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The use of a collaborative common parts catalog to achieve increased efficiency and cost savings in the fleet modernization plan

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THESIS

THE USE OF A COLLABORATIVE COMMON PARTS CATALOG TO ACHIEVE INCREASED EFFICIENCY AND COST SAVINGS IN THE FLEET MODERNIZATION PLAN

by

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December 2011

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Continual modernization and maintenance efforts are essential to ensure the U.S. Navy's ability to commit naval assets to deter adversaries abroad and contribute meaningfully to national security. Despite budgetary pressures to reduce defense expenditures, the need for deployable platforms remains constant. To address this tension between a reduction in resources matched with a constant demand signal, the U.S. Navy has invested considerable fiscal and human capital to develop effective and efficient processes by which to accomplish maintenance, modernization and repair for fleet assets.

Using a Knowledge Value Added (KVA) methodology, this thesis looks to identify and quantify additional cost savings that can be achieved in the U.S. Navy's Ship Maintenance and Modernization Program (SHIPMAIN) through use of collaborative information technologies. Specifically, this study will look at the value of applying the Common Parts Catalog (CPC), a collaborative tool in use at many major shipbuilders, to direct use in SHIPMAIN. An analysis of a To-Be model of the SHIPMAIN process with CPC with the current As-Is model of SHIPMAIN suggests savings in excess of $20 million a year can be achieved over current processes.

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Continual modernization and maintenance efforts are essential to ensure the U.S. Navy's ability to commit naval assets to deter adversaries abroad and contribute meaningfully to national security. Despite budgetary pressures to reduce defense expenditures, the need for deployable platforms remains constant. To address this tension between a reduction in resources matched with a constant demand signal, the U.S. Navy has invested considerable fiscal and human capital to develop effective and efficient processes by which to accomplish maintenance, modernization and repair for fleet assets.

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TABLE OF CONTENTS

I. INTRODUCTION 1
- A. BACKGROUND 1
- B. RESEARCH OBJECTIVES 2
- C. RESEARCH QUESTIONS 3
- D. METHODOLOGY 3
- E. SCOPE 3
- F. ORGANIZATION OF THESIS 4

II. LITERATURE REVIEW 5
- A. THE FLEET MODERNIZATION PLAN 5
- B. THE SHIPMAIN PROCESS 6
- C. THE NAVAL SHIPBUILDING RESEARCH PROGRAM 8
- D. THE COMMON PARTS CATALOG 10
  - 1. Common Parts Catalog Management 11
- E. PRODUCT LIFE CYCLE MANAGEMENT TECHNOLOGY 14
- F. LEAN SIX SIGMA 17
  - 1. Six Sigma 17
  - 2. Lean 18
  - 3. Lean Six Sigma and PLM 18
  - 4. Lean Six Sigma and KVA 20

III. BACKGROUND RESEARCH 23
- A. SEAMAN’S ANALYSIS AND FINDINGS 23
- B. NATIONAL SHIPBUILDING RESEARCH PROGRAM 26
- C. CPC NAVY PILOT PROGRAM 27

IV. METHODOLOGY PROOF OF CONCEPT 31
- A. INTRODUCTION 31
- B. DATA COLLECTION AND METHODOLOGY 31
  - 1. Learning Time Method 32
- C. THE DEFINED SHIPMAIN PROCESS FOR PHASES IV AND V 32
- D. KVA ANALYSIS OF AS-IS SCENARIO 33
  - 1. Number of Employees 34
  - 2. Times Performed in a Year 34
  - 3. Actual Learning Time 35
  - 4. Determining Value 36
  - 5. Cost Estimation 36
  - 6. As-Is Process Data Analysis 37
    - *a. Key Assumptions 37*
    - *b. Block 250 KVA Analysis 38*
    - *c. Block 265 KVA Analysis 39*
    - *d. Block 270 KVA Analysis 39*
    - *e. Block 280 KVA Analysis 40*
    - *f. Block 300 KVA Analysis 40*

g. Block 310 KVA Analysis *41*
h. Block 320 KVA Analysis *41*
i. Block 330 KVA Analysis *41*
E. TO-BE PROCESS DATA ANALYSIS **42**
1. Cost of Implementing the Common Parts Catalog **42**
2. Cost of PLM Technology **43**
3. Reengineered Process **44**
4. TO-BE Data Analysis **44**
a. Block 250 To-Be Analysis *44*
b. Block 265 To-Be Analysis *45*
c. Block 270 To-Be Analysis *46*
d. Block 280 To-Be Analysis *46*
e. Block 300 To-Be Analysis *46*
f. Block 310 To-Be Analysis *47*
g. Block 320 To-Be Analysis *47*
h. Block 330 To-Be Analysis *48*

V. CONCLUSIONS AND RECOMMENDATIONS **49**
A. RESEARCH LIMITATIONS **49**
B. RESEARCH QUESTIONS **49**
1. Cost Savings **50**
2. Improved Product Life Cycle Management **50**
C. RECOMMENDATIONS TO THE NAVY **51**
D. FOLLOW ON AND FUTURE RESEARCH OPPORTUNITIES **52**

LIST OF REFERENCES **55**

INITIAL DISTRIBUTION LIST **59**

LIST OF FIGURES

Figure 1. Decision Flow Process for SHIPMAIN (From NAVSEA, 2010) 7
Figure 2. Collapsing 40+ Alterations into Fleet or Program (From Seaman, 2007).........8
Figure 3. Current NSRP Industry Partners (From NSRP, n.d.) 9
Figure 5. Common Parts Catalog (From Mays, 2011)...12
Figure 6. KVC (KVA) Model Parts and Theories (From Denny, n.d.)...........................21
Figure 7. KVA Model K=knowledge; V=Value (From Denney, n.d.) 22
Figure 8. Graphical Representation of Phases IV and V of SHIPMAIN (From Seaman, 2007)...24
Figure 9. SHIPMAIN Core Processes (From Commander, Naval Sea Systems Command, 2006)...33

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LIST OF TABLES

Table 1. AS-IS SHIPMAIN Process Overview (From Seaman, 2007) 25
Table 2. 3-D Scanning AS-IS/TO-BE Comparison (From Seaman, 2007) 25
Table 3. As Is SHIPMAIN Process Overview (Seaman, 2007)....................................34
Table 4. Block 250 KVA As-Is Analysis (From Seaman, 2007)..................................38
Table 5. Block 265 KVA As-Is Analysis (From Seaman, 2007)..................................39
Table 6. Block 270 KVA As-Is Analysis (From Seaman, 2007)..................................39
Table 7. Block 280 KVA As-Is Analysis (From Seaman, 2007)..................................40
Table 8. Block 300 KVA As-Is Analysis (From Seaman, 2007)..................................40
Table 9. Block 310 KVA As-Is Analysis (From Seaman, 2007)..................................41
Table 10. Block 320 KVA As-Is Analysis (From Seaman, 2007)..................................41
Table 11. Block 330 KVA As-Is Analysis (From Seaman, 2007).................................42
Table 12. Block 250 KVA To-Be Analysis 44
Table 13. Block 265 KVA To-Be Analysis 45
Table 14. Block 270 KVA To-Be Analysis 46
Table 15. Block 280 KVA To-Be Analysis 46
Table 16. Block 300 KVA To-Be Analysis 46
Table 17. Block 310 KVA To-Be Analysis 47
Table 18. Block 320 KVA To-Be Analysis 47
Table 19. Block 330 KVA To-Be Analysis 48
Table 20. As-Is and To-Be ROI Comparison 50

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LIST OF ACRONYMS AND ABBREVIATIONS

ALT	ACTUAL LEARNING TIME
BI	BUSINESS INTELLIGENCE
BIW	BATH IRON WORKS
CCCG	CENTRAL CONFIGURATION CONTROL GROUP
CM	CONFIGURATION MANAGEMENT
CPC	COMMON PARTS CATALOG
DES	DATA EXCHANGE SYSTEM
DoD	DEPARTMENT OF DEFENSE
DON	DEPARTMENT OF THE NAVY
FINS	FORWARD INNER NOZZLE SUPPORT
FMP	FLEET MODERNIZATION PLAN
FY	FISCAL YEAR
GAO	GOVERNMENT ACCOUNTING OFFICE
GD-EB	GENERAL DYNAMICS-ELECTRIC BOAT
GE	GENERAL ELECTRIC
HPT	HIGH PRESSURE TURBINE
ILS	INTEGRATED LOGISTICS SUPPORT
IT	INFORMATION TECHNOLOGY
KVA	KNOWLEDGE VALUE ADDED
LPD	LANDING PLATFORM DOCK
LSS	LEAN SIX SIGMA
NAVSEA	NAVAL SEA SYSTEMS COMMAND
NDE	NAVY DATA ENVIRONMENT
NGSS	NORTHROP GRUMMAN SHIP SYSTEMS
NSRP	NATIONAL SHIPBUILDING RESEARCH PROGRAM
NSWCCD	CARDEROCK DIVISION OF THE NAVAL SURFACE WARFARE CENTER
OC-ALC	OKLAHOMA CITY AIR LOGISTICS CENTER
OPNAV	OFFICE OF THE CHIEF OF NAVAL OPERATIONS
OSD	OFFICE OF THE SECRETARY OF DEFENSE

PEO	PROGRAM EXECUTIVE OFFICE
PEO SUBS	PROGRAM EXECUTIVE OFFICE, SUBMARINES
PLM	PRODUCT LIFE CYCLE MANAGEMENT
RLT	RELATIVE LEARNING TIME
RMA	REVOLUTION IN MILITARY AFFAIRS
ROI	RETURN ON INVESTMENT
ROK	RETURN ON KNOWLEDGE
SC	SHIP CHANGE
SCD	SHIP CHANGE DOCUMENT
SHIPMAIN	SHIP MAINTENANCE AND MODERNIZATION PROGRAM
SME	SUBJECT MATTER EXPERT
SSCEPM	SURFACE SHIPS AND CARRIERS ENTITLED PROCESS FOR MODERNIZATION
TLT	TOTAL LEARNING TIME
TYCOM	TYPE COMMANDER
USAF	UNITED STATES AIR FORCE
USN	UNITED STATES NAVY

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I. INTRODUCTION

A. BACKGROUND

As a consequence of fiscal realities, the U.S. Defense budget is being more closely scrutinized than it has been in a generation. However, global threats and resulting force structure requirements remain unchanged. In order to ensure we can build and maintain effective maritime capabilities in a time of fiscal austerity, we must look to the creation of efficiencies in procurement, maintenance and outfitting. DoD expenditures on maintenance alone are growing at an alarming rate; in 2006 $72 Billon was spent on maintenance related activities, compared with $59 Billion in 2005, a 22% jump in a single year (Siemens PLM Software, 2010). Pressed with their own economic challenges, the American shipbuilding industry has found several innovative ways to leverage the process of collaborative Product Life cycle Management (PLM) combined with three dimensional imaging to create a valuable product with maximum efficiencies in the fields of labor, industrial use, material and logistics. This is primarily done by using powerful collaboration tools that allow for seamless integration of all aspects of a product's life cycle: design, construction, delivery and use. Savings from using these tools are significant: Airbus, in partnership with IBM was able to save $25 million in the elimination of data re-entry alone on the Airbus 380 program by utilizing PLM (Managing Automation, 2006). The Navy, as the primary beneficiary of the shipbuilding industry's initiatives, can and should fully integrate with several information tools already produced by the private sector that will create true PLM. This public-private integration already is taking place in several existing programs, most notably the Royal Dutch Navy's Rotterdam Class of Landing Platform Dock (LPD) ships and the Royal Air Force's Typhoon fighter, which have utilized collaborative PLM (Siemens PLM, 2010). Interestingly, these tools are already in use in the three largest naval shipyards in the U.S.: Bath Iron Works (BIW), General Dynamics-Electric Boat (GD-EB) and Northrop Grumman Ship Systems (NGSS) (NSRP, 2004). The American shipbuilding industry has already implemented collaborative tools and is ripe for integration with the DoD.

One area of potential integration is in part and material management. As several of the above shipyards discovered, sharing production work on vessel designs often means creating shared means of collaborating between shipyards and design firms. Developed in conjunction with the National Shipbuilding Research Program (NSRP) the Common Part Catalog (CPC) was the American shipbuilding industry's successful approach to construct a common standard for part descriptions, integrate existing databases and create efficiencies through part standardization and interchangeability. Although the Navy participated in the initial design of CPC architecture, the Navy failed to fully integrate its own maintenance, part and material databases with CPC. Despite owning the design data created and captured into the CPC, upon delivery that data must be recreated upon Navy systems and then painstakingly tailored to a particular ship, a process that can take years and creates conditions of improper maintenance. If Navy Sea System Command and Navy Supply Command were to integrate their outfitting, logistics and maintenance processes with that of the shipbuilding industry, considerable savings on the order of tens of millions of dollars per shipbuilding design can be achieved both in initial procurement costs as well as life cycle maintenance (NSRP, 2004).

B. RESEARCH OBJECTIVES

Expanding upon previous analysis (Seaman, 2007) of the Ship Maintenance and Modernization (SHIPMAIN) process utilizing KVA, this study will use his AS-IS model to explore the value of integrating a Common Parts Catalog into specific phases of SHIPMAIN. Research conducted via interviews with SMEs in both industry and the Naval Sea Systems Command (NAVSEA) will be applied to a previous model (Seaman, 2007) with appropriate conditional modifications, and the potential cost-savings and reduction in cycle-time will be evaluated. After obtaining reliable Knowledge Value Added (KVA) estimates, the process will be examined factoring in the potential capabilities of CPC.

C. RESEARCH QUESTIONS

To determine potential outcomes from implementation and maintenance of CPC in a SHIPMAIN environment, the following questions will be answered:

- Will implementation and use of CPC provide better ROI for the Navy in the SHIPMAIN environment of the Fleet Modernization Plan than current processes realize?
- What are the potential other uses of the two technologies in such processes as ship maintenance, modernization and repair?

Previous research has shown through quantitative analysis that there can be considerable impact upon SHIPMAIN from Information Technology (IT) systems, especially studies from Seaman (2007), Cornelius (2007) and Komorosky (2005).

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 a Common Parts Catalog. A previous model (Seaman, 2007) of these phases will be mapped directly and the quantitative results of the KVA methodology will be applied to similar processes. All major inputs, processes, and respective outputs will be identified by a comprehensive review of current SHIPMAIN directives. SHIPMAIN subject matter experts (SME) will then validate this model. The sub-process analysis will include estimates for the time 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 that a Common Parts Catalog would 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. 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.

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 will be described. Chapter II contains a literature review to introduce relevant concepts. It will provide a brief discussion on the Fleet Modernization Plan (FMP) and SHIPMAIN, the National Shipbuilding Research Program (NSRP), Common Parts Catalog and PLM technologies, and Lean/Six Sigma (L6S) methodology supported by KVA. Chapter III will be a more detailed discussion of previous research by Seaman (2007), Cornelius (2007) and Komoroski (2007) as well as government and industry research into CPC implementation. 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 CPC 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.

II. LITERATURE REVIEW

A. THE FLEET MODERNIZATION PLAN

The post–Cold War world has been a time of considerable change in the Navy. The end of the Soviet Fleet as a peer competitor meant that the U.S. Navy would be reduced in budget and number of ships in service. Maintenance costs increased dramatically as the fleet increased the number of technologically advanced vessels such as the DDG 51 class of destroyer while attempting to maintain older legacy platforms. New opportunities in computing and information technology allowed for new efficiencies in both maintenance and management. Finally, a new breed of naval leadership looked for new business processes to effectively and efficiently maintain a fleet that shrank in number but not in commitments.

In existence for decades, the Fleet Modernization Program (FMP) was implemented to plan, budget and install military and technical improvements to naval vessels (General Accounting Office, 1991) with the stated goals of improving warfighting capability, ensuring material condition and increasing readiness through an improvement in standardization. It defines a standard methodology to plan, budget engineer and install timely, effective and affordable shipboard improvements while maintaining configuration management and supportability ("Fleet Modernization Program," n.d.). Through the FMP central planning process, unauthorized and non-supported alternations are prevented and inefficiencies associated with systems or equipment that are not officially supported are eliminated.

Although effective in producing naval platforms capable of sustained and successful combat operations, the FMP was equally inefficient in completing modernization projects without undue delays or excessive costs. Between 1976 and 1991, three separate Government Accountability Office (GAO) reports concluded that the FMP, through deficient planning and organization, contributed to multiple deployment delays and modernizations that were improperly managed and completed.

> The March 1991 report also called into question the metrics by which the Navy tracked results of the FMP. It concluded that the FMP could not 'maintain accurate and complete information on the status of planned ship modernization projects. Its management information system does not provide timely information to managers for planning, programming, budgeting, executing and evaluating the program.' (General Accounting Office, 1991)

Poor oversight lead to multiple installation issues. In 1987, the USS Seahorse (SSN 669) had three alterations canceled because they were already installed. The cost for the three alternations was in excess of $97,000. Also in 1987, the cruiser USS Yarnell (CG 17) received over 30 planned alternations at a cost of $32 million and 95,510 workdays. This is greatly in excess of both the original programmed Naval Sea Systems Command estimate of $15.5 million and 38,800 workdays and the initial shipyard estimate of $23.7 million and 59,345 workdays (General Accounting Office, 1991).

In addition to cost and time overruns, reduction in fleet numbers throughout the 1990 has meant that any delay in alternations affected operational taskings. In 1993, there were 458 ships in commission in the Navy with 108 (24%) forward deployed. In 2001 there were 313 ships commissioned in the Navy with 100 (32%) forward deployed (Department of the Navy, 2001). In addition to an 8% increase in operational tempo in less than ten years, the adaptation of the Fleet Response Plan looked to increase the overall readiness of the battle fleet, mandating that half of the Navy's Carrier Strike Groups be ready for deployment in thirty days with another two ready in ninety. New business rules combined with the leveraging of information technology would need to be developed to maintain an operationally strained fleet.

B. THE SHIPMAIN PROCESS

Initiated in 2002, the Ship Maintenance Program (SHIPMAIN) is an U.S. Navy initiative to transform maintenance and modernization planning processes. Designed both in response to and alongside the Fleet Response Plan, SHIPMAIN acknowledged that current modernization activities were "effective but not efficient and that change had to be made to "help deliver a more ready fleet at a lower cost" (Haney, 2003). As shown in

Figure 1, a major goal of SHIPMAIN is to push the majority of decisions to the lowest levels of control, allowing major modernization projects to be given the consideration they demand at high levels. While intuitive, this also places increased burden on the decision/action cycle-time at the O-6 board level.

The objectives for SHIPMAIN are (NAVSEA, 2010):

- Install a common planning process for Surface Ship Maintenance and Modernization
- Increase the efficiency of the process and deliver quantifiable savings without compromising its effectiveness
- Install a disciplined management process with objective measurements
- Institutionalize the process and continuous improvement method

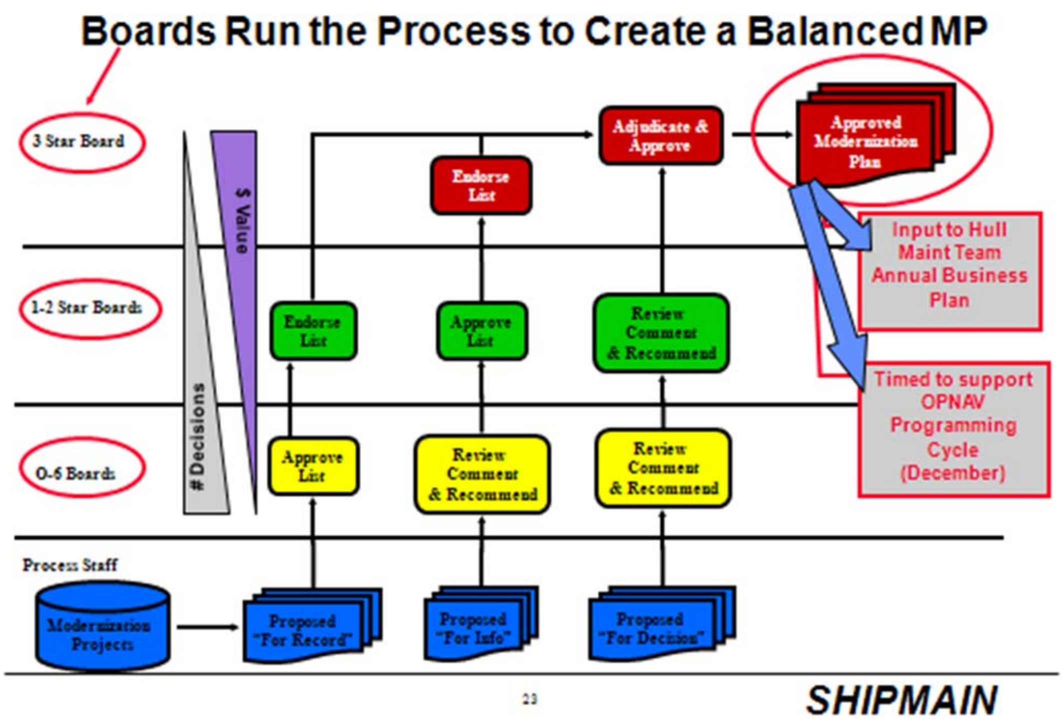

Figure 1. Decision Flow Process for SHIPMAIN (From NAVSEA, 2010)

Although not replacing the overarching concept of the FMP, SHIPMAIN looks to focus its functions, reducing the number of differing alterations from over forty to two, Fleet (managed by NAVSEA) or Program (managed by individual PEOs) as shown graphically in Figure 2.

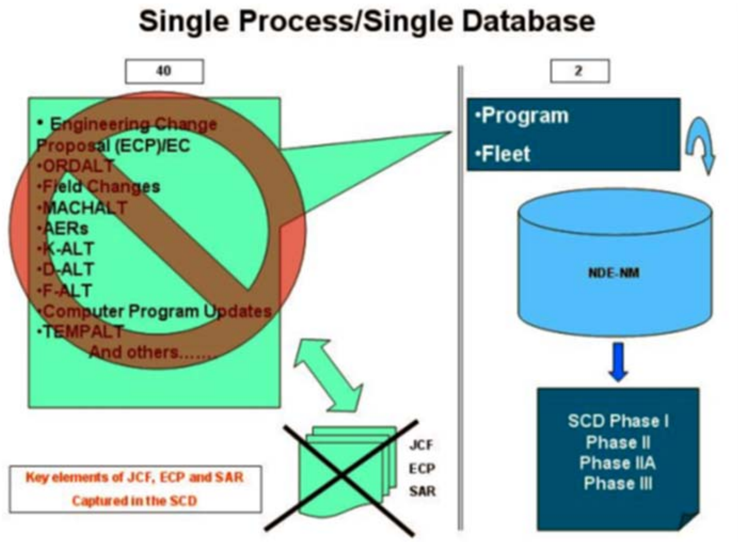

Figure 2. Collapsing 40+ Alterations into Fleet or Program (From Seaman, 2007)

Oversight is also enhanced and refined through the SHIPMAIN program. Decision-making is divided into three levels of Stakeholders at the vice admiral, rear admiral and captain levels with decision-making authority further divided by billet code.

New sets of metrics were developed to monitor Despite a robust database design, SHIPMAIN still has many inefficiencies. Often reviewing part compatibility or system integration becomes time and resource consuming. Industry has also run into this issue.

C. THE NAVAL SHIPBUILDING RESEARCH PROGRAM

The end of the Cold War and the military drawdown that occurred afterward was a seminal event in the American defense industry. Industrial capacity exceeded demand, forcing the merger or outright shuttering of many defense corporations. The consolidation of the defense industry, coupled with the information technology boom of the 1990s presented considerable opportunity to create new tools and strategies for a new defense landscape. As the U.S. military attempted its Revolution in Military Affairs (RMA), a transformative process leveraging new technologies to produce increased warfighting value at reduced costs, so too did the defense corporations try their hand at transformation.

Figure 3. Current NSRP Industry Partners (From NSRP, n.d.)

In 1999, industry partners representing all major defense shipyards as well as government partners founded the Naval Shipbuilding Research Program (NSRP) a public/private research initiative whose stated task was to conduct research “to reduce the cost of building, operating and repairing Navy ships” with a focus on “achieving this by improving productivity and quality through advanced technology and processes” (NSRP, 2011). As shown in Figure 3, NSRP participating members include all major U.S. private shipbuilders and support yards across the East, West and Gulf coasts. All major shipbuilding projects currently funded are included in these yards.

Navy priorities, which the Program’s industry board concurred with, are woven into the mission, strategy and objectives of the Program (NSRP, n.d):

- Improved first-time quality
- Reduction in Total Ownership Cost
- Improved energy efficiency and/or environmental impact in shipyards and/or ships

These core priorities formed the basis for a collaborative research and development framework consisting of shipyards, suppliers, academia and government research entities.

An important realization made by shipyards during this period of contraction was the need to pool resources together for future projects. Consolidation had reduced the nation's shipyards such that no single yard could handle a major building project without assistance from other yards. The use of specialized subcontractors also made industry cooperation a more compelling proposition.

A major hurdle to industry integration was data. Ships exist as much on paper as they do in the water, with plans as detailed as the parts they are outfitted with. Were cooperation to occur, the result must be as complete as a product constructed under the old, stovepiped model for designing and building naval vessels. A centralized database would be required with a standardized architecture that would allow for equivalent data stored in several locations to be used seamlessly and reduced potential for error.

The recognition among the NSRP that there would be value in the sharing of common data on parts and configuration items lead to the creation of the Common Parts Catalog.

D. THE COMMON PARTS CATALOG

Implemented at General Dynamics-Electric Boat, Bath Iron Works and Northrop Grumman Ship Systems (now Huntington Ingalls), the Common Parts Catalog (CPC) is a real-time, searchable inter-shipyard catalog that can provide standardized equivalency/sourcing information across multiple part numbering formats (NSRP, 2004).

The value of such a database to the shipbuilding industry became evident early. Through use of the CPC, shipyards are seeing increased speed and accuracy in information retrieval, a reduction in the number of parts required to be warehoused because of non-duplication. Through CPC's robust search capability the identification of duplicate part numbers is ensured and new part numbers are prevented from being generated for components already existing in the catalog. As shown in Figure 5, the CPC has the potential to be a powerful collaborative tool in ship modernization.

Aside from value generated from streamlining data search and verification, CPC has a beneficial effect on inventory management and logistics. Due to the database design that allows for part comparison and generation of part substitution options, non-standard part requirements can be reduced or eliminated in favor of parts that are more common. In addition, with the pooling of part and inventory data, small quantity orders that are inefficient in cost are unnecessary.

Integration of CPC into entities outside of shipbuilders can yield many benefits as well. With proper integration, CPC has the potential to integrate Navy inventories with that of shipyards, providing a complete Product Life cycle Management (PLM) environment for naval vessels. Inventories can be controlled at a national level, and spare part and component usage can be tracked over the life of a platform.

Currently in use at all five major U.S. shipbuilders, CPC is estimated to have saved hundreds of millions of dollars in reduced inventory. Approximately 65% of all surface combatant, submarine, and amphibious vessel procured material is now standardized and configuration managed in CPC[1]

1. Common Parts Catalog Management

The value of CPC comes from its adaptive schema design and part equivalency rules. Each shipyard contains a Central Configuration Control Group (CCCG) that is tasked with ensuring part catalog data, software and hardware integrity is being maintained to support data sharing, both within and between shipyards.

[1] James Mays, personal communication, July 21, 2011. Use of CPC by General Dynamics-Electric Boat is expected to produce $789M in cost avoidance over the program life of the Virginia Class submarine, $72M from the Seawolf class, and $80M from the four converted Ohio class SSGNs.

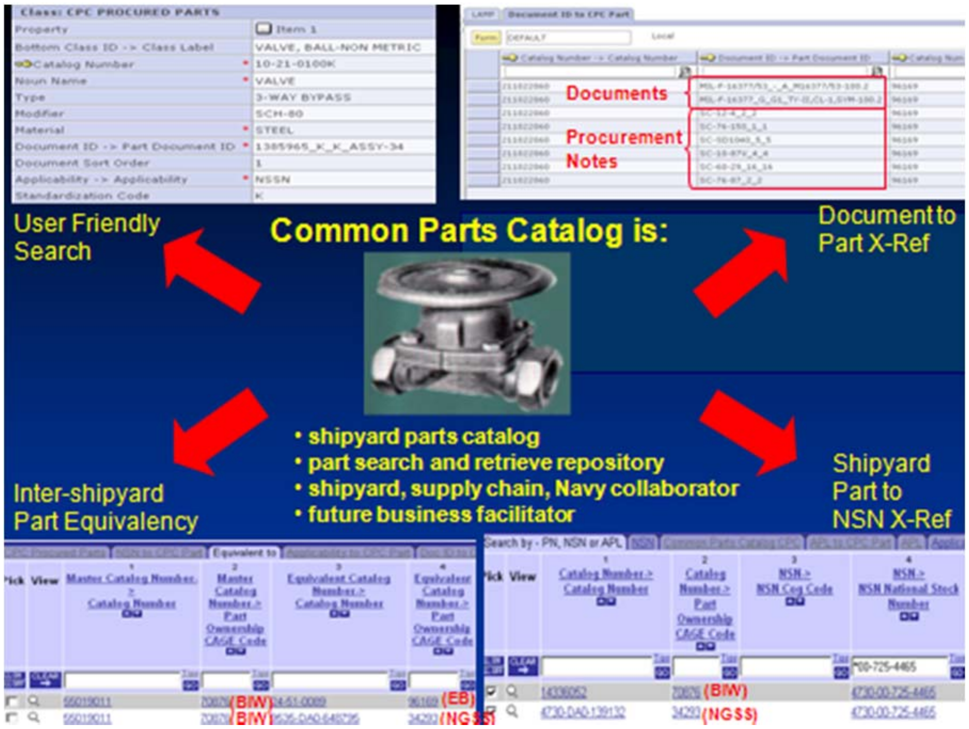

Figure 5. Common Parts Catalog (From Mays, 2011)

Through establishment of part equivalency (the determination that one part meets or exceeds the purpose of another part and can be used as a replacement) and standardization (the linking of identical parts across multiple external databases with identical or different description data) programs CPC can see its benefits fully realized. The responsibilities of the CCCG include (NSRP, 2004):

- Ensuring configuration management of parts and data integrity of attributes across the participating shipyards
- Review part additions and changes from each shipyard and determine impact on remaining shipyards
- If impact is determined, electronically provide data to affected shipyards
- Assure part equivalency links between shipyards are maintained through audits of individual shipyards equivalent part linking activity
- Audit data with management reporting to ensure participating shipyards adherence to agree upon procedures

There are two parts to the creation of a functioning inter-shipyard parts equivalency; establishment and maintenance. The part equivalency establishment process looks to establish part-to-part links within a participating entity. This process will electronically link and provide users visibility of catalog parts that have passed a technical and contractual review. To support the establishment process an entity must have a functioning Common Parts Catalog database, personnel that understand the concept of equivalency and an established plan to enforce a consistent standard of technical and contractual review (NSRP, 2004).

The flexibility of the CPC is shown during the establishment process as parts and components are divided into a coding system for use in comparison.

CPC Interchangeability Code (NSRP, 2004)

- CODE 1: Material is completely interchangeable. Two-way part equivalency, obsolete logic in not applicable.
- CODE 2: Material to the new document or document revision may be used as a replacement for material to the old document or revision. One-way part equivalency and obsolete use is applicable
- CODE 3: material to the old and new documents or revisions is not interchangeable. New catalog parts are required. Part equivalency cannot be established.
- CODE 4: new document or revisions are not acceptable for use due to technical changes or increases in cost or delivery. Part equivalency cannot be established.
- CODE N: Document in not applicable to an interchangeability analysis

The success or failure of the system will come during the equivalency establishment process, particularly the level of grouping to commence review.

After the appropriate level of detail is determined for data, they will be grouped into an appropriate part family for organization and determine what parts qualify as equal or ‘better than’ another part in the family. Parts will also be researched to make sure that they are still required for active design or construction usage.

Equally vital to the CPC establishment process, the maintenance process ensures that the catalog is delivering up to date and accurate equivalency data. Although the CPC is a centralized database connecting all user entities, maintenance is done at the local level. Individual shipyards or other user entities are responsible for assuring that the technical and contractual elements of a part number meets or exceeds the requirements for the catalog part number for which it is designated as equivalent. If that equivalent part number is modified to the point that it is no longer equivalent to another part, a new part number has to be established without the previous equivalency link. Changes taken at the local level must be promulgated to other users for situational awareness; the database will already be updated with the equivalency change.

E. PRODUCT LIFE CYCLE MANAGEMENT TECHNOLOGY

PLM is 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, and spanning from product concept to end of life—integrating people, processes, business systems, and information (CIMdata, 2011). All tasks required for the duration of a product's life that are considered in a PLM solution: requirements management, project management, workflow, change management, product data management, design, engineering analysis, manufacturing process, after-sales support, maintenance-repair-overhaul and disposal. Although not directly connected to PLM, Lean Six Sigma is a complementary methodology that will be discussed later.

Industry has embraced PLM as a strategy to connect all aspects of their business with a common Business Intelligence (BI) backbone. However, truly leveraging PLM is not entirely simple. Due to its inherent nature, PLM solutions tend to accumulate massive amounts of critical data throughout the life cycle of a product, especially in the form of part numbers and part descriptions (Siemens PLM Software, 2011).

On May 5, 1998, an engine room fire onboard HMAS Westralia claimed the lives of four sailors and caused substantial damage, placing the oiler out of service for two years for repairs (Siemens PLM Software, 2010). The cause of the fire was found to be a fuel hose that had been installed during a previous maintenance period. Although the installation of the hose was a part of the approved maintenance work package, that particular hose had not been an approved configuration item. In the aftermath, the Royal Australian Navy (RAN) began a large scale effort to change the way it approached configuration management. After adapting Siemens Teamcenter, the RAN has completely integrated its maintenance, logistics and configuration management. In addition to legacy platforms, the ANZAC frigate will be the first RAN platform designed from inception as part of a PLM system (Siemens PLM Software, 2010).

Additionally, new PLM military initiatives will look like the BAE's Typhoon fighter program for the RAF. In the past, an aerospace company would deliver a product and the purchasing military organization would provide the guidance over the in-service life of the aircraft or system. With the Typhoon, however, BAE will be responsible for the complete life cycle of the Typhoon fighter to include "configuration-driven, through-life maintenance, repair and operational support starting when a product is delivered to a customer. (Siemens PLM Software, 2010). This is a tremendous shift in the role contractors and defense corporations play in platform management. By using PLM solutions BAE has been able to deliver operational aircraft with all aspects of their service life planned with minimal expense. BAE managed RAF Typhoons are currently conducting combat operations over Libya.

Key to any PLM solution in the integration of part numbers into the overall collaborative process. Without ways to describe the large amounts of data produced in modern industry in a way that is convenient and useful, any benefit gained from integration of various business processes and entities is lost. The adaptation of CPC to SHIPMAIN fits in with many key recent changes in how organizations manage their data, especially parts data.

It is believed that the concept of a numbering system for parts or unique items was born in 1932 at Harvard Business School as part of a project headed by famed business innovator Wallace Flint.[2] Flint was attempting to create a means to speed the purchasing and ordering of parts and items via punch card. His system would later become the Universal Barcode System, the ubiquitous method for optical representation of data. In order to systematically describe the data being visually represented, he created a means by which parts and products were alpha-numerically represented (Stewart, 2010).

The Second World War, and the large amount of industrial activity it created, led to the first Intelligent Part Numbering, as the massive increase in the number of individual unique parts for war items increased exponentially. Unlike Flint's early system, in which there was a degree of randomness to the amount and meaning of each character in his part numbering system, new government numbering systems required that either all characters represent some aspect or attribute of a part or document or at a minimum have some significance (also described as semi-intelligent numbering, this is useful in the categoration, classification or representation of families of items).

The digitalization of data did not change the way it is described, but with the advent of powerful BI products it can be translated interpreted in new ways. A bolt that was described using a certain nomenclature in one system and a completely different nomenclature in another can seamlessly be managed between either system, allowing for improved part management and logistics (Stewart, 2010).

For a part numbering system to be valuable, it must do several things. First, it must uniquely identify a component. Second, it must allow for future changes to its catalog. New and modified parts and components that deviate from previous form, fit or function (F3) must be able to be assigned a new part number. Lastly, there must be some sort of intelligent or semi-intelligent design to the system. Random part descriptions are extremely inefficient and ungainly to manage (Stewart, 2010).

[2] Flint is considered the father of the barcode concept of automated item identification, first proposing an automated checkout system for grocery stores in 1932 using punch cards.

F. LEAN SIX SIGMA

On May 3, 2006, Secretary of the Navy Donald Winter issued an official memorandum implored naval leadership to inject Lean Six Sigma (LSS) processes into all performance objectives (DoN, 2006). This day can be viewed as the de facto date Lean Six Sigma became the Department of the Navy business management strategy of record. Shortly thereafter, Deputy Secretary of Defense Gordon England commenced the DoD Continuous Process Improvement (CPI)/Lean Six Sigma program with the goal of complete integration of LSS into all DoD activities (DoD, 2008). Mirroring private industry initiatives that were decades in the making, the DoD recognized the power of the business management strategies of Lean and Six Sigma. Closely related, they both complement PLM and inform the value of the Navy's potential adaptation of CPC.

1. Six Sigma

First implemented by Motorola, Six Sigma attempts to improve the quality of process outputs by identifying and removing the causes of defects and by minimizing variability in manufacturing and business processes (Jiju, 2008). After discovering a correlation between increases in quality and decreases in production costs (contrary to the prevailing wisdom of the time that increases in quality require increased costs), Motorola began to explore how to benefit from this observation. Formally implemented in 1986 by quality control engineer Bill Smith, Six Sigma doctrine asserts that:

- Continuous efforts to achieve stable and predictable process results are of vital importance to business success
- Manufacturing and business processes have characteristics that can be measured, analyzed, improved and controlled
- Achieving sustained quality improvement requires commitment from the entire organization, particularly from top-level management
- Decision making should be based on verifiable data rather than assumptions and guesswork (Jiju, 2008)

The term Six Sigma comes from the concept that if an organization has six standard deviations between the process mean and the nearest specification limit practically no items will fail. Due to prohibitive costs associated with failed upgrades and installations aboard naval platforms application of a Six Sigma process during the design and preinstallation phase of SHIPMAIN and the FMP are of vital importance.

2. Lean

Although the term “Lean Production System” was first coined in 1988, the principles of Lean were first adapted by the Japanese automobile manufacturing industry in the 1970s. Conceptually, Lean is a set of management tools designed to assist in the identification and elimination of waste. As waste is removed, quality is expected to improve while production time and cost are expected to be reduced (Akinlawon, n.d.).

There are three essential pillars to LEAN, just-in-time management of parts and processes, “flow” and smart automation (Akinlawon, n.d.). If production flows smoothly, there is a relevant reduction in waste. Likewise, if only customer valued features are produced then design is simplified while only exerting effort on components the customer values. Smart automation is the concept of giving automated processes the ability to aid humans, (such as by producing nearly perfect copies of products), while not removing the skills that humans do best (problem solving and resolution of abnormalities (Rosenthal, n.d.)

3. Lean Six Sigma and PLM

L6S and PLM, although separate methodologies, both complement and inform each other. Without Lean’s reduction in waste and Six Sigma’s reduction in variation and improvements in product quality a complete concept-to-grave business methodology such as PLM has the potential to wander off course dramatically. PLM requires a thoughtful approach to assessing existing processes, recognizing where problems are occurring and making the necessary changes to eliminate problems and generate efficiencies. Without injecting L6S practices into PLM, any business solution would create a cycle of ineffective changes and increased costs, since the further along the PLM realization path an issue is discovered the more costly the corrective action.

Within the DoD today there is an increasing awareness of the linking of L6S and PLM. An example of this was a joint PLM technology demonstration between General Electric (GE), Siemens and the U.S. Air Force (USAF)'s Oklahoma City Air Logistics Center (OC-ALC) (Siemens PLM Software, 2011). With input from OC-ALC, a pilot part (the F110 high-pressure turbine (HPT) forward inner nozzle support (FINS) structural component) was selected that was undergoing redesign at GE's Evendale, OH facility and whose existing version was being maintained via the OC-ALC facility. Due to the redesign, the support management processes for the F110 HPT FINS would have to be substantially redefined. Siemens Teamcenter™ was contracted provided the PLM backbone.

Throughout the F110 HPT FINS support life cycle, information is continuously flowing between the two facilities. GE communicates updated drawings, specifications and technical orders to OC-ALC and OC-ALC is responsible for requesting design changes that are identified at the Depot or in the worldwide fleet. Additionally, OC-ALC is responsible for implementing GE's changes to internal maintenance and supply chain activities as well as those globally (Siemens PLM Software, 2011).

Prior to implementation of the PLM solution, L6S was used to reduce waste and part variation. An examination of three areas (Product Definition Process, Change Management Process and the Repair and Maintenance Process) was completed using L6S methodology prior to implementing the PLM solution at the design phase. With a cost of $6M the pilot program, the estimated benefits to GE was estimated to be between $11M and $13M a year with savings to OC-ALC to be approximately $8M (Siemens PLM Software, 2011).

4. Lean Six Sigma and KVA

Lean and Six Sigma were developed in an era when the major economies of the world were based in heavy industry and manufacturing. While still effective when analyzing knowledge-based products and their production, L6S is greatly informed when applied with a Knowledge Value Added (KVA) methodology.

KVA methodology provides a means by which to measure the value of knowledge assets within an organizational process. Knowledge contributed by increased use of IT or other knowledge increasing tools can influence input knowledge, as shown in Figure 6. As described by Wu, Wu and Yang,

> Housel and Bell's study in 2001 addressed the theory of knowledge value added, and derived out the return of knowledge (ROK) from KVA. They believed if knowledge can be quantified by 'learning time,' then the input amount of knowledge can be regarded as the representative of a product's ability, with the increase in knowledge introducing amount and the handling procedures of value added, the product's ability can be increased and knowledge is the basic method and knowhow of the creation procedure's production.

In KVA (also referred to as KVC or Knowledge Value Chain by Wu, Wu and Yang), knowledge is defined as "the know-how required to produce process outputs. This kind of knowledge is proportionate to the time it takes to learn it. We have found learning time to be a quick and convenient way to measure the amount of knowledge contained in any given process" (Cook & Housel, 2005). Using knowledge as a resource and learning times as a means by which to measure the productivity of a process, L6S can be applied to organizations that may not produce any tangible products yet still generate value.

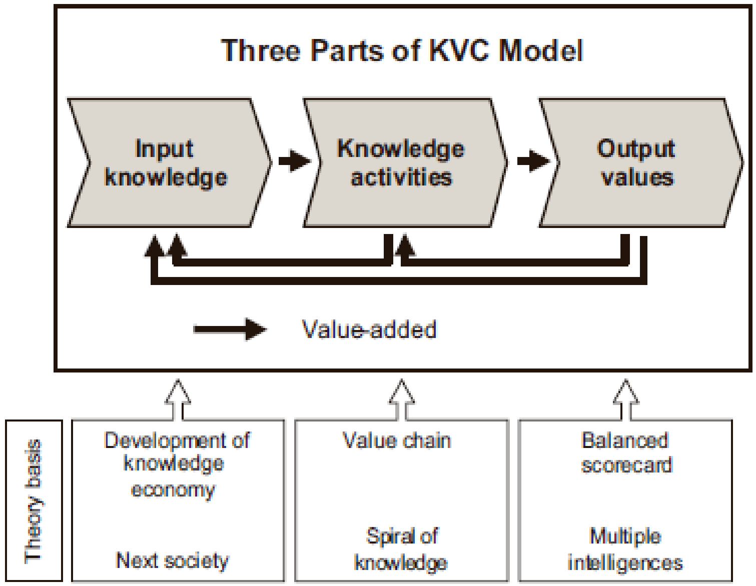

Figure 6. KVC (KVA) Model Parts and Theories (From Denny, n.d.)

As Lean and Six Sigma are concerned with improving and refining processes, KVA inherently contributes to the reduction of waste and the elimination of defects. The knowledge activities introduced have a forward and backward contribution to a value chain as they have a lasting positive effect on input stage processes along with improving current and future iterations of output stage processes. The knowledge inject stage itself is improved via the inherent knowledge interactions with both the output and input activity stages. A graphical representation of the bi-directional contributions of the KVA process is shown in Figure 7.

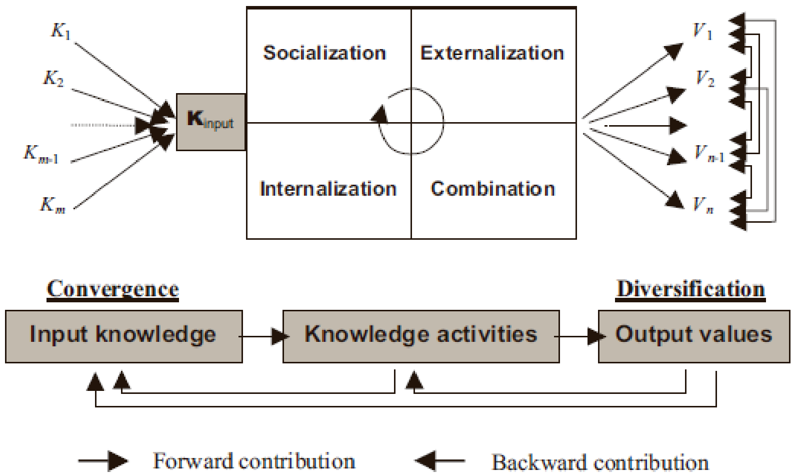

Figure 7. KVA Model K=knowledge; V=Value (From Denney, n.d.)

As the DoD continues to implement CPI/LSS into all business processes, the use of, or at minimum the understanding of, KVA will gain increasing importance. As described by Seaman (2007),

> Performance metrics for productive DoD assets may use many different units of measure of 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 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.

III. BACKGROUND RESEARCH

A. SEAMAN'S ANALYSIS AND FINDINGS

Previous research (Seaman, 2007) into the application of PLM tools and technologies provided a model for the application of KVA methodologies into an analysis of potential cost savings in the SHIPMAIN process. Building off of his analysis of the SHIPMAIN Phase IV and V core processes, will be expanded to include all phases. This new As-Is model will also be compared against savings generated from the application of a Common Parts Catalog vice 3D terrestrial laser scanning.

A previous AS-IS baseline (Seaman, 2007) was created via interactions with subject matter experts from the Naval Sea Systems Command, headquartered at the Washington Navy Yard, Washington, D.C. According to Cornelius's summary of Seaman (2007) research,

> Using business rules from Phases IV and V, the SMEs were interviewed about the amount of knowledge required, average learning time (ALT), and relative learning time (RLT) required for each of the core processes. 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.

Data collected by Seaman during his SME interviews provided an extremely detailed model of SHIPMAIN's core processes along with the costs and manpower required. Due to the variety of ship maintenance projects that are initiated and completed in any given year, he made several assumptions regarding the length, complexity and cost of projects initiated within the SHIPMAIN system. A detailed discussion of these assumptions will be conducted in Chapter IV.

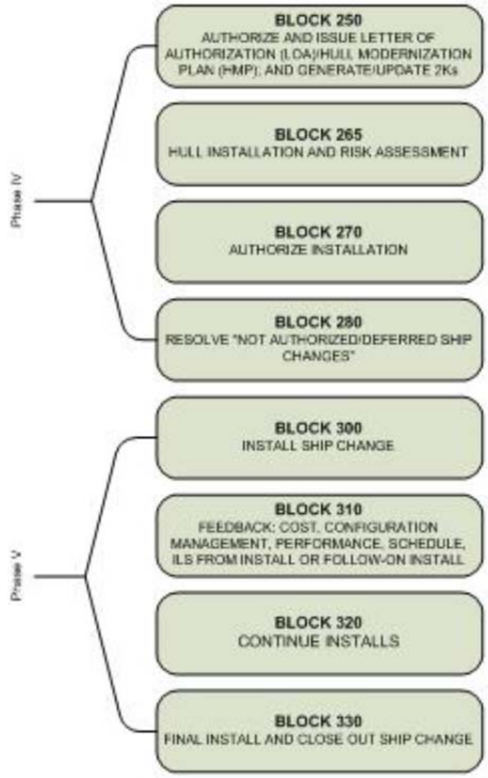

Figure 8. Graphical Representation of Phases IV and V of SHIPMAIN (From Seaman, 2007)

Seaman (2007) constructed his model using data describing eight core processes included in Phases IV and V of SHIPMAIN. All naval vessels that complete an overhaul/refit are affected by these eight core processes, which allows for a more accurate analysis of SHIPMAIN. Phase IV is made of blocks 250–280 and Phase V consists of blocks 300–330.

Using this previous AS-IS model (Seaman, 2007), a TO-BE model featuring the benefits of a common parts catalog can be applied.

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 1. AS-IS SHIPMAIN Process Overview (From Seaman, 2007)

As shown, Seaman (2007) was able to accurately map each process as currently in place. Although he looked to apply a KVA methodology to 3D laser scanning, he also saw value in the application of a PLM suite that allowed collaborative access to data produced by 3D scanning. When coupled together, a PLM suite and 3D laser scanning netted incredible savings as measured in Table 2.

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 2. 3-D Scanning AS-IS/TO-BE Comparison (From Seaman, 2007)

An application of Seaman's (2007) AS-IS model with an examination of solely a PLM solution (such as application of the Common Parts Catalog) would be extremely valuable in understanding the role collaborative tools could have in engineering management and cost estimation.

B. NATIONAL SHIPBUILDING RESEARCH PROGRAM

The initial research into an application of a collaborative parts catalog took place via the NSRP. Spearheaded by Bath Iron Works (BIW) and General Dynamics-Electric Boat (GD-EB) and Northrop Grumman Ship Systems (NGSS), it was an attempt to explore the value of a collaborative parts catalog that could be implemented across multiple shipyards with minimal cost and redesign. Their stated task description was:

> This task requires the installation of a Common Parts Catalog for BIW, EB, NGSS, that will interface with existing catalog functionality, fulfill future technology and provide both short and long term cost saving opportunities. This effort includes the review of present business processes at all three companies to determine 'Best Practices' models in the areas of part commonality/equivalency, part standardization and part data configuration management.
>
> Two identical CPC environments were created in Pascagoula, Mississippi at NGSS and another at Groton, Connecticut supporting BIW and GD-EB. initial implementation costs were within cost estimates, as described at the 2004 ShipTec Information Exchange held in Biloxi Mississippi on 27–28 January 2004.
>
> After an initial contract from NSRP was received on 22 September 2003, GD-EB and BIW went live on 3 May 2004 with NGSS following on 31 May. Successful implementation led to full acceptance of its use at these three entities, with NASSCO and following in 2005.

The immediate functionality benefits as noted by the NSRP in their post-implementation report:

- Inter-shipyard cataloging system that enables part equivalency, part and document data management and part standardization
- Ability to support present integrated design/manufacturing capabilities
- Standard data sharing and reuse across a major portion of the shipbuilding industry
- Structured multi-shipyard organization to maintain and assure parts standards integrity

Although actual cost savings of the pilot program was not released by any of the participating shipyards, they did provide the following savings projections

- Design and Engineering costs savings of 10–20%
- Reduction of Parts through standardization by 5–10%
- Reduction of Material Searches by 30–50%
- Reduction of number of suppliers by 10–50%
- Inventory cost reductions of 10–20%

C. CPC NAVY PILOT PROGRAM

On May 30, 2007, the Program Executive Office, Submarines (PEO SUBS) gave approval to test usage of the Common Parts Catalog at eight Navy sites, with the Carderock Division of the Naval Surface Warfare Center (NSWCCD) Code 2230 organizing and monitoring the test program. Sixteen users were given access for a six month field test of the catalog at the following locations:

- Portsmouth Naval Shipyard Code 200
- Norfolk Naval Shipyard Code 200
- Puget sound Naval Shipyard Code 200
- Pearl Harbor Naval Shipyard Code 200
- TRF Bangor
- NAVICP Code 056 Casualty Repair
- NAVSEA Logistics Center
- NSWC SSES Philadelphia Code 9451/3

As NSWCCD admitted in their after-action review of the pilot program, “the low usage and documentation of user results makes a quantitative analysis impossible.” However, a small qualitative analysis can be made from the comments of participants.

Many commenters noted the potential for the program, should it be fully funded and implemented. A user from Portsmouth Naval Shipyard noted,

> It may be easier to say what CPC doesn't give you than what it does because it has EVERYTHING as far as material information that someone would want from a design or engineering or quality side.

During the live usage phase, many users saw value in the ability to search across multiple data dictionaries and naming schemes, a potential area of increased efficiency. As recorded within the after-action report:

> One user has answered questions on several occasions when only the EB part number was the available reference. Having the ability to access the CPC saved time and allowed the shipyard to get NSN and Procurement information.

Another user from Portsmouth wrote:

> It is useful when you only know an EB part number. We used to have a cheat list that included a MHO-16 report. This report is no longer available. By having only an EB part number (which is listed on many older drawings) I can find out everything about that material. We were able to weld repair two items on a Friday afternoon because we had the information available in CPC. That information was available no where else and a late phone call from home to EB and a LAR would have been required.

Additionally, CPC was shown to support logistics functions as well:

> It supported full description ordering. When no one has the material and we have to locally order the material, we don't want to have to reinvent the wheel. CPC has the clauses that are invoked for that material, the full description, and any special notes for the material. Cross references are required for clauses (since EB's clauses are not the same as other public shipyards but all four public shipyard's clauses including NAVICP's are different as well so this is an area for improvement.) I don't like reinventing the wheel and Level I material description as well (and we still do not have full access to NAVICP material descriptions with clauses, but that is another story.)

While other shipyards saw lower usage rates, there were several observations of CPC's value and possible use within naval support activities. TRF Bangor commented that they didn't understand "why they were stuck with the Single Parts Master access in CITIS (Contractor Integrated Technical Information System) when there was the CPC tool with several magnitudes of improved functionality for sorting, searching and analyzing data."

NSWCCD's conclusions did not include additional testing or a more substantive quantitative study of the business case for CPC. However, it did note the numerous positive comments directed towards its usability and areas of potential efficiencies that CPC can bring to FMP and SHIPMAIN. A quantitative case for CPC can be made by applying these areas NSWCCD's study identified to the AS-IS model of SHIPMAIN that Seaman (2007) established with his research.

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IV. METHODOLOGY PROOF OF CONCEPT

A. INTRODUCTION

Modeling of Phases IV and V of the SHIPMAIN process was based on the work of Seaman (2007) research into 3-D modeling. He based his data upon discussions with various Subject Matter Experts (SME) at NAVSEA, Type Commanders (TYCOM), public and private shipyards, SPAWAR, Office of the Chief of Naval Operations (OPNAV) and other process experts with a stake in maintenance and modernization efforts (Seaman, 2007). Seaman's research will be the basis of the As-Is model. The To-Be model was based upon discussions with additional stakeholders and SMEs in NAVSEA, public and private shipyards and other entities during the summer and fall 2011 timeframe. Due to the unchanged official guidance on Phases IV and V of SHIPMAIN, these two periods of research map well and can provide insight into the value of CPC once applied to SHIPMAIN processes and business rules.

A KVA methodology will be applied to the data collected to determine the potential value of integrating the CPC into phases IV and V of the SHIPMAIN process. If the introduction of CPC has a positive effect, then there should be a net gain in ROI/ROK values along with real cost savings. These figures will be shown as a comparison of the current As-Is scenario to the To-Be scenario.

B. DATA COLLECTION AND METHODOLOGY

Aggregate As-Is baseline data was gathered during an initial KVA knowledge audit conducted by Seaman (2007) via survey and a group interview setting at NAVSEA, Washington Navy Yard, D.C. A SHIPMAIN SME was present at the group interview and had expertise related to the SHIPMAIN process. According to Seaman (2007), the SME had over 30 years' experience in the shipyard industry, with a high degree of expertise in affiliated disciplines. Also included in the initial KVA knowledge audit was a SME recommended by NAVSEA. This SME was a recognized expert in the area of cost estimation and provided valuable guidance and information. The cost estimation process flow model developed from the business rules of the SHIPMAIN process guided the interviews and surveys.

1. Learning Time Method

This proof of concept was analyzed using the KVA Learning Time method (Seaman, 2007). A thorough review of current SHIPMAIN business rules as well as a review of discussions Seaman (2007) had with SMEs and other experts established what processes constitute the core of the SHIPMAIN cost estimation process, identified the inputs and outputs of those processes, and determined the frequency of core process iterations. To effectively apply the KVA methodology, properly identify, and evaluate the knowledge required for each process, boundaries were established between the defined processes. Five core processes were identified and detailed descriptions were developed with the information from the SMEs from NAVSEA and other organizations. The SHIPMAIN business rules were also critical to developing accurate descriptions of the core processes. 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.

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 approved Ship Change (NAVSEA, n.d.). Each block has an official title to reference the core process it accomplishes as shown in Figure 9.

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.

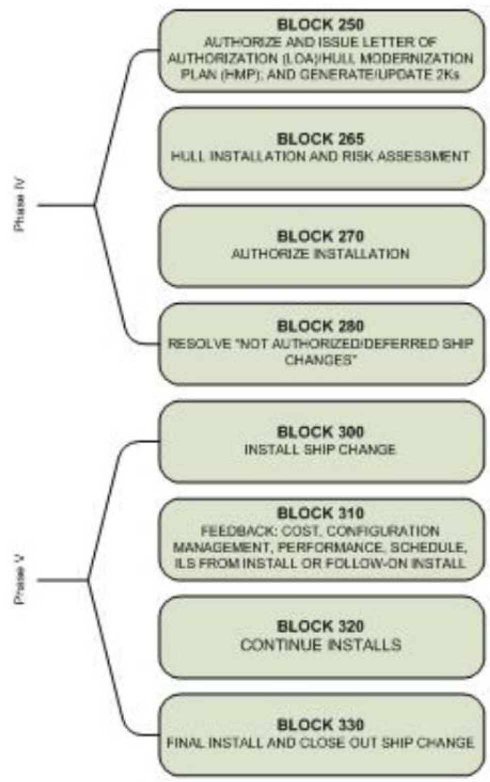

Figure 9. SHIPMAIN Core Processes (From Commander, Naval Sea Systems Command, 2006)

D. KVA ANALYSIS OF AS-IS SCENARIO

A summary of the high level as-is KVA analysis is depicted in Table 3. These estimates were compiled from Seaman's (2007) interviews of SMEs at NAVSEA and historical data contained in the NDE. This sample is representative of availability periods for ships averaged from FY 2002 to FY 2007. All estimates contained in this analysis are as conservative and accurate as possible.

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%
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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 3. As Is SHIPMAIN Process Overview (Seaman, 2007)

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 Seaman's 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 weight 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, which are the vast majority of ship alternations under SHIPMAIN (NAVSEA, n.d.)
- 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, Seaman (2007) estimated 25 percent of availability periods were considered to be simple, 25 percent complex and 50 percent moderate. Six hundred 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 Ship Change Document (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, Seaman instructed the SMEs 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 optimized path to achieve a unit of output must be considered. Each core process was broken down into its component subprocesses 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 revenue surrogate for 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, Seaman referenced 2007 civilian pay chart was referenced. For the purposes of this study all values will be based on FY2007 dollars. 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 e-mail 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 employee. Benefits, locality pay differential and other variables were not compared to establish the rate, only base pay was considered. All government employee rates were increased by 35 percent. This should result in an aggregate revenue that is then divided by the total number of units of output 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 PLM tools such as CPC in the notional to-be model.

a. Key Assumptions

As previously mentioned, this analysis is based on information collected from previous research by Seaman (2007), SMEs from NAVSEA, related research and existing data 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 the Surface Ships and Carriers Entitled Process for Modernization (SSCEPM)(NAVSEA, 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 (Seaman, 2007)

b. Block 250 KVA Analysis

Table 4 shows key KVA estimates used to determine the total process benefits, annual cost, ROK and ROI for block 250.

	Processes	Hourly Personnel Cost	Personnel	Times Perf	Time to Complete	Annual Personnel Cost	%IT	ALT	Total Knowledge	Annual Cost	Total Benefits	ROK	ROI
				Hour	HRS			Hours					
250.1	Create AHMP/EHMP	$ 42.45	3	0.1087	9.2	$1,018,800	75%	40	96000	$1,018,800	$7,127,985	700%	600%
250.2	Create Annual HMP/LOA	$ 42.45	3	0.2174	4.6	$2,037,600	75%	32	153600	$2,037,600	$11,404,776	560%	460%
250.3	Initiate 2Ks into ICMP	$ 35.70	3	0.0942	10.6	$2,227,680	0%	32	49920	$2,227,680	$3,706,552	166%	66%
250.x	Generate/issue QISM	$ 42.45	4	5.4^-4	40	$27,168	90%	32	5120	$27,168	$380,159	1399%	1299%
Sum									Process Totals	5,311,248.0	$22,619,472.00	426%	326.00%

Table 4. Block 250 KVA As-Is Analysis (From Seaman, 2007)

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 of 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 4 only reflect labor cost.

c. Block 265 KVA Analysis

Table 5 shows key KVA estimates used to determine the total process benefits, annual cost, ROK and ROI for block 265.

	Processes	Hourly Personnel Cost	Personnel	Times Perf	Time to Complete	Annual Personnel Cost	%IT	ALT	Total Knowledge	Total Benefits	Total Cost	ROK	ROI
				Per Hour	HRS			Hours					
265.1	Installation Procurement, Desig	$ 43.10	35	0.0081	124	$125,507,200	25%	40	970667	$72,071,847	$125,507,200	57%	-43%
265.2	Hull Installation Readiness Revi	$ 29.78	2	0.1413	7	$1,238,848	80%	40	208000	$15,443,967	$1,238,848	1247%	1147%
265.3	Evaluate Maturity Status	$ 50.16	1	0.2826	4	$521,664	0%	40	20800	$1,544,397	$521,664	296%	196%
265.4	Provide Risk Assessment	$ 50.16	1	0.2826	6	$1,043,328	0%	56	29120	$2,162,155	$1,043,328	207%	107%
265.4.1	Formally Propose Install for Re	$ 50.16	1	0.2826	4	$521,664	0%	40	20800	$1,544,397	$521,664	296%	196%
130	Risk / Readiness Determination	$ 59.01	4	0.1766	3.5	$1,227,408	0%	56	29120	$2,162,155	$1,227,408	176%	76%
Sum									Process Totals	94,928,918	$130,060,112	73%	-27%

Table 5. Block 265 KVA As-Is Analysis (From Seaman, 2007)

According to Seaman (2007), this block was evaluated as the most complex block by all of the SMEs. It involves management and 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 assessments (NAVSEA, 2006)

d. Block 270 KVA Analysis

Table 6 shows key KVA estimates used to determine the total process benefits, annual cost, ROK and ROI for block 270.

	Processes	Hourly Personnel Cost	Personnel	Times Perf	Time to Complete	Annual Personnel Cost	%IT	ALT	Total Knowledge	Total Benefits	Total Cost	ROK	ROI
				Per Hour	HRS			Hours					
270	Installation decision	$ 76.00	4	0.0707	14	$3,161,600	85%	24	332800	$24,710,347	$316,100	789%	682%

Table 6. Block 270 KVA As-Is Analysis (From Seaman, 2007)

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 substantial labor cost. This process has high level of automation which allows a small number of people to execute it often. Accordingly, the cost is 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 IT assets providing the level of automation, only the labor cost.

e. Block 280 KVA Analysis

Table 7 shows key KVA estimates used to determine the total process benefits, annual cost, ROK, and ROI for block 280. 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.

	Processes	Hourly Personnel Cost	Personnel	Times Perf	Time to Complete	Annual Personnel Cost	%IT	ALT	Total Knowledge	Total Benefits	Total Cost	ROK	ROI
				Per Hour	HRS			Hours					
280	Update HMP, LOA and Fielding P	$ 29.78	1	0.2826	3.5	$619,424	75%	24	49920	$3,706,552	$619,424	598%	498%

Table 7. Block 280 KVA As-Is Analysis (From Seaman, 2007)

f. Block 300 KVA Analysis

Table 8 shows key KVA estimates used to determine the total process benefits, annual cost, ROK and ROI for block 300.

	Processes	Hourly Personnel Cost	Personnel	Times Perf	Time to Complete	Annual Personnel Cost	%IT	ALT	Total Knowledge	Total Benefits	Total Cost	ROK	ROI
				Per Hour	HRS			Hours					
300	Complete Installation Testing	$ 42.45	46	0.0061	163	$40,616,160	25%	40	1275733	$94,722,998	$40,616,160	233%	133%

Table 8. Block 300 KVA As-Is Analysis (From Seaman, 2007)

According to Seaman (2007), SMEs rated block 300 a close second to block 265 in complexity. This process is where 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 9 shows key KVA estimates used to determine the total process benefits, annual cost, ROK and ROI for block 310.

	Processes	Hourly Personnel Cost	Personnel	Times Perf	Time to Complete	Annual Personnel Cost	%IT	ALT	Total Knowledge	Total Benefits	Total Cost	ROK	ROI
				Per Hour	HRS			Hours					
310	Provide Feedback Data	$ 29.78	2	0.1413	7.1	$619,424	0%	24	24960	$1,853,276	$619,424	299%	199%

Table 9. Block 310 KVA As-Is Analysis (From Seaman, 2007)

As shown in Table 9, 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 10 shows key KVA estimates used to determine the total process benefits, annual cost, ROK and ROI for block 320.

	Processes	Hourly Personnel Cost	Personnel	Times Perf	Time to Complete	Annual Personnel Cost	%IT	ALT	Total Knowledge	Total Benefits	Total Cost	ROK	ROI
				Per Hour	HRS			Hours					
320	Determine impact on future ins	$ 59.01	5	0.565	18	$3,068,520	0%	24	62400	$4,633,190	$3,068,520	151%	51%

Table 10. Block 320 KVA As-Is Analysis (From Seaman, 2007)

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

	Processes	Hourly Personnel Cost	Personnel	Times Perf	Time to Complete	Annual Personnel Cost	%IT	ALT	Total Knowledge	Total Benefits	Total Cost	ROK	ROI
				Per Hour	HRS			Hours					
330	Verify all SCs have been comple	$ 29.78	1	0.2826	3.5	$309,712	0%	24	12480	$926,638	$309,712	299%	199%

Table 11. Block 330 KVA As-Is Analysis (From Seaman, 2007)

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

Via a combination of verified data from the AS-IS analysis and current industry practices and assumptions based upon SMEs and presumed savings from IT, this scenario represents the reengineered SHIPMAIN processes when CPC is applied. Not all subprocesses will benefit from CPC and as such only those affected will be explained in detail. Any subprocess not stated as reengineered should be assumed to remain in their AS-IS state.

1. Cost of Implementing the Common Parts Catalog

Although CPC is currently in use in private industry, due to proprietary considerations accurate cost data of its use were unable to be obtained. Cost data for implementing CPC therefore must be based upon expected usage, data obtained during the NSRP pilot phase and industry equivalent comparisons. Cost estimated from the 2004 NSRP pilot program have been adjusted by 14% based upon U.S. Department of Labor estimates. Cost and assumptions for CPC are as follows:

- Initial costs for implementation are $3,420,000 for creation of schema and population of system with catalog numbers.

- Maintenance/upkeep annual cost is 20% for management of equivalency and establishment and linking of new part numbers
- Use estimate of 200 days per year
- A lifespan of the system of fifteen years
- The resulting cost per day is $4560

2. Cost of PLM Technology

During the NAVSEA pilot program several licenses of Aspect ® Data Exchange System (DES) were provided to government users by GD-EB for testing purposes. For purposes of cost estimation, it is assumed that Aspect™ would continue to be utilized during full employment of CPC. Current costs in 2011 dollars for DES are $49,000 per year for the core site and $5,000 per additional site or tenant. For the assumption of this study, only the sites utilized in the NAVSEA pilot will use DES for modeling purposes.

The eight sites used in the NAVSEA pilot were

- Portsmouth Naval Shipyard
- Norfolk Naval Shipyard
- Puget Sound Naval Shipyard
- TRIDENT Refit Facility, Bangor
- NAVSUP WSS Code 056 Casualty Repair
- NAVSEA Logistics Center
- NSWC SSES Philadelphia

It is assumed that these eight locations will utilize DES 200 days a year and that the purchase of site licenses provide unlimited user access for those registered at that site. Total costs for DES would equal $84,000 per year and $1,260,000 over the anticipated fifteen-year life of the program. Assuming two hundred work days per year, the daily cost of DES would equal $420 per day. Total costs of PLM and CPC would equal $4980 per day.

3. Reengineered Process

The ship integration, installation and testing phases of SHIPMAIN were reengineered through the addition of CPC supported by a BI software suite. The greatest effect will be seen on processes contained in Blocks 250, 265, 310 and 320. The application of CPC will allow users to reduce time and manpower spent researching part compatibility, in addition to enhanced decision making regarding part and component equivalency. The use of common BI software suite will allow for total visibility across all shipbuilding and repair enterprises, fully exploiting the potential of CPC.

4. TO-BE Data Analysis

Combining the SHIPMAIN process as described in the JFMM ACN 04–02 with SME discussions the following TO-BE scenario was developed. Core processes benefiting from an application of CPC will be described in terms of saving predicted and the assumptions necessary for changes from the AS-IS to the TO-Be model.

a. Block 250 To-Be Analysis

Table 12 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:

	Processes	Hourly Personnel Cost	Personnel	Times Perf	Time to Complete	Annual Personnel Cost	%IT	ALT	Total Knowledge	Annual Cost	Total Benefits	ROK	ROI
				Per Hour	HRS			Hours					
250.1	Create AHMP/EHMP	$ 42.45	2	0.163	6.1	$672,408	90%	48	64000	$672,408	$7,127,985	718%	618%
250.2	Create Annual HMP/LOA	$ 42.45	2	0.3261	3.1	$1,344,816	90%	40	106666	$1,344,816	$11,404,776	598%	498%
250.3	Initiate 2Ks into ICMP	$ 35.70	2	0.1413	7.1	$1,470,269	50%	40	83200	$1,470,269	$3,706,552	426%	326%
250.x	Generate/issue QISM	$ 42.45	4	5.4^-4	40	$27,168	90%	40	5120	$27,168	$380,159	1399%	1299%
Sum									Process Totals	3,514,660.8	$22,619,472.00	785%	685.25%

Table 12. Block 250 KVA To-Be Analysis

• The use of CPC and accompanying BI suite will allow for increasing the amount of automation in Blocks 250.1, 250.2 and 250.3. During the development of the Hull Modernization Plan CPC would be utilized for verification of design as well as for lead-in inventory and logistics functions prior to commencement of work. The during the 2-Kilo update process CPC will be used for similar functions.

• The use of increased automation will allow for reducing personnel by one third due to increased automation.

b. Block 265 To-Be Analysis

Table 13 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:

	Processes	Hourly Personnel Cost	Personnel	Times Perf	Time to Complete	Annual Personnel Cost	%IT	ALT	Total Knowledge	Total Benefits	Total Cost	ROK	ROI
				Per Hour	HRS			Hours					
265.1	Installation Procurement, Desig	$ 43.10	30	0.0094	106	$107,577,600	50%	48	1497600	$72,071,847	$107,577,600	105%	5%
265.2	Hull Installation Readiness Revi	$ 29.78	2	0.1413	7	$1,238,848	80%	40	208000	$15,443,967	$1,238,848	1247%	1147%
265.3	Evaluate Maturity Status	$ 50.16	1	0.2826	4	$521,664	0%	40	20800	$1,544,397	$521,664	296%	196%
265.4	Provide Risk Assessment	$ 50.16	1	0.2826	6	$1,043,328	0%	56	29120	$2,162,155	$1,043,328	207%	107%
265.4.1	Formally Propose Install for Re	$ 50.16	1	0.2826	4	$521,664	0%	40	20800	$1,544,397	$521,664	296%	196%
130	Risk / Readiness Determination	$ 59.01	4	0.1766	3.5	$1,227,408	0%	56	29120	$2,162,155	$1,227,408	176%	76%
Sum									Process Totals	94,928,918	$112,130,512	388%	288%

Table 13. Block 265 KVA To-Be Analysis

• During the certification/risk assessment process, CPC and accompanying BI can be utilized to quickly determine if equivalent parts meet safety and operational standards. The need for such a process was directly mentioned during the NAVSEA trial. This will lead to an estimated increase of 25% automation.

• A reduction of five employees during phase 265.1 can be achieved via automation.

c. *Block 270 To-Be 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 265. Assumptions for Block 270 are as follows:

	Processes	Hourly Personnel Cost	Personnel	Times Perf Per Hour	Time to Complete HRS	Annual Personnel Cost	%IT	ALT Hours	Total Knowledge	Total Benefits	Total Cost	ROK	ROI
270	Installation decision	$ 76.00	4	0.0707	14	$3,161,600	85%	24	332800	$24,710,347	$316,100	789%	682%

Table 14. Block 270 KVA To-Be Analysis

- Application of CPC provides few measurable efficiencies to this process.

d. *Block 280 To-Be 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 280. Assumptions for Block 280 are as follows:

	Processes	Hourly Personnel Cost	Personnel	Times Perf Per Hour	Time to Complete HRS	Annual Personnel Cost	%IT	ALT Hours	Total Knowledge	Total Benefits	Total Cost	ROK	ROI
280	Update HMP, LOA and Fielding P	$ 29.78	1	0.2826	3.5	$619,424	75%	24	49920	$3,706,552	$619,424	598%	498%

Table 15. Block 280 KVA To-Be Analysis

- Application of CPC provides few measurable efficiencies to this process.

e. *Block 300 To-Be 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 300. Assumptions for Block 300 are as follows:

	Processes	Hourly Personnel Cost	Personnel	Times Perf Per Hour	Time to Complete HRS	Annual Personnel Cost	%IT	ALT Hours	Total Knowledge	Total Benefits	Total Cost	ROK	ROI
300	Complete Installation Testing	$ 42.45	46	0.0061	163	$40,616,160	25%	40	1275733	$94,722,998	$40,616,160	233%	133%

Table 16. Block 300 KVA To-Be Analysis

- Application of CPC provides few measurable efficiencies to this process.

f. Block 310 To-Be 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 310. Assumptions for Block 310 are as follows:

	Processes	Hourly Personnel Cost	Personnel	Times Perf	Time to Complete	Annual Personnel Cost	%IT	ALT	Total Knowledge	Total Benefits	Total Cost	ROK	ROI
				Per Hour	HRS			Hours					
310	Provide Feedback Data	$ 29.78	1	0.2826	3.5	$309,712	50%	24	24960	$1,853,276	$309,712	608%	508%

Table 17. Block 310 KVA To-Be Analysis

- Block 310 maintains the feedback data needed to support future installations. Utilizing CPC will allow for increased efficiencies in maintaining Configuration Management and Testing/Integrated Logistics Support data.
- Use of CPC will allow for an estimated 50% increase in automation.
- Increased use of automation will allow for the reduction of employees used in this process from two to one.

g. Block 320 To-Be 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 265. Assumptions for Block 265 are as follows:

	Processes	Hourly Personnel Cost	Personnel	Times Perf	Time to Complete	Annual Personnel Cost	%IT	ALT	Total Knowledge	Total Benefits	Total Cost	ROK	ROI
				Per Hour	HRS			Hours					
320	Determine impact on future ins	$ 59.01	3	0.0942	10.6	$1,841,112	50%	32	99840	$4,633,190	$1,841,112	409%	309%

Table 18. Block 320 KVA To-Be Analysis

- Block 320 utilizes feedback data generated from completed installs to determine impact on future installations. CPC would be utilized for increased efficiencies in updating cost, configuration management, integrated logistics support, technical, material and schedule data.

- Use of CPC will allow for an estimated 50% increase in automation.
- Increased use of automation will allow for the reduction of employees used in this process from five to three.

h. Block 330 To-Be 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 Block 280. Assumptions for Block 280 are as follows:

	Processes	Hourly Personnel Cost	Personnel	Times Perf	Time to Complete	Annual Personnel Cost	%IT	ALT	Total Knowledge	Total Benefits	Total Cost	ROK	ROI
				Per Hour	HRS			Hours					
330	Verify all SCs have been comple	$ 29.78	1	0.2826	3.5	$309,712	0%	24	12480	$926,638	$309,712	299%	199%

Table 19. Block 330 KVA To-Be Analysis

- Application of CPC provides few measurable efficiencies to this process.

V. CONCLUSIONS AND RECOMMENDATIONS

A. RESEARCH LIMITATIONS

The KVA models in this study were generated primarily from the work of Seaman, Cornelius and Komorosky during their study of 3D imaging along with select interviews with SMEs at NAVSEA and GD-EB. Unfortunately, due to proprietary concerns along with high optempos at government activities this study was unable to expand upon their work in order to model the whole of the SHIPMAIN process. However, due to the success previous researchers have had in creating a useful model of the later stages of SHIPMAIN the ability to project potential value of adaptation of CPC is possible. Due to the scope of the SHIPMAIN process some differences may exist between the model of SHIPMAIN described with real-world functions, activities and costs.

B. RESEARCH QUESTIONS

Analysis of this study shows that the application of the Common Parts Catalog to U.S. Navy maintenance and modernization efforts could lead to significant savings. The ability to integrate part data across multiple enterprises would allow for savings in personnel costs and part inventories along with potentially reducing time invested in management activities. This savings is not without precedent since all major U.S. shipbuilders have integrated their part databases with the Common Parts Catalog and have seen considerable value in doing so. The integration of part data from shipbuilder through maintenance and modernization enterprises will also allow for real product life cycle management to take place across naval platforms.

1. Cost Savings

The clear benefit provided by the adaptation of the Common Parts Catalog is a reduction in costs associated with maintenance and modernization efforts. As shown in Table 20, currently the annual costs associated with SHIPMAIN type efforts cost approximately $184 million. Costs post adaptation of CPC was estimated by this study to amount to approximately $162.5 million; savings to the Fleet Modernization Program are estimated to be in the range of $22.5 million. With annual costs of maintaining CPC to amount to less than $4 million, there are considerable benefits to adaptation. An important consideration is that this study only examined Phases IV and V of SHIPMAIN; greater savings can be expected from implementation across all phases of the SHIPMAIN enterprise. Due to the nature of the processes contained in earlier phases, the cost savings could be considered tremendously greater.

	Processes	Annual AS-IS Cost	Annual To-Be Cost	Difference (Cost Savings)	AS-IS ROI	TO-BE ROI
				Per Year	HRS	
250	Authorize and Issue Letter of A	$ 5,311,248	$3,514,660	$1,796,588	326%	685%
265	Hull Installation and Risk Asses	$ 130,060,112	$112,130,512	$17,929,600	-27%	288%
270	Authorize Installation	$ 3,161,600	$3,161,600	$0	682%	682%
280	Update HMP, LOA and Fielding P	$ 619,424	$619,424	$0	498%	498%
300	Install SC	$ 40,616,160	$40,616,160	$0	133%	133%
310	Feedback: Cost, CM, Performanc	$ 619,424	$309,712	$309,712	508%	199%
320	Continue Installs	$ 3,068,520	$1,841,112	$1,227,408	309%	51%
330	Final Install, Closeout SC	$ 309,712	$309,712	$0	199%	199%
Sum		$ 183,766,200.00	$162,502,892	$21,263,308	329%	342%

Table 20. As-Is and To-Be ROI Comparison

There are two factors for the cost savings observed. First, the reduction in manpower allow for the same number of processes to be accomplished by fewer workers. Second, the time needed to accomplish the same number of tasks is reduced. When multiplied across an hourly personnel cost, tremendous savings is generated.

2. Improved Product Life Cycle Management

One of the benefits described in the application of a comprehensive PLM approach is the ability to track platform configuration from cradle to grave both at the unit and class level. Currently configuration management for the surface fleet is tracked on a unit to unit basis with no comprehensive strategy. Often ships are delivered with crews not knowing the exact configuration of the ship they are serving on. Often up to five years go by without a complete picture of necessary maintenance and logistics (Commander, Surface Forces, 2009). As Seaman stated, PLM tools have the potential to build a coherent data structure and consolidate dispersed data into a single record for specific ships, classes of ships or shipboard systems. Common access to a single repository of comprehensive life cycle information will enable decision makers to conduct analysis and make informed decisions based on the full spectrum of product definition data (Seaman, 2007).

Adaptation of CPC to maintenance and modernization efforts will greatly advance the Navy toward a comprehensive PLM strategy. By building a part catalog with the flexibility to include both parts as they are conceived during the design and build portions of a ship’s life with the nomenclature and numbering systems employed once the vessel is commissioned complete awareness of part equivalency and interoperability can be achieved. The efficiencies achieved through this streamlining of life cycle data is in keeping with the DoD’s focus on expanding the application of Lean Six Sigma methologies to business processes. The costs associated with platform configuration data maintenance can be considerable over the course of the life of a ship. Although not researched in any detail in this study, it is anticipated that any successful process efficiencies that can be achieved will generate huge benefits in cost savings along the life of naval platforms.

C. RECOMMENDATIONS TO THE NAVY

Begin integration of CPC into the Navy shoreside shipbuilding, maintenance and modernization activities, to include NAVSEA and NAVICP codes involved in configuration management. With the integration of CPC into Navy enterprises, the Joint Forces Maintenance Manual should be updated to include usage of CPC into SHIPMAIN activities.

To make the use of CPC truly successful in the Navy Surface Enterprise, comprehensive training needs to take place at host facilities. A major failing of the original pilot was the training of only a few members of any facility in CPC's use. Additionally, reports that Navy users require to easily pull data from CPC to answer shipyard, Intermediate Maintenance Facility and Inventory Control Point questions should be determined in advance of implementation.

A NAVSEA owner of CPC needs to be determined to take the lead on system administration and to provide DoN personnel for the Central Configuration Control Group to represent Navy stakeholders. This will allow for comprehensive integration of DoN activities into the configuration management currently being conducted at the shipbuilder level. Unity of data semantics will provide increased efficiencies and work flow from application of CPC.

As stated in the NAVSEA CPC Pilot program results, NAVSEA 05 should require a CPC clause in future acquisition contracts to require examination of the CPC database for parts that meet design needs by ship design organizations before they introduce a new part into the design that will result in an additional part being added to the Navy inventory.

D. FOLLOW ON AND FUTURE RESEARCH OPPORTUNITIES

Although there was value in the limited view of SHIPMAIN from just a study of Phases IV and V, a more comprehensive view of SHIPMAIN to include all phases could yield valuable evidence supporting CPC adaptation and integration. Further evidence supporting the value of data integration could lead to additional studies examining ways to apply PLM methodologies to the Navy Surface Enterprise. Although CPC deals specifically with part management, further research into integration of the Navy's configuration management efforts in support of unit level maintenance with configuration design at the shipbuilder could also yield value. The use of a KVA methodology is recommended for future research due to its ability to both quantify value of the adaptation of information technology to existing processes and reveal ways to alter processes to produce increased value.

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