UNITED STATES AIR FORCE MILCON TRANSFORMATION: BUILDING INFORMATION MODELING CASE STUDIES

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ABSTRACT

This research investigates owners' lessons learned and designers' experiences related with the BIM initiative under military construction (MILCON) Transformation, as well as the implications for shaping future United States Air Force MILCON management and design optimization. Namely, the USAF manages approximately $2B of traditional MILCON per year in a typical portfolio of 100-150 projects. In 2010, the Air Force's MILCON authority having jurisdiction, the Air Force Center for Engineering and the Environment (AFCEE) revised its standard design instruction to supplement how it managed and directed MILCON. One of the primary differences was a requirement for all vertical construction to be designed through a Building Information Modeling (BIM) approach. This paper explores two specific pilot projects to assess Air Force BIM implementation as well as discusses additional initiatives that will be used in future BIM work for the Air Force. First, one project case study explored cost impact on typical MILCON project management practices. The HQ CENTCOM facility implemented a BIM-based approach on a standard design-bid-build project at MacDill Air Force Base, FL. A second project case study explored quality benefits via BIM use for facility optimization on a LEED-platinum facility. Specifically, the Tyndall Air Force Base Fitness Center targeted energy efficiency. The facility's Electronic Management Control System (EMCS) monitored pure consumption, solar photovoltaic (PV) power meter pulse output, and solar hot water recovery systems using Digital Energy Monitors (DEM) tied to the BIM via an exported database file via the EMCS server. Lastly, future AFCEE endeavors are explored through partnerships with design firms and service firms like Jacobs and Onuma to manage and leverage new BIM-based designs to afford greater collaboration from inception onward for USAF facilities worldwide.

Keywords: Air Force, MILCON, BIM, Prototype, Collaboration, Control Systems

1. INTRODUCTION

1.1 Advancing the US Construction Industry through BIM in the US Air Force

According to the Committee on Advancing the Competitiveness and Productivity of the U.S. Construction Industry, "Large corporations and government agencies—the owners that regularly invest in capital facilities and infrastructure—are in the best position to lead an effort to drive change in the construction industry" (NAS 2009). One of the largest facility owners in the world is the U.S. Department of Defense (DoD). The DoD accounts for 545,700 facilities on 5,400 sites with a plant replacement value of $706 Billion (DoD 2008). The U.S. Air Force is one government agency under the DoD that has demonstrated the support and motivation to lead the effort to drive change in the industry.

The mission of the USAF is to "*fly, fight* and *win*...in air, space and cyberspace" (af.mil 2010). To accomplish this mission, the Air Force promulgates six distinctive capabilities. In order to fulfill the sixth distinctive capability, *Agile Combat Support*, the Air Force has a budget of approximately $2B per fiscal year to construct 100-150 unique projects that support the mission.

As of 20 MAY 10, the Air Force Center for Engineering and the Environment (AFCEE), the primary entity responsible for all multi-million dollar Air Force construction was tracking 224 projects in years 2010, 2011, and 2012 in the Automated Civil Engineer System (ACES) for a total value of $3.6B. After a nearly $3Billion dollar budget in 2010, the United States Air Force's capital construction allocation in the President's Budget for 2011 includes 75 projects with a programmed amount of approximately $1.3B (Figure 1). In 2010, under the direction of Colonel Mike Hutchison of the Capital Investment Management Division at AFCEE, the USAF implemented a myriad of new requirements for projects awarded as new designs or design-build contracts. One of these new requirements was a Building Information Modeling (BIM) approach.

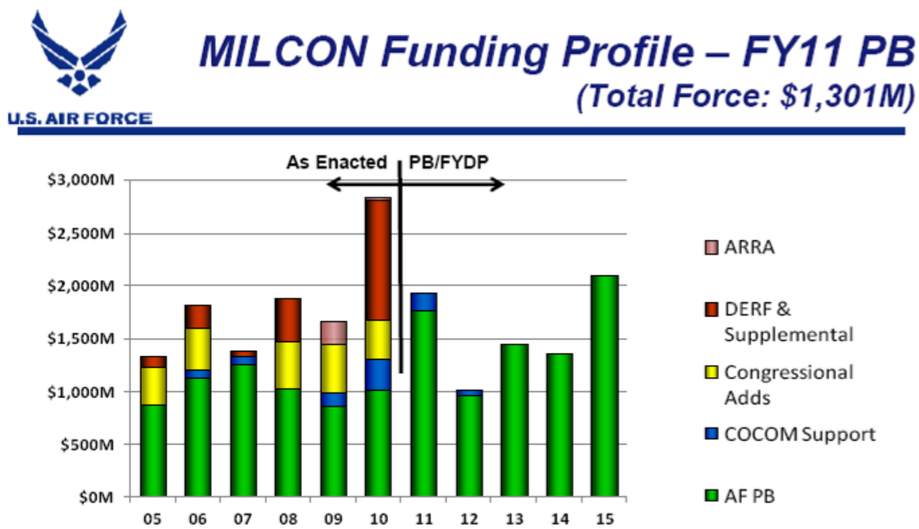

Figure 1: Air Force MILCON Funding Profile for FY11 (Hutchison 2010)

The primary technological innovation implemented in FY10 was BIM. The United States Air Force is one of many large-budget facility and capital investment owners to declare a BIM-based requirement for their portfolio in recent years. Shortly before the beginning of fiscal year 2010 on October 1, 2009, the Air Force established a new standard design instruction for their projects executed by the U.S. Army Corps of Engineers and Naval Facilities Command. The design instruction grew from a relatively simple one page document into a three page listing of new requirements not previously mandatory for USAF MILCON. The three primary new items centered on methodologies espousing design/build, LEED certification with an enhanced commissioning bid option, and a BIM-based design included in the base bid (Hutchison 2009).

The Air Force partnered with the National Institute of Building Sciences (NIBS) Whole Building Design Guide (Figure 2) to create a clearinghouse and support framework for all things BIM related to Air Force projects. The website serves as resource for those working inside and outside the government on projects for the Air Force who have questions on how to successfully accomplish BIM-based projects.

Figure 2: Air Force BIM for MILCON Transformation Area on the Whole Building Design Guide

1.2 Advancing US Construction Competitiveness through Sustainable Innovation in the US Air Force

The buildingSmart Alliance (bSA) is the working entity responsible for updating and administering the US National BIM Standard (NBIMS), which was published in December of 2007. In 2008, Dr. Vladimir Bazjanac of the Lawrence Berkeley National Laboratory reviewed the state of building energy performance (BEP) simulation and the NBIMS impact on standard BEP simulation practices. He described BEP simulation as "rather chaotic" (2008) and noted that no commonly agreed rules existed at the time of publication. Consequently, in the summer of 2008, the bSA sponsored the Architecture, Engineering, Construction, and Owner/Operator (AECOO) joint testbed in Washington, D.C. to help create a standard, interoperable way to conduct BEP simulation.

The final report on the testbed results was published in early 2010 (Hecht and Singh 2010). One of the major contributions from the testbed was the promotion of Industry Foundation Classes (IFCs) and the creation of a Model View Definition for standardizing a process for building performance and energy analysis. This paper will discuss a BIM case study on a LEED Platinum project at Tyndall Air Force Base that followed some of the tenets espoused in the AECOO testbed regarding building performance and energy analysis dynamically in real time into O&M using the post-construction BIM, a cutting edge-first for the Air Force.

The Air Force has joined other federal and state entities by requiring BIM deliverables as part of their capital facility investment strategy. The United States General Services Administration (GSA) was the first main entity to publicly promulgate BIM requirements, followed by the U.S. Army Corps of Engineers (USACE) in 2006 and later by the states, of Wisconsin, Texas, and Veterans' Affairs (VA). Leaders in the GSA include researchers from Stanford's Center for Integrated Facility Engineering (CIFE)'s Calvin Kam who applied the center's research to improve disparate design disciplines (Haymaker et al. 2005). The BIM implementation at USACE laid the groundwork for the USAF to implement their BIM requirements (Brucker et al. 2006), although the USAF implementation ensured a greater use of specific case studies early on to intentionally ensure a greater level of awareness on how BIM affected their MILCON processes. While the USACE roadmap alluded to two pilot projects conducted with BIM, the mandate lacked data demonstrating tangible benefits (Suermann and Issa 2008).

The Air Force sought to improve their BIM rollout through pragmatic case studies targeted at answering specific questions with respect to BIM implementation and its impact on their MILCON program. Although the USAF implemented BIM approximately two years after the "BIM tipping point of 2007" (Gudgel 2007), the USAF implementation sought to refine their roll out by building on others' past lessons learned.

2. AIR FORCE CASE STUDIES

In order to help field verify the advantages and disadvantages of implementing a BIM-based approach in the Air Force, it was deemed necessary to accomplish a number of pilot projects. While there were a number of "experimental" applications of BIM, this paper will discuss two particular case studies. The first is an implementation on a design, bid, build project from MacDill Air Force Base, Florida which is representative of a typical project. Secondly, another case study was conducted on a forward-looking LEED Platinum facility at Tyndall Air Force Base, Florida where work centered on documenting the construction of the facility in the BIM and using it to support unique operations and maintenance concerns for a revolutionary facility. Lastly, a third case study will document where the Air Force is headed with respect to IT management of their BIM-based designs.

2.1 Case Study Research Methodology

As Adrian (1987) enumerated in his book, Construction Productivity Improvement and is frequently used in the construction industry, projects are most typically evaluated according to the time, cost, and quality model. Since none of the USAF-BIM based projects have achieved construction-complete status (time), cost and quality were selected as the variables to track for these exploratory case study projects.

2.2 Case Study #1 Methodology Variable: Cost

The first BIM-mandated project was customer driven, not cost driven. A similar project had been designed with a great deal of conflicts between mechanical and electrical systems. The primary solution for these design challenges was to replace one interstitial void above the ceiling with one below the floor as well as above the ceiling. A secondary effect of this improved design was greatly improved (less costly) bids from contractors. Therefore, cost was not the primary driver for the BIM-mandate, but since it was so substantial, cost is the variable explored in the first case study. More research would have to be accomplished for causation or to determine if the preponderance of the cost savings could be attributed to the BIM-based design.

2.3 Case Study #2 Methodology Variable: Quality (Energy Efficiency)

The second BIM case study project had a primary goal of being the premiere facility in the Air Force with respect to LEED-certification, and namely, energy efficiency.

3. CASE STUDY #1: HQ USCENTCOM

Before the requirement for all projects designed in FY10 or later to use a BIM-based approach was promulgated, the 250,000 square foot HQ US Central Command (CENTCOM) project's visionary client team required it be the first LEED-certified building project on MacDill Air Force Base (AFB), Florida, and first BIM-based job in the Air Force in the summer of 2008 (Figure 3).

As a side note, it is important to mention that the military uses a 15%, 35%, 65%, 95% design progression approach to clarify the phases of design. A design concept or charrette is typically classified as a 15% design and then there are design reviews at the 35%, 65%, and 95% phases before going final with Construction Drawings at the 100% Stage.

Figure 3: HQ US CENTCOM (left) and HQ JICCENT(right) MacDill AFB, FL

The CENTCOM project had several items that made it a unique opportunity for evaluation through case study. First, there was an adjacent building constructed next to its site on MacDill AFB, the Joint Intelligence Center for CENTCOM, that was designed by Burns & McDonnell using a traditional 2-D approach, and constructed by Clark Construction. When the CENTCOM HQ design was awarded and stipulated using the JICCENT building footprint for the new CENTCOM building, it made sense that the winning designer was also Burns & McDonnell again, due to the fact they already had the design in hand. Until the 15% design review, B&M was using their 2-D drawings from the JICCENT facility. However, when the facility manager stipulated a BIM requirement at the15% design review, B&M had to retool and strategize to move forward as efficiently as possible by authoring an original design in a BIM-based approach. The traditional design, bid, build, construction project of the final BIM-based design went to Clark Construction, the same construction contractor, who had also built the adjacent JICCENT facility.

Because of all the similarities, it makes the two projects perfect for statistical comparisons. Discounting the learning curve for the two facilities, due to the new BIM and LEED requirements of the second facility (CENTCOM) it was significant that the awarded cost to construct the CENTCOM facility was 26% less ($3,426/SM as opposed to $4,591/SM) than the cost per square foot to build the JICCENT facility. While some of this could be attributed to the construction bid climate in 2009 versus 2007, the savings are still significant. Without an exhaustive statistical analysis, the CENTCOM project supports the idea that it is possible to accomplish a BIM-based design on a complex project on an Air Force base, get a more detailed design, and still construct the facility for less money.

Table 1: Cost per Square Meter Comparison of JICCENT and CENTCOM HQ buildings

	HQ JICCENT (traditional 2-D)	**HQ US CENTCOM (BIM-based)**
Total Cost ($ Million)	114.6	81.7
Total Square Meters (SM)	24,962	23,844
Total Cost/SM ($/SM)	4,591	3,426

4. CASE STUDY #2: LEED PLATINUM FITNESS CENTER

While Case Study #1 was an exploration into the differences encountered by implementing a “proof of concept” BIM-based approach on a traditional Air Force project, Case Study #2 used BIM in a completely different way. The Tyndall Fitness Center at Tyndall Air Force Base, Florida (Figure 4) had four major components that the Air

Force Center for Engineering and the Environment (AFCEE) explored. These components were a "LEED enhanced commissioning gap analysis," an "energy modeling products comparison and recommendation," a "data enterprise management tool comparison matrix," and finally a BIM that would be tied to the day to day energy consumption data during operations and maintenance.

It is telling that the CENTCOM facility was the first LEED-certified facility on MacDill AFB in 2009 – many other entities began their LEED portfolio much earlier. However, while the Air Force was late to adopt formal support by mandating LEED facilities, some of their projects far exceed the national standard when it comes to implementing sustainable practices. One such facility is the energy showcase, LEED Platinum facility at Tyndall AFB. The facility exceeds the Energy Policy Act 05 and its energy consumption is at least 30% below ASHRAE standard. Moreover, the USAF is hopeful that BIMs will serve a greater role in communicating and analyzing building data in support of obtaining LEED certification in the future. This project was a stepping stone for ensuring this hope is eventually realized.

Figure 4: Tyndall Fitness Center, LEED Platinum and BIM-testbed

By partnering with academic researchers from the Milwaukee School of Engineering, Marquette, and the University of Wisconsin, the Air Force leveraged academic research efforts towards furthering sustainability in the built environment. This preliminary proposal titled, "Cyber-enabled Sustainable Asset Management by Prototyping Data Interdependencies amongst Building Systems, Environments, and Facility Management Processes" was one of 205 preliminary proposals that were submitted in response to the EMERGING FRONTIERS IN RESEARCH AND INNOVATION 2010 (NSF 09-606) solicitation, under the subtopic Science in Energy and Environmental Design (SEED): Engineering Sustainable Buildings. With less than a 2% selection rate, this proposal was one of only a handful of applications selected to submit full proposals. Working with MSOE researchers and the the project's designer of record, Post, Buckley, Schuh, & Jernigan (PBS&J) the project won a U.S. Air Force Merit Award for design concept. Then, in May of 2010, PBS&J received a post construction design award to turn their *BIM-concept* into a *full-BIM* suitable for tying the building geometry to the mechanical systems and controls. PBS&J's work on the two-story, 6,994 square meter fitness center at Tyndall AFB cost $18.6 million for a cost of $2,660 per square meter. The quality or energy efficiency of this facility will be realized when the facility is commissioned and energy usage data can be collected and analyzed in conjunction with the detailed BIM attributes.

The facility's Electronic Management Control System (EMCS) monitored pure consumption, solar photovoltaic (PV) power meter pulse output, and solar hot water recovery systems using Digital Energy Monitors (DEM) tied to the BIM via an exported database file via the EMCS server. The data is subsequently relayed no only to base facility management personnel, but also to the facility's users utilizing the facility; serving as a constant reminder of the facility's return on investment and environmental stewardship. The process implemented at Tyndall is being evaluated as a possible benchmark for changing the way the USAF monitors and manages its mechanical systems in the USAF and BIM is a major component of the interface.

5. CASE STUDY #3: THE FUTURE OF US AIR FORCE BIM: DYNAMIC PROTOTYPES AND THE BIM SERVER

In 2008, AFCEE commissioned Jacobs Global, a worldwide BIM leader to create their first *Dynamic Prototype* BIM component. The design and services project's scope of work included three requirements.

The first requirement was to create three different dorm layouts that maximize and comply with federally mandated allowable space configurations via a BIM approach including all installed and uninstalled equipment/furniture. The result was three Revit™ BIMs of different dormitory configurations with mechanical, electrical, plumbing, and furniture layouts optimized for maximum possible square footage (Figure 5).

The second requirement was to create a web server that allows design firms to learn about the dynamic prototypes, download the model files, and manipulate the models. The result was a secure website http://www.dynamicprototypes.com accessible by all design firms who support dormitory design projects for the USAF.

The third requirement was to provide consultation services to help AFCEE draft a contractual-requirements-document for directing A/E firms on how to design and build projects according to Air Force-specific BIM-based requirements. The result was a modified U.S. Army Corps of Engineers "Attachment F" for U.S. Air Force use to include "software agnostic" terminology and preference for design-build.

Figure 5: AFCEE Dormitory *Dynamic Prototype* Model

In the fall of 2009, the Air Force's sole basic training base, Lackland Air Force Base accomplished a design charrette to replace their aging dormitory inventory. All Air Force enlisted basic training occurs at Lackland Air Force Base, so their dormitories are critical to supporting successful recruiting, training, and retention for thousands of U.S. Air Force personnel annually. Leadership knew it was crucial to fast-track the design and award of these high profile dormitory projects. By partnering with Jacobs Global, the same firm who created the dorm Dynamic Prototype, AFCEE architects, and project managers were able to achieve what would have been the equivalent to a 35% or 65% design level (which usually takes 60-90 days) in approximately four hours. By the end of the charrette, model-based site layouts, quantity takeoffs, and estimates were accomplished – far exceeding expectations of the end users at Lackland Air Force Base (Figure 6).

Figure 6: AFCEE Dormitory *Dynamic Prototype* Model in use for rapid dorm assembly and advanced charrette development (courtesy of Jacobs Global)

While AFCEE is pleased with the progress made in preparation for the BIM rollout accomplished in FY10, it is already looking to the future and planning on a more sustainable plan for maximum collaboration and knowledge management. In the late winter of 2009, early 2010, AFCEE personnel worked with HQ A7C (Air Staff) personnel to accomplish planning for a BIM Flight Plan that would help integrate BIM into the design charrette process and fold in the BIMs created under the new BIM-based project design requirement.

While still under review by the Air Force Information Technology governance board, AFCEE is proposing an approach whereby site-specific designs are converted to dynamic prototypes as 80% solutions that can be site adapted through future design charrettes. All BIMs would be available via the web on Onuma's Planning System in an interoperable file format like the industry foundation class (IFC) extension. Users could query for past BIMs geographically or by facility category code. By using the BIMs' associated databases, users would be able to provide more accurate quantity takeoff and estimating much earlier in the project. Furthermore, by using facilities with demonstrated, optimized layouts, future facilities would provide familiarity coupled with more inherent scope (square meters of useable space) maximization.

6. CONCLUSION

As the National Academies of Science Committee on Advancing the Competitiveness and Productivity of the U.S. Construction Industry National Research Council noted in their 2009 report, large firms and government agencies are in the best position to lead the effort to drive change towards a more competitive and productive U.S. Construction Industry. After centralizing their previously geographically disparate capital investment management leadership into one centralized entity at the AFCEE, the Air Force was uniquely positioned to drive wide-reaching change on their multi-billion dollar annual construction budget. In FY10, the Air Force implemented a variety of initiatives targeted at fulfilling their vision of more efficient, sustainable facilities to support their operational mission. The primary technological component of these changes was aided by the requirement to conduct BIM-based designs for future projects. This paper described three BIM-based initiatives the Air Force accomplished in order to begin the lessons learned process as they endeavor to drive productivity improvement in the US construction industry. Through proof on concept work at the HQ CENTCOM project at MacDill AFB, or cutting edge LEED Platinum-supporting BIM work at the Tyndall AFB Fitness Center, or the future of BIM-based design collaboration, the US Air Force is leveraging their position to drive change which will hopefully result in a more competitive and productive construction industry.

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