potential benefits of commissioning, and recommendations for further research was then compiled.

Chapter 4: Data Analysis

Facilities data collected for this research project included the Chemistry/Physics Building; Bioinformatics Facilities I and II; the Holzman Alumni and Skelton Conference Center, and The Inn at Virginia Tech; and Latham Hall. These facilities were all constructed within the last five years; all had similar scope and/or complexity; and are of similar size. With the exception of the Chemistry/Physics Building, all incorporated commissioning activities during the construction phase of the project; this facility incorporated retro-commissioning on its exhaust fan system. Although the alumni and conference center facility is not used for research purposes, it required complex mechanical systems similar to those in the research facilities.

Information for this research and report was gathered from the Virginia Tech Capital Design and Construction; Virginia Tech Physical Plant Department; and through personal interviews with building managers of the sample projects. The following tables provide information on the individual facilities. Table 1outlines the building description and programs utilizing each of the facilities; commissioning activities are outlined in Table 2; and Table 3 provides a summary of data sources used in gathering information.

Following the summary tables are discussion sections on each facility to include:

1. A description of the project
2. Commissioning efforts included in the project
3. Warranty issues
4. Current status of the facility

Table 1. Capital project descriptions

Project Name	Notice to Proceed	Project Completion	Square Footage	No. Stories	Architect/Engineer	General Contractor	Program occupying space
Alumni Hall, CEC & Hotel	March '03	July '05	193,020	4	Sheretz Franklin Crawford Shaffner, Inc., Roanoke, VA	Branch & Associates, Inc. Roanoke, VA	Holzman Alumni and Skelton Conference Center, and The Inn at Virginia Tech
Bioinformatics Phase 1	March '02	Dec. '03	58,285	3	Calloway Johnson Moore & West, Richmond, VA	Branch & Associates, Inc. Roanoke, VA	Virginia Bioinformatics Institute (Research)
Bioinformatics Phase 2	Feb. '03	Dec. '04	71,560	3	Calloway Johnson Moore & West, Richmond, VA	Skanska USA Building Inc. Winston Salem, NC	Virginia Bioinformatics Institute (Research)
Chem/Physics Phase II	Jan. '02	Jan. '04	85,051	4	Clark Nexsen, Norfolk, VA	Branch & Associates, Inc. Roanoke, VA	Chemistry and Physics Departments (Undergraduate Teaching)
Ag/Forestry	July '03	March '06	84,277	5	Mosely Harris & McClintock, Virginia Beach, VA	J. E. Jamerson & Sons, Inc. Appomattox, VA	Colleges of Agriculture and Natural Resources (Teaching/Research)

Table 2: Commissioning efforts incorporated in projects

Project	Was Cx Performed?	If Yes, to what extent?	At what stage of construction?	Commissioning Agency	Contracting Party
Alumni Hall, CEC & Hotel	Yes	Full Cx of MEP	Beginning of construction	Engineering Economics Inc. Roanoke, VA	Third party, contracted by Virginia Tech
Bioinformatics Phase I	Yes	Partial Cx of MEP	Construction 85% Complete	RMF Engineering, Inc. Baltimore, MD	Contracted by A/E
Bioinformatics Phase II	Yes	Partial Cx of MEP	Toward end of design and bidding stages	RMF Engineering, Inc. Baltimore, MD	Contracted by A/E
Chem/Physics Phase II	No	No initial Cx; retro-Cx of Exhaust Fan System	Post-construction	Affiliated Engineers Inc. Chapel Hill, NC	Third party, contracted by Virginia Tech
Ag/Forestry	Yes	Full Cx of MEP	Beginning of construction	Affiliated Engineers Inc. Chapel Hill, NC	Third party, contracted by Virginia Tech

Table 3: Resources available for data collection

Project	Resources Available			
	Personal Interviews		Logs	
	Building Manager	**Involvement in Process**	**Cx Log**	**Warranty Log**
Alumni Hall, CEC & Hotel	Chris Compton, Chief Engineer, The Inn at Virginia Tech & Skelton Conference Center	Became involved in construction process as owner rep just after site work was complete; currently manages facility	Thorough Cx log; last updated 1/4/05	Auxiliary facility; no warranty logs through VT Physical Plant; no logs on warranty issues currently maintained
Bioinformatics Phase I	David Gibbs, Senior Facilities Mgr. Virginia Bioinformatics Institute	Owner rep; involved in process since substantial completion; currently serves as senior facilities manager	Thorough Cx log; last updated 5/13/05	Detailed warranty log available through VT Physical Plant
Bioinformatics Phase II	David Gibbs, Senior Facilities Mgr. Virginia Bioinformatics Institute	Owner rep; involved in process since completion of structural construction; currently serves as senior facilities manager	Very limited Cx log available; last updated 4/1/05	No warranty log available through VT Physical Plant; limited information available at departmental level
Chem/Physics Phase II	Thomas Bell, Assistant Chair; Research & Special Projects	Owner rep for Chemistry Dept.; design phase; currently manages space assigned to Chemistry	Retro Cx report on exhaust fan system dated 8/29/05	Limited warranty log available through VT Physical Plant (punch list items are available)
Ag/Forestry	Dennis Gehrt, Director of College Facilities, CALS	Was not involved in design or construction of facility; currently manages building	Detailed Cx log available; last update 12/20/05	Warranty log available through VT Physical Plant; however, building came on line only in July '06

4.1 Chemistry/Physics Building

Project Description

The Chemistry/Physics Building opened for classes in spring 2004 and supports programs for both the Chemistry and Physics departments at Virginia Tech. The 85,000-square-foot building reaches four stories high and includes laboratories and classrooms used specifically for teaching of undergraduate courses. To aid the Chemistry Department's teaching program, the building has four laboratories devoted to organic chemistry as well as upper-level chemistry labs, a polymer lab, several computer labs, microbiology labs, and numerous learning centers for students who need tutoring outside of class.

Photo Source: www.phys.vt.edu

In support of the Physics Department, the building features a 100-person lab with state-of-the-art technology measuring everything from electromagnetic fields to friction. A "lecture theater," complete with a "cat walk" to assist in experimental demonstration, accommodates more than 200 students.

Commissioning Efforts

Building commissioning was not incorporated into the Chemistry/Physics capital project initially. However, after several issues were identified with the lab exhaust fans, an engineering firm was hired to conduct retro-commissioning on the facility's lab exhaust system.

In 2005, Affiliated Engineers of Chapel Hill, North Carolina, began a thorough review of the lab exhaust system in the Chemistry/Physics facility. It was determined that the installed system had never functioned as intended or as designed. It is the opinion of the engineer conducting the review that "a competing, yet…non-conforming system was allowed to be installed" (AEI, 2005).

Three primary areas of malfunction were identified. First, the fan motors installed were completely enclosed type units which, with the covers in place, limited cooling airflow. Secondly, isolation dampers were considered inadequate. Leaks on the individual isolation dampers on the exhaust fan inlets resulted in a backward rotation of the fan wheels prior to start up. Finally, the exhaust fan motors were drawing more amperes than the specified rating.

Addressing Problems

Once the problems with the exhaust system were identified, corrective actions were taken. The covers on the fan motors were replaced, allowing for cooling air flow. Figure 7 shows the original covers installed on the fans, and the motor with the replacement cover is shown in Figure 8 .

(Photos: AEI)

Figure 7*:* Original Fan Covers – "Totally Enclosed-Fan Cooled"

Figure 8: Fans with new cover in place

Isolation dampers were replaced with better quality dampers that eliminated the backward rotation of the fans prior to startup. Figure 9 shows the original arrangement and set points of the system and Figure 10 shows the corrected recommendation which was accepted and modifications that were made.

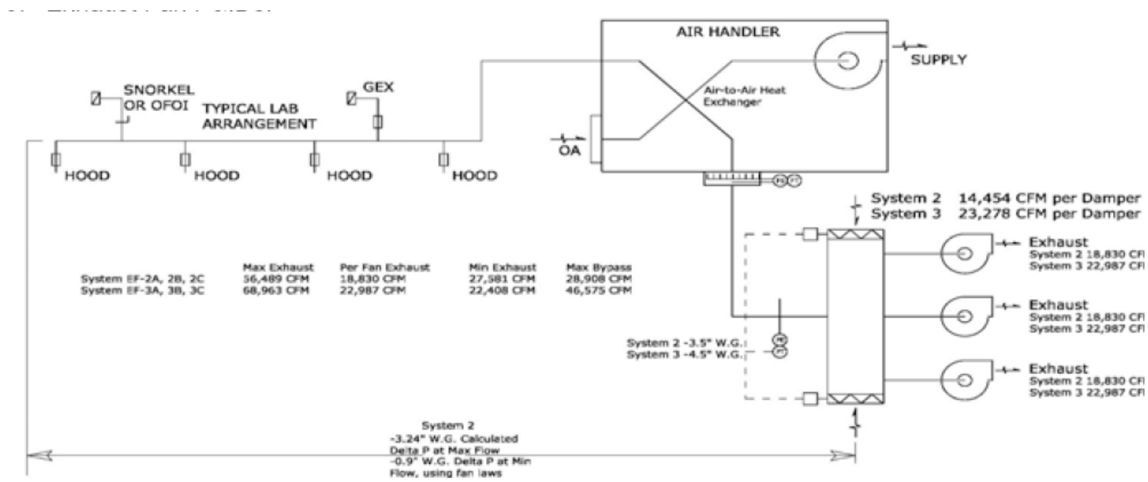


Figure 9: Exhaust System Schematic – Original Arrangement and Set Points
(Source: AEI)

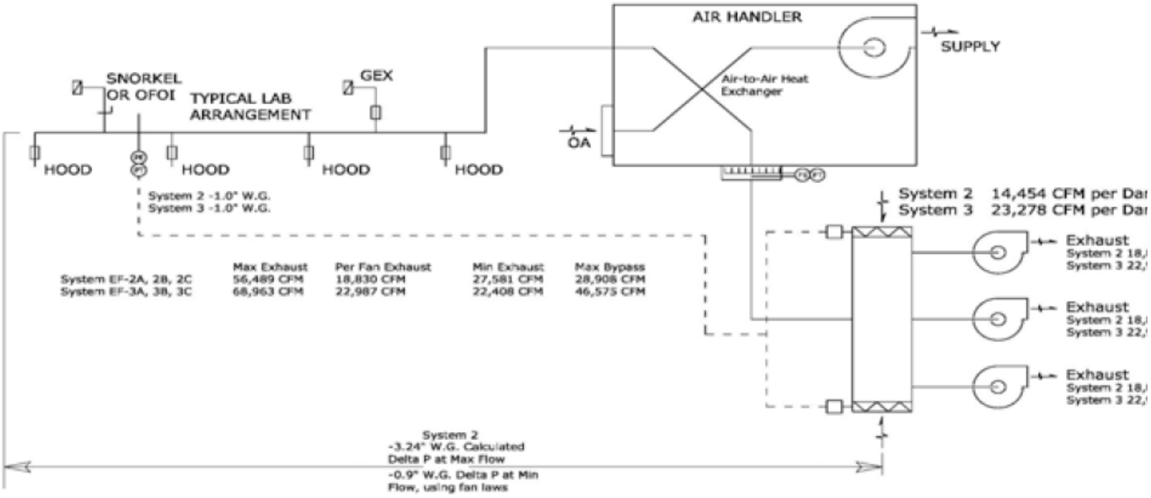


Figure 10: Exhaust System Schematic – Modified Arrangement and Set Points
(Source: AEI)

The commissioning engineer recommends that a university standard be developed for critical systems such as this to avoid similar problems in future projects. Better coordination is needed to ensure non-specified equipment that is accepted conforms to the design intent of the systems. Additionally, if non-specified equipment is approved as a replacement, it is recommended that the engineering consultant for the project be involved in coordinating the change in equipment.

Warranty Issues

The warranty issues log for this facility is very limited. However, as indicated above, many of the issues related to the exhaust system were handled under the retro-commissioning effort. Warranty items remaining on the list in January 2005 pertained mainly to general building conditions versus more serious mechanical issues. These include problems with fume hoods sticking, corrosion in an acid storage cabinet, peeling paint, and reworks required on toilet partitions.

According to the building manager for Chemistry, Thomas Bell, most of the warranty issues reported to him (outside the major problem with the exhaust system) were general in nature as well. There were issues with faulty latches and hardware on cabinets and drawers. A change proposal in the deliveries area resulted in shipments being redirected across the slate flooring in the main entrance of the building. This has caused some breaking of the slate which had to be repaired. Additionally, some drains were not properly installed in the lab sinks, resulting in leaks beneath the sinks.

Current Status

According to Bell, it took approximately a year to get the building to a comfortable level for the occupants. Bell indicated that many of the problems with the facility at this time are being handled by the VT Physical Plant preventative maintenance crew, and he may not be aware of some of the current complaints. However, with the exception of issues resulting from low quality of material in the casework, he considers the building to currently be functioning at an acceptable level.

4.2 Bioinformatics Facility I

Project Description

The Bioinformatics Phase I facility is home to the Virginia Bioinformatics Institute (VBI), a Commonwealth of Virginia shared resource established at Virginia Tech in July 2000. Research performed at VBI incorporates biological research with state-of-the-art computer science. The research serves to increase the understanding of molecular, cellular, and environmental interactions that affect human health, agricultural systems, and the environment.

Photo Source: Ivan Morozov, VBI

By integrating experimental and computational laboratories, VBI provides a unique research platform to all stakeholders, and some services are provided on a cost-recovery basis. Because much of the research is grant funded, it is critical that the facility perform at a high standard to meet sponsor expectations.

The three-story research building, totaling 57,077 square feet of space, includes offices, conference rooms, labs, and lab support areas. VBI faculty and staff occupied the facility in December 2003.

Commissioning Efforts

Bioinformatics Phase I was the first capital project at Virginia Tech to be commissioned (Elvey, 2006). Commissioning of this facility was performed by RMF Engineering, Inc. (RMF), a consultant contracted through the A/E team, Calloway Johnson Moore & West. Cx efforts began at about 85% construction completion and were limited to the performance of the major mechanical, electrical and plumbing (MEP) systems. The scope of commissioning efforts included:

1. Mechanical Systems
    a. Chilled water systems
    b. Heating water systems
    c. Air handling systems
    d. Air distribution and exhaust systems
    e. Computer Room and unitary air conditioning systems
    f. Automatic temperature controls
    g. Testing, adjusting and balancing (TAB) evaluation

2. Electrical Power Distribution Systems

3. Plumbing Systems and Equipment

Despite incorporating the Cx effort well into the construction phase, 86 total issues were identified and submitted for correction by the design team or the contractor. Table 4 provides a sample of the problems identified.

Table 4: Sample of commissioning issues identified - Bioinformatics Facility Phase I

System/Unit	Problem	Area of Responsibility	Date Identified	Date Corrected	Corrected Pre- or Post-Occupancy?
Mechanical - Refrigerant Sensors	Refrigerant sensors location incorrect	Mechanical Contractor	10/03	2/04	Post
Mechanical - Exhaust fan	Exhaust fan isolation damper actuators located on roof not properly weatherproofed	Mechanical Contractor	10/03	1/04	Post
Electrical - Generator	Generator not connected to ATS switches nor is placed in service	Electrical Contractor	10/03	12/03	Post
Electrical - Condenser water piping	Electric heat tracing not installed on condenser water piping	Electrical/Mechanical Contractor	10/03	1/04	Post
Mechanical - Steam pressure	Steam pressures at inlet and outlet of both pressure reducing stations do not match scheduled values	Mechanical Contractor	10/03	2/04	Post
Mechanical - Condensate pumps	Owner furnished duplex condensate pumps – noisy operation	Mechanical Contractor	10/03	3/04	Post
Mechanical - Hot water generators	HX-1 & 2 blocked by floor mounted VFDs serving chilled water pumps; need to relocate	Mechanical Contractor	10/03	7/04	Post
Electrical -Steam generators	No power to steam generators in penthouse	Electrical Contractor	11/03	1/04	Post
Building Automation -O&M documentation	Documentation needed on operational stability and networking status.	Controls Contractor	11/03	2/04	Post
Building Automaton/Mechanical – AC Units (Comp. Lab)	Liebert AC units indicating "New alarm: low humidity."	Controls Contractor	12/03	2/04	Post
Mechanical – Heat recovery wheels	Review purge angle settings and adjust accordingly	Field Engineer	12/03	8/04	Post
Electrical – Emergency power to AHUs	Power circuits to AHU1 and AHU2 supply and exhaust fans not properly coordinated	A&E/GC	12/03	7/04	Post
Electrical – Fume hood	No power to lab fume hood	Electrical Contractor	12/03	1/04	Post

System/Unit	Problem	Area of Responsibility	Date Identified	Date Corrected	Corrected Pre- or Post-Occupancy?
Mechanical – Balancer control setpoints	Control overrides in place on reported room temperature, temperature setpoint and control setpoint in various office areas	Control Contractor	12/03	2/04	Post
Building Automation – Siemens Controls	Graphics package not complete for floor views and lab zones	Control Contractor	12/03	3/04	Post
Plumbing – RO/DI system	RO/DI system in alarm for quality, continuity. Needs proper flushing	Mechanical Contractor/Vendor	12/03	1/04	Post
Mechanical - Air vents	Excessive noise throughout building; missing sound attenuators	A&E/General Contractor	12/03	8/04	Post
Mechanical – Exhaust terminal	Exhaust terminal unit appears to be high on airflow and is noisy.	Control Contractor/A&E	1/04	8/04	Post
Electrical – Power outlets	Wiremold receptacles do not have power.	Electrical Contractor	1/04	1/04	Post
Mechanical – Terminal unit setpoints	Lobby air is too cold; terminal unit appears to be unable to function properly	A&E/Controls Contractor	1/04	8/04	Post
Mechanical – Coordination issue	Office areas near tie-in to new construction on Bio II facility construction; exposed to exterior conditions/air penetration through transfer grills	General Contractor	1/04	8/04	Post
Siemens Controls	No analog thermometers installed at AHUs	Controls Contractor	4/04	8/04	Post
Mechanical – Chiller control	Strainers for chilled water contain debris; need to be blown down	General Contractor	5/04	7/04	Post
Mechanical – AHU sensor cap bulb	ANU temperature sensor cap bulb on floor of discharge section	Mechanical Contractor	7/04	8/04	Post

Source: CJMW/RMF Commissioning Log PC208-16485-01 – May 2005

Addressing Problems

As indicated from the sample above, although many problems were identified during the construction phase, few (if any) were corrected prior to owner occupancy. According to the Senior Facilities Manager of VBI, David Gibbs, callbacks as a result of the delay in correcting these problems post occupancy created a disruption to the occupants of the facility on many occasions. In addressing the atrium HVAC noise concern, an entire lab would have to be shutdown as the VAV supply terminal box to the atrium area is located above the ceiling in the lab. Therefore, this circumstance delayed effective corrective action and ultimately no such action was taken. In other instances, labs were either inoperable or operating at a lower level of performance due to lack of steam resulting from a callback to correct the steam problem.

The discovery of leaking reheat coil control valves due to corrosion caused by improper chemical treatment resulted in inadequate temperature controls and led to all reheat valves needing to be replaced. This problem created an inadequate temperature issue, resulting in many complaints by the faculty and staff occupying this space.

Another item that was identified through Cx but not addressed by the capital project team was overheating in the mechanical room. After the RO water system malfunctioned, it was discovered that inadequate ventilation (through design) resulted in overheating in the mechanical space. Although it was too late for correction through the construction process, Virginia Tech renovations personnel assumed responsibility for this correction using remaining capital project funding.

Warranty Issues

As previously stated, the commissioning efforts at this facility focused on the MEP systems installed in the building. Therefore, many of the items that fall within the MEP category were addressed early in the occupancy stage and are not reported on the warranty (callback) log. Only 6 of the 81 items listed on the warranty list maintained by VT Physical Plant relate to MEP problems. The majority of the items on the list pertain to envelope issues, and specifically window and roof leaks (17 of 81 items).

Current Status

According to Gibbs, the occupants of the Bioinformatics Phase I facility currently are comfortable. There are still issues with the noise from certain air vents, but this has been addressed to the extent of current practicality. In addition, there are still issues with steam hammering noises. This is apparently a design issue that if addressed, will be at the expense of VBI. Humidifiers in this facility are not being demineralized properly, resulting in a residue being left behind due to inadequate blow-down processes.

Of utmost concern are the issues still surrounding the roof and window leaks. The building has been occupied for almost three years, and the window leaks (resulting from incorrect installation of flashing within the CMU, Hokie Stone, and pre-cast wall systems) are still an ongoing complaint. In addition, the roof leak identified during construction still has not been resolved. VT Physical Plant continues to address these problems outside of the contractor’s warranty obligation.

4.3 Bioinformatics Facility Phase II

Photo Source: Ivan Morozov, VBI

Project Description

Bioinformatics Phase II provides an additional 72,000 square feet of space to the Virginia Bioinformatics Institute. This space consists of general and computational labs, lab support, administrative and research office space, as well as a 3,000 square foot conference center.

As this facility and the Phase I facility were being constructed simultaneously, coordination efforts were of utmost importance. In addition, many of the Phase I systems also serve the Phase II facility. This facility was occupied in mid-December 2004.

Commissioning Efforts

As with Bioinformatics Phase I, commissioning of this facility was also performed by RMF Engineering, Inc. (RMF) and were also limited to the performance of the mechanical, electrical and plumbing (MEP) systems. The scope was the same as that of Phase I and also included:

1. Mechanical Systems
    a. Chilled water systems
    b. Heating water systems
    c. Air handling systems
    d. Air distribution and exhaust systems
    e. Computer room and unitary air conditioning systems
    f. Automatic temperature controls
    g. Testing, adjusting and balancing (TAB) evaluation

2. Electrical Power Distribution Systems

3. Plumbing Systems and Equipment

Cx services were incorporated into the latter stages of the design and bidding phase of this facility. As of March 2005, there were 28 issues identified in the commissioning issues log for this facility. Of these, 14 items are shown as resolved and 14 are listed as being still unresolved. No updated logs have been issued to date so it is unclear as to how many of these items are still unresolved. A random sample of the items listed in the commissioning log of March 2005 is provided in Table 5.

Table 5: Sample of commissioning issues identified - Bioinformatics Facility Phase II

System/Unit	Problem	Area of Responsibility	Date Identified	Date Corrected	Corrected Pre- or Post-Occupancy?
Mechanical – Exhaust	Use of plenum boxes at 3rd floor exhaust diffusers; plenum boxes were noted at multiple 3rd floor lab exhaust grilles. Potential for noise	A/E	7/04	9/04	Pre
Mechanical - AHU	Wood insulation inserts: Wood insulation inserts were noted at chilled water pipe hangers in AHU-3/4 service corridor; not per spec.	A/E	7/04	Unavailable	
Mechanical – HVAC	Maintenance access to Supply Terminal Unit 114: Noted limited access; limits maintenance access	Mechanical Contractor	7/04	8/04	Pre
Mechanical – Chiller	Refrigerant evacuation system in Room 153: Chillers operational prior to refrigerant monitoring & evacuation system; safety concern	Mechanical Contractor	7/4	10/04	Pre
Mechanical – Vent Piping	Vent piping on mezzanine: vent pipe from vacuum plant is tied into the steam relief pipe; detrimental to vacuum plant	Mechanical Contractor	10/04	Unavailable	
Mechanical – Chiller	Chiller CH-3 Oil Pump: Oil pump was found to be seized; non functional.	Mechanical Contractor/Vendor	10/04	Unavailable	
Mechanical – Chiller	Pneumatic Control Tubing at Chillers, Compressor Filter Pipe: Needs to be supported properly; incomplete work	Mechanical Contractor	12/04	1/05	Post
Building Automation – Chiller	Location of temperature sensor in chilled water return piping; installed location will not sense true mixed water temperature	Controls Contractor	12/04	1/05	Post
Mechanical – Manual Steam Valves	Lubrication of manual steam valves in mechanical room;	Mechanical Contractor	12/04	Unavailable	

System/Unit	Problem	Area of Responsibility	Date Identified	Date Corrected	Corrected Pre- or Post-Occupancy?
	difficult operation				
Building Automation – Chiller	Missing wire tags in chiller control cabinets; incomplete work	Controls Contractor	12/04	Unavailable	
Mechanical – Condenser Piping	Exposed condenser water piping on roof: heat trace and insulation does not appear to be a contract requirement; potential for freezing	A/E	12/04	12/04	Post
Mechanical – Humidifiers	Steam humidifier operation – Control valves not installed and humidifiers not operational; incomplete work	Mechanical Contractor	12/04	Unavailable	
Building Automation – AHU	Unfamiliar test plan for AHU ATC: a test plan other than one submitted and approved was brought on site by Siemens; impractical to conduct test	Controls Contractor	12/04	12/27/04	Post
Building Automation - Controls	Facility is not connected to campus controls network; incomplete work	Controls Contractor / Owner	12/04	1/05	Post
Mechanical – HVAC	Leaking seal at heat recovery pump in AHU-1	Mechanical Contractor	12/04	Unavailable	
Mechanical – AHU	Suction pressures differ at heat recovery pumps in AHU-1; indicative of plugged strainer	Mechanical Contractor	12/04	Unavailable	
Building Automation – HVAC	Supply Air Terminal: Reheat valve is not responding to automatic control	Controls Contractor	12/04	Unavailable	
Mechanical – HVAC	Supply air Terminal: reheat valve does not appear to be closing fully. High discharge air temperature	Mechanical Contractor	12/04	Unavailable	
Building Automation – Chilled Water	Submit results of chilled water plant automation system testing	Mechanical Contractor/ Siemens Controls	12/04	1/05	Post

Source: CJMW/RMF Commissioning Log PC208-16485-02 – March 2005 (Initial Draft)

Addressing Problems

As noted from the issues presented in the sample commissioning log, there are many issues that are on record as having not been resolved at the time of the commissioning process closeout in March 2005. David Gibbs, who also manages the Bioinformatics Phase I Facility, indicates that some of the issues were resolved, but others still are outstanding.

At the time of turnover, there were still problems with the RO/DI water system in that the total organic carbon was too high; the wrong piping material was used in some areas and the water treatment resins were incorrect. Additionally, piping from the humidifier to the steam distribution units is carbon steel. This is creating a problem with rusting and rapid deterioration in all four air handling unts.

Warranty Issues

At the time of this writing, warranty/callback records are not available from the Physical Plant Department for the Phase II Facility. However, according to Gibbs, the envelope of this facility is performing much better than the Phase I facility, but there have been significantly more mechanical issues.

As with the Phase I Facility, the mechanical room in Phase II also had a problem with overheating. Once this issue was identified in Phase I, additional venting was added in the mechanical room of Phase II. However, this solution still proved inadequate. This problem was addressed by VT Renovations at the same time as the Phase I mechanical room correction.

An ongoing warranty issue resulted from inadequate drainage in the parking lot. This resulted in pools of water and winter ice forming in a large area of the parking lot, and at times running into the mechanical room. This issue was addressed by Virginia Tech outside of the warranty period.

Other issues noted by Gibbs as being present at substantial completion include some curtain wall leaks; high humidity (prior to Cx completion); freeze stat shutdown of the air handling units; and issues with the humidifier controls.

Current Status

Based on information provided by Gibbs, it is his feeling that the commissioning report provided by RMF (indicated to be in draft form) does not provide a demonstrated value of the commissioning project and its management. It is still unclear as to if systems testing was ever completed. Additionally, the commissioning log provided is much abbreviated; an updated log showing status of unresolved issues has not yet been provided.

It has been discovered that the piping from the humidifier to the steam distribution units is carbon steel. This is creating a problem with rusting. Also, there is no trap drain on the humidifier distribution manifolds, even though these drains are clearly shown on the construction drawings. This has resulted in rusty condensation being dumped directly into the bottom of the air handling units. Although the design appears to have been correct initially, a change apparently took place during the construction phase. As currently installed, there is potential for mold and corrosion. No solution has been identified at this time.

Although for the most part occupants appear to be comfortable in the facility, there have been some problems in the open office areas on the southwest side of the building. The glazing in the curtain wall in this area allows too much sun and heat penetration, resulting in overheated offices with too much glare. VBI assumed responsibility for adding light filtering shades as well as reflective coating on this glass to assist in cutting down the glare and reducing the heat penetration.

4.4 Holzman Alumni and Skelton Conference Center, and The Inn at Virginia Tech

Project Description

Virginia Tech's new alumni and conference center facility is composed of three different programs—an alumni center, a conference center and a hotel. The building totals 193,000 square feet of space of which 29,000 square feet supports the Holzman Alumni Center; 75,000 square feet serves as the Skelton Conference Center; and a hotel operation (The Inn at Virginia Tech) utilizes the remaining 89,000 square feet. The facility was occupied June 2005.

Photo Source: www.vtmagazine.vt.edu

The Holzman Alumni Center includes an area known as "the Grand Hall," boardroom, library, museum, gallery, and a conference hall shared with the conference center. Office space for the staff of the Virginia Tech Alumni Association is also included in this section of the facility.

The Skelton Conference Center houses a banquet hall that seats up to 800 people in addition to a pre-function space. There are also two 20-seat private dining salons, a 60-seat restaurant, and a café. More than 5,000 people can be accommodated in the indoor function area and outside terrace spaces.

The Inn at Virginia Tech is made up of 143 guest rooms, six executive suites, and a fitness and wellness facility. It also provides a demonstration kitchen and classroom for use by Virginia Tech's Department of Hospitality and Tourism Management.

Commissioning Efforts

The Alumni/Conference Center project is one of the first capital projects on the Virginia Tech campus to have incorporated a commissioning scope throughout the project (Kuykendall). A third party commissioning agent, Engineering Economics, Inc., was contracted to commission the central building automation system (BAS), the HVAC system, and testing and balancing (TAB) review. The scope of the project included developing the Cx plan, review of equipment submittals for commissioned systems, monitoring system start-ups, and providing a comprehensive Cx record and detailed system manual. Commissioned equipment included:

1. Chilled water system
2. Heating hot water
3. Air handling units (8 total)
4. Exhaust fans (ventilation, dishwasher, rack oven)
5. Kitchen hood exhaust and makeup air system
6. Variable air volume terminal units
7. Unit heaters
8. Vertical and horizontal fan coil units

An executive summary provided by the commissioning agent outlines critical issues discovered and corrected during the following stages:

1. Equipment submittal review and functional test writing
2. Construction observations
3. TAB backcheck
4. Functional testing

The summary also outlines issues discovered that remained to be corrected at the time of completion of the commissioning efforts. A lessons learned section provides helpful information for future commissioning efforts. Based on the opinion of EEI, issues resolved will benefit the operation of the facility through both energy and maintenance cost savings. Table 6 outlines some of the issues identified during the commissioning efforts.

Table 6: Sample of commissioning issues identified

System/Unit	Problem	Area of Responsibility	Date Identified	Date Corrected	Corrected Pre- or Post-Occupancy?
Building Automation – ATU	ATU-324 Max airflow should be 1600 CFM, 660 CFM cooling min and 800 CMF heating min.	Controls Contractor	4/04	7/04	Pre
Documentation	Sequence of operation need to have the correct valve, damper and sensor designations. They do not match schematics.	Controls Contractor	3/04	7/04	Pre
Building Automation – Chilled water system	If hotel is brought online before the conference center the chilled water system must be completed and functionally tested.	Controls Contractor	3/04	2/05	Pre
Mechanical – Vertical fan coil units	During observation…vertical fan coil units were laying in water. Potential IAQ problem with internal insulation getting wet.	Mechanical Contractor	4/04	8/04	Pre
Mechanical – Ductwork	Ductwork on 4th floor Hotel has been installed and insulated with external insulation. During observation rain was pouring into the building on top of the insulation; potential IAQ problem as mold could grow in wet insulation.	Mechanical Contractor	4/04	8/04	Pre
Mechanical – AHU	Unable to open one of AHU-1 access doors due to a conflict with a building column.	Mechanical Contractor	7/04	9/04	Pre
Mechanical – Chilled water system	With the stated cooling tower setpoint optimization parameters entered and programmed, what is the reset curve?	Vendor	9/04	12/04	Pre
Mechanical – AHU	All AHUs: Heating valves are normally closed. Mechanical contractor needs to inform controls contract to open heating valves before flushing heating water system.	Mechanical Contractor	9/04	12/04	Pre
Mechanical – Ductwork	Area where ductwork is being stored on site and areas where ductwork is already hung – must ensure these areas must be covered and sealed. Dirty ductwork will need to be cleaned as specified.	Mechanical Contractor	12/04	5/05	Pre

System/Unit	Problem	Area of Responsibility	Date Identified	Date Corrected	Corrected Pre- or Post-Occupancy?
Mechanical – AHU	Need to receive location of the following sensors for this unit. DPTE-2 – supply duct pressure sensor; DPTE-4 – space pressure sensor and SD-1 return duct smoke detector.	General Contractor	12/05	4/05	Pre
Building Automation – AHU	There is a discharge air and mixed air temperature sensor installed on this unit. The controls submittal does not show these sensors. How are these sensors used, for monitoring or is there a sequence change?	Controls Contractor	12/05	2/05	Pre
Mechanical - AHU	TAB Back Check: AHU-08: A review of the TAB report of the supply diffusers indicates areas of the distribution system that are significantly low on airflow…With few exceptions the readings in the TAB report for the supply diffusers were repeatable. The issue of low airflow in the supply distribution system will require further examination and possibly some mechanical changes.	Owner/Engineer	4/05	8/05	Post
Mechanical – AHU	AHU-08: General: Making a significant amount of noise on the 4th floor. The noise is a mixture of mechanical noise…and air velocity noise…The AHU mechanical noise is a high pitch noise that seems to be coming from the supply fan. It may be possible to install a larger fan to reduce the high frequency noise coming from the supply fan.	Owner/ Manufacturer	4/05	12/05	Post
Mechanical/Building Automation - AHU	FTP-002B: AHU-3: Section IV.A2: Damper calibration: The DDC command value is correct to the damper set; however, the relief damper is not opening fully when commanded to do so.	TAB Contractor	6/05	11/05	Post
General – Chiller Room	Life Safety: Chiller room Access/Egress: The connecting door from the chiller room to the boiler room has a lock on it. This lock will prevent egress from the chiller room in the event of a refrigerant release.	General Contractor	6/05	12/05	Post

Source: Commissioning Final Report for VPI&SU Holzman Alumni Center, Skelton Conference Center, & The Inn at Virginia Tech. February 27, 2006.

Addressing Problems

Based on information provided in the "lessons learned" section of the commissioning report (EEI, 2006), all concerned parties cooperated fully in resolving identified issues. As noted in this section of the report, many of the issues identified may have been found earlier had complete pre-functional checklists of equipment been provided. Although 45 items were identified during equipment review and functional testing as being attributed to limited detail in the controls submittal, both the design engineer and controls contractor's personnel responded in a timely and positive manner.

It is also noted that the Virginia Tech Capital Design team was also supportive of and responsive to the commissioning agent's questions and recommendations. It is the feeling of the commissioning agent (per his comment in the final report) that the owner could further benefit in solving problems as they arise by having their own personnel be more proactive in the commissioning efforts.

As the building manager, Chris Compton, did not participate in the commissioning effort, he was not knowledgeable of the full extent of issues resolved through this effort. However, he did indicate that he feels the systems that were commissioned are functioning properly, and that any issues that did arise were addressed in a timely fashion through coordination by CDCD and the General Contractor.

Warranty Issues

As this facility is considered a university auxiliary, an official warranty log is currently not available through VT Physical Plant. According to the Compton, however, there have been very few callbacks received on HVAC issues. Most air quality issues were resolved within a few months of occupancy. Following substantial completion, there was a problem with one of the cooling towers. However, this was resolved through coordination by the GC with the mechanical and HVAC subcontractors. Compton indicated that the majority of HVAC and controls issues were resolved prior to occupancy. He indicated that there were some initial complaints relative to temperature controls, but that these issues were resolved in a timely fashion and occupants complaints diminished within three months of occupancy.

Current Status

Problems still existing in the building include incorrect placement and specification of sewage vents. In some cases, sewage vents are located near the intake of the HVAC system. The Center assumed the cost of extending the vent pipes to correct this problem. Another major concern is that there are no automatic wet traps in the facility (including restrooms, guest rooms, and equipment rooms). This creates a concern as fumes in the plumbing due to traps getting dry provide a route for gas escape, creating odors in most areas of the facility, including guest rooms. All traps have to be manually flushed to prevent the gases from escaping. In addition, all plumbing for bathtubs in the guest rooms were placed back to back, leaving no access for plumbing leaks without tearing out the walls.

Overall, Compton feels the building is functioning at an acceptable level. Oddly, the primary complaint received by occupants and guests of this facility is not directly related to construction of the facility, but rather complaints of limited cell phone service throughout the building.

4.5 Latham Hall

Project Description

Latham Hall, occupied in July 2006, represents more than 25 years of planning in an effort to replace antiquated research spaces no longer adequate for their intended purposes. The 85,000 square foot facility serves as the Agriculture and Natural Resources Laboratory and bridges the research conducted between the College of Agriculture and Life Sciences and the College of Natural Resources. The facility is comprised of flexible, state-of-the-art research laboratories and lab support spaces, and faculty and staff office space.

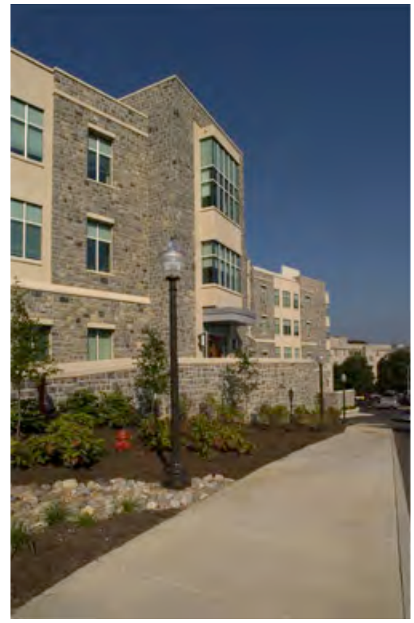


Photo Source: www.cals.vt.edu

For the College of Agriculture and Life Sciences, research conducted in the facility encompasses crop and soil environmental sciences; entomology; plant pathology, physiology and weed science; and horticulture. This program occupies approximately 75 percent of the space in the building. The remaining 25 percent of the space is used by the College of Natural resources in support of programs in the departments of forestry and fisheries and wildlife sciences.

Commissioning Efforts

Affiliated Engineers, Inc. (AEI) of Chapel Hill, North Carolina, was hired by the university as a third party commissioning agent for this project. Commissioned systems include:

1. Mechanical Systems
   a. Air handling units
   b. Water cooled chillers
   c. Cooling towers
   d. Heat exchangers
   e. Pump packages (chilled water, hot water and condensate)
   f. Heat recovery coils
   g. Clean steam generator
   h. Heating terminal units
   i. Exhaust fans
   j. Space temperature and pressurization control of lab space

2. Electrical Systems
   a. Building automation system (BAS)
   b. Emergency generator and related transfer switches

Commissioning efforts for this project began at the beginning stages of construction, and after the contract had been awarded. The Cx agent (CA) was responsible for reviewing project documentation, performing on-site observations, and providing feedback to the project team; participating in test start-ups and equipment training; reviewing of O&M manuals; and coordinating commissioning activities. The CA also verified TAB reports, control component calibration, and equipment performance certification. Recorded Cx results were recorded and are to be included in a final commissioning manual to be provided to the owner. As this project was completed only in July 2006, at the time of the writing of this report, no final commissioning report has been provided. However, a draft commissioning issues log was provided as an example of issues identified. Excerpts from this log are included in Table 7.

Table 7: Sample of commissioning issues identified

System/Unit	Problem	Area of Responsibility	Date Identified	Date Corrected	Corrected Pre- or Post-Occupancy?
Mechanical – Chiller condensers	IAW spec 15010-1.12 C. found piping hookups on the condensers on both chiller 1 & 2 open to possible dirt & debris. Cover opening on installed butterfly valves to prevent debris from entering system and possibly affecting future system operation, dependability and life span.	Mechanical Contractor	4/05	7/05	Pre
Mechanical – HVAC	Location of VAV box…makes it tough to access control panel. Recommend moving gas pip to give better access to the box for maintenance	Mechanical Contractor	4/05	5/0	Pre
Mechanical – Gas	Emergency gas shut off valve for the labs – better design or location? Recommend checking placing on push button electric valves if possible; problem if an emergency for tenants to turn valves; push button would be quick and easy	A&E	5/05	5/05	Pre
Mechanical – Ductwork	Newly insulated stainless ductwork appears to be rusting at the welded joints; ensure no problems exist	General Contractor	5/05	6/05	Pre
Mechanical – Ductwork	Are turning vanes in the anti-microbial supply ducts coated correctly IAW specs?	General Contractor/ A&E	6/05	7/5	Pre
Mechanical – Ductwork	Insulation on ductwork penetrating the wall of cold freezer room does not appear to continue through the wall as required in spec.	Mechanical Contractor	6/05	8/05	Pre
Plumbing – Domestic water	In mechanical room, domestic water backflow station needs more support. There is a lot of movement in the piping on the ends and at the vent lint; could result in future leak and breaks in the joints	Mechanical Contractor	6/05	12/05	Pre
Mechanical – HVAC	Concern with anti-microbial paint applied to Siemen's VAV boxes; after paint dries, damper seals have stuck; upon release, paint has peeled in some places; concern with microbial issues	A&E/Controls Contractor	6/05	Not Available	

System/Unit	Problem	Area of Responsibility	Date Identified	Date Corrected	Corrected Pre- or Post-Occupancy?
Mechanical – Ductwork	Room 4B28 – section of duct that does not fit in space provided; wall stud was notched out. Need to review to ensure within spec.	A&E/ Mechanical Contractor	6/05	8/05	Pre
General – Walls	Many wall and ceiling penetrations in lab spaces not sealed; concern over room pressure problems in the future. Confirm if these should be sealed.	A&E	6/05	Not Available	
Plumbing – Hot water	In mechanical room, drains for hot water heaters are not piped to floor drains; recommend extending above floor drains to ensure proper drainage	A&E/ Mechanical Contractor	7/05	Not Available	
Mechanical – Fume Hood	On 3rd floor where fume hoods have been installed and service piping connections are in process of being made there appears	A&E/ General Contractor	8/05	Not Available	
Mechanical – Ductwork	Rm 4A28 duct insulation appears to be water damaged and needs to be replaced. Need to ensure insulation is repaired before ceiling tiles are installed	General Contractor	8/05	Not Available	
General	Rm 5A12 ductwork is soaked. A bucket has been placed on a couple of beams across the ductwork that appears to be catching water coming through a piece of conduit through the roof. Bucket has not been emptied resulting in over flowing and saturation of the insulation on the ductwork	General Contractor	8/05	Not Available	
Mechanical – Chemical storage fan	The vibration isolators on the chemical storage fan are bottomed out. It appears that the fan end vibration isolators are not sized correctly for the weight of the exhaust fan. Recommend checking specs to ensure proper rating on isolators	General Contractor	8/05	Not Available	
Mechanical – Fume Exhaust	Heat recovery coils are set in place on fume exhaust plenums. Some bent fins that need to be combed out. Due to coils being left out in the elements for months it is recommended that he coils be pressure washed to remove any dirt and debris	A&E/ General Contractor	8/05	Not Available	

Source: AEI Commissioning Issues Log for Ag/Forestry Research Laboratory Facility at Virginia Tech, Last Update December '05

Addressing Problems

Although the Cx report is not currently available, it is evident from the Cx log reviewed that many problems were resolved as they arose. The CA was careful to document area of responsibility as well as chronological progress on each of the issues identified. Based on the notes provided in the log, all parties were cooperative and responsive. The building manager, Dennis Gehrt, confers. Even though he became involved with the process only after occupancy, Gehrt indicates that contractors have been very responsive in addressing callback issues.

Warranty Issues

Having recently come on line, this building is at the beginning of the warranty period. The warranty log indicates some concerns with the fire protection system (missing control valves, leaks at existing valves inadequate drainage). Various issues appear relative to the deionized/pure water system. There are also recorded issues with noisy return ducts. Other warranty issues include window and roof leaks; problems with interior doors; and electrical breakers tripping often.

There are still some balancing issues with the HVAC system, and confirmation of air pressure/air flow is needed. Additionally, a blow-down separator is missing or not installed. It is perceived that this was an oversight in planning. Although there are some outstanding warranty issues, Gehrt feels these are being addressed sufficiently by both the project team and VT Physical Plant.

Current Status

According to Gehrt, the building is performing well overall. Occupants of the facility have expressed concern over the infrastructure available for research equipment, but this is more than likely a design concern rather than a construction issue. Also, heat issues in some of the spaces keep these rooms from being used as intended. Noise in the air supply vents continues to be an annoyance. Additionally, there are still concerns with tripping electrical breakers.

4.6 Summary of Sample Project Discussions

Although the same data was not available for each of the facilities used in the sample, various commonalities in the information collected were noted. Each building seemingly had issues with the Siemens control system. However, this is to be expected as Siemens is the sole proprietor for building automation on the Virginia Tech campus. Another common problem seemed to be with the VAV boxes and noises coming from air return and supply vents. Envelope leaks were also a common malady.

There are varying degrees of commissioning activities included in the sample projects. It was hoped that warranty callback logs would assist in determining the benefits of a thorough commissioning process versus limited or no commissioning efforts being incorporated. However, as some data was missing or limited relative to warranty callbacks, it is unclear as to if commissioning did in fact reduce the number of callbacks.

In speaking with the building managers as to their impression of the effectiveness of commissioning, several potential benefits were identified. At the university level, it is felt that buildings that are fully commissioned will function properly and will therefore be more efficient, reducing repair and energy costs. For building managers, operational issues will be reduced and the department will not inherit as many post-occupancy issues. For the occupants, indoor air quality will be more desirable and there will be fewer disruptions from callbacks post-occupancy.

A few examples of occupants being disrupted following move-in were provided by some of the managers. In one facility, a defect in the steam system resulted in shutting down an entire research lab section. Research in another lab was disrupted when the lab had to be occupied by contractors in order to address an issue with a VAV box. In those facilities where RO/DI water issues were present, multiple lab processes were affected. Occupants in another facility are inconvenienced by inadequate electric supplies.

It is the opinion of some of the building managers that it would be helpful to include the commissioning process in the design phase of all building systems, including the building envelope. It is felt, however, that commissioning during construction on the MEP systems only is sufficient. In buildings with no or limited commissioning, it was felt that incorporating an assertive commissioning effort would have helped to better ensure proper installation and operation of the HVAC, plumbing, and exhaust systems.

It is interesting to note also the benefits identified by the managers that may not be directly linked to the construction process. For instance, downtime of staff due to malfunctioning building systems causes not only productivity issues, but also can be directly related to loss in salary dollars. Additionally, there is a threat to owner-provided and installed equipment. When spaces housing equipment are disrupted by contractors addressing building problems, dust can damage the equipment. This problem may not become evident for several weeks or months following the callback visit, depending on the sensitivity of the equipment to dust. One manager also noted that in his facility, a piece of calibrated equipment was bumped during a callback, resulting in recalibration costs to the department.

It is also acknowledged that there are some issues that create problems for occupants that would not be addressed through the commissioning process. Some examples provided included inappropriate specification of product, the use of low quality materials due to the lowest bid process, and poor workmanship by the finishing contractors.

As to how high of a priority commissioning should be to a capital project, one manager stated, "Although the concept of commissioning seems helpful, budgetary constraints result in too little attention being directed toward maintenance concerns. This tends to be the predominant area of sacrifice." It was the opinion of some that funds should be added to the contingency line item dedicated for site preparation and change proposals as these areas seem to deplete funds that could be used for other purposes, such as commissioning. All managers interviewed are very supportive of commissioning and are pleased the university is moving in this direction with future projects.

Chapter 5: Results and Conclusions

The test hypothesis for this project states:

> Capital projects at Virginia Tech will benefit by incorporating commissioning into the scope of the project. These buildings will have fewer change proposals, fewer callbacks, fewer maintenance costs, and will result in a comfortable, productive environment for the occupants of the facility.

Although it was anticipated that a more comprehensive comparison of complete commissioning versus limited commissioning activities could be conducted, limited data prevented this step in this research process. In addition, data resources that were similar in nature contained different types of information. For instance, warranty logs on some buildings were rather detailed whereas others were very vague. Examples of the differing data provided in the warranty logs are illustrated in Figures 11 and 12.

Figure 11: Sample warranty log – limited details

Chemistry Physics Building Outstanding Warranty Issues

Area	Problem	Notes
Roof	Fans - Bearings and Dampers	Are working to rectify (Jan 2005)
309	Fumehood Sash Sticking	
	Acid Storage Cabinets Corrosion	
210A	Spray Nozzel Leak	
South Stair	Ceiling peeling	
Restroom	Reworked toilet partition issues	Partly completed as of Nov 15 - no other word otherwise
Roof	Panels on roof screens do not match color	
213	Repair Seimens controller in ceiling	
350	Ceiling leak	
Roof	Scraps	Originially thought to be completed, but after check up, there are many scraps on the roof
Rear Loading Dock	Roped off from concrete work	
	No abrasive on loading dock	

Figure 12: Sample warranty log – more complete details

WARRANTY ITEMS FOR BIOINFORMATICS-I

updated 10/8/04 by cf

WI	Warranty Item
OP	Original Punchlist
AP	Added Punchlist

ITEM #	ITEM TYPE	LOCATION SIGN # / PLAN #	DESCRIPTION	RT TRACKING #	DATE REPORTED	CONTRACTOR ACTION STATUS	VBI COMMENTS	BRANCH COMMENTS	CLOSED?
058	AP	Various	Drywall finish or paint poor (including at **projection screen closure at 325/305** and at least one restroom wall)				See Pictures	Branch to contact Service Contracting to remove drywall mud	
059	WI	Various wood veneer bulkheads, wall coverings and overhangs	Delaminating (and wrinkling) veneer; damaged finish; poor finish				See Pictures. Continuing problems. More locations have bubbled up since contractor "reironed" some.	Contractor will address delamination issues only; all others are added punchlist	
060	WI	224M/214 Reception Area Desks	Delaminating veneer; poor fit and elevation problems at mitered corners, etc.				See Pictures	Contractor will address delamination and elevation problems only; all others are added punchlist	
061	WI	114/113	Leak at lab waste line, above ceiling in 114 (coming from lab above?); discovered by Varney when locking steam valve and reported to Linda Correll		6/11/2004; 10/1/04		Per email from Emillie, 6/11/04. Not sure of source. Wet spot on ceiling tile gets bigger and then shrinks, but rarely dries completely. Could be rain water.	Branch to contact G.J. Hopkins to repair.	
062	WI	220A/225 PCR Lab	**Cyclic air flow** (**max** to near zero flow every few seconds) from supply grille, with accompanying metalic scraping sound from the duct during the low flow phase.		15-Jun	Siemens technician visited the room during week of July 4 at request of WDG. PID control was unstable. Technician adjusted PID control for air flow stability. Affect on air balance is unknown.	Per email to Emillie and John K. 6/15/04. VBI questions stability of control parameters, since occasional air flow deviations in other areas are noticed.	Branch to contact Siemens to investigate	
063	WI	Lab Vent Hoods	Noises in common exhaust ducts for **hoods on EF-10/11;** heard most noticably at hoods on 3rd floor; can also be heard from second floor; sounds like a heavy damper or door banging periodically.		May	Siemens technician visited the space during week of July 4 at request of Mechanical Balancing (Garland Hopkins) to adjust vent hood control gain and quiet for sound readings. Noise is quiter but still excessive. Control cylinders are apparantly moving stop-to-stop.	Follow-up conversation on 6/21 with Emillie; note to John K. RMF engineer said at site visit that control "hunt" and sounds from actuators were still excessive.	Branch to contact Siemens to investigate	
064	AP	Roof	Two locations: main roof drain and overflow drain plummed in reverse, or strainer/receptor hardware reversed (which?).		Per conversaton with Chuck Dixon, inspector with F&R, **6/22/04; 10/4/04**			CJMW to review with VT options for correcting: 1) revising tapered roof to slope to roof drain, or 2) plumb overflow drain at grade to nearest DI	
065	WI	Doors 301A, 302A, 123B	Latch mechanisms not functioning properly, causing secruity issues.		6-Jul	Best Access technician (Todd Johnson) responded on 7/8/04. 302A repaired. 301A has fault with locally alarmed push bar mechanism (mechanical) and pushes open at will (Skyline issue). Also worked on door 123B; wired hinge faulty, shows alarm for hold open when closed (Skyline issue).	Per email to Emillie on 7/6/04. Note:on door 301A, hall side permit switch from push bar was not wired and showed "forced" alarm; Best tech fixed. Wiring at door 123B was done very poorly! Best tech improved but then determined that hinge wiring & sensor was faulty.	Branch to contact Skyline/Best to investigate	

The commissioning logs contain a lot of useful information. Information in the commissioning logs were similar but these also varied somewhat. Each had differing qualities that were more helpful than others. However, it was unclear from some of the log entries and as to if the issues were each separate or related to another issue already identified. The following figures outline the characteristics of each log that were found to be helpful during this research process.

Figure 13: Cx Log – AEI

Commissioning Issues Log

Affiliated Engineers
Affiliated Engineers, Inc.
1414 Raleigh Road, Suite 305
Chapel Hill, NC 27517

Project:	Ag/Forestry Research Laboratory Facility, Virginia Tech, Blacksburg, Virginia
AEI Project No:	04445-00
Last Updated:	12/1/2006
File Location:	C:\Documents and Settings\Dawn Maxey\Desktop\P&R\[Running Cx Issue Log - Latham.xls]Log

No.	Date Generated	Noted By	Floor	Sys/Loc. *See *Note 1*	Field Report to Reference	Description	Recommendation	Resp Party	Date Resolved	Status	Date Action Anticipated (if Pending)	Action/Justification Taken
04445-01	4/7/2005	PAF	1st	Growth Rms	Field Report 1 Sec A.1A&B / Refer to Filed Report # 3 Sec. A4	Check access to VAV boxes for maintenance IAW spec #1510 1.07.A.	Move boxes to make them more accessible for maintenance.	~~GJH/ H&O (Boyd Headly)~~ Siemens		Re-opened ~~Closed~~	Pending	**9/14/05, 8/17/05 - Still awaiting drafted letter from Siemens to VT. 7/21/05 It has been determined that this will be investigated by Siemens and then a letter will be drafted to VT stating that they are satisfied with the location of the boxes. Until this letter is drafted this will remain open.** - ~~Boyd determined that the box closest to the wall needs to be reviewed to see if it is possible to make access easier IAW spec 15800-3.01C Steve Fisher and Randy Morrison of VT checked out the box locations and feel that they are satisfactory and feel that this issue is closed.~~
04445-02	4/7/2005	PAF/JJD	1st	Growth Rms	Field Report 1 Sec A.1C	General housekeeping – Found piping, valves and ductwork all just laying around uncovered, un-protected from possible damage and debris.	Recommend cleaning up staging areas and cover piping and valves to preserve till installed.	JEJ / GJH	6/16/05	Closed	X	Space has been cleaned up. Steve Fisher said he would look into this and get back on the outcome.
04445-03	4/7/2005	PAF/JJD	1st	Chiller Rm	Field Report 1 Sec. A.2A	Shrink wrap around control & electrical boxes needs to be resealed to prevent damage to equipment. Found dirt and debris in the bottom of the starter panel on chiller #2.	Recommend resealing shrink wrap on control panels and vacuuming out dirt from panel.	GJH		Pending	7/21/2005	Barry Johnson said he would look into resolving this issue. This is still an issue, Barry said he would follow up on it.
04445-04	4/7/2005	PAF	1st	Chiller Rm	Field Report 1 Sec A.2B	Need to blank	Cover opening on installed butterfly valves to prevent debris from entering system and possibly effecting future system operation, dependability, and life span.	GJH	7/21/05	Closed	X	**During this month's walkthrough it was witnessed that the piping has been installed to the valves on the chillers. Martin of JEJ claims the valves where cleaned off prior to the piping being installed. 7/21/05** ~~Barry Johnson said he would look into resolving this issue.~~
04445-05	4/7/2005	PAF/JJD	1st	Chiller Rm	Field Report 1 Sec A.2C	IAW spec 15010-1.12.C. Found piping hookups on the condensers on both Chiller 1 & 2 open to possible dirt and debris.	Recommend ensuring things like this are covered until install is complete to protect the systems during installation.	GJH	7/21/05	Closed		**It was witnessed that these openings have been taped up to prevent debris from entering chiller.** ~~Barry Johnson said he would look into resolving this issue.~~
04445-06	4/7/2005	PAF	2nd	Mech Rm 2A05 (P)	Field Report 1 Sec B1.A	General housekeeping – Found piping just laying around uncovered, un-protected from possible damage and debris.	Recommend cleaning up staging areas and cover piping and valves to preserve till installed.	JEJ / GJH	6/16/05	Closed	X	**Piping has been cleaned up.** ~~Steve Fisher said he would look into this and get back on the outcome.~~
04445-07	4/7/2005	PAF	2nd	Mech Rm 2A05 (P)	Field Report 1 Sec. B1.B	Foundation pad is not centered under water heater; frame work is N supported by wood blocks.		JEJ / GJH	7/21/05	Closed	X	**During monthly walk through it was witnessed that the pad has been enlarged to fit the base of the hot water heater.** ~~It was explained that the base will be re-poured to fit the foot print of the water heater. The original pad was pored to close to wtr htr #2.~~
04445-08	4/7/2005	PAF	2nd	Mech Rm 2A05 (P)	Field Report 1 Sec B1.C	Damage to top of hot water tank needs to be repaired.	and 1.11.F.	GJH		Pending	No Date	**9/14/05, 8/17/05 - Repairs are still not complete 7/21/05 - Repairs are underway.** ~~Barry Johnson said he would look into having the skin of the~~
04445-09	4/7/2005	PAF/JJD	2nd	Mech Rm 2A05 (P)	Field Report 1 Sec. B1.D	Steam traps on drip legs of steam supply piping to the hot water heaters, should these be inverted bucket traps due to the constant pressure of system?	Recommend checking to see if these are properly installed on a constant pressure condensate line.	H&O (Boyd Headly)	04/15/05	Closed	X	The F&T trap has better characteristics for both high air venting capability and high volume condensate handling without cycling. In the case of system start-up we believe the F&T is the better choice.
04445-10	4/7/2005	PAF/JJD	2nd	Mech Rm 2A05 (P)	Field Report 1 Sec. B1.E	Same question as above for the trap on the steam station. Should it be an inverted bucket?	Recommend checking to see if these are properly installed on a constant pressure condensate line.	H&O (Boyd Headly)	04/15/05	Closed	X	Same as above
04445-11	4/7/2005	PAF/JJD	2nd	Mech Rm 2A05 (P)	Field Report 1 Sec B1.F	There does not appear to be enough support for the piping on the steam station	Recommend placing more piping support on steam station piping. IAW 15610 2.08.					**It was witnessed during monthly walk thru that additional support has been added to sufficiently support the pipe.** ~~GJH stated that piping installation was still ongoing, they will let us know when it is completed so we can close this out.~~
04445-12	4/7/2005	PAF	2nd	Mech Rm 2A05 (P)	Field Report 1 Sec. B1.G	Check piping supports on steam piping coming from utility tunnel	Steam piping should be supported by rollers IAW 15610 2.08	JEJ / GJH/H&O (Boyd Headly)		Pending	No Date	**9/14/05 - Not corrected and now the piping has been insulated. 8/17/05 - Rollers still have not been installed on steam piping. 7/21/05 - Barry Johnson has taken responsibility to ensure that this is taken care of IAW specs.** GJH stated that ~~piping installation was still ongoing, they will let us know when it is completed so we can close this out. 6/16/05 Boyd Headly stated that IAW specs rollers should be installed, he is to send GJH written verification.~~

Note 1: Ensure if you use room numbers to designate whether it is a Planned (P) or a Final (F) room number.

Field report reference

Recommendations include reasons for suggested action

Historical information as to area of responsibility

Detailed historical information as to status

Figure 14: Cx Log – EEI

PROJECT: Virginia Tech Alumni Center — **PROJECT ISSUES LOG** — **Updated:** 8/1/2005

Item No. *	Date	Initiator	Equipment Tag	FTP Test No.	Description	Recommendation	Assigned To:	OPEN Issue	*Resolution/Backcheck Information*	Date Issue Accepted
PCR 004 1	5/25/04	JES	HWS	NA	On the heating water system pumps, we noticed that the contractor has used multi-purpose valves. It appears that these valves are line-sized. The contractor should verify, from the manufacturers pressure drop curves, that the proper pressure drop can be obtained to give an accurate flow reading. EEI requests a copy of the multi-purpose valve performance characteristics with flow vs. pressure drop curves from the contractor. (Mechanical Contractor)	Response needed	MC	Pending	The manufacturer sizes these valves for a pressure drop less than 10 psi. Valves were submitted and approved. If during the balancing of the system, the valves do not provide a n accurate reading. The reading will be taken on the suction and discharge side of the pump and by using the pump curve make the necessary adjustments to the valve (by opening or closing) to achieve the desired water flow. EEI: using the pu[illegible] curves to balancing the pump is a none accurate approach, as the pump curves [illegible] flat and have a high gpm range with a small pressure drop. **Will evaluate d[illegible]AB backcheck.**	
PCR 004 2	5/25/04	JES	CWS	NA	Same as Item #1 for chilled water system pumps.	Response needed	MC	Pending	**Same as 004-1**	
PCR 005 1	7/9/04	JES	Condenser Water	NA	On the condenser water system pumps, we noticed that the contractor has used multi-purpose valves. It appears that these valves are line-sized. The contractor should verify, from the manufacturers pressure drop curves that the proper pressure drop can be obtained to give an accurate flow reading. EEI requests a copy of the multi-purpose valve performance characteristics with flow vs. pressure drop curve from the contractor. (Mechanical Contractor)	Response needed	MC	Pending	**Same as 004-1**	
PCR 011 2	4/25/05	JES	AHU-08	NA	TAB Back Check: AHU-08: The back check of the exhaust diffusers of AHU-08 showed a system that is significantly deviant from design airflow values (Reference: Attached spread sheet). The test also indicated that the exhaust system is not proportionally balanced. These test results do not reflect the readings indicated in the TAB report.	Recommendation: Have the TAB contractor rebalance the exhaust system and submit the new report for a retest of the TAB back check. (TAB)	Owner/ Engineer		TAB rebalanced the entire system. Verify engineer/owner has approved.	
PCR 011 3	4/25/05	JES	AHU-08	NA	AHU-08: General: AHU-8 is making a significant amount of noise on the 4th floor. The noise is a mixture of mechanical noise (nearest the location of the AHU and air velocity noise (primarily in diffusers located closer to the AHU). The AHU mechanical noise is a high pitch noise that seems to be coming from the supply fan. It may be possible to install a larger fan to reduce the high frequency noise coming from the supply fan.	Perform a noise and vibration analysis of the AHU to isolate the source of the noise coming from the AHU. (Engineer)	Owner		Unit was rebalance and supply/exhuast fans were slowed. Verify owner has approved	
PCR 011 4					AHU-08: General: There is a significant amount of air velocity noise coming from diffusers on the 4th floor and from diffusers on the third floor as well. The diffuser noise seems to be primarily caused by the dampers in the supply air grills. The design of the ductwork precluded the proper use of balancing dampers in the duct far enough from the diffusers to reduce the air velocity noise at the grill. Most of the diffusers at fault are in the hall but there are some in the guest rooms that are very noisy.	Investigate the possibility of deleting those diffusers nearest the AHU in the hall and increasing the size of those hall diffusers further from the AHU to accommodate the increase in airflow and reduce any velocity noise at those diffusers. Investigate the possibility of increasing the size of the diffusers in the guest rooms to reduce the velocity noise in those diffusers. (Engineer)	Owner		Diffusers being deleted. Verify Owner has approved.	
PCR 011 5	4/25/05	JES	Boiler Recirculation Pumps	FTP-019	FTP-019: P-5 (A & B)-Boiler Recirculation Pumps: During normal operation these pumps run anytime the boilers are enabled (even when the boilers cycle off on internal setpoint). The building loop has a very hard time making setpoint when these pumps are running, even during periods of light load. If the pumps are secured (off) during operating conditions where the mixing valve is open to the boilers, the system is able to maintain setpoint easily. The purpose of these pumps is to maintain even temperatures in the boilers during periods when the building loop is not circulating water through the boilers and to prevent thermal shock when the building loop opens to the boilers. When the mixing valve is opening to the boilers (even a small amount) these pumps become redundant and in fact inhibit the ability of the building loop to maintain temperature setpoint. This was proven during the functional performance testing.	Have the controls contractor program the pumps to shut down when the mixing valve (V-1) is receiving an operating command signal greater than 10%. (Owner)	Owner			
PCR 011 6	4/25/05	JES	CRU-1	NA	The door to Penthouse Unit (CRU-1) has sprung and will not close fully.	Repair damaged door. (MC)	MC			
PCR 011 7	4/25/05.	JES	AHU-3 & 4	NA	The P/T plugs on the automatic flow control valves for AHU-3 and AHU-4 has been covered with insulation.	Remove insulation to allow access to the P/T plugs. (MC)	MC			
PCR 011 8	4/25/05	JES	Non-DDC Fan coil units	FTP-011	FTP-011: Non-DDC Fan coil Units: While performing the functional testing of the guest room fan coil units the following issues were discovered. [See PCR for unit spreadsheet]	Have the contractor correct the issues and schedule a retest of the failed units.	MC			
PCR 012 02	5/9/05	JES	Free Cooling	FTP-018	FTP-018: Free Cooling: The sequence requires that the chillers be locked out on a call for free cooling until the chilled water temperature exceeds the condenser water temperature by 5°. The controls contractor was unable to set up the control protocol to allow for this control variable. The condenser and chilled water pumps receive their start command from the chiller enable. If the chillers are locked out the pump won't run. If the pumps are given a separate command to run while the chiller is locked out the chiller will produce a fail to stop alarm on the pumps. The contractor programmed the free cooling to initiate at the changeover temperature regardless of the condenser temperature. The tower fans will control to the reduced tower water temperature setpoint until the tower water temperature is 5° below the CHWS temperature at which time the tower fan control will convert to the CHWS setpoint. This should be an appropriate control protocol to meet the design intent.	Leave the control protocol as it is currently programmed and edit the as-built control sequence appropriately.	Owner/ Engineer			

Separate column to record date issue was accepted by owner

Thorough descripton of unit/svstem

Figure 15: Cx Log – RMF, Inc.

CALLOW JOHNSON MOORE WEST
VIRGINIA TECH BIOINFORMATICS PHASE 1
PC#208-16485-01

Open Issues: 0
Closed Issues: 86
Total Issues: 86

COMMISSIONING ISSUES LOG

Item #	Issue	Date Posted	Effects	Initial Responsible Party	Recommendations	Actions Taken	Current Close-Out Responsible Party	Date Resolved
6.5	East Roof: Condensing unit CU-3 (serving IT closet Room 323) was observed to be cycling frequently.	12/08/03		GJH		29/04: GJH stated that the …on was found to be low and …harged today. Cycling …blem has been fixed.		1/29/04
6.6	Offices 256, 257: (Served by terminal unit 50). BAS indicates combined total supply airflow of 252 cfm. RMF measured combined total supply airflow of 390 cfm in maximum cooling. BAS indicates a supply airflow setpoint of 500 cfm in max… BAS indicates all other flow setpoi… heating, control – minimums and m… cfm. Terminal unit is scheduled fo… maximum and 125 cfm minimum. … reheat valve at 100% position and … while supply air temperature was measured at 81°F.	12/08/03	Pertains also to Items: 6.3, 6.4, 7.5A-D, 9.2C-E, 9.3A-B (for control setpoints) 6.3, 8.1-8.5, 9.1, 9.2B, 9.3A, 10.1, 10.2 (for reheat coil control valves)	Siemens/MBI	Siemens to investigate.	1/29/04: See Item 6.4 Actions Taken for air quantity control. 1/29/04: Reheat coil control valve issues to be addressed pending HW system analysis results. 2/10/04: RMF spot-checked these areas for acceptability.	TBD	2/10/04 See Item 8.1
6.7	Lab rooms 231, 237, 321, 325: RMF performed Lab Room Zone Summary tests in these areas. Supply and exhaust air quantities and temperatures were measured, and the Lab Rooms were confirmed to maintain negative pressure relationships to the corridors throughout the full variable range of room operating sequences. Though the Lab Rooms are verified to operate as designed, several issues remain that require further validation.	12/08/03		RMF	Various individual actual air quantity readings must be reconfirmed in both heating and cooling modes. RMF also questions, and must further investigate, the indicated BAS values for free and bypass area at the fume hood sashes for both open and closed positions.	RMF has reviewed Sie… control data for the fum… monitors and accepted … calculations used in fu… control sequences.		…9/04

Chronological updates of action taken

Continuous reference to other related items

Date resolved and reference to other related items

In analyzing the data that is available for the facilities reviewed, it can be concluded that many items were identified through the commissioning process that may otherwise have not been discovered. However, as the commissioning logs in most cases are not complete, it is unclear as to how many of these issues were actually resolved prior to occupancy. It can be concluded from interviews with building managers that commissioning did or could benefit the stakeholders of the facility, but no solid conclusions can be derived from the data collected from warranty and commissioning logs.

It can be perceived, however, from the data available and information received during interviews with building managers that commissioning, when incorporated in the beginning phases of projects, will identify problems that can be addressed prior to owner turnover, therefore limiting callbacks and occupant disruption.

Chapter 6: Recommendations

In order to provide the university with valid conclusions as to the benefit of incorporating commissioning in capital projects, it is recommended that more in-depth research be conducted. This will require a comparison study conducted on commissioned versus non-commissioned buildings. John Beach, Director of Physical Plant, shows support for this recommendation. He explained that most of the projects currently being constructed were approved several years prior to start of construction. As commissioning was not incorporated at the time budgets for these facilities were approved, no funds were slated for this activity. However, he recommends that measures through internal decisions within the Facilities Department be implemented to assure commissioning efforts become and remain a part of the construction budget.

As it will be necessary to have similar data available in conducting a valid analysis of the benefits of commissioning in new construction on the Virginia Tech campus, it is essential to have comparable data sources. By developing a protocol for warranty logs, Virginia Tech Facilities will have a useful tool in determining the number of callbacks and potential for disruption. Having complete commissioning reports is also needed to determine issues identified during the commissioning process as well as those that were resolved pre-occupancy. Having these two data sources, as well as associated maintenance cost data, will provide information needed in determining value added by incorporating commissioning.

Other variables affecting the analysis of this research are the impressions of users and differing facilities management protocol. In order to have valid information from end-user perceptions, all parties involved in building maintenance should be included in the evaluation process. As Virginia Tech has a preventative maintenance staff to address general maintenance issues in all campus facilities, it is recommended that these individuals, along with departmental facilities managers, be included in an end-user evaluation component of future research. Random surveys of building occupants would also prove beneficial in determining the functionality of new facilities.

References

Affiliated Engineers (AEI). 2005. *Chemistry-Physics Phase II laboratory exhaust system analysis.*

Affiliated Engineers (AEI). 2006. *Ag/Forestry Research Laboratory Facility Commissioning Issues Log.*

Auditor of Public Accounts (APA). November, 2004. *Review of the Commonwealth's Capital Outlay Process.*

Beach, J. 2006. Personal interview. November 14, 2006.

Ellis, R. 2004. *Systems commissioning*. Presented at the RAM/SWANA 10th Annual Fall Conference and Show, Session Track III Energy Solutions, November 2004. On the web at http://www.sebesta.com.

Elvey, W. 2006. Personal interview/email.

Friedman, H., Potter, A., Haasl, T., and Claridge, D. *High performance commercial building systems: Persistence of benefits from new building construction.* August, 2004. Proceedings of the 2002 ACEEE Summer Study on Energy Efficiency in Buildings. State of California.

Frye, M.J. et al. 2002. *Building commissioning guideline.* Association of Professional Engineers, Geologists and Geophysicists of Alberta. Alberta, Canada.

Hyatt, J. 2006. University announcement to Deans, Department Heads, and University Center Directors relative to Campus Energy Efficiency Initiatives.

Kuykendall, J. 2006. Personal interview. November 8, 2006.

Maxey, D. 2005. *International Perspective on Building Commissioning.* Independent study, directed by G. Reichard. VPI&SU. Blacksburg, VA.

Mills, E., et al. 2004. *The cost-effectiveness of commercial-buildings commissioning: a meta-analysis of energy and non-energy impacts in existing buildings and new construction in the United States.* December 15, 2004. U.S. Department of Energy, LBNL-56637.

Portland Energy Conservation, Inc. (PECI). *Commissioning.* On the web February 13, 2005, at www.peci.org.

RMF Engineering, Inc. 2005. MEP Commissioning Services Report: Bioinformatics Facility Phase One. PC No. 20816485-01. RMF No. 100151.G0. May 18, 2005. Baltimore, MD.

Tormenta, L.M., et al. 1999. *High performance building guidelines.* City of New York, Dept. of Design and Construction.

US Dept of Energy (DOE) and US General Service Administration (GSA), July 30, 1998. Washington, DC.

WBDG Project Management Committee. 2005. *Building commissioning.* Whole Building Design Guide. Updated January 4, 2005. On the web at www.wbdg.org.

Wigfield, R. 2003. *Building commissioning.* Excerpts from a presentation given at a client workshop March 14, 2003. Used by written permission from Roger Wigfield, January 2005.

APPENDICES

APPENDIX I: Summary of capital projects completed at Virginia Tech – 1996-2006

Project	Gross Square Footage	No. Stories	Budget ($)	New Construction	Addition	Renovation/ Upgrade	Purpose	Project Completion	Anticipated Completion
Construction in Progress									
Boiler Pollution Controls Bldg	n/a	n/a	5,480,770			x	Facilities Support		Feb 07
ICTAS I	99,411	4	37,985,225	x			Research Office/Labs		Jan 08
Life Sciences I	71,799	3	37,750,000	x			Research Office/Labs		Oct 07
Litton Reaves Exterior Structure Repair	n/a	n	4,100,000			x	Research Office/Labs		
Summary			85,315,995						

Completed Projects

Project	Gross Square Footage	No. Stories	Budget ($)	New Construction	Addition	Renovation/ Upgrade	Purpose	Project Completion	Anticipated Completion
Southgate Center Addition	24,732	2	2,925,000	x	x		Administration	Aug 02	
Dairy Facilities	54,542	4	5,342,860	x			Agricultural Research	Apr 04	
Dry Rendering Facility	3,847	2	2,498,000	x			Agricultural Research	May 02	
Hampton Roads Wing Replacement	7,801	2	1,427,655			x	Agricultural Research	Apr 03	
Cassell Coliseum Repairs	n/a	n/a	3,335,000			x	Athletics	Nov 97	
English Field Press Box	24,533	2	488,000	x			Athletics	Dec 96	
Football Practice Fields	n/a	n/a	1,871,000	x			Athletics	Apr 01	
Merryman Athletic Center	42,040	2	7,100,000	x			Athletics	Apr 98	
Recreation Fields	n/a	n/a	1,529,000	x			Athletics	Jul 02	
Stadium Expansion South Endzone	213,792	4	33,800,000	x	x		Athletics	Dec 02	
Stadium West Sideline Expansion	85,744	7	52,520,000	x	x		Athletics	Apr 06	
Track-Soccer Complex	n/a	n/a	1,897,000	x			Athletics	Sep 97	
Lane Stadium Renovations	n/a	n/a	1,900,000			x	Athletics	Oct 98	
Stadium Parking Lot	n/a	n/a	1,915,800			x	Athletics	Sep 97	
Women's Softball Field	n/a	n/a	520,000			x	Athletics	Sep 97	
Worsham Field	n/a	n/a	1,366,500			x	Athletics	Jul 01	
Alumni Center, CEC and Hotel	193,020	4	43,118,000	x			Conference	Jul 05	
Coal Fired Boiler Facility	7,200	2	10,744,800	x			Facilities Support	Oct 98	
Electric Service Facility	30,715	1	3,000,000	x			Facilities Support	Oct 02	
Campus Handicap Improvements - Elevators	n/a	n/a	469,350			x	Facilities Support	Apr 98	

Project	Gross Square Footage	No. Stories	Budget ($)	New Construction	Addition	Renovation/ Upgrade	Purpose	Project Completion	Anticipated Completion
Lee Hall Fire Protection Upgrade	n/a	n/a	159,278			x	Facilities Support	Jul 98	
O'Shaughnessy Hall-Fire Protection Upgrade	n/a	n/a	703,600			x	Facilities Support	Jan 98	
Slusher and Pritchard Fire Protection Upgrade	n/a	n/a	2,149,400			x	Facilities Support	Jul 98	
Ag/Forestry Building	84,277	5	24,791,000	x			Research Office/Labs	Mar 06	
Bioinformatics Phase I	58,285	3	13,527,313	x			Research Office/Labs	Dec 03	
Bioinformatics Phase II	71,560	3	18,547,649	x			Research Office/Labs	Dec 04	
Chem Physics Phase II	85,051	4	27,194,000	x			Research Office/Labs	Jan 04	
Engineering Facility	108,647	4	16,228,000	x			Research Office/Labs	Aug 97	
Geotechnical Laboratory Facility	6,010	1	880,000	x			Research Office/Labs	Oct 02	
Cheatham Hall Addition	9,237	3	2,100,000		x		Research Office/Labs	Dec 02	
Microelectronics Laboratory (Hancock Hall)	n/a	n/a	1,800,000			x	Research Office/Labs	Oct 02	
Torgerson Hall	149,651	3	26,948,800	x			Research/Teaching	Jul 00	
Classroom Improvements Phase I	n/a	n/a	7,270,000			x	Research/Teaching	Jul 06	
Burchard Hall	42,000	2	8,446,000		x		Research/Teaching	Jul 98	
Williams Hall Renovation	n/a	n/a	5,700,519			x	Research/Teaching	Aug 03	
Career Services Building	21,735	2	4,608,000	x			Student Housing/Support	May 04	
Prairie Dorms (2 bldgs.)	126,390	4	16,806,000	x			Student Housing/Support	Aug 98	
Harper Hall Dormitory	72,785	4	10,000,000	x			Student Housing/Support	Jul 99	
Special Purpose Housing Phase III	77,244	2	11,080,000	x			Student Housing/Support	Jul 01	
McComas Hall	118,255	3	21,632,420	x			Student Housing/Support	Sep 98	
Student Services Bldg	36,385	3	6,755,000	x			Student Housing/Support	Jan 03	
AJ Hall Fire Protection Upgrade	n/a	n/a	1,873,000			x	Student Housing/Support	Aug 99	
Cochran Dining Hall - Renovation/Addition	8,124	1	3,269,048		x	x	Student Housing/Support	Nov 98	

Project	Gross Square Footage	No. Stories	Budget ($)	New Construction	Addition	Renovation/ Upgrade	Purpose	Project Completion	Anticipated Completion
Dietrick Servery	n/a	n/a	6,500,000			x	Student Housing/Support	Aug 04	
DBHCC Renovation	n/a	n/a	3,946,000			x	Student Housing/Support	Feb 98	
Graduate Life Center	n/a	n/a	3,000,000			x	Student Housing/Support	Jul 06	
Laundry Bldg. Renovations	n/a	n/a	90,500			x	Student Housing/Support	Feb 98	
Shanks Hall Renovation & Addition	67,500	4	7,896,495		x	x	Student Housing/Support	Jul 01	
Shultz Hall Television Studio (renovation)	n/a	n/a	1,664,200			x	Student Housing/Support	Jul 01	
Airport Parallel Taxiway	n/a	n/a	3,128,500		x		Transportation	Oct 99	
Summary			436,462,687						

APPENDIX II: Summary of commissioning activities on completed new projects

Project	Gross Square Footage	No. Stories	Budget ($)	Purpose	Project Completion	Was commissioning incorporated?	If yes, at what stage and by whom?
Southgate Center Addition	24,732	2	2,925,000	Administration	Aug 02	No	
Dairy Facilities	54,542	4	5,342,860	Agr. Research	Apr 04	No	
Dry Rendering Facility	3,847	2	2,498,000	Agr. Research	May 02	No	
English Field Press Box	24,533	2	488,000	Agr. Research	Dec 96	No	
Merryman Athletic Center	42,040	2	7,100,000	Athletics	Apr 98	No	
Recreation Fields	n/a	n/a	1,529,000	Athletics	Jul 02	No	
Stadium Expansion South Endzone	213,792	4	33,800,000	Athletics	Dec 02	No	
Stadium West Sideline Expansion	85,744	7	52,520,000	Athletics	Apr 06	Yes	Beginning of construction; independent third party
Track-Soccer Complex	n/a	n/a	1,897,000	Athletics	Sep 97	No	
Alumni Center, CEC and Hotel	193,020	4	43,118,000	Conference	Jul 05	Yes	Beginning of construction; independent third party
Coal Fired Boiler Facility	7,200	2	10,744,800	Facilities Support	Oct 98	No	
Electric Service Facility	30,715	1	3,000,000	Facilities Support	Oct 02	Yes	Limited – O&M
Ag/Forestry Building	84,277	5	24,791,000	Research Office/Labs	Mar 06	No	Beginning of construction; independent third party
Bioinformatics Phase I	58,285	3	13,527,313	Research Office/Labs	Dec 03	Yes	85% complete construction; provided by A/E
Bioinformatics Phase II	71,560	3	18,547,649	Research Office/Labs	Dec 04	Yes	Latter stages of design; provided by A/E
Chem Physics Phase II	85,051	4	27,194,000	Research Office/Labs	Jan 04	Retro	Retro Cx to guide modifications/ repairs to exhaust fans
Engineering Facility	108,647	4	16,228,000	Research Office/Labs	Aug 97	No	
Geotechnical Laboratory Facility	6,010	1	880,000	Research Office/Labs	Oct 02	No	
Torgersen Hall	149,651	3	26,948,800	Research/Teaching	Jul 00	No	
Career Services Building	21,735	2	4,608,000	Student Housing/Support	May 04	No	
Prairie Dorms (2 bldgs.)	126,390	4	16,806,000	Student Housing/Support	Aug 98	No	
Harper Hall Dormitory	72,785	4	10,000,000	Student Housing/Support	Jul 99	No	
Special Purpose Housing Phase III	77,244	2	11,080,000	Student Housing/Support	Jul 01	No	
McComas Hall	118,255	3	21,632,420	Student Housing/Support	Sep 98	No	
Student Services Bldg	36,385	3	6,755,000	Student Housing/Support	Jan 03	No	

APPENDIX III: Personal Interview Questionnaire - Building Managers

Building Name: ____

Building Manager: ____

Interview Date: ____

1. Explain your involvement in the project—at what stage of construction did you become involved?

2. Overall, do you feel your building was built at an acceptable level of performance?

3. Are you familiar with the commissioning process?

4. If your building was commissioned, at what stage did the commissioning begin?

    a. Are you aware of any problems identified during the commissioning process that may not have been identified without the commissioning process?

    b. Were there any problems identified that were not corrected, and if so, what were the reasons (time, scope, budget)?

5. Please describe any major problems you experienced during turn over (issues still present that were identified but not corrected by substantial completion).

    a. Are these problems still present?

    b. Approximately how many callbacks have resulted from this problem?

6. From a personnel standpoint, do you feel the employees/guests/other occupants of this facility are comfortable working in this facility?

7. What are the major complaints relative to building performance have you received from the occupants?

8. The University has announced as one of their goals an effort to complete full commissioning of all new construction at Virginia Tech. How do you see this being beneficial to the building managers and occupants of these facilities?