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The Use of Collaborative and Three Dimensional Imaging Technology to Increase Value in the SHIPMAIN Environment of the Fleet Modernization Plan

30 June 2007

by

Nathan L. Seaman, LT, USN

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Abstract

Maintenance and modernization of the US Navy fleet is big business. To get the most value for each dollar spent, the Navy has invested substantial fiscal and human resources to standardize the processes used to accomplish maintenance, modernization and repair for its fleet of ships. As technology continues to advance at an exponential rate, reliable and quantitative measures which capture and measure the full gamut of benefits provided by technology resources are essential. An analytic form of analysis known as the Knowledge Value Added (KVA) methodology will be used in this thesis to capture and quantify the benefits of the ship maintenance and modernization (SHIPMAIN) program and the potential benefits offered by a reengineered process.

A proof of concept case was developed to analyze current maintenance and modernization efforts for combatant ships of the Navy's surface forces. Using the current status as a baseline analysis, the KVA methodology is applied to a notional scenario which uses 3D laser scanning and Product Lifecycle Management to reengineer the current process. The notional scenario demonstrates positive returns from the reengineered process, and the KVA methodology establishes evidence which suggests that operating costs will be reduced by nearly $78 million annually.

Keywords: Knowledge Value Added (KVA), Ship Maintenance and Modernization (SHIPMAIN), Return on Investment (ROI), Return on Knowledge (ROK), Information Technology (IT), Laser Scanners, Collaboration, Planning Yards, Navy Shipyards, Product Lifecycle Management (PLM), Lifecycle Management

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Acknowledgements

Without the endless support and love of my wonderful eternal companion Melodee and my three daughters Annmarie, Hollee and Elise, this work would never have been completed; thank for everything sweetie, I love you. I would also like to thank Dr. Thomas Housel for his support and faith in my ability to accomplish this work. His keen intellect and natural ability to make complex problems manageable provided the path I needed to make it through the dense research jungle. I owe Mr. Albert “Buddy” Barreto and his better half Jane many thanks for taking time out of their busy routines to sit down and help me stay focused on the things that are really important in addition to the academics. I would be remiss if I didn’t thank Mr. Eric Tarantino for his assistance in data collection and review; thanks Eric.

This work could never have been accomplished without the help several Subject-matter Experts from Naval Sea Systems Command. Thank you for taking time out of your busy schedules to help me understand the scope and complexity of the many processes involved in maintaining, modernizing and repairing the finest combat fleet of ships in the world. Your dedication to doing the right thing, for the right reason, will have a lasting effect on the Navy’s modernization efforts.

I owe a debt of gratitude to the United States Navy and the Medical Service Corps for the opportunity to attend the Naval Postgraduate School; this experience has made me a better asset to both. In closing, I must thank my Father in Heaven from whom all blessings in life flow.

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About the Authors

Lieutenant Nathan L. Seaman, Medical Service Corps, United States Navy is a native of Florida. He enlisted in the Navy in 1994 as a Hospital Corpsman (HM). He graduated from Saint Leo University with a Bachelor of Arts Degree in Business Administration and was commissioned an Ensign in April of 2002 via the Inservice Procurement Program.

LT Seaman reported for duty as a staff hospital corpsman assigned to Naval Hospital Camp Lejeune in September of 1994. In March of 1996 he joined the USS McClusky (FFG-41) and deployed throughout the 7th Fleet Area of Responsibility and the Western Pacific. In June 1999 he reported to the Branch Medical Clinic, Key West, Florida for duty as an instructor/trainer and ran the Emergency Medical Technician training program and served as an Affiliate Faculty for the American Heart Association's Basic Life Support Program. Through the Inservice Procurement Program, he was commissioned as an Ensign in the Medical Service Corps in April of 2002 and completed Officer Indoctrination School in Newport, Rhode Island. In June of 2002 he joined the medical staff of Naval Hospital, Yokosuka, Japan as the Business Manager for the Director of Branch Medical Clinics. He later became the Business Manager for the Director of Surgical Services. He reported to the Naval Postgraduate School in June of 2005 as a student in the Graduate School of Information Sciences and deployed in support of Hurricane Katrina recovery operations prior to earning a Masters of Science in Information Technology Management in June of 2007. LT Seaman is currently assigned to the Naval Hospital Camp Pendleton as the Department Head for the Information Management Department.

LT Seaman is Enlisted Surface Warfare designated and his personal awards include the Navy and Marine Corps Commendation Medal (two awards), the Joint Services Achievement Medal and the Navy and Marine Corps Achievement Medal (two awards).

He is married to the former Melodee Noel Benson of Alpine, California. They have three children: Annmarie Noel 4, Hollee Nicole 3, and Elise Elaine 1.

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Table of Contents

List of Abbreviations and Acronyms

3D	THREE DIMENSIONAL
3DIS	3D IMAGING SYSTEM
ALT	ACTUAL LEARNING TIME
ASE	ADVANCED SHIPBUILDING ENTERPRISE
C5I	COMMAND, CONTROL, COMMUNICATIONS, COMPUTERS, COMBAT SYSTEMS AND INTELLIGENCE
CM	CONFIGURATION MANAGEMENT
DoD	DEPARTMENT OF DEFENSE
DoN	DEPARTMENT OF THE NAVY
DP	DECISION POINT
FMP	FLEET MODERNIZATION PLAN
FY	FISCAL YEAR
IEDP	IMPROVED ENGINEERING DESIGN PROGRAM
ILS	INTEGRATED LOGISTICS SUPPORT
IT	INFORMATION TECHNOLOGY
KVA	KNOWLEDGE VALUE ADDED
KVA+RO	KNOWLEDGE VALUE ADDED PLUS REAL OPTIONS
L6S	LEAN SIX SIGMA

NAVSEA	NAVAL SEA SYSTEMS COMMAND
NDE	NAVY DATA ENVIRONMENT
NSRP	NATIONAL SHIPBUILDING RESEARCH PROGRAM
OPNAV	OFFICE OF THE CHIEF OF NAVAL OPERATIONS
PLM	PRODUCT LIFECYCLE MANAGEMENT
RLT	RELATIVE LEARNING TIME
ROI	RETURN ON INVESTMENT
ROK	RETURN ON KNOWLEDGE
SC	SHIP CHANGE
SCD	SHIP CHANGE DOCUMENT
SES	SENIOR EXECUTIVE SERVICE
SHIPMAIN	SHIP MAINTENANCE
SHIPMAIN EP	SHIP MAINTENANCE ENTITLED PROCESS
SIS	SPATIAL INTEGRATED SYSTEMS
SME	SUBJECT-MATTER EXPERT
SSCEPM	SURFACE SHIP AND CARRIER ENTITLED PROCESS FOR MODERNIZATION
SPAWAR	SPACE AND NAVAL WARFARE SYSTEMS COMMAND
TYCOM	TYPE COMMANDER

I. Introduction

A. Background

This thesis builds upon previous research by Lieutenant (LT) Christine Komorosky, USN, utilizing the Knowledge Value Added/Real Options (KVA+RO)[1] valuation framework to evaluate the effects of 3-Dimensional (3D) terrestrial laser scanning technology and Product Lifecycle Management (PLM) technologies in the four public sector naval planning yards**.** LT Komorosky's research demonstrated that by adding 3D terrestrial laser scanning tools and PLM technologies to the planning yards' core processes, the total process cost decreased by 89 percent (2006). Studies conducted by the Naval Shipbuilding Research Program (NSRP) found that adding 3D terrestrial laser scanning tools to just the ship check process[2] decreased cost by as much as 44 percent and cycle-time by 49 percent (2006). Additionally, a follow-on NSRP study found that the technology is beyond the early adoption phase and is mature enough to be used reliably (2007).

The maintenance of Department of Defense (DoD) assets is big business. In Fiscal Year (FY) 2005, more than $81 billion was spent to support approximately 280 ships, 14,000 aircraft 900 strategic missiles and 330,000 ground combat and tactical vehicles (Office of the Deputy Under Secretary of Defense (Logistics and Material Readiness), 2006). That is an increase of nearly 28 percent from FY 2003 expenses of $59 billion. Given the high cost of maintenance activities and the substantial annual increase in budget, it appears that the nation's leaders are committed to maintaining a high level of operational readiness within the DoD.

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[1] See Appendix A for a detailed discussion of the KVA+RO framework.

[2] Ship check is one of seven core processes of the planning yard (Komorosky, 2005, p. 32).

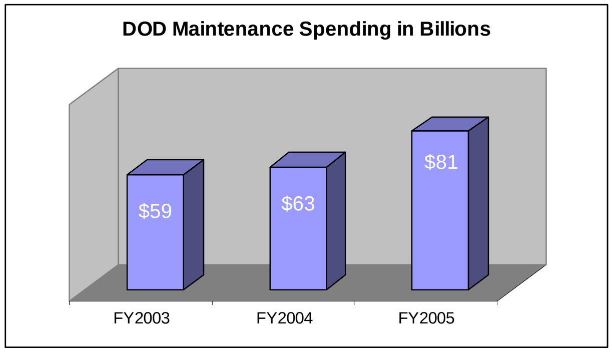

Figure 1. DoD Maintenance Expenses

The US Navy is transitioning into a new era of maintenance on its entire fleet of surface ships, submarines and aircraft within the structure of the Fleet Modernization Plan (FMP). The Navy spent approximately $39.1 billion in FY 2006 (including all wartime supplemental funding) to operate, maintain and modernize its 4,000 plus aircraft and 276 deployable battle force ships (Office of the Deputy Under Secretary of Defense (Logistics and Material Readiness), 2006, p. 3). In order to meet the United States' national defense objectives within cost, schedule and performance constraints, new business processes, coupled with innovative use of technologies like 3D terrestrial laser scanning and PLM, are required to provide for maintenance, modernization, and repair of the Navy's battle force assets.

The current acquisition environment in the DoD and the Navy is moving toward new and innovative ways of getting the most return possible for each dollar spent. Initiatives like Open Architecture (OA), the Entitled Process for Surface Ship and Carrier modernization (SHIPMAIN EP) and rapid acquisition strategies are challenging old business models to get higher levels of mission capability for less cost in less time. Cost estimation and comprehensive lifecycle management are two specific areas in which the Navy needs to become more efficient to enable these new initiatives. PLM management techniques and technologies have the potential to provide DoD leaders the ability to:

- Minimize lifecycle expenses and up-front cost overruns from poor cost estimation.

- Ensure a comprehensive lifecycle portfolio exists for each program of record and specific units of each program (i.e., specific hulls of each ship class).
- Have a means to evaluate total cost of ownership and hold Program Managers (PM) accountable for their efforts to evaluate lifecycle costs, not just up-front cost, in meeting program cost objectives.

B. Research Objectives

Given the remarkable findings of previous research, this study will expand the scope of LT Komorosky's work and map her proof of concept case study using 3D terrestrial laser scanning and PLM technologies to specific phases of the ship maintenance and modernization (SHIPMAIN) process.[3] Findings from LT Komorosky's research will be applied to the SHIPMAIN process, with appropriate conditional modifications, and the potential cost-savings and reduction in cycle-time will be evaluated. An as-is analysis will include the SHIPMAIN process as defined in current directives, and once reliable Knowledge Value Added (KVA) estimates are obtained, the process will be reexamined factoring in the capabilities of 3D terrestrial laser scanning and PLM technologies for a to-be model.

C. Research Questions

To determine potential outcomes from acquiring and using 3D terrestrial laser scanners and collaborative PLM tools in a SHIPMAIN environment, the following questions will be answered:

- Will 3D terrestrial laser scanning and PLM technologies provide better ROI for the Navy in the SHIPMAIN environment of the Fleet Modernization Plan than are currently being realized?
- What are the other potential uses of the two technologies in such processes as ship maintenance, modernization and repair?

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[3] SHIPMAIN refers to maintenance and modernization efforts; SHIPMAIN EP refers to modernization efforts only (Anonymous, personal communication, 2007, May).

Previous research demonstrated promising results through qualitative evidence derived from the use of KVA methodology to assess the impact of Information Technology (IT) systems, specifically 3D terrestrial laser scanners and collaborative PLM technologies, in the legacy planning yard processes.

D. Methodology

This thesis will model Phases IV and V of the current SHIPMAIN process and predict outcomes from a reengineered process model that incorporates 3D terrestrial laser scanning and PLM technologies. Komorosky's proof of concept case study will be mapped directly to applicable areas of SHIPMAIN, and the quantitative results of the KVA methodology will be applied to similar processes. For areas of SHIPMAIN Phases IV and V not covered by Komorosky's research, the KVA methodology will be applied to measure the impact that 3D laser scanning and PLM technologies will have on the current process model. First, all major inputs, processes, and respective outputs will be identified by a comprehensive review of current SHIPMAIN directives. This model will then be validated by SHIPMAIN subject-matter experts (SME). The sub-process analysis will include estimates for the time to learn each process, the number of personnel involved, and the number of times each process is executed. Market comparable values will be used to help estimate cost figures and add value to the methodology.

E. Scope

The intended scope of this thesis is addressing the Knowledge Value Added, and potential benefits, or return on investment (ROI), that 3D terrestrial laser scanning and PLM technologies bring to the SHIPMAIN process. The SHIPMAIN process is a large program with many interrelated concepts, instructions, policies, and specializations for study. Ideally, this research would provide a comprehensive analysis of the entire SHIPMAIN process from Phase I through all decision points and acquisition milestones to the final steps of Phase V. The technologies evaluated in this research are likely to provide additional benefits (e.g., more accurate cost estimation, higher quality, less rework and more efficient system dynamics) across all phases of SHIPMAIN. However, the quantitative scope of this research will be constrained to Phases IV and V of the SHIPMAIN process. Readers of this research should bear in mind that any benefits or ROI demonstrated in this thesis only begin to scratch the surface of the potential these technologies have to offer.

F. Organization of Thesis

Chapter I will include an overview of this research and will identify the primary objectives and questions of focus. The methodology used to reach conclusions and make recommendations is also described. Chapter II contains a literature review to introduce relevant concepts. It will provide a brief discussion on the overall missions of the FMP and SHIPMAIN, 3D terrestrial laser scanning and PLM technologies, and Lean/Six Sigma (L6S) methodology supported by KVA. In the third chapter, more detailed discussion of previous research by LT Christine Komorosky will occur, and the results will be mapped to specific areas of SHIPMAIN for direct application of the KVA methodology. Areas of SHIPMAIN that LT Komorosky's research does not map directly will also be identified. Chapter IV will begin with a brief discussion of the KVA valuation framework along with underlying assumptions. It will continue by applying the KVA methodology to specific areas of the SHIPMAIN environment, identified in Chapter III. A case study applying the KVA methodology comprehensively across Phases IV and V of SHIPMAIN will analyze the potential impact of 3D terrestrial laser scanning technology and collaborative PLM solutions under two scenarios: current as-is and potential to-be. The final chapter will conclude with specific recommendations and conclusions.

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II. Literature Review

A. The Fleet Modernization Plan

Keeping a fleet of 276 deployable ships and more than 4,000 aircraft in acceptable operational condition while modernizing and acquiring new vessels is a difficult task to accomplish within fiscal constraints. In response to this challenge, the US Navy established the FMP[4] to:

> provide a disciplined process that delivers operational and technical modifications to the Fleet in the most operationally effective and cost efficient way. The FMP defines a standard methodology to plan, budget, engineer, and install timely, effective, and affordable shipboard improvements while maintaining configuration management and supportability. (Commander, Naval Sea Systems Command, 2002, p. 1-1)

The FMP is the means by which the Navy leverages technology and innovation to:

- Keep the warfighting edge.
- Fix systemic and safety problems.
- Improve Battle Force Interoperability.
- Improve platform reliability and maintainability.
- Reduce the burden on the sailor. (Commander, Naval Sea Systems Command, 2002, p. 1-1)

The FMP process is designed to prevent unauthorized and non-supported alterations from being installed on ships.

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[4] "Chief of Naval Operations (OPNAV) N43 sponsors the FMP and Naval Sea Systems Command (NAVSEA) 04M3 serves as the FMP Policy Implementation Office and Program Manager for the Navy Data Environment-Navy Modernization (NDE-NM) database (formerly the Fleet Modernization Program Management Information System—FMPMIS) which is the official database in support of the FMP" (Commander, Naval Sea Systems Command, 2002, p. 1-1).

> Unauthorized alterations represent a substantial cost to the Navy in terms of the loss of configuration control, inefficiencies due to unexpected installation interference, systems and equipment which are not logistically supported, and resources expended to support items which are no longer required. Unauthorized and unsupported alterations adversely impact the interoperability of highly computerized and integrated combat systems. This equates to a loss of combat effectiveness due to a reduction in Carrier Strike Group/Expeditionary Strike Group interoperability and individual ship capabilities. (Commander, Naval Sea Systems Command, 2002, p. 1-1)

B. The SHIPMAIN Process

The Navy's Sea Power 21 vision outlines what capabilities naval forces will provide the nation in the decades ahead. In that vision, Sea Enterprise is transforming the way the Navy does business by harvesting efficient ways of getting jobs done, saving resources, reinvesting them into future Navy assets and delivering increased combat capability. SHIPMAIN is one of the newest initiatives aimed at harvesting efficient ways to get the job done. It is a best business practice that fleet sailors and shipyards are utilizing, changing the culture of getting ship work completed.

Beginning in FY 2004, the Navy implemented the SHIPMAIN process to provide a disciplined means to:

- Increase the efficiency of the maintenance and modernization process without compromising their effectiveness.
- Define a common planning process for surface ship maintenance and alterations.
- Install a disciplined management process with objective measurements.
- Institutionalize the process and a continuous improvement methodology for it. (Commander, Naval Sea Systems Command, 2006)

The initiative seeks to identify redundancies in maintenance processes and eliminate them. SHIPMAIN is about doing the right maintenance at the right time, in the right place for the right cost. It provides a single process that will assist the Navy in realizing the maximum benefit per maintenance dollar by eliminating time lags, prioritizing ship jobs and empowering Sailors in their maintenance decisions (Commander, Naval Sea Systems Command, 2006).

In August of 2006, the *Surface Ship and Carrier Entitled Process for Modernization (SSCEPM) Management and Operations Manual*, also known as "The One Book," became the Navy's official document for the modernization of all Surface Ships and Aircraft Carriers (Commander, Naval Sea Systems Command, 2006). It provides the policy and processes associated with SHIPMAIN for planning, budgeting, engineering and installing timely, effective and affordable shipboard improvements while maintaining configuration management and supportability. The SHIPMAIN process represents a sweeping change in the modernization of Surface Ships and Carriers. It significantly reduces the FMP by reducing over 40 change types to just two. Additionally, the SHIPMAIN process streamlines and consolidates a number of existing modernization practices, processes, meetings and supporting documents to provide a single hierarchical decision-making process for modernizing Surface Ships and Carriers.

The SHIPMAIN process is comprised of five distinct phases[5] and three Decision Points (DP)[6] to take a proposed change from concept to completion in one document, the Ship Change Document (SCD).

> The intention of the SCD is to be a single lifecycle management document depicting a modernization change from concept to completion for individual or multiple classes of ships. This single universal streamlined process enables complete documentation of a proposed change and provides a comprehensive review and decision

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[5] Five Phases: I-Conceptual, II-Preliminary Design, III-Detailed Design, IV-Implementation, V-Installation (Commander, Naval Sea Systems Command, 2006).

[6] DPs occur at the conclusion of Phases I-III. Each DP is an approval for funding of successive phases and has an associated Cost Benefit Analysis (CBA), Alteration Figure of Merit (AFOM) and Recommended Change Package (RCP) (Commander, Naval Sea Systems Command, 2006).

> capability with results being reflected in a Navy Modernization Plan (MP). The process begins with the initiation of a SCD and concludes with an update of the ship's configuration, Integrated Logistics Support (ILS), and Configuration Management (CM) records based on actual installations. (Commander, Naval Sea Systems Command, 2006, §3, p. 3-2)

Appendix B provides a detailed description of each of the five phases.

Although SHIPMAIN has a functional governance structure and supporting business rules, it has yet to reach a fully implemented state, especially in Phases IV and V.

> The EP is currently functional through DP 3 from a Navy Data Environment (NDE) perspective. Once a Ship Change (SC) has been approved at DP 3, the submitter will follow existing legacy procedures, unless otherwise documented herein for interim procedures, until such a time as NDE can be modified for full implementation. (Commander, Naval Sea Systems Command, 2006, §3, p. 3-1)

The business rules for Phases IV and V are in a maturing phase, and the process owners are regularly gathering input from stakeholders to resolve issues and refine the business rules in order to move forward with this initiative.

C. Terrestrial Laser Scanning Technology

The market for 3D terrestrial laser scanning is attracting substantial numbers of mainstream users. Sales of terrestrial 3D laser scanning hardware, software and services reached $253 million in 2006, a growth of 43 percent over 2005 (Greaves & Jenkins, 2007). According to a 2007 report by SparView:

> laser scanner manufacturers and related software and service providers report strong activity across many markets including: shipbuilding, offshore construction and repair, onshore oil and gas, fossil and nuclear power, civil and transportation infrastructure, building, automotive and construction equipment manufacturing and forensics. The rapid growth of this market across diverse sectors of industry is a strong indicator of its transition to mainstream adoption. (Greaves & Jenkins, 2007, ¶ 1)

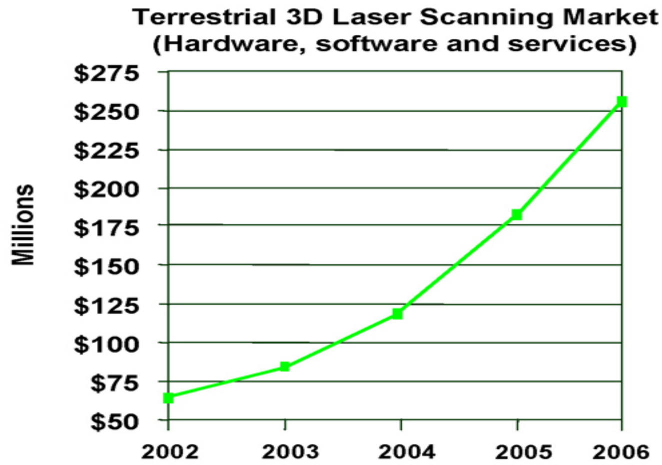

Figure 2. 3D Laser Scanning Market (Greaves & Jenkins, 2007)

Several manufacturers produce a variety of laser scanning models and capture technologies. Previous research by LT Komorosky (2005) evaluated Spatial Integrated System's (SIS) 3D Imaging System (3DIS) model. The 3DIS model provides macro scanning capabilities, and an additional unit, the VZX, can be purchased if a micro capture is required. The 3DIS comes with two software tools which provide for the collection, initial point cloud processing and viewing of point clouds. According to an SIS representative, the current 3DIS scanner captures images in 1/5 the time of previous versions evaluated by LT Komorosky (B. Tilton, personal communication, 2007, May 16). SIS also provides additional software tools as a value added reseller for UGS to conduct point cloud analysis, assembly processing and Product Lifecycle Management. Research by NSRP (2006; 2007) evaluated products from Faro, Leica, Z+F, VisiImage and 3Dguru. Figure 3 shows the percentage of market share by manufacturer.

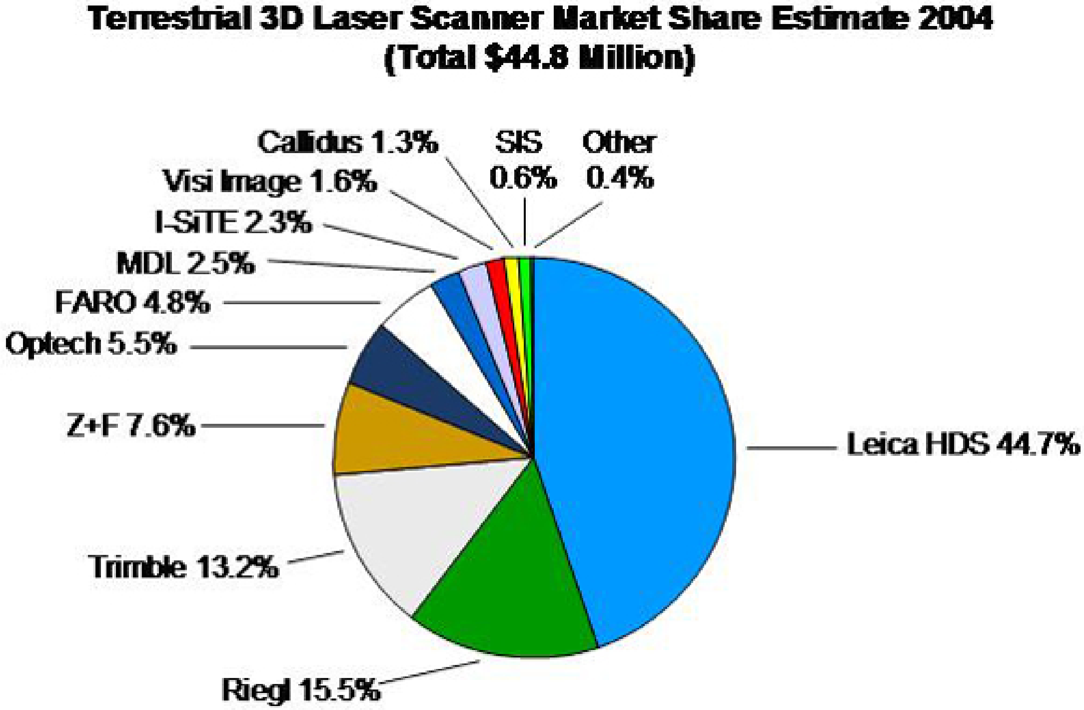

Figure 3. 2004 Market Share Estimate (Jenkins, 2005)

Most manufacturers' scanners work by scanning a target space with a laser light mounted on a highly articulating mount enabling data capture in virtually any orientation with minimal operator input. Some manufacturers also incorporate a digital camera that simultaneously captures a 360-degree field-of-view color photograph image of the target. Once the capture phase is complete, they automatically execute proprietary point processing algorithms to process the captured image. The systems can generate an accurate[7] digital 3D model of the target space, automatically fuse image texture onto 3D model geometry, export file formats ready for commercial high-end design and import into 2D and 3D Computer Aided Design (CAD) packages.

[7] NSRP's study (2006; 2007) requirement was within 3/16 of an inch to actual measurements.

D. Product Lifecycle Management Technology

CIMdata[8] defines PLM as:

> a strategic business approach that applies a consistent set of business solutions in support of the collaborative creation, management, dissemination, and use of product definition information across the extended enterprise from concept to end of life; integrating people, processes, and information […] (2007a, ¶ 1). PLM is not a definition of a piece, or pieces, of technology but rather a business approach enabling longitudinal management of product definition information. PLM can create product definition information, manage it through its life and disseminate it throughout the lifecycle of the product. PLM is a strategic management approach in which processes are as important, or more important, than data. (2007a, ¶ 2)

There are many valuable aspects to a PLM solution, one of which is the opportunity to improve the quality of products and processes, a similar goal of Lean/Six Sigma (L6S) processes. The complimentary role PLM tools provide to a business transformation using L6S will be explored later in this chapter.

Figure 4 shows the impressive growth of the PLM market. CIMdata research indicates that the overall PLM market grew 10.4 percent to reach $20.1 billion in 2006 (2007b). CIMdata attributes this strong growth rate to continued recognition of the value of PLM in improving companies' business performance. PLM investments are forecast to continue their climb over the next five years, increasing at a compound annual growth rate of approximately 8.5 percent—to exceed an estimated $30 billion by 2011.

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[8] CIMdata is a consulting firm with over 20 years of experience in strategic IT applications and is an acknowledged leader in the application of PLM and related technologies (CIMdata, 2007a)

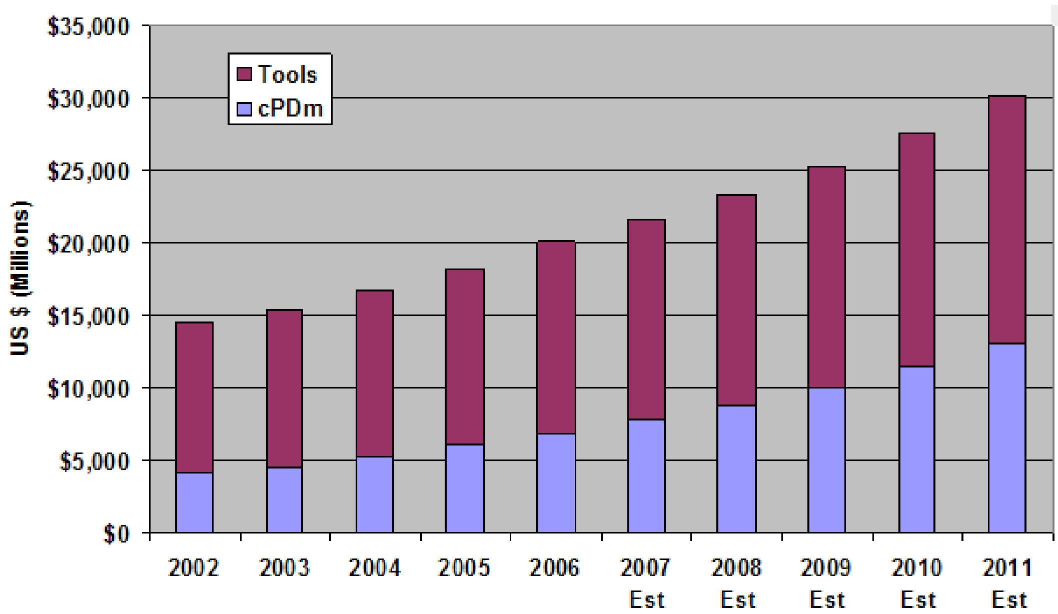

Figure 4. PLM Market Growth History and Forecast (CIMdata, 2007b)[9]

Each year, PLM-related technologies and services are provided by more companies representing all sectors of the PLM industry. In 2006, six companies reported revenues of more than $1 billion as demonstrated in Figure 5. Some companies are focused on specific technologies and functions that are part of an overall PLM environment, while others are distinguishing themselves as "PLM Mindshare Leaders"[10] (CIMdata, 2007b, ¶ 17). PLM Mindshare leaders' revenues are shown in Figure 6.

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[9] CIMdata segments the overall PLM market into two primary sub-sectors: PLM information authoring and analysis applications (Tools), and collaborative Product Definition management (cPDm) (2007b).

[10] These companies are typically considered to be at the forefront of the market in terms of either revenue generation or thought leadership (CIMdata, 2007b).

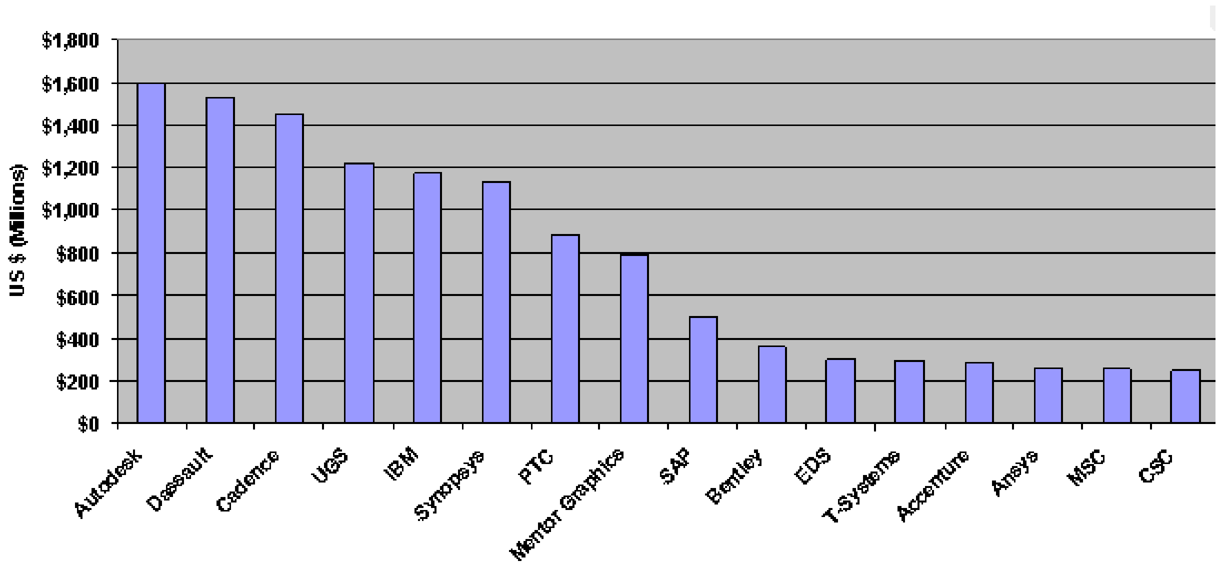

Figure 5. 2006 PLM Revenue Leaders (CIMdata, 2007b)

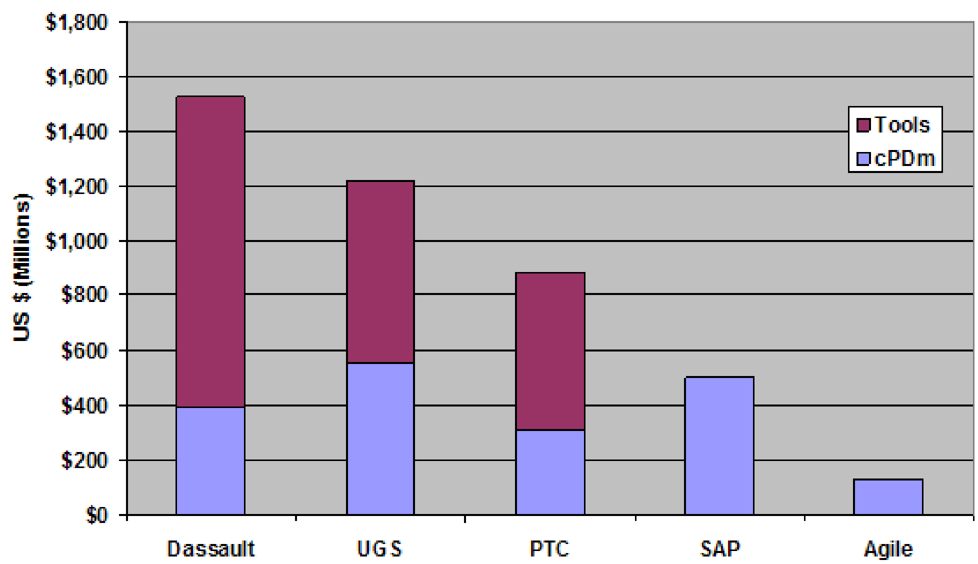

Figure 6. 2006 PLM Mindshare Leaders' Revenue (CIMdata, 2007b)

E. Improved Engineering Design Process

For the past several years, the Navy has been working to establish a common, interoperable IT framework for ship construction and lifecycle management enterprises. Some of the initiatives that have been implemented to realize this vision are the NDE and the Integrated Shipbuilding Environment (ISE). The NDE is a centralized database that contains a wide range of data from many sources related to ship repair, maintenance and modernization. The ISE seeks to attain data interoperability where business processes and IT systems are able to accept, transfer, and disseminate data electronically.

Naval Sea Systems Command (NAVSEA) is currently developing the Improved Engineering Design Process (IEDP) to:

> improve productivity, reduce cost, improve design processes, collect technical data quickly, and allow a greater sharing of information between all activities involved in lifecycle management, modernization and maintenance programs using an easy on-line collaboration process. (Stout and Tilton, 2007)

IEDP is a technology transition project that utilizes 3D terrestrial laser scanning to acquire as-built images of shipboard spaces for repair, maintenance and modernization activities. Figure 7 shows the architecture of the IEDP. IEDP also promotes cross functional collaboration and integrated design environments through UGS' Teamcenter PLM platform. The IEDP fills a void that has long existed in the shipbuilding industry; it addresses needs of ship design and sustainment throughout the ship's lifecycle[11] in a common data environment. Benefits currently realized in the IEDP include:

- Enables L6S implementation for Model/Drawing development and sustainment processes that leverage 3D scanning and collaborative environment.
- Reduced site visits by ship check planning team.
- Captured data can be used to verify dimensional information anytime after site visit (reuse).
- 3D models can be used for many applications such as:
    - Preplanning.

[11] Common lifecycle for a Navy Ship is 30-40 years (Stout & Tilton, 2007).

- Generating cost estimates.
- Virtually reviewing tasks with contractors.
- Perform what-if scenarios for rip-outs and installation of new equipment.

- Engineering collaboration allows cross-functional effort on the same project and data exchange between remote sites.
- Improved Configuration Management and Validation processes:
    - Automated Identification Technology (AIT) (e.g., Bar Codes, RFID).
    - ILS Product Management and visibility (Stout & Tilton, 2007).

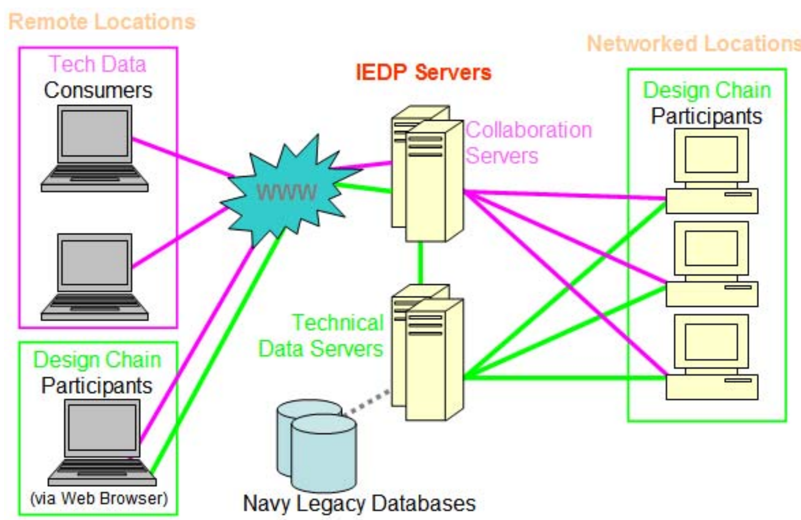

Figure 7. IEDP Architecture (Stout & Tilton, 2007)

SIS is the prime contractor executing the IEDP solution for NAVSEA under a $1.8 million FY 2007 appropriation. The tools provided by the IEDP will let managers and engineers view as-built images and related project information in a virtual collaborative environment. PLM tools provided by the IEDP have the potential to provide Navy leadership with its first ever cradle-to-grave view of an individual hull or class of ship. Having access to complete lifecycle information will enable longitudinal analysis of cost, performance and other items to provide a true picture of the total cost of ownership for our naval battle force assets.

F. Lean Six Sigma

Since the early 1980s, a broad range of businesses have adopted L6S principles to reengineer their business processes. In recent years, the DoD has widely embraced L6S as its preferred business transformation tool. L6S has become the tool of choice for modern business transformation activities across the DoD, and L6S initiatives are being implemented from the level of the Assistant Secretary of Defense down to individual commands. All branches of the DoD have implemented guidance for how and when to apply L6S principles, and some have established L6S training sites for their personnel.[12]

L6S is a business improvement methodology combining tools from both Lean Manufacturing and Six Sigma (George, Rowlands & Kastle, 2004). Lean Manufacturing focuses on speed and traditional Six Sigma focuses on quality. When theses two are combined as L6S and applied properly, the result should be a better quality product generated in less time. Application of L6S principles provide for systematic identification of simple solutions to eliminate waste and produce services at the appropriate speed and quality to meet customer demands.

1. L6S Enabled By PLM

L6S and PLM are enterprise initiatives that focus on business value (Affuso, 2004). The DoD is continuously seeking ways to improve quality, process efficiency, strategic alignment and sustainable growth to get the most out of its scarce resources. The current paradigm being followed in the DoD to achieve these improvements is L6S. Common benefits of L6S initiatives include cost reduction, decreased cycle-time, less material waste, and more reliable products. PLM tools deliver similar benefits.

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[12] The Norfolk Naval Shipyard established a L6S College in 1999 and has trained more than 2,350 students from the Navy, Marine Corps, Army, Coast Guard, Air Force and many other agencies (Brayshaw, 2007).

L6S provides a statistical measure of factors to help organizations meet desired goals, and PLM tools capture, store and distribute the longitudinal data necessary for accurate and reliable statistical measures. One area the DoD has struggled in is keeping accurate longitudinal lifecycle information on its major programs, specifically in ship construction, maintenance, modernization and repair. Without an accurate picture of the past, effective planning and cost estimation for future projects is difficult. With PLM tools, current and historical information are available to any authorized entity in the enterprise in a web-based, collaborative environment. PLM technology provides a shared-data environment for the Navy and shipyards to reduce product development/installation cycle-time, reduce the cost of change and allow collaboration with suppliers to dramatically reduce the cost in the value chain. Theses outcomes will enable the Navy and shipyards to meet desired L6S targets. PLM technology utilized in the IEDP is helping NAVSEA attain its goal of a common, interoperable IT framework for ship construction and lifecycle management by providing data management and product change management to all stakeholders in a collaborative environment. Figure 7 shows the UGS' Teamcenter modules and their supportive role in lifecycle management.

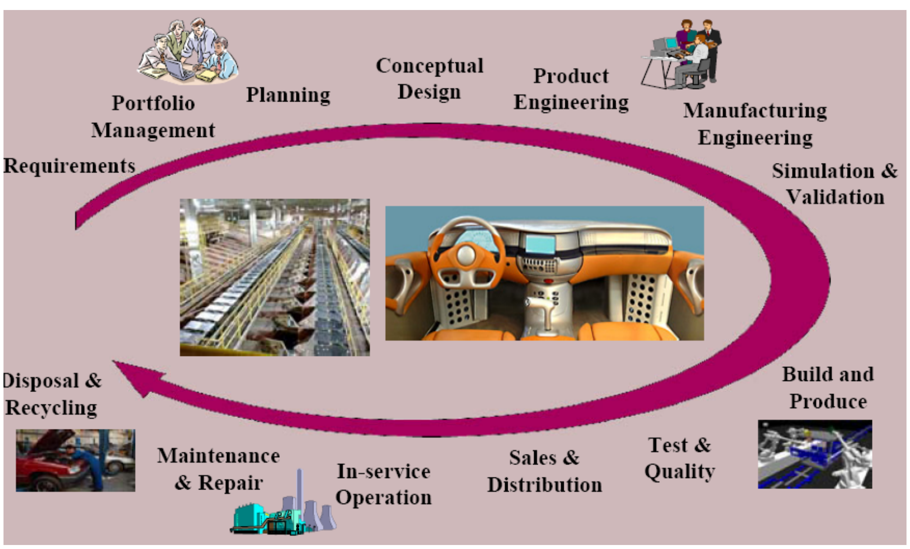

Figure 8. PLM Longitudinal Lifecycle (State of Industry Brief, 2005)

2. L6S Supported By KVA

The KVA methodology provides a framework for quantitative analysis of knowledge assets in an organization and has been applied in academic research and various business consultations for nearly 20 years. “KVA theory is based on an entropic concept, which is predicated upon changes in the environment (Housel & Bell, 2001, p. 95).” As organizations process inputs, value is added to the original input as it is transformed into an output. The value that is added to during the transition from input to output is proportionate to the amount of change necessary to cause the transformation, as shown in Figure 8. Therefore, a unit of change is simply considered as a unit of complexity. This assertion provides a means to measure all outputs in common units.

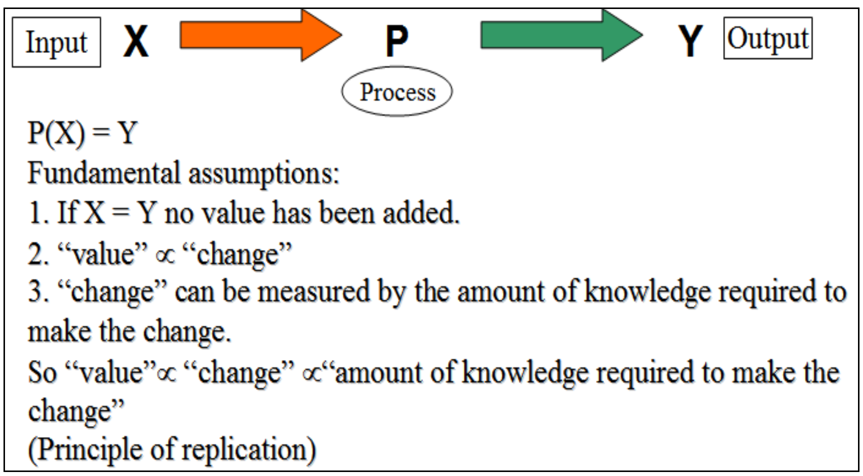

Figure 9. Fundamental Assumptions of KVA (Housel & Bell, 2001)[13]

L6S has two key methodologies: DMAIC (Define, Measure, Analyze, Improve and Control) and DMADV (Define, Measure, Analyze, Design and Verify) (Affuso,

[13] “The principle of replication states that given that we have the knowledge necessary to produce the change then we have the amount of change introduced by the knowledge. By definition, if we have not captured the knowledge required to make the changes necessary to produce the output, we will not be able to produce the output as determined by the process. This allows a test to determine if the amount of knowledge required to produce an output has been accurately estimated” (Housel & Bell, 2001, p. 94).

2004). Regardless of which methodology is used, measurement is a primary means to determine if the initiative is having the desired results. When enterprise implementations are initiated without metrics, there is no way to measure the value achieved—and that often results in a failed implementation. A client of UGS (a market leader of PLM products) explains the importance of measurement in the following way:

- We don't know what we don't know.
- If we can't express what we know in the form of numbers, we really don't know much about it.
- If we don't know much about it, we can't control it.
- If we can't control it, we are at the mercy of chance. (Affuso, 2004, p.7)

Performance metrics for productive DoD assets may use many different units of measure for benefits. It is easy to discuss cost because it is usually monetized, but discussing value in a non-profit environment proves much more difficult. KVA methodology provides a way to measure value as common units of output, dollars for instance, and it provides a more accurate comparison for developing key metrics supporting L6S initiatives in the DoD.

A metric commonly used in business and government is ROI. ROI can be derived by subtracting the cost to produce an output from the revenue, or value, generated by the output and then dividing that value by the cost (Rev-Cost/Cost). The denominator, cost, is usually easy to determine and quite reliable. The numerator, revenue, can be a bit more difficult to determine—especially in government and non-profit organizations. It is difficult to estimate ROI on organizational assets such as IT systems, but KVA provides a framework to allocate revenue to productive assets by describing all outputs in common units. Consequently, the DoD can utilize a reliable and standardized measure of value for ROI or other metrics that require a quantitative measurement of value in support of L6S initiatives.

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III. Previous Research

A. Komorosky's Analysis and Findings

In 2005, LT Komorosky conducted research which evaluated, "the conjectural benefits resulting from the integration of new IT assets[14] into existing Navy shipyard design processes, with focus on the work and output generated at the public-sector Planning Yard facilities" (2005, p. 2).

In her work, LT Komorosky identified seven sequential core processes, shown in Figure 9, utilized by planning yards to accomplish ship alterations on US Navy surface ships. A baseline as-is environment was modeled and compared to notional environments representing "maximum utilization of the new IT resources" (2005, p. 44). LT Komorosky's baseline data for the as-is environment was compiled by conducting extensive interviews with SMEs of the Puget Sound Planning Yard, "Key KVA data points of actual learning time (ALT), ordinal ranking, and relative learning time (RLT) were compared and a correlation of greater than 80 percent was attained, proving the estimates as credible" (2005, p. 23).

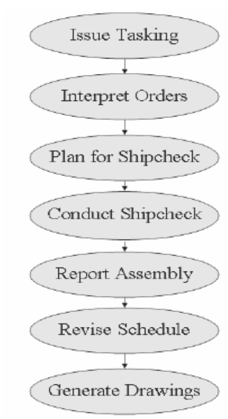

Figure 10. Planning Yard Core Processes (Komorosky, 2005)

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[14] The specific IT assets evaluated were SIS's 3DIS laser scanner and UGS's Teamcenter PLM software suite (Komorosky, 2005).

The first notional environment, the to-be scenario, evaluated the effects of adding 3D laser scanning to the as-is baseline. In the as-is environment, $45 million was spent annually to execute the defined shipyard planning process cycle 40 times across the four public shipyards. By adding 3D laser scanning to the planning process cycle, costs were forecast to drop a remarkable 84 percent to less than $8 million as seen in Table 1. Introduction of 3D laser scanning in the to-be environment had a profound effect on process steps 3, 4 and 7, leading to a cost savings of nearly $37 million (Komorosky, Housel, Hom & Mun, 2006).

The second notional environment, the radical-to-be scenario, evaluated the effects of adding 3D laser scanning and a collaborative PLM suite of software to the as-is baseline. The forecast from this scenario was a cost savings of nearly $40 million, a 90% reduction, from increased savings in process steps 3, 4 and 7 and additional savings realized in steps 2 and 5.

Process Title	"AS IS"	"TO BE"	"RADICALTO BE"	*"AS IS" & "TO BE" Cost Savings*	*"AS IS" & "RADICAL" Cost Savings*
ISSUE TASKING	$173,500	$173,500	$173,500	***$0***	***$0***
INTERPRET ORDERS	$520,000	$520,000	$328,000	***$0***	***$192,000***
PLAN FOR SHIP CHECK	$1,655,000	$714,000	$374,500	***$941,000***	***$1,280,500***
CONDUCT SHIP CHECK	$2,604,500	$1,364,000	$1,041,000	***$1,240,500***	***$1,563,500***
REPORT ASSEMBLY	$235,000	$235,000	$122,000	***$0***	***$113,000***
REVISE SCHEDULE	$131,000	$131,000	$131,000	***$0***	***$0***
GENERATE DRAWINGS	$39,386,000	$4,716,000	$2,319,000	***$34,670,000***	***$37,067,000***
TOTALS	**$44,705,000**	**$7,853,500**	**$4,489,000**	***$36,851,5000***	***$40,216,000***

Table 1. KVA Results—Analysis of Costs (Komorosky et al., 2006)

LT Komorosky's research was conducted within the scope of the core processes of the planning yard. This represents a small piece of the overall process leading to the actual installation, modernization or repair of surface ships. By expanding the micro view of previous research across the larger realm of the SHIPMAIN environment, the impact of 3D laser scanning and PLM technologies can be evaluated in a more comprehensive manner.

B. National Shipbuilding Research Program Studies

NSRP was created by U.S. shipyards at NAVSEA request to reduce the cost of building and maintaining U.S. Navy warships. NSRP is structured as a collaboration of 11 major U.S. shipyards focused on industry-wide implementation of solutions to common cost drivers. NSRP's flagship R&D program, Advanced Shipbuilding Enterprise (ASE), targets solutions to priority issues that exhibit a compelling business case to improve the efficiency of the U.S. Shipbuilding and Ship Repair Industry. Solutions include leveraging of best commercial practices and creation of industry-specific initiatives. Aggressive technology transfer to, and buy-in by, multiple U.S. shipyards is a requirement of all funded efforts. (National Shipbuilding Research Program Advanced Shipbuilding Enterprise, 2007)

Komorosky's (2005) evaluation of "the conjectural benefits resulting from the integration of new IT assets into existing Navy shipyard design processes" was predictive in nature (p. 2). It relied on validated estimates from SMEs in the shipbuilding industry. While these estimates attained a desirable level of correlation, none of the data points were from physical experiments using the technologies evaluated. However, NSRP has recently completed a two-part field experiment utilizing 3D laser scanning technologies from several vendors on actual shipyard projects.

1. NSRP 2005 Ship Check Data Capture Project

In the spring of 2005, the NSRP's Strategic Investment Plan added a new initiative to focus on as-built data capture for performing ship repairs and maintenance (National Shipbuilding Research Program Advanced Shipbuilding Enterprise, 2006). The objectives of the NSRP ASE Ship Check Data Capture Project in 2006 were:

- To develop a process that captures the as-built measurement data in digital/electronic format during a ship check.
- To process the as-built measurement data into 3D CAD models using available COTS modeling technologies (software and hardware)
- To ultimately provide a building block process for the anticipated development of the capabilities to generate 3D CAD models of the as-built space envelope from the geometric measurement data captured during the ship check.

The process investigated and developed through this research was focused on providing acquisition and lifecycle cost relief to the government through the generation and management of accurate 3D CAD models and geometric measurement data.

During the project, multiple vendors conducted data capture onboard a Torpedo Weapons Receiver (TWR 841) and the USS Georgia (SSGN 729) using either 3D laser scanning or Digital Photogrammetry. Software solutions for post-collection processing of ship check data were also evaluated. Once data capture and post processing were completed, each vendor's product was evaluated for accuracy of measurement, and its individual data process flow and the overall process was evaluated for cost savings and cycle-time reduction.

Findings on cost and time savings were categorized as for a small ship check or a large ship check and are summarized in Table 2.

SMALL SHIP CHECK:	Traditional	Laser Scanning	Realized Savings
Cost	$9,351	$6,398	32%
Labor Hours	112	72	36%
LARGE SHIP CHECK:	**Traditional**	**Laser Scanning**	**Realized Savings**
Cost	$47,650	$26,465	44%
Labor Hours	660	336	49%

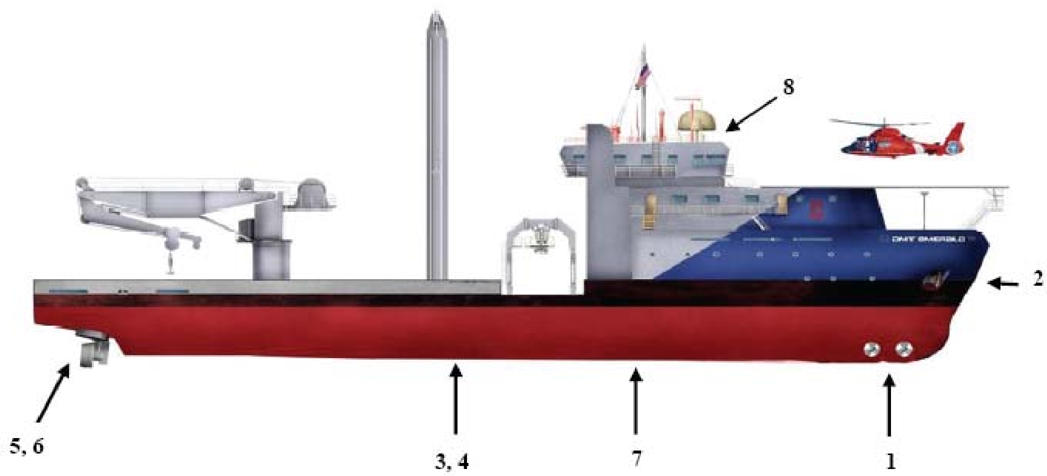
Table 2. Ship Check Data Project Cost/Time Savings (Komorosky et al., 2006)

One of the goals of this project was to demonstrate a 50 percent time savings over traditional methods (National Shipbuilding Research Program Advanced Shipbuilding Enterprise, 2006). The large ship check environment was very close to attaining that goal. The savings demonstrated in Table 2 are only for the first ship check and do not account for elimination of future ship checks on the same space, so it is likely that on successive ships a 50 percent time savings will be realized. For a detailed table of cost savings analysis see Appendix C.

2. NSRP 2006 Ship Check Data Capture Follow-On Project

Electric Boat was awarded a FY 2006 follow-on ship check project by NSRP ASE (2007) to evaluate the FY 2005 ship check process further and provide a refined ship check process to the U.S. shipbuilding and repair industry using available COTS technology. To accomplish these goals, the project team conducted a ship check aboard a 280 foot Inspection, Maintenance and Repair (Candies IMR) vessel under construction. A ship check was also conducted aboard SSGN 729 to validate the data accuracy/repeatability of the SSGN 729 ship check data collected from the FY 2005 project and to refine the ship check process.

The ship evaluated at Bender was the 280 foot Candies IMR vessel under construction. Figure 10 shows the spaces that were ship checked.



- Bow thruster recesses (Port and Starboard)/Anchor pockets (Port and Starboard) – (1,2)
- Moon pool/Door fit-up (3,4)
- Z-drive Recesses (Port and Starboard) and Z-drives (Port and Starboard) – (5,6)
- Engine room bulkhead (7)
- Pilot House (8)

Figure 11. Candies IMR Ship Check Spaces (National Shipbuilding Research Program Advanced Shipbuilding Enterprise, 2007)

The ship checks conducted in this study lead to the creation of a refined ship check process intended to provide cost savings as compared to traditional ship checks using manual methods. The cost and time savings demonstrated in this study are from typical ship check post processing efforts of the valve station from the ship check data capture compared to the traditional ship check using tape measures and manual sketches. Findings on cost and time savings are shown in Table 3.

	Traditional	Laser Sacnning	Realized Savings
Cost	$8,327	$5,248	37%
Labor Hours	118	72	39%

Table 3. Follow-On Ship Check Project Cost/Time Savings (National Shipbuilding Research Program Advanced Shipbuilding Enterprise, 2007)

The 2006 project demonstrated that laser scanning technology is mature enough to support the ship check process, and provides desirable time and cost savings during ship checks. It found laser scanning also eliminates return visits to the site to obtain measurements that are normally missed using traditional ship check methods. Finally, the project validated that a significant vendor network exists to support ship checks with laser scanning based data capture and post-processing and recommends that shipyards consider using vendor services to aid their initial use of the technology.

C. Map to SHIPMAIN

The cost and time savings demonstrated in NSRP's ship check data project indirectly support LT Komorosky's predictive study findings in that both demonstrate a remarkable cost savings and decreased cycle time when 3D laser scanning tools are used to acquire as-built configurations of ships. Komorosky's seven core processes describe the navy planning yard process in a legacy FMP context and are still relevant in the current SHIPMAIN EP as validated by a SME with 38 years of experience in the shipyard industry (Anonymous, personal communication, March 2007). Figure 12 shows a detailed view of Komorosky's evaluation of the core processes in the navy planning yard.

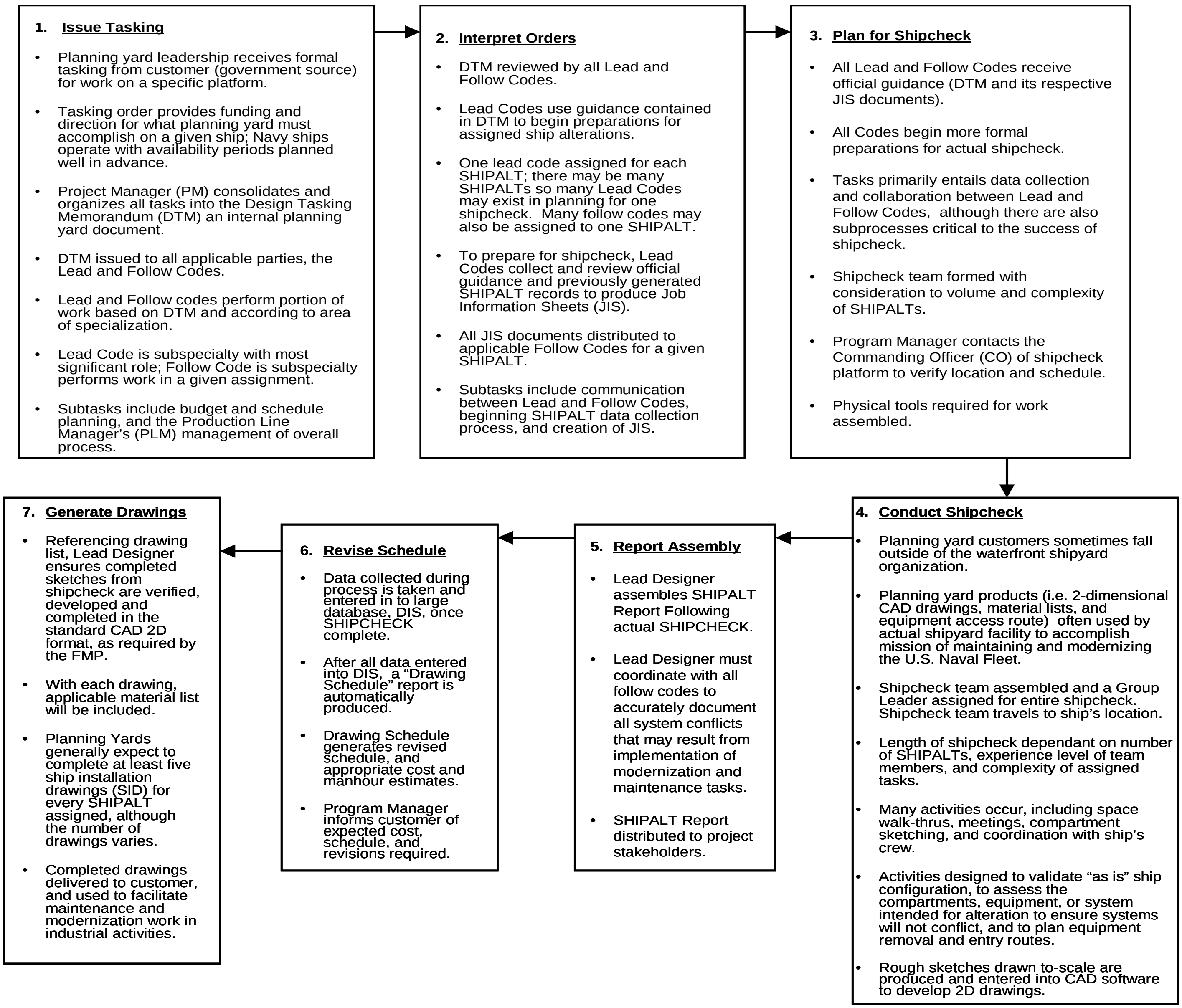


Figure 12. Planning Yard Core Processes (Komorosky et al., 2006)

Phases IV and V of the SHIPMAIN process consist of eight core processes referred to as blocks (Commander, Naval Sea Systems Command, 2006). Blocks 250 and 265 of the core can be further decomposed to 11 sub-processes. Komorosky's planning yard process maps directly to Block 265, specifically Sub-block 265.1 of the SHIPMAIN process as shown in Figure 13. Sub-block 265.1 is where Komorosky's detailed sub-processes, as described in Figure 12, can be applied. The detailed process flow chart for Sub-block 256.1 is shown in Figure 14.

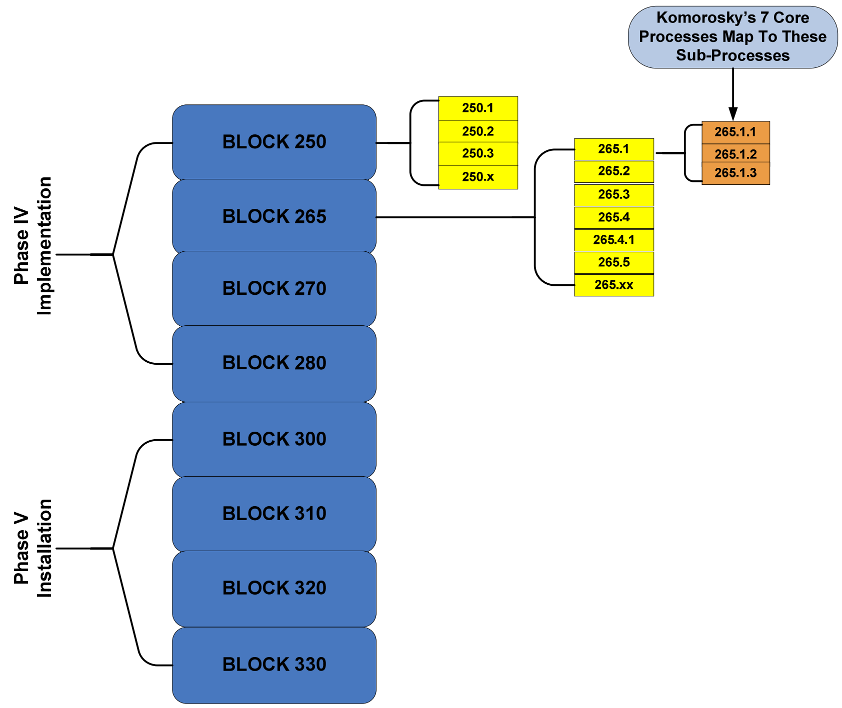


Figure 13. Mapping of Komorosky's Core Processes to SHIPMAIN

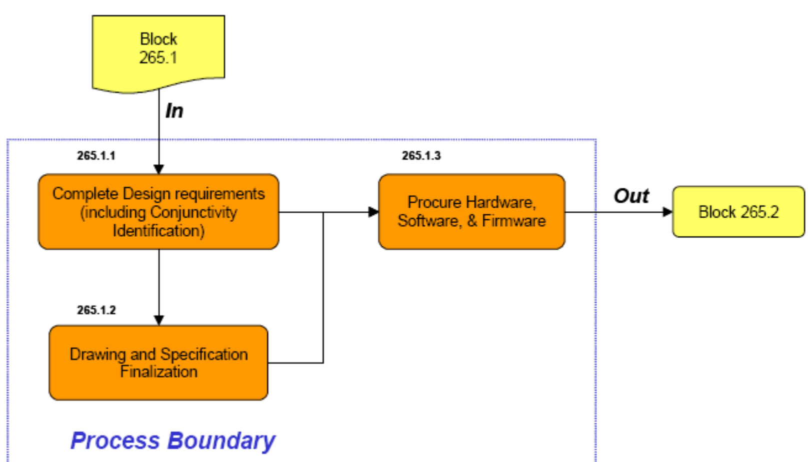


Figure 14. Detailed View of Block 265.1. (Commander, Naval Sea Systems Command, 2006)

Figure 13 may give the impression that Komorosky's research was very small, and therefore not remarkably significant, when placed into the context of SHIPMAIN. However, when the blocks are placed into context based on their complexity, number of personnel involved and number of times executed that impression should fade. Three SMEs, each with more than 30 years of experience in the shipyard industry, rated Block 265 as the most complex and difficult to learn. Block 265 is where LT Komorosky's research maps to, and in addition to being the most complex, it requires 5 times more personnel to accomplish than six of the seven other blocks[15] and is utilized in every instance of SHIPMAIN.

In the next chapter, Komorosky's findings will be conditionally applied to related sub-processes of Block 265 in the creation of a to-be version of SHIPMAIN. The seven remaining blocks and their sub-processes will also be evaluated using the KVA methodology based on reliable SME estimates for ALT, RLT and process difficulty.

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[15] Block 300 is equivalent to Block 265 in complexity, training time and personnel involved (Anonymous, personal communication, May 2007).

IV. Methodology Proof of Concept

A. Introduction

Phases IV and V of the SHIPMAIN process were created from input and discussion by various stakeholders at NAVSEA, Type Commanders (TYCOM), public and private shipyards, Space and Naval Warfare Systems Command (SPAWAR), Office of the Chief of Naval Operations (OPNAV) and other entities with a vested interest in maintenance and modernization efforts (Commander, Naval Sea Systems Command, 2006). Business rules for these phases are regularly reviewed and updated to be properly aligned with business goals and the needs of Fleet Commanders. Currently, Phases IV and V of SHIPMAIN are not in a functionally implemented state but are rather in an early adoption period while business rules/processes mature and long standing legacy practices give way to the SHIPMAIN process. A key assumption of this proof of concept case is that the SHIPMAIN process functions as described in the business rules listed in Appendix D of the SSCEPM dated 11 December 2006.

The following proof of concept case will use the as-is process information compiled from interviews, conversations and correspondence with a select group of SMEs from NAVSEA. Their input will be statistically analyzed for reliability, and all estimates will be aggregated to reflect the cost and number of process executions averaged over five years. The KVA methodology will be applied to determine the potential effects of introducing 3D terrestrial laser scanning and PLM technologies into Phases IV and V of the SHIPMAIN process. The effects of adding 3D laser scanning have been evaluated by LT Komorosky (2005) and NSRP (2006; 2007) and will be applied in a single notional scenario with PLM technologies. If the introduction of these IT assets has a positive effect on the SHIPMAIN process, it will be evident through increased return on knowledge (ROK)/ROI values and associated cost estimates. If there is a negative effect, the inverse will be evident.

These figures will be shown as a comparison of the current as-is scenario to the to-be scenario using defendable future process estimates.

B. Data Collection and Methodology

Aggregate data was gathered during an initial KVA knowledge audit conducted via survey and a group interview setting at NAVSEA, Washington Navy Yard, DC. Three SHIPMAIN SMEs were present at the group interview, and each had expertise related to the SHIPMAIN process. Each of the three SMEs has over 30 years experience in the shipyard industry, with a high degree of expertise in his/her affiliated disciplines. The business rules for Phases IV and V of the SHIPMAIN process guided the interview.

1. Learning Time Method

The method of analysis for this proof of concept is the Learning Time method.[16] A thorough review of current SHIPMAIN business rules and discussion with SMEs established what processes constitute the core of SHIPMAIN Phases IV and V, identified the inputs and outputs of those processes, and determined the frequency of core process iterations. Boundaries were established between the defined processes in order to effectively apply the KVA methodology and to properly identify and valuate the knowledge required for each. Eight core processes were identified, and detailed descriptions of each were provided by SMEs and the SHIPMAIN business rules. Each core process requires a certain level of knowledge in one or more of the following areas: administration, management, scheduling, budgeting, basic computer skills, engineering, shipboard systems, logistics or project management.

The SMEs spent considerable time contemplating the amount of knowledge embedded in each core process, and provided ALT estimates for each. The

[16] See Appendix A for a detailed discussion of Learning Time.

established baseline level of knowledge for consideration was a GS-13 employee with 1 year of experience and a college degree (no field specified). Finally, the team of SMEs provided individual and uninfluenced RLT and rank order estimates which lead to a correlation of greater than 80 percent, thereby establishing a high level of reliability on the ALT figures obtained. Additional discussion occurred spontaneously among the SMEs, which led to a group conclusion that Blocks 265 and 300 were equivalent in complexity. Adjusting the relative learning time and rank order to reflect that conclusion leads to greater than 90 percent correlation across the data fields.

C. The Defined SHIPMAIN Process for Phases IV and V

Before a business process can be reengineered or automated, the current as-is process must be understood. The business rules for Phases IV and V of SHIPMAIN describe eight core processes, referred to as blocks, which encompass implementation and installation of an approved SC. Each block has an official title to reference the core process it accomplishes, as shown in Figure 15.

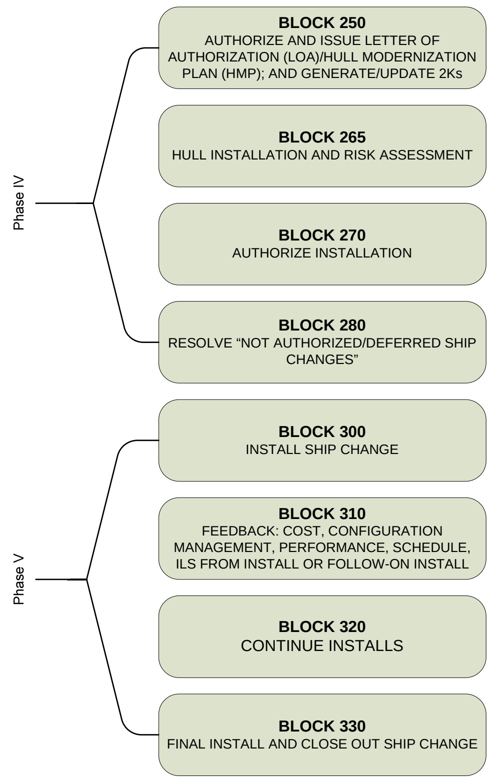

Figure 15. SHIPMAIN Core Processes (Commander, Naval Sea Systems Command, 2006)

This chain of core processes is executed for every naval vessel as it approaches and completes a shipyard availability period. The schedule timeline and location for ship availabilities are established by Navy leadership far in advance, but calendar dates and work assigned may be constrained by budget allowances and other prioritization factors. Availability schedules may be affected if world events trigger an unanticipated demand for operational naval assets.

The core processes for SHIPMAIN Phase IV (Block 250-280) and Phase V (Block 300-330) are described in detail in Appendix D. As mentioned previously, Phases IV and V are still in an early adoption period and are not widely used across shipyards at this point. A key assumption for the purpose of this study is that Phases IV and V are being conducted as described in the business rules listed in Appendix D of the SSCEPM dated 11 December 2006.

D. KVA Analysis of As-Is Scenario

A summary of the high level as-is KVA analysis is depicted in Table 4. These estimates were compiled from interviews of SMEs at NAVSEA and historical data contained in the NDE. This sample is representative of availability periods for ships of the Pacific and Atlantic Fleet, to include Aircraft Carriers, averaged from FY 2002 to FY 2007. All estimates contained in this analysis are as conservative and accurate as possible.

As Is SHIPMAIN Process Overview

Core Process	Process Title	Number of Employees	Total Benefits	Total Cost	ROK	ROI
Block 250	Authorize and Issue Letter of Authorization (LOA)/Hull Maintenance Plan (HMP); Generate 2Ks	9	$22,619,472	$5,311,299	426%	326%
Block 265	Hull Installation and Risk Assessment	44	$94,928,918	$130,071,059	73%	-27%
Block 270	Authorize Installation	4	$24,710,347	$3,161,555	782%	682%
Block 280	Resolve "Not Authorized/Deferred SC	1	$3,706,552	$619,523	598%	498%
Block 300	Install SC	46	$94,722,998	$40,617,720	233%	133%
Block 310	Feedback: Cost, CM, Performance, Schedule, ILS	2	$1,853,276	$619,523	299%	199%
Block 320	Continue Installs	5	$4,633,190	$3,068,367	151%	51%
Block 330	Final Install, Closeout SC	1	$926,638	$309,762	299%	199%
			$248,101,392	**$183,778,809**	**135%**	**35%**

Table 4. SHIPMAIN Phases IV and V As-is Core Process Model

1. Number of Employees

The number of employees value used to build this model represents the number of employees assigned to complete the given process for each cycle or iteration. The numbers assigned are based on interviews with SMEs. By accounting for the number of personnel involved in each process, it can be determined how often knowledge is used. It also provides an approximate way to weigh the cost of using knowledge in each process.

2. Times Performed in a Year

Estimations for the number of times each process is executed per year are based on the aggregated number of occurrences for each process. The number of times performed for Blocks 265 to 330 is based on the number of installations of maintenance or modernization items. The number of times performed for Block 250 is based on the number of availability periods. The NDE was queried with the following filters to gather the raw data:

- The search was limited to title “K” and “P” alterations
- FY 2002 through 2007
- Ships of the following TYCOMs:
    - Commander, Naval Air Force Atlantic
    - Commander, Naval Air Force Pacific
    - Commander, Naval Surface Force Atlantic
    - Commander, Naval Surface Force Pacific

These filters were put in place to establish a five-year average of maintenance or modernization availability periods for all surface combatant ships to include Aircraft Carriers. The result of the query was that an average of 1,200 availability periods occur each year. This number was conditionally modified to take the complexity of installs during availability periods into consideration. Some availability periods conduct routine software upgrades and have a low complexity, while the other end of the scale would be modernization efforts for Ticonderoga class Cruisers. To provide a reasonable scope, 25 percent of availability periods were considered to be simple, 25 percent complex and 50 percent moderate. 600 moderately complex installations frame the scope of this model.

The number of times performed for the remaining blocks is based on the number of installations that occur. For each installation that occurs, a SCD is generated, and the number of SCDs provides a reliable proxy for the number of installations. SMEs provided data and analysis which estimates an average of 20 SCDs are initiated per week—leading to 1,040 SCDs generated annually. Again, applying the same conditional modifier to account for complexity, 520 SCDs or installs would occur each year.

3. Actual Learning Time

In order to determine the ALT from a common point of reference, the SMEs were instructed to imagine a baseline individual of a college graduate at the GS-13 civilian rank level with a year of experience in some sector of the shipyard industry. All experts understood that each process learning-time estimate must adhere to the basic assumptions that knowledge is only counted if in use, and the most succinct path to achieve a unit of output must be considered. Each core process was broken down into its component sub-processes, and respective ALT values were assigned for each sub-process. The final ALT value for each core process is a summation of the sub-process ALT estimates. Finally, all ALT values are based on the following time assumptions:

- One year = 230 work days
- One month = 20 work days
- One week = 5 work days
- One day = 8 hours

4. Determining Value

Each process contains a certain amount of process automation—ranging from zero to 100 percent. The amount of automation is a proxy for how much knowledge is embedded in IT supporting the automation. It is important to estimate how much of each process is automated, and to be consistent in those estimates, so that the knowledge embedded in the technology resources is accounted for. Upon determination of the percentage estimate, the Total Learning Time (TLT) is calculated by dividing ALT by the percentage of process automation for that process.

The TLT value is then multiplied by the number of employees and the number of times the process is performed per year to establish a Total Knowledge factor. The Total Knowledge factor is then multiplied by a price per common unit, based on market comparables, to derive the “benefits” or “value” of each process. The resulting product is then used as the numerator for determining ROK and ROI.

5. Cost Estimation

To estimate the cost of government employees involved in the processes, the 2007 civilian pay chart was referenced. Each civilian pay grade has associated "steps" to account for various unique factors of each job. All pay estimates are based on step six of the associated pay grade. Since the processes take place across the globe, no locality pay differentials were taken into consideration to minimize variation. Also, because basic computing hardware and software is utilized in every scenario, IT cost is not included in the as-is analysis. It is assumed that each employee in this process has an email account, laptop or desktop computer with identical software, and access to a printer. Material, travel, and other miscellaneous costs are not included in this analysis, so labor cost may be isolated.

Establishing a market comparable for government labor was accomplished by comparing the pay of contractors who conduct the same type and scope of work as the government employee. The contracted base pay was, on average, 35 percent higher than the government employees. Benefits, locality pay differential and other variables were not compared to establish this rate: only base pay was considered. All government employee rates were increased by 35 percent to achieve the values for the market price used to establish a price per common unit of output.

6. As-Is Process Data Analysis

Each core process is depicted in a table format to show the respective process instructions and values derived from them. It is necessary to evaluate each sub-process at this level of detail to best capture the impact of introducing 3D laser scanning and PLM software in the notional to-be model.

a. Key Assumptions

As previously mentioned, this analysis is based on information collected from previous research by LT Christine Komorosky (2005), SMEs from NAVSEA, data contained in the NDE and current directives. For the purposes of this study, all maintenance and modernization efforts are assumed to occur as described in the current business rules listed in Appendix D of the SSCEPM, dated 11 December 2006. It is also important to keep in mind that maintenance and modernization efforts vary substantially in number, manpower requirements, duration and complexity. After conducting extensive interviews with SMEs and conducting a thorough review of current directives, related research and existing data in the NDE, the following assumptions were made:

- Of 1,200 annual modernization and maintenance availability periods, 25 percent involve low complexity installations, 25 percent high complexity installations, and 50 percent involve medium complexity installations. Assume all efforts in this study involve efforts of medium complexity.
- On average, 20 SCDs are generated per week.
- The market comparable labor rate is 35 percent greater than the government labor rate.
- Price per common unit of output is $75.45.

b. Block 250 KVA Analysis

Table 5 shows key KVA estimates used to determine the total process benefits, annual cost, ROK and ROI for Block 250.

Block 250 Authorize and Issue Letter of Authorization (LOA)/Hull Maintenance Plan (HMP); Generate 2Ks													
	Sub process	Hourly Personnel Cost	Head count	Times Perf. Per Year	Time to Complete (Hrs)	Annual Personnel Cost	%IT	ALT (Hrs)	Total Knowledge	Total Benefits	Annual Cost	ROK	ROI
250.1	Create AHMP/EHMP	$42.45	1	600	40	$1,018,800	75%	40	96000	$7,127,985	$1,018,800	700%	600%
250.2	Create Annual HMP/LOA	$42.45	1	1200	40	$2,037,600	75%	32	153600	$11,404,776	$2,037,600	560%	460%
250.3	Initiate 2Ks into ICMP	$35.70	3	520	40	$2,227,680	0%	32	49920	$3,706,552	$2,227,680	166%	66%
250.x	Generate/issue QISM	$42.45	4	4	40	$27,168	90%	32	5120	$380,159	$27,168	1399%	1299%
									Process Totals:	**$22,619,472**	**$5,311,248**	**426%**	**326%**

Table 5. Block 250 As-is KVA

Block 250 is primarily a management-based activity. The annual cost is relatively low since there are few employees involved in the management activities of this process. This process contains a large percentage of automation, which enables a small number of people to execute the process many times—leading to high ratios for ROK and ROI. One thing to consider is that the cost of the IT assets is not addressed in this model; the actual costs shown in Table 5 only reflect labor cost.

c. Block 265 KVA Analysis

Table 6 shows key KVA estimates used to determine the total process benefits, annual cost, ROK and ROI for Block 265.

Block 265 Hull Installation and Risk Assessment													
	Sub process	Hourly Personnel Cost	Head count	Times Perf. Per Year	Time to Complete (Hrs)	Annual Personnel Cost	%IT	ALT (Hrs)	Total Knowledge	Total Benefits	Annual Cost	ROK	ROI
265.1	Installation Procurement, Design & Advance Planning	$43.10	35	520	160	$125,507,200	25%	40	970667	$72,071,847	$125,507,200	57%	-43%
265.2	Hull Installation Readiness Review	$29.78	2	520	40	$1,238,848	80%	40	208000	$15,443,967	$1,238,848	1247%	1147%
265.3	Evaluate Maturity Status	$50.16	1	520	20	$521,664	0%	40	20800	$1,544,397	$521,664	296%	196%
265.4	Provide Risk Assessment	$50.16	1	520	40	$1,043,328	0%	56	29120	$2,162,155	$1,043,328	207%	107%
265.4.1	Formally Propose Install for Readniess Assessment and Auth.	$50.16	1	520	20	$521,664	0%	40	20800	$1,544,397	$521,664	296%	196%
265.5	Risk/Readiness Determination	$59.01	4	130	40	$1,227,408	0%	56	29120	$2,162,155	$1,227,408	176%	76%
									Process Totals:	**$94,928,918**	**$130,060,112**	**73%**	**-27%**

Table 6. Block 265 As-is KVA

This block was evaluated as the most complex block by all of the SMEs. It involves management of operational tasks requiring significant knowledge assets, a large budget and significant manpower. Once approval has been given from Block 250, the goal of Block 265 is to, "Complete all required design, procurement of material, pre-installation testing, and obtain all required certifications/risk assessment(s)" (Commander, Naval Sea Systems Command, 2006, Appendix D, p. 77).

LT Komorosky noted that, "reducing the time required to conduct a ship check provides the greatest opportunity to improve Navy ship cycle time" (2005, p. 42). The ship check process LT Komorosky refers to is contained in sub process 265.1 and should demonstrate a reduced cycle-time at less cost when 3D laser scanning and PLM tools are introduced to this sub-process.

For alterations involving Command, Control, Communications, Computers, Combat Systems and Intelligence (C5I) assets, a quarterly meeting takes place to conduct sub-processes 265.2 through 265.5. Representatives from across the globe meet in a single conference hall quarterly to address the issues at hand

(Anonymous, personal communication, 2007, May). Introducing comprehensive collaboration tools to these processes has the potential to remarkably decrease cost and cycle-time by eliminating costly travel expenses and associated travel time.

d. Block 270 KVA Analysis

Table 7 shows key KVA estimates used to determine the total process benefits, annual cost, ROK and ROI for Block 270.

Block 270 Authorize Installation													
	Sub process	Hourly Personnel Cost	Head count	Times Perf. Per Year	Time to Complete (Hrs)	Annual Personnel Cost	%IT	ALT (Hrs)	Total Knowledge	Total Benefits	Annual Cost	ROK	ROI
270	Installation decision	$76.00	4	520	20	$3,161,600	85%	24	332800	**$24,710,347**	**$3,161,600**	**782%**	**682%**

Table 7. Block 270 As-is KVA

Block 270 involves management decisions at the highest levels of the organization, typically the GS-15 or Senior Executive Service level. Therefore, there are few employees involved, but they carry a substantial labor cost. This process has a high level of automation which allows a small number of people to execute it often. Accordingly, the cost is very low when compared to the benefits leading to high ROK and ROI ratios. It is important to mention again that this model does not account for the cost of the IT assets providing the high level of automation, only the labor cost.

e. Block 280 KVA Analysis

Table 8 shows key KVA estimates used to determine the total process benefits, annual cost, ROK and ROI for Block 280.

Block 280 Resolve "Not Authorized/Deferred SC"													
	Sub process	Hourly Personnel Cost	Head count	Times Perf. Per Year	Time to Complete (Hrs)	Annual Personnel Cost	%IT	ALT (Hrs)	Total Knowledge	Total Benefits	Annual Cost	ROK	ROI
280	Update HMP,LOA and Fielding Plan	$29.78	1	520	40	$619,424	75%	24	49920	**$3,706,552**	**$619,424**	**598%**	**498%**

Table 8. Block 280 As-is KVA

Block 280 also contains a process that is primarily a managerial task. It involves a low number of employees at one of the lowest labor rates. The high level of automation coupled with a low labor cost and high levels of process execution lead to favorable ROK and ROI ratios.

f. Block 300 KVA Analysis

Table 9 shows key KVA estimates used to determine the total process benefits, annual cost, ROK and ROI for Block 300.

Block 300 Install SC													
	Sub process	Hourly Personnel Cost	Head count	Times Perf. Per Year	Time to Complete (Hrs)	Annual Personnel Cost	%IT	ALT (Hrs)	Total Knowledge	Total Benefits	Annual Cost	ROK	ROI
300	Complete installation and testing	$42.45	46	520	40	$40,616,160	25%	40	1275733	**$94,722,998**	**$40,616,160**	**233%**	**133%**

Table 9. Block 300 As-is KVA

SMEs rated Block 300 a close second to Block 265 in complexity. This is the process in which alterations to the ship are actually installed and tested. This process requires significant knowledge assets, a large budget and significant manpower, similar to Block 265. This block has few management review sub-processes and is primarily focused on completing installations and testing them. Due to the high number of times the process is performed per year, the cost is relatively low when compared to the benefits.

g. Block 310 KVA Analysis

Table 10 shows key KVA estimates used to determine the total process benefits, annual cost, ROK and ROI for Block 310.

Block 310 Feedback: Cost, CM, Performance, Schedule, ILS													
	Sub process	Hourly Personnel Cost	Head count	Times Perf. Per Year	Time to Complete (Hrs)	Annual Personnel Cost	%IT	ALT (Hrs)	Total Knowledge	Total Benefits	Annual Cost	ROK	ROI
310	Provide Feedback Data	$29.78	2	520	20	$619,424	0%	24	24960	**$1,853,276**	**$619,424**	**299%**	**199%**

Table 10. Block 310 As-is KVA

As shown in Table 10, there is no automation for this process. The process involves taking the raw feedback data and manually entering it into required forms and databases. This manual process could become much more efficient with some form of automation tool leading to lower process cost and increased benefits.

h. Block 320 KVA Analysis

Table 11 shows key KVA estimates used to determine the total process benefits, annual cost, ROK and ROI for Block 320.

Block 320 Continue Installs													
	Sub process	Hourly Personnel Cost	Head count	Times Perf. Per Year	Time to Complete (Hrs)	Annual Personnel Cost	%IT	ALT (Hrs)	Total Knowledge	Total Benefits	Annual Cost	ROK	ROI
320	Determine impact on future installs from Feedback in 310	$59.01	5	520	20	$3,068,520	0%	24	62400	**$4,633,190**	**$3,068,520**	**151%**	**51%**

Table 11. Block 320 As-is KVA

Block 320 is a management-based process which uses the feedback provided in the previous block to determine potential impact on follow-on installs. This process is a completely manual process reliant upon the feedback provided in Block 310. This process has the potential to become more efficient and reliable from an automation and analysis tool.

i. Block 330 KVA Analysis

Table 12 shows key KVA estimates used to determine the total process benefits, annual cost, ROK and ROI for Block 330.

Block 330 Final Install, Closeout SC													
	Sub process	Hourly Personnel Cost	Head count	Times Perf. Per Year	Time to Complete (Hrs)	Annual Personnel Cost	%IT	ALT (Hrs)	Total Knowledge	Total Benefits	Annual Cost	ROK	ROI
330	Verify all SCs have been completed	$29.78	1	520	20	$309,712	0%	24	12480	**$926,638**	**$309,712**	**299%**	**199%**

Table 12. Block 330 As-is KVA

Block 330 is a review of all planned installations to determine if they have been completed. This is accomplished by manually comparing planned installations against reported completions and verification of all ILS completion/delivery for all installs. If all planned installs are complete and ILS is delivered, the SC can be closed out. This process is also completely manual and could potentially become more efficient if an automation and analysis tool was introduced to the process.

E. To-Be Process Data Analysis

This scenario represents a combination of notional and verified data to portray current activities contained in the SHIPMAIN process reengineered to maximize utilization of 3D laser scanning and PLM assets. Not every sub-process will be affected in this scenario; instead, only affected processes will be used for comparison. All others may be assumed static, as described in their as-is state.

1. Cost of 3D Terrestrial Laser Scanning Technology

The cost for laser scanning equipment and required software was provided by the IEDP Project Manager for SIS. SIS's IEDP Project Manager stated that the current cost has not changed from the estimates LT Komorosky used in her 2005 research (B. Tiltion, personal communication, 2007, May 16). For this study, the cost for IT used in LT Komorosky's 2005 study will be increased by 3 percent to account for inflation and will be amortized over a 10-year period. Cost and assumptions for the 3DIS are:

- Current inflation adjusted initial cost is $90,640 for one 3DIS scanner and its applicable software suite.
- Maintenance/upkeep annual cost estimate is 20 percent.
- Use estimate of 200 days per year.
- A lifespan estimate of 10 years.
- The resulting cost per unit per day is: $135.96.
- For analysis of the to-be KVA model, this cost is absorbed by the actual scanning process contained in Block 265.1.

The six planning yards that support naval surface force assets are:

- Bath Iron Works, Bath, ME
- Norfolk Naval Shipyard, Norfolk, VA
- Northrop Grumman Ship Systems, Avondale OP, New Orleans, LA
- Northrop Grumman Ship Systems, Ingalls OP, Pascagoula, MS
- Puget Sound (DET) Boston, Boston, MA

- Puget Sound Naval Shipyard, Bremerton, WA (NAVSEA Shipbuilding Support Office, 2007)

To properly account for the enterprise-wide cost of the 3DIS product, the daily cost was increased by a factor of six under the assumption that each planning yard received one scanner with the required software. Accordingly, the daily cost to introduce 3DIS across the enterprise would be $815.76.

2. Cost of PLM Technology

SIS is a Value Added Reseller of UGSs PLM suite of software called Teamcenter. Under the IEDP, Teamcenter products will be introduced to establish an Integrated Data Environment using team collaboration and configuration data management platforms. The Teamcenter suite contains the following specific product solutions:

- Community Collaboration
- Compliance Management
- Engineering Process Management
- Enterprise Knowledge Management
- Lifecycle Visualization
- Maintenance, Repair and Overhaul
- Manufacturing Process Management
- Portfolio and Program Management
- Reporting and Analytics
- Simulation Process Management
- Supplier Relationship Management
- Systems Engineering (UGS Corporation, 2007)

For the scope of this study, Community Collaboration, Engineering Process Management, Lifecycle Visualization, Portfolio and Program Management, Reporting and Analytics and the Supplier Relationship Management solutions will be considered. These solutions will be part of the complete PLM solution evaluated in the to-be model. Cost estimation for these tools has proven to be difficult.

According to a leading PLM provider, “Identifying an accurate, average or generalized pricing schema for respective toolsets within the PLM space is almost unachievable. It is safe to say, however, that vendor’s price-models have been decreasing over the years” (Anonymous, personal communication, 2007, June).

To establish a reasonable cost for the Teamcenter solution, the following cost estimation will be used:

- An assumption that PLM and Enterprise Resource Planning (ERP) initiatives are similar in cost and scope.
- DoD spent an average of $250 million per ERP initiative in FY 06 (Service Cost Estimating Organizations, 2007).
- The Department of the Navy (DoN) budget for FY 06 was $122.9 billion including supplemental transfers (Bozin, 2006).
- DoN budget for Ship Depot Maintenance was $3.72 billion or 3 percent of the entire DoN budget (Bozin, 2006).
- 3 percent of a $250 million (the cost for an ERP) is $7.5 million.

The $7.5 million PLM solution will be deployed at the six planning yards listed earlier in this section and all SYSCOMs/TYCOMs supporting surface force combatant assets. The cost for the PLM suite will be amortized over 10 years with a 2 percent annual increase for the cost of version upgrades bringing the total cost to $9 million, which will be amortized over a ten-year period. It is assumed that the PLM software will be used 230 days per year, making the daily cost of PLM software $3,913. This cost will be distributed equally across all processes of Phases IV and V of SHIPMAIN.

3. Reengineered Processes

The SHIPMAIN process was reengineered by adding 3D laser scanning tools and a comprehensive suite of PLM products to the as-is state. Implementation of 3D laser scanning tools will primarily affect Block 265.1 by enabling the planning yard to acquire images and output their drawings in a highly accurate and electronically transferable 3D format as opposed to static installation drawings delivered on paper. The 3D scanning tools can produce a 2D output also, as currently required under the FMP. With the addition of a robust PLM product suite, the 3D images generated can be shared across the enterprise in an Integrated Data Environment—allowing all stakeholders real-time access to highly accurate as-built imagery through a single interface.

Implementation of an enterprise-wide PLM product suite demonstrated a remarkable effect on each core process. Providing stakeholders access to real-time information related to all iterations of the product lifecycle in a collaborative environment enabled nearly all sub-processes to benefit. Processes that didn't demonstrate a quantitative improvement in this model will likely show qualitative improvements, which will be discussed in the Conclusions section. Table 13 depicts the change in cost and ROI factors from the as-is to the to-be scenario. The majority of the estimates contained in this table were derived from interviews with SMEs from NAVSEA and SIS and a comprehensive review of the business rules listed in Appendix D of the SCEPM dated 11 December 2006.

Core Process	Process Title	Annual As-Is Cost	Annual To-Be Cost	Difference (Cost Savings)	As-Is ROI	To-Be ROI
Block 250	Authorize and Issue Letter of Authorization (LOA)/Hull Maintenance Plan (HMP); Generate 2Ks	$5,311,248	$2,287,671	**$3,023,577**	326%	**565%**
Block 265	Hull Installation and Risk Assessment	$130,060,112	$63,437,554	**$66,622,558**	-27%	**155%**
Block 270	Authorize Installation	$3,161,600	$3,217,805	**($56,205)**	682%	**668%**
Block 280	Resolve "Not Authorized/Deferred SC	$619,424	$427,964	**$191,460**	498%	**766%**
Block 300	Install SC	$40,616,160	$33,433,420	**$7,182,740**	133%	**183%**
Block 310	Feedback: Cost, CM, Performance, Schedule, ILS	$619,424	$242,107	**$377,317**	199%	**665%**
Block 320	Continue Installs	$3,068,520	$2,510,944	**$557,576**	51%	**131%**
Block 330	Final Install, Closeout SC	$309,712	$304,059	**$5,653**	199%	**205%**
	Totals:	**$183,766,200**	**$105,861,524**	**$77,904,676**		

Table 13. As-is and To-be Cost and ROI Value Differences

The results shown in Table 13 demonstrate that despite the additional expense of acquiring 3D laser scanning and PLM tools, the overall cost would be reduced by nearly $78 million dollars in this scenario. It is apparent that cost savings are achieved in all processes, with the exception of Block 270, as a result of

3D laser scanning and PLM tools. As the technologies mature and work processes are modified to maximize their potential, cost savings and ROI should continue to improve over time.

4. To-be Data Analysis

Reengineering the to-be scenario proved to be quite challenging. While the formal guidance for SHIPMAIN is relatively mature for Phases I-III, that is not so for Phases IV and V. Remarkable effort has been put into developing and refining the business rules associated with Phases IV and V, and they continue to be in a maturing phase at the time of this study. According to one SME, the processes currently in use to accomplish the tasks in Phases IV and V are the legacy procedures—until all areas become aligned with the business rules and the required technology to support them is acquired. As the business rules, governance structure and core technologies mature, the processes as defined in current SHIPMAIN business rules should become the standard practice. In order to model the notional to-be scenario, strict observation of currently defined business rules were coupled with SME assessments of their practical implementation for each core process. For additional clarity, all core processes will be described in terms of their sub-processes and the assumptions affecting key parameter changes from the as-is to the to-be scenario.

a. Block 250 To-be KVA Analysis

Table 14 shows all KVA estimates used to determine the total process benefits, annual cost and ROI of the notional to-be revision of Block 250. Assumptions for Block 250 are as follows:

- The PLM product suite would provide the means for processes identified in the business rules as “future enhancements” to become a reality.
- A conservative estimate of 20 percent greater efficiency was applied to the times fired per year for Blocks 250.1 and 205.3 due to automation.

Block 250 Authorize and Issue Letter of Authorization (LOA)/Hull Maintenance Plan (HMP); Generate 2Ks														
	Sub process	Hourly Personnel Cost	Head count	Times Perf. Per Year	Time to Complete (Hrs)	Annual Personnel Cost	IT Cost	%IT	ALT (Hrs)	Total Knowledge	Total Benefits	Annual Cost	ROK	ROI
250.1	Create AHMP/EHMP	$42.45	**0**	**720**	**1**	$0	**$56,250**	**100%**	40	28800	$2,138,395	$56,250	3802%	3702%
250.2	Create Annual HMP/LOA	$42.45	1	1200	40	$2,037,678	**$56,250**	75%	32	153600	$11,404,776	$2,093,928	545%	445%
250.3	Initiate 2Ks into ICMP	$35.70	**1**	**624**	**1**	$22,276	**$56,250**	**99%**	32	19968	$1,482,621	$78,526	1888%	1788%
250.x	Generate/issue QISM	$42.45	**2**	4	**8**	$2,717	**$56,250**	90%	32	2560	$190,080	$58,967	322%	222%
										Process Totals:	**$15,215,872**	**$2,287,671**	**665%**	**565%**

Table 14. KVA Analysis of To-be for Block 250

The business rules for Block 250.1 and 250.3 identify that their processes will become automated, and the output will be auto-generated as a "future enhancement" (Commander, Naval Sea Systems Command, 2006, p. 67). Accordingly, the values for head count, times fired per year, time to complete and percent IT were adjusted to reflect the effects of automation.

Block 250.2 does not realize any quantitative changes with the implementation of 3D laser scanning or PLM. However, the accuracy of the outputs from this block will potentially become much higher with the PLM suite. PLM tools provide some benefit to Block 250 through centralization of required inputs necessary to accomplish the task, reducing the number of personnel involved and the time to complete the process.

b. Block 265 To-be KVA Analysis

Table 15 shows all KVA estimates used to determine the total process benefits, annual cost and ROI of the notional to-be revision of Block 265. Assumptions for Block 265 are as follows:

- There are 17 unique tasks involved in Block 265.1.
- The 15 employees required for the ship-check task of Block 265.1 don't use the entire time allotted to complete the process. The 15 ship check employees are notionally reallocated to remaining tasks of a similar pay grade.
- Two additional employees are required to accomplish the 17 tasks.
- Cycle-time will improve by a conservative estimate of 20 percent with the addition of PLM and 3D laser scanning. PLM will allow suppliers and purchasers to share requirements and plan for delivery in a real-

time Integrated Data Environment. 3D laser scanning will provide more accurate design parameters to suppliers than hand-drawn images, reducing the amount of “field engineering” required.

Block 265
Hull Installation and Risk Assessment

	Sub process	Hourly Personnel Cost	Head count	Times Perf. Per Year	Time to Complete (Hrs)	Annual Personnel Cost	IT Cost	%IT	ALT (Hrs)	Total Knowledge	Total Benefits	Annual Cost	ROK	ROI
265.1	Installation Procurement, Design & Advance Planning	$43.10	17	624	128	$58,527,196	$219,402	75%	40	1697280	$126,022,772	$58,746,598	215%	115%
265.2	Hull Installation Readiness Review	$29.78	2	520	32	$991,238	$56,250	85%	40	277333	$20,591,956	$1,047,488	1966%	1866%
265.3	Evaluate Maturity Status	$50.16	1	520	20	$521,696	$56,250	0%	40	20800	$1,544,397	$577,946	267%	167%
265.4	Provide Risk Assessment	$50.16	1	520	40	$1,043,391	$56,250	0%	56	29120	$2,162,155	$1,099,641	197%	97%
265.4.1	Formally Propose Install for Readniess Assessment and Auth.	$50.16	1	520	20	$626,035	$56,250	0%	40	124800	$9,266,380	$682,285	1358%	1258%
265.5	Risk/Readiness Determination	$59.01	4	130	40	$1,227,347	$56,250	0%	56	29120	$2,162,155	$1,283,597	168%	68%
										Process Totals:	**$161,749,816**	**$63,437,554**	**255%**	**155%**

Table 15. KVA Analysis of To-be for Block 265

Block 265.1 is directly affected by the introduction of 3D laser scanning and PLM technologies, and the cost for each is shared by this process. Using Komorosky’s findings (2005) related to the planning yard process to accomplish a ship check, personnel involved for ship check would be reduced by at least 50 percent, and cycle-time would improve by at least 20 percent. However, ship check is one of many tasks involved in 265.1. There are 17 individual tasks which make up Block 265.1, leading Subject-matter Experts to rank it as the most complex process involved throughout Phases IV and V of the SHIPMAIN process. Using a baseline of 15 employees required for ship check, which will be notionally reallocated upon completion of the task, two additional employees would be required to accomplish the 17 tasks of Block 265.1.

Blocks 265.2 through 265.5 are primarily processes that involve decision-makers evaluating available information on readiness, risk, maturity and systems integration to determine if a proposed installation should be approved for actual installation. For C5I installations, a quarterly meeting is held to discuss the issues for pending installations, and all stakeholders travel to a central location to discuss the issues in person (Anonymous, personal communication, 2007, May). The majority of the inputs for decision-makers are generated by systems and processes which exist in the as-is scenario. Introducing a PLM suite would not have much effect on the quantitative items measured in this study. However, it would allow all stakeholders to conduct their meeting in a virtual setting, with all of them having access to the same information in real-time—thereby eliminating travel expenses and lost productivity due to travel time. Using a conservative estimate that each decision-maker brings a support staff of at least five to each meeting, and the cost per traveler is $1,800, the annual expense for travel alone would be $352,000. While that value is not reflected in the to-be model as a cost, it is worth mentioning.

c. Block 280 To-be KVA Analysis

Table 16 shows all KVA estimates used to determine the total process benefits, annual cost and ROI of the notional to-be revision of Block 280.

Block 280 Resolve "Not Authorized/Deferred SC"														
	Sub process	Hourly Personnel Cost	Head count	Times Perf. Per Year	Time to Complete (Hrs)	Annual Personnel Cost	IT Cost	%IT	ALT (Hrs)	Total Knowledge	Total Benefits	Annual Cost	ROK	ROI
280	Update HMP,LOA and Fielding Plan	$29.78	1	520	24	$371,714	$56,250	80%	24	49920	$3,706,552	$427,964	866%	766%

Table 16. KVA Analysis of To-be for Block 280

This process updates key planning and authorization documents after installation review in Block 265 and Fleet Commander or platform-specific TYCOM authorization in Block 270. The process will become more efficient when it is accomplished with PLM tools because the personnel involved will have access to all documents and process owners in a collaborative environment. To account for the increased efficiency, cycle-time was reduced by two days.

d. Block 300 To-be KVA Analysis

Table 17 shows all KVA estimates used to determine the total process benefits, annual cost and ROI of the notional to-be revision of Block 300. Assumptions for Block 300 are as follows:

- The majority of management and verification tasks will be accomplished by 30 percent fewer staff due to collaboration and access to a common data environment provided by PLM.
- Cycle-time will improve by 20 percent due to:
    - Improved coordination between suppliers and the shipyards.

- Less rework due to installation items being built more accurately from the 3D imagery provided of an as-built configuration.

Block 300 Install SC														
	Sub process	Hourly Personnel Cost	Head count	Times Perf. Per Year	Time to Complete (Hrs)	Annual Personnel Cost	IT Cost	%IT	ALT (Hrs)	Total Knowledge	Total Benefits	Annual Cost	ROK	ROI
300	Complete installation and testing	$42.45	36	624	35	$33,377,170	$56,250	35%	40	1275733	$94,722,998	$33,433,420	283%	183%

Table 17. KVA Analysis of To-be for Block 300

Block 300 is where the actual installation of SCs occurs. Although the majority of the tasks involved are physically installing modifications, several oversight tasks will benefit from the introduction of PLM tools. Improved communication and coordination between material suppliers and shipyards through the PLM products will increase efficiency and minimize project delays. Also, 3D imagery from Block 265 shared with suppliers in real-time will enable delivery of higher quality and better performing "plant engineered" parts, minimizing rework and reducing "field engineering" to accomplish the install.

e. Block 310 To-be KVA Analysis

Table 18 shows all KVA estimates used to determine the total process benefits, annual cost and ROI of the notional to-be revision of Block 310. Assumptions for Block 310 are as follows:

- PLM will enable a 50 percent reduction in staff by having all related information available through a single interface.
- Time to complete the tasks will be reduced by 75 percent by eliminating lengthy manual data collection and aggregation.
- The process will be executed 20 percent more often annually.

Block 310 Feedback: Cost, CM, Performance, Schedule, ILS														
	Sub process	Hourly Personnel Cost	Head count	Times Perf. Per Year	Time to Complete (Hrs)	Annual Personnel Cost	IT Cost	%IT	ALT (Hrs)	Total Knowledge	Total Benefits	Annual Cost	ROK	ROI
310	Provide Feedback Data	$29.78	1	624	10	$185,857	$56,250	50%	24	24960	$1,853,276	$242,107	765%	665%

Table 18. KVA Analysis of To-be for Block 310

There are six tasks contained in this block which lead to the final outputs. The process for collecting the required information to accomplish the tasks contained in Block 310 is primarily manual. Introduction of a PLM product suite would allow a user to access all product information (cost, schedule, performance, CM and ILS) related to an installation, a specific hull, or a class of hulls through a single interface and auto-generate pre-defined feedback reports. The feedback reports generated will be more reliable and output faster than those in the as-is model. Another key benefit of the PLM products is that each ship, system or class of ships will have complete lifecycle information documented in one place, allowing leadership to truly understand the total cost of ownership for a hull, class or system.

f. Blocks 320 and 330 To-be KVA Analysis

Table 19 shows all KVA estimates used to determine the total process benefits, annual cost and ROI of the notional to-be revision of Blocks 320 & 330.

Block 320 Continue Installs														
	Sub process	Hourly Personnel Cost	Head count	Times Perf. Per Year	Time to Complete (Hrs)	Annual Personnel Cost	IT Cost	%IT	ALT (Hrs)	Total Knowledge	Total Benefits	Annual Cost	ROK	ROI
320	Continue Installs	$59.01	5	520	16	$2,454,694	$56,250	20%	24	78000	$5,791,488	$2,510,944	231%	131%
Block 330 Final Install, Closeout SC														
	Sub process	Hourly Personnel Cost	Head count	Times Perf. Per Year	Time to Complete (Hrs)	Annual Personnel Cost	IT Cost	%IT	ALT (Hrs)	Total Knowledge	Total Benefits	Annual Cost	ROK	ROI
330	Verify all SCs have been completed	$29.78	1	520	16	$247,809	$56,250	50%	24	12480	$926,638	$304,059	305%	205%

Table 19. KVA Analysis of To-be for Blocks 320 & 330

Block 320 is a decision-based process in which risks from previous installations are evaluated and decisions are made to adjust the follow-on installation plan and if required, refine the Cost Benefit Analysis estimates. This process remains mainly a human thought process in the to-be scenario, but it is supported by accurate and timely information available through the PLM product. A conservative estimate of 20 percent less time to complete the task was applied.

Block 330 is where planned installations are compared to installations reported as complete to determine if a SCD can be closed out. Verification that all ILS is completed and delivered also occurs. The to-be scenario introduces the PLM product—which would place all verification items into a virtual environment accessible through a single interface leading to a 20 percent reduction in time to complete the task.

V. Conclusions and Recommendations

A. Research Limitations

The KVA models in this study were generated primarily from data gathered by interviewing SMEs at NAVSEA and generalized across enterprise management and shipyard activities. Therefore, the data contained in this research can not be assumed to be perfect, but it can be assumed to be reliable due to the high levels of correlation across key KVA data points of ordinal ranking, ALT and RLT. As stated earlier, Phases IV and V of the SHIPMAIN process are not functionally in practice as described in formal business rules; legacy processes are still being used to accomplish the goals of Phases IV and V. Therefore, some disparity may exist between the realities of functional practice and the process as described in the business rules. Due to time constraints and the exceptionally large scope of Phases IV and V of SHIPMAIN, the scope was limited to only the core processes and the first level of sub-processes. Several additional sub-layers could be modeled for higher levels of accuracy specific to a given community of interest.

B. Research Questions

Analysis of this study reveals the significant potential value that 3D laser scanning and PLM technologies have to offer maintenance and modernization efforts for US Navy warships. High-quality, reliable, accurate and reusable digital 3D data capture, paired with the information storage, distribution and collaboration capabilities of PLM can provide a single digital thread connecting as-desired, as-planned, as-built and as-maintained product data throughout the lifecycle of any ship or program. This single digital environment has the potential to provide decision-makers longitudinal views of a product from cradle to grave that have never been available. However, it can’t be assumed that these technologies will provide optimal performance without a strategic policy to guide information management. Leadership must continually evaluate the overall environment and adapt to changing economic, political and technical environments without losing sight of their strategic goals. Application of this KVA methodology to Phases IV and V of the SHIPMAIN process has yielded one type of decision support model to demonstrate the potential impact of 3D laser scanners and PLM technologies within this environment.

1. Cost Savings

Cost savings is the most apparent and profound benefit potentially offered by 3D data capture and PLM tools. The US Navy currently spends nearly $184 million to accomplish the implementation and installation of 520 medium-complexity ship changes to all surface combat vessels. This cost estimate is based solely on labor rates and doesn't include expenses for travel or material. In the reengineered to-be scenario, this cost drops to less than $106 million—a remarkable reduction of 43 percent. Within the KVA analysis framework, there are two distinct factors which account for the savings. The obvious reductions are accomplished by a reduction in manpower, allowing the same number of jobs to be accomplished with fewer people. The less obvious is the ability of the decreased workforce to accomplish the same tasks at a faster rate. Regardless of which path is evaluated, the cost savings potential for this application is remarkable.

Cost is only one factor to consider when evaluating ROI. An easy way create high ROI ratios is to simply cut costs, but cost cutting can potentially have a negative impact on the benefits or value provided by the process. The KVA analysis conducted on this case reveals that total benefits increased from $248 million to nearly $319 million—a substantial measure of 33 percent. As shown in Table 20, the decrease in cost, coupled with an increase in benefits leads to an improved ROI ratio of 201 percent for the to-be model compared to the as-is model ROI ratio of 35 percent.

Core Process	Process Title	Annual As-Is Cost	Annual As-Is Benefits	Annual To-Be Cost	Annual To-Be Benefits	As-Is ROI	To-Be ROI
Block 250	Authorize and Issue Letter of Authorization (LOA)/Hull Maintenance Plan (HMP); Generate 2Ks	$5,311,248	$22,619,472	$2,287,671	$15,215,872	326%	**565%**
Block 265	Hull Installation and Risk Assessment	$130,060,112	$94,928,918	$63,437,554	$161,749,816	-27%	**155%**
Block 270	Authorize Installation	$3,161,600	$24,710,347	$3,217,805	$24,710,347	682%	**668%**
Block 280	Resolve "Not Authorized/Deferred SC	$619,424	$3,706,552	$427,964	$3,706,552	498%	**766%**
Block 300	Install SC	$40,616,160	$94,722,998	$33,433,420	$94,722,998	133%	**183%**
Block 310	Feedback: Cost, CM, Performance, Schedule, ILS	$619,424	$1,853,276	$242,107	$1,853,276	199%	**665%**
Block 320	Continue Installs	$3,068,520	$4,633,190	$2,510,944	$5,791,488	51%	**131%**
Block 330	Final Install, Closeout SC	$309,712	$926,638	$304,059	$926,638	199%	**205%**
	Totals:	**$183,766,200**	**$248,101,392**	**$105,861,524**	**$318,820,901**	**35%**	**201%**

Table 20. As-is and To-be ROI Comparison

2. Fleet Cycle-time

An improved fleet cycle-time will provide Operational Commanders greater availability of their operational assets. If availability periods are reduced without reducing level of work accomplished, fleet cycle-time could potentially improve. This study demonstrated that the cycle-time for Phases IV and V of SHIPMAIN would be reduced from 80 days to 56 days, a 2.5-week reduction in cycle-time. Komorosky explains, "If every operational Navy ship was available for one additional week of tasking, over a two year time-span, the DoN would have 280 additional weeks for tasking assignments, training, or crew rest and relaxation opportunities" (2005, p. 60).

3. Lifecycle Planning and Improved Business Process Efficiency

According to an SME from NAVSEA (Anonymous, personal communication, 2007, May), the Navy doesn't have a single portfolio that contains all product lifecycle information from cradle to grave for individual ships, classes of ships or shipboard systems. PLM tools have the potential to build a coherent data structure and consolidate dispersed information sources of as-designed, as-planned, as-built and as-maintained product data into a single record for specific ships, classes of ships or shipboard systems. Common access to a single repository of comprehensive lifecycle information will enable decision-makers to conduct analysis and make informed decisions based on the full spectrum of product definition data.

As the DoN continues to seek more efficient ways of doing business, Six Sigma initiatives are likely to be one of the primary tools used to drive change. However, the DoN lacks necessary tools to acquire the historical data necessary for Six Sigma initiatives to produce optimal results. Using PLM as a strategic business approach will provide decision-makers access to product definition information across the enterprise in support of Six Sigma initiatives. An important relationship between Six Sigma and PLM is that they are both enterprise initiatives that focus on business value as the driver for change, not cost in isolation. Six Sigma initiatives supported by PLM have the potential to provide DoN leadership an effective and comprehensive means to accomplish desired enterprise business transformation.

C. Real Options

While this research is not specifically conducting a Real Options analysis, the technologies presented in this research can be implemented in many different ways—including phased-in acquisitions, several up-front purchases, and ways to extend use of the technology to other areas. Several options scenarios are listed below:

- Do nothing and allow the as-is process to continue.
- Immediately acquire the 3D laser scanning capability for the public planning yards without PLM tools. If successful, expand to all planning yards.
- Immediately acquire 3D laser scanners and PLM technologies for the public planning yards. If successful, expand implementation across all planning yards.
- Immediately acquire comprehensive PLM software for all government agencies involved in Surface Fleet Modernization and Maintenance (SYSCOM, TYCOM, Fleet Commander, OPNAV, RMC, public shipyards, etc.) Once business rules are established and mature, extend PLM to all maintenance and modernization efforts (Submarine, Aircraft, Missiles, etc.)

- Immediately acquire a minimal set of the PLM product suite for enterprise maintenance and modernization efforts. If successful, acquire additional functionality to support additional areas.

D. Recommendations to the Navy

Continue efforts to standardize processes across all shipyards and supporting industrial activities. If the desired end-state of initiatives like SHIPMAIN and the FMP are to improve processes through data sharing and standardization of business rules, it will be difficult to attain desired levels of interoperability without standardized processes. Also, stakeholders need to have access to, and a means to discuss, the most current and reliable information across the enterprise.

Navy leadership must continually evaluate its vision, and the means it is using to implement it, in order to harness the power of modern technologies that increase in capability at an exponential rate. To stay competitive, Navy leadership must not allow its vision to become static or rest on the success of past initiatives. It must maintain the momentum that initiatives like SHIPMAIN and the Fleet Modernization Plan have to continually improve naval business processes.

Measuring the success of program managers only by how well they meet cost, schedule and performance goals of their project is shortsighted. PMs must be held accountable, and rewarded, for how well they steer their programs to meet modern transformation initiatives like SHIPMAIN or open architecture (OA) and how their decisions affect the total lifecycle cost of the program, not just the initial program objectives. Much more focus must be placed on providing the means for effectively managing the lifecycle of naval battle force assets.

All IT investments involve substantial amounts of risk, and the cost of IT tends to be front-loaded. The technologies discussed in this research are not an exception to traditional risks associated with large scale IT initiatives. Navy leadership must adequately consider the amount of risk in proportion to the potential value IT initiatives provide over time and continually strive to improve business processes so the maximum benefits of IT initiatives can be realized. Implementation of 3D laser scanning and PLM technologies would not result in immediate returns, and the SHIPMAIN processes would require additional modification to optimize their potential. However, the value of 3D laser scanning and PLM technologies is not only outwardly intuitive, it is also backed by the analytical methodology presented in this research and the respective ROI values associated with it.

Conducting a study similar to NSRP's Ship Check Data Capture project with the introduction of PLM tools could demonstrate the actual benefits this technology pair can provide. This study was purely predictive in nature; conducting an actual field experiment with 3D laser scanning and PLM paired as a system could demonstrate far more of the capabilities and limitations of these technologies.

E. Follow-on and Future Research Opportunities

SHIPMAIN is a large program involving many personnel from several large organizations. This study took a top-level view at Phases IV and V of the SHIPMAIN process and how 3D laser scanning and PLM tools could potentially affect the ROK and ROI. There may be value added for specific communities of interest in conducting additional research on specific blocks of the SHIPMAIN program down to the lowest level of decomposition. Additionally, specific processes of the SHIPMAIN program should be evaluated to compare the current state to a notional state after the introduction of PLM products. The cost-estimation process would be a prime target for such an evaluation, and establishing contact with NAVSEA 017 would help in this effort. Other potential processes for evaluation are material procurement, post-installation testing and lifecycle management.

List of References

Affuso, T. (2004, June). PLM and Six Sigma, complementary strategies for success. [Electronic version]. *PLM Perspective.* Retrieved April 27, 2007, from http://www.ugs.com/about_us/newsletter/perspective/2004_june/affuso_article_six_sigma.doc

Bozin, S. R. (2006). *Department of the Navy FY 2007 President's Budget.*

Brayshaw, M. (2007). *Lean Six Sigma college reaches throughout DoD.* Retrieved April 06, 2007, from http://www.marinelink.com/Story/NNSY%E2%80%99sLeanSixSigmaCollegeReachesThroughoutDOD-206722.html

Chief of Naval Operations. (1995). *Fleet Modernization Program (FMP) policy* (OPNAV Instruction 4720.2G ed.). Retrieved April 27, 2007, from http://doni.daps.dla.mil/Directives/04000%20Logistical%20Support%20and%20Services/04-700%20General%20Maintenance%20and%20Construction%20Support/4720.2G.pdf

Chief of Naval Operations. (2003). *Maintenance policy for US Navy ships* (OPNAV INSTRUCTION 4700.7K ed.). Retrieved March 1, 2007, from http://doni.daps.dla.mil/Directives/04000%20Logistical%20Support%20and%20Services/04-700%20General%20Maintenance%20and%20Construction%20Support/4700.7K.pdf

CIMData. (2007a). *All about PLM.* Retrieved April 14, 2007, from http://www.cimdata.com/PLM/plm.html

CIMData. (2007b). *CIMdata reports 10.4% PLM market growth for 2006.* Retrieved April 20, 2007, from http://www.cimdata.com/press/PR07-0403.htm

Commander, Naval Sea Systems Command. (2002). *Fleet Modernization Program (FMP) management and operations manual* (NAVSEA SL720-AA-MAN-010 Revision 2nd ed.). Retrieved March 03, 2007, from http://www.fmp.navy.mil/FMPACTIVE/BusinessPolicy/FMPDocuments/FMP_Manual/FMPManpageinit.htm

Commander, Naval Sea Systems Command. (2006). *Surface ship and carrier entitled process for modernization management and operations manual* (SL720-AA-MAN-030 ed.). Retrieved April 27, 2007, from http://www.fmp.navy.mil/FMPACTIVE/BusinessPolicy/FMPDocuments/draft_onebook_1a.htm

George, M. L., Rowlands, D., & Kastle, B. (2004). *What is Lean Six Sigma?* New York: McGraw-Hill.

Greaves, T., & Jenkins, B. (2007). 3D laser scanning market red hot: 2006 industry revenues $253 million, 43% growth. [Electronic version]. *SparView, 5*(7). Retrieved May 01, 2007, from: http://www.sparllc.com/archiveviewer.php?vol=05&num=07&file=vol05no07-01

Housel, T. J., & Bell, A. H. (2001). *Measuring and managing knowledge*. Boston, Mass: McGraw-Hill/Irwin.

Jenkins, B. (2005, November). 3D Laser Scanner sales top $44.8 million in 2004—65% growth. [Electronic version]. *SparView, 3*(34). Retrieved April 16, 2007, from http://www.sparllc.com/archiveviewer.php?vol=03&num=34&file=vol03no34-01

Jenkins, B. (2007, March 14). Ship check data capture 37% cheaper, 39% faster with 3D Laser Scanning, NSRP and Electric Boat report. [Electronic version]. *SparView, 5*(6). Retrieved May 01, 2007, from http://www.sparllc.com/archiveviewer.php?vol=05&num=06&file=vol05no06-01

Jensen, M. D. (2004, SHIPMAIN and the Sea Power 21 vision. [Electronic version]. *Navy News Stand.* Retrieved March 12, 2007, from http://www.navy.mil/search/display.asp?story_id=12343

Komoroski, C. L. (2005). *Reducing cycle time and increasing value through the application of Knowledge Value Added methodology to the US Navy shipyard planning process*. Monterey, CA: Naval Postgraduate School.

Komoroski, C. L., Housel, T., Hom, S., & Mun, J. (2006). *A methodology for improving the shipyard planning process: Using KVA analysis, risk simulation and strategic real options*. Monterey, CA: Naval Postgraduate School.

National Shipbuilding Research Program Advanced Shipbuilding Enterprise. (n.d.) *NSRP home page.* Retrieved June 09, 2007, from http://www.nsrp.org/

National Shipbuilding Research Program Advanced Shipbuilding Enterprise. (2006). *Ship check data capture/data analysis final report* (Technical No. NSRP 04-01-08).

National Shipbuilding Research Program Advanced Shipbuilding Enterprise. (2007). *Ship check data capture follow-on project* (Technical No. NSRP ASE 05-01).

NAVSEA Shipbuilding Support Office. (2007). *Planning yard (hull) assignments.* Retrieved June 04, 2007, from http://www.nvr.navy.mil/nvrships/S_PY.HTM

Office of the Deputy Under Secretary of Defense (Logistics and Material Readiness). (2006). *DoD maintenance, policy, programs and resources FACT BOOK*. Retrieved March 17, 2007, from http://www.acq.osd.mil/log/mrmp/factbooks/FACT_BOOK_2006_09_06_06.pdf

Service Cost Estimating Organizations. (2007). *Improving cost estimation in the DoD.* Retrieved June 04, 2007, from https://acc.dau.mil/CommunityBrowser.aspx?id=149301

Stout, R., & Tilton, B. (2007). US Navy leverages 3D scanning with design and technical data management. Paper presented at the *Spar View Conference,* Houston, Texas.

UGS Corporation. (2007). *UGS Teamcenter.* Retrieved June 04, 2007, from http://www.ugs.com/products/teamcenter/

Wikipedia Contributors. (2007). *Lean Six Sigma.* Retrieved April 26, 2007, from http://en.wikipedia.org/w/index.php?title=Lean_Six_Sigma&oldid=136347307

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Appendix A. KVA+RO Methodology

A. KVA+RO[17]

The Naval Postgraduate School (NPS) developed the Knowledge Value Added/Real Options (KVA+RO) valuation framework which quantifies elements of uncertainty and risks and includes ways to mitigate these risks through strategic options. KVA+RO analysis is designed to support IT portfolio acquisitions and to empower decision-makers by providing performance-based data and scenario analysis (Komorosky et al., 2006). Analyses like Return on Investment (ROI) on individual projects, programs and processes within a portfolio of IT acquisitions can be derived through KVA methodology. With historical data provided by KVA, potential strategic investments can then be evaluated with Real Options analysis. The analysis applied is a robust and analytical process incorporating the risk identification (applying various sensitivity techniques), risk quantification (applying Monte Carlo simulation), risk valuation (Real Options analysis), risk mitigation (Real Options framing), and risk diversification (analytical portfolio optimization).

B. The Value Problem[18]

Before investigating the potential returns or benefits knowledge assets, either human or IT, can provide, one must understand the concept of "value." When new and promising IT resources are introduced into an organization, the value derived may take a variety of intangible forms, such as improved market competitiveness, expanded markets, new capabilities, or increased efficiency. What value an organization receives from that IT asset depends on many factors beyond the entire capability of the asset, such as organizational culture, the management climate, and the organization's commitment to training and maintenance. Also important to note

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[17] This entire section is taken directly from (Komorosky et al., 2006)

[18] Sections B-D are taken directly from (Komorosky, 2005)

is the percentage of the IT resource's full potential that is actually in use. If the asset is rarely used or used at baseline functionality, then the perceived and actual value derived from the IT asset is likely low. Leveraging people, technologies, and information effectively within an organization can promote team cohesion and provide value.

In other definitions of value, financial metrics tend to prevail. In fact, most value assessments focus on return and cost of ownership for IT investments. Monetary benefits are determined in commercial applications by assigning a price per unit to each process output. However, these financial-based methods seldom capture the benefit streams produced by processes and resources in common, comparable units of measurement. At the same time, financial metrics and benefits are difficult to apply in private-sector and government organizations. The DoD, for example, will not be able to establish the monetary benefits, or the value added from combat effectiveness, operational readiness, and national defense. Therefore, an alternate common unit must be used to determine the value added in public-sector process analysis.

C. The KVA Solution

The Knowledge Value-Added (KVA) methodology provides a framework for the analytical analysis of organizational knowledge assets. Developed by Drs. Thomas Housel (Naval Postgraduate School) and Valerny Kanevsky (Agilent Lab), the theory of KVA has been published internationally, and has been applied in academic research and 20 various business consultations for over 15 years. Executed properly, KVA will measure the value of knowledge embedded in an organization's core processes, employees, and IT investments. This measure is quantified in a return-on-knowledge (ROK) ratio, which can be used to identify how much value knowledge assets provide within each core business process. In instances where revenue comparisons or other market-comparable values are available, a return on investment (ROI) figure can be ascertained.

1. The Theory of KVA

With its roots in the Information Age, the theory behind KVA follows the basic principles of thermodynamics by purporting that organizational outputs can be described in units of complexity. More specifically, KVA theory is based on the concept of entropy, which connotes changes in the environment. It follows that as all organizations collect input from various sources and add value in some way, the inputs are transformed to outputs, and the value added during that transition is proportionate to the amount of transformation necessary to change the inputs to the desired output. A unit of change, therefore, is considered simply as a unit of complexity. Belief in this assertion provides a method by which all organizational outputs can be measured in common units. The value added to each process comes from organizational knowledge assets: people, processes, capabilities, or information technology. Through estimation of this value, an analytical method for estimating the return on knowledge, using the knowledge inherent in organizational assets to describe process outputs with a common unit of measurement, is achieved.

The knowledge used every day in the core processes of an organization can be translated to a numerical format, because knowledge is a surrogate for the process outputs measured in common units. By capturing corporate knowledge into value, with clear figures to measure the value contained in each process, decision and policy makers can reengineer processes to maximize value. Then, by seeing the returns each process generates, better decisions can be made for an organization. Whether the knowledge is contained in IT systems or in the minds of an organization's employees is irrelevant, because common units of knowledge can be observed in the organization's core processes, and measured in terms of cost. Similarly, this approach provides management a verifiable way to assign benefit streams and costs to sub-organizational outputs produced by its knowledge assets, and can effectively redirect management's investment focus from cost containment to value creation.

Figure [16], below, shows a visual depiction of the KVA methodology's underlying model and primary assumptions.

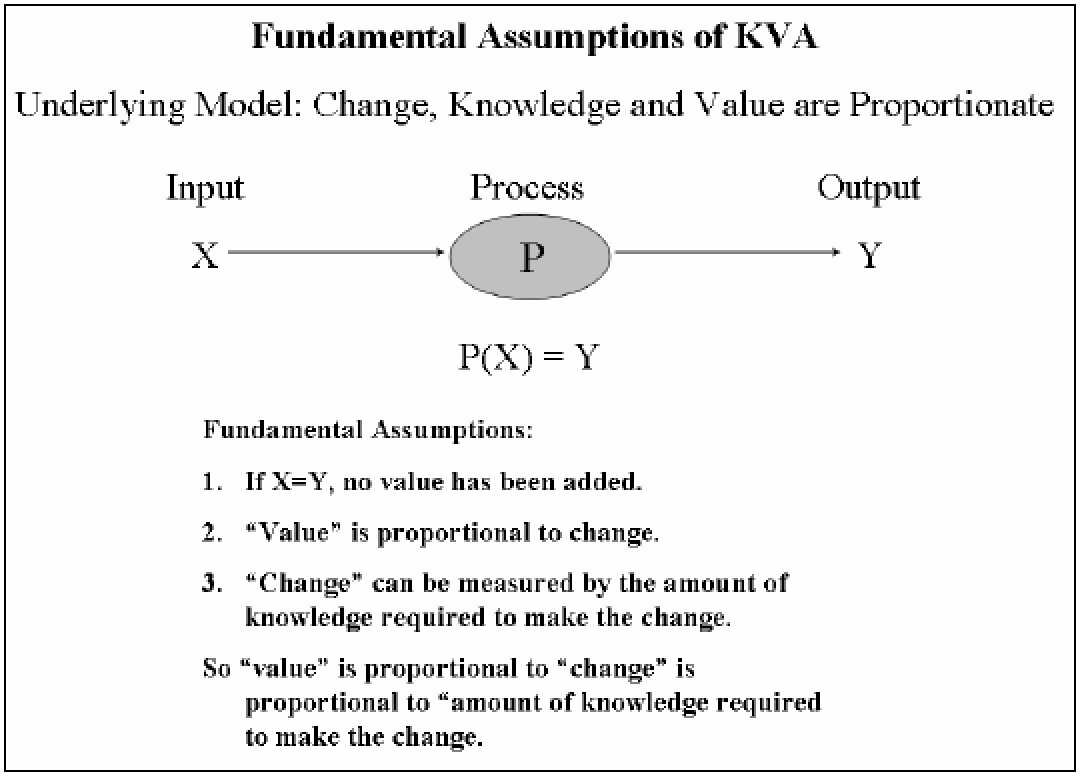

Figure 16. Assumptions of KVA (Housel & Bell 2004)

The assumptions presented in Figure [16] are the foundation of the KVA process. Accepting these assumptions allows the methodology to work in a way that breaks all input down into a common unit of output, allowing all processes to be evaluated from a common baseline reference. Because of this, how data is collected, analyzed, and how easily it can be monetized, the methodology functions much like accounting. As such, KVA results can be utilized in corporate finance and valuation problems.

2. Core Process Identification

In order to translate the knowledge utilized in an organization's core processes to numerical form, it is important to accurately define what those core processes are, and to define the amount of change each process produces.

Typically, corporate executives or other Subject Matter Experts are able to identify the main processes executed by their organization. In some instances, work flow models exist and may be referenced. In most instances, five to seven core processes sufficiently cover the core processes executed by an organization. For each of those processes, boundaries must be established by identifying the end output of the process, including all subprocess outputs that eventually create the end product. Any contribution IT provides to the process must be isolated.

3. Approaches to KVA

The knowledge within a process can be represented as learning time, process instructions, or information bits. In theory, any approach that satisfies the basic KVA assumptions will create the same results; however, it must capture the "know-how" in the production of process outputs, given particular inputs. Table [21] illustrates the steps used in three primary methods used to apply KVA. The Binary Query Method will not be addressed in this research.

Steps	Learning time	Process description	Binary query method
1.	Identify core process and its subprocesses.		
2.	Establish common units to measure learning time.	Describe the products in terms of the instructions required to reproduce them and select unit of process description.	Create a set of binary yes/no questions such that all possible outputs are represented as a sequence of yes/no answers.
3.	Calculate learning time to execute each subprocess.	Calculate number of process instructions pertaining to each subprocess.	Calculate length of sequence of yes/no answers for each subprocess.
4.	Designate sampling time period long enough to capture a representative sample of the core process's final product/service output.		
5.	Multiply the learning time for each subprocess by the number of times the subprocess executes during sample period.	Multiply the number of process instructions used to describe each subprocess by the number of times the subprocess executes during sample period.	Multiply the length of the yes/no string for each subprocess by the number of times this subprocess executes during sample period.
6.	Allocate revenue to subprocesses in proportion to the quantities generated by step 5 and calculate costs for each subprocess.		
7.	Calculate ROK, and interpret the results.		

Table 21. Three Approaches to KVA (Housel & Bell, 2001)

a. Learning Time Approach

In the learning time approach, the amount of knowledge embedded in a core process is represented by an estimate of the amount of time it would take an individual of average ability to learn that process's execution well enough to successfully create the same process output. In capturing this estimate, learning time is proportional to the amount of knowledge learned, and thus indicates how much knowledge is embedded in that process. In the context of this methodology, this figure is called "Actual Learning Time," or ALT. Learning Time must be measured in common units of time, and these units represent common units of output, which are described by the variable *K*. Following this line of thought, a single execution of any process is equal to a single unit of output, represented by a given number of common units, K.

The obvious question, then, is how one correctly estimates how long it would take for an average person to learn a certain process. In practice, most Subject Matter Experts can provide quality estimates based on formal training times, on-the-job training, training manuals, and other programs, given a minimum explanation of what ALT is in terms of the KVA methodology. It is important that SMEs understand that for each estimate, knowledge must only be counted when it is in use; otherwise, there is a tendency to overestimate the amount of knowledge contained in a given process. Further, knowledge must only be counted if it is truly necessary to execute the process. The shortest, most succinct approach to the process output must be considered, again, to avoid overestimation.

b. Establishing Reliability

Critics would argue that the Learning Time Approach is subjective and anecdotal. However, several methods exist to ensure reliability and confidence of all estimates. The most common way of ensuring reliable estimates is by calculating the correlation between the ALT, ordinal ranking, and relative learn time (RLT) for each process. A correlation value greater than or equal to 80% is sufficient for establishing reliability, and is the preferred method of proving the estimates credible. The three terms are described in detail below:

- Actual Learn Time (ALT) is an estimate for the period of time it would take to teach an average individual to execute a given process. There is no limit to the amount of time required.
- Ordinal Rank is a measure of process complexity described as its difficulty to learn. Subject Matter Experts, or Executives within an organization are asked to rank the processes in order from that which is easiest to learn, to that which is the most difficult to learn.
- Relative Learn Time (RLT) is a measure of the time it would take to teach an average individual the core processes of an organization given only 100 hours, days, months, or other unit of time.

Subject Matter Experts or Executives must allocate the time appropriately to each process, with regard to that process's complexity. Estimates may also be verified using actual knowledge measures such as on-the-job training time, or the number of process instructions within each core process. However, attaining a high degree of correlation and reliability between ALT, RLT, and Ordinal Rankings is the preferred method (Housel & Bell, 2001).

c. Total Learning Time

The amount of knowledge embedded into the existing IT used in each core process must be captured. This estimate is best achieved by considering what percentage of a process is automated. This percentage estimate for IT is used to calculate the total learning time (TLT), and revenue is allocated proportionally. Interestingly, the revenue attributed to IT-based knowledge, plus the cost to use that IT, often reveals that the value added to processes by IT applications, shown in the resulting ROK ratio, is not always equal to the percentage of IT and automation used in a process (Housel & Bell, 2001).

d. Process Instructions Approach

In some cases, the Process Instruction Approach must be used to gain reliability of estimates. This approach requires Subject Matter Experts to truly break apart each core process into the various subtasks that comprise it, in order to describe the products in terms of the "instructions required to reproduce them." By capturing the actual learning time of the subprocesses, one is better able to assign reliable estimates of the knowledge contained therein. Just as the case in the Learning Time Approach, it is important that the estimates cited in Process Instructions only contain the knowledge required, or "in use" during execution of each individual process, without overlap. By adding the ALT results for each subprocess within a core process, one has a more reliable estimate of the core process's ALT.

4. Measuring Utility and Knowledge Executions

A count must be taken to determine the number of times the knowledge is executed (value) and the time is takes to execute (cost) in a given sample period. These values are needed to determine the ROK value. The actual time it takes to execute the process, multiplied by cost, is a flow-based estimate of its cost. It is important to note that process costs alone, without reference to value, present a different picture of the core process's value.

5. The Relevance of Return on Knowledge (ROK)

The return ratio known as ROK is expressed with a numerator representing the percentage of revenue allocated to amount of knowledge required to complete a given process successfully, in proportion to the total amount of knowledge required to generate the total outputs. The denominator of the equation represents the cost to execute the process knowledge. With knowledge as a surrogate for the process outputs measured in common units, a higher ROK signifies better utilization of knowledge assets. In this way, KVA makes is possible to measure how well a specific process is doing in converting existing knowledge into value. Similarly, it gives decision-makers an idea of how an investment in knowledge and learning is paying off, and not simply how much it costs. The ROK value provides decision makers an analytical way to determine how knowledge can be more effectively used to produce better return on performance. If increased automation does not improve the ROK value of a given process, steps must be taken to improve that process's function and performance.

D. Real Options

Real Options Analysis is a market-based methodology invented to address the investment challenges faced by corporations in the modern day economy. It suggests that corporate valuation depends less on traditional fundamentals, and more on future expectations. The traditional discounted cash flow analysis methods: the income, cost, or market approach, tend to view risk and return on investment in a static view. Dr. Johnathan Mun, an expert in Real Options Theory, and credited with making it operational in practice, theorizes that not all risk is bad; in fact, upside risk can often be advantageous. Upside risk is defined simply as the opportunities that coincide with the threats for any given risk. Dr. Mun's interpretation of Real Options is often described as "a new way of thinking," and he views capital investments in terms of a dynamic approach, since all decision making processes have generic and dynamic options associated with them. Real Options Analysis is done by considering these real options, then using options theory to evaluate physical, vice financial assets.

Dr. Mun identifies eight phases in the real options process framework. The first phase begins with the qualification of projects through management screening, which eliminates all but those projects management wants to evaluate. The second phase starts with the construction of a discounted cash flow model under the base case condition. Next, Monte Carlo simulation is applied, and the results are inserted in the real options analysis. This phase covers the identification of strategic options that exist for a particular project under review. Based on the type of problem framed, the relevant real options models are chosen and executed. Depending on the number of projects as well as management set constraints, portfolio optimization is performed. The efficient allocation of resources is the outcome of this analysis. The next phase involves creating reports and explaining to management the analytical results. This step is critical in that an analytical process is only as good as its expositional ease. Finally, the last phase involves updating the analysis over time (Mun, 2002). Real options analysis adds tremendous value to projects with uncertainty, but when uncertainty becomes resolved through the passage of time, old assumptions and forecasts have now become historical facts. Therefore, existing models must be updated to reflect new facts and data. This continual improvement and monitoring is vital in making clear, precise, and definitive decisions over time.

Appendix B. The Five Phases of SHIPMAIN

There are five phases leading to the completion of an alteration/modification. These five phases are: conceptual, preliminary design, detailed design, implementation and installation.

A. Phase I—Conceptual

The purpose of this phase is to identify a need for change, propose a resolution, and gain approval to proceed with development of that resolution into an engineered Ship Change (SC). Products developed during this phase include:

- Requirement and proposed conceptual solution.
- Proposed fielding plan.
- Estimate for Phase II and III design development.
- “Best Guess” estimate for Phase IV and V implementation and execution.

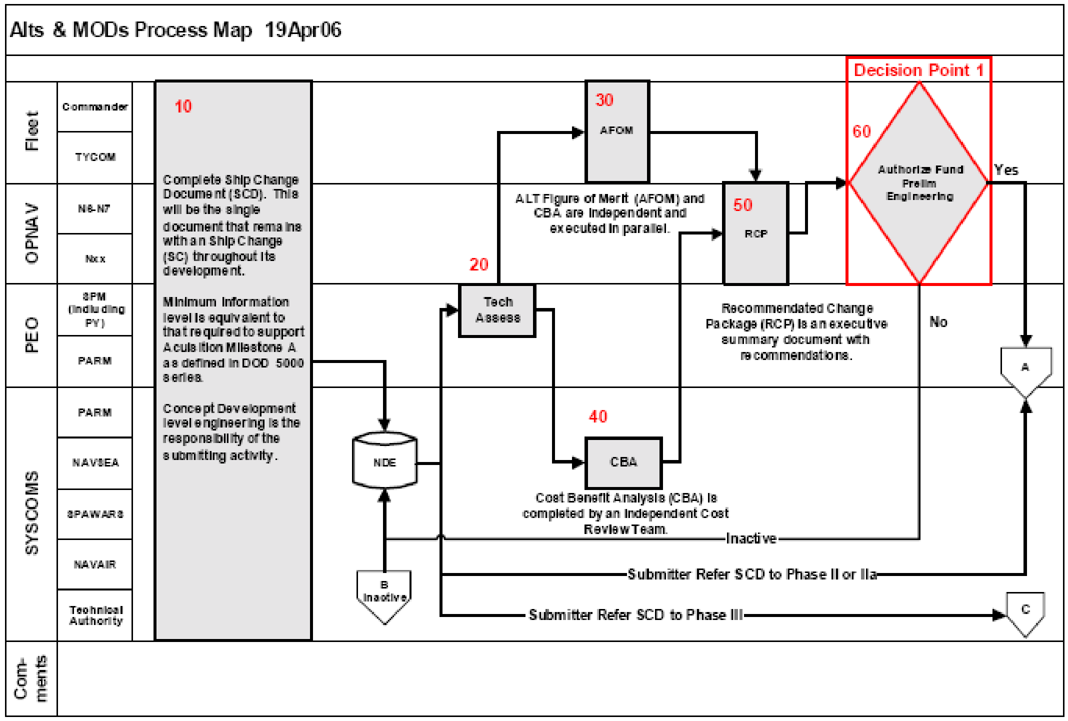

Figure 17. Phase I Top Level Flow Chart (Commander, Naval Sea Systems Command, 2006)

B. Phase II—Preliminary Design

The purpose of this phase is to initiate design work for the SC, perform preliminary design development of the SC, and gain approval to continue to detailed design. Preliminary design development can include selection of technologies, establishment of design parameters, and prototype development. Products developed during this phase can include:

- Design parameters.
- Updated fielding plan.
- Refined estimates for Phases III, IV, and V.
- Initiation of Installation Control Drawings (ICDs) and performance specifications.
- Identification of interfaces and distributive system impacts.
- Design Budget Execution Plans.
- Prototype Design.

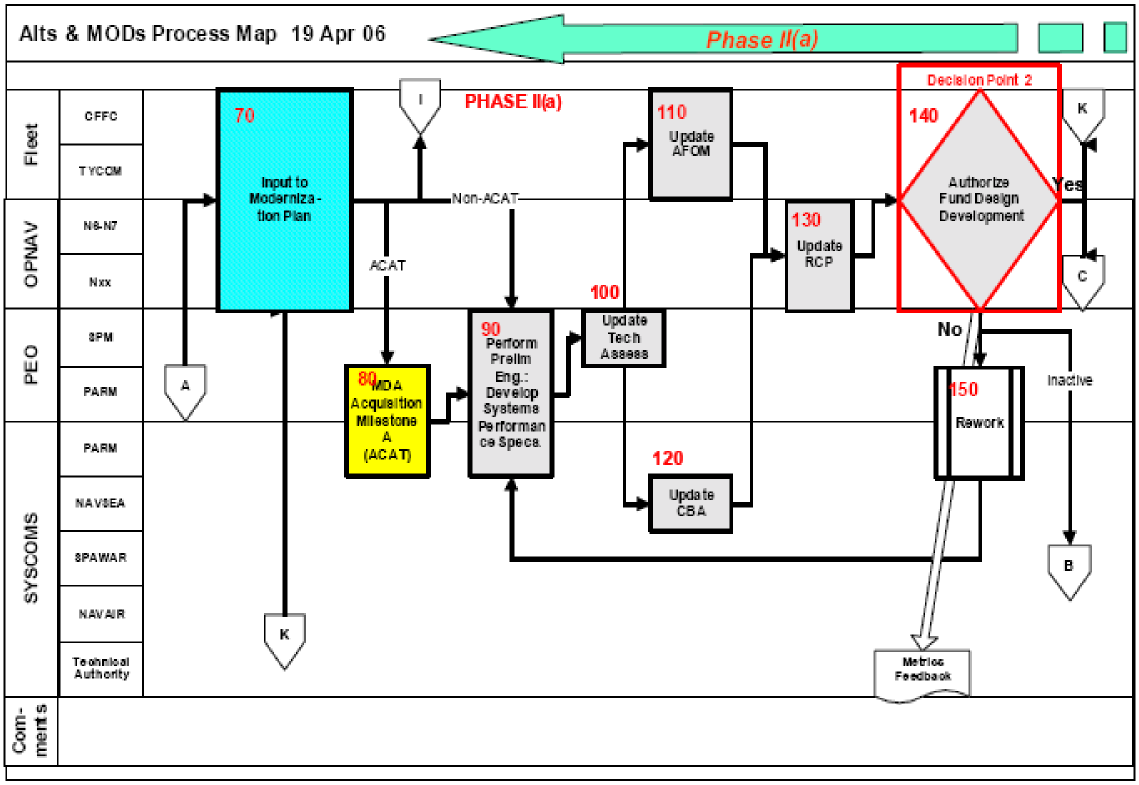

Figure 18. Phase II Top Level Flow Chart (Commander, Naval Sea Systems Command, 2006)

C. Phase IIA

Upon approval at Decision Point (DP) 1, the approving authority may determine a SC is eligible to move through Phase IIa. Phase IIa is utilized when a proposed SC design is mature to the point that DP 2 is not required. Phase IIa is a combination of the Phase II and III development and review processes and ends at DP 3. In order to qualify for Phase IIa, the following criteria must be met:

If the scope of the SC is an Internal Equipment Modification, all of the following criteria must be met:

- The SC can be accomplished without changing an interface external to the equipment or system.
- The change is made within the equipment or system.

- The change does not negatively impact Strike Force Interoperability (SFI).
- The change does not impact shipboard distributive systems, Ship Selected Records (SSRs) or interfacing equipment or systems, compartmental arrangement records, or Damage Control records.

If the scope of the SC is a Ship Modification, all of the following requirements must be met:

- The change does not negatively impact SFI.
- The change does not impact ship stability records (weight & moment).
- The change does not impact or alter the 3-dimensional footprint of the equipment being replaced.
- The change does not impact shipboard distributive systems, SSRs or interfacing equipment or systems, compartmental arrangement records, or Damage Control records.
- The change does not impact manning levels.

Installation may not begin until authorized in Phase IV.

D. Phase III—Detailed Design

The purpose of this phase is to complete detailed design development of the SC. Once approved at DP 3, SCs are added to the Authorized or Planned but Not Authorized section of the Ship Program Manager (SPM) Letter of Authorization (LOA). Installations may not begin in Phase IV until they have been added to the Authorized Section of the SPM LOA in accordance with the milestones identified. The Technical Data Package (TDP) for a Ship Change Document (SCD) at DP 3 must include the level of detail equivalent to preliminary class-level Ship Installation Drawings (SIDs) or preliminary ICDs. Products developed during this phase can include:

- A Technical Data Package.
- Installation Control Drawings.
- Performance Specifications.

- Quantification of interfaces and distributive system impacts (i.e., parametric data).
- Refined estimates for Phases IV and V.
- Refined fielding plan.
- List of required certifications and Plan of Action and Milestones (POA&M) for completion.
- Alteration Bill of Material (ABOM) including Long Lead Time Material (LLTM), Government Furnished Equipment (GFE), and logistically significant material 3-4.

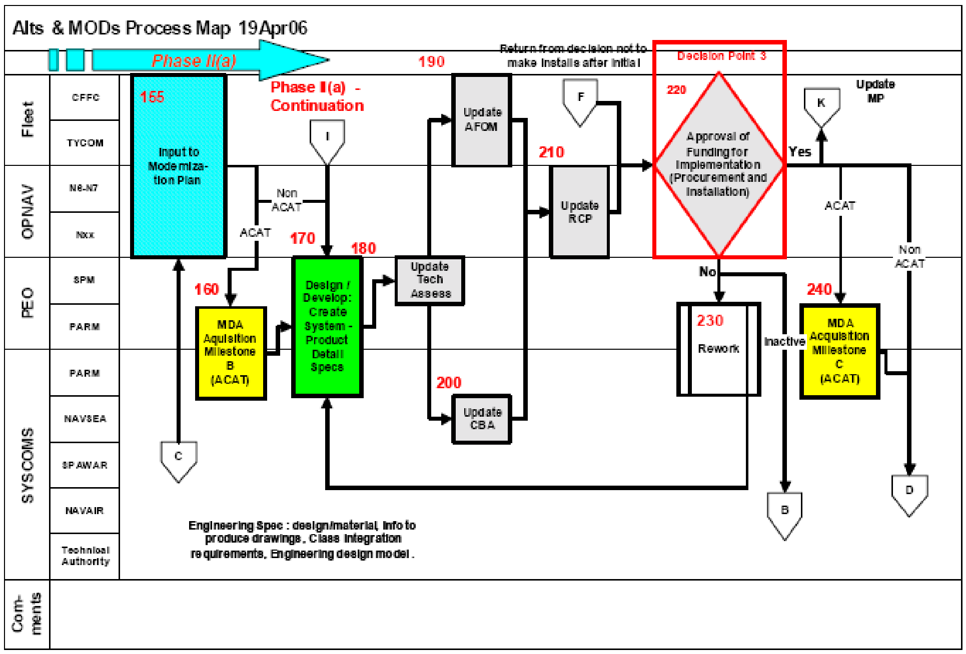

Figure 19. Phase III Top Level Flow Chart (Commander, Naval Sea Systems Command, 2006)

E. Phase IV—Implementation

The purpose of Phase IV is to accomplish site-specific advanced planning of the SC. The attention is redirected from overall SC applicability to design for installation on a specific hull or at a specific location. This phase includes finalized design (including Ship Check/site survey, drawings, technical installation instructions, etc.), initiation of procurement, pre-installation certification and testing, installation readiness assessments, and risk assessments. Products developed during Phase IV can include:

- Ships Installation Drawings.
- ILS Certification.
- Government Furnished Equipment (GFE) and Industrial Activity Furnished (IAF) material procurement.
- Pre-installation certifications.
- Pre-installation testing.
- Risk assessments.
- Installation documents.
- Alteration Installation Team (AIT) Plan of Action and Milestones (POA&M).

Funding for Phase IV is budgeted as part of the Modernization Plan (MP) after Phase IIa or III approval.

1. SCD Revision

There are currently two reasons to have a SCD revised, post DP 3. The first is capability difference between what was planned for procurement and what was actually procured. This capability difference includes changes inherent through design, provided by the manufacturer, for a multi-year procurement requirement. The second is if SCD actual costs are projected to increase by a factor greater than +/- 10% more than estimated costs; then, a revised SCD must be resubmitted to DP 3.

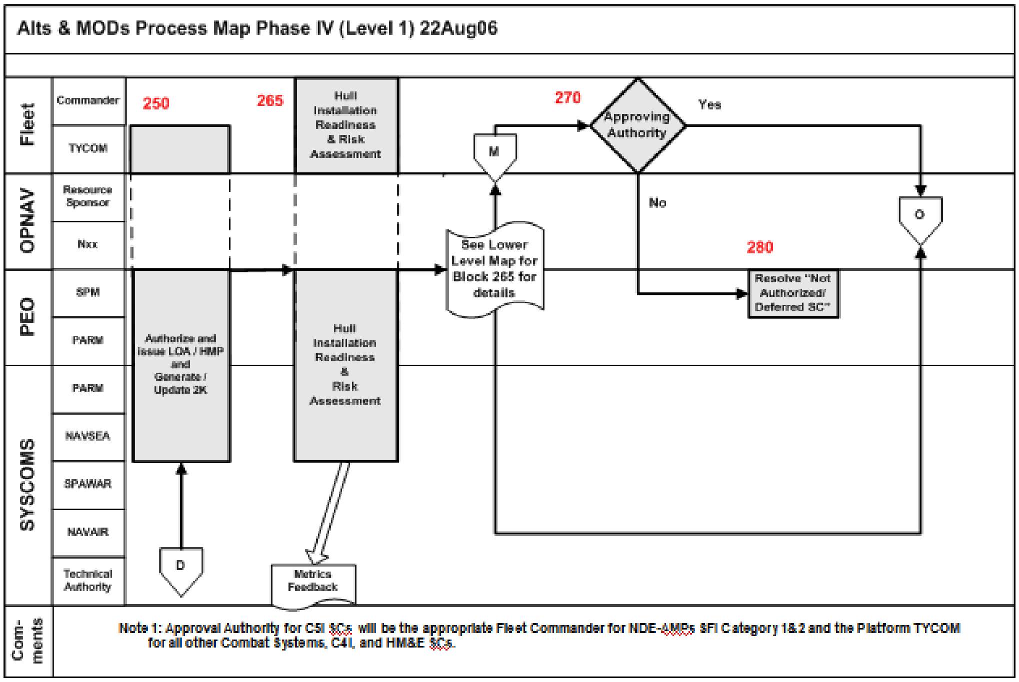

Figure 20. Phase IV Top Level Flow Chart (Commander, Naval Sea Systems Command, 2006)

F. Phase V—Installation

The purpose of Phase V is to execute the SC and provide feedback for future installation decisions. It is possible for a SC to be in Phase IV and V in parallel for different individual installations. Feedback from each individual installation is provided to update and refine technical information and installation cost estimates. Once all planned installations have been completed, this phase and the SC are closed out by providing feedback data reflecting final installation and closeout. Products developed and services performed during Phase V can include:

- Return Cost Reports.
- Liaison Action Requests (LARs).
- Post-installation certification and testing.
- ILS Product delivery.
- Alteration Completion Reports.

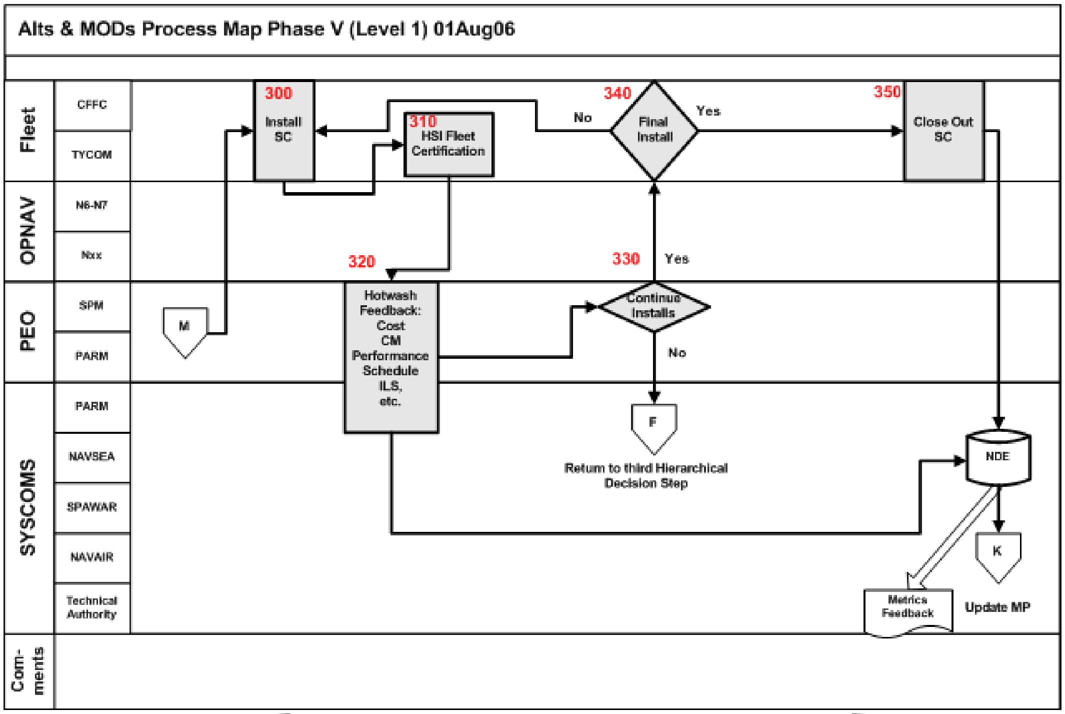

Figure 21. Phase V Top Level Flow Chart (Commander, Naval Sea Systems Command, 2006)

Appendix C. 2005 NSRP Ship Check Cost/Time Savings

	Traditional Ship Check					Ship Check with Laser Scanning						
		Total Labor Hours	Labor Cost	Expense Cost	Total Cost		Total Labor Hours	Labor Cost	Expense Cost	Total Cost	Total Cost Savings	Total Time Savings
Total Number of Design Personnel	4					3						
Estimated labor cost per hour $50												
Number of hours for ship check	12	48	$2,400		$2,400	8	24	$1,200		$1,200	$1,200	24
Travel time	16	64	$3,200		$3,200	16	48	$2,400		$2,400	$800	16
Total expense days	3					2						
Estimated Travel Expense: Airfare $400 Lodging $125 Car Rental $45 Per Diem $43				$1600 $1500 $135 $516	$3,751				$1200 $750 $90 $258	$2,298	$1,453	
Scanner/Software Investment & Maintenance									$500	$500	($500)	
Total Cost/Time		112	$5,600	$3,751	$9,351		72	$3,600	$2,798	$6,398	$2,953	40

Table 22. Traditional vs. Laser Scanning Small Ship Check (National Shipbuilding Research Program Advanced Shipbuilding Enterprise, 2006)

	Traditional Ship Check					Ship Check with Laser Scanning						
		Total Labor Hours	Labor Cost	Expense Cost	Total Cost		Total Labor Hours	Labor Cost	Expense Cost	Total Cost	Total Cost Savings	Total Time Savings
Total Number of Design Personnel	10					6						
Estimated labor cost per hour $50												
Number of hours for ship check	50	500	$25,000		$25,000	40	240	$12,000		$12,000	$13,000	260
Travel time	16	160	$8,000		$8,000	16	96	$4,800		$4,800	$3,200	64
Total expense days	6					5						
Estimated Travel Expense: Airfare $400 Lodging $125 Car Rental $45 Per Diem $43				$4,000 $7,500 $540 $2,580	$14,620				$2,400 $3,750 $225 $1,290	$7,665	$6,995	
Scanner/Software Investment & Maintenance									$2,000	$2000	($2000)	
Total Cost/Time		660	$33,000	$14,620	$47,620		336	$16,800	$9,665	$26,465	$21,155	324

Table 23. Traditional vs. Laser Scanning Large Ship Check (National Shipbuilding Research Program Advanced Shipbuilding Enterprise, 2006)

Appendix D. Business Rules for Phases IV and V

A. Block 250

Goal/Description: Develop Hull Modernization Plan (HMP), and associated time-phased Advanced Planning HMP (AHMP) and Execution Planning HMP (EHMP), issue Letter of Authorization (LOA), and generate/update 2Ks to reflect decisions made by the appropriate Voting Boards and depicted in the MP.

Sub-tasks:

- 250.1 Develop AHMP/EHMP.
- 250.2 Develop HMP.
- 250.3 Generate/Update 2K.

Input:

- SCD and specific NDE-NM data elements (covered in BR 250.2), scheduled to an applicable hull as reflected in the MP.
- C5I Baseline Status as discussed in BR 250.2 for Strike Force Interoperability (SFI) CAT 1 and 2.
- Legacy Alteration (D, K, Engineering Changes) JCF and SAR approval status.

Output:

Time Phased, Critical Milestone based NDE-NM reports:

- AHMP/EHMP and associated Advance Planning Letter (APL).
- HMP/LOA.
- 2Ks.

B. Block 265

Goal/Description: Complete all required design, procurement of material, pre-installation testing, and obtain all required certifications/risk assessment(s) prior to final installation. Evaluate maturity of an installation and determine if the SC is ready for installation. Perform a risk assessment for SCs that have not achieved maturity IAW the milestone charts to determine whether or not to proceed with installation planning.

Sub-tasks:

- 265.1 Installation Procurement, Design & Advanced Planning.
- 265.2 Hull Installation Readiness Review.
- 265.3 Installation Maturity Determination.
- 265.4 Hull Installation Risk Assessment.
- 265.5 Operational Risk/Readiness Determination.
- 265.xx (Future Enhancement) Generate Readiness Assessment Form.

Input:

- SCs approved at DP 2 for Non Permanent Change (NPC) installations or DP 3 (Phase IIa/III) for permanent installations.
- AHMP/HMP/LOA.
- Completed readiness assessment form (*Future Enhancement).*
- Documentation of completed milestones entered in appropriate authoritative data sources.
- Installation risk(s), if any.

Output: Installation recommendation based on maturity and installation risk.

C. Block 270

Goal/Description: Authorize the installation of an SC on a specific hull based upon the installation readiness assessment, installation risk assessment (as applicable), and operational risk. After authorization, installation can be moved to the authorized portion of the HMP/LOA. If an installation is disapproved, that item shall be removed from the HMP/LOA. If the disapproval will cause a change in the SCD funding profile, the PARM must update the SCD and resubmit it to the boards for approval.

Sub-tasks:

- Installation decision.

Input:

- Installation recommendation.
- Endorsements from ESG/CSG staff.
- Endorsements from Numbered Fleet staff.
- For C5I SFI Cat 1 and 2, endorsement from Platform TYCOM.

Output:

- Approval for installation.
    - Update of HMP/LOA.
- Disapproval of installation and removal.
- Issue Updated LOA/Quarterly Scheduling Message IAW Block 250.

D. Block 280

Goal/Description: Update HMP, Letter of Authorization and Fielding Plan (if required) and reschedule in NDE-NM.

Sub-tasks:

- Update Mod Plan (if required).
- SC rescheduling in NDE-NM.
- Update HMP/LOA/Quarterly Installation Scheduling Message (QISM).

Input:

- Disapproval and/or deferral of Installation.

Output:

- Updated HMP/LOA.
- Updated SCD for submission to the O-6 Board at DP 3 (if required IAW the Fielding Plan change process in section 3 of the SSCEPM).

E. Block 300

Goal/Description: Complete installation and testing IAW drawings and other technical guidance and deliver all Integrated Logistic Support (ILS) products.

Sub-tasks:

- SC Check in (for AIT installs).
- Installation of SC.
    - Provide government oversight of AIT (as required).
    - Provide RMC/NSA Installation.
- Progress Reports.
- Testing of SC.
- Delivery of ILS.
- Validation of installation and ILS delivery.
    - Final SSRs and SRDs typically delivered 3 months post-install.
- Release completion message.

Input:

- Authorized SC and supporting documentation to support installation and checkout of specific installations.
- Installation Readiness Assessment.
- Installation POA&M and MOA (for AIT jobs).
- Installation QA Plan.
- CDMD-OA COP Data submission.
- ILS Certification Sheets.
- PY Approved Drawings and ship-specific Bill of Material (BOM).

Output:

- Installed SC
- Completion Reports (IAW NAVSEAINST 4790.14 series, JFMM, Appendix H, and SSCEPM Section 6).
- CDM Planned/Emergent Installation Reports.
- Ship availability ILSMT Action Items.

- Completion message.
- Closed out 4790/2Ks and 4790/CKs (IAW NAVSEAINST 4790.8 series).

F. Block 310

Goal/Description: Provide feedback data to support future installation decisions and (if necessary) revise portions of the Ship Change (SC).

Sub-tasks:

- Provide feedback.
  - Cost.
  - Configuration Management (CM).
  - Schedule.
  - Testing/Integrated Logistics support (ILS).
  - Technical Feedback.
  - Schedule (Completion Date).
  - System Performance/QA.
  - HSI Fleet Certification.

Input:

- Completed Installation.
- Completion Report (IAW NAVSEAINST 4790.14 series, JFMM, Appendix H, and SSCEPM Section 6).
- Closed out 4790/2Ks and 4790/CKs (IAW NAVSEAINST 4790.8 series).
- Closed out RMMCO check-out form for AITs.

Output:

- Completed SC with actual Return Cost, CM and Testing/ILS.
- NSA EOA/EOI Reports.
- Ship ILSMT Minutes/Action Items.
- HSI Fleet Certification Message.

G. Block 320

Goal/Description: Using feedback information from completed installs, determine impact on follow-on installs.

Sub-tasks:

- Assess risk based on information from initial/follow-on installation.
- Decide whether to adjust follow-on installation plan.
- If required, refine CBA estimates.

Input:

- Updated Cost, Configuration Management (CM), Integrated Logistics Support (ILS), Technical, Material, and Schedule data from initial and/or follow-on installation.
- LARs or other design configuration changes/updates.
- Ships Superintendent Reports.
- Completion Reports.
- Ships Situation Reports.

Output:

- Participating Acquisition Resource Manager (PARM)/Resource Sponsor dialog on whether to continue follow-on installs (if required).
- If necessary, revised Ship Change (SC) to reflect changes to cost, material, fielding plan, etc.

H. Block 330

Goal/Description: Verify all planned installations of the Ship Change (SC) have been completed.

Sub-tasks:

- Determine that all planned installations have been completed.

Input:

- Mature SC and supporting installation completion documentation.

Output:

- Determination that all planned installations are complete.
- Close out of SC in the MP.

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