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Building Information Management (BIM) implementation in naval construction

Raymond Rohena

Louisiana State University and Agricultural and Mechanical College

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BUILDING INFORMATION MANAGEMENT (BIM) IMPLEMENTATION IN NAVAL CONSTRUCTION

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science in Engineering Science
in The Interdepartmental Program in Engineering Sciences

By
Raymond Rohena
B.S.C.E., The University Texas at El Paso, 1999
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ABSTRACT

Traditional two-dimensional (2D) delivery systems in the construction industry can hinder the way information is communicated between owners, architects, and contractors. This hindrance exists in all phases of a project, from design and construction to the operation and maintenance of the completed facility. Building Information Management (BIM) is an emerging information technology that promotes a collaborative process for the Architectural, Engineering, Construction and Facilities Management (AECFM) industry; it can aid the exchange of information and provide improved project data accessibility to all stakeholders of a construction project.

The Naval Facilities Engineering Command (NAVFAC), in conjunction with the facility management (FM) chiefs of the other Department of Defense (DoD) agencies, is committed to adopting the standards and technologies used in the private sector that promote efficient and effective business and construction management practices. The AECFM industry shift to BIM is resonating to the public sector and implementation plans to accommodate the shift are being developed by many public agencies at all levels of government. NAVFAC recognizes the need to develop and adopt BIM technologies in order to keep pace with private sector advances and has drafted a BIM *Road Map* document (NAVFAC, 2009) to provide BIM implementation guidance to the NAVFAC organizations responsible for providing and maintaining facilities and infrastructure to Supported Commanders.

The objective of this thesis is to evaluate the NAVFAC BIM *Road Map*, analyze BIM tools and processes currently used in the construction industry, and provide recommendations for best practices and improvements to the NAVFAC BIM *Road Map*. The methodologies used in this research includes three phases: Phase 1- evaluate the current NAVFAC BIM Road Map, Phase 2:

Case Study and Phase 3: Develop recommendations to improve BIM Road Map. The outcome of this research effort will be a set of recommendations that ensure that all parties are clearly aware of the opportunities and responsibilities associated with incorporation of BIM into the organizational workflow for naval construction projects.

CHAPTER 1. INTRODUCTION

Building Information Modeling (BIM) is dramatically reshaping the way construction project teams work together to increase productivity and improve the final project outcomes (cost, time, quality, safety, functionality, maintainability, etc.) for all the parties involved. The use of BIM on construction projects is growing rapidly. According to statistics from BIM Trends SmartMarket Report 2008 (McGraw Hill Construction, 2008), 62% of BIM users indicated that they were going to use BIM on over 30% of their projects in 2009. BIM use is spreading in all construction sectors, and development of the best practices for BIM implementation varies according to specific needs and existing practices of the agencies concerned. According to the Naval Facilities Engineering Command (NAVFAC) Chief Information Officer (CIO), NAVFAC is just beginning their BIM implementation initiative, which is based on leveraging existing tools, data and hardware into a cohesive whole. This entails incorporating Computer Aided Design (CADD), Regional Shore Installation Management Systems (RSIMS), Maximo, and other software tools and the relational database technologies into a total information management environment capable of providing the data and information to engineering professionals when and where they need it throughout the facilities life cycle. To date, NAVFAC has not done any true BIM projects and has drafted an initial BIM Road Map and Guidance document that will be further developed through pilot projects that will test design and engineering tools (i.e. Revit and Navisworks) and study compatibility of BIM life cycle building operation and maintenance applications with existing NAVFAC procedures. NAVFAC is in the process of defining the details of the pilots, which will help determine how to leverage BIM technology to develop and sustain in-house engineering/architecture employee competency, determine how to manage models developed by

contractors, and eventually demonstrate how to leverage BIM data into the life cycle of the facilities owned and maintained by NAVFAC (C. Dean, personal communication, October 12, 2010).

The researcher is a U.S. Navy Civil Engineer Corps (CEC) Officer with duty assignments that are predominantly with NAVFAC and he has a vested interest in the successful implementation of BIM within NAVFAC. The NAVFAC Capital Improvements (CI) Business line is charged with BIM implementation and their assistance is available and may be requested by the researcher as needed. The current BIM Road Map and Guidance document includes a section on getting started which provides a self-help guide to implementing BIM. The objective of this research is to evaluate and apply the NAVFAC BIM Road Map implementation guidance and identify major issues and concerns that a typical Public Works Department may encounter when using BIM to execute a project.

The methodologies of this research were performed in three phases. The first phase consists of an evaluation and SWOT analysis of the current NAVFAC BIM Road Map, interviews with personnel at NAVFAC managed facilities and projects, review of other facilities and owners' experience with BIM, and providing NAVFAC with improvement opportunities for the BIM Road Map; in the second phase, a case study analysis was conducted to explore and understand the details involved with implementing BIM in the design, construction, operation and maintenance of naval facilities; recommendations for NAVFAC's consideration and inclusion in the BIM Road Map, that are suitable for implementing BIM at all levels of the NAVFAC organization, were developed in the third phase.

The outcome of this research will benefit the NAVFAC CI business line by providing them with recommendations that can be used to establish the final BIM Road Map and guidance. In

addition, this research will be used to provide BIM Best Practice recommendations for information sharing during construction and information management during the facility management (FM) and maintenance phases of a project life-cycle. A project currently being managed by the Facilities Engineering Acquisition Division (FEAD) at Naval Station, Oceana, VA was selected for conducting a case study in support of the research.

CHAPTER 2. LITERATURE REVIEW

2.1 - Overview of NAVFAC Construction Management Methods

The NAVFAC P-1205 (2008) provides current guidance for Navy public works management, and includes the details of command relationships, roles and responsibilities of all activities involved in Naval Construction. All new naval installation construction activities and service contracts are managed and controlled by the Public Works Department (PWD). The PWD assigns engineering support, construction project management, and service contract management, to the FEAD. The FEAD is an essential element of the PWD providing engineering and acquisition in the delivery of NAVFAC products and services to the installation and other supported commands. The FEAD plays a significant role in ensuring proper contract performance. In most cases, the FEAD will share contract administration duties with the contracting officer assigned to support the awarded contract. Typically, these are the major components and steps followed for a naval construction project:

- The end user activity or installation is responsible for developing the performance work statement (PWS), preparing the Quality Assurance (QA) plan, and the safety plan. The Navy employs the use of the contractor's quality control (CQC) program and the government's QA program to monitor and measure performance.
- Project package development -When a work request is initiated at the PWD, it is assigned to the FEAD or Facility Engineering Command (FEC) Integrated Product Team (IPT) for engineering support. The ultimate product from this effort is a project package with a cost estimate, defined scope of work and enough technical details of the requirements so that the type of contractor or in-house workforce can be chosen.

- Design management and Request for Proposal (RFP) preparation - An RFP for design build (DB) design-bid-build (DBB) contract vehicles can be prepared in-house with qualified design engineers. In lieu of preparing a project package in-house, the PWD FEAD or the FEC IPT may use Architect/Engineer services to prepare RFPs for DB and DBB contract vehicles.
- Construction management - Includes the safety compliance, overall administration of the construction and quality assurance efforts by the government team. Effective construction management includes coordinated oversight of contractor submittals, quality assurance, prospective contract modifications, scheduling and progress payments, and liaison with Supported Commands. After award of the construction contract, the Construction Manager (CM) assumes the role of project manager and is the lead point of contact for the project duration.
- Schedule and cost control - The government project team works closely with the contractor on each project to ensure an accurate schedule and corresponding schedule of prices. As the contract progresses, the reviewing and processing of each invoice and prospective retainage for punchlist work or withholding for possible liquidated damages becomes critical for the government to protect its interests.
- Maintenance engineering - The FEC IPT or PWD FEAD can coordinate maintenance engineering requirements for base operating support contracts (BOS) and in-house maintenance workforces.

All the facilities data and information currently generated and regenerated to support the PWD/FEAD functions and ultimately deliver and maintain installation related products and services are managed with multiple methods and applications, to include: cost-estimating,

scheduling and CAD software, accounting and finance systems, QA/QC/Safety administration, maintenance and job order tracking procedures, and various clerical and record keeping processes. With the rapid pace of today's technology, hardware and software must be viewed as a short term investment. Data and people, however, represent a long term investment. In this regard, NAVFAC is constantly concerned with improving information management processes and has begun an initiative to implement BIM use across the organization to help consolidate the various information and processes into a comprehensive management system (NAVFAC, 2009).

2.2 – NAVFAC BIM Data Flow

In an e-mail to the researcher, NAVFAC's CIO stated their initial focus is on the information management aspect of BIM. That is the life cycle entry; use, re-use, and maintenance of data and information generated by each of the data owners: Asset Management (AM), Capital Improvements (CI), Public Works (PW), etc. (Dean, 2010).

A subset of NAVFAC's BIM initiative is conducting a Pilot using Revit and Navisworks. This pilot will help NAVFAC determine how they can leverage this technology to assist with developing and sustaining in-house engineering/architecture competency of employees, determine how they will manage Models developed by their contractors and how they will leverage the data into the life cycle of the facilities they own and maintain (Dean, 2010). The inclusion and leveraging of existing hardware, software and data investments, entails support components including communications, processes and procedures, and motivated engineering professionals to create a successful working environment (NAVFAC, 2009).

Figure (1) displays the BIM data flow for NAVFAC facility management, and includes the relationships between contractors (KTR) and the AM, CI and PW business lines and the information exchanges between the Regional Shore Installation Management Systems (RSIMS),

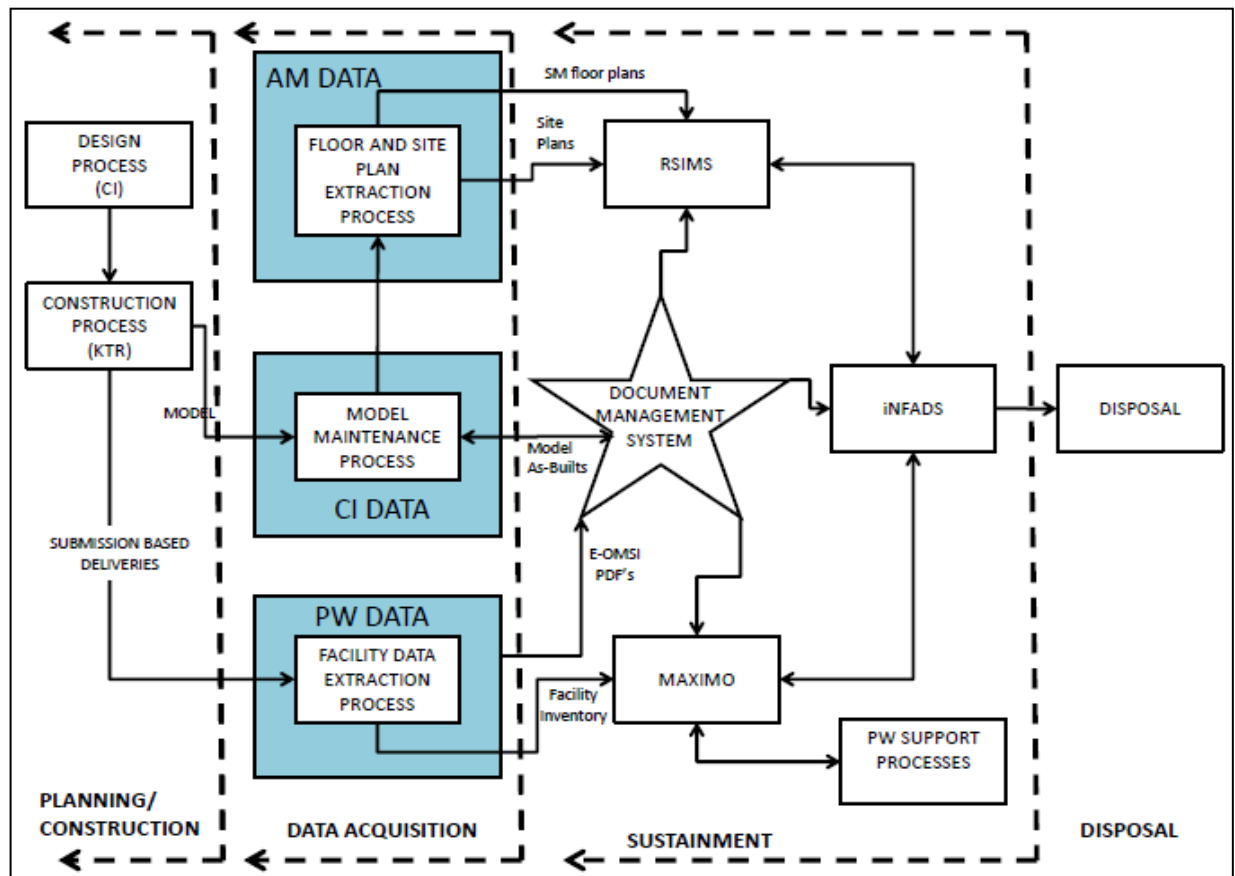


Figure 1: NAVFAC BIM Data Flow (source: NAVFAC, 2010)

internet Navy Facilities Assets Data Store (iNFADS) and MAXIMO applications. RSIMS uses aerial photography, database info, and GIS technology to put critical installation decision data into a map environment. MAXIMO is an IBM software application that plays a vital role in BIM, and provides lifecycle & maintenance management, work order tracking and cost recording for all asset types on a single platform. The iNFADS system is used to store and manage the Real Property Inventory (RPI) for the Department of the Navy. New facilities information for all three of these systems, for the most part, is entered after construction is

completed and all required operations & maintenance (O&M) manuals, as-built drawings and product information is turned over to Navy end users. On large/complex projects this often is a tedious and lengthy process. Having the project A/E and contractors update the BIM model with the necessary FM data throughout the project cycle would ultimately save the owner time, money and avoid any inconsistencies with the O & M data when it is needed after warranty periods have expired and the design/construction team are no longer available. Ideally, a shared database for the three systems could be utilized to reduce inherent inefficiencies of data re-entry, multiple databases, handoffs and locating information.

NAVFAC's long term BIM goal is to make all necessary facility information accessible to multiple users to support a wide variety of processes throughout the FM lifecycle. Full implementation of BIM within NAVFAC is a mammoth undertaking, specifically adapting existing applications and processes to manage the Navy's real property, which consists of 76 major shore installations with more than two million acres of land and 110,000-plus facilities valued at greater than \$150 billion, with over 525 million square feet of space (NAVFAC, 2010)

2.3 - Overview of BIM

The NIBS (National Institute of Building Sciences) thought of BIM as a digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition (National Institute of Building Sciences 2007).

Simply stated, BIM is a philosophy for managing and accessing common building and facilities data and information. It is applied throughout the facilities life-cycle, from

requirements definition through disposal. Its goal is to provide installation owners and caretakers with the best information available for making best value decisions and reducing total ownership costs (TOC). Although it relies on automated tools, it is not about computers, software, and hardware specifically. Rather, BIM concentrates on the process of organizing, managing, accessing, and sharing building and facilities information, and making it accessible to multiple users throughout the Navy and DoD to support a variety of life-cycle management and business processes (NAVFAC, 2009). A subset of BIM is modeling. That software supported process provides a building model that can be viewed and manipulated in 3D. Added to that is clash software that makes building modeling an extremely powerful tool to achieve reduction in TOC via designs and constructed facilities that achieve the goals of reliability, maintainability and accessibility (RMA).

2.3.1 - Benefits and Obstacles of BIM

BIM users face a very broad range of drivers and hurdles on the path to adoption. In general, BIM users see the need to balance the benefits of improved productivity and coordination with the challenges of BIM related costs and training issues. According to a McGraw-Hill survey (McGraw Hill Construction, 2008), the top benefits of BIM are:

- Easier coordination of different software and project personnel
- Improved productivity
- Improved communication
- Improved quality control

Top obstacles to BIM adoption are:

- Adequate training
- Senior management buy-in

- Cost of software
- Cost of required hardware upgrades
- A/E risk of losing intellectual property and liability issues and sharing of information between A/E, contractors and facility owners

The National Institute of Standards and Technology reported that inefficiencies in facility management have an average yearly unit cost of \$0.20/ft² for existing space (NIST, 2004). For the Navy, this amounts to over \$100M/year. The same NIST report estimates that utilizing electronic systems in the O & M phases saves an average of 2 hours per work order (WO). Worldwide, the Navy generates hundreds of thousands of work orders every year, and using a very conservative estimate of 1M work orders and an average pay rate of \$50/hr results in (2 hrs x \$50 x 1,000,000 WO) = \$100M/year. There is no arguing that the investment in BIM implementation will pay dividends, but implementing BIM will take time. Although the Navy does not require building modeling software for design and construction of projects, numerous contractors voluntarily use it extensively on some of their larger and more complex Naval projects as well as in their projects outside Navy, since the design applications alone provide immediate benefits over 2D CAD. Although there is no set dollar value or level of project complexity for when the benefit of using BIM exceeds its cost, a cost threshold in the \$5-10M range is where most contractors on NAVFAC projects have opted to utilize BIM.

2.3.2 - Usage of BIM

The great promise of BIM is its expansive range of applications for users, including the Navy. At its basic level, BIM represents an evolution from traditional 2D design to a dynamic 3D model built around a database of a project's physical functional characteristics. The more data users add to the model, the more benefits can be leveraged from it. Beyond 3D

visualization of a project, information about specific objects within the model can be used for a wide range of analyses such as building performance, schedule and costs (McGraw Hill Construction, 2008).

3D modeling is currently the most popular use of BIM, with architects leading the way. Other users, such as engineers, are finding selective ways to model elements in BIM and contractors are building momentum for the use of BIM in scheduling and cost estimating (McGraw Hill Construction, 2008).

It is likely that as all users continue to gain expertise with BIM, they will realize the technology's potential and develop new ways to derive benefits in areas such as sustainability and building operations.

The NAVFAC CAD manager, Mr. Mark Couture, believes the largest return on investment (ROI) for BIM implementation will be seen in the facilities operations and management phases of the 70+/- years project life-cycle. (M. Couture, personal communication, October 14, 2010). However, it is in these areas that best practices have not been fully identified and where the least amount of historical data is available for comparison. This research will focus on providing NAVFAC with best practice recommendations for those BIM categories offering the largest ROI.

The design and modeling and construction phase functions tend to be the primary BIM categories that are most frequently used in the construction industry and it is those categories that have the most metrics and trend data available for development and refining best practices (Maldovan, 2010). Post-Construction and facility management categories of BIM are on the low end of frequency used and those have less information available for best practice development. In addition, buildingSMART alliance (bSa) has begun the formal case study

documentation procedure with the goal of capturing design and construction presentations on all BIM uses outlined in the BuildingSMART BIM Project Execution and Planning Guide (Maldovan, 2010). The bSa case studies committee is developing a standard template whereby consistent metrics can be tracked on all projects for use by industry.

The article, *BIM for Construction Handover*, discusses current practices at project handover, where the contractor gives a box of paper documents describing warranties, replacement parts lists, operating manuals, etc. to the facility manager who then has to duplicate efforts of entering the information into their building management system, if a system even exists (East, 2007). This is currently standard practice within NAVFAC and it has been a problem for too long. East goes on to discuss how Operations and Maintenance Support Information (OMSI) standards evolved to the National Building Information Model Standard (NBIMS) effort and subsequent initiation of the Construction Operations Building Information Exchange (COBie) in December 2006. Several Federal Agencies are including COBie requirements in their contracts, and the capture of COBie data often takes place at the conclusion of construction. Future practices need to adopt information technology that allows capture of COBie data during design and construction to best utilize the knowledge of designers and manufacturers and not burden the contractor and facility owner at the end of construction.

The need to extend BIM benefits downstream to improve lifecycle facilities management are discussed in the article *BIM and FM: The Portal to Lifecycle Facility Management*. As discussed in the article, increasing numbers of owners are requesting and requiring delivery of BIMs, when examples of FMs actually using that data are almost non-existent. To be effective, data captured in BIMs needs to be channeled into FM systems, Computerized Maintenance and Management Systems (CMMS), Integrated Workplace Management Systems (IWMS), Building

Control Systems and a variety of other management and accounting systems regularly used in FM (Jordani, 2010). Capturing data for new construction projects is easy, but owners, like NAVFAC, with large portfolios of existing facilities face greater challenges. The buildingSMART alliance has developed the BIM for FM Portal Project to address, define and process a model for using BIM data to achieve FM objectives.

The magnitude of BIM design and modeling use pales when compared to BIM lifecycle management potential. According to a 2006 International Facility Management Association (IFMA) study, Annual operations & maintenance (O&M) costs are about \$7.26/ft² and typical construction costs of a building are about \$120/ ft². Thus, using the DoD mandated 67-year life cycle represents an O&M cost four times greater than the cost to construct. Hence the 15% reduction in O&M gained through BIM implementation produces twice the savings than just using BIM to reduce construction costs would produce (Watson, 2009).

A couple other categories not frequently associated with BIM and needing defined best practices are incorporation of construction safety and convergence of GIS into BIM models. The paper *Research needs for Building Information Modeling for Construction Safety* (Ku, 2010), provides several research suggestions for creating BIM tools to model and simulate safety hazards associated with construction activities and improve safety by giving constructors a visualization of processes. Basically, designers could get involved early on in the construction process to incorporate codes and regulations and assist contractors with tying safety plans into the definable features of work. A need exists for these types of tools that can support integrated design-construction teams to better recognize hazards and handle the complexity of specific jobsite conditions.

The article *Convergence and Standards* (Reichardt, 2007) discusses how cooperation between AEC and geospatial standards organizations is helping to advance interoperability necessary to benefit those involved with building lifecycle, first responders, urban planners and others who support the urban environment. The article explains how efficiency losses associated with inadequate operability of CAD, engineering and software systems was in the billions of dollars. Most of the cost is borne by facilities owners, who for whatever reason have to re-create information that was originally available in documents created by planners, architects and engineers who sited and designed the building. Common web services infrastructure was needed to facilitate BIM/geospatial convergence and the Open Geospatial Consortium, Inc. (OGC), has developed an open standards service oriented architecture (SOA) framework and developed partnerships with AIA chapters and bSa to organize testbed activities to validate BIM standards that enable convergence of AEC and geospatial information.

The data and metrics for refining the design and modeling best practices of BIM are more common and readily available than the less used life-cycle management, geospatial, safety and data sharing categories of BIM. Architects and designers using BIM modeling software are able to provide immediate tangible benefits to facility owners, but the long term life-cycle management benefits are not as readily appreciated or observed. More research, case studies and pilot projects need to be conducted to gain a greater knowledge base and full understanding of BIM principles and applications. As more case studies and pilot projects are completed, the full range of BIM benefits will be substantiated and examples of best practices will become more widespread for use in all areas of the construction industry.

2.3.3 - BIM Use on Construction Projects

Research shows that BIM is being broadly adopted across the construction industry with

over 50% of each survey segment - architect, engineers, contractors and owners (AEC/O) - utilizing the tools at moderate levels or higher. (McGraw-Hill construction 2008)

- Architects are the heaviest users of BIM with 43% using it on more than 60% of their projects in 2009.
- Contractors are the lightest users of BIM with nearly half (45%) using it on less than 15% of projects and a quarter (23%) using it on more than 60% of projects in 2009.
- BIM use within the Department of Defense has grown primarily in the design and modeling applications through expectations of construction contractors to develop BIM capabilities and RFP requirements for firms to describe their BIM qualifications. Continuous initiatives are also in-place to fully implement BIM data management capabilities across DoD.

2.3.4 - BIM Best Practices

Part of the preparation for BIM implementation within NAVFAC includes awareness and education of BIM and bringing best practice examples into the organization. One of the objectives listed in the NAVFAC Road Map is to normalize data standards across the enterprise by working with FIATECH and NIBS to identify Industry Leaders and pursue best practices and also setup meetings to share current knowledge and best practices. Best practices can vary greatly depending on multiple factors such as: which standards will be used, communication methods and formats used, frequency of data exchange, ownership and responsibility for controlling BIM elements, nomenclature, level of detail, and decision status. The USACE BIM Road Map (2006) and Pennsylvania State University's "BIM Project Execution Planning Guide – Version 2.0" (PSU, 2010) both provide a large volume of information for implementing BIM at large organizations and include structured guidelines that can be followed for creating and implementing a BIM Project Execution Plan. The joint venture of Clark McCarthy recently

began construction of the \$250M+ Camp Pendleton Naval Hospital Replacement project for NAVFAC. BIM is being used extensively on the project and a BIM execution plan was developed by Clark McCarthy for the project to ensure the successful implementation and use of BIM that includes information sharing and passing of models from design, to construction, and then to operations (Clark McCarthy, 2010). The project has significant NAVFAC attention and will provide valuable lessons for the development of NAVFAC's BIM initiatives and development of best practices.

The staff of Sandia National Laboratories (<http://www.sandia.gov/index.html>), gave a presentation in conjunction with a Northwest Construction Consumer Council conference on November 17, 2010 that briefly introduced their understanding of BIM and the potential uses of BIM for Facility Management (FM). Sandia has endeavored to find solutions of the interoperability issue between Maximo and Revit that NAVFAC also faces, so Sandia may possibly share experience with NAVFAC in the future in this regard. One slide in Sandia's presentation showed that 43% of FM professionals surveyed said their accessibility to O & M information was average and most information was available but not in one place (Foster, 2010). Establishing BIM best practices for FM may help in consolidating information and make it more readily available.

2.3.5 - Using BIM in Naval Facilities: Tri-Service Collaboration

As stated in the *Draft BIM Road Map and Guidance*, NAVFAC and all field activities will continue to operate under the spirit and intent of the 1994 Tri-Service Memorandum of Understanding and subsequent strategic partnering agreements. Through the MOU, NAVFAC joined the installation management and engineering service chiefs of the Army, Air Force and Marine Corps in agreeing to standardize the data terminology, elements and structure necessary

to maintain and operate DoD installation infrastructure, consistent with the conventions used by the private sector (NAVFAC, 2009). The private sector has fully embraced BIM and DoD is committed to adapting and developing the technology required for efficient business practices.

2.3.6 - Role of BIM in Naval Construction Projects

NAVFAC and all field activities will continue to embrace the philosophy and practice of BIM in support of the Tri-Service Memorandum of Understanding, the NAVFAC Strategic Plan, the NAVFAC Improvement Plan, and related Pentagon business process improvement initiatives. Detailed information on the philosophy and role of BIM within NAVFAC is provided in the BIM OPLAN. POC – Clay Dean, NAVFAC Deputy CTO, (202) 685-9174 (NAVFAC. 2009).

After evaluating current BIM requirements, issues, processes & best practices; assessing supporting BIM IT technologies, and developing the BIM implementation plan, NAVFAC plans to collaborate with external participants (USACE, CADD BIM Center, National Institute of

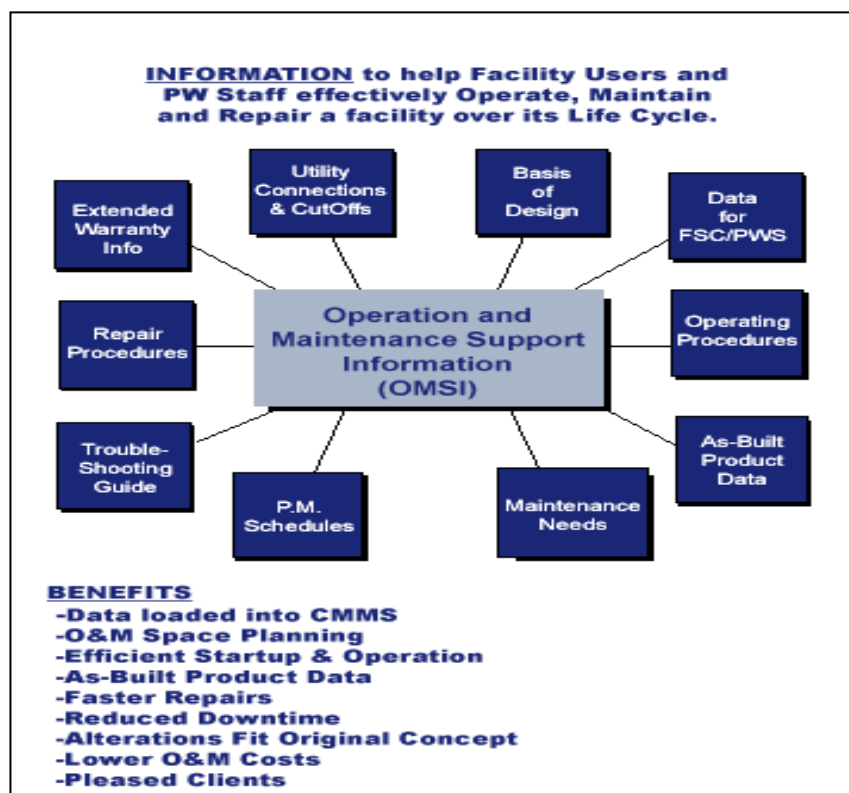


Figure 2: Operation Maintenance Support Information (OMSI)
(source:<https://portal.navy.mil>)

Building Sciences (NIBS), other federal, state and municipal agencies, and private industry

companies) to determine the feasibility and develop specific details for incorporating their current OMSI data, as depicted in figure (2), into a BIM based management platform.

The USACE has published ERDC TR-06-10, “Building Information Modeling (BIM): A Road Map for Implementation To Support MILCON Transformation and Civil Works Projects within the U.S. Army Corps of Engineers” which is simply known as “USACE BIM Road Map”. The USACE BIM Road Map is a 96-page guide and requirements listing for successful BIM implementation in the Army Corps of Engineers. While the USACE BIM Road Map addresses many areas of possible contribution, the primary impetus for pursuing BIM, according to the authors, is to “improve the planning, design, and construction processes of the U.S. Army Corps of Engineers” and “drive down costs and delivery time” (2006) . Figure (3) was taken from the USACE BIM Road Map and depicts the long-term strategic goals for BIM, NBIMS

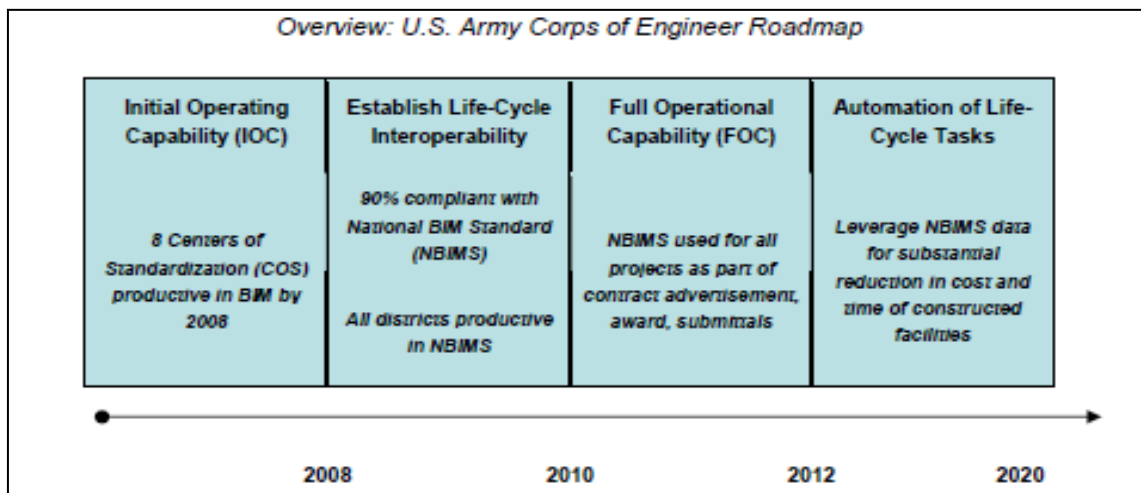


Figure 3: USACE Long-Term Strategic Goals for BIM, NBIMS and interoperability in the USACE (Source: USACE BIM Road Map)

and interoperability in the USACE. While the USACE BIM implementation plan has been more aggressive than NAVFAC’s, the long-term goals are similar and life-cycle management and interoperability with NBIMS is required to achieve Full Operational Capability (FOC).

2.3.7 - BIM at Pennsylvania State University

The PSU BIM “Guide” provides development of a BIM Project Execution Plan. The purpose of the BIM Project Execution Plan is to ensure that all parties are clearly aware of the opportunities and responsibilities associated with the implementation of BIM into the project workflow. (PSU, 2010)

The PSU Guide outlines a four step procedure to develop a detailed BIM Plan, as detailed in figure (4) below. The procedure is intended to steer owners, program managers, and early project participants through a structured process to develop detailed and consistent project

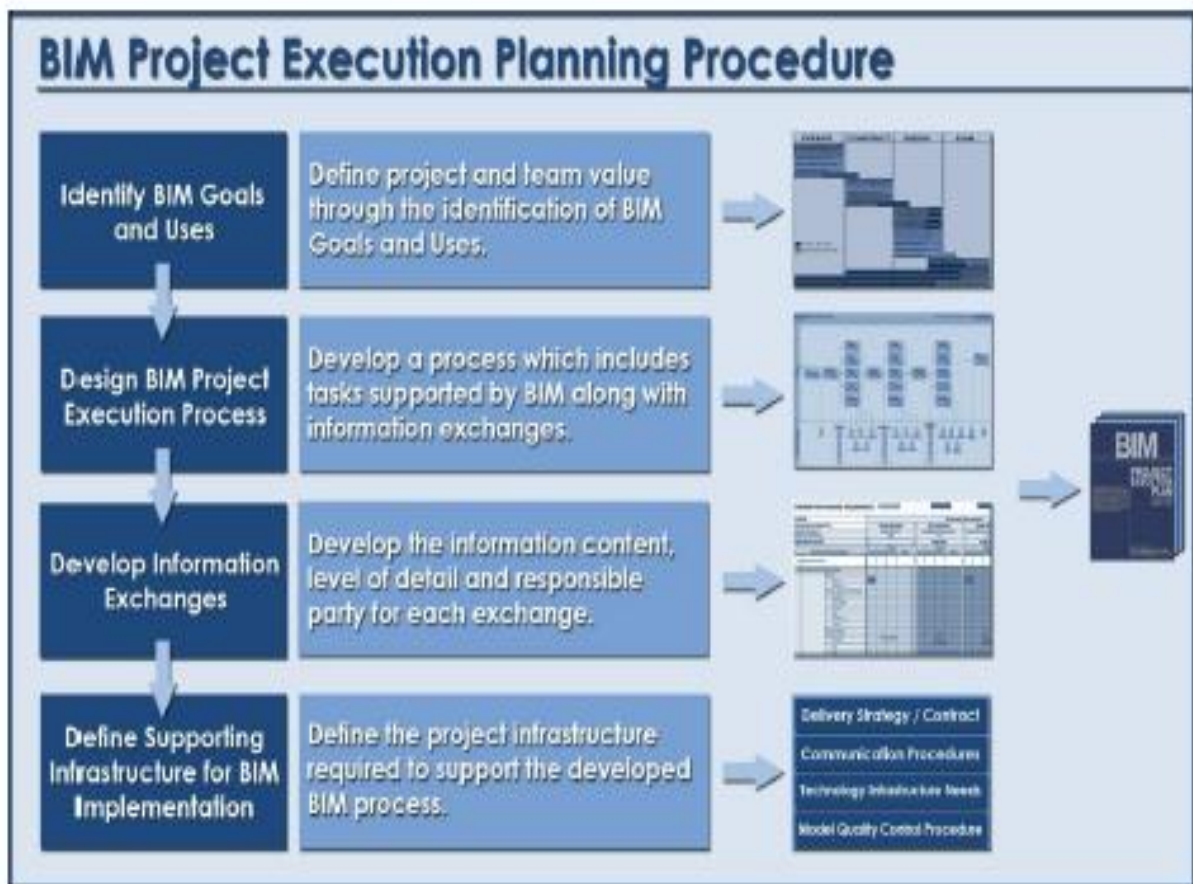


Figure 4: BIM Project Execution Planning Procedure (PSU, 2010)

The first step is to identify the appropriate BIM uses based on project and team goals.

Figure (5) lists twenty-five possible uses for consideration on a project and the Guide provides a method for identifying the appropriate BIM uses for a target project.

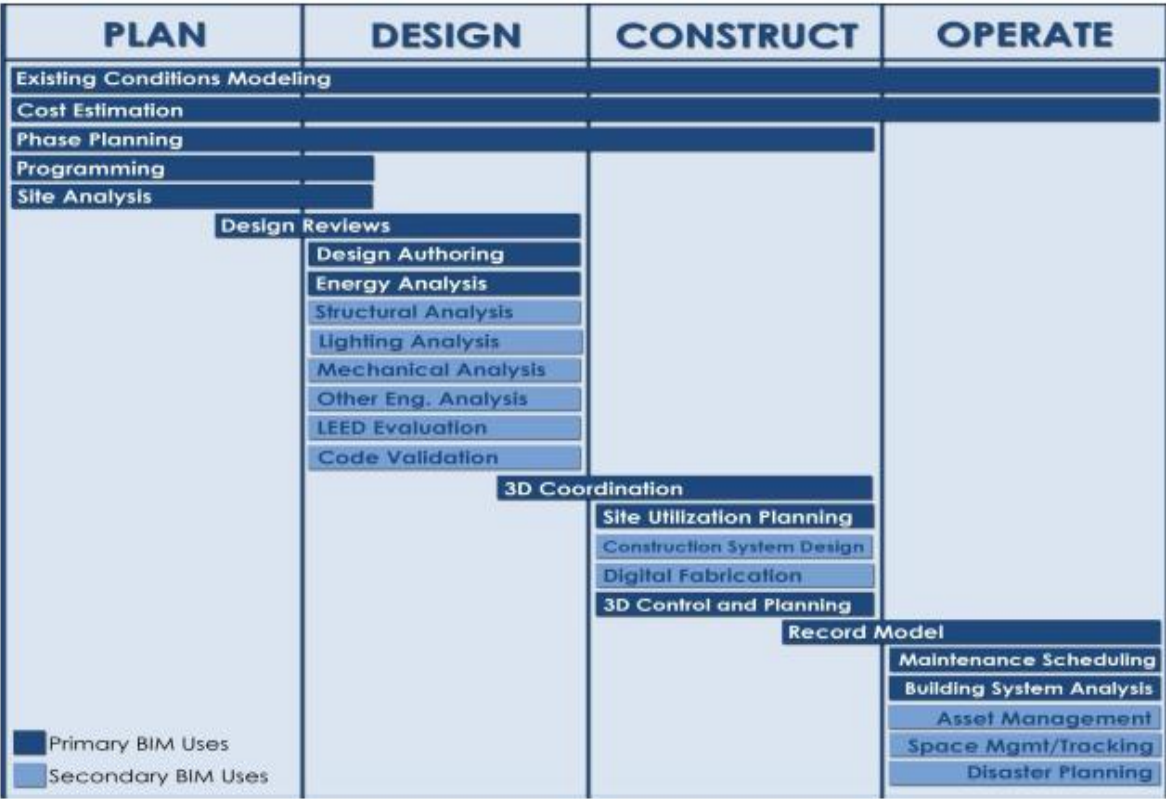


Figure 5: BIM Uses Throughout A Building Lifecycle (PSU, 2010)

The second step is to design the BIM Project Execution Process, which includes BIM supported tasks along with information exchanges. The Guide contains procedures to develop a process map, shown in figure (6), that allows the team to understand the overall BIM process, identify information exchanges that will be shared between parties, and clearly define the various processes to be performed for the identified BIM uses (PSU, 2010).

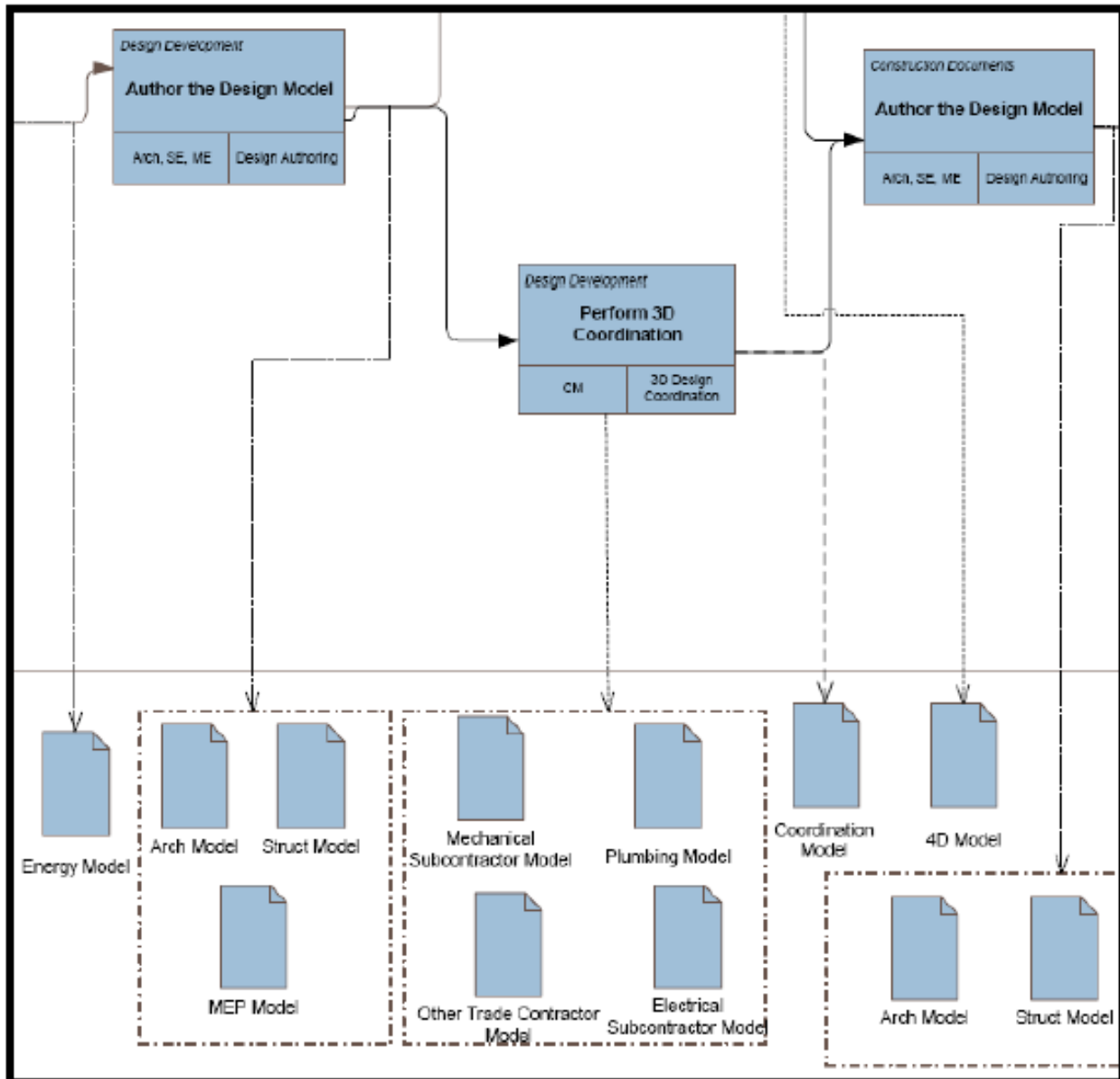


Figure 6: Portion of a BIM Overview Map (PSU, 2010). (See Appendix E of PSU BIM Execution Planning Guide for larger formatted version)

After the process map has been developed, the next step would be defining the requirements for information exchanges. The Guide presents a method for defining information exchanges by means of a information exchange worksheet, which can be seen in figure (7) below.

The final step in the Guide is to identify and define the supporting infrastructure required to support the developed BIM Project Execution Plan. Fourteen specific categories support the

BM Use*	Value to Project	Responsible Party	Value to Resp Party	Capability Rating			Additional Resources / Competencies Required to Implement	Notes	Proceed with Use
	High / Med / Low		High / Med / Low	Scale 1-3 (1 = Low)					YES / NO / MAYBE
				Resources	Competency	Experience			
Record Modeling	HIGH	Contractor	MED	2	2	2	Requires training and software		YES
		Facility Manager	HIGH	1	2	1	Requires training and software		
		Designer	MED	3	3	3			
Cost Estimation	MED	Contractor	HIGH	2	1	1			NO
4D Modeling	HIGH	Contractor	HIGH	3	2	2	Need training on latest software	High value to owner due to	YES
							Infrastructure needs	phasing complications	
								Use for Phasing & Construction	
3D Coordination (Construction)	HIGH	Contractor	HIGH	3	3	3			YES
		Subcontractors	HIGH	1	3	3	conversion to Digital Fab required	Modeling learning curve possible	
		Designer	MED	2	3	3			
Engineering Analysis	HIGH	MEP Engineer	HIGH	2	2	2			MAYBE
		Architect	MED	2	2	2			
Design Reviews	MED	Arch	LOW	1	2	1		Reviews to be from design model	NO
								no additional detail required	
3D Coordination (Design)	HIGH	Architect	HIGH	2	2	2	Coordination software required	Contractor to facilitate Coord.	YES
		MEP Engineer	MED	2	2	1			
		Structural Engineer	HIGH	2	2	1			
Design Authoring	HIGH	Architect	HIGH	3	3	3			YES
		MEP Engineer	MED	3	3	3			
		Structural Engineer	HIGH	3	3	3			
		Civil Engineer	LOW	2	1	1	Large learning curve	Civil not required	
Programming	MED							Planning Phase Complete	NO

* Additional BIM Uses as well as information on each Use can be found at <http://www.engr.psu.edu/ae/cic/bimex/>

Figure7: BIM Use Selection Worksheet Example (PSU, 2010). (Partial List – See Appendix F of PSU BIM Project Execution Planning Guide for full information exchange worksheet)

BIM project execution process. The categories, as displayed in figure (8), were developed by PSU after analyzing various BIM documents, reviewing current execution plans, discussing the issues with industry experts and revised through extensive review by various industry organizations. (PSU, 2010) Information for each category can vary significantly by project and subject to decisions made by the project team.



Figure 8: BIM Project Execution Plan Categories (PSU, 2010)

CHAPTER 3. METHODOLOGY

3.1 - Overview

This research is being conducted to determine and make recommendations to the NAVAC Capital Improvements business line for the best practices that should be included in the implementation of BIM within the NAVFAC organization. Identifying the advantages and disadvantages of BIM as they apply to naval construction are also part of the objectives. The research attempts to answer the research questions when should BIM be implemented and why, what level of information is needed at each stage and who is responsible for it, and how to work collaboratively on a model(s) on naval construction projects and facilities.

The objectives of this research are:

1. To evaluate the current NAVFAC BIM Road Map .
2. To conduct a case study to explore and understand the details involved in implementing BIM for the design, construction, operation and maintenance of naval facilities.
3. To develop recommendations, for NAVFAC's consideration and inclusion in the BIM Road Map, that are suitable for implementing BIM at all levels of the NAVFAC organization.

3.2 - Research Scope

In order to address these research objectives and goals, the researcher conducted a case study of one typical construction project currently being managed by the Facilities Engineering Acquisition Division (FEAD) at a Naval Air Station, in Oceana, Virginia. The project is being built for the Moral, Welfare and Recreation (MWR) Activity at Naval Air Station Annex in Dam Neck, Virginia, and consists of five, single-story, one and two bedroom beach cottages with a combined total of 11,648 ft².

3.3 - Research Method Methodology Flow Chart

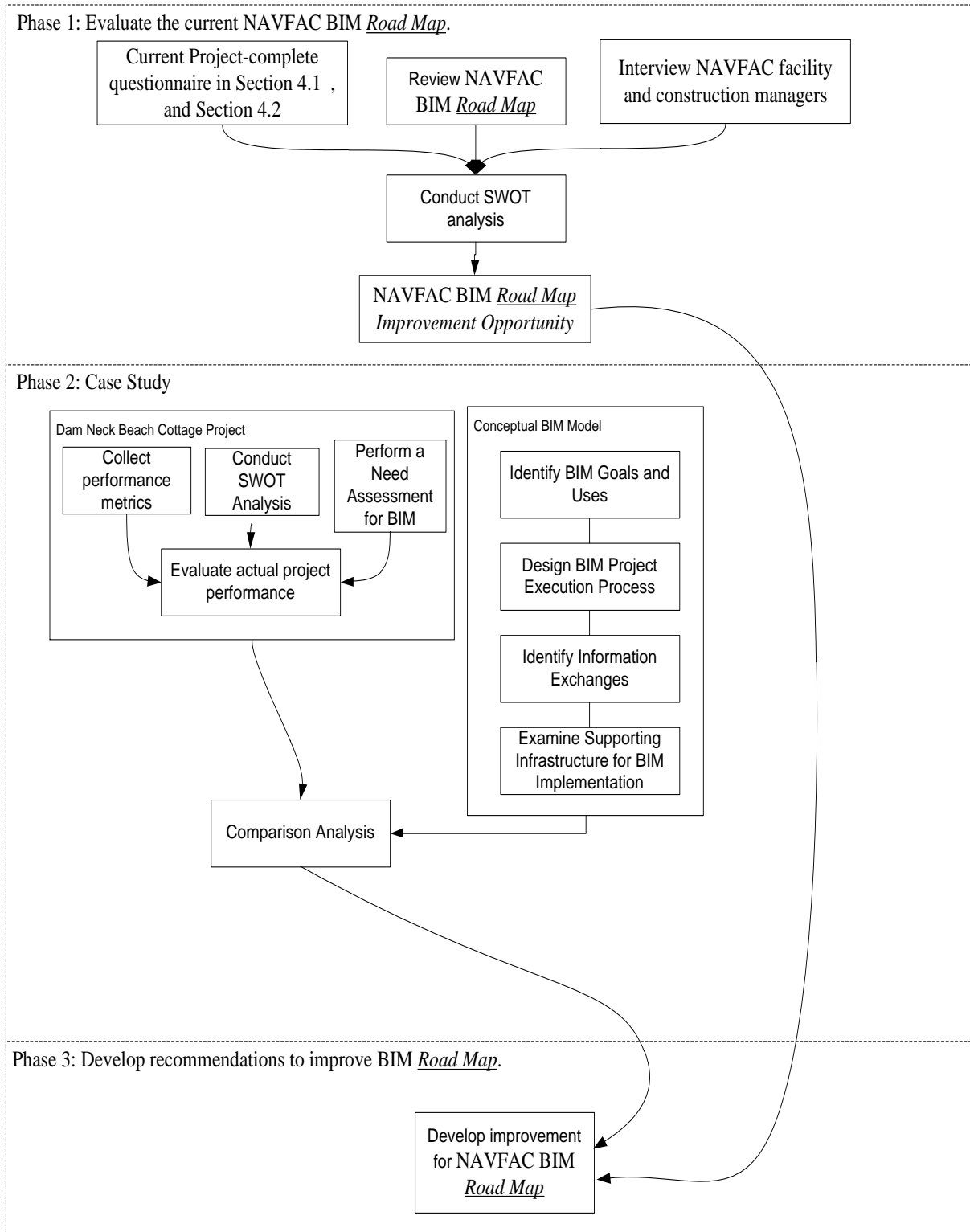


Figure 9: Research Methodology Flowchart.

3.4 - Research Methods

Phase1: Evaluate the current NAVFAC BIM Road Map.

1. Data collection plan – The researcher was in contact with the team managing the Beach Cottage project and utilized the team to assist in evaluating the current BIM Road Map by requesting they answer the questions in section 4.1 and provide feedback and comments for section 4.2 of the document. Section 4.1 contains a questionnaire titled “Determine Where You Are”, and Section 4.2 is titled “Determine What You Need to Do” and contains a ten-step BIM implementation process. The complete sections and responses are included in Appendices A & B of this document. Since the command structure of NAVFAC consists of regional FECs around the globe, with multiple Public Works departments and FEADs that may have variations in their business practices, the NAVAC Southwest and NAVFAC Midlant PW/FEAD departments also provided feedback and comments on sections 4.1 and 4.2 of the current BIM Road Map. This provides data that overlaps NAVFAC regions and more accurately represents the BIM posture and identifies variations at different NAVFAC regional commands. In addition to the current BIM Road Map questions, the researcher conducted several unstructured interviews of various NAVFAC facility and construction managers to collect information and feedback about potential and actual use of BIM and to obtain a better understanding of how to adapt BIM to current construction and business processes. Interviews included but were not limited to: Naval Weapons Station Seal Beach PWO; NAB Little Creek FEAD Director; NAVSTA Oceana FEAD Director; Work Control Branch Supervisor NAVFAC North West, and the NAVFAC South West Supervisory Architect.

2. Data Analysis plan – Feedback and results obtained from the Beach Cottage project team and FEADs were used to compare current processes and procedures to the desired end-state processes and procedures required for successful BIM utilization. A data comparison was conducted to identify variations between the different FEC regions. Current levels of technology, information technology (IT) assets, required training and costs of implementation relative to added value are all considered when determining the appropriate levels of detail needed in the BIM process. Based on the data and insight gained from the data collection process, a strengths, weaknesses, opportunities and threats (SWOT) analysis of the NAVFAC current BIM Road Map was completed to ascertain any additional facts and data needing revision.
3. Expected Output – Using the “Best Practices” identified in the literature review and industry practices as a basis of measure, specifically the PSU Project Execution Planning Guide, USACE BIM Roadmap, and the Camp Pendleton Naval Hospital Project BIM Execution Plan, any issues and concerns will be identified and appropriate course of action recommendations will be developed and provided to the NAVFAC CI business line for consideration and inclusion in the final BIM Road Map. The general type and complexity of naval construction projects that are suitable for BIM applications will be evaluated and the criteria at which BIM use is beneficial will be included in the BIM Road Map recommendations.

Phase 2: Conduct a case study.

1. Data Collection Plan – The research centered on a case study that evaluated a Beach Cottage construction project managed with traditional NAVFAC procedures and no BIM applications or processes, and a concept model based on the PSU BIM Guide, the

Camp Pendleton Hospital Project BIM Execution Plan and BIM drawings of the Dam Neck Beach Cottages that the researcher recreated in Revit using portions of the architectural, structural and civil sections of the project 2D AutoCad drawings.

- a. Dam Neck Beach Cottages: Data was gathered via weekly reports, project specifications and drawings and interviews. Data includes performance metrics from the beach cottage project team that NAVFAC typically tracks in recurring bi-weekly progress reports to their chain of command. A few of the metrics are: project delivery method, actual total project cost, initial predicted project cost, actual total project duration, initial predicted project duration, frequency of As-Built updates (redlines), reported safety mishaps, total project square feet and total number of project RFIs. Project square footage will be used to normalize cost data. The collected data, combined with a SWOT analysis and BIM needs assessment, were used to evaluate the actual project performance.
- b. Conceptual Model: A BIM model of one of the two bedroom Dam Neck Beach Cottages was modeled using Revit Architecture 2010 to familiarize the researcher with BIM modeling capabilities and determine the level of training required to proficiently create a model from existing drawings that were originally drawn with AutoCAD software. The model contains the architecture, structural and some civil portions of one beach cottage. Autodesk Revit® Architecture was the modeling software chosen because of its wide spread applications and use in the AEC/FM industry and accessibility to the researcher (e.g., computers at LSU have it installed and the researcher has a free student license for the software which normally costs \$6000/seat). The conceptual

model was developed to identify BIM goals and uses that are common to construction and management of facilities. Additionally, The PSU BIM Guide and the Clark-McCarthy BIM execution plan being used for their hospital construction project at Camp Pendleton were analyzed and pertinent processes were applied to the conceptual model to identify successful practices and procedures common to the BIM process that could be included in the NAVFAC BIM Road Map improvement recommendations. The Camp Pendleton hospital project is being constructed for NAVFAC by the Joint Venture of Clark-McCarthy and their BIM Execution Plan contains guidance on achieving BIM requirements from the project Request for Proposal (RFP) to achieve BIM scope of work goals. The goals include: Eliminating physical clashes, streamlined decision-making and improved project documentation (Clark-McCarthy, 2010). The PSU and Clark-McCarthy BIM plans provide valuable information for developing the concept model plan and subsequent improvement recommendations to the NAVFAC Road Map. The cost of suitable BIM software licenses and required computer workstations were determined to obtain an estimated per capita unit cost for BIM implementation.

2. Data Analysis Plan – The purpose of the case study is to explore and understand the details involved in implementing BIM for design, construction, operation and maintenance of facilities. Metrics and data from the actual beach cottage project related to design issues that generated RFIs, caused delays, increased the price or resulted in safety mishaps were compiled for comparison to a simulated BIM project model to identify any advantages/disadvantages using BIM may have provided. Current Building

turnover and acceptance procedures will be evaluated to determine if and how the current procedures can be converted to BIM applications. Figure (10), was created using guidance from the “BIM Project Execution and Planning Guide” (PSU, 2010) and provides an overview of the procedures and information the researcher will attempt to conceptually develop. The conceptual model processes and procedures will be compared to the practices used in constructing the Beach Cottage in order to identify the impacts and feasibility of BIM usability. Additionally, a SWOT analysis of utilizing BIM concepts and applications on the Beach Cottage project will be used to identify the internal and external factors that affect successful BIM implementation and should be included in the Road Map recommendations.

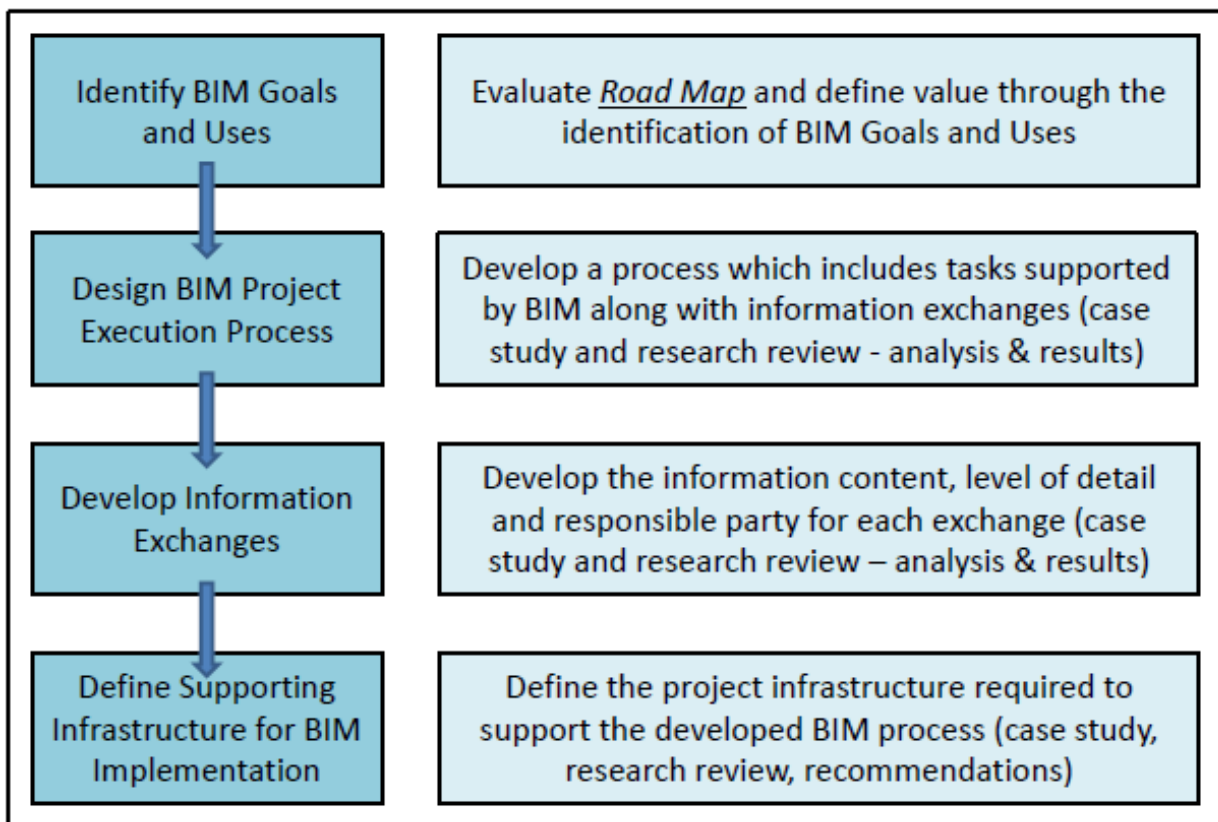


Figure 10: BIM Project Execution and Planning Procedures (source: PSU, 2010)

3. Expected Output – Specific applications, limits and features of Revit Architecture will be identified by the researcher, and a conceptual BIM plan for new buildings and feasibility of BIM use with existing NAVFAC FM tools and applications will be discussed.

Phase 3: Develop recommendations to improve BIM Road Map.

1. Data Collection Plan – Phases 1 and 2 provide the data necessary to make improvement recommendations to the current BIM Road Map to effectively implement BIM in Naval projects and facilities.
2. Data Analysis Plan – The data analysis for the final Road Map improvement recommendations is described in phases 1 and 2.
3. Expected Output – Well documented Road Map improvement recommendations for NAVFAC’s consideration and use in successfully implementing BIM within their organization. Well documented recommendations will ensure that all parties are clearly aware of the opportunities and responsibilities associated with incorporation of BIM into the organizational workflow.

3.5 - Research Limitations

Due to time and BIM software proficiency constraints, this research was limited to one small naval construction project that provides limited data for basis of comparison and may not fully identify all of the advantages and/or disadvantages of implementing BIM throughout NAVFAC. Although the FEAD practices and procedures are somewhat standard throughout NAVFAC, the scope of this research is limited to one specific project and the data collected may be insufficient to identify trends across all NAVFAC regions. Geographic distance to the actual project being constructed at Naval Air Station Annex in Dam Neck, Virginia did not

allow site visits to monitor progress or discuss project details with construction crews onsite. Ground breaking for the Camp Pendleton Naval Hospital project occurred one month before this thesis research ends and no actual data from the project will be considered to determine if the Clark-McCarthy BIM Execution Plan was effective. Since the Navy does not currently include BIM requirements in its solicitations, architects and contractors only use it voluntarily and it is difficult to find projects that were successfully designed/constructed with extensive BIM use.

CHAPTER 4. RESULTS AND DISCUSSION

Phase 1: Evaluate the current NAVFAC BIM Road Map.

1. Data collection – Sections 4.1 and 4.2 of the NAVFAC BIM Road Map were provided to the Beach Cottage management team and the completed form with comments and feedback can be seen in Appendix B. Several presentation slides prepared for the NAVFAC BIM Strategic Planning Meeting held in June 2010 are included in Appendix C, and provide an overview of the current BIM status at several of the NAVFAC FECs. Additional interviews of NAVFAC supervisors and managers were conducted and are included in Appendix D. They include the NAVWEPSTA Seal Beach PWO, the NAB Little Creek FEAD Director, the Work Control Branch Supervisor at NAVFAC NW, and the Supervisory Architect at NAVFAC SW.
2. Data Analysis – After review of the NAVFAC BIM Road Map, it was evident that the document contains a great deal of BIM background information and general knowledge that are necessary to define BIM and summarize NAVFAC's intentions for implementation, but it does not include specific guidance or address the concerns presented at the NAVFAC Strategic Planning Meeting or discussed in the interviews conducted by the author. Common areas of concern include: Data management standards not defined, insufficient hardware, software not determined or licensing problems, uniform plan for all FECs, IT services are currently provided via the Navy-Marine Corps Intranet (NMCI) which is managed under contract by Hewlett-Packard (HP) and upgrading hardware/software is a slow process, but it is expected to improve since the Navy is transitioning to a new contract with HP that improves IT services and engineering support. Biggest needs/concerns at the FEC level are: new workstations,

BIM standards in place, Project fit, Coordinating multiple software, disk storage and limited server shared storage require frequent archive of files to external disks which are difficult to share, In-house BIM experience resides with new hires, Integration of all FEC divisions (AM, FEAD, FM), Speed & bandwidth constrained, Best Practices TBD, Facility end users (maintenance shops) have no knowledge of BIM.

The ten-step process in NAVFAC's Road Map makes sense, but more specific guidance and defined standards and requirements are needed to ensure uniform and consistent implementation across the NAVFAC enterprise. Additionally, differences between BIM plans for existing buildings and facilities and BIM plans for new buildings and facilities is not addressed in the current BIM Road Map. Although it is fundamentally a judgement call, Jean-Claude Chamaa, Supervisory Architect at NAVFAC Southwest, indicated in an informal phone interview with the author that the unofficial industry dollar value is in the \$4-5M range, but depends more on complexity than price criteria for selecting projects suitable for the BIM design. A SWOT analysis of the collected data was conducted and a summary chart of the analysis results is provided in Appendix E.

3. Expected Output - The Ten-Step process in the current BIM Road Map could be modified to adapt the 4 step process developed by Pennsylvania State University (PSU, 2010) and discussed in section 2.3.7 of this document. Although historical data for BIM designed and constructed projects is very limited, the type and complexity of projects suited for BIM use should be discussed in the BIM Road Map. A section to define and describe A/E/C CAD standards, corporate configuration of network file server folder structure and content, and a dataset template is critical to ensure uniform application of

BIM across the NAVFAC enterprise. The specific computer workstation requirements and BIM application software should also be discussed in the Road Map. Training and development of NAVFAC personnel is vital for BIM development and a plan for training and hiring of personnel proficient in BIM use is necessary to ensure successful implementation and continued success. A final observation is the draft Road Map makes no mention of BIM contract language or “boilerplate” that will eventually have to be added to the “Specs Intact” documents when NAVFAC begins including BIM requirements in its contract solicitations.

Phase 2: Conduct a case study

1. Data Collection Plan – the objectives of the case study were to address the following issues:

- The feasibility of BIM based information system within NAVFAC
- Determine how to create and manipulate a model
- Identify strength and weakness of the current NAVFAC BIM Road Map
 - a. Dam Neck Beach Cottages: A summary of the project data collected follows
 - Projects Delivery method: Design-Build
 - Contract award price: \$1.8M
 - Predicted total cost: \$2.12M
 - Initial project duration: award 30JUL09, Design/approval>job start 19MAR10, Completion 11FEB11
 - Actual completion date: 01APR11
 - Significant delay and reason: Time extension granted to 1APR 11 due to material delays, geotechnical and pile driving problems.

- Frequency of As-Built updates (redlines): Constantly as job tasks are completed.
 - Delivery method for O&M manuals: Traditional paper method. O&Ms from subcontractors submitted to the primes for inclusion in the master file that is turned-over upon acceptance and completion of the project.
 - Reported safety mishaps: Two occurred. 1) Pile auger hit an unmarked underground power line. 2) overhead communications wire hit and damaged by entering/exiting truck (unknown, no witness to mishap)
 - Total number of RFIs: 7, written clarifications
- Working relations with the Architect and Engineer were excellent

Figures (11) thru (14) below show the actual project at various stages of construction



Figure 11: Cutting foundation Piles.



Figure 12. Framing & Sheathing



Figure 13: Weatherproof House wrap



Figure 14: siding installed

and were provided by the project QC Manager, Mr. Richard Howell. Discussions with the Beach project construction management team led to the conclusion that the use of BIM would not have made a considerable improvement in completion time or overall project cost since the delays and cost increases experienced were primarily geotechnical in nature and would not have been solved by creating a BIM model.

However, if a BIM model was being updated with As-Built, O&M data and product information it would have improved the turnover process and greatly benefited the project owner with maintenance and future repairs of the cottages.

- b. Conceptual Model: Figure (15) shows sheet A1.2 of the Beach Cottage project AutoCAD drawings. The complete AutoCAD set of drawings consists of 42 sheets, but only 10 sheets with Architectural and Structural details were used to re-create the Revit model for this research. The partial beach cottage model took approximately 100 hours for the researcher with a beginner drafting proficiency and no previous

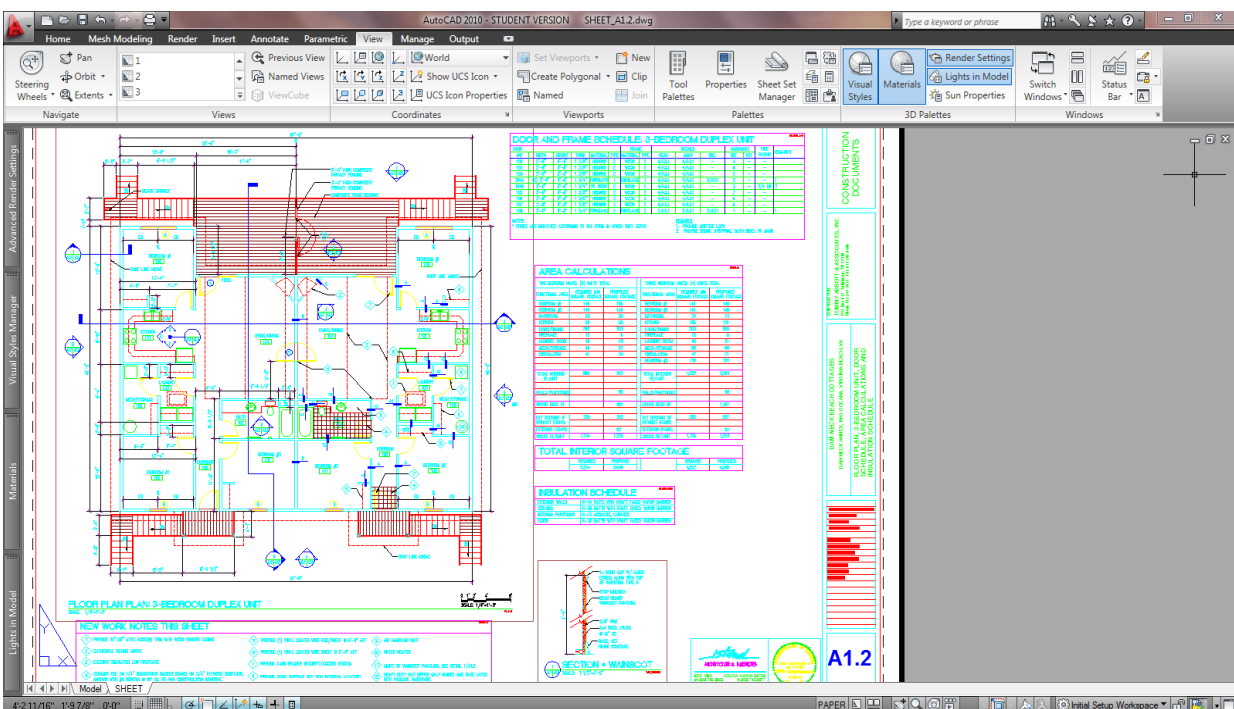


Figure 15: Screen shot of Dam Neck Beach Cottage 2D AutoCad Drawing

Revit experience to complete. Ideally the mechanical, electrical, and plumbing (MEP) sections could have been included in the Revit Model to demonstrate the potential uses of BIM for displaying inter-building connections of systems like pipes, ducts and electrical and to build the facilities database for the exact types of MEP systems used in the building. To develop the inter-building systems more accurately, Revit MEP is needed. Revit MEP is better than Revit Architecture in terms of building pipes, ducts and wire. However, in this research, the detailed systems are not necessary since the focus is on general BIM capabilities not accuracy of the model. In Revit, a family is a group of elements with a common set of properties, parameters and related graphical representation (Autodesk 2009). For example, the Doors family includes families and family types that can be used to create different types of doors, like Bifold, Double-Glass, Single-Flush, etc. The appropriate families for the model can be downloaded from the internet, but for this research only the generic families included with the Revit Architecture 2010 – Student version were used. In actual practice, the exact families would be used in the model and could be updated as necessary by either the A/E, construction contractor or facility end-user if design changes occur or are installed. The Revit “screen shots” in figures (16) thru (19) show one of the Beach Cottages recreated in Revit by the researcher, using the 2D AutoCAD drawings provided by the projects A/E. The drawings were created over the course of a semester to familiarize the researcher with Revit features and capabilities.

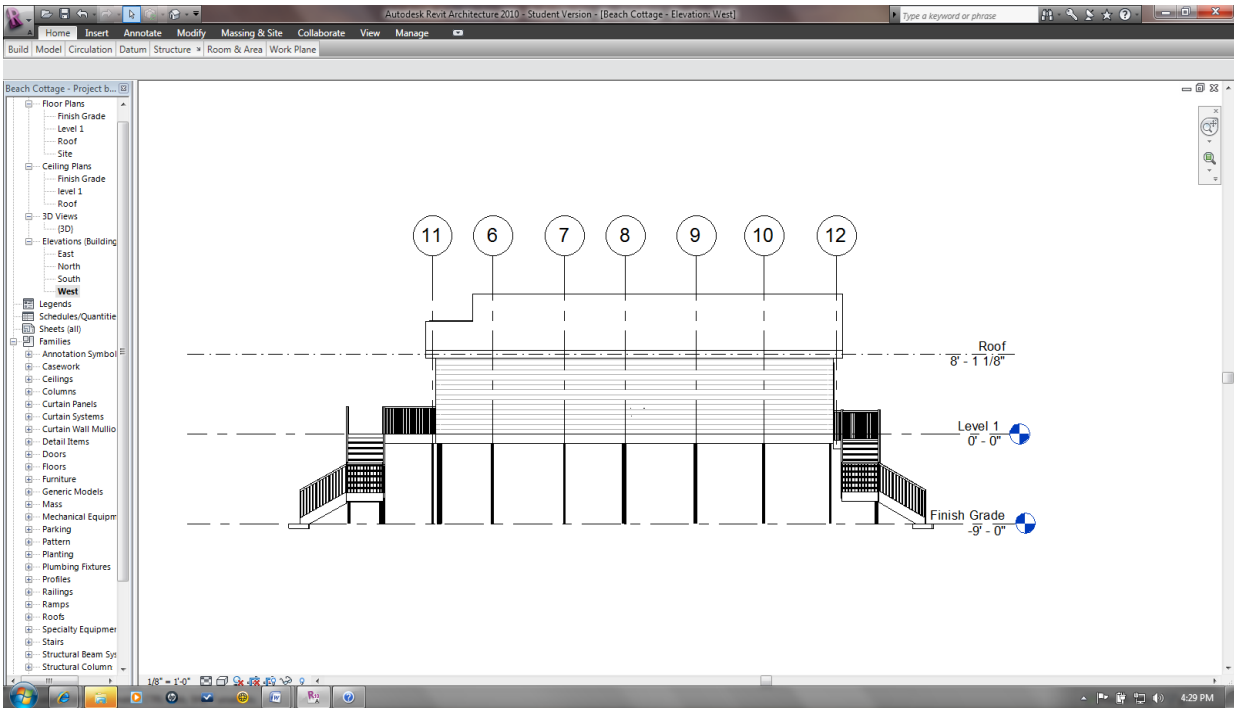


Figure 16. West Elevation View

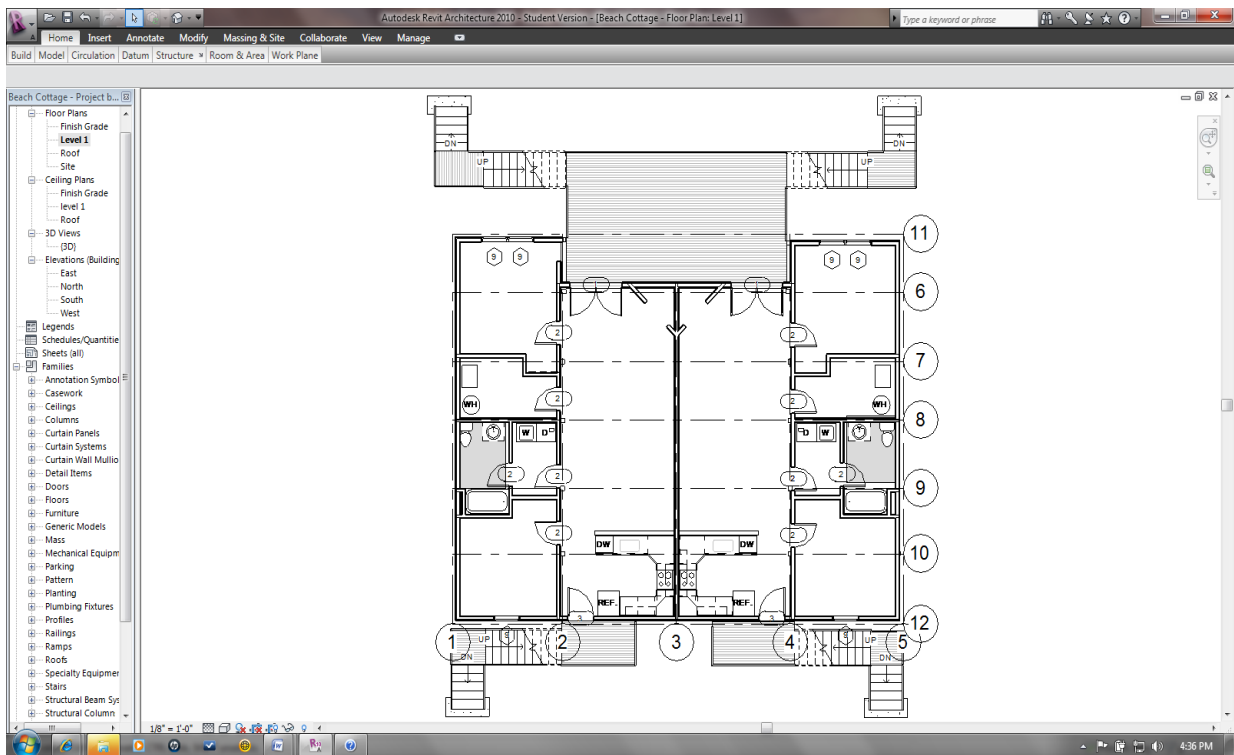


Figure 17: Level 1 Floorplan View

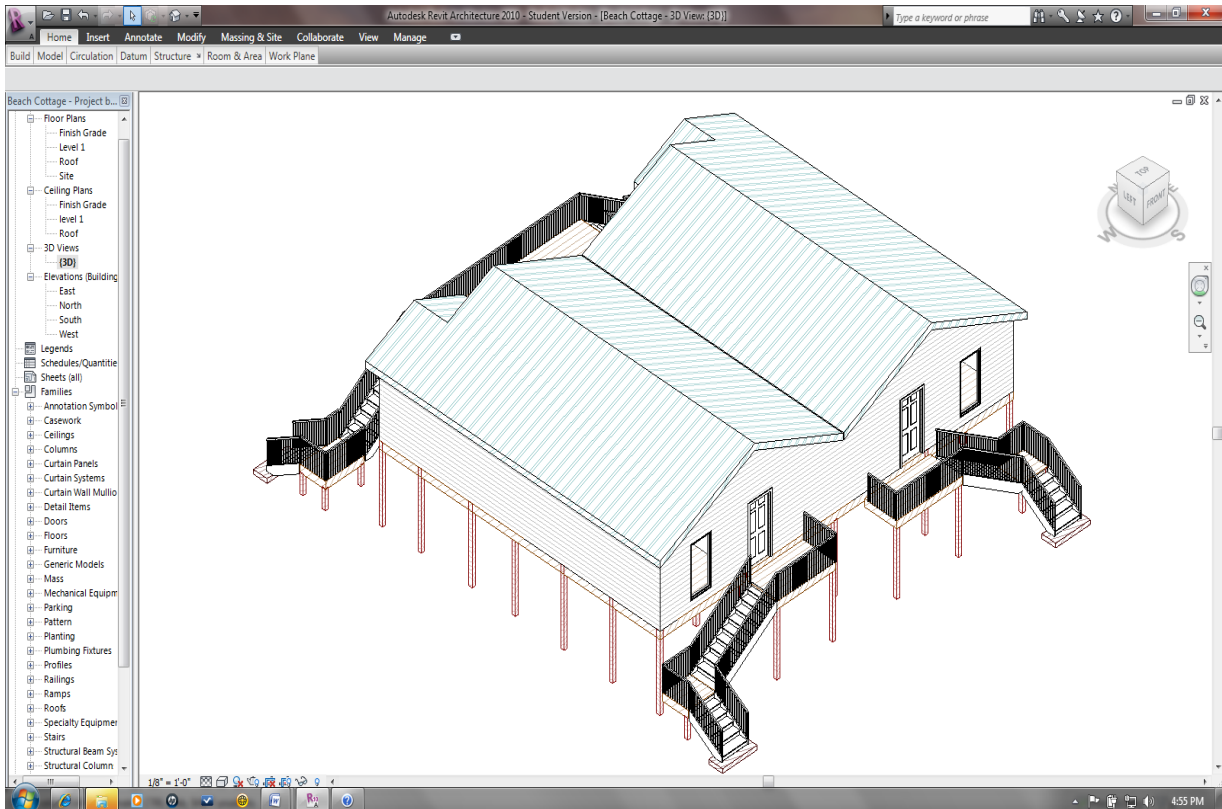


Figure 18: 3-D View with Southwest Orientation

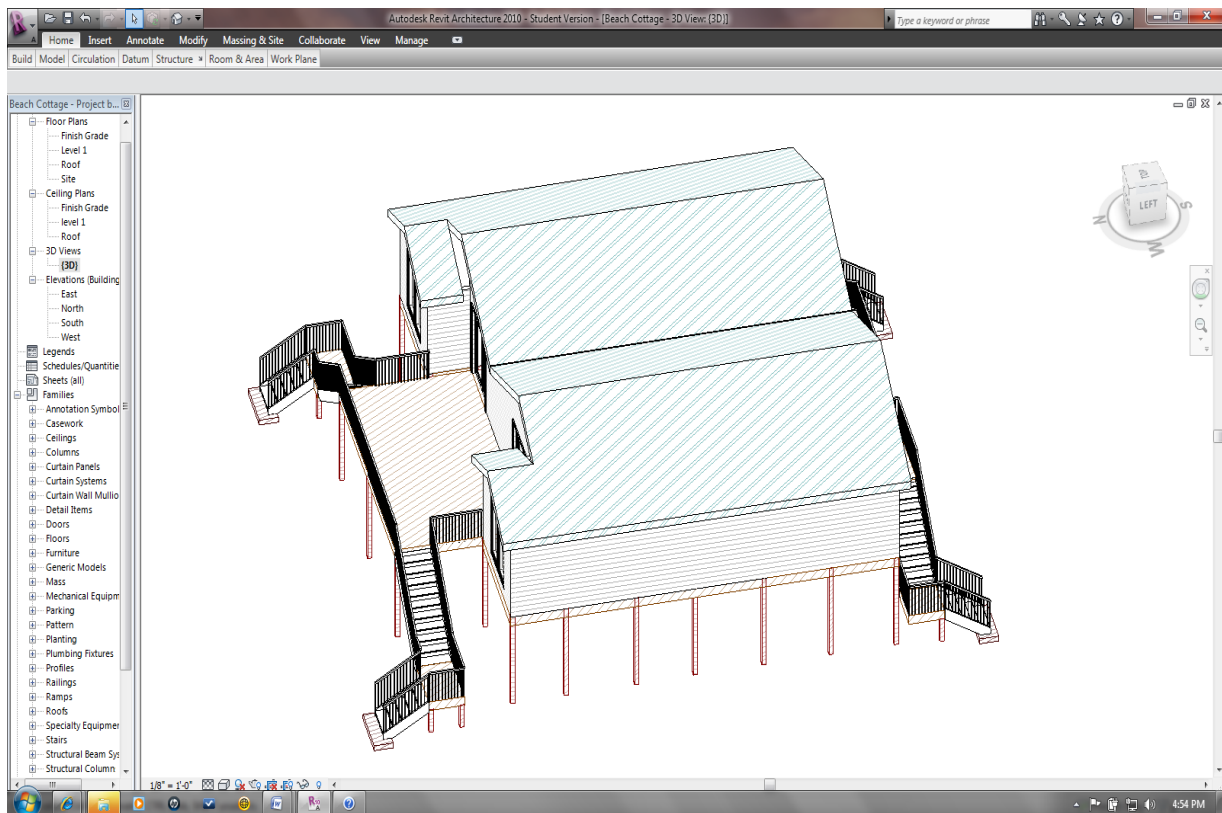


Figure 19: 3-D View with West orientation

In actual practice, team collaboration is necessary to ensure a high quality set of drawings and plans. The approach used by Clark-McCarthy JV for the Camp Pendleton Hospital project is an effective method that shares the knowledge of the entire team and assigns model creation responsibilities to each of the construction specialties. See figure (20) for a visual explanation of the different model definitions used in Clark-McCarthy BIM Execution Plan. The key concept to understand is that individual contributors create their Design or Construction Models, which then create a Federated (Full Design or Construction Model) model which is used for

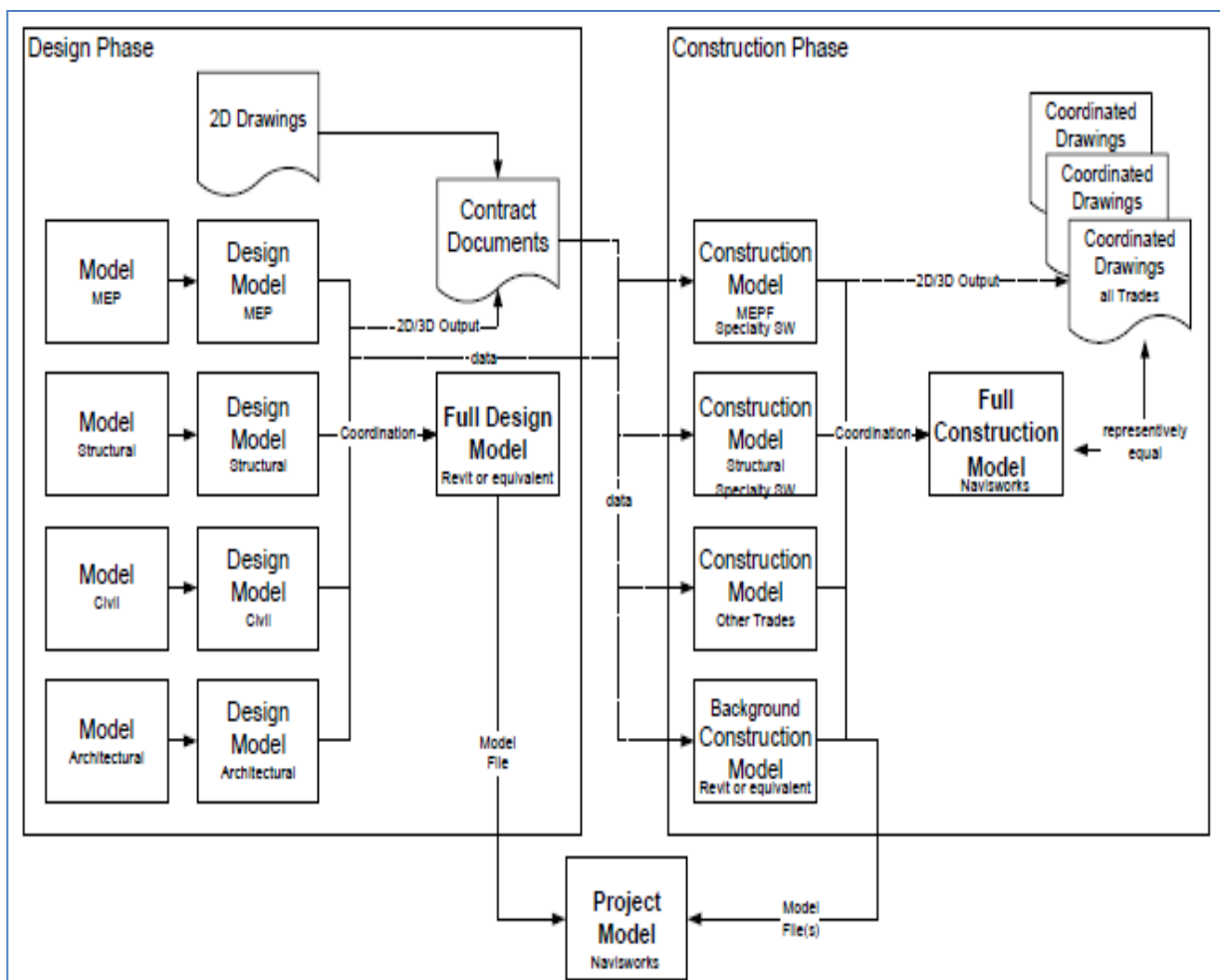


Figure 20: Graphical Model Definitions (Clark-McCarthy, 2010)

coordination purposes.

Autodesk® Navisworks® software is used in the Clark-McCarthy execution plan and supports the model with scheduling, visualization, and collaboration capabilities, and includes advanced clash detection capabilities, which integrate datasets from the various specialty sections into a single project model for interference management to resolve identified problems. Navisworks® costs approximately \$9000/license.

The Clark-McCarthy BIM Execution Plan incorporates the 4 steps outlined in the PSU Execution planning procedure, but separates and expands the procedure into 14 sections which includes: Introduction, Definitions, Project Participants, Model Parameters & Priorities, Model Details, Model Coordination Process, Model Approval & Contract Documents, Model Storage, Technological Infrastructure, 2D Reference Drawings, Requests for Information, Change Orders, Information Manager and As-Built/Close-out Model.

Conceptually, the Beach Cottage Project could have followed a similar process. Starting with a BIM introduction and definition of project goals. The Goals could include:

- Eliminate Physical Clashes – identify and eliminate physical clashes so installation issues and rework are eliminated during construction.
- Streamline Decision Making – enable streamlined decision making through presentation of models to the owner that clearly show the issue and solution.
- Improved Project Documentation – provide the owner and operation and maintenance personnel with improved project documentation that allows them to better understand what has been installed and where it is installed.

Next, the pertinent BIM definitions and a graphical model similar to figure (20) could have been created to explain the general process.

The project participants could be listed in the execution plan in table form similar to figure (21) below. In addition to listing all the participants, the table should include their roles, contact information and level of involvement with the project.

Firm	Role	Name	E-mail		Oversight	Model Creation	Model Analysis	Model Coordination
Construction								
RPM	HVAC	Ben Tepper	Btepper@AOReed.com	(619) 666-5236		X		X
	Mechanical Pipe	Ben Tepper	Btepper@AOReed.com	(619) 666-5236		X		X
	Plumbing	Tim Allinson	tallinson@murraycompany.com	(310) 991-0016		X		X
Schuff Steel	Structural Steel					X	X	X
Concrete Subcontractor	Concrete	TBD				X		X
Bergelectric	Electrical	Carrie Dragman	cdragman@bergelectric.com	(760) 746-1003		X		X

Figure 21: Sample partial table of project participants (Clark-McCarthy, 2010)

A separate table similar to figure (22) outlining the specific models to be created, the analysis of the models, and their coordination could also be included in the participant section. The next step is setting Model parameters and priorities. The following example parameters and priority of systems could be utilized in the creation of models and their coordination:

- Coordinate System – The 0,0,0 Coordinate for all models will be established by A/E at the BIM Kick-Off Meeting. X,Y = 0,0 at Grid A-1. Z= 100' at Level 1.
- Unit Convention – All models will be created at full scale with units of measure being Feet and Inches.

Scope	Design	Construction	Operations
Model Creation	Architectural	Framing and Drywall	Energy, Control and Facility Management
	Civil	Building Enclosure	Record Update
	Structural	Structural	
	Mechanical	Mechanical	
	Electrical	Electrical	
	Plumbing	Plumbing	
	Fire Protection	Fire Protection	
	Finishes	Owner Furnished Equipment	
	Landscaping		
Model Analysis	LEED Evaluation	LEED Documentation	Building Operation Optimization
	Air Distribution	Constructability	Space Management Planning
	Water/Mechanical Piping	Digital Fabrication Planning	Disaster Planning
	Structural	Access Clearances	
	Code Validation	Productivity Analysis	
	Lighting and Day lighting		
	Energy		
Model Coordination	Underground MEP	Underground MEP	
	Overhead MEP	Overhead MEP	
	In-Wall MEP	In-Wall MEP	
	On-Wall	On-Wall	
	Exterior Enclosure	Exterior Enclosure	
Documentation	Contract Documents	Change Order Updates	Record / As-Built Drawings
		Coordinated Shop Drawings/Models	

Figure 22: Sample BIM Scope of Work - Model creation, analysis, & coordination (Clark-McCarthy, 2010)

- Priority of Systems – The following provides a sample of some typical systems of a model that could be listed for design and coordination. List is in descending order of precedence.

A few typical priorities of systems for MEP Coordination efforts:

- Plumbing waste and roof drainage
- Recessed light fixtures and supports
- Fire protection (sprinkler system)
- HVAC piping

	S4 Submittal	S5 Submittal	S6 Submittal / Design Model	Shop Drawings / Construction Model	Project Record Model [As-Built Models]
MEP Coordination					
General				<ul style="list-style-type: none"> - Seismic/Vibration Supports - Rack Systems - Anchors (System and Equipment) - Equipment and Components - Clearance Requirements for Access - No-fly Zones - Insulation - Penetration Sleeves - Housekeeping Pads - Piping, conduit and ductwork 	
Mechanical				<ul style="list-style-type: none"> - Dampers - Valves - Air Vents - Actuators - Access Doors 	
Electrical				<ul style="list-style-type: none"> - Conduits 2" and Larger [may be all] - Cable Trays - Homerun Conduits 	
Plumbing				<ul style="list-style-type: none"> - Valves - Cleanouts - Air Vents 	
Fire Protection				<ul style="list-style-type: none"> - Valves - Heads - 1" clearance halo around mains 	
Framing/Drywall				<ul style="list-style-type: none"> - Full-Height Walls - Interior Wall/Door/Support Structures that Penetrate Above Ceiling Height - King Studs - Interference Walls - Bracing - Soffit and Ceiling Metal Framing - Openings - Top of Wall 	
Ceiling				<ul style="list-style-type: none"> - Reflected Ceiling Grid and Bracing - Architectural Ceiling Panels and Supports 	

Figure 23: Sample Model Level of Detail (Clark-McCarthy, 2010)

- Electrical conduit and cable tray
- Controls

A few typical priorities of systems for Exterior Enclosure Coordination efforts:

- Owner dictated access requirements
- Building structure or miscellaneous steel
- Architectural components including but not limited to walls and ceilings
- Metal studs/sheathing/plaster

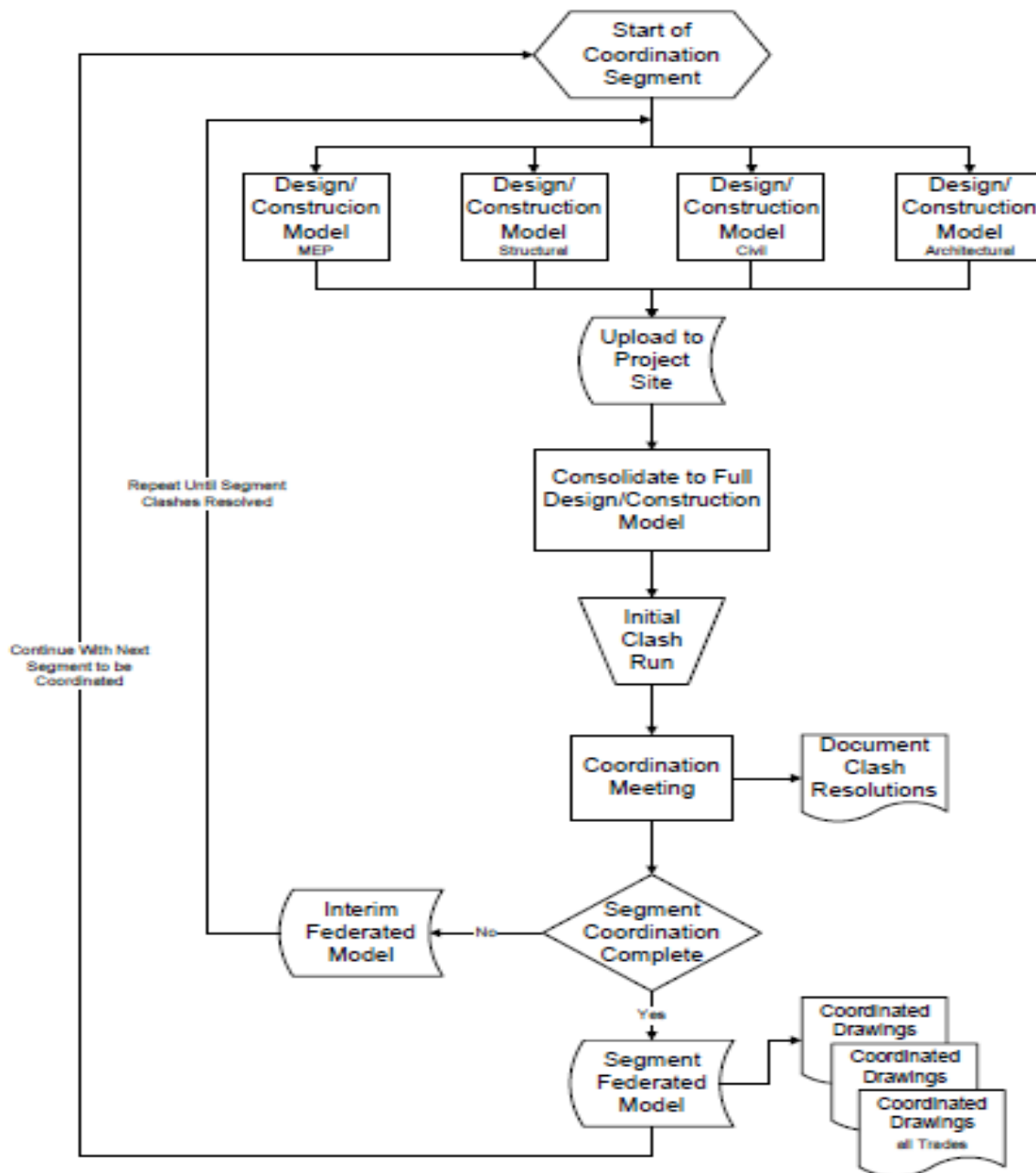


Figure 24: Sample Process Coordination Flowchart (Clark-McCarthy, 2010)

The Model Details then need to be added to the execution plan. Figure (23) provides a sample of the minimum level of detail for Model Creation by the various project Participants.

Next, the Model Coordination Process should be outlined to ensure the intended purpose of identifying and eliminating physical and sequence conflicts prior to construction is achieved. Figure (24) displays a sample stepwise Model Coordination Process that could be used. The coordination process includes both Gross Coordination and Detailed Coordination.

Gross Coordination consists of indicating and locating all major components such as wall types, stud framed walls, ceilings, structural support steel, decks & concrete, foundations, all M.E.P. system mains, ceiling mounted light fixtures and ceiling mounted air distribution.

Detailed Coordination consists of locating all framed and sleeve openings in decks, walls, supports, bracing, anchors & inserts, M.E.P. point-of-connection and casework.

For each segment to be coordinated, a series of coordination meetings are required to identify and resolve constructability issues.

The next step is to include the procedure for review and model approval. This step is dependent on contract requirements, but generally provides the A/E submittal requirements for approval by the Owner. Also required in this step is guidance for access to the model, tracking changes and stamping of the final approved documents.

Model Storage requirements need to be included and a secure File Transfer Protocol (FTP) site should be used throughout the project duration for maintaining current and historic model files. A designated Information Manager should be

responsible for establishing, providing access and managing all aspects of the FTP site. A sample file directory structure is provided in figure (25) below.

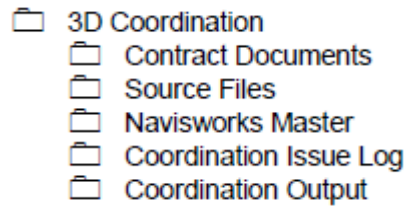


Figure 25: Sample file directory structure (Clark-McCarthy, 2010)

Additionally, the file naming and object-naming convention for the Model needs to be detailed. A sample of naming convention is detailed below:

- YYYY-MM-DD BLD-TR-ZN
 - YYYY-MM-DD = date file was created
 - BLD = building designation
 - CVL = civil site work
 - PKS = parking structure
 - TR = Trade partner/discipline
 - AR = architectural
 - ST = structural
 - MH = Mechanical HVAC
 - ZN = Coordination Zone
 - UG = Underground
 - L1 = level 1
 - Ex. 2011-05-30 CVL-AR-L1.dwg

The Technology Infrastructure should then be included in the BIM Execution Plan with details of the software used on the project, the requirements for each

participant and the computer hardware necessary to meet recommended requirements and specifications to run the software.

The process for handling requests for information (RFIs) and Change orders needs to be included in the Execution Plans and the duties and responsibilities of the Information Manager should be specifically spelled out and defined in the Execution plan.

Finally, As-Built/Close-out procedures for the model should be included in the plan and IAW contract provisions.

2. Data Analysis Plan – Comparing the actual Beach Cottage project summary of collected data with the procedures and processes developed in the concept model does not identify any significant issues that would have been mitigated by using BIM. Although the cost and complexity of the Beach Cottage project was in the range of suitable projects executed with BIM use, the work was redundant and the construction crews became proficient after completion of the first Beach Cottage and constructability issues were not a factor. No significant issues were encountered other than material delivery delays and geotechnical concerns that would not have been mitigated with BIM use. Use of BIM would have improved the turnover process by having the contractor update the model with accurate As-Built data, material & equipment specifications, manufacturer operation & maintenance recommendations and warranty information. Appendix F contains table summarizing a SWOT analysis of using BIM on NAVFAC projects.

In regard to the usability of the software, considerable architecture and drafting experience is required to create a Revit model with sufficient level of detail for use in actual construction. NAVFAC has very few in-house architects with the experience level to prepare

project drawings in Revit, and even reviewing and revising Revit drawings created and submitted by contract A/E firms would pose problems to NAVFAC design teams due to capabilities of current computer workstations do not meet the recommended system requirements to run Revit at optimum levels of performance. In addition to the items listed in the SWOT analysis in Appendix F, a long term BIM training plan is needed to properly implement BIM and ensure NAVFAC personnel foster a culture in the organization that is centered on BIM principles. The initial BIM implementation should focus on training and equipping the NAVFAC Architects and Engineers involved with developing project packages and reviewing A/E contract proposals and submittals, since BIM use in the private sector is rapidly expanding and NAVFAC needs to accommodate contractor requests to submit BIM models with their proposals instead of traditional 2D drawings. Revit is an excellent database but not a convenient way for facility management personnel to extract and restore information for daily use. Revit is slow and/or not capable of running on most of the computers available to NAVFAC personnel supported by NMCI and it is very complex for those who do not have knowledge or experience in using BIM. The end users of facilities, such as maintenance and repair, need a simpler and faster tool to convey and restore information. Navisworks Freedom® can meet this need. Navisworks Freedom® is a free program used for reviewing .DWF files. Navisworks Freedom® enables the project team to view, print, measure, and markup .DWF files containing 3D content. Fully integrated with AutoCAD and Revit, Navisworks Freedom® extends project to all stakeholders and improves communication and collaboration with project team members who may not know how to use design software (Autodesk, 2009).

Phase 3: Develop Recommendations to Improve BIM Road Map

1. Data Collection Plan - Phases 1 and 2 provide the data necessary to make improvement recommendations to the Road Map to effectively implement BIM in Naval projects and facilities.
2. Data Analysis Plan - The data analysis for final Road Map improvement recommendations is described in phases 1 and 2.
3. Expected Output - Based on the results from Phase 1 and 2 the following 12 recommendations for the NAVFAC BIM Road Map are proposed:

1. Although NAVFAC's 10 step process extends beyond the construction phase into facility management and BIM compatibility with existing tools, the ten-step process discussed in the current BIM Road Map could be modified to reflect the 4-step

Step No.	NAVFAC Road Map 10-step Process	Conceptual process based on Clark-McCarthy plan
1	Start with the Organization-Involve the Command	Introduction & definition of project goals
2	Evaluate the Business Process	Project participants
3	Develop an Implementation Plan	Model parameters & priorities
4	Complete a Data Inventory	Model details
5	Understand the Life-Cycle Data Flow	Model coordination process
6	Develop a Communications Infrastructure Strategy	Model approval & contract documents
7	Develop a Data Management Strategy	Model storage
8	Implement a User Interface Tool	Technological infrastructure
9	Use BIM Compliant Products	Information management
10	Develop a Strategy to Transition Legacy Systems to BIM Compliant Products	As-Built/Close-Out and project turn-over to facility managers

Figure 26: NAVFAC BIM Implementation process and modified conceptual process

process developed by PSU and incorporate the procedures developed in the Clark-McCarthy BIM Execution Plan, in order to improve the short term BIM objectives

and establish initial BIM operational capabilities. Figure 26 shows the modified version.

2. Further research the types of NAVFAC projects successfully completed using BIM concepts and include general guidelines of appropriate BIM use. This research used the Clark-McCarthy Camp Pendleton Hospital BIM Execution plan to outline a conceptual process that just scratched the surface of BIM planning, further analysis and documentation of completed, ongoing and planned projects needs to continue in order to define and improve upon BIM best practices. Specific projects need to be targeted to fully develop NAVFAC's BIM *Road Map* and Guidance document
3. Include A/E/C CAD standards, corporate configuration of Network file server folder structure (model storage), and a dataset template for consistent application of BIM standards across the entire NAVFAC enterprise. Without defined standards, the effects of entropy will proliferate throughout the organization and each region will create their own operating procedures. Providing standardized procedures in the *Road Map* will make implementation easier and reduce confusion in determining business practices.
4. Include a glossary of terms and BIM model definitions.
5. Specify the minimum technology infrastructure required across the NAVFAC enterprise and provide details for submitting requests for necessary Hardware and software via Navy Marine Corps Internet (NMCI) service providers.
6. Include a section in the *Road Map* that outlines a specific BIM training and development plan for NAVFAC Architects, Engineers and end user maintenance personnel. The training plan should provide a description of recommended training

courses required, contact information for requesting training, continuing education requirements and certification programs available. Training is vital to successful BIM implementation and the *Road Map* is a venue for ensuring consistent progress and development at all NAVFAC organizations is maintained.

7. Include a section to address Human Resource (HR) actions required to properly staff personnel with BIM proficiency and experience. At a minimum discuss the creation of a BIM Manager position at the Facility Engineering Command (FEC) level and include position description and minimum job qualifications.
8. Provide guidance for the creation and development of contract language and required BIM deliverables for standard facility types. Include any automated tools available to develop and create a request for proposal (RFP) for various facility types including barracks, dining facilities, training facilities, aircraft hangars and headquarters buildings (i.e. the USACE RFP Wizard portal located at <http://mrsi.usace.army.mil/rfp>).
9. Include Navisworks® and Navisworks Freedom® descriptions and applied uses, specifically explain the scheduling, visualization, collaboration, and advanced clash detection capabilities of Navisworks® and how the free software Navisworks Freedom® is better suited for end users with little design knowledge that need a simpler and faster tool to convey and review information.
10. Initial primary implementation focus should be on NAVFAC personnel directly involved with development of project packages and reviewing contractor proposals.

11. Provide a Plan of Action and Milestones (POAM) that establishes initial operating capability (IOC), Full Operational Capability (FOC) and the desired end state of BIM implementation with Chief of Engineer's intent clearly stated.
12. Include requirements for a BIM transition team and provide specific guidance of the team's duties and responsibilities.

CHAPTER 5. SUMMARY AND CONCLUSIONS

BIM has quickly gained momentum as the technology brings greater collaboration and communication between project participants. Over half of the AEC/FM industry is using BIM or BIM related tools today (McGraw Hill Construction, 2009), and the number of BIM users will increase exponentially in the next few years. Designers, contractors, and owners have seen the benefits that are directly or indirectly brought up by BIM use. NAVFAC must expedite their initiatives to implement BIM to keep pace with the private sector and ensure they are capable of accommodating increasing requests from contractors to submit their design proposals using 3D BIM instead of conventional 2D drawings and specifications. NAVFAC will seize the opportunities and benefits of BIM use in due time just as they have with so many other technologies since their beginning as the Bureau of Yards and Docks in 1870. The weaknesses and threats identified in the SWOT analysis can be overcome by proactive leadership and development of measurable key performance indicators (KPIs). The primary weaknesses of the NAVFAC BIM Road Map include: IOC/FOC dates not specified and a POAM for measuring progress is not in place; SME qualifications and staffing goals are not defined; Enabling technology and a plan for procurement is not established; Training requirements and certification procedures are not in place. All of these weaknesses have associated KPIs that could be tracked by senior leadership to evaluate if satisfactory progress is being made. The threats tied to the Road Map are mainly associated with lack of leadership and measurable KPIs. The threats include: undefined or inconsistent standards; uncertain contract requirements; lack of training and in-house BIM use; lack of direction; under staffed and high work volume does not allow employees to spend time focusing on BIM transition; limited information available for FM phase of building life-cycle. In order to facilitate prompt implementation, the concepts,

practices and procedures of other successful organizations and companies should be duplicated. The recommendations included in this research are derived from observations of basic measures that have already been exercised to achieve the goal of using BIM to design, construct and manage buildings and facilities in both the public and private sectors. Of all the recommendations presented, it is the researcher's opinion that a diverse and fully funded training program for NAVFAC architects, engineers and facility managers is the key to long term success of BIM. To ensure continuity and consistency across the NAVFAC enterprise, BIM manager job positions and implementation teams need to be established at all the NAVFAC FECs around the globe. Just as each FEC has a "Black Belt" to facilitate and guide the LEAN Six-Sigma process, a BIM manager will ensure the BIM end state goals set by the Chief of Engineers are achieved and continuously improved upon.

The stated goal of this research was to answer the questions when should BIM be implemented and why, what level of information is needed at each stage and who is responsible for it, and how to work collaboratively on a model(s) on naval construction projects and facilities. Although no exact dollar figure or project size is established for maximizing the benefits of BIM use, BIM is clearly intended to be used as a tool for Facility management, though there are few post-occupancy applications currently in practice. BIM encompasses more than a 3D computer-rendered model of buildings. The model contains all the building's information, from wall systems, structural systems, HVAC equipment, plumbing fixtures, door and window schedules, and finishes, all the way down to the manufacturer, supplier and square footage of every material specified on a project. Therefore, it makes sense to use BIM when it will reduce inefficiencies in the 70+ year Naval facility life-cycle. Example of inefficiencies include manual re-entry of data, duplication of business functions, and the continued reliance

on paper-based information management systems. The level of information required changes with the type and intended use of the facility. The procedure outlined in the case study for setting model parameters and priorities and establishing the minimum level of detail is an effective method for project participants to follow. Basically the level of detail required is that which will eliminate physical and sequence conflicts prior to construction. Responsibility for model information can be assigned during team coordination meetings and by specifically assigning the responsible participant in the model coordination process of the execution plan. Working collaboratively on a BIM project requires the same team building and partnering required of conventional construction projects. The coordination process flowchart shown in figure (24) of this document provides details of the iterative process that team members should follow to ensure their respective sections of the model are compatible with each other and free of clashes prior to commencing actual construction.

REFERENCES

Autodesk. "Revit Tutorial 2010". Revit Tutorial 2010, 2009.

Clark McCarthy Joint Venture. (2010). Naval Hospital Camp Pendleton BIM Execution Plan.

East, W.E. "BIM for Construction Handover." Journal of Building Information Modeling. Fall 2007. 28-35.

Foster, B. (2010). BIM for Facility Management: "Design for Maintenance". Sandia National Labs.

Jordani, D.A. "BIM and FM: The Portal to Lifecycle Facility Management." Journal of Building Information Modeling. Spring 2010. 13-16.

Ku, K. "Research needs for Building Information Modeling for Construction Safety." Diss., Virginia Tech. 2010.

Maldovan, K. "BIM Best Practices: A Rapid Fire Review of Industry Metrics and Trends." Journal of Building Information Modeling. Spring 2010. 21-22.

McGraw-Hill Construction (2008). "Building Information Modeling Trends SmartMarket Report." www.analyticsstore.construction.com.

National Institute of Building Sciences. United States National Building Information Modeling Standard. National Institute of Building Sciences, 2007.

NAVFAC. (n.d.). Real Property Inventory Brief. Retrieved November 7, 2010 from <https://portal.navfac.navy.mil/portal/page/portal/AM/>.

Reichardt, M. "Convergence of Standards." Journal of Building Information Modeling. Fall 2007. 36-38.

The Computer Integrated Construction Research Program. (2010). "BIM Project Execution Planning Guide – Version 2.0." July, The Pennsylvania State University, University Park, PA, USA.

United States. Naval Facilities Engineering Command. "Draft – Building Information Management *Road Map* and Guidance." Washington. 2009.

United States. Naval Facilities Engineering Command. "Public Works Department Management Guide P-1205." Washington. 2008.

United States Army Corps of Engineers, Engineer Research and Development Center (ERDC TR-06-10). “*Building Information Modeling (BIM):A RoadMap for Implementation To Support MILCON Transformation and Civil Works Projects Within the U.S. Army Corps of Engineers*”. Washington. 2006.

U.S. Department of Commerce, National Institute of Standards and Technology (NIST GCR 04-867). “Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry. Maryland. 2004.

U.S. Department of Veterans Affairs, Office of Construction & Facilities Management, VA BIM Guide v1.0. April 2010.

Watson, J.R. “Post Construction BIM Implementation and Facility Asset Management.” Journal of Building Information Modeling. Spring 2009. 34-35.

APPENDIX A- NAVFAC BIM ROAD MAP SECTIONS 4.1 & 4.2

4.1 Determine Where You Are

Take this simple test, answering the following Yes - No questions

<i>General Business Practices</i>	<i>Yes</i>	<i>No</i>
Mission and tasks have been identified.	_____	_____
Customers have been identified	_____	_____
Customer requirements have been verified.	_____	_____
Responsibility for providing the service has been verified.	_____	_____
Need for product and process improvement has been established.	_____	_____
Requirement for automation has been identified.	_____	_____
Performance metrics are available.	_____	_____
 <i>Automation Practices</i>		
<i>Data</i>	<i>Yes</i>	<i>No</i>
User interactions and requirements have been identified (who, how, what, when, where, why, how often, how much)	_____	_____
A data management strategy (for acquisition and maintenance) has been developed and is in place	_____	_____
A document management strategy (for distribution) has been established and is in place	_____	_____
Standards have been identified and are in place	_____	_____
A data dictionary and database structure has been identified and is in place	_____	_____
 <i>Support Infrastructure</i>		
Policies and procedures for data maintenance, access and distribution have been established and are in place	_____	_____
Roles and responsibilities have been identified; position descriptions have been prepared; people have been trained	_____	_____
LAN and other base-wide communications interfaces to customers are in place	_____	_____

<i>Hardware/Software</i>	<i>Yes</i>	<i>No</i>
Applications programs have been identified and are in place	_____	_____
A hardware strategy has been established and is in place	_____	_____
An upgrade strategy has been established and is in place	_____	_____

4.2 Determine What You Need to Do

Follow this Ten-Step process:

1. Start with the Organization - Involve the Command

<i>Take a Proactive Role</i>	Information is a corporate asset. It has value and needs to be shared. Take a proactive role in developing a corporate approach throughout your command.
<i>Establish a Field Implementation Team</i>	Work with your Commanding Officer and other department heads to establish a Field Implementation Team. The Field Implementation Team (FIT) leader provides a single point of contact for external linkages. The FIT is comprised of representatives from each of the functional organizations. It is the responsibility of each representative to coordinate the efforts of their organization.

2. Evaluate the Business Process

<i>What do we do?</i>	Develop a list of the business activities and functions that are performed
<i>Who are our customers?</i>	Identify your customers for the functions performed
<i>Is there still a requirement?</i>	Verify the customer need. Are the products and services still required?
<i>Should we be doing it?</i>	Determine if these businesses are appropriate for your activity to perform. Can or should someone else be doing the task? Are the tasks mandated? Is the mandate still valid?
<i>Can we improve the product?</i>	Are we delivering the right product? Can we improve the delivery process
<i>Is automation beneficial?</i>	Is there an easier way of accomplishing the function. Eliminate duplicative activities. Are there commercial off the shelf tools to help?
<i>How can we measure our cost, time, and performance?</i>	What is the baseline from where we are starting? How are we going to measure improvements in cost, time and performance?

3. Develop an Implementation Plan. The plan should include:

<i>Goal Statement</i>	Where do we want to be at the end of the day?
<i>Business Functions</i>	Determine which business functions will be implemented to obtain quickest payback. Demonstrate value by selecting a single application that has potential for sharing common data elements: a security application; an environmental application; or other day-to-day application involving customer support.
<i>Plan of Action and Milestones</i>	What are the steps needed to achieve the goal? When are we going to achieve with each step?
<i>Resource Plan</i>	How much will it cost and when do we need the money? Where are the funds coming from?
<i>Return on Investment</i>	What's the anticipated payback?
<i>Approvals and "buy-in"</i>	Obtain concurrence of all involved within the chain of command. Include the Doers, the Users and the Viewers.

4. Complete a Data Inventory

<i>Ownership</i>	Identify essential data and assign data ownership rights
<i>Data Dictionary and Data Structure</i>	Use mature data dictionary, the Tri-Service Spatial Data Standards, as the basis for local data dictionary to accommodate a data structure that will support CADD, CAFM and GIS. As a minimum, data dictionary should be normalized from the following data sets: <ul style="list-style-type: none">• iNFADs• BPIP and AIS• Tri-Service Spatial Data Standards
<i>Data Sharing</i>	Share with locally and regionally

5. Understand the Life-cycle Data Flow

<i>Identify Local Interactions</i>	Determine how information will flow from one department to the next for the scope defined in the Implementation Plan
<i>Identify Reporting Requirements</i>	Legacy data and stovepipe processes were originally developed to perform certain programmatic functions with point solutions. The data should be separated out and entered only once, at its source.

6. Develop a Communications Infrastructure Strategy

Identify Options

Determine how information will be shared

- Local area networks
- Wide area networks
- Internet
- Intranet
- CD-ROM

Coordinate Efforts

Plan globally; implement locally. Coordinate local implementation requirements with those of higher authority

Update

Develop a process, such as a night-time manager, to update linked data in a timely manner.

7. Develop a Data Management Strategy

Document Management

Implement a document management approach for locating information

Access

Initiate a capability to provide access to specific data for uploading to higher authority

Data Repository

Determine how and what data shall be stored in a higher level or historic repository

8. Implement a User Interface Tool

COTS Products

Implement one of the COTS point-and-shoot data interface tools available on the FCAD2 contracts or their equivalent. These include Intergraph's FACStar and Cordant's Facilities Information Management Environment.

Use New Tools

Use rapid application development tools to develop prototypes and prove concepts. Scale up to client-server or browser Internet applications using open database standards and compliant programs.

9. Use BIM Compliant Products

Open Architecture Rule

Must meet open architecture model:

- Interoperable
- Multi-platform
- Scaleable
- Portable
- API-able

60-30-10 Rule

The implementation effort must meet the 60-30-10 model:

- 60%, or the majority of product must be usable to the "viewer" out-of-the-box

- 30% of the product should be adaptable by the “user”
- 10% of the product should allow a level of flexibility for the “doer” to modify to perform specific customizable tasks.

BIM Compliance Council

As an aid to users, a Council will soon be in place to identify COTS products which are BIM compliant. This will enable each site to choose from a list of acceptable products. Questionable products can be submitted to the Council for determination and certification.

10. Develop a Strategy to Transition Legacy Systems into BIM Compliant Products

Dismantle the Stovepipes

Convert stove pipe systems to shared data base applications. Divide systems into component parts and coordinate where possible. Keep applications small and focused on specific tasks. This enable quicker response to change and more flexibility as COTS products are found.

Focus on the Data

The data will live throughout the facilities life cycle. By concentrating on the data and the sharing of information, you will automatically be turning to the correct CADD, GIS and related database products that fit and support the respective business process. Remember: the technology is a moving target. Hardware generations are below six months; software lasts approximately a year. Your people and data investment should last forever

Transition Logically

Maintain existing central systems during the transition period using a “nighttime data management system”. This will allow local operation on a daily basis and then upload data to the existing Command wide data reporting tools prior to Command conversion to all BIM compliant products. Local activities are not the only organizations undergoing change. With reduced budgets adapting to the BIM philosophy is not an overnight exercise, but an approach that can be grown into while staying in business and continually improving our products to our customers.

APPENDIX B – NAVFAC BIM ROAD MAP SECTIONS 4.1 & 4.2 FEEDBACK

4.1 Determine Where You Are		
<i>Take this simple test, answering the following Yes - No questions</i>		
General Business Practices	YES	NO
Mission and tasks have been identified.	X	
Customers have been identified	X	
Customer requirements have been verified.	X	
Responsibility for providing the service has been verified	X	
Need for product and process improvement has been established.		X
Requirement for automation has been identified.		X
Performance metrics are available.		X
Automation Practices		
Data		
User interactions and requirements have been identified (who, how, what, when, where, why, how often, how much)		X
A data management strategy (for acquisition and maintenance) has been developed and is in place	X	
A document management strategy (for distribution) has been established and is in place		X
Standards have been identified and are in place		X
A data dictionary and database structure has been identified and is in place		X
Support Infrastructure		
Policies and procedures for data maintenance, access and distribution have been established and are in place	X	
Roles and responsibilities have been identified; position descriptions have been prepared; people have been trained		X
LAN and other base-wide communications interfaces to customers are in place	X	
Hardware/Software		
Applications programs have been identified and are in place		X
A hardware strategy has been established and is in place		X
An upgrade strategy has been established and is in place	X	

4.2 Determine What You Need to Do			
<i>Follow this Ten-Step process:</i>			
1. Start with the Organization - Involve the Command			<i>Comments/Recommendations/Feedback</i>
<i>Take a Proactive Role</i>	Information is a corporate asset. It has value and needs to be shared. Take a proactive role in developing a corporate approach throughout your command.		Correct, information is shared within NAVFAC via a the NAVFAC portal
<i>Establish a Field Implementation Team</i>	Work with your Commanding Officer and other department heads to establish a Field Implementation Team. The Field Implementation Team (FIT) leader provides a single point of contact for external linkages. The FIT is comprised of representatives from each of the functional organizations. It is the responsibility of each representative to coordinate the efforts of their organization.		BIM Implementation not at field level yet. NAVFAC Capital Improvements Business Line has established a strategic planning team that is charged with BIM implementation across the enterprise. The team is split into three task teams, which are: Process Requirements Task Team, Data Management Task Team and the Hardware/Software Task Team. Each FEC has capability of assigning a FIT when needed.
2. Evaluate the Business Process			
<i>What do we do?</i>	Develop a list of the business activities and functions that are performed		Activities & functions documented in NAVFAC publications, Command Standard Operating Procedures,
<i>Who are our customers?</i>	Identify your customers for the functions performed		Customers identified
<i>Is there still a requirement?</i>	Verify the customer need. Are the products and services still required?		Well defined
<i>Should we be doing it?</i>	Determine if these businesses are appropriate for your activity to perform. Can or should someone else be doing the task? Are the tasks mandated? Is the mandate still valid?		Based on customers needs
<i>Can we improve the product?</i>	Are we delivering the right product? Can we improve the delivery process		Yes, absolutly.
<i>Is automation beneficial?</i>	Is there an easier way of accomplishing the function. Eliminate duplicative activities. Are there commercial off the shelf tools to help?		Yes
<i>How can we measure our cost, time, and performance?</i>	What is the baseline from where we are starting? How are we going to measure improvements in cost, time and performance?		Maintain database of all projects and with data fields developed for pertinent data.


	3. Develop an Implementation Plan.		
	<i>The plan should include:</i>		
	Goal Statement	Where do we want to be at the end of the day?	Projects delivered on time and within budget and after
	Business Functions	Determine which business functions will be implemented to obtain quickest payback. Demonstrate value by selecting a single application that has potential for sharing common data elements: a security application; an environmental application; or other day-to-day application involving customer support.	Don't fully understand what this requires
	Plan of Action and Milestones	What are the steps needed to achieve the goal? What are we going to achieve with each step?	The steps required should be standard across the enterprise or similar to plans of successful projects
	Resource Plan	How much will it cost and when do we need the money? Where are the funds coming from?	Based on HQ decision of which specific applications will be used. Funding should be programed for in future
	Return on Investment	What's the anticipated payback?	Another tool to increase efficiency and productivity. Payback unknown.
	Approvals and "buy-in"	Obtain concurrence of all involved within the chain of command. Include the Doers, the Users and the Viewers.	Buy in is done during the funding debate
	4. Complete a Data Inventory		
	Ownership	Identify essential data and assign data ownership rights	
	Data Dictionary and Data Structure	Use mature data dictionary, the Tri-Service Spatial Data Standards, as the basis for local data dictionary to accommodate a data structure that will support CADD, CAFM and GIS. As a minimum, data dictionary should be normalized from the following data sets: <ul style="list-style-type: none">• iNFADs• BPIP and AIS• Tri-Service Spatial Data Standards	NAVFAC does maintain data dictionaries for various systems but need to be consolidated
	Data Sharing	Share with locally and regionally	Networks are regional and with local access allowed
	5. Understand the Life-cycle Data Flow		
	Identify Local Interactions	Determine how information will flow from one department to the next for the scope defined in the Implementation Plan	Local interactions should follow a enterprise standard to maintain consistency and allow centralized training and education of personnel
	Identify Reporting Requirements	Legacy data and stovepipe processes were originally developed to perform certain programmatic functions with point solutions. The data should be separated out and entered only once, at its source	Existing systems for information management are effective and proven reliable. Replacement should be phased-in and simultaneous data maintained until new systems fully functionl and

6. Develop a Communications Infrastructure Strategy			
<i>Identify Options</i>		Determine how information will be shared	NMCI provided network
		• Local area networks	
		• Wide area networks	
		• Internet	
		• Intranet	
		• CD-ROM	
<i>Coordinate Efforts</i>		Plan globally; implement locally. Coordinate local implementation requirements with those of higher authority	NMCI controls infrastructure.
<i>Update</i>		Develop a process, such as a night-time manager, to update linked data in a timely manner.	NMCI provides updates
7. Develop a Data Management Strategy			
<i>Document Management</i>		Implement a document management approach for locating information	Standard NAVFAC template should be developed at H level and provided to all regions for implementation
<i>Access</i>		Initiate a capability to provide access to specific data for uploading to higher authority	CIO controls
<i>Data Repository</i>		Determine how and what data shall be stored in a higher level or historic repository	SIPR net available at all NAVAC regions, but limited to secure buildings.
8. Implement a User Interface Tool			
<i>COTS Products</i>		Implement one of the COTS point-and-shoot data interface tools available on the FCAD2 contracts or their equivalent. These include Intergraph's FACStar and Cordant's Facilities Information Management Environment.	Need explanation of this requirement
<i>Use New Tools</i>		Use rapid application development tools to develop prototypes and prove concepts. Scale up to client-server or browser Internet applications using open database standards and compliant programs.	Not feasible, since upgrades to computer assets are managed by NMCI and changes require contract modifications.


9. Use BIM Compliant Products			
	<i>Open Architecture Rule</i>	Must meet open architecture model: <ul style="list-style-type: none"> • Interoperable • Multi-platform • Scaleable • Portable • API-able 	Need to work with NMCI to ensure workstations adequate.
	<i>60-30-10 Rule</i>	The implementation effort must meet the 60-30-10 model: <ul style="list-style-type: none"> • 60% , or the majority of product must be usable to the “viewer” out-of-the-box • 30% of the product should be adaptable by the “user” • 10% of the product should allow a level of flexibility for the “doer” to modify to perform specific customizable tasks. 	NAVFAC HQ decision and should be standard across enterprise
	<i>BIM Compliance Council</i>	As an aid to users, a Council will soon be in place to identify COTS products which are BIM compliant. This will enable each site to choose from a list of acceptable products. Questionable products can be submitted to the Council for determination and certification	NAVFAC HQ responsibility
10. Develop a Strategy to Transition Legacy Systems into BIM Compliant Products			
	<i>Dismantle the Stovepipes</i>	Convert stove pipe systems to shared data base applications. Divide systems into component parts and coordinate where possible. Keep applications small and focused on specific tasks. This enable quicker response to change and more flexibility as COTS products are found.	Does NAVFAC have examples or specific stove pipe applications that should be converted?
	<i>Focus on the Data</i>	The data will live throughout the facilities life cycle. By concentrating on the data and the sharing of information, you will automatically be turning to the correct CADD, GIS and related database products that fit and support the respective business process. Remember: the technology is a moving target. Hardware generations are below six months; software lasts approximately a year. Your people and data investment should last forever	Standardized BIM model structure and network file storage/sharing requirements and template should be developed at HQ level and provided to FECs in order to maintain consistency across the organization.
	<i>Transition Logically</i>	Maintain existing central systems during the transition period using a “nighttime data management system”. This will allow local operation on a daily basis and then upload data to the existing Command wide data reporting tools prior to Command conversion to all BIM compliant products. Local activities are not the only organizations undergoing change. With reduced budgets adapting to the BIM philosophy is not an overnight exercise, but an approach that can be grown into while staying in business and continually improving our products to our customers	Transition to BIM compliant products does not seem feasible. If BIM is implemented it needs to be compatible with existing systems. A common interface to share separate applications should be used. Duplicate efforts can be identified over time and processes can be refined to eliminate redundancy.

APPENDIX C – NAVFAC BIM STRATEGIC PLANNING MEETING PRESENTATIONS

IN-HOUSE DESIGN SUPPORT & BIM REQUIREMENTS



- New Workstations
- Address Technical Issues
 - File Sizes Across WAN
- BIM Standards in place
- Project Fit
- Coordinating multiple design software's
 - Civil has no BIM solution
 - AutoCAD still necessary/beneficial in CD's



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NAVFAC SE PRESENTATION

0/15/2010

Software, Hardware, Data Storage & Retrieval Issues



Software

Structural Engineering Software Applications-

Difficult to upgrade to new releases or updates to keep up with current code/criteria.

Difficult to receive approval to purchase new software applications that improve productivity- process is lengthy.

Majority running using a license server such as AutoCAD/AutoDesk, however, some applications Cannot use NMCI server as the license server, therefore, attempts have been made using CITRIX. CITRIX attempts have thus far been unsuccessful. CITRIX support has been poor to Non-existent.

PCASuite (concrete design), Support IT (sheet pile bulkhead design).

Software Availability – Majority running on NMCI License server not available on OneNet (NF Marianas, NF Far East, Europe, other countries).

HEW computer roll-out suppose to solve most of these issues.

Revit was only used for NOAA PRC project review. NF PAC does not use it for any in-house designs.

Software, Hardware, Data Storage & Retrieval Issues



Hardware, Data storage, Retrieval issues

Disk storage is a major problem.

Desktop High-End Workstations will improve situation. Most Design Managers and Design Engineers receiving HEW. Installation at NFP began June 10, 2010.

Others (PMs) still using old, slow, limited-storage workstations.

HEW includes Win XP, 32-bit, 4.0Gb RAM.

Autodesk Revit requires Win 7.0, 64-bit, 4 Gb RAM is Minimum, 8 Gb recommended.

NFP requested 64-bit PCs w/32Gb RAM- got HEW instead.

With current PCs loading only Revit Arch model takes 5-10 mins. Due to inadequate RAM, Models (Arch, Mech, etc.) need to be "split"- can't view all at once. Performance Depends on model size.

Limited server shared storage at command. Storage and retrieval is a problem.

Shared server space (S: drive) is often near capacity. CIO require users to frequently Archive files off to external HDDs or CDs/DVDs. External disks difficult to share.

Modeling Efforts



- A/E Firms for DB and DBB efforts requesting to use BIM for production. Starting to see Engineering Services proposals for conversion of drawings from BIM to .dwg format.
- BIM models being produced but not delivered to NAVFAC per Design Procedures UFC
- In-house efforts have been limited to individuals using their own hardware and software to produce models to supplement NAVFAC systems. This has been deemed unacceptable and prohibited.
- Architectural Desktop being used as primary tool for In-House efforts but use of 3D objects is limited to the more experienced users.
- No substantial rendering efforts being undertaken

Comments



- Strong interest among architects in implementing BIM authoring software as a design tool
- MIDLANT BIM experience resides with new hires from private sector
- Demand from A/E firms to be allowed to provide BIM deliverables
- We are passing on the opportunity to accept these products and to use them for future Facilities Management purposes

Army Corps using Bentley Microstations (mid '90s) with Bentley Architecture (2004)

95 Design professionals in different branches. Design Branch for person per discipline

Army Corp has a **Technical Integration Branch** built into their operation to assist with CAD/BIM issues, data storage, computer file standards and as-built drawing documentation. The Technical Integration Branch is made up of 15 staff members and interns. It is headed up by an IT specialist with a strong grasp at engineering deliverables

DM equipped with:

- Dell Laptops with special video card synced into a docking station
- 30" screen
- 20" support screen
- Microsoft Windows XP, 64 bit, 6 MB of RAM



Building Information Modeling Roadmap, Vol. 3, April 2010, Army Corps of Engineer

ARMY CORPS OF ENGINEERS (HAWAII)



1. Properly vet which BIM vehicle is best for NAVFAC
2. Ease and cultivate the Paradigm Shift needed to incorporate this new program
3. Integrate the other divisions in the FEC (AM, EV, HP, ROICC, FM) into the development and integration of BIM
4. Insure that all divisions are able to reap the benefit of an integrated BIM program

NAVFAC HAWAII'S GOAL

NAVFAC Midwest “Where We Are”



❖ **Software, hardware, data storage & retrieval issues**

- Data Storage is an issue with cost and also with remote site location (speed)
- Software tools are minimal (PWC vs. EFD legacy)

❖ **Best Practices**

- TBD

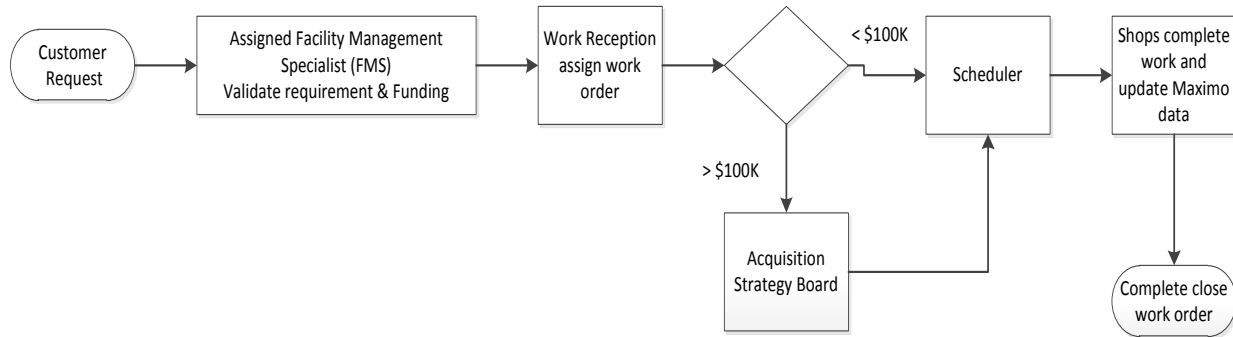
❖ **In-house and AE Design Support & BIM requirements**

- More of our work will become DBB and BIM needed for coordination and QC.
- BIM usage is primarily with contractors for construction conflict resolution.
- BIM usage with A/E for cost estimating and design coordination.

APPENDIX D – INTERVIEWS

INTERVIEW WITH BOB HUNT, WORK CONTROL SUPERVISOR, NAVFAC NORTHWEST:

MAXIMO WORK ORDER (By thesis author)



1. How do you use Maximo?

Basically it is used in two ways:

- a. The public works shop uses the system to manage the thousands of service tickets each year. These are mainly low effort and relatively inexpensive problems: fix the toilet, replace the door, install an electrical outlet, etc. Maximo tracks the tickets, provides metric information, and assignments. This work also includes the scheduling and accomplishment of the preventive maintenance required for the installed equipment.
- b. For work outside the purview of the shop (or contractor work) accumulates as a backlog and is racked and stacked into a priority system and accomplished as funding becomes available.

2. Where is the server NAVFAC NW uses for Maximo? Southern California. It is used by NAVFAC Worldwide

3. How do you record costs? There are fields to record: budgeted cost, engineered estimates, contractor proposal

4. Are codes used and if so how are they defined? Process document delineates most of the codes

5. How many people work on work orders in your department? About 500 for PWD Kitsap 350 mechanics 150 support staff

6. What type of reports are generated with Maximo? Many types: overdue, completion, metric reports, backlog reports, assignments, etc

7. What is the average number of work orders processed by your department? 4-5000/week not including the contractor who does at least that many also

8. If BIM is implemented in NAVFAC, should it be for only new construction or should models be built to include existing infrastructure as well?

Don't know

9. What do you think that BIM can help on Maximo and the maintenance process?

Don't know for sure, don't see how it would help Maximo. Seasoned workforce has strong working knowledge of facilities and locations. Not sure how the building model would provide more benefit than 2D drawings and maintenance data already maintained. Considerable effort to build models for all real property and mechanics doing the work would need training and a simplified means of pulling up building info. Maximo works well to track all work orders and mechanics are familiar with recurring preventive maintenance. Consolidating O&M data in electronic files/folders on the network would be a benefit for new employees that have less experience and are unfamiliar with base facility locations and details.

E-MAIL RESPONSE FROM NAVWEPSTA SEAL BEACH PWO:

Question: Please see the spreadsheet and kindly provide yes/no answers to the questions listed in section 4.1, and also provide feedback in the comments column in section 4.2. for section 4.2, please comment on the whether the step in the process has relevance and makes sense and if so, provide a hypothetical answer of how the step would be accomplished at your command.

Reply: I have answered the yes/no questions below. As for the 10 step implementation process, I don't have any comments for any of the specific steps themselves, as they all sound pretty reasonable. My only comment is that the time and effort to implement the process should be considered. The concept sounds good, but I'll have to say that if this process was mandated right now, I would have a hard time supporting w/ the resourcing issues at hand. Specifically, Software applications, IT hardware & network support, and training for staff to effectively use BIM. This is something that HQ sometimes forgets to account for when rolling out initiatives like these.

APPENDIX E – SWOT ANALYSIS OF DRAFT NAVFAC BIM ROAD MAP:

	POSITIVE	NEGATIVE
INTERNAL FACTORS	<p><u>Strengths:</u></p> <ul style="list-style-type: none"> - Corporate technology goals are stated - Seven BIM implementation success factors: <ul style="list-style-type: none"> · Recognizes need to convert stove pipe systems to shared database applications. · Recommends proponent and BIM subject matter expert (SME) within the organization · Acknowledges uniform enabling technology must be and support infrastructure must be in place. · Recognizes that accurate and continuous data Access must be available. · Acknowledges training and education are key to success. · States that continuing commitment and long range vision must be assured. - Getting started checklist and 10-step process includes pertinent and important information to determine BIM posture and start BIM planning. 	<p><u>Weaknesses:</u></p> <ul style="list-style-type: none"> - Detailed Plan of Action and Milestones (POAM) to attain technology goals not defined. Initial and final operational capability (IOC/FOC) dates not established and endstate goals not defined. - The stove pipe systems needing conversion to shared data base not listed or specified. - SME qualifications, position description and the types of activities and assigned locations are not defined. - Specific enabling technology and software plan not developed or defined (Revit, Navisworks ?). - IT Hardware and infrastructure requirements and capabilities not specified (NMCI or legacy?). - Training requirements and possible training sources with contact and course information not provided. - 10 step process does not have specific instructions or provide resources for achieving endstate goals. - Glossary of terms not included.
EXTERNAL FACTORS	<p><u>Opportunities:</u></p> <ul style="list-style-type: none"> - Defined data management standards. - Human resources (HR) involvement in recruiting - BIM standards and development of A/E contract Language and development of “specs-in-tact”. - Use of BIM models in planning and decision charrettes. - Establish BIM transition/implementation team members, responsibilities, management and sites or locations that require the teams. - Establish BIM training plan with requirements, Pre-requisites, available training, new hire training requirements and BIM manager position description. - Develop standards, configurations and data sets for NAVFAC projects to include: <ul style="list-style-type: none"> · A/E/C/ CAD standards · Corporate configuration of network file server standard folder structure. · Corporate dataset template with basic data and objects typically encountered when creating a BIM model. 	<p><u>Threats:</u></p> <ul style="list-style-type: none"> - Undefined data management standards with much variation and incompatibility between the multiple NAVFAC regions and activities. - Uncertain contract requirements and differences among contractors in different geographic regions. - Lack of in-house BIM use to develop competencies and skills needed to accommodate private sector A/E firms requests to submit proposals with 3D BIM models. - Transition/implementation at the local and regional levels hampered by lack of direction and skills that a well prepared and trained team could provide. - Under staffed and untrained organizations within NAVFAC unable to find time or resources to properly execute BIM implementation at a high quality level. - Standards, configurations and data sets not uniform and standard across the corporation increase duplication of effort and reduce efficiency and transportability of resources. - Additional information collection for the planning phase, construction phase, O&M phase and contract language development is needed before the topics can be properly addressed in the Road Map document.

APPENDIX F – SWOT ANALYSIS OF BIM USE ON NAVFAC PROJECTS:

	POSITIVE	NEGATIVE
INTERNAL FACTORS	<p><u>Strengths:</u></p> <ul style="list-style-type: none"> - A/E and contractors can update and revise the model to have exact families with detailed specifications of materials used built into the model - Defined model parameters and clash detection of model to avoid conflicts during construction and provides facility managers with exact information of materials, dimensions, constraints and properties in one data base. 	<p><u>Weaknesses:</u></p> <ul style="list-style-type: none"> - A/E, contractor, and owner coordination and defined responsibilities for updating the model is required to avoid duplication of effort and confusion in which changes are supposed to be in the final approved model. - Exact direction, connections, location, slopes and properties are needed for an accurate model and field construction workers most likely will need A/E or CM assistance to manipulate the model. - End users not trained to use BIM model to fully access and utilize information contained in the model.
EXTERNAL FACTORS	<p><u>Opportunities:</u></p> <ul style="list-style-type: none"> - Operations and Maintenance management and smooth and accurate turn-over of completed project to owner and end user maintenance personnel. - Review of materials and shared model in 3D visualization gives owner a better understanding of design characteristics and allows owner to identify conflicts and make changes during the design phase to avoid costly changes after construction commences. - Standardized model/data storage and retrieval Procedures can be developed across the NAVFAC enterprise. 	<p><u>Threats:</u></p> <ul style="list-style-type: none"> - End user maintenance personnel not knowledgeable in BIM use and prefer existing management tools and are resistant to change. - Insufficient training and continuous long-term incorporation of BIM models into the O&M phase of project life-cycles diminish the chances of continued success and expanded use of BIM . - IT hardware and network infrastructure upgrades do not keep pace with private sector improvements and do not meet the specifications and recommended requirements to run the BIM software in a optimum condition.

VITA

Lieutenant Commander Raymond Rohena was born in El Paso, Texas on September 10, 1966. After graduating High School he enlisted in the U.S. Navy, and served on a combination of active and reserve duty from 1984 to 1997, achieving the rate of Information Systems Technician First Class.

He earned a Bachelors of Science in Civil Engineering from the University of Texas at El Paso in 1999, and participated in the U.S. Public Health Service Commissioned Officer Training Program while in College. He was released from the USPHS in April 1999 to attend Navy Officer Candidate School, and received his Commission after completing OCS on August 4th, 2000.

After completion of the Civil Engineer Corps Officer School in December 2000, he reported to Engineering Field Activity West, and served as an Assistant Resident Officer in Charge of Construction (AROICC) onboard Naval Air Station, Lemoore, California. As the AROICC he provided project management for a wide variety of construction projects valued at over \$35M.

In May 2003, He transferred to Engineering Field Activity Mediterranean, and served as the Resident Officer in Charge of Construction on board Naval Support Activity Souda Bay, Crete. He held a Level II Contracting Officer Warrant while serving in Souda Bay.

In June 2004 LCDR Rohena commenced his tour with Naval Mobile Construction Battalion Three. He performed Communications Officer, Headquarters Company Commander, Material Liaison Officer and Assistant Operations Officer duties while assigned to NMCB THREE. He accompanied the Battalion Main body on deployments to Guam in 2004 and to Iraq/Kuwait in 2005.

In September 2006, he transferred to NAVFAC Northwest and served as the Assistant Production Officer for Naval Base Kitsap, Washington. His primary duties during his tour were focused on leading the Transportation and Self-Help Divisions.

LCDR Rohena was assigned to the Twenty Second Naval Construction Regiment from April 2008 to July 2010, serving as the Regimental Communications Officer (R6) and joining the Regiment on deployments to Iraq in 2008 and Afghanistan in 2010.

His military awards include the Navy Commendation Medal, Navy Achievement Medal (5), Navy Good Conduct Medal, Naval Reserve Meritorious Service Medal (2), Armed Forces Expeditionary Medal, Afghanistan Campaign Medal, Iraq Campaign Medal, Fleet Marine Force Ribbon and various other service awards and medals. He is Seabee Combat Warfare qualified and is a Licensed Professional Engineer in the State of Texas.

He is married to the former Patricia Escandon, of El Paso, Texas, and they have a eight year old son, Raymond Amador.