REPORT

Title: Three Case Studies On Design, Construction and Initial Operation of a High Efficiency, Small Building Retrofit

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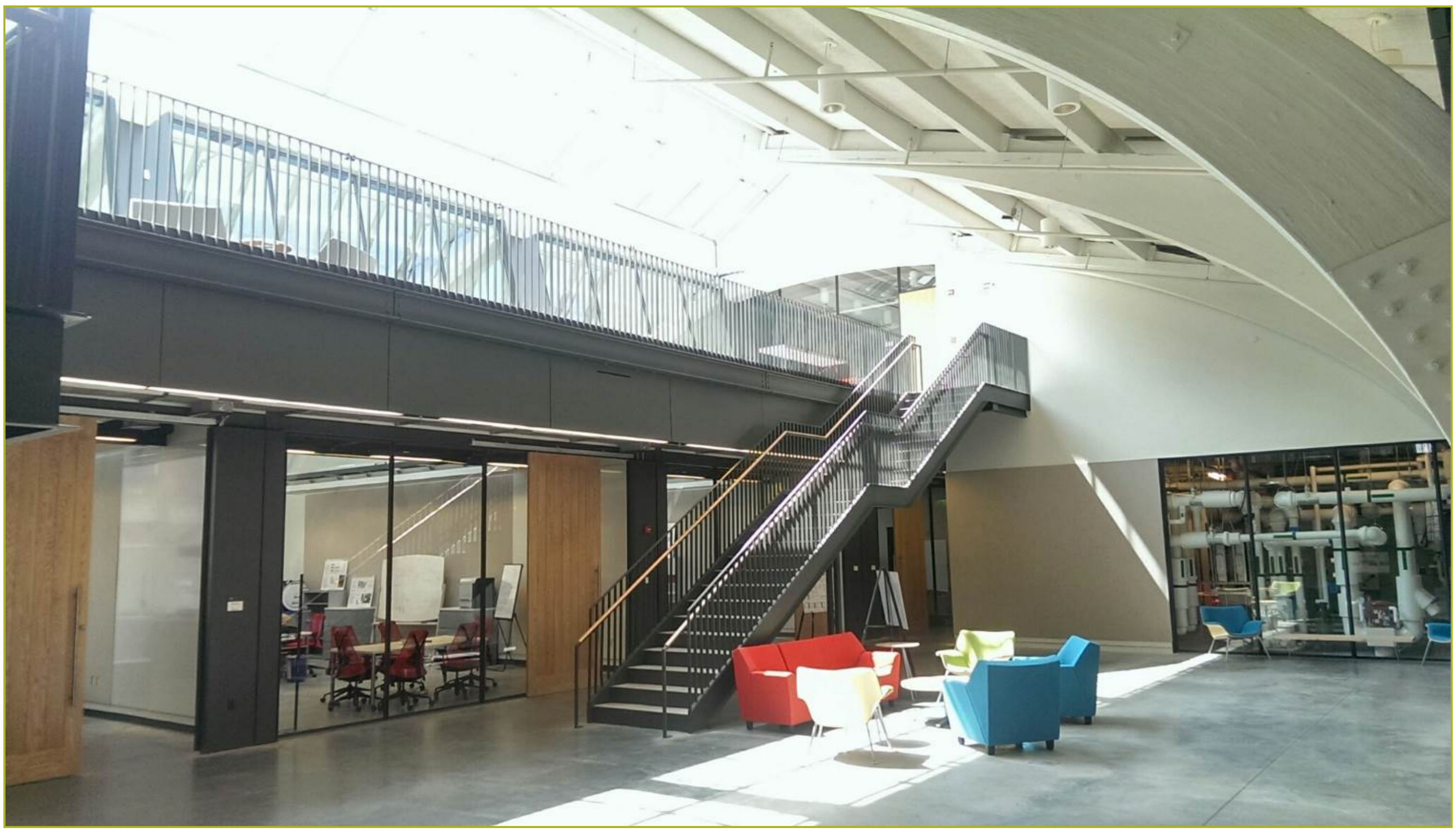
Report Author: Mark B. Stutman, The Pennsylvania State University



CONSORTIUM for BUILDING ENERGY INNOVATION

REPORT

Report Abstract

Building 661 represents a signature project of the Consortium, an investment by the Commonwealth of Pennsylvania to demonstrate a comprehensive integrated design and construction delivery process for building retrofits, using state-of-the-art equipment, systems, and controls. Document and analyze the effectiveness of the Integrated Design process on this energy retrofit project. Quantify performance of the three major HVAC systems and other energy-consuming systems in the building, compared to modeled predictions and design intent. Develop and implement additional commissioning activities, and program enhancements to the installed Building Automation System. Develop additional market facing documents to increase market impact and awareness: Case study documenting the evaluation of installed chilled beam/DOAS system (a system type which could find increased application in temperate climates) in terms of both comfort and energy consumption relative to conventional solutions based on data acquired from B661.

Three case studies will be created and widely distributed: 1) targeting engineers and designers, 2) targeting building owners, and contractors. 3) evaluation of installed chilled beam/DOAS system. Three case studies were prepared and submitted that incorporate CBEI Investigators experience with demonstration testbed sites:

Case Study #1 - Building 661: Dedicated Outdoor Air System (DOAS) & Chilled Beam Cooling Retrofit Performance
Case Study #2 - Building 661: Lessons Learned from Implementing a Publically-Funded Integrative Design and Delivery Retrofit Project – Building Owners and Contractors
Case Study #3: Performance Building 661: Lessons Learned from Implementing a Publically-Funded Integrative Design and Delivery Retrofit Project – Architects and Design Engineers

Abstracts for Case Studies #2 & #3 were submitted to:
abstract submission #1 - High Performance Buildings magazine
abstract submission #2 - 2016 World Energy Engineering Congress

Contact Information for lead researcher

Name: Mark B. Stutman
Institution: The Pennsylvania State University
Email address: mbstutman@psu.edu
Phone number: 215-218-7584

Contributors

Mark Stutman, Ben Cohen, Scott Wagner, The Pennsylvania State University
Rich Sweetser, Exergy Partners

CONSORTIUM for BUILDING ENERGY INNOVATION

Case Study

Building 661 Dedicated Outdoor Air System (DOAS) & Chilled Beam Cooling Retrofit Performance

Scott Wagner
CBEI Building Energy Data Manager, The Pennsylvania State University

Ben Cohen
CBEI Building Energy Data Analyst, The Pennsylvania State University

Mark Stutman
M.S., CEM, LEED AP O&M, CBEI Demonstration Program Manager, The Pennsylvania State University

Richard Sweetser
President, Exergy Partners Corp.

Building 661

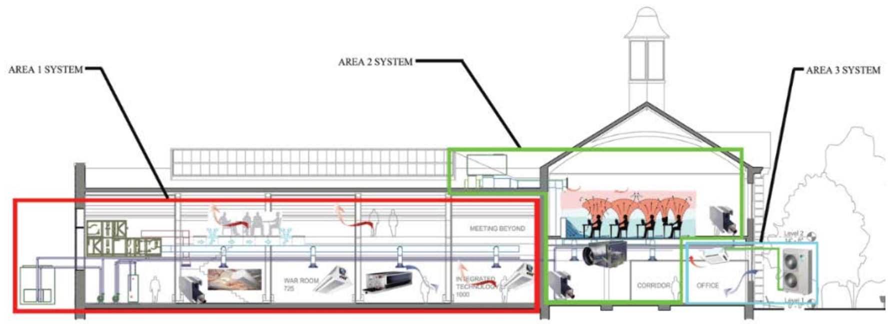
Building 661 (B661) was intended is to be the CBEI Headquarters and was designed to encourage collaboration, and to serve as a catalyst to demonstrate energy efficient retrofit innovations, advocacy, practice and commercialization strategies to radically reduce energy use in the existing commercial/institutional building stock. The key feature of B661 is its ability to test, measure and verify performance of building energy systems with three distinct building HVAC system retrofit approaches and lighting schemes.

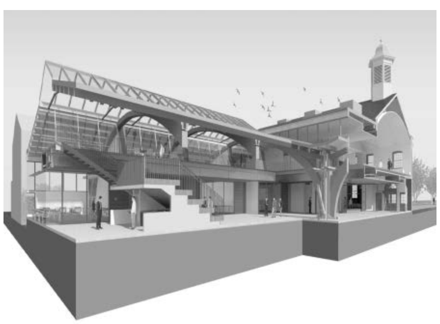
The B661 deep energy retrofit project was undertaken to deliver a living laboratory, education and outreach center to provide the built environment community with clear evidence of replicable methods and means of scaling deep energy retrofits in existing small to medium sized buildings. This ambitious goal was expected to expose the successes and issues in applying an Integrative Design and Delivery (IDD) process within a state that that requires separation of key contractors on public projects.

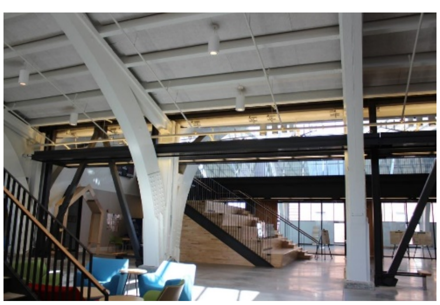
B661 is CBEI's ultimate building testbed which is being offered to researchers and companies determined to reduce their energy use by testing and deploying the most energy efficient technologies as integrated systems under real-world conditions targeting medium and small building retrofits which remains the largest sector of the existing building stock.

DOAS / Chilled Beam Retrofit

Introduction







B661 consists of three separate and discrete building areas each with a unified deep energy retrofit approach for demonstration and research purposes. This case study focuses on the high bay area in the rear of the building and the two floor entry and gathering place in the front of the building (head-house) called Area 1.

Chilled beams (active and passive) provide an important retrofit opportunity, (particularly among the older building stock in the Midwest and Eastern Unites States). The repurposing of buildings within urban cores often means adding air conditioning to buildings that were not designed for air conditioning. Here chilled beams have a distinct space and cost advantage of chilled water piping versus ductwork.

Chilled beams theoretically offer a space cooling advantage, particularly in spaces with high ceiling height, as the radiant (passive) and induced (active) chilled beams provide a significant thermal gradient, satisfying occupants while allowing temperatures to increase in the space above the occupied zone.

Chilled beams require dewpoint control to avoid cold surface condensation. This is typically performed using a DOAS unit.

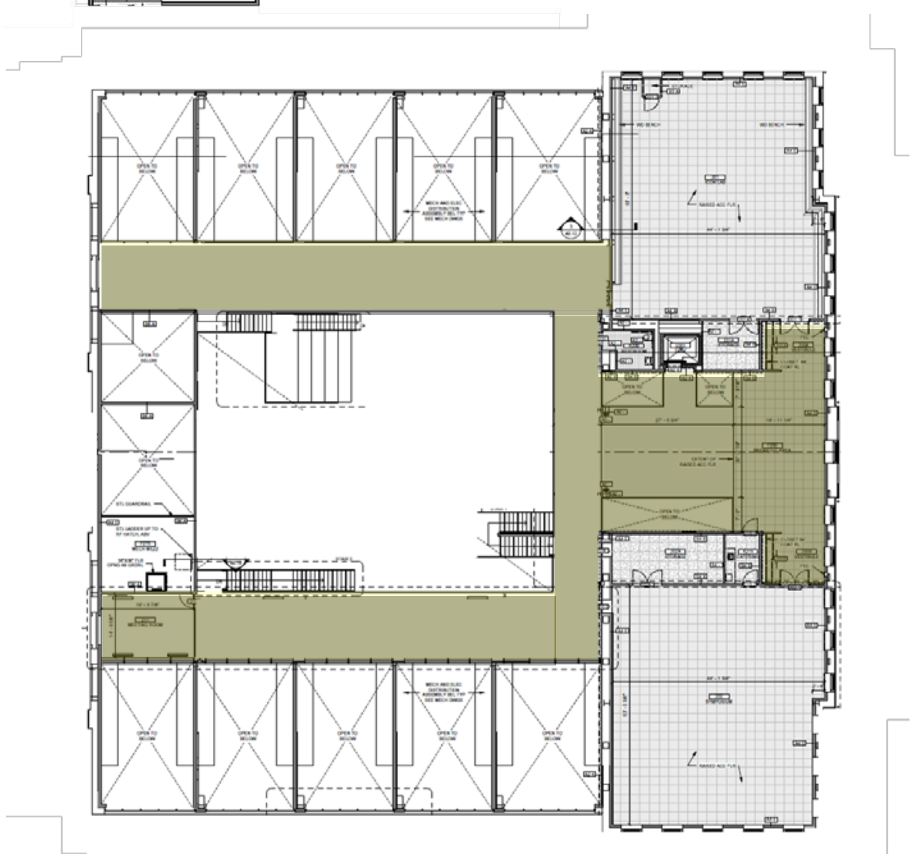
This case study focuses of the initial year of operation of the DOAS/Chilled Beam systems providing cooling and dehumidification to Area 1 of B661.

Area 1

Area 1 consists of two high bays (~25 ft. ceiling height) designed to accommodate 10 full ceiling height workrooms, a large gathering/display space, first floor reception, second floor meeting room reception and two mezzanine walkways (one with an enclosed conference room) designed for breakout meeting space. The two high bays structure was a good chance to demonstrate the cooling efficiency of child beams. This decision drove the HVAC system design for Area 1.

Cooling and heating for the workrooms is provided by active chilled beams (providing cooling and fresh air) and perimeter radiant heating. Cooling for the gathering space is provided by passive chilled beams and cooling and heating is also provided through ducted diffusers mounted under the mezzanine walkways. Cooling and heating for the mezzanine walkways is provided through ducted diffusers mounted in the mezzanine walkway floors. Cooling and heating for the first floor reception and second floor meeting room reception is provided by active chilled beams and perimeter radiant heat.

A dedicated outdoor air system (DOAS) unit with exhaust air energy recovery (enthalpy wheels), desiccant dehumidification and hot water regeneration (chiller heat recovery and supplemental condensing boiler) provides cool dehumidified air to the space. A heat recovery chiller provides regenerative heating and reheat during the cooling season.



Chiller and DOAS

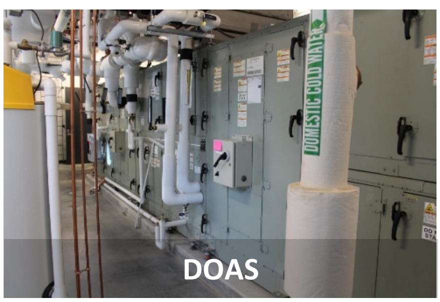
System Description

Chiller – A nominal 60 ton HFC-410A air-cooled scroll chiller designed for outdoor use in ambient temperatures of 0 to 125°F. The scroll chiller is equipped with two refrigerant circuits, four scroll compressors, air cooled condenser, fans, evaporator and controls. The chiller is equipped with a condenser heat recovery heat exchanger to provide cooling season hot water for the DOAS preheating and reheat coils.

Air-Cooled Chiller

The DOAS – is designed to maintain a dew point temperature within the chilled beam areas of 57°F at all times. The supply air temperature shall vary between 62°F on a call for cooling from all zones, and 85 °F upon a call for heating from all zones. The system uses factory controls for the dehumidification wheel operation as well as the energy recovery wheel operation. The system shall operate in three modes; occupied, unoccupied, and holiday, per the times and setpoints listed below for initial start-up.

Minimum Outside Air Ventilation - Carbon Dioxide (CO_2) Control: When in the occupied mode, the controller measures the space CO2 levels and modulate the outside air dampers closed to 1,500 CFM outdoor air minimum and the return air damper open on dropping CO_2 concentrations, overriding 100% outdoor air normal damper operation to maintain a CO_2 setpoint of 700 ppm (adjustable) within the space. The controller shall measure the outside airflow in CFM.



DOAS

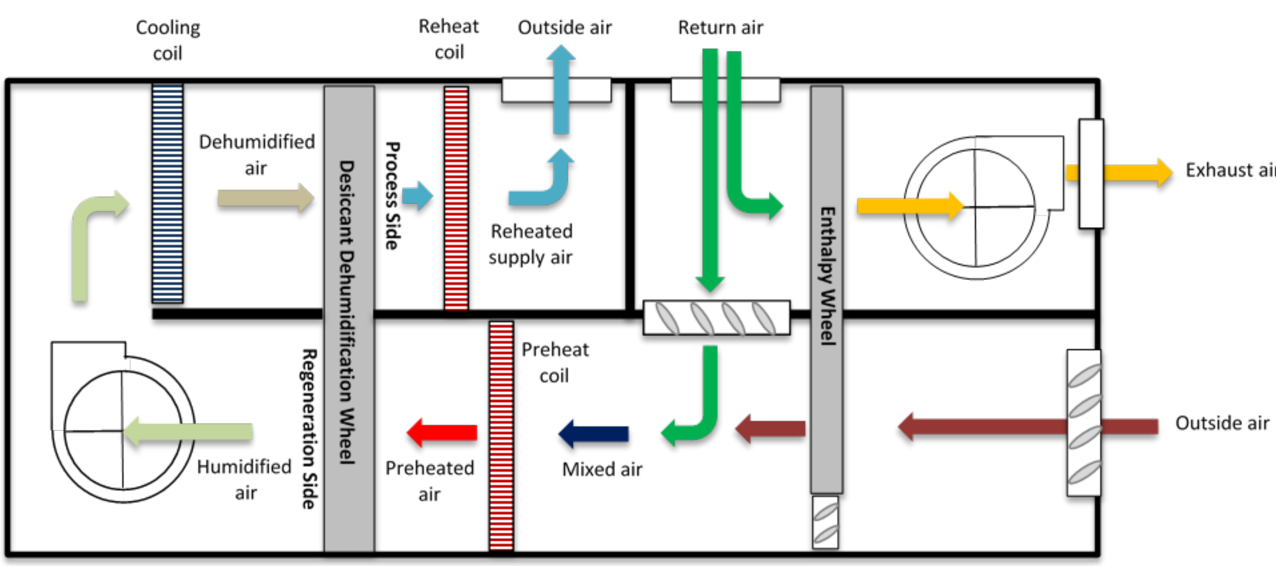
Temperature Control: During Occupied periods the supply fan will run continuously and the outside air damper will open fully before the fan starts. The chilled water valve will modulate to maintain the discharge air temperature cooling setpoint of 62°F. The discharge air temperature will reset based on call for cooling or heating from each chilled beam zone. As majority of zones are satisfied, the chilled water valve will close, and the hot water valve will modulate to maintain the discharge air temperature of 70°F. Upon a call for heating from all zones, the discharge air temperature shall be 85°F.

Humidity Control: When the dew point is greater than 57°F, the discharge air dewpoint temperature setpoint will be dynamically reset based on the deviation of actual space dew point from the active space dew point setpoint. Space dew point calculation is through the chilled beam zone temperature and humidity sensors, with the space dew point the greatest of all polled. Rotation of the CDQ wheel will be enabled, the pre-heat and the chilled water valve will modulate to maintain space dew point of 57°F (adjustable) and the reheat will modulate to maintain the discharge air temperature cooling setpoint as stated above. Mode will terminate at 54°F, when the space dew point falls below the dew point setpoint (57°F) minus 3°F.

DOAS

The desiccant wheel is used to enhance the dehumidification performance of a traditional cooling coil. The wheel is configured in series with the coil such that the “regeneration” side of the wheel is located upstream of the coil and the “process” side of the wheel is located downstream of the coil. The desiccant wheel adsorbs water vapor from the air downstream of the cooling coil and then adds it back into the air upstream of the coil where the coil removes the water vapor through condensation. This process is accomplished without the need for a second regeneration air stream. The addition of the desiccant wheel to the system enhances the dehumidification performance of the traditional cooling coil. The desiccant wheel transfers water vapor, and the cooling coil does all the dehumidification work in the system. The latent (dehumidification) capacity of the cooling coil increases without increasing its total cooling capacity. The system can achieve a lower supply-air dew point without lowering the coil temperature. Unlike a system with a cooling coil alone, the dew point of the air leaving the system can be lower than the coil surface temperature. Preheat may be used to obtain lower supply-air dew points in applications in which there may be an ample supply of chilled water available, but it is not at a cold enough temperature for the system to achieve the required dew point. Preheat may be used to obtain lower supply-air dew points in applications in which there may be an ample supply of chilled water available, but it is not at a cold enough temperature for the system to achieve the required dew point.

The this DOAS system does not require a separate exhaust air stream to regenerate the desiccant, so recovering energy from the exhaust air stream can easily be accomplished with a n enthalpy “total” energy recovery wheel to precondition the entering outdoor air.

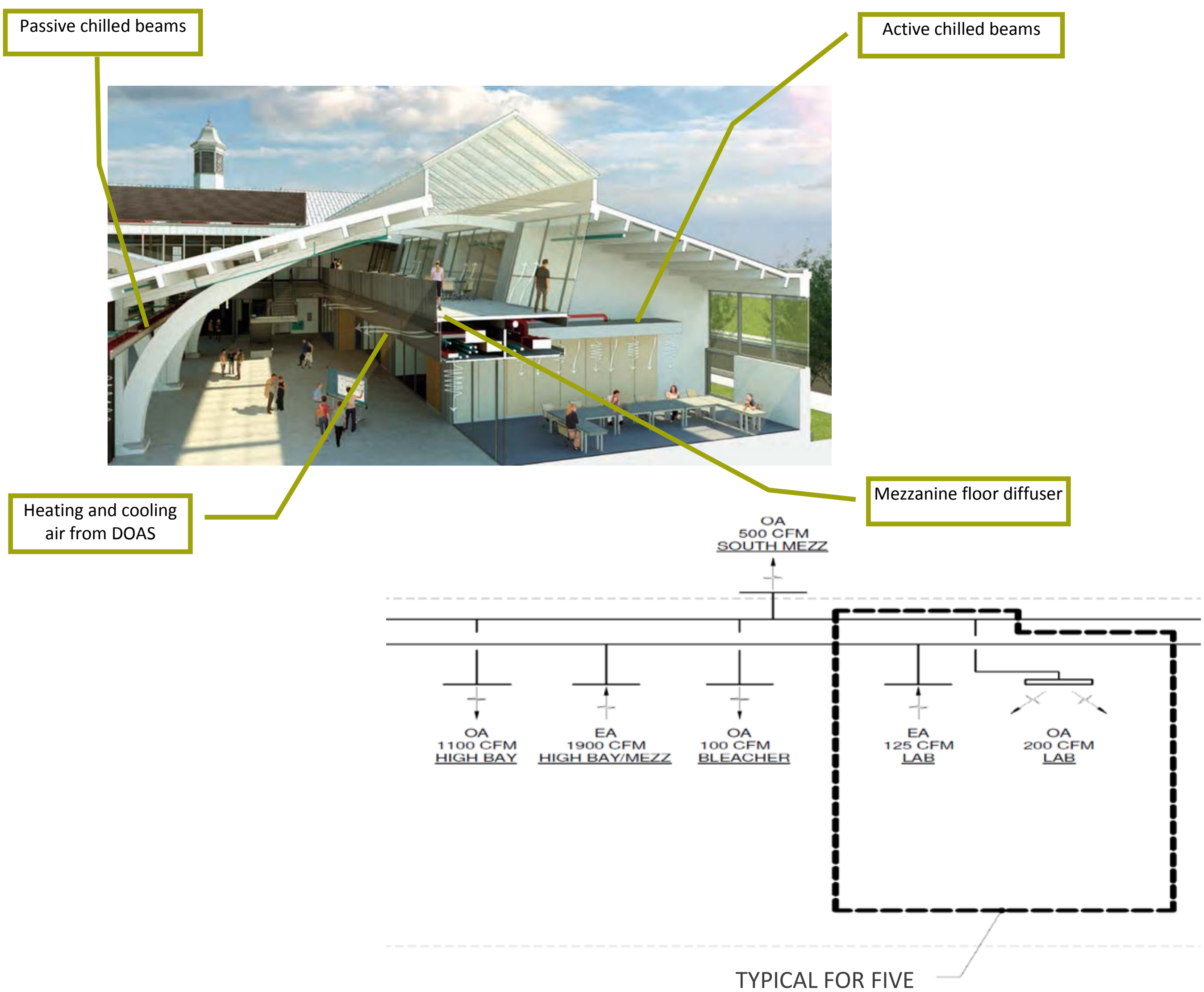


DOAS Air Supply

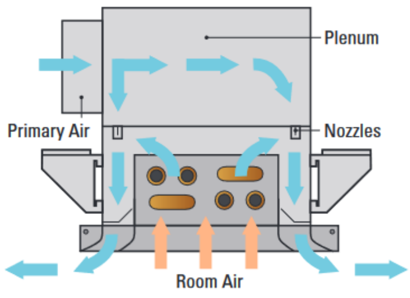
DOAS supply air is delivered to the core meeting space through fan power boxes to two of the workrooms (133 and 137), through diffusers mounted in the bleacher risers, and supplying air to the lobby space. The DOAS provides condition air directly to the active chilled beams mounted in the five south labs, the breakroom area and in the 2nd floor meeting room lobby. DOAS air is also supplied to the space through slot diffusers in the mezzanine floor side wall and floor mounted diffusers in the mezzanine walkway.

The north workroom space has not been fitted out at this point. DOAS air is supplied to the entire north workroom space through a single diffuser.

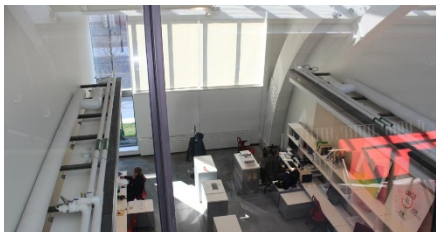
Return air is returned to the DOAS through duct work mounted under the mezzanine walkways.



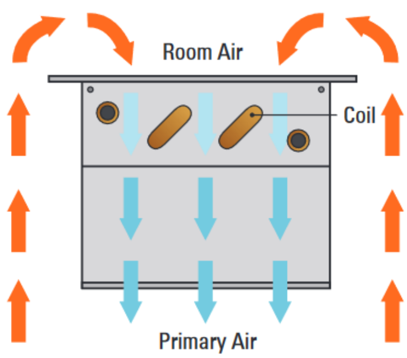
Chilled Beams



Active Chilled Beam



Active Chilled Beams



Passive Chilled Beam

Passive Chilled Beams

System Description

Active Chilled Beam - the air is supplied by the DOAS (primary air) to the active chilled beams at a constant volume and at a relatively, low static pressure (typically under 0.5" wc). Within the active chilled beam terminal unit, the primary air is discharged into a mixing chamber through a series of nozzles. A zone of relative low pressure is created within the mixing chamber, thereby inducing room air through the secondary water coil into a mixing chamber. The induced room air is called secondary air. In the cooling mode the primary air is cool and dry, satisfying a portion of the room's sensible load and all of its latent load. The secondary water coil within the active chilled beam terminal unit is supplied with chilled water to offset the remaining internal sensible load of the room. The chilled water temperature is always provided above the room design dew point temperature to preclude sweating/condensation on the water coil.

Passive Chilled Beams - use a heat exchanger to change the temperature of the adjacent air, transferring heat and creating a difference in density with the ambient air. The density difference creates air movement across the heat exchanger, transferring heat from the heat exchanger to the air. Passive beams condition a space using natural convection and are primarily used for handling the sensible cooling load of a space. They are water-only products, and require a separate air system for ventilation air and to remove the latent load. As warm air in the room rises, it comes into contact with the heat exchanger and flows downward through the cool coils back into the space.

BAS & M&V

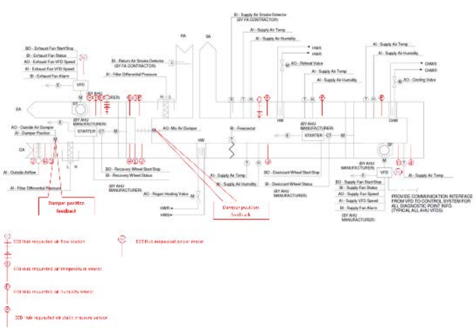
BAS System

System Description

BAS system – Building 661 was instrumented to understand the performance of the whole building, the performance of the three discrete and different HVAC systems approaches, and, in some cases, equipment level performance. The additional M&V data points were specified as a do-no-harm overlay to be connected through the BAS.

The Johnson Controls Niagara BAS installation and Facility Explorer software, including M&V instrumentation specified in the construction documents, was provided by the mechanical contractor. All M&V performance data is automatically acquired from the BAS by CBEI data analytics staff and placed on the Penn State server at the Navy Yard using OSIsoft’s PI server.

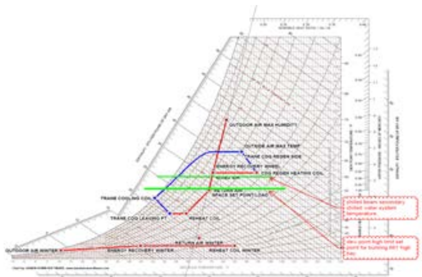
M&V sensors - The objective was clear with respect to B661. The system design intent was to measure all energy flows across the building boundary, measure all energy flows across the three inside area boundaries, measure all major equipment and sub-system energy and state points, and measure space conditions throughout the building including air temperatures, relative humidities, and CO2 levels. Lighting energy use was also expected to be incorporated within the system, including the ability to measure lighting energy delivered at the room level. This information was contained on the drawings and within the written specifications. However, a distinct holistic M&V plan incorporating all these requirements was not created because too many entities were involved in developing the project. CBEI researchers, as the main tenant, presented their requirements for the project in the form of specifications and additions to engineering drawings.



System (black) & Research (red) measurement sensors

A B661 M&V system issue arose when the IDD design package was split into four packages for the public bid. The design intent of the M&V system for B661 was that all data streams would be fed back to the BAS for central collection and visualization. This would require that the lighting system be integrated with the BAS for data collection and analysis by the CBEI research team using a specific software package for data analytics. During the delivery process, without an M&V system “champion”, this element was lost.

First Year Energy Performance Metrics



Chiller / DOAS Operation

Performance metrics were developed by CBEI evaluation staff to assess the first year energy performance of B661's chiller/DOAS/ Chilled beam system. Using average hourly sub-metered 1-min interval data ranging from kW power readings to Btu/hr readings, system performance was measured for the cooling season covering 5/1/2015 to 8/31/2015. Data relating to chiller energy consumption, DOAS supply fan and exhaust fan power consumption and delivered tonnages were analyzed in terms of system Coefficient of Performance (COP), seasonal cooling end use Energy Use Intensity (EUI) and peak Sq. Ft./Ton. In certain cases, performance metrics were developed both for all hours of the cooling season and just the building's occupied hours (6:00am to 8:00pm M-F).

One important performance metric is system COP, which is an efficiency measurement of the energy required to deliver a specific amount of cooling tons, and is a common metric used to compared the efficiency of one type of cooling system to another (e.g., scroll chiller compared to direct expansion roof top unit). To develop the chiller/DOAS/chilled beam system COP for B661, total chiller input energy data (i.e., compressor and condenser fan energy use combined) was compared to delivered chiller tonnage data. The delivered chiller tonnage data was further disaggregated into cooling tons consumed by the DOAS system and tons consumed by the secondary loop which supplies chilled water to the chilled beams (via a heat exchanger).

Figure 1 shows a comparison of the total chiller tonnage to the DOAS and secondary loop tonnages for all hours of the cooling season. Starting with the second week in June 2015, the cooling coil in the DOAS typically delivered more tonnage than what was delivered to the secondary loop. This finding was a bit of a surprise to CBEI since, for most chilled beam system, DOAS tonnage typically are smaller than chilled beam tonnage. Further investigation since the summer of 2015 has revealed issues with the DOAS in terms of drawing in excessive amounts of outside air and proper control of the preheating coil required for 2nd stage dehumidification.

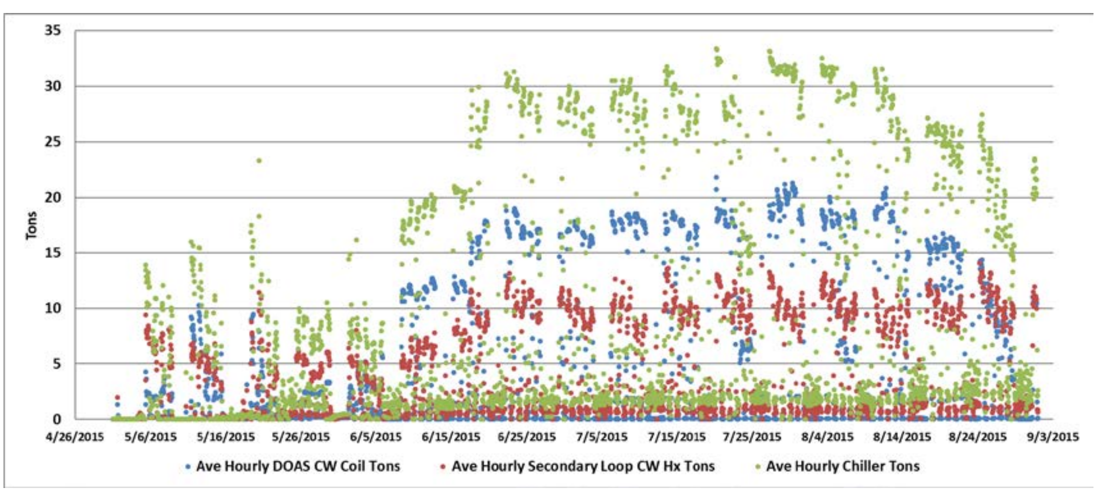


Figure 1. Comparison of Chiller Tonnage to DOAS CW Coil and Secondary Loop CW Heat Exchanger (Hx) Tonnage 5/1/2015 to 8/31/2015 (All Hours)

[1] DOAS tonnages should only reflect what cooling is necessary to dehumidify both return air and outside air coming into the building along with some sensible heat removal. The majority of cooling should be handled by the chilled beams.

First Year Energy Performance Metrics

Figure 2 shows a comparison of the DOAS chilled water coil tonnage and the secondary loop tonnage for just occupied hours of operation (6:00am to 8:00pm M-F). DOAS tonnage exceeded secondary loop tonnages by about 35% for this time frame.

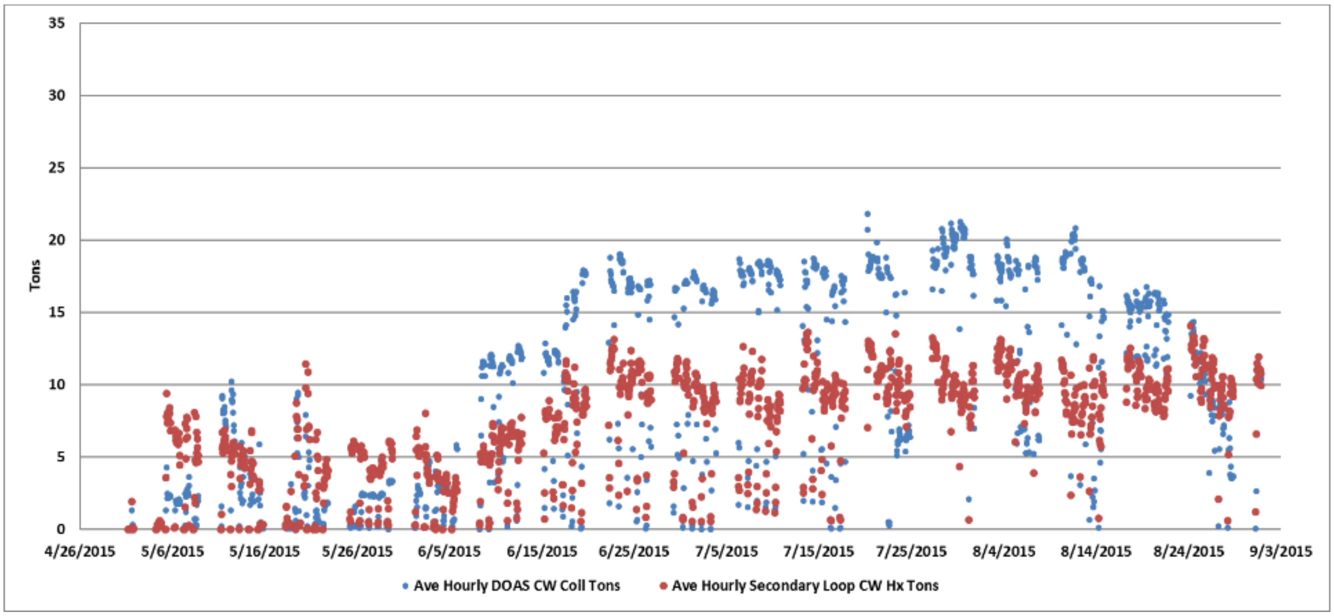


Figure 2. Comparison of DOAS CW Coil Tonnage and Secondary Loop CW Heat Exchanger (Hx) Tonnage 5/1/2015 to 8/31/2015 (Occupied Hours)

An associated metric to COP is the kW/ton metric[2]. Figure 3 shows the graphical relationship of B661's chiller input kW[3] and its associated delivered tonnage as a function of average hourly outside air temperature (OAT). During the cooling season, typical calculated hourly kW/ton values ranged from 1.1 to 1.7.

This finding was also a bit of surprise to CBEI since neither the chiller kW or delivered tonnage correlates strongly with outside air temperature (which would be typical for, say, a direct expansion rooftop unit). Even after extensive investigation into why this is the case, it is still somewhat uncertain as to why this is happening. However, CBEI believes the actual relationship between the chiller kW draw and delivered tonnage is more reflective of issues with the DOAS (as mentioned above) and compressor staging at low to minimum cooling loads.

[2] kW/ton = 12/(COP x 3.412

[3] In this case, chiller input kW relates only to power consumed by the chiller's compressors, controls and condenser fans.

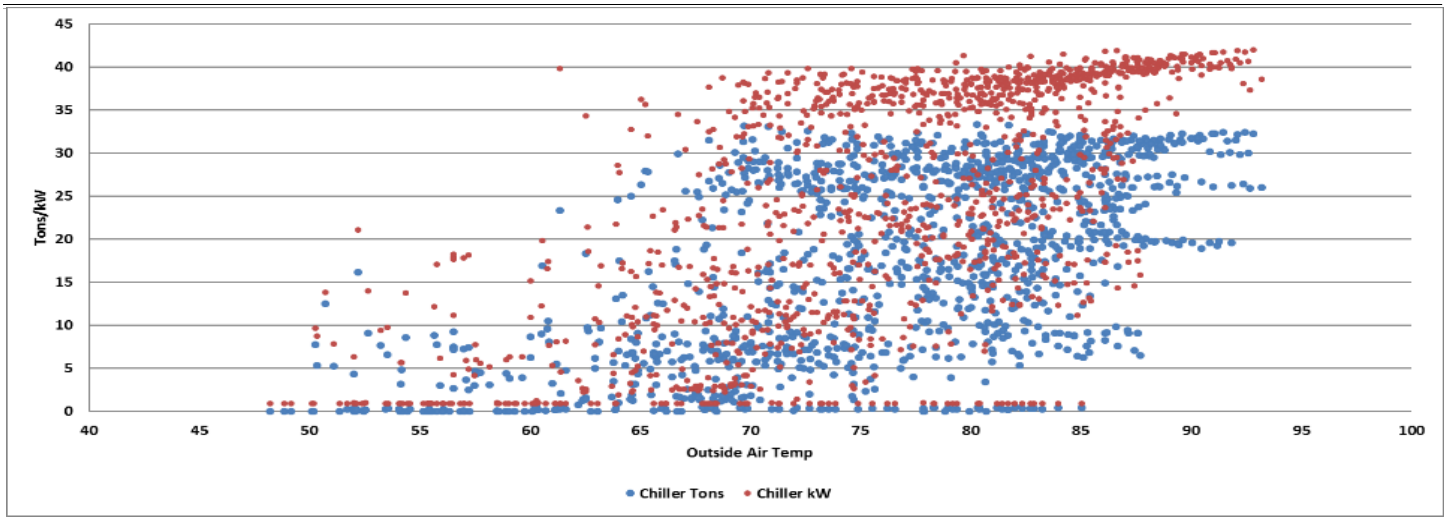


Figure 3: Chiller Tons and kW vs Average Outside Air Temperature 5/1/2015 to 8/31/2015 Occupied Hours

First Year Energy Performance Metrics

In order to do comparisons to other system types like rooftop units, system COPs calculated for this type of chiller/DOAS/chilled beam system need to include both supply and exhaust fan energy consumption. Figure 4 shows the DOAS exhaust fan and supply fan average hourly power readings over the cooling season. As can be seen in Figure 4, exhaust fan energy consumption was only about 13% of supply fan energy use (during occupied hours, the VFD controlling the supply fan typically ramped the supply fan motor up to kW levels of between 4.5 and 5 kW, while exhaust fan consumption was less than 1 kW).

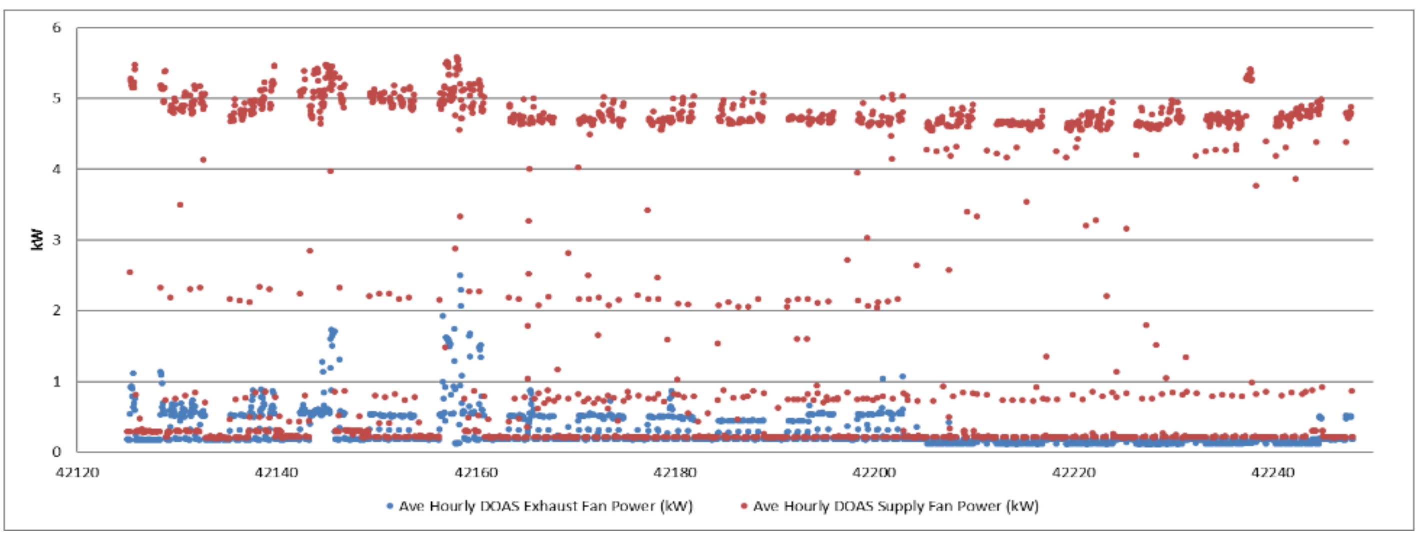


Figure 4: Ave Hourly DOAS Exhaust and Supply Fan Power (kW) 5/1/2015 to 8/31/2015 (All Hours)

Table 1 lists the various performance metrics used to evaluate B661's chiller/DOAS/chilled beam system. All cooling is initially generated by the chiller and is then distributed to either the DOAS chilled water coil or the secondary chilled water loop that supplies the chilled beams. The total energy consumed by the chiller for all hours during the cooling season was found to be 37,525 kWh. For just occupied hours, the chiller consumed 32,222 kWh (86% of the energy used for all hours).

First Year Energy Performance Metrics

An additional 827 and 6,278 kWh were consumed by the DOAS exhaust fan and supply fan, respectively, for all hours during the cooling season. The combined energy use of the chiller, exhaust fan and supply fan was 44,630 kWh, which gave a seasonal cooling EUI of 6.5 kBtu/sq. ft. for the 23,249 square feet of building space cooled by this system[4].

For this building type and low occupancy rate, a seasonal cooling EUI of 6.5 could be considered high compared to other similar buildings in this region[5].

In terms of delivered cooling, the combined ton-hours measured at the DOAS coil and secondary loop were 13,133 and 10,756, respectively. The total delivered cooling was about 92% of the 25,860 ton-hours generated by the chiller. Since the DOAS is usually shut off during unoccupied hours, the ton-hours consumed by the DOAS coil during occupied hours (12,739) were 97% of the ton-hours consumed for all hours. The peak amount of cooling provided by the chiller was 33.4 tons, which translate into a peak sq. ft./ton of 697.

CBEI calculated two system COPs, one using just chiller compressor and condenser fan energy use (Case I), and one with additional exhaust fan and supply fan usage (Case II). For all hours, the COP for Case I was determined to be 2.49, while for Case II the COP was 2.04. Unfortunately, both of these COPs can be considered low and are indicative of a cooling system which is not operating efficiently[6]. (This inefficient operation also shows up in the portion of the total annual building energy use consumed by this system, which is 13.7% - a relatively high percentage.) However, in terms of delivered cooling, the design and use of this chilled beam system to provide building space cooling is efficient, needing only one ton of cooling per 697 sq. ft. of space. (It's the energy efficiency of supplying that cooling which is proving to be costly.)

CBEI believe issues with DOAS operation and low cooling loads seen by the chiller have resulted in these low system COPs. CBEI is currently in the process of developing operational strategies to boast these COPs into a more acceptable range.

Table 1: Performance Metrics for B661 Chiller/DOAS/Chilled Beam System (5/1/2015 to 8/1/2015)

	All Hours	Occupied Hours[7]
Total Chiller Consumption (kWh):[8]	37,525	32,222
Chiller Ton-Hours:	25,860	22,805
DOAS Ton-Hours:	13,133	12,739
Secondary Loop Hx Ton-Hours:	10,756	9,443
DOAS Exhaust Fan Consumption (kWh):	827	508
DOAS Supply Fan Consumption (kWh):	6,278	5,625
Case I - System COP: Chiller Compressor and Condenser Fan Usage:	2.42	2.49
Case II - System COP: Chiller Compressor, Condenser Fan, Exhaust Fan and Supply Fan Usage:	2.04	2.09
Building Square Footage Served by Chiller/DOAS/Chilled Beam System:	23,249[9]	
Cooling EUI (for Cooling Season 5/1/2015 to 8/31/2015) kBtu/sqft:	6.5	
Electric Consumption:	13.7%	
Peak Chiller Tons:	33.4	
Peak Sq.Ft./Ton:	697	

4 The 23,249 sq. ft. of building space served by the chiller/DOAS/Chilled Beam system represents 64% of B661's total 36,320 sq. ft.
5 Based on recent CBEI analysis of interval data for similar buildings in the Philadelphia area, seasonal cooling EUIs can typically be 3 to 4 kBtu/sq. ft.
6 A COP of an energy efficient cooling system of this type should be on the order 3.0 or higher.
7 Occupied hours are 6:00am to 8:00pm, M-F
8 Includes chiller compressor, controls and condenser fans
9 Chiller/DOAS/Chilled Beam system serves 64% of B661's total 36,320 sq. ft.

Next Steps

The current setup and efficiency of the Chiller/DOAS/Chilled Beam system represents an opportunity for researchers to further refine operation and retro-commission the system. These efforts should result in a system COP approaching the chiller's rated COP of 3.0.

Disclaimer
This material is based upon work supported by the Consortium for Building Energy Innovation, sponsored by the U.S. Department of Energy under Award Number DE-EE0004261.

Consortium for Building Energy Innovation (CBEI)
4960 South 12th Street
The Navy Yard
Philadelphia, PA 19112

Building 661: Lessons Learned from Implementing a Publically-Funded Integrative Design and Delivery Retrofit Project – Building Owners and Contractors

Mark B. Stutman, CEM, LEED AP O+M, The Pennsylvania State University
Rich Sweetser, Exergy Partners

Figure 1. Building 661 at The Navy Yard in Philadelphia. Schematic diagram shows three major HVAC zones. (courtesy of Kieran-Timberlake).

Figure 2. Building 661 at The Navy Yard in Philadelphia. The Penn State Center for Building Energy Science.

Abstract

Building 661 at The Navy Yard in Philadelphia, PA was built as a recreational facility during WWII. This ~36,320 sq. ft. building was operated by the U.S. Navy until the base closed in 1996. In 2011, the building was acquired by Penn State University to become headquarters for the Penn State Consortium for Building Energy Innovation (CBEI). An Integrative Design & Delivery (IDD) approach was selected by Penn State to guide the renovation project. However, the IDD approach for B661 required modification, due to constraints imposed by the law governing public procurement of construction services in the Commonwealth of Pennsylvania. The Pennsylvania Separations Act of 1913 requires a multiple-prime contractor 'design-bid-build' project delivery structure, and forbids bidding contractor involvement in the design process. This constraint severely hampered the effective delivery of the integrative design. CBEI investigators conducted extensive post-construction interviews with nine design team professionals and prime contractors. This article, addressed to building owners and contractors, presents an analysis of the effectiveness of the B661 IDD effort, and provides suggested measures for attempting to preserve and deliver the design intent in building renovation projects prohibited by law from deploying a straightforward IDD process.

Introduction

The Pennsylvania State University Building 661 deep energy retrofit project at The Navy Yard in Philadelphia was undertaken to deliver a highly instrumented and sub-metered 'living laboratory', education and outreach center for the Consortium for Building Energy Efficiency (CBEI). The renovation project, funded by the Commonwealth of Pennsylvania, was a major effort of the CBEI, a five-year program funded by the Department of Energy. The CBEI's goals included enabling 'deep' energy retrofits in small to medium sized commercial buildings (SMSCBs), and demonstration of energy efficient systems tailored for SMSCBs in existing, occupied buildings.

Building 661 was built by the U.S. Navy in 1942 as a recreational facility. The facility was abandoned in the mid-1990s. The gut rehabilitated building was occupied in 2015, and now consists of 36,320 sq. ft. of individual offices, utility spaces, various sized meeting and conference rooms, collaborative workspaces and mezzanine breakout spaces[1,2,3]. Depicted in the figures above, the brick building consists of a two-story 'headhouse' (Figure 1, right) coupled to a 'high-bay atrium' (Figure 1, left) that originally housed an indoor swimming pool and gymnasium space. The most striking feature of the renovated building is undoubtedly the arched high bay spaces and the extensive daylighting provided by the skylights and windows (Figure 2).

One of the core assumptions of the CBEI was that a 'systems approach' to evaluating building systems was the appropriate framework for delivering deep energy retrofits in existing buildings. In the world of sustainable architecture, the Integrative Design and Delivery (IDD) process is a method for applying a systems approach to building design and renovation, with the goal of delivering healthier, comfortable, sustainable buildings in an economic manner over the entire lifecycle of the building. The process is essentially a 'design-build' project delivery process, since the contractor becomes a member of the design team early in the project. Advocates of the IDD process assert that it will significantly improve

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[1] http://cbei.psu.edu/the-center-for-building-energy-science-building-661-cbei-headquarters/, accessed 19 April 2016

[2] Building 661 HVAC Design Intent to Occupancy, February 2015, http://cbei.psu.edu/design-intent-to-occupancy-in-building-661-hvac/, accessed 19 April 2016

[3] Building 661 Lighting Design Intent to Occupancy, March 2015, http://cbei.psu.edu/design-intent-to-occupancy-in-building-661-lighting/, accessed 19 April 2016

the design and deep retrofit process, delivering a superior product at reduced cost over conventional practice.

The objective of this article is to report on the effectiveness of the modified IDD process in delivering the benefits and value desired for Building 661. Specifically, this research assessed the effectiveness of the integrative design process on a publically-funded project with a very real set of regulatory constraints – a statutory requirement for a multi-prime contract award and delivery process, which also forbids bidding contractors from participation in the design process.

The method for assessment of the design and delivery process for the deep energy retrofit of Building 661 consisted of structured interviews of nine retrofit design and construction project professionals at the conclusion of the project, using the same set of questions for each participant. The interviews documented the success of the design effort, but also highlighted the shortcomings in delivering that design intent when constrained by Pennsylvania state public-procurement law. Potential workarounds to achieving IDD for buildings in jurisdictions that prohibit contractor involvement in the design process are discussed below.

Integrative Design and Delivery Process

Conventional building design and delivery (construction) usually involves a series of hand-offs from owner to architect, from builder to occupant and is deemed by many in the industry as a wasteful, broken business model. The conventional design-bid-build[4] approach does not invite all affected parties into the planning process, and therefore does not take into account their needs, areas of expertise or insights. In some cases, using the conventional method, incompatible elements of the design are not discovered until late in the process when it is expensive to make changes.

In contrast, the integrative design process incorporates multidisciplinary collaboration, including key stakeholders and design professionals, from project conception to completion[5]. A team of highly experienced building professionals identified both early team collaboration and Integrative Project Delivery as keys to transforming the building construction process into one that lowers costs, raises quality and cuts waste[6]. Decision-making protocols and complementary design principles must be established early in the process in order to satisfy the goals of multiple stakeholders while achieving the overall project objectives. In addition to extensive collaboration, integrative design involves a "whole building design" approach. A building is viewed as an interdependent system, as opposed to an accumulation of its separate components (site, structure, systems and use). The goal of the design and delivery team is to look at all the systems together to make sure they work in harmony rather than against each other.

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[4] A useful guide to the various construction project delivery 'models' may be found in Chapter 7 of: "The CSI Project Delivery Practice Guide", Construction Specifications Institute, John Wiley & Sons, 2011.

[5] 7 Group and Bill Reed, "The integrative design guide to green building: redefining the practice of sustainability", John Wiley & Sons, 2009.

[6] Miller, R. et. al., "The Commercial Real Estate Revolution", John Wiley & Sons, 2009.

The resulting conceptual work flow plans for conventional design practice and integrative design practice are shown in Figure 3.

The workflow diagrams depict a central tenant of Integrative Design, which is that expending collaborative work effort in the early stages of a project's design leads to reduced effort (and cost) during construction.

The Retrofit Roadmap[7], developed by CBEI investigators over several years, is one attempt to provide a methodology, tools and guidance for applying systems thinking and integrative design principles in a streamlined way for use by building owners and contractors working in SMSCBs.

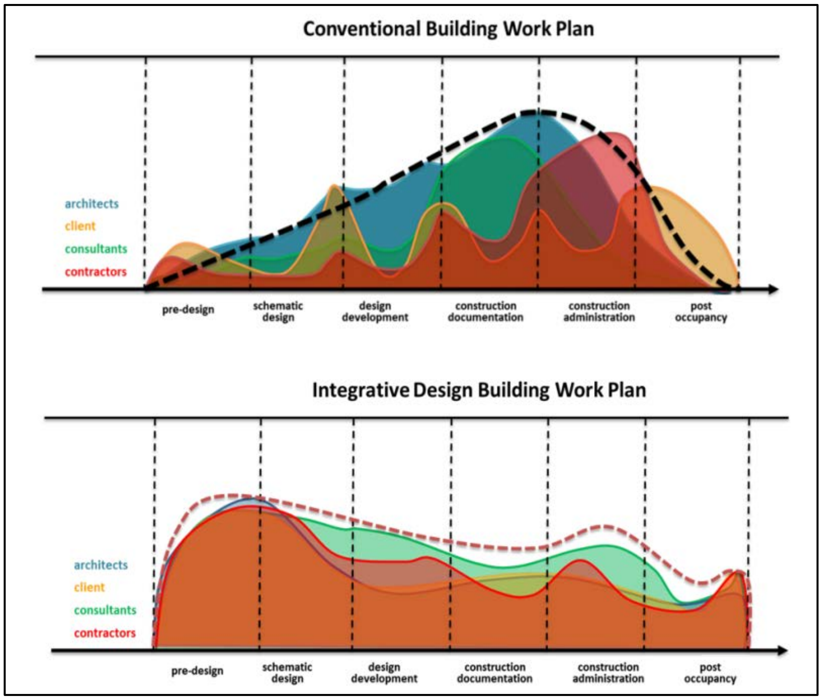

Figure 3. Schematic Level of Effort vs. Project Phase for Conventional and Integrative Design Work Plans. (courtesy of Kieran-Timberlake)

Asset Management Planning

The vast majority of opportunities to implement energy retrofits in occupied SMSCBs are severely limited in scope and budget. Building systems (i.e. envelope, lighting and mechanical) reaching end of life, tenant changes and fit-outs, and financing or re-financing represent the context for most building renovations[8]. To assist with planning and budgeting, owners often develop and maintain an 'asset management plan' to chart the expected cosmetic and appearance improvements, fit-outs and investments anticipated over the ensuing 5-10 years of ownership. CBEI work suggests a 'phased' asset management planning process[9] is a conceptual model for applying systems thinking and incorporating energy efficiency into the conventional asset management process.

Motivations – Building Owners and Contractors

In most cases, building owners of SMSCBs are reliant solely on small contractors (i.e. HVAC, service or general contractors), and are unlikely to have either the budget or the awareness to interact with professionals such as architects or design engineers that would be involved in projects of larger scope and budget.

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[7] F. Trubiano, http://cbei.psu.edu/integrated-design-roadmaps-for-aer/, accessed 3 February 2016.

[8] Rocky Mountain Institute, Retrofit Depot, http://www.rmi.org/retrofit_depot_101_specifying_triggers, accessed 3 February 2016.

[9] M. Stutman, 'A Phased Asset Management Framework for Incorporating Energy Efficient Planning & Operation in Small Commercial Buildings', ACEEE Market Transformation Symposium, March 2016.

Building owners' typically have three clear objectives for a construction project:

- Achieve on-time project delivery,
- Deliver the project at or below budget,
- 'As-installed' building performance and function matches 'as-designed' projections.

We suggest that a fourth goal of owners should be to reduce energy consumption and increase occupant comfort whenever renovations and system replacements are undertaken and economics are favorable. A method for achieving this goal is to apply integrative design principles to the evaluation of the building, and to incorporate the resulting opportunities identified into their asset management plan which will guide anticipated renovations and replacement of systems that will reach end of life over the ensuing decade.

Contractors' motivations for a construction project are to:

- Make a profit on a winning bid,
- Control project budget and profit through change-orders,
- Minimize call-backs and warranty issues once construction is complete.

Contractors are typically familiar just with their area of expertise (i.e. HVAC contractors upgrade or replace HVAC systems, they do not generally consider load reduction strategies involving the building envelop or lighting system replacements), and therefore would normally offer similarly sized systems to replace systems reaching end of life. CBEI researchers submit that contractors could recognize the value of helping a business owner to conduct a deeper energy analysis of their building, the results of which are incorporated into the building's asset management plan. Successfully executed, this could result in multiple construction opportunities over time, and consequently greater revenue from the same client.

Building Owners and Contractors can work together to employ principles of IDD to explicitly explore and articulate the owner's project values and desired outcomes, which may then be incorporated into an asset management plan to be implemented in stages. The Retrofit Roadmap tool described above may be useful in this capacity. When done well, the results could be similar to that of a well-executed integrative design project – resulting in a 'deep' energy retrofit featuring lower-cost, higher-performing building systems.

Pennsylvania Separations Act of 1913

Pennsylvania is now one of only a few remaining states to require public construction projects to be based on "multi-prime contracting". For well over 100 years, most public authorities in Pennsylvania – currently unlike most other states[10] – have been required to use one specific delivery method to build public construction projects: the multiple-prime contractor method. In Pennsylvania, the multi-prime statute requires public authorities to bid out separate contracts for a construction project's general construction, plumbing, electrical and mechanical (HVAC) elements. The statute also forbids the participation of contractors (who wish to bid on the project) in the design phase of the project. Thus, one of the explicit goals of integrative design, early participation of the contractor(s) in the design phase in order to incorporate 'constructability' considerations into the project, is precluded by law.

[10] Attempts to amend the Separations Act in Pennsylvania have so far not succeeded. Literature that we have examined on this topic list Pennsylvania, New York, New Jersey, Illinois and North Dakota as still having similar statutory restrictions. Davisson, E.R., "Rebuilding Ohio's Public Construction Law: Construction Reform in House Bill 153", Schottenstein, Zox and Dunn, www.szd.com, October, 2011.

The multiple prime project delivery process requires public entities to hold and manage multiple prime contracts, making the public entity responsible for the coordination of those contracts. As a result, the public entity increases its contractual liability exposure and is forced to be involved in contractual disputes, project delay claims by contractors, and the project's day-to-day budget, schedule, and scope. Despite some advantages to multi-prime, other researchers have reported that projects sometimes were beset with multiple disputes among the prime contractors, who were unable to coordinate their work effectively, resulting in lawsuits, delays and cost overruns[11].

Ohio faced a similar situation until September 2011, when House Bill 153 gave Ohio public authorities the ability to procure construction work with three additional delivery methods, as well as still retaining the option of multi-prime[12]. The additional tools are: 'general contracting', 'construction manager at-risk' and 'design/build'. These methods have all been used in the private sector for a very long time, as well as by the federal government and other states.

In 1913 it was a simple task to isolate the general construction, mechanical, electrical and plumbing issues from one another. Today code changes and technology have complicated the forced isolation of trades and building systems. When design professionals develop a set of contract documents for a building it is developed as one Integrative and unified document. Under the Separations Act this unified document is then broken into at least four pieces for bidding purposes and the contractors are effectively expected to put it all back together without coordination problems between the trades. As well intentioned and thorough as the contract documentation may try to distinguish the division of those pieces, "gray zones" frequently arises as items of responsibility and financial contention. This method unquestionably opens the door for numerous and expensive change orders.

Building 661 Planning Process

The Building 661 retrofit project was funded by an appropriation from the Commonwealth of Pennsylvania, triggering the requirement for a multi-prime contract structure. Working with the project architects, an integrative design and project delivery process was created to develop plan specifications using a whole building design approach and which endeavored to incorporate expertise from all disciplines. The team established a governance structure to guide the retrofit construction project, and worked together to make decisions for the design of the buildings. This deep retrofit was targeted from inception to be a research project to test the following hypothesis and measure the results:

> *The Integrative Design and Delivery Process will significantly improve the design and deep retrofit process delivering a superior product at reduced cost over conventional practice for public buildings under multi-prime contracting conditions.*

Building 661 Values

During the pre-design phase of the Building 661 deep retrofit project, the project team developed project values that the building design and operations was to accomplish. Given the research and education mission of CBEI (the tenant), these values were critical to deliver:

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[11] Scotti, D.A., "Pennsylvania's Separations Act: Recognizing and Addressing Limitations of the Multiple –Prime Delivery system", www.scottilaw.net, undated.

[12] Ohio DAS General Services Division, "Gov. Kasich Signs Ohio Construction Reform into Law", State Architect's Office eNews, July 2011.

1) **Learning:** We will use processes and technologies that allow us to learn about the efficacy, affordability, repeatability, and constructability of building retrofits
2) **Influence:** We will influence the industry to design, implement and operate energy efficient renovations to unlock the value in existing buildings and to foster job growth and robust economic development.
3) **Collaborative Environments:** We will create a collaborative, multi-dimensional, and highly functional work environment to serve both short and long term goals and provide a nexus for learning and influence.
4) **Systems Integration:** We will create efficient and effective energy retrofits through synergistic integration of dependable components as well as of proven processes.
5) **Reliable Value:** We will demonstrate the energy and occupant performance of collaborative environments and systems integration so that they become the new normal.
6) **Consistent Cost:** We will be good financial stewards and will spend all available initial funds to maximize scope, minimize long term facility costs and with constant consideration of premium/ affordability.
7) **Reliable Time:** We will be a highly reliable team who makes decisions at the most responsible moment and creates a safe and quality work environment.

The values listed above for the B661 project are not representative of typical SMSCB owners, but provide an example and starting point for the development of value statements for other projects.

Building 661 - Vision and Values to Completion Survey

To test the hypothesis stated above, investigators at the Penn State Consortium for Building Innovation prepared a survey consisting of a set of structured interview questions that were used to guide up to two-hour interviews of key members of the project design and delivery team[13]. These surveys attempted to follow the IDD process from the pre-design stage through post occupancy to unpack performance, identify issues, and develop recommendations for improving the process. The interviews revealed a clear distinction between the experiences of the owner/design team and the contractors. The first clear difference was a result of the Separations Act requirement that bidding contractors legally could not interact with the owner/design team before the public bid process. A second and perhaps more profound difference was that the contractors based their successful (lowest) bids solely on the content of the written plans and specifications, without any benefit of the design team's months of interaction and shared vision and values for the project (a key feature of integrative design).

Owner/Design Team – Discussion and Lessons Learned

Interviews were conducted with the following owner/design team professionals: owner's representative, tenant's representative, project manager, construction manager, architect, design engineer, and commissioning agent. The following key lessons learned provide important guidance for deep energy retrofits moving forward:

1) **Project Values –** The project values process was universally agreed as worthwhile. Several of the survey respondents have incorporated the project values process into their standard practice. This process should be further developed as a specific project design tool.

[13] Sweetser, R. & M. Stutman, "Report on Building 661 Integrated Design and Delivery retrofit project from perspective of participating professionals and constructors", CBEI report BP5 M5.4.a, November 2015.

2) **Project Governance –** The project governance structure (Figure 4, below left) provided an effective means to deliver the project design served to be a quick and reliable means of decision-making. Several of the survey respondents reported they have subsequently incorporated this structure of overlapping personnel executive, steering and IDD team responsibilities across the typical decision–making bodies as shown (Figure 4, below right).

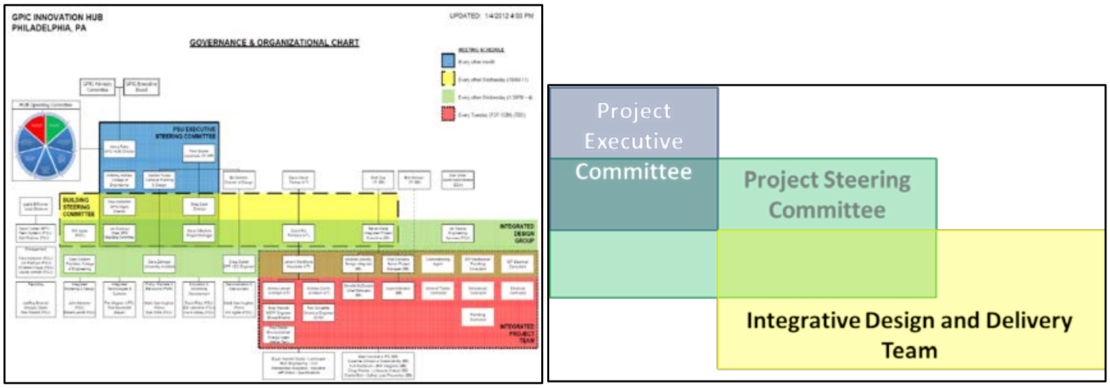

Figure 4. The Project Governance and Organizational Chart (left), showing the overlapping memberships of the Executive, Steering, and Design and Delivery Teams (right).

3) **Multi-prime contracting –** It is clear that the extraordinary efforts to deliver Building 661 in an integrative manner fell short of that goal during the construction administration phase of the project. The analysis revealed two possible considerations to resolve the problems identified during construction:
   a. If the bulk of the failure largely occurred during the design phase then the following efforts could make a difference:
      i. Significantly tighten down on the process of transforming the IDD drawings and specifications into the four prime bid packages. This would add more design cost, but if every 'i' is dotted and 't' crossed, there would be less room for misunderstanding, inappropriate 'value engineering', and change orders.
      ii. Increase bidder qualification requirements, to be sure that all bidders can communicate with the latest tools (like BIM) to minimize confusion and design gaps; and to require prior demonstrated experience with IDD projects.
   b. If the bulk of the failure cannot be avoided in the bid document specification phase then successful implementation of IDD in public projects may require statutory amendment, as discussed above.

The Delivery Team – Discussion and Lessons Learned

The prime contractors essentially entered the project during the construction administration phase. In accordance with university practice, awards were made to the lowest acceptable bidders. Interviews were conducted with two of the four prime contractors, the mechanical and electrical contractors. The plumbing and general contractors did not respond to repeated requests to be interviewed.

1) **Plans and Specifications –** The contractors consistently commented that the plans and specifications provided design intent and general system architecture, but provided inadequate guidance on detailed integration of systems, and integration into the building structure. The notion that "too

much was left to the contractor to decide" was mentioned by both contractors. The tension came when the contractors submitted their interpretation of the design intent based on what they initially bid, versus the design team's intent which they felt was not specifically stated on the drawings or in the specifications. Future efforts at delivering Integrative design project, within the multi-prime context, must include complete detailed plans describing all aspects of general and MEP scope of supply[14].

2) **Architect's Supplemental Instruction** – An architect's supplemental instruction -- more commonly referred to as an ASI -- is similar to a contract addendum. Just as a contract addendum allows one to provide additional information or changes in a contract without entirely rewriting it, an ASI allows an architect to provide additional instructions or make changes without having to rework the entire construction plan. The architect issued 85 ASIs on this project. This is a high number and the contractors commented that the ASIs were not simple and short like past projects, but multipage documents. From the contractor's perspective, this was another sign of the lack of detail within the specifications, as well as a source of ongoing confusion.

3) **Time Management and the Construction Schedule –** Building 661 occupancy began in November 2014 under a partial certificate of occupancy. This was at least one year late. The most significant issue with respect to Building 661 was the unexpected need to completely replace the headhouse roof early in the project. The project timeline never recovered from this event.

   The delivery team used a 2-to-3 month outlook 'pull planning' process for construction delivery. The pull planning process was done using sticky notes on a horizontal time line. These sticky notes were used to identify essential elements of work, identified backwards from the actual project schedule. The sticky notes were located on a large white board (housed in the on-site construction trailer) that had the overall project timescale at the top. The time scale was divided by weeks or period, and all major activities were identified and pull together in sequence. The sticky notes were generally used to identify areas that can be improved along the project schedule, identifying all tasks, and key players required to complete a task without any delays. The contractors interviewed felt that this process did not create a fixed delivery date, and contributed to continual slippage of the project delivery date. Furthermore, no one delivering the building was responsible for the schedule; instead it was the weekly outlook pull planning team that apparently held the schedule responsibility. From the contractor's perspective, future multi-prime projects need to explicitly assign and compensate the general contractor to maintain a critical path project schedule.

   The project contemplated that Building 661 and the new education building 7R were to essentially be constructed at the same time. In reality, 7R significantly lagged Building 661 which added to further time delays for the complete project completion and putting further stress on contractor budgets. It is unclear whether the scheduling process was the sole contributor to the delay in completion, because the owner did not project the typical sense of urgency to complete the project.

[14] Scope of supply, in the building construction context, means the goods and services provided by the delivery participant (contractor) to meet the specified requirements. Scope of supply can be inadequate because of lack of specificity in the construction documents, misunderstanding of the contractor, or 'value engineering' by one or more parties in an attempt to lower initial construction costs.

4) **Construction Leadership –** There appeared to be confusion about leadership structure within the delivery team and on the design team. The general contractor merely acted as a pass-through agent to the owner. There was also some confusion on the decision-making roles of the owner's project manager and the owner's construction manager, mirroring the published experiences of others in Pennsylvania[15]. It was observed that lack of defined site management roles likely left a void in the day-to-day mediation of issues/disputes.

Recommended Practices – Building Owners and Contractors

Widespread conversion of existing buildings to a more energy efficient and comfortable state will require a change in mindset about building renovations. Traditionally, the commercial response to a building system reaching end of life is for the relevant trade contractor to replace the system with a like-sized system. If upgrades are considered, this is still only done in the context of that single system, without considering life-cycle operating costs or interactions with other systems in the building. In order for existing buildings to achieve dramatic, 'deep' energy retrofits, the entire building must be analyzed as a system, in accordance with the principles of integrative design.

Contractors wishing to differentiate themselves from their competitors and cultivate repeat business and projects from a single client might develop the internal expertise within their shop to apply principles of integrative design and learn to apply them to their client's building in as expedient a manner as possible. Owners, most of whom are not building professionals, can be introduced to this approach and the potential value it could provide to them – lower life-cycle building operating costs, increased occupant comfort and productivity, and increased value of their building asset. Contractors who help owners to prepare a phased asset management plan that looks out over the next decade of planned renovations may develop a book of business into the future from returning clients who have received successful earlier phase projects. (This strategy may apply to some privately funded projects, but may not be workable for projects subject to public procurement laws.)

At any rate, contractors who develop experience with IDD techniques may find that it provides their firm with a competitive edge in bidding, winning and delivering publically funded projects such as Building 661 that employ an integrative design process but are required to follow a design-bid-build and multi-prime project delivery model.

The post-construction analysis of the Building 661 IDD project suggests several actions that building owners may take to increase the effectiveness of their publically funded IDD projects.

1) **Stringent qualifications** – Owners should insist upon prior experience with successful IDD projects as a qualification for all invited participants, to successfully develop and translate bid specifications into a successful 'as-delivered' project that realizes the project design intent. We suggest that building owners should require that all potential participants in an IDD project be required to provide references that demonstrate successful participation in several IDD projects, and that building owners contact these references to gauge prior successful IDD project delivery.

2) **Detailed bid specifications –** One of the potential sources of cost savings in design-build IDD projects derives from the 'internalization' of shared project values and collaboration between all parties from the early project stages, through design development. By the time projects reach the

[15] Scotti, pp. 5-10

construction documentation phase, the contractors are intimately familiar with the design intent, and can prepare accurate bid documents by 'filling in' any gaps or 'missing' details in the bid documents. When a multi-prime contract structure is imposed by law, and the bidding prime contractors are forbidden by statute from participating in the design process, an alternative means must be employed to communicate the design intent.

We suggest a work-around for this prohibition on bidding contractor involvement in the design stages of the project is for the owner to prepare a much more detailed set of bid specifications than would normally be required if the contractors had been allowed to participate in the integrative design process. Both the written bid specifications, and the schematic bid drawings, should be prepared with a level detail that thoroughly communicates and preserves the design intent. In critical cases, for example, placement of sensors, or detailed piping or ducting of complex equipment, isometric drawings should be prepared to show proper placement. The purpose of this unusual detail is to avoid misunderstandings of scope that result in compromised design intent.

A statement of the project values should introduce the design intent, and the building owner should make clear that energy efficiency measures and system design concepts incorporated into the specifications are intertwined into the intended operation and functioning of the building, and are not to be value-engineered out of the project. Also, qualified bidders should be given adequate time to prepare their bid documents – attempting to keep a project timeline on schedule by rushing the bid preparation process is common but counterproductive.

3) **Contract administration** – If a multi-prime contract structure is followed, the project should establish a clear line of authority during contract administration, in order to manage the construction timeline in a multi-prime contract. The building owner should budget for, establish, communicate and enforce a clear mechanism for addressing scheduling issues as they arise. A clear change order policy, communicated in the bid documents and in the contract, should also be developed and enforced to ensure that design intent is not lost in the frenzy of change orders.

The post-construction interviews documented that effectively addressing these three issues might have prevented many of the issues encountered in delivery of the Building 661 retrofit project.

Concluding Remarks

Integrative Design principles have been broadly demonstrated to provide an effective framework for managing the design and construction processes of a building renovation. A detailed set of post-construction interviews with the design team and constructors revealed a number of lessons learned, discussed above. The design team members embraced the development of project values and governance structures, and reported that they have subsequently begun to incorporate these elements into their business practices. However, the construction phase of this project showed that a multi-prime design-bid-build project delivery structure negated portions of the potential value creation from a renovation guided by an IDD process. The lessons derived from interviews suggest a set of potential measures that might be implemented by future IDD teams in the bid specification development stage of a project constrained by a multi-prime contractual structure, in order to obviate some of the weaknesses encountered in the Building 661 contract administration phase of the project.

Despite the shortcomings of the construction administration process described above, the actual EUI[16] of the building over the first year of operation[17] was 40.5, within the range of the design goal of 40 – 45, albeit with significantly fewer first-year building occupants than was anticipated during the design process. The performance data, operation discoveries and the occupancy all point to an eventuality whereby B661 has the potential to meet the energy performance design intent. A typical existing office building of this size and type would have an EUI of 70 – 80.

Acknowledgements

"This material is based upon work supported by the Consortium for Building Energy Innovation (CBEI) sponsored by the U.S. Department of Energy under Award Number DE-EE0004261."

[16] EUI is the Energy Utilization Index, a measure of total annual energy consumption divided by the occupied square footage of the building [kBTU/sq. ft./year].   EUI is a metric of the relative energy intensity of a building's operation, and is affected both by weather-driven and occupant-driven 'process' and 'plug' loads that together determine space heating and cooling loads and energy consumption.

[17] CBEI Headquarters Building 661 Baseline Assessment and Research Testbed, CBEI report BP5 M5.4.c, April 2016 .

Building 661: Lessons Learned from Implementing a Publically-Funded Integrative Design and Delivery Retrofit Project – Architects and Design Engineers

Mark B. Stutman, CEM, LEED AP O+M, The Pennsylvania State University
Rich Sweetser, Exergy Partners

Figure 1. Building 661 at The Navy Yard in Philadelphia. Schematic diagram shows three major HVAC zones. (courtesy of Kieran-Timberlake).

Figure 2. Building 661 at The Navy Yard in Philadelphia. The Penn State Center for Building Energy Science.

Abstract
Building 661 at The Navy Yard in Philadelphia, PA was built as a recreational facility during WWII. This ~36,320 sq. ft. building was operated by the U.S. Navy until the base closed in 1996. In 2011, the building was acquired by Penn State University to become headquarters for the Penn State Consortium for Building Energy Innovation (CBEI). An Integrative Design & Delivery (IDD) approach was selected by Penn State to guide the renovation project. However, the IDD approach for B661 required modification, due to constraints imposed by the law governing public procurement of construction services in the Commonwealth of Pennsylvania. The Pennsylvania Separations Act of 1913 requires a multiple-prime contractor 'design-bid-build' project delivery structure, and forbids bidding contractor involvement in the design process. This constraint severely hampered the effective delivery of the integrative design. CBEI investigators conducted extensive post-construction interviews with nine design team professionals and prime contractors. This article, addressed to architects and design engineers, presents an analysis of the effectiveness of the B661 IDD effort, and provides suggested measures for attempting to preserve and deliver the design intent in building renovation projects prohibited by law from deploying a straightforward IDD process.

Introduction
The Pennsylvania State University Building 661 deep energy retrofit project at The Navy Yard in Philadelphia was undertaken to deliver a highly instrumented and sub-metered 'living laboratory', education and outreach center for the Consortium for Building Energy Efficiency (CBEI). The renovation project, funded by the Commonwealth of Pennsylvania, was a major effort of the CBEI, a five-year program funded by the Department of Energy. The CBEI's goals included enabling 'deep' energy retrofits in small to medium sized commercial buildings (SMSCBs), and demonstration of energy efficient systems tailored for SMSCBs in existing, occupied buildings.

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One of the core assumptions of the CBEI was that a 'systems approach' to evaluating building systems was the appropriate framework for delivering deep energy retrofits in existing buildings. In the world of sustainable architecture, the Integrative Design and Delivery (IDD) process is a method for applying a systems approach to building design and renovation, with the goal of delivering healthier, comfortable, sustainable buildings in an economic manner over the entire lifecycle of the building. The process is essentially a 'design-build' project delivery process, since the contractor becomes a member of the design team early in the project. Advocates of the IDD process assert that it will significantly improve

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Integrative Design and Delivery Process

Conventional building design and delivery (construction) usually involves a series of hand-offs from owner to architect, from builder to occupant and is deemed by many in the industry as a wasteful, broken business model. The conventional design-bid-build[4] approach does not invite all affected parties into the planning process, and therefore does not take into account their needs, areas of expertise or insights. In some cases, using the conventional method, incompatible elements of the design are not discovered until late in the process when it is expensive to make changes.

In contrast, the integrative design process incorporates multidisciplinary collaboration, including key stakeholders and design professionals, from project conception to completion[5]. A team of highly experienced building professionals identified both early team collaboration and Integrative Project Delivery as keys to transforming the building construction process into one that lowers costs, raises quality and cuts waste[6]. Decision-making protocols and complementary design principles must be established early in the process in order to satisfy the goals of multiple stakeholders while achieving the overall project objectives. In addition to extensive collaboration, integrative design involves a "whole building design" approach. A building is viewed as an interdependent system, as opposed to an accumulation of its separate components (site, structure, systems and use). The goal of the design and delivery team is to look at all the systems together to make sure they work in harmony rather than against each other.

[4] A useful guide to the various construction project delivery 'models' may be found in Chapter 7 of: "The CSI Project Delivery Practice Guide", Construction Specifications Institute, John Wiley & Sons, 2011.

[5] 7 Group and Bill Reed, "The integrative design guide to green building: redefining the practice of sustainability", John Wiley & Sons, 2009.

[6] Miller, R. et. al., "The Commercial Real Estate Revolution", John Wiley & Sons, 2009.

The resulting conceptual work flow plans for conventional design practice and integrative design practice are shown in Figure 3.

The workflow diagrams depict a central tenant of Integrative Design, which is that expending collaborative work effort in the early stages of a project's design leads to reduced effort (and cost) during construction.

The Retrofit Roadmap[7], developed by CBEI researchers over several years, is one attempt to provide a methodology, tools and guidance for applying systems thinking and integrative design principles in a streamlined way for use by building professionals, contractors and building owners.

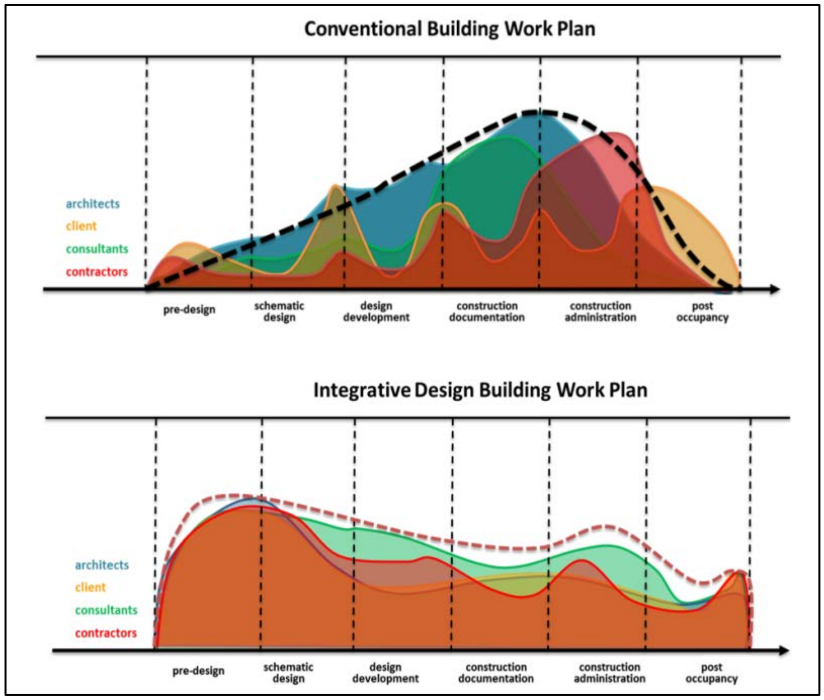

Figure 3. Schematic Level of Effort vs. Project Phase for Conventional and Integrative Design Work Plans. (courtesy of Kieran-Timberlake)

Asset Management Planning

The vast majority of opportunities to implement energy retrofits in occupied SMSCBs are severely limited in scope and budget. Building systems (i.e. envelope, lighting and mechanical) reaching end of life, tenant changes and fit-outs, and financing or re-financing represent the context for most building renovations[8]. To assist with planning and budgeting, owners commonly develop and maintain an 'asset management plan' to chart the expected improvements, fit-outs and investments anticipated over the ensuing 5-10 years of ownership. CBEI work suggests a 'phased' asset management planning process[9] is a conceptual model for applying systems thinking and incorporating energy efficiency into the conventional asset management process.

Motivations – Architects and Design Engineers

If the project scope is large enough, the owner will require the services of an architect who can facilitate an integrative design approach and, along with design engineering assistance, develop a set of measures to be incorporated into the building's asset management plan.

Broadly, architect's motivations are to:

- Build their firm's reputation via differentiation of their offering from competitors,
- Delivery of higher quality buildings that meet owner's wants and expectations, at lower cost.

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[7] F. Trubiano, http://cbei.psu.edu/integrated-design-roadmaps-for-aer/, accessed 3 February 2016.

[8] Rocky Mountain Institute, Retrofit Depot, http://www.rmi.org/retrofit_depot_101_specifying_triggers, accessed 3 February 2016.

[9] M. Stutman, 'A Phased Asset Management Framework for Incorporating Energy Efficient Planning & Operation in Small Commercial Buildings', ACEEE Market Transformation Symposium, March 2016.

Design engineers motivations are to:

- Deliver system designs and specifications that can be reliably installed by the winning installation contractor,
- Minimize their requirement for unplanned effort during contract administration and occupancy phases of building retrofit delivery.

We suggest that an additional goal of long-term business growth for both types of practices could be realized by offering an integrative analysis of an owner's building, identifying the owner's project values and desired outcomes so they are clearly understood and are incorporated into a plan that will incorporate energy efficiency considerations and guide the owner through the next decade or so of anticipated building renovations and system replacements in a cost effective manner. The Retrofit Roadmap tool described above may be useful in this capacity. Such a service may provide a degree of differentiation to both architects and design engineers, and may also provide them with an opportunity to expand their practices to include medium sized retrofit projects that would normally be too small to contract their services. The development of a collaborative relationship between owners, architects, design engineers and contractors in the course of preparing a phased asset management plan may also increase the likelihood of repeat business from the same client, with minimal additional client acquisition costs at each phase of the project.

Pennsylvania Separations Act of 1913

Pennsylvania is now one of only a few remaining states to require public construction projects to be based on "multi-prime contracting". For well over 100 years, most public authorities in Pennsylvania – currently unlike most other states[10] – have been required to use one specific delivery method to build public construction projects: the multiple-prime contractor method. In Pennsylvania, the multi-prime statute requires public authorities to bid out separate contracts for a construction project's general construction, plumbing, electrical and mechanical (HVAC) elements. The statute also forbids the participation of contractors (who wish to bid on the project) in the design phase of the project. Thus, one of the explicit goals of integrative design, early participation of the contractor(s) in the design phase in order to incorporate 'constructability' considerations into the project, is precluded by law.

The multiple prime project delivery process requires public entities to hold and manage multiple prime contracts, making the public entity responsible for the coordination of those contracts. As a result, the public entity increases its contractual liability exposure and is forced to be involved in contractual disputes, project delay claims by contractors, and the project's day-to-day budget, schedule, and scope. Despite some advantages to multi-prime, other researchers have reported that projects sometimes were beset with multiple disputes among the prime contractors, who were unable to coordinate their work effectively, resulting in lawsuits, delays and cost overruns[11].

Ohio faced a similar situation until September 2011, when House Bill 153 gave Ohio public authorities the ability to procure construction work with three additional delivery methods, as well as still retaining

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[10] Attempts to amend the Separations Act in Pennsylvania have so far not succeeded. Literature that we have examined on this topic list Pennsylvania, New York, New Jersey, Illinois and North Dakota as still having similar statutory restrictions. Davisson, E.R., "Rebuilding Ohio's Public Construction Law: Construction Reform in House Bill 153", Schottenstein, Zox and Dunn, www.szd.com, October, 2011.

[11] Scotti, D.A., "Pennsylvania's Separations Act: Recognizing and Addressing Limitations of the Multiple –Prime Delivery system", www.scottilaw.net, undated.

the option of multi-prime[12]. The additional tools are: 'general contracting', 'construction manager at-risk' and 'design/build'. These methods have all been used in the private sector for a very long time, as well as by the federal government and other states.

In 1913 it was a simple task to isolate the general construction, mechanical, electrical and plumbing issues from one another. Today code changes and technology have complicated the forced isolation of trades and building systems. When design professionals develop a set of contract documents for a building it is developed as one Integrative and unified document. Under the Separations Act this unified document is then broken into at least four pieces for bidding purposes and the contractors are effectively expected to put it all back together without coordination problems between the trades. As well intentioned and thorough as the contract documentation may try to distinguish the division of those pieces, "gray zones" frequently arises as items of responsibility and financial contention. This method unquestionably opens the door for numerous and expensive change orders.

Building 661 Planning Process

The Building 661 retrofit project was funded by an appropriation from the Commonwealth of Pennsylvania, triggering the requirement for a multi-prime contract structure. Working with the project architects, an integrative design and project delivery process was created to develop plan specifications using a whole building design approach and which endeavored to incorporate expertise from all disciplines. The team established a governance structure to guide the retrofit construction project, and worked together to make decisions for the design of the buildings. This deep retrofit was targeted from inception to be a research project to test the following hypothesis and measure the results:

> *The Integrative Design and Delivery Process will significantly improve the design and deep retrofit process delivering a superior product at reduced cost over conventional practice for public buildings under multi-prime contracting conditions.*

Building 661 Values

During the pre-design phase of the Building 661 deep retrofit project, the project team developed project values that the building design and operations was to accomplish. Given the research and education mission of CBEI (the tenant), these values were critical to deliver:

1) **Learning:** We will use processes and technologies that allow us to learn about the efficacy, affordability, repeatability, and constructability of building retrofits
2) **Influence:** We will influence the industry to design, implement and operate energy efficient renovations to unlock the value in existing buildings and to foster job growth and robust economic development.
3) **Collaborative Environments:** We will create a collaborative, multi-dimensional, and highly functional work environment to serve both short and long term goals and provide a nexus for learning and influence.
4) **Systems Integration:** We will create efficient and effective energy retrofits through synergistic integration of dependable components as well as of proven processes.
5) **Reliable Value:** We will demonstrate the energy and occupant performance of collaborative environments and systems integration so that they become the new normal.

[12] Ohio DAS General Services Division, "Gov. Kasich Signs Ohio Construction Reform into Law", State Architect's Office eNews, July 2011.

6) **Consistent Cost:** We will be good financial stewards and will spend all available initial funds to maximize scope, minimize long term facility costs and with constant consideration of premium/ affordability.
7) **Reliable Time:** We will be a highly reliable team who makes decisions at the most responsible moment and creates a safe and quality work environment.

The values listed above for the B661 project are not representative of typical SMSCB owners, but provide an example and starting point for the development of value statements for other projects.

Building 661 - Vision and Values to Completion Survey

To test the hypothesis stated above, investigators at the Penn State Consortium for Building Innovation prepared a survey consisting of a set of structured interview questions that were used to guide up to two-hour interviews of key members of the project design and delivery team[13]. These surveys attempted to follow the IDD process from the pre-design stage through post occupancy to unpack performance, identify issues, and develop recommendations for improving the process. The interviews revealed a clear distinction between the experiences of the owner/design team and the contractors. The first clear difference was a result of the Separations Act requirement that bidding contractors legally could not interact with the owner/design team before the public bid process. A second and perhaps more profound difference was that the contractors based their successful (lowest) bids solely on the content of the written plans and specifications, without any benefit of the design team's months of interaction and shared vision and values for the project (a key feature of integrative design).

Owner/Design Team – Discussion and Lessons Learned

Interviews were conducted with the following owner/design team professionals: owner's representative, tenant's representative, project manager, construction manager, architect, design engineer, and commissioning agent. The following key lessons learned provide important guidance for deep energy retrofits moving forward:

1) **Project Values –** The project values process was universally agreed as worthwhile. Several of the survey respondents have incorporated the project values process into their standard practice. This process should be further developed as a specific project design tool.

2) **Project Governance –** The project governance structure (Figure 4, below left) provided an effective means to deliver the project design served to be a quick and reliable means of decision-making. Several of the survey respondents reported they have subsequently incorporated this structure of overlapping personnel executive, steering and IDD team responsibilities across the typical decision–making bodies as shown (Figure 4, below right).

3) **Multi-prime contracting –** It is clear that the extraordinary efforts to deliver Building 661 in an integrative manner fell short of that goal during the construction administration phase of the project. The analysis revealed two possible considerations to resolve the problems identified during construction:
    a. If the bulk of the failure largely occurred during the design phase then the following efforts could make a difference:

[13] Sweetser, R. & M. Stutman, "Report on Building 661 Integrated Design and Delivery retrofit project from perspective of participating professionals and constructors", CBEI report BP5 M5.4.a, November 2015.

i. Significantly tighten down on the process of transforming the IDD drawings and specifications into the four prime bid packages. This would add more design cost, but if every 'i' is dotted and 't' crossed, there would be less room for misunderstanding, inappropriate 'value engineering', and change orders.

ii. Increase bidder qualification requirements, to be sure that all bidders can communicate with the latest tools (like BIM) to minimize confusion and design gaps; and to require prior demonstrated experience with IDD projects.

b. If the bulk of the failure cannot be avoided in the bid document specification phase then successful implementation of IDD in public projects may require statutory amendment, as discussed above.

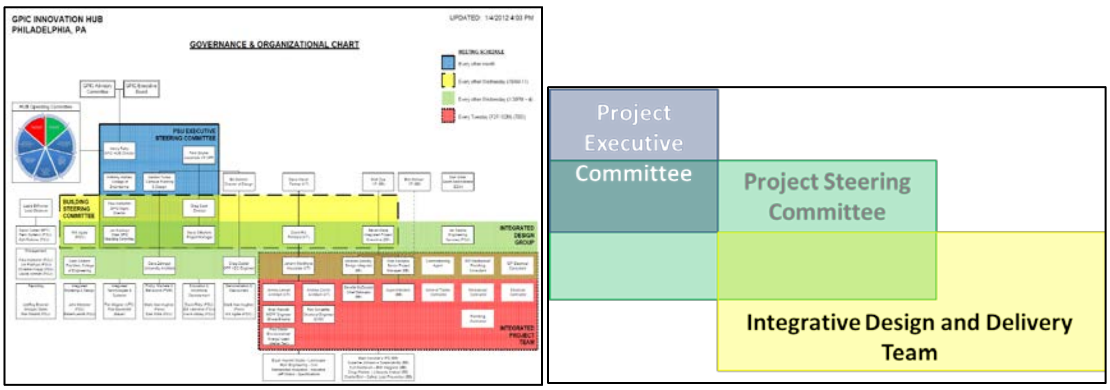

Figure 4. The Project Governance and Organizational Chart (left), showing the overlapping memberships of the Executive, Steering, and Design and Delivery Teams (right).

The Delivery Team – Discussion and Lessons Learned

The prime contractors essentially entered the project during the construction administration phase. In accordance with university practice, awards were made to the lowest acceptable bidders. Interviews were conducted with two of the four prime contractors, the mechanical and electrical contractors. The plumbing and general contractors did not respond to repeated requests to be interviewed.

1) **Plans and Specifications –** The contractors consistently commented that the plans and specifications provided design intent and general system architecture, but provided inadequate guidance on detailed integration of systems, and integration into the building structure. The notion that "too much was left to the contractor to decide" was mentioned by both contractors. The tension came when the contractors submitted their interpretation of the design intent based on what they initially bid, versus the design team's intent which they felt was not specifically stated on the drawings or in the specifications. Future efforts at delivering Integrative design project, within the multi-prime context, must include complete detailed plans describing all aspects of general and MEP scope of supply[14].

2) **Architect's Supplemental Instruction** – An architect's supplemental instruction -- more commonly referred to as an ASI -- is similar to a contract addendum. Just as a contract addendum allows one

[14] Scope of supply, in the building construction context, means the goods and services provided by the delivery participant (contractor) to meet the specified requirements. Scope of supply can be inadequate because of lack of specificity in the construction documents, misunderstanding of the contractor, or 'value engineering' by one or more parties in an attempt to lower initial construction costs.

to provide additional information or changes in a contract without entirely rewriting it, an ASI allows an architect to provide additional instructions or make changes without having to rework the entire construction plan. The architect issued 85 ASIs on this project. This is a high number and the contractors commented that the ASIs were not simple and short like past projects, but multipage documents. From the contractor's perspective, this was another sign of the lack of detail within the specifications, as well as a source of ongoing confusion.

3) **Time Management and the Construction Schedule –** Building 661 occupancy began in November 2014 under a partial certificate of occupancy. This was at least one year late. The most significant issue with respect to Building 661 was the unexpected need to completely replace the headhouse roof early in the project. The project timeline never recovered from this event.

   The delivery team used a 2-to-3 month outlook 'pull planning' process for construction delivery. The pull planning process was done using sticky notes on a horizontal time line. These sticky notes were used to identify essential elements of work, identified backwards from the actual project schedule. The sticky notes were located on a large white board (housed in the on-site construction trailer) that had the overall project timescale at the top. The time scale was divided by weeks or period, and all major activities were identified and pull together in sequence. The sticky notes were generally used to identify areas that can be improved along the project schedule, identifying all tasks, and key players required to complete a task without any delays. The contractors interviewed felt that this process did not create a fixed delivery date, and contributed to continual slippage of the project delivery date. Furthermore, no one delivering the building was responsible for the schedule; instead it was the weekly outlook pull planning team that apparently held the schedule responsibility. From the contractor's perspective, future multi-prime projects need to explicitly assign and compensate the general contractor to maintain a critical path project schedule.

   The project contemplated that Building 661 and the new education building 7R were to essentially be constructed at the same time. In reality, 7R significantly lagged Building 661 which added to further time delays for the complete project completion and putting further stress on contractor budgets. It is unclear whether the scheduling process was the sole contributor to the delay in completion, because the owner did not project the typical sense of urgency to complete the project.

4) **Construction Leadership –** There appeared to be confusion about leadership structure within the delivery team and on the design team. The general contractor merely acted as a pass-through agent to the owner. There was also some confusion on the decision-making roles of the owner's project manager and the owner's construction manager, mirroring the published experiences of others in Pennsylvania[15]. It was observed that lack of defined site management roles likely left a void in the day-to-day mediation of issues/disputes.

[15] Scotti, pp. 5-10

Recommended Practices – Architects and Design Engineers

Widespread conversion of existing buildings to a more energy efficient and comfortable state will require a change in mindset about building renovations. Traditionally, the commercial response to a building system reaching end of life is for the relevant trade contractor to replace the system with a like-sized system. If upgrades are considered, this is still only done in the context of that single system, without considering life-cycle operating costs or interactions with other building systems. In order for existing buildings to achieve dramatic, 'deep' energy retrofits, the entire building must be analyzed as a system, in accordance with the principles of integrative design.

Design professionals wishing to differentiate their practice from their competitors and potentially cultivate repeat business and projects from a single client might develop the internal expertise within their shop to apply principles of integrative design and learn to apply them to their client's building in as expedient a manner as possible. Owners, most of whom are not building professionals, can be introduced to this approach and the potential value it could provide to them – lower building life-cycle operating costs, increased occupant comfort and productivity, and increased value of their building asset. Helping the owner to prepare a phased asset management plan that looks out over the next decade may result in a book of business from returning clients who have received successful earlier phase projects. Design professionals who develop experience with IDD techniques may find that it provides their firm with a competitive edge in bidding, winning and delivering publically funded projects such as Building 661 that employ an integrative design process but are required to follow a design-bid-build and multi-prime project delivery model.

The post-construction analysis of the Building 661 IDD project suggests several actions that architects and design engineers might take to assist an owner to incorporate energy efficiency measures into their asset management plan, to communicate project design intent to bidding contractors, and to increase the effectiveness and success of publically funded projects.

1) **Stringent qualifications –** Prior experience with successful IDD projects is a qualification that may allow all invited participants – architects, design engineers and multi-prime contractors – to successfully develop and translate bid specifications into a successful 'as-delivered' project that realizes energy efficiency goals and project design intent. We therefore suggest that architects and design engineers who wish to participate in publically-funded IDD projects develop experience with the process via participation in a few privately-funded design-build projects. They should be prepared to provide references that demonstrate successful participation in several IDD projects, and encourage their prospective clients to contact these references.

2) **Detailed bid specifications –** One of the potential sources of cost savings in IDD projects derives from the 'internalization' of shared project values and collaboration between all parties from the early project stages, through design development. By the time projects reach the construction documentation phase, the contractors are intimately familiar with the design intent, and can prepare accurate bid documents by 'filling in' any gaps or 'missing' details in the bid documents. When a multi-prime contract structure is imposed by law, and the bidding prime contractors are forbidden by statute from participating in the design process, an alternative means must be employed to communicate the design intent.

   We suggest a work-around for this prohibition on bidding contractor involvement in the design stages of the project is to prepare a much more detailed set of bid specifications than would normally be required if the contractors had participated in the Integrative design process. With advance knowledge that the contractual structure is multi-prime, architects and design engineers on the team should recommend that the owner incorporate language in the bid documents that anticipates and addresses the co-ordination problems between the trades that will arise from breaking the bid documents into separate pieces. Both the written bid specifications, and the schematic bid drawings, should be prepared with a level of detail that thoroughly communicates and preserves the design intent. In critical cases, for example, placement of sensors, or detailed piping or ducting of complex equipment, isometric drawings should be prepared to show proper placement. The purpose of this unusual level of detail is to avoid misunderstandings of scope that result in compromised design intent.

A statement of the project values should introduce the design intent, and the building owner should make clear that energy efficiency measures and system design concepts incorporated into the specifications are intertwined into the intended operation and functioning of the building, and are not to be value-engineered out of the project. Also, qualified bidders should be given adequate time to prepare their bid documents – attempting to keep a project timeline on schedule by rushing the bid preparation process is common but counterproductive.

3) **Contract administration** – If a multi-prime contract structure is followed, the design team should advise the owner to establish a clear line of authority during contract administration, in order to manage the construction timeline. Design team professionals should also recommend the owner establish clear contractual responsibility that minimizes the "gray zones" that frequently arises as items of responsibility and financial contention in multi-prime contracts. The building owner should budget for, establish, communicate and enforce a clear mechanism for addressing scheduling issues as they arise. A clear change order policy, communicated in the bid documents and in the contract, should also be enforced to ensure that design intent is not lost in the frenzy of change orders.

Concluding Remarks

Integrative Design principles have been broadly demonstrated to provide an effective framework for managing the design and construction processes of a building renovation. A detailed set of post-construction interviews with the design team and constructors revealed a number of lessons learned, discussed above. The design team members embraced the development of project values and governance structures, and reported that they have subsequently begun to incorporate these elements into their business practices. However, the construction phase of this project showed that a multi-prime design-bid-build project delivery structure negated portions of the potential value creation from a renovation guided by an IDD process. The lessons derived from interviews suggest a set of potential measures that might be implemented by future IDD teams in the bid specification development stage of a project constrained by a multi-prime contractual structure, in order to obviate some of the weaknesses encountered in the Building 661 contract administration phase of the project.

Despite the shortcomings of the construction administration process described above, the actual EUI[16] of the building over the first year of operation[17] was 40.5, within the range of the design goal of 40 – 45,

[16] EUI is the Energy Utilization Index, a measure of total annual energy consumption divided by the occupied square footage of the building [kBTU/sq. ft./year]. EUI is a metric of the relative energy intensity of a building's operation, and is affected both by weather-driven and occupant-driven 'process' and 'plug' loads that together determine space heating and cooling loads and energy consumption.
[17] CBEI Headquarters Building 661 Baseline Assessment and Research Testbed, CBEI report BP5 M5.4.c, April 2016

albeit with significantly fewer first-year building occupants than was anticipated during the design process. The performance data, operation discoveries and the occupancy all point to an eventuality whereby B661 has the potential to meet the energy performance design intent. A typical existing office building of this size and type would have an EUI of 70 – 80.

Acknowledgements
"This material is based upon work supported by the Consortium for Building Energy Innovation (CBEI) sponsored by the U.S. Department of Energy under Award Number DE-EE0004261."

From:	Scott, Jay
To:	Mark Stutman
Cc:	Foster, Sarah
Subject:	RE: abstract submission
Date:	Wednesday, April 27, 2016 8:05:16 AM

Good morning, Mr. Stutman,

Thank you so much for both abstracts. We would love to run both articles, one in the magazine (and online) and the second one as an online-only article. Both abstracts are strong. I'm kind of leaning toward the abstract below with the post-construction interviews for print, but, please, you tell me what makes sense for you and your co-authors.

Once you have decided on your preferences and if this approach is acceptable, our managing editor Sarah Foster, copied here, will work with you on development of both articles.

Thank you for thinking of HPB. We look forward to hearing from you.

Regards,
Jay Scott

ASHRAE
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Jay Scott
Editor, High Performing Buildings Magazine and ASHRAE Journal
ASHRAE
1791 Tullie Circle NE
Atlanta, GA 30329
Tel: 678-539-1210
JayScott@ashrae.org
www.ASHRAE.org

From: Mark Stutman [mailto:mbstutman@engr.psu.edu]
Sent: Tuesday, April 26, 2016 1:56 PM
To: hpbmagazine
Subject: abstract submission

Greetings:

I would like to submit the following abstract of an article for consideration:

Title:

Building 661: Lessons Learned from Implementing a Publically-Funded Integrative Design and Delivery Retrofit Project

Authors:
Mark B. Stutman, CEM, LEED AP O+M, The Pennsylvania State University
Rich Sweetser, Exergy Partners Corp.

Abstract:
Building 661 at The Navy Yard in Philadelphia, PA was built as a recreational facility during WWII. This ~36,320 sq. ft. building was operated by the U.S. Navy until the base closed in 1996. In 2011, the building was acquired by Penn State University to become headquarters for the Penn State Consortium for Building Energy Innovation (CBEI). An Integrated Design & Delivery (IDD) approach was selected by Penn State to guide the renovation project. However, the IDD approach for B661 required modification, due to constraints imposed by the law governing public procurement of construction services in the Commonwealth of Pennsylvania. The Pennsylvania Separations Act of 1913 requires a multiple-prime contractor 'design-bid-build' project delivery structure, and forbids contractor involvement in the design process. These constraints severely hampered the effective delivery of the integrated design. CBEI investigators conducted extensive post-construction interviews with nine design team professionals and prime contractors. This article presents an analysis of the effectiveness of the B661 IDD effort, and provides suggested measures for attempting to preserve and deliver the design intent in building renovation projects prohibited law from deploying a straightforward IDD process.

Thank you,

Mark B. Stutman, M.S., LEED® AP O&M, CEM®
Demonstration Program Manager
Consortium for Building Energy Innovation
The Pennsylvania State University
The Navy Yard
4960 South 12th Street
Philadelphia, PA 19112
mbstutman@psu.edu
O: (215) 218-7584
C: (302) 565-4618
http://www.cbei.psu.edu/
www.linkedin.com/in/mbstutman

From:	valentina@aeecenter.org
To:	Mark Stutman
Subject:	Web Form Received on www.aeecenter.org - 2016 WEEC Call for Papers
Date:	Tuesday, January 12, 2016 1:58:19 PM

Notice of acceptance will be emailed in April 2016. Deadline for formal manuscripts to be included in the conference Proceedings is August 2016. Any questions, please contact Valentina Sweeten at 770-447-5083 Ext. 215 or Valentina@aeecenter.org

PRESENTATION TITLE: A case study of the 'design intent' vs. 'as delivered' performance of a deep energy retrofit of a small masonry office building

SUGGESTED TOPICS: Energy Auditing, Energy Basics, Energy Management, Energy Policy, Energy Services, Federal & State Energy Management (FedEnergy Works, Green & High Performance Buildings

If "Other", please list topic here:

I would like for this abstract be considered for a poster session: no

Full Name: Mark Budner Stutman

Job Title: Demonstration Program Manager

Company Name: Penn State Consortium for Building Energy Innovation

Street Address: 4960 S. 12th St.

City: Philadelphia

State: PA

Zip code: 19112

Country: United States

Phone: 215-218-7584

Email: mbstutman@engr.psu.edu

ABSTRACT (max 2000 characters-remove all extra spacing): This paper documents the design intent and first-year as-built performance of Building 661 at The Navy Yard in Philadelphia, PA. Built as a recreational facility during WWII, this ~38,000 sq. ft. building was closed in 1996. In 2011, it was acquired by the Pennsylvania State University to become headquarters for the Consortium for Building Energy Innovation (CBEI). An Integrated Design & Delivery (IDD) approach was selected for the project. The IDD process for B661 required modification due to constraints imposed by laws governing procurement of construction services in Pennsylvania. CBEI's mission to promote building energy efficiency and systems

thinking in existing small- and medium-sized commercial buildings dictated that B661 be equipped with high performance yet ‘off-the-shelf’ HVAC, envelope and lighting systems, selected by the design team with initial guidance from CBEI investigators. Highly efficient solutions that are unlikely to become cost-effective in the near future were intentionally avoided. The design intent for the retrofit was to demonstrate, via a measurement & verification system (M&V), that the selected systems provide occupant comfort with substantially reduced energy consumption compared to current practice. The project was intended to highlight cost-effective solutions that could be broadly applied to the existing building stock in regions with similar climates. Few buildings achieve their design comfort and energy performance goals on ‘day one’ of occupancy. Once CBEI occupied B661, significant challenges remained in ensuring the performance of the building matched the design intent. The extensive M&V system used for B661 has been instrumental to evaluating the performance of the building’s energy systems. Based on energy data analytics and lessons learned from extensive post-construction interviews with the design team and contractors, recommendations for avoiding the challenges encountered in this project are discussed.

BIOGRAPHY (max 2000 characters-remove all extra spacing): Mark B. Stutman is employed by The Pennsylvania State University as the Demonstration Program Manager at the Penn State Consortium for Building Energy Innovation,located at The Philadelphia Navy Yard. (CBEI was formerly the U.S. Department of Energy's Energy Efficient Buildings Hub). In this role, Mark oversees the development of building retrofit projects and coordinates the deployment of CBEI tools and techniques in the regional small to medium size commercial building marketplace. These include building energy models and evaluation tools, measurement and verification systems and strategies, integrated project design and delivery techniques, and integrated packages of building energy efficiency technologies and systems. Mark has 30 years of commercial experience developing, demonstrating and marketing new products and businesses with significant technology and engineering content. Prior to coming to the CBEI, he was a North American Product Manager and a Building Energy Specialist at Camfil Inc., a privately owned global manufacturing company. Mark revamped a North American product portfolio; segmented it by application, performance and value propositions; and expanded sales with new product offerings, enhanced distributor training, field sales support, and new marketing tools. Earlier in his career, Mark was Director of Marketing and New Product Development at Compact Membrane Systems, Inc., and a Program Manager and Product Specialist at W. L. Gore and Associates, Inc. He began his building energy career as a 'House Doctor' for Princeton Energy Partners. Mark earned an M.S. in Climatology from the University of Delaware. He is a LEED Accredited Professional (LEED AP O&M), and a Certified Energy Manager (CEM).

Selection Criteria (hold ctrl key for multi-select): I am an AEE member, Non-profit organization

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Additional Comments:

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